E-FILED
Wednesday, 21 December, 2005 01:06:04 PM
Clerk, U.S. District Court, ILCD

40-B are also used to inject the pilot fuel from two or more systems, especially important for FIG. 19-B and FIG. 19-C systems.

In the engine of this invention, when diesel fuel is used, the density of the air-fuel charge can reach and even far exceed that which is obtainable in any Diesel Cycle engine, while maintaining a temperature before combustion, lower than the auto-ignition temperature of a diesel oil-air mixture which is produced by about an 8:1 compression ratio, thus making practical spark ignition, modified HCCI or true HCCI.

Further instruction for engine operation for HCCI Method C is found under HCCI Method A with references to the advantages of the various engine designs. The HCCI ignition system only has been described above. The engine working cycle is described below and in HCCI Method, A. HCCI Method C operates in any of the thirteen Operational Designs of the engine of this invention.

HCCI operation of the engine of FIG. 1 to FIG. 18-D operates selectively with an extended expansion ratio (with the exception of Operational Designs 1 and 2). All Operational Designs provide:

Higher efficiency.

Greater power and torque.

Longer engine life (due to lower RPM allowed by higher torque).

Multi-fuel capabilities.

Greater reliability.

All Methods after ignition of charge the power stroke take place in 4-stroke or 2-stroke engines, followed by scavenging process.

Method D HCCI, Operational Design 17 Pilot Fuels with Low Auto-Ignition Temperature

The primary propulsion charge is taken into cylinder according to any of the Operating Designs 1 through 13. The compression stroke continues or takes place with the supplementary supercharging charge being injected and with the propulsion air-fuel homogenized and the temperature of the fuel-air mix at piston TDC adjusted to near auto-ignition, but the air-fuel propulsion charge is at a higher temperature than that of the auto-ignition temperature of the pilot fuel.

The propulsion air-fuel charge is now compressed stroke in cylinder 7 by piston 22 with preparation chamber 38' and combustion chamber 38 containing the entire propulsion charge above piston 22, at near auto-ignition temperature, at near TDC. The fuel-air charge is ignited by conventional spark plug or by HCCI for HCCI operation. Conduit 41, with fuel injector pump 42, (in phantom), FIG. 19 through FIG. 19-B, receives and contains pilot fuel, perhaps from a common fuel-rail. The pilot-fuel is an air-fuel mixture where the pilot fuel is one that has a lower auto-ignition temperature than that of the auto-ignition temperature of the fuel or air-fuel mix which powers the engine. Diesel fuel or diesel-air mix could be an appropriate pilot fuel for gasoline-air, dimethyl ether-air, natural gas-air or some of the alcohols as propulsion fuel operation.

The small amount of the engine's propulsion fuel mix in combustion chamber 38, is at a temperature less than its own auto-ignition temperature, but higher than the auto-ignition temperature of the pilot fuel, and is now pressed into pre-combustion chamber 38' near piston TDC. Simultaneously, a small amount of pilot fuel or pilot fuel-air mix in line 41 is injected by fuel injection pump 42, FIG. 19, into pre-combustion chamber 38'. (Alternatively, the pilot fuel or pilot air-fuel mix can be injected through conduit 36 with valve 40, FIG. 19, controlling the injection.) The propulsion fuel-air mixture, now in pre-combustion chamber 38', which is hotter than the auto-ignition temperature of the pilot fuel, which is alternatively sans oxygen or pilot fuel-air mix, catalyzes the ignition of the pilot fuel which then causes oxidation of the engine's propulsion fuel and all expands into combustion chamber 38 where it raises the temperature of the entire air-fuel propulsion mix, broadly catalyzing the reaction, and causes oxidation of the entire charge by quickly raising the temperature of the air-fuel mix propulsion in combustion chamber 38. Piston 22 is pressed into the power stroke. (In the compact combustion chamber with the fuel air premixed (homogenized) and with the turbulence of the new engine system, the combustion will be far more complete than in a compression ignited (CI) engine).

Direct Combustion Chamber Combustion

Again, the charge can be ignited by spark or alternatively, ignition can be catalyzed in the following manner: The pre-combustion chamber is eliminated, fuel pump injector 42 has an inlet conduit 41, FIG. 19, which is directly connected with combustion chamber 38 (not shown) and may intrude into chamber 38. After completion of the compression stroke and near TDC, with the entire propulsion charge being above piston 22 in combustion chamber 38, a small amount of pilot low-self-ignition-point fuel or air-fuel mix, which itself is at a temperature lower than auto-ignition, is injected by fuel pump 42 directly into the combustion chamber 38 of cylinder 7. The temperature of the propulsion air-fuel mix in combustion chamber 38, being higher than that which will cause the pilot or pilot air-fuel to auto-ignite, raises the temperature of the pilot fuel injected and catalyzes the ignition of the pilot fuel which in turn catalyzes the oxidation of the entire air-fuel charge in combustion chamber 38. The power stroke then takes place.

Detailed Methods

More detailed operating methods are discussed in method A.

True HCCI Method E, Operational Design 18 Universal Spontaneous Combustion

Referring now to FIG. 19-B, cylinder 7 is fitted with a combustion chamber 38 or, in addition, a pre-combustion chamber 38'. The fuel-air charge can be ignited by spark or by HCCI. For HCCI, either or both chambers have sensors to detect conditions in the chamber, e.g., temperature sensor 21', density sensor 21", and any other sensors needed to monitor other conditions such as oxygen levels, crank angle etc. These sensors relay messages to ECM-27, FIGS. 1 through FIG. 10, FIGS. 18, 18-B and 18-C which contains a computer to send messages to activators to operate various controls. These controls then adjust fluid flows and valve happenings and to either increase or decrease electrical energy, charge air density, in regard to the duty cycle of the engine, and to adjust the valving 3, 4, 5 and 6, along with heat-of-compression and to control the charge temperature near piston (TDC). The latter will be just above the temperature to cause the air-fuel charge to self ignite at TDC. The controls and methods are described in the descriptions for FIG. 19, FIG. 19-B, FIG. 19-C, FIG. 19-D, FIG. 1 and FIG. 2.

Optionally, each cylinder can have separate controls if needed. For multi-cylinder engines, as described under FIG.

19, FIG. 19-B and FIG. 19-C descriptions, each combustion chamber 38 or 38-B or pre-combustion chamber 38' can have at least two temperature sensors 21' and two pressure or density sensors 21". The computer of ECM-27 receives the message from each cylinder, finds the mean value of each, sums up the values individually or collectively, and calculates the mean values. ECM-27 then instructs the various heat and valving controls to adjust the density and temperature (in conjunction with the cylinders heat-of-compression) of the engine air-fuel charge in each cylinder near piston TDC to produce a proper density charge and temperature, which would be at auto-ignition temperature at piston TDC for the air-fuel propulsion mixture fueling the engine. The charge should ignite preferably at 10–15 degrees before or at TDC as detected by crank angle sensor. The arrangement, described for FIG. 16, provides double the "bum" time at piston TDC for many advantages in any engine.

In using the pre-combustion chamber 38', the temperature sensors 21' in combustion chamber 38, sense the temperature and relay the message to various controls to adjust conditions, including electrical heating or fluids in cooling ducts, to produce a temperature at that of auto-ignition, preferably at 10–15 degrees before or at piston TDC. Sensors 21' in pre-combustion chamber 38' relay a message to ECM-27 to adjust the controls of heating elements 37 and 39 in FIG. 19-B and/or to adjust cooling fluid flows, FIGS. 19-B, 19-C and 19-D to the proper temperature for catalyzing auto-ignition of the air-fuel charge in the pre-combustion chamber at that point. This will start the engine running and maintain smooth operation. The ancillary individual cylinder cooling system of FIG. 6 and FIG. 5, in which cooling is provided by cool air or by air chilled by expansion valve 4', all controlled by ECM-27, may be employed in temperature control.

After the engine is in operation, the heat of combustion will likely supply all of the needed heat plus some in excess. In order to reduce the heat level of either the pre-combustion chamber 38' or the combustion chamber 38, chill cooling channel 36-B and/or 41-B with control valves 40-B and/or 42-B and the appropriate cooling or heat control jackets and conduits arranged surrounding the chambers 38 and/or 38', as shown in FIGS. 19-B, 19-C and 19-D can be utilized, perhaps in conjunction with temperature control of FIGS. 6 and 5. The proper temperature and density air-fuel charge can be supplied by an arrangement similar to compressors 1, 5 and 2" and intercoolers 6, 9 and 11 of FIG. 11-B, with conduit 9', alternatively leading directly to valve 40 on conduit 36-B, FIGS. 19-B, 19-C and 19-D or alternatively to expansion valve 10', pressure-drop distributor 11', optional bypass system R-X and evaporator tubes 27'*a*–27'*f*, leading to valve 40-B on conduit 36-B of FIG. 19-B, FIGS. 19-C and 19-D. Water cooling may also be used, either in addition to air or chill air cooling, or alone. The water can also be pumped through channel 41-B, FIGS. 19-B, 19-C and 19-D with any optional pilot fuel taking a different route (not shown), if conduit and fluid jacket 36-B are occupied, to chamber 38', 38'B or to combustion chamber 38 or 38-B of FIG. 19-C or 19-D.

Optional Operating Modes

Particular engine working cycles and Operational Designs are described under HCCI method A.

True HCCI Method F, Operational Design 19 Universal Spontaneous Combustion

Referring now to FIG. 19-C, there is shown a hemispheric-plus (perhaps 300 degrees, more or less), shaped combustion chamber 38-B, containing all of the ducts, jackets, valves and controls pictured and described for FIG. 19-B which are operated and controlled in the manner suggested for FIG. 19-B system. The shape of the combustion chamber allows control of charge temperatures by the charge being surrounded by combustion chamber 38 and piston crown and by being fitted with a centralized temperature control 37 which are surrounded by the same channels 36-B and 41-B and heat elements 24 and 37. Accurate control of the temperature of the air-fuel charge near piston TDC in combustion chamber 19-C allows spark ignition or HCCI operation which is the auto-ignition and general simultation oxidation of the air-fuel propulsion charge. In FIGS. 19-B, 19-C and 19-D, the sensors 21' and 21" signal ECM-27, which in turn signals various valves, one being a variable opening expansion valve 40-B for expanding chilled high pressure air through the evaporator coil or jacket of 36-B of FIG. 19-B, FIGS. 19-C and 19-D. The sensors also adjust the appropriate air and/or water controls and the electric heater controls to balance the temperature at the required level to spontaneously ignite the charge at the time piston is near or at TDC. After starting and warming up, ECM-27 may alternatively begin using chill cooling with the aid of water cooling, if needed, to maintain auto-ignition temperature in the combustion chamber 38 of FIG. 19-B, FIG. 19-C or FIG. 19-D and the cylinder, FIG. 6, as needed. If combustion chamber 38-B, FIG. 19-C or 19-D requires cooling between firing strokes, the primary fresh or chilled charge air can be pulled through inlet intake valves 40 and/or 40' of chamber 38-B, FIG. 19-C or FIG. 19-D and through channel 22', instead of through intake valve 18'. Alternatively, fresh cool air may be inducted by conduit 41 and 41' of chamber 38-B and out through cylinder inlet channel 22' of chamber 38' of FIG. 19-B or 38-B of FIG. 19-C or FIG. 19-D by the intake (1^{st}) stroke of piston 22. In either case, the inlet valves would close after receiving the desired initial charge of air according to the Operational Design chosen.

Control of heating elements 37 and 39 in FIGS. 19-B, 19-C and 19-D, also controlled by ECM-27 in balance with cooling and/or heating system 41-B and 36-B, in conjunction with the heat-of-compression and combustion heat keeps the charge heat at auto-ignition at piston 22 TDC. The cooling system for FIG. 6, with expansion valve 4' of FIG. 5, also controlled by ECM-27, can regulate the temperature of the charge in-cylinder to keep it below auto-ignition temperature until the charge is out of the cylinder and in the combustion chamber.

Engine Operational Design 4 of FIG. 2 could be used in some engines to help control the temperature. In this design, cylinder 7 and pre-combustion chamber 38' of FIG. 19, FIG. 19-B and FIG. 19-C or combustion chamber 38-B, FIG. 19-C and FIG. 19-D can receive and pump through a fresh, cool or expansion chilled air charge between each firing cycle, pulling fresh or chilled primary air through inlet valves 40 and/or 40' or through conduits 36-B or 41-B, which can optionally be present in engine design of FIG. 19-C and FIG. 19-D also and out the lower passage 22 on the intake stroke of piston 22. Then this cool or chilled primary charge air can be pumped through and out of cylinder 7, and out exhaust valve (not shown) or through combustion chamber 38-B or preparation chamber 38' of FIGS. 19-B, 19-C or 19-D, out ancillary outlet valve 40 and/or 40' and/or back out conduit 36-B or 41-B, FIG. 19-B, FIG. 19-C or FIG. 19-D or ancillary outlet valves 40 or 40' (not shown) in chamber 38' or 38-B.

As stated, in any of HCCI Designs A through G, cylinder 7, combustion chamber 38 and 38-B and preparation cham-

ber **38'**, if the latter is present, can also be cooled between firing strokes, if necessary, by inducing and expelling a fresh cool or expansion chilled air charge. Methods are described for Design 4, of the engine of FIG. **2**, and for FIG. **2**-C, FIG. **11**-B, FIG. **18**-B and FIG. **18**-C.

Further instruction for engine operation for HCCI Method F is found under HCCI Method A with references to the advantages of the various engine designs. The engine working cycle is described for engines Operational Designs 1 through 13. HCCI Method F operates in all Operational Designs 1 through 13.

The advantages of this engine cycle are:

Higher efficiency.

Greater power and torque.

Longer engine life.

Multi-fuel capabilities.

Greater reliability.

The operation of the engine is the same as the basic engines of FIG. **1** to FIG. **5** and FIG. **7** and FIGS. **8**–**10** and FIG. **18**, FIG. **18**-B and FIG. **18**-C, utilizing either of engine Operational Designs 1 through 13 for greater torque, power, and durability with low fuel consumption and ultra low polluting emissions.

Advantages:

Ultra low emissions.

Greater power.

Increased fuel economy.

Increased engine durability.

Multi-fuel capability.

True HCCI Method G, Operational Design 20
Universal Spontaneous Combustion

Referring now to FIG. **19**-D, there is shown a hemispheric-plus (perhaps 300 degrees, more or less, shaped combustion chamber **38**-B, containing all of the ducts, jackets, valves and controls pictured and described for FIG. **19**-B and FIG. **19**-C which are operated and controlled in the manner suggested for FIG. **19**-B, FIG. **19**-C system. The shape of the combustion chamber allows control of charge temperatures by the charge being surrounded by combustion chamber **38** and piston crown. Alternatively, the combustion can be cylindrical as indicated by phantom lines **38**-C. Accurate control of the temperature of the air-fuel charge near piston TDC in combustion chamber **19**-D allows spark ignition or HCCI operation which is the auto-ignition and general simulation oxidation of the air-fuel propulsion charge. In Designs, FIGS. **19**-B, **19**-C and **19**-D, the sensors **21'** and **21"** and any other sensors required, signal ECM-**27**, which in turn signals various valves, one being a variable opening expansion valve **40**-B for expanding chilled high pressure air through the evaporator coil or jacket of **36**-B of FIGS. **19**-B, **19**-C and **19**-D. The sensors also adjust the appropriate air and/or water controls and the electric heater units **39** and **37** (**37** being both optional spark plug **37** and central heater optionally combined as needed), in conjunction with heat-of-compression, to balance the temperature at the required level to spontaneously ignite the charge at the time piston is near or at TDC. After starting and warming up, ECM-**27** may alternatively begin using chill cooling with the aid of water and cooling, if needed, to maintain auto-ignition temperature in the combustion chamber **38**-B of FIG. **19**-B or FIG. **19**-C and FIG. **19**-D and the cylinder (FIG. **6**), as needed. If combustion chamber **38**-B, FIGS. **19**-B, **19**-C and **19**-D requires cooling between firing strokes, the primary fresh or chilled charge air can be pulled through inlet valves **40** and/or **40'** of chamber **38**-B, FIGS. **19**-C and **19**-D. Alternatively, fresh cool air may be inducted through conduit **41**-B and its cooling jacket of chamber **38**-B of FIGS. **19**-B, **19**-C and **19**-D and through cylinder inlet channel **13** of chamber **38'** of FIG. **19**-B or channel **22'** of FIGS. **19**-C and **19**-D by the intake (1st) stroke of piston **22**. In either case, the inlet valve **40** or **40'** would close after receiving the desired initial charge of air according to the Operational Design desired.

Control of heating elements **37** and **39** in FIGS. **19**-B, **19**-C and **19**-D, also controlled by ECM-**27** in balance with cooling system **41**-B and **36**-B in conjunction with the heat-of-compression, and combustion heat keeps the charge heat at auto-ignition level at piston **22** TDC. The cooling system for FIG. **6**, with inlet orifice or expansion valve **4'** of FIG. **6**, also controlled by ECM-**27**, can regulate the temperature of the charge in-cylinder to keep it below auto-ignition temperature until the charge is out of the cylinder and in the combustion chamber.

Engine Operational Design 4 of FIG. **2** could be used in some engines to help control the temperature. In this design, cylinder **7** and pre-combustion chamber **38'** of FIG. **19** and FIG. **19**-B or combustion chamber **38**-B of FIG. **19**-C and FIG. **19**-D can receive and pump through a fresh, cool or expansion chilled air charge between each firing cycle, pulling fresh or chilled air on the intake stroke through inlet valves **40** and/or **40'** or through conduits **36** or **41**, which can optionally be present in engine design of FIG. **19**-C and FIG. **19**-D also and out the lower passage **22"** on the intake stroke of piston **22**. Then this cool or chilled primary charge air can be pumped through and out of cylinder **7**, and out exhaust valve (not shown) or through combustion chamber **38**-B or preparation chamber **38'** of FIG. **19**-B, out ancillary outlet valve **40** and/or **40'** and/or back out conduit **36**-B or **41**-B, FIG. **19**-B-FIG. **19**-C or ancillary outlet valves (not shown) in chamber **38'**, **38** or **38**-B.

As stated, in any of HCCI Designs A through G, cylinder **7**, combustion chamber **38**, **38**-B and preparation chamber **38'**, if the latter is present, can also be cooled between firing strokes, if necessary, by inducing and expelling a fresh cool or expansion chilled air charge. Methods are described for Design 4, of the engine of FIG. **2**, and for FIG. **2**-C, FIG. **11**-B, FIG. **18**-B and FIG. **18**-C.

Further instruction for engine operation for HCCI Method G is found under HCCI Method A with references to the advantages of the various engine designs. The engine working cycle is described for engines Operational Designs 1 through 13. HCCI Method G operates in all Operational Designs 1 through 13.

The advantages of this engine cycle are:

Higher efficiency.

Greater power and torque.

Longer engine life.

Multi-fuel capabilities.

Greater reliability

Method G

Operation of the HCCI Engine

The operation of the engine is the same as the basic engines of FIG. **1** to FIG. **5**, FIG. **7**, FIGS. **8** to **10**, FIG. **18**, FIG. **18**-B and FIG. **18**-C, utilizing any of engine Operational Designs 1 through 13 for greater torque, power and durability with low fuel consumption and ultra low polluting emissions.

The means on initial temperature control is described above and for method G consisting of adjusting charge temperature at a level just below auto-ignition temperature of the fuel-air propulsion mix. Auto-ignition is accomplished by a last moment, sudden increase in heat-of-compression at near piston TDC with an alternative and optional means of spark ignition, the latter to insure reliability.

Ignition

Charge density has been adjusted to the requirements of the duty cycle of the engine. The charge temperature has been adjusted to a level less than auto-ignition for spark ignition and at near TDC, the charge is ignited in that manner.

The HCCI operation charge temperatures are adjusted by means described in method **1**, FIGS. **19**, **19**-B, **19**-C and **19**-D. At near TDC, for example, at the point projection **22'** on piston **22** enters port **22"** of combustion chamber **38**-B, sensors **21'** and **22"** with perhaps other sensors sense and signal the temperature and density levels to ECM-**27** to adjust flow rates by way of valves **3**, **4**, **5**,**6** and **10'** to produce the conditions of the air-fuel charge desired at that particular point.

This temperature is slightly lower than auto-ignition temperature. As piston **22** completes the compression stroke, the outer face of the piston rises to nearly flush with the face of the engine head **10** and piston projection **23** has entered port **24** of head **4** and is now flush with the lower part of combustion chamber **38**-B (chamber **38**-B may be semi-hemispherical or cylindrical in shape as illustrated by **38**-B and **38**-C [the latter in phantom] of FIG. **19**-D).

As piston crown A approaches face of engine head **4**, piston projection **22'** enters and continues to travel in the restricted space of combustion chamber port **22"**. (There are no pressure sealing rings on piston projection **22'**). This means that as piston crown A approaches engine head face **4**, all of the fuel-air charge above the full piston crown is compressed toward and into port **22"** and escapes confinement in the cylinder **7** by being forced through the small space surrounding projection **22'** traveling up into combustion chamber **38**-B or optionally **38**-C. As pressures above piston crown A and in chamber **38**-B attempt to equilibrate, vortical motion occurs in the fluids in the narrow passages between **22'** and **22"** and throughout chamber **38**-B, further stirring and mixing the fuel-air charge. This produces equilibration in fuel, air and temperature of mixture and assures absence of cyclic variations as combustion occurs.

The sudden rise of temperature in the fuel-air charge at this time, caused by the short projection **22'** producing instantaneous pressure and heat increase. causes a uniform low temperature universal oxidation of the charge which is true HCCI operation.

The engine can be alternatively started up by spark plug **37** firing at TDC which is the last position for firing and obtaining maximum efficiency. In a few moments, the temperature in chamber **38**-B will become conducive to spontaneous ignition and ECM-**27** tells spark plug to cease firing.

Optionally, ECM-**27** tells the electronic ignition system each time a cylinder should fail to fire, then spark plug **37** will spark just after auto-ignition should fail to occur. This assures reliable cylinder firing.

Alternatively, spark plug **37** may continue firing at TDC. This is a little later than optimum ignition timing. Therefore, at such a time that auto-ignition should fail to occur, then only perhaps 5 degrees crank angle later, spark plug **37** fires to ignite the charge, assuring fail-safe and smooth engine ignition.

Refrigeration Cooling and Powering by Compressed or Liquified Natural Gas or Hydrogen

Briefly noted, there is shown three schematic drawings, (FIG. **20**, FIG. **21** and FIG. **23**) representing yet another embodiment of apparatuses useful in the field of air conditioning, power generation and heating, from which yet other methods of operation can be performed and will be described. Six alternative systems are depicted, utilizing highly condensed gas, such as compressed natural gas or hydrogen or liquefied natural gas or liquefied hydrogen for, (1) compression refrigeration before the gas is combusted by being consumed for (2) gas fired absorption chillers, or (3) burned in reciprocating or rotary turbine engines or (4) consumed for furnace for steam turbines or (5) consumed for space heating. For liquefied natural gas, the first task is optionally cryocooling which is then followed by the several succeeding tasks.

Co-Generation Using Compressed Natural Gas or Compressed Hydrogen for Compression-Expansion and Absorption Chilling or Fueling Other Combustion Tasks with Only Combustion Consuming the Gas

Referring now to FIG. **20**, shown is a schematic sectional view of a natural gas or hydrogen transmission pipeline, **1** or a compressed natural gas or hydrogen gas storage tank **1***a*, (in phantom). Both of these have an associated outlet conduit **2**, a conduit (in phantom) from conduit **43**, FIG. **21**, optional pressure regulator **3**, conduit **3'** optional pressure regulator **4**, metering or expansion valve **10'**, pressure-drop-distributor **11'**, distributor tube(s) or evaporator coils **17***a*, freezer-chiller box **5**, air inlet conduit **6***a*, air outlet conduit **6**, collective conduit **7**, optional gas heater/cooler or compressor **8**, and box **9**. Apparatus **5** in FIG. **20** represents a compression-expansion refrigeration system for various cooling tasks, including space cooling, engine intake air cooling, refrigerator or freezer, etc. Box **9** represents a gas fueled refrigerator (absorption chiller) or a gas fueled and cooled internal combustion engine (ICE) or a gas fueled and cooled gas rotary turbine engine or a gas fueled steam turbine or a gas fueled boiler furnace, or a gas fueled furnace space heater, or any other system operated or fueled by gas, natural or hydrogen or by any other suitable flammable gas. Associated with item **9** are a vent or exhaust pipe **12**, optional heat exchanger **13** and vent or exhaust line **14**. All of these are designed for utilizing compression cooling, absorption cooling and fueling by compressed natural gas (CNG), compressed hydrogen (CH_2) or as depicted and described for FIGS. **21** and **22** for liquefied natural gas (LNG) or liquefied hydrogen (LH) to perform work before the gas is consumed as fuel in **9** of FIG. **20**.

In addition, optional components in FIG. **20** (in phantom) are: a desiccant system **18**, desiccant wheels containing silica gel or other desiccants **19**, drying heater **20**, drying vent **22**, gas supply line **23** leading from conduit **16**, to fuel control-pressure regulator **21** (optional), optional hot exhaust line **28** leading to desiccant dryer **20**, for drying desiccant, chilled air outlet register **25**, optional conduit **6** line block **26** (in phantom) and chilled air outlet register **27**.

Co-Generation Using Liquefied Natural Gas (LNG) or Liquefied Hydrogen (LH) for Cryogenic Cooling Compression-Expansion Cooling, Absorption Cooling and Fueling Tasks

Referring now to FIG. **21**, there is shown a schematic sectional view of a storage tank **18**, containing liquefied gas,

such as liquefied natural gas (LNG) or liquefied hydrogen (LH), with associated liquid outlet withdrawal tube **20**, flow economizer regulator **5**, associated conduit fuel shut off valve **11** and associated conduit leading to excess flow valve **9** with associated conduit leading to optional cryogenic pump **40**. Optional pump **40** has an optional bypass system comprised of bypass valve **35** and conduit **34**, to be used at any time cryogenic pump **40** is not required. A conduit **43** conveys liquefied gas to optional pressurizer **15** through which the conduit optionally forms coils and exits to an optional shut-off valve **5'** on associated conduit **43**. Pressurizer **15** receives the LNG or LH effluent in a conduit **43** which coils inside the pressurizer casing in order to expose the coil to an optional fluid which is optionally pumped through, and then, after operating pressure builds in pressurizer **15**, the LNG or LH exits to conduit **43** outlet. An inlet port **41** to the pressurizer **15** can optionally conduct fluid (air or liquid) through and around pressurizer **15** coils. The warming fluid is then expelled through duct or port **42**, optionally to the atmosphere. The LNG or LH is slightly warmed in **18** or **15**, if necessary, to raise boil-off vapor pressure in tank **18** or in pressurizer **15** to expel the liquefied gas through conduit **43** which is alternatively connected to conduit **2** in FIG. **20**. Conduit **43** is first alternatively connected to inlet of flexible duct **4** within electric superconductor cable **3** of FIG. **23** with the exit port **4'** of duct **4** being now connected to conduit **2** in FIG. **20**. (When liquefied gas is used first to super cool electric power cable **3**, FIG. **23**, the liquefied gas tank **18** or pressurizer **15** is kept cold and not heated, but pumped from tank **18** by cryogenic pump **40** and out conduit **43** and first through conduit **2**, FIG. **20** and to succeeding apparatuses.) This provides two preferred means of supplying LNG or LH at a volume and pressure needed to alternatively push the liquefied natural gas or hydrogen through (a) cryocooling tube **4** in FIG. **23** for sub-cooling electric superconductor power cable **3**, as depicted in FIG. **23** and then into a pressurizer, as **15**, FIG. **21**, to build pressure required for (b) compression-expansion refrigeration shown in FIG. **20**. These two refrigeration systems can be accomplished with no chemical change in the gases. Another use of the same gas can be for a third refrigeration system which is labeled here as (c) absorption-refrigeration, a system which consumes the gas as fuel. Therefore, the gas can be used for two tasks before being consumed in a third task, thus providing a co-generation system in which one volume of gas performs three services. Other optional tasks for this chemically unchanged fuel are (d) firing a gas turbine for producing power, (e) firing steam turbine for electric power production, (f) engine (ICE or turbine) charge air chilling, (g) firing a reciprocating ICE for electric power production and (h) firing space heating furnace and other apparatuses, depicted in FIG. **20**. These latter described operations are accomplished and fueled by CNG or LNG, or CH^2 or LH and associated apparatuses. System (c) to (g) consume LNG or LH as operating fuels after the LNG or LH has already performed tasks (a) and/or (b), indicated above. As indicated above, the same units of liquefied gas can supercool electric superconductor cable **3**, air-condition the power plant (after exiting the cable duct), spin an impulse turbine and fuel a gas turbine or ICE which produces the electric power, or alternatively provided absorption chilling, steam turbine, heating furnace, etc.

Operation of LNG or LH Fuel Tank

Boil-off vapor pressure in fuel tank **18**, with back pressure up o 280 psi, presses the liquefied gas out liquid withdrawal tube **20** through valves **11** and **9**, through valve **35**, bypass conduit **34**, through optional pressurizer **15** and out conduit **43**, which in use is alternatively connected to inlet port **4** of cryogenic cooler tube **4** of electric superconductor cable **3**, shown in FIG. **23** and which outlet **4'** of tube **4** is alternatively connected to conduit **2** in FIG. **20**. Alternatively, outlet **43** of FIG. **21** is connected directly to conduit **2** in FIG. **20** when cryogenic cooling is not needed. If the boil-off pressure in tank **18** is too low, bypass valve **35** optionally directs the LNG or LH_2 from tank **18** to cryogenic pump **40** which pumps the effluent through conduit **43**. If needed and cryogenic cooling is not required, atmospheric air or other fluid is pumped into inlet duct **41** of pressurizer **15** and circulates around conduit **43** and the exists through port **42** after imparting slight heat to the liquefied gas, causing pressurizer **15** to build desired pressure. Alternatively, boil-off vapor pressure is allowed to build in tank **18** by inducing slight heat in tank and/or by restraining the boil-off pressure until desired operating pressure is attained to express the liquefied gas from conduit **4**. At the point the boil-off pressure is to drive the vanes of the turbine, the liquefied gas is completely vaporized, optionally in a system such as vaporizer **15** of FIG. **23**. When an impulse turbine is to be driven by compressed or vaporized liquid gas, it is a driver solely or in a co-generation system and is fitted into the scheme at the place in the system that the compressed gas or the liquefied gas vapor is best suited as an impeller. Then the gas is collected for further use.

The LNG or LH in tank can be kept at the desired temperature and the liquefied gas is pressed out conduit **43** outlet, and, in the case of the first use suggested, into inlet **4** of superconductor conduit and through conduit **4** of FIG. **23**. Then after cooling superconductor cable **3**, it exits an outlet duct or valve **4'**, FIG. **23** into a system to re-liquefy or store what now may be partial gas effluent, or alternatively into conduit **2** of FIG. **20** by way of conduit (in phantom) depicted as being from **43** of FIG. **21**. Hereafter, it can operate any or all of the apparatuses depicted and described for FIG. **20** and alternatively driving a turbine. Alternatively, the LNG or LH from conduit **43** may go directly from conduit **43** of FIG. **21** to conduit **2** of FIG. **20**, or to any or all of the apparatuses depicted and described for FIG. **20**. For example, it can go directly to fuel the turbine or ICE **9** of FIG. **20** which is preferable to the engine producing the electric power going through electric superconductor cable **3**. Alternatively, expansion valve **10'** of chilled system of FIG. **20** creates back-pressure needed in pressurizer **15** or LNG or LH_2 tank **18**, to build operating pressure (ideally 200–280 psi) for expansion chilling of item **5** (in this case, a refrigerator) of FIG. **20**, or to drive a turbine, also represented by item **5**, whether conduit **43**, FIG. **21**, leads first to conduit **2** of FIG. **20**, or to conduit **4** of FIG. **23**.

The boil-off pressure in tank **18** can be sufficient to present the amount of liquefied gas needed to supply the equipment depicted in FIG. **23** and FIG. **20**. Alternatively, valve **35**, FIG. **21** is closed to bypass conduit **34** and the liquefied gas is pumped by cryogenic pump **40** through the pressurizer **15**, where the liquefied gas builds pressure, if needed, to the desired level within pressurizer **15** and then, at the pressure desired, expels the LNG or LH out conduit exit port **43** into conduit **2** of FIG. **20** or alternatively, (without the temperature being changed and preferably at minus 260° F. or lower) through inlet **4** of conduit **4'** of FIG. **23** and from outlet of conduit **4'** FIG. **23**. From there, the liquefied gas can be optionally ducted to conduit **2** of FIG. **20** and/or to any of the other apparatuses described. Cryogenic pump **40** prevents any unwanted pressure escaping the pressurizer **15** back into LNG or LH tank **18**, if the pressure

in **15** is greater than that desired in tank **18**. Ideally, boil-off vapor pressure in storage tank **18** will present the LNG or LH to conduit **43** bypassing cryogenic pump **40**, by bypass system **35** and **34** when the level of pressure in tank **18** is that desired. The temperature in tank **18** is determined by the pressure of the LNG or LH stored in the tank and which pressure can be adjusted as also in pressurizer **15** (As stated earlier, the pressure desired in tank **18** can be produced by exerting back pressure on the tank **18** until working pressure is attained or by slight heating of contents).

If necessary, the pressure is produced in pressurizer **15** by passing fluid in inlet port **41**, through casing of pressurizer **15** and out port **42**. The temperature adjusting fluid in casing of **15** can be a fluid such as liquid or other type of coolant or preferably return or ambient temperature-air from cooled or heated space such as a building, or even ambient temperature atmospheric air. In either case, the chilled fluid exiting port **42** can be directed to supplement other means of chilling or provide primary chilling for a truck-cab or bus, etc. Not much heat is required to raise the pressure of LNG or LH in tank **18** or **15**. The former generally is stored at 260° below zero F. temperature. LH is stored at minus 460 degrees Fahrenheit For expansion chilling with LNG or LH, the temperature in **18** or **15** could be as low as minus 168° F., or lower, and for compressed gas, perhaps a pressure of 260 psi or even lower. (A passenger bus powered by CNG, LNG, CH or LH can very economically provide air conditioning for the passengers and then use the chemically unaltered gas to power the bus engine.) This system can also be utilized for refrigerated trucks, etc.)

Using a conventional air-conditioning system, a fifty passenger bus would require about 50 horse power of energy to air-condition the vehicle. This amount of fuel can be conserved by utilizing a co-generation system in which expanding gas produces work as described herein.

Operation Method

Compressed gases, such as natural gas and hydrogen are obtained from a storage tank such as tank **1***a* or from pipeline **1**, of FIG. **20**. Liquefied gases are provided by tanks as in FIG. **21**, item **18**. In the case of compressed gas, it can be stored at pressures of 3,600 psi, and can be obtained by pipeline at nearly the same pressures. Liquefied gases can super-cool and afterward develop working pressure and perform work and the same gas can then be consumed as fuel. Described here are methods of utilizing the super-cooling ability of liquefied gas and the pressure drop of liquefied or compressed gas, in either case, to perform work before the gas is consumed as fuel.

Item **4**, FIG. **23** is a flexible duct for (a) cryo-cooling an electric super-conductor cable. Box **5**, FIG. **20** represents (b) a refrigerator/freezer or air conditioner or (c) an impulse turbine. Box **9** represents one or more additional tasks which can be performed in which the same gas can now be consumed as fuel. These are (1) gas fueled absorption chiller, (2) a gas fueled internal combustion engine (ICE), (3) a gas fueled rotary turbine, (4) a gas fueled steam turbine, (5) a gas fueled space heating furnace, or any other system fueled by gas, natural or hydrogen. The gas can be used as in FIG. **20** and FIG. **23** for one or more chilling systems or to drive an impulse turbine and then, as shown in conduits **16** and **29**, the gas can then be directed to one or more other tasks, or conduit **16** can have any number of division into conduits to supply any or all of the systems (1) through (5) suggested herein.

System (A), in which LNG or LH alternatively is ducted first for (a) supercooling superconductor cable **3** through flexible duct **4**, FIG. **23** and then by conduit **2** through optional pressure regulators **3** or **4**, FIG. **20** for optionally adjusting the mixture of liquid and gaseous gas volume and pressure to that ideal for performing the next task, in which the fuel is expanded by expansion valve **10'** for the second task, (b) freezing, chilling or air conditioning, (c) driving an impulse turbine and (d) providing fuel needed for the third task, absorption chilling or fueling a gas turbine or any other system described for **9** of FIG. **20**. First, the liquefied gas is channeled into flexible duct opening **4** of superconductor electric cable **3** and out end of duct **4'** to go collectively with other gases already used for super-cooling to be re-liquefied or alternatively directed to conduit **2**, FIG. **20** to first provide "expansion" chilling or optionally, if the pressure is too low, to pressurizer similar to item **15**, FIG. **21**, if necessary, to build operating pressure. It is then directed through conduit **2** of FIG. **20** or, alternatively, the affluent goes directly from conduit **43** of FIG. 21 to conduit **2** of FIG. **20**. It then goes to metering or expansion valve **10'**, pressure-drop-distributor **11'** and distribution tubes (evaporator coils) **17***a*. The LNG gaseous mixture or LH gaseous mixture expands in expansion valve **10'**, pressure drop distributor **11**, evaporator coils **17***a*, thus forming a refrigerator system, alternatively providing chill cooling for space air-conditioner, freezer-chiller, or for chilling through-put dry air or for driving an impulse turbine, all represented by **5**, FIG. **20**. Alternatively, the air is dried by **19** before chilling in **5** and the chilled air with increased flow is then passed to **9** where the air is further chilled by **9** (as **9** here represents an absorption chiller). Alternatively, the chilled air in duct **6** from chiller **5** is blown through register **25** for servicing one purpose. In this case, duct **6** is blocked at **26** and absorption cooler receives dry air from duct **24**, off of duct **6***a* from desiccantor **18**, after drying by desiccant **19** in **18**. The air from duct **24** is then chilled in absorption chiller **9** and blown through register **27**, to fulfill the same purpose or a different one from the chilled air that emitting from duct **25**.

Alternatively, the compressed or liquefied gas is directed from the first chosen task to any task or tasks suggested and is not necessarily used in the order suggested.

After the liquefied gas has been used to a) cryogenically cool superconductor cable **3** and after the gas has emerged from b) the task of chiller box **5** (intake charge air for a gas turbine, or ICE, or refrigerating/freezing or providing air conditioning **25**), the chemically unaltered gas is collected and directed by duct **7** through **8** which is a heat exchanger for heating the gas as for fueling a gas turbine or alternatively, **8** is a compressor for recompressing the gas fuel, and for suction to enhance cooling, and for c) fueling ICE or gas turbine **9**. The gas is ducted by conduit **16** to fuel absorption cooler **9** or for one or more of the other tasks mentioned that consumes gaseous fuel, such as gas turbine, steam turbine, internal combustion engine (ICE), steam engine, space heating, etc.

The description of the desiccantor **18** system, FIG. **20**, that air passes through for drying contains wheels **19'**, containing a desiccant, such as silica gel through which the air passes. The desiccant is dried by gas or electric burner **20** which is alternatively supplied gas fuel through tubing **23**, fed from conduit **16**. The dry air is then passed through chiller **5** and alternatively to register **25** where the cold air is dispersed to a room, etc., with duct **26** being closed. Alternatively, a second portion of dry air is fed absorption chiller **9** by conduit **24** where it is chilled by absorption chiller **9** and blown through register **27** for more cooling of perhaps another or same place or for another task. After firing (fueling) absorption chiller **9**, the combusted gases are