Questions and Answers

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Q : What electric motor would be suitable for the Revolution Energy Converter?

A : For our first prototypes we are considering low power stepper motors and using a versatile controller like the Arduino which is a well known prototyping tool that can be bought off-the-shelf. You may also control a stepper using a parallel or serial port, but this is about to become as rare as a floppy drive on a PC, and in modern operating systems this requires much more programming, so a USB downloadble controller facilitates experimenting. Connect a computer to this, like the Raspberry PI 3 and you have a free open development platform for the "Revolution Dynamic Link" software. The motor totally controls the revolving shutter that runs freely inside the Revolution Energy Converter independent of power output, so being able to feed back data to the controller from the powered application is essential. We call that "dynamic linking".

Q : Is it possible to use piston, connecting rod, crankshaft and bearings from combustion engines? Like from a 4-stroke lawn mower?

A : Combustion engines strikes every forth (4-stroke) or every second (2-stroke) time but compensate with a very hard stroke on a fairly small piston top area. The Revolution Energy Converter delivers low pressure compared to internal combustion engines, but it delivers work at every stroke, both push and pull, so it preferably acts on a fairly large piston top area or large membrane top area suited for a relative short stroke. But, of course, we have to search for components from existing technologies that we may use.

The Revolution Energy Converter - Questions and Answers

Q : How large power pistons and what stroke length will we use?

A: The ideal gas law $pV = nRT$ will give us a hint on how large piston and what stroke length we will use.. It's the (V) , the work generating volume, in the ideal gas law that decides what power piston area (A) and stroke length (ds) we will use.

Let's assume a small Revolution Energy Converter (REC) with a 12 liter work generating volume, and a larger REC with a 120 liter work generating volume. If the temperature range ΔT is 70°, both work generating volumes will produce the same pressure (p) difference i.e. 24kPa. But the 120 liter work generating volume REC is capable of delivering much more work (w) with a larger power piston area and an adapted stroke length.

$w = F \cdot ds$ tells us that work (w) is done when a force (F) is applied through a distance (ds) .
The pressure (p) is the amount of force (F) acting per unit area (A).We may write this as force (F) is equal to the pressure (p) times an area (A) , $p \cdot A = F$, so let's substitute force (F) in the work formula and we get $w = F \cdot ds \iff w = p \cdot A \cdot ds$

Area (A) times height, in this case (ds), is a volume (V). So we may substitute ($A \cdot ds$) with (V) and say work (w) is pressure (p) times volume(V) and write $w = p \cdot A \cdot ds \iff w = p \cdot V$

Conclusion: A larger work generating volume (V) is able to feed a larger piston area (A) a longer stroke (ds)
$pV = nRT \iff p \cdot A \cdot ds = nRT$

Q : How do we handle the imbalance in the revolving shutter segments given its asymmetrical mass?

A : The revolving shutter in the first prototypes will be statically balanced, but a production Revolution Energy Converter needs to be dynamically balanced as well, and have a well calculated low critical speed setting. In a prototype built for a higher source temperature, the motor will be placed outside the closed system transmitting its rotation with magnets also acting as balance weights on each side of "the revolving shutter opening". In future generations the revolving shutter itself will act as rotor in an electrical motor keeping the closed system well sealed.

Q : How do we distribute the heat to and from the Revolution Energy Converter (How do we connect a warm and a cold source to the Revolution Energy Converter?)

A : This is a wide open field! It depends very much on the application, i.e. where you want to use the Revolution Energy Converter to deliver power. The “base” or “outside” of the conducting blocks are the interfaces to the sources for heating and cooling. The prototypes are built to prove that we can get a certain amount of power from a certain temperature difference (ΔT). In the first experiments, boiling water circulating in an integrated bucket on the warm side and an ice bucket integrated on the cold side.

Q : What gas or vapor is used for the work generating volume?

A : In the first prototype of the REC the work generating volume will simply be air. If the construction allows, pressurised air is also a possibility. The temperature span and the choice of the working fluid sets the power per unit volume. The working fluid for future REC will depend on the application and the temperature span available. High temperatures may benefit from a working fluid like helium, while operation with lower temperature differences may use a saturated vapor with a liquid-vapor critical point suitable for the intended temperature range letting a phase transition create a significantly higher pressure difference.

Q : What system pressure is used (max/min) for the work generating volume?

A : When running the first tests with the Revolution Energy Converter we will let the temperature difference set the maximum and minimum pressure following the formula $pV = nRT$ While the piston moves, the closed volume gets larger. Let's assume that the volume expand from V_1 to V_2 and that the pressure goes down to atmospheric. We could plot this function by filling in all $w = -p(V_2 - V_1)$ and we know how it relates thanks to the “ideal gas law”:

$\frac{p_2}{p_1} = \frac{n}{n}\frac{R}{R}\frac{T_2}{T_1}\frac{V_1}{V_2}$ we may cancel out n and R and get $\frac{p_2}{p_1} = \frac{T_2}{T_1}\frac{V_1}{V_2}$

The formula $pV = nRT$ can be expressed as $p = nRT/V$ in this operation. So let's do the integral $w = -\int_{V_1}^{V_2} p dV$ and substitute p $w = -\int_{V_1}^{V_2} dV \frac{nRT}{V}$. Since nRT are constant we may write our favorite integral $w = -nRT \int_{V_1}^{V_2} \frac{dV}{V}$. This transforms into $w = -nRT \ln(\frac{V_2}{V_1})$. This expression is easy to program into an excel spread sheet calculation. It becomes a little more complicated when we start with testing vapors with a phase shift within the interval that will generate a lager pressure span.

Q : If the system is not completely tight? Do we need to refill the media for the work generating volume? If so, how long will it work without re-filling?

A: A REC with an internal electric motor to control the revolving shutter and a membrane for power output is completely tight. It is a real “**closed system with a moving boundary**” and does not need refilling. No rotating shafts passing the sealed system, no potentially leaking pistons. There will be no leak.

Other ways of building the REC that are not completely tight might need a refill. The refill frequency depends on the tightness of the construction, e.i. the piston type used, if the revolving shutter shaft passes through to an external motor, etc. In these cases refilling could be done automatically with a spring loaded one sided valve.

Another way of building completely tight systems is to pair systems (volumes) having a common double acting piston and sync their revolving shutters with 180 degrees difference.

Q : What temperatures can we use?

A: Temperature limits are set by choice of material for the construction and by the gas or vapor used as a work generating volume.

Q : How much warm and cold water do we need? How much electricity do we need?

A : The prototype will use 10 liter water buckets connected to the warm and cold side. The stepper motor and its controller for the revolving shutter uses 5v and a 12v (motorbike) battery. At a later stage the prototype project will connect a generator to the Revolution Energy Converter, not only charging the battery but also showing that there will be a surplus of green power to use. If you want to calculate you may meditate like this: the revolving shutter exposes the swirls of the work generating volume to the conducting fins for a quarter of a revolution. The warm fins need to contain the heat needed to heat up the work generating volume close to it's own temperature. The rest ¾ of the revolution the warm fins need to recharge its energy, i.e. warm up again. Do the same calculation on the cold side and you will be able to set some geometries of the Revolution Energy Converter and the duration of the sweep, the revolving shutter exposure. See also "Q : How come that the Revolution Energy Converter is possible to scale to large power outputs ..." further down.

Q : Do we need to sync the revolving shutter with the piston delivering the power? How? Mechanical? Electromechanical? Microprocessor?

A : The REC prototype will do tests with variable speed as well as varying loads that will depend on sync between the revolving shutter and the piston delivering power. There are constant speed applications that do not require sync but those are not given special attention in our tests. The prototype uses a stepper motor with a controller and the electromechanical sync is done in software called "Revolution Dynamic Link" that keeps track of the revolving shutter angel and the work output piston position and/or flywheel angel. The Revolution Dynamic Link software is continuously adjusting the revolving shutter speed according to input from the running application.

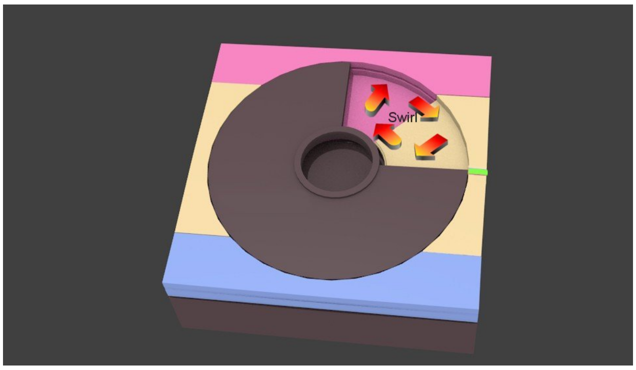
Q : What dead volume (percentage) will the working fluid sustain?

A : In a spread sheet one can calculate the impact of the dead volume and find a tolerable level. Everything not contained in the revolving shutter opening called work generating volume is dead volume.

Q : Where are the dead volumes? How do they affect the power?

A :The dead volume of the system is the air/gas which is not contained in the work generating volume of the revolving shutter. Dead volume consumes power acting as a shock absorber and has to be minimized.

The neutral "nil" fins take up space to reduce the dead volume, but they also have another very important role. The work generating volume of the revolving shutter will never be situated in both the warm and the cold zones simultaneously thanks to the "nil" blocks with insulating fins. (The "nil" blocks and the conducting blocks may also become stator acting on the revolving shutter as a rotor of an electrical motor keeping the closed system as a well sealed unit) .



The revolving shutter is "scrubbing" the work generating volume against the surfaces of the fins to enhance the forced convection. This creates a controlled swirl in the work generating volume. The shutter opening of the revolving shutter contains the work generating volume. The rotation speed, the distance between the revolving shutter and the fins, and the fin surface affect this vortex that will optimize the portion of the heat exchange that occurs by forced convection. Even the neutral fins maintains this important swirl in the work generating volume. Note that the revolving shutter will never be in contact with the fins, but we want them close to the fins to reduce the dead volume. But we use this thin dead volume space between the revolving shutter and the fins to build a laminar flow that reduces friction and also reduces unwanted heat transfer between the material of the revolving shutter and the fins. All heat exchange should preferably be done in the work generating volume of the revolving shutter opening and nowhere else. In our first prototype the space of the dead volume between the revolving shutter and the fins is in the order of half a millimeter. That adds to the dead volume. Another more important dead volume is the variable volume of the connected working cylinder or membrane, and finally parts of the revolving shutter shaft may be used as a pipe-line to distribute the pressure difference, directly connecting the segmented work generating volume of the revolving shutter to the connected cylinder or membrane where the pressure becomes movement.

Q : How come that the Revolution Energy Converter is possible to scale to large power outputs, when other external heat engines like the Stirling stays small or very moderate in a cost/power perspective?

A : The Revolution Energy Converter architecture keeps the ratio between the total work generating volume and the very large surface area for heat transfer constant during scaling. The work generating volume always remains thin for fast heat transfer. This is valid from a few liters to several hundreds of liters. How to heat up and cool down a large work generating volume as fast as possible is a question of heat transfer surface area ***A*** and time ***t***. and this is very well explained by “Newton's law of cooling”.

In principle the Stirling Engine heat transfer is done in its cylinders. Cylinder volume grows with the cube, while the heat transfer area only grows with the square, so when you need more volume for power, you will run out of area for heat transfer. You may compensate with external heat exchangers and re-generators, but that means adding dead volume. Finally the transport of the vapor used as working volume between the source and the sink will approach the speed of sound when passing through the extended heat exchangers and the re-generator. A very real upper limit.

The Revolution Energy Converter architecture permits scaling keeping the relation between volume and surface for heat transfer constant. And maybe more important: keeping the time-dependent thermal gradient between the conducting fins and the work generating volume constant!

Newtons Law of Cooling is $\frac{dQ}{dt} = h \cdot A \Delta T(t)$ where :

Q is the thermal energy in joules.

h is the heat transfer coefficient (assumed independent of ***T*** here) (W/m^2 K)

A is the heat transfer surface area (m^2)
T is the temperature of the thermal magazine's surface and interior (since these are the same in this approximation)
t is time
$\Delta T(t) = T(t) - T_{wv}$ is the time-dependent thermal gradient between the work generating volume and the magazine
T_{wv} is the temperature of the work generating volume; i.e. the temperature suitably far from the surface.

You may use a recipe book to set time and temperature, or a stick to control if your potatoes are done, but you could also use Newtons law as “Newtons Law of Cooking” to get a good timing for every potato. You may think of the Revolution Energy Converter as frying pancakes. The thinner pancakes the faster they get ready, but you have to compensate by using a larger diameter frying pan so you don't have to fry all morning to get a good meal and the energy you need. The larger surface of the frying pan and the thinner the pancake the faster it gets, i.e. the shorter frying time per pancake.

It's like sweeping the large surface areas of the source and the sink with perfect timing. Filling in the formulas with the parameters for temperature, the heat transfer surface area will calculate the time, i.e. the rotation speed, and it will also indicate the theoretical maximum power.

To conclude, how much power we get out of the Revolution Energy Converter depends on:

- the revolving shutter speed
- the temperature difference between the source (red) and the sink (blue)
- the geometry, that is what volume we have, what ratio volume to heat transfer area we use, the distance between the convector fins in the work generating volume, what radius of the revolving shutter we use.
- what working fluid we use

There are more parameters than these, but this is how we start to get an idea of the Revolution Energy Converter's potential.

Long live the Revolution Energy Converter!

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