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passed through vent or stack **12** through heat exchanger **13** where heat can be extracted for some other task. Alternatively, some of it is directed by duct **28** to the desiccator **18** to dry the desiccant, eliminating the need for burner **20**.

System (B). Chilling charge air for internal combustion engines (ICE) in which **9** is an ICE or turbine and in which CNG, LNG or CH, LH both chills air charge and fuels engines. As in system (A), the liquefied and/or gaseous fuel (LNG, CNG, LH or CH), optionally cryocooling superconductor electric cable **3**, is ducted by conduit **2** through optional pressure regulator **3** or **4** for adjusting the gas volume and pressure to the pressure needed for compression-expansion refrigerator **5** or impulse turbine and then the gas performs the end task of fueling an ICE **9**, in which the fuel is consumed after first providing air charge cooling (by refrigerator **5**) needed for the duty cycle of the system. First, the liquefied gas is channeled alternatively from conduit **43** of FIG. **21**, optionally through superconductor duct **4**, out duct exit **4'** and to conduit **2** of FIG. **20** and to metering or expansion valve **10'**, pressure drop distributor **11'** and distribution tubes (evaporator coils) **17***a*. As the gases expand in expansion valve **10'**, pressure drop distributor **11'**, the evaporator coils **17***a* perform task listed heretofore as that of chilling through-put dry air in chiller **5** through which duct **6***a* and **6** conducts air, alternatively dried by desiccantor **18**, which air enters **9**, here representing an internal combustion engine (ICE) wherein the chilled air charge is inleted into the air intake system or a carburetor or central port, or any place deemed appropriate.

The gases have been channeled, expanding through the evaporator **17***a* of chiller **5**. The gases are then received collectively by conduit **7** and passed through item **8**, which is a fuel heater, or a suction pump-compressor for recompressing the gas fuel for turbines, if found necessary. The gaseous fuel is then introduced and mixed with the chilled air from duct work **24**, in item **9**, now an ICE, preferably in the carburetor or air intake or at any place known to those in the art. The fuel is ignited in the engine to produce greater-than-normal power. The exhaust valve (not shown) opens and the exhaust gases are expelled through exhaust line **12**, heat exchanger **13** and exhaust pipe **14** to atmosphere.

System (C) Chilling Air Charge for Rotary Turbine, where **9** in FIG. **20** is a gas fired turbine engine and **8** is an optional gas reheater or compressor, if needed. After cryocooling electric cable, the partly liquefied and/or gaseous fuel chills incoming charge air by chillers, drives an impulse turbine and fuels gas turbine. Alternatively, after the gaseous fuel has emerged from the task of expansion-chilling intake air for a turbine engine **9**, it is collectively directed by duct **7** through **8**, which is a heat exchanger for heating the gas, as for fueling a turbine. Alternatively **8** is a compressor for optionally recompressing the gas charge for fueling turbine, **9**. The cold charge air is then mixed with the turbine fuel and combusted for a more dense charge. Chilling the air charge for a turbine produces greater steady-state power and hence will also change the factors for calculating the de-rate value when operating the turbine in a hot climate or high altitude.

System (D). The high pressure partly liquefied and/or gaseous fuel, after cooling superconductor electric cable **3**, provides both compression chilling such as for air conditioning and/or as an impulse turbine in **5**, FIG. **20** and also fuels boiler furnace for a steam turbine **9**.

System (E). The high pressure partly liquefied and/or gaseous fuel, after cooling superconductor electric cable **3**, provides compression chilling, such as for air conditioning and to drive an impulse turbine in **5**, FIG. **20** and also fuels space heating furnace **9** or, alternatively fuels absorption chiller, also represented by **9**.

## Compressed or Liquefied Natural Gas or Hydrogen for Refrigeration Systems, Continued Discussion

The percentage of natural gas or hydrogen mixed in the air charge for fueling an engine is as high as 15% of the total charge. If the first task in a co-generation is refrigeration or air conditioning, the pressure of the liquefied or compressed gaseous fuel, (natural gas, hydrogen, etc.) is adjusted to the ideal pressure, perhaps 280 psi, more or less, for most efficient expansion cooling and to be then used mixed with the air for fuel requirements.

Triple or quadruple co-generation of LNG or LH can provide (a) cryo-cooling superconductor electric cables, (b) compression expansion chilling and/or (c) driving an impulse turbine and (d) absorption chilling. Alternatively, it then provides for fueling of the associated power generator turbines for which the liquefied gas is serving as electric cable cryo-cooler or fueling any of the systems suggested for item **9** of FIG. **20**.

## Dual or Triple Use (Co-Generation) of Liquid Super-Coolant for Superconductor Cable

Referring now to FIG. **23**, there is shown an electric superconductor cable used for transferring electric current without resistance in the conductor. FIG. **23** shows skid wires C for protecting the cable. C-**1** is electrical insulation; **2** is two layers of thermal insulation; **3** is superconductor tape (electric wire); **4** is the entrance port to flexible duct **4'** for liquid coolant; **5** is liquefied natural gas (LNG) or liquefied hydrogen (LH) or, alternatively liquefied nitrogen (LN). In a co-generation system, liquefied nitrogen is capable of performing the first two tasks, that of cooling superconducting cable and compression expansion refrigeration as described herein for co-generation systems using liquefied natural gas or liquefied hydrogen. After task two, the nitrogen can be expelled into the atmosphere or can be re-liquefied.

## Co-Generation

Either LNG or LH is a very efficient coolant for superconductor electric cables. LNG has a temperature of minus 296° F. while the temperature of liquid hydrogen is minus 423° F. Either can be used as (a) an efficient electric superconductor coolant and at the power plant (or taken off at sub-stations and piped to point of use), the exiting LNG or $LH_2$ can be utilized for (b) expansion cooling. (Liquefied nitrogen can perform tasks a and b only.) The same flammable gas, chemically unaltered, can be used for (c) driving an impulse turbine and thereafter for any of the following: (1) fueling gas fired absorption cooling, for (2) fueling gas fired engines (ICE generator), for (3) fueling gas fired turbine generator, for (4) fueling gas fired steam turbine generator and/or for (5) fueling gas fired heating boilers, etc. These uses are depicted and described for FIG. **20** through FIG. **23**. The triple or quadruple service use of the LNG or LH is in cooling superconductor cable **3** in FIG. **23**, then channeling the liquefied gas to an expansion chiller **5** in FIG. **20** and then for spinning a fueling or for gas fired absorption chiller **9**, also in FIG. **20** or alternatively, for fueling (having consumed for) one or more tasks (a), (e), (f) and (g) above. Therefore, the same LNG or LH provides cryocooling and two other types of chilling FIG. **20** on the same volume of

gas. In addition, the same coolant gas can first turn a turbine and then any or all of the following: fuel engines, turbines and boilers as described above and in FIG. **20** and FIG. **21**.

To reiterate briefly, the coolant LNG, or LH can be put into flexible duct **4** of superconductor cable **3**, FIG. **23** at the sub-stations and taken off at the power plant or taken off at other substations and piped collectively to the power plant and used there to chill (expansion) cool and drive the impulse turbine and then fuel the generators or gas turbines or ICE generators and/or be used as fuel for further chilling absorption. After using to super cool electric cable **3**, the coolant liquefied gas can be ducted off at the power station or at a sub-station and transported to the plant in a conduit formed under another layer of insulation **2** and can be used or stored at any convenient place for use in cooling, firing turbines, etc., or can be stored, re-liquefied or sold. Alternative liquefied gas, after use as sub-coolant, can be taken off flexible duct **4'** and ducted collectively in a separate conduit to the power plant or to whatever point the gas can be used or stored.

[1]Liquid nitrogen, boiling point of 77K (−320 degrees F.), can efficiently perform the first two tasks: (a) cryocooling superconductor electric cable and (b) provide expansion cooling as described above for LNG or $LH_2$ for FIG. **20** to FIG. **23**. The nitrogen can then be vented to the atmosphere at conduit **29**, FIG. **20** or may be re-liquefied.

[1]New Scientist, 13 Oct. 2001, vol. 172 #2312

A British publication[1] in an article entitled *The Big Chill* discusses the need for and the progress of transmitting electric power long distance by way of superconductor cables, which improves the efficiency of electrical transmission by at least ten percent. Among other statements, they say "Superconducting cables can carry at least three times the power of the copper it replaces" and "We are at the point where it is worth running superconductors, and everyone is beginning to realize it".

[1]New Scientist, 13 Oct. 2001, vol. 172 #2312

They further discuss the very significant progress made in researching the technology and have performed a large test project in Frisbie, a neighborhood in Detroit, Mich. In this system, the superconductor cables must be kept very cold. In the wrap-up of the article they state: "The remaining problem is that the refrigeration technology needed to keep the superconductor cable supplied with liquid nitrogen is not ready for commercial use. The cryogenic shed at Frisbie is reliable, but it was put together specifically for this project. It has lots of back-up systems to ensure that the project doesn't fail simply for lack of coolant, which means that it wouldn't be economical for general use."

The invention described for FIG. **20**, FIG. **21** and FIG. **23** provides a very reliable answer to the problem of the cooling of superconductor cables with the added benefit of providing a system of co-generation, whereby liquefied flammable gases (and also compressed gases) can be used for many other purposes after being used for cooling the superconductor electric cables or compression chilling, etc. Also, compressed gases form a co-generation system as described for FIGS. **20** through **23**.

Cold Air Supercharged Epitrochoid Rotary Engine Operating in Any of Operational Designs 1, 2, 3 or 4

Referring now to FIG. **24**, there is shown a perspective view (with portions in cross-section and schematically) an improved epitrochoid (Wankel) type rotary internal combustion engine which is cold air supercharged and operating optionally in any of the four Operational Designs as described for engines of FIG. **2**.

These Designs briefly described are:

Operational Design 1: In this Design, intake port **3N** (dotted line) FIG. **24** with normal port size, the quantity of a primary air charge drawn into compression chamber **5**-C through port **3N** by rotor **2**, is as in the normal Wankel rotary engine with the engine receiving as large amount of air or fuel-air charge as possible, which with the combustion chamber being of normal size, produces normal compression and expansion ratios. Compression of the charge begins as the following rotor lobe covers port **3N**. During the compression process, a dense, cooled or chilled supplementary supercharging charge of air or fuel-air (received, compressed and cooled externally) is injected by valve **9** through port **4'** or port **9'**, which optionally is fitted with an expansion valve **4**, into the compression chamber **5**-C, preferably late in the compression process. This provides cooling along with increased charge density and turbulence. Compression continues as rotor **2** continues motion until combustion chamber **5**-A is at or near TDC, FIG. **24B**. There, the charge is ignited, expanding into expansion chamber **5**-E, producing rotor movement for the power, scavenging, air intake and compressing functions of rotor **2** lobes for great power, torque and efficiency with low polluting emissions. With exhaust port **6** placed in the wall of stator **1** end plate **18'** and away from the periphery of the end plate as the expansion chamber is scavenged through port **6**, centrifugal force spins the heavier fuel fumes away from and past the exhaust port **6** to be returned to combustion chamber **5A** with the new air charge for further combustion. In this Design, compression and expansion ratios are equal.

Operational Design 2: In Design 2, the primary air or fuel-air drawn in the port **3N** is again as normal for the epitrochoid rotary engine, to capture again a full charge, but the combustion chamber **5**-A of FIGS. **24** and. **24**-B is significantly larger in volume than that of current engines, thus producing a low substandard compression ratio for low heat-of-compression for the initial portion of charge. Also, in this Design, compression and expansion ratios are equal.

During the compression process of the primary air drawn through inlet port **3**-N, a dense cooled or chilled air or fuel-air charge, which was received, compressed and cooled or chilled outside of the engine, is injected by valve **9**, through port **4'** or port **9'**, which can be an expansion valve **9'**. Since the initial (primary) charge is a very low compression ratio, it produces small heat-of-compression. The cooled supercharging air or fuel/air charge, depending on the point it is injected into the compression stroke, also has a low "effective" compression ratio and combined with the cool initial charge, produces very small heat-of-compression for very low peak temperatures and pressures. Compression continues and at combustion chamber **5**-A, near or at TDC, the charge is ignited causing the power, scavenging, compression and intake action of rotor **2**, thus providing great power, torque and efficiency with ultra low polluting emissions, completing a power cycle.

Operational Design 3: In Design 3, the air intake port **3N** has been elongated and is now port **3E** (solid line) of FIG. **24**. The port **3**-E is significantly elongated so that when the rotor **2** passes the port, it begins to draw the air or fuel-air charge into the compression chamber **5**-C at a later point in its travel, thus pulling in significantly less charge than that received by normal epitrochoid rotary engines. Hence, it produces a low, subnormal effective compression ratio, which in this Design results in an extended expansion ratio.

Now, the rotation of rotor **2** pulls in a light air or fuel-air charge and during the compression process, which begins

when intake port 3E of FIG. 24 is closed by a trailing lobe of rotor 2 of FIG. 24, an externally pre-compressed, cooled air or fuel/air charge is injected by valve 9, through inlet port 4' or port 4, which is optionally an expansion valve 9' Compression continues and when the combustion chamber 5-A is at TDC, the charge is ignited, causing rotor 2 to rotate producing great power and torque to the drive shaft, producing higher efficiency with ultra low polluting emissions. This Design is also selectively supercharged to any desired level even though the effective compression ratio is very low.

The inlet port 3N of FIG. 24 is optionally constructed in such a manner that it is selectively variable in length. The port is alternatively made as long or even longer than that of 3E as illustrated in FIG. 24. And FIG. 24-B. Alternatively, a sliding panel (dotted line 3N, FIG. 24) is so positioned behind port 3E that it can be moved by a servo system, controlled by ECM-27. Thus the length can be manipulated selectively from a normal inlet port length, as 3N of FIG. 24, to any length of 3E desired. This allows the "effective" compression ratio of the engine to be equal to the expansion ratio or it can be reduced to any desired compression ratio. The compression ratio can be varied infinitely and inversely to the expansion ratio. Port 3E of FIG. 24 is an illustration of the means of reducing the volume of primary air charge since the charge intake suction is delayed for low effective compression ratio for very low heat-of-compression and an extended expansion ratio. Also, the compression ratio is alternatively varied by fitting a variable control orifice control valve in outlet port 28 with proper activator, controlled preferably by ECN-27 of FIG. 2. By using normal intake port 3N and by opening outlet valve 28 and varying the percentage of fresh charge pumped in by rotor 2 which is expelled through port 28, the compression ratio can be varied from normal (compression ratio equal to the expansion ratio) to an effective compression for that portion of charge as low as 2:1 or 3:1. Then the very dense supercharging air, having a similar effective compression ratio, produces very low heat-of-compression with an expansion ratio which is extended inversely to the effective compression ratio.

Because of the cool or chilled air charge, the compression ratio can be varied from as much as 40:1 or higher to an effective compression ratio of 3:1 or 2:1 with the expansion ratio being inversely extended.

Operational Design 4: Design 4 describes another means of charging the engine and combustion chamber 5-A. Whereby inlet port 3 can be normal (3N) or elongated (3E), but using port 3N, the initial intake charge is pulled in and then during the majority of the compression process, is pumped out through an ancillary outlet valve 28. If mixed with fuel, the charge, which is expelled, is conducted from conduit 28 to the suction side of either compressor 14 or compressor 16 of FIG. 24, preventing the pollution of the air or the wasting of fuel. Optionally, a bypass valve $R_1$ and conduit $X_1$ are used to partly bypass compressor 16 and a similar bypass system, $R_2$ and $X_2$, together allow control of charge pressures and temperatures, preferably controlled by ECM-27 of FIG. 2, making spark, compression ignition or HCCI operation feasible for all fuels, including diesel.

In any Operational Design, the dense, cooled or chilled supercharged air is alternatively injected directly into the combustion chamber as depicted in FIGS. 24-B and 25-B where conduit 11 and injector valve 9" inject the air or fuel-air directly into combustion chamber 5-A. In this case, combustion chamber 5-A already contains the residual low effective compression effective ratio air or fuel-air charge, thus producing a doubly cool initial combustion process.

As most of the initial charge is expelled and ancillary port 28 is closed, preferably by rotor 2, inlet valve 9 (optionally, an expansion valve 9') opens and injects the pre-compressed cooled or chilled air or fuel/air charge into the compression process above the combustion chamber as it swings into TDC position to be sealed and ignited. Now, the charge is ignited by spark or HCCI, thereby depressing the rotor into the power, scavenging, intake and compression processes to complete a power cycle.

In this system, the pumping through an initial air or fuel-air charge is helpful in cooling the combustion chamber 5-A, making the task of controlling charge temperatures simpler, especially in HCCI engine operations.

The supplemental charge injection in this system is cold and has an "effective compression ratio of perhaps 2:1 to zero and being the entire working charge, is very adequate in density to provide superior power and torque with ultra low emissions.

Referring now to FIG. 24-B, there is shown a schematic illustration of the engine of FIG. 24, to show the combustion chamber 5-A in firing position and the optional methods of inducing air charges through ports 3E (charge B) and 4 (charge A) respectively for any Operational Design, the latter injected from conduit 11, combined and now in the combustion chamber 5-A. And also depicting the heavy unburned hydrocarbons 18 being moved to the outer side of the exhaust port 6 by centrifugal force and how they are sent along with the fresh charge to pass again through combustion chamber and ignition. In addition, FIG. 24-B shows an alternative scheme for injecting the supercharging air through conduit 11 into the primary charge in the combustion chamber 5-A. In this system, the secondary charge is injected directly by conduit 11 and valve 9" into combustion chamber 5-A of FIG. 24-B as combustion chamber 5-A rotates into TDC position.

Bypass system valve $R_1$ and conduit $X_1$ are optionally used to bypass wholly or partially compressor 16 or to through-put the entire charge. A similar bypass system, valve $R_2$ and $X_2$ offer optional through-put of charge or to wholly or partially bypass charge going through intercooler 17. Thus, charge pressure, temperature and density may be closely controlled by a control unit such as ECM-27 of FIG. 2. With ECM-27 monitoring temperatures and pressures in combustion chambers and adjusting all activator systems to the optimum for the ignition system used, allows spark ignition, compression ignition or HCCI operation for all fuels including diesel oils.

As described earlier and depicted in FIG. 24-B and FIG. 25-B, the supplementary charge is alternatively injected directly into combustion chamber 5-A by diverting or channeling conduit 11, carrying the cool dense supplementary charge to go directly to the chamber 5-A, being injected by valve 9", which is alternatively is an expansion valve after the order described for FIG. 2-B or FIG. 2-C.

As described heretofore, in this system, the homogenized diesel fuel/air mixture temperature is kept below auto-ignition temperatures until combustion chamber TDC position and is then ignited by spark or HCCI.

By keeping the charge temperature below the temperature[2] which will cause auto-ignition of diesel-air mixture (normally about 8:1 compression ratio), the increased density of the charge permits spark ignition with much increased power.

[2] The auto-ignition temperature of diesel fuel/air mixtures in current engines is that produced at about 8:1 compression ratio. The engines of the present invention, rotary or reciprocating design keeps the mixture temperature below that point until the point that ignition is desired.

In any of the Designs of the epitrochoid rotary (Wankel) type of FIGS. **24–25**-B or the straight rotary engines of FIGS. **26–32**, the supplementary and selectively supercharging air or fuel/air charge is optionally injected through inlet valve **9** which alternatively is an expansion valve **9'** injecting compression "chilled" charge whose system provides an even cooler working cycle. Expansion valve **9'** is discussed as expansion valve **10** in great detail, both means and methods in FIGS. **2**-B, **2**-C, **2**-D, **6–10**, **11**-B, **18**-B, **19**-C and **19**-D. The improvements of the new working cycle of the engines of FIGS. **24–32** is discussed in detail under the description of engine of FIG. **2** and includes:

Results

1) Low peak temperatures and pressures.
2) A denser charge.
3) Greater efficiency.
4) Greater power and torque.
5) Improved engine durability.

Advantages

1) Lower polluting emissions.
2) Increased vehicle range.
3) Longer engine life.
4) Greater reliability.
5) Lower RPM. (Due to greater torque, the engine of this invention will develop power and torque at one-half of the RPM of current technology epitrochoid rotary engines).

Supercharge density is selectively much greater than that of state-of-art engines, providing greater power and torque with increased efficiency while producing ultra low polluting emissions.

Referring now to FIG. **25**, there is shown a perspective view (with portions in cross-section and schematically), a epitrochoid (Wankel) type rotary internal combustion engine operating in a variant system, different from the Wankel engine and the engine of FIG. **24**. Optionally, the air or fuel-air charge is doubly compressed and cooled and with a much smaller than normal compression chamber **5**-A, produces a significantly denser charge.

Operation

Epitrochoid engine **1** receives into compression chamber a normal or pressure boosted air or fuel-air charge through the normal size inlet port **3**N. As soon as the charge is pulled in by rotor **2**, port **3**N is closed by rotation of trailing lobe of the rotor **2** and compression of charge begins.

Ancillary valve **13** is opened by pressure differential and allows the charge being compressed to exit and pass through conduit **7**, intercooler **8**, compressor **9**, intercooler **19** (items **9** and **19** optional) and conduit **11** to return to inlet valve **14** and port **4** or to conduit **11"** and valve **9"** of FIG. **25**-B. Inlet valve **14** remains closed until proper engine operating pressure has built in cooling compressing system **13** to **14**. Compression continues on the small charge remaining in combustion chamber **5** after outlet port **13** is passed by rotor **2** and optionally with valve in port **13** closed. As soon as operating pressure has built in compressed cooling system **13-4**, inlet valve **14** (which is optionally an expansion valve **10** in FIG. **2**-B) injects the doubly compressed and cooled air or fuel-air charge into the compression chamber **5**-C, adding this denser portion late to that charge remaining in the compression chamber **5**-C, as soon as valve **13** is closed or passed by rotor **2**, or at any time later, optionally even during combustion. (The latter case requires the charge to be injected into combustion chamber **5**-A. Any of the ports of **4***a*–**14** are optionally constructed through wall of stator **1** or through end plate **18** of stator **1**).

Alternatively, compressor **9** and intercooler **19** may be eliminated and the primary simply cooled and reinjected into compression chamber **5**-C or into combustion chamber **5**-A through valve **9"** of FIG. **25**-B.

At the usual point that the current epitrochoid rotary engine is ignited (TDC), the charge is ignited by spark or HCCI. Because of the charge density and temperature control possible, the engine of this invention can be fueled by diesel-air mix and is ignited alternatively by spark or HCCI. HCCI is feasible due to the possibility of keeping the density up and the charge temperature under control by ECM-**27** (see HCCI systems in FIGS. **19–19**-D). For a denser charge, the inlet air is pressure boosted. Intercooler **19** is utilized or optionally partly bypassed through bypass system valve R and conduit X by which the charge temperature is adjusted and controlled preferably by ECM-**27**, FIG. **2**.

At ignition, the extremely dense and temperature adjusted charge expands into expansion chamber **5**-E turning the rotor and producing more power, torque and efficiency while reducing polluting emissions. Again, exhaust port **6**, being placed in the end-plate of the stator and at a proper distance from the periphery of the end-plate, allows any unburned liquid fuel to be centrifuged along the outer edge of end-plate **19**, FIG. **25**-B and past exhaust port **6** to pass along with the fresh charge through combustion again to further reduce HC emissions.

In the engine of FIG. **25**, the effective compression ratio is greatly reduced, producing an extended expansion ratio, but with normal to heavier charge-weight.

Referring now to FIG. **25**-B, there is shown a perspective of the engine of FIG. **25**, showing alternate inlet ports for the doubly compressed and cooled charge air or fuel-air mix. The air inlet port **3**N is as in a normal epitrochoid rotary engine. Outlet port **13** to conduit **7** is placed near the end of rotor travel in compression chamber **5**-C. Inlet port **4**-C shows one choice with the charge leaving the chamber **5**-C through port **4**-C and conduit **7**. Port designated **4**-d provides a later point of ejection. Conduit **11** shows the conduit opening into port **4***a* in stator wall or alternatively, into port **4***b* (in phantom) before diminutive combustion chamber **5**-A is TDC and now blocked by rotor **2** being in firing position. An alternative point of introducing the doubly compressed charge is to have port **4***a* from conduit **11** lead to the combustion chamber **5**-A at the point that ignition is occurring.

The advantages of the engine of FIG. **25** and FIG. **25**-B are the same as those of FIG. **24** engine, but producing somewhat less power.

Referring now to FIG. **26**, there is shown in perspective and cut-away view of a rotary internal combustion engine in which vanes **4** in compressing and expanding, rotate on a central axis. Illustrated in this figure is the complete engine with the principal components shown. The engine is comprised of FIGS. **26**, **27**, **28** and **29** which will be described in detail as well as will the method.

There is shown engine housing **1**, compressor rotor **2**, expander rotor **2**-B, vanes **4**, vane seals **24**, vane guide rollers or "trucks," **3**, compressor stator **8**, expander stator **9**, combustion chamber **5**, exhaust port **17**, main bearing **6**, drive shaft **7**. Other principal components are illustrated and disclosed in FIGS. **27**, **28** and **29**.

Referring now to FIG. **27**, there is shown in a cross-section and a partially schematic view of the compressor section of the rotary internal combustion engine of FIG. **26**. The important components are compression chamber **5**-C, stator **8**, rotor **2**-A, central shaft **7**, vanes **4**, vane seals **10**, vane guide rollers **3**, air intake port **11**, compression ratio adjustment port **12**, valve for compression ratio adjustment

conduit, compression ratio adjustment conduit **13**, air intake port **3**-B, vane loading springs **23**, exhaust conduit **18** from **18** of FIG. **28**, turbocharger **15**, air intake **16**, carburetor **51**-C, intercooler **17**, compressor **18**, intercooler **19**, intercooler bypass system valve $R_1$, conduit $X_1$, compressor bypass system valve $R_2$ conduit $X_2$, intercooler bypass system valve $R_3$ conduit $X_3$, conduit **20**, injection valve (optionally an expansion valve **21**), supercharging air injection port **22**, outlet port **14**-A, leading to optional valve **14**-B in FIG. **28**, leading to combustion chamber **5**-A and port **14**-C, leading to combustion chamber **5'** in rotor **2**-B.

Referring now to FIG. **28**, there is shown a cross-section of the expansion rotor assembly of the rotary internal combustion engine of FIG. **26**. The principal components are intake valve **14-B** receiving air or fuel/air charge from port **14**-A in FIG. **27**, spark plug **12**, optional spark plug **12A**, rotor combustion chamber **5'**, alternative combustion chamber **5**-B, rotor **2**-B, vanes **4**, alternative vanes **4**-B, vane seals **10**, vane guide rollers **3**, vane loading springs **23**, exhaust port **17** and exhaust conduit **18** (goes to conduit **18** of FIG. **27**).

Method of Operation

Compressor section of FIG. **27** receives charge air or fuel-air charge from two sources 1) Port **3**-B and conduit **11** receives primary air or fuel/air mix at atmospheric or boosted pressure. 2) A secondary supercharging charge portion of air is inducted through a compressor in this figure, a turbo-charger **15**, which receives atmospheric air through port **16** which is optionally mixed with fuel which is optionally carbureted by **15**-C. The supercharging air or fuel-air charge taken in and compressed by compressor **15** now passes through a conduit to intercooler **17**. Then after cooling, it is received and highly compressed by compressor **18** and then conveyed to intercooler **19** to conduit **20** and to high pressure valve **21** and to intake port **22**, to be injected by intake valve **21** into the primary air charge while it is being compressed. Intake valve **21** is alternatively an expansion valve such as valve **10** of FIG. **2**-B.

Now, the primary air intake port **3**-B is fitted with an adjustable volume air return which is used to adjust the compression ratio of the engine from normal (equal to the compression ratio) to a compression ratio which is less than the expansion ratio. The purpose of this system is to selectively and alternatively adjust valve **14** to allow conduit **13** to return some part of the air or fuel-air charge back into suction port **3**-B as rotary rotor vanes **4** pull in atmospheric pressure or pressure boosted air. This, when used, further reduces the "effective" compression ratio for the primary charge.

As vanes **4** rotate, compression of the primary charge begins at inlet conduit **11** of port **3**-B, if valve **14** is closed. If valve **14** is open at all, the "effective" compression ratio of this initial portion of charge is low which creates small heat-of-compression for this primary charge. (The number of vanes **4** in compression rotor **2**-A would be of any magnitude above one and would probably be three or four in number).

Rotor **2**-A continues the compression process toward high pressure intake valve **21**, which is alternatively an expansion valve on the order of valve **10** of FIG. **2**-B engine. As a vane **4** approaches port **22** and at the appropriate moment before vane **4** passes port **22**, intake valve **21** injects the very dense, cooled or optionally "chilled" air or fuel-air "supercharge" into the compression chamber **5**-C, bounded on the backside by a vane **4** and which charge is rotatably compressed and expelled out port **14**-A, which is optionally closed by valve **14**-B between port **14**-A of FIG. **27** and combustion chamber **5**-A of FIG. **28**. The charge then goes through port **14**-C, FIG. **28**, which optionally constitutes a sliding valve between stator combustion recess **5**-A and rotor combustion chamber **5'**. In this case, combustion chamber **5**-A is charged and ignited as it rotates past port **14**-C.

Combustion System A: Now, in FIG. **28**, optional outlet valve **14**-B opens and closes at such a time that vane **4** seals the front side of combustion chamber **5'** and the back side of the combustion chamber **5'** is sealed by close proximity between stator **9** and rotor **2**-B. This is described in detail for FIG. **30**. The fuel-air charge is ignited by spark plug **12** for the power pulse while combustion chamber **5'** is open to plug **12**.

Combustion System B: As described for engine of FIG. **30**, compression chamber **5**-B accepts a charge as it rotates past port **14**-C. As back side of combustion chamber **5**-B is sealed by close proximity to rotor with back side of combustion chamber **5**-B, spark plug **12**-A ignites charge for power pulse. In System B, the charge is ignited, preferably by spark, the exploding gases now expand against leading vane **4** with the pressure contained on the back side by the closeness of the surface of stator **9** surface to the surface of the rotor **2**-B which can sealed by a sliding seal on rotor or stator. Therefore, the only expansion that can occur is against vane **4** as it extends as the space increases in expansion chamber **5**-E on the lead side. The volume of expansion space increases until vane **4** passes exhaust port **17** as the exhaust gases are expelled. The difference between compression ratios and the expansion ratio can be adjusted by changing the amount of air which is passes back from outlet port **12** to inlet port **3**-B of FIG. **27**. The engine of FIG. **26** always operates with equal compression and expansion ratios, except when valve **14** of FIG. **27** allows part of the primary charge to return to inlet port **3**-B.

The engine can be supercharged far beyond the density allowed by conventional engines while producing, with great turbulence, low peak temperatures and pressure, assuring very low polluting emissions.

The temperature and pressure to and in the combustion chamber **5'** and **5**-B can be adjusted by speed control of compressor **18**, FIG. **27**, the amount of charge sent through or bypassed coolers **17** and **19** and compressor **18**, selectively utilizing bypass systems of components, with R valves being controlled by ECM-**27**. Friction is reduced to near zero due to close tolerance rollers and guide grooves and extension springs. Vane tips, which are preferably only three per rotor, will not touch stator surfaces, traveling with two mils clearance. Vane seals **10** are alternatively used with very light rubbing friction. The system described eliminates problems with rubbing surfaces. The engine of FIG. **26** provides all of the advantages stated for the epitrochoid rotary engine of FIG. **24**.

Referring now to FIG. **29**, there is shown a perspective view of one of two stator side or end-plates **24** of the internal combustion rotary engine of FIG. **26**, showing vane guide roller guide track **8**, drive shaft opening **7** and bearing assembly **6**.

Referring now to FIG. **30**, there is shown a perspective view, with sections in cross-section and other sections schematically, of an internal combustion engine with rotor(s) rotating on a central axis having an elliptical stator and an elliptical path for vane tips which are guided to prevent rubbing against stator housing and which provide charge intake, compression, combustion and scavenging in a single rotor and stator for each power unit.