The Proell Effect: A Macroscopic Maxwell's Demon

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Background

Since the early days of the Industrial Revolution and the advent of the steam engine, scientists and engineers have developed a clear but incomplete understanding of the nature of heat and its conversion into work. The Second Law of Thermodynamics is the culmination of this understanding regarding the interrelationship of heat and work.

The Second Law of Thermodynamics is often stated as: "Heat flows spontaneously from a hotter to a colder object but not vice versa."[1] It is most succinctly stated as, "When an isolated system undergoes change, its change in entropy will be zero or greater than zero."[2-5]

One interpretation of the Second Law is the Kelvin-Planck Statement: "It is impossible to construct an engine that, operating continuously, will produce no effect other than the extraction of heat from a single reservoir and the performance of an equivalent amount of work."[6]

Another is the Klausius Statement: "It is impossible to construct a device that, operating continuously, will produce no effect other than the transfer of heat from a cooler body to a hotter body."[7]

In the late 1800s, James Clerk Maxwell was asked to comment upon the collective knowledge of thermodynamics at that time. His response accepted what was presented him, with one exception. That exception was voiced as a thought experiment that became known as "Maxwell's Demon." He proposed that thermal energy could separate, given conditions that would support this separation, without the addition of energy to do it. An intelligent being[8] of super-human capabilities of presence in space and time would operate a small, massless and frictionless trap door in a wall separating some air in an otherwise sealed chamber. Initially, that air would be at the same temperature and pressure on both sides of the partition. The being would open and close the door in response to approaches by atoms and molecules in the air. The being would open the door if a particle on one side were fast, allowing it to pass to the other side; a slow particle from that side would be reflected by the closed door. On the other side, the door would only be opened for slow particles, leaving fast particles on that side. The eventual result would be fast particles on one side and slow particles on the other. By the Kinetic Theory of Heat proposed in the late 1800s, it would mean a separation of heat into hot and cold zones without the expenditure of energy to do the separation.

Maxwell's Demon has remained an intellectual curiosity, but mainstream science and engineering have rejected this concept as false; Maxwell's thought experiment has been regarded as a violation of the Second Law. To date, no one has demonstrated a Maxwell's Demon—at least not publicly, so the persistence of this paradox has not bothered the scientific and engineering communities.

Theory

The science of thermodynamics is not complete. Some fundamental knowledge has been missing. A new understanding of the behavior of a confined gas that undergoes a temperature change in an isometric (constant volume, or "isovolumetric," as the author suggests) process has bearing on the Second Law.

Classical thermodynamics analyzes the constant volume process simply, succinctly, and solely as

$$Q = m\,C_v\,\Delta T = \Delta U, \tag{1}$$

where Q is heat, m is the mass of the confined gas, C_v is the specific heat capacity at constant volume, ΔT is the temperature change experienced by the gas, and ΔU is the change in internal energy of the gas. This is for a homogeneous mass and is the only analysis presented by classical thermodynamics. The author is not aware of any other treatment of the constant volume process. See Figure 1 for a graphic presentation of the classical understanding. Analyses of the Stirling cycle, the only common application of the constant volume process in an engine or heat pump cycle, ignore what happens in the constant volume processes. Such cycle analyses use ideal gases and thus claim that its two processes cancel each other completely, since the energy changes are of opposite directions, and the ΔU of each is the same magnitude since U is only a function of T for an ideal gas and the two processes operate over the same temperatures. The details of what transpires in each isovolumetric process with displacement and regeneration are not presented.[9,10]

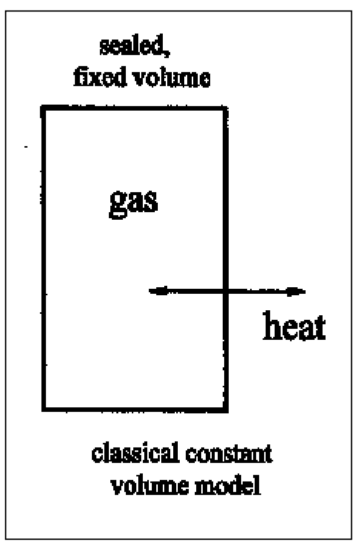

Figure 1. The classical constant volume model.

Wayne Proell[11] was the first person, as far as can be determined, to describe in detail what goes on with gases in a constant volume process which is non-homogeneous, where the volume is separated by a displacer into two different temperature zones that are connected via a regenerative heat exchanger. The author acknowledges Wayne Proell's astute observations by calling the detailed behavior in a constant volume process with displacement and regeneration "the Proell effect." The Proell effect is unrecognized by classical thermodynamics, though it is consistent with classical thermodynamics. It is not seen in the Stirling cycle, because the two constant volume processes in the Stirling cycle are symmetrical, cancel each other, and thus have no net Proell effect on the cycle.

In a non-homogeneous constant volume process with displacement and regeneration (see Figures 2 and 3), the change in volume, ΔV, of an ideal gas discrete element of tiny volume displaced through a regenerator with a ΔT across the regenerator, will change in proportion to that ΔT in accordance with the Ideal Gas Law,

$$PV = nRT, \tag{2}$$

where P is pressure, V is volume, n is the number of moles of gas, R is the gas constant providing engineering unit conversion, and T is absolute temperature. Because of constant volume conditions, the localized ΔV discrete volume element in the porous regenerator must be compensated by an equal and opposite ΔV in the remainder of the gas not in the regenerator. *The corresponding pressure-volume work, W, involved with all localized expansions and compressions, transfers unexpected thermal energy between the regenerator and the gas of the hot and cold sides of the constant volume. Q is converted to W, which is immediately dissipated as Q in another location at a different T.* When a gas is cooled through a regenerator, it compresses, causing compensatory expansion of the gas not in the regenerator, which causes extra cooling of the gas, called self-refrigeration (SR). When a gas is heated through a regenerator, it expands, causing compensatory compression of the gas not in the regenerator, which causes extra heating of the gas, called self-heating (SH). These energy transfers are the essence of the Proell effect. See Figures 2 and 3 for graphic depictions of the processes.

The environment of the regenerator calls for the exchange of Q with the gas at its specific heat capacity at constant pressure, C_P. Intimate contact of the gas and the regenerator material insures constant temperature between the two media at any one location. Since the small parcel of gas undergoes a ΔT via displacement along the regenerator and therefore undergoes a ΔV, the associated compression or expansion W must come from or go to the regenerator, as the gas can only source or sink energy from its ΔU.

$$\Delta U + W = m\ C_P\ \Delta T = \Delta H, \tag{3}$$

where C_P is the heat capacity at constant pressure and ΔH is the change in enthalpy. $\Delta U + W$ implies C_P for the energy transformations inside the regenerator, and not as C_v, predicted by simplistic, classical analyses. This is merely an oversight, a lack of attention to detail. *Its implications are profound.*

The gas outside the regenerator can be in adiabatic hot and cold zones, as analyzed in this presentation. Isothermal conditions have the same anomalous energy flows, but do not exhibit the anomalous temperatures of adiabatic conditions. Adiabatic compression or expansion calls for C_v, as

$$W = m\ C_v\ \Delta T.^{12} \tag{4}$$

W is a transient form of energy. It must be stored or dissipated. It can be stored as kinetic energy, $mv^2/2$, or as potential energy, mgh, for example. It can also be dissipated as Q. Regardless of the pathway, W generated must be balanced according to the First Law of Thermodynamics by W absorbed. For example, W generated in the regenerator by constant volume heating must be compensated by W absorbed as Q in the gas in the bulk-volume, adiabatic zones outside the regenerator,

$$W_{gen} = W_{abs}. \tag{5}$$

Sign convention is ignored since absolute values are all that are important in this presentation, and the temperature changes in the following equations could be misunderstood. By the addition of W to ΔU, the total energy exchange becomes

$$m\ C_P\ \Delta T_{regen} = m\ C_v\ \Delta T_{bulk}, \tag{6}$$

which rearranges to

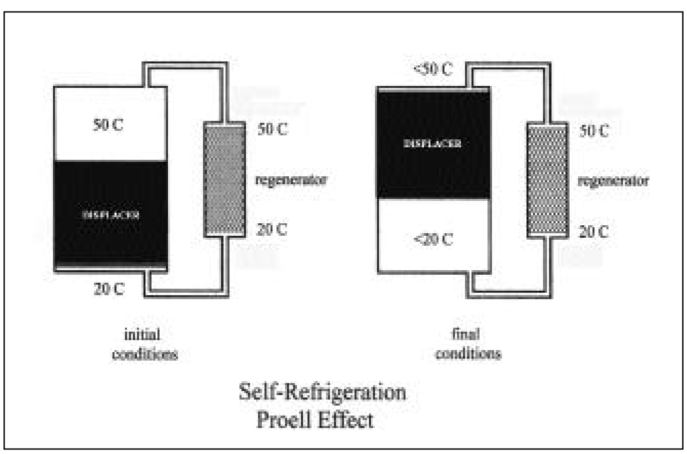

Figure 2. The self-refrigeration Proell effect.

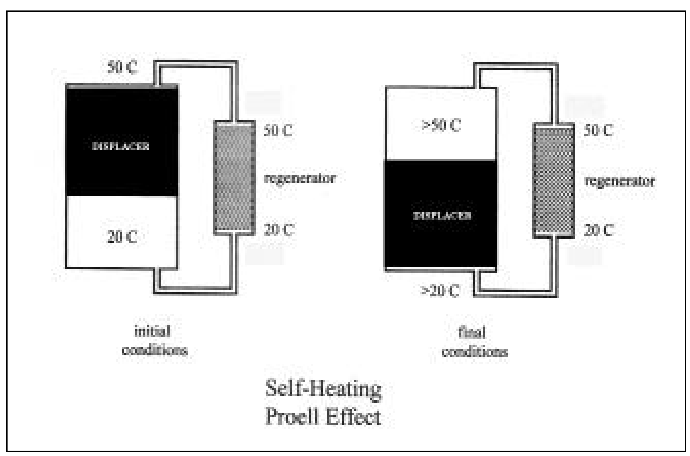

Figure 3. The self-heating Proell effect.

$$\Delta T_{bulk} / \Delta T_{regen} = C_P / C_v = \gamma. \quad (7)$$

The W exchanged in a constant volume process with displacement and regeneration is in addition to the classical analysis of simple heat exchange at C_v with the heat exchanger. As an example of isovolumetric cooling, heat, as internal energy of the gas, is given to the regenerator. The resultant compression work is also absorbed by the regenerator as additional heat, making the total heat absorbed in the regenerator proportional to C_P. The compression work came from the expansion work in the bulk volumes outside the regenerator, which came from the remainder of the gas at C_v outside the regenerator. This is manifest under adiabatic conditions in the bulk sub-volumes of the system constant volume as temperature changes beyond the temperatures of the regenerator. When heat is allowed to flow in and out of those bulk sub-volumes under isothermal conditions, that heat is the heat sourced or sinked by the regenerator corresponding to the W energy.

The extra ΔT in adiabatic conditions is either SR (self-refrigeration) or SH (self-heating):

$$\Delta T_{SR} = \Delta T_{bulk} - \Delta T_{regen} \quad (8)$$

when the bulk volume and regenerator ΔTs are negative, and

$$\Delta T_{SH} = \Delta T_{bulk} - \Delta T_{regen} \quad (9)$$

when the bulk volume and regenerator ΔTs are positive.

The SR or SH energies are capable of being $(\gamma - 1)$ times the ΔU of the gas in the process. This is a potentially large energy transition, which could be used in a practical application. It is comparable to the proportion of work that can be derived from a heat input to boil water under high pressure.

These anomalous energy flows constitute a Maxwell's Demon on a macroscopic level. Thermal energy is transferred "uphill" from one location to another with no energy input under reversible conditions, but the transfer requires a perturbation of the system in order to occur. The displacement of a gas under reversible,[13] constant volume conditions has no work. Work is defined as force times distance. Force is zero, since there is no friction of the displacer and there is no pressure differential across the displacer. The heat separations that occur in the Proell effect are *in addition* to the pre-existing temperature difference between the hot and cold gas zones outside the regenerator and the temperature difference across the regenerator. Half of one Proell effect process, say the heat transfer on the cold side in a cooling stroke, is what constitutes a Maxwell's Demon, as heat is lifted from the cold side into the regenerator over a range of temperatures that are all greater than the resultant gas temperature in the cold side. The same is true for a heating process on the hot side, as heat is likewise lifted with no energy input under reversible conditions. (We mean "no energy input" in the sense of an ideal, reversible perturbation—but in a practical implementation it will be "in the limit, no energy input.")

If constant volume cooling starts with the cold side of the regenerator in dynamic thermal equilibrium with the cold side bulk volume and the ambient environment, the result will be a cold side bulk gas T that is *below ambient T*. This goes strongly against what would have been expected from common intuition. This internal heat sink may be used to advantage. Heat pumps and heat engines that apply the Proell effect have been designed by the author, and patents have been applied for by a corporation, Cool Engines, Inc.

By the most strict definition of the Second Law, the Proell effect is in conformance with it; the net isolated energy system entropy change is zero or greater than zero. The Second Law may be mathematically reduced to

$$\Delta S_{net} \geq 0, \quad (10)$$

where S is entropy. See Addenda One and Two.

For comparison, the same analysis can be applied to Maxwell's traditional thought experiment. What is found is that the isolated system entropy change, assuming the being doing the sorting is adding no energy to the system, is zero! See Addendum Three. This is contrary to the assumed entropy decrease of creating a system with two masses of different temperature from one initial mass at one temperature, as the system is more ordered than it was to begin with. Maxwell's Demon is assumed to be a violation of the Second Law, because the physical principle upon which the Second Law is based is the observation that heat spontaneously flows from high temperature to low temperature to establish thermal equilibrium and does not spontaneously exhibit thermal separations.

The Proell effect has practical considerations that limit its application.

When displacement occurs from one thermal zone to the other, the SR or SH is shared equally between the hot and cold sides. This reduces the maximum temperature excursions beyond the regenerator temperature extremes that may be achieved in one stroke. ΔT_{SR} and ΔT_{SH} are reduced to half of the full theoretical value previously identified with complete displacement. Compensatory work in the bulk volumes of the gas occur in both the hot and the cold sides, for both the heating and the cooling strokes, and throughout each stroke. Summed throughout an entire stroke, the hot and cold sides source or sink the same amount of W. As an increment of gas passing through the regenerator heats up, for instance, its V increases in direct proportion to the T increase by the Ideal Gas Law,

$$dV_{increment} = (nR/P_{increment})\, dT_{regenerator}, \quad (11)$$

where P is variable and incremental because the overall constant volume process will see a P increase as the entire mass of gas is heated from low to high-T in a fixed total V. As P increases over the entire constant volume stroke, the incremental V of gas passing through the regenerator decreases, keeping the incremental W transferred the same.

Full displacement results in half of the Q_{SH} or Q_{SR} manifesting on one side of the displacer,

$$Q_{SHcoldside} = 0.5\ m\ C_v\ \Delta T_{regen}\ (\gamma - 1), \quad (12)$$

and

$$Q_{SHhotside} = 0.5\ m\ C_v\ \Delta T_{regen}\ (\gamma - 1), \quad (13)$$

and

$$Q_{SRcoldside} = 0.5\ m\ C_v\ \Delta T_{regen}\ (\gamma - 1), \quad (14)$$

and

$$Q_{SRhotside} = 0.5\ m\ C_v\ \Delta T_{regen}\ (\gamma - 1). \qquad (15)$$

$Q_{SHcoldside}$ and $Q_{SRhotside}$ are deposited in the regenerator, on the side that received the gas, stored as a change in the thermal profile across the regenerator. It is recognized that the thermal profile in the regenerator will be altered by the entrance of gas with temperatures altered by SR or SH. This decreases ΔT_{regen}, creating a significant engineering challenge to maintain a large ΔT_{regen}.

This effect upon the regenerator temperature differential manifests in practical Stirling cycle engines, though it has not been recognized. The inability of practical Stirling engines and heat pumps to approach the Carnot efficiency closely has likely been attributed to the smearing of the cycle processes by sinusoidal piston and displacer motion; this undoubtedly is a factor, but the Proell effect contributes another significant loss mechanism. A discontinuity is created in the thermal gradient of the regenerator, with the hot side T depressed and the cold side T elevated. This creates entropy-increasing irreversibilities in subsequent heat flows through the regenerator that decrease the manifestation of the separation of heat according to the Proell effect.

Seeing *a net Proell effect in a useful device* requires exceptionally good engineering to make it show up well. Thermal conduction and convection losses also work against a useful application of the Proell effect.

Partial displacement shifts the portions of the Q_{SH} or Q_{SR} manifested on each side. Some gas can remain undisplaced, either on one side or on both sides of the displacer.

If only one side has an undisplaced mass of gas, called a minimum volume by the author, that side is the dominant side, where more than half of Q_{SH} or Q_{SR} will manifest. For a given constant V, less gas will traverse the regenerator and thus less energy will be transferred. For a given mass displaced, partial displacement calls for a larger constant V, and the amount of the Proell effect energy transferred to or from the larger bulk V of gas is increased.

The increased compliance of the larger gas sub-volume is what causes the compensatory W to preferentially interact with that mass and volume of gas. The smaller mass and volume on the other side of the regenerator is stiffer, and less able to source or sink the W, as V will change less for a given, applied P. The new formulae for Q_{SH} and Q_{SR} in processes with a minimum volume on one side of the displacer are,

$$Q_{SRcoldside} = (\text{minimum cold side mass fraction} + 0.5 \text{ hot side mass fraction}) \times (\text{mass transferred})\ C_v\ (\Delta T_{regen})\ (\gamma - 1), \qquad (16)$$

and

$$Q_{SRhotdside} = (0.5 \text{ hot side mass fraction})\ (\text{mass transferred})\ C_v\ (\Delta T_{regen})\ (\gamma - 1), \qquad (17)$$

and

$$Q_{SHhotside} = (\text{minimum hot side mass fraction} + 0.5 \text{ cold side mass fraction}) \times (\text{mass transferred})\ C_v\ (\Delta T_{regen})\ (\gamma - 1), \qquad (18)$$

and

$$Q_{SHcoldside} = (0.5 \text{ cold side mass fraction})\ (\text{mass transferred})\ C_v\ (\Delta T_{regen})\ (\gamma - 1), \qquad (19)$$

where mass transferred is the mass transferred through the regenerator.

The self-refrigeration and self-heating temperature changes in full displacement become,

$$\Delta T_{SRcoldside} = \Delta T_{SHcoldside} = 0.5\ (\Delta T_{regen})\ (\gamma - 1). \qquad (20)$$

The self-refrigeration and self-heating temperature changes in partial displacement with only one minimum V become,

$$\Delta T_{SRcoldside} = (\text{minimum cold side mass fraction} + 0.5 \text{ hot side mass fraction}) \times (\Delta T_{regen})\ (\gamma - 1), \qquad (21)$$

and

$$\Delta T_{SRhotside} = (0.5 \text{ hot side m fraction})\ (\Delta T_{regen})\ (\gamma - 1), \qquad (22)$$

and

$$\Delta T_{SHhotside} = (\text{minimum hot side mass fraction} + 0.5 \text{ cold side mass fraction}) \times (\Delta T_{regen})\ (\gamma - 1) \qquad (23)$$

and

$$\Delta T_{SHcoldside} = (0.5 \text{ cold side m fraction})\ (\Delta T_{regen})\ (\gamma - 1) \qquad (24)$$

More than half of the theoretical Proell effect can be captured, approaching the full theoretical value, when the majority of the gas confined to constant volume is on one side of the displacer, providing regenerator irreversibilities previously identified are minimized. The application of partial displacement of the Proell effect has been incorporated into new heat engine and heat pump cycles, which have patents pending.

The Proell effect is symmetrical and reciprocal, meaning its mere reversal (not to be confused with thermodynamic reversibility) will produce a null net result under reversible conditions if its regenerator is designed to minimize irreversibilities. Regenerator irreversibilities will promote more rapid conduction of heat from the hot side to the cold side, thus decreasing efficiencies or COPs.

Experimental Verification

New Energy Research Laboratory has confirmed the Proell effect. The initial tests were conducted in May 2000, when the laboratory was located in Bow, New Hampshire, and have been confirmed many times, and their significance confirmed with many control experiments.

A plastic cylinder enclosing a fixed volume of gas is heated electrically on one side of a displacer to create a temperature differential across the displacer. See Figures 4, 5, and 6. The displacer doubles as the regenerator, composed of steel wool contained in an open-ended plastic cylinder placed inside the constant volume outer cylinder. Packed plastic drinking straws and coffee stirrer straws have also been used as regenerator material. Displacer motion is controlled manually by magnetic

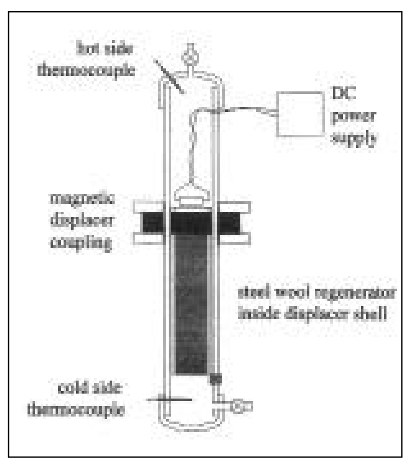

Figure 4. A cut-away view of the test apparatus.

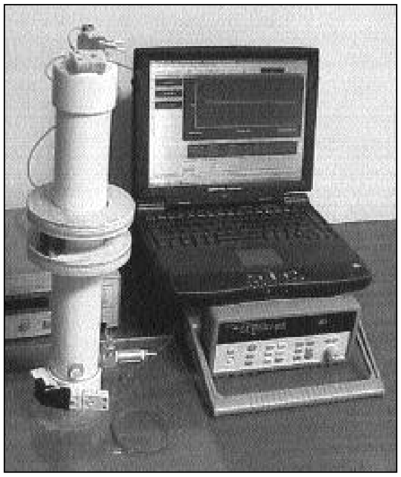

Figure 5. Photograph of the test apparatus.

Figure 6. Photograph of the displacer prior to assembly. Note the acrylic cylinder which forms the displacer shell holds a bar magnet and the steel wool which composes the regenerator. The acrylic shell forms a slip fit inside the PVC tubing seen in Figure 5.

coupling between permanent magnets embedded in the displacer shell and magnets outside of the constant volume cylinder. Thermocouples monitor the temperatures in both cylinder ends, the hot and cold zones. The test apparatus is mounted vertically, with displacer motion in the vertical direction. Electrical resistance heating in the upper gas sub-volume provides the thermal differential across the regenerator before the test begins. Dynamic equilibrium of the apparatus with applied heat is achieved before the displacer is stroked from its equilibrium position, with the displaceable gas present predominantly on the hot side and with the displacer at its lowest gravitational potential. The displacer is then stroked upward to move the heated air through the regenerator to the cold side. After thermal stability is established again, the displacer is lowered to its starting position. The up stroke demonstrates SR and the down stroke demonstrates SH. Thermocouple temperatures are monitored by a computer-controlled datalogger, a Hewlett Packard HP 34970A, with BenchLink software running on a personal computer. The sample period was every 0.3 seconds. Various mechanical configurations of the test apparatus have been used, all demonstrating the effect, but with differing ΔT_{SR} and ΔT_{SH} in the cold zone. Only one is reported in this paper. Different gases have been used in some testers (air, nitrogen, argon, carbon dioxide), with valving on the hot and cold sides of the constant volume cylinder used for flushing and venting. The reported Proell effect temperatures are approximately 60% of theoretically predicted. A 40 gauge (0.001 inch diameter) type K thermocouple was used in the cold zone and a 30 gauge type J was used in the hot zone. Hot zone Proell effects were not monitored in this tester due to noisy T fluctuations caused by turbulence from the heater, so the slower response time of the 30 gauge thermocouple was not a limiting factor. Non-adiabatic conditions cause rapid readjustment of the thermocouple readings after the constant volume is displaced, so the 40 gauge sensor was useful for good detection of thermal changes.

Figures 7 through 13 are data from a series of tests for one test apparatus, done sequentially during one day over a period of about one hour. Hot side temperature and room temperature were recorded in addition to cold side temperature, but only the cold side thermocouple data is graphically presented here. Figure 7 displays the cold side temperature noise characteristics, without stroking the displacer.

In Figures 8 through 13, the displacer was stroked upward 10 seconds into the test and was stroked downward at the 15-second mark.

The displacer was stroked in static thermal equilibrium with the ambient environment, both with the hot side valve open and later closed. Figure 8 is the isobaric (valve open) condition and Figure 9 is the isometric (valve closed, constant volume) condition, respectively. Little above the noise (about 0.1˚C) was seen in either valve state; these are important control test results, to be discussed later.

The test apparatus was then heated to dynamic thermal equilibrium, establishing a thermal gradient across the regenerator, Δ21˚C for air as the gas inside the tester. With the hot side vent open to the atmosphere, establishing constant pressure conditions and preventing thermal disruption of the cold side thermocouple from not using the cold side vent, the displacer was stroked; approximately +/-0.15˚C was seen, mostly displaying a +0.1˚C rise. This is another important control experiment, to be discussed later. See Figure 10. Note that this several second trend (barely visible in this presentation of the data) only occurred on the cooling stroke (the up stroke) and not on the heating stroke (the down stroke). This is attributed to hot air bypassing the regenerator between the regenerator shell and the cylinder wall, and to breakthrough of heat through the regenerator. Convection currents take time to reach the cold side thermocouple.

The hot side valve was then closed, making the device constant volume, and the displacer was then stroked again.

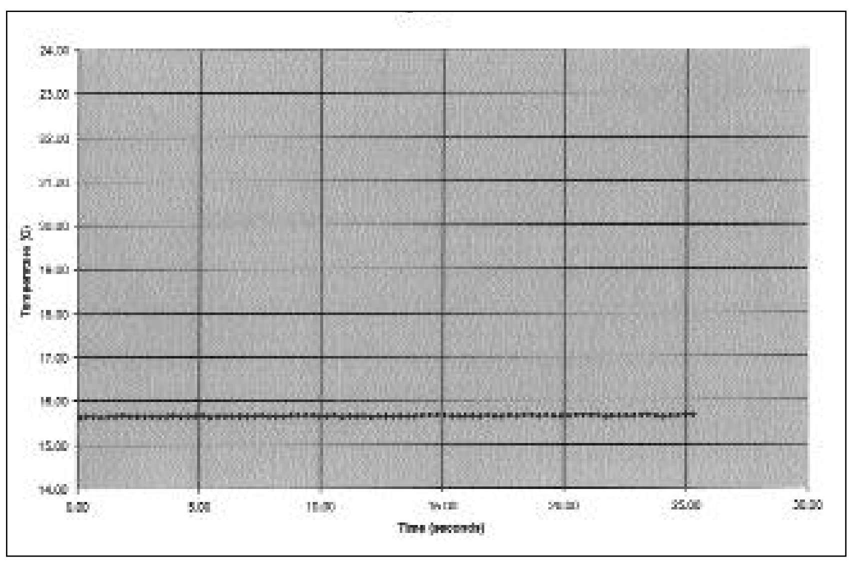

Figure 7. Temperature data for the system charged with air at thermal equilibrium and mechanical rest.

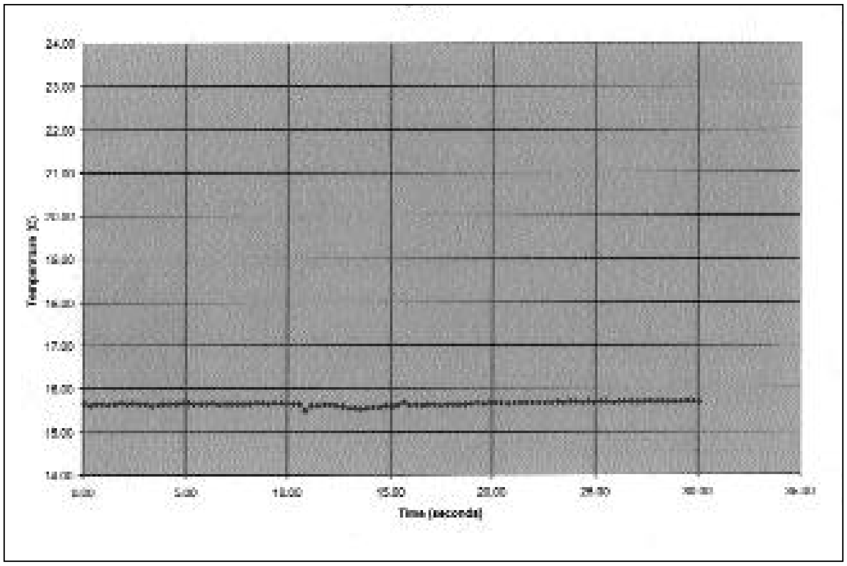

Figure 8. Temperature data for the system charged with air at thermal equilibrium with constant pressure conditions.

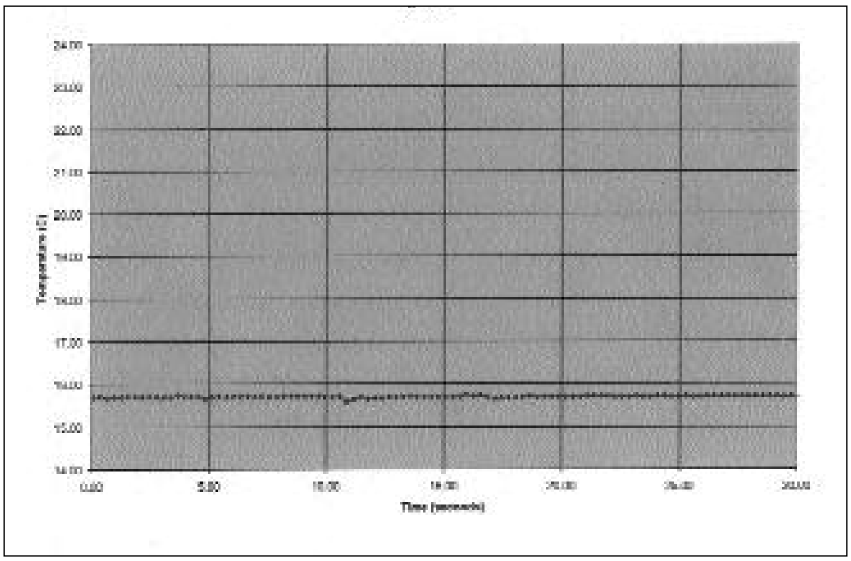

Figure 9. Temperature data for the system charged with air at thermal equilibrium with constant volume conditions.

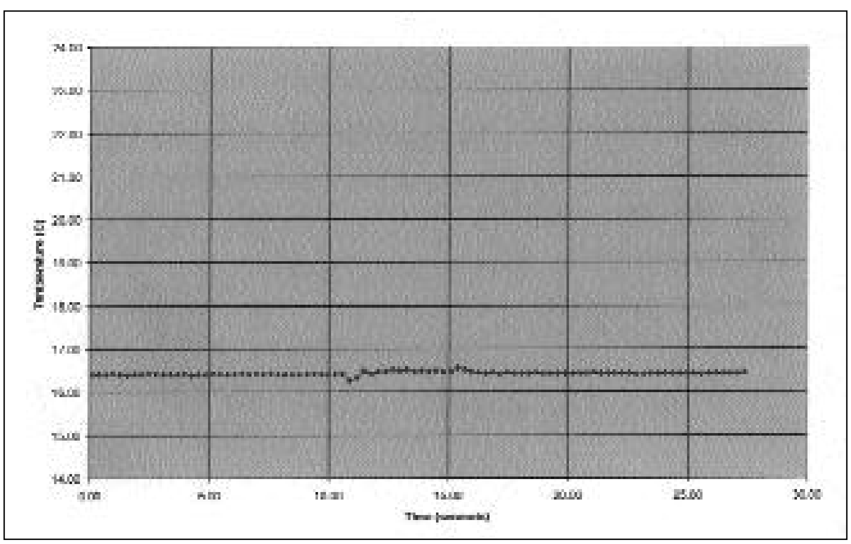

Figure 10. Temperature data for the system charged with air with a temperature difference across the regenerator, in constant pressure conditions.

See Figure 11. The up stroke (cooling) cold side thermocouple falls by several degrees and quickly rises, overshooting its pre-stroke value, and the down stroke (heating) cold side thermocouple rises by several degrees and quickly falls back to its pre-stroke value with some baseline turbulence seen again. The magnitude of the anomalous cooling ΔT is lower than the anomalous heating ΔT, explained by the breakthrough and bypass modalities identified before, which partly cancel the Proell effect self-refrigeration. Note that the Proell effect temperature spikes occur rapidly and the convection effects occur more slowly. The rapid Proell effect spikes *indicate the instantaneous nature of the work transfers*. The rapid re-equilibration of the temperatures is due to non-adiabatic Q flow; previous prototypes—made from insulating materials—produced step-like temperature responses that re-equilibrated much more slowly. Those insulated prototypes were not robust and they deteriorated after a few uses.

Figure 12 is the constant volume stroking of argon, and Figure 13 is the constant volume stroking of carbon dioxide.

When the gas confined in the device is changed, the ΔT_{SR} changes in proportion to the heat capacity ratio γ of the gas. Gases tested other than air have been nitrogen, argon, and carbon dioxide. The results measured in the author's crude test apparatus correlate with the γ values within 22% for the more substantial self-heating spikes. This is a key confirmation of the Proell effect. See Table 1. Four runs were done of each gas under constant volume conditions with a temperature differential.

After the constant volume data of Figures 11, 12, and 13 are understood, the constant pressure data of Figure 10 can be seen to have a miniature temperature excursion pattern just like what is seen in Figures 11 through 13. This could be residual Proell effect of the temperature spikes at the time of the strokes, caused by residual flow restriction from the use of a needle valve for venting the chamber to atmospheric pressure, or it could be Ideal Gas behavior caused by suction or compression from displacer motion.

It is now clear from the analyses in this paper that constant volume conditions produce the same energy transfers inside the regenerator as do constant pressure conditions. The distinction is that in isobaric conditions the work inside the regenerator is balanced by work to or from the atmosphere or the connecting work source or sink such as a compressor or an expander, while in isometric conditions the work inside the regenerator is balanced by the gas within the confined volume.

Arguments against the Proell effect's

experimentally measured temperature anomalies have been presented to the author. The responses to the criticisms are indented for ease of identification.

• The thermocouple test results are artifacts or the thermocouples are faulty.

> Correct thermocouple wiring was verified by applied heat.
>
> Multiple thermocouples track each other, as seen in other test apparati.
>
> Thermocouple outputs correspond in time to the strokes.
>
> There is no noise problem with the thermocouple signals; resolution is generally about 0.02˚C and background thermal fluctuations are about 0.1˚C or less. Relative measurements are all that are necessary. Calibration is not needed because only relative change is needed to document the phenomenon.

• There is a prosaic explanation for the "anomalous" phenomenon.

> The phenomenon is unknown in conventional science to the best of the author's knowledge. (At a bare minimum, this will mandate the revision of *all* textbooks on thermodynamics, in the opinion of my associate, Dr. Eugene Mallove.)
>
> The phenomenon *is not* predicted by conventional thermodynamics, according to general principles. The Second Law of Thermodynamics denies a spontaneous separation of heat.
>
> The phenomenon *is* predicted by conventional thermodynamics, *according to its fine details.*
>
> Control tests of constant pressure at the same temperatures as constant volume, achieved by opening a valve to the apparatus, show no anomalous temperature changes, also in conformance with classical understanding.
>
> Control tests of thermal equilibrium of the regenerator show no anomalous temperature changes, also in conformance with classical understanding.

• The anomalous temperature drops are too small compared to the predictions of the hypothesis to support the hypothesis.

> When the argument is whether or not a phenomenon exists, all that is required to verify its existence is a measurement in that direction. The quality of the measurement is what is important, not the quantity. Is there evidence or is there not? Any result that is well beyond the background noise of the measuring technique will be evidence of its existence and we certainly have that. Optical and spectral observations in astronomy use this technique. Classical electricity and magnetism uses this technique, such as the repulsion of like charges in electrostatics.
>
> Adjustment of stroke portion, using gases with different heat capacity ratios, and reducing pressure differential within the regenerator by the use of flow restrictors on the inlet side of the regenerator all give supporting evidence to the hypothesized phenomena, because these test permutations produce changes in the measured temperatures commensurate with the changes. Though absolute numbers range between 10 to 80% compared to theoretical, gases of different heat capacity ratios track within 25% of each other, which is strong support for the hypothesis.
>
> Slow thermocouple response time, small leaks which compromise constant volume conditions, heat breakthrough from imperfect heat exchange, gas bypass of the regenerator from a poor displacer seal, and non-adiabat-

Gas	Gamma	ΔT_{regen}	Cold Side ΔT_{SS}	Cold Side ΔT_{SS}	Theoretical ΔT_{theory}	Self-Heating Fraction of Theoretical
Air	1.40:1[43]	21°C	-2.0°C	+3.2°C	+/-4.1°C[44]	0.78
		21	-1.7	+3.0		0.73
		21	-1.9	+3.2		0.78
		21	-1.7	+3.2		0.75
Argon	1.67[45]	21	-2.0	+4.3	+/-6.8	0.63
		21	-3.0	+4.0		0.59
-		21	-2.1	+3.8		0.56
		21	-2.0	+4.0		0.59
CO_2	1.30[46]	24	-0.8	+2.5	+/-3.5	0.71
		24	-1.5	+2.3		0.66
		24	-2.0	+2.1		0.60
		24	-1.1	+2.2		0.63

[43] 1997 ASHRAE Fundamentals Handbook, Atlanta, p. 19.77.
[44] The test apparatus has both hot and cold side minimum volumes. Equations 30 and 32 are given the following structure by substituting fractional bulk volume for mass, as absolute temperatures are nearly the same. Cold side minimum fractional V = 6.3 in^3 / (6.3 in^3 cold side min. V + 7.1 in^3 hot side min. V + 14.1 in^3 displaced V) = 0.229. Displaced V = 14.1 / (6.3 + 7.1 + 14.1) = 0.513. $\Delta T_{SS/AH} = (0.229 + 0.5(0.513)\Delta T(\gamma - 1) = 0.486\Delta T(\gamma - 1)$.
[45] 1997 ASHRAE Fundamentals Handbook, p. 19.81.
[46] Buccho, p. 276.

Table 1. Data associated with Figures 11-13. (Author references are sequentially out of order here because this paper is a condensed version of the original paper.)

ic conditions explain the low results.

• Joule-Thompson cooling caused by the displacer's differential pressure explains the anomalous results.

The J-T coefficient, $(\partial T/\partial P)_H$, for air at STP is vanishingly small because the temperature is nearly constant with a change in pressure at constant enthalpy. It will not show up with the conditions of these experiments and the measurement resolution of 0.02˚C.

• Normal behavior for expansion or compression caused by the displacer's suction or compression explains the anomalous results.

Since the hypothesized effect is *not present* in constant pressure conditions as verified experimentally with an open vent on the hot side, and constant pressure conditions still have the ideal gas displacer suction and compression effects on the cold side, a lack of the anomalous T drop eliminates the purported "masking effect" of normal gas behavior.

No anomalous temperature changes are observed when the displacer is stroked while the system is in static, thermal equilibrium, being entirely at room temperature. Since the ideal gas behavior applies whenever the displacer is stroked, regardless of temperatures in the apparatus, the lack of a temporary temperature change with the stroking of the displacer when the apparatus is in thermal equilibrium also eliminates the purported masking effect of normal gas behavior. What is seen in Figures 8 through 10 may be due to normal gas behavior, but cannot explain the results of Figures 11 through 13.

• Since normal gas behavior is a masking effect to the purported effect, quantitative measurement is essential.

As explained above, normal expansion due to suction on the cold side is too small to explain the temperatures measured in Figures 11, 12, and 13.

The open hot side vent test adequately dismisses the normal gas behavior.

• There is a conventional heat pumping action hidden in the test apparatus.

No conventional heat pumping mechanisms have been identified.

By Ocham's Razor, the details of classical thermo provide the explanation.

• Gravity causes heating stroke anomalous heating by the release of potential energy upon decent.

As explained before, a lack of a temperature anomaly in thermal equilibrium and constant pressure conditions with thermal differential disprove this explanation.

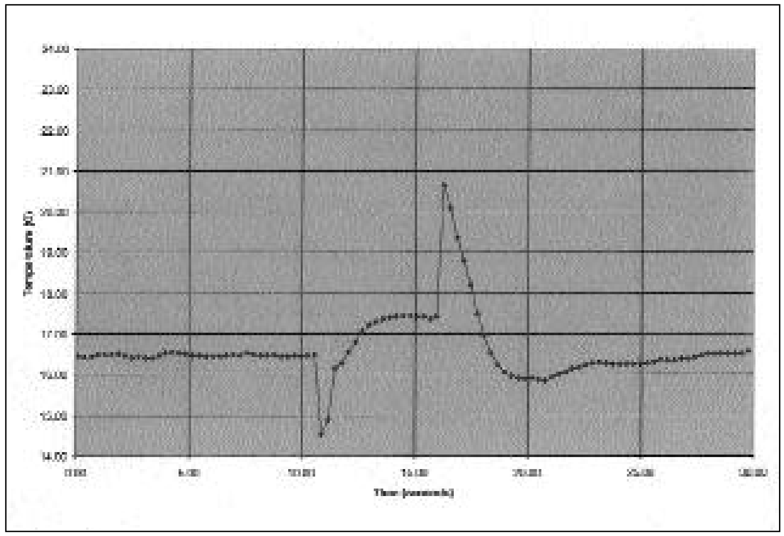

Figure 11. Temperature data for the system charged with air with a temperature difference across the regenerator, in constant volume conditions.

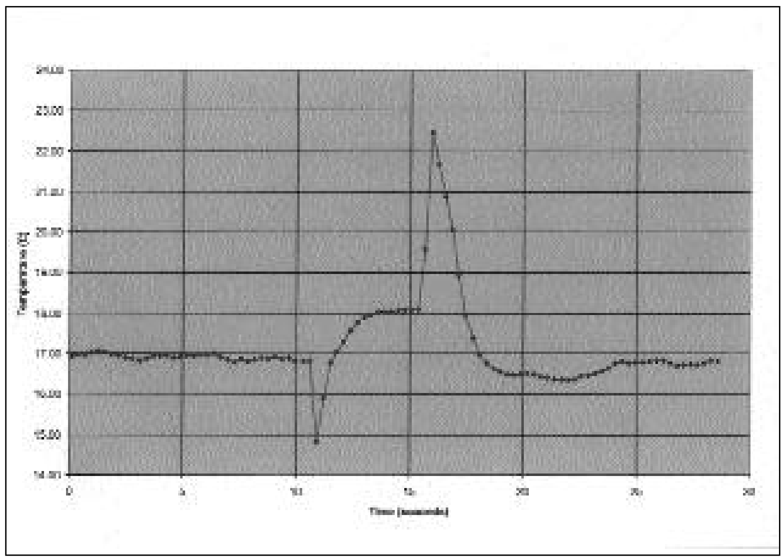

Figure 12. Temperature data for the system charged with argon with a temperature difference across the regenerator, in constant volume conditions.

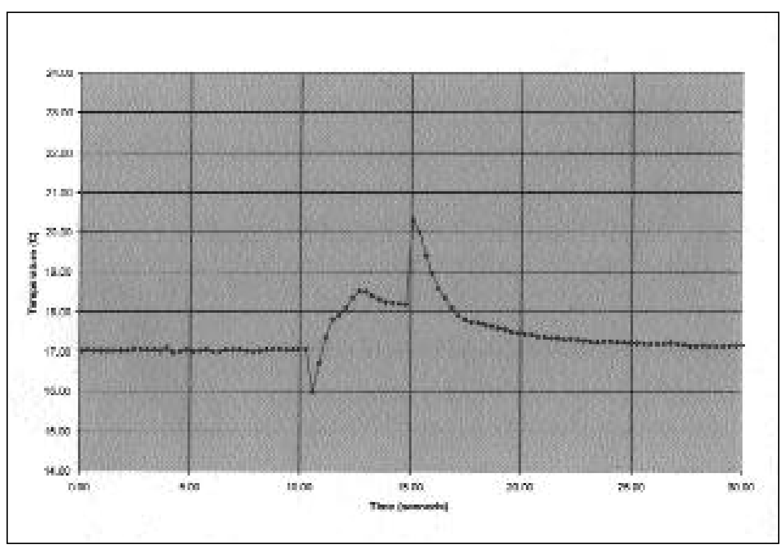

Figure 13. Temperature data for the system charged with carbon dioxide with a temperature difference across the regenerator, in constant volume conditions.

Anomalous cooling of the cooling strokes cannot be explained by this argument.

Conclusions and Discussion

The theoretical prediction of the Proell effect with the aid of analytical details according to standard thermodynamics, plus experimental evidence, prove that this Maxwell's Demon is true and confirmed beyond a reasonable doubt.

The true shock of Maxwell's Demon is not only the separation of heat in violation of Carnot's Theorem, but also the ability to use thermal energy in ways that we have not been able to do until now.

The implications of this Maxwell's Demon are that:

1) This Maxwell's Demon, incorporated into an engine cycle or a heat pump cycle, can in theory make them super-Carnot when the self-refrigeration or self-heating reservoirs are exploited.

2) The heat of the environment is available to do useful work. Since a super-Carnot heat pump or heat engine are possible via the Proell effect, the classical argument of pairing a heat pump and heat engine in contact with high T and low T thermal reservoirs which was used to "disprove" a perpetual motion machine of the second kind (PMM2)[14] can now be used to prove conceptually that a PMM2 *is* possible.

3) Thermal energy is a perpetual source of energy to be transformed into work. Thermal energy does not degrade under all circumstances and is self-sustaining, being capable of doing useful work over and over again. Once-through energy transformations are not necessary.

The Proell effect indicates that Maxwell's thought experiment does apply to the physical universe exactly as devised. The heat reservoirs created beyond the bounds of Carnot's Theorem allow PMM2s to be built that spontaneously cause a reduction in entropy. The Second Law of Thermodynamics must be amended to include negative entropy changes in isolated energy systems under certain conditions, limiting the Second Law's applicability by denying its presumed universality. *The Second Law does not apply when heat can transfer elastically according to the Kinetic Theory of Heat across greater distances between particles than statistically allowed for single particle pair collisions*. Such a condition creates an intermediate form of energy, pressure-volume work, which has no entropy, which breaks the statistically randomizing interactions upon which macroscopic thermal irreversibility is based. In other words, the Kelvin-Planck and Klausius Statements of the Second Law are *false*.

When unity efficiency is possible, there is no need to provide a specific source of heat to a heat engine. A unity efficient heat engine can use the classical heat sink, the environment, as its heat source. A major energy source, once thought to be forever unavailable, has now been made available to meet most of Humankind's energy needs, and without deleterious effects to our planet. It is always available and always has been, and is completely reusable, fulfilling our wildest dreams for abundant energy. The old sayings, "There is no such thing as a free lunch," and, "It is too good to be true," embody a perspective of our physical universe that now must change. This, along with other new energy sources now emerging, may be one of the largest paradigm shifts Humanity has ever experienced. Welcome to the future. Welcome to a new world of astounding potential, when devices based on the now verified Proell effect are eventually built into robust engines and heat pumps. It is, of course, possible that some as yet unknown error has crept into this methodology, but that will be for others to determine. For the author's part, no such error has been found after examining these results for three years.

The author presented the Proell effect and its engine and heat pump cycle designs to Dr. Peter Hagelstein, Professor of Electrical Engineering and Quantum Mechanics, from Massachusetts Institute of Technology, in May 2002. Professor Hagelstein found no flaws in the experiment. He was only able to suggest that the effect might be due to some kind of "chemical potential" at the air-regenerator interface.

The author mentioned the Proell effect phenomenon in discussion with Dr. John Wheeler, Professor of Physical Chemistry, from the University of California at San Diego. In email communication, Professor Wheeler now recognizes the Proell effect as real and as fully consistent with conventional science in its basic form. He intends to write a pedagogical paper for a mainstream physics journal on this subject, particularly as it relates to the Stirling cycle. He does not accept the author's claim that the Proell effect can be exploited to circumvent the Second Law, and does not recognize it as a Maxwell's Demon. The author met with Professor Wheeler at the Gordon Research Conference at the Holderness School, in Holderness, New Hampshire, on August 5, 2003; the Proell effect was demonstrated to Professor Wheeler and no alternate explanations were identified.

This research on the Proell effect was conducted while under the employment of Cold Fusion Technology, Inc., in its New Energy Research Laboratory (NERL), along with various cold fusion and other new energy investigations. This work on the Proell effect and its related applications were not reported in *Infinite Energy* at that time because of intellectual property concerns. Because of NERL's loss of funding (partly collateral damage of 9-11) and the resulting stagnation of the research, Dr. Mallove and the author decided to publish the basic science, which is in the public domain anyway with Wayne Proell's book. (However, particular embodiments of the technology which employ the effect are covered in patent-pending applications.) A manuscript of this work was submitted to *Foundations of Physics*, a mainstream scientific journal that has a history of publishing papers on controversial topics such as this. *Foundations of Physics* rejected the manuscript *without peer review*, citing its unusual nature and the strong opinion that favorable reviews would not be received from enough of the "referees." *Infinite Energy* was then selected as the publication venue for this valuable advancement in thermodynamics. We welcome feedback and amplifications from others—pro and con.

The author thanks Dr. Eugene F. Mallove of Cold Fusion Technology, Inc., and New Energy Foundation, Inc. for his support and assistance with the research and in the writing of this paper. Gratitude is also due to William Zebuhr of Ovation Products Corporation of Nashua, New Hampshire, for his review of the thermodynamic concepts of this paper, and to Peter and October Craig for their personal support of the author's efforts.

Epilogue

This paper stands in stark comparison to mainstream, conventional thermodynamics. Because of the facts it contains and the conclusions that are drawn from them, one wonders how thermodynamics got so far afield that an adjustment based on these recent findings will have to be so severe. Percy Bridgman, 1946 Nobel Laureate in physics, wrote his perspective on the historical acceptance of scientific developments in the introduction of his book, *The Thermodynamics of Electrical Phenomena in Metals*. It illuminates one source of error in science and a good reason for the shock that this paper will undoubtedly create:

> The progress of physics is unsystematic. . .The result is that physics sometimes passes on to new territory before sufficiently consolidating territory already entered; it assumes sometimes too easily that results are secure and bases further advance on them, thereby laying itself open to future possible retreat. This is easy to understand in a subject in which development of the great fundamental concepts is often slow; a new generation appears before the concept has been really salted down, and assumes in the uncritical enthusiasm of youth that everything taught in school is gospel truth, and forgets the doubts and tentative gropings of the great founders in its eagerness to make applications of the concepts and pass on to the next triumph. . .But each new young physicist. . .is in danger of forgetting all the past rumination and present uncertainty, and of starting with an uncritical acceptance of the concepts in the stage of development in which he finds them.[15]

Addendum One: Second Law Analysis of the Proell Effect at Full Displacement

The Second Law of Thermodynamics, in its most basic form, has a mathematically rigorous definition: the net entropy change of an isolated system will be zero or greater than zero.

Three points are defined for this analysis, taking the system change through the isometric process. The initial and final points are mediated by another point corresponding to the classical isometric endpoint, Point 2. The actual endpoint, Point 3, is defined by the Proell effect. The analysis starts with air at 60˚C = 140˚F = 600˚R on the hot side of a displacer, Point 1. The cold side of the displacer is 20˚C = 68˚F = 528˚R, Point 2. By the Proell effect from complete displacement, the SR temperature change, creating Point 3, is

$$\Delta T_{SR} = ((\ 1.40 - 1\ )\ /\ 2\ )\ (\ \Delta T = 600 - 528 = 72˚R\ ) = \Delta 14˚R\ .$$

The final cold T is 514˚R.

Point 1

Using the 1997 *ASHRAE Fundamentals Handbook* table for air at one atmosphere, page 19.77 (not shown here), 14.696 psia and 600˚R = 140˚F gives the following state variables,

P = 14.696 psia,
T = 600˚R,
V = 15.13 cu ft / # (from the reciprocal of 0.0661 # / cu ft),
H = 143.47 Btu / #,
S = 1.6659 Btu / # ˚R,
Cp= 0.2408 Btu / # ˚F,
γ = 1.400,
U = 102.3 Btu / #,

where internal energy, U, does not appear on the table nor on the plot, and is derived from

H = U + PV, or
U = H - PV.

The conversion factor from psia cubic feet per pound to Btu per pound is multiplication by 0.1852. The math, shown once for example, is

(psia) (cu ft / #) = (psia) (cu ft / #) (1.013 x 10^5 N/m^2 / 14.696 psia) x ((12 in / ft) (2.54 cm / in) (m / 100 cm $))^3$ (1 J / Nm) x (1 Btu / 1054 J) = 0.1852 Btu / #.

(14.696 psi) (15.13 cu ft / #) (0.1852 Btu/# / psia cu ft/#) = 41.18 Btu / #,

U = 143.47 - 41.18 = 102.29 Btu / #.

Point 2

Point 2 is derived from the PH plot (not shown here), as the table does not list these conditions. Interpolated from the plot are the following points derived from the first two, given.

V = 15.13 cu ft / #,
T = 528˚R,
H = 126.5 Btu / #,
S = 1.644 Btu / # ˚R.

Pressure is calculated from the Ideal Gas law as a change from Point 1, a more accurate method than interpolation.

constant = P_1V_1/T_1 = (14.7) (15.13) / (600) = 0.371.

P_2 = (constant) T_2/V_2 = (0.371) (528) / (15.13) = 12.9 psia.
U is calculated the usual way.

U = 90.4 Btu / #.

Point 3

Point 3 is also from the PH plot (not shown here), as pressure is not one atmosphere. The first two states are given. Pressure is also from an Ideal Gas calculation referenced to Point 1.

V = 15.13 cu ft / #,
T = 514˚R,
P = 12.6 psia,
H = 123.0 Btu / #,
S = 1.640 Btu / # ˚R,
U = 87.7 Btu / #.

The heat capacity at constant volume, Cv, is calculated from the data from Point 1:

Cv = Cp / γ = 0.2408 / 1.400 = 0.1720 Btu / # ˚F.

The internal energy change from Point 1 to Point 3 is calculated by two methods,

$\Delta U_{13} = U_3 - U_1 = 87.7 - 102.3 = -14.6$ Btu / #, and
$\Delta U_{13} = (\Delta T_{13})$ Cv = (514 - 600) (0.1720) = -14.8 Btu / #.

The discrepancy between the two is due to plotting and interpolation errors which affects the state variables derived from the PH plot.

The entropy change of the air from Point 1 to Point 3 is

$\Delta S_{13} = S_3 - S_1 = 1.640 - 1.666 = -0.026$ Btu / # ˚R.

The entropy change of the regenerator is

$\Delta S_{regen13} = (Q_{13} = -\Delta U_{13}) / (T_{regen}$ = the average of T_1 and T_2) = (14.8) / ((600 + 528) / 2 = 564 ˚R) = +0.0262 Btu / # ˚R.

The net entropy change of this isolated system, as a reversible isometric process has no work input or output, and therefore is simply

$\Delta S_{net} = \Delta S_{13} + \Delta S_{regen13} = -0.026 + 0.0262 \approx$ zero.

Addendum Two: Second Law Analysis of the Proell Effect at Partial Displacement

Another Second Law analysis is presented here, this time for partial displacement. For comparison, the same system as Addendum One is used with modifications for partial displacement.

Three points are defined for this analysis, taking the system change through the isometric process. The initial and final points are mediated by another point corresponding to the classical isometric endpoint, Point 2. The actual endpoint, Point 3, is defined by the Proell effect. Because partial displacement creates split states, the state variables at Point 1 are not as straightforward as in the previous analysis of full displacement. The analysis starts with some air at 60˚C = 140˚F = 599.8˚R on the hot side of a displacer, and some air at 20˚C = 68˚F = 527.8˚R on the cold side of the displacer.

Point 1

Using the 1997 *ASHRAE Fundamentals Handbook* table for air at one atmosphere, page 19.77 (not shown here), 14.696 psia and 599.8˚R = 140˚F gives the following state variables for the hot side of the displacer,

P = 14.696 psia,
T = 599.8˚R,
V = 15.13 cu ft / # (from the reciprocal of 0.0661 # / cu ft),
H = 143.47 Btu / #,
S = 1.6659 Btu / # ˚R,
Cp = 0.2408 Btu / # ˚F,
γ = 1.400.

Internal energy, U, does not appear on the table nor on the plot, and is derived from

H = U + PV, or
U = H - PV.

The conversion factor from psia cubic feet per pound to Btu per pound is multiplication by 0.1852. The math, shown once for example, is

(psia) (cu ft / #) = (psia) (cu ft / #) (1.013 x 10^5 N/m^2 / 14.696 psia) x ((12 in / ft) (2.54 cm / in) (m / 100 cm))^3 (1 J / Nm) x (1 Btu / 1054 J) = 0.1852 Btu / #.

(14.696 psi) (15.13 cu ft / #) (0.1852 Btu/# / psia cu ft/#) = 41.18 Btu / #,

U = 143.47 - 41.18 = 102.29 Btu / #.

The state variables for the cold side of the displacer at Point 1 are still from the ASHRAE table, as pressure is still one atmosphere in both split states of Point 1. The interpolation factor between the lines of data at 60 and 80˚F is

interpolation factor = (68 - 60) / (80 - 60) = 0.4000,

so

P = 14.696 psia,
T = 527.8˚R = 68˚F,
V = 0.4000 (0.0735 - 0.0763) + 0.0763 = 0.0752 # / cu ft = 13.30 cu ft / #
H = 0.4000 (129.03 - 124.22) + 124.22 = 126.14 Btu / #,
S = 0.4000 (1.6406 - 1.6315) +1.6315 = 1.6351 Btu / # ˚R.

U is calculated the usual way, but from the interpolated values above.

U = 89.94 Btu / #.

The average state variables which define Point 1 are calculated from the distribution between the hot and cold sides. Assume one pound of air is the total mass in the fixed volume. It is given that the mass of air is divided between hot and cold sides in Point 1 as 0.2 # on the hot side and 0.8 # on the cold side. Point 1's average state variables are as follows:

P = 14.696 psia,
T = 0.2 (599.8˚R) + 0.8 (527.8∞R) = 542.2˚R, where average T fits the Ideal Gas Law,
V = 0.2 x (15.13 cu ft / #) + 0.8 # (13.30 cu ft / #) = 13.67 cu ft/#,
H = 0.2 x (143.47 Btu / #) + 0.8 # (126.14 Btu / #) = 129.61 Btu/#,
S = 0.2 x (1.6659 Btu / # ˚R) + 0.8 # (1.6351 Btu / #) = 1.6413 Btu / ˚R/#,
U = 0.2 x (102.29 Btu / #) + 0.8 # (89.94 Btu / #) = 92.41 Btu/#.

Point 2

Point 2 is not a split state and one set of variables applies. The first two variables are given:

T = 527.8˚R = 68˚F,
V = 13.67 cu ft/#.

Pressure is most accurately calculated from an Ideal Gas derivation that references the tabulated variables of Point 1's hot side:

constant = PV/T = (14.696) (15.13) / (599.8) = 0.3707.

P_2 = (constant) T_2/V_2 = (0.3707) (527.8) / (13.67) = 14.31 psia.

Enthalpy is nearly parallel to temperature in this range of the PH plot. Since the temperature of Point 2 is the same as the cold side of Point 1, the enthalpy is taken to be that of the cold side of Point 1:

H = 126.1 Btu / #

Entropy is linearly extrapolated from the PH plot by means of a ruler measurement of Point 3 between each isocline and perpendicular to the isoclines.

S = 1.6374 Btu / # ˚R

Internal energy is calculated in the usual way.

U = 89.9 Btu / #

Point 3

According to the Proell effect, the extra temperature change in isometric cooling, or self-refrigeration, SR, is

ΔT_{SR} = ((1.40 - 1) (X_{cold} + 0.5 (X_{hot}) = 0.8 + 0.5 (0.2) = 0.9)) x (ΔT = 542.2 - 527.8 = 14.4˚R) = Δ5.2˚R.

The final cold T is

T3 = T2 - ΔT_{SR} = 527.8 - 5.2 = 522.6˚R.

The volume is still the same,

V = 13.67 cu ft/#.

Pressure is calculated from Ideal Gas Law relations as before:

P = (constant) T/V = (0.3707) (522.6) / (13.67) = 14.17 psia.

The remaining variables of Point 3 come from the PH plot.

H =125.0 Btu / #
S = 1.6358 Btu / # ˚R
U = 89.1 Btu / #

The heat capacity at constant volume, Cv, is calculated from the data from Point 1:

Cv = Cp / γ = 0.2408 / 1.400 = 0.1720 Btu / # ˚F.

The internal energy change from Point 1 to Point 3 is calculated by two methods,

$\Delta U_{13} = U_3 - U_1$ = 89.1 - 92.4 = -3.3 Btu, and
$\Delta U_{13} = (\Delta T_{13})$ Cv = (522.6 - 542.2) (0.1720) = -3.37 Btu / #.

The discrepancy between the two is due to plotting and interpolation errors which affects the state variables derived from the PH plot. The second calculation has more precision and therefore is preferred.

The entropy change of the air from Point 1 to Point 3 is

$\Delta S_{13} = S_3 - S_1$ = 1.6358 - 1.6413 = -0.0055 Btu / # ˚R.

The entropy change of the regenerator is

$\Delta S_{regen13}$ = ($Q_{13} = -\Delta U_{13}$) / (T_{regen} = the average of T_1 and T_2) = (3.37) / ((542.2 + 527.8) / 2 = 535.0 ˚R) = +0.00630 Btu / # ˚R.

The net entropy change of this isolated system, since a reversible isometric process has no work input or output, is simply

$\Delta S_{net} = \Delta S_{13} + \Delta S_{regen13}$ = -0.0055 + 0.00630 = +0.0008 Btu /#˚R.

The non-zero result is likely due to state variable inaccuracy, particularly the graphically interpolated values.

Addendum Three: Second Law Analysis of Maxwell's Demon

The Proell effect has been analyzed under two different conditions and found to conform to the mathematical definition of the Second Law of Thermodynamics, shown in Addenda One and Two. This seems odd because it effects a separation of heat, which normally is construed to be an ordering of the thermal energy and thus a decrease in entropy.

For comparison, the classical description of Maxwell's Demon, that of a partitioned gas enclosure, has been mathematically analyzed and found to likewise conform to the Second Law! The Second Law's mathematical definition is

$\Delta S_{net} \geq 0$.

State variables for a simple system were selected from the 1997 *ASHRAE Fundamentals Handbook*, p. 19.77, for air at one atmosphere. It is assumed that the system starts at thermal equilibrium at one atmosphere and ends at one atmosphere. The partition just happens to be where the mass is distributed properly at the end to produce no net pressure difference across the partition, and to split the total mass in half at the end of the transfer. Heat capacity at constant P is virtually unchanged throughout the Ts used, so the equal T deviations in the separation, high and low, reflect First Law balancing of Q between the two sides. For the sake of simplicity, the analysis starts with a total mass of one pound of air. Its initial state is given as

Initial State

Temperature, T_1 =	60˚F,
Entropy, S_1 =	1.6315 Btu/#˚F,
Mass, m_1 =	1 pound,
Heat capacity, Cp =	0.2403 Btu/#˚F.

Its final state is given as

Final State

Temperature, T_{2hot} =	80˚F,
Entropy, S_{2hot} =	1.6406 Btu/#˚F,
Mass, m_{2hot} =	0.5000 pounds,
Heat capacity, Cp =	0.2404 Btu/#˚F.
Temperature, T_{2cold} =	40˚F,
Entropy, S_{2cold} =	1.6221 Btu/#˚F,
Mass, m_{2cold} =	0.5000 pounds,
Heat capacity, Cp =	0.2403 Btu/#˚F.

The change in entropy is

$\Delta S_{net} = (S_{2hot} + S_{2cold}) - S_1 = 0.5(1.6406 + 1.6221) - 1.6315 = -0.0001$ Btu/#˚F.

This negative system entropy change is at the resolution of the data and could reflect state variable inaccuracy.

Isn't it amazing that something as simple as this has not been identified before? Here is simple evidence that the foundations of science are not as solid as we thought.

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