“BOUNDARY LAYER TURBINE ENGINE”

BLTE Dynamic Operation

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BLTE Dynamic Operation

This document is the explanation of dynamics associated with the "Boundary Layer Turbine Engine (BLTE) Construction and Operation" document. This document offers a simplified explanation of the internal relationships of engine speed, disk size, disk spacing, working fluid pressure and working fluid paths. This should serve as a basis for a mathematical description of interactions and/or a computer automated design (CAD) simulation. The hyperlinked items shown below are linked to the table of References at the end of this document. The numbers associated with those hyperlinks are the index number of the reference items. The references are themselves linked to appropriate websites which offer further explanation.

The BLTE is an "internal combustion" version of the Tesla Turbine engine patented circa 1910[1]. This engine ran as an external combustion engine in various forms to produce outputs between 110 to 10,000 horsepower. The 110 horsepower version was attained with 9 ¾ inch runners (disks) in a stack of 25 blades using a head of steam generated by an external source. This engine, in the words of Doctor Tesla, "could have produced twice that much horsepower" and (excluding the fire box and boiler) all this from a machine weighing 20 pounds!

Fluid Shapes:

Common wisdom is that the shapes of fluids, gases or liquids assume the shape of their containers. Expansion of that concept is that the shape of fluids, air for instance, is the shape of a room and all of its contents; the shape of the atmosphere conforms to the surface of the earth with its land masses, oceans and all of their intricacies. Moreover, fluids of different densities and energies impose form upon themselves; streams, vortices, turbulence, are dynamic shapes while layers and pools are more static in nature. Layers and pools form as the result of fluids finding levels of least energy while streams and vortices follow paths of least resistance.

Fluid Boundary Layering:

On boundary surfaces between fluids and solids there exist a fluid layer which adheres to the solid surface the thickness of which depends on the fluid density, viscosity, temperature and pressure. In the case of a gaseous fluid its viscosity is a function directly proportional to gas temperature, pressure and density. Air (78% nitrogen and 21% oxygen) forms a boundary layer on and around the exposed surfaces of a solid object. At standard temperature and pressure, that boundary layer[3] is approximately .020 inches (20 mils) thick. The boundary layer exerts a considerable force of attachment to the adjacent object and undergoes "slip" as the distance from the object increases. On a smooth surface that boundary layer is smooth and so provides maximum drag whereas the drag is less on a rough surface which allows turbulence to form.

Resistance and Fluid Drag:

Resistance is the process of energy balancing between or among contacting or mutually influencing objects. This balancing usually results in tidal protuberances, electrical induction, heat transfer and kinetic or potential disturbances which will ultimately come to rest in an equilibrium state. The energy released between objects in contact which have relative motion or relatively different energy states is the condition that is usually associated with a resistive interaction. Resistance is most readily associated with the heat released between the contacting surfaces of solid objects sliding one along the other.

Drag is a special condition of resistance where the energy released between a solid object and fluid results in heating, turbulence, vortices or other kinetic disturbances such as tumbling and sometimes surface pitting as a result of cavitations.

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BLTE Basics:

The BLTE is a radial turbine engine that incorporates all of the features of a conventional radial turbine but excludes the vaned or bladed construction which requires such considerable working fluid flow for operation and expensive blade construction that is subject to blade failure. The BLTE uses flat disks ordered in a close arrangement (a stack) which has the advantage of restricting the working fluid (combustion exhaust) flow to an amount dependent on the disk spacing. With flat disks instead of vanes or blades in the path of the hot exhaust stream the incident of blade stretching is eliminated, thus eliminating the high cost of bladed construction and maintenance. As with conventional turbine operation, the BLTE is "fuel type" insensitive which means it can use diesel types, kerosene, JP types, gasoline alcohol, butane or methane. Its quiet, smooth and high speed operation is particularly well suited to interface with a generator which will efficiently produce a controllable electrical output.

The BLTE is a machine based on drag, a phenomenon that in transportation is usually considered to be an undesirable effect. In a closely spaced disk stack, the boundary layers of adjacent disks are either touching or overlapping. These boundary layers impede the flow of a working fluid attempting to exit across the power disks faces to the center ports. Under combustion pressure the working fluid will force its way through the boundary layers producing a drag in a spiral path to the center ports. This spiral drag rotates the disks and as the working fluid's radial path decreases with decreasing circumference, its energy also decreases, that energy is imparted to the shaft as a rotational torque. The energy gained by the disk stack causes the stack to increase its speed in turn causing an increased pressure at disk peripheries and increased resistance to the combustion pressure.

High speed rotation of the disk assembly normally forces the working fluid to the periphery of the disk stack where the pressure developed is proportional to the disk diameter and disk velocity. The introduction of fuel (kerosene, diesel, alcohol, gasoline or bio-diesel) along with ignition increases the working fluid heat and pressure which is forced through the power disks in opposition to the disk periphery pressure and ultimately forced out through the rear exhaust ports (see **Figure 1**). From this point of view the BLTE's speed is self limiting. Engine operation of the BLTE literally "captures a tornado" internally directing it in and out of the disk stacks to produce compression input and power output.

Figure Descriptions:

The **Figure1** diagram is a schematic representation of the BLTE system concept. A "schematic" means the sizes of the disks shown in this drawing are not proportional to their spacing. An idea of actual sizes for the compressor section would be 9 inch diameter disks, .030 inch thick and with a .030 inch separation. One of the main purposes of this schematic representation is to emphasize the relative sizing of the disk diameters and to demonstrate the internal working fluid flow. It is important to note that simultaneously, the working fluid is expanding and contracting between the BLTE disks and spiraling in the direction of the spinning blades. It is this spiral of gases that comprise an internal "vortex" and it is from that natural vortex formation that the BLTE is able to derive its energy. Every working fluid expansion represents energy removed from the disk assembly (delivered to the vortex) in order to: a.) start the spiraling action, b.) provide compression or, c.) evacuate the previous stage, while every working fluid contraction delivers energy to the BLTE disk assembly and shaft.

Figure 1 provides descriptions of the engine components which are detailed in the "BLTE Construction and Operation" document. In **Figure 1** from left to right, the "Primary Stage 1" consists of the front seal (in blue and grey), the compression disk stack (black), the shaft mounted baffle disk (red), the power disk stack (black), the chassis mounted baffle disk (blue) which signifies the end of Stage 1. The Primary Stage 2 has the same arrangement of disks. The Auxiliary Stage has the same disk compliment as the compression disk stack and functions to evacuate the previous stage(s).

Figure 2 shows acceleration due to combustion and the deceleration of engine loading.

Figure 3 is a block diagram representation of the BLTE and its corresponding battery bank and motor/generator (dynamo) output configuration. The output of the BLTE in an electrical form is far more distributable, manageable and efficient than a mechanical (transmission or gear box) conversion.

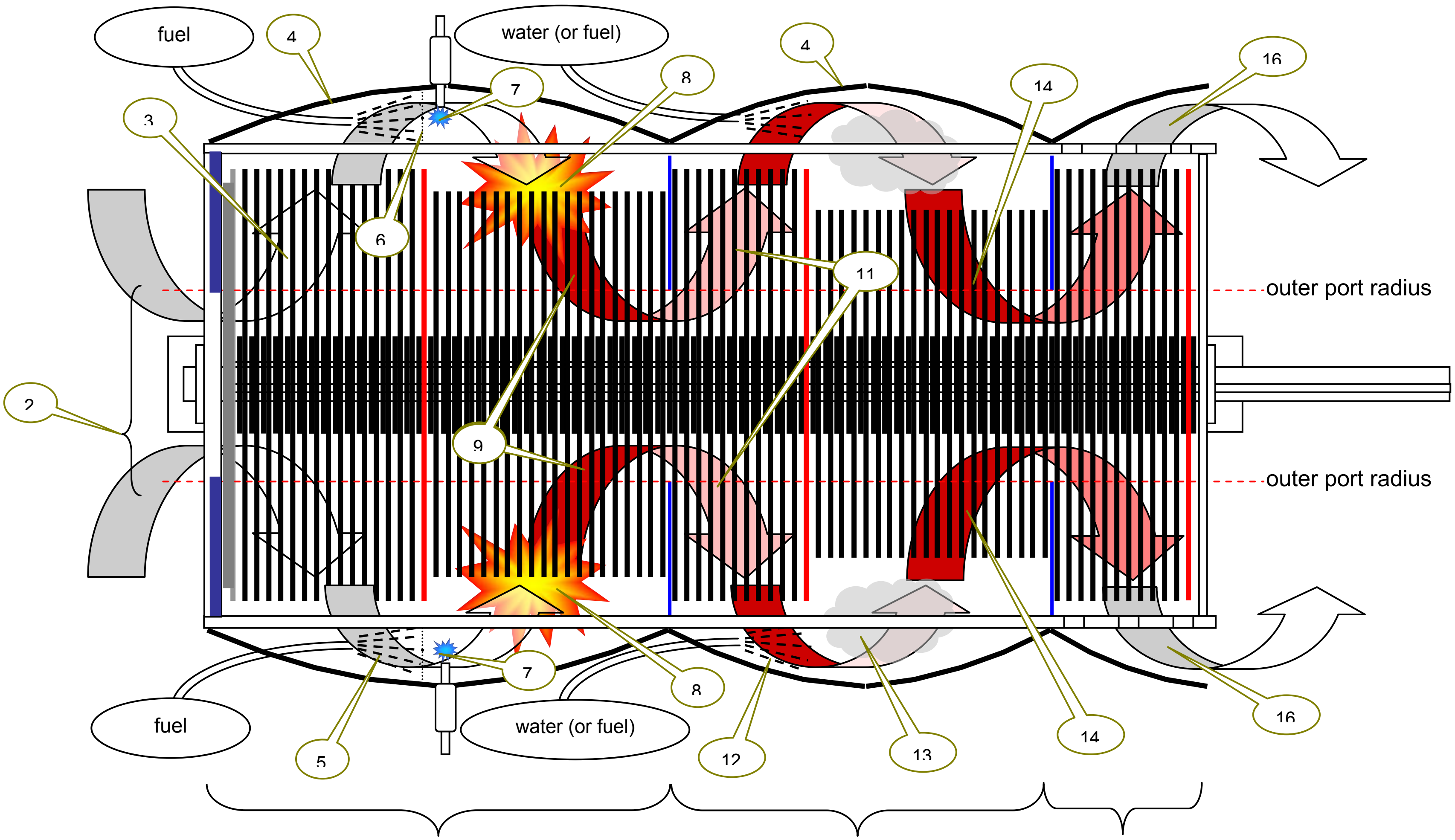
Figures 4 **&** Figure 5 show working fluid paths exiting the compression disk faces and entering the power disk faces relatively. This flow pattern will develop during mild rotational acceleration and at constant speeds.

Figures 6 **&** Figure 7 show working fluid paths exiting the compression disk faces and entering the power disk faces relatively. This flow pattern will develop when accelerating and decelerating the disk assembly.

Figure 1

Schematic Operation of the Complex (Single Chassis) Internal Combustion BLTE

Side View



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Complex (Single Chassis) BLTE Operation Description:

1. **Stage 1**
2. Air Intake Centrifuge Compression/Intake Ports
3. Air Compression (Stage 1 - larger compression disks)
4. Chassis Containment/Pressure Vessel
5. Fuel Injection
6. Flame Barrier
7. Ignition
8. Combustion Power Production
9. Exhaust/Power Extraction Flow (Stage 1 - smaller power recovery disks)
10. **Stage 2**
11. Exhaust Evacuation (Stage 2 - larger compression/evacuation disks)
12. Power Boost Water/Air Injection (or after-burn Fuel Injection)
13. Water Vaporization/Air Expansion (or auxiliary ignition for Fuel Injection)
14. Exhaust/Power Extraction Flow (Stage 2 - smaller power recovery disks)
15. **Auxiliary Stage**
16. Exhaust Evacuation (optional)

BLTE Operational Analogy:

The boundary layering of the working fluid to the faces of the BLTE disk stacks can be compared to water adhering to the surface of a platter on a turntable; as long as there is no rotational platter motion then there is no movement of the water. When rotation of the platter is started the water is slung from its periphery. The force of that water movement is proportional to the tangential velocity of the platter and the drag imposed on the water by the platter surface. The water energy (E_{water}) developed at the platter periphery would be equal to one half the mass of water ($^1/_2\, M_{water}$) being flung, times the drag coefficient (K_{drag}), times its tangential velocity (V_{tan}) squared.

$$E_{water} = {}^1/_2\, M_{water}\, (K_{drag} \bullet V_{tan})^2$$

The energy gained by the water was imparted by the torque of the motor as the water spun out from the platter's center. As the energized water progresses to the periphery and leaves the platter, the platter's rotation is slowed in accordance with the conservation of angular momentum. If that water could instead be pushed onto and towards the center of the platter, the platter's torque and speed would increase which is also in accordance with the conservation of angular momentum. This increase in energy is imparted to the shaft and to the connected motor/generator producing an electrical power output.

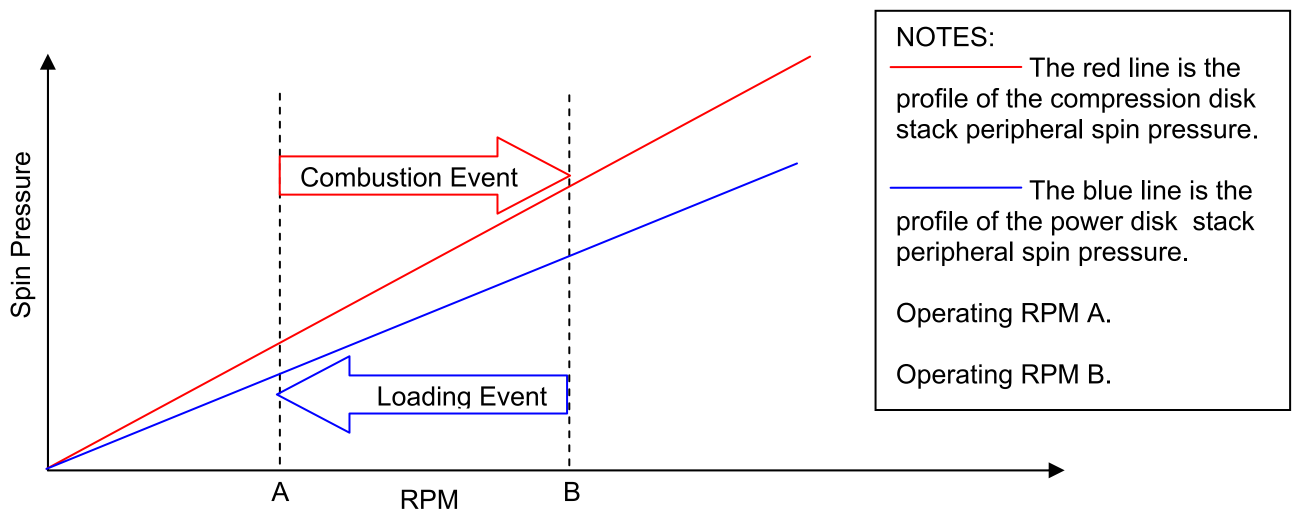
The pressure developed by a turning disk in the absence of combustion is the force of the working fluid pressing against the surface of a containing vessel, which in the case of the BLTE would be the interior walls of its chassis. That pressure is proportional to the disk diameter and its angular velocity (disk speed). The larger compression disks develop a higher periphery pressure than smaller power disks. In a contained BLTE stage this action would ingest air into and across the compressor disks, forcing that air through the power disks and ultimately out of the power disk ports. Moreover, the stage containment and the differential disk sizes impose this path of least resistance. The increasing and decreasing radius of spiraling gases across the compression disks then through and out of the more numerous power disks is referred to as "BLTE respiration" (**Figure 1**).

The working fluid adheres to the disk surface and moves the disks by virtue of the Coandă effect. The Coandă effect addresses the action of air moving along the surface of an aircraft wing and attempts to explain how pressure differences are formed between the low pressure top wing surface and the high pressure bottom wing surface. The spinning BLTE inner disk spaces have overlapping boundary layers where the advancing disk surfaces represent the high pressure and the lower pressure is in the direction of the retreating disk surface. A natural pressure gradient also exists from the hub outward to the disk periphery (high to low) by virtue of the spinning disk, which is overcome by the combustion pressure that pushes exhaust gases from disk periphery to the central ports. The energy difference is imparted to the disk assembly by increasing its radial velocity and is also imparted to the disk hub and shaft by virtue of the decreasing radius or circumference of the working fluid flow.

Disk Stack Pressure Analogy:

Maximum disk stack pressure is developed at the disk stack periphery. The case considered here are disk stacks of different radiuses mounted on the same shaft and turning at the same radial velocity. For any single BLTE stage the interior of the chassis is the pressure barrier for both the compression disk and the power disk stacks. Since the compression disks have the greater radius they will potentially produce a greater pressure at the stack periphery relative to the power disks of lesser radius (**Figure 2**). The difference in potential pressures means the working fluid will flow into the central ports of the compression disk stack, into the combustion chamber then through the power disks and out of their central ports. During the combustion event, while the rise of pressure occurs across both the compression and the power disk stacks, the working fluid will flow though the power disk stack due to its smaller opposing peripheral pressure and larger exhaust orifice; this represents the path of least resistance. Typically the power disks will be more numerous and therefore have a greater escape orifice and depending on the number of disks will have the greater stack surface area. The **Figure 2** diagram also demonstrates the relationship between compression stack peripheral pressure and power stack peripheral pressure. The additional pressure of combustion drives the disk array to a higher speed and in turn greater loading tends to decrease that disk array speed.

Figure 2



Start Mode is when the BLTE is being turned by the motor/generator operating in its motor mode. The working fluid flow is slowly moved into the compressor stack ports (**Figure 4**) and out of the power stack ports (**Figure 5**).

Idle Mode is a transient operational mode where the BLTE is accelerated from a stop by an outside source (motor/generator) to a speed that when combustion is started can then be maintained (**Figure 1**). The BLTE would be operating at a minimal power output.

Acceleration Mode is a transient operational mode typically from a lower speed to a higher speed caused by an increasing working fluid pressure (**Figure 7**). Acceleration and Deceleration events may be occurring alternately during normal BLTE operation (**Figure 4** & **Figure 5**). To compensate for the time lag between increased engine speed demand and a higher engine speed, the dynamo will motor the disk assembly to the higher engine speed drawing on the battery bank to supply the necessary energy while fuel is delivered. This is accomplished with the Engine Control Module (ECM) which inputs Engine Speed Demand, monitors Engine Speed and meters Fuel Delivery.

Standard Operation is when the disk assembly is turning at start speed or above. The BLTE speed is relatively constant as the result of a constant combustion pressure turning a constant load (**Figure 5**).

High Speed Mode which may produce compression shock waves is the condition of operation where the disk periphery exceeds the speed of sound. Because the working fluid has a vortex motion inside the BLTE chassis the sound barrier may be much higher than the disk tangential velocity might indicate (@1088 feet per second).

High Pressure Acceleration occurs if a sudden combustion event causes that pressure to rise above the compressor periphery pressure tending to cause a reversal of the compressor air flow producing compressor stall. To offset this risk, the arrangement of power disks will have a greater periphery orifice (meaning more disks than the compressor stack) which presents a path of lesser resistance and greater disk surface area than the compressor disk stack. This means more power disk torque will be developed causing the disk assembly to accelerate in-turn increasing compressor pressure. Additionally, the ECM can motor the disk assembly to a higher speed before injecting fuel thus preventing compressor stall and allowing the BLTE to operate at its most appropriate accelerations.

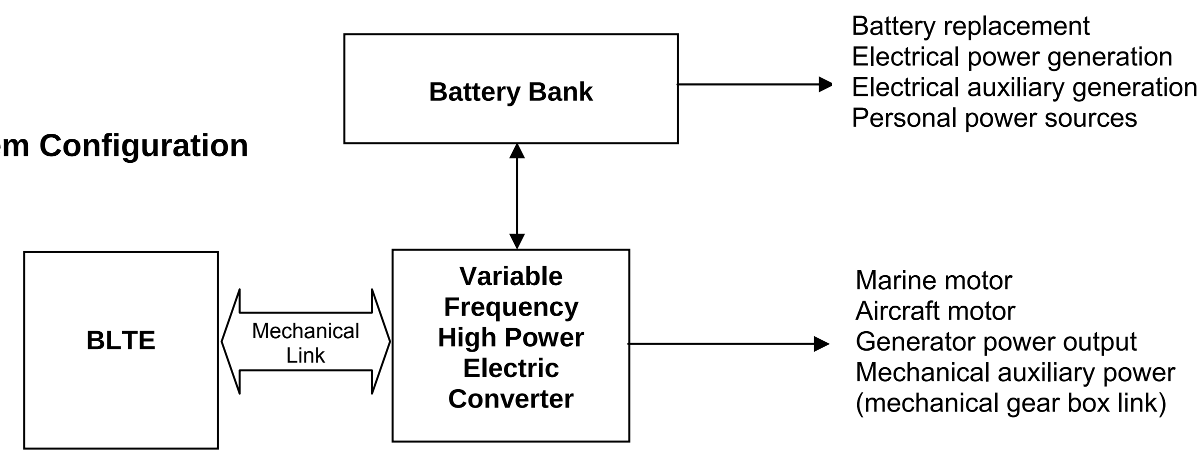
Deceleration Mode (slow and stop) is incurred with a decrease of fuel relative to the output power. BLTE deceleration may also be considered as a negative acceleration or the opposite of the “Acceleration Mode”. Where rapid deceleration is desired to slow or stop engine operation, the associated generator can be used as an engine brake by increasing the demand of electrical power output and using that energy to charge the battery bank.

The Motor/Generator (Dynamo) primarily functions as the output device which converts the BLTE energy to an electrical form. The motor/generator will deliver its energy after conditioning to some external load device, for instance, the power grid in the case where the BLTE is used for consumer power generation. The motor/generator would also provide a means of starting the BLTE from stopped to an idle mode. The motor/generator could provide conditioned electrical energy to fully charge a battery bank for use as battery replacements with handheld power tools or portable computer supplies. Complimentarily, the BLTE would draw battery pack energy for starting, faster acceleration or compensation for increasing load response.

The spiraling of air currents without the encumbrances of blades or vanes allows those currents of higher energy to occupy the higher energy locations on the disk surface nearer the periphery. Lower energy currents circulate closer in to the hub and eventually become exhausted. The implications are that blades or vanes impose an “optimal speed” on conventional turbine engine operation while the BLTE will have a much wider optimal speed range.

Figure 3

BLTE System Configuration



Compression Disk Working Fluid Paths:

In the start mode the energy delivered by the motor/generator immediately affects the “spin disk pressure” increasing internal pressure in the chassis (**Figure 6**). As the flow and the chassis pressure increases, fuel injection and ignition will initiate combustion. This increased combustion pressure in turn motors the power disks (**Figure 7**) to a point where spin disk pressure equals chassis pressure and chassis pressure is high enough across the power disk stack to keep the disk assembly speed constant under a constant load (**Figure 5**). It is important to keep in mind that at a constant disk assembly speed the combustion pressure is equal to or less than the compression disk periphery pressure but greater than the power disk periphery pressure.

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BLTE Size and Scaling:

The BLTE, due to its smooth operation, efficiency (reduced heating) and miserly fuel consumption, can conceivably be produced with disks the size of a quarter or many yards across. The application will determine the size, system configuration and power output. Generally the larger the disk diameter, the slower this engine will run but the greater will be its power output due to the increased circulation paths of the working fluid (**Figure 5**). Another way that power output may be conceived is that it is proportional to the ratio of disk periphery diameter to disk outer port diameter.

The BLTE simplicity of construction is what primarily lends to its scalability. Without valves, gears, radiator, pumps and intricate manifold construction, the BLTE brings incredible simplicity and maintenance free operation due to the lack of the many moving parts that can and will fail.

The initial prototype construction will be with 9¾ inch diameter compression disks and 7 inch diameter power disks. The BLTE width, in this case, would be approximately 7½ inches per main stage.

BLTE Power Output:

The BLTE is capable of producing phenomenal output power for its size[2] due to the fact that so little energy is being used to run the engine itself. In the conventional reciprocating internal combustion engine between 78 to 82 percent of the fuels energy is used to run the engine which produces an 18 to 22 percent output efficiency. So for a reciprocating engine with a 200 horsepower output, approximately 1000 horsepower is being input in the form of fueling while 700 to 800 horsepower of that input is being used to run the engine itself! This characterizes present "conventional internal combustion technology" at the beginning of the 21st Century as the result of over 170 years of piston driven engine development beginning with external combustion devices. Gasoline has been used as the fuel of choice for over 120 years and is truly a noble fuel being used to run a very inefficient tool. In addition to the energy waste of the reciprocating engine, the hydraulic-mechanical automatic transmission types commonly in use by the automotive companies have a 30 to 35 percent output efficiency representing an overall 5 to 8 percent energy delivery for vehicle propulsion.

The BLTE has been conservatively measured at 45% efficiency in an external combustion configuration. This represents 2.6 times the efficiency of the reciprocating engine with almost no recent development effort placed into the Tesla Engine to improve its basic operation. This engine produces no counter torque to the accelerations of the shaft unlike piston driven engines because combustion pressure is produced in all directions perpendicular to the internal chassis walls while being vectored parallel to the power disk surfaces. Ultimately it produces a perpendicular thrust component to the disk radius resulting in a working fluid spiral path to the disk ports; this, in turn provides a balanced torque to the shaft. The engine torque turns the shaft in the initial start-up direction.

BLTE speed and power output will be controlled by metering the fuel and possibly air intake. The natural path of flow through the BLTE is as is shown in **Figure 1** if the source of energy moving this fluid is the turning of the disk assembly by the motor/generator attached to the rear of the engine. The BLTE may be driven in either direction unless some bias is imposed by the operation of external equipment. The inherent 45% energy efficiency of the BLTE along with the 85 percent efficiency of the common generator and 85 percent efficiency of the common motor implies that the BLTE system could provide an un-enhanced 31.8 percent usable output for driving a vehicle. The BLTE system will have four to six times the efficiency of the equivalent conventional automotive propulsion system.

When the combustion pressure in the chassis equals the power disk stack pressure then no energy is being exchanged therefore no work is being done.

As fuel is added and ignited, increased combustion pressure causes a steeper spiral flow of working fluid to the power stack central ports. Very high pressure working fluid spends less time transitioning across the power disk surfaces which reduces efficiency but increases the total energy transfer from combustion gases to the disk stack. The result is an increase in the disk assembly torque and speed (**Figure 7**).

The output load, engine speed, ignition energy, temperature, pressure (primary and secondary), vibration and combustion emissions are some of the parameters that will be continuously monitored and controlled by the ECM.

Figure 4

Compression Disks at constant speed

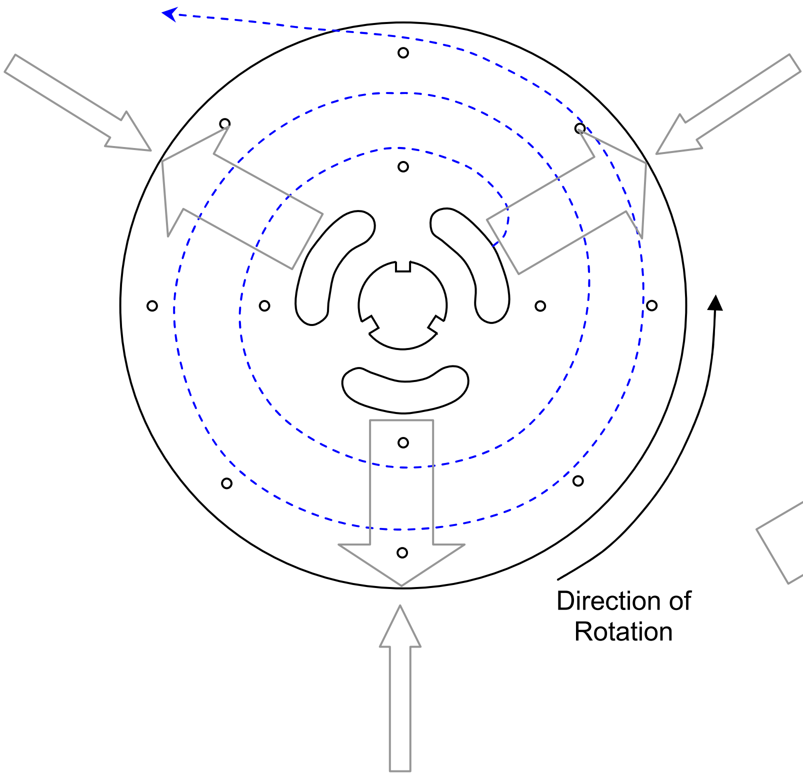
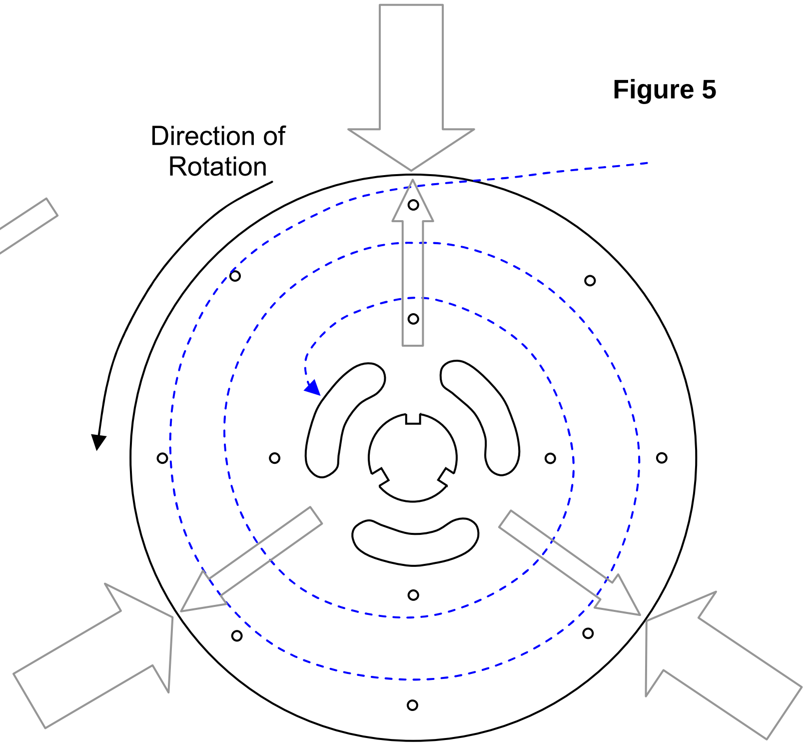


Figure 5



Power Disks at constant speed

Optimum Load and Torque:

The natural action of a disk stack when turned by an external source (pumping action) produces a pressure at the disk periphery which is the result of an induced flow of fluid from the center ports spiraling out across the disk surfaces. While the disk assembly is turning without combustion the main stage internal pressure (outside of the compression or power disks) is represented by the blue line of Figure 2 and is at the power disk stack peripheral spin pressure, at the appropriate RPM. During a stable combustion process the main stage internal pressure (outside of the compression or power disks) is represented by the red line of Figure 2 and is at the compression disk stack peripheral spin pressure, at the appropriate RPM.

The path that the working fluid takes across the disk face is dependent on combustion pressure, disk speed and engine load. Another way of characterizing working fluid paths is to consider opposing pressures at the disk periphery. The disk stack outward pressures are a result of disk speed (Figure 4) while the propelling force is characterized by the inwardly directed combustion pressure (Figure 5). Any particular path can recur at any engine speed with favorable factors of ambient or combustion pressure versus disk spin periphery pressure. The most efficient working fluid paths are those which are longest or spend the greatest amount of time on the disk surface. This would imply a relatively constant speed for best operational efficiency (Figure 5).

During engine operation both sides of the BLTE disks are active in compression, evacuation and power generation. For a 9¾ inch diameter compression disk with a 3 inch outer port radius the active area is 135.2 square inches and a 7 inch diameter power disk provides 62.83 square inches. The active surface of a 4 inch diameter piston is 12.57 square inches per cylinder times the number of cylinders available for power conversion during one quarter of the 2 revolution (4-stroke) engine cycle. The active surface area of a disk stack composed of 20 – 7 inch disks is 1256.64 inches squared, a huge active area for power conversion which is available for 100 percent of the engine cycle time.

Figure 6

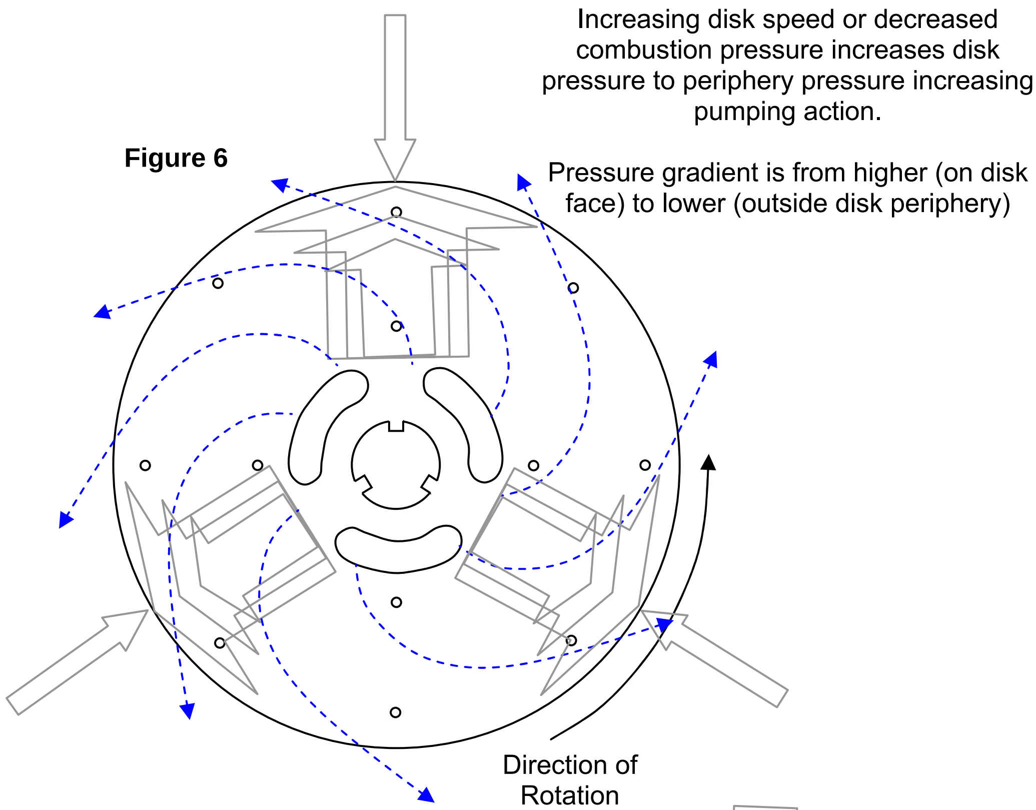
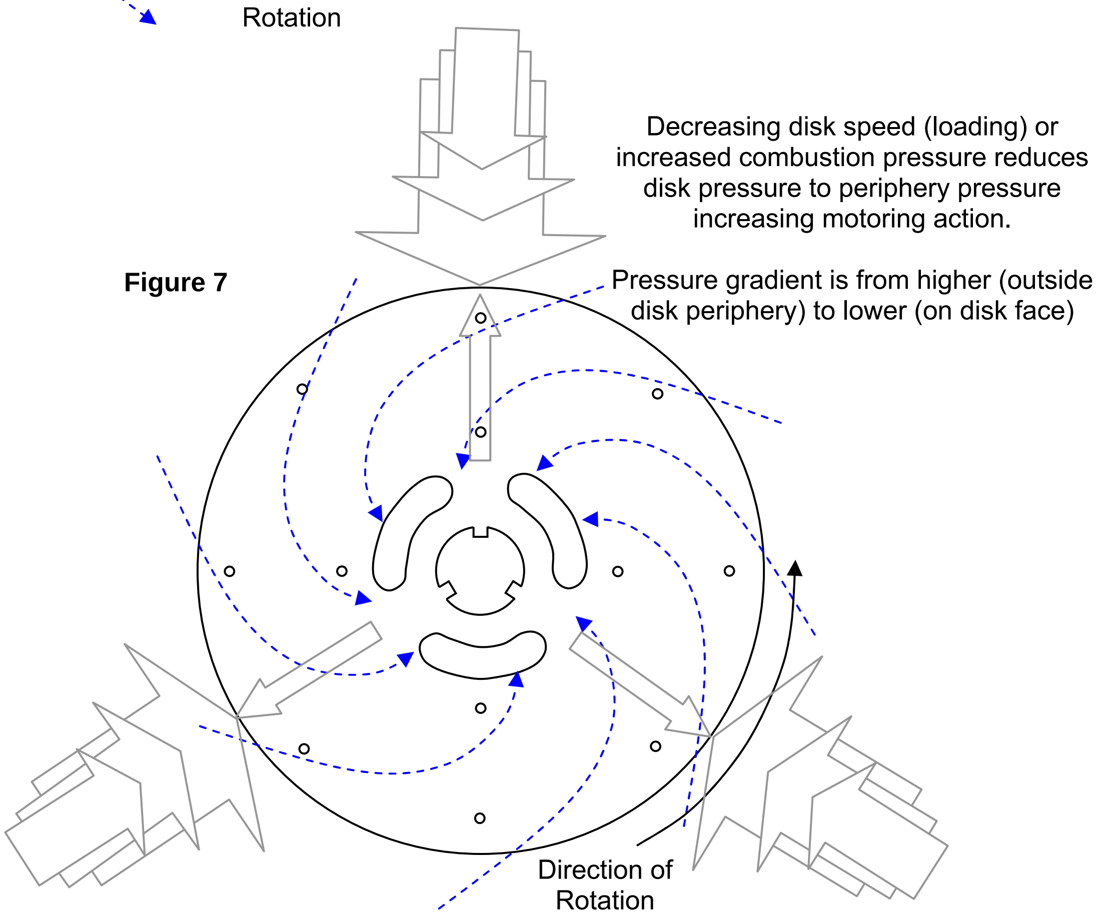


Figure 7



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Stage Sealing:

Sealing[5] at the front and the rear of each stage will drastically influence the efficiency and the operation of the BLTE. Fortunately a huge amount of work in the form of invention and documentation has been accomplished in this area. This is as a result of the requirements of conventional turbine engine development, an advantage that Doctor Tesla did not have during his conception of this motive component. Satisfactory sealing then is a matter of choice and testing as opposed to invention which reduces the risk of an unsuccessful development outcome. Several sealing methods are discussed below:

Close Fitting Disk Faces

Close fitting disk faces to the static chassis walls is a method that was used to seal this type of engine operating in its external combustion configuration. Doctor Tesla initially employed a system of labyrinth seals to provide an internal versus external chassis pressure differential. In later versions of the same machine, “close fitting disk to chassis wall” methods were chosen with satisfactory results. The close fit was provided as concentric ring locations in the chassis wall leaving voids between rings for formation of flow restricting vortices. This method of sealing is also termed “straight through labyrinth” seal. Doctor Tesla’s working fluid was steam. Steam has the advantage over combustibles that upon escaping to a lower pressure causes cooling and condensation. The liquid of condensation in a small gap helps to prevent further leakage. At the higher temperatures of combustion, greater cautions must be exercised to maintain the critical gaps when the chassis and disk assembly have undergone thermal expansion.

Labyrinth Seals

Labyrinth seals[4] are devices that provide a torturous path[6] to fluids attempting to reach pressure equilibrium. Labyrinth seals can only operate while the device being sealed is in motion. Since the starting action of the BLTE is imparted via the motoring of a dynamo then start-up performance from a standstill state should not be an issue. Care must be taken to provide proper distancing at operating speeds and temperature.

Ferro-Fluidic Seals

Ferro-fluidic seals[7] are those where a bead of a ferro-fluid is maintained at the apex of concentric rings in a labyrinth configuration and is maintained by the action of a permanent magnet. This type of seal has good high speed and high temperature characteristics within limits but must be engineered for specific applications. Many firms are available for custom design of this product to customer requirements.

Bearings and Lubrication:

Reducing friction in bearings is important for efficiency, wear reduction, extended use at high speeds, overheating avoidance and premature bearing failure. Essentially, a bearing can reduce friction by virtue of its shape, by its material, by introducing and containing a fluid between surfaces or by separating the surfaces with an electromagnetic field.

- By shape, gains advantage usually by using spheres or rollers, or by forming flexure bearings.
- By material, exploits the nature of the bearing material used (an example would be using plastics that have low surface friction).
- By fluid, exploits the low viscosity of a layer of fluid, such as a lubricant or as a pressurized medium to keep the two solid parts from touching, or by reducing the normal force between them.
- By fields, exploits force fields, such as magnetic fields, to keep solid parts from touching.

Combinations of these can even be employed within the same bearing. An example of this is where the cage is made of plastic and it separates the rollers/balls which reduce friction by their shape and finish. Bearing speed is a function of bearing type, temperature, load, material, dynamics (vibration) and mode of operation. Some bearing configurations can attain angular velocities of 500,000 rpm which is far higher than what now is considered to be nominal BLTE operational speed.

The chassis should incorporate lubrication and electrical subsystems commonly found in turbine equipment to support the above mentioned functionality.

BLTE Prototyping and Funding:

Engine Builds

The "Prototype build" is a compressed air or external combustion operated "proof of concept" unit, which demonstrates fundamental design concepts. This unit will accommodate instrumentation for logging speed, acceleration, vibration, temperature, pressure and flow relationships. This unit, which is presently under construction, will also establish some expectations of efficiencies over the speed range.

The "Test Platform build" will be a fuel-operated unit that will test seals, bearings, fasteners, tubing and various other materials used for BLTE construction.

The "Pulsed Mode build" is the flattest form of the Tesla Engine. This will explore the ignition modes, power output and other operational characteristics of a pulse fueled BLTE. It may be of interest to point out that even operating in a pulsed mode the BLTE would be less emissive than its reciprocating counterpart.

This "Continuous Mode build" will be used to explore the upward and downward scaling characteristics of the BLTE.

The "Multistage build", which is the most sophisticated assembly, will demonstrate high power output and sustained operation.

Electrical generation is the end stage of the BLTE and is intended to convert the engine output totally to electrical power which can efficiently be made available to any application.

The Department of Energy[13] disperses funds for Alternative Energy Development.

The BLTE requires funding for development of its applications which will allow it to fulfill its potential as an efficient fuel conversion prime mover. The time is right. The search for fuel efficient, low emission, high power systems puts the BLTE on center stage as a most viable candidate.

Any perceived risk of investment is offset by the US Department of Energy (DOE) search and incentives for green energy systems. This engine falls squarely into the definition of an Alternative Energy Device. The only thing lacking is the expertise to apply for this government funding. Below are examples of ongoing (DOE) government incentive programs.

U.S. DOE Energy Efficiency and Renewable Energy (EERE) Home Page

Government agencies, private investors, venture capitalist and the like are comforted by the association of established business with this prototyping and manufacturing effort. Reduced development risk with funding from DOE for prototyping is real and is now…

DOE Awards $8.4 Million to Improve Engine and Powertrain Efficiency
DOE Awards $175 Million for Advanced Vehicle Research and Development

The development of this engine will require seed capital for the purpose of legal positioning and business plan execution. Financial support from a larger company is desirable since this supporting position is more encouraging to investors and venture capitalist[14].

International Patenting
Relationship of Disk Speed, Shaft Torque and Engine Load
Support of the Business Plan

These items represent the outstanding tasks to be accomplished.

Application Organization:

Electrical Power Generation

Electrical Power Generation is one of the fundamental aspects of this engine as originally conceived. The coupling of the BLTE with a motor/generator of matching size allows electrical generation at the frequency of the engine speed and producing phases proportional to the number of generator poles. If at some optimum BLTE speed, for instance 36,000 RPM, a 10:1 reduction gear can be used to derive a 3600 RPM frequency. With proper control, the output phase and amplitude can be managed to allow this system to synchronize with the power grid or be synchronized with other power generating units. In addition the generator output can be conditioned with an inverter to supply or match any power, voltage and frequency combination required by an application.

The main aspect of BLTE operation is the efficiency and durability of this equipment allowing stand alone operation for powering of mobile, remotely located, stand-by or emergency equipment.

Battery Replacement

The BLTE in a very small form will have the capability to quietly and efficiently produce electrical power from LPG Butane[19] or lighter fluid. This power production, again coupled to rechargeable batteries[18] and an engine management system (ECM), should be able to supply power at battery power levels for extended lengths of time as compared to contemporary battery charge life. Below are conservative energy calculations based on the abovementioned BLTE efficiency claims, the energy content of the identified fuel (Butane @ 27.7MJ/L[17]), the conversion efficiencies to various electrical forms and battery storage efficiency.

Power Hand Tools

An 18 volt battery powered hand drill can operate continuously for (2400 mAH)/(20 A) = 0.12 Hrs = **7.2 min**. The calculations shown below use efficiencies that are very conservative:

The energy in 1 liter of LPG Butane = 27.7MJ, the energy in 1 ounce ($^1/_8$ cup) of LPG Butane = 801.442 KJ.
Energy available after BLTE conversion (@ .44 efficiency) = 352.634 KJ
Energy available after dynamo conversion (@ .80 efficiency) = 282.108 KJ
Energy available after electrical conversion (@ .60 efficiency) = 169.264 KJ

This estimation makes the mini BLTE application compatible to a bank of 15 sub-C size Lithium Ion batteries. The exception is that batteries do not expend all of their energy after discharging to a low level. The mini BLTE would be immediately rechargeable from the butane container.

Usage per ounce of LPG Butane @ **169.264 KJ /(20 Amps)*(20 VDC)** = 169.264 KJ/20 volts = 423 sec
423 sec/60 = **7.05 min**

To extend the endurance then the fuel reservoir should be enlarged or the fuel container could be the 320mL butane container. The dimensions of the 18 volt cordless drill battery pack are 13 cm x 7 cm x 5 cm = 455cc which in addition to the mini BLTE volume would allow a 4.5 ounce fuel reservoir.

1 watt = 1J/sec: 1J = (1 volt)* (1 amp)*sec
1 ounce[16] of LPG Butane = 0.02957 Liter = 29.57mL = 29.57cc OR 33.8 fl oz = 1 Liter.
The volume of one subminiature C size battery . 1.6 fl oz

Computer Laptop Supply

A laptop supply specified at 14.4 volts DC & 4000mAH will power a laptop for about 4 hours so current consumption averages 1 Ampere-Hour. The average is referred to because the actual current draw is dependent on screen intensity and duty cycle, hard drive duty cycle, peripheral power consumption, “On” versus “Stand-By” operation, and processor activity.

Dimensions of the laptop internal power supply are 13.5 cm x 8 cm x 2 cm = 110.7 cc. In this flat form the BLTE as shown has too wide of a profile for this space although a flatter version exists, the pulsed BLTE.

In the case of the laptop, a BLTE external power supply analogous to the external charger pack and similar in function to the above “Power Hand Tool” application can be configured to supply laptop power. The length of its endurance depends only on the fuel reservoir capacity which can be the entire butane canister, examples of which contain approximately 140 cc to 320 cc of LPG Butane.

Personal Power Generation

Possibly the most unusual application is as a mobile power generation unit that can be produced small enough to allow electrical power generation for a single person. The purpose would be to power motors, compressors, lighting, battery recharge and electronics to augment personal capabilities. These capabilities could be an exoskeleton capable of providing an artificial environment, lifting or moving heavy loads, infrared, ultraviolet, telescopic or microscopic vision enhancement, heating and cooling.

Prime Movers:

Aircraft

Main Propulsion Power

Light weight and high power
High speed prop driven cargo aircraft, private and passenger craft using direct reduction gearing
Prop-driven Vertical Take-Off OR Landing (VTOL) craft employing a high power BLTE

Aircraft Equipment Power Generation Auxiliary Power Unit (APU)

With a 400 Hz supply @ 115 volts and at a predefined current load the BLTE is powerful and light weight
With the use of an inverter the BLTE can simultaneously supply many voltages and frequencies while operating on aviation gasoline or jet fuel

Marine

Cargo, passenger, military shipping
Leisure boats
High speed hydrofoil, Hydroplane racing

Automotive

Commercial transport
Rail
Off Road
Over-the-road
Military transport & fighting vehicles
Passenger vehicles

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Engine Performance Criteria

Problems with the MPG Comparison Method

The Criteria for engine comparison as suggested and derived from the automotive industry is measured in "Miles per Gallon" (MPG) which would be (loosely considered) vehicle fuel efficiency versus "Gallons per Mile" (GPM) which would be (loosely considered) vehicle fuel consumption. With an initial inspection this method of engine comparison has little to do with engine performance except how an engine may be performing in a land vehicle. This method of analysis is subject to many external influences which makes this measurement technique almost useless. Even in two identical vehicles or the same vehicle driven by different operators at different times can produce wildly different results.

Some problems inherent with this technique are:

- Fuel consumption results are dependent on the road conditions (especially curves, hills, stops, smoothness, wet pavement where water is pumped away from the tire contact to the roadway)
- Driver differences as with rates of acceleration, accelerations and decelerations while attempting a constant speed, idle time, friction braking frequency, turns and lane changing
- Precipitation where every drop of rain or snow get accelerated to the vehicle speed
- Barometric pressure where the engine has more power with increasing pressure and less power with reduced pressure
- Fuel consumption is dependent on which way the wind is blowing

In every instance the criteria and the basis of MPG comparison are vehicle based, poorly measured and subjectively compared.

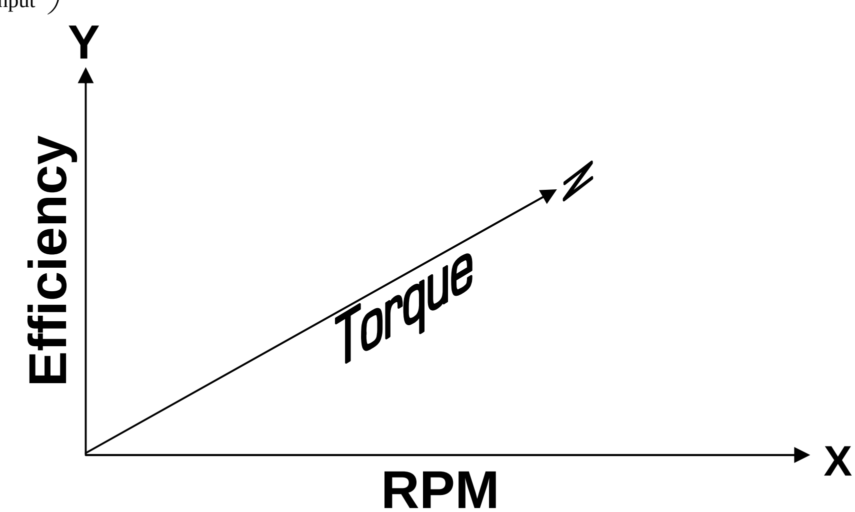
In addition different types of vehicles equipped with the same engine will produce different results. For instance a pick-up truck versus an excavator would also produce wildly different results.

Other problems inherent with this technique are:

- Aircraft fuel consumption does not translate without creative math to "Miles per Gallon"
- Marine fuel consumption does not translate without creative math to "Miles per Gallon"
- Rail fuel consumption does not translate without creative math to "Miles per Gallon"
- Generator fuel consumption has no relationship to this measurement criteria
- Other technologies such as external combustion, solar powered and fuel cell conversions are not even considered because they cannot be applied to this measurement method

The alternative offering is to use true engine characteristics represented by a 3-dimentional (3D) graph to make power plant comparisons. These 3D characteristics are "RPM" (Revolutions per Minute or revs) on the X-Axis, "Efficiency" $\left(\frac{\text{Power Output}}{\text{Power Input}}\right)$ on the Y-Axis and Power or Torque (where Power=Torque • RPM) on the Z-Axis (Figure 8).

Figure 8



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Woody's Engine Criteria & Comparison (WoodECC)

Observing engine data in this manner allows a person to judge at a glance (Figure 9) power output, fuel savings and the ideal operating point. The graphs, figures 9 & 10 are examples and only refer to this discussion.

1. "Power Output" is equal to RPM x Torque. The RPM (revs) is the engine speed and Torque is the work output. The Efficiency delineates the available power output relative to the total power (energy per second) being provided, by the fuel, to the engine. As an example: at 60% (0.6) efficiency, 6/10 of the fuel being supplied is being provided as desired output power. The remaining 40% of the fuel provided is being used to run the engine itself, produce heat, vibration, air currents, etcetera.
2. For "Fuel Savings", the graphic representation of engine data in such a manner allows a person to compare different engines for application suitability and economy.
3. The "Ideal Operating Point" is the location on the graph (Figure 10) where the torque output is "equal to" or "greater than" the work load required by the application. This point is actually an ideal operating area of equal efficiencies.
    - If the output torque chosen is "S57" then an equivalent efficiency range is between 35000 to 50000 RPM. Said in other words:
    - Power setting S57 x 35000 revs is a lesser power setting than S57 x 50000 revs but the conversion ratio of power output to fuel consumption input at both points is roughly the same.
    - Power setting S57 x 35000 revs which is a lesser power setting than S81 x 35000 revs but the conversion ratio of power output to fuel consumption input at both points is still roughly the same.
    - Similarly colored areas on the graphs have similar efficiencies but different power settings.

Other Conversion Engine Analysis

This graph characterizes and relates the efficiency aspect of energy conversion devices in terms of power output versus power input. Efficiency and power are the most important aspects of engine operation where power output may be represented as "Force x Velocity", "Torque x Angular Velocity", "Pressure x Flow" or "Voltage x Current". Power output is the characteristic that can be applied to a load.

Other methods of conversion such solar cells, hydrogen powered fuel cells, nuclear powered, steam or compressed air external combustion driven engines may be treated with this analysis method.

Figure 9

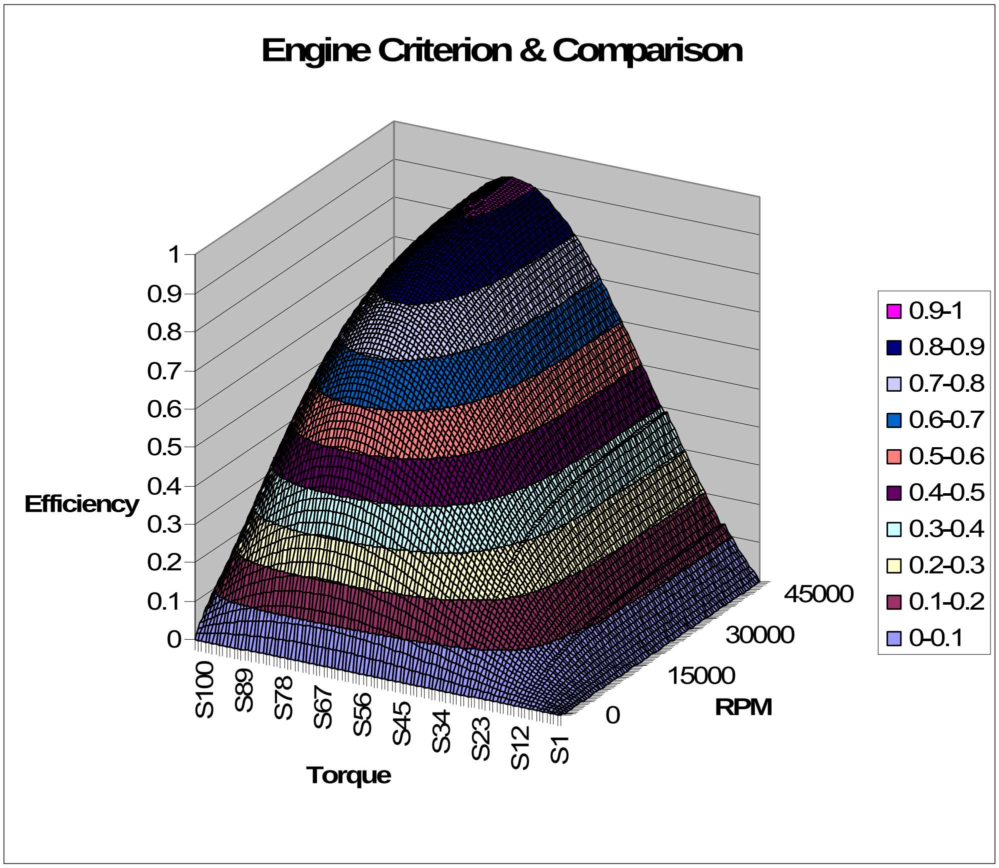
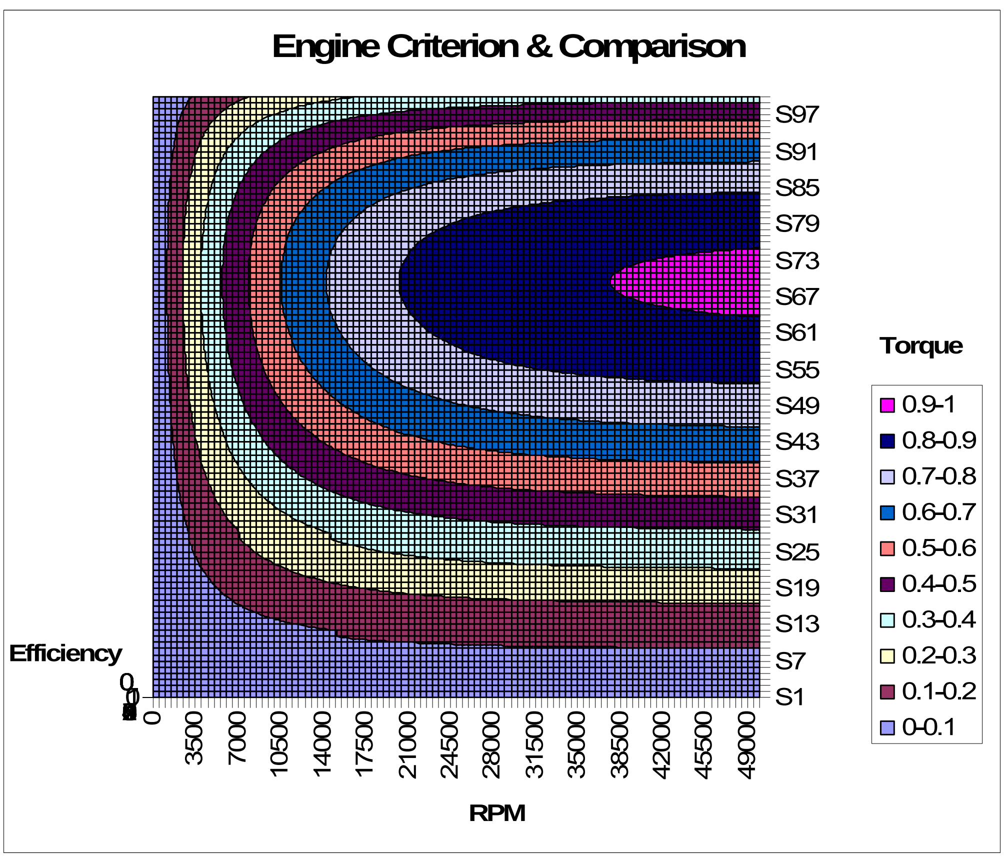


Figure10



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Terms and Relationships:

Disk Speed

1 revolution (rev) is the complete turn of a disk through 360° or 2π radians.
Disk speed is measured in "Radians per Seconds (rads)", "Revolutions per Second (rps)" or "Revolutions per Minute (RPM)".

RPM = 60 x RPS
rads = 2 x Pi x rps = 6.283 x rps = 377 x RPM

Disk Acceleration

Disk acceleration (Acc_D) is the rate of disk speed increase/decrease per unit of time.

Acc_D = rps/sec = revolutions/sec^2

Effective Disk Area

The effective disk area is that area of the disk(s) actually performing the functions of compression, evacuation and power generation. The area of the disk(s) occupied by the shaft and that area bounded by the Inner Port Radius to the Outer Shaft Radius provide disk support and power connection and are shielded from dynamic working fluid interaction.

C_A – circumferential aperture
P_A – port aperture
S_A – shaft area
H_A – hub area
nD – number of disks
D_r – disk radius
D_D – disk diameter = $2 \bullet D_r$
S_D – disk spacing
R_D – disk radius
EA_D – effective disk area
A_P – port area
R_{POT} – port outer radius
R_{PIN} – port inner radius
A_{SUP} – support area
W_{SUP} – support width
L_{SUP} – support length
A_{SHAFT} – shaft area
R_{FIL} – fillet radius
nPO – number of port orifices = 3
nD – number of disks
π - 3.1415926

Circumferential Aperture = $(D_D \bullet \pi) \times (S_D) \times (nD - 1)$ = (disk circumference) x (disk spacing) x (number of disks -1)

Port Aperture = $(\pi \bullet R_{POT}^2) - (\pi \bullet R_{PIN}^2) - (A_{SUP})$ = [(port outer radius^2 • π) – (port inner radius^2 • π)] – (support area)

Support Area = $A_{SUP} = (L_{SUP} \times W_{SUP}) + (nPO \bullet \pi \bullet R_{FIL}^2) = ((R_{POT} - R_{PIN}) \times (W_{SUP})) + (3 \bullet \pi \bullet R_{FIL}^2)$

Effective Disk Area = $(\pi \bullet D_r^2) - [(\pi \bullet R_{POT}^2) + (A_{SUP})]$

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Efficiency Calculations:

Power Output – P_{OUT}
Power Input – P_{IN}
Efficiency = P_{OUT}/ P_{IN}
% Efficiency = Efficiency x 100
Sync = (1-Efficiency) = $1- P_{IN}/P_{OUT} = (P_{OUT} - P_{IN})/P_{OUT}$

Efficiency Gain Ratio – EGR

Example

Reciprocating Engine Efficiency = 20% = .20
Sync(Reciprocating) = 1 – .20 = .80

BLTE Efficiency = 44% = .44
Sync(BLTE) = 1 – .44 = .56

EGR = $\mathrm{LOG}_{\mathrm{Sync(Reciprocating)}}$ Sync(BLTE)
EGR = LOG (Sync(BLTE)) / LOG(Sync(Reciprocating)) = LOG (.56)/LOG(.8) = **2.6**

References:

1. **Tesla Turbine Engine** http://en.wikipedia.org/wiki/Tesla_turbine
2. **The Tesla Bladeless Turbine** http://www.ncoic.com/turbine.htm
3. **Aerodynamic Drag** http://www.grc.nasa.gov/WWW/K-12/airplane/boundlay.html
4. **Labyrinth Seals** http://en.wikipedia.org/wiki/Labyrinth_seal
5. **Leakage Calculations** http://www.asr.org.tr/pdf/vol9no3p435.pdf
6. **Images** http://www.google.com/search?q=labyrinth+seal&hl=en&rlz=1W1GCNV_en&biw=983&bih=770&prmd=imvnsb&tbm=isch&tbo=u&source=univ&sa=X&ei=VpZ2Ts2IAoTniALN8u2yAg&sqi=2&ved=0CE4QsAQ
7. **Ferro Fluidic Seals** http://en.wikipedia.org/wiki/Ferrofluidic_seal
8. **Ferro Tec Company & Operational Video** http://www.ferrotec.com/technology/sealsVideo/
9. **Rigaku Mechatronics** http://en.rigaku-mechatronics.com/index.html
10. **Department of Energy** http://lpo.energy.gov/
11. **Obama's Wager On America** http://www.boisestatepublicradio.org/2011/06/13/is-obamas-bet-on-green-jobs-risky/
12. **DOE (energy.gov)** http://energy.gov/
13. **DOE Grants and Contracts** http://www.er.doe.gov/grants/
14. **Venture Capital** http://www.entrepreneur.com/vc100
15. **Early Stage Venture Capital** http://www.entrepreneur.com/vc100/stage/early.html
16. **Online Conversions** http://www.onlineconversion.com/
17. **Energy Densities** http://en.wikipedia.org/wiki/Energy_density
18. **Battery Specifications Explained:** http://mit.edu/evt/summary_battery_specifications.pdf
19. **Butane** http://en.wikipedia.org/wiki/Butane