

On Clausius', Post-Clausius', and Negentropic Thermodynamics

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How to cite this paper: Íñiguez, J.C. (2021) On Clausius', Post-Clausius', and Negentropic Thermodynamics. *Journal of High Energy Physics, Gravitation and Cosmology*, 7, 1425-1458.
<https://doi.org/10.4236/jhepgc.2021.74087>

Received: August 4, 2021

Accepted: October 17, 2021

Published: October 20, 2021

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Abstract

The evidence here provided shows that the thermodynamics of the second law, as currently understood, originated in a correction of the flaws affecting Clausius original work on this matter. The body of knowledge emerging from this correction has been here called post-Clausius' thermodynamics. The said corrections, carried on with the intended goal of preserving the validity of Clausius' main result, namely the law of increasing entropy, made use of a number of counterintuitive or logically at fault notions. A joint revision of Clausius' and post-Clausius' work on the second law, carried on retaining some of Clausius original notions, and disregarding others introduced by post-Clausius thermodynamics, led this author to results in direct contradiction to the law of increasing entropy. Among the key results coming out of this work we find the one stating that the total-entropy change for spontaneous thermodynamic processes is the result of the summation of the opposite-sign contributions coming from the entropic (energy degrading) and negentropic (energy upgrading) changes subsumed by any such process. These results also show, via the total-entropy change for a non-reversible heat engine, that negentropic thermodynamics subsumes post-Clausius thermodynamics as a special case.

Keywords

Clausius' Entropy Law in Contradiction with Its Premises, Post-Clausius' Thermodynamics Emerges from the Biased Correction of the Flaws in Clausius Entropy Law, Negentropic Thermodynamics and the Transformation of Heat into Work as a Negentropic Process

Thermodynamics gives me two strong impressions: first of a subject not yet complete or at least of one whose ultimate possibilities have not yet been

explored, so that perhaps there may still be further generalizations awaiting discovery, and secondly and even more strongly as a subject whose fundamental and elementary operations have never been subject to an adequate analysis [1].

Clausius' Thermodynamics

1. Antecedents

1.1. Reversibility

The notion of thermodynamic reversibility can be traced to the work of Sadi Carnot, who in the coupling of an optimally efficient engine with the inverse cycle recognized that "... these two series of operations annul each other, after a fashion, one neutralizing the other" [2]. In terms of entropy, this notion finds re-expression in the following statement by Planck:

*A process which can in no way be completely reversed is termed *irreversible*, all other processes *reversible*. That a process may be irreversible, it is not sufficient that it cannot be directly reversed... The full requirement is, that it be impossible, even with the assistance of all agents in nature, to restore the exact initial state when the process has once taken place... The significance of the second law of thermodynamics depends on the fact that it supplies a necessary and far-reaching criterion as to whether a definite process which occurs in nature is reversible or irreversible [3].*

The criterion Planck is referring to is the entropy function. It is in terms of entropy that the said law finds what Planck considers "(Its) most general statement...", namely.

Every physical or chemical process in nature takes place in such a way as to increase the sum of the entropies of all bodies taking any part in the process. In the limit, i.e. for reversible processes, the sum of the entropies remains unchanged [3].

1.2. A Detailed Look at Carnot Engines

The cyclical concatenation of reversible changes to be described below was devised by Carnot to study the continuous transformation of heat into work taking place in heat engines. With some particular substance as the subject of these changes, in our particular case an ideal gas, which is to be also referred as the working substance, this concatenation, known as Carnot cycle, finds, with A as starting point, the following description: AB) an isothermal expansion at some temperature T_h ; BC) an adiabatic expansion which lowers the temperature of the gas from T_h to some smaller temperature T_c ; CD) an isothermal compression at T_c , and closing the cycle; DA) an adiabatic compression which raises the temperature of the working substance from T_c to T_h .

When the said cycle is, in a way of speaking, inserted between a hot reservoir

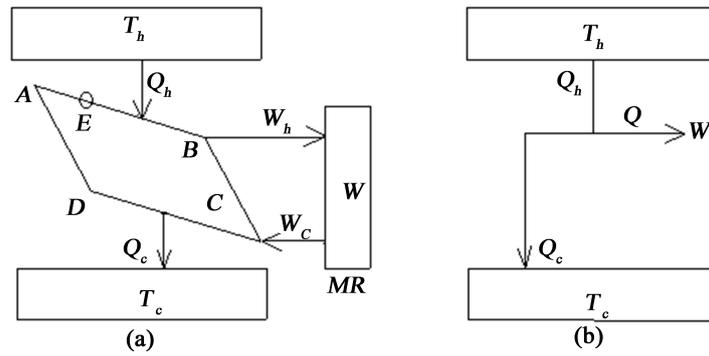


Figure 1. Two representations of a reversible heat engine: the cyclical evolution of the ideal gas defined in 1(a) by the concatenation of processes $AB-BC-CD-DA$ produces, out of the amount of heat Q_h released by the hot reservoir, the two effects or transformations, as Clausius called them, depicted in 1(b), these being the reversible transformation of the amount of heat Q_c to the cold reservoir, and the reversible transformation of the amount of heat Q into the equivalent amount of work W . It is understood that $Q_h = Q_c + Q$, and $Q = W$. Point E is used below in the argument directed to the identification and evaluation of the total-entropy changes of the two transformations depicted in 1(b).

of temperature T_h and a cold reservoir of temperature T_c with the purpose of transforming into work W a portion of the cyclical amount of heat Q_h delivered by the hot reservoir to the gas, with the remaining portion $Q_c = Q_h - W$ discarded to the cold reservoir, we have a (Carnot) reversible heat engine.

Carnot’s analysis of this engine was continued and eventually concluded some forty years later by Clausius via the introduction of the thermodynamic state function which he named the entropy, defined, using current notation, as dQ_{rev}/T , and with the advancement of the law of increasing entropy [4].

In reference to one mole of working substance as well as to **Figure 1(a)**, the following quantitative description of Carnot reversible engine can be provided.

In process AB an amount of heat Q_h transferred by a hot reservoir of temperature T_h to an ideal gas of the same temperature is transformed, via the reversible expansion of the gas, into the equivalent amount of work W_h which ends up increasing the potential energy of a certain weight in a weight-and-pulley mechanical reservoir. The quantitative transformation of heat into work taking place in this process finds explanation in the fact that the internal energy of an ideal gas is a sole function of its temperature. Thus, for isothermal process

$A \rightarrow B$ we have $\Delta U_{AB} = 0$ in which case the expression of the first law for this process, written here as $\Delta U_{AB} = Q_h - W_h$, reduces to $Q_h = W_h$, result evincing the quantitative transformation of heat into work taking place under this condition. It should be kept in mind that in the expression of the first law here being used work produced and heat absorbed are positive quantities.

Process BC , an adiabatic and reversible expansion, reduces the temperature of the gas from T_h to that of the cold reservoir T_c . This process takes place in the absence of any exchange of heat between the gas and its surroundings, *i.e.*, $Q_{BC} = 0$. Under this restriction the expression for the first law reduces to $W_{BC} = -\Delta U_{BC}$ and in doing so makes evident the fact that the work here pro-

duced ($W_{BC} > 0$) comes from an equivalent depletion in the internal energy of the gas ($\Delta U_{BC} < 0$), producing along the way, given the previously noted sole dependence of U on T , a corresponding decrease in the gas temperature. Here $\Delta U_{BC} = C_v(T_c - T_h)$, where C_v is the constant-volume heat capacity of the gas.

In Process CD , an isothermal and reversible compression at the temperature of the cold reservoir, the portion W_c of the work W_h previously transferred to the mechanical reservoir is retrieved from it and used to drive this process to completion. On reason of the common isothermal nature of processes AB and CD we have that the form adopted by the first law in the former is also applicable in the latter. Here, however, it will be written as $Q_c = W_c$ and interpreted by saying that the work dissipated in forcing the compression ends up as the equivalent amount of heat Q_c in the cold reservoir.

Process DA , the final step of the cycle, is an adiabatic and reversible compression taking the gas to its initial condition which in terms of temperature is given by T_h . The condition $Q = 0$ common to processes 2 and 4 allows us to write $W_{DA} = -\Delta U_{DA}$, with $\Delta U_{DA} = C_v(T_h - T_c)$. Note that here $\Delta U_{DA} > 0$ and $W_{DA} < 0$ in accord with the fact that the work done here on the gas ends up increasing its internal energy and also its temperature. A closer inspection of the previous results in regard to adiabatic and reversible processes BC and DA allows us to conclude that any one of these processes is the precise inverse of the other. This assertion finds sustenance from the following facts: $\Delta U_{BC} + \Delta U_{DA} = 0$ and $W_{BC} + W_{DA} = -(\Delta U_{BC} + \Delta U_{DA}) = 0$. The decrease in internal energy and the associated lowering of the temperature of the gas along process BC are offset by the increases these magnitudes experience along process DA . The amount of work produced along the isentropic expansion is also identical to the amount consumed along process DA . This last fact allows us to realize that processes BC and DA have no saying in the work-effect of the engine. If so, this effect is quantified by the work remaining in the mechanical reservoir in the amount of $W = W_h - W_c$ which is precisely the difference between the work produced by the isothermal and reversible expansion (process AB) and that consumed by the isothermal and reversible compression (process CD).

1.3. Clausius, His Transformations, and Their Total-Entropy Changes

As indicated in **Figure 1(b)**, Clausius summarized the effects of a reversible heat engine (refrigerator) in the following terms:

Two transformations are produced, a transformation from heat into work (or vice-versa) and a transformation from heat of a higher temperature to heat of a lower (or vice-versa)... The relation between these two transformations is therefore that which is to be expressed by the second Main Principle [4].

A transformation is a process which through the concerted participation of a number of bodies brings forward a particular effect, particular in the sense of its

importance for the purposes of the particular thermodynamic analysis being considered. A transformation is a universe in itself as it includes all the bodies involved in the production of the said effect. As such its entropy change, given by the summation of the individual entropy changes of all these bodies, is a total-entropy change. In certain situations, and for the purposes of simplifying or enlightening the analysis being carried on, it is possible to break down a thermodynamic process into a number of simpler or elementary processes or transformations. The evident requirement of such a procedure being the combination of these transformations reproducing the original process, its effects, and if so, also its total-entropy change.

As should be obvious, the inverse of any given reversible transformations produces a total-entropy change of the same magnitude but opposite sign; negation of this condition implies the negation of the state function nature of the entropy.

What we have called the “total-entropy change” of a transformation was originally referred to by Clausius as its “value”. If the two transformations subsumed by a reversible cyclical process or heat engine—those referred to by Clausius in his previous quote—are, in the order there introduced, represented via the following self-evident notation: $[Q(T_h) \rightarrow W]$ and $[Q_c(T_h) \rightarrow Q_c(T_c)]$, then the total entropy change of a reversible heat engine will take the following form:

$$\Delta S_{tot} [rev. eng] = \Delta S_{tot} [Q(T_h) \rightarrow W] + \Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)] \quad (1)$$

In regard to the total-entropy change for the reversible transformation of heat into work (or vice versa) Clausius tells us that:

With regard to the magnitude of the equivalence-value, it is at once seen that the value of a change from work into heat must be proportional to the quantity of heat generated, and that beyond this it can only depend on its temperature. We may therefore express generally the equivalence-value of the generation out of work of the quantity of heat Q , of temperature T , by the formula $Qxf(T)$, where $f(T)$ is a function of temperature which is the same for all cases. If Q is negative in this formula, what is expressed is that the quantity of heat Q has been transformed, not out of work into heat, but out of heat into work [4].

The function $f(T)$ was eventually identified by Clausius as $f(T) = 1/T$, with T representing the absolute temperature in which case Clausius values or entropy changes for the reversible transformation of work into heat and heat into work can be respectively written as $\Delta S_{tot} [W \rightarrow Q(T_h)]_C = Q/T_h$ and $\Delta S_{tot} [Q(T_h) \rightarrow W]_C = -Q/T_h$.

The sub-index C attached to the previous expressions identify the values there appearing as those of Clausius’ thermodynamics.

As to the transformations of heat from one reservoir to another taking place in reversible heat engines or refrigerators, he states:

Similarly, the value of the passage of the quantity of heat Q_c from the temper-

ature T_1 to the temperature T_2 must be proportional to the quantity of heat which passes, and beyond this can only depend on the two temperatures. We may therefore express it generally by the formula $Q_c X F(T_1, T_2)$, in which $F(T_1, T_2)$ is a function of the two temperatures, also constant for all cases, and which we cannot at present determine more closely; but of which it is clear from the commencement that, if the two temperatures are interchanged, it must change its sign, without changing its numerical value. We may therefore write... $F(T_2, T_1) = -F(T_1, T_2)$ [4].

Eventually Clausius was able to express the F function in terms of the f function involved in the reversible inter-conversions between heat and work. The form taken by F for the transference of heat from the temperature T_1 to the temperature T_2 was $F(T_1, T_2) = (1/T_2) - (1/T_1)$.

Being this so, the total-entropy changes for the reversible transformations of heat from one temperature to another taking place in reversible heat engines and refrigerators take, respectively, the following forms:

$$\Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)]_C = Q_c [(1/T_c) - (1/T_h)], \text{ and}$$

$$\Delta S_{tot} [Q_c(T_c) \rightarrow Q_c(T_h)]_C = Q_c [(1/T_h) - (1/T_c)] \text{ with } Q_c \text{ representing the amount of heat transferred.}$$

Out of the results just obtained and for the purposes of the arguments that follow we have written below the total-entropy changes of the two transformations taking place in a reversible heat engine:

$$\Delta S_{tot} [Q(T_h) \rightarrow W]_C = -Q/T_h \tag{2}$$

$$\Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)]_C = Q_c [(1/T_c) - (1/T_h)] \tag{3}$$

In terms of Equations (2) and (3) and in accordance with Equation (1) the following expression for the total-entropy change of a reversible engine can be written:

$$\Delta S [rev. eng.]_C = (-Q/T_h) + [(-Q_c/T_h) + (Q_c/T_c)] = 0 \tag{4}$$

And on reason of $Q_h = Q + Q_c$, as follows:

$$\Delta S [rev. eng.]_C = (-Q_h/T_h) + (Q_c/T_c) = 0 \tag{5}$$

The equality to zero of Equation (5), a result previously obtained by Clausius via the application of the laws of ideal gases to the isothermal and reversible volume changes taking place in Carnot reversible engine, allowed him to voice the result given by this equation in the following manner, "... in a reversible Cyclical Process the total value of all the transformations must be equal to nothing" [4].

The extension of his analysis to non-reversible processes, both cyclical and non-cyclical, led him to the following statement:

The theorem which... was enunciated in reference to circular processes only... has thus assumed a more general form, and may be enunciated thus: the algebraic sum of all the transformations occurring in any alteration of condition whatever can only be positive, or as an extreme case, equal to

nothing [5].

In terms of total-entropy, Clausius' previous statement can be written as $\Delta S_{total} \geq 0$, where the equality applies to reversible processes and the inequality to all others.

Equations (1) to (5) are the central elements of what we can call Clausius' thermodynamics of the second law, or Clausius' thermodynamics (*CT*) for short. More specifically, Equations (2) and (3) represent the premises of a thermodynamic argument whose conclusion is given by Equations (4) or (5).

1.4. The Flaws in Clausius Thermodynamics

Notwithstanding the reverence with which Clausius work on the second law is treated by many a thermodynamicist, the truth of the matter is that Clausius' thermodynamics is nothing short of a logical aberration. That this is so finds validation in the following three arguments

i. Equation (4), the mathematical expression of the law of increasing entropy in the form it applies to reversible processes, namely the total-entropy change of any reversible process is equal to zero, is negated by the non-zero total-entropy of the reversible transformations [Equations (2) and (3)] constituting the very premises of such a conclusion. Here, from the non-zero total-entropy changes of the two reversible processes in which he had divided the operation of a reversible heat engine, he managed to conclude that the total-entropy change of any reversible process should be equal to zero. Carrying two black swans in his hands he advances the claim that all swans are white.

ii. For the law of increasing entropy the total-entropy changes of thermodynamic processes are either zero, for reversible processes, or positive for all others. A negative total-entropy change becomes this way the indication of an impossible process *i.e.*, one in the same league as the spontaneous flow of heat from a colder to a hotter body. Looking, however, at Equation (2) we learn that in Clausius' thermodynamics not all thermodynamically impossible processes are equally impossible, as here we have a process taking place in a heat engine which according to the said notion shouldn't be taking place at all!

iii. In his quote on 1.1 Planck tells us that "The significance of the second law of thermodynamics depends on the fact that it supplies a necessary and far-reaching criterion as to whether a definite process which occurs in nature is reversible or irreversible" [3]. The said criterion taking form in the different total-entropy changes produced by reversible and irreversible processes. The total-entropy change becomes this way the ultimate discriminator between those two kinds of processes. This conclusion is, however, negated by Clausius own results which on one side affirm, via Equation (3), that the total-entropy change of the reversible transformation of heat taking place in a reversible-engine amounts to $(-Q_c/T_h) + (Q_c/T_c)$, and in the other, as the following quote attests, that the very same total-entropy change rules for the irreversible transfer of the same amount of heat between the same two temperatures:

If a quantity of heat Q_c has passed by conduction from a body of temperature T_h to another of temperature T_c , then the uncompensated transformation is $Q_c \left[(1/T_c) - (1/T_h) \right]$ [5].

A slight change in notation was introduced in Clausius' quote to make it directly comparable to that stated by Equation (3). In Clausius' thermodynamics, what Planck calls the significance of the law of increasing entropy appears to be not so significant at all.

1.5. The Impact of Clausius' Law of Increasing Entropy

The previous flaws apparently went undetected for a long period of time, long enough for Clausius results to be called "... the greatest scientific achievement of the nineteenth century" [6], as well as taken to hold "... the supreme position among the laws of Nature" [7]. From the previous qualifiers it can be inferred that the impact of the law of increasing entropy, as some of the following quotes and discussions evince, was wide and profound.

In April 1850 (Clausius) published his most famous paper, "On the Motive Power of Heat and on the Laws Which Can Be Deduced from it for the Theory of Heat," in *Poggendorff Annalen*, which presented the second law of thermodynamics for the first time... By August 1850 Thomson had read "On the Motive power of Heat", which he quickly followed with his own "On the Dynamical Theory of Heat"... In 1854 Clausius developed the concept of entropy to describe the transformational content of a body, although he did not introduced the term entropy for another decade... Clausius was awarded the Royal Society's Copley Medal in 1879 and published his papers on thermodynamics in a two-volume work, *Die Mechanische Wärmetheorie* (translated as *The Mechanical Theory of Heat*) in 1865-67, revisiting it in 1875 [8].

Even if as the previous quote attest, the priority in presenting the second law for the first time belongs to Clausius, it was Thomson's the one to use the notions subsumed by this law to advance, in a paper published in April 1852, what Raman calls "... the first severe statement that physics made about the fate of man" [9]. Published in the *Proceedings of the Royal Society of Edinburgh* with the title "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy", it contained the following statements [10]:

1. There is at present in the material world a universal tendency to the dissipation of mechanical energy.
2. Any restoration of mechanical energy, without more than an equivalent of dissipation, is impossible in inanimate material processes, and is probably never effected by means of organized matter, either endowed with vegetable life or subjected to the will of an animated creature.
3. Within a finite period of time past, the earth must have been, and within a finite period of time to come the earth must again be, unfit to the habita-

tion of man as at present constituted, unless operations have been, or are to be performed, which are impossible under the laws to which the known operations going on at present in the material world are subject.

After the introduction of the entropy function in 1865, Clausius was ready to “... make the leap from technology to cosmology” [11]. This he did by extrapolating the law of increasing entropy from terrestrial thermodynamic systems to the universe as a whole, *i.e.*, from entropy production in irreversible processes to “... the entropy of the world tends toward a maximum” [3]. This point of universal maximum entropy, none other than the “end of the world”, or “judgement day” [12], was christened as

‘*Wärmetod* of the universe’ by Clausius. It has been translated as ‘heat death’ but must be imagined not as a death of flame and fire, but rather as a prosaic end of completely uniform, uninteresting temperature, and monotonous randomness in everything else [13].

As hinted above via the association of the universal entropy maximum with “judgement day”, it was religion the one to experience one of the most profound impacts from the law of increasing entropy:

If the religious frenzy engendered by the first and second laws of thermodynamics now seems more rash than was warranted, more subjective than was proper, and more trusting in the incorruptibility of truth than seems legitimate, it was nevertheless quite real [14].

Clausius’ cosmological extrapolation, just like that of Thomson in 1852, provided, in the eyes of those concerned with the connection of science and religion, a scientific foundation for some of the central dogmas of religious belief. Thus, from “Kelvin’s dissipation system Stewart and Tait inferred that ‘we have reached the beginning as well as the end of the present visible universe, and have come to the conclusion that it began in time and will in time come to an end’” [12].

Writing in 1902, C. K. Edmunds let us know that:

Next to Lord Kelvin, perhaps the most notable figure among the physicists of Great Britain during the last forty years has been Peter Guthrie Tait, professor of natural philosophy in the University of Edinburgh since 1860... He was the joint author with Balfour Stewart of the ‘Unseen Universe’ (first printed privately in 1875), a book showing, to use Tait’s own words, how baseless is the common belief that science is incompatible with religion [15].

One of the declared goals of the book ‘The Unseen Universe’ was “... to overthrow materialism by a purely scientific argument” [16]. Serves to note that Tait was a close collaborator of Lord Kelvin, having co-authored with him in 1867 the book ‘Treatise of Natural Philosophy’.

In 1869, in reference to Clausius’ entropy law, Engels wrote to Marx saying

‘I am simply waiting for the moment the clerics seize upon this law’. Indeed, both the clerics and W. Thomson (Lord Kelvin) brandished the second law, the latter in religious tirades about ‘heat death’... In 1867 Josef Popper-Lynkeus (1838-1921), who with Ernst Mach became one of the sources of inspiration for the anti-metaphysical philosophy of the Vienna Circle, complained... about Thomson’s ‘theological handling of (the second) law’” [17].

The following quote provides an illuminating example of said W. Thomson’s “theological handling” of the entropy law:

Traditional Christian concepts appear to have deeply influenced many of the scientists who stated and developed the second law as a universal principle. To cite Lord Kelvin (William Thomson), one of the originators of the second law, the law meant that “... all motion except that of heat must have an end unless it pleases God to restore by an act of new creative power the dissipation of mechanical energy that always goes on”. Seen in its historical context, the law seems to be less a law and more of a daring... designed to be a contender in the running cosmological debates of its time [12].

According to Bazarov:

The (second) law has caught the attention of poets and philosophers and has been called the greatest scientific achievement of the nineteenth century. Engels disliked it, for it supported opposition to Dialectical Materialism, while Pope Pius XII regarded it as proving the existence of a higher being [6].

In this regard, Pope Pius XII advanced the following statement

Through the laws of entropy... discovered by Rudolf Clausius, it was recognized that the spontaneous processes of nature are always accompanied by a diminution of free and utilizable energy. In a closed material system this conclusion must lead, eventually, to the cessation of processes on a macroscopic scale. This unavoidable fate, from which only hypothesis—sometimes unduly gratuitous—such as that of continued supplementary creation, have endeavored to save the universe, but which instead stands out clearly from positive scientific experience, postulates eloquently the existence of a necessary being [18].

Along this apparently smooth and uneventful path that even today witnesses Clausius’ law of increasing entropy (*LIE*) permeating practically all the fields of inquiry of the human mind, a dramatic as well as surreptitious (covert) change took place in the form of a modification of the premises underpinning the said law. At some point in time the logical fiasco at the core of Clausius’ work, the same exposed via the three faults described in comments *i*, *ii*, and *iii* of 1.4, must have been discovered. As to the who or the when of this realization and its further correction the present author has no factual information. This is a matter

for historians of thermodynamics, a field which in McGlashan's opinion "is in fact a much more difficult subject than thermodynamics itself and much less understood" [19]. This notwithstanding, it can be speculated that the coming to light of these flaws and their subsequent correction must have taken place in *petite comité*, i.e. unknown to the masses of both followers and critics of Clausius entropy law, and necessarily limited to those with the required knowledge to understand Clausius work at depth. As to the time frame, and also speculating, it seems logical to think that it might have taken place in the interval of time bound on one side by Clausius death in 1888—I have no doubt that Clausius would have subjected his work to a profound revision had he been aware of the said flaws—and on the other by the appearance in the thermodynamic literature of discussions asserting, in opposition to Clausius notion represented by Equation (2), the zero total-entropy change for the transformation of heat into work.

The correction of the flaws in Clausius analysis embodies the divide between Clausius thermodynamics, represented here by Equations (2)-(5), from what we will call post-Clausius thermodynamics, namely the thermodynamics of the second law as currently understood, recognized by the different values it assigns to equations (2) and (3) to get to the result shown in (4) or (5).

Post-Clausius' Thermodynamics

2. The Correction of the Flaws in Clausius' Thermodynamics

2.1. Some Comments on Post-Clausius' Thermodynamics

Post-Clausius' thermodynamics, as will be detailedly discussed below, is the body of knowledge arising from the—for most thermodynamicists—unknown correction performed at least a century ago on Clausius original analysis on the second law on reason of a number of critical flaws present in it. Clausius work on the second law, as presented in his 1875 book "The Mechanical Theory of Heat" is what has been here referred as Clausius' thermodynamics. The thermodynamics of the second law as presented in textbooks printed around the first or second decade of the past century up to the present corresponds to post-Clausius thermodynamics. Our alternative to this last formulation, to be introduced down below, will be referred to as negentropic thermodynamics.

2.2. A Simple Path to the Correction of the Flaws in Clausius' Thermodynamics

Most students and studios of thermodynamics believe that the thermodynamics of the second law they have been exposed to is a compendium of Clausius' work. This belief, however, bears no correspondence with reality. The version of the second law that the present author, and you, the reader, have become familiar with is actually a radically different version of the second law developed by Clausius as detailed in his book "The Mechanical Theory of Heat" whose English translation dates to 1879. The current version of the thermodynamics of the second law, which will here be referred to as post-Clausius' thermodynamics

(*pCT*) differs from Clausius' thermodynamics (*CT*) in the total-entropy changes assigned by one and the other to the transformations taking place in a reversible heat engine. While *CT* proves the zero total-entropy change of a reversible engine via the addition of two non-zero quantities, namely $\Delta S_{tot} [Q(T_h) \rightarrow W] = -Q/T_h$ and $\Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)] = Q_c [(1/T_c) - (1/T_h)]$, as previously detailed in Equations (4) and (5), post-Clausius thermodynamics does it via the addition of two zero total-entropy changes, *i.e.* *pCT* proves that $\Delta S_{tot} [rev. eng.] = 0$ via the addition of $\Delta S_{tot} [Q(T_h) \rightarrow W]_{pCT} = 0$ and $\Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)]_{pCT} = 0$.

Post-Clausius thermodynamics managed to maintain the validity of Clausius' conclusion—the law of increasing entropy via the expedient of changing its premisses!

The logical failures of Clausius' law of increasing entropy, the ones previously detailed, must have produced a profound impact in those thermodynamicists privy to this knowledge. Here we have “The greatest scientific achievement of the nineteenth century...” [6] plagued by logical inconsistencies. A decision had to be taken by those ‘in charge’ of thermodynamics at the time, *i.e.*, by some of the leading workers in the field, either to carry on a profound revision of all of Clausius work in order to correct whatever was there that needed correction, irrespective of the nature of the conclusion this action might lead to, even a result disagreeing with the law of increasing entropy, or simply introduce corrections in order to guarantee the continued validity of the said law. The fact that it was this last the option selected shows that in the end idiosyncrasies ruled over science; science was sidestepped in the name of the beliefs and prejudices—religious or otherwise—of the correctors.

The correction to be introduced to achieve the intended goal wasn't all that difficult to find. Clausius' conclusion about the zero-total entropy change for reversible engines was found in contradiction with the non-zero total-entropy changes of the reversible transformations from which such a result was obtained. Eliminating the contradiction required finding a way to make zero the total-entropy change of the said transformations. This was accomplished by fiat, *i.e.*, by the expedient of *decreeing* the zero total-entropy change for reversible heat-work inter-conversions; in other words, by making $\Delta S_{tot} [Q(T_h) \rightarrow W] = 0$ in the case of a reversible heat engine (and $\Delta S_{tot} [W \rightarrow Q(T_h)] = 0$ for a reversible refrigerator). It was the recognition of the fact that, as already discussed in 1.2, heat-work inter-conversions in reversible heat engines are the exclusive parcel of isothermal and reversible expansions, [*IRE*], and isothermal and reversible compressions, [*IRC*], what explains the fact that the *fiat* or decree through which Clausius' thermodynamics was corrected took the following form:

$$\Delta S_{tot} [IRE]_{pCT} = \Delta S_{tot} [IRC]_{pCT} = 0 \tag{6}$$

The identity existing between $[Q(T_h) \rightarrow W]$ and [*IRE*], as well as between $[W \rightarrow Q(T_h)]$ and [*IRC*] will be discussed at length in 3.2.

The arbitrary assignation of a zero total-entropy change for the isothermal

expansion and compression taking place in a reversible heat engine leads, as will be proven below, to the zero total-entropy change for the other transformation associated to a reversible heat engine (refrigerator), namely the transformation of heat from the hot to the cold reservoir (or vice versa); the reason for this is found in the following statement by Clausius “...we may, in the mathematical determination of Equivalence-Value, treat every transference of heat, in whatever way it may have taken place, as a combination of two opposite transformations of the first kind” [4]. By transformation of the first kind Clausius is referring to reversible heat-work interconversions. Making zero the total-entropy change of the first-kind leads, inevitably, to a zero total-entropy change of the second kind which this way becomes determined by the addition of the two zeros associated to the said double transformation.

Let us bring here Carnot’s reversible cycle $ABCD$ described in 1.2 and let us assume that the cycle’s starting point corresponds, as shown in **Figure 1(a)**, to point E , located between A and B on the hot isotherm. The location of this point makes sure that the heat transferred by the hot reservoir to the ideal gas in its expansion from E to B is identical to the amount of heat Q_c released by gas to the cold reservoir along its CD compression. This condition is made possible by the fact that in any such cycle $Q_h > Q_c$. With this condition fulfilled let us now center our attention on the total-entropy change of the concatenation of processes $EBCDA$. Actually, on reason of the fact that processes BC and DA are isentropic, the total-entropy change of this concatenation will be solely determined by the contributions of isothermal and reversible expansion EB and isothermal and reversible compression CD . In the former Q_c is transformed, via the expansion of the gas, into an equivalent amount of work W_c which finds its way into the mechanical reservoir. In the latter W_c is retrieved from the mechanical reservoir in order to carry on compression CD , with the spent work, in the form of its equivalent amount of heat Q_c , being transferred from the gas to the cold reservoir. Let us then write the total-entropy change assigned to this concatenation in the following manner

$$\Delta S_{tot} [EBCDA]_{pCT} = \Delta S[EB]_{pCT} + \Delta S[CD]_{pCT} \quad (7)$$

The already discussed fact that for post-Clausius thermodynamics the total-entropy changes for isothermal and reversible volume changes of ideal gases are zero, translates here into $\Delta S[EB]_{pCT} + \Delta S[CD]_{pCT} = 0 + 0 = 0$, and if so, then

$$\Delta S[EBCDA]_{pCT} = 0 \quad (8)$$

That concatenation $EBCDA$ is the vehicle for the reversible transformation of heat taking place in heat engines is evinced by the fact that no other effect can be associated to this series of changes but the transfer of Q_c from the hot to the cold reservoir: Q_c leaves the hot reservoir to become W_c and W_c finds its eventual way into the cold reservoir as Q_c . With base on the previous consideration, we can then write Equation (8) in terms of the effect produced by $EBCDA$, as follows:

$$\Delta S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)]_{pCT} = 0 \tag{9}$$

That this is indeed the value assigned by post-Clausius' thermodynamics to this transformation can be confirmed in the post-Clausius' thermodynamic literature [20] [21]. Let us now recognize that the process *EA* required to close the cycle is another isothermal and reversible expansion. Through it the ideal gas absorbs an amount of heat Q from the hot reservoir ($Q = Q_h - Q_c$) and transforms it into an equivalent amount of work W . Since no other effect but this can be associated to this expansion it then follows that it is isothermal and reversible expansion *AE* the one responsible for what we have designated as $[Q(T_h) \rightarrow W]$, *i.e.*, for the work effect of the engine. According then to the zero total-entropy change assigned by *pCT* to this kind of processes we can write the following expression for *AE* in terms of the effect by it produced:

$$\Delta S_{tot} [Q(T_h) \rightarrow W]_{pCT} = 0 \tag{10}$$

The total-entropy change assigned by post-Clausius thermodynamics to a reversible heat engine can now be obtained via the summation of the total-entropy changes provided by Equations (9) and (10):

$$\begin{aligned} \Delta S_{tot} [rev.eng]_{pCT} &= \Delta S_{tot} [Q(T_h) \rightarrow W]_{pCT} + S_{tot} [Q_c(T_h) \rightarrow Q_c(T_c)]_{pCT} \\ &= 0 + 0 = 0 \end{aligned} \tag{11}$$

Note then that in *pCT* the zero total-entropy change for a reversible engine is obtained via the addition of two zeros, while in Clausius thermodynamics it comes as the result, as shown by Equations (4) and (5), via the addition of two non-zero quantities. It is the irreducible difference existing between Equations (4) and (11) what evinces the divide between Clausius' and post-Clausius' thermodynamics.

As should be noted, in *pCT* no more disagreement between conclusion and premises exist as the zero total-entropy change for a reversible engine is here obtained via the addition of the zero total-entropy changes for its two subsumed transformations. The fact that apart from the *petit comité* performing the corrections, they passed unnoticed for most of the rest of those concerned, must have assured the former of the soundness of their correction, when in reality all that it proved was the gullibility of most thermodynamicists which apparently tend to believe whatever nonsense is thrown their way.

2.3. The Reversible Heat Engine According to Post-Clausius (Current) Thermodynamics

Whatever the perspective from which it is approached—Clausius', post-Clausius', or negentropic thermodynamics—the procedure for calculating the total-entropy change for one cycle in the operation of a reversible engine starts recognizing that at the conclusion of any such cycle three are the bodies left in a condition different from the one they originally had, namely the two heat reservoirs, and the mechanical reservoir. The return of the working substance or variable body

to its initial condition is precisely what defines a cycle in the operation of these devices.

According then to Planck's prescription of Section 1.1 the total-entropy change for one cycle in the operation of a heat engine is to be determined by the algebraic summation of the entropy changes sustained in it by the said three bodies. This, however, happens not to be so. As described in one of the classic textbooks in post-Clausius' thermodynamics, the total-entropy change is determined solely by the entropy changes of the heat reservoirs:

If a heat engine operates reversibly and passes through a whole number of complete cycles, so that it is in the same state at the end of the operation as at the beginning, it will itself suffer no change of entropy. Hence all the entropy changes are in the rest of the system, and these must sum zero in a reversible process... If Q_h is the heat *taken from* the hot reservoir at T_h and Q_c is the heat given to the cold reservoir at T_c then the increase in entropy of the hot reservoir is $-Q_h/T_h$, and that of the cold reservoir is Q_c/T_c . (Therefore) $-(Q_h/T_h)+(Q_c/T_c)=0\dots$ [22].

For the sake of notation congruence, the q 's from the original quote were here replaced by Q 's.

The absence in the previous equation of the entropy change associated to the effect that the production of work out of heat has on the weight (mechanical reservoir) is explained by these authors in the following manner "The work term does not appear... since it involves no entropy" [22].

Bent, on his part, writes the equation for the engine's total-entropy change explicitly including the entropy change of the mechanical reservoir ($\Delta S_{wt.}$) alongside those corresponding to the heat reservoirs, *i.e.*

$$\Delta S_{total} = (S_{total})_{final\ state} - (S_{total})_{initial\ state} = \Delta S_{400K\ res.} + \Delta S_{300K\ res.} + \Delta S_{wt.} = 0$$

The previous equation refers to a cycle operating between heat reservoirs of 400 K and 300 K. In the next step of his analysis, Bent reduces the previous equation to one written excluding the entropy term of the weight. The reason with which Bent justifies this action being the following: "(as) we know... the entropy of the weight does not change: $\Delta S_{wt.} = 0$ " [23].

Another explanation for the exclusion of this third entropy change from the total-entropy equation for a reversible engine is that of Barrow:

We are at liberty, you should recognize, to ascribe any features to this new entropy function that we like, the requirement being that we construct a function that is self-consistent and allows us to form a useful expression for the second law. In this vein we further specify that, for all processes,

$$dS_{mech\ res} = 0 \quad [24].$$

Instead of the procedure described above, we can also calculate the total-entropy change of the reversible engine via the summation of the entropy changes of the four processes subsumed by it, this in the understanding that these four processes

subsume themselves the totality of the bodies taking any part in the engine's operation. According then to our previous discussion of Carnot reversible engine of **Figure 1(a)**, we might write its total entropy change as the summation of the total-entropy changes of the hot isothermal and reversible expansion [IRE], the adiabatic and reversible expansion [ARE], the cold isothermal and reversible compression [IRC], and the adiabatic and reversible compression [ARC], in the following form

$$\Delta S_{total} [rev. eng.] = \Delta S_{total} [IRE] + \Delta S_{total} [ARE] + \Delta S_{total} [IRC] + \Delta S_{total} [ARC] \quad (12)$$

These four processes correspond, in the order given, to processes AB, BC, CD, and DA of 2.2. As already noted, that the two adiabatic and reversible processes are by definition isentropic, permits reducing the previous equation to the following form:

$$\Delta S_{total} [rev. eng.] = \Delta S_{total} [IRE] + \Delta S_{total} [IRC] \quad (13)$$

The currently accepted procedure for the calculation of the total entropy change for an isothermal and reversible expansion, as will be explained below, is in essence identical to that described in the previous section for the determination of the engine's total-entropy change. In correspondence with the fact that the collection of bodies here involved are the heat reservoir, the gas, and the mechanical reservoir, the following expression can then be written:

$$\Delta S_{total} [IRE] = \Delta S [heat res.] + \Delta S [gas] + \Delta S_{wt.} \quad (14)$$

The rightmost term in the previous equation was written following Bent's notation. The fact that isothermal and reversible expansions (compressions) take place with the heat reservoir and the gas at the same temperature T , allows us to write, for an amount of heat Q transferred from the former to the latter, the following equations: $\Delta S [heat res.] = -Q/T$ and $\Delta S [gas] = Q/T$. Entropy changes of the same magnitude but different signs apply to the transfer of heat taking place in isothermal and reversible compressions. When the previous results, alongside that bit of knowledge provided to us by Bent in the previous section consisting in the "known" constant entropy condition of the weight, *i.e.*

$\Delta S_{wt.} = 0$ [23], are substituted in Equation (14), it becomes, as shown below, equal to zero

$$\Delta S_{total} [IRE] = \Delta S [heat res.] + \Delta S [gas] + \Delta S_{wt.} = -Q/T + Q/T + 0 = 0 \quad (15)$$

A similar equation follows for an isothermal and reversible compression

$$\Delta S_{total} [IRC] = \Delta S [heat res.] + \Delta S [gas] + \Delta S_{wt.} = Q/T - Q/T + 0 = 0 \quad (16)$$

3. The Logical Inconsistencies of Post-Claiuis' Thermodynamics

3.1. An Isothermal and Reversible Expansion is not a System in Equilibrium

Let us consider the conductive transfer of an element of heat dQ from a heat re-

servoir of temperature T to another heat reservoir also of temperature T . Those, which unfamiliar with the subtleties of reversible thermodynamics might object the previous statement, will indeed benefit from the following quote of Clausius on this matter:

This condition cannot indeed be completely fulfilled, since between equal temperatures there can in general be no passage of heat whatever; but we may at least assume that it is to be so nearly fulfilled that the small remaining differences of temperatures may be neglected... for it is only in this case that the heat can pass as readily (in the stated) as in the reverse direction, and if the process is reversible it is requisite that this should be the case [4].

The fact that the said two heat reservoirs are the only bodies taking part in this reversible process allows writings its total entropy change in the following form:

$$dS_{total} [dQ(T) \rightarrow dQ(T)] = (-dQ/T) + (dQ/T) = 0 \quad (17)$$

In the previous equation the self-evident expression inside the bracket identifies the process whose entropy change is being calculated. Read from left to right, the two terms on the right-hand side stand, respectively, for the entropy changes of the heat releasing, and heat receiving reservoirs. The fact that the entropy change produced by the previous equation is the result of the combination of the entropy changes of all the bodies involved in the process being considered is what makes it a total-entropy change. The equality to zero of the total-entropy change indicates that this system, composed of two identical temperature heat reservoirs, is a system in equilibrium and as such, unable to output any work.

Let us now replace one of the heat reservoirs of the previous discussion with a diathermal-walled cylinder which appropriately fitted with a weightless and frictionless piston serves as vessel to one mole of an ideal gas at the same temperature of the reservoir. The piston has been appropriately coupled to a weight-in-pulley mechanical reservoir. Here, as before, an element of heat dQ is transferred from the heat reservoir to the gas in order to be transformed, via the gas opposed expansion, into an equivalent amount of work dW which ends up increasing the weight's potential energy. The constancy of the internal energy of the ideal gas, and with it the constancy of its temperature, stems from the fact that the energy gained by it as heat is subsequently lost as work. The fact that $dQ = dW$ implies, in accord with first law, expressed as $dU = dQ - dW$, that $dU = 0$ and this, in turn, given the sole dependence of U from T in ideal gases, that $dT = 0$. Let us agree from the start that this [IRE] is not a system in equilibrium, but a system in its way to equilibrium. The fact that it is capable of outputting work is the proof of this: "From a system in equilibrium no work can be obtained, but a system on the way to equilibrium may be made to yield useful work" [25]. This consideration hinders us from making any a priori statement about its total-entropy change.

For that system composed by the two heat reservoirs in thermal equilibrium discussed above the statement about constant total-entropy comes easy on rea-

son of the fact that in a system in equilibrium there is no change in state variables or in state functions, such as the entropy. All the trivial, inconsequential changes taking place in such a system produce no alteration in its thermodynamic condition. The situation with the [IRE] is completely different. Here at the conclusion of the process each and every one of the bodies taking part in it finds itself in a completely different state: the heat reservoir has lost an amount of heat dQ , the gas is now in an expanded condition, and the mechanical reservoir at a height different from the one it initially had. If anything, such a situation would lead us to expect a different total-entropy change than that obtained for the heat transfer. This is not, however, what current thermodynamic wisdom asserts. As previously illustrated in 2.3 via Bent's quote, the accepted calculation for the total-entropy change of an ideal gas isothermal and reversible expansion (or compression) goes as follows: "If Q is the heat absorbed by the (gas) then Q must be the heat absorbed by the (heat reservoir). Therefore $\Delta S_{total} = 0$ " [26].

As the previous quote attest, the accepted thermodynamic approach reduces the [IRE], a system in its way to equilibrium, to a reversible heat transfer process, *i.e.*, to a process *in* equilibrium, a move in blatant opposition to the law of contradiction as "...opposite assertions are not simultaneously true" [27]. As the previous discussion evinces, among the notions constituting the logical foundation of the law of increasing entropy we find the one stating that opposite assertions can be simultaneously true. In reference to thermodynamic systems Norton has expressed the law of contradiction in the following terms "A system cannot be out of equilibrium and in equilibrium at the same time" [28].

The fact that $dS_{total} = 0$ is, according to current thermodynamic wisdom, a property of systems in equilibrium means that such a condition does not hold for systems out of equilibrium. This is a solid indication that the total-entropy change for an isothermal and reversible expansion (compression) might not be, as currently accepted, equal to zero.

3.2. Heat and Work as Energy Forms of Different Quality

That work is a higher-quality energy form than heat finds sustenance in a number of experimental facts: 1) the almost total convertibility of work from one form to another; 2) the full convertibility of work into heat; 3) the limited convertibility of heat into work.

As expressed by Smith & Van Ness these considerations point to the fact that:

There is an intrinsic difference between heat and work... heat is a less versatile or more degraded form of energy than work. Work might be termed energy of a higher quality than heat. To draw further upon our experience of natural phenomena, it is known that heat is always transferred from a higher temperature level to a lower one and never in the reverse direction. This suggests that heat itself may be assigned a characteristic quality as well as quantity and that the quality depends upon the temperature. Finally, this use of temperature to measure the quality of heat may be related to the effi-

ciency of conversion of heat into work. Experience shows that, the higher the temperature of the heat used for partial conversion to work, the greater the efficiency of conversion [29].

The positive total-entropy change associated to irreversible processes—the direct, conductive transfer from a hotter to a colder body or the frictional transformation of work into heat, etc.—is commonly interpreted “...as a quantitative measure, or index, of the degradation of energy as work to energy as heat...” [30]. Extension of this interpretation to processes in which energy is upgraded would end up associating those processes with a negative total-entropy change. In simpler words, if the loss of quality or degradation of energy is entropic, it is only natural that the gain of quality or upgrading of energy be negentropic. After all, as Heraclitus pointed out some 2500 years ago: “The way up is the way back” [31].

For post-Clausius thermodynamics while reversible interconversions between heat and work are non-entropic, the irreversible transit from work into heat is entropic. The problem with this position is that the nature of the path, reversible or irreversible, has no saying on, nor power to change at will the different qualities of heat and work which, as Smith & Van Ness recognize, are intrinsic, essential properties of one form of energy and the other. If any saying the nature of the path, reversible or irreversible, has in these processes is in regard to whether the change in quality is permanent, as in the latter, or not, as in the former. In other words, a quality gain emerges every time heat is upgraded into work, and a quality loss every time work is transformed into heat, whatever the path this last transformation might follow, and this in turn means identical positive entropy changes for the reversible and irreversible transformations of a given amount of work into heat of a given temperature.

3.3. The Absurd Position of Post-Clausius' Thermodynamics in Regard to the Entropy Change of the Mechanical Reservoir

It isn't certainly difficult to realize that the gas needs to be in possession of dQ before it can actually start transforming it into dW , and that on reason of this in an [IRE] the transference of heat from the reservoir to the gas, and the transformation of heat into work by the expansion of the gas are two different processes, one taking place after the other. If so, the total entropy change for this expansion must be written, in all strictness, as follows:

$$dS_{total} [IRE] = dS [heat\ res.] + dS [gas] + dS [dQ(T) \rightarrow dW] \quad (18)$$

Or as follows

$$dS_{total} [IRE] = dS [dQ(T) \rightarrow dQ(T)] + dS [dQ(T) \rightarrow dW] \quad (19)$$

In Equation (18) the combination of the entropy changes for the heat reservoir and the gas defines the entropy change for the transference of dQ from the former to the latter. These two terms have been re-expressed in Equation (19) as $dS [dQ(T) \rightarrow dQ(T)]$. In both of the previous equations the term $[dQ(T) \rightarrow W]$ represents the actual transformation of the amount of heat dQ

of temperature T into the equivalent amount of work dW via the opposed expansion of the gas. Even if Equation (19) is similar to Equation (14), there is indeed, as will be shown below, an essential difference between what $dS[dQ(T) \rightarrow dW]$ and dS_{w_i} respectively represent.

The fact that $dS[dQ(T) \rightarrow dQ(T)]$ is necessarily equal to zero allows us to write any of the two previous equations in the following form:

$$dS_{total}[IRE] = dS[dQ(T) \rightarrow dW] \quad (20)$$

The previous equation makes evident the fact that the validity of the second law in the form it applies to the reversible processes under consideration, namely $dS_{total}[IRE] = 0$ requires, demands the entropy change for the transformation of heat into work to be equal to zero. Let me be clear in this regard, no statement about the zero-total entropy change of a reversible and isothermal expansion can be made without previously proving that $dS[dQ(T) \rightarrow dW] = 0$. If proven different from zero then, just like a counterexample disproves a universal, the validity of the second law will be disproved as in this case we will have a reversible process, an [IRE], taking place with a non-zero total-entropy change. Being this so, one would expect to find in thermodynamics treatises, textbooks, and related materials an elegant and rigorous proof that such is the case. After all, the validity of the so-called supreme law of nature depends on it. This proof, however, is absent from any and all thermodynamic sources the present reader may consult. The inability of post-Clausius thermodynamics to provide a proof to this effect is the reason why their constructors opted for the only other option open: they made $dS[dQ(T) \rightarrow dW]$ equal to zero by fiat, by decree, and this they did by decreeing the zero total-entropy change for isothermal and reversible expansions, and with this notion in their hands they proceeded to correct Clausius analysis. It is this action the one resonating in Pitzer & Brewer's statement "The work term does not appear... since it involves no entropy". If anyone wants to know what a scientific fiat looks like, then look at Barrow's quote in 2.3. Bent decided, on his part, to provide some justification, a kind of explanation to said fiat. After all this is a scientific fiat not a religious one nor one coming from some dictatorial regime, i.e., a modicum of scientific hygiene is absolutely necessary. As evinced by Bent's previous quote in 2.3, the justification came via the entropy change of a weight in a weight-and-pulley mechanical reservoir; the underlying assumption being the identity between the entropy change for the thermodynamic process transforming heat into work, and the one associated to the internal condition of the weight. By doing this the problem shifted from providing a proof to the effect that $dS[dQ(T) \rightarrow dW] = 0$, to providing an explanation for why $dS_{w_i} = 0$. The explanation was not difficult to find, it was already common notion. For example, in regard to the raising or lowering of weights taking place in thermodynamic processes Planck states:

Since the weights change only their position and not their internal state, no changes are left in them, since in general all purely mechanical processes

are essentially reversible [3].

With its reversibility thus established, and per Planck's own definition given in 1.1, $dS_{wt} = 0$ follows. This is precisely what Bent is telling us when stating that ΔS_{wt} is equal to zero because (as we know) "... the entropy of the weight doesn't change" [23]. This conclusion reminds me of that quote lifted from the web and attributed to Schrödinger "Once a problem is removed by a feeble excuse there is no further need to ponder over it".

The previous argument has, however, no bearing in the problem at hand. The reason for its irrelevance boils down to the fact that as a conservative mechanical body, the weight in the mechanical reservoir happens to be in a perpetual state of internal equilibrium due to its lack of interaction with other bodies through its boundary, which apart of assumed adiabatic [32] is also assumed to be non-deformable. The previous considerations raise the question: how is it that the internal state of such system, an internal state that in the confines of our discussion doesn't change no matter what, is being used as gauge, as indicator of change? We certainly can't. Its incapability for discriminating a working engine from a non-working one disqualifies its entropy change as proxy for $dS[dQ(T) \rightarrow dW] = 0$. Looking solely at the internal state of the weight we will be prone to assure that the entropy change associated to the work produced out of heat by an inactive, non-working engine is zero! Choosing the internal condition of the weight as measure for the entropy change of the transformation of heat into work is like using a broken speedometer, with its needle fixed at 0 mph, to measure the speed of an automobile. We can always use it as "proof" that the vehicle is not moving, even if we are moving with it.

The previous argument brings to light the proclivity of post-Clausius thermodynamics to describe change in terms of no-change. As previously evinced in 3.1 in its attempt to identify the out of equilibrium isothermal and reversible expansion of an ideal gas with that equilibrium process represented by the transfer of heat between two bodies of the same temperature, now we see its attempt to equate the entropy change for the production of work out of heat with the entropy change of the always in equilibrium internal condition of the weight. A peculiar leaning indeed to the philosophy of Parmenides with its concomitant disregard to that of Heraclitus; while the latter one affirms becoming and change, the former denies them [33].

The previous considerations negating the possibility of using the entropy change for the internal state of the weight as measure for the entropy change of the transformation of heat into work in no way implies the irrelevance of the weight's participation in said process. The role of each of the bodies involved in the production of work out of heat in an [IRE] (or heat engine) is indeed essential, fact that comes to light once it is understood that work-production is the result of the concerted actions of the heat reservoir, the gas and the weight. If there is no heat released by the heat reservoir, there is no work; if heat is made available by this reservoir but not taken in by the gas, no work; if this heat is

taken in by the gas but there is no expansion, no-work; If heat is taken in by the gas but the expanding piston is not connected to the weight we then have a free, unopposed expansion and if so, no work; It is only when we have a weight-opposed gas expansion when the heat dQ released by the reservoir is transformed into the equivalent amount of work dW . The entropy change resulting from this energy upgrading process is this way a property of this collective of bodies. This notwithstanding, the moment the weight, through its displacement in the gravitational field, becomes the vessel, in the form of an increase in its potential energy, of the work produced, it becomes also the repository of the intrinsic qualities of work, namely its chaos ordering, change inducing, and structure forming abilities. These capacities, and the negentropy subsumed by them, accompany the work output in its transit from the moving piston to the displacement of the weight. This couldn't be otherwise. The ultimate purpose of a heat engine, providing us with the work required to transform and upgrade our reality, comes to fruition when in its descent to its original level the weight makes available to us the work originally transferred to it by the engine with all of its previously noted capacities included. No better argument than that for understanding that even if the said capacities are the product of the concerted action of the bodies participating in this transformation, they reside at the core of "work" as its quintessential quality, and are, as such, transferred to the weight.

The displacement of the weight in the gravitational field—the tangible manifestation of the transformation of heat into work taking place in a heat engine or [IRE]—makes this body not only the repository of the product of transformation $[dQ(T) \rightarrow dW]$ and its intrinsic capacities, it also makes it the natural proxy for $dS[dQ(T) \rightarrow dW]$.

The previous notion goes against currently accepted wisdom. This is understandable, after all the thermodynamics of heat, work and their interconversions, as currently understood, were developed under the aegis of that already noted certainty expressed by Pitzer & Brewer as "The work term does not appear (in the entropy balance)... since it involves no entropy" [22].

The above-mentioned qualities or capacities of work are real, that is why work is the vector of progress. If we accept this fact we will also be accepting that there has to be an entropy change for the transformation of heat into work, an entropy change that accounts for the acquisition by the latter energy form of a number of change-inducing capacities absent in heat; in short, we will be accepting that $dS[dQ(T) \rightarrow dW] \neq 0$. Acceptance of this notion, it should be obvious, implies the rejection of the law of increasing entropy as with it we are asserting the existence of reversible processes—an [IRE] in this case—with a total-entropy change different from zero.

3.4. The Quality Identity between Heat and Work at Infinite Temperature

The quality perspective previously described allows us to realize that post-Clausius thermodynamics' position asserting constant entropy for reversible heat-work

interconversions, *i.e.* $dS[dQ(T) \rightarrow dW] = 0$ and $dS[dW \rightarrow dQ(T)] = 0$, subsumes the notion that heat and work are energy forms of the same quality, this with independence of the temperature of the heat. The problem with such a notion is that there is only one temperature where it actually holds. The proof of this assertion is given in what follows.

According to Pitzer & Brewer “If an amount of work dW is degraded to heat at temperature T , the increase in entropy is $dS_{irr} = dW/T$ ” [22]. In accordance with the postulated entropy increase, the ‘*irr*’ sub-index means the transformation is irreversible. Let us then apply the previous equation to the process through which an amount of work dW is degraded into an equivalent amount of heat dQ of infinite temperature, *i.e.*, $dS_{irr}[dW \rightarrow dQ(T = +\infty \text{ K})] = (dW/\infty) = 0$. This result, a zero total entropy change instead of a positive one, indicates, in accord with post-Clausius’ thermodynamics accepted notions, that contrary to assumption, the process is reversible, an indication of the fact that at infinite temperature there is no more an apex and a bottom of quality, rather the quality landscape between heat and work is flat and no change in it occurs when one of these energy forms is transformed into the other. In terms of our notation, we can write $dS[dW \rightarrow dQ(T = +\infty \text{ K})] = dS[dQ(T = +\infty \text{ K}) \rightarrow dW] = 0$. The other salient feature of this result is that infinite temperature is the only temperature at which the quotient dW/T vanishes. For any other temperature the landscape becomes hilly again and in it heat and work retake their roles as different quality energy forms. If the entropy change is indeed and index of quality change in these transformations then for $0 \text{ K} < T < +\infty \text{ K}$ it should be true that

$$dS[dW \rightarrow dQ(T)] = -dS[dQ(T) \rightarrow dW] \neq 0 \quad (21)$$

In the limit of absolute zero the difference in quality between heat and work becomes infinite, *i.e.*, $dS[dW \rightarrow dQ(0 \text{ K})] = dW/0 = \infty$. It is at the absolute zero limit for T where heat, at its lowest quality level, becomes as different as possible from work.

The previous arguments make evident the lack of internal consistency of post-Clausius’ thermodynamics. Contrary to its *fiat* asserting the identity of quality between heat and work, the previous arguments assert, on their part, that the only temperature at which such identity is possible is $+\infty \text{ K}$.

3.5. Final Comments on Post-Clausius’ Thermodynamics

As the popular American saying goes, “there is no such thing as a free lunch”, the debt to be paid for post-Clausius thermodynamics fiat, latent for around one hundred years, having reached maturity, has made itself evident in the patent inability of second-law thermodynamics—the one dealing with order and chaos—to provide a rational, logical, and experimentally-testable model for self-organizing phenomena. The explanation is simple: there is no way for a discipline whose essential tenet is the negation of the difference in quality between heat and work to make sense of the kind of phenomena that emerge precisely on reason of that difference [34]. More on this in Section 10.

Negentropic Thermodynamics

4. The Thermodynamics of Heat and Work as Energy Forms of Different Quality

4.1. Our Conjecture

The essential notion guiding our revision of Clausius work, to be presented below, is the indisputable difference in quality between heat and work. If no such difference existed, as *pCT* claims, then it would be possible for us to accomplish the very same things with an electric motor as with a bonfire. In other words, the starting point of our work on the second law is to negate the zero total-entropy assigned by *pCT* to the reversible inter-conversions between heat and work.

But if not equal to zero, what are then the entropy changes for $[dQ(T) \rightarrow dW]$ and $[dW \rightarrow dQ(T)]$? It is here that we adopt as our conjecture the validity of the values Clausius assigns to the reversible interconversions between heat and work which, as expressed in his quote in 1.3, can be written in the following form

$$dS[dW \rightarrow dQ(T)]_{NT} = dQ/T \quad (22)$$

And

$$dS[dQ(T) \rightarrow dW]_{NT} = -dQ/T \quad (23)$$

The *NT* sub-index attached to the previous equations identifies them as part of negentropic thermodynamics.

It needs to be noted here that also in agreement with Clausius views, as the following quote will make evident, is the conclusion of our argument of 3.2, which based on quality considerations recognized the necessity of entropy changes of the same magnitude for the reversible and irreversible transformations of a certain amount of work into heat of a given temperature:

If... a quantity of heat Q is generated by any process such as friction, and this is finally imparted to a body of temperature T , the uncompensated transformation thus produced has the value Q/T [4].

4.2. Our Conjecture and the Important Notion Subsumed by It

Let us assume that an $[IRE]$ has taken place in which the amount of heat $dQ(T)$ released by the heat reservoir has been transformed through the expansion of the ideal gas, into an equivalent amount of work dW which appears as an increase in the potential energy of the weight in a weight-and-pulley mechanical reservoir. Our previous discussion in 3.1 allows us to write the following equation for the total entropy change of this process in the following manner:

$$\begin{aligned} dS_{total} [IRE]_{NT} &= dS[dQ(T) \rightarrow dQ(T)] + dS[dQ(T) \rightarrow dW]_{NT} \\ &= [(-dQ/T) + (dQ/T)] + (-dQ/T) = -dQ/T \end{aligned} \quad (24)$$

The fact that irrespective of the perspective-Clausius', post-Clausius', or negentropic thermodynamics, the total-entropy change associated to the exchange

of heat between bodies of the same temperature, is zero, explains the absence of a sub-index in the corresponding expression of Equation (24). Let us now use the work dW available in the mechanical reservoir to carry on the inverse process represented by the isothermal and reversible compression of the gas to its initial volume, with the dissipated work transferred to the heat reservoir. At the end of this concatenation of processes we will find that all the bodies changed by the expansion are brought back to their respective initial conditions by the compression: the mechanical reservoir on reason of it releasing along the compression an amount of work identical to that it originally received from the expansion; the ideal gas on reason of it recovering its initial condition (volume and temperature), and the heat reservoir on reason of it taking in an amount of heat identical to that it originally released. The fact that this inverse process takes place with an entropy change of:

$$dS_{total} [IRC]_{NT} = dS [dW \rightarrow dQ(T)]_{NT} + dS [dQ(T) \rightarrow dQ(T)] = dQ/T \quad (25)$$

allows us to see that, as expected, the recovery of the initial condition is accompanied by a zero total entropy change, as follows:

$$dS_{total} [IRE + IRC]_{NT} = -(dQ/T) + (dQ/T) = 0 \quad (26)$$

Let us now, at the light of the previous argument, address the issue of the non-zero total-entropy changes for these two reversible processes by saying that, as Planck's quote in Section 1.1 makes clear, the reversibility—or lack of it—of a given process is determined by the possibility of recovering the initial state. This condition, however, imposes no restriction whatsoever on the value of the entropy changes of the forward ($i \rightarrow f$) and reverse ($f \rightarrow i$) process through which the recovery of the initial condition will occur. The only total-entropy change requirement for the recovery of the initial condition once a process has taken place is that $\Delta S_{total} [i \rightarrow f] + \Delta S_{total} [f \rightarrow i] = 0$. The previous condition, it should be noted, originates on the state function nature of the entropy and as such is fulfilled as long as

$$\Delta S_{total} [i \rightarrow f] + \Delta S_{total} [f \rightarrow i] = a - a = 0$$

with a any real number whatsoever, such as those defining the combination

$$\Delta S_{total} [IRE + IRC]_{NT} = -(Q/T) + (Q/T) = 0$$

An important bit of knowledge emerging from our previous discussion appears subsumed by the total-entropy equation for $[IRE]$, namely

$$dS_{total} [IRE]_{NT} = [(-dQ/T) + (dQ/T)] + (-dQ/T) = -dQ/T \quad (27)$$

In it we can see that the entropy term associated to the release of heat by the heat reservoir, the first term of the right-hand side bracket, represents an entropic effect separate and distinct from that which, with the same magnitude and sign, corresponds to the actual transformation of heat into work, the rightmost term of the expression in the middle. A similar comment applies to the entropy

change of the heat reservoir and the one associated to the actual transformation of work into heat in an [IRC].

4.3. Our Conjecture Leads to a Different Result for

$$\Delta S_{total} [rev. eng]_{NT}$$

If in Carnot reversible cycle $ABCD$ of **Figure 1(a)** we assume zero total-entropy at the beginning (i) of the operation, *i.e.*, $S_{total} [A_i] = 0$, then at the conclusion of process AB we will have $S_{total} [B] = S_{total} [A_i] + \Delta S [AB] = -(W_h/T_h)$. Recall here that at the conclusion of this process the amount of heat Q_h of temperature T_h has been transformed into an equivalent amount of work W_h with an associated entropy change, in accord with our conjecture, of $-W_h/T_h$. This work appears in the mechanical reservoir in the form of an equivalent increase in the potential energy of the weight.

In the adiabatic and reversible transit BC , even if there is no change in the entropy of the gas, there is however a modification—a correction—on the entropy change associated to the transformation of heat into work. The reason is actually very simple. When isentropic process BC disengages the work-producing system—the gas and associated paraphernalia, including the mechanical reservoir—from the hot reservoir, and engages it to the cold reservoir, the work attached to this now cold system becomes indistinguishable from an equivalent amount of work generated at T_c , and on reason of this in the transit BC the entropy effect associated to W_h transits from $-W_h/T_h$ which is the one corresponding to T_h , to $-W_h/T_c$ which is the one which would have been produced had the same amount of work been generated at T_c . Since no other effect but this is produced in this BC transit, we can then write $S_{total} [C] = -(W_h/T_c)$. The quality of heat, it should be remembered, changes with its temperature.

Let us now retrieve W_c from the mechanical reservoir in order to drive isothermal and reversible compression CD which is to take the gas to condition D . Recall here that the total entropy change for process CD or [IRC] in the amount W_c/T_c corresponds to the dissipation and further transfer of W_c in the form of the equivalent amount of heat Q_c to the cold reservoir. The total entropy at D can now be written as

$S_{total} [D] = S_{total} [C] + \Delta S_{total} [CD] = -(W_h/T_c) + (W_c/T_c) = -W/T_c$. In the previous equation $W = W_h - W_c$ represents the work remaining at this point in the mechanical reservoir.

In opposition to the effect brought about by BC we find isentropic process DA disengaging what we called above the work producing system from the cold reservoir and then engaging it to the hot reservoir. In this new condition, as part of the hot isotherm, W becomes indistinguishable from an identical amount of work generated at T_h and if so its negentropy transits from $-W/T_c$ at D to $-W/T_h$ at A . Since no other effect but this takes place along DA we can then write $S_{total} [A_f] = -W/T_h$, where sub-index f stands for final. Therefore

$$\Delta S_{total} [rev. eng]_{NT} = S_{total} [A_f] - S_{total} [A_i] = -W/T_h - 0 = -W/T_h \quad (28)$$

Contrary then to the postulates of the second law of thermodynamics, as currently understood, we find that the total-entropy change for a reversible engine is given by $-W/T_h$, with W , the work available in the mechanical reservoir, representing now the work effect of the cycle, *i.e.*

$$\Delta S_{total} [rev. eng.]_{NT} = -W/T_h \tag{29}$$

An identical result is obtained if we assume that the cyclical evolution of the working substance is to start at point E as shown in **Figure 1(a)**, chosen, as previously explained, in a way such that the amount of heat Q_c transferred by the hot reservoir to the gas in this EB isothermal and reversible expansion is identical to that transferred by the gas to the cold reservoir along isothermal and reversible compression CD . Let us then define $S_{total} [E_i] = 0$ and let us agree that at the conclusion of process EB the total entropy at B will be $S_{total} [B] = -W_c/T_h$. Here W_c is the work produced out of $Q_c(T_h)$. At the conclusion of BC , and for the same reason advanced above for the similar transit of W_p , we will find the total entropy at C being given by $S_{total} [C] = -W_c/T_c$. Isothermal and reversible compression CD takes now place via the consumption of the whole of the work W_c available in the mechanical reservoir. This work ends up as the equivalent amount of heat Q_c in the cold reservoir. In accord with this we can write the following expression: $S_{total} [D] = -W_c/T_c + \Delta S[CD] = -(W_c/T_c) + (W_c/T_c) = 0$. The fact that D finds the gas in contact with the cold reservoir and attached to a depleted mechanical reservoir means that along DA no temperature correction takes place and if so we will have $S_{total} [A] = S_{total} [D] = 0$. If we take a closer look at the series of operations which starting at E , conclude at A , we will realize that they define the reversible transit of Q_c from the hot to the cold reservoir, and that according to our results this process, one of the original transformations with which Clausius defined the effects of a reversible engine, has an associated total entropy change of

$$\Delta S_{total} [Q_c(T_h) \rightarrow Q_c(T_c)]_{NT} = 0 \tag{30}$$

Had Clausius recognized the temperature dependence of the quality of heat, a notion subsumed by the $\pm Q/T$ values he assigned to his two transformations of the first kind, he would have gotten an identical result as the one given by Equation (30), and we wouldn't be having this discussion. Let us now agree that the process required to bring the cycle to its completion is reversible and isothermal expansion AE . In it the amount of heat $Q = Q_h - Q_c$ is transformed into the equivalent amount of work W . The fact that in the transit EA no work effect has taken place means that W is the work output of the cycle and on reason of this, it is process AE the one embodying the second of Clausius transformations. For such a process we will have that $\Delta S_{total} [AE] = -W/T_h$. In terms of this result we can write $S_{total} [E_f] = S_{total} [A] + \Delta S[AE] = 0 - W/T_h = -W/T_h$, and the total-entropy change for this reversible engine will then be given by the following expression

$$\Delta S_{total} [rev eng.]_{NT} = S_{total} [E_f] - S_{total} [E_i] = -W/T_h - 0 = -W/T_h \tag{31}$$

In a display of internal consistency, the total entropy change for the reversible engine takes a form identical to that obtained via the previous approach.

The previously exposed notions lying at the core of each of the three different formulations of the second law have been displayed, in tabular form in **Table 1** below.

4.4. Our Conjecture and the Total-Entropy Change for Non-Reversible Heat Engines

Let us center our attention on the non-reversible heat engine of efficiency η shown in **Figure 2**, which out of the amount of heat Q_h received from a hot reservoir of temperature T_h , manages to output an amount of work $W = \eta Q_h$, where $\eta < \eta_{rev}$, and discard an amount of heat Q_c to the cold reservoir of

Table 1. The three different versions of the second law previously discussed are characterized in the table above by the total-entropy changes assigned by them to the fundamental thermodynamic transformations -those appearing in almost all thermodynamic processes. Note that the difference between Negentropic Thermodynamics (NT) and Clausius work boils down to the entropy changes of the reversible transformations of heat from one temperature to another.

Transformation	Clausius'	Post-Clausius'	NT
$[Q(T_h) \rightarrow W]_{rev}$	$-Q/T_h$	0 (By fiat)	$-Q/T_h$
$[W \rightarrow Q(T_h)]_{rev}$	Q/T_h	0 (By fiat)	Q/T_h
$[W \rightarrow Q(T_h)]_{irr}$	Q/T_h	Q/T_h	Q/T_h
$[Q_c(T_h) \rightarrow Q_c(T_c)]_{rev}$	$Q_c \left(\frac{1}{T_c} - \frac{1}{T_h} \right)$	0	0
$[Q_c(T_c) \rightarrow Q_c(T_h)]_{rev}$	$Q_c \left(\frac{1}{T_h} - \frac{1}{T_c} \right)$	0	0
$[Q_c(T_h) \rightarrow Q_c(T_c)]_{irr}$	$Q_c \left(\frac{1}{T_c} - \frac{1}{T_h} \right)$	$Q_c \left(\frac{1}{T_c} - \frac{1}{T_h} \right)$	$Q_c \left(\frac{1}{T_c} - \frac{1}{T_h} \right)$

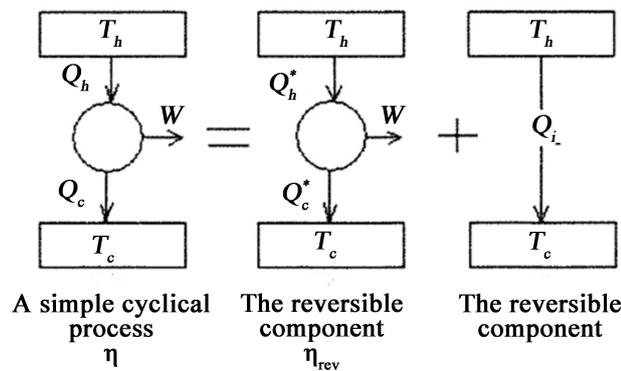


Figure 2. A heat engine of efficiency η is shown here separated in its reversible and irreversible components.

temperature T_c . Had this operation been reversible then instead of W the work output would have been $W_{rev} = \eta_{rev} Q_h > W$.

In order to identify the reversible (*rev. comp.*) and irreversible (*irr. comp.*) components of this non-reversible operation which will also be referred to as [*engine* (η)], we will start defining $Q_h^* = W/\eta_{rev}$ as the amount of heat released by the hot reservoir had the production of W taken place in a reversible fashion. Here $Q_c^* = Q_h^* - W$. The reversible cycle (engine) defined by the triad (T_h, T_c, Q_h^*) becomes this way *the reversible component* of [*engine* (η)] and its contribution to this engine's total-entropy change, in accord with Equation (31) of the previous section, is the following:

$$\Delta S_{tot} [rev. comp.]_{NT} = -W/T_h < 0 \tag{32}$$

The fact that [*engine* (η)] was not capable of tapping the whole of the work-producing potential of Q_h means that a fraction of this heat managed to transit in a direct, irreversible fashion from the hot to the cold reservoir, bypassing this way the work-producing cycle of the working substance.

This amount of heat, to be here designated as Q_i is the irreversible component of [*engine* (η)], and finds quantification in the excess heat received by the cold reservoir in the non-reversible operation in comparison to that received by it in the reversible component, or, equivalently, by the difference between the amounts of heat released by the hot reservoir in the former and the latter operations, *i.e.* $Q_i = Q_c - Q_c^* = (Q_h - W) - (Q_h^* - W) = Q_h - Q_h^*$. The total-entropy change associated to the transit of Q_i from the hot to the cold reservoir is, as known,

$$\Delta S_{tot} [irr. comp.]_{NT} = Q_i [(T_h - T_c)/(T_h T_c)] > 0 \tag{33}$$

That the combination of the reversible component defined by the triad (T_h, T_c, Q_h^*) with the irreversible component defined by the irreversible transfer of Q_i define [*engine* (η)] finds sustenance in the following facts: 1) the amount of heat Q_h released by the hot reservoir in the non-reversible operation is identical with the combined amount released by it for the said components, namely $Q_h = Q_h^* + Q_i$, 2) the work W produced by this engine is identical with that outputted by its reversible component, and 3) the heat received by its cold reservoir identical with the combined amount received by it from the said components, namely $Q_c = Q_c^* + Q_i$. Being this so, the total entropy change for [*engine* (η)] can be written as the addition of the entropy changes of its components as given by Equations (32) and (33)

$$\Delta S_{total} [engine(\eta)]_{NT} = Q_i [(T_h - T_c)/(T_h T_c)] - W/T_h \tag{34}$$

Let us note here that the expression for $\Delta S_{tot} [irr. comp.]_{NT}$ given by Equation (33) can also be written as

$$\Delta S_{tot} [irr. comp.]_{NT} = (Q_i \eta_{rev})/T_c = W_{lost}/T_c \tag{35}$$

In the previous expression W_{lost} represents the wasted work producing potential that Q_i takes with it to the cold reservoir. The use of this last result allows us express Equation (34) in the following form, in which W has been assigned the

“gained” qualifier to emphasize this is the work the engine’s operation has put at our disposal:

$$\Delta S_{total} [engine(\eta)]_{NT} = (W_{lost}/T_c) - (W_{gained}/T_h) \quad (36)$$

Let us now recognize that the law of increasing entropy (*LIE*) is subsumed by Equation (36) as that special case in which $(W_{gained}/T_h) = 0$. Under the application of this condition the previous equation reduces to:

$$\Delta S_{total} [engine(\eta)]_{LIE} = W_{lost}/T_c \quad (37)$$

As an expression of the law of increasing entropy, the previous equation subsumes its two prescriptions as follows: 1) for reversible processes, characterized by the condition $W_{lost} = 0$, we get $\Delta S_{total} [engine(\eta_{rev})]_{LIE} = 0$; 2) for those non-reversible, characterized by $W_{lost} > 0$, we get $\Delta S_{total} [engine(\eta)]_{LIE} > 0$.

The elimination of the work-gained term from Equation (36) even if occurring naturally in all those irreversible processes wastefully dissipating into heat of some temperature the whole of their work-production potential, becomes, however, a matter of *fiat* or decree for all those processes capable of using productively a fraction or the whole of their work producing potential. The *fiat* or decree forcing all these processes to follow Equation (30) is embodied in the previously described position of Pitzer & Brewer, Bent and Barrow which find eloquent expression in the former authors’ justification “the (gained) work term does not appear... since it involves no entropy” [20]. Let us finally note that in our construction’s perspective all those reversible processes whose net effect is the transformation of work into heat, such as Carnot refrigerator or an [IRC], fall also, on reason of being entropic, under the aegis of the law of increasing entropy. These notions are further discussed in Section 9.

Our Equation (36) in terms of W_{lost} and W_{gained} evinces, in this author’s opinion, the essential meaning of what we call a total-entropy change, namely the numerical expression of the result of the battle between chaos (energy degrading) and order (energy upgrading) taking place in the entrails of spontaneous thermodynamic processes; A battle whose outcome depends on the efficiency of those processes. This result is a simple expression of the fact that “... opposing and contradictory motions are the rule throughout the universe, and this is an essential aspect of the mode of things” [35].

Now, while the first term on the right-hand side of Equation (36) can be described by saying that “Entropy reminds us that something we value has been lost-work” [36], the other term, on its part, is the embodiment of *NT*’s essential notion “Negentropy reminds us that something we value has been gained-work.”

Let us finally note, also in Equation (36), that on reason of $T_c < T_h$ the entropic effect of every unit of work wasted or work lost is larger than the negentropic effect associated to every unit of work gained, If the image is allowed, it may be said that the punishment for wasting work is larger than the reward for gaining it.

4.5. The Umbral Efficiency

The fact that within the conceptual frame of our conjecture the total-entropy change for any given heat engine is positive at the irreversible limit ($\eta = 0$) where it reduces to the irreversible transfer of Q_h from the hot to the cold reservoir, and negative at the reversible limit ($\eta = \eta_{rev}$), suggests a zero total-entropy change at some intermediate efficiency. The identification of this efficiency requires setting Equation (36) equal to zero, followed by the performance of the substitution $Q_c = Q_h - W$. The algebraic rearrangement of the resulting expression will lead us to $Q_h \left[(T_h - T_c) / (T_h T_c) \right] = W \left[(T_h + T_c) / (T_h T_c) \right]$ and from here, by properly solving for W/Q_h , to:

$$\eta_{umbral} = W/Q_h = (T_h - T_c) / (T_h + T_c) \quad (38)$$

Any heat engine working at the umbral efficiency will have a total-entropy change of zero; this condition being the simple reflection of the fact that at this efficiency the entropic contribution of the irreversible component is precisely offset by the negentropic contribution of the reversible component represented by the gained work. Engines operating with efficiencies η , $\eta_{umbral} < \eta \leq \eta_{rev}$ are negentropic, those where $0 \leq \eta < \eta_{umbral}$ are, on their part, entropic. The “umbral” qualifier stems from the fact that this efficiency is the borderline between entropic and negentropic operations.

In heat engines the ultimate criterion for an entropic, negentropic, or non-entropic operation is efficiency.

Just like irreversible processes—those wastefully degrading the totality of their work-producing potential into heat of some temperature—are entropic, so are isothermal compressions and Carnot refrigerators, this on reason of their net effect being the transformation of a certain amount of work into heat. Entropic are also all those engines working with efficiencies smaller than the umbral efficiency. On the negentropic side we find all those heat engines and related energy upgrading processes with efficiencies greater than their respective umbral efficiencies.

In our construction the access to negentropic universes is not forbidden, neither total-entropy increase represents a fundamental aspect of the behavior of our universe. As our previous discussion has evinced, the negentropic condition is the result of our access to increasing efficiencies in our energy transforming processes, and this, in turn, depends on nothing else but the working hands and the creative minds of men *i.e.* on nothing else but human effort; in other words, the entropic, unidirectional nature of the law of increasing entropy, and the *Wärmetod* of the universe with it, find themselves, in our construction, replaced by a universe in which the dissipation and decline inherent to entropic processes is opposed by the constructive and ordering power associated to the negentropy of work. The destiny of our world is thus taken away from the grip of supernatural and eschatological forces beyond our understanding and control, to be put back in the hands of men, where it belongs.

This perspective, inherent to negentropic thermodynamics, brings us closer to what Teilhard de Chardin calls the real aim of physics, "... to integrate Man as a totality in a coherent representation of the world" Quoted in [37].

4.6. A Final Comment on Post-Clausius Thermodynamics

The following is a list of characteristics that make of post-Clausius' thermodynamics a unique scientific construction:

For taking as true Clausius conclusion represented by the law of increasing entropy in spite of the logical shortcomings associated to its derivation.

For choosing to support that conclusion with pseudo-scientific notions like the one resorting to the unvarying quality of the inner state of mechanical bodies.

For not attempting to correct the said shortcomings of Clausius analysis in order to properly conclude his enterprise by bringing forward a law that correctly evaluated the effects of energy-transforming processes, as well as:

For adopting the most anti-scientific position possible with the apparent objective of shielding this law from scrutiny, namely that of discouraging us from doubting it, from criticizing it, and from further studying it or, in short, for forcing us to renounce our critical-thinking abilities in the name of this dogma called the law of increasing entropy. The best example of this position can be found in that famous Eddington quote which ends as follows: "... But if your theory is found to be against the Second Law of Thermodynamics I can give you no hope; there is nothing for it but to collapse in deepest humiliation" [7].

No doubt it is to this state of things what Césarman was referring to when saying "Magic and myth take over when reason gives up" [38].

A lot of material—new notions, new perspectives to common notions, etc.—have been omitted. There just so much which can be included in a paper of reasonable length.

4.7. Final Comments

We (thermodynamicists) haven't up to now been able to understand the generation of order in the universe because it was decided by the founders of post-Clausius' thermodynamics to ignore, to left out of their construction the essential role that work plays in it. While the current formulation of the second law is suited for energy degrading, for obliteration of quality, for destruction of order, for the proliferation of chaos; self-organizing phenomena demand a law capable of recognizing as well as quantifying the generation of order.

As evinced by Equation (36), our conjecture has managed to take into account both of these effects, as well as to establish, via Equation (38), the condition for the prevalence of any one of them over the other.

Notwithstanding the logical appeal of our results, we cannot forget that our

Equations (36) and (38) are the products of a conjecture and as such they must be taken, paraphrasing Planck "... to the highest court of appeal-experience" [2] for their validation or rejection. The first step in this direction has already been taken by the present author. It consists in the development of an experimentally testable model for the self-organizing phenomenon known as Rayleigh-Bénard Convection. The first contrasts of this model with available experimental data have produced extremely positive results [34].

Let it finally be stated here that the conjecture introduced in 4.1 in the form of Equations (22) and (23) has become, on reason of the proof advanced to that end by the present author, a certainty. The proof, to be published in the near future, is available now as a preprint in Research Gate [39].

As Immanuel Kant once said, it's funny how categorically wrong you can be about a lot of stuff you think just has to be true [40].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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