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Woods et al.

(10) **Patent No.: US 7,969,030 B2**
(45) **Date of Patent: Jun. 28, 2011**

(54) **POWER GENERATION SYSTEMS AND METHODS OF GENERATING POWER**

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(73) Assignee: **Powersys, LLC**, Carmel, IN (US)

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(21) Appl. No.: **12/719,726**

(22) Filed: **Mar. 8, 2010**

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Related U.S. Application Data

(63) Continuation of application No. 10/577,577, filed as application No. PCT/US2004/032857 on Oct. 5, 2004, now Pat. No. 7,675,187.

(60) Provisional application No. 60/508,857, filed on Oct. 6, 2003.

(51) **Int. Cl.**
H02P 9/00 (2006.01)
H02P 9/44 (2006.01)

(52) **U.S. Cl.** ..... **290/1 A**; 290/7; 322/37

(58) **Field of Classification Search** ..... 290/1 A, 290/1 B, 4 R, 40 R, 40 C, 40 E, 7; 322/37, 322/28

See application file for complete search history.

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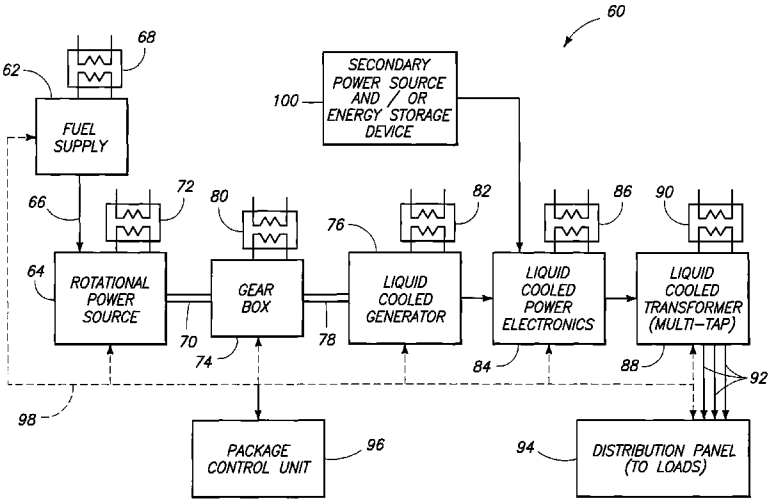
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Primary Examiner — Nicholas Ponomarenko
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(57) **ABSTRACT**

A power generation system is provided that includes an internal combustion engine configured to provide rotational mechanical energy. A generator is configured to receive the rotational mechanical energy and generate electrical power in response to the rotational mechanical energy. A fluid medium is provided to the internal combustion engine and to the generator for removing thermal energy from the internal combustion engine and from the generator.

17 Claims, 23 Drawing Sheets



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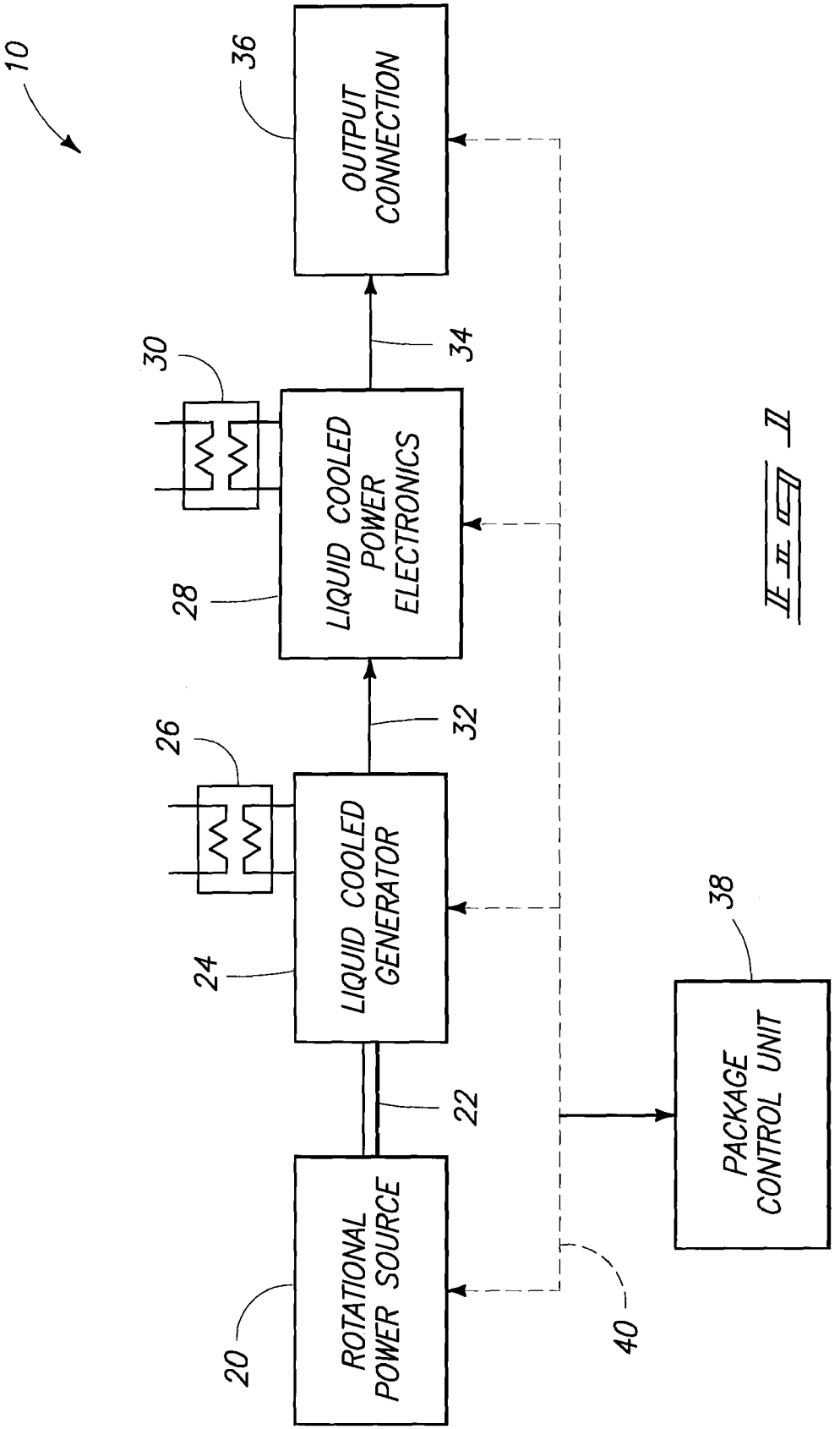
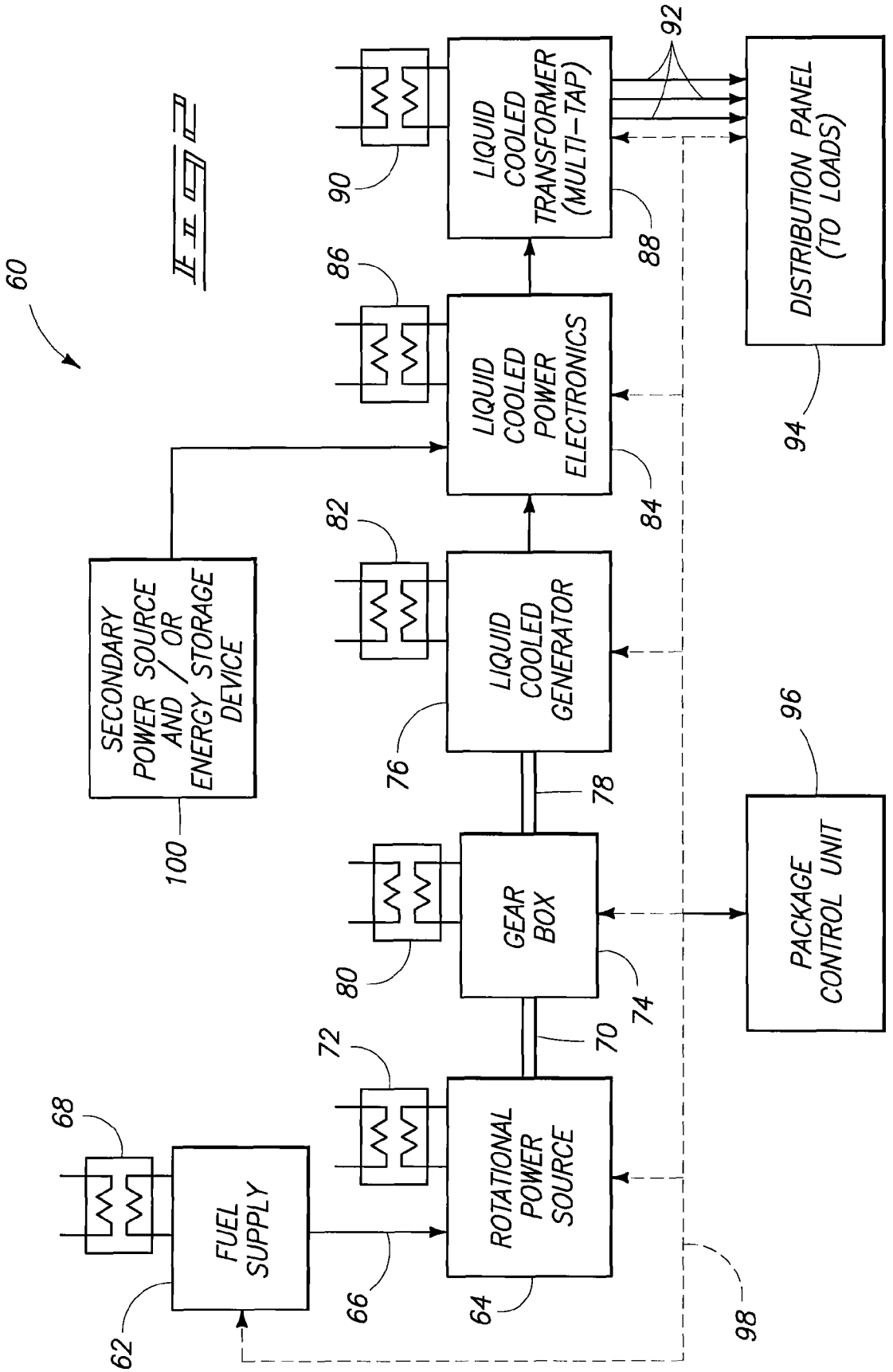

10
36
OUTPUT CONNECTION
34
30
LIQUID COOLED POWER ELECTRONICS
28
32
26
LIQUID COOLED GENERATOR
24
22
38
PACKAGE CONTROL UNIT
ROTATIONAL POWER SOURCE
20
40

FIG. 1


60
FIG 2
FUEL SUPPLY
62
68
ROTATIONAL POWER SOURCE
64
66
72
GEAR BOX
70
74
80
LIQUID COOLED GENERATOR
76
78
82
LIQUID COOLED POWER ELECTRONICS
84
86
LIQUID COOLED TRANSFORMER (MULTI-TAP)
88
90
92
DISTRIBUTION PANEL (TO LOADS)
94
PACKAGE CONTROL UNIT
96
98
SECONDARY POWER SOURCE AND / OR ENERGY STORAGE DEVICE
100

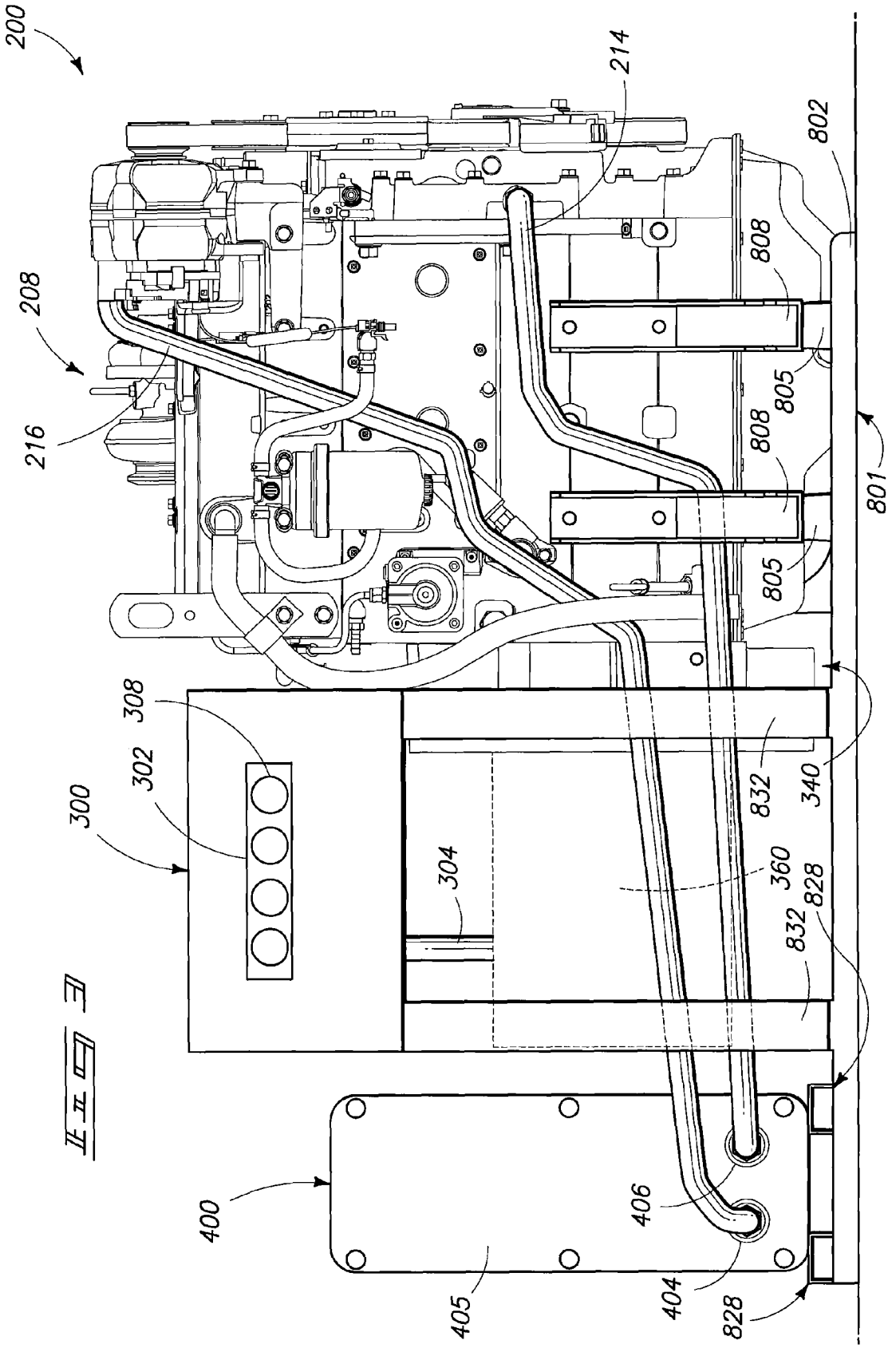

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404
828

FIG 3

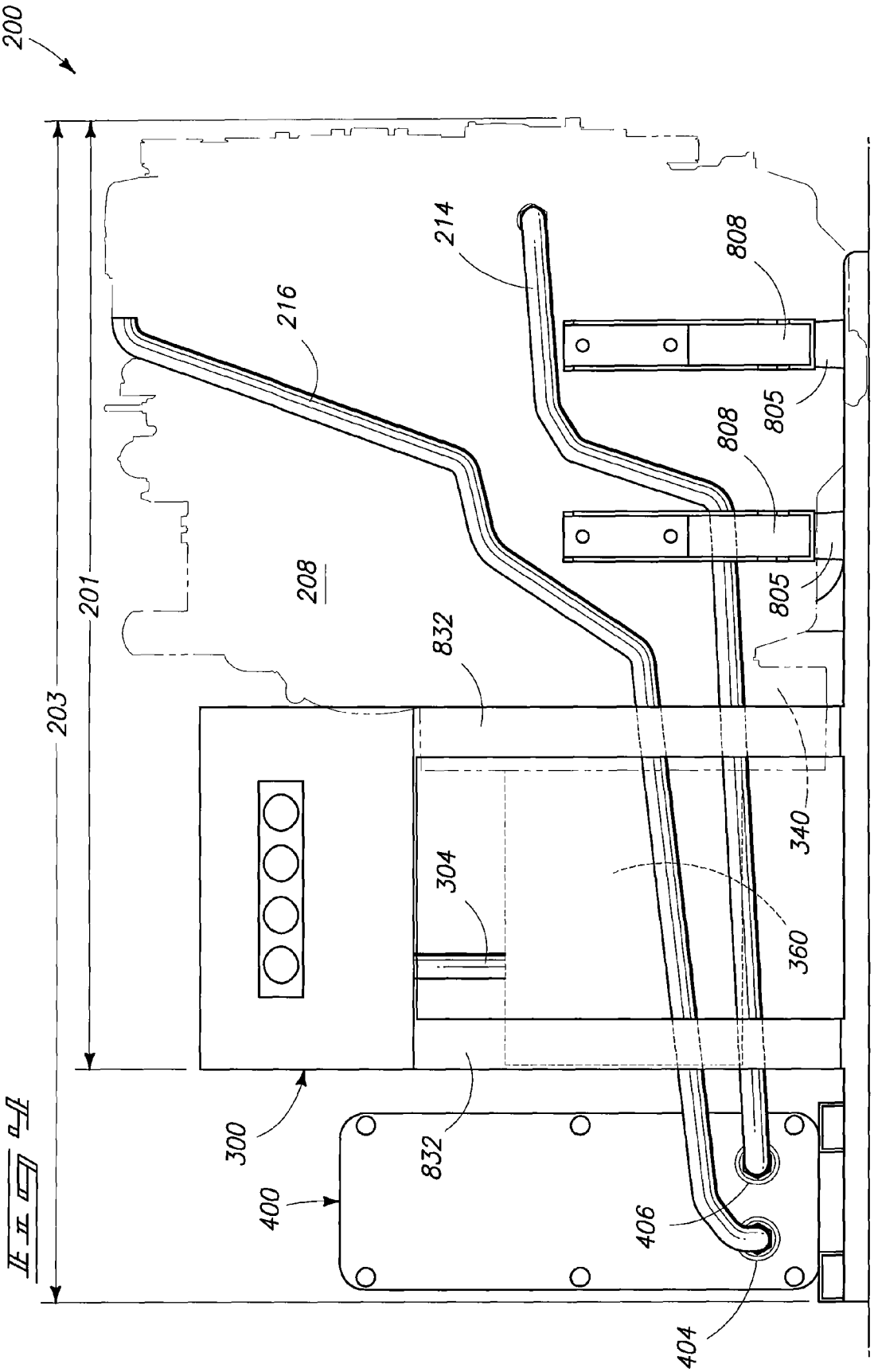


Fig. 3A

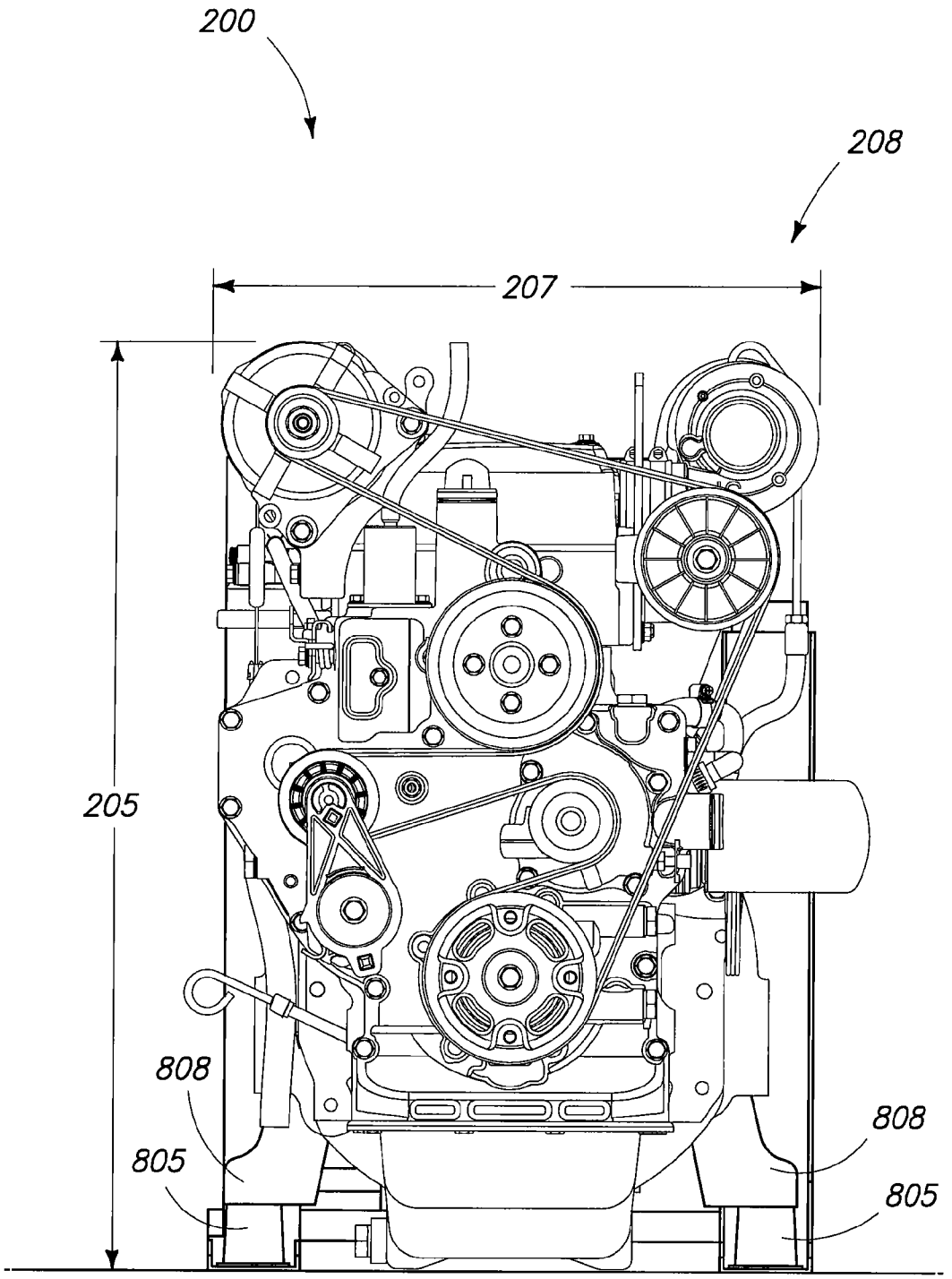


FIG 5

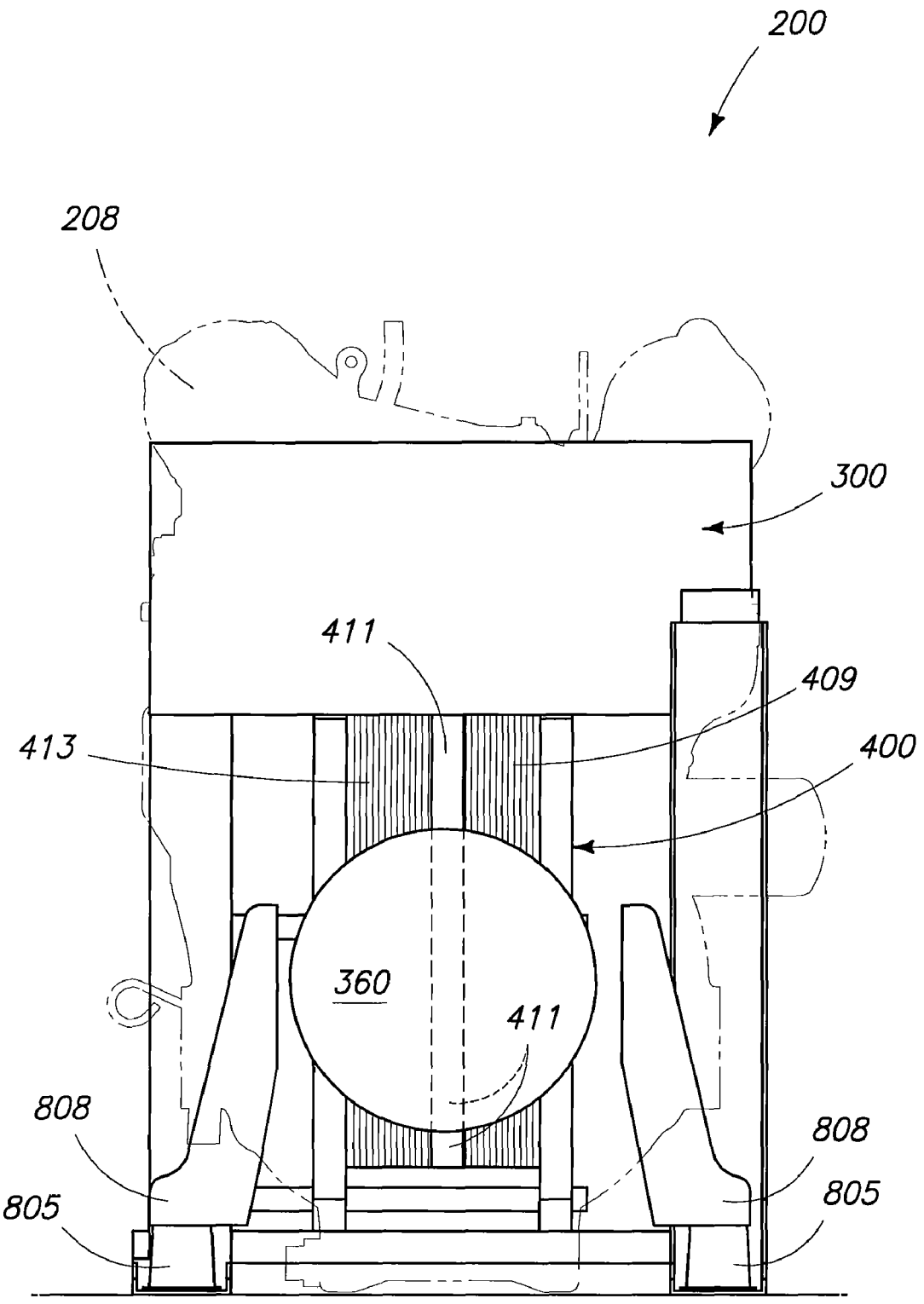


Fig 6

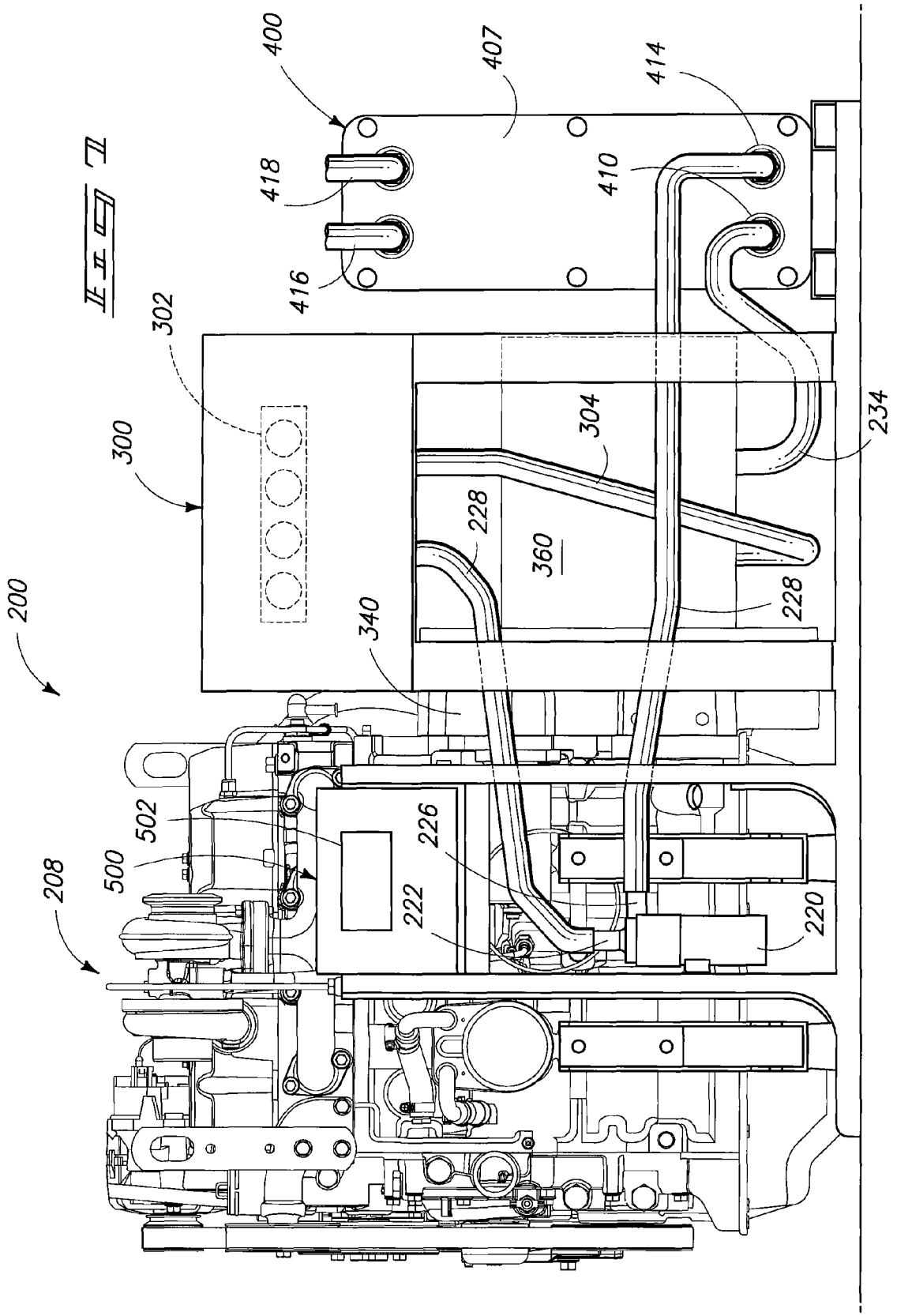
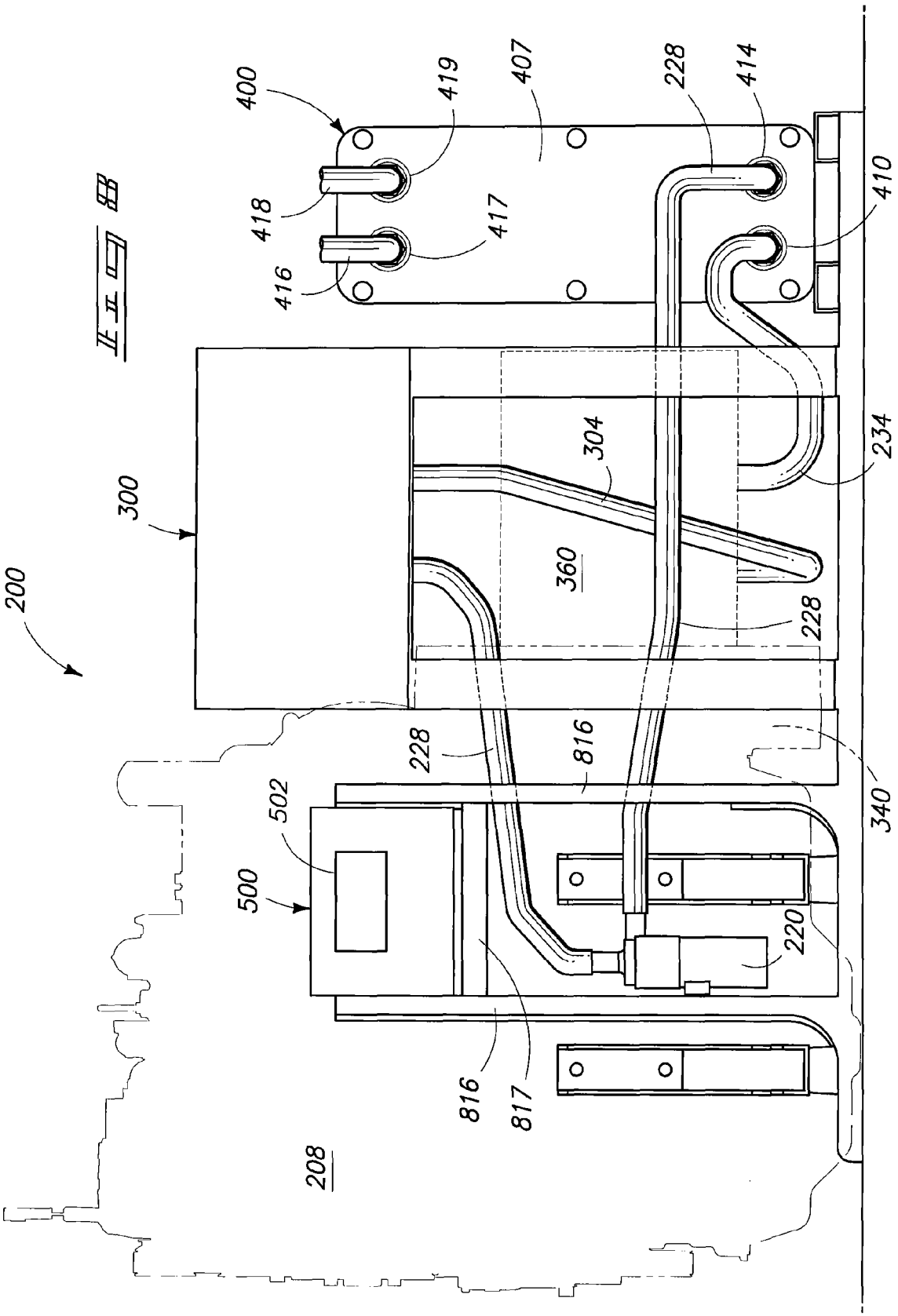

FIG 7
400
407
414
418
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416
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304
234
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228
360
228
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502
226
500
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222
220

FIG 8B


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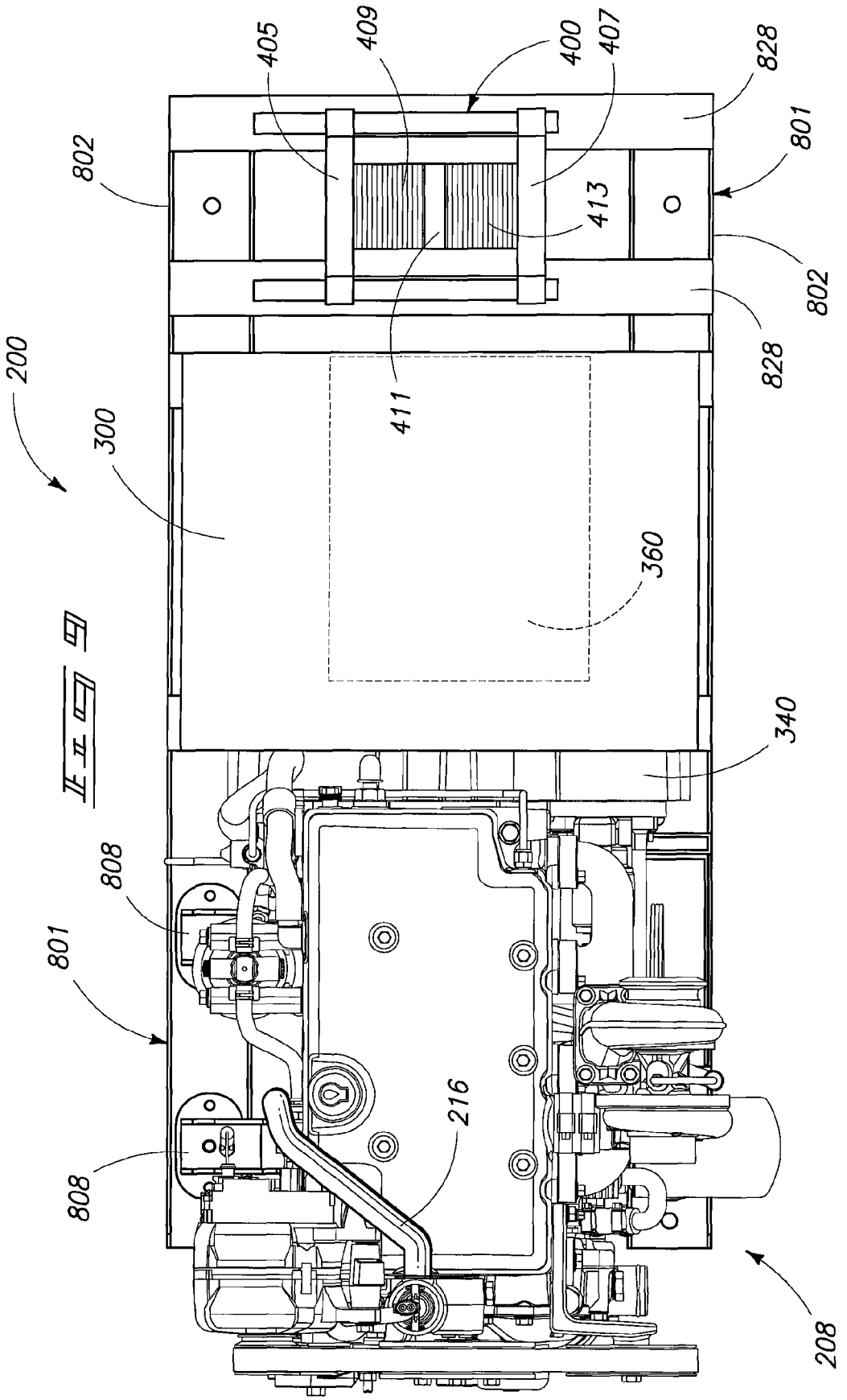

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FIG 9

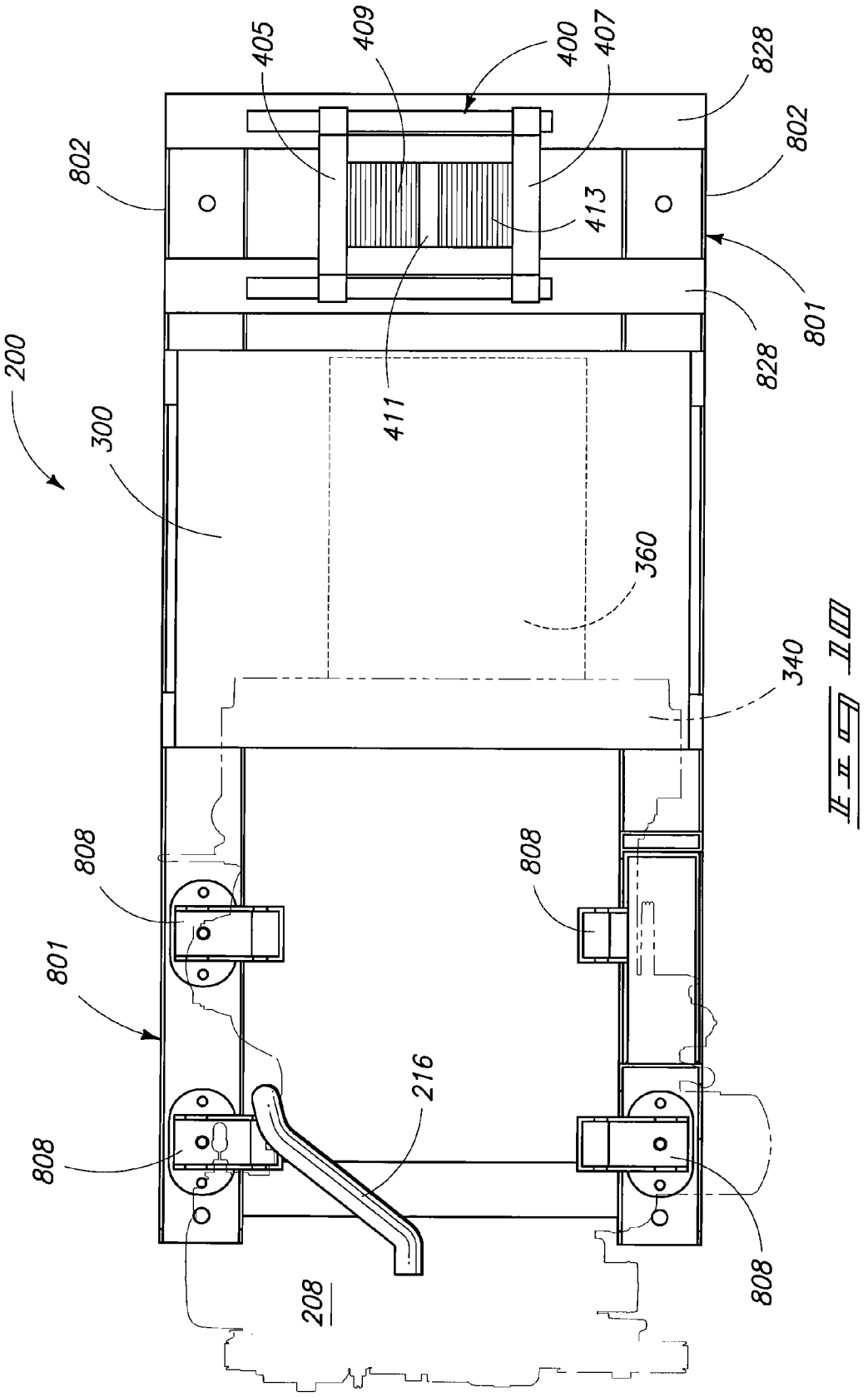

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FIG. 11

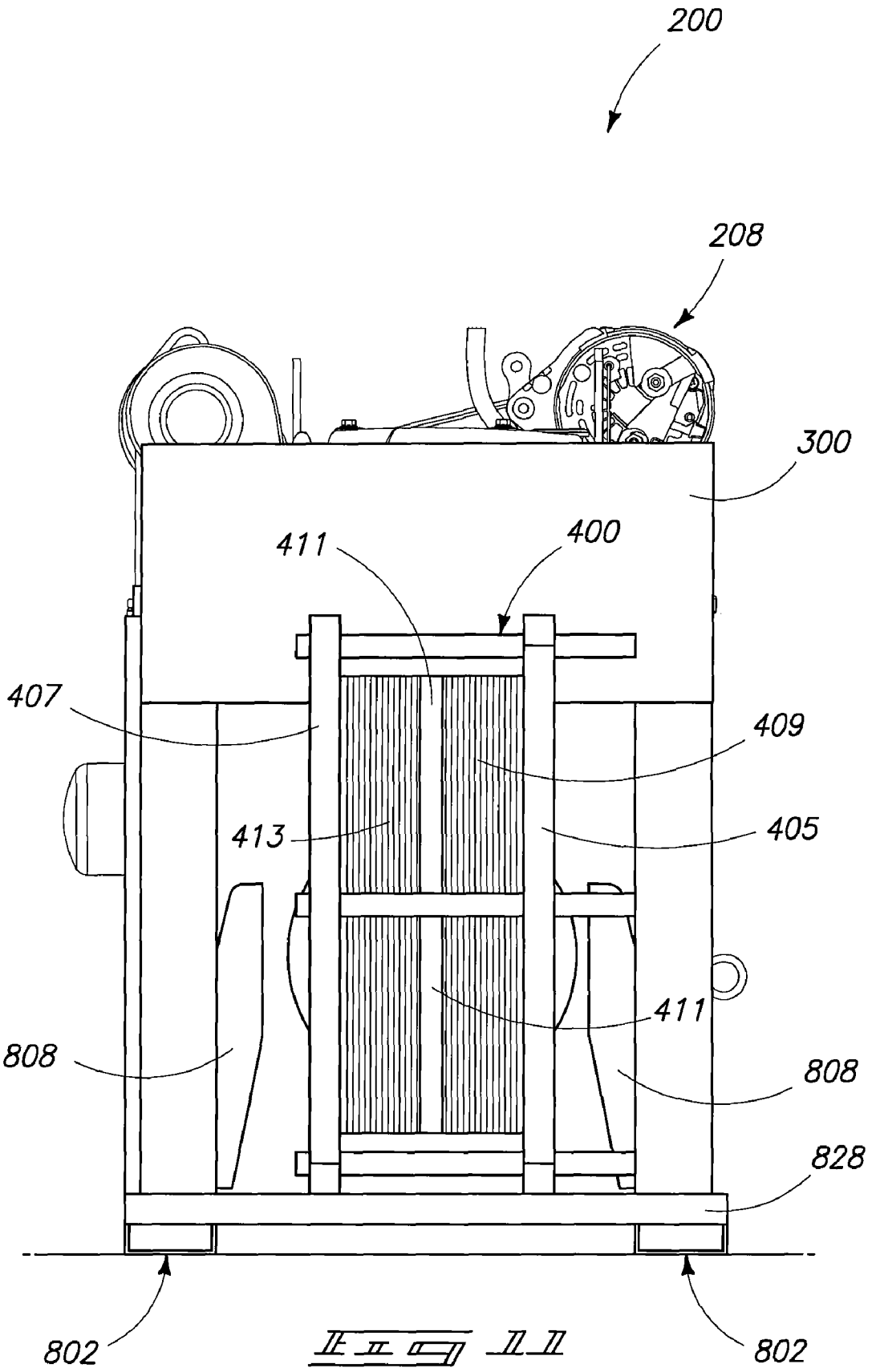


Fig. 11

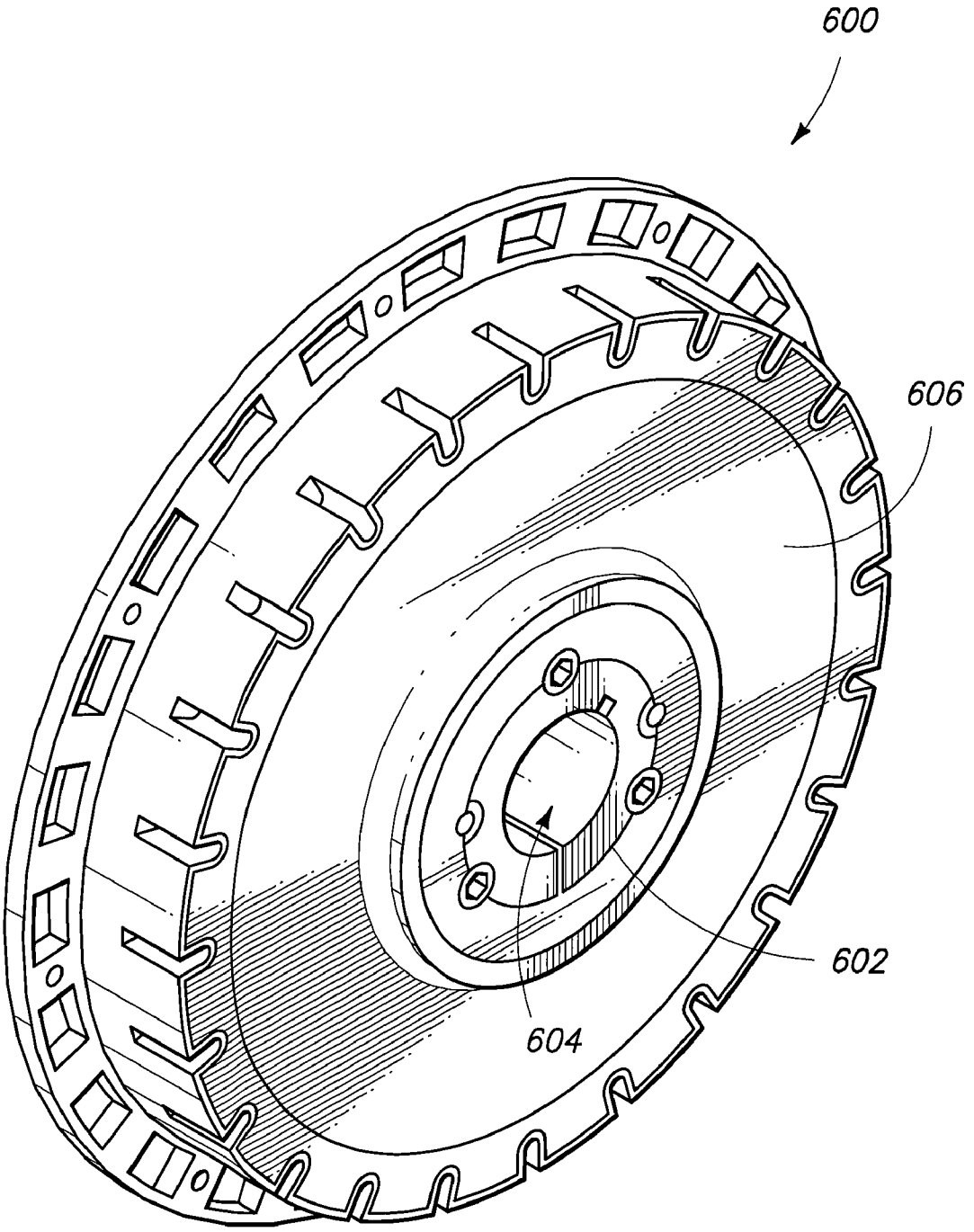


Fig 12

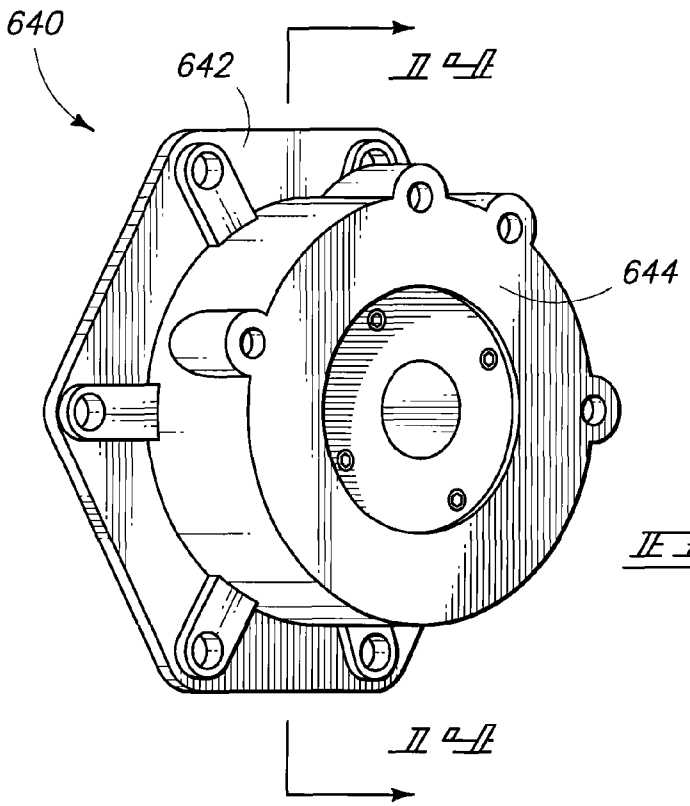


Fig. 13

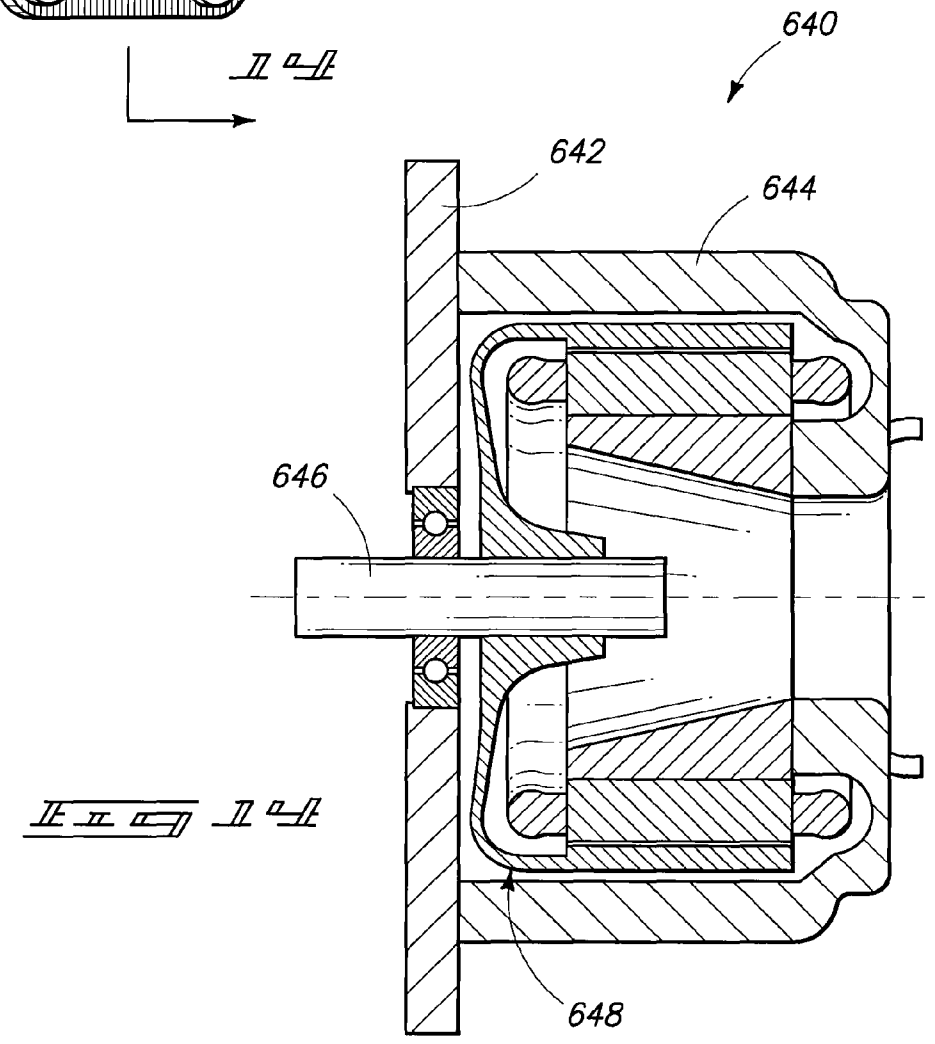


Fig. 14

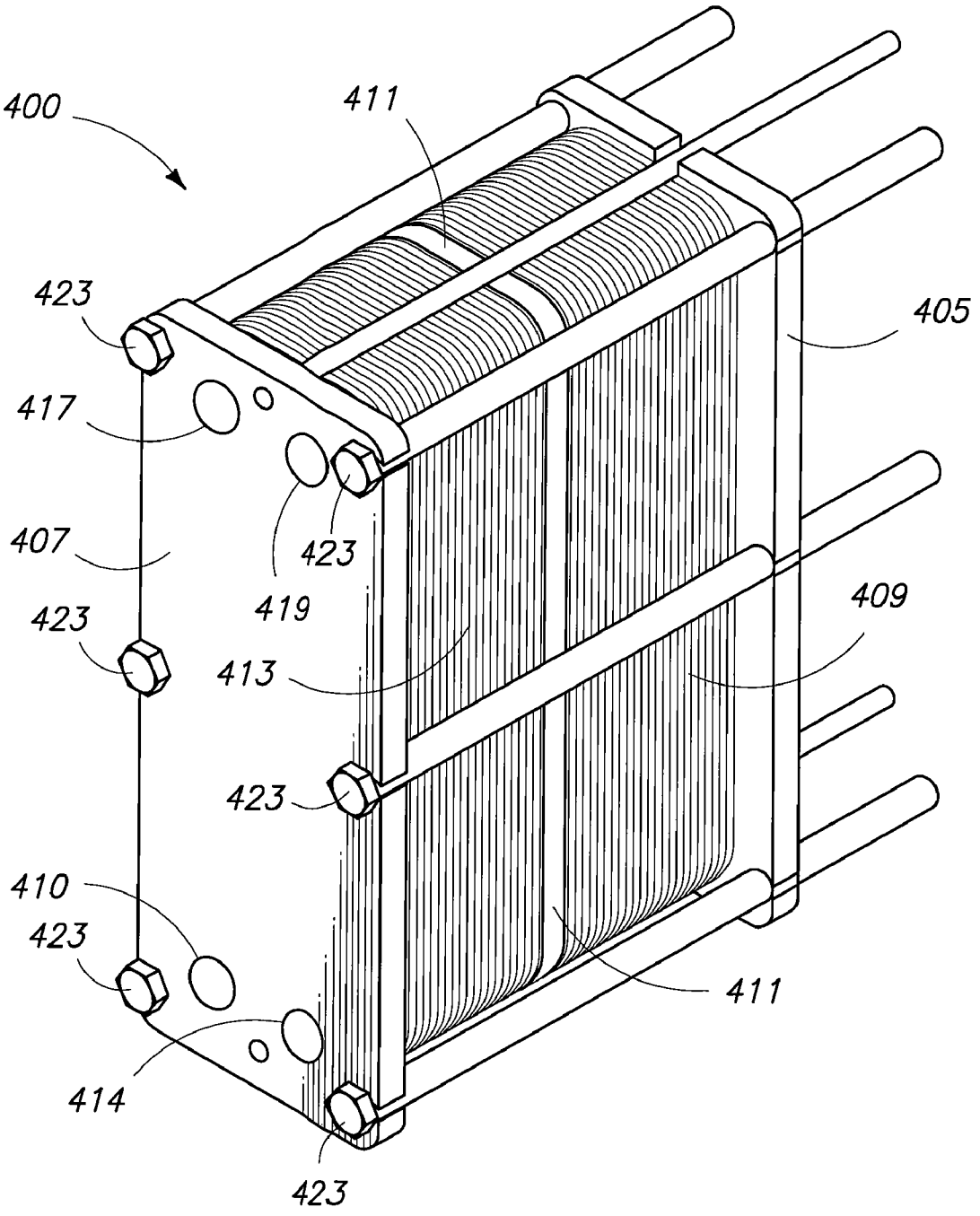

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Fig 15

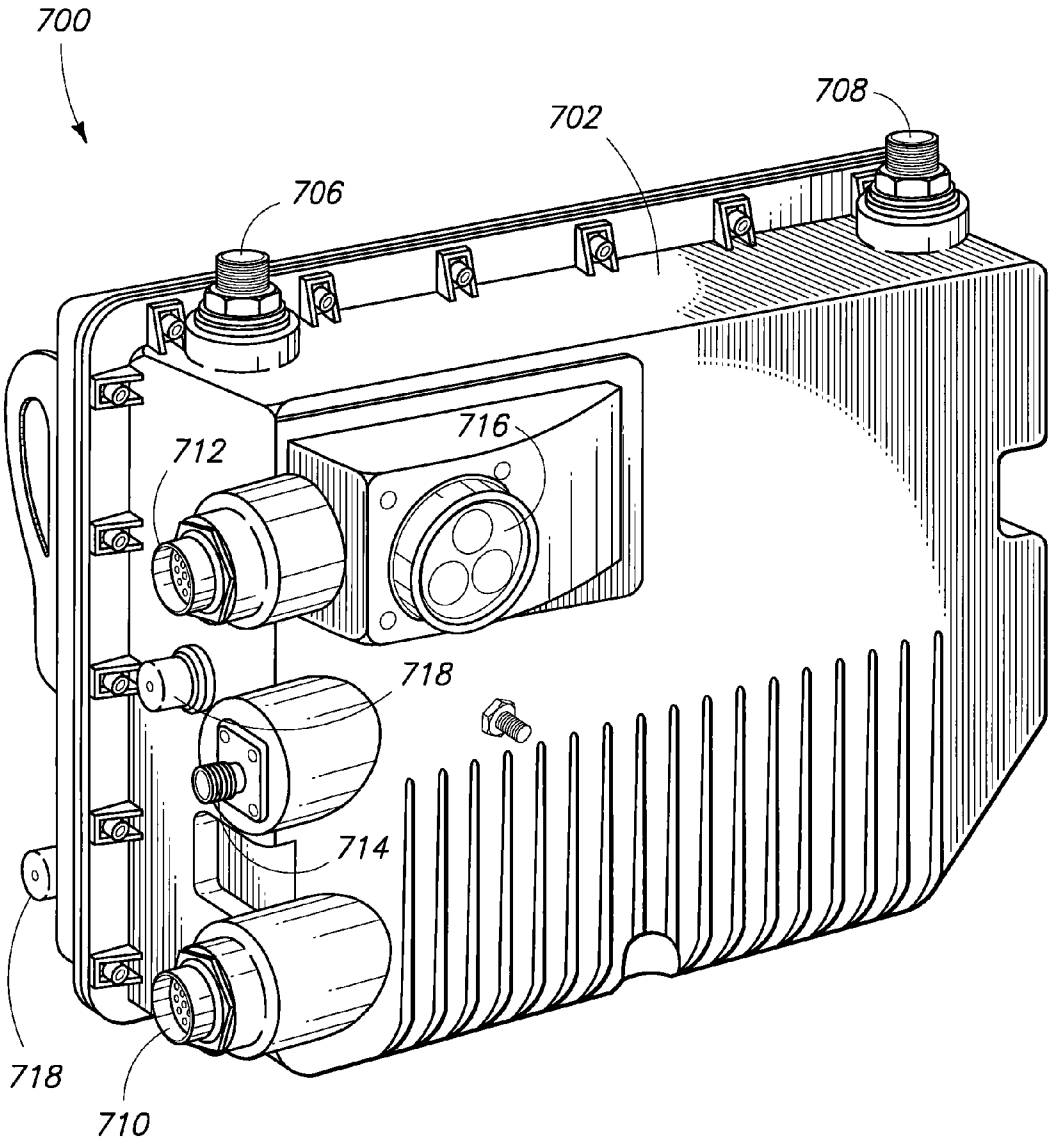


Fig 16

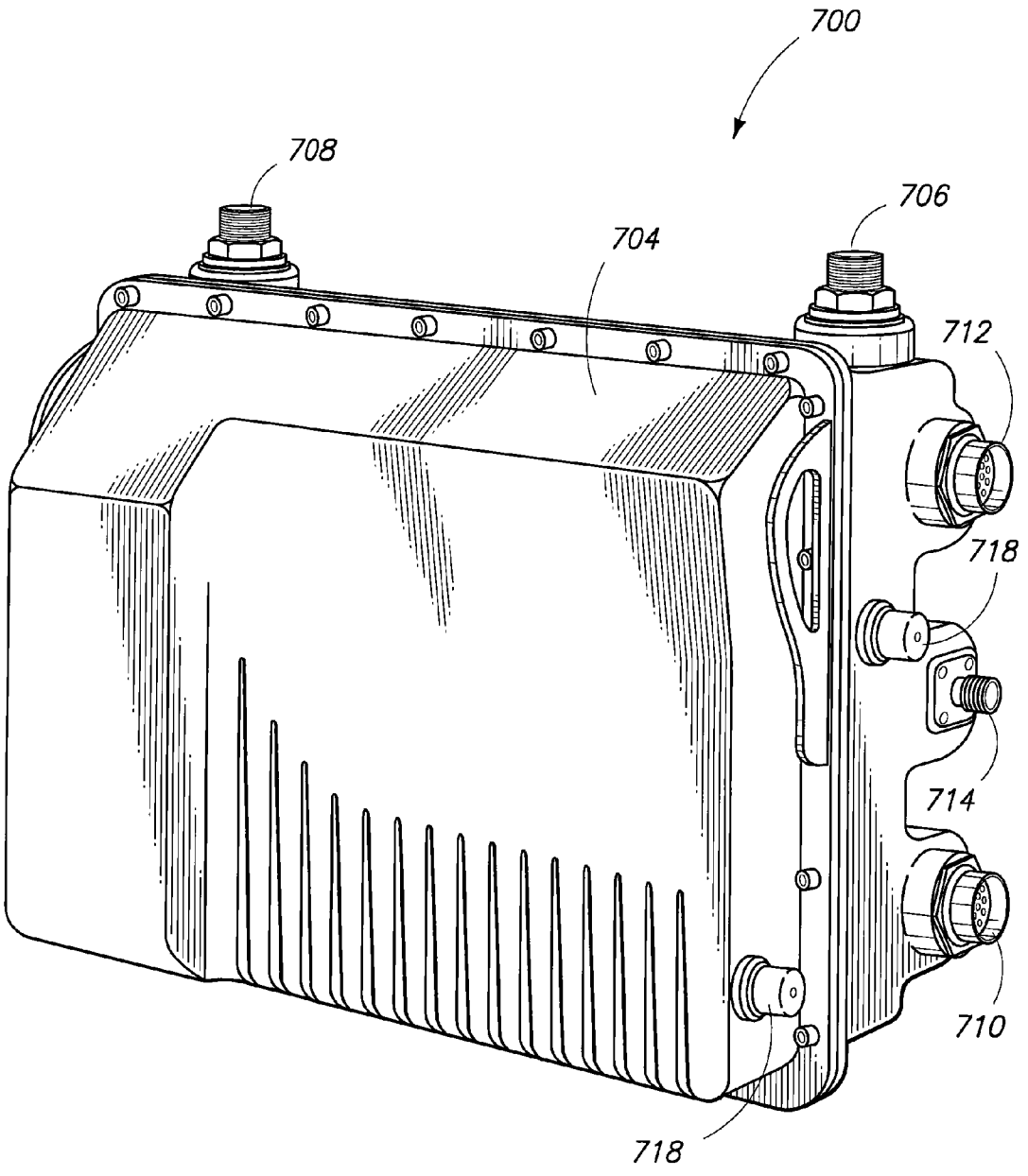


Fig 17

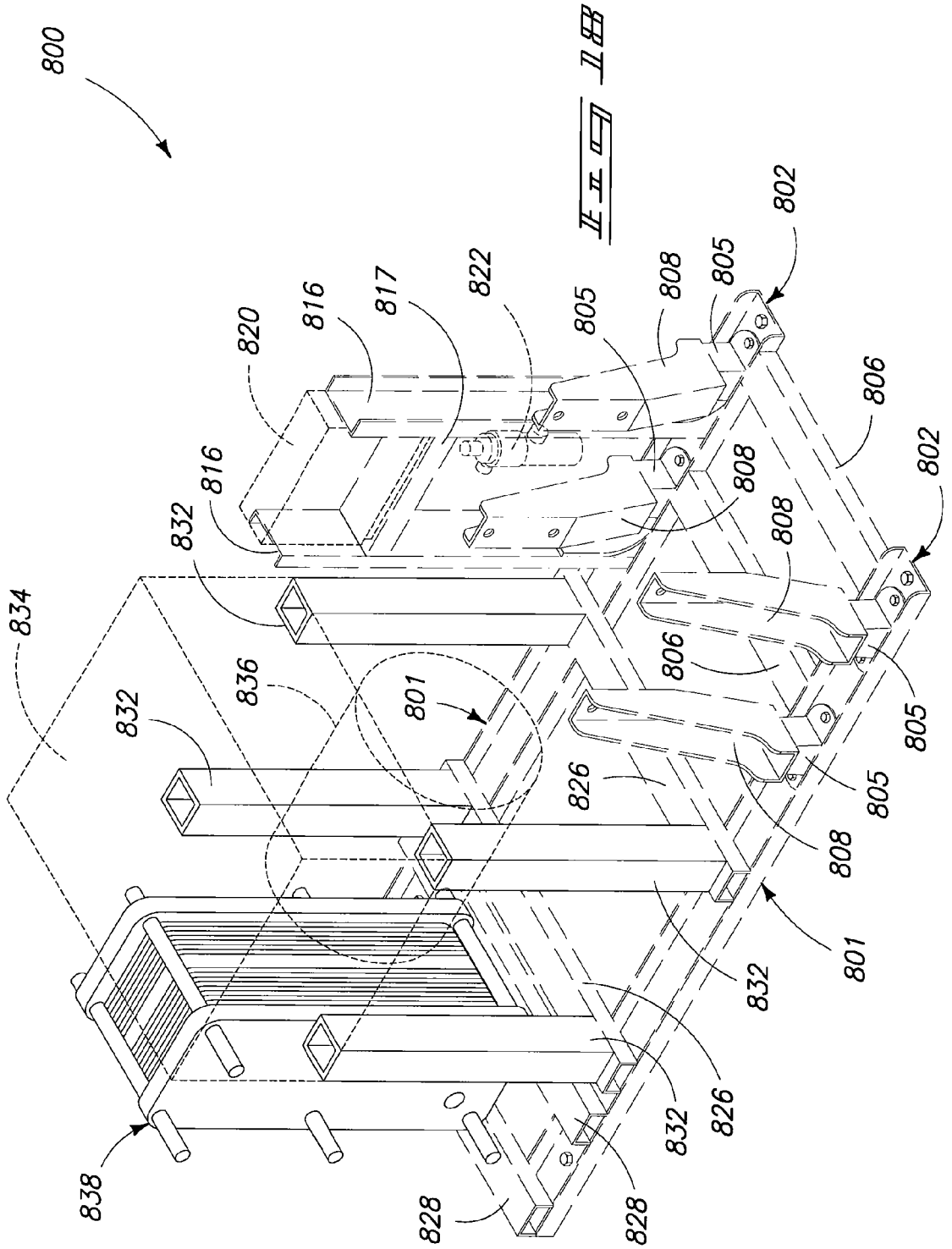


FIG. 11B

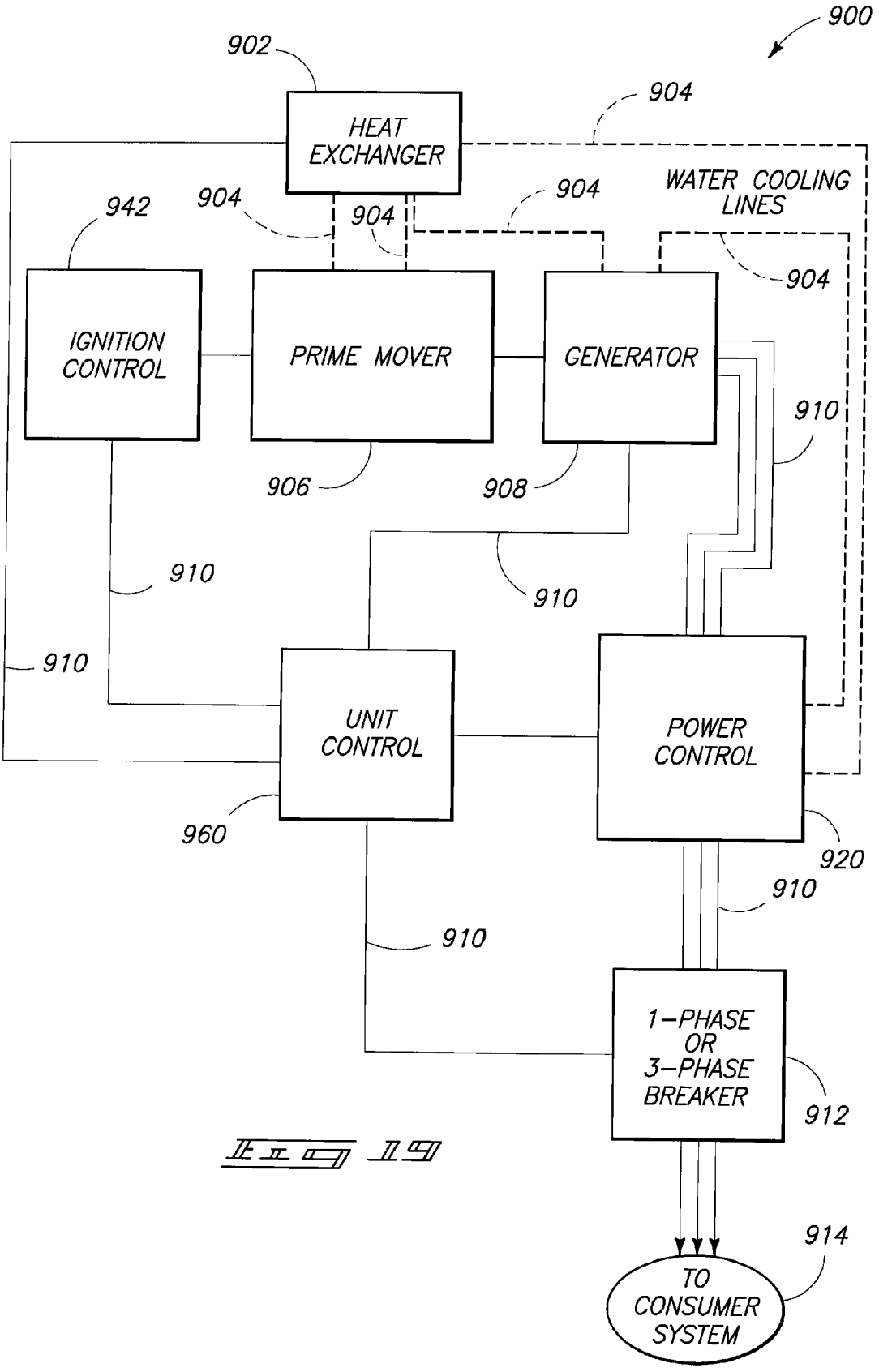

900
902
HEAT EXCHANGER
904
WATER COOLING LINES
942
904
904
904
904
IGNITION CONTROL
PRIME MOVER
GENERATOR
910
906
908
910
910
910
UNIT CONTROL
POWER CONTROL
960
920
910
910
1-PHASE OR 3-PHASE BREAKER
912
914
TO CONSUMER SYSTEM

Fig 19

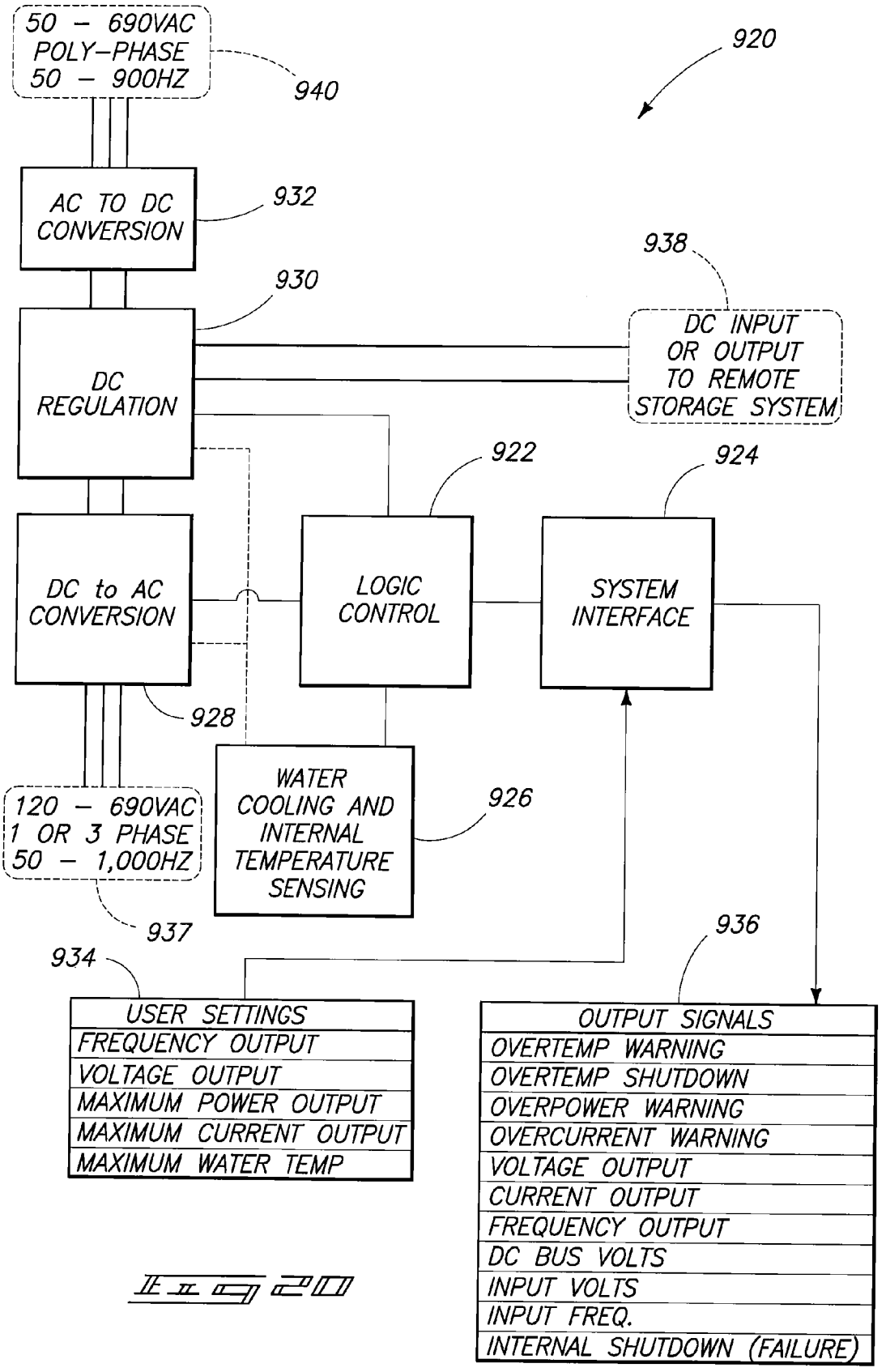

50 – 690VAC
POLY–PHASE
50 – 900HZ
940
920
AC TO DC
CONVERSION
932
938
930
DC INPUT
OR OUTPUT
TO REMOTE
STORAGE SYSTEM
DC
REGULATION
922
924
DC to AC
CONVERSION
LOGIC
CONTROL
SYSTEM
INTERFACE
928
WATER
COOLING AND
INTERNAL
TEMPERATURE
SENSING
926
120 – 690VAC
1 OR 3 PHASE
50 – 1,000HZ
937
936
934
USER SETTINGS
FREQUENCY OUTPUT
VOLTAGE OUTPUT
MAXIMUM POWER OUTPUT
MAXIMUM CURRENT OUTPUT
MAXIMUM WATER TEMP
OUTPUT SIGNALS
OVERTEMP WARNING
OVERTEMP SHUTDOWN
OVERPOWER WARNING
OVERCURRENT WARNING
VOLTAGE OUTPUT
CURRENT OUTPUT
FREQUENCY OUTPUT
DC BUS VOLTS
INPUT VOLTS
INPUT FREQ.
INTERNAL SHUTDOWN (FAILURE)

Fig 20

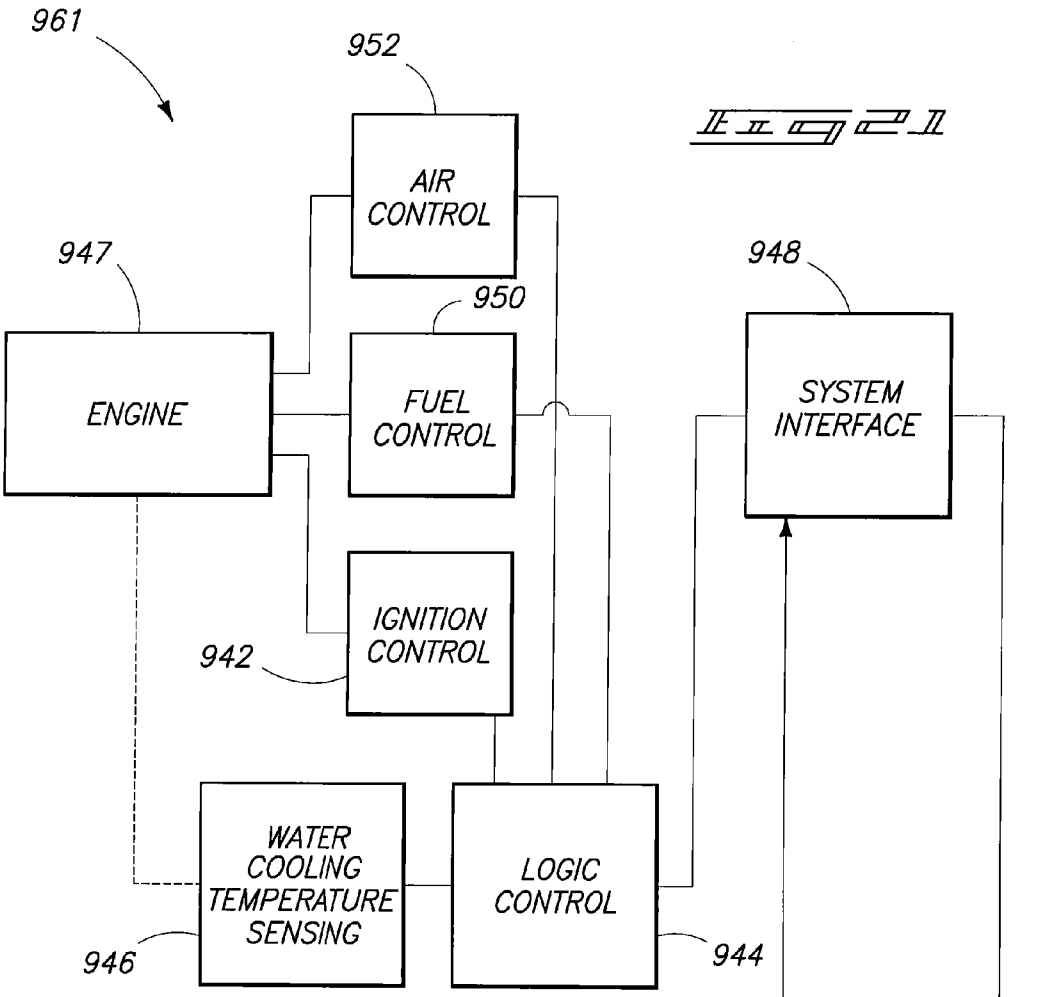


Fig. 21

USER SETTINGS
OPERATING MODE:
– MAXIMUM POWER
– MAXIMUM TORQUE
– MINIMUM FUEL
– MINIMUM EMISSIONS
DESIRED SPEED
TEMPERATURE WARNING LEVEL
TEMPERATURE SHUTDOWN LEVEL
RUN / START CONTACT
(REMOVE TO SLOW DOWN
AND STOP ENGINE)

OUTPUT SIGNALS
OVERTEMP WARNING
OVERTEMP SHUTDOWN
OVERLOAD WARNING
SPEED (RPM)
DELTA RPM
(DESIRED SPEED – ACTUAL SPEED)
ACTUAL ENGINE MODE
(USER SET OPERATING MODE)
FUEL CONTROL STATUS
AIR CONTROL STATUS
IGNITION CONTROL STATUS
INTERNAL SHUTDOWN (FAILURE)

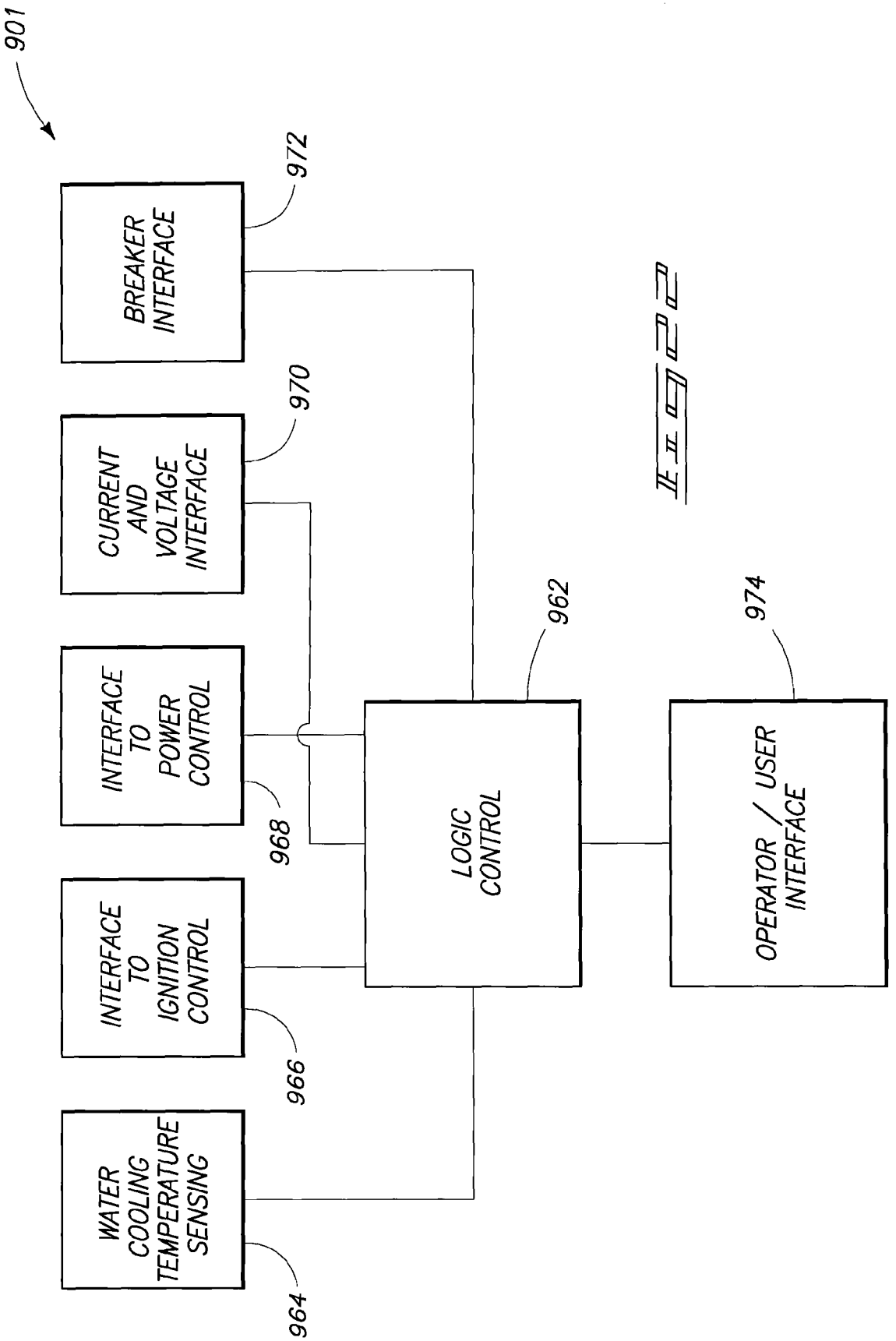
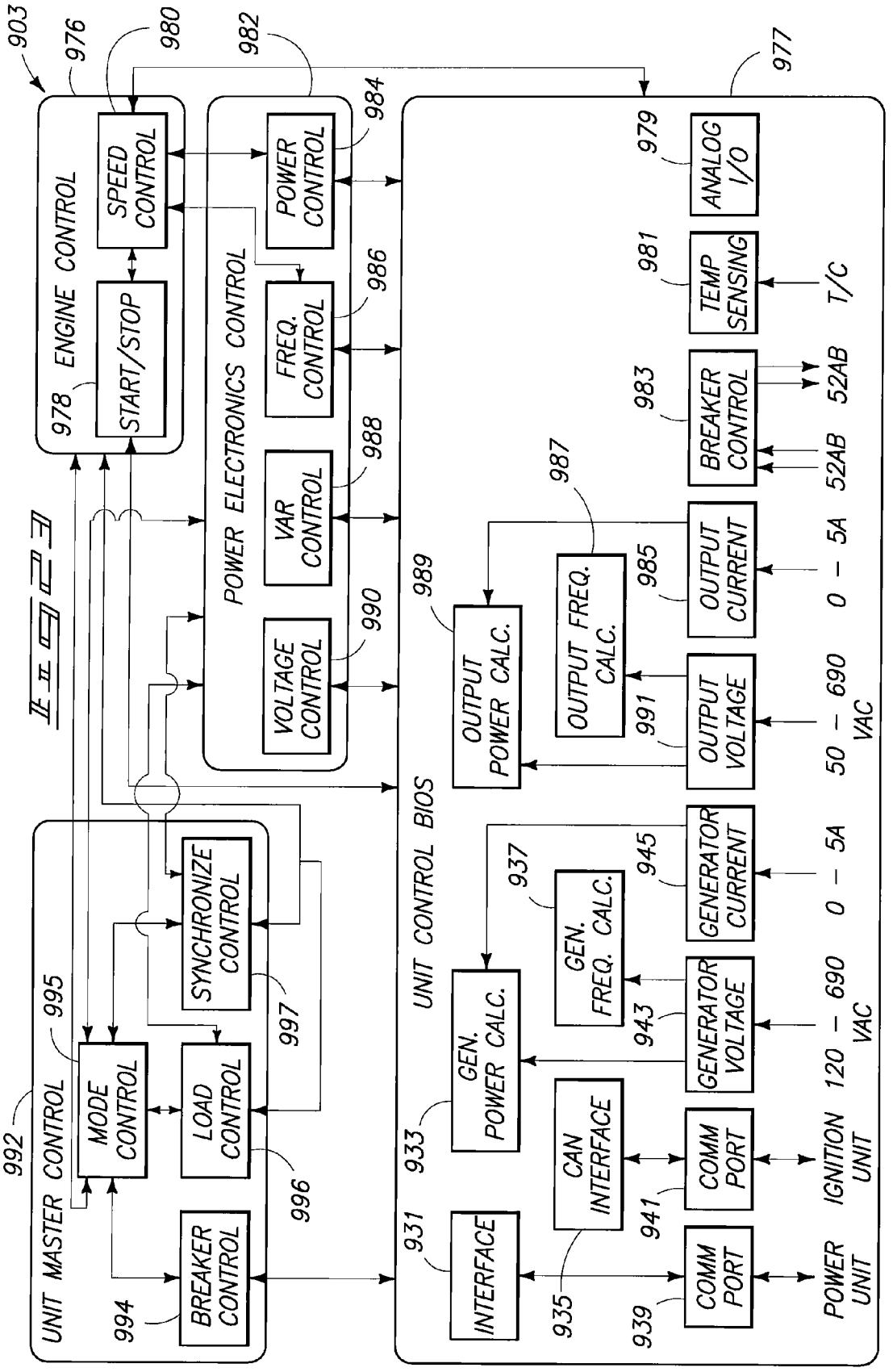

901
BREAKER INTERFACE
972
CURRENT AND VOLTAGE INTERFACE
970
INTERFACE TO POWER CONTROL
968
INTERFACE TO IGNITION CONTROL
966
WATER COOLING TEMPERATURE SENSING
964
LOGIC CONTROL
962
OPERATOR / USER INTERFACE
974

FIG 23


FIG 23
903
976
ENGINE CONTROL
978
START/STOP
SPEED CONTROL
980
982
POWER ELECTRONICS CONTROL
984
POWER CONTROL
986
FREQ. CONTROL
988
VAR CONTROL
990
VOLTAGE CONTROL
977
UNIT CONTROL BIOS
979
ANALOG I/O
981
TEMP SENSING
T/C
983
BREAKER CONTROL
52AB
52AB
987
OUTPUT CURRENT
0 – 5A
985
OUTPUT FREQ. CALC.
989
OUTPUT POWER CALC.
991
OUTPUT VOLTAGE
50 – 690 VAC
945
GENERATOR CURRENT
0 – 5A
937
GEN. FREQ. CALC.
943
GENERATOR VOLTAGE
120 – 690 VAC
933
GEN. POWER CALC.
931
INTERFACE
935
CAN INTERFACE
941
COMM PORT
939
COMM PORT
POWER UNIT
IGNITION UNIT
992
UNIT MASTER CONTROL
995
MODE CONTROL
997
SYNCHRONIZE CONTROL
996
LOAD CONTROL
994
BREAKER CONTROL

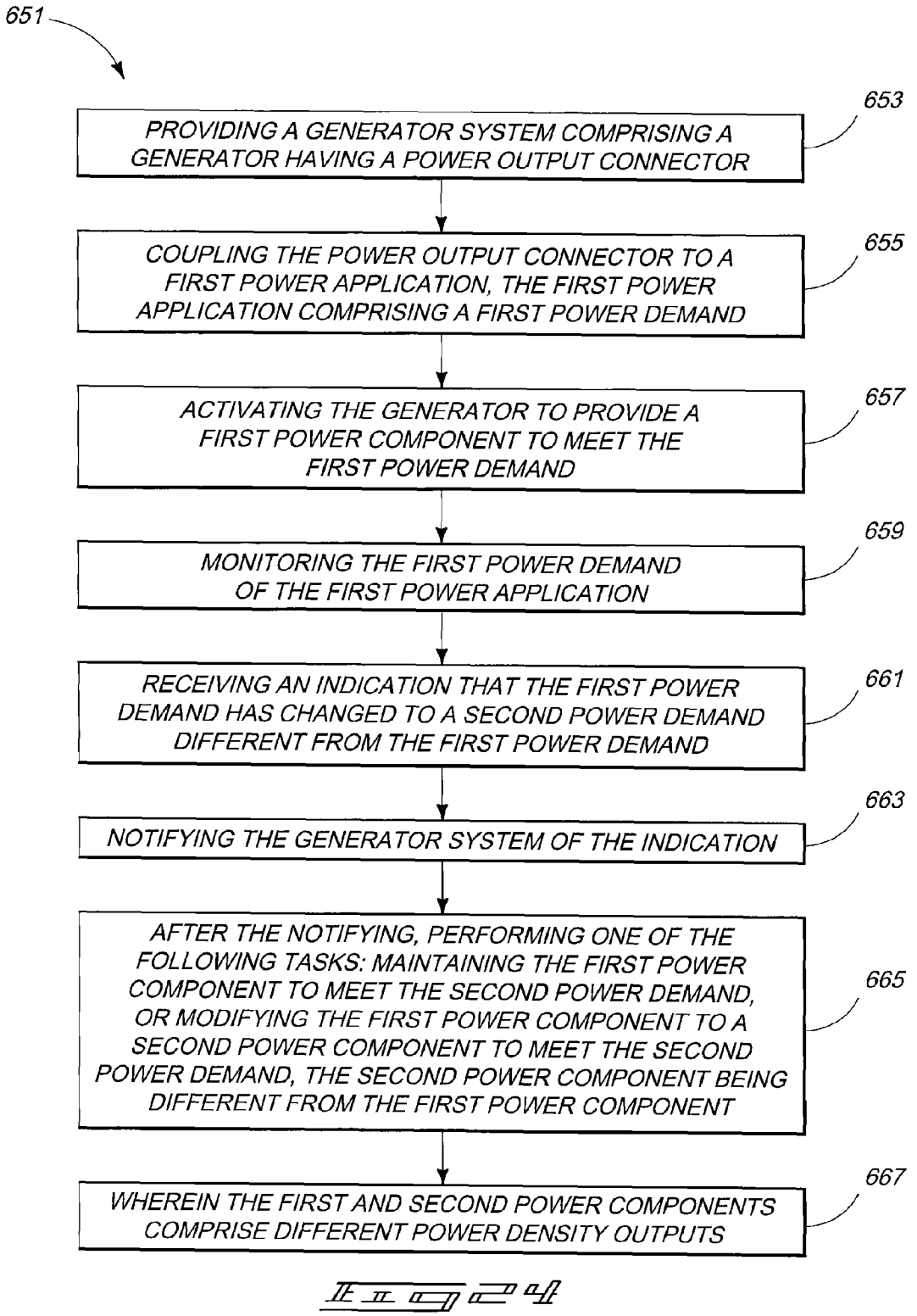

651
PROVIDING A GENERATOR SYSTEM COMPRISING A GENERATOR HAVING A POWER OUTPUT CONNECTOR
653
COUPLING THE POWER OUTPUT CONNECTOR TO A FIRST POWER APPLICATION, THE FIRST POWER APPLICATION COMPRISING A FIRST POWER DEMAND
655
ACTIVATING THE GENERATOR TO PROVIDE A FIRST POWER COMPONENT TO MEET THE FIRST POWER DEMAND
657
MONITORING THE FIRST POWER DEMAND OF THE FIRST POWER APPLICATION
659
RECEIVING AN INDICATION THAT THE FIRST POWER DEMAND HAS CHANGED TO A SECOND POWER DEMAND DIFFERENT FROM THE FIRST POWER DEMAND
661
NOTIFYING THE GENERATOR SYSTEM OF THE INDICATION
663
AFTER THE NOTIFYING, PERFORMING ONE OF THE FOLLOWING TASKS: MAINTAINING THE FIRST POWER COMPONENT TO MEET THE SECOND POWER DEMAND, OR MODIFYING THE FIRST POWER COMPONENT TO A SECOND POWER COMPONENT TO MEET THE SECOND POWER DEMAND, THE SECOND POWER COMPONENT BEING DIFFERENT FROM THE FIRST POWER COMPONENT
665
WHEREIN THE FIRST AND SECOND POWER COMPONENTS COMPRISE DIFFERENT POWER DENSITY OUTPUTS
667

Fig 24

POWER GENERATION SYSTEMS AND METHODS OF GENERATING POWER

CROSS REFERENCE TO RELATED APPLICATION

This patent resulted from a continuation application of U.S. patent application Ser. No. 10/577,577, filed Sep. 21, 2006, which is a 35 U.S.C. §371 application of and claims priority to PCT International Application Number PCT/US04/32857, which was filed Oct. 5, 2004, and was published in English, and which was based on U.S. Provisional Patent Application No. 60/508,857, filed Oct. 6, 2003, and the teachings of all the applications are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to power generation systems and methods of generating power.

BACKGROUND ART

The current products offered by the portable power generation industry are deficient in meeting customer needs. For example, current portable generator sets are limited to single voltages at a designed output frequency, that is, the generator sets operate at fixed revolutions per minute (rpms) which is limiting the usefulness of current portable power generation systems. To handle the needs of customers that operate in a global environment, portable generator sets are either reconfigured after purchase, or multiple portable generator sets are purchased that operate with different respective frequencies and voltages. Portable power generation systems are needed to resolve these issues and more readily meet the needs of customers.

Moreover, the portable power generation industry continues to strive to meet customer demands for products that are light in weight, small in size (including footprint dimensions) and fuel efficient. For example, a conventional generator set (gen set) comprises a longitudinal or length-wise dimension of approximately sixty inches without a heat exchanger and weighs approximately 2,000 pounds.

Furthermore, the portable power generation industry continues to strive to meet the needs of customers that use generators and generator sets as auxiliary power units (APUs). For example, improvements are needed for auxiliary power units used in the trucking business such as the tractor trailer and/or long haul trucking industry. As environmental concerns result in more stringent noise and air emission regulations, truck operators are continually being prevented from operating their engines in more areas, for example, truck stops, loading docks and rest areas due to emission regulations and no-idle laws. This translates into the truck operator being prevented from operating modern conveniences such as an on-board air conditioner, refrigerator, radio and/or television. It also translates into the truck operator not being able to perform business tasks that are work-related which require an on-board computer. Portable power generation systems are needed as solutions to resolve these issues and respond to market and regulatory pressures in the trucking industry. Additionally, the portable power generation industry continues to strive to meet the demands of truck drivers for APUs that ensure that parasitic loads of a truck engine are maintained at a minimum.

Still further, the transportation industry continues to strive to produce fuel efficient and environmentally-friendly vehicles. This motivation as led to alternative power generation designs and technologies for the vehicles, such as electric vehicles and hybrid electric vehicles. These vehicular designs have unique power applications and demands wherein a power plant provides battery charging, power for peak load requirements, absorption of braking energy and power for prime loads. Important design considerations and parameters for the power plants are size and weight because such parameters drive the load and physical size of the vehicle. An additional design consideration should be reflected in a customer's need for systems capable of withstanding exposure of rain, dust or other external environmental conditions. A need exists for power generation systems designed to meet the unique considerations and parameters of electric vehicles and hybrid electric vehicles.

Additionally, conventional motor-generator systems or generator sets are used to transform power and/or isolate power from one source to another. The application typically involves the coupling of an AC motor which is coupled with an AC or DC radial gap generator to create DC power or a different voltage & frequency of AC power. There is a continual need to optimize the size, weight and cost of conventional motor-generator systems. This is especially true for military applications, for example the Navy branch and any industry dealing with boating, which require high tolerance parameters and specifications with regard to cooling, weight and space requirements for power generation. Thermodynamic management in these applications have proven difficult and very expensive. Accordingly, there is a need to provide a motor-generator system or set that resolves these problems of the conventional motor-generator systems.

SUMMARY

In one aspect of the invention, a power generation system is provided that includes an internal combustion engine configured to provide rotational mechanical energy. A generator is configured to receive the rotational mechanical energy and generate electrical power in response to the rotational mechanical energy. A fluid medium is provided to the internal combustion engine and to the generator for removing thermal energy from the internal combustion engine and from the generator.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

FIG. **1** is a block diagram of an exemplary power generation system according to embodiments of the invention.

FIG. **2** is a block diagram of an exemplary power generation system according to other embodiments of the invention.

FIG. **3** is a side elevational view of an exemplary power generation system according to an embodiment of the invention.

FIG. **4** is the FIG. **3** view emphasizing components of the exemplary power generation system.

FIG. **5** is an elevational front view of the FIG. **3** power generation system.

FIG. **6** is the FIG. **5** view emphasizing components of the exemplary power generation system.

FIG. **7** is a side elevational view of the FIG. **3** power generation system illustrating a side view opposite the FIG. **3** side view.

FIG. **8** is the FIG. **7** view emphasizing components of the exemplary power generation system.

FIG. **9** is a top plan view of the FIG. **3** power generation system.

FIG. **10** is the FIG. **9** view emphasizing components of the exemplary power generation system.

FIG. **11** is an elevational back view of the FIG. **3** power generation system.

FIG. **12** is a perspective view of an exemplary flywheel according to an embodiment of the invention.

FIG. **13** is a perspective view of an exemplary generator according to an embodiment of the invention.

FIG. **14** is a sectional view of the FIG. **13** generator.

FIG. **15** is a perspective view of an exemplary heat exchanger according to an embodiment of the invention.

FIG. **16** is a perspective side view of an exemplary power electronics device according to an embodiment of the invention.

FIG. **17** is a perspective side view of the FIG. **16** power electronics device illustrating a side view opposite the side view of FIG. **16**.

FIG. **18** is a perspective view of an exemplary support structure according to an embodiment of the invention.

FIG. **19** is a block diagram of the exemplary components monitored by an exemplary package control unit (also referred to as unit control) according to embodiments of the invention.

FIG. **20** is a block diagram of the exemplary components monitored by an exemplary power control (also referred to as power electronics device) according to embodiments of the invention.

FIG. **21** is a block diagram of an exemplary ignition control according to embodiments of the invention.

FIG. **22** is a block diagram of an exemplary Unit Control/Logic Control according to embodiments of the invention.

FIG. **23** is a block diagram of an other exemplary Unit Control/Logic Control according to embodiments of the invention.

FIG. **24** is a block diagram of an exemplary method for generating power according to one of various embodiments of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. **1**, an overview of an exemplary embodiment of a power generation system **10** according to the invention is illustrated as a block diagram. An exemplary power generation system **10** includes a system for a generator and/or a generator set. In one exemplary embodiment of the power generation system **10**, a rotational power source **20** has an output in the form of rotational mechanical energy provided by an output shaft **22** which rotates having a rotational speed in revolutions per minute (rpm). The rotational mechanical energy of rotating output shaft **22** is transferred to a generator **24** which converts the rotational mechanical energy of rotating output shaft **22** into electrical energy and thermal energy (i.e., electricity and heat, respectively). Electrical output of the generator **24** is in relation to the speed of the output shaft **22** of the rotational power source **20**. Energy loss in the form of heat is incurred in the process of converting rotational mechanical energy into electrical energy. In one exemplary embodiment of system **10**, generator **24** is coupled in fluid communication with a heat exchanger **26** wherein at least a portion of the thermal energy (i.e., heat) produced in generator **24** is transferred to a fluid medium, for example, air and/or a liquid which is provided to generator **24** via a fluid conduit (shown subsequently), for example, a hose or pipe between the generator **24** and heat exchanger. Additionally, portions of heat are transferred to outside surfaces of generator **24** from which the heat is transferred to the surrounding air or environment. In some embodiments, the power generation system includes a heat exchanger **26**. In some embodiments, heat exchanger **26** or cooler is included within an array or network of heat exchanger units. An exemplary array or network is coupled in heat exchanging relation to fluid using a fluid conduit, for example, a hose or tube.

Still referring to FIG. **1**, the generator **24** is coupled, using interface **32**, with a power electronics device **28**, or power conversion device. Electricity produced by the generator **24** is transferred to the power electronics device **28** to be converted into a form desired by the operator of the power generation system **10**. In one embodiment of system **10**, thermal energy generated by a power electronics device **28** is at least partially removed by a fluid, for example, by air and/or a liquid. In some embodiments of system **10**, thermal energy generated by a power electronics device **28** is at least partially removed by a liquid. The power electronics device **28** comprises a heat exchanger **30** coupled in fluid communication with a heat exchanger **30** by a liquid cooling circuit (illustrated more thoroughly subsequently). Heat produced in the process of converting the generated electricity into a form that is selected by the operator is transferred to the liquid cooling circuit from the power electronics device **28** and to a heat exchanger **30**. Heat from the heat exchanger **30** is transferred to the environment and/or another medium. In some embodiments of system **10**, the heat exchanger **30** comprises an independent unit. In other embodiments of system **10**, the heat exchanger **30** is combined within a network of at least one other heat exchanger unit, for example, a network that includes heat exchanger **26**. A power electronics device **28** is capable of power conversions or signal conversions from an input source to an output source, for example, from AC to DC, DC to AC, and AC to AC. The power electronics device **28** is capable of one or a multiple of the aforementioned conversions. In some embodiments of power generation system **10**, an operator is able to configure, reconfigure and/or modify the power electronics device **28** such that output current, frequency, voltage and/or polarity are selectable.

Still referring to FIG. **1**, the power electronics device **28** is coupled to output connection(s) **36**. Converted electricity having the selected output current, frequency, voltage and/or polarity is transferred to the output connection(s) **36**. In some embodiments, the output connection **36** is an integral component of the power electronics device **28**. In other embodiments, the output connection **36** comprises a stand-alone component connected to the power electronics device **28** by an interface **34**. The output connection **36** provides an interface between the power generation system **10** and an electrical load (not shown).

Still referring to FIG. **1**, an exemplary power generation system **10** comprises a control unit **38** that monitors the respective components and devices discussed previously, for example, rotational power source **20**, generator **24**, power electronics device **28** and output connection **36**, respectively. An array **40** of data conduits are coupled between the package control unit **38** and the respective devices to communicate input and output data between the respective devices. The exemplary control unit **38** has the capability to perform one or more of the following functions: monitor the power generation system **10**, diagnose problems within the power generation system **10**, control components of the power generation system **10**, annunciate status of components of the power generation system **10**, and supervise the power generation

system **10**. In some embodiments, the package control unit **38** may also function as an interface for local and/or remote monitoring and control.

It should be understood that various combinations of devices (e.g., rotational power source **20**, generator **24**, power electronics device **28** and output connection **36**, respectively) can be coupled in fluid communication to various combinations of heat exchangers. For example, a power generation system **10** can comprise a single heat exchanger standing alone and coupled in fluid communication with a single device **20**, **24**, **28**, **36**. That is, a single heat exchanger can be coupled to a single device **20**, **24**, **28**, **36**. Alternatively, one or more heat exchangers can be coupled to a single device. For example, two or more heat exchangers can be coupled in fluid communication with generator **24**, and the combination of heat exchangers can be in fluid communication with one another, or not in fluid communication with one another. Alternatively, one or more devices can be coupled to a single heat exchanger. For example, two or more devices, for example, rotational power source **20** and generator **24**, can be coupled in fluid communication with a single heat exchanger **26**, and the combination of devices can be in fluid communication with one another, or not in fluid communication with one another. Moreover, an exemplary power generation system **10** can include a single device **20**, **24**, **28**, **36** coupled to a single heat exchanger and include another single device coupled to a plurality of heat exchangers. Additionally, an exemplary power generation system **10** can include a single device coupled to a single heat exchanger and include another single heat exchanger coupled to a plurality of devices. Furthermore, an exemplary power generation system **10** can include any combination of the examples presented above. For example, an exemplary power generation system **10** can include a plurality of devices coupled to a single heat exchanger or a plurality of heat exchangers; and include another single device coupled to another single heat exchanger; and include a plurality of heat exchangers coupled to another single device or coupled to another plurality of heat exchangers; and added to this exemplary power generation system **10** can include any additional combination of devices coupled to additional combination of heat exchangers.

Referring to FIG. **2**, an overview of another exemplary embodiment of a power generation system **60** is illustrated as a block diagram. Power generation system **60** includes a system for a generator and/or a generator set. In one exemplary embodiment of the power generation system **60**, a fuel supply **62** provides chemical energy to a rotational power source **64** via a fuel conduit **66**. In some embodiments, fuel supply **62** is cooled by a fluid, for example, a liquid. In these embodiments, fuel supply **62** is coupled, for example, in fluid communication to a heat exchanger **68** to at least partially remove thermal energy from the fuel supply **62**. An exemplary heat exchanger **68** defines an independent component of power generation system **60**. In another embodiment, heat exchanger **68** is combined within a network of at least one other heat exchanger units. Rotational power source **64** comprises an output shaft **70** and converts chemical energy from fuel supply **62** into rotational mechanical energy at the output shaft **70**. Rotational power source **64** is coupled in fluid communication with a heat exchanger **72**. At least a portion of heat generated in converting chemical energy to rotating mechanical energy is transferred to a fluid medium, for example, a liquid provided to the rotational power source **64** via a cooling circuit. An exemplary heat exchanger **72** defines an independent component of power generation system **60**. In other embodiments, heat exchanger **72** is combined within a network of at least one other heat exchanger unit, for example, heat exchanger **68**.

Still referring to FIG. **2**, the rotating output shaft **70** of rotational power source **64** is coupled to a gearbox **74** to transfer rotating mechanical energy from the rotational power source **64** to the gearbox **74**. The gearbox **74** comprises an output shaft or drive shaft **78** that is coupled to a generator **76**. The shaft **78** transfers rotational mechanical energy of output shaft **70** from rotational power source **64** to the drive shaft **78** which drives generator **76**. An exemplary gearbox **74** is configured to selectively increase or decrease the rotating speed of output shaft **70** of rotational power source **64** which corresponds to selectively increasing or decreasing the rotating speed of drive shaft **78** which corresponds to selectively increasing or decreasing the rotating speed of generator **76**. Such exemplary selectivity of gearbox **74** ensures generator **76** operates at an optimal speed. Thermal energy is generated within the gearbox **74** during the conversion of increasing or decreasing rotational speed of the output shaft **70** to drive shaft **78**. In one exemplary embodiment, drive shaft **78** is coupled in fluid communication with a heat exchanger **80** wherein at least a portion of heat generated in converting the rotating mechanical energy of respective shafts **70** and **78** is transferred to a fluid medium, for example, air and/or a liquid which is provided to the gearbox **74** via a conduit, for example, a hose or pipe (shown subsequently). An exemplary heat exchanger **80** defines an independent component of power generation system **60**. In other embodiments, heat exchanger **80** is combined within an array or network of at least one other heat exchanger unit, for example, with heat exchanger **68** or with heat exchanger **72**, or with both. An exemplary array or network is coupled in fluid communication by an exemplary conduit, for example, a hose or tube.

The generator **76** converts rotating mechanical energy into electrical energy and thermal energy (i.e., electricity and heat). In one exemplary embodiment, generator **76** is coupled in fluid communication with a heat exchanger **82** wherein at least a portion of heat generated in the process of converting mechanical energy into electricity is transferred to a fluid medium, for example, air and/or a liquid which is provided to the generator **76** via a conduit, for example, a hose or pipe (shown subsequently). An exemplary heat exchanger **82** defines an independent component of power generation system **60**. In another embodiment, heat exchanger **82** is combined within an array or network of at least one other heat exchanger unit, for example, with heat exchanger **68** or with heat exchanger **72**, or with both. An exemplary array or network is coupled in fluid communication by an exemplary conduit, for example, a hose or tube.

Electricity produced by the generator **76** is transferred to a power electronics device or power conversion device **84**. Electricity produced by the generator **76** is transferred to the power electronics device **84** to be converted into one or more forms as desired by the operator of the power generation system **60**. In one exemplary embodiment, power electronics device **84** is coupled in fluid communication with a heat exchanger **86** wherein at least a portion of heat generated in the process of converting one form of electricity to another form of electricity is transferred to a fluid medium, for example, air and/or a liquid which is provided to the power electronics device **84** via a conduit, for example, a hose or pipe (shown subsequently). An exemplary heat exchanger **86** defines an independent component of power generation system **60**. In another embodiment, heat exchanger **86** is combined within an array or network of at least one or more heat exchanger units, for example, with heat exchanger **68**, **72**, **80**,

and/or **82**, singularly or in any combination thereof. An exemplary array or network is coupled in fluid communication by an exemplary conduit, for example, a hose or tube. In an exemplary embodiment, the power electronics device **84** has the capability to interface with a secondary power source **100**. The secondary power source **100** is capable of providing a secondary power input to the power electronics device **84** via an interface and/or receiving power from the power electronics device **84** for distribution or storage. Exemplary devices for exemplary secondary power source **100** include another generator, utility feed, flywheel energy storage device, batteries, capacitors (super) or other energy sources. An exemplary power electronics device **84** will manage various combinations of electrical current for example:

Primary input	Secondary input	Output
AC	—	AC*
AC	AC	AC*
AC	DC	AC*
AC		DC*
AC	AC	DC*
AC	DC	AC*
DC		AC*
DC	AC	AC*
DC	DC	AC*
DC		AC*
DC	AC	DC*
DC	DC	DC*

*Capable of one or a multiple of the outputs.

An exemplary power electronics device **84** provides an output that is frequency selectable, voltage selectable, and polarity selectable. An exemplary power electronics device **84** provides an output that includes digital grade power. An exemplary power generation system **60** comprises an output of the power electronics device **84** that is transferred to transformer **88** via an interface. An exemplary power generation system **60** comprises an exemplary transformer **88** coupled to a distribution panel **94** via an interface **92** wherein the distribution panel **94** is coupled to power loads to be used by a consumer. In one exemplary embodiment, an exemplary transformer **88** is coupled in fluid communication with a heat exchanger **90** wherein at least a portion of heat generated in the transformer **88** is transferred to a fluid medium, for example, air and/or a liquid which is provided to the transformer **88** via a conduit, for example, a hose or pipe (shown subsequently). An exemplary heat exchanger **90** defines an independent component of power generation system **60**. In another embodiment, heat exchanger **90** is combined within an array or network of at least one or more heat exchanger units, for example, with heat exchanger **68**, **72**, **80**, **82** and/or **86**, singularly or in any combination thereof. An exemplary array or network is coupled in fluid communication by an exemplary conduit, for example, a hose or tube.

Still referring to FIG. **2**, power generation system **60** comprises a package control unit **96** that monitors the respective components and devices discussed previously, for example, fuel supply **62**, rotational power source **64**, gearbox **74**, generator **76**, power electronics device **84**, transformer **88** and distribution panel **94**, respectively. An array **98** of data conduits are coupled from the power electronics device **84** to the respective devices to communicate input and output data between the respective devices and the power electronics device **84**. The exemplary package control unit **96** has the capability to perform one or more of the following: monitor components of the power generation system **60**, diagnose problems with components of the power generation system **60**, control components of the power generation system **60**, annunciate status information relating to components of the power generation system, and supervise the power generation system **60**. In another exemplary embodiment, the package control unit **96** may also function as an interface for local and/or remote monitoring and control.

It should be understood that the plurality of various combinations of devices (e.g., fuel supply **62**, rotational power source **64**, gearbox **74**, generator **76**, power electronics device **84**, transformer **88**, respectively) can be coupled in fluid communication to the following plurality of various combinations of heat exchangers for an exemplary power generation system **60**. For example, an exemplary power generation system **60** can comprise a single heat exchanger standing alone and coupled in fluid communication with a single device. That is, a single heat exchanger can be coupled to a single device. Alternatively, one or more heat exchangers can be coupled to a single device. For example, two or more heat exchangers can be coupled in fluid communication with generator **76**, and the combination of heat exchangers can be in fluid communication with one another, or not in fluid communication with one another. Alternatively, one or more devices can be coupled to a single heat exchanger. For example, two or more devices, for example, rotational power source **64** and generator **76**, can be coupled in fluid communication with a single heat exchanger, and the combination of devices can be in fluid communication with one another, or not in fluid communication with one another. Moreover, an exemplary power generation system **60** can include a single device coupled to a single heat exchanger and include another single device coupled to a plurality of heat exchangers. Additionally, an exemplary power generation system **60** can include a single device coupled to a single heat exchanger and include another single heat exchanger coupled to a plurality of devices. Furthermore, an exemplary power generation system **60** can include any combination of the examples presented above. For example, an exemplary power generation system **60** can include a plurality of devices coupled to a single heat exchanger or a plurality of heat exchangers; and include another single device coupled to another single heat exchanger; and include a plurality of heat exchangers coupled to another single device or coupled to another plurality of heat exchangers; and added to this exemplary power generation system **60** can include any additional combination of devices coupled to additional combination of heat exchangers.

Referring to FIGS. **3-11**, an exemplary embodiment of a power generation system **200** is illustrated Components of an exemplary embodiment of a power generation system **200** are illustrated in FIGS. **12-18**. It should be understood that power generation system **200** can be used for the power generation systems discussed above with respect to FIGS. **1** and **2**. It should also be understood that the specific components of FIGS. **12-18** and schematics presented in FIGS. **20-24** can be used for the power generation systems discussed above with respect to FIGS. **1-2** and power generation system **200**. It should be understood that FIG. **19** illustrates another exemplary power generation system **840** that can be used for the power generation systems discussed above with respect to FIGS. **1** and **2**, and include the specific components of FIGS. **12-18** and include the schematics presented in FIGS. **20-24**.

Power generation system **200** comprises a rotational power source **208**, for example, an internal combustion engine, such as a gasoline engine or a diesel engine. In one exemplary embodiment, the rotational power source comprises a diesel engine **208**. An exemplary diesel engine **208** is designed with an optimal gear train (not shown) within the engine by having

a front gear train of two high-contact-ratio gears mounted to the engine block and has the added benefit of low noise characteristics. An exemplary diesel engine **208** includes a fuel system that has mechanically governed unit pumps (not shown) mounted inside the engine block which eliminates external high-pressure lines, minimizes leak paths and reduces noise levels. This fuel system contributes to cost effectiveness and clean design. One example of a diesel engine that could be employed for the diesel engine **208** is an industrial engine that is commercially available from John Deere as model 4024T 66 hp Diesel Engine (www.deere-.com).

The diesel engine **208** has an output providing rotational mechanical energy in the form of an output shaft (not shown) which is rotatable and is coupled to a rotational coupling device which couples engine **208** to a generator (only generator housing **360** shown in FIG. **3**). An exemplary rotational coupling device comprises a flywheel which provides the rotational mechanical energy of rotating output shaft to the generator for conversion into electrical and thermal energy (i.e., electricity and heat, respectively). An example of a flywheel that could be employed for the flywheel **600** illustrated in FIG. **13** (only flywheel housing **340** is shown in FIG. **3**) is commercially available from ARCUSAFLEX® Flywheel Couplings as model Ringfeder Arcusaflex Coupling (www.ringfeder.com).

Referring to FIG. **12**, an exemplary flywheel **600** comprises a coupling ring **602** which forms a cylindrical opening **604** to receive the shaft of the generator which provides the coupling of the flywheel **600** to the generator. In one embodiment, an exemplary flywheel **600** comprises a rubber disk component **606** which permits the shaft of the generator to be provided at angular, axial and parallel misalignments and also dampens vibrations.

Referring to FIGS. **13-14**, an exemplary generator **640** is illustrated (only generator housing **360** is shown in FIG. **3**) and comprises a flange portion **642** for securing generator **640** to a structure or component of power generation system **200** (FIG. **3**). An exemplary generator **640** comprises a housing **644** integral with flange portion **642** for protecting and enclosing the internal structure and components **648** of generator **640**. Referring to FIG. **3**, an exemplary generator housing **360** seals and protects generator **640** from the environment and can withstand water and sand exposure. An example of a generator that could be employed for the generator **640** is commercially available by TM4 Energy as model TM4 40 kw generator.

Referring to FIG. **3**, an exemplary power electronics device **300** is illustrated positioned elevationally above generator housing **360**. It should be understood that power electronics device **300** could be positioned in any location relative the other components of power generation system **200**. Power electronics device **300** comprises an array **302** of output connections **308**. Output connections **308** comprise electrical ports to be used by the consumer for connection to loads permitting the consumer to use the electrical energy produced by the generator. An exemplary power electronics device **300** is a power conversion device that converts the output of the generator (AC or DC) into a useable voltage (AC or DC) and frequency (50 Hz, 60 Hz, etc.). The exemplary power electronics device **300** is sealed from the environment and can withstand water immersion and survive up to 50 g repetitive shock (vibration) loads. Components of the power electronics device **300** are mounted on a hollow plate wherein fluid (coolant) from an heat exchanger passes through the hollow portion of the plate to remove heat from the power electronics device **300** generated in the power conversion process (loss due to inefficiencies). In one embodiment, the power electronics device **300** is integrated into the generator housing **360**, or be an independent component that is mounted on the frame (discussed more thoroughly subsequently). An exemplary power electronics device **300** comprises a size that ranges from five times to ten times less than the size of a conventional power electronics device.

Referring to FIGS. **16-17**, an exemplary power electronics device **700** is illustrated in more detail. Power electronics device **700** comprises cooling ports **706** and **708** for coupling to an exemplary heat exchanger for fluid transport. Power electronics device **700** further comprises electrical connections/ports **716** and communication ports **710** and **712**. An exemplary power electronics device **700** comprises a resistance temperature device (RTD) **714** and center-of-gravity mounts **718** to impede shock and vibrations to the power electronics device **700**. Housing portions **702** and **704** protect and enclose structure within power electronics device **700**. An example of a power electronics device that could be employed for the power electronics device **700** is commercially available from Rockwell Automation as model LiquiFlo ProPulse Power Module.

Referring to FIGS. **7-8**, an exemplary power generation system **200** includes a package control unit **500** illustrated as being positioned adjacent engine **208** and includes a display window **502**. It should be understood that package control unit **500** could be positioned in any location relative the other components of power generation system **200**. An exemplary package control unit collects, shares and transmits pertinent information between specific system components of power generation system **200** to effectively manage and optimize the collective cooperation between the components of the power generation system **200**. For example, with respect to the engine, an exemplary package control unit **500** will monitor engine output (hp, torque, speed), battery voltage, engine temperature, exhaust temperature and engine oil temperature. With respect to the generator, an exemplary package control unit **500** will monitor the generator output and the temperature of the fluid (coolant) within the generator from the heat exchanger. With respect to the power electronics device, an exemplary package control unit **500** will monitor the temperature of the fluid (coolant) within the power electronics device, and monitor the electrical input to and output from the power electronics device.

With respect to the heat exchanger, an exemplary package control unit **500** will monitor two components (discussed more thoroughly below) of the heat exchanger, a hot circuit and a cold circuit. The hot circuit has two components which is represented here as hot circuit #**1** and hot circuit #**2**, and the cold circuit has one component. The exemplary package control unit **500** will monitor inlet and outlet temperatures of the cold circuit and monitor the inlet and outlet temperatures of the hot circuit #**1** and hot circuit #**2**, respectively. An example of a package control unit that could be employed for the package control unit **500** is commercially available from Woodward as model easY™gen generator set control model "1500".

Referring to FIG. **3**, an exemplary heat exchanger **400** is illustrated positioned at an end of the power generation system **200** opposite engine **208**. It should be understood that the heat exchanger could be positioned in any location relative the other components of power generation system **200**. An example of a heat exchanger comprises a plate and frame design and is commercially available by Sondex as model Jernet 9 (www.sondexuk.com/gasketed). This plate and frame design of the exemplary heat exchanger comprises two fluids that pass in opposite directions up and down alternative

channels formed in exemplary pressed plate packs **409** and **413** discussed more thoroughly below.

Referring to FIG. **15**, in one exemplary embodiment, the heat exchanger **400** comprises frame side structures **405** and **407** secured on opposite sides of the respective plate packs **409** and **413** by, for example, clamping bolts **423**. Exemplary frame side structures **405** and **407** comprise metal and exemplary plate packs **409** and **413** comprise metal. Plate packs **409** and **413** are divided by a center frame structure **411** which comprises, for example, a metal plate. Each frame side structure defines openings which function as inlets and outlets, for example, openings **410**, **414**, **417**, **419** defined by frame side **407**.

In some embodiments, the plate and frame design of the exemplary heat exchanger comprises the two hot circuits and the single cold circuit. In some embodiments, hot circuit #**1** is represented as plate pack **413** and is dedicated for the power electronics and generator. In some embodiments, hot circuit #**2** is represented as plate pack **409** and is dedicated for the engine cooling circuit. Hot circuit #**1** and hot circuit #**2** (plate packs **409** and **413**) are separated by the center frame structure or plate **411**. The cold circuit passes first through hot circuit #**1** (plate pack **413**), and then through hot circuit #**2** (plate pack **409**) before exiting the heat exchanger **400**. That is, each hot circuit #**1** and hot circuit #**2** (plate packs **409** and **413**) also comprises a cold fluid wherein the two fluids, one hot and one cold, pass in opposite directions, up and down in alternative channels formed in the respective plate packs **409** and **413**. It should be understood that other exemplary heat exchangers could be used and include a water to air heat exchanger, for example, a radiator and/or cooling tower.

Referring to FIGS. **3-4**, an exemplary conduit system for transferring a fluid medium between the heat exchanger **400** and respective components of power generation system **200**. The conduit system includes a plurality of discrete conduits which can comprise, for example, flexible materials such as rubber hoses or inflexible materials such as metal pipes, or any combination of the various materials. Conduit **216** extends from an opening **404** in heat exchanger **400** to an opening (not referenced) in engine **208** and provides a cooled or cold fluid medium to engine **208** from heat exchanger **400**. The fluid medium enters engine **208** wherein heat energy from engine **208** is transferred to the fluid medium, and then the fluid medium exits engine **208** from an opening (not referenced) of engine **208** to enter conduit **214** wherein the warmed fluid medium returns to enter the heat exchanger through opening **406** to be cooled and re-circulated through conduit **216** and engine **208**. It should be understood that the path just described for the fluid medium could be reversed through the respective conduits **214** and **216**, and engine **208** and heat exchanger **400**.

Referring to FIGS. **7-8**, an exemplary conduit system for transferring a fluid medium between the heat exchanger **400** and respective components of power generation system **200** is shown. The plurality of discrete conduits comprise, for example, flexible materials such as rubber hoses or inflexible materials such as metal pipes, or any combination of the various materials. A first conduit **228** extends from an opening **414** in heat exchanger **400** to a first nipple **226** of a pump **220**, for example an auxiliary pump, and a second conduit **228** extends from a second nipple **222** of auxiliary pump **220** to power electronic device **300**. An exemplary auxiliary pump **220** provides pumping power to transfer a cooled or cold fluid medium to power electronics device **300** from heat exchanger **400**. The fluid medium enters power electronics device **300** wherein heat energy from power electronics device **300** is transferred to the fluid medium, and then the fluid medium exits power electronics device **300** and enters conduit **304**. Conduit **304** extends from power electronics device **300** to the generator (represented as generator housing **360**) and receives the warmed fluid medium from the power electronics device **300** wherein the warmed fluid medium is further warmed by receiving heat energy from the generator. Conduit **234** extends from the generator to opening **410** of heat exchanger **400** and provides the path for the fluid medium to return to the heat exchanger **400** from the generator. The fluid medium is re-circulated through the heat exchanger to be cooled and re-circulated through the respective conduits **228**, **304** and **234**, and the respective components.

It should be understood that conduits **416** and **418** from respective openings **417** and **419** of heat exchanger **400** are provided to receive a fluid medium furnished by a consumer. For example, if power generation system **200** is to be provided on a vessel such as a boat, the fluid medium provided to conduits **416** and **418** can include seawater from the ocean. Other exemplary fluid medium include water or air. Either conduit **416** and **418** will be an inlet for the fluid medium with the other conduit comprising an outlet for the fluid medium to be dumped, for example, back into the ocean.

It should be understood that the path just described for the fluid medium could be reversed through the respective conduits and the respective components. It should be understood that pump **220** can be positioned in any location relative the respective components of power generation system **200**, for example, below power electronics device **300** and adjacent generator housing **360**. It should be understood that pump **220** can comprise an electric pump or a mechanical pump. It should be understood that pump **220** can be an independent pump driven under its own power or driven from engine **208**.

Referring to FIG. **4**, power generation system **200** has a length **203** ranging from about 45 to about 49 inches and defined from one end of engine **208** to an opposite end of heat exchanger **400**. Power generation system **200** has a length **201** ranging from about 36 to about 40 inches without the heat exchanger **400**, and defined from the one end of engine **208** to an opposite side of the power electronics device **300**. Referring to FIG. **5**, power generation system **200** has a height **205** ranging from about 28 to about 32 inches and defined from a bottom of engine **208** to a top of engine **208** opposite the bottom. Still referring to FIG. **5**, power generation system **200** has a width **207** ranging from about 18 to about 22 inches and defined from the one side of engine **208** to an opposite side of engine **208**. Power generation system **200** comprises a weight ranging from about 800 to about 900 pounds, for example, 850 pounds. Other dimensions or weights are possible.

Referring to FIG. **18**, an exemplary support structure **800** for power generation system **200** is illustrated and comprises a frame **801** of any material that is adequately sturdy to support engine **208** and system components, for example, a metal such as steel. In one exemplary embodiment, u-shaped base portions **802** extend longitudinally and generally in parallel relation wherein spacers **806** are used to maintain the spaced relation of the u-shaped base portions **802** by extending between and secured to the respective u-shaped base portions **802**. It should be understood that while only two base portions **802** and two spacers **806** are shown, any number of base portions **802** and spacers **806** can be provided for support structure **800**. In one exemplary embodiment, base portions **802** comprise the portion of frame **801** to which the additional structure pieces or sections of frame **801** are secured. Moreover, the exemplary base portions **802** comprise the portion of frame **801** which rests and contacts a surface (not shown) to support an exemplary power generation system.

Still referring to FIG. **18**, an exemplary frame **801** comprises brackets **808** that are secured to and extend upwardly from base portions **802** at one end of an exemplary support structure **800**. In one exemplary embodiment, brackets **808** are secured to base portions **802** by bushings **805** that comprise, for example, rubber to dampen vibrations of the power generation system **200**. Brackets **808** are secured to engine **208**, either directly or with additional bushings (not shown) between brackets **808** and engine **208**. A pair of cross rails **826** extend between and are secured to respective base portions **802**. In one embodiment, cross rails **826** support posts **832** which extend upwardly from cross rails **826**. Exemplary posts **832** comprise at least two in number, for example, four and are in space relation defining a square or rectangle. Exemplary posts **832** are used to support any combination of plurality of components for power generation system **200**, for example, a power electronics device **834**, a generation housing **836**, and other components not shown secured to posts **832** such as a package control unit and auxiliary pump. Another pair of cross rails **828** are located adjacent posts **832** and extend between and are secured to respective base portions **802** to support heat exchanger **838**. A pair of pillars **816** extend vertically from one base portion **802** adjacent two brackets **808** and include a crossbar **817** extending there between, and in one exemplary embodiment, pillars **816** and cross bar **817** support an auxiliary pump **822** and package control unit **820**.

It should be understood that additional structure and beams can be provided on frame **801** to support additional components, for example, the generator. It should be understood that vibration isolators can be provided between any of the components of the exemplary power generation system and frame **801**. Conventional generator sets use frames and/or frame rails strong enough to withstand torsional flexing between the engine and generator. However, the exemplary power generation systems disclosed herein can be comprised of materials other than steel as a result of the engine being coupled directly to the generator. That is, with the engine directly coupled to the generator, torsional flexing is reduced and the design allows for off-board components to be better isolated from vibrations of the engine. Accordingly, in exemplary embodiments, frame **801** does not have to be designed to overcome the substantial torsional flexing of the conventional frames, and therefore, can be designed with materials to provide a frame that is compact and lightweight.

Referring to FIG. **19**, an overview **900** of the major components being monitored by the Package Control Unit (identified as Unit Control **960** in FIG. **19**) according to the invention is illustrated as a block diagram. The Package Control Unit **960** monitors the engine (referenced as prime mover **906**), generator **908**, an ignition control **942** for the engine (prime mover **906**), heat exchanger **902**, the power electronics device (identified as power control **920**) and customer connections, for example, a 3-phase breaker **912** to a consumer system **914**. These components are coupled by electrical and/or communication lines **910** and a conduit system **904** of water cooling lines.

Referring to FIG. **20**, in some embodiments of the power control (power electronics device) **920**, an exemplary system interface **924** is coupled to logic control **922** that allows the consumer/user to input user settings **934**. The interface **924** also provides output signals **936**. Exemplary output signals **936** can be in text or graphical format on the system interface **924**, and can be exported as an electronic signal for remote viewing. The system interface **924** communicates with the logic control **922** wherein the logic control **922** receives the user settings **934** from the system interface **924** and monitors/regulates Water Cooling and Internal Temperature Sensing **926**, DC Regulation **930** and DC-AC Conversion **928**. In one embodiment, DC Regulation **930** is coupled with DC input or output to remote storage system **938**. In one embodiment, DC Regulation **930** is coupled with AC to DC conversion **932** for exemplary conversion outputs **940** of 50-690 VAC, polyphase (for example, 3-18 phases) and 50-900 Hertz (Hz). In one embodiment, DC Regulation **930** is coupled with DC to AC conversion **928** for exemplary conversion outputs of 120-690 VAC, 1 or 3 phase and 50-1,000 Hertz. Based on User Settings **934** conditions, the Logic Control **922** will manage the power generation system and communicate with the System Interface **924** to provide Output Signals **936**.

Exemplary User Settings **934** comprise: Frequency Output which sets the output frequency of the generator set; Voltage Output which sets the output voltage of the generator set; Maximum Power Output which sets the maximum power of the generator set and can not exceed a rated maximum output of the engine/generator; Maximum Current Output which sets the maximum current output of the generator set; and Maximum Water Temperature which sets the maximum water temperature of water (or of any exemplary fluid medium) exiting an exemplary heat exchanger to the generator, power electronics device, and engine.

Exemplary Output Signals **936** comprise: Overtemp Warning which warns of an over-temperature condition for coolants, fluids, intake air and exhaust of the power generation system; Overtemp Shutdown wherein a shutdown signal is provided due to an over-temperature condition for coolants, fluids, intake air and exhaust of the power generation system; Overpower Warning which is a warning of an overpower condition for the engine, generator, and/or generator set; Overcurrent Warning which is a warning of an over-current condition for the generator, and/or generator set; Voltage Output which indicates voltage output for the generator, and/or generator set; Current Output which indicates current output for the generator, and/or generator set; Frequency Output which indicates frequency output for the generator, and/or generator set; DC Bus Volts which indicates voltage of a DC Bus; Input Volts which indicates input volts to power electronics and/or from secondary power supply; Input Freq which indicates input frequency to power electronics and/or from secondary power supply; and Internal Shutdown (Failure) which provides a signal to indicate internal shutdown due to failure of a component internal to the generator set.

Referring to FIG. **21**, an overview **961** of an exemplary ignition control **942** according to embodiments of the invention is illustrated. The ignition control **942** monitors, manages and controls logic blocks that influence ignition of the engine **947**. Control logic blocks that influence the ignition of the engine **947** include Air Control **952**, Fuel Control **950**, Ignition Control **942**, and Water Cooling Temperature Sensing **946**. Based on User Settings **954** (via the System Interface **948**), the Logic Control **944** will monitor, manage and control logic blocks that influence ignition of the engine **947**.

An exemplary Logic Control **944** receives the User Settings **954** from the System Interface **948**. Via the user settings **954**, the Logic Control **944** will monitor all parameters for specified maximum or minimum limits. The Logic Control **944** will then manage one, any combination or all of the blocks that influence the ignition of the engine **947** to prevent the overall power generation system from exceeding the specified maximum or minimum limits. Based on User Settings **954**, the Logic Control **944** will also communicate with the System Interface **948** to provide Output Signals **956**.

Still referring to FIG. **21**, exemplary User Settings **954** comprise: Operating Mode which can be user specified or

automatically determined wherein Generator Set (engine) can be configured to operate for maximum torque, maximum power, minimum fuel (fuel efficiency), and/or minimum emissions (low emissions) mode; Desired Speed which specifies the desired speed of the generator set and/or components of the power generation system; Temperature Warning Level which sets the warning level for various temperatures of coolants, fluids, intake air and/or exhaust of the power generation system; Temperature Shutdown Level which sets the shutdown level for the power generation system or components thereof based on various temperatures of coolants, fluids, intake air and exhaust of the power generation system; and Run/Start Contact which specifies time to crank engine for starting the power generation system.

Still referring to FIG. **21**, exemplary output signals **956** comprise: Overtemp Warning which warns of an overtemperature condition for coolants, fluids, intake air and exhaust of the power generation system; Overtemp Shutdown which provides shutdown signal due to an overtemperature condition for coolants, fluids, intake air and exhaust of the power generation system; Overpower Warning which warns of an overpower condition for the engine, generator, and/or generator set; Speed (RPM) which indicates speed of prime mover (engine) and generator in RPM; Delta RPM which indicates differential in desired and actual speed of prime mover and generator in RPM. (Differential is used when comparing engine speed and electrical load (demand) at the output connections); Actual Engine Mode which indicates actual Mode of engine; Fuel Control Status which indicates actual Mode of Fuel Control **950**; Air Control Status which indicates the actual Mode of the Air Control **952**; Ignition Control Status which indicates the actual Mode of the Ignition Control **942**; Internal Shutdown (Failure) which provides signal to indicate internal shutdown due to failure of a component which is internal to the generator set.

Referring to FIG. **22**, an exemplary Unit Control/Logic Control **901** interacts with the Ignition Control, Heat Exchanger, Generator, Power Control and Electrical Breaker. The Logic Control **962** is managed based on inputs from the Operator/User Interface **974**. The Operator/User Interface **974** can be onboard or remote via communication connection. The Logic Control **962** will monitor and manage the following: Water Cooling Temperature Sensing **964** which senses inlet and outlet temperatures of cooling fluid medium (e.g., water) and coolant circuits; Interface to Ignition Control **966** which monitors and manages the Ignition Control unit; Interface to Power Control **968** which monitors and manages parameters associated with the Power Control unit; Current and Voltage Interface **970** which monitors the current and voltage of the generator output; and Breaker Interface **972** which determines if circuit breaker is open or closed. If a powered breaker is used, the Logic Control **962** may be used to control the opening and closing of the breaker.

Referring to FIG. **23**, another exemplary Unit Control/Logic Control **903** configuration is illustrated. An exemplary Unit Control/Logic Control comprises a high level interaction between various system control components. Control components include: Unit Master Controller **992**, Engine Control **976**, Power Electronics Control **982**, and Unit Control BIOS **977**. For example, an exemplary Unit Control BIOS **977** interacts with Unit Master Control **992**, Engine Control **976**, and Power Electronics Control **982**. The Unit Control Bios **977** contains: Communications Port **939** for the Power Unit; Communications Port **941** for the Ignition Unit; monitoring for Generator Voltage **943**; monitoring for Generator Output Current **945** (the parameter values provided in this Fig. for any element/component are only exemplary, with the ranges of values provided throughout this document being applicable); monitoring for Output Voltage **991**; monitoring for Output Current **985**; monitoring of the Breaker Control **983**; monitoring of Temperature Sensing components **981**; and monitoring for optional Analog I/O **979**.

Still referring to FIG. **23**, in exemplary embodiments, Generator Frequency **937** is calculated from Generator Voltage **943**. Generator Power **933** is calculated from Generator Voltage **943** and Generator Current **945**. Output Frequency **987** is calculated from Output Voltage **991**. Output Power **989** is calculated from Output Voltage **991** and Output Current **985**. Moreover, in an exemplary embodiment, the Engine Control **976** interacts with Unit Control BIOS **977**, Power Electronics Control **982**, and Unit Master Control **992**. The Engine Control **976** contains Start/Stop **978** and Speed Control **980** blocks. Start/Stop **978** interacts with Unit Control BIOS **977** and Speed Control **980** blocks. Speed Control **980** interacts with Unit Control BIOS **977**, Power Electronics Control **984** and Frequency Control **986**. An exemplary Power Electronics Control **984** interacts with Unit Control BIOS **977**, Engine Control **976**, and Unit Master Control **992**. Power Electronics Control **984** contains Voltage Control **990**, VAR Control **988**, Frequency Control **986**, and Power Control **984**. An exemplary Voltage Control **990** block interacts with Unit Control BIOS **977**, an exemplary VAR Control **988** interacts with Unit Control BIOS **977**, an exemplary Frequency Control **986** interacts with Unit Control BIOS **977** and Engine Control **976**, and an exemplary Power Control **984** interacts with Unit Control BIOS **977** and Engine Control **976**.

In an exemplary embodiment, Unit Master Control **992** interacts with Engine Control **976**, Power Electronics Control **982** and Unit Control BIOS **977**. The Unit Master Control **992** contains Mode Control **995**, Breaker Control **994**, Load Control **996**, and Synchronize Control **997** blocks. Mode Control **995** interacts with Breaker Control **994**, Load Control **996**, and Synchronize Control **997** within the Unit Maser Control **992**. Mode Control **995** also interacts with Engine Control **976** and Power Electronics Control **982**. Breaker Control **994** interacts with Unit Master Control **992**, Mode Control **995**, and Unit Control BIOS **977**. Load Control **996** interacts with Unit Master Control **992**, Mode Control **995**, Engine Control **976**, and Power Electronics Control **982**. Synchronize Control **997** interacts with Unit Master Control **992**, Mode Control **995**, Engine Control **976**, and Power Electronics Control **982**. It should be understood that all the schematic

Exemplary embodiments described herein provide advantages and benefits not recognized by the conventional power generation systems. For example, embodiments of power generation systems described through out this application (for example, as described in FIGS. **1** and **2**, and for power generation system **200**) comprise exemplary generator sets with the ability to provide multiple load capability. These exemplary generation sets are capable of managing a primary electrical load as well as a secondary electrical load. In contrast, conventional generator sets are capable of having only one output for one load which is distributed at a switchgear or a switchboard. Additionally, the exemplary generation sets according to the invention of this disclosure are capable of managing multiple loads, each having a different voltage, wherein again, the conventional generator sets are capable of having only one output for one load.

Moreover, the exemplary power generation systems/generation sets disclosed herein comprise global power generation packages that can be configured for selectable voltage and/or selectable frequency. Additionally, due to the size (e.g., footprint and weight) of the exemplary power generation systems/generation sets disclosed herein, advantageous

mounting configurations are possible. For example, because of the smaller footprint and/or size of the generation sets provided herein, the generator can be directly mounted to the engine (prime mover) and/or flywheel housing. By being able to mount the generator directly to the engine, unique and beneficial mounting configurations are possible that are not possible with conventional generation sets. Furthermore, the support structure **800** for exemplary power generation systems disclosed herein, for example, frame **801** illustrated in FIG. **18** is lighter in weight compared to frame rails of conventional generation sets, and allows for sensitive components to be isolated from engine vibration.

Furthermore, since the exemplary power generation systems disclosed herein comprise liquid cooled components, for example, the engine (prime mover), generator and power electronics, and in combination with the variable speed operation possible with the system disclosed herein, the combination allows for a quieter operating power generation system. Additionally, the liquid cooled components of exemplary power generation systems disclosed herein removes heat from the respective components to the air in a more optimum mode by, for example, a radiator, cooling tower, keel cooler, etc. Still further, the liquid cooled components allow for an enclosure of the power generation systems, or various components thereof, to be more tightly sealed which reduces sound waves produced from the operation of the power generation systems to exit outside the environment of an exemplary enclosure. Additionally, tightly sealed power electronic devices and generators are less prone to ingress by environmental contaminants such as snow, dirt, sand, bugs and other debris. This increases the reliability of the exemplary power generation systems disclosed herein compared to conventional systems, which is important if not imperative for some applications, such as military operations. In fact, the exemplary power generation systems disclosed herein have a N+2 reliability built in, and as a result, is a comparatively higher reliable system.

Furthermore, the variable speed capability of the exemplary power generation systems in combination with the liquid cooled components allows the power generation systems to operate at higher RPMs than conventional power generation systems. Higher RPMs produce shorter sound waves emanating from the exemplary power generation systems, and therefore, less sound attenuation material is needed to sound proof the power generation system. Since less soundproof material is used, the exemplary power generation system will be lighter in weight than conventional power generation systems. Alternatively, if the same amount of soundproof material routinely used for conventional power generation systems is used for the power generation systems disclosed herein, then the power generation system disclosed herein will be quieter.

Moreover, the liquid cooled components of the exemplary power generation systems can contribute to increased fuel utilization. For example, conventional combined heat and power (CHP) applications consist of a generator set producing electricity with a heat recovery equipment on the exhaust system. This conventional CHP has the heat from the engine (for example, transmitted to an engine jacket water system) and exhaust system transferred to the environment, for example, a building for heating and cooling applications. Moreover, heat rejected from air passing through the generator is vented to the atmosphere as lost energy. However, the exemplary power generation systems disclosed herein can capture the heat energy rejected from the components that are coupled to heat exchanger(s) in addition to the heat energy captured from the engine water and exhaust system. Additionally, the exemplary power generation systems disclosed herein allow for more efficient cooling of the environment, for example, the engine room of a vessel or ship because the fluid medium which has captured the thermal energy from the respective components can be transmitted to remotely mounted cooling devices such as radiators, cooling towers, etc. The remotely mounting of cooling devices reduces the need for sizable air handling equipment in the exemplary engine room of the vessel or ship.

Another advantage/benefit of the exemplary power generation systems disclosed herein is the addition of a secondary input allows for zero (0) cycle power outage. For example, the exemplary power generation systems can use batteries as a secondary input connected to a building distribution system. If the power supply from a municipality is interrupted or fails, the secondary input will provide power until the generator set of the power generation system can be operational. In contrast, conventional power generation systems need to ramped up to approximately 1,800 RPMs before closing a coupled breaker system to provide the power energy to the load (for example, the building distribution system). The exemplary power generation systems disclosed herein will begin producing and providing power energy as soon as the generator is turning without any noticeable interruption of power to the consumer/customer.

Referring to FIG. **24**, an exemplarily method for generating power **651** is described according to one a various embodiments of the invention.

Still referring to FIG. **24**, a first method step **653** includes providing a generator system comprising a generator having a power output connector.

Still referring to FIG. **24**, another exemplary method step **655** includes coupling the power output connector to a first power application, the first power application comprising a first power demand.

Still referring to FIG. **24**, another exemplary method step **657** includes activating the generator to provide a first power component to meet the first power demand.

Still referring to FIG. **24**, another exemplary method step **659** includes monitoring the first power demand of the first power application.

Still referring to FIG. **24**, another exemplary method step **661** includes receiving an indication that the first power demand has changed to a second power demand different from the first power demand.

Still referring to FIG. **24**, another exemplary method step **663** includes notifying the generator system of the indication.

Still referring to FIG. **24**, another exemplary method step **665** includes after the notifying, performing one of the following tasks: maintaining the first power component to meet the second power demand, or modifying the first power component to a second power component to meet the second power demand, the second power component being different from the first power component.

Still referring to FIG. **24**, another exemplary method step **667** includes wherein the first and second power components comprise different power density outputs.

Regarding exemplary control schemes for some exemplary embodiments of the power generation systems disclosed herein, the system is designed to provide the engine RPM and generator output to follow the electrical load. Alternatively, for some exemplary embodiments of the power generation systems disclosed herein, the systems can have the capability to manage or have the operator (consumer/customer) select between torque, horsepower and fuel consumption. These configurations for exemplary systems will allow the operator

(consumer/customer) to optimize capabilities of the exemplary systems with respect to different applications requiring different power demands.

What is claimed is:

1. A power generation system, comprising:

a generator;

a power electronics device coupled to the generator and comprising first and second power application connectors, the first power application connector configured to be coupled to a first power demand, and the second power application connector configured to be coupled to a second power application wherein the second power application is connected to a second power demand, the second power demand being different from the first power demand; and

wherein a power transformation of the first power application to meet the first power demand via the power electronics device is independent of the generator.

2. The system of claim **1** wherein the power electronics device further comprises the capability to regulate and transform power to meet connected power demands.

3. The system of claim **1** wherein the generator can become an other power demand to the first power application as a torque and rotational speed producing component.

4. A power generating system comprising:

a generator comprising a power connector coupled to a first power application, the first power application comprising a first power demand; and

logic control configured to:

activate the generator to provide the first power application to meet the first power demand;

monitor the first power demand and the first power application;

receive an indication that the first power demand has changed to a second power demand different from the first power demand;

couple the first power application to a second power application independent of the generator, the second power application comprising a third power demand, the third power demand being different from the first and second power demands;

receive an indication that a state of the generating system has changed; and

notify the generating system of the indication to modify the activation of the generator.

5. The system of claim **4** wherein the first power application can provide or receive power from the second power application.

6. The system of claim **4** wherein the first power demand is met by the first power application connected to the second power application.

7. The system of claim **4** wherein the first and second power demands comprise different power density outputs.

8. The system of claim **4** further comprises an input source coupled to the generator, wherein the logic control is configured to activate the input source to drive the generator at a rotational speed, and wherein the logic control is configured to modify the rotational speed of the generator.

9. The system of claim **4** wherein the logic control is configured to activate the generator to optimize the generating system to a preferred generating system power application.

10. The system of claim **9** wherein the logic control is configured to combine the power applications in proportion.

11. The system of claim **4** wherein the logic control comprises the capability to diagnose changes within the system, and the capability to organize, indicate and notify components of the system in collective cooperation to optimize the generating system within the designed capability.

12. The system of claim **11** wherein the collective cooperation optimizes reduction in the total available power available from the system to a level sustainable under conditions indicated by the logic control.

13. The system of claim **11** wherein the collective cooperation selectively modifies demand connections under indicated conditions when the demand exceeds a sustainable designed capability of the generating system.

14. The system of claim **11** wherein the collective cooperation creates an alternative load acceptance behavior which occurs when a load requirement is added to a demand connection which requires a system response greater than the system design capability.

15. The system of claim **11** wherein the collective cooperation levels power between the combination of power applications to ensure proper sharing of power within and amongst the generating system.

16. The system of claim **11** wherein the collective cooperation restores an ideal designed capability of the system after an indicated state is resolved and the logic control unit has notified the system components.

17. A method for generating power, comprising:

providing a generator system comprising a generator having a power output connector;

coupling the power output connector to a first power application, the first power application comprising a first power demand;

activating the generator to provide a first power component to meet the first power demand;

monitoring the first power demand of the first power application;

receiving an indication that the first power demand has changed to a second power demand different from the first power demand;

notifying the generator system of the indication;

after the notifying, performing one of the following tasks: maintaining the first power component to meet the second power demand, or modifying the first power component to a second power component to meet the second power demand, the second power component being different from the first power component; and

wherein the first and second power components comprises different power density outputs.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,969,030 B2
APPLICATION NO. : 12/719726
DATED : June 28, 2011
INVENTOR(S) : Edward Woods and Douglas Alan Koeneman

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 2, line 1 – Replace "motivation as led" with --motivation has led--

Column 8, line 48 – Replace "illustrated Components" with --illustrated. Components--

Column 10, line 3 – Replace "or be an" with --or can be an--

Column 10, line 49 – Replace "is represented" with --are represented--

Column 12, line 21 – Replace "416 and 418" with --416 or 418--

Column 15, line 63 – Replace "Control Bios" with --Control BIOS--

Column 16, line 45 – Remove "It should be understood that all the schematic"

Column 18, line 27 – Replace "an exemplarily" with --an exemplary--

Column 18, line 28 – Replace "one a various" with --one of various--

Signed and Sealed this
Fifth Day of March, 2013

Teresa Stanek Rea
Acting Director of the United States Patent and Trademark Office