GAS ENGINE DRIVEN HEAT PUMP SYSTEM WITH INTEGRATED HEAT RECOVERY AND ENERGY SAVING SUBSYSTEMS

Inventors: Larry Copeland, Las Vegas, NJ (US); Robert Gaylord, Las Vegas, NV (US); Mark Haught, Las Vegas, NV (US); Isaac Mahderekal, Las Vegas, NV (US); Dudley J. Sondeno, Las Vegas, NV (US); Tommis E. Young, Las Vegas, NV (US)

Correspondence Address: GREENBERG TRAURIG 3773 HOWARD HUGHES PARKWAY, SUITE 500 NORTH LAS VEGAS, NV 89169 (US)

Appl. No.: 12/401,799
Filed: Mar. 11, 2009

Related U.S. Application Data
Division of application No. 11/464,060, filed on Aug. 11, 2006, now Pat. No. 7,503,184.

Publication Classification
Int. Cl. F25B 3/00 (2006.01)
U.S. Cl. 165/240

ABSTRACT
A gas heat pump system powered by natural gas, propane or similar gaseous fuel is disclosed. The system uses heat recovery and heat addition to manage efficient heating and cooling cycles. In a cooling cycle excess heat is vented to the atmosphere while in a heating cycle, excess heat is used to heat a subject structure and to prevent frost from forming on outdoor heat exchangers. A control system monitors the system's operation and corrects abnormal operational conditions or shuts down the system until the system can be manually inspected. The costs of system operation are less than electric systems because of the efficiencies and use of natural gas or propane.
GAS ENGINE DRIVEN HEAT PUMP SYSTEM
WITH INTEGRATED HEAT RECOVERY AND
ENERGY SAVING SUBSYSTEMS

CROSS-REFERENCE TO RELATED
APPLICATIONS

[0001] This application is a divisional of application Ser.

FIELD OF THE INVENTION

[0002] The embodiments of the present invention relate to
thermodynamic cycle) driven by combustion engine
prime movers with a frostless outdoor heat exchanger, multi-
tiple refrigeration circuits, integrated heat recovery, engine
cooling and auxiliary heating function configured in single or
multiple units.

BACKGROUND

[0003] Vapor compression heat pump systems are widely
used to provide heating and cooling air conditioning to resi-
dential and, to a lesser extent, commercial facilities. One
drawback of the vapor compression heat pump systems is that
the heating capacity decreases as the ambient temperature
decreases. Thus, during winter months the vapor compression
heat pump systems lack efficiency. Moreover, with low ambient
temperatures, building heat losses increase such that
building temperatures decrease. One well-known solution to
the inefficiency problem has been the addition of auxiliary
electric heat strips. Unfortunately, the heat strips increase
power usage and therefore system cost.

[0004] In recent years, combination air conditioner/heat
pump systems have been suggested as a solution to the inefficiencies discussed above. A gas engine driven air condi-
tioner/heat pump system utilizes a natural gas engine, instead of a traditional electric motor, to drive a compressor in the
refrigerant circuit. An air conditioner/heat pump system uti-
lizing a natural gas engine is known as a gas heat pump type
air conditioner ("GHP"). The GHP uses natural gas, which is
less expensive compared to other fuels such that the operating
cost of the GHP is less than an air conditioner/heat pump system
driven by a conventional electric motor ("EHP").

[0005] One advantage of using a combustion type engine, in
lieu of an electric motor, in a heat pump system is the ability
to use excess heat of combustion generated by the engine. The
excess heat is available for wintertime heat augmentation thereby reducing or eliminating the need for auxiliary heaters.
It has been a common practice with combustion engine heat
pump systems to recover the excess heat from the engine by
conveying a working fluid (e.g., water and ethylene glycol
antifreeze) through the cooling and sometimes the exhaust
system such that waste heat from the engine is absorbed by
the working fluid. The heated working fluid is then pumped to
a heat exchanger or radiator located in the air flow leading to
the air-conditioned space.

[0006] Another advantage of using a combustion engine is
the significant reduction is costs associated with the use of
inexpensive fuel sources such as natural gas, propane and
similar gaseous fuels.

[0007] While the advantages of using waste heat from a
combustion engine are well recognized, the wide range of
options for recovering and using the waste heat has required
numerous, separate components to facilitate the heat
exchange, auxiliary heating, defrosting and heat rejection.
The complexity, size and cost of the heat pump systems
having desirable heat recovery and use capability have
increased accordingly. In addition, the use of small internal
combustion engines at high ambient temperatures and at
increased altitudes is problematic in that the environmental
conditions reduce output horsepower.

[0008] Therefore, the need exists for a heat pump systems
which recovers and applies wasted heat effectively into the
air-conditioned space and minimizes the use of electrical
power demand and costs during both the heating and cooling
heat pump cycles in high temperature environments.

SUMMARY

[0009] Accordingly, one embodiment of the present invention
is a gas heat pump systems having an engine compressor
section, indoor section and outdoor section comprising: one
or more refrigeration circuits comprising a refrigeration com-
pressor and switching device, said switching device operable
to direct refrigerant into the indoor section during a heating
cycle and into the outdoor section during a cooling cycle; said
engine compressor section comprising: an engine capable of
running on a gaseous fuel; an engine cooling system; a fuel
intake system; and an exhaust gas system; said indoor section
comprising: an indoor heat exchanger; one or more fans oper-
able to pass indoor air across the indoor heat exchanger; and
one or more expansion valves corresponding to the indoor
heat exchanger; said outdoor section comprising: a radiator;
one or more outdoor heat exchangers; one or more fans oper-
able to pass outdoor air across the radiator and the outdoor
heat exchangers; and one or more expansion valves corre-
responding to each outdoor heat exchanger.

[0010] The embodiments of the present invention satisfy the
need providing a system that integrates waste heat recovery,
maximizes load efficiency, maintains comfortable indoor
air supply temperatures during low ambient outside tempera-
tures while minimizing electricity demand and cost during
a heating and cooling cycle.

[0011] The GHP system disclosed herein comprises three
primary components: an engine compressor section, an
indoor section and an outdoor section. Ideally, the primary
components are contained within a single unit.

[0012] In one embodiment of the present invention, the
engine compressor section comprises an internal natural gas
engine, waste heat recovery components and multiple belt
driven scroll type compressors. In this embodiment, engine
coolant is pumped through the waste heat recovery compo-
nents and the engine thereby removing and recovering the
waste heat.

[0013] In one embodiment, the indoor section comprises an
indoor heat exchanger containing multiple interlaced refrig-
erant circuits and an auxiliary heat circuit and an air blower
driven by a multi-speed motor. Also contained within the
indoor section are thermostatic expansion devices, check and
control valves and miscellaneous refrigeration and electrical
components.

[0014] In one embodiment, the outdoor section comprises
dual outdoor heat exchangers with one heat exchanger dedi-
cated to a separate refrigerant circuit and anti-frost circuit and
multiple high efficiency fans driven by high efficiency multi-
speed motors. Also contained within the outdoor section are
an engine coolant radiator and various valves and controls.

[0015] A refrigeration system of one embodiment of the
present invention comprises two complete heat pump circuits
Driven by a single natural gas internal combustion engine. The refrigeration system is designed and controlled such that system efficiency is maximized by varying the number of running compressors and refrigerant flow rate through the circuits to satisfy the heating and cooling load requirement for the subject air-conditioned space. The refrigerant flow rate is adjusted by varying the speed of the natural gas internal combustion engine. Load efficiency is maximized by inter-lacing refrigerant circuits within the indoor heat exchanger and varying the airflow across the indoor and outdoor heat exchangers to match the ambient conditions and load requirements.

By providing cooling of the internal combustion engine’s combustion air and additional surface area on the outdoor heat exchanger, the refrigeration system becomes ideal for high desert environments.

When the GHP is operated in a cooling mode, waste heat is removed from the engine and exhaust by coolant which is directed to the radiator where the waste heat is either rejected to the atmosphere or further directed to an auxiliary heating device like a hot water heating system, swimming pool heating system or other domestic water systems requiring heat.

When the GHP is operated in a heating mode, waste heat is removed from the engine and exhaust by coolant which is directed to the indoor and outdoor heat exchangers. Unless the outdoor ambient temperature is below a threshold frost point temperature (e.g., freezing), all the coolant is directed to the auxiliary heat circuit in the outdoor heat exchanger thereby causing all recoverable heat to be transferred from the engine into the subject air-conditioned space. Such an embodiment maximizes the coefficient of performance (COP), where COP is defined as the ratio of the useful heating energy output to the total energy input (fuel and electricity consumed). If the ambient temperature is below the threshold frost point temperature, part or all of the engine coolant is directed to the anti-frost circuit in the outdoor heat exchanger. The COP is once again increased based on the higher inlet air temperature to the refrigerant portion of the outdoor heat exchanger.

The embodiments of the present invention also incorporate the capability to add additional heat to the system via an auxiliary natural gas heater (AXTHHR) to reduce engine warm up time and provide, in colder climates, additional heat to the subject air-conditioned space without the need for auxiliary electric strips.

Other variations, embodiments and features of the present invention will become evident from the following detailed description, drawings and claims.

**BRIEF DESCRIPTION OF THE DRAWINGS**

- FIG. 1 illustrates a schematic diagram of a first embodiment of a gas engine driven heat pump system of the present invention;
- FIG. 2A illustrates a schematic diagram depicting refrigerant and engine coolant flows during a cooling cycle without an optional hot water waste heat exchanger (HWXGR);
- FIG. 2B illustrates a schematic diagram depicting the refrigerant and engine coolant flows during a cooling cycle with the optional hot water waste heat exchanger (HWXGR);
- FIG. 3A illustrates a schematic diagram depicting the refrigerant and engine coolant flows during the heating cycle operating at ambient temperatures above a threshold ambient temperature without an optional cold climate auxiliary heater (AXTHHR);
- FIG. 3B illustrates a schematic diagram depicting the refrigerant and engine coolant flows during the heating cycle operating at ambient temperatures at or below the threshold frost point ambient temperature without an optional cold climate auxiliary heater (AXTHHR); and
- FIG. 3C illustrates a schematic diagram depicting the system with the optional cold climate auxiliary heater (AXTHHR) installed.

**DETAILED DESCRIPTION**

For the purposes of promoting an understanding of the principles in accordance with the embodiments of the present invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended. Any alterations and further modifications of the inventive feature illustrated herein, and any additional applications of the principles of the invention as illustrated herein, which would normally occur to one skilled in the relevant art and having possession of this disclosure, are to be considered within the scope of the invention claimed.

Reference is now made to the figures wherein like parts are referred to by like numerals throughout. FIG. 1 shows a schematic diagram of a gas engine driven heat pump system of the present invention generally referred to by reference numeral 50. The system 50 includes an engine compressor section 51, an indoor section 52 and an outdoor section 53 divided by lines 54, 55.

The system 50 comprises two identical refrigeration circuits referred to as circuit A and circuit B. Internal combustion engine 1 runs on natural gas (or propane or other suitable gases) and drives two refrigeration compressors 2A, 2B. The refrigeration circuits operate using classic Rankine cycle principals. A Rankine cycle is a thermodynamic cycle familiar to those skilled in the art.

Combustion air (CA) first enters an inlet silencer device 32 that reduces air flow noise. The combustion air then travels through an air cooler device 33 that, depending on the combustion air temperature, may cool the combustion air several degrees. Reducing the combustion air temperature increases the horsepower output of the internal combustion engine 1. The cooled air then passes through an air filter 34 that filters any particulate matter. The clean air then enters an air fuel mixture device 35 located on, or in proximity to, the internal combustion engine 1.

Engine combustion exhaust gases exit the engine 1 through water cooled exhaust manifold 22 where the gases are cooled by engine coolant circulated through the manifold 22. The exhaust gases then enter a catalytic converter 36 that reduces NOx and hydrocarbon emissions. The gases then flow through an exhaust air exchanger 21 such that the gases are cooled to approximately 200° by engine coolant circulated through the exchanger 21. Next, the cooled exhaust gases flow through exhaust separator 19 where any condensed water (a product of combustion) is removed. The remaining exhaust vapors are vented to the atmosphere. The exhaust liquids (e.g., water), which may be acidic, flow to an exhaust liquid filter 36 that neutralizes any acid in the liquid. The neutralized liquid may then be dispensed through a drain.
Natural gas, or propane, from a gas source first enters the system via safety cutoff device and pressure regulator. The pressure regulator lowers the gas pressure to a suitable and useable level for receipt by an engine carburetor, which causes the gas to be mixed with combustion air. In embodiments utilizing an optional cold climate auxiliary heater, natural gas, or propane, is also piped thereto.

An extended engine life and maintenance cycle (e.g., 10,000 hours) may be accomplished by the addition of an auxiliary oil storage tank.

Cool low pressure refrigerant vapor is compressed to high pressure by compressors. Pursuant to the principal defined by the ideal gas law (PV=nRT), as the vapor is compressed, its temperature increases. The hot vapor of refrigerant flows to oil separators which separate oil from the refrigerant. The separated refrigerant is returned to compressor suction line through metering devices and solenoid valves and are activated by a control system in response to changing operating conditions to provide optimum oil flow to the compressors.

The hot, high pressure refrigerant vapor flows from the oil separators to reversing or switching valves where the vapor is diverted to the indoor exchanger or the outdoor exchangers.

When the system is in the cooling mode or cycle, the switching valves divert hot, high pressure refrigerant to the outdoor heat exchangers which, in the cooling mode, act as condensers. Refrigerant from valve is directed to outdoor heat exchanger and refrigerant from valve is directed to outdoor heat exchanger.

Each outdoor heat exchanger contains a refrigerant circuit and a heating circuit. The heating circuit is used during the heating mode to prevent frost accumulation on the outdoor heat exchangers. The hot, high pressure refrigerant is then condensed to a high pressure liquid and sub-cooled by removing heat from the refrigerant. The heat is removed by drawing cooler outdoor air across the outdoor heat exchangers.

The high pressure refrigerant liquid then flows through check valve devices to the thermostatic expansion devices. The thermostatic expansion devices regulate the refrigerant flow which lowers the pressure of the refrigerant as it flows through the device. The pressure reduction causes expansion of the refrigerant liquid whereby a portion flashes into a vapor that, according to the Joule-Thompson effect, causes the temperature of the two-phase refrigerant to be reduced.

The cold two-phase refrigerant then enters indoor heat exchanger which functions as an evaporator in the cooling mode. Warm return air from the subject air-conditioned space is drawn across the indoor heat exchanger by an indoor blower. Heat is removed from the return air thereby cooling the air stream. The cool air stream is then returned to the subject air-conditioned space. The heat removed from the air stream is transferred to the cold two-phase refrigerant flowing through the tubes of the indoor heat exchanger causing the liquid refrigerant to boil. After all liquid refrigerant has boiled into vapor, additional heat is added to the heat exchanger causing the refrigerant vapor to become superheated. The amount of superheat is controlled by the thermostatic expansion devices.

The indoor heat exchanger includes two interlaced refrigeration circuits and a auxiliary heating circuit used during the heating cycle. The interlacing of the refrigerant circuits provides optimum heat exchanger efficiency during full and partial load cycles.

The superheated refrigerant vapor then flows back to the switching valves and then to the suction accumulators where any liquid refrigerant that may have condensed is separated from the refrigerant vapor. The refrigerant vapor is then drawn into low pressure inlets of the compressors such that the cycle can be repeated.

During both heating and cooling cycles, engine coolant is circulated through the system by a coolant pump. Warm coolant is pumped through the exhaust air exchanger where the coolant temperature is raised a few degrees by waste heat recovered from the engine exhaust. The coolant then flows to the water-cooled exhaust manifold located on the internal combustion engine, such that the coolant temperature is additionally raised. The coolant then enters the internal combustion engine where it removes heat from the engine. This portion of the coolant circuit collects waste heat for efficient use during the heating and cooling cycles.

Now referring to FIG. 2A, the system is shown operating in a cooling cycle without any optional devices installed. Engine coolant flows from engine to engine temperature control valve. A proportional integral derivative (PID) control loop in the control system maintains an efficient engine temperature by directing the coolant flow either to the engine or to radiator. Upon initial startup, in order to bring the engine to a proper operating temperature, the coolant is directed by engine control valve to the engine. As the engine temperature approaches the desired operating temperature, the engine temperature control valve directs the coolant to switching valve. During the cooling cycle, the switching valve directs the engine coolant to the radiator where excess engine heat is removed. The excess engine heat is removed from the coolant as the result of outside air being drawn across the radiator by outdoor fans.

The coolant then flows to the coolant pump where the coolant cycle begins again.

FIG. 2B shows the system operating in the cooling cycle with an optional hot water exchanger installed. Hot coolant exiting the switching valve flows to the hot water temperature control valve. Hot coolant is then directed to the hot water exchanger where waste heat is used to heat domestic water, swimming pools and the like. A PID control loop in the control system regulates the hot coolant flow to the hot water exchanger and the radiator. Once a pre-established threshold temperature of the heated water is achieved, the remaining coolant flow is directed to the radiator. Coolant exiting the hot water exchanger and radiator flows to the coolant pump where the cycle begins again. This embodiment, waste heat in efficiently used thereby increasing overall system efficiency.

FIG. 3A shows the system without any optional devices installed, operating in the heating cycle when the ambient temperature is above a threshold frost point temperature of the outdoor exchangers. The switching valve directs the hot engine coolant to a frost avoidance valve. Since the outdoor ambient temperature is above the threshold
frost point temperature, the PID control loop of the control system directs all hot coolant to circuit (C) of the indoor heat exchanger 6.

[0045] The indoor heat exchanger 6 includes two interlaced refrigerent circuits (A, B) and an auxiliary heat circuit (C). The auxiliary heat circuit (C) is located on the outlet side of the indoor heat exchanger 6 downstream of the refrigerent circuits with respect to the air flow created by the indoor blower 31. This configuration of the refrigerant and engine coolant circuits provides several primary benefits. First, due to the sizing and arrangement of the outdoor heat exchangers 11A, 11B, heat recovery from the outside air is maximized and transferred to the subject air-conditioned space. Second, due to the interlacing circuits (A, B) within the indoor heat exchanger 6, partial load efficiency is maximized. Third, waste heat recovered from engine 1 is transferred to the subject air-conditioned space and provides significantly higher air temperatures than possible with conventional heat pump systems during low ambient temperature cycle. Moreover, a significant increase in the COP over conventional heat pump systems is achieved.

[0046] Now referring to FIG. 3B, the system 50, without optional devices installed, is shown operating in the heating cycle when ambient temperatures are at or below the threshold frost point temperature of the outdoor exchangers 11A, 11B. The switching valve 25 directs the hot engine coolant to the frost avoidance valve 28. Sensors or similar devices located in the outdoor section 53 sense and report when temperatures are such that frost is likely to form on coils of the outdoor exchangers 11A, 11B. As temperatures approach the threshold frost point, the PID control loop adjusts the flow through the frost avoidance valve 28 by directing some or all of the engine heat coolant from the indoor heat exchanger 6 to the frost avoidance circuit (C) in the outdoor heat exchangers 11A, 11B. The frost avoidance circuit (C) is located on an inlet side of the outdoor heat exchangers 11A, 11B wherein the inlet side is upstream with respect to the air flow created by fans 30A, 30B. Cooled engine coolant exits the indoor heat exchanger 6 and the outdoor heat exchangers 11A, 11B and flows back to the coolant pump 20 where the cycle begins again. This configuration offers two primary benefits. First, the outdoor exchangers 11A, 11B never require defrosting thereby eliminating the high energy used by conventional heat pumps to defrost exchanger pipes. Second, even though the hot engine coolant is directed from its primary function of increasing the heat delivered to the subject air-conditioned space, the energy is not wasted since it is reabsorbed into the system 50 by increasing the temperature of the entering the refrigerent circuits (A, B) of the outdoor heat exchangers 11A, 11B which function as evaporators during the heating cycle of cycle. The effect is that the inlet temperature of the outdoor air to the evaporator is increased several degrees, thus raising the overall heating effect of the system 50 and the corresponding COP.

[0047] FIG. 3C shows the system 50 including supplemental heating for system cycle in climates not suitable for conventional heat pump systems. An auxiliary heater 23 is installed between the internal combustion engine 1 and the engine temperature control valve 24. Hot engine coolant exits the internal combustion engine 1 and flows to the auxiliary heater 23 where it is heated to a higher temperature by a natural gas burner using the natural gas (or propane) supplied from the combined safety cutoff device and pressure regulator 16. The engine coolant then flows to the engine temperature control valve 24. The system 50 continues to operate as described above with respect to the heating cycle. However, since the engine coolant now has a higher temperature, it provides additional heat to the subject air-conditioned space. Another advantage of the auxiliary heater 23 is that it facilitates a shorter startup time for the internal combustion engine 1 resulting in the ability to more quickly heat the subject air-conditioned space.

[0048] An electrical control system including circuitry, logic and related electronic components, is operable to manage the system 50. A thermostat controllable by a user dictates whether the system 50 is in the cooling or heating cycle and at what temperature level. More particularly, the control system can vary the speed of the engine 1, indoor blower 31 and outdoor fans 30A, 30B and the number of running refrigeration compressors 2A, 2B. The control system includes sensors designed to monitor the system 50 for irregular operational conditions. Based on the detection of irregular or abnormal operational conditions, the control system automatically takes steps to correct the irregularities or abnormalities or shut down the system 50 when the irregularities cannot be corrected. The control system further controls coolant flow during the different cycles. Air-fuel mixture is also managed by the control system.

[0049] Although the invention has been described in detail with reference to several embodiments, additional variations and modifications exist within the scope and spirit of the invention as described and defined in the following claims.

We claim:
1. A method of utilizing a system to generate heated or cooled air for supply to a subject structure comprising: supplying pressure-regulated a gaseous fuel to an engine and optional auxiliary heater; directing engine combustion air through an air cooler device, filter and then into an air-fuel mixture device operable to mix the natural gas or propane with the combustion air; directing refrigerant through indoor or outdoor heat exchangers depending on whether the system is in a heating or cooling cycle; directing coolant through said engine such that coolant temperature is raised by waste heat; when in a cooling cycle:
   directing coolant from the engine to an engine temperature control valve that directs the coolant to a radiator that dispenses any excess heat;
   when in a heating cycle:
   determining an ambient temperature;
   if the ambient temperature is below a threshold frost point temperature, directing the engine coolant from the engine to a frost avoidance valve that directs the coolant to outdoor heat exchangers; and
   if the ambient temperature is above a threshold frost point temperature, directing the engine coolant from the engine to an indoor heat exchanger.

2. The method of claim 1 further comprising directing, during the cooling cycle, engine coolant to a hot water exchanger operable to heat a domestic water source.

3. The method of claim 1 further comprising utilizing a pool or hot water heater as the domestic water source.

4. The method of claim 1 further comprising adding heat, during the heating cycle, to the coolant between the engine and the engine temperature control valve.
5. The method of claim 1 further comprising directing all coolant to the engine at engine start-up until the engine reaches a desired operating temperature.

6. The method of claim 1 further comprising utilizing natural gas or propane as the gaseous fuel.

7. A method of utilizing a system to generate heated or cooled air for supply to a subject structure comprising:
   - supplying pressure-regulated natural gas or propane to an engine and optional auxiliary heater;
   - directing engine combustion air through an air cooler device, filter and then into an air-fuel mixture device operable to mix the natural gas or propane with the combustion air;
   - directing refrigerant through indoor or outdoor heat exchangers depending on whether the system is in a heating or cooling cycle;
   - directing coolant through said engine such that coolant temperature is raised by waste heat;
   - when in a cooling cycle:
     - directing coolant from the engine to an engine temperature control valve that directs the coolant to a radiator that dispenses any excess heat;
   - when in a heating cycle:
     - determining an ambient temperature;
     - if the ambient temperature is below a threshold frost point temperature, directing the engine coolant from the engine to a frost avoidance valve that directs the coolant to outdoor heat exchangers;
     - if the ambient temperature is above a threshold frost point temperature, directing the engine coolant from the engine to an indoor heat exchanger; and
     - varying engine speed, number of refrigeration compressors running and blower speed in response to a thermostat setting.

8. The method of claim 7 further comprising directing, during the cooling cycle, engine coolant to a hot water exchanger operable to heat a domestic water source.

9. The method of claim 8 further comprising utilizing a pool or hot water heater as the domestic water source.

10. The method of claim 8 further comprising adding heat, during the heating cycle, to the coolant between the engine and the engine temperature control valve.

11. The method of claim 8 further comprising directing all coolant to the engine at engine start-up until the engine reaches a desired operating temperature.

12. The method of claim 8 further comprising utilizing a control system for varying engine speed, number of refrigeration compressors running and blower speed in response to a thermostat setting.

13. A method of utilizing a system to generate heated or cooled air for supply to a subject structure comprising:
   - supplying pressure-regulated a gaseous fuel to an engine and optional auxiliary heater;
   - directing engine combustion air through an air cooler device, filter and then into an air-fuel mixture device operable to mix the natural gas or propane with the combustion air;
   - directing refrigerant through indoor or outdoor heat exchangers depending on whether the system is in a heating or cooling cycle;
   - directing coolant through said engine such that coolant temperature is raised by waste heat;
   - when in a cooling cycle:
     - directing coolant from the engine to an engine temperature control valve that directs the coolant to a radiator that dispenses any excess heat;
     - further exchanging water heat from said engine coolant to a domestic water source; and
     - regulating an amount of heat transferred to said domestic water source by diverting a portion of said hot engine coolant;
   - when in a heating cycle:
     - determining an ambient temperature;
     - if the ambient temperature is below a threshold frost point temperature, directing the engine coolant from the engine to a frost avoidance valve that directs the coolant to outdoor heat exchangers; and
     - if the ambient temperature is above a threshold frost point temperature, directing the engine coolant from the engine to an indoor heat exchanger.

14. The method of claim 13 further comprising utilizing a hot water heat exchanger apparatus to exchange water heat from said engine coolant to a domestic water source during a cooling cycle.

15. The method of claim 13 further comprising utilizing a control valve to regulate an amount of heat transferred to said domestic water source by diverting a portion of said hot engine coolant.