Physics of the Fuelless Generator

Voltage Gains: Tesla vs. Standard Design

This paper argues that Tesla's fuelless generator follows the Second Law of Thermodynamics, that it is not an "over unity" device putting out more energy that it takes in. It is a device that performs little physical work and expends little of its stored energy.
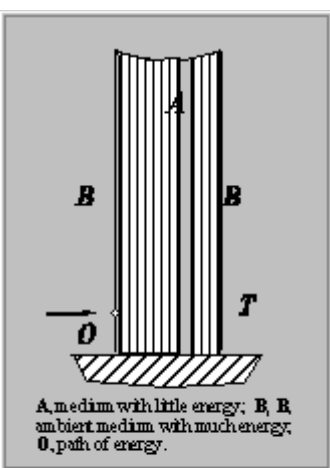
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The Second Law Thermodynamics and Tesla's Fuelless Generator

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During an address commemorating the installation of his electrical generators at Niagara Falls , Nikola Tesla told his listeners:

> We have to evolve means for obtaining energy from stores which are forever inexhaustible, to perfect methods which do not imply consumption and waste of any material whatever. I now feel sure that the realization of that idea is not far off. ...the possibilities of the development I refer to, namely, that of the operation of engines on any point of the earth by the energy of the medium...(Tesla, 1897)

In 1902, Tesla wrote to his friend and publisher Robert Underwood Johnson that he had already developed a device for using the energy of the surrounding medium to generate electricity (Nichelson, 1993). In the letter he stated that the design principles for this new type of generator were discussed in his June 1900 *Century* Magazine article (Tesla, 1902) on page 200, "particularly where I refer to novel facts."

A, medium with little energy; B, B, ambient medium with much energy; O, path of energy.

1. Ambient Medium Energy

An Energy Sink

His reference is to the article "The Problem of Increasing Human Energy - Through the Use of the Sun's Energy" (Tesla, 1900). The "novel facts" are mentioned in a section entitled "Energy from the Medium." It is in this and in the following section where the theoretical and developmental discussions of this new generator take place. Tesla uses two versions of simple graphic image to explain how such an energy extracting generator would work.

In the first example he asks that we consider a closed cylinder

> such that energy could not be transferred across it except through a channel or path *O*... and ... that, by some means or other, in this inclosure a medium were maintained which would have little energy, and that on the outer side of the same there would be the ordinary ambient medium with much energy.

Tesla continues:

> Under these assumptions the energy would flow through the path *O*, as indicated by the arrow, and might then be converted on its passage into some other form of energy. Could we produce artificially such a "sink" for the energy of the ambient medium to flow in [and]... be enabled to get at any point of the globe a continuous supply of energy, day and night (Tesla, 1900).

In the next paragraph Tesla gives another version of how this energy extraction process would take place. He asks if we can produce cold in a given portion of space and cause the heat to flow in continually. Creating such a "cold hole" in the medium would be like creating in a lake either an empty space or a space filled with something much lighter than water.

> This we could do by placing in the lake a tank, and pumping all the water out of the latter. We know, then, that the water if allowed to flow back into the tank, would, theoretically, be able to perform exactly the same amount of work which was used in pumping it out, but not a bit more. (Tesla, 1900)

He notes that in such an operation, nothing would be gained by pumping the water out and letting it fall back down the tank. It would be impossible, in this case, to create a sink in the medium.

Tesla, then, asks that we "reflect a moment" and adds:

> Heat, though following certain general laws of mechanics, like a fluid, is not such; it is energy which may be converted into other forms of energy as it passes from a high to low level...assume that the water, in

its passage into the tank, is converted into something else, which may
be taken out of it without using any, or very little, power. For example,
if heat [is represented] by the water of the lake, the oxygen and
hydrogen composing the water may illustrate other forms of energy
into which the heat is transformed in passing from hot to cold.

Corresponding to this ideal case, all the water flowing into the tank would be
decomposed into oxygen and hydrogen before reaching the bottom (Tesla, 1900),
and the result would be that water would continually flow in, and yet the tank would
remain entirely empty, the gases formed escaping. We would thus produce, by
expending initially a certain amount of work to create a sink for the heat or,
respectively, the water to flow into, a condition enabling us to get any amount of
energy without further effort.

Second Law of Thermodynamics

Understanding the operation of Tesla's new generator is a two part task - picturing it
as he did in terms of 19th century science and explaining it in terms of today's
science. Fortunately, he framed his explanation within the context of the Second Law
of Thermodynamics as it was being formulated by the leading physical theorists of the
day.

Rudolph Clausius put it, in 1850: "It is impossible for a self-acting machine unaided
by an external agency to convert heat from one body to another at higher
temperature." As given by Kelvin, "It is impossible by means of inanimate material
agency to derive mechanical effect from any portion of matter by cooling it below the
temperature of surrounding objects." If a machine was able, by itself, to take heat
energy out of the surrounding environment and use that energy to run its cooling
work, it would be a perpetual motion machine. Cooling the surrounding medium
requires energy from an external source.

In his *Century* Magazine article, Tesla takes up the thermodynamics question in a
section entitled "Possibility of a Self-Acting Engine...Inanimate, yet Capable of
Deriving Energy from the Medium." He challenges the assertion about the
impossibility of a cooling machine's ability to operate from the heat derived from the
medium with a simple thought experiment.

If two metal rods ran from the earth to outer space, the temperature difference
between the ends of the rods would create an electric current in the rods which could
operate an electric motor. This would be a device that would cool the medium and do
work from the heat of the medium.

With this example, Tesla does not refute the Second Law of Thermodynamics but
shows the limits of its popular understanding. He does not deny the most basic tenant
that energy flows from hot to cold, from a high energy state to a lower state. What he
asserts is that good engineering can cause work to be done in the change from a
higher to lower energy state without creating a perpetual motion machine.

Ambient Medium

How an energy sink can be created on earth requires two additional pieces of information presupposed by Tesla's thermodynamics discussion - the nature of the fluid that makes up the ambient medium and what constitutes a low temperature in this medium.

To understand the concept of the energy of the ambient medium, it is necessary to return to the historical roots of electrical science. From the time of Franklin until the beginning of this century, electricity was pictured as a fluid that flowed through conductors and, like steam that powered the engines of the day, could be condensed out the medium. The capacitors of today were once known as condensers due to this concept.

Before the last paradigm shift at which the universe came to be viewed as atomic particles moving randomly in a void, physics believed all matter was made from a primary substance. It was this primary material, the aether (Dunlap, 1934) of Maxwell and Kelvin, that filled the ambient medium.

As for temperature, Tesla wrote (Tesla, Feb. 1919) that "in light of present knowledge we may liken electric potential to temperature." Creating a low temperature region in the high energy ambient medium meant creating a sustained low electrical potential. Relative to the medium, the device creating this low pressure region could be seen as a self-cooling apparatus.

In principle, the electrical fluid would enter the device, transform into a lower form of energy and perform work as the fluid continued to flow into the device. The nature of this transformation is conjecture at this point, but it seems that the electrical fluid was seen to be transformed into positive and negative potential.

Thermodynamic Work

In accordance with the Second Law of Thermodynamics, Tesla's device would make use of energy moving from a higher temperature to a lower temperature, but would be self-sustaining, or self-cooling by converting the energy coming from the environment into a different form in a process that consumed only a small amount of the incoming energy.

This last element in the operation of the device - that it consume very little of the working energy - is mentioned (Tesla, Feb. 1919) in connection with his wireless receiver. He wrote that "energy will be economically transmitted and very little power consumed as long as **no work is done** in the receiver." Here "work" is meant in the technical sense - power expended over time.

The Tesla device for extracting energy from the ambient medium, then, operated by transforming the input energy into potential and doing no or little work in the device itself. Electrical energy, the units of work, is measured in watt-secs or amperes x volts x secs. Volts and amperes are the quantities of the electrical fluid and because potential is enhanced, the conclusion is that work, or energy, is conserved by reducing conduction current in the device. The new generator appears to have operated by potential variations and with no or very little current. It seems to have been an electrostatic device.
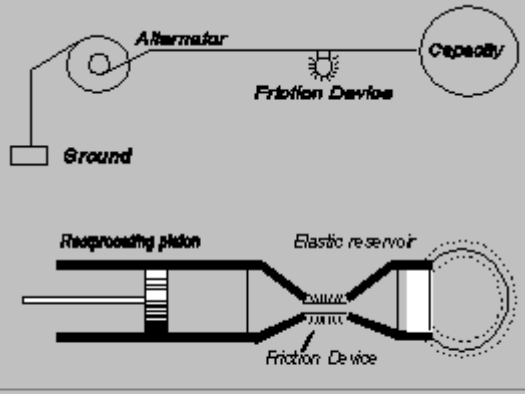
3. Electric Transmission Thru a Single Wire
Hydraulic Analog

Tesla wireless system and new energy generator share the [...] or very little, power," it is useful to examine how the [...] operated. In 1919, Tesla detailed his wireless method in [...], using hydraulic analogies.

[...] ansmission system requiring two wires is equated to a [...] iprocating piston, Fig. 2. The working fluid is pushed and [...] thru the small channel" so "that virtually all the energy of [...] ormed into heat by friction, similarly to that of the electric current in the lamp filament."

On the other hand, the wireless method is like the one-wire transmission system Tesla demonstrated several times, Fig. 3. A reciprocating cylinder pushes the working fluid through the friction device and into a large elastic reservoir. When the piston has reached the end of its stroke, the elastic reservoir is filled with the working fluid and sends it back through the friction device...the fluid is made to surge thru the restricted passage with great speed, this resulting in the generation of heat as in the incandescent lamp. Theoretically considered, the efficiency of conversion of energy should be the same in both cases. Tesla seems to be saying that for a light bulb of a given wattage, it can be powered either by a commercial power source of a certain voltage and amperage, or by a single wire of much smaller amperage but much greater voltage. For example, a 100 watt light bulb could be powered by 100 volts and 1 ampere

or by 1000 volts and .1 ampere.

For an electrical device to do no work, this arrangement has to be taken another step. Work consists of a force moving something over a period of time. In the case of electricity this is a voltage pushing a charge carrier through a cross sectional area of a conductor. The number of coulombs of charge passing a certain point in a conductor in a second constitutes a current, $q/s=i$. Doing no electrical work means the number of charge carriers passing a point in the conductor has to approach zero.

Displacement Current

The condition in which an alternating current can be maintained with no translational movement of charge carriers is found in a capacitor. A displacement current consists of the back and forth movement of bound charges within the lattice structure of a non-conducting dielectric material.

No work would be done if the device operated with a displacement current. If a large voltage displaced a small amount of bound charge, the power requirements of a load, like a light bulb, would be met with no conduction current, therefore, with no expenditure of energy.

Tesla's thermodynamic argument with the rods-reaching-into-space thought experiment is that energy differences in the environment can be used to power a device that extracts that energy without being a perpetual motion machine. With his new energy extraction device, his argument is that energy can be taken from the
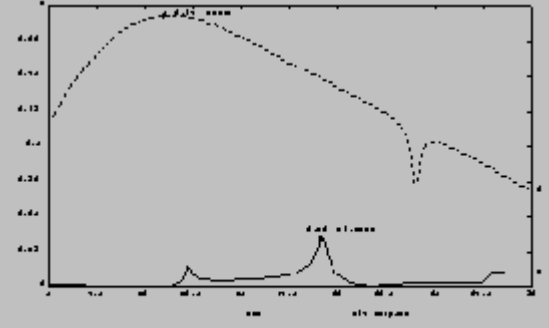
Voltage Gains: Tesla vs. Standard Design

environment, and, if converted to pure potential, can power a load while doing no work within the device. In the first example the long rods will allow a motor to operate until the earth has the same temperature as outer space. In the second instance, he describes a device that incorporates an energy difference within itself and expends no, or very little of that energy in powering a load. Though the second device may appear outwardly to be a perpetual motion machine, it does, as he shows, follow the Second Law of Thermodynamics.

7. Linde's condenser
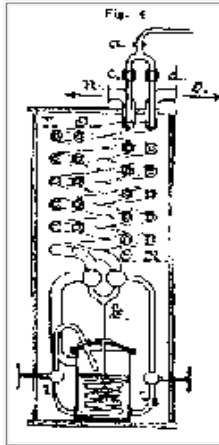
Tesla's comparison (Tesla, 1900) of his self cooling energy extractor with Carl Linde's double coiled apparatus for liquefying air, Figure 4, points to his double wound coil (Tesla, 1894) design, Fig. 5, as one likely embodiment (Nichelson, 1991) of his energy extraction device.

Measurements (Nichelson, 1991) of the same size single and double wound coils, both with approximately the same inductance have shown that, at resonance, both the voltage response and voltage gain to be several orders of magnitude greater for the double wound design . The figure below shows the voltage gain of two 4 inch diameter helix wound coils with the same number of turns. The lower plot is of the single wound coil and the upper curve is that of the double wound coil.

Assuming this bifilar coil is related to Tesla's design for a new energy device, it can be theorized that it would be driven at a voltage as great as could be tolerated by the wire's insulation and that the amount of stored charge would be at least as great as required by the load at the operating voltage and frequency. To take a purely hypothetical example, if the load is a 100 watt light bulb and the potential in the coil is 5000 volts and the coil is oscillating at a frequency of 1000 Hz, then in a period of a quarter cycle a charge of 5×10^{-6} coulombs would have to be displaced.

$$100 \; watts/ \; 5000 \; volts \; = \; .02 \; amperes$$
$$and \; 1/ \; 4 \times 1000 Hz \; = \; 2.5 \times 10^{-4} \; s$$
$$\therefore \quad q \; = \; I \times s \; = \; .02 \times 2.5 \times 10^{-4}$$
$$= \; 5 \times 10^{-6} \; coulombs$$

This would give a system capacitance of

$$C \; = \; q/ \; v \; = \; 5 \times 10^{-6} / 5000 \; = \; .001 \; \mu f$$

Like the equations of Maxwell and the AC motor of Tesla, both conceived within the context of 19th century aether based physics and are still used after the physics has been discarded, the new energy device does not require belief in an energetic ambient medium. The concept served only to explain the source of electricity to earlier researchers who naively sought an answer to this fundamental question. Modern

engineering practice does not require a primary source of electricity be given, but only a description of how it operates or makes a device operate.

Tesla's new "generator" can be explained solely on the basis of its electrical activity. A bifilar coil is capable of holding more charge than a single wound coil. When operated at resonance, the distributed capacitance of the bifilar coil is able to overcome the counter force normal to coils, inductive reactance. It does not allow what Tesla described (Tesla, 1894) as the formation of "false currents."

Because the electrical activity in the coil does not work against itself in the form of a counter-emf, the potential across the coil quickly builds to a high value. The difference between the turns becomes great enough that (Tesla, 1892) "the energy would be practically all potential." At this point, the system becomes an electrostatic oscillator.

Minimal work is done in the system due to absence of translational movement in the displacement current. As small heat losses occur, oscillations are maintained by the surplus charge stored in the coil. Very low energy expenditure allows power delivery to a load over an extended time period without an external fuel supply. After an initial input of energy from an outside source, Tesla's new electrical generator would operate as a fuelless device.

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