Heat engines are powered by pressure – not heat

Vesa J. Hukkanen

Hotbenefits, Oulu

December 14, 2021

Author note

Declaration of interests: The author has filed a patent application for an engine technology that is relevant to this article's contents.

Correspondence: Correspondence concerning this article should be addressed to juha.hukkanen@hotbenefits.com

Abstract:

The gas laws bind together volume, pressure and temperature. Despite that, Sadi Carnot discovered in 1824 that only the heat engine's hot- and cold-side temperatures determine its maximum efficiency. Since then, the engineers have been calculating efficiencies using temperatures and an equation:

$$\eta_{max} = \eta_{Carnot} = 1 - T_{(cold\ reservoir)} / T_{(hot\ reservoir)}$$

This article shows that the same Carnot efficiency values can be obtained using the exit- and entry-side pressures. Also, the more universal equation for calculating maximum efficiencies for heat engines is:

$$\eta_{max} = 1 - P_{(exit\text{-}side)} / P_{(entry\text{-}side)}$$

This article demonstrates that it is the entry-side's relative over-pressure that is powering the heat engines. When the Carnot efficiency's share of energy has been removed from the system, the pressure coming from the entry-side has been reduced to an equal level with the exit-side pressure. At that moment, the exit-side's pressure pushes the heat engine with equal force from the opposite direction than the entry-side's pressure is pushing it. Ultimately, these equal but opposite forces end the heat engine's ability to obtain energy with a higher efficiency from the system - precisely at that Carnot efficiency level. The functional role of the exit-side pressure is to reduce the heat engine's ability to remove heat energy from the system in form of useful work. This article also links together the Newton's laws of motion and the engine efficiency.

Keywords: Carnot's theorem, heat engine, pressure engine, opposing exit-side, internal energy, Newton's first law, engine efficiency, thermal efficiency

Introduction:

Efficiency of an engine

A dictionary definition for an ”*engine*” suggests that it is primarily ”*a machine for converting any of various forms of energy into mechanical force and motion”* (Merriam-Webster. Engine., n.d.). Another online dictionary says it is ”*a machine for converting thermal energy into mechanical power to produce force and motion”* (Random House Dictionary. Engine., n.d.*).* These definitions open up a field of technology, which provides energy for the everyday needs of mankind. There are many kinds of engines, and each engine type is more or less successfully tailored for harvesting energy from specific energy sources. A dictionary definition for a ”*heat engine*” suggests that it is ”*a mechanism (such as an internal combustion engine) for converting heat energy into mechanical or electrical power”* (Merriam-Webster. Heat engine., n.d.).

Engines do not create energy. They take a portion of the system's internal energy and convert it into motion. After that, that motion can be further converted into other forms of energy. These energy conversions happen with varying efficiencies as a portion of energy always tends to be lost in the form of heat(Q) or is lost due to technical inefficiencies of the engine. Thermal efficiency(η_{th}) is a dimensionless performance measure of a device that uses thermal energy. Heat engine’s thermal efficiency represents a fraction of the thermal energy, which the heat engine is able to capture from the amount of thermal energy which is passing through the engine and convert into net work(W_{output}) output. Heat engines are unable to convert all of the system’s added heat (Q_{input}) into work (W_{output}), which leads to a dissipation of waste heat ($Q_{waste\ output}$) into the environment.

$$Q_{(input)} = W_{(output)} + Q_{(waste\ output)}$$

Theoretical and practical maximum efficiencies of different types of engines vary greatly. For example, hydroelectric generators can operate with up to a 90% efficiency (Elbatran et al., 2015). The theoretical maximum efficiency percentage for wind-power generators is about 59.3%, and this limit is known as the Betz law. In reality, the maximum efficiency percentage for wind-power generators is about 30-45%. (Bright Hub Engineering, 2010). It should be noted that the turbines of the hydroelectric and wind-power plants do not need to have a temperature gradient between their entry- and exit-sides. Thus, they are not classed as heat engines. It would be impossible for a Carnot heat engine to have such high efficiencies, having a ”cold reservoir” in normal atmospheric temperature and without a very hot temperature at its ”hot reservoir’s” side.

Real heat engines have wildly varying theoretical and practical maximum efficiencies. The theoretical maximum efficiency for the heat engine is 100% when the heat engine's ”cold reservoir” would be at absolute zero; 0 degrees Kelvin (Lumen Learning, 2020a; Srinivasan, 1996). In fact, Lord Kelvin used this theorized upper limit in his attempts the discover the accurate value of absolute zero temperature (Chang & Yi, 2005; Thomson, 1851).Most practical heat engines operate well below the 50% efficiency level (“Thermal efficiency,” 2021). For example, thermal efficiency levels of most road legal gasoline-driven automobiles are only around 20-35% (“Engine efficiency,” 2021).

Carnot’s theorem

A heat engine’s thermal efficiency represents a share of the energy, which the heat engine can transform into useful work. Thermal efficiency can be defined using the following formulas (“Thermal efficiency,” 2021).

$$\eta_{th} = \frac{W_{output}}{Q_{input}} = \frac{Q_{input} - Q_{output}}{Q_{input}} = 1 - \frac{Q_{(output)}}{Q_{input}}$$

In 1824 Sadi Carnot published (Carnot, 1824) his observation-based findings, which suggested that the maximum efficiency of a reversible Carnot heat engine would only depend on the temperatures of the heat engine’s hot and cold reservoirs (“Carnot's theorem,” 2021). This would lead to a predefined maximum efficiency limitation for all heat engines, which could be solved using the following equation.

$$\eta_{max} = \eta_{Carnot} = 1 - \frac{T_{(cold\,reservoir)}}{T_{(hot\,reservoir)}}$$

Sadi Carnot’s main objective was to investigate the ability of heat to provide mechanical work. His groundbreaking observations have been confirmed in various ways and by numerous researchers. However, the Carnot’s theorem has been observed to have some issues, which in some cases may limit its usefulness. For example, Koeck (2017) had observed an “Apparent contradiction between Carnot's theorem and efficiency calculations”, when he wrote:

> A Carnot engine running between two temperatures Tc and Th has the efficiency 1-Tc/Th. According to Carnot’s theorem all reversible engines running between Tc and Th would have the same efficiency. However if I calculate the efficiency for an engine with two isotherms at Tc and Th which are connected by either isobars or isochors I get an efficiency lower than that of the Carnot process unless I let the compression ratio become infinite. How do I resolve this contradiction.

The typical Carnot engine terms ”hot reservoir” and ”cold reservoir” do not fit properly to the contents of this article, as this article will show that the heat engine’s cold- and hot-side temperatures are not powering the heat engine. Later in this article, evidence system 3 will show that sometimes the heat engine’s higher temperature reservoir can even be found at the heat engine’s exit-side. Therefore, this article uses ”Hot Entry Side” and ”Cold Exit Side,” or just entry-side and exit-side, instead of a hot and cold reservoir.

The Purpose

The purpose of this article is to show that the heat engine’s entry-side relative over-pressure is powering the heat engine – irrespective of the hot- and cold reservoir temperatures. If the article’s central discovery, the critical role of the entry-side’s relative over-pressure, would turn out to be correct, then it would liberate the heat engine’s efficiency from being limited by the current mandatory requirement of having a significant temperature difference between the heat engine’s entry-side and exit-side. Such increased knowledge might help in facilitating the innovation of new energy technological breakthroughs and speed up the ”Green Transition.”

Materials and methods

This article uses five simple heat engine evidence systems and some widely accepted equations and physics laws to demonstrate that the entry-side's relative over-pressure powers the heat engines and that the heat engine's ability to obtain energy with higher efficiency ends when the over-pressure has been fully consumed. Each of the five utilized heat engine systems provides a slightly different kind of supporting evidence for the primary role of the entry-side's over-pressure for the heat engine's ability to operate. It is then assumed that the results of these five heat engine systems will together form enough tight net of evidence that forces a paradigm shift in the thinking of what powers the heat engines.

Evidence system:	**What the evidence system will show:**
1	Heat engine's entry- and exit-side pressures can be used for obtaining the same temperature-based Carnot efficiency values. A complete lack of exit-side pressure enables a 100% maximum efficiency. The higher the exit-side pressure is, the less is the heat engine's maximum efficiency.
2	The heat engine's maximum efficiency percentage is equal to its entry-side's over-pressure percentage. Exit-side pressure will be equal with the entry-side pressure, when the Carnot efficiency share of energy has been converted to useful work by the heat engine. Also, the connection between the Newton's laws of motion and the engine efficiency will be shown.
3	When the heat engine's entry- and exit-side temperatures and pressures compete, the pressure-derived effects will dominate over the effects of the temperatures.
4	Different external pressures at the heat engine's entry- and exit-sides influence the maximum efficiency the heat engine can achieve.
5	Different or changing volumes at the heat engine's entry- and exit-sides influence the maximum efficiency the heat engine can achieve.

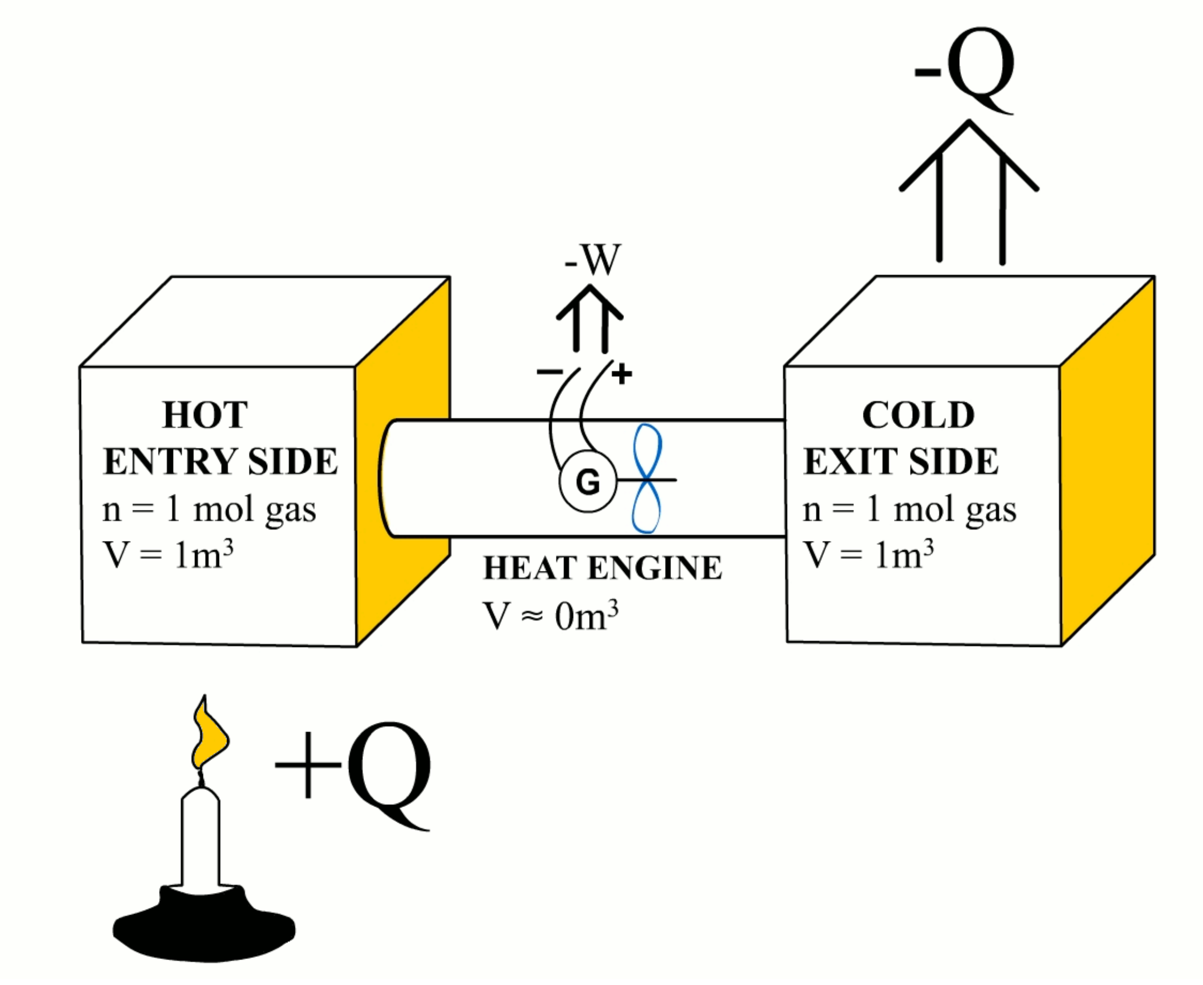
Table 1: List of the used evidence systems and their intended use

Descriptions of the structures of "evidence systems" are presented together with the results of those evidence systems.

Results

Evidence system 1: Heat engine's entry- and exit-side pressures can be used for obtaining the same temperature-based Carnot efficiency values

Evidence system 1 has one heat engine device placed inside a pipe, which itself is connected to two rigid and closed containers. These containers have a known volume of $1m^3$ and initially contain 1 mole of ideal gas substance at the same original temperature and pressure. In addition, it can be assumed that the pipe, which includes the heat engine device, is itself volumeless or at least has an insignificantly small volume compared to the volume of the entry- and exit-side containers. Picture 1 shows the overall technical structure of evidence system 1.



Picture 1: The overall technical structure of evidence system 1.

Picture 1 shows the ”Hot Entry Side” being heated with an external heat source to achieve certain target temperatures, while the ”Cold Exit Side” remains unheated at its original temperature. It was assumed that the heating of the ”Hot Entry Side” container was instantaneous, causing the temperature and pressure inside the container to reach the given target temperature and pressure instantaneously. Also, the heat engine was assumed to react instantaneously to the increase of pressure coming from the direction of the ”Hot Entry Side”-container. In addition, the heat engine inside the connecting pipe was assumed to operate with ideal efficiency and, together with a generator, be able to irreversibly remove all of the captured energy out of the system.

Let’s assume that the “Hot Entry Side” was initially heated to 1089K, while the ”Cold Exit Side” remained at 294K. At this point, the pressure inside the “Hot Entry Side” can be calculated to be 9054.45Pa, and the pressure inside the “Cold Exit Side” can be calculated to be 2444.45Pa. A handy Online calculator (Furey, 2021) was used in making those calculations.

Carnot efficiency value obtained from the Hot Entry Side and Cold Exit Side temperatures	The same efficiency value obtained using the Hot Entry Side and Cold Exit Side pressures
$\eta_{Carnot} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$ ==> η_{Carnot} = 1 – 294K / 1089K ==> η_{Carnot} = 0.73003	$\eta_{alternative} = 1 - P_{(exit)}/P_{(entry)}$ ==> $\eta_{alternative}$ = 1 – 2444.45Pa / 9054.45Pa ==> $\eta_{alternative}$ = 0.73003

Table 2: Similar Carnot efficiency values can be obtained using ”Hot Entry Side” and ”Cold Exit Side” temperatures or pressures

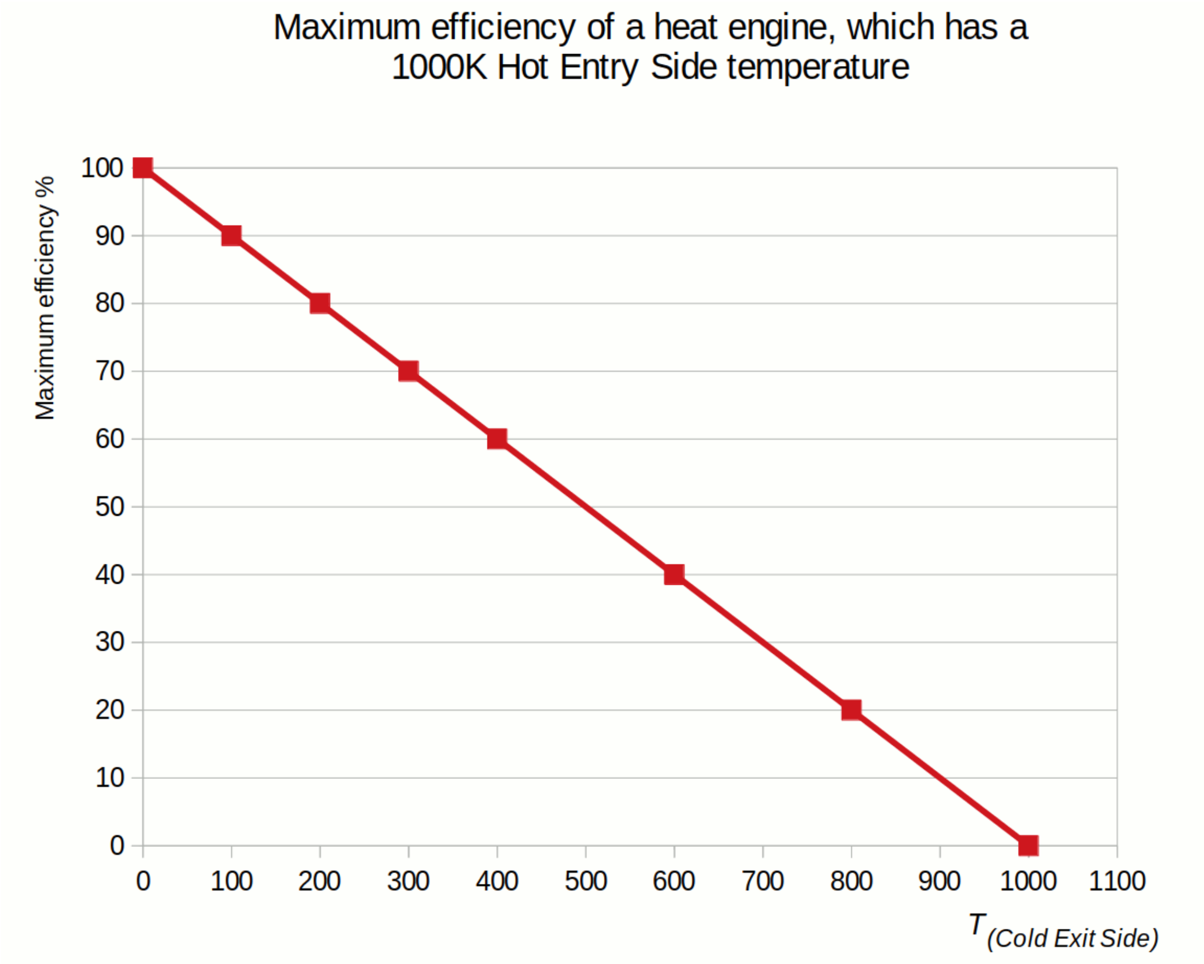
To prove that this was not just a coincidence, different entry- and exit-side temperatures and pressures were used for obtaining various Carnot efficiency values. The results of these calculations are shown in table 3.

Entry-side container temperature (K)	Exit-side container temperature (K)	Entry-side container pressure (kPa)	Exit-side container pressure (kPa)	$\eta_{(Carnot)}=1-T_{Cold}/T_{Hot}$	$\eta_{(max,alternative)}=1-P_{exit}/P_{entry}$
300	300	2.4943	2.4943	0.0000	0.0000
301	300	2.5027	2.4943	0.0033	0.0033
400	300	3.3258	2.4943	0.2500	0.2500
450	300	3.7415	2.4943	0.3333	0.3333
500	300	4.1572	2.4943	0.4000	0.4000
600	300	4.9887	2.4943	0.5000	0.5000
700	300	5.8201	2.4943	0.5714	0.5714
800	300	6.6516	2.4943	0.6250	0.6250
900	300	7.4830	2.4943	0.6667	0.6667
1000	1000	8.3145	8.3145	0.0000	0.0000
1000	800	8.3145	6.6516	0.2000	0.2000
1000	600	8.3145	4.9887	0.4000	0.4000
1000	400	8.3145	3.3258	0.6000	0.6000
1000	300	8.3145	2.4943	0.7000	0.7000
1000	200	8.3145	1.6629	0.8000	0.8000
1000	100	8.3145	0.8315	0.9000	0.9000
1000	0	8.3145	0.0000	1.0000	1.0000
1089	294	9.0545	2.4445	0.7300	0.7300

Table 3: Similar Carnot efficiency values can be obtained using various entry- Vs. exit-side temperature and pressure combinations

The results in table 3 demonstrate a systematic correlation between the heat engine’s entry- Vs. exit-side temperatures and pressures. The results in table 3 also confirm the usability of the used virtual heat engine, shown in picture 1, as it was constantly and parallelly able to produce similar efficiency values, using the heat engine’s entry- and exit-side temperatures or pressures.

Results in table 3 also reveal an important effect caused by the exit-side temperatures or pressures. The results indicate that when the exit-side temperature or the pressure is zero (0K or 0.0Pa), then the heat engine can achieve 100% efficiency. Another way to interpret those results is that the higher the exit-side temperature or pressure, the lower the efficiency a heat engine can achieve for the given entry-side temperature or pressure. Picture 2 shows the calculated maximum efficiency values, as a function of ”Cold Exit Side” temperatures, for a heat engine that has a 1000K ”Hot Entry Side” temperature.



Picture 2: Efficiency values for various exit-side temperatures for a heat engine that has an entry-side temperature of 1000K

The graph in picture 2 displays those data-points taken from table 3, which had an entry-side temperature of 1000K. As the entry-side's chosen target temperature was always 1000K, the exit-side's actual temperature was the only remaining variable. The data-points, shown in picture 2, suggest that the higher the exit-side's temperature was, the more it could inhibit the maximum efficiency that the heat engine could achieve. If the exit-side's temperature was 0K, then the heat engine's maximum efficiency could be up to 100%. If the exit-side's temperature was 1000K then the heat engine's maximum efficiency would be 0%.

Evidence system 2: The heat engine's maximum efficiency percentage is equal to its entry-side's over-pressure percentage

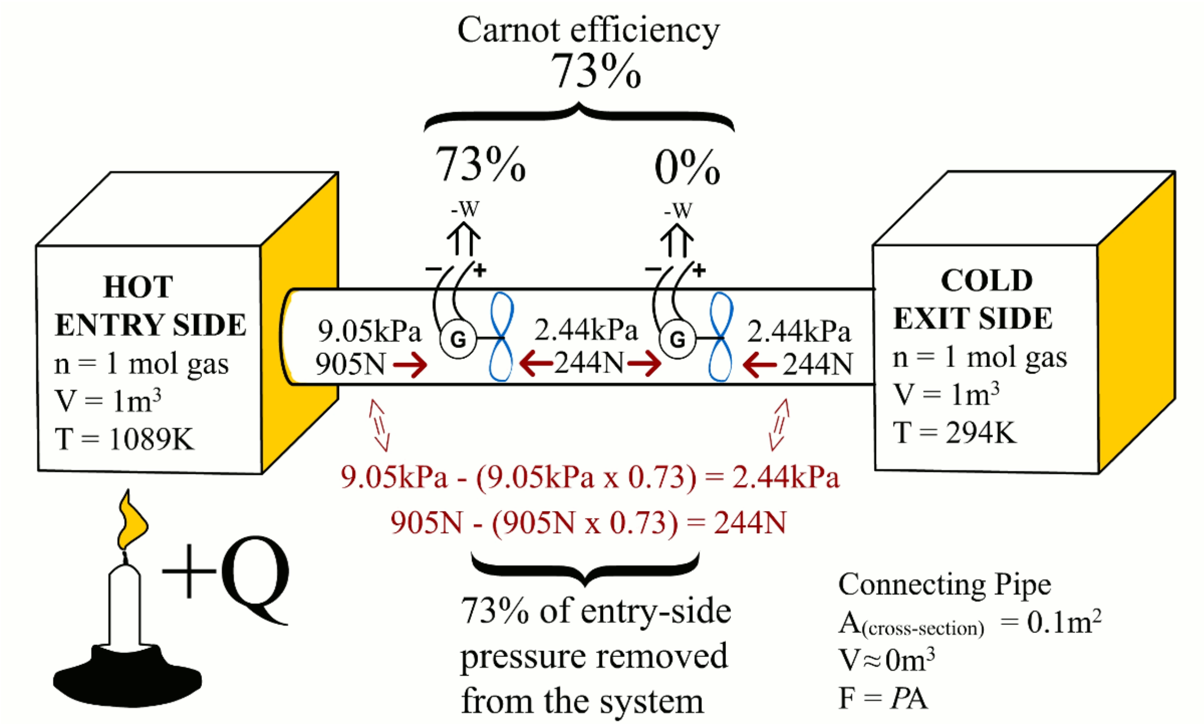
Evidence system 2 uses an almost similar heat engine system as in evidence system 1. However, the connecting pipe between the two closed containers contains two independent heat engines instead of just one. Evidence system 2 is used for demonstrating that the over-pressure at the heat engine's entry-side is linked to the heat engine's maximum efficiency, and when as much energy as was initially used for creating that over-pressure has been removed from the system, then the heat engine is operating at a Carnot efficiency level.

Picture 3 shows the arrangement used by the evidence system 2. Let's assume that the ”Hot Entry Side” was heated to 1089K, which caused the 1 mole of ideal gas substance inside the $1m^3$ container to obtain a pressure of 9054.45Pa. Similarly, the “Cold Exit Side” container with 1 mole of an ideal gas substance and a temperature at 294 degrees Kelvin and a volume of $1m^3$ will obtain itself a 2444.45Pa pressure. The Carnot efficiency for this kind of system is 0.73003, which indicates that a heat engine can operate in this environment with a maximum efficiency of 73.003% and at least 26.997% of the added heat will be lost in form of waste heat.

$\eta_{(Carnot)} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$

$\Longrightarrow \eta_{(Carnot)} = 1 - 294K/1089K \times 100\%$

$\Longrightarrow \eta_{(Carnot)} = 73.003\%$



Picture 3: The reduction of entry-side's pressure by the Carnot efficiency percentage, lowers the entry-side pressure to the level of exit-side pressure

Let's calculate what happens to the entry-side pressure if we remove 73.003% of it?

9054.45Pa – (9054.45Pa x 0.73003) = 2444.43Pa

Bingo! When we reduce the Carnot efficiency share of pressure from the "Hot Entry Side"-pressure, what then remains of the "Hot Entry Side's"-pressure equals to "Cold Exit Side's" pressure; 2444.43Pa Vs. 2444.45Pa.

Furthermore, this result suggests that there exists a second alternative method for calculating the Carnot efficiency values:

$\eta_{(max,2^{nd}\text{ alternative method})} = (P_{entry\text{-}side} - P_{\text{exit-side}}) / P_{entry\text{-}side}$

$\eta_{(max,2^{nd}\text{ alternative method})} = (9054.45\text{Pa} - 2444.43\text{Pa}) / 9054.43\text{Pa}$

$\eta_{(max,2^{nd}\text{ alternative method})} = 0.73003$

This "second alternative method" ($\eta_{max,2^{nd}\text{ alternative method}}$) for calculating the heat engine's maximum efficiency can also be used for calculating the efficiency of real-life heat engines.

For example, suppose the car engine's entry-side pressure ($P_{(entry\text{-}side)}$) inside the combustion chamber is 905445Pa, and the exit-side pressure ($P_{\text{exit-side}}$) outside of the exhaust pipe is 6066.21Pa. In that case, we can calculate the heat engine's efficiency as follows:

$\eta_{\text{example-car}} = (P_{entry\text{-}side} - P_{\text{exit-side}}) / P_{entry\text{-}side}$

$\eta_{\text{example-car}} = (905445\text{Pa} - 606621\text{Pa}) / 905443\text{Pa}$

$\eta_{\text{example-car}} = 0.33003$

Lets get back to maximum efficiencies and to ensuring that obtaining similar Carnot efficiency values using this ”second alternative method” ($\eta_{\text{2nd alternative-method}}$) was not a coincidence. In order to achieve that, calculations were performed using the ”second alternative method”-equation and various ”Hot Entry Side” Vs. ”Cold Exit Side” temperature Vs. pressure combinations. The results of those calculation are shown in table 4.

Entry-side container temperature (K)	Exit-side container temperature (K)	Entry-side container pressure (kPa)	Exit-side container pressure (kPa)	$\eta_{(\text{max,2nd alternative})} = (P_{entry} - P_{\text{exit}}) / P_{entry}$	$\eta_{(\text{Carnot})} = 1 - T_{\text{Cold}}/T_{\text{Hot}}$
300	300	2.4943	2.4943	0.0000	0.0000
301	300	2.5027	2.4943	0.0033	0.0033
400	300	3.3258	2.4943	0.2500	0.2500
450	300	3.7415	2.4943	0.3333	0.3333
500	300	4.1572	2.4943	0.4000	0.4000
600	300	4.9887	2.4943	0.5000	0.5000
700	300	5.8201	2.4943	0.5714	0.5714
800	300	6.6516	2.4943	0.6250	0.6250
900	300	7.4830	2.4943	0.6667	0.6667
1000	1000	8.3145	8.3145	0.0000	0.0000
1000	800	8.3145	6.6516	0.2000	0.2000
1000	600	8.3145	4.9887	0.4000	0.4000
1000	400	8.3145	3.3258	0.6000	0.6000
1000	300	8.3145	2.4943	0.7000	0.7000
1000	200	8.3145	1.6629	0.8000	0.8000
1000	100	8.3145	0.8315	0.9000	0.9000
1000	0	8.3145	0.0000	1.0000	1.0000
1089	294	9.0545	2.4445	0.7300	0.7300

Table 4: Carnot efficiency values can also be obtained by calculating:

$\eta_{(\text{max,2nd alternative})} = (P_{entry} - P_{\text{exit}}) / P_{entry}$

Results in table 4 confirm the earlier ”bingo!”- observation, which suggested that when a Carnot efficiency percentage share of heat has been removed from the heat engine's entry-side pressure, the pressure of the fluid which passes through the heat engine into its exit-side, will have a pressure that equals with the pre-existing “Cold Exit Side” pressure. The logical interpretation of the results in table 4 suggests that the ”Cold Exit Side” pressure directly inhibits the ”Hot Entry Side’s” pressure from being able to cause the heat engine to achieve its natural maximum efficiency level of 100%. This conclusion arises from thinking that:

1) The heat engine can reduce the passing fluid’s pressure precisely to the same pressure level that already exists at the heat engine’s “Cold Exit Side”.

2) Thus, if no pressure exists at the exit-side (P=0Pa or T=0K), the heat engine can extract more and more energy from the passing fluid until it has been able to lower the passing fluid’s pressure to zero (P=0Pa).

3) When the passing fluid’s pressure has been lowered to zero, the heat engine has been able to operate with 100% efficiency as there doesn't exist any more thermal energy to take; all molecular movement has been halted.

4) if the heat engine would have been able to (miraculously) cause a lower pressure than pre-existed at the ”Cold Exit Side” and if any pressure pre-existed at the ”Cold Exit Side”, then the molecules which caused that pre-existing exit-side pressure would flow from the ”Cold Exit Side” and into the heat engine.

This conclusion of the exit-side’s pressure opposing the heat engine’s ability to reach a 100% efficiency level can also be confirmed using actual Newtonian forces. Picture 3 did contain some additional properties of the used heat engine system. The cross-sectional area of the connecting pipe was marked to be 0.1m^2 , which allows calculating the forces coming from the ”Hot Entry Side”- and ”Cold Exit Side”- containers towards the heat engines entry- and exit-sides using an equation $F=PA$. The pressures at the ”Hot Entry Side”- and ”Cold Exit Side”- containers were already calculated; 9054.45Pa respective 2444.43Pa. Thus, the calculated pressure forces pressing the cross-sectional area of the connecting pipe from the opposite directions could be calculated and are shown in table 5.

Pressure force coming from the ”Hot Entry Side”- container and towards the cross-sectional area of the connecting pipe	Pressure force coming from the ”Cold Exit Side”- container and towards the cross-sectional area of the connecting pipe
$F_{(from\text{-}entry\text{-}side)}=PA$ $F_{(from\text{-}entry\text{-}side)}$=9054.45Pa x 0.1m^2 $F_{(from\text{-}entry\text{-}side)}$=905.445N	$F_{(from\text{-}exit\text{-}side)}=PA$ $F_{(from\text{-}exit\text{-}side)}$=2444.43Pa x 0.1m^2 $F_{(from\text{-}exit\text{-}side)}$=244.443N

Table 5: pressure forces pressing the cross-sectional area of the connecting pipe from opposite directions.

The results in table 5 show that the opposite pressure forces impacting the heat engine’s entry- and exit-sides can be expressed using conventional forces(F). The calculation of “net pressure force” reveals an interesting connection.

$F_{(net\ pressure\ force)} = F_{(from\text{-}entry\text{-}side)} - F_{(from\text{-}exit\text{-}side)}$

==> $F_{(\text{net pressure force})}$ = 905.445N - 244.443N

==> $F_{(\text{net pressure force})}$ = 661.002N

The interesting connection is that, we can obtain the same “net pressure force” ($F_{(\text{net pressure force})}$) values by multiplying the original pressure force(F) coming from the “Hot entry-side” container with the Carnot efficiency value.

$F_{(\text{net pressure force})} = F_{(\text{from-entry-side})} \times \eta_{Carnot}$

==> 661.002N = 905.445N x 0.73003

Combination of the two previous equations reveals yet another way for calculating the Carnot efficiency value, but this time only using the Newtonian forces:

$\eta_{(\text{max,3}^{\text{rd}}\text{ alternative method})} = (F_{(\text{from-entry-side})} - F_{(\text{from-exit-side})}) / F_{(\text{from-entry-side})}$

==> $\eta_{(\text{max,3}^{\text{rd}}\text{ alternative method})} = F_{(\text{net pressure force})} / F_{(\text{total-from-entry-side})}$

==> $\eta_{(\text{max,3}^{\text{rd}}\text{ alternative method})}$ = 661.002N / 905.445N

==> $\eta_{(\text{max,3}^{\text{rd}}\text{ alternative method})}$ = 0.73003

That calculation and its result suggest of a clear connection between the Newton’s laws of motion and the operation of the heat engines; possibly even with other kinds of “engines”. The results suggest that, the pressure force impacting the heat engine from the exit-side must be subtracted from the pressure force impacting the engine from the entry-side. When that has been done, the (heat) engine may convert the entire remaining net force into useful work. As proof of that, we had already calculated the Carnot efficiency value, which suggested that the heat engine operating under these same conditions can convert up to 73.003% of the added energy into useful work.

$\eta_{(\text{Carnot})} = 1 - T_{(\text{cold-side})}/T_{(\text{hot-side})}$

$\eta_{(\text{Carnot})}$ = 1 – 294K/1089K

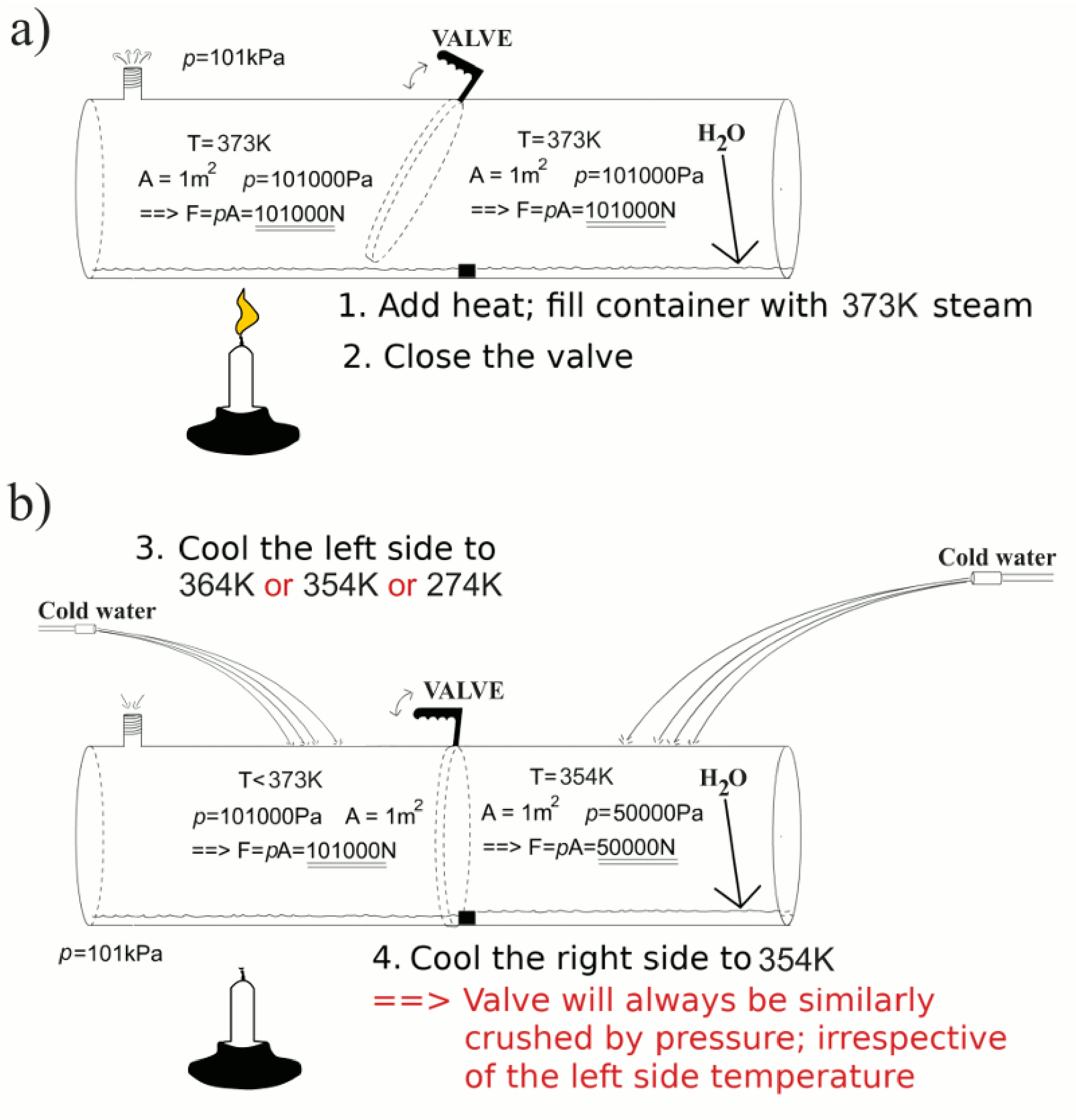
$\eta_{(\text{Carnot})}$ = 0.73003

Evidence system 3: When the heat engine’s entry- and exit-side temperatures and pressures compete, the pressure-derived effects will dominate over the effects of the temperatures

Picture 4 illustrates a special purpose, “metal plate deforming”- heat engine and its operation process, which consists of four phases. The first two process phases are shown in picture 4 section-a, and the last two process phases are shown in picture 4 section-b. The purpose of this arrangement is to demonstrate two things. Firstly, the heat engine’s efficiency can not be determined by just knowing its hot-side and cold-side temperatures. Secondly, the arrangement also shows that when a heat engine’s entry- and exit-sides are being subjected to different temperatures and pressures, the (hypothetical) impact of temperature differences can be completely overrun by the influence of the pressure differences.

Description of the system

The heat engine arrangement shown in picture 4 has a simple four-phase process, which converts some of the added thermal energy into a metal deforming work, which causes the metal plate to bulge to the right. The container shown in picture 4 has a metallic valve plate in it. The valve plate's cross-sectional area is $1m^2$ at both sides of the plate. Valve-plate can be closed using a handle so that it divides the container into two hermetically sealed halves. The container’s left side has an opening into the ambient air, which allows the molecules to escape the container during heating and enter back into the container’s left- side during the cooling. Picture 4 section-a describes what happens during the system's heating, and picture 4 section-b describes what happens when the system is cooled.



Picture 4: Entry- and exit-side pressures alone can provide necessary forces to the heat engine's operation; irrespective of the temperature conditions

Closer inspection of the system's process phases

Phase-1: External heat is added to the system, which causes the water inside the container to boil and fill the entire interior with saturated water steam. As the container's left-side has a permanently open connection to the ambient air, the pressure inside the container can not become higher than the pressure outside the container – as the excess pressure can escape from the container. Thus, the pressure of steam inside the entire container will be about 101kPa.

Phase-2: The valve-plate gets closed, causing the division of the container into two hermetically sealed halves. The pressure inside both left- and right-side halves will still be 101kPa.

Phase-3: Next, the container's left-side is cooled by hosing cold water to its external surface. The cooling action can continue until the temperature of the container's left-side reaches any of the following temperatures: 364K(91ºC), 354K(81ºC), or 274K(1ºC). Because of the external cooling, the temperature inside the container's left-side will go down. Also, the pressure of the water vapor inside the container's left-side will go down. However, the water vapor's pressure drop inside the container's left-side will be immediately compensated by the air molecules flowing into the container. Therefore, even as the temperature and water vapor's partial pressure inside the container's left-side will go down, the pressure inside the container's left side will remain at 101kPa, i.e., at an equal level with the air pressure outside the container.

Phase-4: Next, the container's right-side's external surface will be cooled with cold water. As the right-side cools down, its internal pressure will become significantly lower because there is no opening for the ambient air. When the container's right-side temperature reaches 354K(81ºC), the saturated vapor pressure inside the container's right-side will only be about 50kPa. At that moment, two different pressures are pressing the valve-plate from its opposite sides. The 101kPa pressure inside the container's left side is pressing the $1m^2$ surface of valve-plate from the left with a force of 101kiloNewtons. Simultaneously, the pressure inside the container's right-side is pressing the $1m^2$ valve-plate from the right with a force of 50kiloNewtons.

$F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}left\text{-}side)}=PA$

==> $F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}left\text{-}side)}=101kPa \times 1m^2$

==> $F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}left\text{-}side)}=101kN$

$F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}right\text{-}side)}=PA$

==> $F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}right\text{-}side)}=50kPa \times 1m^2$

==> $F_{(towards\text{-}valve\text{-}plate\text{-}from\text{-}right\text{-}side)}=50kN$

The collected heat engine efficiency results for all the left-side alternative temperatures are shown in table 6.

Left side cooled to	Right side cooled to	$P_{(left-side)}$ kPa	$P_{(right-side)}$ kPa	$F_{(left-side)}$ kN	$F_{(right-side)}$ kN	$\eta_{(Carnot)} =$ $1 - T_{(cold)}/T_{(hot)}$	$\eta_{(max,alternative)} =$ $1 - P_{(left)}/P_{(right)}$
364K	354K	101	50	101	50	+0.0274	0.50495
354K	354K	101	50	101	50	+0.0000	0.50495
274K	354K	101	50	101	50	-0.2260*	0.50495

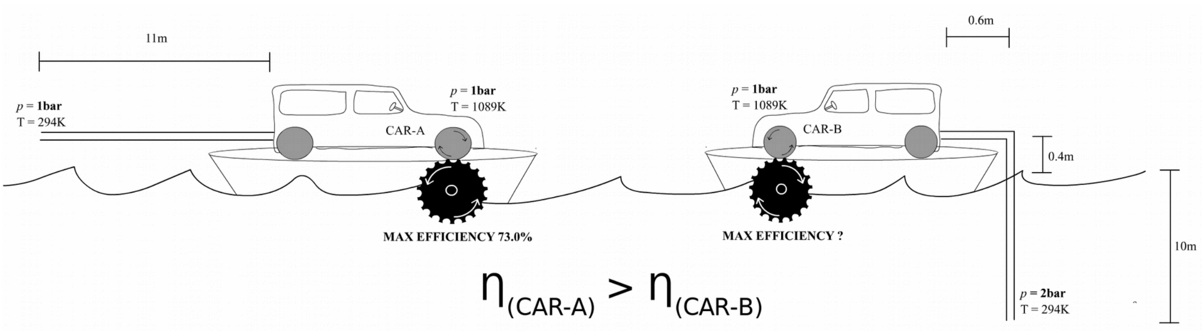
Table 6: Results of applying the higher(364K), the same(354K), or the lower(274K) left-side temperatures to the device arrangement shown in picture 4
* Note: in this set up, the hot- and cold-sides had been reversed; the left-side being (surprisingly) the cold-side

The results in table 6 show that in all cases, the container's left-side's internal pressure is pushing the valve-plate with 51kiloNewtons greater force than the right-side's internal pressure is pushing it from the right-side. The critical thing to notice here is that the "net pressure force" pressing the valve-plate from left to right is 51kiloNewtons irrespective of the chosen left-side temperature. Thus, the left-side temperature can be higher, lower, or the same as the right-side's temperature, but the valve-plate will still always bend or bulge towards the right-side half of the container. The pressure-derived efficiency ($\eta_{(max,alternative)}$) – values suggest that the heat engine works in all cases with similar 50.5% efficiency percentage. However, the calculated Carnot efficiency-values ($\eta_{(Carnot)}$) show different efficiency values for each left-side temperature alternatives. The temperature-derived Carnot-efficiency values, shown in table 6, suggest that when the left-side is cooled to a colder (364K) temperature than the right-side (354K), then the heat engine system would be bending the valve-plate to the right with a 2.74% thermal efficiency. And if the left- and right-side temperatures were cooled to the same 354K temperature, then the heat engine system would not be bending the valve plate at all; calculated Carnot efficiency is 0.0%. Finally, if the left side were to be cooled to 274K and the right side to 354K, the heat engine system would operate with a negative efficiency and bend the valve-plate towards the left side with a 22.6% thermal efficiency.

The calculated Carnot efficiency values ($\eta_{(Carnot)}$) appear to behave illogically, considering the stable pressure forces always present at the left-side of the container. In fact, despite the constant and significant pressure difference at the valve-plates left- and right-side, the Carnot efficiency values promise the valve-plate to be weakly bent to the right, not bend at all, or even bulging to the left. On the other hand, the pressure-derived efficiency values ($\eta_{(alternative)}$) show significant stability, as the pressure-derived efficiency values promise the heat engine to be able to do its "metal bending work towards the right-side"- with up to a 50.5% efficiency. Thus, evidence system 3 suggests that the correct efficiency values can be obtained using pressure-derived efficiency values, not the temperature-derived Carnot efficiency values.

Evidence system 4: Different external pressures at the heat engine's entry- and exit-sides influence the maximum efficiency the heat engine can achieve

Picture 5 shows two heat engines powering two identical automobiles, "CAR-A" and "CAR-B," both causing a motive force to the boats carrying them. The only difference between those heat engine systems is at the CAR-B's exhaust pipe, which points downwards into the water, while the exhaust pipe of a CAR-A points horizontally into the ambient air. Both automobiles have the same exit-side temperature. CAR-A pushes exhaust gases into 294 degrees Kelvin warm air, and CAR-B pushes exhaust gases into 294 degrees Kelvin warm water. The entry-sides of both heat engines are connected to the same atmospheric pressure. The heat engines in both automobiles are burning gasoline, which causes the temperature inside the engines ($T_{(entry\text{-}side)}$) to reach 1089 degrees Kelvin.



Picture 5: Higher exit-side pressure lowers the heat engine's maximum efficiency

The Carnot efficiency value to both of these heat engine systems can be calculated using the equation:

$\eta_{(Carnot)} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$

$\eta_{(Carnot)} = 1 - 294K/1089K$

$\eta_{(Carnot)} = 0.73003$

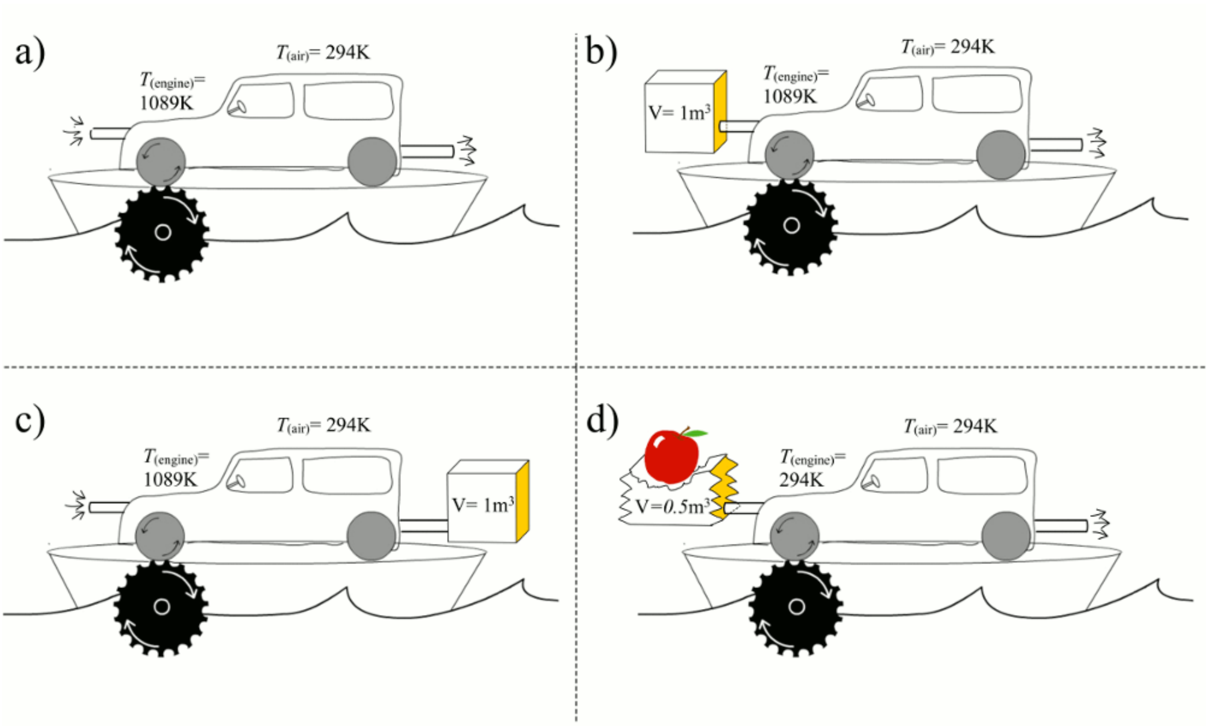
Neither automobile heat engine can reach anywhere near the theoretical maximum efficiency (73%) for their front wheel rotating action. Still, whatever the CAR-A's actual efficiency is, the CAR-B's efficiency will be less than that. The reason for CAR-A's constantly higher efficiency is the necessity of the CAR-B to always consume some additional energy for pushing its exhaust gases deep into the water and overcoming the hydro-static pressure caused by the mass of 10 meters high pillar of water. The pressure at a depth of 10 meters is about 2 bar. Thus, the CAR-B's exhaust gases can not get away from the vertical exhaust pipe unless the pressure inside the entire exhaust pipe is more than 2 bar (~202kPa). Because the pressure inside the CAR-B's exhaust pipe must rise to at least ~202kPa, it will be the heat engine's exit-side pressure. In other words, the CAR-B's heat engine's efficiency inhibiting exit-side pressure is twice as high than it is in CAR-A. Therefore the CAR-B's efficiency must be less than CAR-A's efficiency.

It is also thermodynamically impossible for CAR-A and CAR-B to produce equal amounts of front wheel rotating work(W_{output}). If it were possible, the CAR-B's identical heat engine would have to somehow generate an additional amount of energy. The first law of thermodynamics forbids the creation of energy. Therefore, we must accept that CAR-B will always have less energy available for rotating its front wheels; as it must consume a portion of its heat engine's energy to overcome the hydro-static pressure at its exit-side.

Evidence system 5: Different or changing volumes at the heat engine's entry- and exit-sides influence the maximum efficiency the heat engine can achieve

The gas laws bind together volume, pressure and temperature. In 1824 Sadi Carnot demonstrated the impact of the entry- and exit-side temperatures on the heat engine's efficiency. Earlier in this article, evidence systems 1-4 have demonstrated how the entry- and exit-side pressures influence the heat engine's efficiency. Next, the impact of different entry- and exit-side volumes on the heat engine's efficiency will be shown. To achieve that, some already familiar technical components that were used with the evidence systems 1-4 will be re-used. Especially than means re-using the car engine-powered boat and the closed and rigid $1m^3$ containers. Picture 6 contains four different device arrangements, which will be used for demonstrating the volume-related effects to the heat engine's maximum efficiency.

Picture 6 section-a demonstrates the basic situation without any of the entry- or exit-side's volume-limiting special arrangements. Picture 6 section-b shows a situation in which the volume of the heat engine's entry-side has is limited. Picture 6 section-c demonstrates the impact which the heat engine's limited exit-side volume causes to its efficiency. Finally, picture 6 section-d will show that the heat engine does not necessarily need any added heat for its operation - added pressure can replace the added heat.



Picture 6: Four heat engine system arrangements, with four volume-related scenarios, each differently influencing the heat engine's efficiency

Picture 6 section-a: The automobile is shown on a boat. Its heat engine is being used to power the rotation of its front wheels and provide the necessary motive force for the movement of the entire boat. In this scenario, the heat engine's entry- and exit-sides are connected to an equal and unlimited ambient air reservoirs. In this scenario, and only in this scenario, the heat engine's maximum efficiency can be correctly calculated using Carnot's equation:

$\eta_{max} = \eta_{(Carnot)} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$
$\eta_{max} = 1 - 294K/1089K$
$\eta_{max} = 0.73003$

Picture 6 section-b: In this scenario, the heat engine's air inlet has been connected to a closed and rigid $1m^3$ air containing container; with an initial internal pressure of 101kPa. The air pressure inside that container will decrease as the car's engine sucks air from the container and keeps blowing away the exhaust gases through the exhaust pipe into the ambient air. As the supply of oxygen-rich air to the engine becomes increasingly limited, the engine can burn less and less fuel, and the heat engine's internal pressure ($P_{(entry\text{-}side)}$) decreases. The air pressure inside that rigid $1m^3$ container can go down much below its original 101kPa pressure. This developing vacuum inside the container will oppose the heat engine's pursuit of pushing the fluid towards the exit side. Ultimately, the heat engine's efficiency would go down to zero when the heat engine's chemical reaction-derived heat can no longer elevate the engine's combustion chamber's internal pressure ($P_{(entry\text{-}side)}$) above the exit-side's pressure ($P_{(exit\text{-}side)}$); caused by the 101kPa pressure of ambient air. First data rows in tables 3 and 4, did already show that when the entry-side pressure equals the exit-side pressure, the heat engine's efficiency will be zero.

==> $\eta_{(max\ initial)}$= 0.73

==> $\eta_{(max\ final)}$= 0.00

Picture 6 section-c: In this scenario, the heat engine's exhaust pipe has been connected to a closed and rigid $1m^3$ air containing container; with an initial internal pressure of 101kPa. The combined pressure of air and exhaust gases inside that container will increase as the automobile's heat engine blows more and more exhaust gases into that container. As the pressure inside the container increases, it also increases the pressure-derived force(F), which opposes the pressure-derived force(F) coming from the heat engine's entry-side. Ultimately, the heat engine's exit-side pressure ($P_{(exit\text{-}side)}$) will be equal to the heat engine's combustion chamber's internal pressure ($P_{(entry\text{-}side)}$). At that moment, as was shown by the first data rows in tables 3 and 4, the heat engine's efficiency drops to zero.

==> $\eta_{initial\text{-}max}$= *0.73*

==> $\eta_{final\text{-}max}$= *0.00*

Picture 6 section-d: In this scenario, the heat engine's air inlet has been connected to a closed and semi-rigid $1m^3$ air container with an initial internal pressure of 101kPa. In addition, in this scenario, the engine would not be hot or running. Therefore, the pressure forces pushing the heat engine from its entry- and exit-sides are initially equal. Then suddenly, a giant apple falls from the sky and impacts the $1m^3$ air container with its massive kinetic energy. Upon impact, the volume of the container becomes instantly reduced to $0.5m^3$, which causes the entry-side pressure to increase suddenly. Surely, the air container will get hotter for a moment, but it will be allowed to cool back to its original temperature of 294K before the air inside the container gets released into the heat engine's combustion chamber.

According to Boyle's law, in an isothermic system $P_1V_1 = P_2V_2$. This implies that reducing volume by half will have doubled the pressure. Thus, it can be assumed that in this scenario, the entry-side pressure inside the ($1m^3$ => $0.5m^3$) size-reduced container at a (original) temperature of 294K would be 202kPa, and the exit-side pressure would still be 101kPa. As has already been shown in table 3, same Carnot efficiency values can be obtained using a entry- and exit-side pressure-based calculation $\eta_{(max,alternative)} = 1 - P_{exit\text{-}side} / P_{entry\text{-}side}$, instead of the traditional way of calculating $\eta_{Carnot} = 1 - T_{cold\text{-}side} / T_{hot\text{-}side}$. In addition, during the presentation of the evidence system 3, it was demonstrated that the heat engine's entry- and exit-side temperatures were not the real defining factor for its ability to operate. Instead, the entry- and exit-side pressures would always dictate the heat engine's actual ability to do useful work(W_{output}). Taken together, it can be assumed that the heat engine in this scenario can be powered by that reduction of the entry-side container's volume, because the entry-side's volume reduction will cause a relative entry-side over-pressure. This will be true, even if the temperatures at the heat engine's entry- and exit-sides remain unchanged and equal at 294K. Thus, a theoretical maximum efficiency for this pressure powered heat engine can be calculated using the equation:

$$\eta_{(max,alternative)} = 1 - P_{exit\text{-}side} / P_{entry\text{-}side}$$

$$\eta_{(max,alternative)} = 1 - (101\text{kPa} / 202\text{kPa})$$

$$\eta_{(max,alternative)} = 0.50$$

In contrast, if one would try to calculate this heat engine's maximum efficiency using the entry- and exit-side temperatures, the person would find this heat engine's maximum efficiency to be zero; as the temperatures at the heat engine's entry- and exit-sides are equal.

$$\eta_{(max,Carnot)} = 1 - T_{cold\text{-}side} / T_{hot\text{-}side}$$

$$\eta_{(max,Carnot)} = 1 - (294\text{K}/294\text{K})$$

$$\eta_{(max,Carnot)} = 0.00$$

It is common knowledge that there are automobiles and power tools that are powered by compressed air. Air tanks which contain that compressed air do not need to be pre-heated, but can be used at the same temperature as is the ambient air. Those compressed air-powered automobiles and power tools can be used with non-zero efficiency, which suggests that even in this case, the apple-derived generation of compressed air can be used for powering the automobile's engine with some non-zero efficiency. Thus, the use of temperature-based Carnot efficiency calculation would lead to a wrong maximum efficiency result. Instead, one would be able to achieve a non-zero maximum efficiency value using the entry- and exit-side pressures and the equation:

$$\eta_{(max,alternative)} = 1 - P_{exit\text{-}side} / P_{entry\text{-}side}$$

Discussion

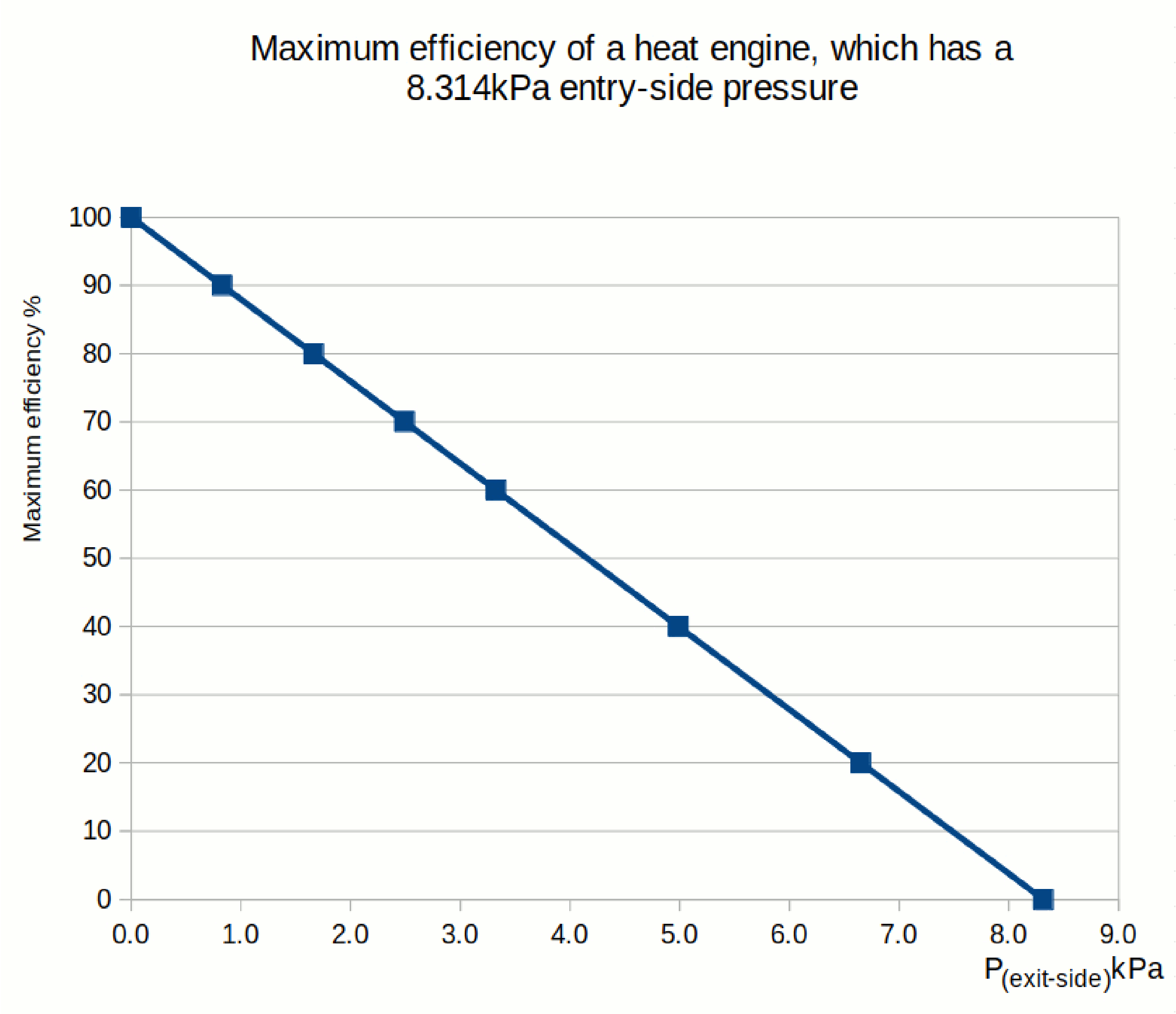
...about the evidence system 1

The heat engine system, with its two rigid and closed containers at its entry- and exit-sides, was able to simultaneously provide temperature-based Carnot efficiency values and similar values ($\eta_{(max,alternative)}$) based on the entry- and exit-side pressures shown in table 2. The obtained efficiency values were also similar over a wide range of chosen entry- and exit-side temperatures, as shown by the values in table 3. This ability to obtain similar Carnot efficiency values using temperatures and pressures is not a coincidence or achievable only using a similar device arrangement as is shown in picture 1. No, the obtained similar results with temperatures and pressures must be intimately linked to the nature of all heat engines. This conclusion can be motivated by the fact that the heat engine can not know where the entry- and exit-side pressures come from. For example, the entry-side container's volume can be as large as the size of a planet's entire atmosphere, or it can have the size of a $1m^3$ – the heat engine doesn't know or care.

If the same Carnot efficiency values can be obtained using entry- and exit-side temperatures or pressures, does it really matter which ones are used to calculate the efficiencies of heat engines? It does matter, because the entry- and exit-side pressures are not determined by just entry- and exit-side temperatures. The gas laws bind together volume, pressure and temperature. Therefore, the final entry- and exit-side pressures can be expected to result from combined effects of entry- and exit-side pressures, temperatures, and volumes. This leads to an expectation that the pressure-based efficiency values will not always be the same as the temperature-based Carnot-efficiency values. Which in turn, leads to a question: "If the temperature and pressure-based efficiency values would be different, which ones would be correct?". The answer to that question is that the pressure-based efficiency values are the correct ones. This is shown by the evidence system 3.

The results in table 3 and picture 2 show that when both the entry- and exit-side temperatures are 1000K, the heat engine's maximum efficiency will be zero. However, the lowering of the exit-side temperature leads to a linearly increased maximum efficiency. Ultimately, the heat engine could achieve a 100% maximum efficiency when the exit-side temperature reached absolute zero. Interestingly, the results in table 3 also suggested that when the exit-side pressure reached zero and the entry-size pressure was non-zero, then the heat engine's maximum efficiency could also reach that 100% maximum efficiency. This raises an important question about the nature of the heat engine's exit-side pressure. Suppose the 100% efficiency is achievable when the exit-side pressure doesn't exist. In that case, the existence of the exit-side pressure must be considered to be an inhibiting factor for the heat engine's ability to obtain energy from the system with a higher efficiency.

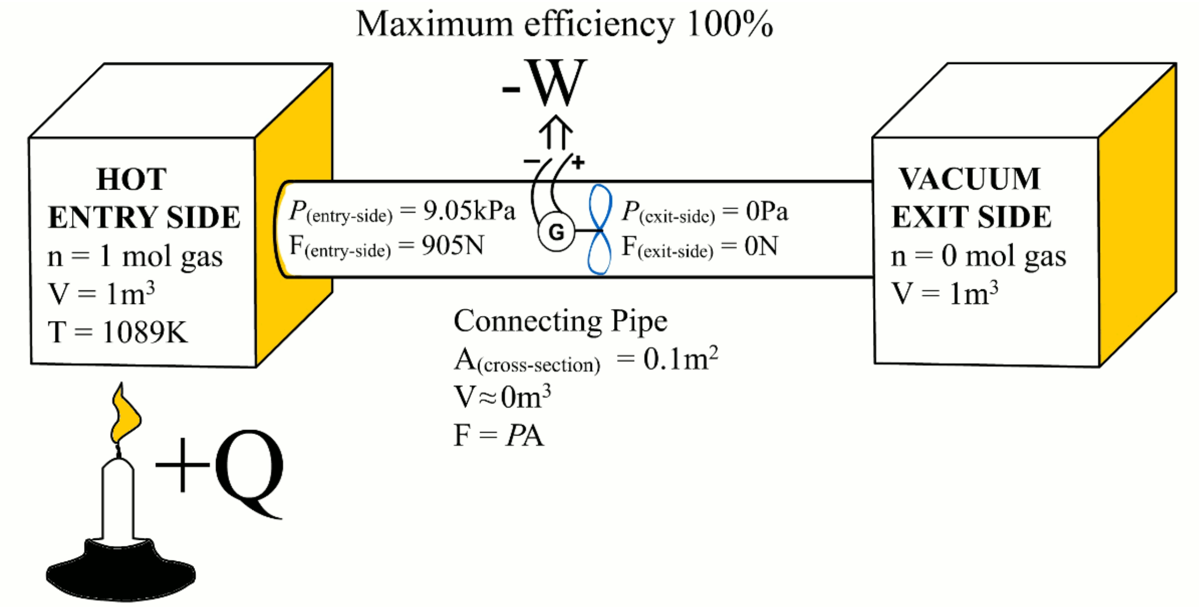
Picture 7 shows a diagram that used pressure values taken from table 3. Only those rows with an entry-side pressure of 8.31446kPa were plotted into a diagram. Thus, the entry-side pressure was 8.31446kPa in all data points, and the only variable was the exit-side pressure.



Picture 7: Efficiency values for various exit-side pressures, for a heat engine that has an entry-side pressure of 8.314kPa

Picture 7 shows how the heat engine's efficiency decreases linearly as the heat engine's exit-side pressure increases, as shown by the data in table 3. When the exit-side's pressure is equal to the entry-side's pressure, the maximum efficiency of the heat engine is zero. When the exit-side's pressure is zero, then the heat engine's maximum efficiency is 100%. This system has only one variable ($P_{(exit\text{-}side)}$), which logically concludes that the exit-side's pressure somehow acts as an inhibiting factor for entry-side pressure's ability to obtain energy from the system with a 100% efficiency.

As table 3 and picture 7 show, 100% efficient heat engines may be achievable if the exit-side pressure is 0Pa; or the exit-side temperature is 0K. Picture 8 demonstrates how such a theoretical 100% efficient heat engine might be constructed - using those two rigid and closed exit- and entry-side containers and a volumeless instantly optimally efficient heat engine.



Picture 8: Structure of a 100% efficient heat engine system, which has a vacuum at its exit-side container

Picture 8 shows a turbine-generator arrangement inside a pipe, which has been placed between a rigid $1m^3$ ”Hot Entry Side”- container(T=1089K) and the $1m^3$ ”Vacuum Exit Side”-container. To enable calculations of the forces(F) within the system, the pipe’s cross-sectional area is assumed to be $0.1m^2$ and its volume neglectable small; $V_{(pipe)} \approx 0m^3$. The pressure inside the ”Hot Entry Side” container can be estimated using the ideal gas law formula $PV=nRT$. Thus, the pressure impacting the heat engine’s entry side can be calculated to be 9054Pa. Similarly, the pressure impacting the heat engine’s exit-side can be calculated to be 0Pa. As the pipe's cross-sectional area is $0.1m^2$ and the pressures inside both of the containers are known, the forces impacting the heat engine from the entry- and exit-sides can be calculated. The results of those force calculations are shown in table 7.

Force coming from the ”Hot Entry Side”	Force coming from the ”Vacuum Exit Side”
$F_{(from-entry-side)}=PA$ $F_{(from-entry-side)}=9054Pa \times 0.1m^2$ $F_{(from-entry-side)}=905.4N$	$F_{(from-exit-side)}=PA$ $F_{(from-exit-side)}=0Pa \times 0.1m^2$ $F_{(from-exit-side)}=0N$

Table 7: The pressure forces coming from the entry- and exit-side containers;
as shown in picture 8

The results in tables 3 and 7 already begin to hint at an interesting connection between the Newton’s laws of motion and the nature of the heat engines. Newton’s first law states that an object at rest will stay at rest, and an object in motion will stay in motion unless acted on by a net external force. As the results in table 7 and picture 8 show, the molecular objects coming from the ”Hot Entry Side” can jointly cause a pressure force(F) of 905.4 Newtons. Individual molecular objects pursue to spread to all directions and one of those available directions is towards the ”Vacuum Exit Side”-container. In contrast, the non-existing molecules at the ”Vacuum Exit Side” can not create any force which might influence or oppose the motion of the molecular objects coming from the ”Hot Entry Side”.

The molecular objects, coming from the ”Hot Entry Side,” are carriers of the system’s internal energy. As they pass with their mass and velocity through the heat engine, they will interact with the border layer areas of the heat engine’s moving parts and hand over some of their energy to the benefit of the kinetic energy of those moving parts. This temporarily captured internal energy will then be given to the generator(“G”), which will irreversibly move the captured energy out of the system. That irreversibly lost internal energy will manifest in a lowered temperature and pressure among those molecular objects that remain within the system. Without the opposing pressure force coming from the ”Vacuum Exit Side,” there exists no force which might ”act against” or stop the molecular objects coming from the ”Hot Entry Side.” Thus, the temperature of molecules traveling through the heat engine will be heading towards absolute zero. Upon reaching absolute zero, the molecules will be crystallized, their thermal movements have been halted, and their ability for further ”energy dispersal” or ”spreading of energy” is zero. Thus, the molecules passing through one or more heat engines and towards a volume that exhibits zero pressure, due to 0K temperature or lack of molecules, can hand over and irreversibly lose all of their thermal energy to the heat engine. In such cases, the heat engine could operate with a 100% efficiency, as suggested by the data points indicating 100% efficiency in picture 7 and in tables 3 and 4.

...about the evidence system 2

Picture 3 reveals the nature of all heat engines, what really limits their maximum efficiency and why the Carnot efficiency values are what they are. The results obtained from evidence system 1 have already shown that the heat engine's efficiency is zero if the temperature or pressure difference doesn't exist between its entry- and exit-sides. In addition, evidence system 2 shows how the exit-side's pressure can be interpreted as creating an actual pressure force, which is measurable in Newtons, and which opposes the heat engine's ability to convert systems internal energy into work.

The first law of thermodynamics states that energy can not be created, nor can it just vanish. Therefore, when a heat engine takes energy from the system, it must do so by capturing and removing a portion of the systems existing internal energy. In evidence systems 1 an 2 the used thermodynamic process is isochoric; the volume doesn't change. Before the heating, both the rigid ("isochoric") entry- and exit-side containers had 1 mole of ideal gas substance at the same temperature ("isothermic") and pressure ("isobaric"). The addition of energy from the external heat source to the entry-side container would initially cause only the rise of the entry-side container's ideal gas substance's temperature and pressure. As the fluid flows from the entry-side container and through the heat engine, the fluid's temperature and pressure will go down towards the exit-side's temperature and pressure. The more efficient the engine is, the closer to the exit-side's original temperature and pressure it can lower the passing fluids temperature and pressure.

In both evidence systems 1 and 2, the heat engines irreversibly remove a portion of the system's internal energy by converting it into motion and other removable forms of energy. All of that irreversibly taken energy must reduce the temperature and pressure of the ideal gas substance. If a heat engine would be able to operate with an optimal Carnot efficiency, then that heat engine would need to be able to reduce the temperature and pressure of the fluid substance, which is passing through it, to the same pressure and temperature level which had been present at the entry-side before any of external heat was added to the system. In other words, the addition of external heat to the entry-side increases the system's internal energy by the amount which can be removed from the system using an ideally efficient heat engine. If the fluid's temperature or pressure, after it had passed the optimally efficient heat engine and lost all of the added heat, would be anything higher than the original temperature and pressure present at the entry-side container, then the heat engine would have to have created new energy; in violation of the first law of thermodynamics. Also, if the fluid's temperature or pressure, after passing the optimally efficient heat engine, would be anything lower than the original pressure and temperature present at the entry-side container, then some of the systems internal energy would have been vanished; in violation of the first law of thermodynamics.

The optimally efficient left-side heat engine, shown in picture 3, was only able to reduce the passing fluid's temperature and pressure by 73% because after that reduction the passing fluid's temperature and pressure were at the same level as was the temperature and pressure at the exit-side container.

A quick interpretation of the notes written into picture 3 is as follows:

a) When 73% of the pressure which initially existed at the ”Hot Entry Side” has been removed by the first encountered (left-side) and optimally efficient heat engine, the fluid’s pressure becomes reduced to the same level as is the pressure at ”Cold Exit Side”-container. More specifically, the fluid, which came from the ”Hot Entry Side”-container and had a pressure of 9054.45Pa upon arriving at the heat engine’s entry-side, would have its pressure reduced to 2444.43Pa upon reaching that heat engine’s exit-side. This pressure reduction percentage is equal to the Carnot Efficiency value, expressed using a thermal efficiency percentage.

b) The second encountered (right-side) and optimally efficient heat engine would then receive its entry-side fluid at a pressure of 2444.43Pa. The fluid the heat engine already has at its exit-side is already at a pressure of 2444.45Pa. Thus, the second heat engine has no pressure difference between its entry- and exit-sides and can only achieve a 0% efficiency, as shown by the values in tables 3 and 4.

c) If the first encountered (left-side) heat engine would somehow be able to remove 74% of the system’s added heat, the pressure of the fluid that passed through the first heat engine would be less than the pressure which already existed at the ”Cold Exit Side”-container, causing the molecules of the ”Cold Exit Side”-container to begin flowing towards that lowest pressure area within the system which would be found between those two heat engines. The counter-flow of molecules coming from the ”Cold Exit Side”- container would then oppose the heat engine’s operation and reduce the efficiency to 73% efficiency level. And that is why the Carnot efficiency limit is 73% for this kind of system, with an entry-side temperature of 1089K and exit-side temperature of 294K. In reality, the entry-side pressure of 9054.45Pa and the exit-side pressure of 2444.45Pa actually determine its maximum efficiency. A heat engine can not reduce the passing fluid’s pressure to a lower level than the pressure which already exists at that heat engine’s exit-side.

Let's re-examine the heat engine system shown in picture 3 by assuming that the first (left-side) heat engine had been partially broken and not been able to operate with optimal 73.003% efficiency, but instead operated with only a 33.003% efficiency, and only being able to reduce the passing fluid’s pressure by 33.003%. In that case, there had been a significant pressure difference still available between the entry- and exit-sides of the second (right-side) heat engine. Therefore, the second(right-side) heat engine would have had the opportunity to capture and remove up to 40% of the heat that had been originally added to the system. So, the first (left-side) heat engine reduced the pressure coming from the “Hot Entry Side”-container by 33.003%. Thus, the pressure of the fluid, which passes through the first heat engine and arrives at the entry-side of the second (right-side) heat engine, is:

9054.45Pa – (9054.45Pa x 0.33003) = 6066.21Pa

The first (left-side) heat engine's efficiency can be calculated from its entry- and exit-side pressures. The equation is the same as the previously introduced "second alternative method" ($\eta_{(max,2nd\ alternative\text{-}method)}$) for obtaining Carnot efficiency values. Still, this time it is used for showing that we can calculate the heat engine's real efficiency if its entry- and exit-side pressures are known:

$\eta_{(left\text{-}side\ heat\ engine\ efficiency)} = (P_{entry} - P_{exit}) / P_{entry}$

$\eta_{(left\text{-}side\ heat\ engine\ efficiency)} = (9054.45Pa - 6066.21Pa) / 9054.45Pa$

$\eta_{(left\text{-}side\ heat\ engine\ efficiency)} = 0.33003$

Thus, the second (right-side) heat engine receives an entry-side pressure of 6066.21Pa, while its exit-side pressure is at the 2444.45Pa pressure level; i.e. the original pressure level coming from the "Cold Exit Side" container. Suppose the second heat engine is able to operate with its theoretical maximum efficiency. In that case, it can reduce its 6066.21Pa entry-side pressure to the level of its exit-side pressure 2444.45Pa, but not lower than that. Also, we can now calculate the maximal efficiency percentage of the optimally efficient second (right-side) heat engine.

$\eta_{(max,for\ right\text{-}side\ heat\ engine)} = \eta_{(max,alternative)} = 1 - P_{(exit\text{-}side\ of\ right\text{-}side\ heat\ engine)} / P_{(entry\text{-}side\ of\ right\text{-}side\ heat\ engine)}$

$\eta_{(max,for\ right\text{-}side\ heat\ engine)} = 1 - 2444.45Pa / 6066.21Pa$

$\eta_{(max,for\ right\text{-}side\ heat\ engine)} = 1 - 2444.45Pa / 6066.21Pa$

$\eta_{(max,for\ right\text{-}side\ heat\ engine)} = 0.597038$

This pressure reduction equals 40% of the pressure difference which initially existed between the (9054.45Pa) "Hot Entry Side" container and the (2444.45Pa) "Cold Exit Side" container. Thus, the exit-side pressure after completing the pressure reduction by the maximally (59.70%) efficient second (right-side) heat engine will be...

*6066.21*Pa - (*6066.21*Pa x 0.597038) = 2444.45Pa

As can be seen, the optimally 59.70% efficient second (right-side) heat engine can reduce its entry-side pressure to the level of its exit-side pressure coming from the "Cold Exit Side" container; 2444.45Pa Vs. 2444.45Pa.

Thus, the total pressure reduction achieved by both of the heat engines is...

9054.45Pa – 2444.45Pa = 6610Pa

This pressure reduction was achieved by the first (left-side) heat engine operating with 33.003% efficiency and reducing pressure from 9054.45Pa to 6066.21Pa. Then the second (right-side) heat engine operating with theoretically maximal 59.704% efficiency reduced its entry-side over-pressure from 6066.21Pa to 2444.45Pa.

Pressure reduction by first (left-side) heat engine

9054.45Pa - 6066.21Pa = 2988.24Pa

==> Which equals 33.003% of the original “Hot Entry-Side” container pressure:

2988.24Pa / 9054.45Pa x 100% = 33.003%

Pressure reduction by second (right-side) heat engine

6066.21Pa - 2444.45Pa = 3621.76Pa

==> Which equals 40.000% of the original “Hot Entry-Side” container pressure:

3621.76Pa / 9054.45Pa x 100% = 40.000%

The original “Cold Exit Side”-container pressure 2444.45Pa is 26.997% of the “Hot Entry-Side” container’s pressure, and it can not be removed from the system with any heat engine.

2444.45Pa / 9054.45Pa x 100% = 26.997%

Notice that the first (left-side) heat engine had had an opportunity to achieve maximum efficiency of 73.003%. The lower maximum efficiency of the second heat engine is because the first heat engine had already reduced a 33.003% of the original “Hot entry Side” pressure. This pressure reduction by the first heat engine caused a reduction the second heat engine’s entry- and exit-side pressure difference and therefore also lowered the second heat engines maximum efficiency. Thus, the maximum available efficiency for the second (right-side) heat engine is lower than it was for the first (left-side) heat engine. In addition, if the second (right-side) heat engine had not been optimally 59.704% efficient and not able to reduce the passing fluid’s pressure to the level of the “Cold Exit Side” container, then some additional successive heat engines could still have been placed between the second (right-side) heat engine and the “Cold Exit Side” container. Each of those additional heat engines would remove energy from the system as long as there existed the pressure difference between their entry- and exit-sides. However, the maximum available efficiency of each of those successive heat engines would be less than the previous heat engine had because the pressure difference between the entry- and exit-sides would get less and less.

...about the evidence system 3

The evidence systems 1 and 2 have already shown that the same Carnot efficiency values can be obtained using the heat engine's entry- and exit-side pressures or the temperatures. However, a problem arises when the entry- and exit-side pressures are connected to different external pressures. In such situations calculating the efficiency values from the entry- and exit-side pressures or the temperatures can yield different results. In those cases, only one of the obtained efficiency values can be right, but which one is it? Is it the temperature-derived Carnot efficiency value, or is it the pressure-derived "alternative" efficiency value?

The arrangement shown in picture 4 did provide a fair chance for the entry- and exit-side pressures and temperatures to show which one can give the correct results. The results in table 6 did show that the temperature-derived maximum efficiency results would be inconsistent and illogical; considering the easily calculated pressure forces present in all cases at the left- and right-sides of the valve plate. In contrast, the pressure-derived efficiency values were logically following the stable pressure force values at the valve plate's left- and right-sides. Thus, evidence system 3 suggests that the heat engine's entry- and exit-side pressures are the ones ruling over the heat engine's ability to operate and to obtain useful work from the system.

One can obviously wonder whether the arrangement used with the evidence system 3 was a heat engine? Of course, it was! If there had been a hole drilled into that valve plate and, for example, a Tesla-turbine's fluid-inlet attached to that hole, the heat engine's useful work would not be metal-plate's deformation, but instead making a rotor to rotate. In all left-side temperature cases, that Tesla-turbine's rotor would be rotating in the same direction because the molecules coming from the container's left-side would, in all cases, be rushing towards the container's right-side. In contrast, if the heat engine had been powered by the entry- and exit-side temperatures, then that Tesla-turbine's rotor would have been rotating to different directions depending on whether the container's left-side had been cooled to a lower or a higher temperature than the container's right-side.

To summarize obtained results so far. Evidence system 1 has shown that the same Carnot efficiency values can be obtained using the heat engine's entry- and exit-side pressures or temperatures. Evidence system 2 demonstrated that the heat engine's exit-side pressure causes a force(F) that opposes the pressure force(F) coming from the entry-side. Now, the results from evidence system 3 have shown that the entry side's relative over-pressure powers the heat engine. In addition, the influence of heat engine's entry- and exit-side temperatures can be completely overrun by the influence of the entry- and exit-side pressures. Therefore, the Carnot's theorem concerning the maximum efficiency of heat engines appears to be incomplete and needs to be replaced with something else. So, let's explore the maximum efficiency of all pressure engines, including the heat engines, by taking another look at the 100% efficient virtual heat engine shown in picture 8. The author of this article believes that the thermodynamic system shown in picture 8 is at the intersection of four laws, principles or famous conclusions of physics:

- Firstly, Max Planck had observed(“Second law of thermodynamics,” 2021) that: ”The internal energy of a closed system is increased by an adiabatic process, throughout the duration of which, the volume of the system remains constant.” The author believes that, the Plank’s observation applies to the heating of the “Hot Entry Side”-container shown in picture 8.

- Secondly, Borgnakke and Sonntag had come to a conclusion(“Second law of thermodynamics,” 2021) that ”... there is only one way in which the entropy of a [closed] system can be decreased, and that is to transfer heat from the system.” A simple equation for heat engines is $Q_{(hot\text{-}side)} = W_{output} + Q_{(waste\ heat\ from\ cold\text{-}side)}$. Therefore, it should be obvious that a portion of added heat energy can be removed from the system in the form of useful work (W_{output}) joules and not just in the form of waste heat ($Q_{(waste\ heat\ from\ cold\text{-}side)}$) joules. Thus, the author also assumes that the entropy decreasing heat removal from the system, shown in picture 8, can be achieved using a heat engine that removes heat energy from the systems in the form of mechanical force and motion. In addition, tables 3 and 4 and pictures 2 and 7 have shown that 100% efficiency is possible if the heat engine’s exit-side is at absolute zero or otherwise causes zero pressure. The entropy at absolute zero is zero. Therefore, a theorized heat engine, with an exit-side pressure of 0Pa and which is operating with a 100% efficiency, would be able to decrease the system’s entropy to zero. All the added heat energy to the heat engine’s entry-side would first increase the system’s internal energy and then be completely removed from the system by the heat engine. Upon passing the 100% efficient heat engine, the (point-like ideal gas) molecules would not show signs of thermal movement and would not cause any pressure. Real-life molecules might exit such 100% efficient heat engine system in the form of crystals.

- Thirdly, Newton’s first law states(Lumen Learning, 2020b) that an object at rest will stay at rest, and an object in motion will stay in motion unless acted on by a net external force. The author believes that Newton’s first law applies to the “molecular objects” moving from the “Hot Entry Side”-container and into the “Vacuum Exit Side”. As no molecular objects are coming from the “Vacuum Exit Side”, those non-existing molecules can not influence the velocity of the molecular objects coming from the “Hot Entry Side”. Without the heat engine’s physical structures, the (ideal gas) molecules would maintain their velocity as they are passing inside the, by nature, adiabatic connecting pipe between those two containers. Importantly, there is no need for the opposing pressure force to exist. For example, suppose a gas turbine-type heat engine operates inside a space station and pushes its exhaust gases into the emptiness of space. In that case, the heat engine’s exit-side pressure ($P_{(exit\text{-}side)}$) is pretty close to zero and hardly causes any opposing pressure force(F). Thus, the same heat engine which on earth might only achieve a 40% efficiency can achieve a well above 90% efficiency in space.

- Fourthly, the first law of thermodynamics forbids creating or destroying energy. The fluid molecules' speed will necessarily slow down as they get closer to the border layer areas of the heat engine's moving parts. The kinetic energy of the fluid's molecules does not vanish, but at least a portion of it is handed over to the benefit of the kinetic energy of the heat engine's moving parts. This motion can then be irreversibly removed from the system in the form of useful work (W_{output}).

Based on those four principles, laws, and observations of physics, and because Carnot's theorem needs to be completed with another and more universally applicable theorem, the author takes the liberty to present his theorem concerning the efficiency of all engines that produce force and motion by utilizing the engine's entry-side's relative over-pressure. Hukkanen's theorem is as follows:

> Pressure engine's maximal and real efficiency is always 100%. It is just a technical problem if the pressure engine's user can not get all of its added energy from the system in a desired form of energy.

...about the evidence system 4

Evidence system 4 shows two automobiles powering the movement of the boats they are on. Those two automobiles can not provide rotational force to their front wheels with the same efficiency because the CAR-B has to consume additional energy for overcoming the hydro-static pressure at a depth of 10 meters. This simple arrangement again demonstrates that the heat engine's entry- and exit-side pressures must influence its overall efficiency. If the heat engines of CAR-A and CAR-B were able to achieve similar efficiencies, then the CAR-B's identical engine would somehow have to create additional energy. Such creation of extra energy would violate the first law of thermodynamics. Therefore, one is now forced to choose whether to believe that the first law of thermodynamics is wrong or accept that, besides entry- and exit-side temperatures, also the ambient entry- and exit-side pressures influence the efficiency of heat engines.

The design of the evidence system 4 is also helpful in understanding the mathematics of the heat engine's ambient entry- and exit side pressures. The simple virtual heat engine, shown in picture 1, can be re-used to calculate CAR-A and CAR-B efficiencies. This can be done even if the pressures and molar amounts of substance inside the “Hot Entry Side” and “Cold Exit Side”- containers are very different from evidence systems 1 and 2. To show that this is the case, CAR-A's efficiency will be calculated first using both the temperature-derived Carnot efficiency calculation (η_{Carnot}) and the pressure-derived alternative-efficiency calculation ($\eta_{(max,alternative)}$).

CAR-A's temperature-derived efficiency calculation

$\eta_{Carnot} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$

$\eta_{Carnot} = 1 - 294K / 1089K$

$\eta_{Carnot} = 0.73003$

CAR-A's pressure-derived efficiency calculation

$R = 8.31446261815324\ m^3{\cdot}Pa{\cdot}K^{-1}{\cdot}mol^{-1}$

$V_{(exit\text{-}side)} = 1m^3$

$T_{(exit\text{-}side)} = 294K$

$P_{(exit\text{-}side)} = 101kPa$

$n_{(entry\text{-}\ and\ exit\text{-}side)} = ?$

$V_{(entry\text{-}side)} = 1m^3$

$T_{(entry\text{-}side,\ before\ heating)} = 294K$

$T_{(entry\text{-}side,\ after\ heating)} = 1089K$

$P_{(entry\text{-}side,\ before\ heating)} = 101kPa$

$P_{(entry\text{-}side,\ after\ heating)} = ?$

To solve CAR-A's entry-side pressure after the entry-side container has been heated to 1089K, the molar amount of substance in entry- and exit-side containers before the addition of heat to entry-side container were first calculated using the equation $n = PV / RT$. Thus, in that calculation the initial container temperature was 294K. A handy Online calculator (Furey, 2021) told that the initial amount of substance(n) in both the entry- and exit-side containers was 41.318 mol. After solving the amount of substance in both containers, the pressure inside the heated (1089K) entry-side container could then be calculated using the equation $PV=nRT$. The entry-side's pressure ($P_{(entry\text{-}side,\ after\ heating)}$) was calculated to be 374.1122kPa.

Now that the pressures inside the virtual heat engine's "Hot Entry Side" and "Cold Exit Side"- containers have been calculated, the efficiency of the CAR-A's heat engine could be calculated using the equation $\eta_{(max,alternative)} = 1 - P_{(exit)}/P_{(entry)}$.

$\eta_{alternative} = 1 - P_{(exit)}/P_{(entry)}$
$\eta_{alternative} = 1 - 101\text{kPa} / 374.1122\text{kPa}$
$\eta_{alternative} = 0.73003$

The results of CAR-A's pressure- and temperature-based efficiency calculations show that both methods can be used to calculate CAR-A's efficiency as the obtained efficiency values are the same; 0.73003 Vs. 0.73003.

The virtual heat engines that simulate the CAR-A's and CAR-B's entry-side containers and their heating processes are similar. Therefore, the pressures of both of those entry-side containers will be similarly increased; pressure before heating is 101kPa and after heating to 1089 degrees Kelvin 374.1122kPa. However, the CAR-B heat engine's exit-side pressure will be different than the CAR-A heat engine's exit-side pressure because the CAR-B's exhaust gases can not leave the exhaust pipe unless the pressure inside the entire exhaust pipe exceeds the pressure at a depth of 10 meters of water. The pressure at the exhaust pipe's open end consists of the atmospheric pressure of 101kPa and hydro-static pressure of (roughly) 101kPa, caused by the weight of a 10-meter high pillar of water. Therefore, the CAR-B heat engine's exit-side pressure will be (roughly) 202kPa.

CAR-B's temperature-derived efficiency calculation

$\eta_{Carnot} = 1 - T_{(cold\text{-}side)}/T_{(hot\text{-}side)}$
$\eta_{Carnot} = 1 - (294\text{K} / 1089\text{K})$
$\eta_{Carnot} = 0.73003$

CAR-B's pressure-derived efficiency calculation

$P_{(entry\text{-}side,\ after\ heating)} = 374.1122\text{kPa}$

$P_{(exit\text{-}side)} = 202\text{kPa}$

$\eta_{alternative} = 1 - P_{(exit\text{-}side)}/P_{(entry\text{-}side)}$

$\eta_{alternative} = 1 - (202\text{kPa} / 374.1122\text{kPa})$

$\eta_{alternative} = 0.46005$

Thus, the CAR-B heat engine's temperature- Vs. pressure-derived efficiency calculation results are different; η_{Carnot} = 0.73003 Vs. $\eta_{alternative}$ = 0.46005. Earlier, the evidence system 3 results showed that when the temperature- and pressure-derived efficiency calculations result in different values, one should trust the pressure-derived efficiency values. Therefore, it can be assumed that CAR-B's heat engine can only convert heat to useful work (rotating front wheels) with a maximum efficiency of 46.0%, while CAR-A's maximum efficiency was 73.0%.

So, the CAR-B's heat engine's efficiency would be lower if its exhaust pipe was put deep into the water. Table 8 shows how the CAR-B's efficiency would be impacted if its exhaust pipe was placed into various depths. The calculations were done similarly to the previous CAR-B heat engine's efficiency calculations. Calculations also used rough estimates of the water's temperature being 294 degrees Kelvin at all depths and each increase of depth by 10 meters increasing the hydro-static pressure by 101kPa. The entry-side's pressure inside the CAR-B's combustion chamber was in all cases assumed to be 374.1122kPa and reach a temperature of 1089 degrees Kelvin.

Depth of exhaust pipe's open end (m)	$P_{(Exit\text{-}side)}$ ("inside the exhaust pipe") (kPa)	$\eta_{Carnot} = 1 - T_{(cold)}/T_{(hot)}$	$\eta_{(max,alternative)} = 1 - P_{(exit)}/P_{(entry)}$
0.00 "CAR-A"	101.0	0.7300	0.7300
5.00	151.5	0.7300	0.5950
10.00 "CAR-B"	202.0	0.7300	0.4601
15.00	252.5	0.7300	0.3251
20.00	303.0	0.7300	0.1901
25.00	353.5	0.7300	0.0551
27.04	374.1	0.7300	0.0000

Table 8: Calculated temperature- and pressure-derived efficiencies in situations in which different hydro-static pressures are influencing the heat engine's exit-side

Results in table 8 show that the temperature-derived Carnot-efficiency values(η_{Carnot}) are unaffected by the water depth which the CAR-B's exhaust pipe reaches. In contrast, the pressure-derived efficiency values ($\eta_{(max,alternative)}$) decrease as a function of increased depth. The author believes the pressure-derived efficiency values are more correct.

The last data row in table 8 suggests that the maximum depth to which the CAR-B's heat engine could manage to push exhaust gases is 27.04 meters. At that depth, inside the CAR-B's exhaust pipe, the exit-side pressure would equal the heat engine's entry-side pressure; 374.1kPa Vs. 374.1kPa. The exact depth in which the exit-side pressure inside the exhaust pipe would reach 374.1kPa was obtained by calculating how many meters of water would be needed for causing the hydro-static pressure of 273.1122kPa.

$P_{(hydro\text{-}static)}$ 273.1122kPa = $P_{(total\text{-}exit\text{-}side)}$374.1122kPa – $P_{(atmosphere)}$101kPa

$$h_{(maximum\ depth)} = \frac{273.1122\,kPa}{10.1\,kPa/m}$$

It should be noticed that Carnot’s theorem has a qualification that forbids using the equation $\eta_{(Carnot)} = 1 - T_{(cold\text{-}side)} / T_{(hot\text{-}side)}$ for calculating the maximum efficiency for CAR-B. This qualification arises from the word “reversible” because Carnot's theorem is only valid for reversible heat engines (Hari Dass, 2013). Thus, it excludes all heat engine systems with natural or man-made pressure differences on entry- and exit-sides. All heat engine systems with pre-existing external entry- Vs. exit-side pressures automatically make the system non-reversible because “reversing” such externally pre-pressurized heat engines would also require doing the energy-consuming reversal of those external pressure conditions.

...about the evidence system 5

Evidence systems 1-4 have already shown the role of the heat engine’s entry- and exit-side pressures, but the impact of different or limited entry- and exit-side volumes have so far not been discussed in detail. Firstly, why is it important to consider the impact of the entry- and exit-side volumes? It is because, the entry- and exit-side volumes are just as important components to the heat engine’s pressure as the entry- and exit-side temperatures. The ideal gas law equation (*PV=nRT*) can be easily converted into solving just the pressure values. This conversion enables seeing all of the components that cause the pressure of gaseous substances at the heat engine’s entry- and exit-sides. Components of the (virtual) heat engine’s entry- and exit-side pressures are shown in table 9.

Components of ideal gas pressure at entry-side	Components of ideal gas pressure at exit-side
$P_{(entry\text{-}side)} = \frac{nRT_{(entry-side)}}{V_{(entry-side)}}$	$P_{(exit\text{-}side)} = \frac{nRT_{(exit-side)}}{V_{(exit-side)}}$

Table 9: Components of heat engine’s entry- and exit side pressures

As shown in table 9, some of the pressure components are supposed to be the same at the entry- and exit-sides of a typical heat engine. For example, the value of ”gas constant” R is supposed to be the same (R = 8.31446261815324 $m^3 \cdot Pa \cdot K^{-1} \cdot mol^{-1}$) at entry- and exit sides of a heat engine. Thus, removing the ”gas constant” from the entry- and exit-side pressure calculations will not impact the final efficiency value. Similarly, if there are no leaks inside the heat engine, then the molar ”amount of substance” (*n*) can also be removed from the entry- and exit-side pressure calculations. It will not impact the final efficiency value. Finally, if the volume (*V*) at the heat engine’s entry- and exit-sides is unlimited, then the volumes can also be removed from both the entry- and exit-side pressure calculations as they will not impact the final efficiency value. The only variables that remain for the entry- and exit-side pressure calculations are the entry- and exit-side temperatures. And this is why the Carnot efficiency values have appeared to provide correct estimations of the heat engine’s efficiency! Those engineers who have used the equation $\eta_{max} = \eta_{carnot} = 1 - T_{(cold\text{-}side)}/T_{(Hot\text{-}side)}$ have done so mostly in situations where the heat engine was not leaking, the entry- and exit sides were connected to the same external pressure and unlimited volumes of the fluid substance. Under those conditions, the Carnot efficiency values would usually be correct. However, there are special circumstances and systems where the Carnot efficiency values are wrong, as shown by the evidence systems 3, 4, and 5. At least, in those special cases, the efficiencies should be calculated using the equation:

$$\eta_{max} = 1 - P_{(exit\text{-}side)}/P_{(entry\text{-}side)}$$

The focus with the evidence system 5 was in showing that the heat engine’s entry- and exit-side volumes influence its maximum efficiency. Picture 6 section-a did show a device arrangement, in which the traditional equation $\eta_{(Carnot)} = 1 - T_{(cold\text{-}side)} / T_{(hot\text{-}side)}$ would produce correct results. The correctness of those Carnot efficiency values was achievable due to the heat engine’s entry- and exit-sides being connected to the same external pressure conditions and equally unlimited volumes. At least theoretically, both the Carnot efficiency values (η_{Carnot}) and the pressure-derived efficiency values ($\eta_{alternative}$) could still be wrong, even if the entry- and exit-sides were connected to unlimited volumes and the same external pressures. Those errors could occur if there were a leak inside the heat engine or if the fluid’s phase transition took place inside the heat engine.

The leak inside the heat engine would cause the fluid’s exit-side temperature and pressure to become lower than those would be without that leak. As a result, the heat engine would appear to have decreased the fluid’s temperature and pressure more than it actually could, which would allow the heat engine to obtain a too high efficiency value. In case that there was a fluid’s phase transition taking place inside the heat engine, the Carnot efficiency value and the pressure-derived efficiency values would also be distorted. All heat engines remove a portion of the system’s internal energy. Thus, the possible phase transitions that can take place inside the heat engine are those that are achievable by reducing the system's internal energy. Condensation of gas into a liquid and freezing a liquid into a solid are the two most relevant phase transitions which can take place inside a heat engine. Both of those phase transitions are typically exothermic (”heat-releasing”) processes.

Observation of the ideal gas law equations, shown in table 9, make it easy to understand why the changes and limitations in entry- or exit-side volumes will influence the pressure at the entry- and exit-sides. For example, if the entry-side's volume was limited to only $1m^3$, as shown in picture 6 section-b, then the automobile's heat engine's ability to produce sufficient pressure inside the combustion engine would suffer very quickly. One reason for that is because the engine would be getting less and less oxygen-rich air into the combustion chamber. But importantly, as the vacuum would be developing at that $1m^3$ entry-side container, that vacuum would also be sucking the pressurized molecules back from the combustion chamber every time a passage from that $1m^3$ container was opened into the combustion chamber. These factors would inhibit achieving the entry-side's over-pressure (inside the combustion chamber) and ultimately make it impossible, even if its temperature increased to 10 thousand degrees Kelvin. Thus, the entry-side's volume limitation causes a decrease in the heat engine's efficiency. Similarly, if the exit-side would have a limited volume, as it has in picture 6 section-c, pretty soon the pressure at the exit-side would become so high that it would be impossible to push any more gaseous components through the heat engine and into the exit-side container, even if one would increase the entry-side temperature by 10 thousand degrees Kelvin.

Picture 6's section-d did show a heat engine that was being operated without adding any heat. The system only experienced a sudden reduction of the entry-side's volume by 50%. This 50% reduction of the entry-side's volume caused a 100% increase in the entry-side pressure, as suggested by the Boyle's law; $P_1V_1= P_2V_2$. Thus, this arrangement shows a very different kind of automobile heat engine, which is not being powered by the heat - but by increasing its entry-side pressure. Zeng and Xu (2019) have modeled a 4-stroke engine being powered by the pressurized air. They used both numerical studies and an experimental system in their research, and the results show that it is possible to power a 4-stroke engine using compressed air. Importantly, in their study Zeng and Xu discovered that...

> - Compared with other working parameters, supply pressure has a greater influence on the performance of the CAE [“*Compressed Air Engine*”], and the increase of the supply pressure can effectively improve the indicated work and work efficiency.
>
> - The supply temperature has little effect on the performance of the CAE [*“Compressed Air Engine”*], with the increasing of supply temperature, the average effective torque, effective power and work efficiency will decrease slightly.

Thus, the results obtained by Zeng and Xu (2019) appear to be in line with this article's key findings of heat engines being powered by the entry-side over-pressure and not the slightest by the heat.

The engine shown in picture 6 section-d was also being powered by the pressurized air. Therefore, it is more correct to call it a pressure engine - instead of a heat engine. If that engine's efficiency had been calculated using the typical Carnot efficiency equation, the results would have been zero, suggesting that an air pressure-powered heat engine can not produce useful external work without a temperature difference between its entry- and exit-sides. In contrast, if that engine's efficiency was calculated using the entry- and exit-side pressures and the equation: $\eta_{(max,alternative)} = 1 - P_{(exit\text{-}side)}/P_{(entry\text{-}side)}$, that engine could produce external work with up to a 50% efficiency. This pressure-derived efficiency value also suggests that the existing compressed air-powered automobiles and power tools can produce useful work (W_{output}).

Heat engines Vs. other engines

Evidence system 2 did show that the entry-side's relative over-pressure powers the heat engines. When that over-pressure has been fully consumed, the heat engine's ability to obtain more energy from the system with a higher efficiency is not possible. The pressurized air powered the heat engine shown in picture 6's section-d, but what if the entry-side container had been filled with water instead? If the entry-side container had been filled with water and then suddenly impacted by the force of a falling giant apple, then the pressure inside the container would have increased, and the water would have tried to find its way through the engine - just like the compressed air did. The automobile's combustion engine is not optimally shaped for being powered by pressurized air or water, but that is not the point. The point is that, given enough pressure and some engine tuning, the automobile's crankshaft could have been put into motion even with the pressurized air or water. Thus, the same automobile could be powered by the heat, compressed air, and the motion of pressurized water flowing through the engine. This realization of a heat engine being powered by fast moving air ("wind power") or water ("hydropower") leads to a brazen prediction that there are no actual heat engines and the fast moving wind or falling water powers no engines. Instead, they all appear to be pressure engines! Some of the pressure engines may use heat for achieving the entry-side over-pressure, while some other engines obtain their entry-side over-pressure from the mass of fast-moving air (”wind turbines”) or water (”water turbines”).

The reversibility of pressure engines

Sadi Carnot had noticed that, in all work performing heat engines the heat enters the engine at a higher temperature, and leaves at a lower temperature. He then assumed that this temperature fall, from a higher temperature to a lower temperature, is equal with the energy that the heat engine could remove from the system. Therefore, Carnot interpreted the heat engine's work output to arise "not due to an actual consumption of caloric, but to its transportation from a warm body to a colder body." His observation that the heat engine was not consuming or destroying heat energy, only taking energy from the system, become a essential foundation for the thermodynamics. Carnot elaborated his observation into a prediction that, "the most efficient(perfect) engine is such that, whatever amount of mechanical effect it can derive from a certain thermal agency, if an equal amount be spent in working it backwards, an equal reverse thermal effect will be produced". Thus, according to Carnot, an ideal heat engine is at least in theory "reversible" (Hari Dass, 2013).

The reversibility of this article's virtual heat engines can also be shown. Especially easy it is to do using the virtual heat engines that lack the opposing pressure force(F) coming from the exit-side container; due to having vacuum or 0K temperature inside the exit-side container. The results of reversibility can then be applied to all pressure engines, including those which obtain their relative entry-side over-pressure using heat energy. The following "proof of reversibility"-system uses the first law of thermodynamics by assuming that energy can not be created or destroyed. Still, it can be converted into other forms of energy.

1. Equation $Q_{(input)} = W_{(output)} + Q_{(waste\ output)}$ represents an operation of a typical heat engine.

2. Picture 7 and the results in tables 3 and 4 demonstrate that when a heat engine's exit-side pressure ($P_{(exit\text{-}side)}$) is zero, a heat engine can remove useful work ($W_{(output)}$) energy joules from the system with up to a 100% efficiency. Thus, if the exit-side pressure is zero, 0% of the heat energy gets dissipated from the system; $Q_{(waste\ output)}$ is zero.

3. If all of the heat energy joules that were added to the system's entry-side ($Q_{(input)}$) can be removed from the system in the form of useful work output ($W_{(output)}$) joules, then the amount of those useful work output ($W_{(output)}$) joules equals with the amount of the heat energy joules that were initially added to the system's entry-side.

4. The heat energy joules ($Q_{(input)}$) that are added to the heat engine's entry-side and the obtained useful work ($W_{(output)}$) joules can cause a similar temperature and pressure increase inside of an isochoric heat engine's entry-side. Once the temperature increase has taken place, it is not possible to tell whether the heat energy joules ($Q_{(input)}$) or the obtained useful work joules ($W_{(output)}$) caused that temperature and pressure increase.

5. Thus, the heat engine's 100% work output ($W_{(output)}$) can be used for heating the entry-side of another and similarly 100% efficient heat engine. Later, that second heat engine's work output ($W_{(output)}$) joules can be re-used for heating and increasing the pressure inside the first heat engine's entry-side. The achieved increase of temperature and pressure would be equal to that increase that was achieved with the original amount of added heat.

That kind of theoretical "proof of reversibility"-system, in which two 100% efficient heat engines would be powering each other's operation, could be considered a *perpetual machine*. However, it could not be used to produce useful work for external purposes – not for a very long time at least. If the system's operator tried to remove any amount of useful work or heat energy joules from the system, the entire system's internal energy would be reduced. As a result, the system could still keep circulating the decreased amount of energy. However, if the system's operator would want to maintain the original amount of internal energy while removing work or heat energy joules from the system, additional external energy would need to be added to that "proof of reversibility"-system. For example, if that "proof of reversibility"-system would initially circulate 1000 joules of internal energy within the system. Then, the system's operator would remove 500 joules per second from the system in the form of useful work. The system would run out of its added internal energy in two seconds and stop. However, suppose the system's operator could compensate the removed useful work joules by adding 500 joules of external heat energy into the system per second. In that case, the system could continue its operation forever. This externally powered engine system, as a whole, would keep converting the added heat into useful work with 100% efficiency. The obvious practical problem with this kind of "proof of reversibility"-system is that the engine would soon be unable to operate due to the accumulation of fluid to the engine's exit-side. Somehow, the accumulated fluid would need to be shoveled back to the entry-side. It would be challenging to achieve that because any practical system, which would take heat energy from only one container and convert it into useful work, would violate the Kelvin-Planck statement ("Kelvin–Planck statement," 2020).

Sadi Carnot had interpreted the hot and cold reservoir temperatures to be of fundamental importance to the heat engine's ability to produce useful work (W_{output}). He wrote, "*...wherever there exists a difference of temperature, motive power can be produced*" (Carnot & Thurston, 1824/1897, p. 51). The results that have been presented in this article suggest that he was wrong with that prediction. There exists an equal and opposing exit-side pressure for all the entry-side pressures, which any given entry-side temperature can generate. For example, the discussion "*about the evidence system 4*" did show that if an isochoric heat engine system's entry-side ("hot reservoir") temperature is 1089K and the exist-side's ("cold reservoir") temperature is 294K, then the motive power cannot be produced if the entry-side's ambient pressure is 101kPa and the exit-side's ambient pressure is 374.1kPa. Or at least, under those conditions, a motive power cannot be produced by the entry-side's hot temperature. Instead, it would rather be produced by the higher exit-side pressure.

The universality of pressure engines

Carnot's theorem suggests that all ideal heat engines can deliver the same amount of work for the same amount of thermal energy (Hari Dass, 2013). Therefore, the ideal heat engine's maximum efficiency would not be depended on the heat engine's design. Instead, the hot- and cold reservoir temperatures would dictate the heat engine's maximum efficiency.

The results in tables 3 and 4 show how the same Carnot's efficiency values can be obtained using the heat engine's entry- and exit-side temperatures or pressures. Therefore, if all of the Carnot's reversible heat engines have a property of universality, the same universality must also be present when only the entry- and exit-side pressures are used to determine the reversible heat engine's maximum efficiency. If the engine's efficiency results are the same, also "the universality" of the results must be the same.

Why the Carnot efficiency values are what they are? The author is unaware if there exists an explanation to why a certain combination of Carnot's hot and cold reservoir temperatures would dictate the heat engine to have a certain maximum efficiency value. For example, what is the explanation that causes a heat engine with a hot reservoir temperature of 1089K and a cold reservoir temperature of 294K to have a maximum efficiency of 0.73003? Why can't a heat engine with those temperature parameters have a maximum efficiency of 0.202112 or

0.50505? This question is relevant because the evidence system 2 and the results in table 4 were able to show with great accuracy how the heat engine’s exit-side pressure force(F) can inhibit the entry-side pressure force(F) from achieving a 100% engine efficiency and at the same time how these opposing forces will define the value of the heat engine’s maximum efficiency.

Evidence systems 3, 4, and 5 demonstrated how a temperature-derived heat engine’s maximum efficiency values would sometimes be illogical and likely wrong. In contrast, the pressure-derived efficiency values for similar systems would produce more logical and more reasonable results which, would not violate the laws of thermodynamics. For example, the evidence system 3 showed that, when the temperature-derived and pressure-derived maximum efficiency values were different, the temperature-derived efficiency values behaved illogically, considering the easily calculated and strong pressure-derived Newtonian forces(F) present within the system. Next, the evidence system 4 did show that, when the temperature-derived and pressure-derived efficiency values differed, the temperature-derived efficiency value could only be correct if the CAR-B’s heat engine could generate energy; in violation of the first law of thermodynamics.. Furthermore, the evidence system 5 and especially its picture 6 section-d demonstrated that, when the temperature-derived and pressure-derived efficiency values were different, the temperature-derived efficiency value could only be correct, only if it was not possible to power an automobile’s heat engine in an isothermic environment and just by using compressed air. Zeng and Xu have simulated and built models of compressed air powered 4-stroke engines that show those kinds of pressure powered heat engines to be possible. They even wrote, “The effect of supply temperature on working characteristics seems to be non-significant different with the range of whole work cycle” (2019). Thus, in all of those previously mentioned evidence systems 3, 4, and 5, the temperature-derived efficiency values appear to be incorrect and illogical. In contrast, the pressure-derived efficiency values seem more logical and seemingly do not violate the laws of thermodynamics.

The similarity of Carnot efficiency values and the pressure-derived efficiency values in evidence systems 1 and 2 suggests that both of those efficiency values are caused by the same physical phenomenon; the exit-side pressure inhibiting the entry-side pressure from achieving a 100% engine efficiency. The evidence systems 3 and 4 have shown how the external entry- and exit-side pressures can influence the heat engine’s entry- and exit-side pressures. Furthermore, the evidence system 5 showed how the limited entry- and exit-side container volumes can influence the heat engine’s entry- and exit-side pressures. These differences in ambient pressures and volumes will influence the heat engine’s available efficiency and make the system non-reversible. The influence of different entry- and exit-side container volumes and external pressures on the heat engine’s efficiencies are probably related to those observations which Philip Koeck had done (2017) regarding the joining of the additional containers with different volumes and temperatures to the heat engine’s hot- and cold-side reservoirs.

So, the temperature-based Carnot efficiency values require a heat engine system to be reversible. Evidence systems 3, 4, and 5 were non-reversible device arrangements with different external pressures or container volumes. Thus, the Carnot's theorem would not provide correct heat engine efficiency values in those evidence systems. Therefore, Carnot's theorem's validity and universality remain – thanks to the obligatory requirement of the heat engine's reversibility. On the other hand, the pressure engines used with the evidence systems 3, 4, and 5 do not require the engine system to be reversible. Instead, the pressure engine's entry- and exit-side pressure forces would always determine its maximum efficiency. The engine itself doesn't know or care where the pressures that impact its entry- and exit-sides come from. The pressure engine receives a relative over-pressure to one of its sides and automatically assigns that side the role of being the incoming fluid's entry-side. And if the fluid can flow through the pressure engine, the other side has to have a lower pressure than the entry-side had. Thus, the side with a lower pressure will become the pressure engine's exit-side. The entry- and exit-side temperatures are not dictating the pressure engine's maximum efficiency but can be overrun by the pressure-derived forces(F) that impact the pressure engine's entry- and exit-sides. Thus, the universality of the efficiency of pressure engines includes all engines powered by the pressure-derived forces(F) that impact the engine's entry- and exit-sides differently.

Results in table 9 and the texts around it can be used for demonstrating the universal validity of the Carnot's theorem for reversible heat engines. The central idea is to use the ideal gas law-equation in showing and isolating the components that are causing the entry- and exit-side's pressures. If a similar component of pressure exists at both the entry- and exit-sides, it must be similarly building up the pressures at the entry- and exit-sides and similarly it can be eliminated from both the entry- and exit-sides. If all of the components that can cause different entry- and exit-side pressures would be identical, the entry- and exit-side pressures would be identical. In that case, there would not exist an entry-side over-pressure which the heat engine could capture and remove in form of useful work (W_{output}). The pressure engine's maximum efficiency would be 0%. However, if the ambient pressures impacting the entry- and exit-sides are identical($P_{ambient\text{-entry}}=P_{ambient\text{-exit}}$), the entry- and exit-side volumes are unlimited ($V_{entry}=V_{exit}$), the engine does not leak fluid($n_{entry}=n_{exit}$), and the fluid doesn't become "different" or otherwise change its character ($R_{entry}=R_{exit}$), then the only remaining variables able to influence the entry- and exit-sides pressures are the entry- and exit-side temperatures. If the entry- and exit-side temperatures would not be the same, then the pressure engine's maximum efficiency would be non-zero.

The evidence systems 1 and 2 have shown that the same Carnot efficiency values can be obtained using the equation:

$$\eta_{(max,alternative)}=1-P_{exit}/P_{entry}$$

If the entry- and exit-side temperatures are different, but all of the other components of pressure are identical and have been eliminated, the previous equation can be reduced to the Carnot's equation:

$$\eta_{(\max,\mathrm{Carnot})}=1-T_{cold\text{-}side}/T_{\mathrm{hot\text{-}side}}$$

In this case, Sadi Carnot's observation about the defining role of the cold and hot reservoir temperatures to the heat engine's maximum efficiency would also be correct.

Conclusions

Heat engine's ability to obtain energy from a system was found to be depending on the existence of an entry-side over-pressure – irrespective of the entry- and exit-side temperatures, as was shown by the evidence system 3. As the fluid passes through the heat engine, its pressure decreases. If the heat engine has been able to reduce the passing fluid's pressure to the same level as already existed at its exit-side, then the heat engine would have been operating exactly at its maximum efficiency level. Tables 3 and 4 showed that if the heat engine's already existing exit-side pressure equals the heat engine's entry-side pressure, then the heat engine can only operate with a 0% efficiency. Also, suppose the already existing exit-side pressure is zero (or the exit-side temperature is at absolute zero), and the heat engine's entry-side's pressure is non-zero. In that case, the heat engine can operate with up to a 100% efficiency.

Information and results in picture 3 and table 4 show that a (reversible) Carnot heat engine can not reduce its "Hot Entry Side" pressure by more than is the heat engine's Carnot efficiency percentage. If a heat engine could reduce its entry-side's pressure by the "Carnot efficiency"-amount, then the pressure of the passing fluid would be at the pressure level that already existed at the "Cold Exit Side." If, for example, in picture 3, the first (left-side) heat engine could (miraculously) operate with a 74% efficiency, it would cause the "Cold Exit Side" container to have a higher pressure than is the pressure between those two heat engine units. This would cause the molecules from the "Cold Exit Side" container to flow towards the area between those two heat engine units. As shown in tables 3 and 4, the heat engine's efficiency is zero when its entry-side pressure equals the existing exit-side pressure. Thus, the successive heat engine units and turbine blade rows can obtain more energy from the system as long as the pressure at their entry-sides is higher than their already existing exit-side pressure.

If the heat engine's entry- and exit-sides are connected to equal and practically unlimited external pressure sources, then and only then, the heat engine's maximum efficiency can be calculated using the Carnot's theorem and its related equation:

$$\eta_{\text{max}} = \eta_{\text{Carnot}} = 1 - T_{\text{(cold-side)}} / T_{\text{(hot-side)}}$$

In such cases, an optimally efficient heat engine can remove up to a Carnot efficiency share of energy from the passing fluid. And when that happens, the heat engine would be able to reduce the passing fluid's pressure exactly to the same pressure level which pre-existed at the heat engine's exit-side. This article did show that a more universally applicable way for calculating the heat engine's efficiency is available using the following equation:

$$\eta_{\text{(max,alternative)}} = 1 - P_{\text{(exit-side)}} / P_{\text{(entry-side)}}$$

The results presented in this article suggest that the operation of heat engines can be explained and accurately predicted using Newtonian mechanics and the laws of thermodynamics.

The isochoric virtual heat engines, shown in pictures 1 and 3, appear to produce useful estimations of heat engine efficiencies. The most significant benefit of using such virtual heat engine systems is that those allow simultaneous evaluation of the entry- and exit-side pressures(P), temperatures(T), and pressure-derived forces(F). Also, this kind of virtual heat engine can help evaluating the efficiency influence of pre-existing entry- and exit-side pressures.

Carnot’s theorem is often used for estimating the maximum efficiency of the heat engines. Apparently, the Carnot’s theorem’s validity can only be proven indirectly using ”a proof of contradiction”(“Carnot's theorem,” 2021). As was shown in tables 3 and 4, the Carnot’s efficiency values can be the same (and equally correct) as the entry- and exit-side pressure-derived efficiency values ($\eta_{(max,alternative)}$), but the correctness of temperature-derived efficiency values requires that the heat engine’s entry- and exit-sides are connected to equal and unlimited external pressure sources. However, when a pre-existing pressure difference exists between the entry- and exit-sides, the heat engine’s pressure-derived efficiency values are different and more correct than the temperature-derived Carnot’s efficiency values.

Does the observation of obtaining “wrong” efficiency values with different pre-existing entry- and exit-side pressures mean that the Carnot’s theorem is wrong? No, Carnot’s theorem is saved by an additional qualification, which mandates the applicable ideal Carnot heat engine to be “reversible.” Energy is needed for the creation of those different pre-existing entry- and exit-side pressures. Thus, reversing a heat engine with its pre-existing entry- and exit-side pressures would require using, at least, an equal amount of energy for reversing the external pressure conditions, as was initially used for the original creation of entry- and exit-side pressure difference. Therefore, Carnot’s theorem is still valid. It is just a bit incomplete. Completing the Carnot’s theorem requires also considering the pressure influence of entry- and exit-side volumes and the external sources of pressures. Additional factors that can still prevent the entry- and exit-side pressure-derived efficiency values from being correct include fluid leakage from inside the heat engine and possible phase transitions that the fluid substance may experience when it passes through the heat engine.

Summary of findings

1. All heat engines are powered by the pressure difference between their entry- and exit-sides.
2. A heat engine cannot reduce the fluid's pressure to a lower pressure level than is already present at its exit-side.
3. The pressure at the heat engine's exit-side reduces the efficiency that the heat engine can achieve.
4. If the pressure at the exit-side is zero, the heat engine can operate with up to a 100% efficiency.
5. Carnot's equation for calculating the maximum efficiency for heat engines can and, if possible, should be replaced with an equation: $\eta_{max} = 1 - P_{(exit\text{-}side)} / P_{(entry\text{-}side)}$
6. The heat engine's ability to obtain energy from the system with a higher efficiency ends when the pressure-derived forces(F) coming from the entry-side have been reduced, by the irreversible removal of the system's internal energy, to the level of the pressure-derived forces(F) coming from the exit-side.
7. When a heat engine has consumed all of its added heat-derived over-pressure, it may continue to operate if there is an additional source of entry-side over-pressure.
8. Heat engines are pressure engines, which just happen to use heat for achieving the entry-side over-pressure. Other types of engines may obtain their entry-side over-pressure using other means.
9. As long as the entry-side over-pressure exists, more energy can be taken from the system by adding successive heat engine units. Each successive heat engine will have less entry-side over-pressure available and a lower maximum efficiency.
10. The entry-side over-pressure will seek its way through the system and into its area with the lowest pressure, but no further.

These results open up for a new interpretation of what happens inside a heat engine. In short, an average molecule traveling through the heat engine will hand over a portion of the energy it is carrying to the heat engine's energy harvesting parts. However, the molecules at the heat engine's exit-side cause an opposing pressure force which pushes back the molecules coming from the entry-side and inhibit their influence to the heat engine's energy harvesting parts.

The evidence systems presented in this article should convince any sensible reader of what powers the heat engines and what lies behind their efficiency limits. The author rests his case.

References

Bright Hub Engineering. (2010, May 27). The efficiency of power plants of different types. https://www.brighthubengineering.com/power-plants/72369-compare-the-efficiency-of-different-power-plants/

Carnot, S. (1824) Réflexions sur la puissance motrice de feu et sur les machines propres a développer cette puissance. Paris : Bachelier. Retrieved from https://archive.org/details/bub_gb_QX9iIWF3yOMC

Carnot, S. (1824); Thurston, H. (editor and translator) (1897). Reflections on the motive power of heat. New York: J. Wiley & Sons. https://doi.org/10.5962/bhl.title.17778

Carnot's theorem (thermodynamics). (2021, September 7). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Carnot%27s_theorem_(thermodynamics)&oldid=1043005181

Chang, H. & Yi, S. W. (2005). The Absolute and Its Measurement: William Thomson on Temperature. Annals of Science. 62. 281–308. https://doi.org/10.1080/00033790410001712246

Elbatran, A. H., Abdel-Hamed, M. W., Yaakob, O. B., & Ahmed, Y. M. (2015). Hydro Power and Turbine Systems Reviews. Jurnal Teknologi, 74(5). 83-90 https://doi.org/10.11113/jt.v74.4646

Engine. (n.d.). In *Merriam-Webster's online dictionary*. Retrieved November 11, 2021a, from https://www.merriam-webster.com/dictionary/engine

Engine. (n.d.). In *Random House's online dictionary*. Retrieved November 11, 2021, from https://dictionary.reference.com/browse/engine?s=t

Engine efficiency. (2021, June 3). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Engine_efficiency&oldid=1026667262

Ericnutsch. (2016, September 20). What is the theoretical maximum energy efficiency of hydro turbines?. *Stackexchange.com*. Retrieved November 11, 2021, from https://engineering.stackexchange.com/questions/11554/what-is-the-theoretical-maximum-energy-efficiency-of-hydro-turbines

Furey, E. (2021). CalculatorSoup: Ideal Gas Law Calculator [software]. Available from https://www.calculatorsoup.com/calculators/physics/ideal-gas-law.php

Hari Dass, N.D. (2013) A critique of Sadi Carnot's work and a mathematical theory of the caloric. Retrieved from: https://arxiv.org/pdf/1306.1939.pdf

Heat engine. (n.d.). In *Merriam-Webster's online dictionary*. Retrieved November 11, 2021b, from https://www.merriam-webster.com/dictionary/heat%20engine

Kelvin–Planck statement. (2020, November 29). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Kelvin%E2%80%93Planck_statement&oldid=991323062

Koeck, P. (2017). Re: Apparent contradiction between Carnot's theorem and efficiency calculations!?. Retrieved from: https://www.researchgate.net/post/Apparent-contradiction-between-Carnots-theorem-and-efficiency-calculations/59007efbdc332d580573bb47/citation/download

Lumen Learning. (2020a). Carnot's Perfect Heat Engine: The Second Law of Thermodynamics Restated. Retrieved November 11, 2021, from https://courses.lumenlearning.com/physics/chapter/15-4-carnots-perfect-heat-engine-the-second-law-of-thermodynamics-restated/

Lumen Learning. (2020b). Newton's first law of motion: Inertia. Retrieved November 19, 2021, from https://courses.lumenlearning.com/physics/chapter/4-2-newtons-first-law-of-motion-inertia/

Srinivasan, R. (1996). Approach to absolute zero 1: Liquefaction of gases. Resonance, 1(12). 6-16. https://www.ias.ac.in/article/fulltext/reso/001/12/0006-0016

Second law of thermodynamics. (2021, November 3). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Second_law_of_thermodynamics&oldid=1053277443

Thermal efficiency. (2021, November 7). In *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Thermal_efficiency&oldid=1053985853

Thomson, W. (1851). On an absolute thermometric scale founded on Carnot's theory of the motive power of heat, and calculated from Regnault's observations. Mathematical and Physical Papers, 1, 100–106. Retrieved November 11, 2021 from https://zapatopi.net/kelvin/papers/on_an_absolute_thermometric_scale.html

Zeng, F., & Xu, J. (2019). Performance analysis of a four-stroke compressed air engine. Thermal Science. 24. 61-61. https://doi.org/10.2298/TSCI180601061Z