“BOUNDARY LAYER TURBINE ENGINE”

BLTE Construction and Operation

by

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of

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BLTE THEORY OF OPERATION

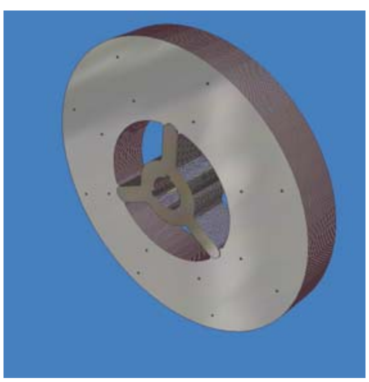
This Boundary Layer Turbine Engine (BLTE) product is a continuous-burn internal-combustion high efficiency converter of hydrocarbon fuels to kinetic energy. This engine design is based on the Tesla turbine[1] flat bladed external combustion engine but has been modified with intake, compression, combustion and exhaust components which will form a basic BLTE "main stage". Auxiliary (minor stages) can be used as additional pre-compression, post-combustion (exhaust evacuation) stages to enhance engine performance. The difference between the auxiliary compression and exhaust stages will be the relative placement of these stages in a compound (multi-stage) or complex engine arrangement.

This invention, the **Boundary Layer Turbine Engine** (**BLTE**), is a flat disk (bladeless) turbine that operates on the principal of "aerodynamic drag". Multiple disks with aligned center ports, closely arranged in a stack will take advantage of the energy of a working fluid forced into a chassis at the outer perimeter of a compression disk stack. Control of the BLTE speed or power output is done by metering fuel and/or air into the BLTE Chassis. After combustion this fluid flow will impart its energy to the exhaust/power disks as it is forced to spiral its way towards and out of their center ports. The method of this energy exchange is by virtue of the working fluid's viscosity that attaches (drags) it to the contours of the disk faces and by virtue of the decreasing radius of its path, where the corresponding decreasing speed of the working fluid flow, will ultimately torque the attached center shaft (page 23). This engine is essentially a radial flow turbine that takes advantage of the close fittings of its bladeless disks and chassis walls to provide high compression and especially low working fluid flow as compared to fan-bladed and/or vane-disk radial flow turbines.

This particular application solves the problem of internal combustion and multi-stage operation for this type of engine.

This invention provides internal combustion in both single chassis (complex) and multi-chassis (compound) configurations. The BLTE design allows the combustion of fuel in the first stage and the injection of either water to provide steam expansion, air to provide air expansion or fuel into a second stage providing an afterburning effect to boost the power output.

This invention provides scalable power (high, medium or low) output configurations, and provides these outputs at approximately three times the efficiency of a reciprocating engine and at a higher efficiency than a conventional radial turbine engine. The physical scalability ranges from battery replacement applications (dime-size) to maritime applications (yards across), where the intention is the replacement of reciprocating (piston driven) engines and much more.



The picture to the left illustrates a "disk stack" concept rendered in 3D CAD. Take notice of the bumps on the disk surfaces and the star washer in front of the first disk shown. These devices are employed to maintain disk spacing. This drawing shows disks with slots, as opposed to tabs (referred to in the remainder of this document) in the central hub. This slotted version was originally designed to mate with a tabbed shaft and is referred to as a possible mounting option in the "Shaft Construction" section below. This picture is for information only and demonstrates the design flexibility of the BLTE.

Figure 1

Document Standards

The BLTE in this document is shown in both compound and complex arrangements for the purpose of demonstrating two basic arrangements of the same engine operation. A particular arrangement is used to achieve a desired "torque" at a desired "power" output to satisfy an application (page 29). For the purposes of the discussion herein, the front of the engine in the schematic drawings is to the left and the back is to the right. When referring to the figures as "Figure X-Y", the "X" is the figure number and the "Y" is the callout number in that figure. Items highlighted in blue are hyperlinks to locations in this document or to other helpful websites.

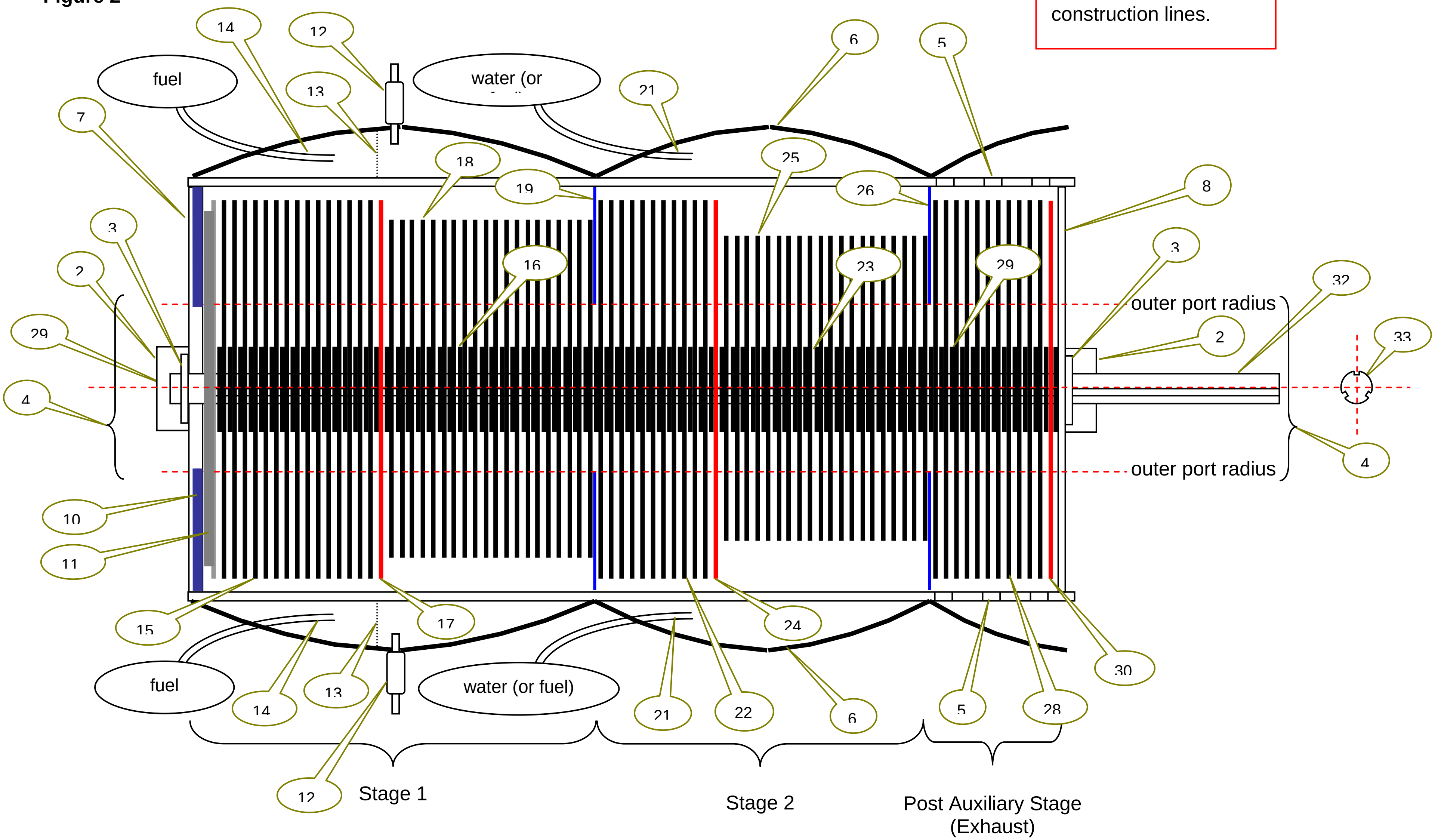
Complex BLTE Construction Diagram

Schematic Construction of the Complex Internal Combustion BLTE

Side View

Notes:
Red dotted lines are construction lines.

Figure 2



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Complex BLTE Construction Description:

1. **Chassis**
2. Bearing Housings
3. Frictionless Bearings
4. Intake Ports
5. Exhaust Ports
6. Bubble Chassis Enclosure (also see Cylinder Chassis (page 30))
7. Chassis Front Cover
8. Chassis Rear Cover (portless)
9. **Stage 1**
10. Front Female Labyrinth Seal
11. Front Male Labyrinth Seal
12. Igniter
13. Flame Barrier
14. Fuel Injector
15. Compression Disk Stack
16. Star Washers
17. Shaft Mounted Baffle Disk
18. Exhaust/Power Disk Stack
19. Chassis Mounted Baffle Disk
20. **Stage 2**
21. Fuel/Water Injector
22. Compression Disk Stack
23. Star Washers
24. Shaft Mounted Baffle Disk
25. Exhaust/Power Disk Stack
26. Chassis Mounted Baffle Disk
27. **Auxiliary Exhaust Stage**
28. Exhaust Evacuation Disks (optional)
29. Star Washers
30. Shaft Mounted Baffle Disk
31. **Shaft**
32. Slotted Shaft (or Keyed Shaft)
33. Shaft End View

BLTE Operation:

Conventional radial and axial flow turbine engines employ vanes arranged at inclined angles on disk peripheries which are separated by the vane depth. This arrangement demands a high velocity flow which wastes a tremendous amount of heat energy and employs expensive vane construction to withstand centrifugal forces at high exhaust temperatures. The BLTE has no vanes and employs solid disk construction that inherently resists centrifugal deformity at exhaust temperatures.

The BLTE is a superior radial turbine engine due to its miserly working fluid flow through closely spaced flat disks. This allows exhaust currents of different energy levels to proceed along their own paths insuring greater efficiency and a wider operating range (engine speed) than conventional vane turbine engines. When compared to reciprocating (piston driven) engines, the incredible efficiency gain is due to the lack of internal friction arising from pistons sliding on cylinder walls, valve trains, system pumps and especially the parasitic sapping of heat removed by the cooling system from a heat driven engine, the analog of which is a device to remove wind from the sails of a wind driven vessel.

Aerodynamic Drag

The BLTE Internal Combustion Radial Turbine Engine operates on the principal of aerodynamic drag[5] (page 31) with air adhered to the disk surfaces and vortex dynamics due to disk rotation. The Tesla Turbine Engine[1] (page 31) configuration was originally conceived as an external combustion (steam driven) engine, a form of which has long been used in industry as a centrifugal pump[2] (page 31).

Disk Pumping Action

Each set of disk stacks attached to the turbine shaft will naturally act as a centrifugal pump. When rotated, the compression disk stack (Figure 3-3) of the first stage will accelerate the fluid attached to its disk surface in a vortex pattern to the disk periphery. This action in an enclosed space will produce a pressure which is proportional to the disk radius and the disk stack speed. The larger compression disks will produce a higher pressure/flow than the smaller power/exhaust disks (Figure 3-9) such that even without combustion, the turning of the disk assembly within an enclosure will cause a natural flow of air from front to rear of the engine.

Fueling

The BLTE is fuel insensitive, as is the case with most turbine engines and may be run on multi-grade diesel, bio-diesel, multi-grade gasoline, alcohols, natural gas, etcetera without significant change of hardware. Fuel injection (Figure 3-5) and an ignition source (Figure 3-7) will produce combustion (Figure 3-8) which will boost the pressure above the compression and power/exhaust disks exhausting through the power/exhaust disks following the “path of least resistance”.

Exhaust and Power Output

The combustion exhaust exiting through the power/exhaust disks imparts its energy to those disks by virtue of their decreasing radius (thus the decreasing circumference) where it exits the center ports, in turn driving the shaft, the forward compression disks as well as any other assemblies or loads attached to the shaft.

Second Stage Power Augmentation

The compression disk stack of the second engine stage will serve to evacuate the first stage (Figure 3-11) exhaust and help with insuring the direction of working fluid flow. Into this stage it would be possible to inject outside air, the expansion of which in the hot exhaust stream would provide additional drive to the system as it exits through the power/exhaust disks of the second stage. Alternatively, an injection of water spray into the hot exhaust stream would be flashed into steam (Figure 3-13) the expansion of which driven past the second stage power/exhaust disks would also provide additional torque. The greatest auxiliary drive source would be the result of injecting fuel (perhaps with an auxiliary ignition source) into the hot exhaust stream in an after-burn fashion for movement across the power/exhaust disks.

Auxiliary Stage Augmentation

The addition of augmenting stages for compression or exhaust enhancement (Figure 16A) can be used to either increase compression or to evacuate exhaust. Auxiliary or supplementary stages will serve to optimize compatibility of the BLTE for a particular application.

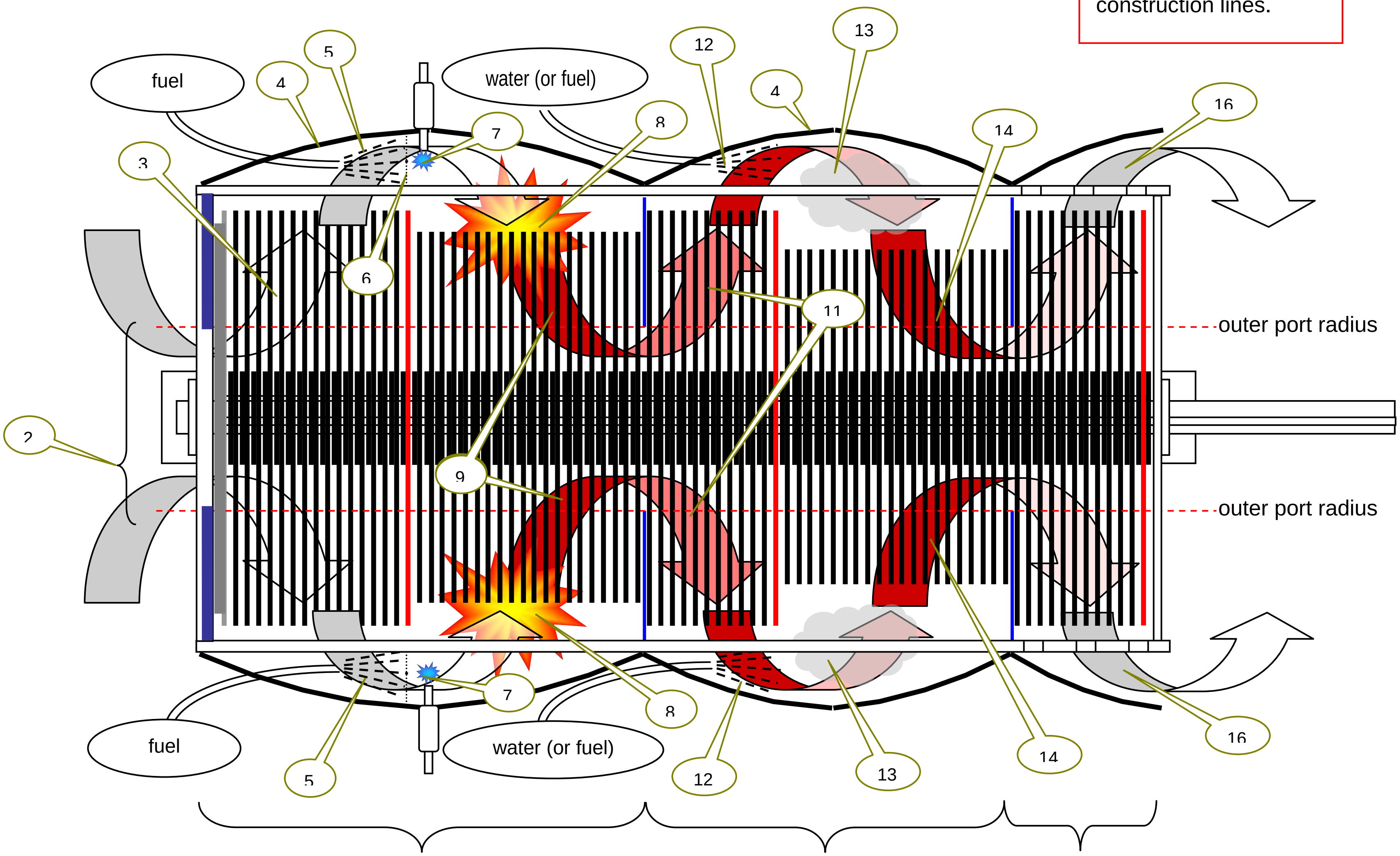
Complex BLTE Operation Diagram

Schematic Operation of the Complex Internal Combustion BLTE

Figure 3

Side View

Notes:
Red dotted lines are construction lines.



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Schematic Diagram of the Complex BLTE Disks

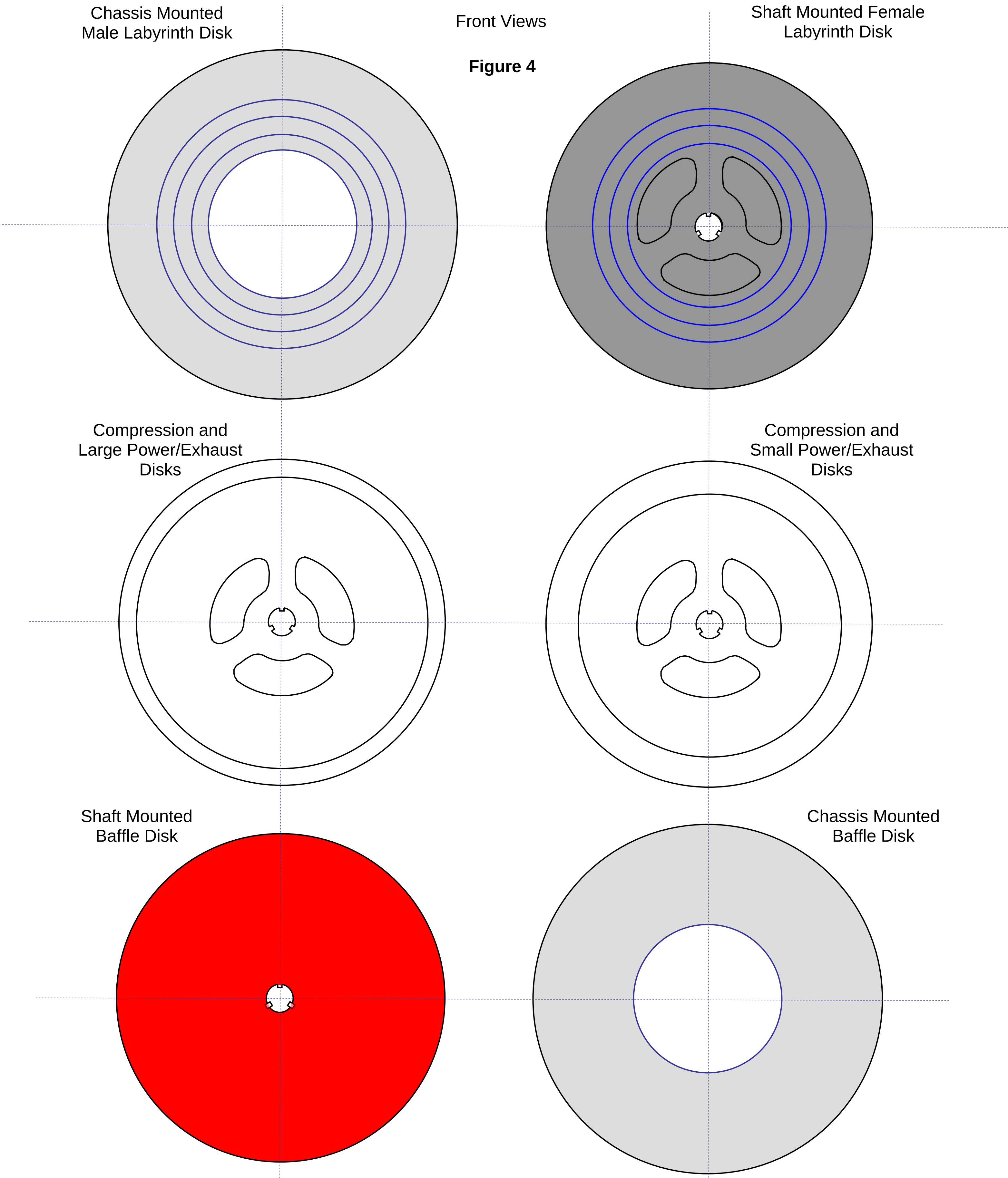

Figure 4

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Complex BLTE Operation Description:

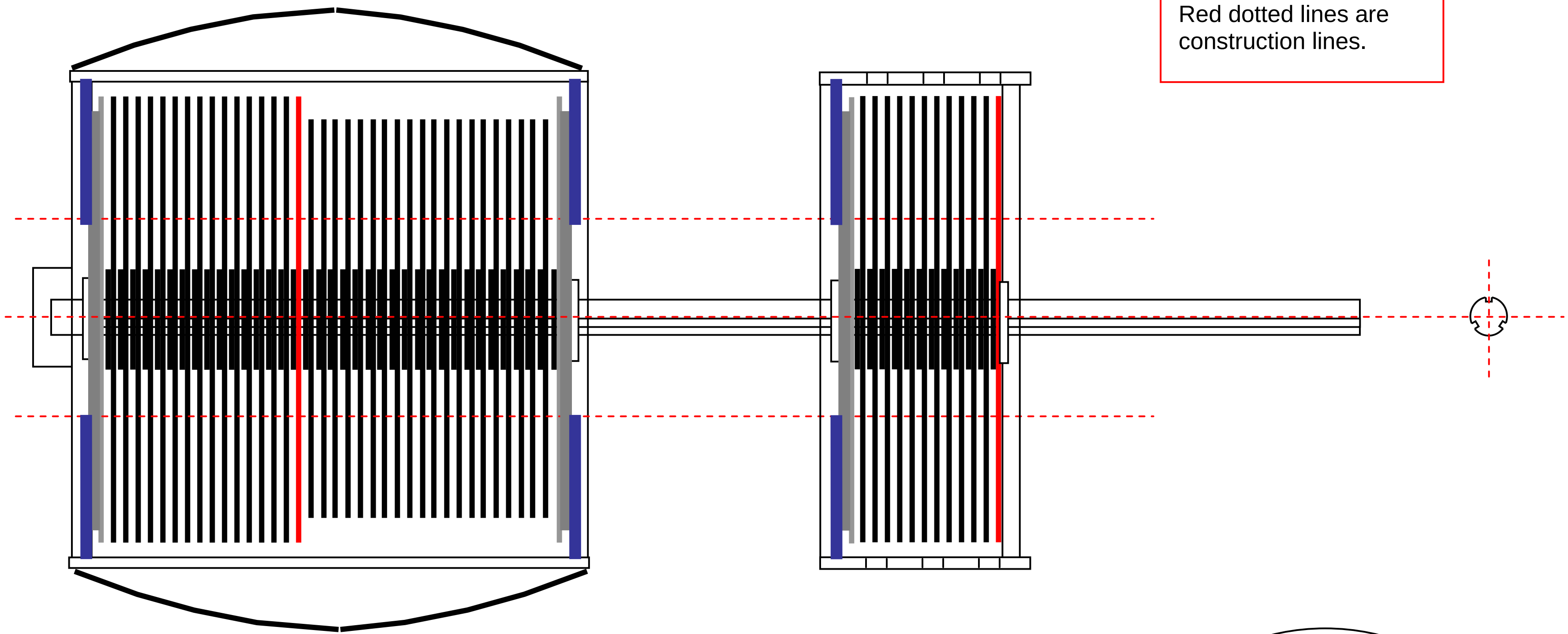
1. **Stage 1**
2. Air Intake Centrifuge/Intake Ports
3. Air Compression
4. Chassis Containment/Pressure Vessel
5. Fuel Injection
6. Flame Barrier
7. Ignition
8. Combustion
9. Exhaust/Power Flow (Stage 1 - larger power recovery disks)
10. **Stage 2**
11. Exhaust Evacuation (possible compression)
12. Power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

Schematic Construction of the Single Stage and Auxiliary Stage of a Compound Internal Combustion BLTE

Side View

Figure 5

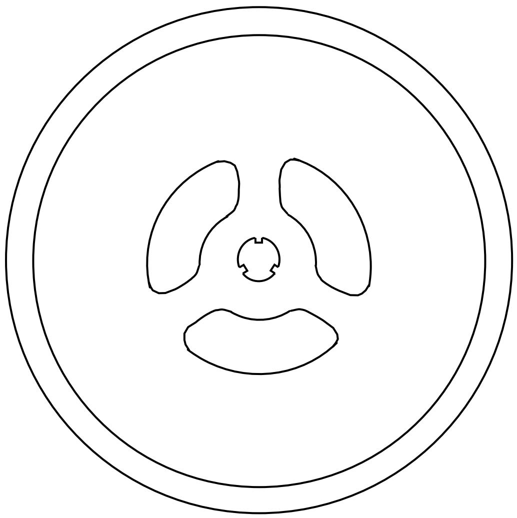
Notes:
Red dotted lines are construction lines.



Main Stage Detail

Auxiliary Stage Detail
(Exhaust)

Figure 6



Main Stage
1 Disks
Front View

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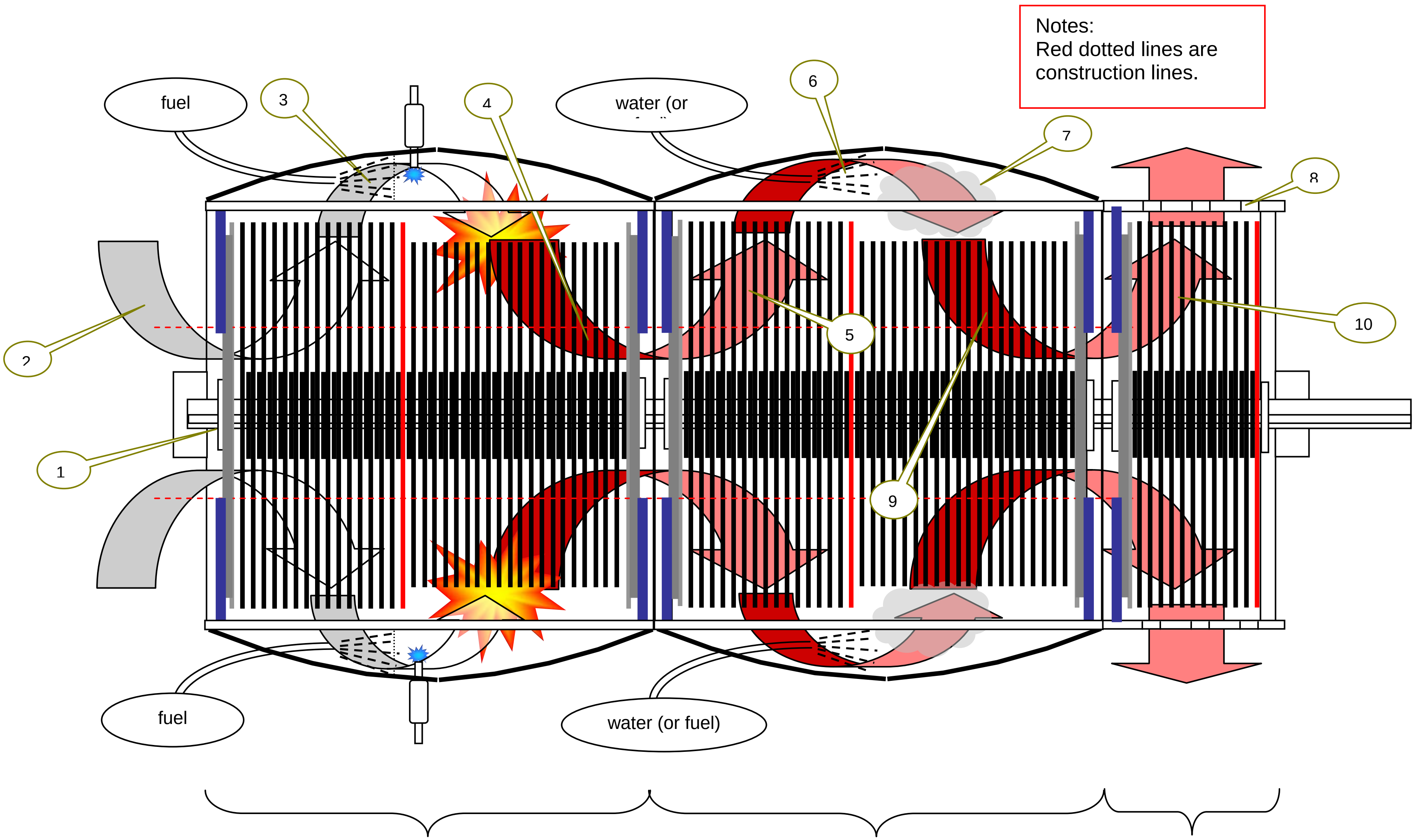
Figure 7

Schematic Operation of a Single Stage and Auxiliary Stage of a Compound Internal Combustion BLTE

Side View



Stage 1

Stage 2

Post Auxiliary Stage
(Exhaust)

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Compound BLTE Description:

This section describes the operation of a Compound BLTE. This operation is exactly the same as the Complex BLTE as described previously with the exception that more (optional) may be added to enhance BLTE operation.

Stage 1

1. Shaft Bearings (before and after each stage & auxiliary stage)
2. Air Intake Centrifuge/Intake Ports
3. Air Compression & Fuel Injection
4. Combustion, Power Flow & Exhaust

Stage 2

5. Stage 1 Exhaust Evacuation/Stage 2 Compression
6. Power Boost Water/Air Injection (or after-burn fuel injection)
7. Water Vaporization/Air Expansion (or auxiliary ignition)
8. Exhaust Ports
9. Exhaust/Power Flow (Stage 2 - smaller power recovery disks)

Auxiliary Stage

10. Exhaust Evacuation (optional)

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BLTE Dynamics:

A BLTE stage consists of a set of large disks which will act as an intake compressor and is separated from the rear part of the stage by a blocking (baffle) disk. The rear portion of a BLTE stage has a smaller disk set from which it extracts the energy from the internal combustion process and applies that energy to the shaft.

The rotation of the shaft mounted disk assembly accelerates the working fluid in the first stage through the intake ducts (Figure 7-1) and forms a vortex which is expanded for fuel injection (Figure 7-3) and combustion (Figure 7-2). The hot working fluid vortex is exhausted through the power/exhaust disk assembly and out of the first stage exhaust ports (Figure 7-4).

All disks are positioned on a single shaft (the shaft may incorporate variable speeds) (Figure 5) where the compressor disks provide air intake and compression into the combustion/expansion chamber. The exhaust disks extract energy from the working fluid (combustion gasses) and exhaust those gasses through the center ports (Figure 7-5) to the next stage if any.

No parts of the disk assembly come into contact with the chassis except the bearing surfaces which support the shaft and disk assembly (Figure 7-1).

All components described previously in terms of a "stage" are necessary for the operation of this engine and are, in essence, a stand alone BLTE stage (Figure 5). Multiple stages are optional, other compression or expansion auxiliary stages are optional, the variable speed shaft is optional and the electrical generator output device is optional in lieu of a geared output. Any if not all of the optional devices would improve the operation of the BLTE. The addition of an electronic engine controller (ECM) would greatly enhance engine efficiency, operation and applicability.

Simple and standard manufacturing tools are all that is necessary to produce the BLTE which is one the main aspects of its desirability. The resistance of the BLTE disk construction to high temperature deformity means reduced costs of materials and elimination of expensive noble metals and single-crystal grown, hollow (for cooling) turbine blades which are characteristic of conventional turbines. Otherwise centering and balancing tools with high speed and high temperature frictionless (pneumatic, oil or magnetic) bearings are necessary for correct operation. Such devices are commonly used in the production of conventional turbine engines and/or turbo compressors for reciprocating engines.

The individual stages as described previously may be operated in series to increase working fluid pressure or in parallel to increase working fluid flow. The compressor stages may be ganged before introduction of the compressed air into the main stage combustion chamber (Figure 16A) and an exhaust evacuation stage may follow any stage to evacuate combustion gases (Figure 18) from main stage(s).

The operation of either the **Complex or Compound BLTE** is similar regardless of the minor differences in construction. The primary difference between the Complex and Compound BLTE is that all main stages and auxiliary stages of the Complex BLTE are housed in a single chassis. For the Compound BLTE, all main stages or auxiliary stages are housed in separate chassis that may be concatenated or ganged for appreciation of various engine characteristics related to different applications.

Disk Construction and Assembly:

There are basically five types of disks which depending on their relative positions perform various functions. There are also disk bump features and star washers which maintain disk separation. All of the disks described herein are smooth (polished) stainless steel or other noncorrosive materials that have a good resistance to deformity at high combustion temperatures and high speed centrifugal forces. Each shaft mounted disk will have tabs positioned around the shaft opening that will allow mounting onto the center shaft. Various shaft configurations are shown in the **Shaft Construction** section (page 23). Each shaft mounted component will be balanced for high speed operation.

These disk types are:

1. A front or rear chassis mounted disk with features composing the receiving side of a female labyrinth seal (Front Receptacle Labyrinth Seal).
2. A front or rear shaft mounted disk with features composing the protruding side of a male labyrinth seal (Front Plug Labyrinth Seal).
3. Star Washers
4. The Compression Disk which can be larger than the labyrinth disks and is larger than the power disks. This disk is shaft mounted and has a port arrangement that is concentric to the shaft.
   - A star washer is mounted forward of these disks.
   - A bump configuration is constructed with the same height as the width of the star washers to maintain disk spacing.
5. The Compression Baffle is a shaft mounted disk with no concentric porting used to terminate the compression sub-stage and conduct the working fluid to the fuel injection and combustion locations.
6. The Power Disks are shaft mounted and have a port arrangement that is concentric to the shaft. These disks are arranged as a stack of disks which determine engine torque and speed.
   - A star washer is mounted forward of these disks.
   - A bump configuration is constructed with the same height as the width of the star washers to maintain disk spacing.

The labyrinth seal disks are optional and may vary in size from one another. Another chassis to disk stack sealing arrangement may be simply a very close fit of the disk stack to specially channeled chassis walls.

The BLTE chassis can also have threaded holes which will allow water injection or instrumentation to facilitate operation. Stages other than the main combustion stage may have threaded ports that allow fuel injection in an after-burn mode, water injection as an expandable working fluid medium, air or other fluids as desired. These threaded ports may be plugged when not used to obtain a desired performance. The chassis may incorporate a lubrication pump and a lubrication cooling system (**Chassis Construction**) (page 24).

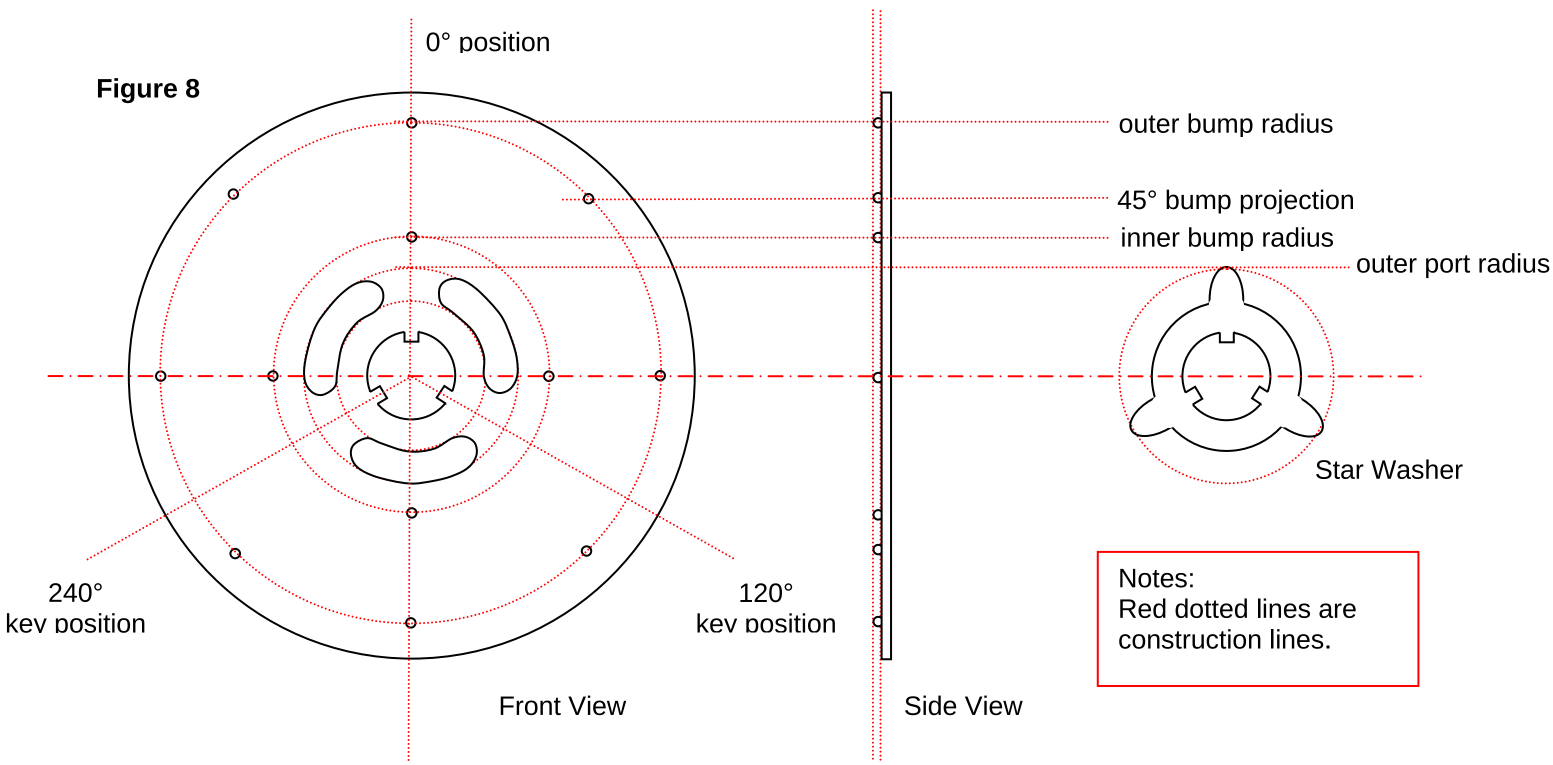
Power/Compression Disks:

The operation of this engine is centered on the compression disks, the power (or exhaust) disks and their associated baffling constructions. Each disk will have a front and rear side which is determined by the protrusion of bumps (front) also upon which the star washers are mounted. There are narrow gaps between disks which are maintained by the bump and star washer (standoff) thicknesses; for the purpose of discussion, I will assume a .030 inch gap thickness. The compression and power disks are rotated 120° from adjacent disks (to be assembled in groups of three) to guarantee that standoff features (bumps and star washers) of these disks are misaligned, maintaining the desired disk spacing and preventing disk warping.

Details of a Power Disk

The power disk is made with a smooth thin stainless material which can be stamped from a roll of material of the desired thickness; for this discussion, I will assume a .030 inch disk thickness. Each power disk will have the same construction. The power disks have a front and rear side which is determined by the protrusion of bumps (front) and upon which the star washers will be mounted (Figure 1).

Figure 8



The inner layer of bumps are positioned every 90° while the bumps in the outer layer are positioned every 45° with the 0° position being the one where the tab aligns with the bumps (top vertical position). This arrangement of bumps and tabs will insure that adjacent disks when rotated 120° (to the next tab position) will have bumps rotated to nonaligned positions. Three tabs provide three positions in this example and so a disk stack will be arranged in repeating groups of three disks. Other tab and bump arrangements are possible and may be desirable depending on performance and cost (Figure 15).

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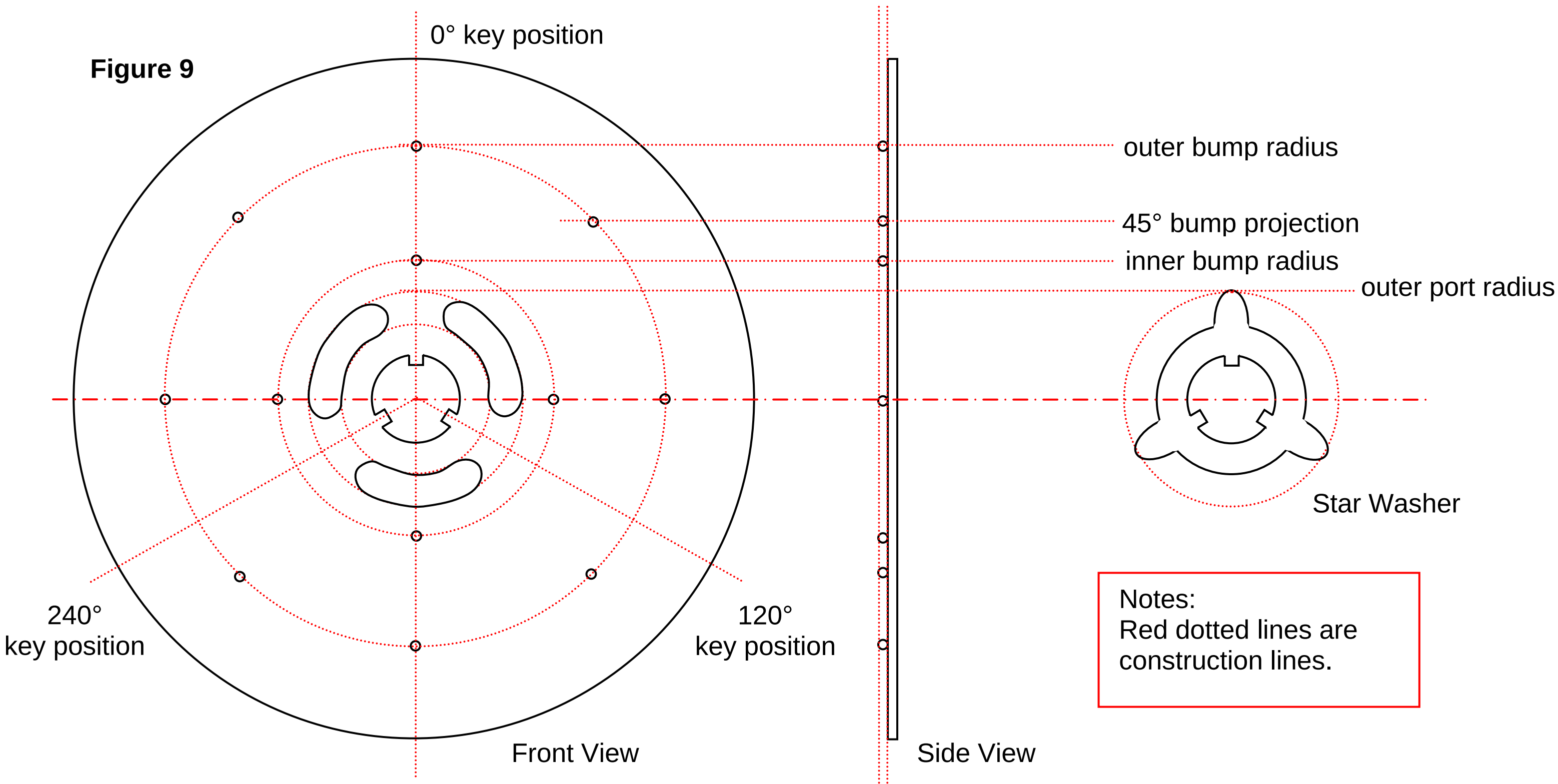
Details of a Compression Disk

The primary difference between power and compression disks is size, the compression disks are larger. The relative locations of the compression disks are before (relative to air flow) the power disks (Figure 2-15 & 22). The compression disk is made with a smooth thin stainless material which can be stamped from a roll of material of the desired thickness; for this discussion I will assume a .030 inch disk thickness. Each compression disk will have the same construction. The compression disks have a front and rear side which is determined by the protrusion of bumps (front) and upon which the star washers will be mounted (Figure 2).

Figure 9



The inner layer of bumps are positioned every 90° while the bumps in the outer layer are positioned every 45° with the 0° position being the one where the tab aligns with the bumps (top vertical position). This arrangement of bumps and tabs will insure that adjacent disks when rotated 120° (to the next tab position) will have bumps rotated to nonaligned positions. Three tabs provide three positions in this example and so a disk stack will be arranged in repeating groups of three disks. Other tab and bump arrangements are possible and may be desirable depending on performance and cost (Figure 15).

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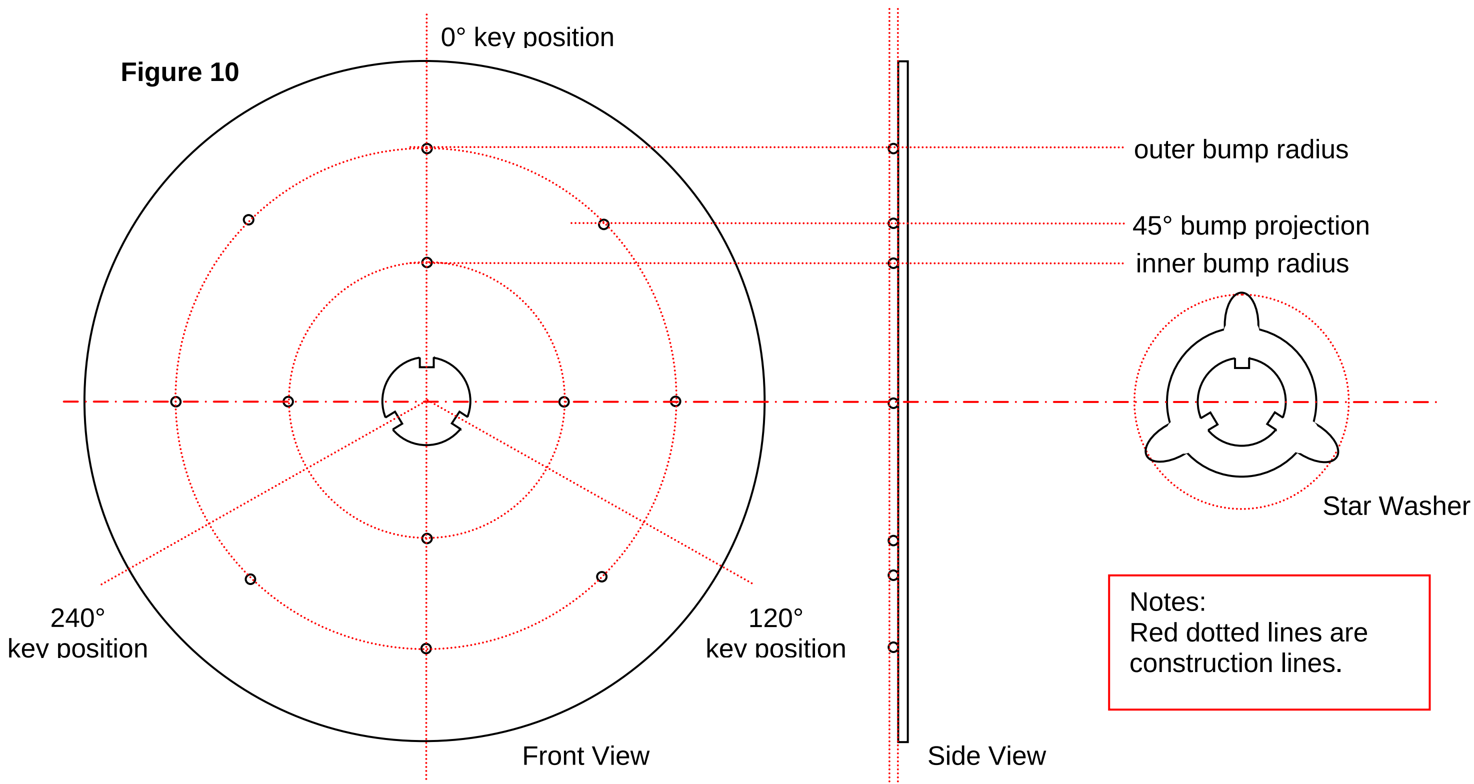
Baffle Disk Construction:

The Baffle Disks are devices that conduct the working fluid from the previous disks assembly to the following assembly changing the mode of operation and thus the working fluid flow. Two types of baffle disks will be available, shaft mounted and chassis mounted.

Details of a Flat Shaft Mounted Baffle Disk

The purpose of baffle disks is to redirect the working fluid flow either into the chassis cavity or out toward the disk periphery. The primary difference between compression or power disks and the shaft mounted baffle disks is concentric porting. The shaft mounted baffle disk is typically the same size as the compression disks and is typically located at the rear of a compression disks assembly (Figure 2-17 & 24). The baffle disk is made with a smooth thin stainless material which can be stamped from a roll of material of the desired thickness; for this discussion, I will assume a .030 inch disk thickness. Shaft mounted baffle disks have the same construction as shown below. The shaft mounted baffle disk has a front and rear side which is determined by the protrusion of bumps (front) and upon which the star washers will be mounted (Figure 2).

Figure 10



The inner layer of bumps are positioned every 90° while the bumps in the outer layer are positioned every 45° with the 0° position being the one where the tab aligns with the bumps (top vertical position). This arrangement of bumps and tabs will insure that with adjacent disks rotated 120° (to the next tab position) bumps will be rotated to nonaligned positions. Three tabs provide three positions in this example and thus a disk stack will be arranged in repeating groups of three. Other tab and bump arrangements are possible and may be desirable depending on performance and cost (Figure 15).

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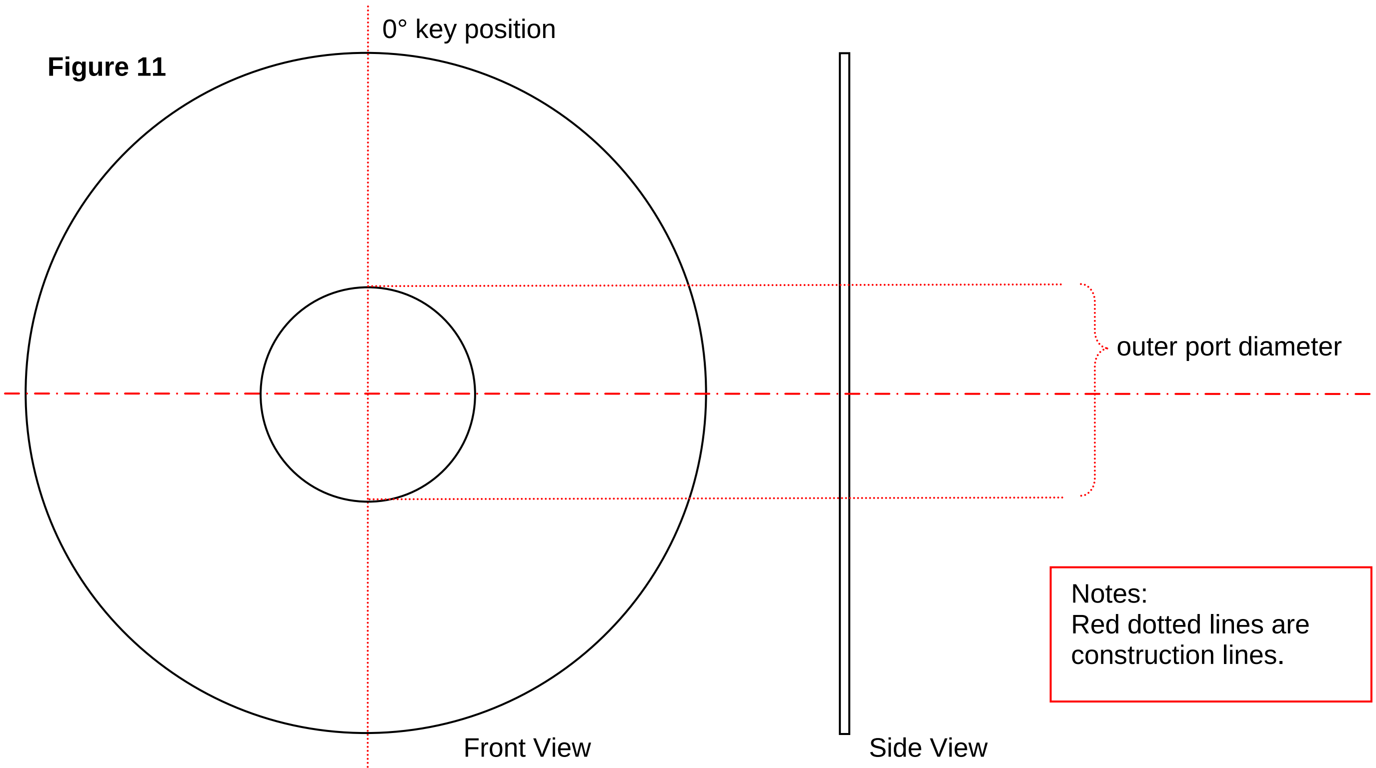
Details of a Flat Chassis Mounted Baffle Disk

The purpose of baffle disks is to redirect the working fluid flow either into the chassis cavity or into the concentric ports. The primary difference between a shaft mounted baffle disk and a chassis mounted baffle disk is that there is no provision for shaft mounting or spacing bumps for this disk as shown below. Chassis mounted baffle disks are typically larger than either compression or power disks and is typically the diameter of the chassis. The chassis mounted baffle disk is typically located at the rear of a power disk assembly or may be the rear of the chassis in a modular chassis arrangement. Otherwise the chassis mounted baffle disk orifice is typically the same size as the outer port aperture and is typically located at the rear of a power/exhaust disk assembly. The baffle disk is made with a smooth thin stainless material which can be stamped from a roll of material of the desired thickness; for this discussion, I will assume a .030 inch disk thickness. Each chassis mounted baffle disk will have the same construction. The chassis mounted baffle is featureless (Figure 2-19 & 26).

Figure 11



The large circular hole in the disk center is the same size as the outer periphery of the port opening and allows the working fluid to exit the previous stage and enter the next. The function of these chassis mounted baffle disks are similar to the shaft mounted versions in that they change the direction of the working fluid which in this case is directed through the center ports.

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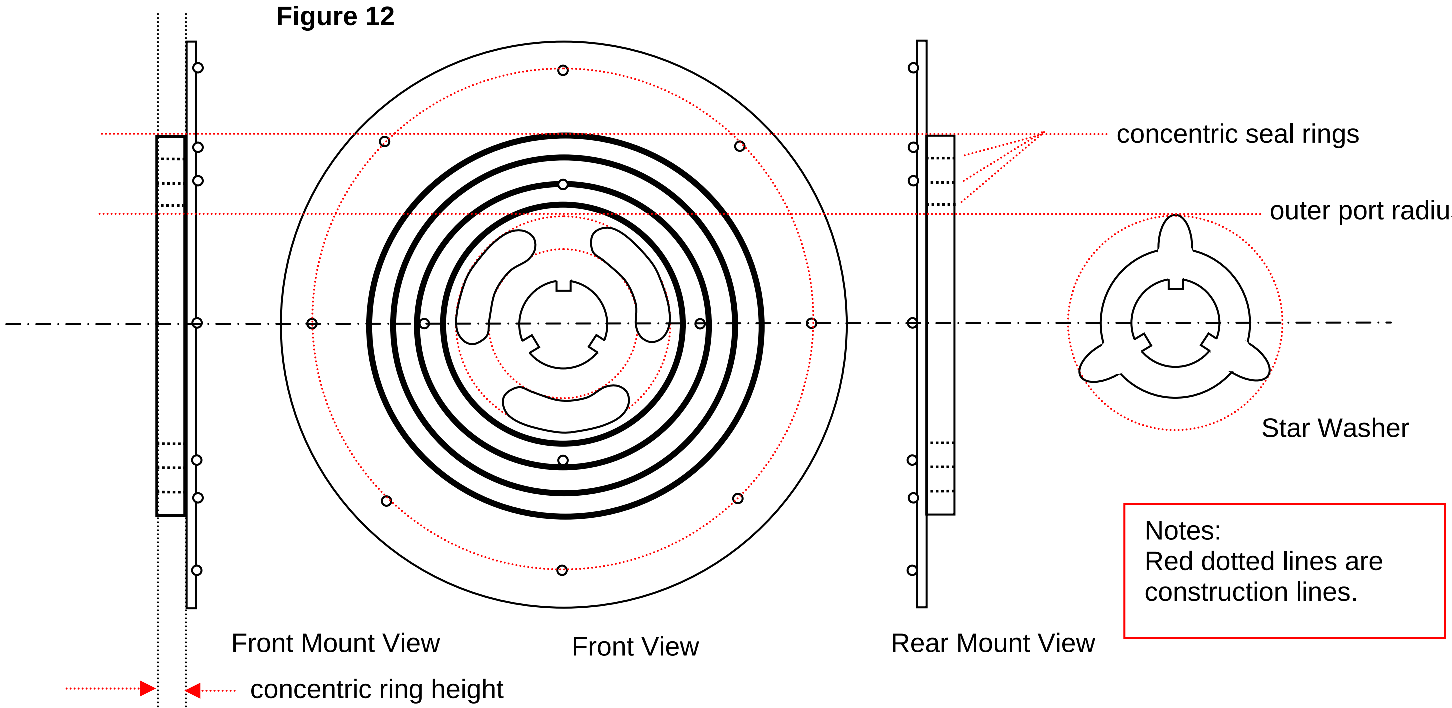
Labyrinth Seal Construction:

The Labyrinth Seal is a device which will allow sealing off of the interior chassis, working fluid higher pressures from the ambient chassis exterior. When used, these devices are arranged in pairs of male (shaft mounted) and female (chassis mounted) disks as illustrated below (Figure 14). Male and female labyrinth seal rings fit alternately one within the other again as shown in Figure 14. The female (chassis mounted) disk will typically fix the beginning or end of an engine stage. These devices will be used in the event of working fluid leakage that cannot be restricted by merely the close fit of baffle disks to the chassis front and rear walls. Outside of this section, the discussion of engine component arrangement may be shown without these labyrinth seals in place.

Shaft Mounted Male Labyrinth Seal

The Shaft Mounted Male Labyrinth Seal is a smooth (polished) solid stainless steel or other noncorrosive material that has a good resistance to deformity at high combustion temperatures and high speed centrifugal forces. The male labyrinth seal will provide a leak proof non-contact barrier between the outer and inner chassis (exterior and chassis chamber). The diameter of the male labyrinth seal should be the same or greater than the engines compression disks. This male labyrinth seal will feature a set of concentric cylinders raised perpendicularly from the disk surface which will fit without contact into a complimentary female fixed labyrinth seal that will be mounted to the chassis front and rear. The front and rear male labyrinth seals are identical where both seals are turned to a 120° tab position so as not to interfere with the bump pattern of their adjacent disks. Both disks will use a star washer mounted on the bump pattern (front) side. The male labyrinth seal will be balanced for optimal high speed operation.

Figure 12



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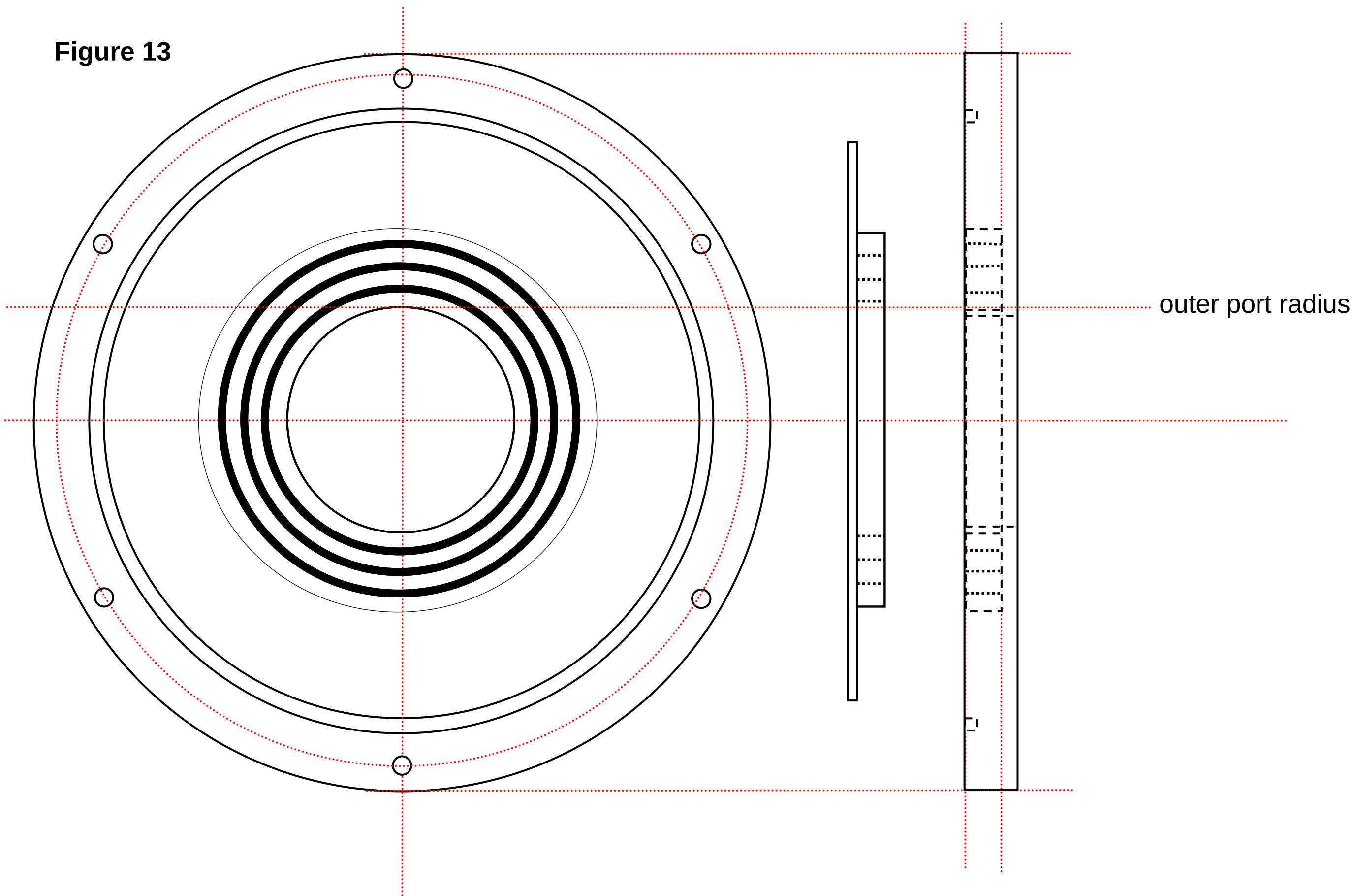
Chassis Mounted Female Labyrinth Seal

The Chassis Mounted Female Labyrinth Seal is a smooth (polished) solid stainless steel or other noncorrosive material that has a good resistance to deformity at high combustion temperatures. The female labyrinth seal will provide a leak proof non-contact barrier between the outer and inner chassis (exterior and chassis chamber). The diameter of the female labyrinth seal should be the same as or greater than the male labyrinth seal. The female labyrinth seal surface will feature a set of concentric cylinders indented perpendicularly from the disk surface which will accommodate, without contact, a complimentary male shaft mounted labyrinth seal. Male and female labyrinth seal sets are mounted to the front and rear of the engine (Figure 16A-9 & 10). The front and rear female labyrinth seals are identical. The female labyrinth seal will be sized to provide a close non-contacting fit when the engine is operating in either a hot or cold mode.

Figure 13



In the illustration shown here and below, the female labyrinth is incorporated into the front or rear walls of the chassis covers.

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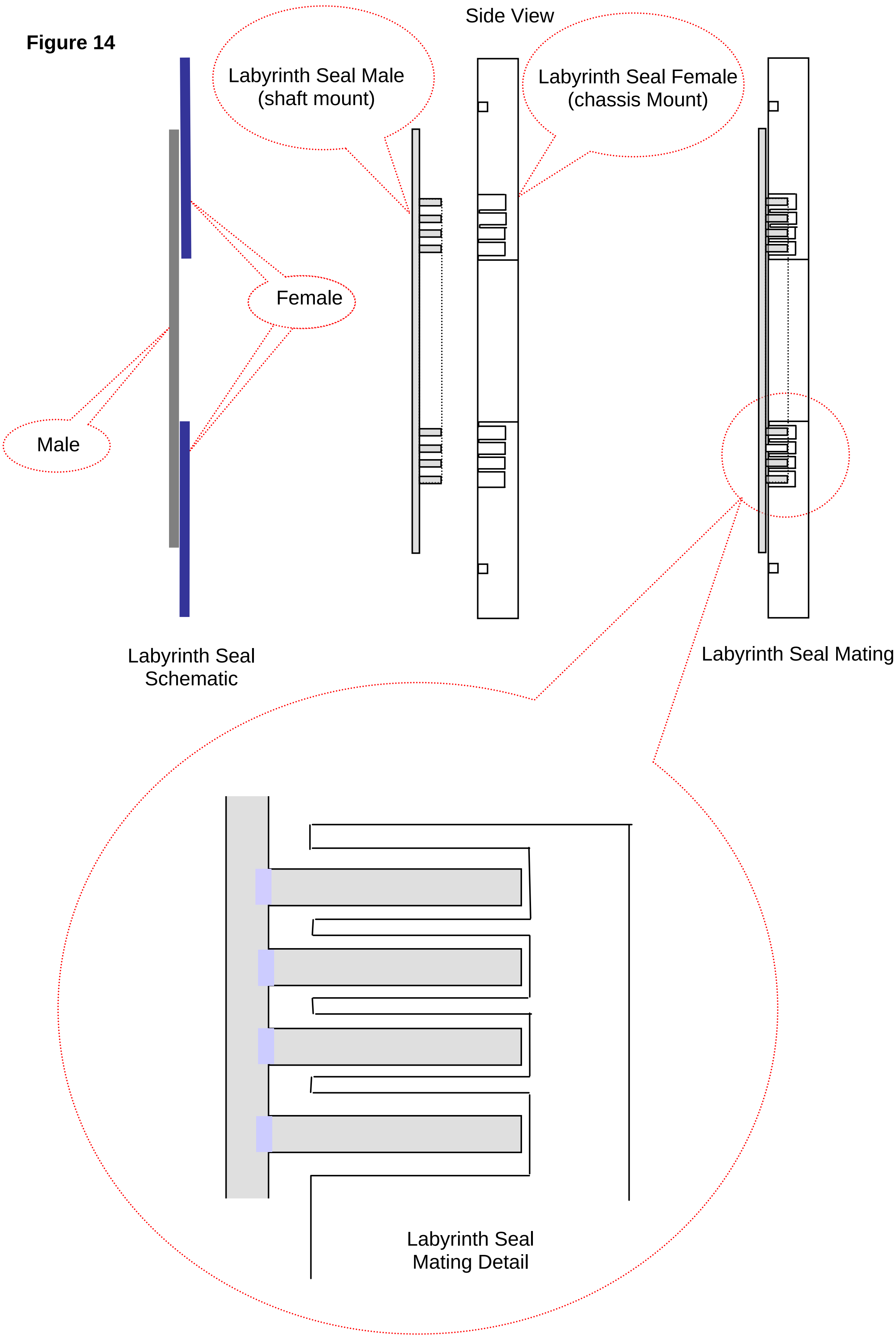
Labyrinth Seal Schematic and Labyrinth Seal Detail

Figure 14



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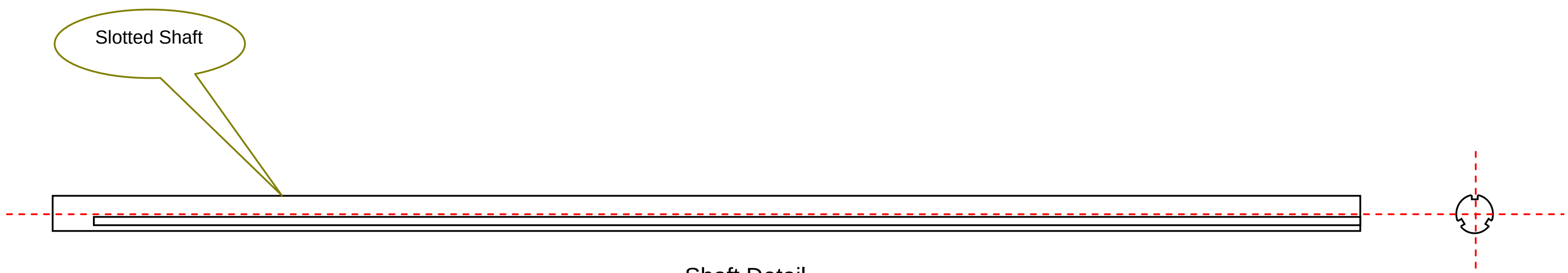
Shaft Construction:

The shaft is a smooth (polished) stiff solid stainless steel or other noncorrosive material that has a good resistance to deformity at high combustion temperatures and high speed centrifugal forces. The diameter of the shaft is determined by its desired speed and torque output. The shaft will feature a balanced slot (2, 3 or 4 slots) arrangement to accommodate the disk and star washer tabs that will be mounted onto it. Bearing mounts will secure the shaft to the chassis stage (or stages) and will be supplemented by a lubrication system that will also provide some degree of cooling. The shaft will be balanced for optimal high speed operation.

Figure 15

End View of Shaft Types



Shaft Detail

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Chassis Construction:

A modular (compound) BLTE is composed of multiple chassis fixed one to the other and each containing a single main stage or an auxiliary stage. Compound stages will be fixed to one another by cast features such as threads, locks or bolt holes. A complex BLTE is a configuration where a single chassis contains multiple main stages or a single main stage and multiple auxiliary stages. The chassis is the component that will determine if the BLTE is a modular (compound) or a single (complex) engine arrangement. The chassis (page 30) is basically a cylindrical pressure vessel with bearing mounting features (Figure 20-1) at either end of the chassis cylinder and threaded ports to allow fueling and ignition (Figure 20-4 & 5). The front end may either be made as a solid attachment to the cylindrical container or as a separate disk cover (Figure 20-3). The rear end is a separate disk cover attachable to the cylindrical container through which the disk assembly and various other internal components may be inserted for mounting. The internal wall of the containment cylinder will have a rough finish (brushed, pitted or dimpled) to prevent working fluid adherence to it by introducing surface (minimal) turbulence. The external portion of the chassis will provide mounting points to allow the BLTE engine to be fixed to a larger external framework.

Pressure Vessel

The chassis (page 30) as a pressure vessel will accommodate sealing at the front and rear of compound stages, at the front of auxiliary stages and at the front of the complex engine vessel.

Front Wall

The front wall (page 21) of a compound BLTE stage will incorporate a female (chassis mounted) labyrinth seal mated with a male (shaft mounted) labyrinth seal. The complex BLTE stage is sealed in the same manner.

Rear Wall

The rear wall (page 20) of a compound BLTE stage will also incorporate a female (chassis mounted) labyrinth seal mated with a male (shaft mounted) labyrinth seal. Each complex BLTE stage is sealed with a male and female labyrinth seal pair. The auxiliary exhaust stage has exhaust ports in the rearmost cylindrical portion of the chassis while the rear wall has only an exit hole for the shaft and a bearing mount.

Chassis Mounted Baffle Disk

The chassis mounted baffle disk (page 19) or (Figure 2–19) is portless and is used to redirect working fluid flow. Shaft mounted baffle disks are mounted as the rearmost disk in the stack of any auxiliary stage to redirect the working fluid to the disk periphery and to impede the working fluid from escaping in an undesired fashion.

Bearing Mounts

Bearing mounts (page 30) or (Figure 20-1) are located in the front or the rear of either the complex BLTE or each stage of the compound BLTE. These mounts will be located in the coolest locations possible avoiding hot exhaust gasses if possible. These mounts will also provide pressurized lubrication if necessary.

Porting

Chassis intake ports (Figure 20-2) are the features located in the front of either the complex BLTE or each stage of the compound BLTE allowing the intake of air for combustion. Chassis exhaust ports are features located near the rear periphery of the complex BLTE chassis or around the periphery of the post-auxiliary stage to allow exhaust gases to escape to the ambient.

Frictionless Bearings:

High Speed Fluid Bearings

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

- Shape, gains advantage usually by using spheres or rollers, or by forming flexure bearings.
- Material, exploits the nature of the bearing material used. (An example would be using plastics that have low surface friction.)
- 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 reducing the normal force between them.
- Fields, exploit electromagnetic and 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 or 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[3,4] (page 31) which is far higher than what now is considered to be nominal BLTE operational speed.

Fluid Pumping

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

Single Stage BLTE with Compression & Exhaust Auxiliary Stages:

The following diagram demonstrates the flexibility of the Compound BLTE using ganged stages (Figure 16A). This diagram shows a compression auxiliary stage (left), a main combustion stage (center) and an exhaust/evacuation auxiliary stage (right). The disks in the auxiliary stages are typically the same size as main stage compression disks (Figure 17).

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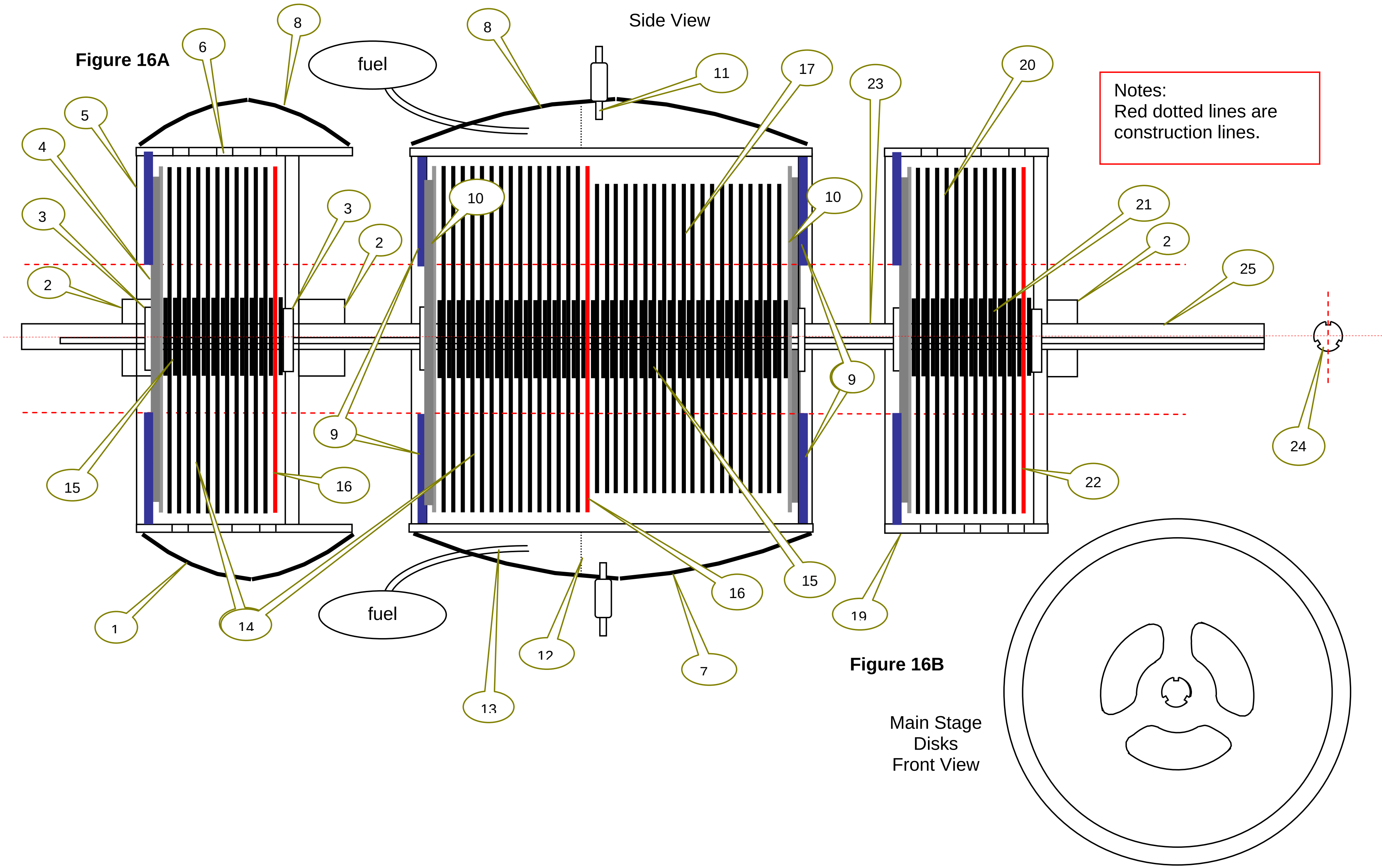
Compound BLTE Construction Diagram

Schematic Diagram of a Compound Internal Combustion BLTE with Single and Auxiliary Stages



Notes:
Red dotted lines are construction lines.

Figure 16B

Main Stage
Disks
Front View

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Compound BLTE Construction Description

1. **Pre-Compression Stage Chassis**
2. Bearing Housings
3. Frictionless Bearings
4. Intake Ports
5. Chassis Front Cover
6. Compressed Air Ports
7. **Main Stage**
8. Bubble Chassis Cylinder
9. Female Labyrinth Seal
10. Male Labyrinth Seal
11. Igniter
12. Flame Barrier
13. Fuel Injector
14. Compression Disk Stack
15. Star Washers
16. Shaft Mounted Baffle Disk
17. Exhaust/Power Disk Stack
18. Chassis Mounted Baffle Disk
19. **Post-Exhaust Stage**
20. Exhaust Evacuation Disks (optional)
21. Star Washers
22. Shaft Mounted Baffle Disk
23. **Shaft**
24. Keyed Shaft (or Slotted Shaft)
25. Power Output Shaft (shaft extension)

Note: Shaft mounted components, fuel and ignition components serve the same functions as they do in the **Complex BLTE Diagram** (page 5).

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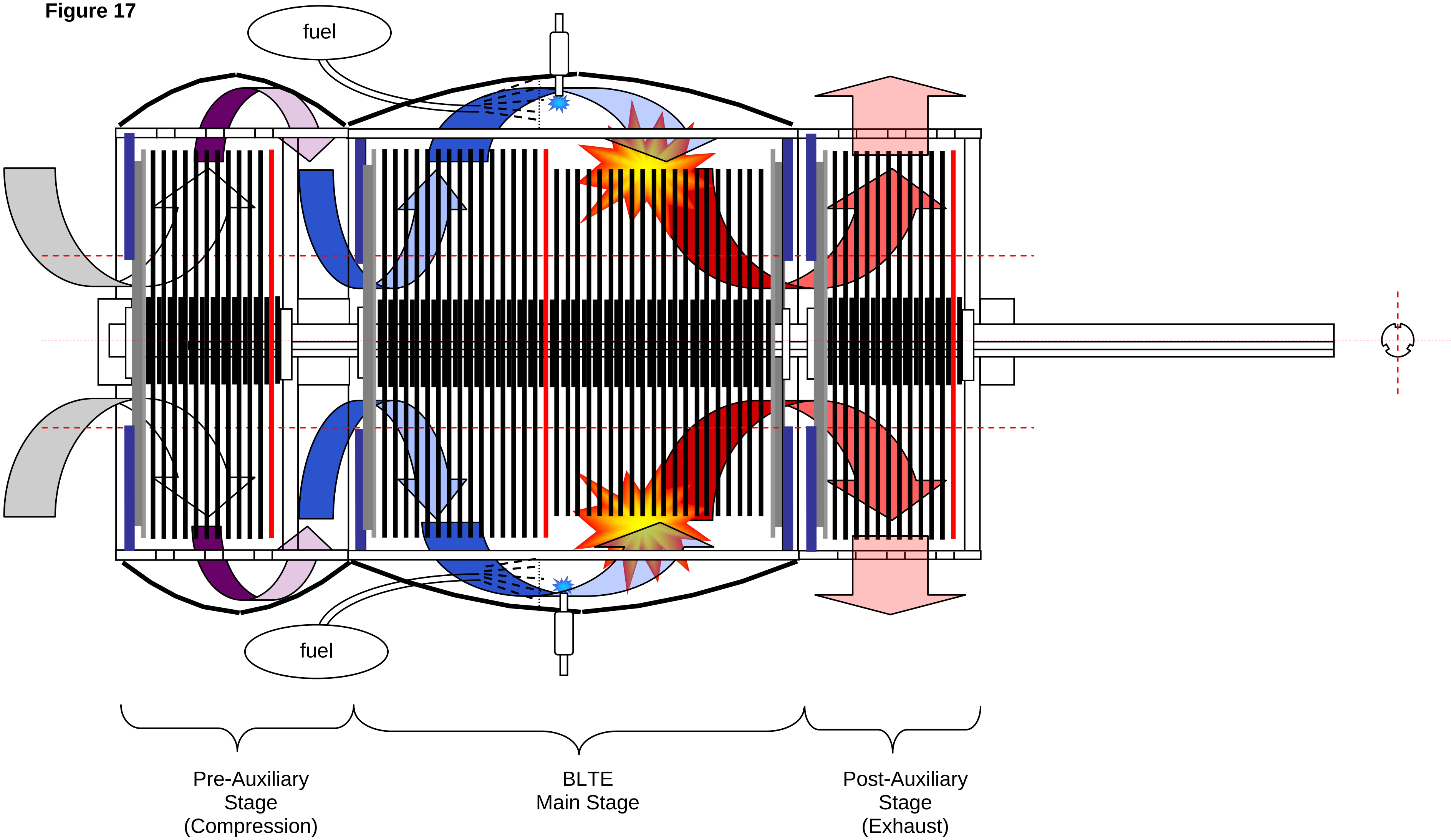
Compound BLTE Operation Diagram

Schematic Operation of a Compound Internal Combustion BLTE with Single and Auxiliary Stages

Side View

Figure 17



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Turbo Electric Configuration:

The Boundary Layer Turbine Engine's output may be applied to any conventional torque conversion (transmission) device but the best performance can be expected when it is coupled with a motor-generator (or dynamo) to convert its output to an electrical form. For example, an automobile operating with a reciprocating engine, a hydro-mechanical transmission and friction brakes is less than 7% efficient from fueling to vehicle propulsion. A BLTE system operating at 50% efficiency ($2^1/_2$ times the efficiency of the piston driven engine), an electric dynamo operating at 80% efficiency (2½ times the efficiency of the hydro-mechanical transmission), and 4 electric motor driven wheels, each delivering an 80% conversion efficiency from electrical to kinetic energy promises a 32% efficiency fueling to vehicle propulsion. In addition, dynamic recovery of braking or downhill energy to battery storage for the next propulsion cycle and battery output used to augment to the typical turbine response lag from accelerator demand to power delivery, increases the overall system efficiency. This system conservatively, promises greater than a 4½ times gain of efficiency over the present day methods of vehicle propulsion without inclusion of the regenerative braking energy contribution.

This fuel to road performance boost is due to the higher overall operational efficiency of the BLTE and dynamo based system as contrasted to today's reciprocating engine and hydro-mechanical transmissions.

This invention can be used in place of any reciprocating engine application (automotive, airspace, marine, power tools, and many battery applications).

Battery replacement applications can be achieved using butane , propane, methane or any (but not necessarily) clean burning fuel with a small high speed generator output, a physically small electrical storage device (to filter transients), and single chip computerized controller to optimize engine efficiency and control battery charging. This combination can be produced in a very small package and can produce electrical power on demand for laptop computers, hand tools, personal power sources and a host of such applications supplying far more power and more endurance than rechargeable batteries.

Applications of variations of this device used as:

1. **Automotive Power Applications**
2. **Marine Power Applications**
3. **Aircraft Power Applications**
4. **Battery replacement power applications**
    - **Computer mobile and stationary devices power applications**
    - **Hand held tools power applications**
5. **Electrical power generation**
6. **Electrical auxiliary power applications**
7. **Mechanical auxiliary power applications**
8. **Personal power sources**

BLTE System Configuration

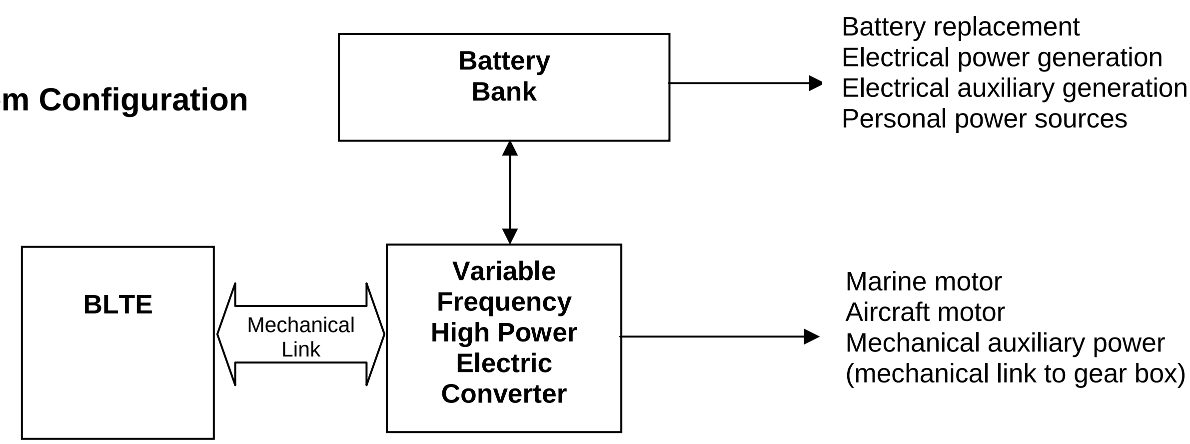

Figure 18

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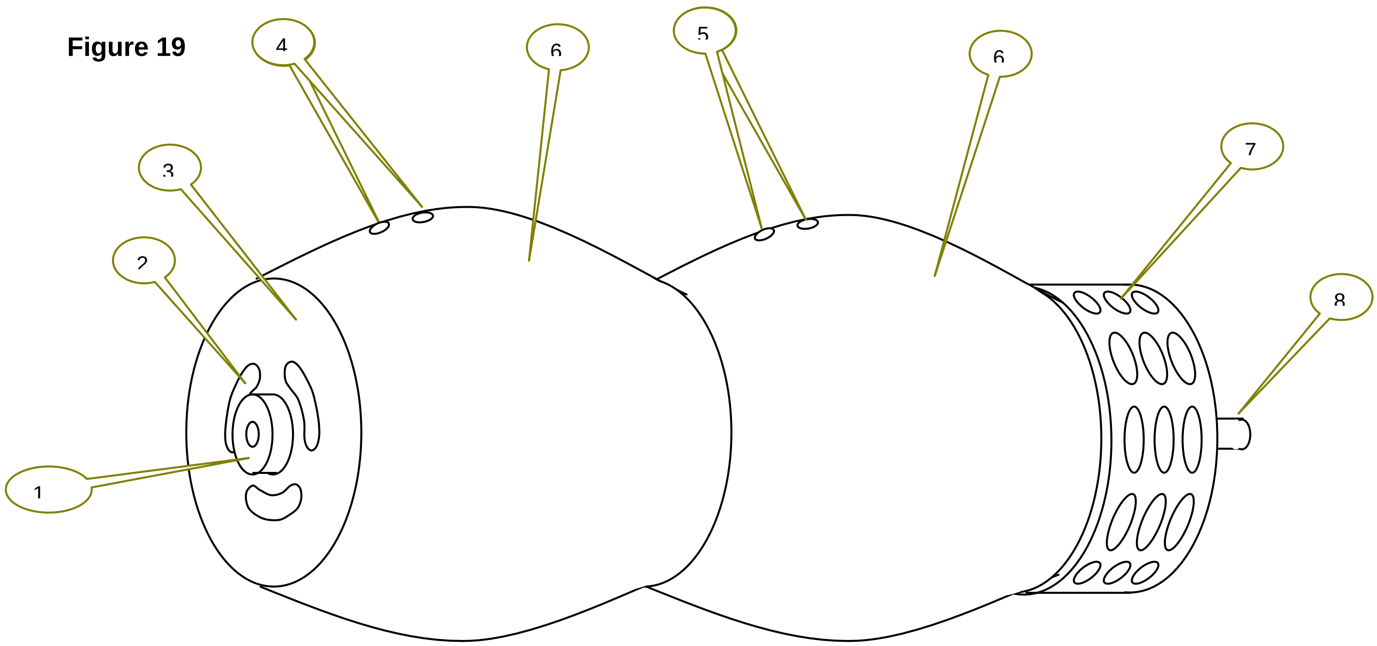
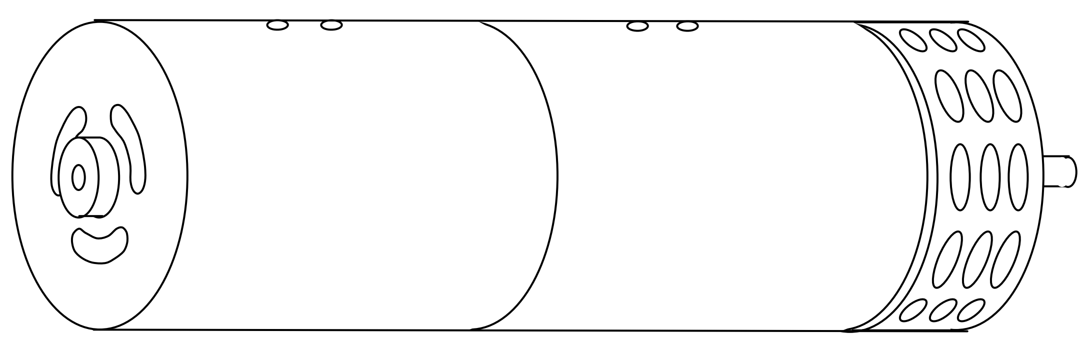
Chassis Diagram:

The BLTE chassis is a pressure vessel which supports fuel/water/air injection, ignition, bearing support, lubrication, intake and exhaust. The chassis will also support instrumentation for measuring disk speed, intake flow, combustion temperature, combustion pressure, stage 2 flow (if populated with a second stage), chassis temperature, pressure, exhaust flow and temperature. The material from which the chassis is constructed must withstand high temperature and medium pressure. The interior of the chassis will be machined with a surface which provides the least amount of drag to the working fluid vortex contained within.

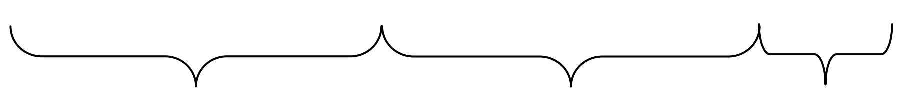
Figure 19



Bubble BLTE Chassis



Cylindrical BLTE Chassis



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Stage 1
1. Shaft Bearing Cover (before and after each compound stage)
2. Air Intake Centrifuge/Intake Ports
3. Front Cover
4. Fuel Injection & Ignition Ports Combustion, Power Flow & Exhaust

Stage 2

5. Water/Air/Fuel Injection & Ignition Ports
6. Containment Jacket

Auxiliary Stage (optional)

7. Exhaust Ports
8. Shaft (output coupling)

Note: The **Cylindrical BLTE Chassis** has analogous features to the **Bubble BLTE Chassis.**

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