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Prosser

(54) CHARGING SERVICE VEHICLE NETWORK

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(73) Assignee: **GREEN CHARGE NETWORKS LLC**, Huntington Beach, CA (US)

(21) Appl. No.: **13/481,232**

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Related U.S. Application Data

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(51) **Int. Cl.**

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H02J 7/00	(2006.01)

(52) **U.S. Cl.** **705/7.12**; 320/104

(57) **ABSTRACT**

Charging service vehicle networks are among the embodiments disclosed herein, including battery module-powered EV charging roadside service vehicles. Battery modules are removably mounted to the service vehicles and manually exchanged within a system of battery module storage locations. Some embodiments provide resupply vehicles for delivering battery modules between storage locations and/or service vehicles, and may be used to exchange battery modules. Controllers are used to reserve battery modules at the storage locations to ensure availability for high priority activities. Some storage locations have charging apparatus to recharge battery modules stored there, and some storage locations are repositionable mobile units. Multiple tiers or levels of system controllers used by service vehicles to control centers are implemented to manage operations and optimize usage of battery modules and charging services across wide areas, including providing additional service vehicles to supply temporary needs for charging services.

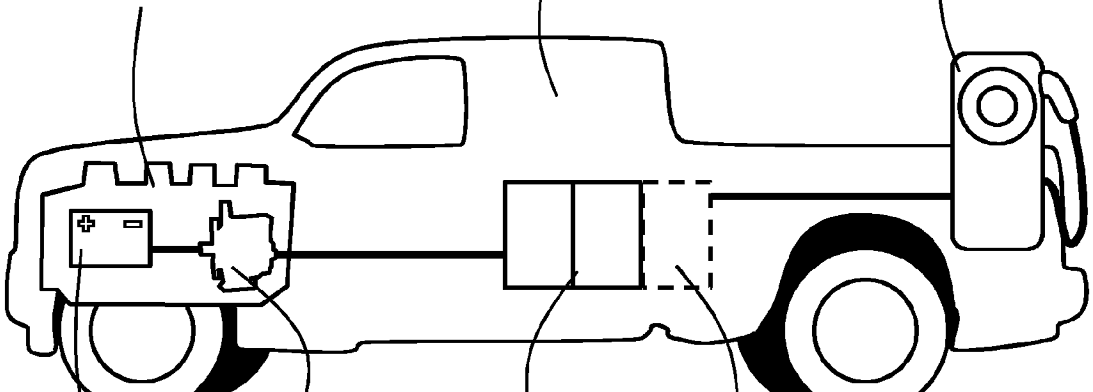


FIG. 1A

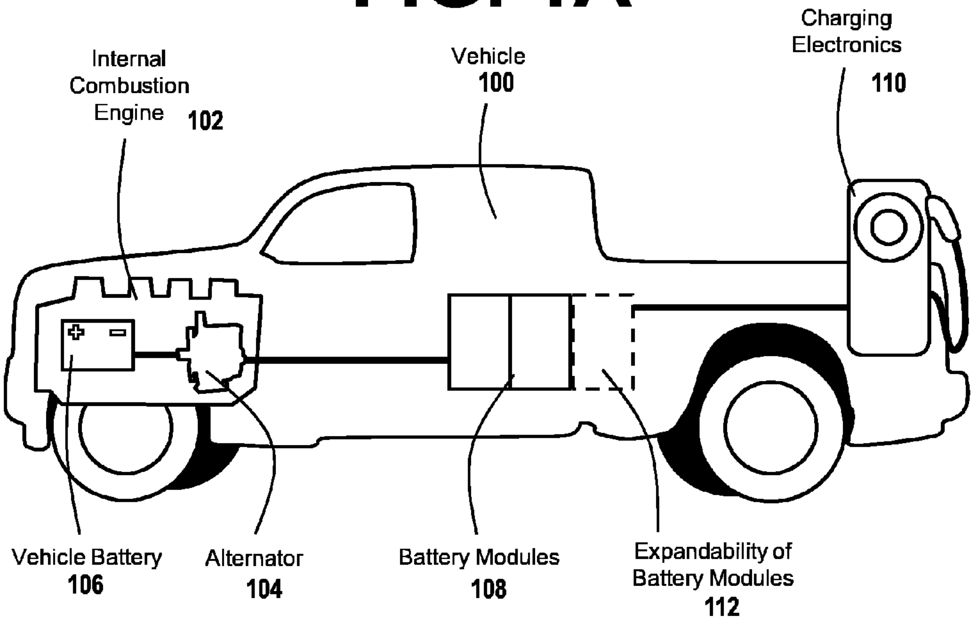

Internal Combustion Engine 102
Vehicle 100
Charging Electronics 110
Vehicle Battery 106
Alternator 104
Battery Modules 108
Expandability of Battery Modules 112

FIG. 1B

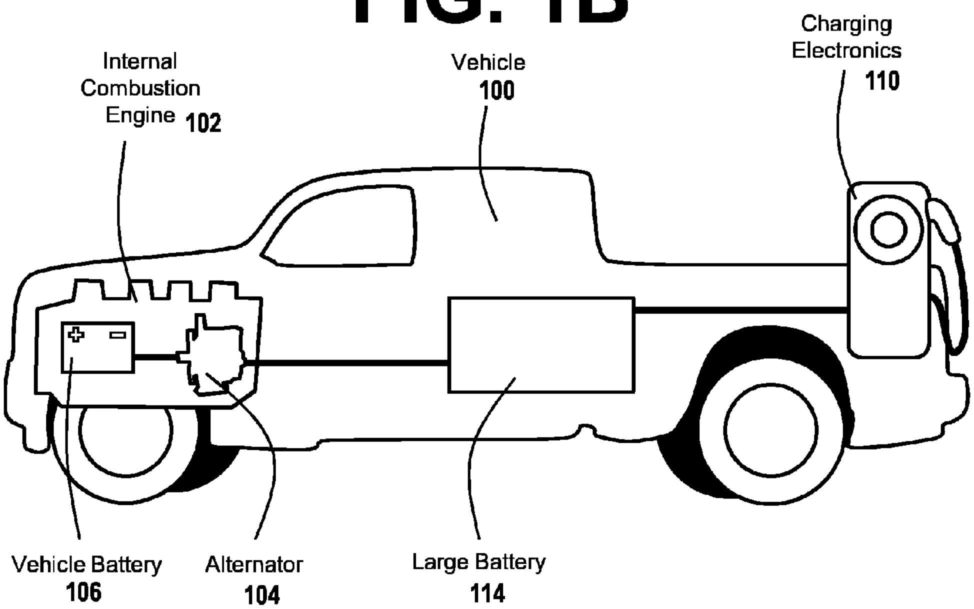

Internal Combustion Engine 102
Vehicle 100
Charging Electronics 110
Vehicle Battery 106
Alternator 104
Large Battery 114

FIG. 1C

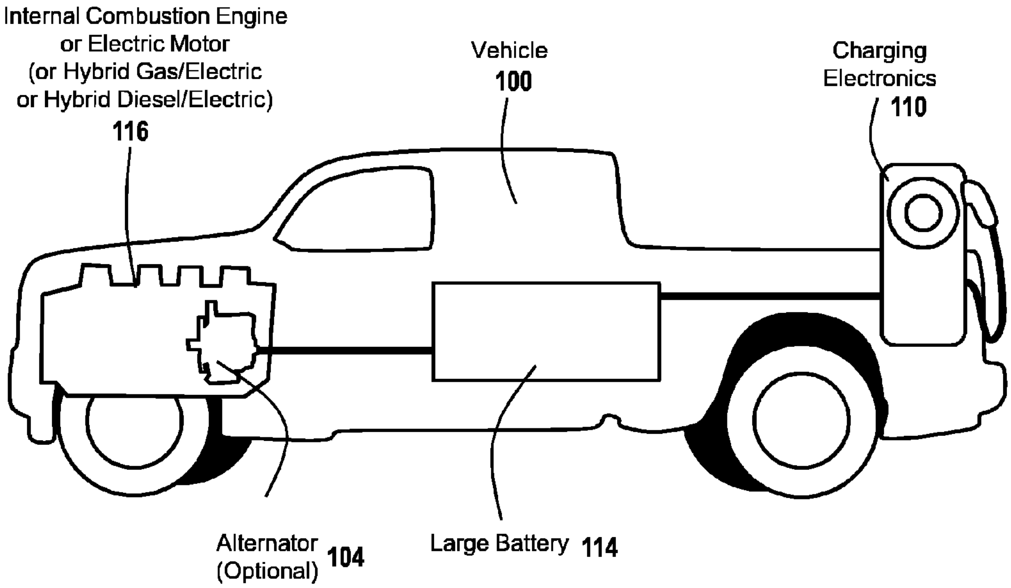

Internal Combustion Engine
or Electric Motor
(or Hybrid Gas/Electric
or Hybrid Diesel/Electric)
116
Vehicle
100
Charging
Electronics
110
Alternator
(Optional) 104
Large Battery 114

FIG. 1D

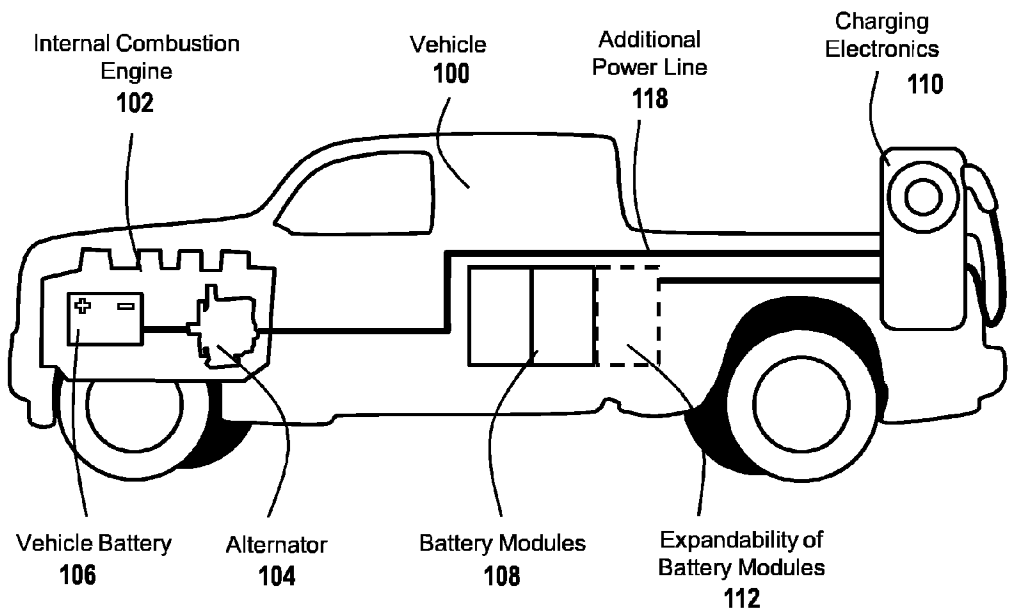

Internal Combustion
Engine
102
Vehicle
100
Additional
Power Line
118
Charging
Electronics
110
Vehicle Battery
106
Alternator
104
Battery Modules
108
Expandability of
Battery Modules
112

FIG. 2A

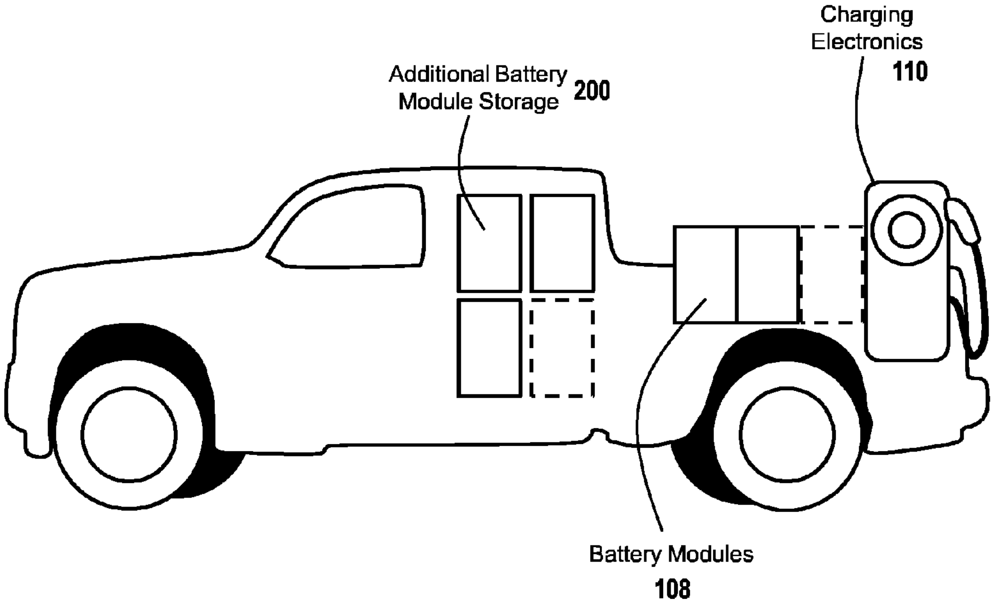

Charging
Electronics
110
Additional Battery
Module Storage
200
Battery Modules
108

FIG. 2B

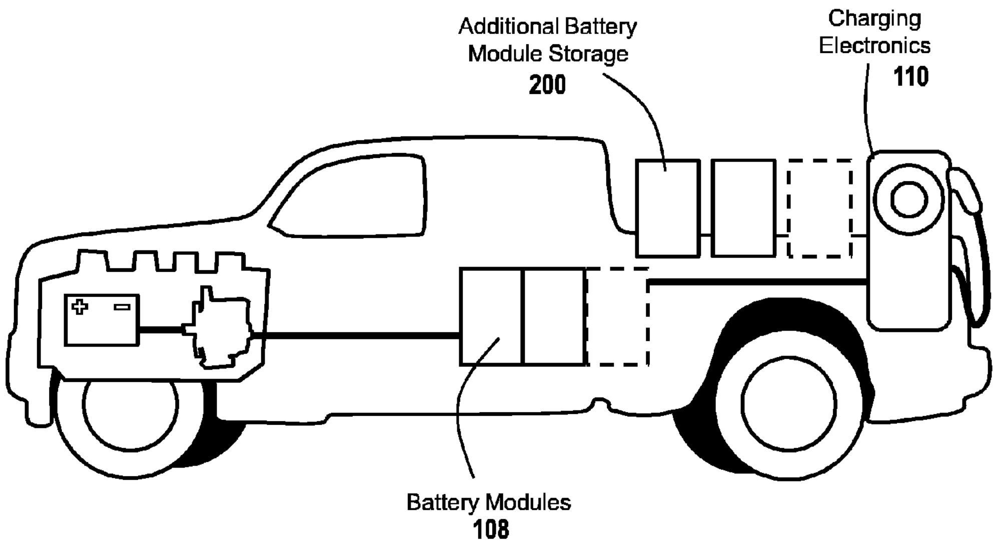

Additional Battery
Module Storage
200
Charging
Electronics
110
Battery Modules
108

FIG. 2C

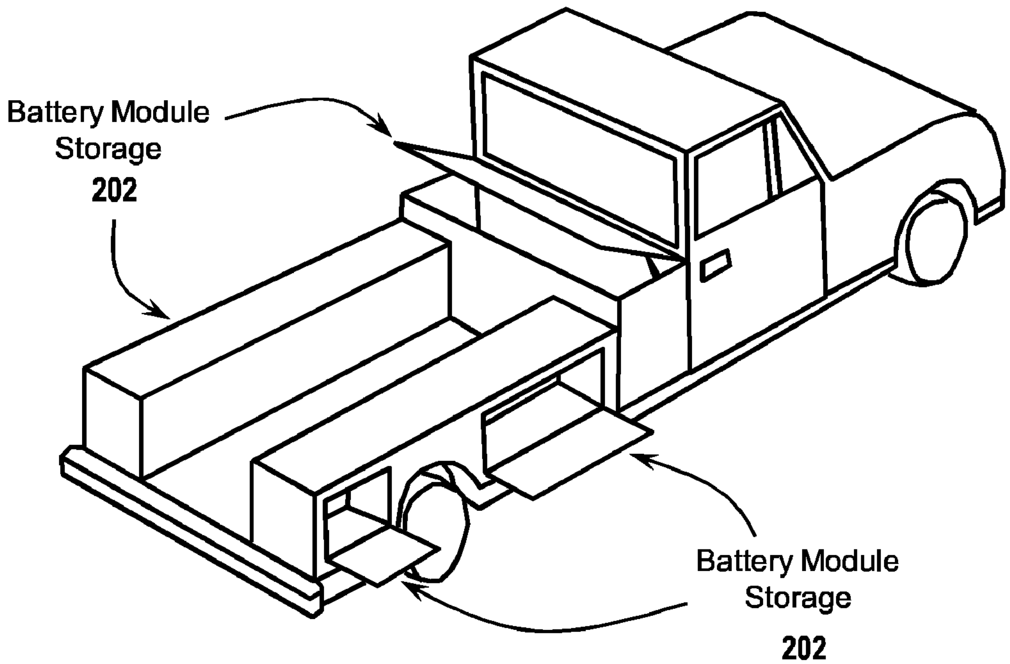

Battery Module
Storage
202
Battery Module
Storage
202

FIG. 2D

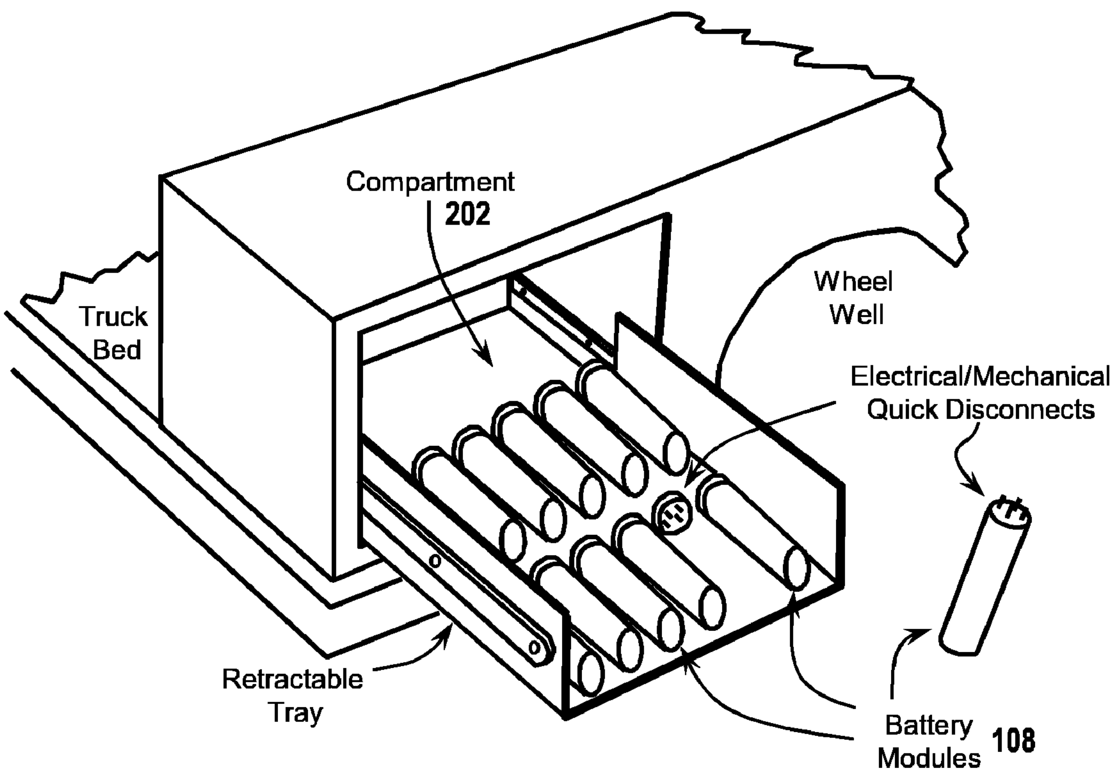

Compartment
202
Truck
Bed
Wheel
Well
Electrical/Mechanical
Quick Disconnects
Retractable
Tray
Battery
Modules
108

FIG. 3

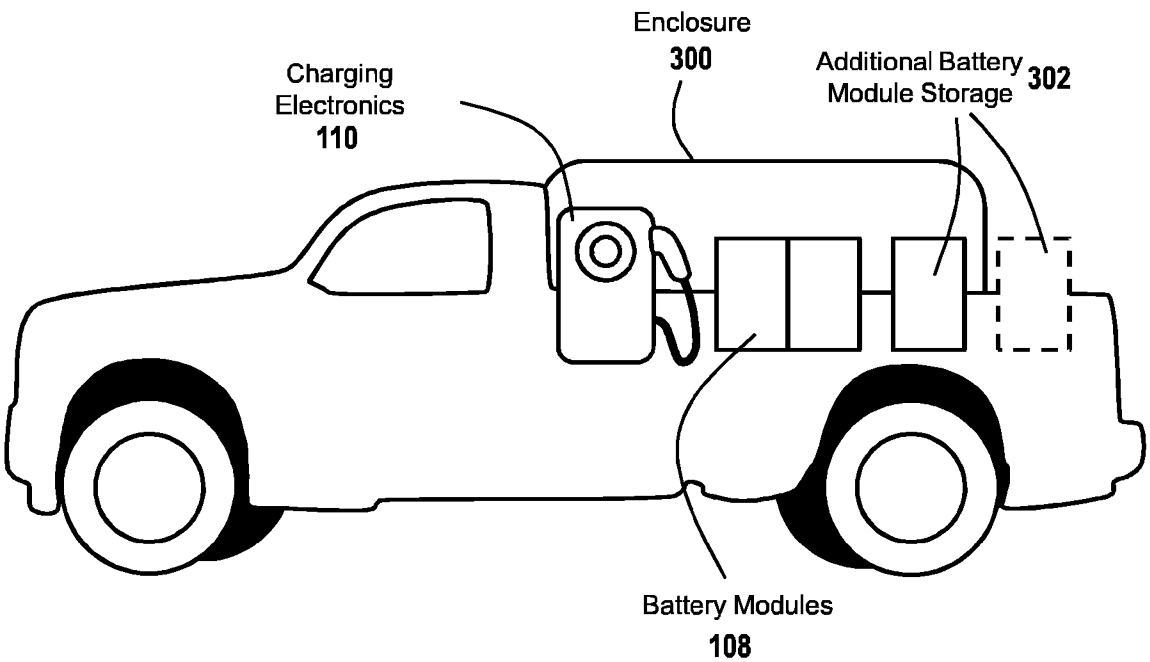

Enclosure
300
Charging
Electronics
110
Additional Battery
Module Storage
302
Battery Modules
108

FIG. 4

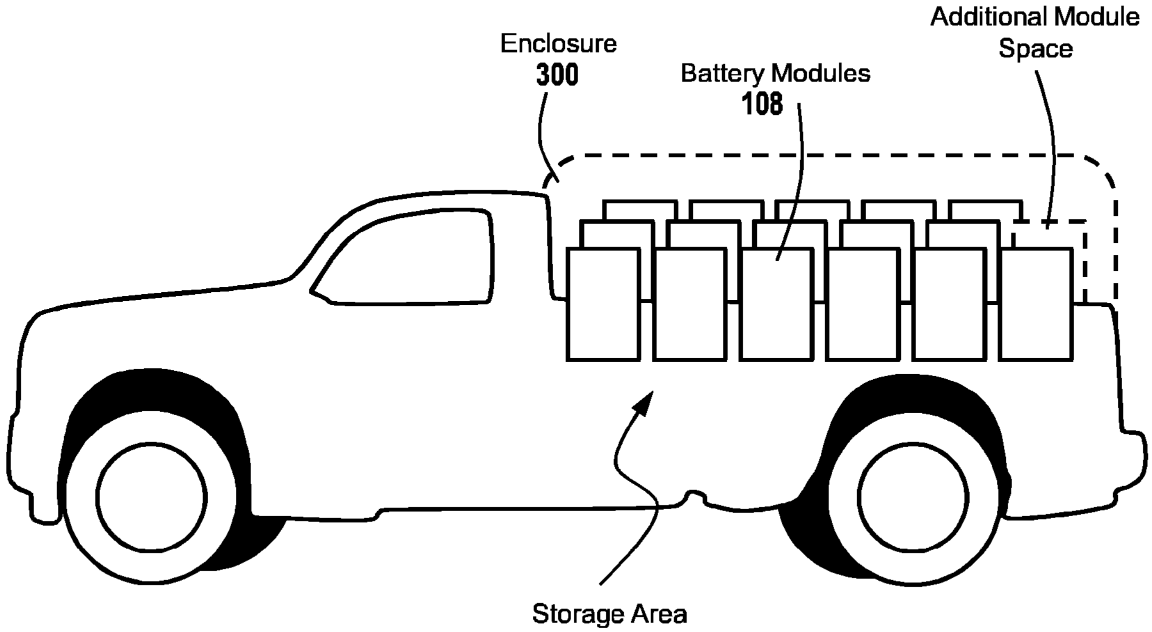

Enclosure
300
Battery Modules
108
Additional Module
Space
Storage Area

FIG. 5A

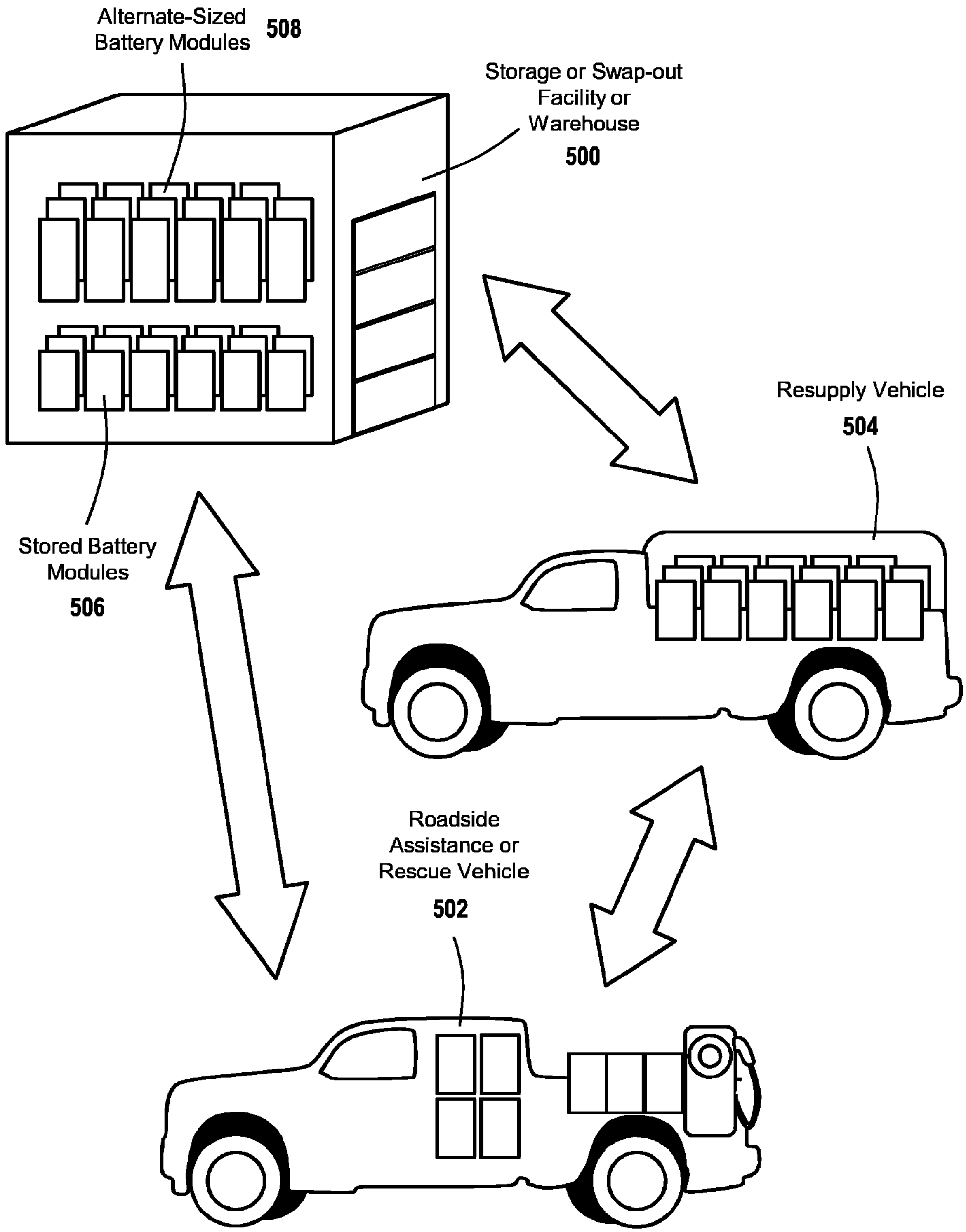

Alternate-Sized Battery Modules
508
Storage or Swap-out Facility or Warehouse
500
Resupply Vehicle
504
Stored Battery Modules
506
Roadside Assistance or Rescue Vehicle
502

FIG. 5B

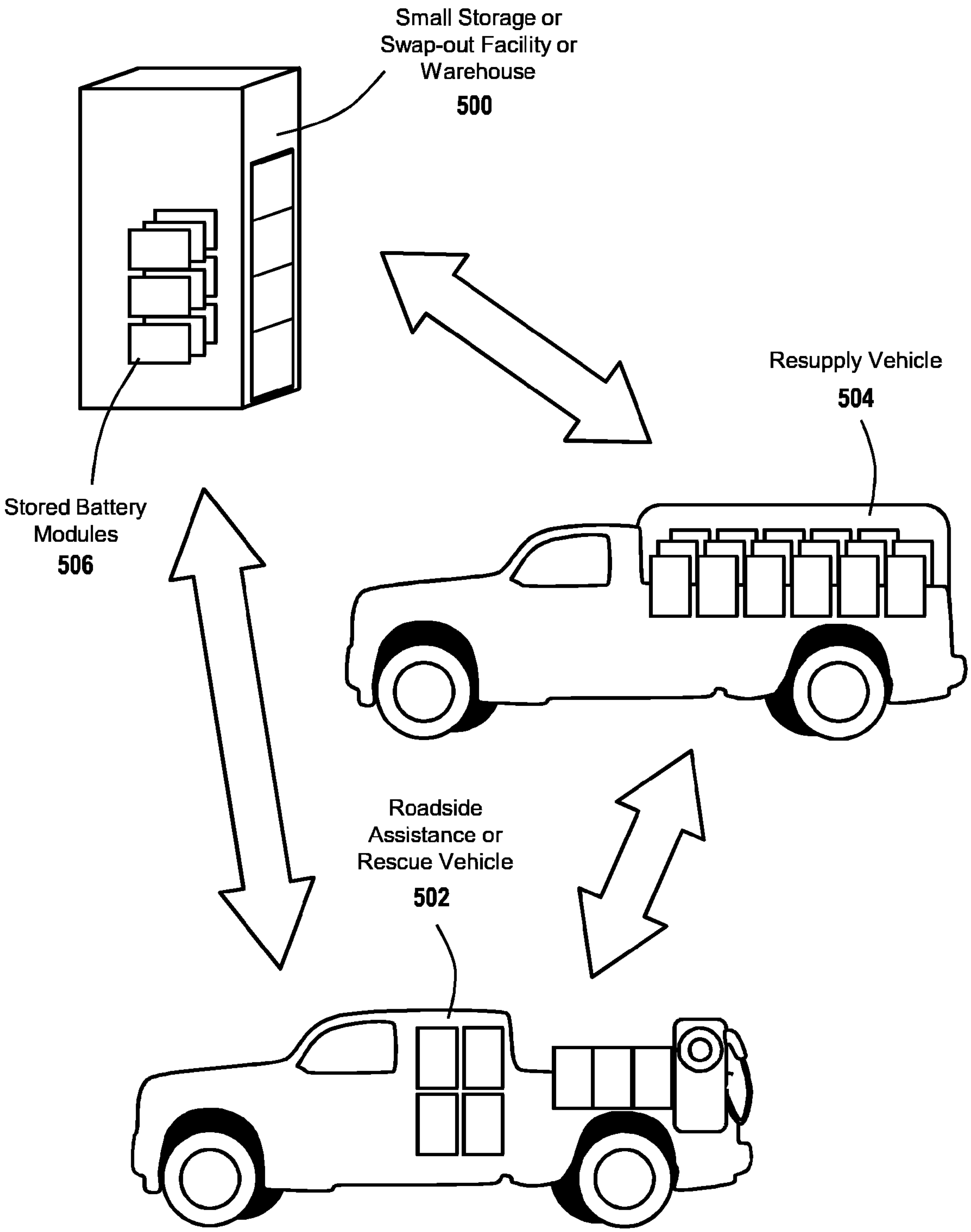

Small Storage or
Swap-out Facility or
Warehouse
500
Stored Battery
Modules
506
Resupply Vehicle
504
Roadside
Assistance or
Rescue Vehicle
502

FIG. 5C

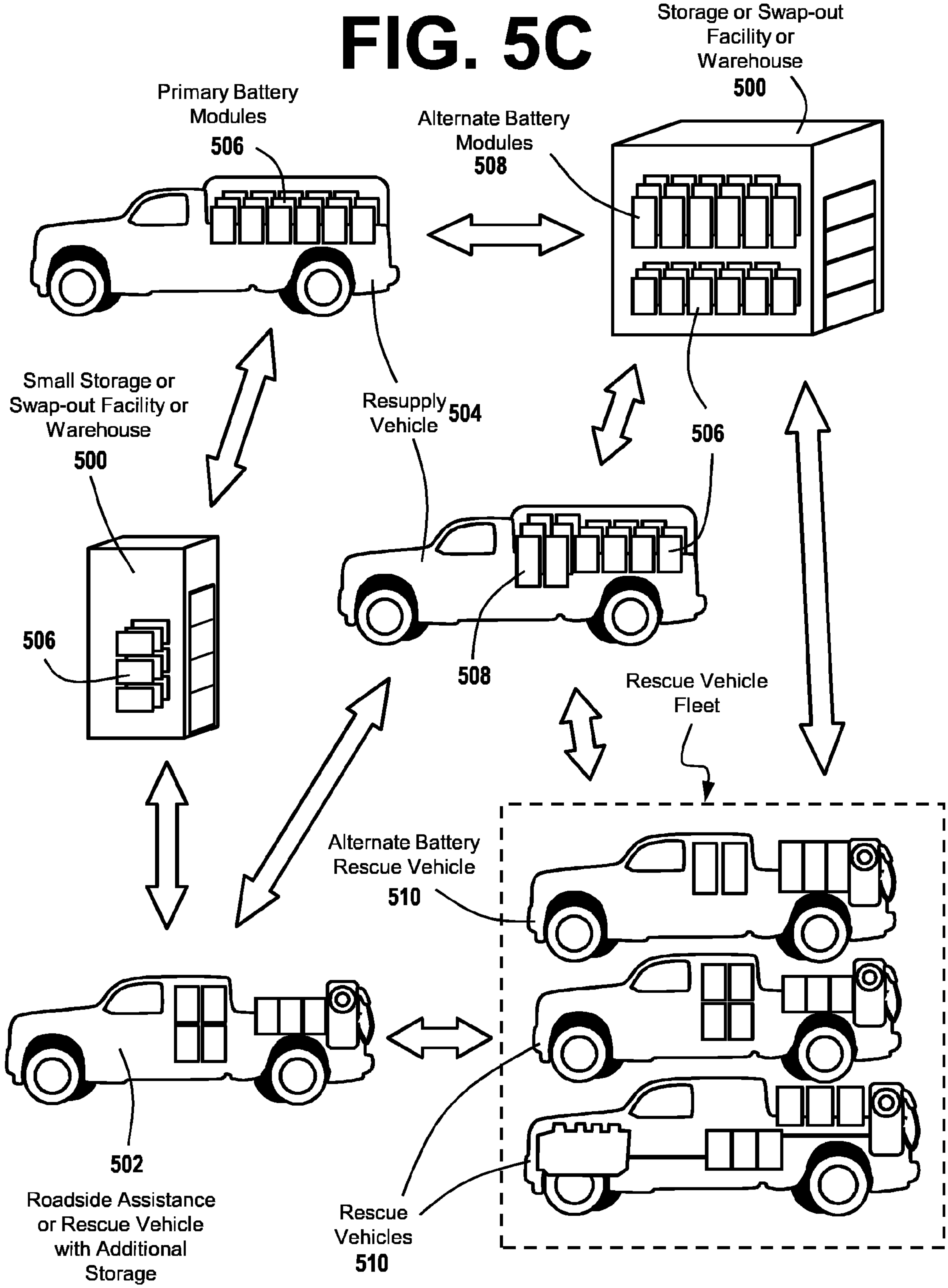

Storage or Swap-out
Facility or
Warehouse
500
Primary Battery
Modules
506
Alternate Battery
Modules
508
Small Storage or
Swap-out Facility or
Warehouse
500
Resupply
Vehicle
504
506
506
508
Rescue Vehicle
Fleet
Alternate Battery
Rescue Vehicle
510
502
Roadside Assistance
or Rescue Vehicle
with Additional
Storage
Rescue
Vehicles
510

FIG. 5D

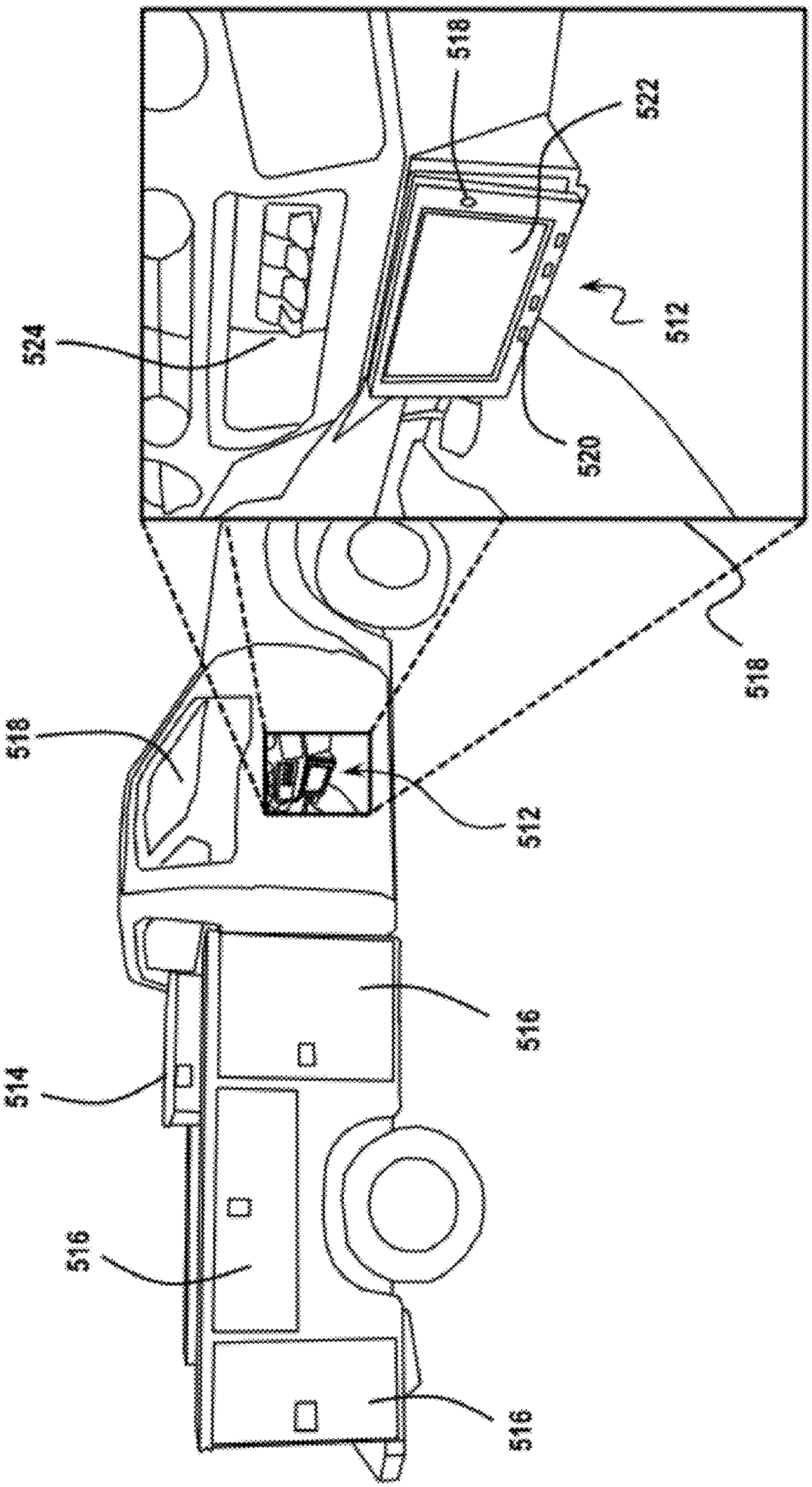


FIG. 5E

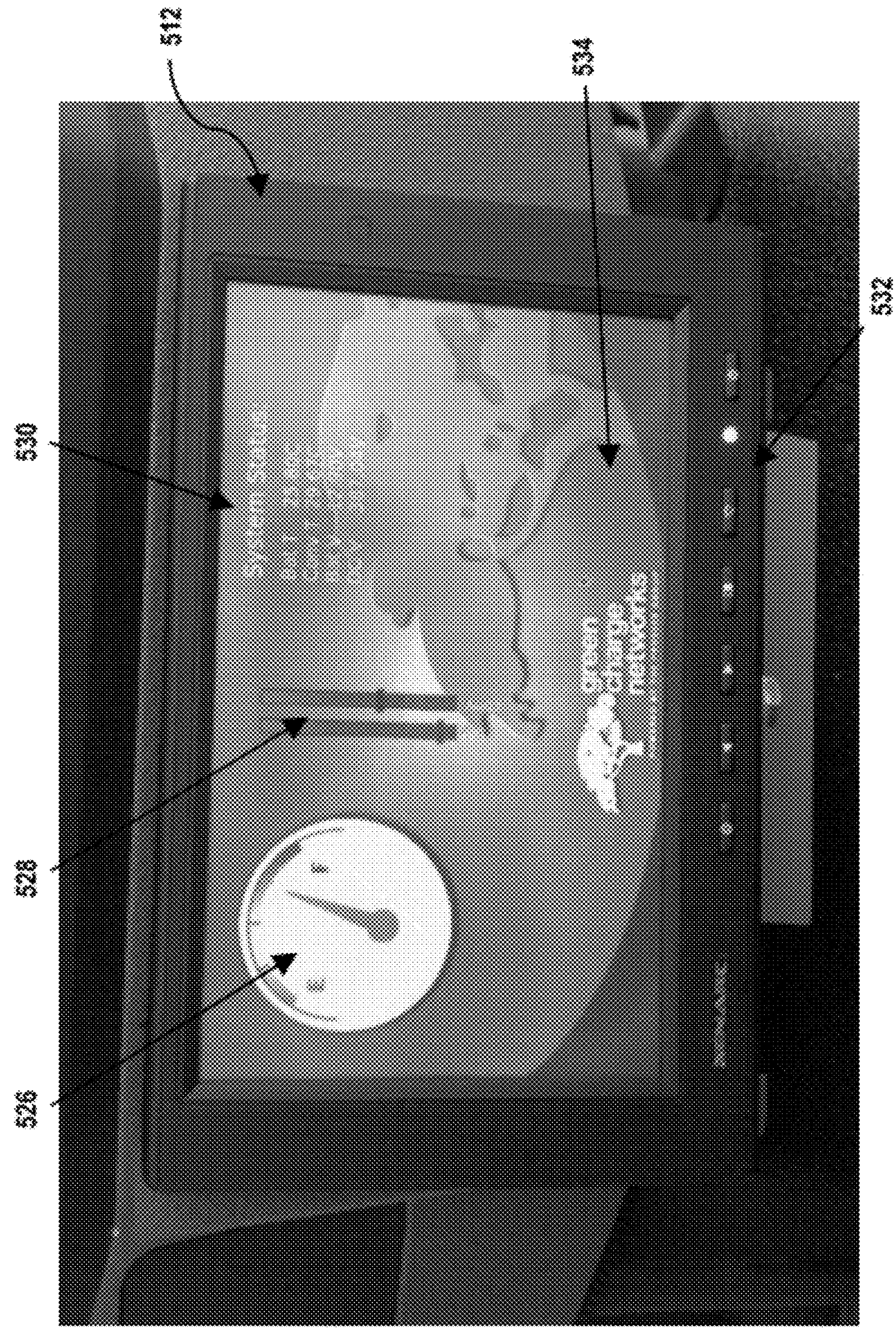


FIG. 5F

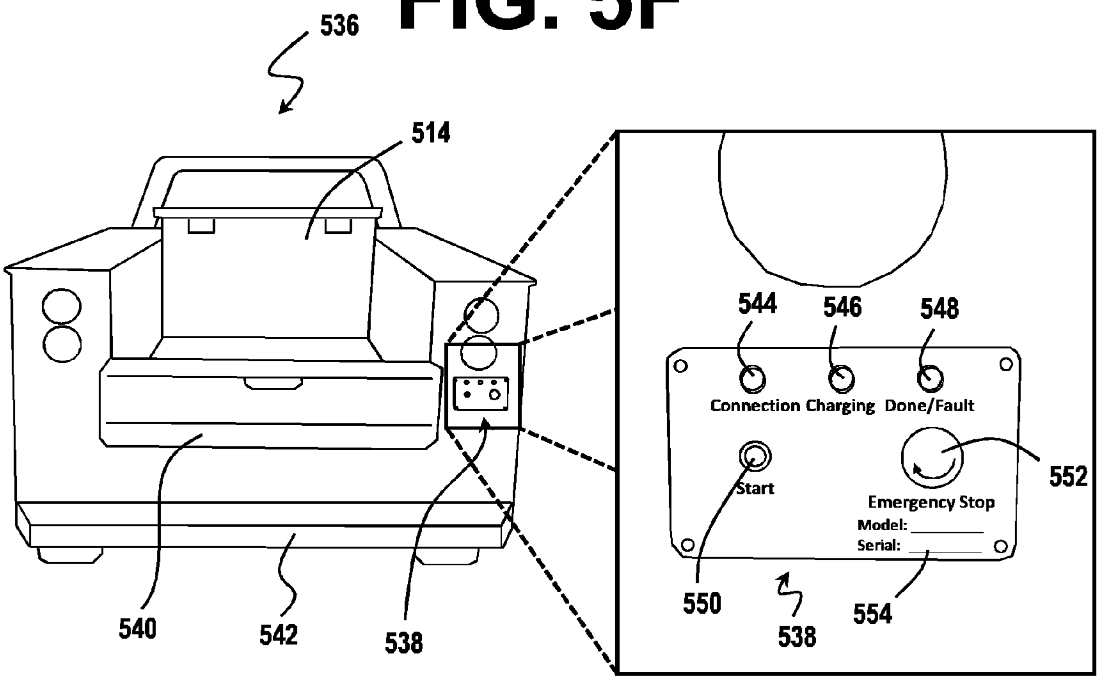

536
514
544
546
548
Connection
Charging
Done/Fault
Start
Emergency Stop
Model:
Serial:
552
550
538
554
540
542
538

FIG. 5G

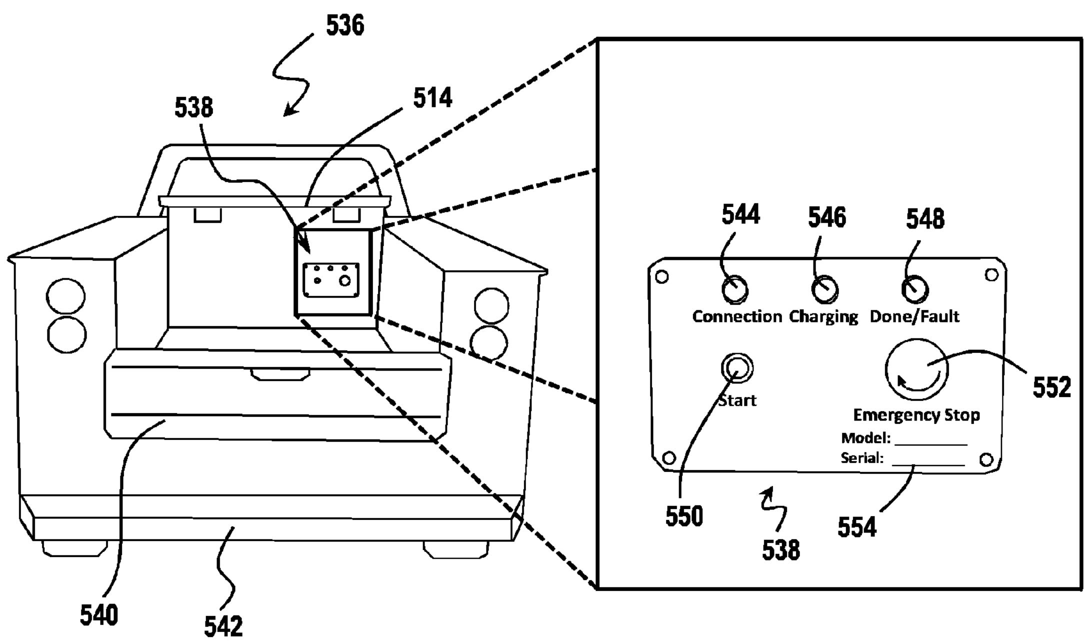

536
538
514
544
546
548
Connection
Charging
Done/Fault
Start
Emergency Stop
Model:
Serial:
552
550
538
554
540
542

FIG. 6A

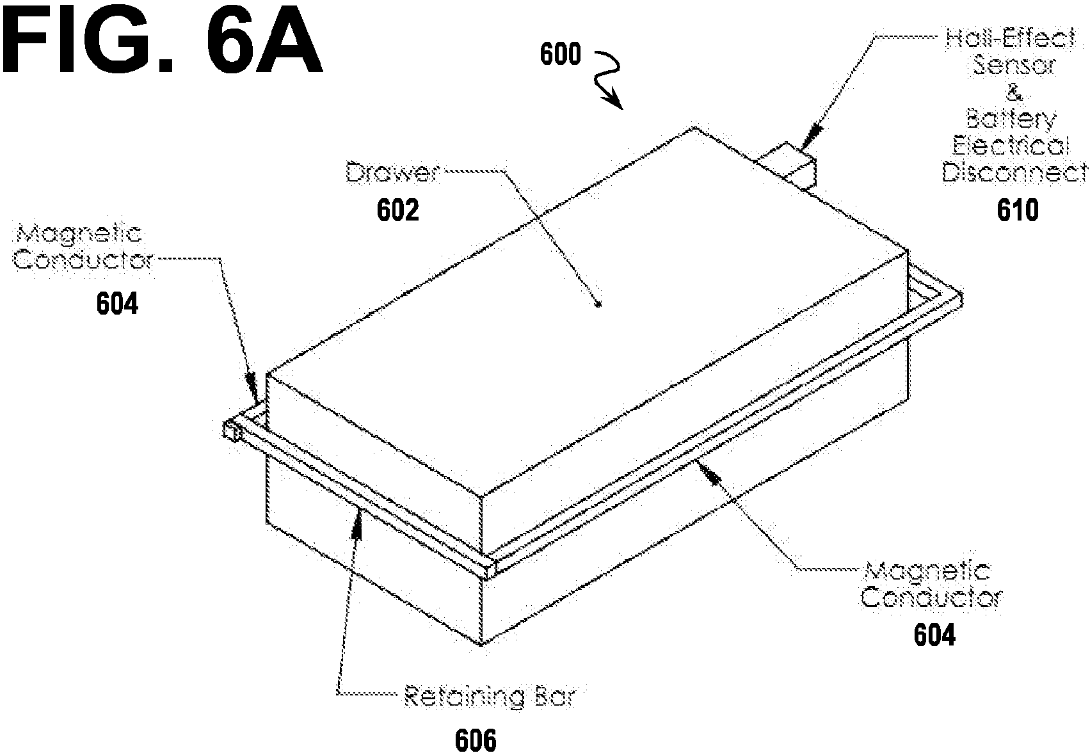

600
Hall-Effect Sensor & Battery Electrical Disconnect
610
Drawer
602
Magnetic Conductor
604
Magnetic Conductor
604
Retaining Bar
606

FIG. 6B

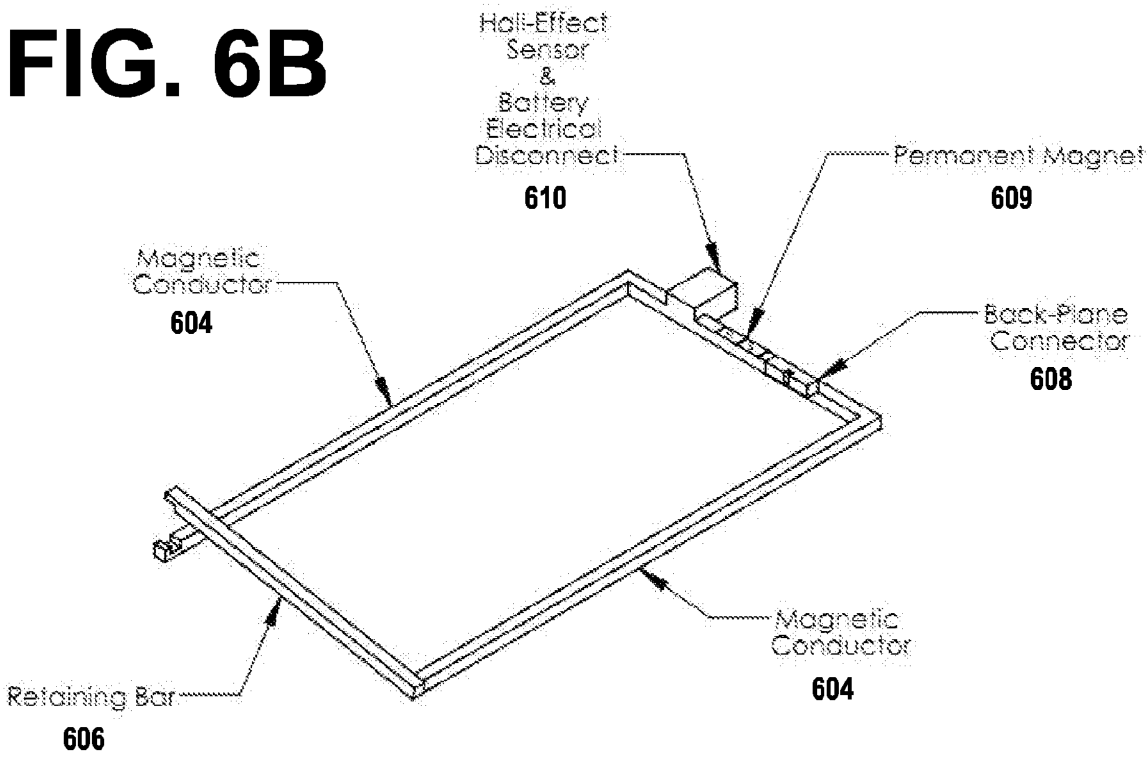
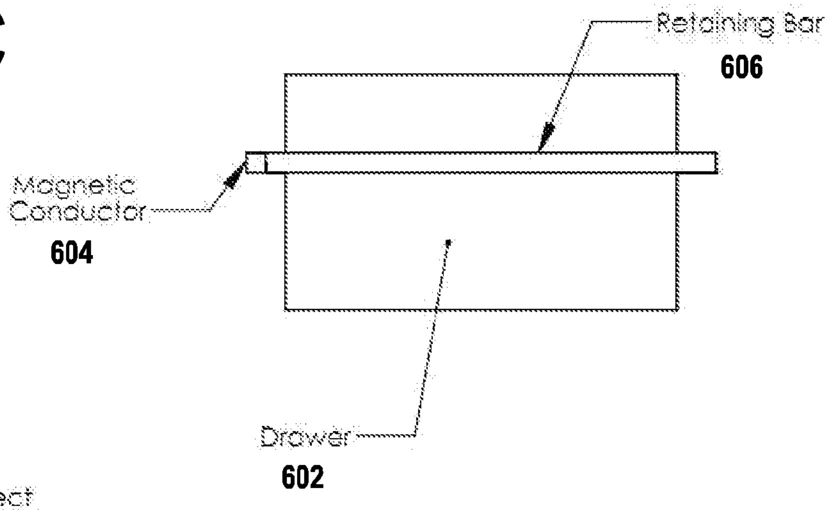

Hall-Effect Sensor & Battery Electrical Disconnect
610
Permanent Magnet
609
Magnetic Conductor
604
Back-Plane Connector
608
Magnetic Conductor
604
Retaining Bar
606

FIG. 6C


Retaining Bar
606
Magnetic Conductor
604
Drawer
602

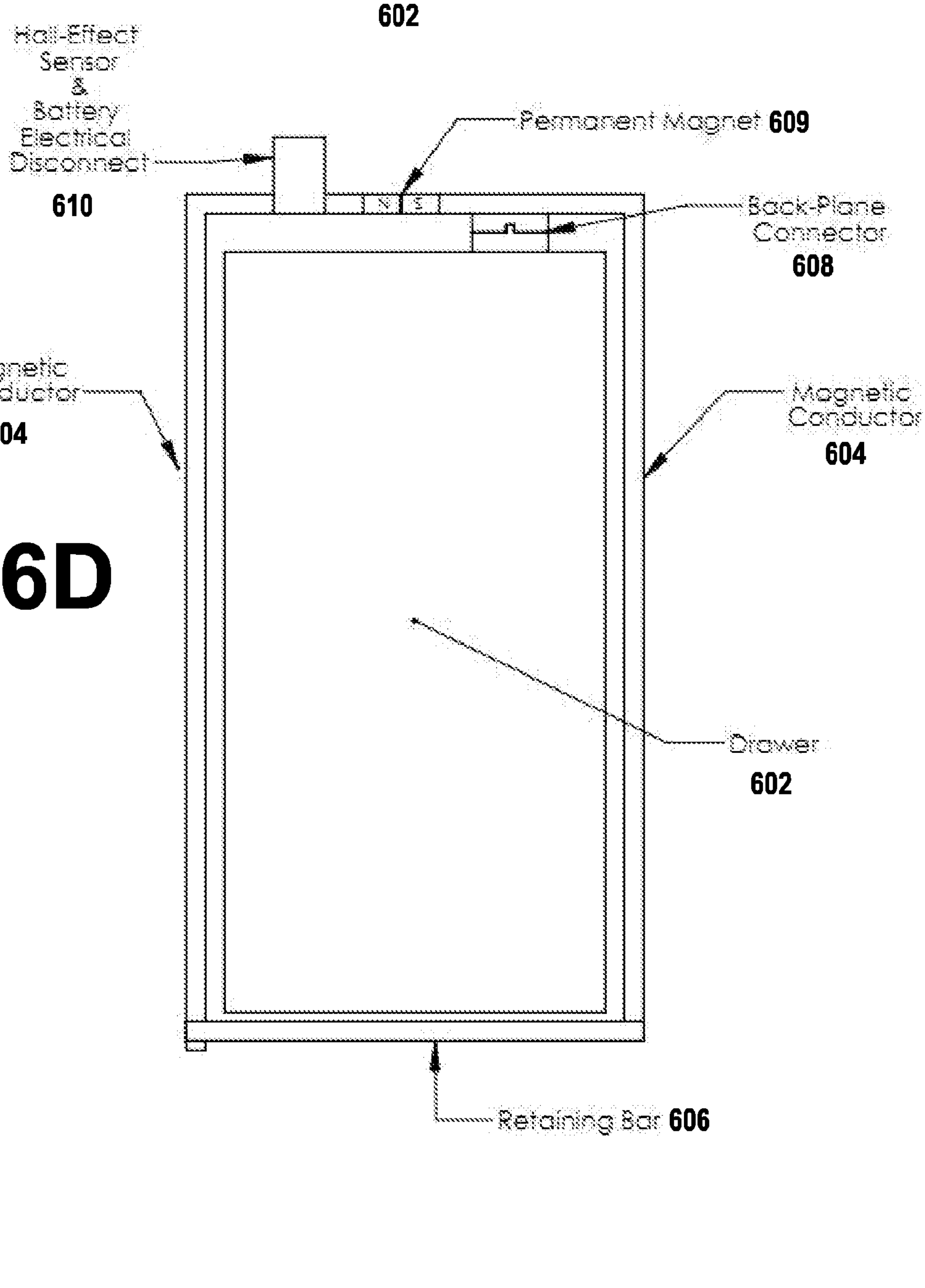

Hall-Effect Sensor & Battery Electrical Disconnect
610
Permanent Magnet 609
N
S
Back-Plane Connector
608
Magnetic Conductor
604
Magnetic Conductor
604
Drawer
602
Retaining Bar 606

FIG. 6D

FIG. 6E

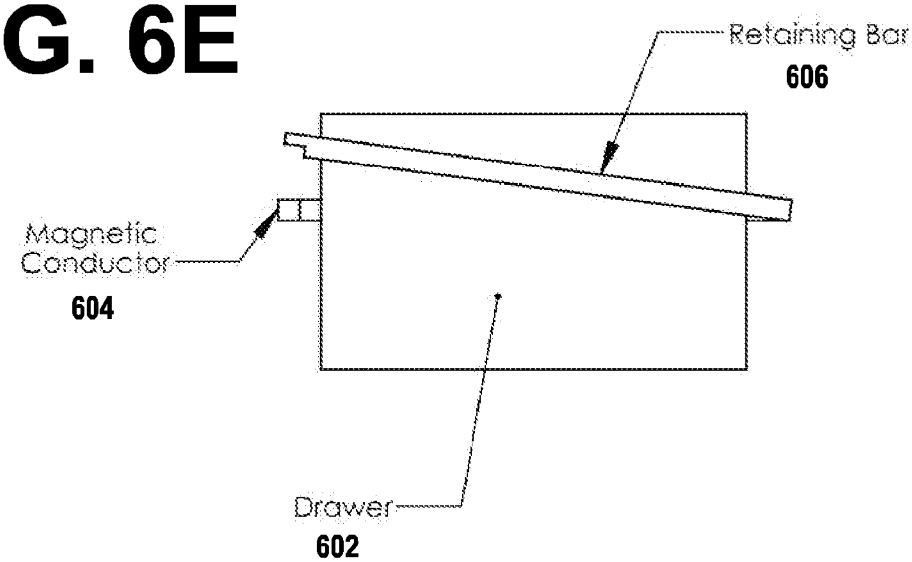

Retaining Bar
606
Magnetic Conductor
604
Drawer
602

FIG. 6F

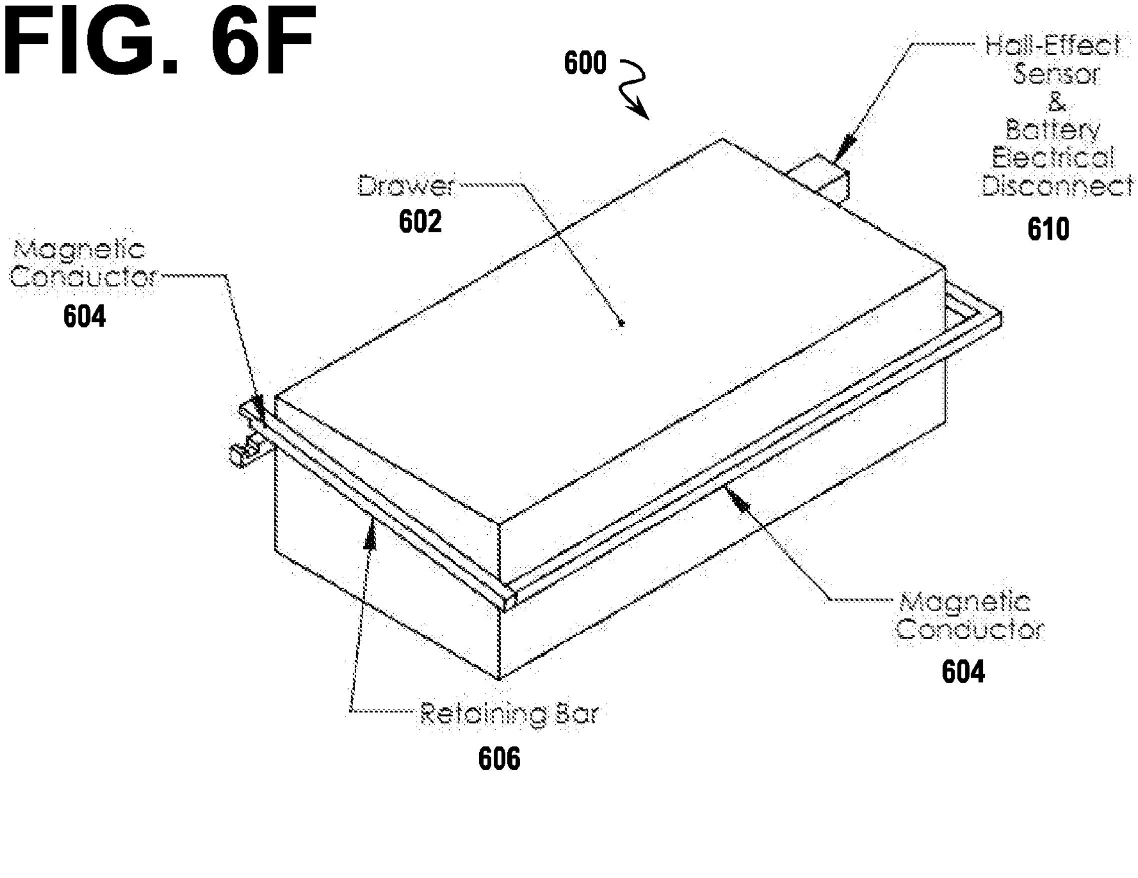

600
Hall-Effect Sensor & Battery Electrical Disconnect
610
Drawer
602
Magnetic Conductor
604
Magnetic Conductor
604
Retaining Bar
606

FIG. 7A

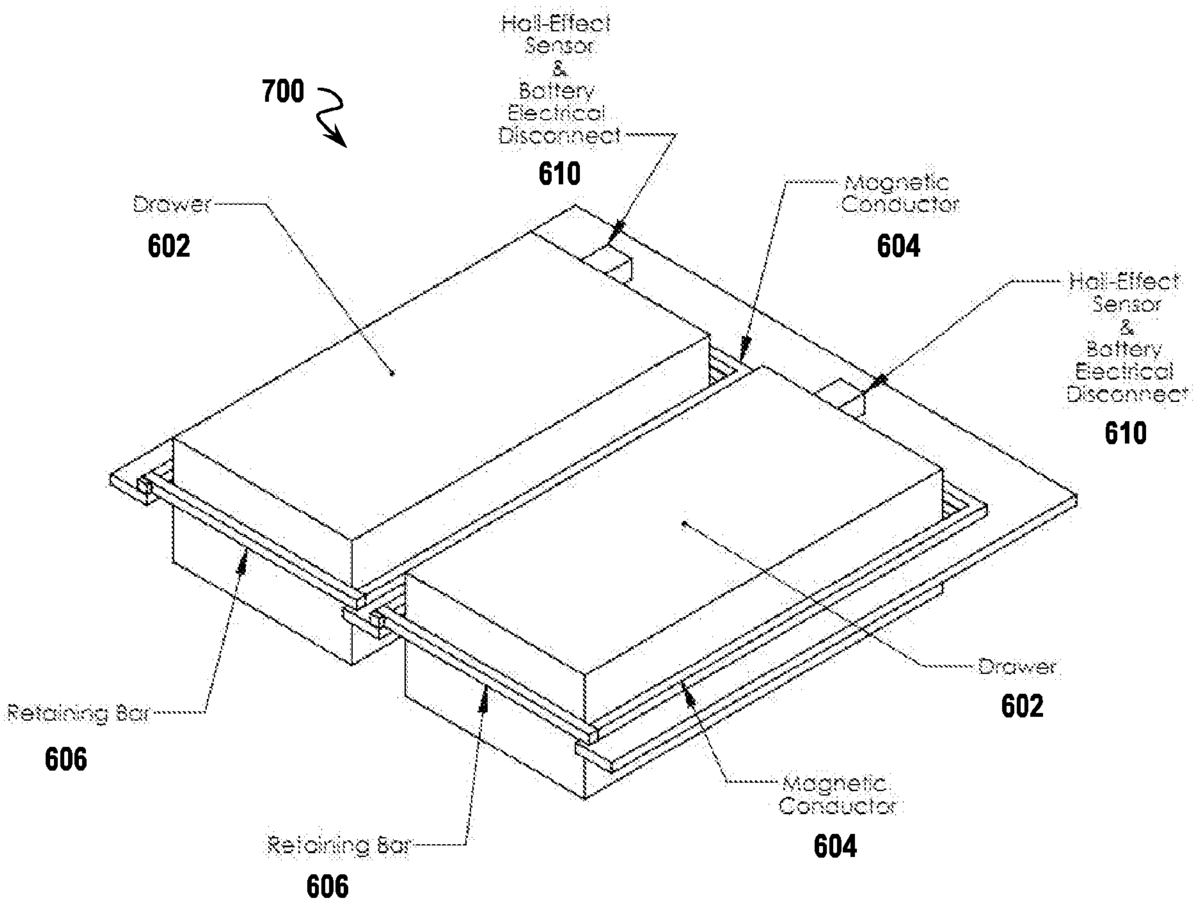

700
Hall-Effect
Sensor
&
Battery
Electrical
Disconnect
610
Drawer
602
Magnetic
Conductor
604
Hall-Effect
Sensor
&
Battery
Electrical
Disconnect
610
Drawer
602
Retaining Bar
606
Magnetic
Conductor
604
Retaining Bar
606

FIG. 7B

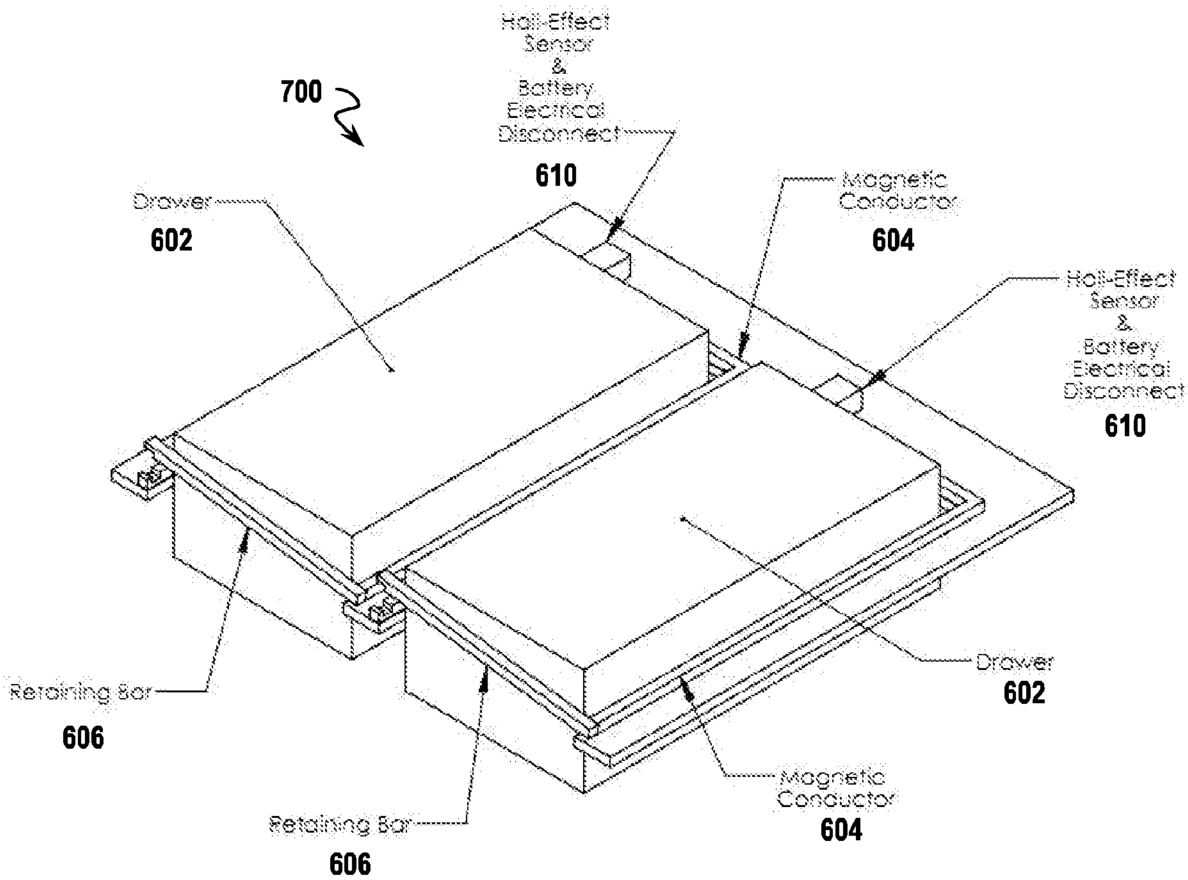
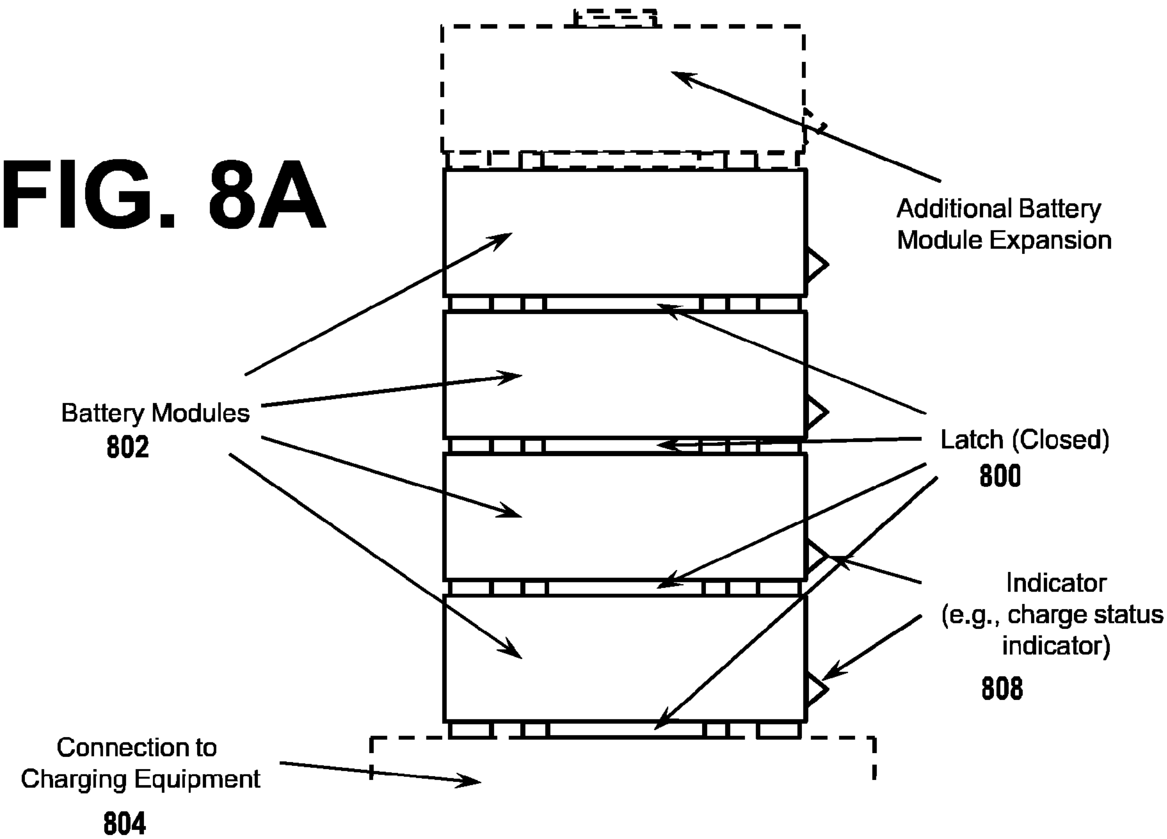
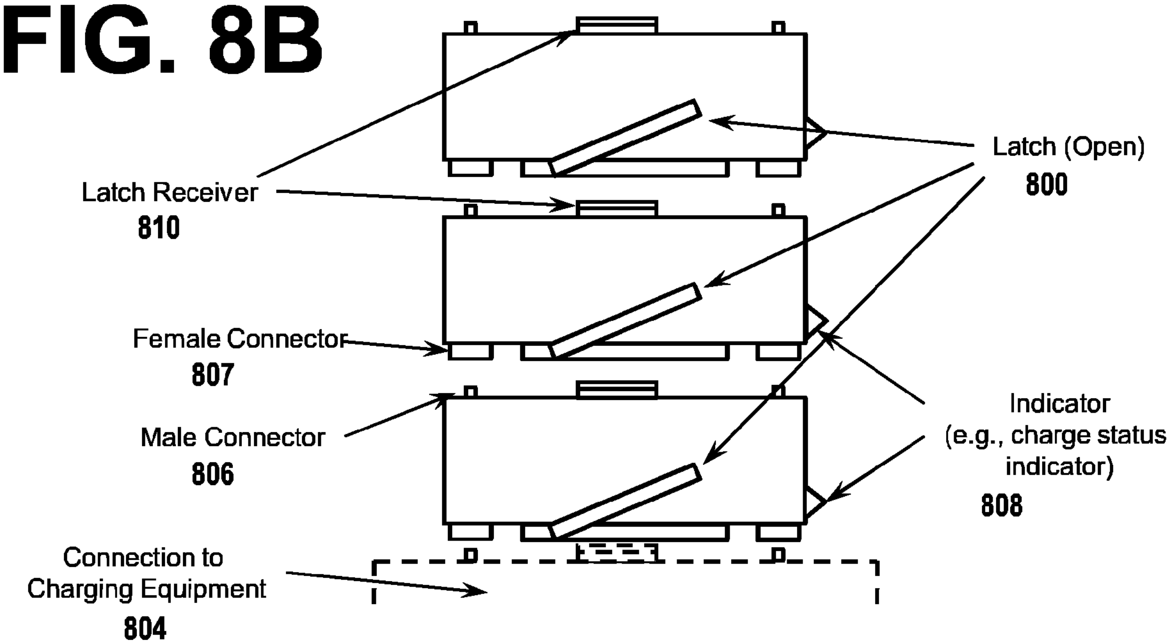

700
Hall-Effect Sensor & Battery Electrical Disconnect
610
Drawer
602
Magnetic Conductor
604
Hall-Effect Sensor & Battery Electrical Disconnect
610
Drawer
602
Retaining Bar
606
Retaining Bar
606
Magnetic Conductor
604

FIG. 8A



Additional Battery
Module Expansion
Battery Modules
802
Latch (Closed)
800
Indicator
(e.g., charge status
indicator)
808
Connection to
Charging Equipment
804

FIG. 8B



Latch Receiver
810
Latch (Open)
800
Female Connector
807
Male Connector
806
Indicator
(e.g., charge status
indicator)
808
Connection to
Charging Equipment
804

FIG. 9A

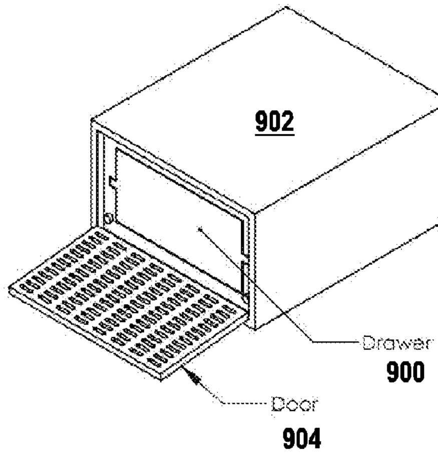


FIG. 9B

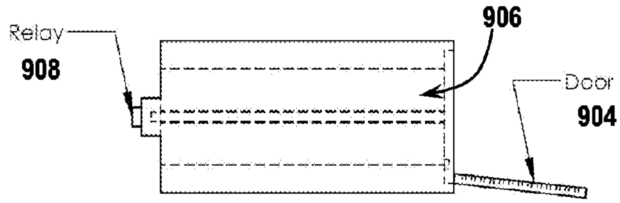


FIG. 9C

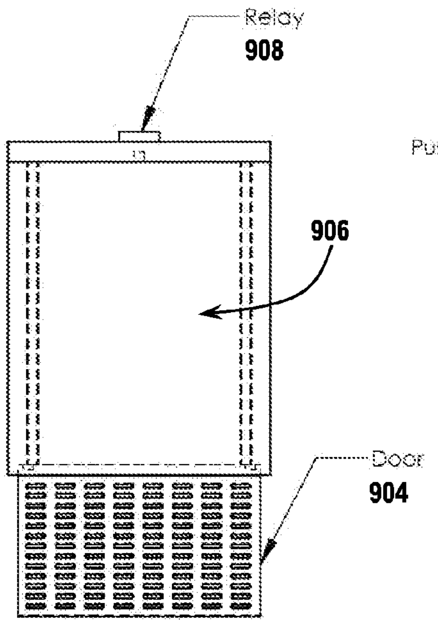


FIG. 9D

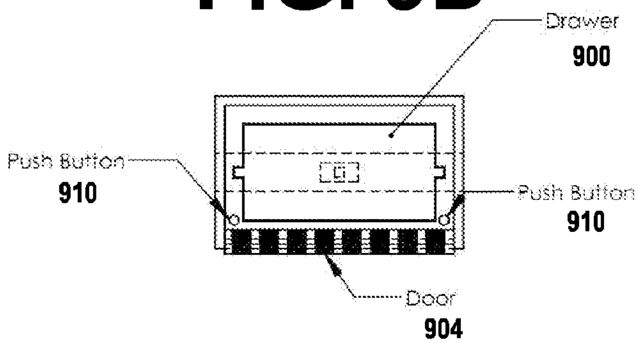


FIG. 9E

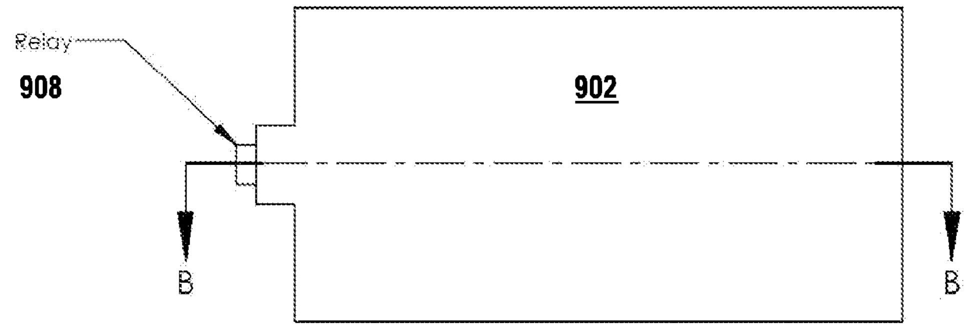

Relay
908
902
B
B

FIG. 9F

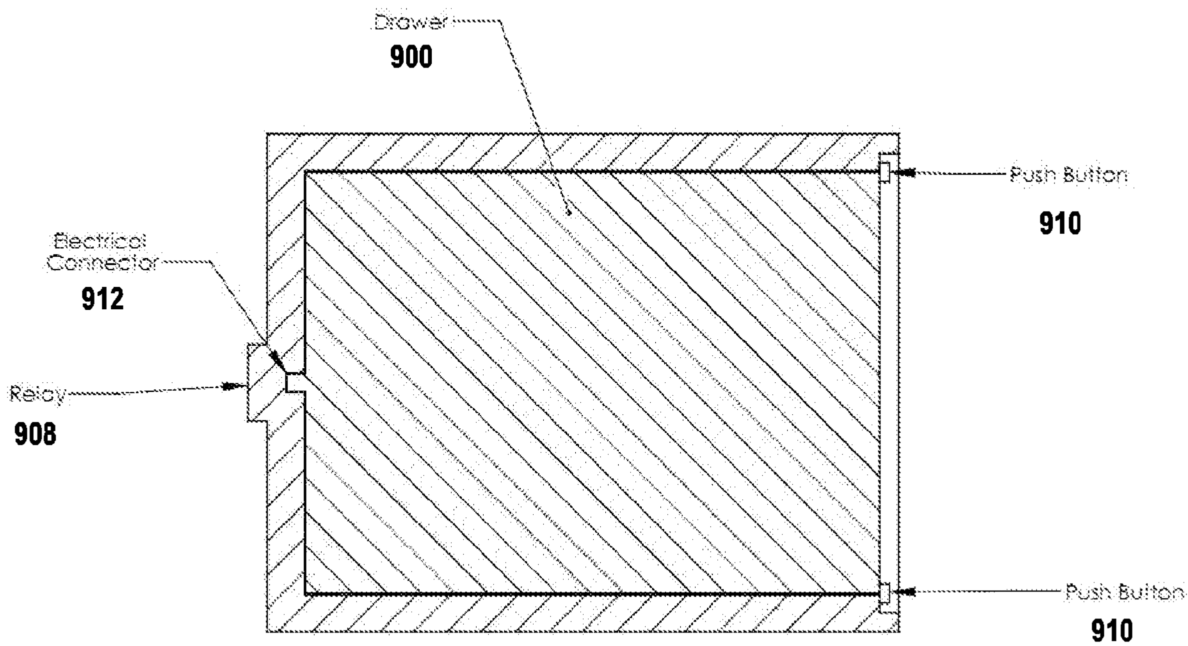

Drawer
900
Push Button
910
Electrical Connector
912
Relay
908
Push Button
910

FIG. 10A

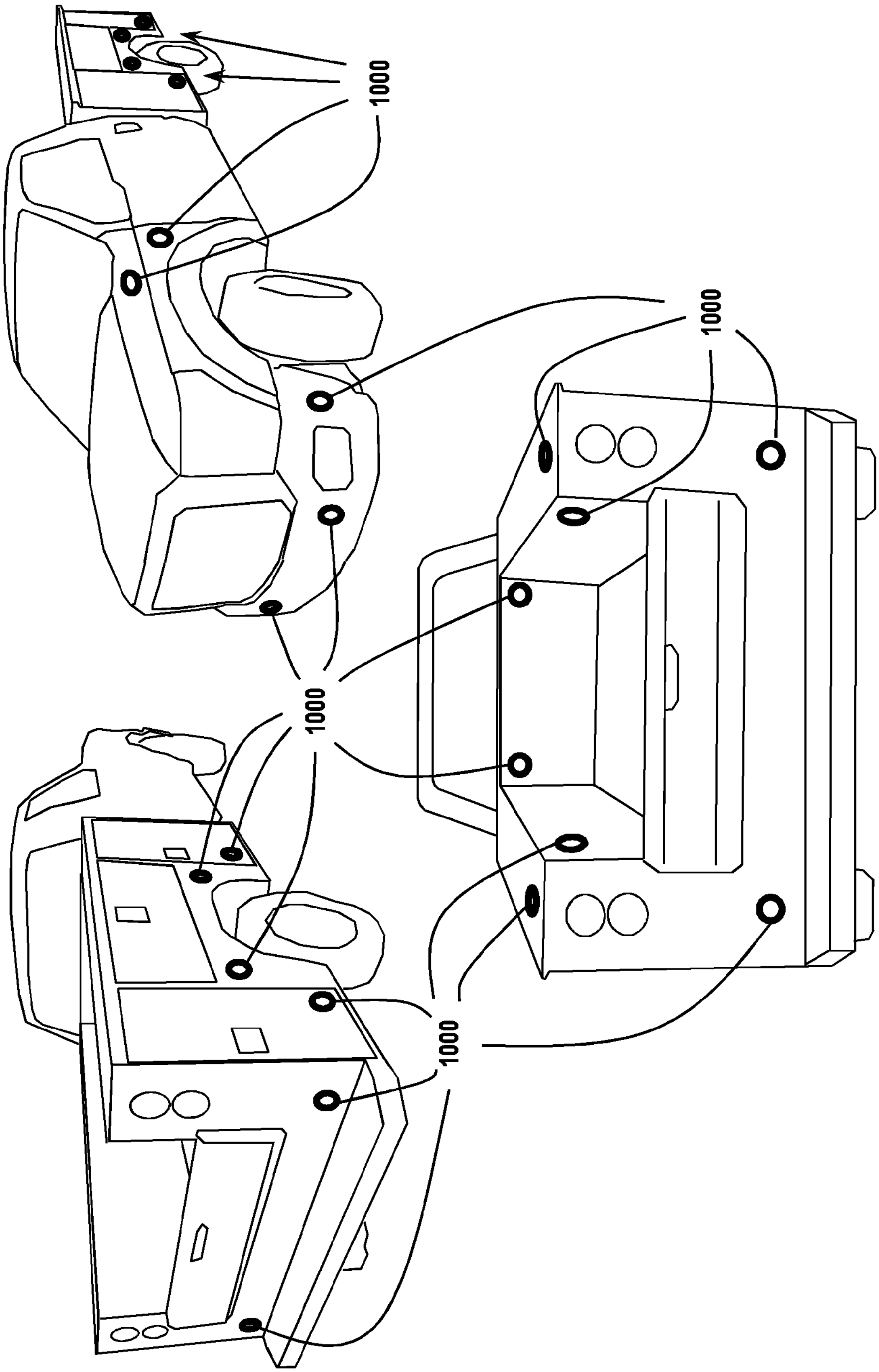


FIG. 10B

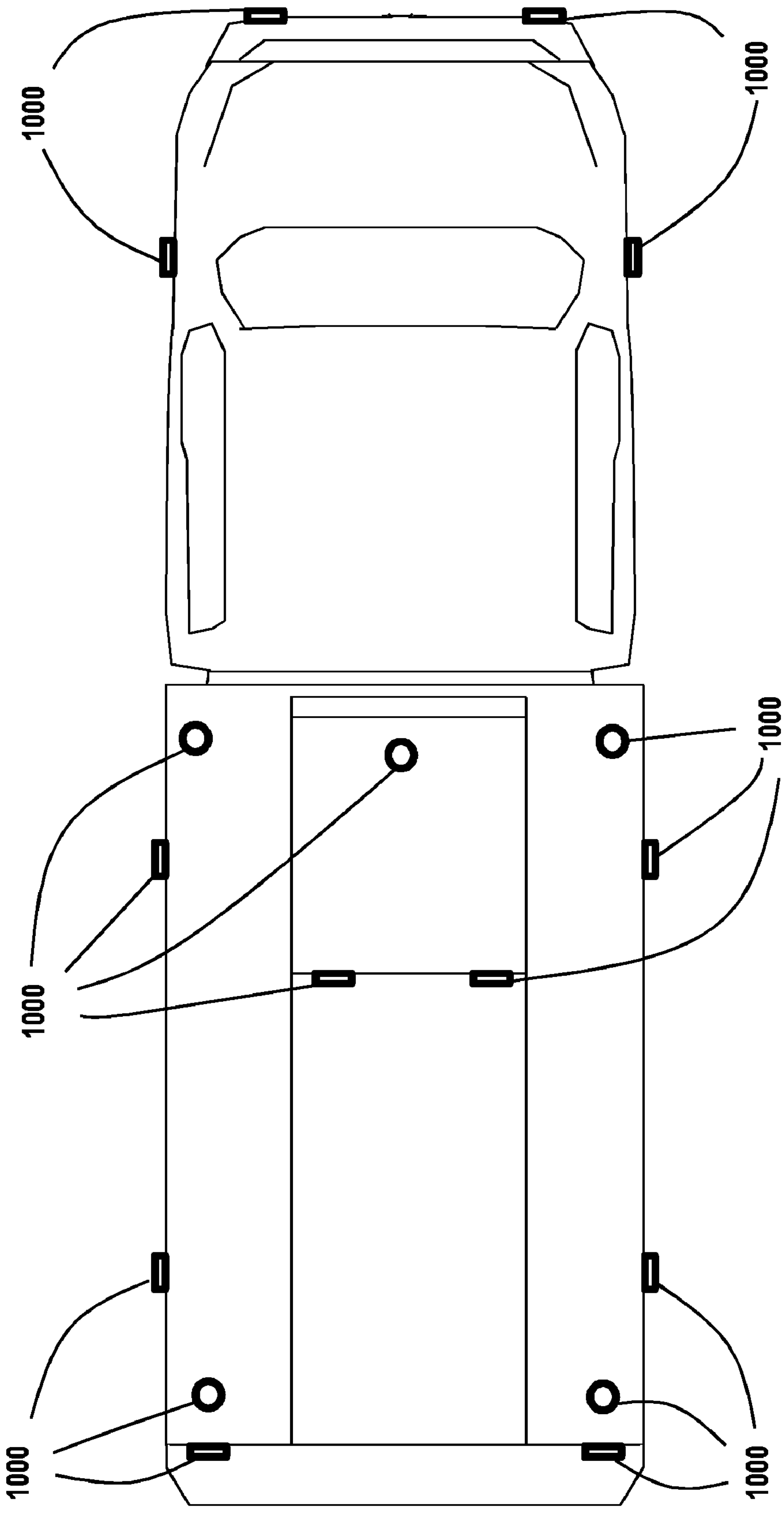


FIG. 11A

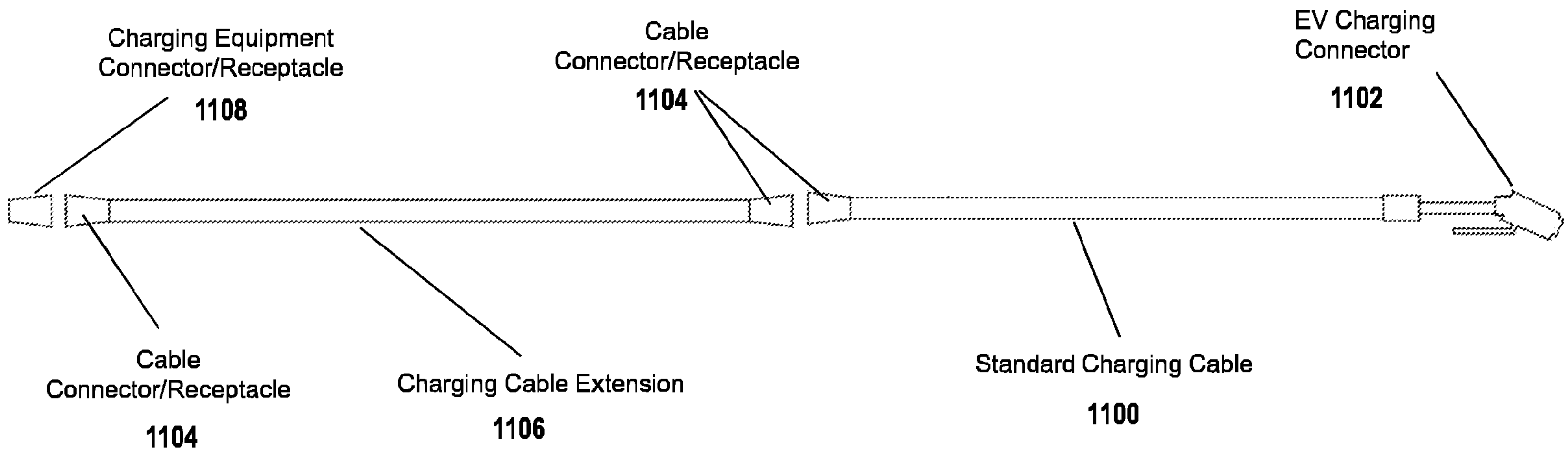


FIG. 11B

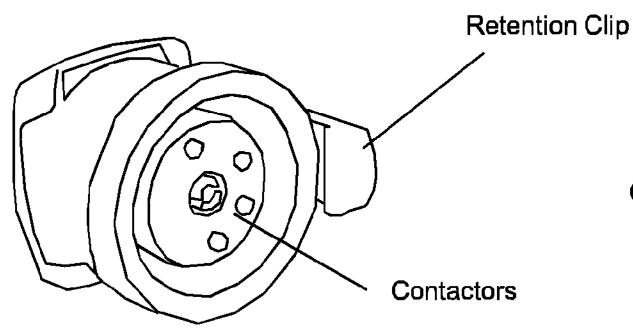
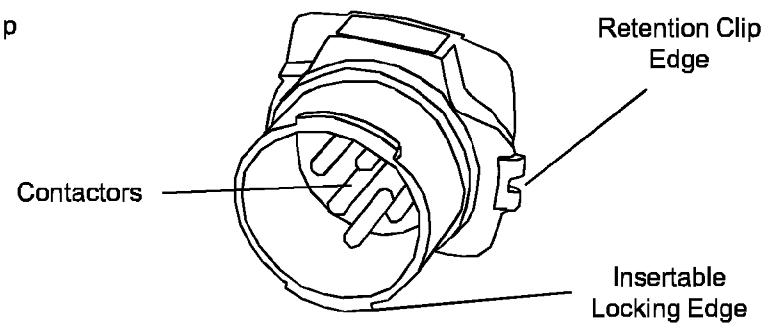


FIG. 11C



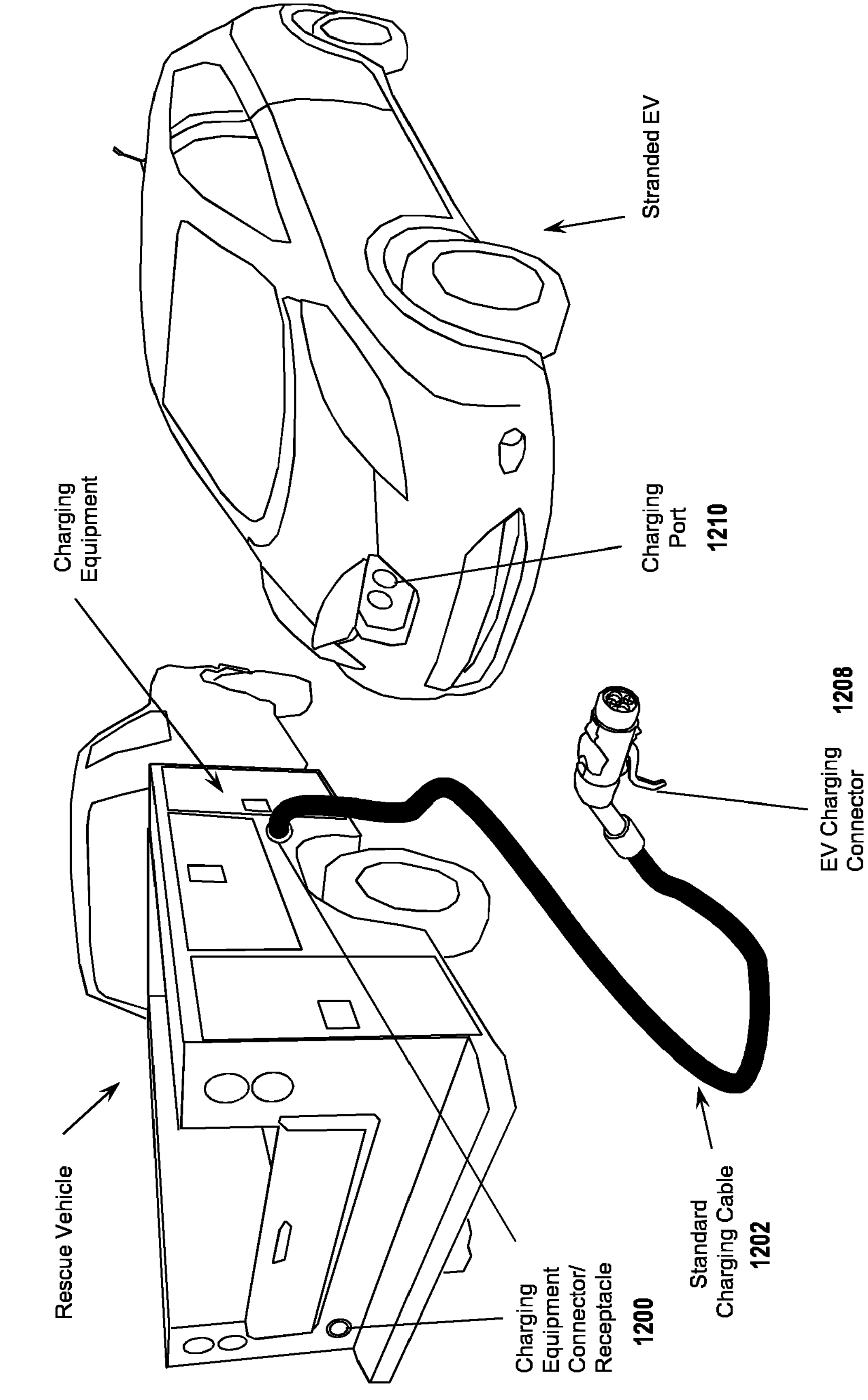
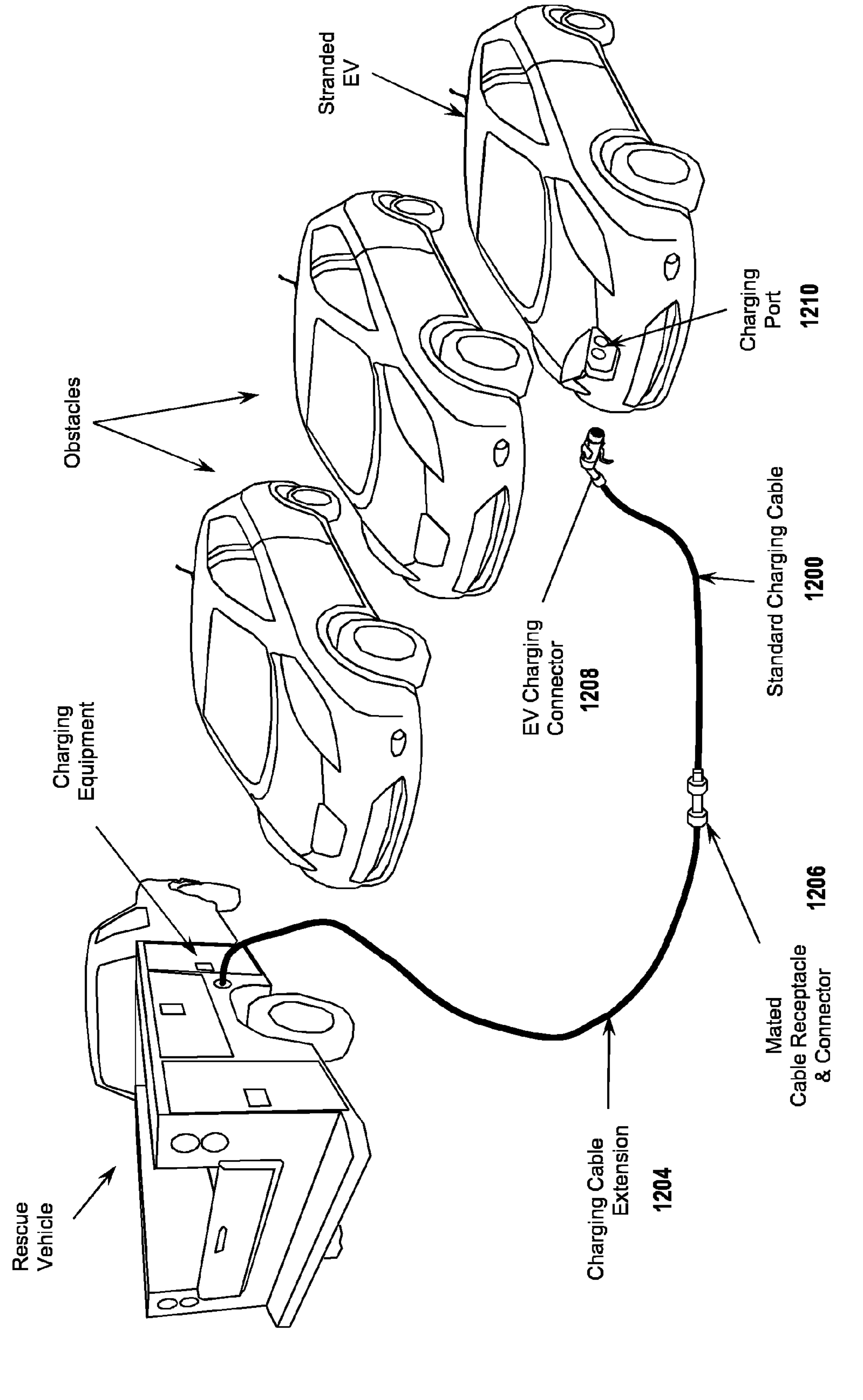

Charging Equipment
Stranded EV
Charging Port
1210
Rescue Vehicle
Charging Equipment Connector/ Receptacle
1200
Standard Charging Cable
1202
EV Charging Connector
1208

FIG. 12A

FIG. 12B



Stranded EV
Obstacles
Charging Equipment
Charging Port
1210
EV Charging Connector
1208
Standard Charging Cable
1200
Rescue Vehicle
Charging Cable Extension
1204
Mated Cable Receptacle & Connector
1206

FIG. 13A

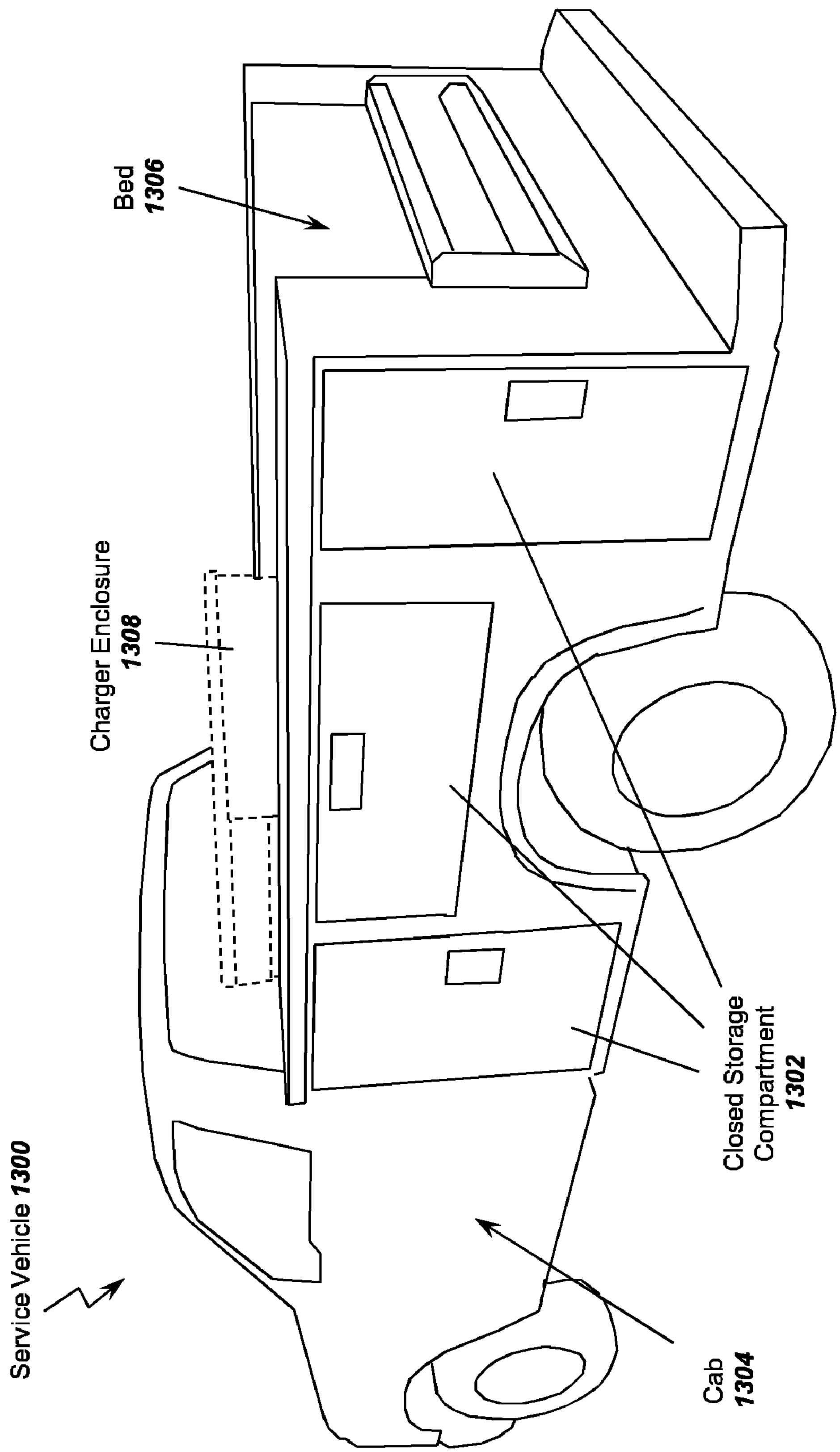

Service Vehicle 1300
Cab 1304
Charger Enclosure 1308
Bed 1306
Closed Storage Compartment 1302

FIG. 13B

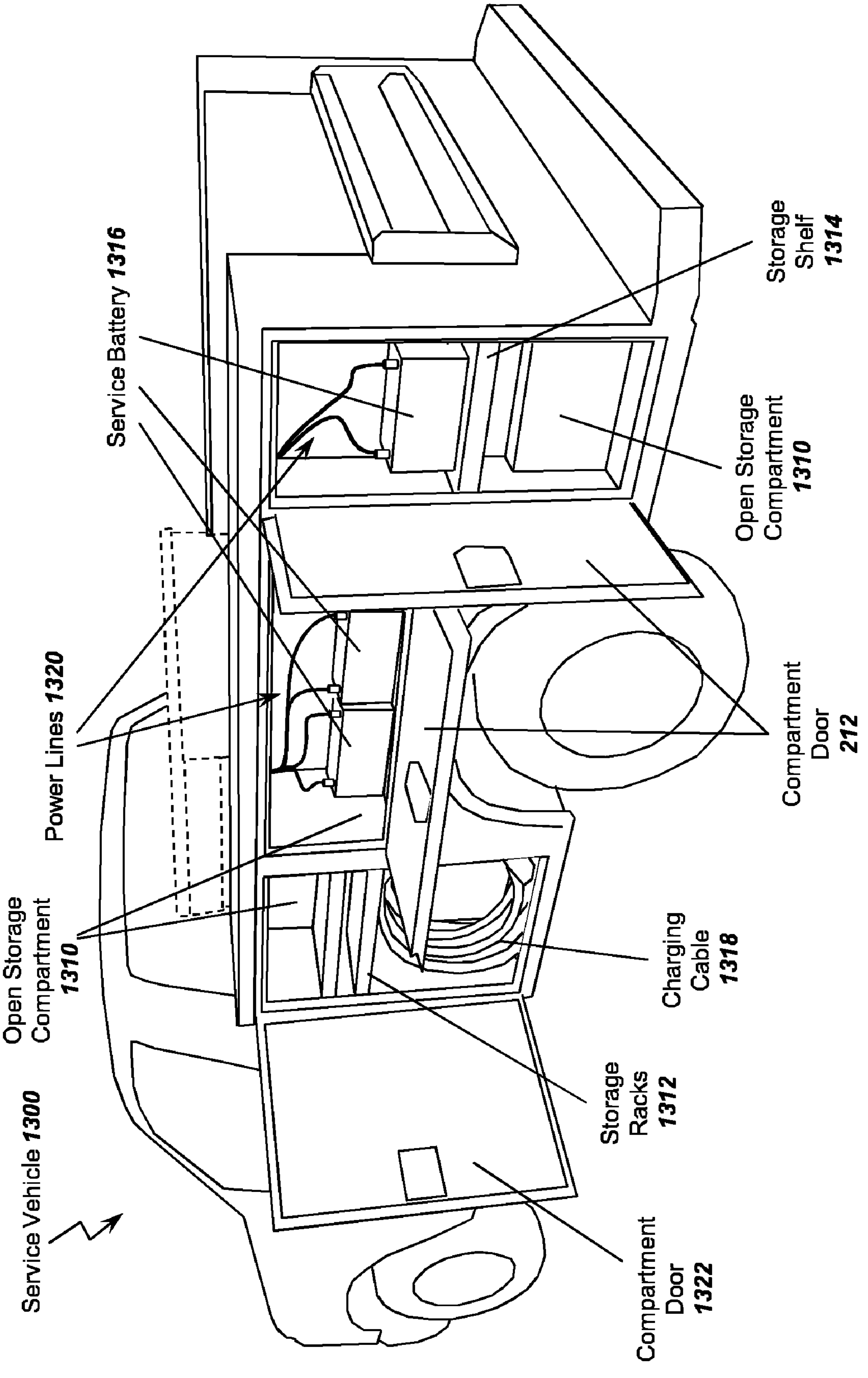

Service Vehicle 1300
Open Storage Compartment 1310
Power Lines 1320
Service Battery 1316
Storage Shelf 1314
Open Storage Compartment 1310
Compartment Door 212
Charging Cable 1318
Storage Racks 1312
Compartment Door 1322

FIG. 14A

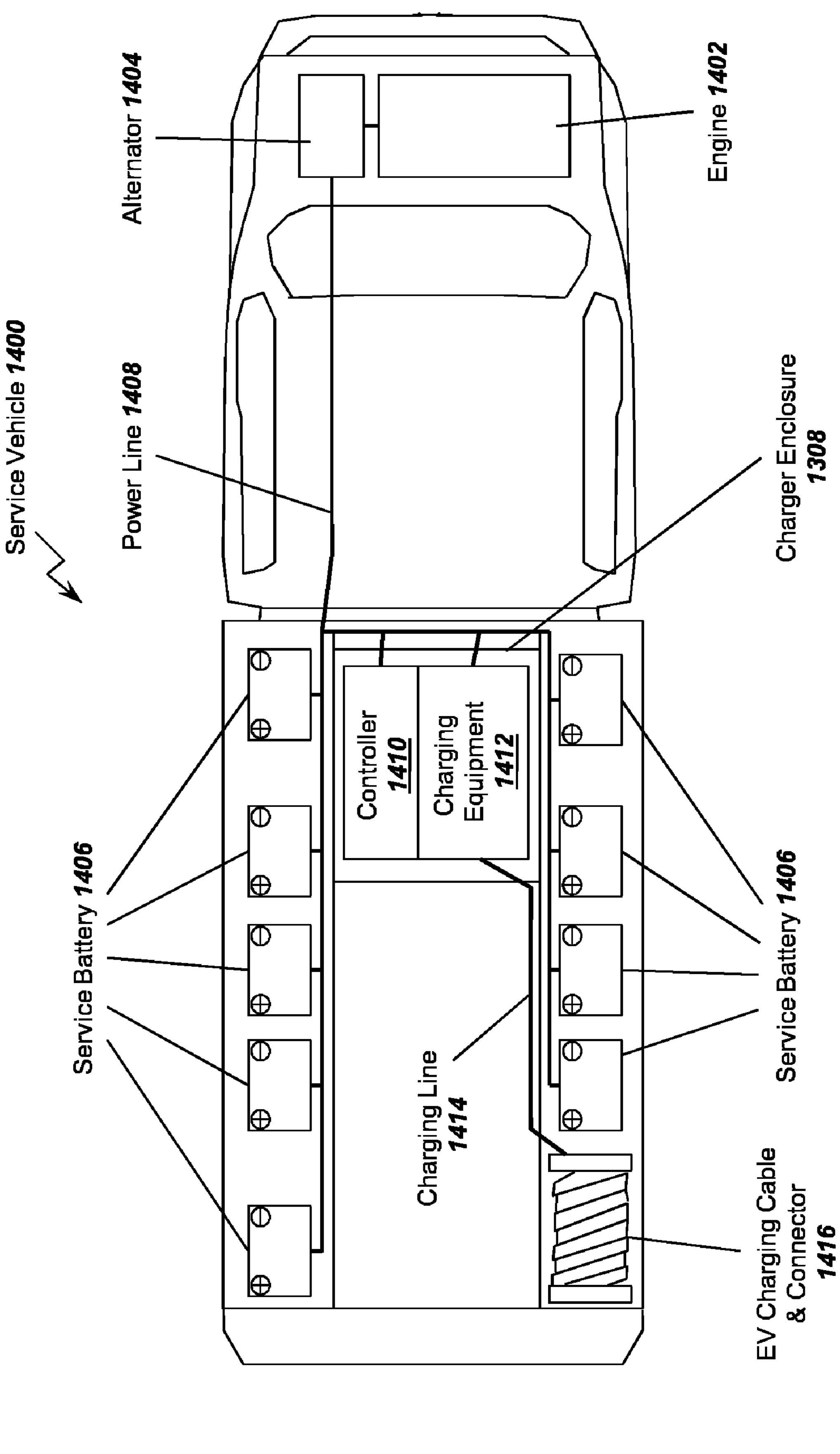
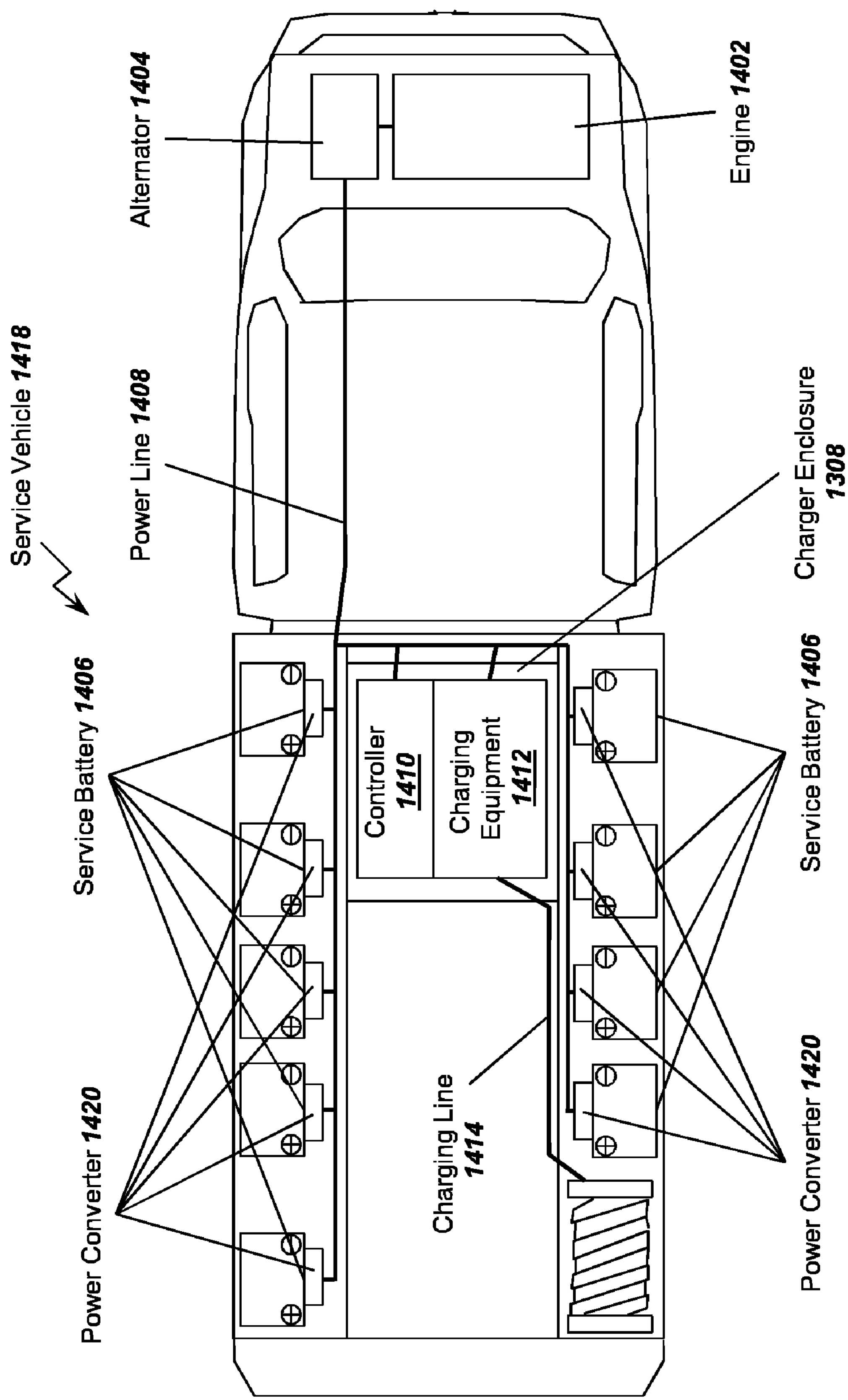

Service Vehicle 1400
Alternator 1404
Engine 1402
Power Line 1408
Charger Enclosure 1308
Service Battery 1406
Controller 1410
Charging Equipment 1412
Charging Line 1414
Service Battery 1406
EV Charging Cable & Connector 1416

FIG. 14B


Service Vehicle 1418
Alternator 1404
Engine 1402
Power Line 1408
Charger Enclosure 1308
Controller 1410
Charging Equipment 1412
Service Battery 1406
Service Battery 1406
Charging Line 1414
Power Converter 1420
Power Converter 1420

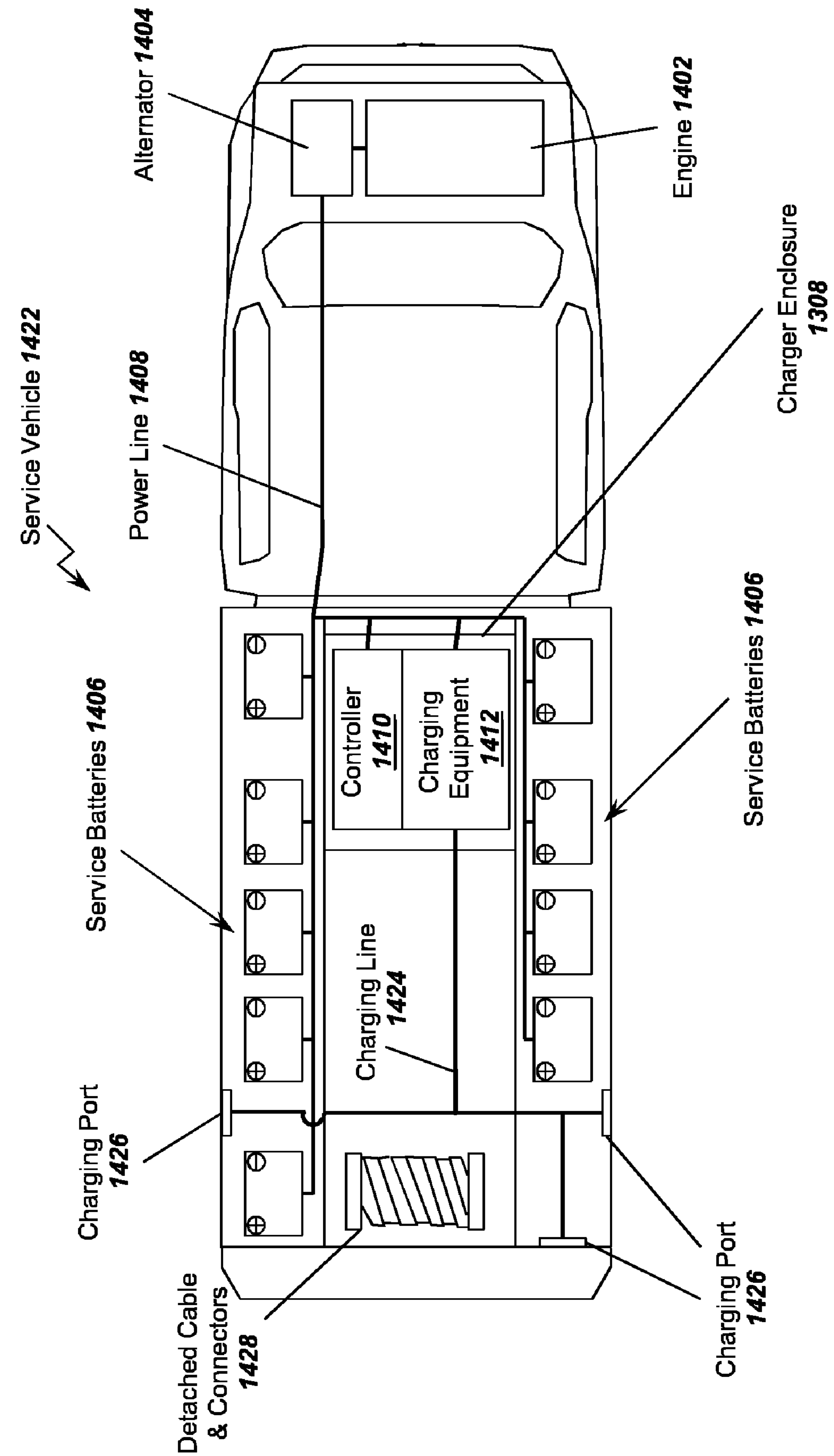

Alternator 1404
Engine 1402
Service Vehicle 1422
Power Line 1408
Charger Enclosure
1308
Service Batteries 1406
Service Batteries 1406
Controller
1410
Charging
Equipment
1412
Charging Line
1424
Charging Port
1426
Charging Port
1426
Detached Cable
& Connectors
1428

FIG. 14C

FIG. 14D

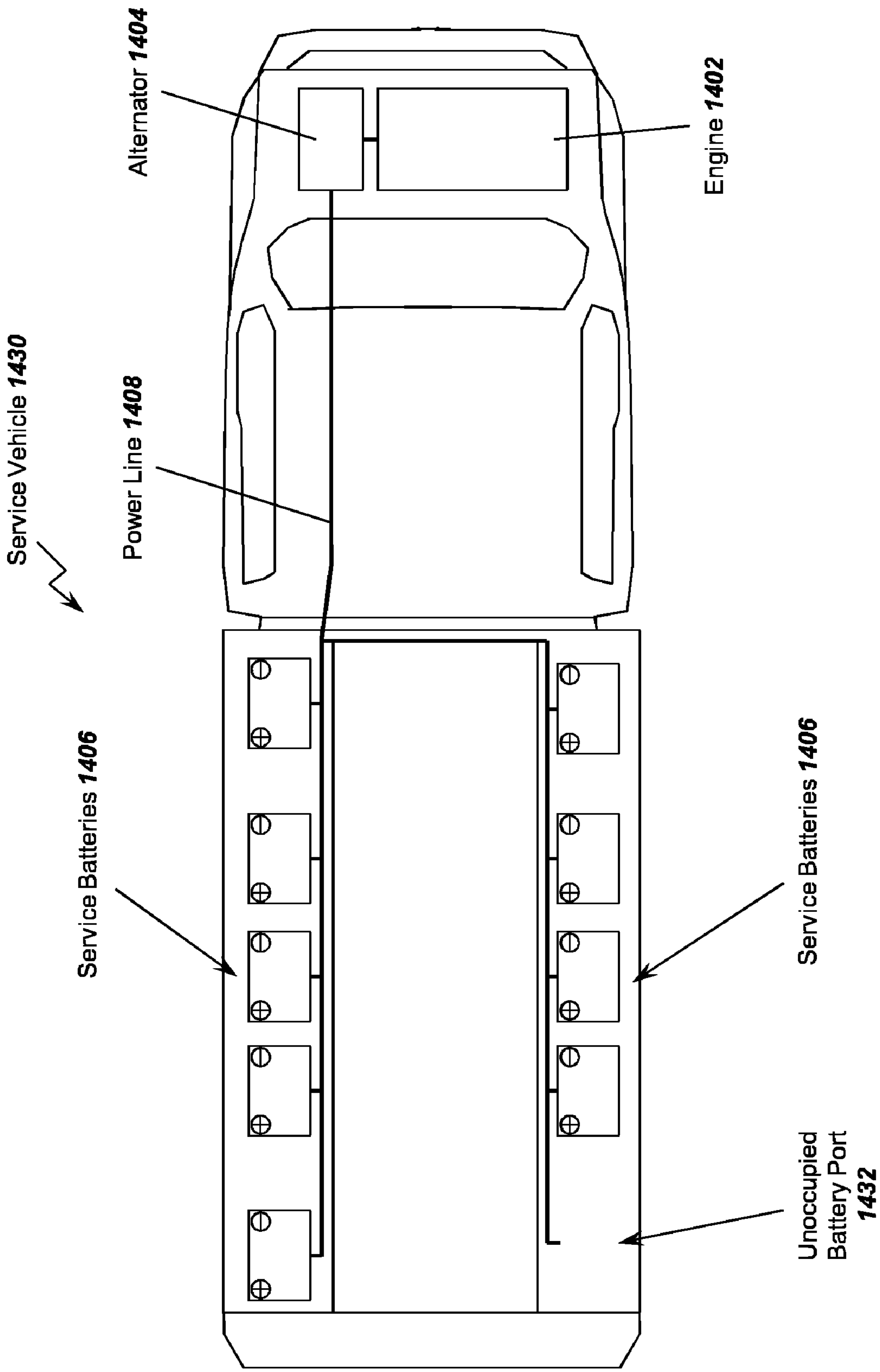

Alternator 1404
Engine 1402
Service Vehicle 1430
Power Line 1408
Service Batteries 1406
Service Batteries 1406
Unoccupied Battery Port 1432

FIG. 14E

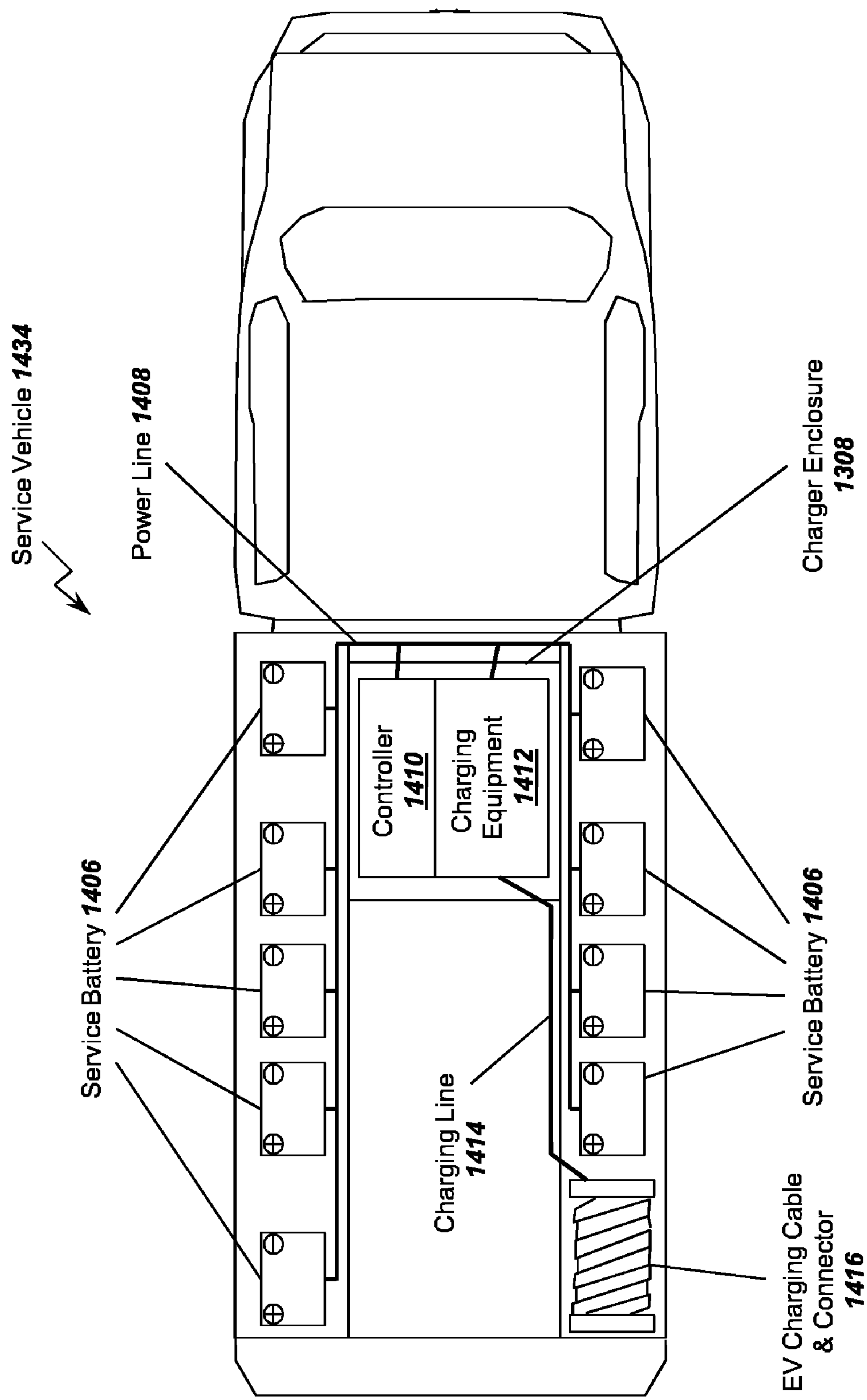

Service Vehicle 1434
Power Line 1408
Charger Enclosure 1308
Service Battery 1406
Controller 1410
Charging Equipment 1412
Charging Line 1414
Service Battery 1406
EV Charging Cable & Connector 1416

FIG. 14F

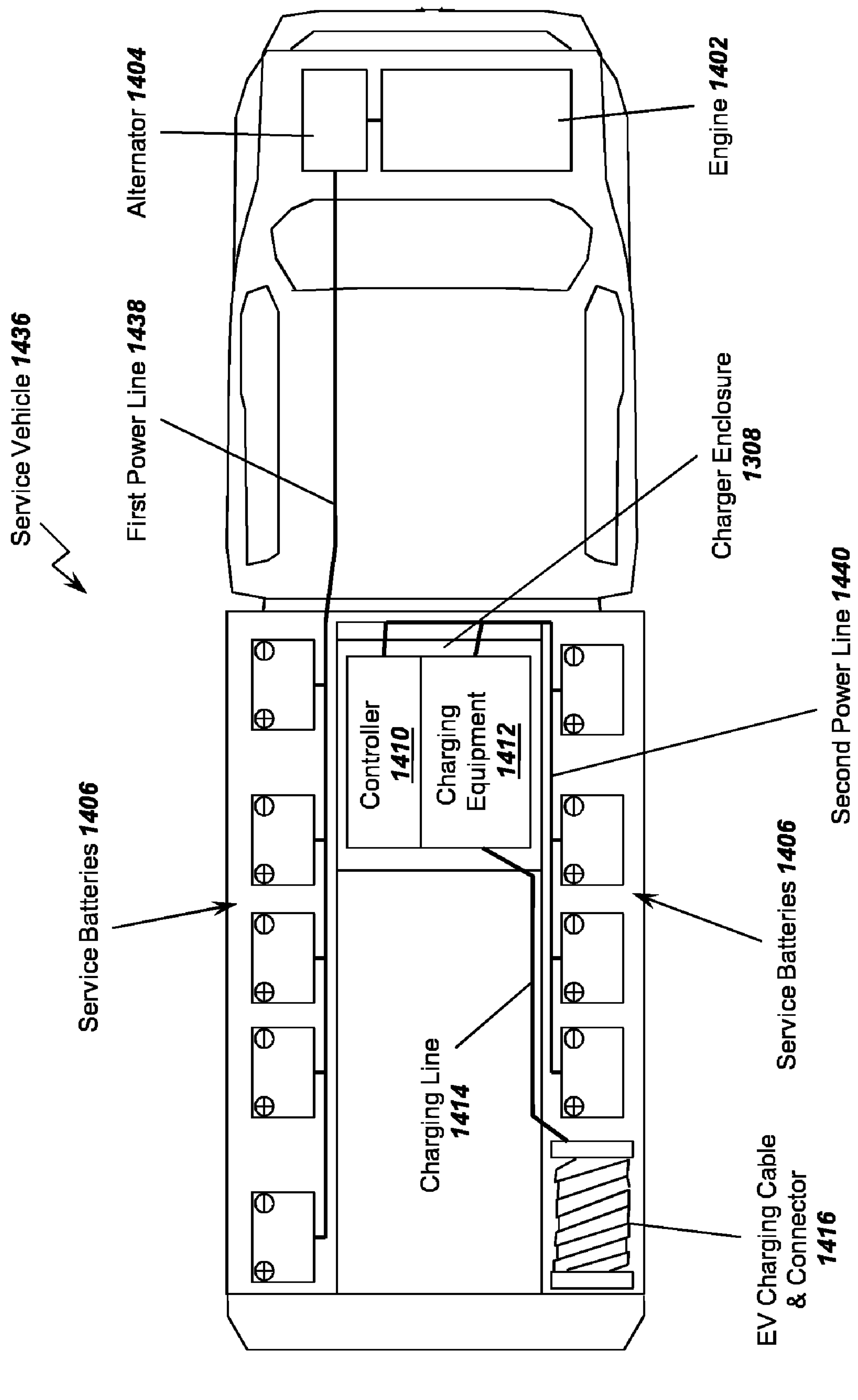

Service Vehicle 1436
First Power Line 1438
Alternator 1404
Engine 1402
Charger Enclosure 1308
Second Power Line 1440
Controller 1410
Charging Equipment 1412
Service Batteries 1406
Service Batteries 1406
Charging Line 1414
EV Charging Cable & Connector 1416

FIG. 15

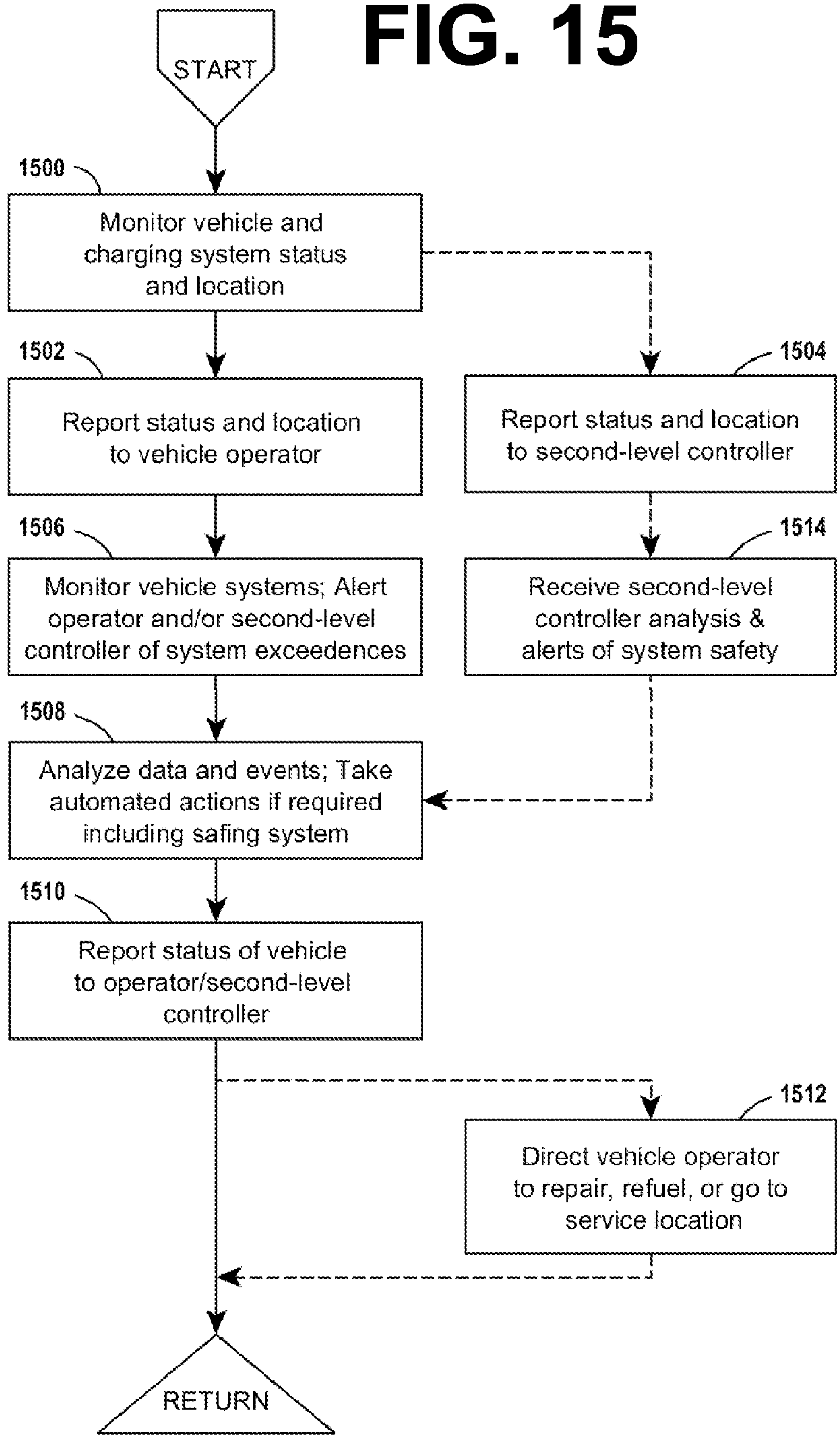
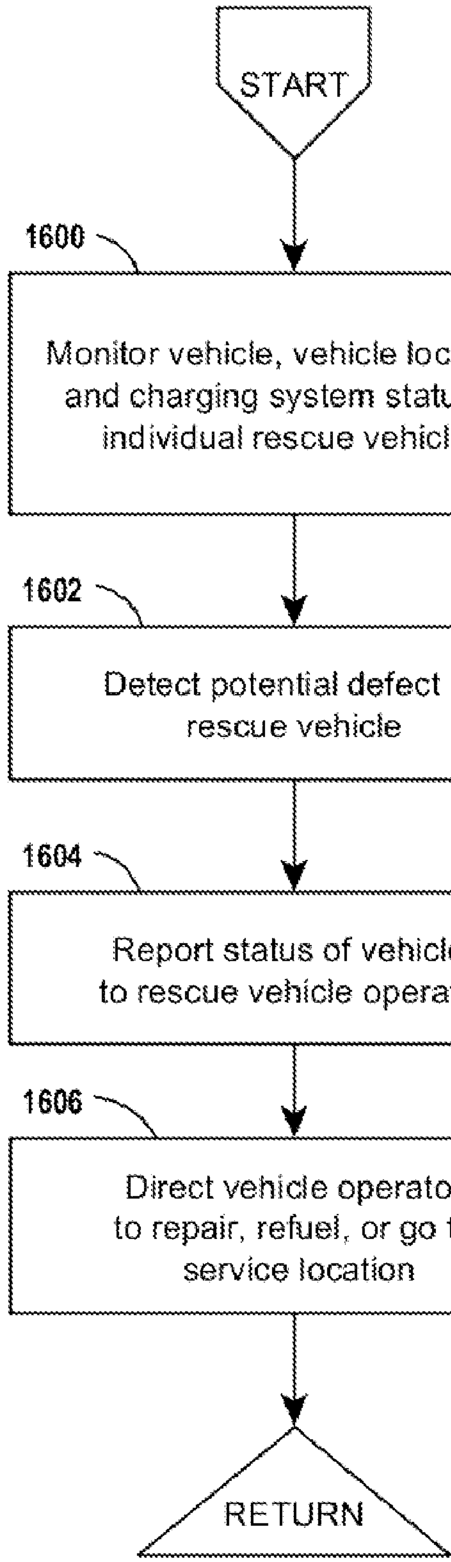

START
1500
Monitor vehicle and charging system status and location
1502
Report status and location to vehicle operator
1504
Report status and location to second-level controller
1506
Monitor vehicle systems; Alert operator and/or second-level controller of system exceedences
1514
Receive second-level controller analysis & alerts of system safety
1508
Analyze data and events; Take automated actions if required including safing system
1510
Report status of vehicle to operator/second-level controller
1512
Direct vehicle operator to repair, refuel, or go to service location
RETURN

FIG. 16


START
1600
Monitor vehicle, vehicle location, and charging system status for individual rescue vehicles
1602
Detect potential defect in rescue vehicle
1604
Report status of vehicle to rescue vehicle operator
1606
Direct vehicle operator to repair, refuel, or go to service location
RETURN

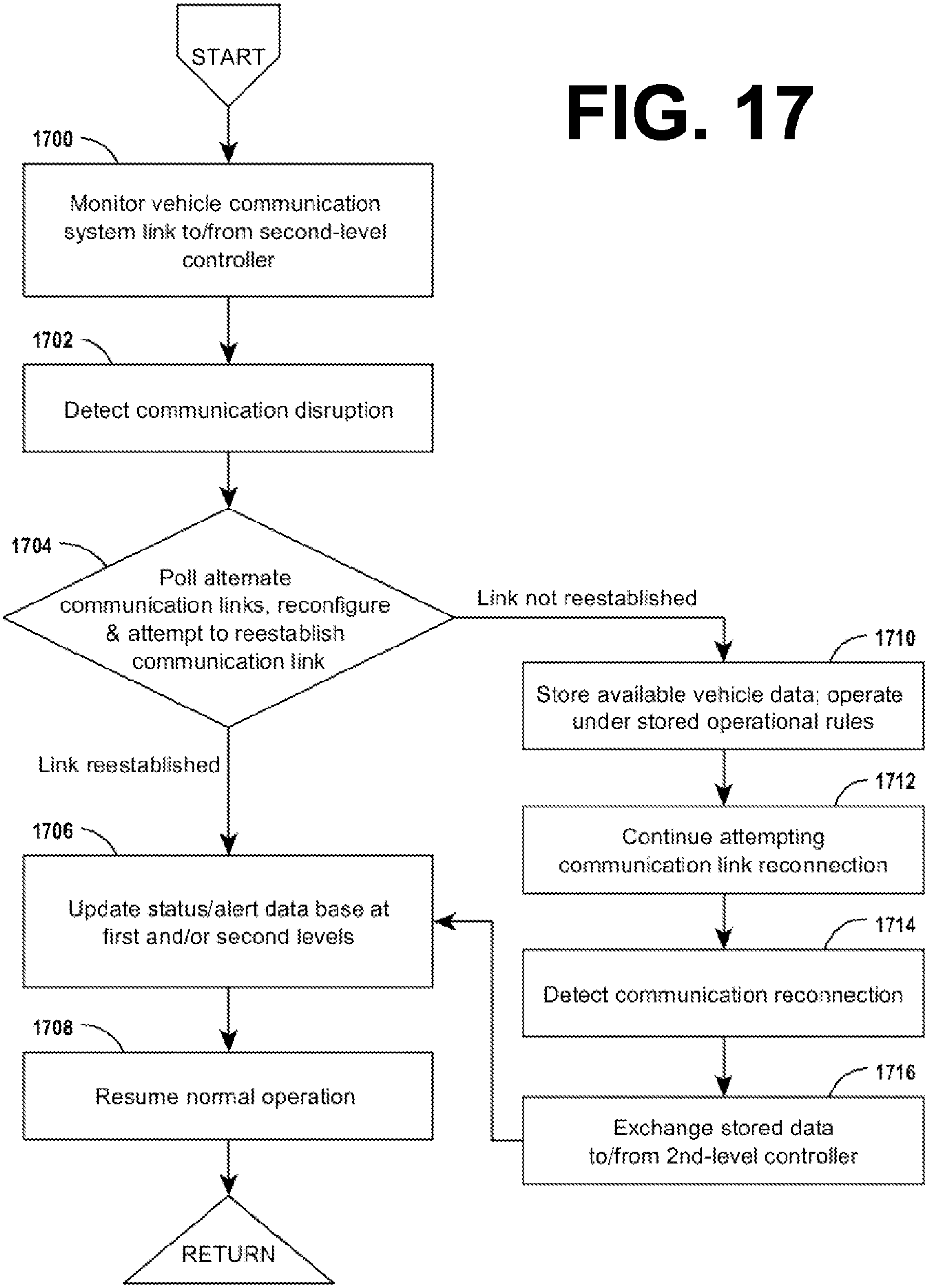

START
1700
Monitor vehicle communication system link to/from second-level controller
1702
Detect communication disruption
1704
Poll alternate communication links, reconfigure & attempt to reestablish communication link
Link not reestablished
1710
Store available vehicle data; operate under stored operational rules
1712
Continue attempting communication link reconnection
1714
Detect communication reconnection
1716
Exchange stored data to/from 2nd-level controller
Link reestablished
1706
Update status/alert data base at first and/or second levels
1708
Resume normal operation
RETURN

FIG. 17

FIG. 18

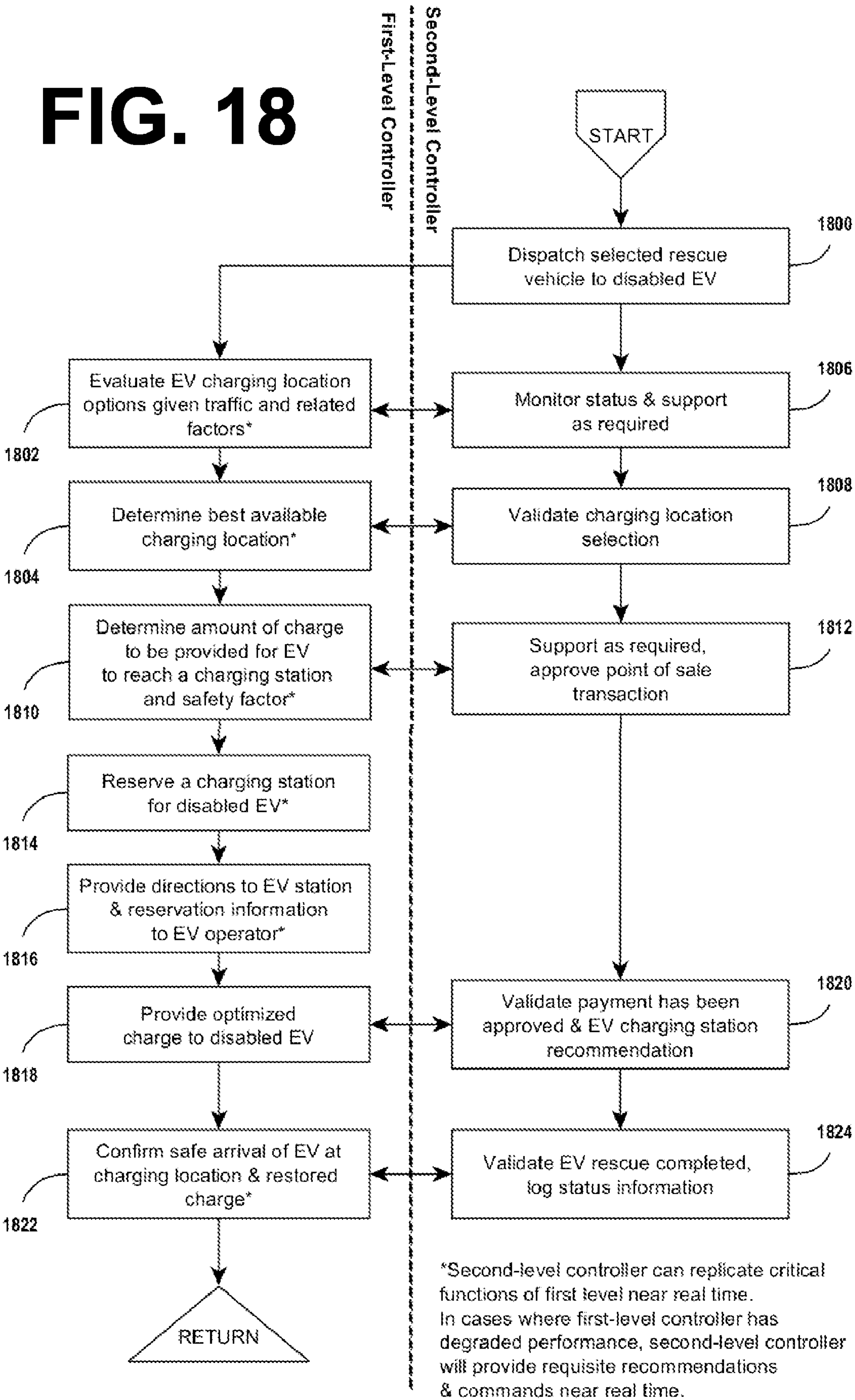

First-Level Controller
Second-Level Controller
START
Dispatch selected rescue vehicle to disabled EV
1800
Evaluate EV charging location options given traffic and related factors*
1802
Monitor status & support as required
1806
Determine best available charging location*
1804
Validate charging location selection
1808
Determine amount of charge to be provided for EV to reach a charging station and safety factor*
1810
Support as required, approve point of sale transaction
1812
Reserve a charging station for disabled EV*
1814
Provide directions to EV station & reservation information to EV operator*
1816
Provide optimized charge to disabled EV
1818
Validate payment has been approved & EV charging station recommendation
1820
Confirm safe arrival of EV at charging location & restored charge*
1822
Validate EV rescue completed, log status information
1824
RETURN
*Second-level controller can replicate critical functions of first level near real time.
In cases where first-level controller has degraded performance, second-level controller will provide requisite recommendations & commands near real time.

FIG. 19

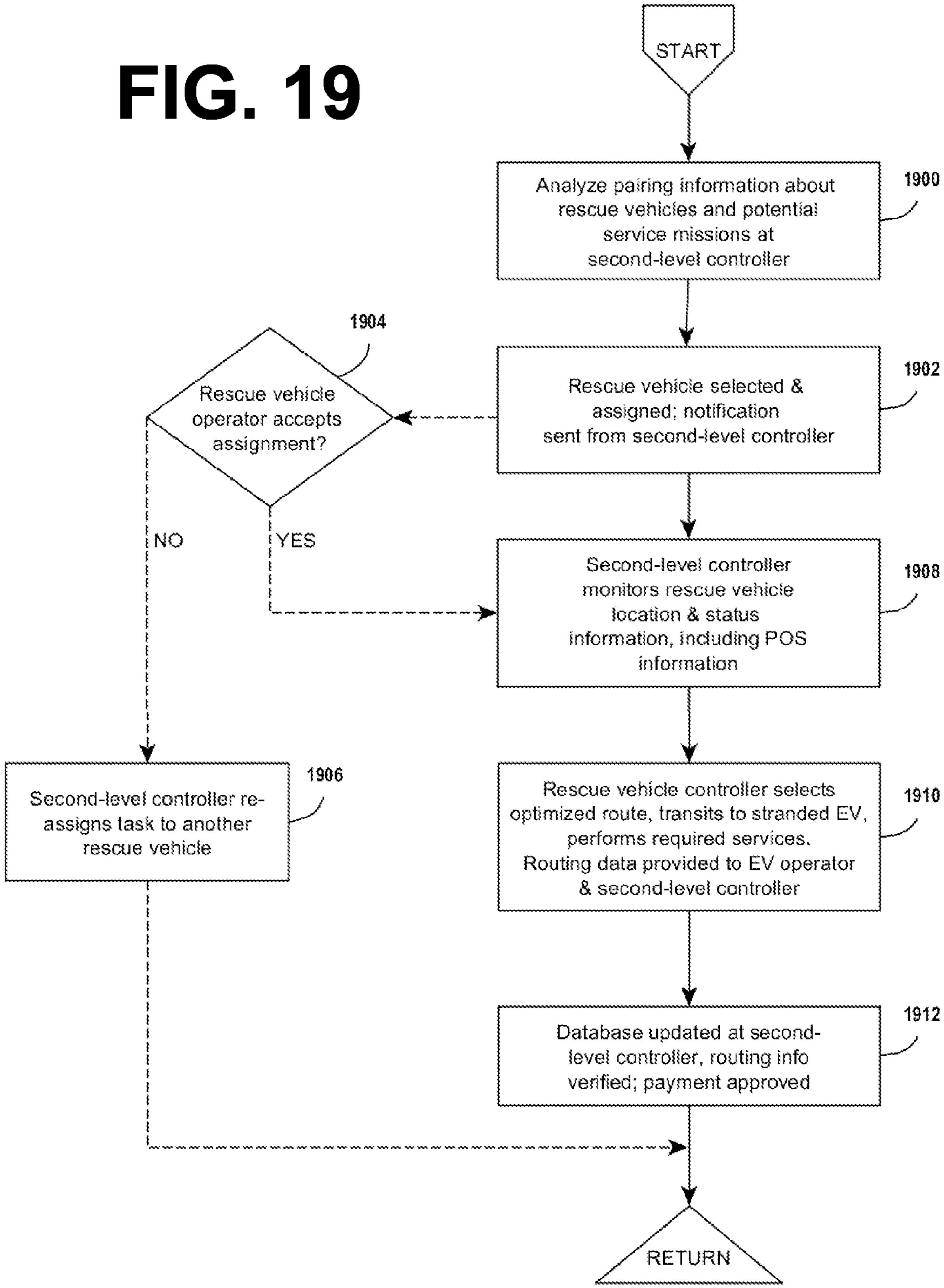

START
Analyze pairing information about rescue vehicles and potential service missions at second-level controller
1900
Rescue vehicle selected & assigned; notification sent from second-level controller
1902
Rescue vehicle operator accepts assignment?
1904
NO
YES
Second-level controller monitors rescue vehicle location & status information, including POS information
1908
Second-level controller re-assigns task to another rescue vehicle
1906
Rescue vehicle controller selects optimized route, transits to stranded EV, performs required services. Routing data provided to EV operator & second-level controller
1910
Database updated at second-level controller, routing info verified; payment approved
1912
RETURN

FIG. 20

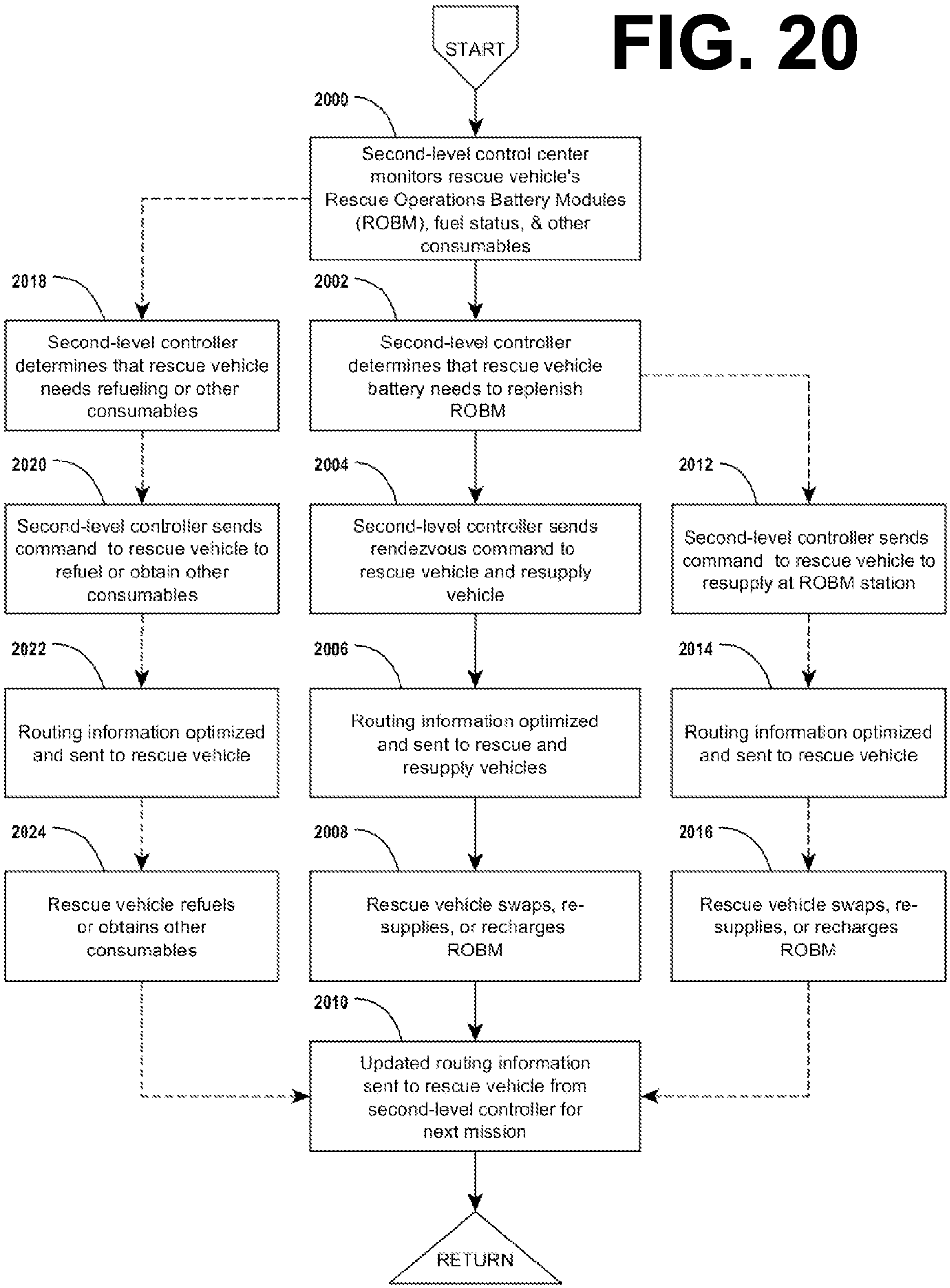

START
2000
Second-level control center monitors rescue vehicle's Rescue Operations Battery Modules (ROBM), fuel status, & other consumables
2018
Second-level controller determines that rescue vehicle needs refueling or other consumables
2002
Second-level controller determines that rescue vehicle battery needs to replenish ROBM
2020
Second-level controller sends command to rescue vehicle to refuel or obtain other consumables
2004
Second-level controller sends rendezvous command to rescue vehicle and resupply vehicle
2012
Second-level controller sends command to rescue vehicle to resupply at ROBM station
2022
Routing information optimized and sent to rescue vehicle
2006
Routing information optimized and sent to rescue and resupply vehicles
2014
Routing information optimized and sent to rescue vehicle
2024
Rescue vehicle refuels or obtains other consumables
2008
Rescue vehicle swaps, re-supplies, or recharges ROBM
2016
Rescue vehicle swaps, re-supplies, or recharges ROBM
2010
Updated routing information sent to rescue vehicle from second-level controller for next mission
RETURN

FIG. 21

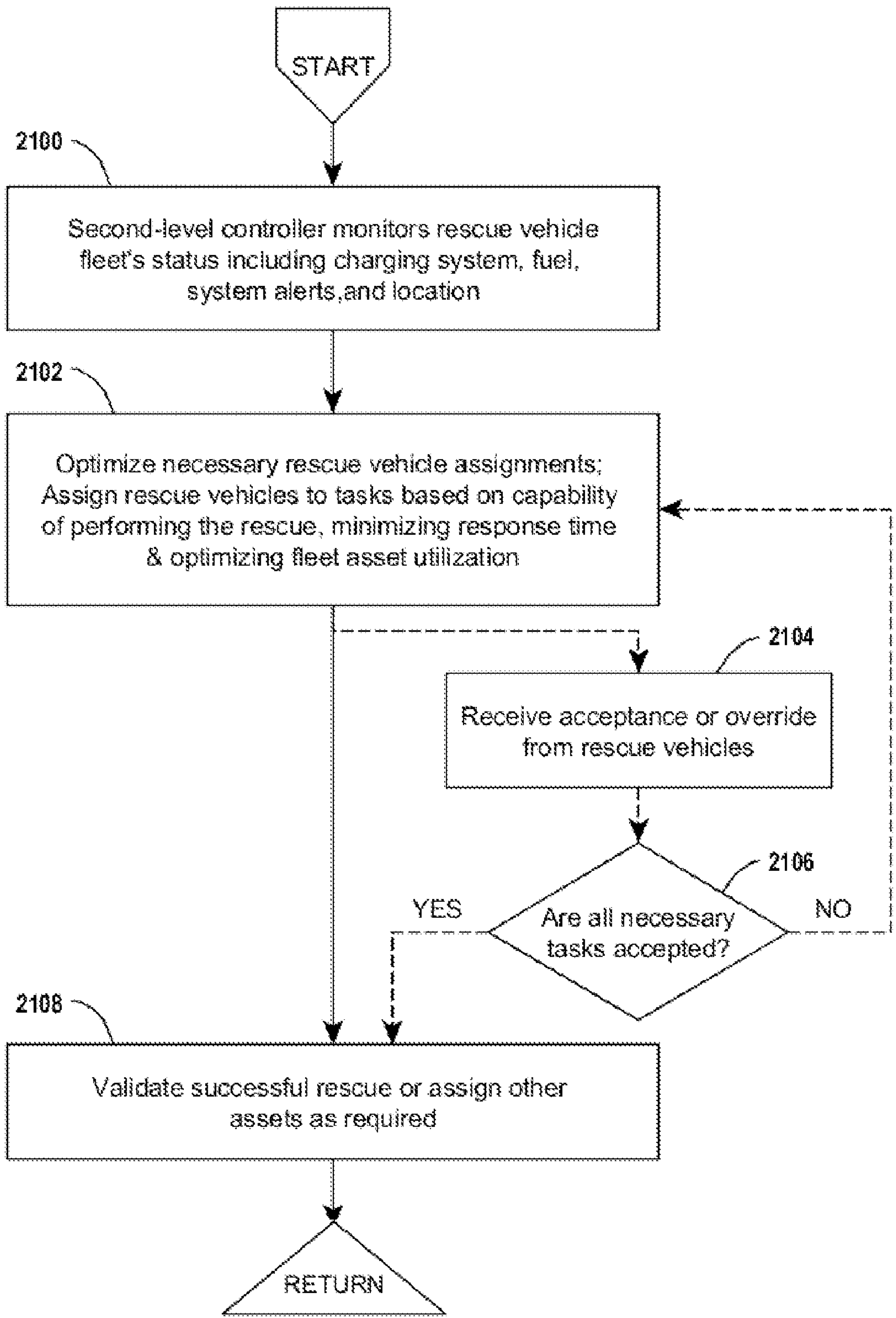

START
2100
Second-level controller monitors rescue vehicle fleet's status including charging system, fuel, system alerts,and location
2102
Optimize necessary rescue vehicle assignments; Assign rescue vehicles to tasks based on capability of performing the rescue, minimizing response time & optimizing fleet asset utilization
2104
Receive acceptance or override from rescue vehicles
2106
Are all necessary tasks accepted?
YES
NO
2108
Validate successful rescue or assign other assets as required
RETURN

FIG. 22

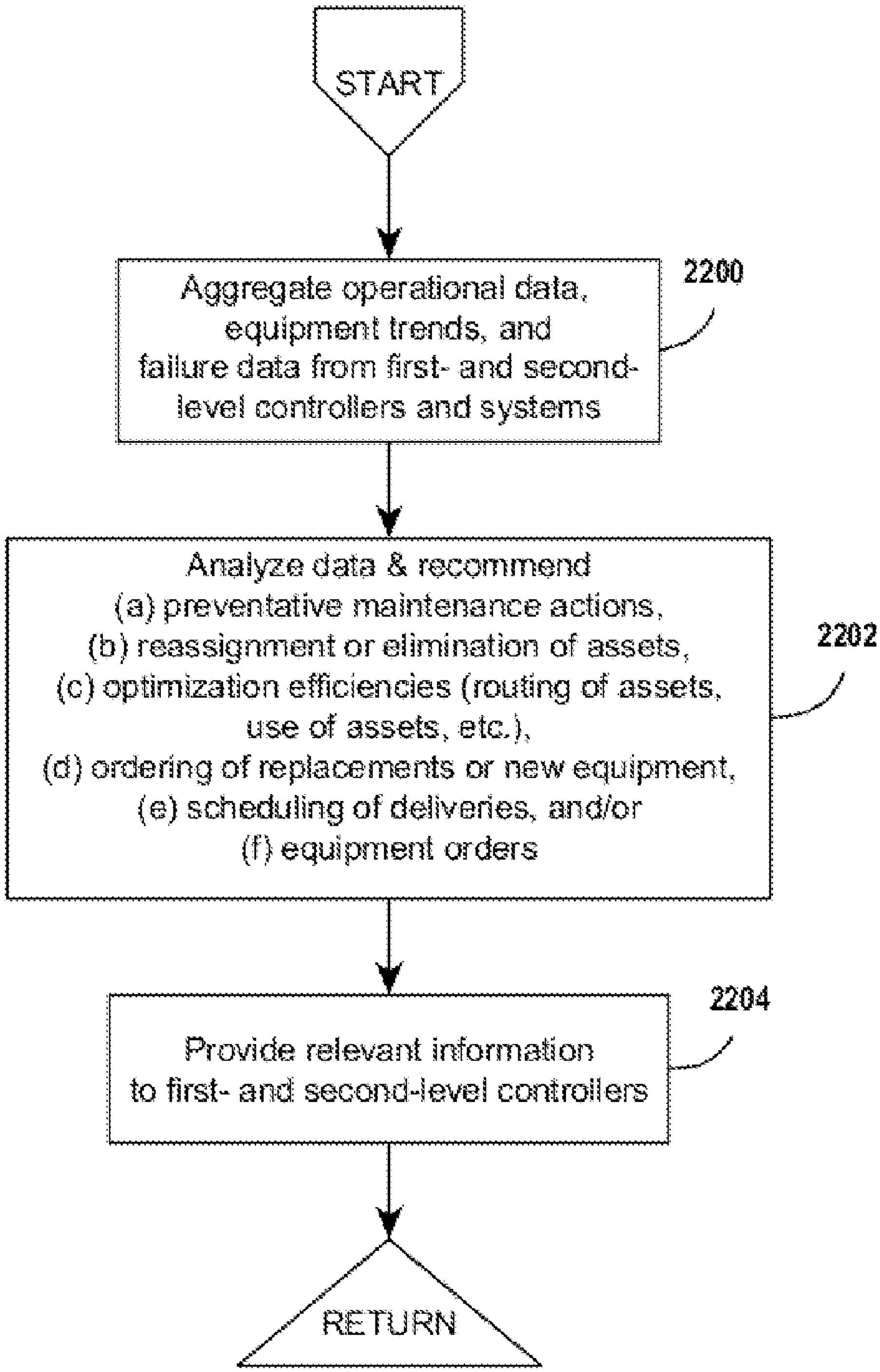
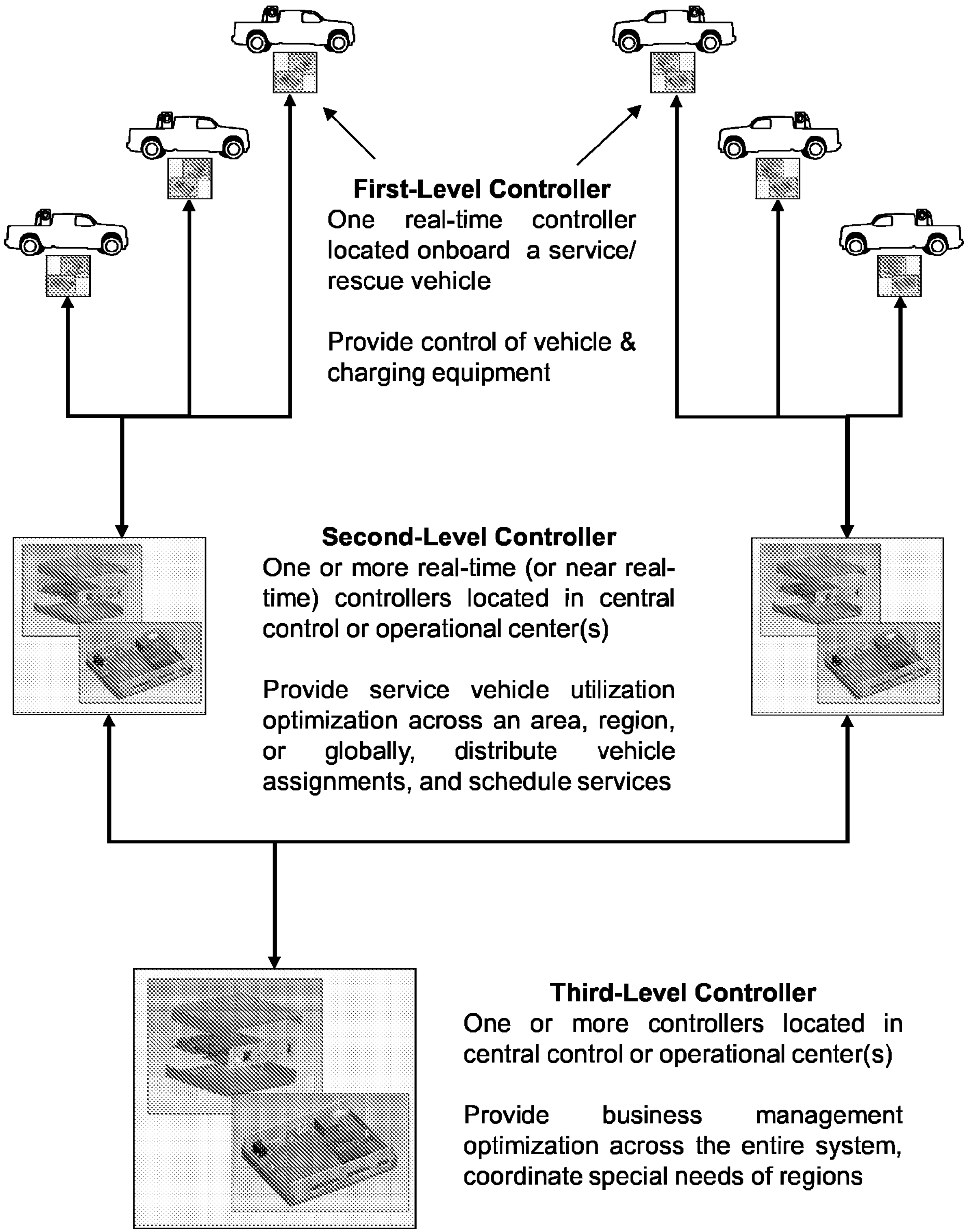

START
Aggregate operational data, equipment trends, and failure data from first- and second-level controllers and systems
2200
Analyze data & recommend
(a) preventative maintenance actions,
(b) reassignment or elimination of assets,
(c) optimization efficiencies (routing of assets, use of assets, etc.),
(d) ordering of replacements or new equipment,
(e) scheduling of deliveries, and/or
(f) equipment orders
2202
Provide relevant information to first- and second-level controllers
2204
RETURN

FIG. 23


First-Level Controller
One real-time controller located onboard a service/ rescue vehicle
Provide control of vehicle & charging equipment
Second-Level Controller
One or more real-time (or near real-time) controllers located in central control or operational center(s)
Provide service vehicle utilization optimization across an area, region, or globally, distribute vehicle assignments, and schedule services
Third-Level Controller
One or more controllers located in central control or operational center(s)
Provide business management optimization across the entire system, coordinate special needs of regions

CHARGING SERVICE VEHICLE NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Priority is claimed to the following related co-pending U.S. Provisional Patent Applications, which are hereby incorporated by reference in their entirety: (1) Ser. No. 61/489,849, filed May 25, 2011, (2) Ser. No. 61/489,879, filed May 25, 2011, (3) Ser. No. 61/493,970, filed Jun. 6, 2011, (4) Ser. No. 61/494,878, filed Jun. 8, 2011, and (5) Ser. No. 61/497,216, filed Jun. 15, 2011.

BACKGROUND

[0002] The present invention is directed to the fields of roadside assistance, electric vehicle charging, modular energy storage systems, and related fields.

[0003] In recent years, the popularity and affordability of electric vehicles (EVs) such as battery-powered EVs, hybrid gasoline-electric EVs (or HEVs), and other vehicles having motors and engines powered by electrical energy has grown dramatically. As these vehicles gain more market penetration and presence, there will be a need for increased on-the-road-services for EVs, such as providing a "boost charge" to the EV, similar to how service vehicles provide a motorist with a gallon of gasoline to get them to the next fueling station today. One of the challenges in providing these services will be the numerous differing standards used in the batteries of electric vehicles that are coming to market, since their various battery chemistries, capacities, and dimensions make the range and charging requirements of each vehicle quite different. For example, small EVs will only need a small amount of energy to allow them to travel safely to a dedicated service or charging area, but large electric vehicles will require a relatively large charge of energy to reach a service area due to their larger energy consumption rates.

[0004] Furthermore, vehicles involved in roadside assistance will be compelled to recharge or refill their boost charging equipment, resulting in losses due to inefficiency and downtime. Recharging energy storage takes time, so although batteries and chargers are improving in their ability to accomplish this in less time, this process will always set a lower limit on the time interval between uses of a battery-based EV-recharging rescue vehicle with built-in energy storage.

[0005] Removable batteries are common in electrical equipment, and even some EVs have removable batteries to provide motive power to the vehicle. One of the challenges in using removable batteries is the danger to operators that arises from the high powered connectors for the batteries. Some inventors use plastic shrouds or robotic battery manipulation for personal protection from exposed electrodes or simply use no protection at all, leaving the operator and equipment at risk. These systems can make it dangerous to use and store a battery-powered EV charging system. Some systems with removable batteries insert a "dead" power supply or other electronic device into a "live" backplane. This configuration is not ideal since it doesn't allow for the de-activation of a "live" battery tray during handling without some human intervention, like opening a switch or removing a fuse, and since humans can forget to take these safety measures there is a greater risk of personal injury in these systems. Some systems envision large battery swap-out stations for EV batteries instead of recharging them while in the EV. The EV batteries swapped out therein can be approximately 25 kWh in capacity, can weigh 500 pounds or more, and require robotic devices to remove and install them. They also typically have a multi-person crew. This is expensive, and the proprietary nature of the swappable battery designs leads to difficulties in compatibility of vehicle systems and swapping stations.

[0006] Another challenge in this field relates to how to minimize the size and weight of the battery and the balance of the onboard systems of the rescue vehicle's onboard electrical generation system. This optimization makes it more efficient to recharge an energy store for repeated uses over relatively short time intervals. Sizing an onboard battery pack for the most demanding, worst-case stranded vehicle is impractical and expensive. Some assistance solutions use permanently installed batteries which occupy the battery housing at all times and can only be removed with labor-intensive and time-consuming effort. Permanently installed batteries render the host vehicle completely dependent on said batteries both in charging time and charging frequency, since it takes time for a charging event to complete, and the batteries require a resting period between recharges to prevent overheating. Large batteries are also expensive and heavy so a generator system having them is burdensome and oversized when charging events are relatively infrequent when compared to other activities of a rescue vehicle.

[0007] Near-term future deployments of rescue vehicles are likely to initially require minimal electrical storage capability due to the limited market penetration of EVs. However with increased EV market penetration it will become increasingly important to gracefully grow rescue vehicle electrical capability to meet customer demand without needlessly expending large capital outlays for battery systems before such larger systems are required by the marketplace. Even if charging systems are designed with removable batteries and quick disconnects, swapping them out between one location and another can raise challenges for operators. Operators may need to rapidly respond to an emergency situation while on heavy trafficked road, and there are many potential safety-related issues associated with moving high-energy battery modules.

BRIEF SUMMARY

[0008] Various embodiments of the invention disclosed herein provide a roadside assistance and rescue vehicle charging system (which system may be alternately referred to herein as an Adaptable Multifunction Emergency EV Charging System or "AMEECS") and related systems and methods that allow the charging system to charge EVs in need. An EV rescue vehicle of one such embodiment has a set of a modular batteries (which modules may be alternately referred to herein as Rescue Operation Battery Modules or "ROBM") which may be linked together to form a high-capacity battery, such as a high-capacity 12-volt battery bank, having much larger energy storage capacity than the onboard battery of a traditional roadside assistance vehicle or tow truck. The battery modules are used to provide power to an EV charging station transported by the vehicle.

[0009] The modular features of the battery system allow service providers to anticipate and adapt to future growth of the rescue vehicle's onboard recharging capacity by allowing the user to add additional battery modules and thereby increase capacity of the energy storage. In some embodiments, future battery module additions may be placed inside an enclosure of the charging system of the rescue vehicles or may be stowed elsewhere on the vehicle.

[0010] In some embodiments the battery modules are linked to the rescue vehicle or charging system with quick-disconnecting links and contactors. Such quick-disconnecting apparatuses provide safety by preventing users from electrical shock exposure or arcing due to improper removal of the battery modules. In some embodiments the battery modules in a vehicle have electrical and mechanical disconnects so that, after one or more stranded EVs are charged, depleted batteries can be quickly replaced with fully charged batteries when they are available. A quick disconnect system minimizes the need to wait for the charging system's battery module to be recharged either at a charging location or by using the onboard organic charging system/alternator and enables more efficient redeployment of the rescue vehicle.

[0011] In some embodiments battery modules are sized to comply with individual lifting recommendations, such as Occupational Safety and Health Administration (OSHA) recommendations, to allow a rescue vehicle operator to manually lift them and install them in a vehicle, but in some embodiments the modules may be larger in size. Therefore, in some embodiments, this means that the OSHA-approved National Institute for Occupational Safety and Health (NIOSH) lifting guidelines are followed. In many cases these rescue vehicle battery modules are housed, charged and deployed from enclosures (which may be unstaffed) that are conveniently located for rescue vehicles to resupply when their battery modules are depleted. Additionally, some embodiments of the invention include a system of resupplying vehicles that deliver modules as needed to service vehicles to keep the service vehicles operational.

[0012] In some embodiments the rescue vehicle's onboard battery system is configured to provide energy for normal rescue vehicle functions and electrical equipment but also has adequate capacity to provide a boost charge to a stranded EV. In these embodiments the built-in, inherent, or "organic" electrical system of the vehicle (e.g., a commercial truck or van) is modified by adding connections to the charging system and battery modules. In some of these embodiments, battery modules are used to supplement the energy supplied by the organic electrical energy storage of the vehicle. In some embodiments the vehicle's alternator or other electrical generation device will work with the modular battery system to power the charger or recharge the battery modules at some rate. In yet further embodiments the battery modules are recharged by a connection to a distribution grid while carried by the rescue vehicle or when stored at a grid-connected charging station.

[0013] Some embodiments of the invention allow the battery modules to be recharged remotely and/or separately from the rescue vehicle's onboard charging system, such as at a warehouse or other facility. In effect, this system de-couples the time required for charging an onboard energy storage system from the minimum time required between EV service events performed by rescue vehicles. In these embodiments, instead of having to wait for batteries to recharge, the lower limit is constrained only by how long it takes to disconnect a discharged battery module and reconnect a charged module. In this embodiment any exposed electrodes are de-energized as long as they are accessible to human hands.

[0014] Battery modules in a rescue vehicle may be discharged sequentially or simultaneously. Sequential discharging means fewer batteries are dealt with daily since only certain modules will need recharging after a day of assisting EVs instead of all batteries being partially discharged, but sequential discharging means the batteries are subjected to deeper discharges before they are replaced.

[0015] Embodiments of the invention using battery modules allow rescue vehicles to follow economic incentives to be out and ready to serve customers as many hours of the day as possible so that they can maximize turnover of successful assignments. Running out of electrical charge and having to return to a home base charging station to recharge onboard energy storage is time consuming, and therefore reduces the number of operations each rescue vehicle can achieve. In some embodiments the rescue vehicles run on diesel and do not have large battery modules.

[0016] Additional embodiments describe quick disconnectable battery modules and enclosures that provide safety to users while providing accessibility to components by using relays and disconnects to energize battery modules when they are securely positioned. Some embodiments use deliverable automotive batteries as a power source of charging equipment, or charge the deliverable batteries using an alternator or generator on the service vehicle while the batteries are transported by the vehicle. Battery modules may be subject to charging and discharging while on the vehicle in accordance with reservation and prioritization systems and methods employed by a system controller on the vehicle.

[0017] Some embodiments include service vehicles having ports for connection of charging cables positioned on the service vehicle for accessibility and efficiency. The charging cables may be segmented to allow extension of the cables to greater distances and to allow a single user to be able to move the cables longer distances while being OSHA recommendation-compliant.

[0018] In some embodiments, a networked system for providing energy to discharged batteries of electric vehicles (EVs) is provided wherein service vehicles transporting EV charging equipment, controllers, and removably-mounted battery modules and storage locations storing battery modules compatible with the charging equipment wherein the battery modules are manually exchangeable between the storage location and the service vehicle. In some additional embodiments, resupply vehicles are provided to deliver and resupply batteries for service vehicles and/or storage locations. A scheduling controller may be employed to reserve battery modules at stations, and the stations may be configured to recharge the battery modules while they are stored. In other embodiments, the storage location is a mobile unit that is repositionable when needed.

[0019] The networked system may also comprise three levels of controllers configured to organize and implement the charging service vehicles throughout a region.

[0020] Embodiments of methods of charging service operation are also described, including charging an EV with a limited amount of charge that is calculated based on the distance between the EV and a grid-connected charging station or other factors. Routing of service vehicles, routing of EVs being charged, and distributing assignments and information may be performed at a control center and then sent to relevant recipients.

[0021] Additional and alternative features, advantages, and embodiments of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The features and advantages of the invention may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims.

These and other features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] In addition to the novel features and advantages mentioned above, other objects and advantages of the present invention will be readily apparent from the following descriptions of the drawings and exemplary embodiments.

[0023] FIG. **1**A shows a vehicle with a charging system powered by battery modules according to an embodiment of the present invention.

[0024] FIG. **1**B shows a vehicle with a charging system powered by a large battery module according to another embodiment of the present invention.

[0025] FIG. **1**C shows a vehicle with a charging system powered by a large battery module according to yet another embodiment of the present invention where the vehicle may use an electric or hybrid motor or engine without a vehicle battery, or the large battery is used as the vehicle battery, and an alternator is optionally also included.

[0026] FIG. **1**D shows a vehicle with a charging system powered by battery modules and a vehicle alternator/generator according to yet another embodiment of the present invention.

[0027] FIG. **2**A shows a vehicle with a charging system powered by battery modules disconnected from the electrical system of the vehicle wherein the vehicle has additional battery module storage according to another embodiment of the present invention.

[0028] FIG. **2**B shows a vehicle with a charging system powered by battery modules connected to the electrical system of the vehicle wherein the vehicle has additional battery module storage according to yet another embodiment of the present invention.

[0029] FIG. **2**C shows a perspective view of a vehicle with compartments for battery storage trays and additional battery storage indicated.

[0030] FIG. **2**D shows a perspective view of a vehicle section with a compartment for battery storage and replaceable battery modules connected according to an embodiment of the present invention.

[0031] FIG. **3** shows a vehicle with a charging system and enclosure according to yet another embodiment of the present invention.

[0032] FIG. **4** shows a vehicle for transporting battery modules according to an embodiment of the present invention.

[0033] FIG. **5**A is a diagram of the relationship between a storage facility, resupply vehicle, and roadside assistance or rescue vehicle according to an embodiment of the present invention.

[0034] FIG. **5**B is a diagram of the relationship between another storage facility, resupply vehicle, and roadside assistance or rescue vehicle according to an embodiment of the present invention.

[0035] FIG. **5**C is a diagram of the relationship between multiple storage facilities, resupply vehicles, and roadside assistance or rescue vehicles according to an embodiment of the present invention.

[0036] FIG. **5**D shows a side perspective view of a service vehicle with detail showing the interior of the vehicle having a status display component of an embodiment of the invention.

[0037] FIG. **5**E shows a frontal perspective view of a status display component installed in the interior of a service vehicle with detail of the information presented on the display of an embodiment of the invention.

[0038] FIG. **5**F shows a rear perspective view of a service vehicle with a status display component installed near the rear tailgate and bumper of the vehicle.

[0039] FIG. **5**G shows a rear perspective view of a service vehicle with a status display component installed on the rear portion of a charging system enclosure installed on the vehicle.

[0040] FIG. **6**A is an isometric view of a quick-disconnect system with a battery module drawer installed and a retaining bar closed according to an embodiment of the present invention.

[0041] FIG. **6**B is an isometric view of a quick-disconnect system with a retaining bar open according to an embodiment of the present invention.

[0042] FIG. **6**C is a front plan view of a quick-disconnect system with a battery module drawer installed and a retaining bar closed according to an embodiment of the present invention.

[0043] FIG. **6**D is a top plan view of a quick-disconnect system with a battery module drawer installed according to an embodiment of the present invention.

[0044] FIG. **6**E is front plan view of a quick-disconnect system with a battery module drawer installed and a retaining bar open according to an embodiment of the present invention.

[0045] FIG. **6**F is an isometric view of a quick-disconnect system with a battery module drawer installed and a retaining bar open according to an embodiment of the present invention.

[0046] FIG. **7**A is an isometric view of a quick-disconnect system with multiple battery module drawers installed and retaining bars closed according to an embodiment of the present invention.

[0047] FIG. **7**B is an isometric view of a quick-disconnect system with multiple battery module drawers installed and retaining bars open according to an embodiment of the present invention.

[0048] FIG. **8**A is a side plan view of a modular battery system with quick-disconnect capability according to an embodiment of the present invention with stackable and/or chain-connecting characteristics.

[0049] FIG. **8**B is an exploded side plan view of the modular battery system with stackable and/or chain-connecting characteristics wherein battery modules are separated from one another according to an embodiment of the present invention.

[0050] FIG. **9**A is an isometric view of a quick-disconnect battery module drawer and receptacle embodiment with the door open.

[0051] FIG. **9**B is a left side plan view of a quick-disconnect battery module receptacle embodiment.

[0052] FIG. **9**C is a top plan view of a quick-disconnect battery module receptacle embodiment.

[0053] FIG. **9**D is a front plan view of a quick-disconnect battery module drawer and receptacle embodiment.

[0054] FIG. **9**E is a left side plan view of a quick-disconnect battery module receptacle embodiment with section lines indicated.

[0055] FIG. **9**F is a section view of a quick-disconnect battery module drawer and receptacle embodiment according to section line B-B in FIG. **9**E.

[0056] FIG. **10**A shows various isometric perspective views of a rescue vehicle and identifies a number of potential sites on the vehicle where a charging cable connection port may be located.

[0057] FIG. **10**B shows a top perspective view of a rescue vehicle and identifies a number of potential sites on the vehicle where a charging cable connection port may be located.

[0058] FIG. **11**A shows a side view of exemplary charging equipment connectors and cables.

[0059] FIG. **11**B shows a perspective view of an exemplary female cable connector and/or charging equipment connector.

[0060] FIG. **11**C shows a perspective view of an exemplary male cable connector and/or charging equipment connector.

[0061] FIG. **12**A is a diagram of a rescue vehicle with a charging cable and connectors and an EV.

[0062] FIG. **12**B is a diagram of a rescue vehicle with charging cables and connectors and an EV with a charging cable extension in use.

[0063] FIG. **13**A shows a side perspective view of a service vehicle with storage capability according to an embodiment of the invention.

[0064] FIG. **13**B shows a side perspective view of a service vehicle with open storage compartments according to an embodiment of the invention.

[0065] FIG. **14**A shows a top view of a service vehicle with electrical lines indicated according to an embodiment of the invention.

[0066] FIG. **14**B shows a top view of a service vehicle with electrical lines and converters indicated according to an embodiment of the invention.

[0067] FIG. **14**C shows a top view of a service vehicle with alternate charging lines indicated according to an embodiment of the invention.

[0068] FIG. **14**D shows a top view of a service vehicle with batteries that are connected to an alternator according to an embodiment of the invention.

[0069] FIG. **14**E shows a top view of a service vehicle with batteries that are connected to charging equipment according to an embodiment of the invention.

[0070] FIG. **14**F shows a top view of a service vehicle with batteries that are connected to charging equipment and batteries that are connected to an alternator according to another embodiment of the invention.

[0071] FIG. **15** is a process flowchart showing an example of a monitoring and alert process performed by a first- and second-level controller according to an embodiment of the invention.

[0072] FIG. **16** is a process flowchart showing an example of a monitoring, notification, alert and direction process performed by a second-level controller or control center according to an embodiment of the invention.

[0073] FIG. **17** is a process flowchart showing an example of a communication link management process performed by a first- and second-level controller according to an embodiment of the present invention.

[0074] FIG. **18** is a process flowchart showing an example of an optimized EV recommendation and rescue process performed by a first and second-level controller according to an embodiment of the present invention.

[0075] FIG. **19** is a process flowchart showing an example of a fleet optimization process performed by a first and second-level controller according to an embodiment of the present invention.

[0076] FIG. **20** is a process flowchart showing an example of a consumable management and optimization process performed by the first- and second-level controllers and/or vehicles and control centers according to an embodiment of the present invention.

[0077] FIG. **21** is a process flowchart showing an example of a fleet optimization process performed by the second-level controller(s) according to an embodiment of the present invention.

[0078] FIG. **22** is a process flowchart showing an example of a regional fleet management process performed by the third-level controller(s) according to an embodiment of the present invention.

[0079] FIG. **23** is a hierarchical diagram of the controller levels according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0080] Vehicle-Mounted EV Charging System

[0081] Some embodiments of the invention may be referred to as an Adaptable Multifunction Emergency EV Charging System ("AMEECS"). The AMEECS is designed to carry enough energy in a chemical battery pile and, potentially, in onboard gasoline, diesel or other fuel, to recharge an EV. Preferably, the EV is charged with sufficient kilowatt-hours permit the EV to get out of a roadway and/or get to a suitable charging station.

[0082] FIGS. **1**A, **1**B, **1**C, and **1**D show various examples of a vehicle-mounted EV charging system according to embodiments of the present invention. The system of FIG. **1**A is a vehicle **100** that is used to assist stranded EVs that has an internal combustion engine **102**. The vehicle **100** may run on gasoline, diesel, or another standard fuel. The vehicle engine **102** has an alternator **104** used to provide electricity to the vehicle systems and to recharge the vehicle battery **106**, which may be a standard 12-volt type. In some embodiments, the alternator **104** may be a generic electricity generator powered by the engine **102** of the vehicle or an output from the engine such as through a power take-off. This vehicle has additional battery modules **108** (e.g., Rescue Operation Battery Modules or "ROBM") connected to the electrical system of the vehicle, and the battery modules **108**, vehicle battery **106**, and/or the alternator **104** of the vehicle are the power source for the charging electronics **110** used for recharging EV batteries. The battery modules are preferably configured to be expandable (as indicated by module **112**), so that a user can insert more battery modules into the system to increase overall storage capacity or instantaneous available output power from the charging electronics **110** by using more modules **108** at once. In this embodiment, the battery modules **108** essentially act as an oversized vehicle battery, and can therefore also provide energy to the vehicle electrical system (e.g., starter, lights, etc.) and can be recharged by the vehicle's alternator **104**.

[0083] In some embodiments the modules **108** are discharged according to a predetermined sequence, and in other embodiments, the modules **108** are discharged simultaneously. If the modules **108** are discharged according to a sequence, discharged modules may be exchanged for fully charged modules with less work required since fewer modules need to be exchanged. However, the circuitry may be less expensive and complicated, and the time for recharging may be reduced when the modules discharge simultaneously, so simultaneous discharging may also be a feature of some embodiments.

[0084] The charging electronics **110** include electric vehicle supply equipment (EVSE), indicators, EV connectors, step-up transformers or DC-DC converters for converting the battery voltage to the desired EV charging voltage, and/or inverters or other DC-AC converters to provide the proper current to the EVs being charged. Some embodiments use a 12-volt charge system of the service vehicle along with a small battery pack (e.g., ROBM) to charge an EV using a step-up transformer in order to comply with the TEPCO® CHAdeMO specification, the SAE J1772 specification, or other similar vehicle battery charging interface.

[0085] FIG. **1**B shows a similar system to FIG. **1**A, but the interchangeable battery modules **108** are replaced by a large battery **114** that is designed to be changed as a whole instead of in parts. The large battery has high capacity and supplements the vehicle battery **106** in providing energy to the vehicle electrical system and to the charging electronics **110**. This large battery **114** can be recharged by the alternator, and may also need to be recharged by external means if a substantial charge is required. A vehicle having a large battery **114** in place of interchangeable battery modules **108** may have reduced maintenance requirements due to the lower number of batteries in total and may be more efficient in charging using the electronics **110** due to needing fewer inefficient connections between the large battery **114** and the electronics **110**. The large battery **114** may be comprised of an array of smaller batteries, but these batteries do not feature quick-disconnects, individual lifting requirement compliance, and other modular features that allow the interchangeable battery modules **108** to be exchanged with fresh modules when the batteries are depleted. These features make the large battery **114** more permanently installed than the interchangeable battery modules **108** while still providing power to the charging electronics **110** and being charged by an alternator **104**. The large battery **114** is also integrated into electrical systems of the vehicle **100** and supplements and replicates the functions of the vehicle battery **106** in supplying energy to the other vehicle electrical systems such as lighting, powered windows, engine starter, and other electricity-consuming systems and devices of the vehicle.

[0086] FIG. **1**C shows another vehicle-mounted EV charging system. In this embodiment the large battery **114** is the vehicle battery, and no additional vehicle battery (e.g., **106**) is provided to the vehicle. Instead of merely supplementing or replicating the functions of the vehicle battery as in FIG. **1**B, the large battery **114** in this embodiment replaces the vehicle battery altogether. Thus, this alternative vehicle **100** has an electric motor or hybrid internal combustion/electric engine **116**, where at least the electrical portion of the propulsion system is powered by the large battery **114** for locomotion of the vehicle **100**. The rescue vehicle **100** is therefore itself an EV or partially electric vehicle that uses its storage battery as the reserve energy storage for charging other EVs using the charging electronics **110** that are linked to the large battery **114**. This storage battery can be supplemented by battery modules in a manner similar to how battery modules are added to the 12-volt standard vehicle batteries in FIG. **1**A. The vehicle **100** may also have onboard generation capabilities, such as an alternator **104**, that are used to recharge the large battery **114** using the fuel-based portion of the engine or hybrid engine **116**.

[0087] FIG. **1**D illustrates another embodiment with battery modules **108** where the battery modules **108** provide energy to the charging electronics **110** and the alternator **104**/vehicle battery **106** provides energy to the charging electronics **110** along a separate power line **118**. Thus, when the charging electronics **110** are used to recharge an EV, the alternator **104** may be used to provide additional energy to the charging electronics **110** along the additional power line **118** when desired. This embodiment may also connect the alternator **104** to the battery modules **108** to recharge them while the vehicle is in motion if the connection between those parts is included. In this embodiment, it may be preferable to exchange the alternator for a higher-power generator operated by a power source such as a power take-off when available in order to provide more support to the charging electronics **110**.

[0088] Spare Battery Module Management

[0089] FIG. **2**A shows another embodiment of the vehicle charging system. As shown here, the charging electronics **110** and battery modules **108** may be isolated from the vehicle's electrical system. In other embodiments, connection to the electrical system is also contemplated (see, e.g., FIG. **2**B). In either case, these vehicles provide additional battery module storage **200**, wherein the additional or spare battery modules **200** are transported by the vehicle without being electrically connected to power lines between the vehicle engine and charging electronics **110** like the other battery modules **108**.

[0090] FIGS. **2**A and **2**B show vehicles with capacity to transport or store additional battery modules **200**. When they store additional modules **200**, this configuration allows the vehicle operator to simultaneously connect as many modules at once as required to the charging electronics for higher power requirement scenarios, swap in or swap out modules when other modules are depleted, provide modules to other parties such as other vehicle operators, or charge the additional battery modules with the vehicle's electrical system while the other modules are isolated or are busy charging an EV battery.

[0091] In some embodiments, spare battery modules **200** can be carried on the rescue vehicle, delivered to the rescue vehicle, or can be made available at a battery swap-out station. Additional spare electrical battery modules can be carried onboard the rescue vehicle. See, for example, FIGS. **2**A, **2**B, **2**C, **2**D, and **3**, where additional battery modules are shown being stored on a vehicle. This configuration enables the possibility of greater average electrical capacity for the rescue vehicles and provides a means to gracefully increase that overall total as demand for rescue missions increases over time. Since the battery modules are interchangeable, they can serve to gracefully increase the electrical capacity of the rescue vehicle (such as its charging capacity) without significant infrastructure cost. In some cases the size or number of battery modules may increase or decrease over time as mission requirements evolve, but quick disconnect points on the vehicle will remain substantially in the same configuration. Quick disconnect features of battery modules are discussed in more detail below.

[0092] The modular feature of the battery system allows for future growth of the rescue vehicle's onboard battery capacity. Future battery module additions may be placed inside the rescue vehicle's charging enclosure or may be stowed elsewhere on the vehicle. This defers capital investment in expensive batteries until market demand warrants that investment. Spare battery modules may in some cases be located in the rescue truck main box/enclosure, a storage rack, or at other locations on the vehicle. FIGS. **2**C and **2**D show that storage compartments **202** for battery trays or modular racks may be located on the rescue vehicle in some embodiments. FIG. **2**D is an example of a battery management tray apparatus. The battery modules/cells are stowed on a retractable battery tray and have quick-disconnects for easy replacement. Battery wiring is not shown in FIG. **2**D.

[0093] FIG. **3** depicts another embodiment of the charging system mounted in a vehicle. Here, an enclosure **300** keeps the battery modules **108** and charging electronics **110** under common protection, and optionally has space for additional battery module storage **302** inside and/or outside the enclosure **300**. The embodiments discussed in connection with FIGS. **1**A through **2**B may also incorporate enclosures to protect the equipment borne by the vehicle which may or may not have storage capability.

[0094] Battery Module/ROBM Resupply Vehicles and Delivery

[0095] Rescue vehicle operators and administrators have an economic incentive to maximize turnover of successful missions and as such want to be out on the road and ready to serve the maximum number of hours per day. Among other problems, running out of electrical charge and having to return to a "home base" or other charging location to recharge a built-in or large battery takes time and reduces the number of recharging operations each vehicle can achieve. Some embodiments of the invention provide that rescue vehicle battery modules may be resupplied in the field by a battery resupply vehicle. A resupply vehicle of these embodiments is in communication with rescue vehicles and provides replacement battery modules for depleted batteries.

[0096] FIG. **4** is a depiction of a dedicated resupply vehicle according to an embodiment of the invention. Battery modules **108** are stored in the vehicle and are transported to rescue vehicles or battery module roadside swap-out locations or battery charging stations. The vehicle can store various types of battery modules **108** if its delivery destinations use different types of batteries (see also FIG. **5**C). The resupply vehicle's onboard electrical system can be utilized to provide charge to the battery modules **108** in order to keep them at full charge at the time of delivery. In some embodiments the resupply vehicle carries other EV rescue-related equipment, handheld devices capable of providing EV operators with essential information, and/or communication links.

[0097] In some embodiments a smart controller optimizes the routes of the rescue vehicles and of resupply actions. In some embodiments resupply action may be initiated at the time the rescue vehicle identifies that it is being routed to a stranded EV. In other embodiments the controller optimizes based on rescue vehicle location, resupply vehicle location, traffic, onboard ROBM status, rescue call volume, and other factors. It may also wait until a predetermined number of stranded EVs have been serviced by the same rescue vehicle or until the rescue vehicle's onboard system indicates that it is "low" or out of available energy storage, then dispatch battery modules to replenish the storage of the rescue vehicle.

[0098] FIGS. **5**A and **5**B illustrate the relationship between battery module storage facilities **500**, rescue vehicles **502**, and resupply vehicles **504**. The modules **506** and/or **508** may be exchanged between the storage facilities **500** and the resupply vehicles **504**, between the resupply vehicles **504** and the rescue vehicles **502**, and/or between the facilities **500** and the rescue vehicles **502**.

[0099] Some embodiments would allow the resupply vehicle **504** to provide multiple battery modules **506** and/or **508** to one or more rescue vehicles **502** during a single delivery trip. Other embodiments would permit the rescue vehicles **502** to act as resupply vehicles when they have enough battery modules to respond to another rescue vehicle's need for modules **506** and/or **508**. See, for example, FIG. **5**C, wherein a rescue vehicle **502** is shown transferring modules **506** and/or **508** to other rescue vehicles **510**.

[0100] In additional embodiments, a smart controller routes the resupply vehicle **504** to an optimal roadside battery swap-out station **500** or to an optimal central battery module recharging station **500** to keep the battery modules **506** and/or **508** of the fleet at full capacity for the maximum length of time. To this end, in additional embodiments, a system of quick disconnects is utilized to facilitate fast and efficient battery module change out from the resupply vehicle **504** and these battery modules **506** and/or **508** may be sized to meet Occupational Safety and Health Administration (OSHA) recommendations or other safety or regulatory lifting requirements for manually exchanging the modules.

[0101] FIG. **5**C shows the relationship between the resupply vehicles **504**, the rescue vehicles **502** and **510**, and the storage facilities **500**. Resupply vehicles **504** transfer and/or recharge battery modules **506** and/or **508** and provide them to rescue vehicles **502** or storage facilities **500**. Different resupply vehicles **504** may be necessary to provide different types of batteries (e.g., **506** or **508**) to rescue vehicles **502** and **510** or storage facilities **500**, since in some embodiments not all of the facilities/vehicles will be compatible with the same battery modules.

[0102] Battery Module Optimization

[0103] In some embodiments, the battery modules are designed to be lightweight and/or U.S. Occupational Safety and Health Administration (OSHA) recommendation compliant, thereby allowing manual removal and installation of the modules. The modules are therefore analyzed under the National Institute for Occupational Safety and Health (NIOSH) lifting equation, where a recommended weight limit is calculated by multiplying a load constant (LC), horizontal multiplier (HM), vertical multiplier (VM), distance multiplier (DM), asymmetric multiplier (AM), frequency multiplier (FM), and coupling multiplier (CM) from a NIOSH table described in connection with the NIOSH lifting equation (last revised in 1991). To avoid lifting injuries, the recommended weight limit is at or below 3.0 as calculated by this formula. In some embodiments, this means battery modules are light enough to be carried by a user and are changed out either manually or with a labor-saving device, and if manual labor is required, the weight of the device is 42 pounds or less, and ideally 35 to 42 pounds each, in order to maximize the capacity of each module by making them as large as possible. The 35-pound lower boundary is selected according to a recommendation set by OSHA. These figures also assume that the battery modules are stored in the service vehicle in such a manner that the lifting does not take place at full arm-extension nor with the lifter's trunk twisted to a significant degree. These weight and size figures are not intended to define the absolute limits of the scope of the dimensions and weight of the battery modules, but as a preferred guideline for common embodiments of the invention.

[0104] These OSHA-recommendation-compliant embodiments are advantageous because no special lifts or other equipment are required for the quick disconnection and replacement of the on-board energy store, so the overall system has the flexibility of single-operator operation. Only the rescue vehicle driver is required to operate the system, with no additional supporting personnel or lifting equipment. Other embodiments use OSHA-compliant lifting equipment to manipulate the battery modules if the size and number of modules requires.

[0105] Some embodiments feature battery modules with a capacity sized to correspond with logical units of charge required to move an EV sufficient distance to reach an EV charging station. For example, consider a typical EV assistance scenario. Since typical EVs can currently travel approximately 4 miles per kWh of battery storage, and since most rescue operations can be accommodated in 12 miles, and assuming a battery size of 4 kWh would weigh approximately 85 pounds, two battery modules of approximately 42 pounds each would be used to perform this rescue recharging operation. Other similarly optimized system sizes are envisioned over time. Battery modules would be optimized to provide a boost charge to less-efficient vehicles stranded on the roadways by increasing the capacity or number of modules set to be used for those charging events. This optimization allows standardized battery modules to be used to charge EVs with a wide range of different electrical efficiencies. The rescue vehicle is therefore sized in some embodiments to carry many more battery modules than are necessary for a charging event of a single, efficient EV, so that the rescue vehicle can be dispatched to provide charge to less efficient EVs, additional EVs, and can be loaded to meet other demands of the charging assignments given.

[0106] Onboard Battery Module Charging

[0107] Some embodiments of the invention minimize the required capacity of battery modules by leveraging the rescue vehicle's onboard electrical system to provide additional charging capacity when needed. See, for example, FIGS. **1**A, **1**B, **1**C, **1**D, and **2**B, where the alternator of the vehicle is used to assist in charging the battery modules. In this manner the onboard energy storage modules can be maximized beyond the physical constraints of the isolated battery capacity since recharging supplies additional energy that can then be used in rescue operations. The onboard organic charging system typically comprises the vehicle's alternator, battery, and other electrical components, but it may also include a more substantial or modified electrical system used in the normal function of the vehicle. The vehicle's electrical system may be merely involved by recharging a storage battery or battery modules, or the vehicle's system may be directly involved in providing power to the charging electronics on the vehicle.

[0108] For example, some embodiments allow battery modules to be stowed in a rack which provides a trickle charge from the rescue vehicle's alternator or another onboard energy generation device. This system ensures that fully charged batteries remain charged and can eventually recharge a battery to a normal state of full charge from a state of depletion.

[0109] Connecting and Managing Multiple Battery Modules

[0110] In some embodiments, battery modules are grouped together into clusters of modules. These clusters can be reconfigured into OSHA-recommendation-complaint weight groupings in some embodiments when appropriate.

[0111] In some embodiments, the battery modules (ROBM) stowed in the rescue vehicle's storage rack systems may be electrically connected to the AMEECS, charging equipment, or vehicle's electrical system. Each battery module or cluster of battery modules may have a connector switch that can be enabled or disabled, wherein when the switch is disabled, the battery module is isolated from other modules. In some embodiments these switches are opened or closed manually and in another embodiment they are controlled through use of an onboard command panel of the vehicle or module charging station. In one embodiment the command panel may be manually overridden by a manual switch. In this manner individual battery modules or clusters do not have to be moved to a particular rack to be used or recharged. This reduction in battery module movement improves field operations efficiency and reduces exposure of operators to potential safety issues.

[0112] Some module storage locations may not have electrical connectivity and require the battery module to be moved to be utilized to support rescue operations. This condition may occur during periods of capability expansion or to address unique storage requirements.

[0113] Where practical, the systems are automated and/or provide the operator with a mechanical advantage. This facilitates installation and removal of the modules.

[0114] In some embodiments, depleted battery modules are identified and displayed on an onboard controller or display. FIG. **5**D shows side perspective view of a rescue vehicle having an onboard display **512** for indicating the status of onboard charging electronics **514** and battery modules stored in compartments on the vehicle **516**. In this embodiment, the display **512** is located in the passenger compartment **518** of the vehicle. The onboard controller is a computer, microprocessor, or other similar programmable logic device that reads and executes instructions or code. The controller may have output connections, input connections, and displays or other elements designed for user access and interaction. The controller may be "smart," meaning the controller's functions may be automated to some extent to serve the user with minimal user input, such as by predicting and anticipating future user needs. Furthermore, controls **520** and indicators **524** of the display **512**, which may be a touchscreen display **522**, may allow the vehicle to send and receive information about nearby stranded EVs, instructions to or from a control center, or control the operation of the onboard charging electronics **514** or battery modules **516**. The instrument panel **524** of the vehicle may also be available to the user to integrate the controller and display with other functions of the vehicle. Buttons may adjust the power, brightness, and/or contrast, navigate through menus, or input commands into the display **512**. Lights may be used to indicate alternative information such as charge status or power indication, for example. In this embodiment, the display assembly **512** is positioned below the instrument panel **524** of the vehicle, but it may also be placed in other locations in the vehicle, such as, for example, above the dashboard, near the vehicle dials or other controls, integrated into a screen already installed in the vehicle (such as a global positioning system (GPS) navigation client or media control display), placed in a compartment or enclosure on the service vehicle, or placed on the exterior of the vehicle.

[0115] The display **512** may present various pieces of data to the user, as indicated in the frontal perspective view of FIG. **5**E. Here, the charging system status display **512** shows a status dial **526**, status gauges **528**, and status text/messages

530 on an LCD screen. Buttons **532** on the status display **512** allow the user to adjust the settings of the display and/or charging equipment. For example, the buttons **532** may be used in one embodiment to adjust the amount of charge transferred to a stranded EV in a single charging event, enabling an automatic charging cutoff of energy at a predetermined energy level. Graphics **534** are also shown on the display, and may be modified to provide status information, alerts, graphs, and other system information to the service vehicle operator.

[0116] In this embodiment, the status dial **526** shows a representation of the state of charge of the battery storage of the charging station in a manner similar to a fuel gauge of a vehicle, with full state of charge of the battery modules at "F" and depleted state of charge at "E". Color coding with green near "F" and red near "E" allows a user to quickly determine the health and state of the batteries on one dial. Other charging system information may be displayed on the status dial **526**, such as, for example, voltage of the batteries or converter.

[0117] The sliding gauges **528** in this embodiment show temperatures of the battery module bank and the voltage converter of the charging system, and the black bar overlaid on the gauge slides up and down to indicate temperature rises and drops, respectively. Color coding is also implemented in the gauges **528**, such as with red indicating high temperature to give a quick reading to the user regarding whether temperatures are in a safe range. The gauges may also show other or additional information as the user sees fit, such as state of charge of batteries, battery health, or other important factors for charging station operation.

[0118] The status text/messages **530** show detailed information about the battery temperature, converter temperature, battery voltage, and DC voltage of the charging system. This allows more detailed information to be accessed by the user for statistical analysis or data logging. The status text **530** may display any information displayed using other indicators as well. Messages from other vehicles and control centers may also appear on the display **512** to notify the service vehicle operator of instructions or nearby needs for charging or charged battery modules.

[0119] Some embodiments use a system of coded lights (such as red, yellow, and green) at each battery module's rack storage location visible to the operator which identifies the individual battery's state of charge. This allows the user to quickly identify batteries requiring a swap out or recharge. In an alternate embodiment the state of charge of individual battery modules is displayed on meters or a control panel or display such as display **512** that is located out of the cabin area **518** of the vehicle.

[0120] FIGS. **5**F and **5**G show a rear perspective view of a service vehicle **536** with a status display component **538** installed. The view of FIG. **5**F has a status display component **538** installed near the rear tailgate **540** and bumper **542** of the vehicle **538**, and the view of FIG. **5**F has a status display component **538** installed on the rear portion of a charging system enclosure **514** installed on the vehicle **536**. In these embodiments, lights **544**, **546**, **548** indicate connection status, charging status, and done/fault status, respectively. A start button **550** and emergency stop button **552** are provided as user inputs for operation of the charging system, and other system information **554** is recorded for convenience of the user.

[0121] The lights **544**, **546**, and **548** may vary in size, shape, color, and signal indicated, and may be used to indicate multiple signals using a single lamp. For example, the done/fault light **548** is used to indicate when charging is done, but it can also indicate when there has been a fault in the charging system by indicating a different color, blinking pattern, brightness, etc. The start button **550** and emergency stop button **552** may be used in similar fashion by varying in size, shape, appearance, and function, and may directly or indirectly adjust the operating conditions of the charging system on the vehicle.

[0122] FIGS. **5**F and **5**G are an example of an exterior-mounted status display, wherein the components are weatherproofed and designed for operation in extreme and outdoor conditions and may be soiled without serious interference with operation of the charging system or display. The embodiment in FIG. **5**F is advantageously positioned for being accessed while charging a stranded EV that is behind the service vehicle, or when cords and connectors for the charging system are located at the rear of the service vehicle, and the embodiment of FIG. **5**G is advantageously positioned for access when the user is charging a stranded EV that is positioned to the sides of the service vehicle since he or she may look over the side of the service vehicle without having to go to either end of the service vehicle to check on the status of the charging equipment. It is noted that the display may beneficially be located at the front of the vehicle, on the sides or on the compartments of the sides of the vehicle, on top of the vehicle at any point, or within the vehicle or enclosure **514** of the charging system.

[0123] Battery Module/ROBM Resupply Facilities

[0124] In some embodiments depleted battery modules/ROBM on a rescue vehicle are changed out at resupply stations. Such resupply stations are not intended to provide batteries that power EV propulsion systems, but instead provide batteries and battery modules that are used in EV recharging stations, especially recharging stations mounted in rescue vehicles, unless the rescue vehicles themselves are incidentally propelled by energy from the battery modules which power their onboard EV recharging stations. Battery modules are not used for traction or providing motive power directly to an EV motor, but are used to provide a boost charge to stranded EVs, requiring, e.g., 4-8 kWh of charge.

[0125] In some embodiments, these stations are repositories for battery modules capable of providing a boost charge through the charging systems of the rescue vehicles. Resupply stations are normally unmanned and can be conveniently located for use by emergency rescue vehicles to respond to rescue calls in high-traffic or freeway areas. The stations may also include quick disconnect systems for the batteries to facilitate quick, efficient, and safe battery exchanges.

[0126] In some embodiments, batteries are housed in a secured recharge bin populated with level 1, 2 or 3 EV chargers at roadside stations. The chargers provide different rates of charge and can charge different types of modules depending on their power output and other electrical characteristics. See, e.g., FIGS. **5**A and **5**C, where a storage facility **500** stores more than one type of battery module, and, in FIG. **5**C, where the rescue vehicles use different types of modules (e.g., **506** and **508**). The battery modules stored in the stations may therefore also vary in size and capacity. In that case, the battery modules may be recharged and stored on shelves holding similar types of battery modules to simplify the electrical system of the facility.

[0127] In the storage area, a state of charge (SOC) indicator or additional display may show the charge status of battery modules. The battery modules' state of charge is therefore available locally but may also be provided to remote rescue vehicles via cellular, Wi-Fi, or other electronic communications transmission media. In some embodiments, rescue vehicles may reserve battery modules available at roadside resupply stations so as to provide time economies. A controller or computer at the roadside battery module exchange station can be programmed to reserve battery modules based on first come first serve, state of emergency service required, prepaid priority, or other reservation prioritization schemes. For example, if the controller uses the state of emergency service required in a reservation program, the relative urgency of assignments given to various service vehicles is compared, and the more urgent assignments are given heightened priority so that even if the service vehicles having extra urgent needs are not first to arrive at a storage location, those vehicles are still able to complete their assignments due to a delay in allowing other service vehicles to access batteries.

[0128] In some embodiments a controller at the station determines which module is to be charged on a rack and manages facility electrical load to avoid exceeding the facility or local grid load requirements. The battery modules may be charged in groups or phases in order to comply with overall facility loads or utility requirements and preferences. For example, the scheduling or reservation controller would not allow certain battery modules to be reserved at a location if charging those modules before they are picked up would cause the overall facility load to exceed a certain limit, such as a demand charge-inducing limit or a utility service limit or rating for the facility.

[0129] Chargers at the stations may be connected to individual or multiple batteries. Systems with level 2 and/or level 3 chargers may be configured to charge multiple battery modules sequentially or simultaneously according to rules executed by a charging controller. Larger charging systems may use multiple “hoses” or cables per charger or may utilize a bus to connect to multiple modules.

[0130] Embodiments with the smaller storage or swap out facilities **500** (as shown in FIGS. **5**B and **5**C) are advantageous in that the smaller facilities can be more easily distributed in a service area, thereby reducing the need for resupply vehicles since the roadside assistance vehicle operators can more readily access the battery modules stored in the smaller facilities.

[0131] In another embodiment a battery module roadside facility may provide energy storage support to an adjacent facility such as an office complex, convenience store, fast food store etc. In this way the energy management capability could at times provide a secondary service to load level a local facility or provide load relief to congested areas on the local distribution grid by discharging the stored battery modules into the electrical system of those areas when provident.

[0132] In another embodiment, the battery module roadside facility may be a mobile unit. It may have significant energy storage capability and may be connected to the grid in different areas. A facility such as this is dispatched when needed to areas having temporary high demand for electricity. This could include being dispatched to a sports arena on a weekend or to a truck stop near a freeway during peak commuting hours. The mobile system plugs into local grid power (e.g., 240-volt, 208-volt or 480-volt) at locations that are configured to accept the system. This system provides the advantage of enabling the system cost to be amortized over multiple use cases and allows more strategic positioning of roadside battery module facilities when needs are temporary.

[0133] Quick-Disconnecting Battery Modules

[0134] In some embodiments electrical energy for the AMEECS is stored in modular battery packs. In some of these embodiments each module has a mechanical quick-disconnecting apparatus to facilitate rapid and convenient change-out of discharged batteries with charged batteries. The quick-disconnect renders a battery easily swappable, and the vehicle’s onboard electrical generation system is therefore not the only method of replenishing the energy store in the short interval between uses since discharged modules can be exchanged for charged modules. In other embodiments, the quick-disconnectable energy storage battery uses an electrical disconnect that does not use a mechanical switch for mechanical safety interlocking, but instead uses a fully electrical safety interlock.

[0135] The apparatus and processes described herein help to ensure that any electrodes that are exposed during equipment operation or maintenance are de-energized before they become accessible to human hands. Replacement of battery trays/drawers or otherwise accessing equipment internals necessitates an action on the part of the person performing the operation to unfasten the tray, drawer, top cover or other protective fixtures surrounding the high-powered electronics inside. Each tray can contain one or more battery module. According to these embodiments, the action required to unfasten electronics is the same action required to de-energize the electronics therein. This design helps to eliminate risks associated with forgetting to shut down the system prior to disassembly.

[0136] In one embodiment of the invention, tray fasteners for the battery modules are equipped with a magnetically conductive material such as iron or ferrite which would need to be moved out of the way to unfasten a tray or module. This in turn would break an otherwise continuous magnetic circuit. The loss of magnetic flow is detected elsewhere in the system and used as a signal to shut down (or disconnect from a contactor) the battery tray terminals. The use of the magnetic circuit affords flexibility and reliability. Flexibility is provided because the magnetic flow can be routed anywhere in the system (similarly to electric flow) and thus can be used to trigger the disconnect in places far removed from the original source. This provides convenience and practicality to the implementation of the safety interlock. Reliability is provided because magnetic continuity is easier to maintain than electric continuity; even in a small signal circuit the battery disconnect electrical circuits are easily broken or defeated by impatient operators. The magnetic flow would be required to energize the system, so that either opening the interlock or some other unforeseen failure of the magnetic path would de-energize the battery tray with equal surety. Persons with ordinary skill in the art will recognize several pre-existing methods for detecting the magnetic flow in the system and causing the battery de-energization triggered by the loss of magnetic flow.

[0137] FIGS. **6**A, **6**B, **6**C, **6**D, **6**E, and **6**F show various views of one possible embodiment of the present invention. These figures generally show a battery module quick disconnect apparatus and circuit **600** wherein a battery module drawer **602** is inserted into a void between magnetic conductors **604** and a retaining bar **606**, and is held in place when the retaining bar **606** is brought down to close contact with a magnetic conductor **604**. The battery module drawer **602** connects with a back-plane connector **608** when it is fully inserted (as shown in FIG. **6**D), and electrical flow through the connector **608** is engaged when the retaining bar **606** contacts the magnetic conductor **604**. In this embodiment, the magnetically-conductive retaining bar **606** closes a continuous magnetic circuit driven by a permanent magnet **609** or electromagnet and simultaneously locks the drawer **602** in place. When the retaining bar **606** is opened, sensors, such as the hall-effect sensor **610** shown, detect the loss of magnetic flow in the system and shut down (disconnect with a contactor) the battery tray back-plane connector.

[0138] FIGS. **7**A and **7**B show an embodiment of the quick disconnect and battery module system with multiple drawers of modules **700** that can be quickly installed or removed. Each drawer **602** can be installed and removed independently, allowing uninterrupted power supplied by the apparatus if a battery module needs to be changed out. Also, if the charging system that the battery modules are powering needs additional storage capacity, the system is expandable to take on additional modules to meet those demands. These figures may represent a battery quick-disconnect system that is present on an apparatus that charges the battery modules when they are removed from a charging station on a rescue vehicle in addition to showing a rack in a vehicle-mounted charging system.

[0139] In another embodiment, a battery tray is de-energized by turning a handle (such as the latches **800** of FIGS. **8**A and **8**B) to disconnect a control signal pathway connected to a de-energization trigger. This embodiment minimizes the need to wait for the battery to be recharged either at a charging location or by using the onboard organic charging system, so the rescue vehicle can be more quickly redeployed with new battery modules.

[0140] In another embodiment, the quick-disconnectable energy storage battery (or ROBM) features an electrical disconnect and interlock that prevent removal and replacement of the battery unless the battery is electrically disconnected from the rest of the system, and it is connectable only after mechanical connections of the battery are complete and secure. One advantage provided by the electrical disconnect and interlock is the protection of the operator from electrical shock or burns associated with accidents common to the manipulation of electrical energy storage devices including shorts causing damage to equipment and electrocution causing personal harm. Another advantage of the electrical disconnect and interlock is the preservation of the delicate contacts used in electrical connections by transferring the function of making the initial electrical connection from the connector contacts themselves to a more suitable device such as a circuit breaker or electrical switch which is specifically designed with springs and vacuum chambered contacts in order to handle the sparks and surges associated with this function. This embodiment may also incorporate the interlocking electrical disconnect with a suitably-rated switch or circuit breaker attached to it such that it cannot be moved into the "ON" position unless and until the mechanical connections are complete and secure, and the electrodes of the connector are safely removed from access by human hands.

[0141] In some embodiments, the quick-disconnectable energy storage battery module uses a self-aligning connector at the back of the battery drawer for connecting a battery (e.g., ROBM) to a backplane of a battery connection point which employs extra conductors arranged to complete the connection of a relay coil which, in turn, energizes a larger contactor which completes the electrical connection. In this embodiment, oversized yet delicate contacts in the connector or a mechanical interlock are not needed to prevent the inrush of current through the delicate contacts before they are fully inserted and secure. This embodiment is advantageous because it is fully automated and has no moving parts other than the one necessary moving part inside the contactor that actually does the contacting. Full automation allows for adaptability in function, like a time delay or any other behavior that may be programmed into a processor for deciding if and when to complete the high-current connection. By closing the contactor the extra conductors in the self-aligning connector merely enable the main contactor, but do not necessarily immediately activate the main contactor.

[0142] In yet another embodiment, the extra electrical contacts in the self-aligning connector at the back of the battery (e.g., ROBM) tray are used to activate a fully electronic contactor such as a MOSFET or other solid-state switching device inside the battery tray and electrically positioned between the battery and the connector at the back of the tray. This embodiment deactivates the battery tray and makes the electrical contacts of the tray safe to touch with human hands without human intervention. Using the fully-electronic contactor confers benefits to the battery tray including but not limited to: (1) the extra reliability of no moving parts, (2) the gradual ramp-up of electrical current flow which reduces thermal shock on associated components and the EM pulse associated with sudden current flow, and (3) the option of computer checking of safety conditions before the final decision is made to complete the electrical connection.

[0143] In yet another embodiment, the battery modules are designed to permit expandability of the charging system by connecting to each other. The module housings may be designed much like building blocks that interlink until they are finally connected to the charging station at one end. In this embodiment, the battery modules indicate their present charge capacity and may be sequentially discharged to make a resupply action more fluid.

[0144] For example, if three out of five battery modules are used during the course of a day of use of the charging equipment on the rescue vehicle, the battery modules, arranged in a chain fashion, the modules on the outside end of the chain are discharged and the modules on the inside end of the chain are still charged, so when the operator changes out the discharged batteries for charged batteries, it is easier to see that three of the five need to be switched out and easier to access them as well. Then, because the modules are connected in a chain fashion, the three modules can be removed while they are still interlinked by releasing a quick disconnect latch **800** between the discharged and charged modules without having to disconnect modules one at a time. Likewise, when the battery modules are replaced, three replacement modules can be interlinked and reconnected at the point of the latch at the same time with only one quick-connect latch to reengage. Additional/supplemental battery modules can be added to this embodiment by latching a module to the end of the outermost connected module as many times as possible. See also FIGS. **8**A and **8**B which show a sample embodiment of an expandable battery module design arranged in a chain fashion. The chaining connection pattern allows depleted modules to be positioned at the most convenient (outermost) position in the chain and reduces complexity of adding new modules or the need for additional wiring and connection points that would be needed in another configuration such as a grid-like connection pattern.

[0145] FIG. **8**A shows a number of battery modules **802** connected with closed latches **800** that keep the modules **802** from disconnecting from the connection to the charging equipment **804** or from other battery modules. FIG. **8**B shows a number of disconnected battery modules with open latches to show the individual shape of the battery modules, their male and female electrical connectors **806** and **807**, and indicators **808**. The latches secure the battery modules together by engaging latch receivers **810** on the modules that keep them secured. In some embodiments, the latch receivers **810** have electrical connections that are closed when a latch **800** is closed on the receiver **810**, and when the electrical connections are closed, the female connectors **807** are energized to provide energy to the charging equipment **804**. The indicators **808** in these embodiments can be gauges, lights, output connections such as VGA ports, USB ports, simple electrical outputs (e.g., a voltage signal), and other like means of indicating charge or connection information.

[0146] FIGS. **9**A, **9**B, **9**C, **9**D, **9**E, and **9**F show an alternative embodiment for a quick disconnect system for securing battery modules with a safety relay. FIG. **9**A is a perspective view of a battery module drawer **900** loaded into an enclosure **902** that has an open door **904**. FIG. **9**B is a left side plan view of the battery module receptacle **906** indicating the door **904** and relay **908** portions. FIG. **9**C is a top plan view of the battery module receptacle **906**. FIG. **9**D is a front plan view of the drawer **900** and door **904** with push buttons **910** indicated. FIG. **9**E shows an embodiment of the battery module enclosure **902** indicating the relay **908**. FIG. **9**F is a section view across section line B-B of FIG. **9**E showing the internal portions of the battery module drawer **900** and receptacle **906** within the enclosure **902**, including the push buttons **910**, electrical connector **912** on the rear side of the module drawer **900**, and the corresponding relay **908** on the module enclosure **902**. In this embodiment, the drawer **900** may be quickly disconnected from the receptacle **906** with no risk of electrical shock-related injury to the user. The relay **908** is not energized until the drawer **900** is fully inserted, with the electrical connector **912** in position, and the door is closed **904**, thereby depressing the push buttons **910**. Since there are two push buttons **910**, there is less opportunity for a user to accidentally energize the relay **908** when the drawer **900** is removed by pressing a button inadvertently when the drawer **900** is open. Yet because the relay **908** is not energized unless the door **904** is closed, the battery module drawer **900** can be quickly replaced by another without risk of electrical shock while the drawer **900** is being or has been removed. Additionally, since the relay **908** is at the rear of the cavity in which the drawer is positioned in this embodiment, it is further removed from human interaction, since the user-operative end of the drawer **900** and receptacle **906** is the front end.

[0147] The principles embodied in the subparts of FIG. **9** may be extended to other embodiments as well. For example, the door **904** may be enlarged to cover multiple battery module drawers at once, and the push buttons may be configured to vary in size, position, and number. In such an embodiment, when the door is opened, multiple relays which are connected to the multiple battery module drawers are preferably disengaged simultaneously. This embodiment may be advantageous in reducing the complexity of the hardware used to secure the battery module drawers and to allow the user to quickly deactivate many modules at once. Additionally, the push buttons may instead send a signal to a microcontroller or computer controller of the battery module receptacles that uses other sensors to detect whether energization of the power relays is safe and appropriate.

[0148] Furthermore, combinations of the preceding embodiments are possible. Module drawers **900** may comprise battery modules themselves that are inserted into receptacles **906** and locked in by doors **904**, and the entire enclosures **902** may be used as battery module drawers shown in embodiments having a retaining bar-activated magnetic conduction system such as the apparatus **600** seen in FIGS. **6**A through **7**B inclusive. Combining these embodiments allows the user to have an extra layer of protection against accidental energization of battery modules since a door (e.g., **904**) and retaining bar (e.g., **606**) must both be in the correct positions in order for the battery modules to discharge.

[0149] Connection Between Service Vehicle and EV

[0150] Rescue vehicles for EVs may need charge depleted batteries onboard distressed EVs using a charging cable that goes from the charging device on the rescue vehicle to a charging port on the EV. Some existing EV charging stations have charging cables that are permanently attached to the charger that connect the charging electronics to an EV charging port. The charging cables may be permanently attached to the charging station, resulting in limits on how far the cables can reach due to their positioning on the service vehicle and their fixed length. Long cables, especially those used in current standards for fast DC charging, are heavy and their transportation is difficult and dangerous by a single human operator. This danger is magnified in situations where the charging station is transported by a vehicle where a misstep by an operator may result in exposure to fast-moving traffic and other hazards.

[0151] An aspect of some embodiments of the present invention is a segmented EV charging cable that may be used to connect a service vehicle charging system to a stranded EV. The segmented EV charging cable system may include a port on the service vehicle's charging system for attachment of one end of the segmented charging cable, but it may also include multiple ports that are on the charging system or that are at different points on the service vehicle but are wired to the charging system components.

[0152] A charging equipment system may provide multiple charging ports on the rescue vehicle, enabling the operator maximum convenience and safety while setting up charging equipment by allowing the user to choose the most convenient port to use. Having multiple ports is particularly useful in allowing the rescue vehicle operator to select a port that minimizes exposure to vehicle traffic and road-related hazards when operating near a roadway. Allowing the operator to select the outlet port most convenient to his operation also permits him to reduce the length of the cable required to support his operational need when connecting to EVs at various distances from the charging cable port on the charging system. Some embodiments of the invention use a Risk Class **0** NFPA 70 E or equivalent connector which enables an operator who is not a certified electrician to assemble the segmented EV charging cable in the field. The charging ports of the service vehicle and/or charging equipment are preferably capable of performing level 2, level 2 "fast charge", level 3, or otherwise comparable fast EV charging rates and standards in order to minimize the time that the service vehicle is charging the stranded EV and exposing the users, service vehicle, stranded EV, and associated charging equipment to dangers.

[0153] The segmented charging cable system also permits the user to change overall length of the charging cable into user-manageable segments or lengths. The length of the charging cable required to service EV rescue operations depends on how close the rescue vehicle is to the charging port on the EV. In many cases a charging cable of 5 to 15 feet in length is sufficient to service a distressed EV, but in certain configurations the EV's charging port could be a full car length or more away from the rescue vehicle. Charging an EV from such a distance necessitates that the charging cable be longer than a standard length of 5 to 15 feet, and it could require 30 feet or more in length. Due to the bulk of the wiring and wire sheathing used in EV charging cables and their connectors, the cabling may weigh more than the Occupational Safety and Health Administration (OSHA) lifting recommendations set by the United States Department of Labor, and is typically too weighty and cumbersome to handle manually. Therefore, by segmenting the charging cable, a user can transport manageable lengths of extension cables without having to carry too much weight at once to connect to an EV. For example, instead of having a cumbersome and heavy 25 to 35 foot cable the cabling system may enable the operator to use multiple cable segments of approximately 6 to 15 feet and a charging connector to accommodate routine rescue missions. These shorter cable segments are therefore ideally 35 to 42 pounds in weight to fit within OSHA recommendations when the NIOSH lifting equation of 1991 is used, as discussed in connection with the battery module sizes in this document. When the charger operator is confronted with a rescue operation requiring a longer cable he may add a second and/or third cable segment to extend its effective range without having to reposition the service vehicle or charging system. These weight and size figures are not intended to define the absolute limits of the scope of the dimensions and weight of the cables, but as a preferred guideline for common embodiments of the invention.

[0154] In some embodiments a basic or standard cable segment includes a charging connector designed to mate with the EV at a charging port, and this basic cable segment can be augmented with other extension cable segments to increase its length. Connections between the segments may include NFPA 70 E compliant connectors (or equivalent) which do not require a certified electrician to make connections in the field. A second modular extension segment may be roughly 12 to 30 feet in length, one end of which having a connector shaped for attaching to a charging port on the service vehicle or another modular segment, and the other end having a connector shaped for attaching to an extension port on the basic cable segment or another end of another modular segment. One end of this cable segment attaches to the charger while the other end attaches to either another charging cable segment or the cable segment that contains the connector to the EV. Such component cable segments may be designed to stay within OSHA weight lifting recommendations.

[0155] FIG. **10**A shows various isometric perspective views of a rescue vehicle and identifies a number of exemplary sites on the vehicle where a charging cable connection port **1000** may be located. The thickened ovals and circles show some advantageous positions for a charging cable connection port that may be installed to provide power from an onboard charging system to an EV. FIG. **10**B shows a top perspective view of a rescue vehicle and also identifies a number of potential sites on the vehicle where a charging cable connection port **1000** may be located.

[0156] When two or more of these ports **1000** on the service vehicle are installed, the user may select an advantageous position to connect an EV charging cable, such as on the side of the service vehicle that is closest to the stranded EV's charging port or on the side of the service vehicle that is safest (e.g., farthest) from nearby roadway traffic. In some instances, the user may connect the charging cable to one of the ports because another port is blocked or inaccessible, such as, for example, if one side of the service vehicle is too close to a wall or a restricted police zone or roadside construction zone. In other cases, one port may be preferable because the surroundings near the other port would pose a danger to the charging cord or the user, such as if the ground near that port was covered in glass shards, thorny plants, deep mud, or water. In yet other embodiments, the port selected would be determined by whether the nearby surroundings could properly support the charging cable, such as when one side of the service vehicle is on a downward slope and the charging cable would have to hang down a long distance to reach the ground and cause strain in the charging cable and connectors.

[0157] By selecting one port over another, the user gains the benefit of safer conditions, easier access to the target stranded EV, and less risk to himself and the charging equipment used with the EV. Alternatively, the presence of multiple charging ports on the service vehicle may give rise to the benefit of connecting multiple target stranded EVs to the vehicle for simultaneous charging, with each EV being connected to the nearest or otherwise most appropriate charging port on the service vehicle. These ports are even more beneficial when they are capable of level 2 charging, level 2 fast charging, level 3 charging, or another fast charging standard, as they may allow the EV and service vehicle to return to the roadway in a short time, thereby minimizing exposure to dangerous conditions and maximizing the time that the service vehicle may be out servicing other stranded vehicles. In some embodiments, the charging electronics are capable of output of multiple different charging standards, such as J1772 and TEPCO® CHAdeMO®, and the charging electronics can route the charging output of either standard to the same port. The user then attaches the appropriate charging cable to the port, such as a J1772 cable with a J1772 connector when the charging electronics provide a J1772 level 2 output from the port. When another charging standard is set to output from that port, then the user replaces the charging cable or an attachment of the charging cable such as the charging connector with a cable or attachment that is compatible with the different charging standard.

[0158] The depictions of a rescue or service vehicle and EV in the figures are not intended to introduce limitation into the size, shape, and type of vehicles that may be compatible with the present invention, but are merely presented as exemplary embodiments of one potential application of the invention. For instance, a truck is seen as a rescue vehicle in these figures, but a car, van, bus, watercraft, motorcycle, or other vehicle may be selected as well without departing from the invention. Likewise, connection ports **1000** may be positioned on the vehicle at positions other than those illustrated in the figures.

[0159] FIG. **11**A depicts a segmented charging cable with two segments. A first segment is a standard charging cable **1100** having at a first end an EV charging connector **1102** and at a second end a cable connector or receptacle **1104**. In some embodiments, a TEPCO® CHAdeMO® connector is the EV charging connector **1102**, but other EV connector types may be used. The other end **1104** of the first segment may be a NFPA 70 E compliant connector capable of being mated to either a charging equipment connector/receptacle on the rescue vehicle charger or on a cable extension **1106**. FIGS. **11**B and **11**C show perspective views of an exemplary cable connector or receptacle that may be used for this purpose. FIG. **11**B is a female connector, and FIG. **11**C is a male connector. The male connector is inserted into the female connector, then turned to secure a locking edge and clipped into place by a retention clip.

[0160] Referring again to FIG. **11**A, a second segment of the charging cable is a charging cable extension **1106** having a cable connector or receptacle **1104** on both ends that is NFPA 70 E compliant. A first end of the charging cable extension is a cable connector or receptacle **1104** capable of being mated to a cable connector or receptacle **1104** on the standard charging cable **1100**. A second end of the charging cable extension is a cable connector or receptacle **1104** compatible with being mated to the charging equipment connector or receptacle **1108** on the service vehicle or the service vehicle charging station. All connectors of FIG. **11**A may be NFPA 70 E compliant connectors capable of being field installed without the help of a certified electrician. This may allow a user to quickly set up and break down a charging cord in the field to minimize the exposure of the user, the charging equipment, the service vehicle, and the stranded EV to potentially hazardous roadside conditions.

[0161] FIG. **12**A is a diagram of a rescue vehicle with a charging cable and connectors and an EV. The rescue vehicle in this diagram has multiple charging ports **1200**, one of which has a standard charging cable **1202** used to charge an EV located near the rescue vehicle. By selecting the charging equipment connector or receptacle that is nearest to the stranded EV, the operator may use the standard cable **1202** without need for extensions, resulting in reduced tripping hazards and risk of damage to the cable from exposure to the roadway. A charging cable extension in this case may be stored in the rescue vehicle, allowing further reach for the charging station if necessary, but protecting the cable extension from potential wear and damage while stored.

[0162] FIG. **12**B is a diagram of a rescue vehicle and stranded EV with charging cables and connectors partially connected with the stranded EV beyond the range of a standard charging cable **1200**. In a configuration such as this, the rescue vehicle requires a longer charging cable than is normally needed, so the operator elects to use a charging cable extension **1204** and combine the extended length with a selection of the most opportune charging equipment connector on the rescue vehicle. The standard charging cable **1200** is transported near to the stranded EV, the charging cable extension **1204** is moved and mated to the standard charging cable **1200**, the charging cable extension **1204** is connected to the rescue vehicle, and the EV charging connector **1208** is connected to the EV charging port **1210**. In this manner, the user is not forced to transport a single extra-long heavyweight charging cable to the stranded EV over a long distance, but only has to travel with two smaller and more manageable cables. This may help reduce the manual labor performed by the operator and keep the operation of the charging equipment within OSHA recommendation standards while helping the operator remain away from traffic and other hazards and providing a direct route from the rescue vehicle charging equipment to the EV charging port. In this figure additional vehicles are between the rescue vehicle and the stranded EV, resulting in the inability of the rescue vehicle to reach the stranded EV without a charging cable extension, but other obstacles or hazards may result in a need for connecting to a far-away stranded EV, such as, for example, terrain, structures, other emergency vehicles, fire, oversized stranded EVs, stranded EVs with irregularly-placed charging ports, or even just operator neglect in parking the rescue vehicle too far away from the stranded EV.

[0163] Use and Integration of Deliverable Automotive Service Batteries

[0164] In some embodiments, service vehicles are used to transport and transfer automotive batteries to and from disabled vehicles when their batteries fail. Generally, the deliverable batteries are 12-volt lead-acid batteries (which may also be referred to as starting, lighting, ignition batteries or SLI batteries) transported and used in internal combustion engine (ICE)-based vehicles to start the vehicles and provide electricity when the alternator is not providing electricity to the vehicle. Service vehicles bearing the batteries of these embodiments store them in compartments and bring them to vehicles in need for switching out, and in some embodiments, the service vehicles charge the SLI batteries or use them for supplying energy to EV charging equipment of the service vehicle.

[0165] In another embodiment, the batteries are connected to the alternator of the service vehicle but are not connected to charging equipment on the vehicle. This may allow the batteries to remain at maximum charge when self-discharge would otherwise slowly deplete the batteries. It may also allow the service vehicle to restore energy to a battery if it is placed in the service vehicle having less than full charge. Some more embodiments have connections to allow the batteries to provide power to vehicle electrical systems such as lighting, radio, an electric motor, a winch, or other electrical devices on the vehicle.

[0166] In some embodiments the service batteries may be enabled or disabled for charging/discharging to the charging equipment, such as would be desired if the service vehicle operator received a call for a reservation of a particular type of battery. He or she could then disable discharging of that battery to ensure that it was fully charged for the customer who made the reservation. In other embodiments, some of the batteries stored on the vehicle may be used to transfer charge to another battery on the vehicle. For example, if a certain battery type is needed for a service call, but it is not currently fully charged, the other batteries may transfer charge to that battery to ensure that it has maximum charge when it is provided to the customer.

[0167] In some embodiments a controller is provided that may switch charging and discharging of individual batteries on and off as desired, may control the operation of power converters of the batteries, monitor and control charging equipment, and perform other monitoring, recording, and controlling tasks. In some embodiments the power converters are DC-DC converters or AC-DC converters/inverters that are unidirectional or bidirectional, have manual or remote control features, and can be set to receive and output a variety of signals, voltages, and currents.

[0168] These embodiments of the invention may provide cost savings to service vehicle fleet operators that wish to provide charging services to EVs. The service batteries are put to multiple uses by assisting internal combustion engine customers with failed batteries, and may be additionally used to assist charging stranded EVs. Customer satisfaction is improved because the batteries they receive are more fully charged and the service vehicle may also serve their EVs. Providing charging services to EVs has lower barriers to entry for service vehicle fleet operators since the batteries purchased for EV charging may also be used in a battery replacement program using the same service vehicles and transporting structures.

[0169] FIG. **13**A shows a side perspective view of a service vehicle **1300** with storage capability according to an embodiment of the invention. Such a service vehicle **1300** may be dispatched with batteries in the closed storage compartments **1302**, the cab **1304**, the bed **1306**, or a charger enclosure **1308** (if present) that may be given to stranded vehicles with failed or depleted batteries. The batteries in the service vehicle **1300** may also be electrically connected for charging electric vehicles (EVs). FIG. **13**B shows a side perspective view of a service vehicle **1300** such as the one shown in FIG. **13**A with open storage compartments **1310**. The open storage compartments **1310** may contain storage racks **1312** or shelves **1314** and may contain service batteries **1316**, charging cables **1318**, and other electrical equipment. One or more of the service batteries **1316** is connected to other electrical equipment in the service vehicle **1300** by power lines **1320**. The compartment doors **1322** may be closed to protect the sensitive electronics within the compartments **1310**.

[0170] FIG. **14**A shows a top view of a service vehicle **1400** with electrical lines indicated according to an embodiment of the invention. The service vehicle **1400** has an engine **1402** that drives an alternator **1404**. The alternator **1404** may include a standard vehicle alternator, an increased output capacity or heavy duty alternator, or other means of converting power from the engine **1402** into electrical power. Other means of electricity generation may also be implemented with the vehicle **1400**, such as renewable energy generation from solar panels or windmills that are also directly or indirectly connected to the power line **1408** or other electrical systems of the vehicle **1400**.

[0171] The alternator **1404** is linked to service batteries **1406** by a power line **1408** running through the vehicle. The service batteries **1406** may include electrochemical cells, arrays, or banks of lead-acid, lithium-ion, nickel metal hydride, nickel cadmium, zinc-based batteries, combinations thereof, and other similar rechargeable energy storage devices, such as, for example, capacitors, supercapacitors, and fuel cells. Preferably, the service batteries **1406** are comprised of models having standardized sizes, voltages, capacities, and other physical characteristics so that they may be more readily connected to disabled vehicles with standardized receptacles and electrical requirements, such as automotive SLI batteries. There may be one service battery **1406**, two, three, four, five, ten, twenty, fifty, or more in the service vehicle **1400**. Each battery **1406** has a positive and negative terminal that can provide a voltage difference when the battery **1406** is charged.

[0172] One or more of these batteries **1406** is connected to the power line **1408** in the vehicle **1400** to send and receive electricity to and from the alternator **1404**, charging equipment **1412**, controller **1410**, and other batteries **1406**. It may also be the case that there are no service batteries **1406** present in or on the service vehicle **1400**, but provided that sufficient connectors exist on the vehicle to connect a service battery **1406** to the power line **1408** for the purposes mentioned in this document, a vehicle having this absence of batteries **1406** is still appraised to be within the scope of the invention. These connectors may include wires, plugs, clamps, clips, sockets, conducting racks, or other similar means for linking the electrical connections on the service batteries **1406** to the power line **1408**.

[0173] A controller **1410** and charging equipment **1412** are also connected to the power line **1408**. The controller **1410** may include a computer, processor with associated memory, control panel, or other means for monitoring, controlling, or recording the flow of electricity through the power line **1408** and charging line **1414**, and possibly other electrical systems of the service vehicle **1400**. Preferably the controller **1410** may be able to measure voltage, state of charge, current, temperature, and other factors related to the status and operation of the service batteries **1406**, power line **1408**, alternator **1404**, charging equipment **1412**, charging line **1414**, and charging cables and connectors **1416**. However, in some embodiments the controller **1410** may only be able to observe and control a subset of these portions of the systems on the vehicle. The controller **1410** may also be able to issue instructions to these portions of the systems of the vehicle, such as, for example, setting the charging equipment **1412** to a certain output voltage, or electrically disconnecting certain service batteries **1406** from the power line **1408** when appropriate. The controller **1410** may also be able to send and receive information from a remote controller or server via a wired or wireless connection means such as infrared or optical transmission, Wi-Fi, Bluetooth®, cellular, or other RF transmission.

[0174] A charging line **1414** comes from the charging equipment **1412** to EV charging cables and connectors **1416**. In some embodiments, one structure comprises the charging line **1414** and the cables and connectors **1416**. The charging equipment **1412** may include one or more DC-DC buck/boost converter, one or more single- or bi-directional inverters, signal conditioning circuitry such as filters and stabilizing capacitors, and combinations thereof. The selection of these elements is significant in relation to the electrical signal(s) required for charging an EV. In some embodiments the settings of the components of the charging equipment **1412** may be set and adjusted by the controller **1410**. For example, in order to comply with the SAE J1772 AC charging standard, an inverter would be included in the charging equipment **1412** to convert the DC voltage of the service batteries **1406** into a single-phase 240-volt AC signal that would be supplied to the charging line **1414**, and a boost converter may be required to upconvert the voltage of the batteries **1406** to a DC voltage suitable for conversion by the inverter. The charging equipment **1412** may be stored in a charger enclosure **1308**, or may be integrated into other portions of the service vehicle **1422** including the cab, the bed, and the storage compartments in which the batteries **1406** are shown. Additionally, charging equipment **1412** may be removable from the vehicle and in that case it may have quick disconnecting connectors between the equipment **1412** and the power line **1408**.

[0175] The charging cables and connectors **1416** may include wires, cords, and similar conductors to link the charging equipment **1412** to a nearby EV. The connectors may be standardized connectors such as the SAE J1772 connector or may be non-standardized, popular connectors such as the TEPCO® CHAdeMO® connector, or unpopular or customized connectors, as necessary for EV charging. The charging cables and connectors **1416** may be stored in compartments or other areas of the vehicle, and may be disconnectable from the charging line **1414** to be replaced with other charging cables and connectors **1416** or safety caps to prevent soiling or tampering with the vehicle.

[0176] In some embodiments, it may be advantageous to program the controller **1410** to allow one or more service batteries **1406** to discharge to another service battery **1406** or number of service batteries **1406**. For example, if a customer needs a fully charged service battery **1406**, but it has recently been used to supply energy to the charging equipment **1412**, the controller **1410** may direct other batteries **1406** to discharge into the customer's needed battery in order to increase its state of charge prior to turning it over to the customer. The alternator **1404** may then be used to restore charge to the remaining service batteries **1406** and a battery collected from the customer, if any.

[0177] FIG. **14**B shows top view of a service vehicle **1418** similar to FIG. **14**A but with power converters **1420** disposed on the power line **1408** between the service batteries **1406** and the charging equipment **1412**, controller **1410**, and alternator **1404**. The power converters **1420** may be useful to install on one or more battery **1406** or on a group of batteries to stabilize and standardize the electrical signals provided to the charging equipment **1412**. It may also increase efficiency of charging differing batteries **1406** with the alternator **1404** by preventing circulating currents through the batteries **1406**. It may also be advantageous to implement power converters according to the apparatuses described in U.S. patent application Ser. No. 13/100,152 (which is hereby incorporated by reference) that render the service batteries **1406** parallelable without regard to the voltage, capacity, or other characteristics of the batteries **1406** to enhance compatibility of the service vehicle **1418** with a wider range of batteries **1406**. Another advantage of using converters **1420** with some or all of the batteries **1406** is realized when a controller **1410** is connected to the converters **1420** to enable or disable the converters **1420** to connect or disconnect batteries **1406** from the power line **1408**.

[0178] FIG. **14**C shows a top view of a service vehicle **1422** with alternate charging lines indicated according to an embodiment of the invention. In this embodiment the charging line **1424** extends to multiple charging ports **1426** that serve as connectors to a detachable charging cable and charging connectors **1428**. The charging cable and connectors **1428** may be selectively connected to a charging port **1426** that is most convenient and/or safe for charging an EV to which the service vehicle **1422** is brought. For example, a detachable cable and connector **1428** may be connected to the left side of the vehicle if it is closer to the stranded EV than the right side, or if the right side of the service vehicle **1422** is more exposed to traffic or other hazards.

[0179] FIG. **14**D shows a top view of a service vehicle **1430** with batteries **1406** that are connected to an alternator **1404** without being connected to charging equipment. This alternate configuration shows that the batteries **1406** are not required to be used in charging EVs. This figure also shows that an unoccupied battery port **1432** may be present in the system without negatively affecting the operation of the service vehicle. Likewise, all of the battery ports may be unoccupied while still practicing the invention as long as when a service battery **1406** is electrically connected to the power line **1408** in one of the storage port areas of the vehicle **1430**, the battery may be charged by the alternator **1404** or discharged to other batteries in the vehicle. A service vehicle **1430** of this embodiment may be routed to a disabled vehicle, exchange a service battery **1406** to the disabled vehicle and take its battery to be recharged via the alternator **1404** and power line **1408** when it is connected to an unoccupied battery port **1432**.

[0180] FIG. **14**E shows a top view of a service vehicle **1434** with batteries **1406** that are connected to charging equipment **1412** and a controller **1410** without being connected to an alternator. In this embodiment, the batteries **1406** are not recharged while borne by the service vehicle **1434**, but may still be leveraged as an energy source of the charging equipment **1412**. This system would eventually exhaust its energy storage and would have to be connected to a charging station to restore charge to the batteries **1406** either by connecting directly to the batteries or by connecting the power line **1408** or charging line **1414** to a power source and charging the batteries **1406** indirectly through the power line **1408** and/or charging equipment **1412**.

[0181] FIG. **14**F shows a top view of a service vehicle **1436** with service batteries **1406** that are connected to a first power line **1438** that is linked to an alternator **1404**, and service batteries **1406** that are connected to a second power line **1440**. In this configuration, the user may opt to use service batteries **1406** as a source of power for the charging equipment by connecting them to the second power line **1440**, or may connect the batteries **1406** to the first power line **1438** for recharging (or maintenance of charge) via the alternator **1404**. In this embodiment, the controller **1410** may be able to control the charging operations of the devices connected to the second power line **1440**, and may also be able to monitor and control the charging of the service batteries **1406** in the first power line **1438**. This embodiment allows the user to easily manage whether the batteries **1406** on the service vehicle **1436** will be charging or discharging by deciding which power line the batteries should be connected to. Thus it may be advantageous to arrange the power lines **1438** and **1440** in the vehicle so that it is clear to the user whether a battery receptacle is connected to a charging line or a discharging line, such as, for example, making all battery receptacles or connections on the left side of the vehicle charging connections and making all battery receptacles or connections on the right side of the vehicle discharging connections. This embodiment may also be advantageous in simplifying a battery reservation system, since if a battery is reserved on the service vehicle **1436**, the vehicle operator can reserve that battery by simply connecting the battery to the first power line **1438** with an assurance that it will not discharge any more until the reserved battery is delivered to the entity that made the reservation. In an alternative embodiment, the first and second power lines **1438** and **1440** are connected to a switch at each service battery **1406** receptacle/connector such that the vehicle operator may selectively choose a preferred power line for each battery **1406** without having to move the battery to a new receptacle or connector.

[0182] Monitoring, Management, and Control of Service Vehicles and Battery Modules

[0183] In some embodiments a network of system controllers tracks the status of a number of rescue vehicle charging systems, evaluates options, recommends actions, and, at times, takes automated action regarding the control of the service vehicles or battery modules. In one embodiment, "first-level" controllers in the network are associated with each of the rescue vehicles, where they monitor the health and status of the vehicle and its systems. They record vehicle location, operational status, fuel level, and vehicle maintenance alerts. In some embodiments, the first-level rescue vehicle controllers communicate this information to the rescue vehicle operator and in some embodiments this information is sent to a second level of controllers (that may, for example, reside in a control center) for analysis and optimization of multiple first-level controller operations. The first-level controllers may use one or more computers or other interfaces located on the vehicle or a handheld device to gather and serve this information to the rescue vehicle operator.

[0184] In some embodiments the first-level controllers communicate with "second-level" controllers via cellular, radio or other electronic communication systems. In the case of communication link failures, the first and second level controllers search for alternate link pathways while storing accumulated relevant data for future transmission. The first-level controllers may also take automated actions where appropriate.

[0185] The second-level controllers receive data feeds from the first-level controllers on rescue vehicles in their service area. The data feeds may include, for example, location, the state of energy storage available for EV charging, and health management data from vehicle systems including alerts and trends for key systems. The rescue vehicle power electronics data may include, for example, temperature, high and low voltage, current draw, electric fault exceedances, and unusual trends of the energy storage, chargers, inverters, and other power electronics. The second-level/control center controller may maintain a maintenance log and may recommend preventative maintenance actions and schedules and communicate this information to the rescue system operators and/or their supervisors.

[0186] In some embodiments the control center controllers optimize overall rescue systems scheduling based on the availability of assets, state of preparedness, location, lack or presence of system rescue vehicle alerts, customer rescue requests and locations, etc. In some embodiments the control center controllers also schedule rescue vehicle recharging or swap-out of battery module/Rescue Operations Battery Modules (ROBM) procedures based on vehicle location, work load, and asset status (including but not limited to energy storage status).

[0187] In some embodiments the control center controllers optimize decisions regarding whether fully charged ROBM should be sent to a rescue vehicle by a ROBM resupply/replacement vehicle or to route the rescue vehicle to a ROBM swap out station. Either way, ROBM are reserved for specific rescue vehicles based on a rules-based prioritization system. In this manner, every rescue vehicle is guaranteed availability of a ROBM swap out at a specific time and location. In some cases, the controller directs a rescue vehicle to recharge without unloading any modules, as that may be the most efficient operation at the time.

[0188] A third level of controllers may be utilized in large areas to support long-term asset optimization and logistics coordination and facilitate economies of scale in purchasing and deploying assets. In another embodiment the "third-level" controllers provide recommendation of targeted preventative maintenance, elimination of high failure rate equipment, and provide recommendations for preventative maintenance, training, and order delivery.

[0189] The controller systems may be designed to optimize rescue operations in some of the following ways: (1) minimizing the time required for a rescue vehicle to respond to the stranded vehicle, such as by coordinating rescue vehicles so that the nearest vehicle is assigned to respond to the stranded vehicle, (2) minimizing the time required for the rescue vehicle to recharge the stranded vehicle by deselecting rescue vehicles who do not have adequate consumables (energy storage, fuel, etc.), (3) minimizing the time required for a stranded vehicle to reach a location where a greater charge can be obtained, such as by measuring the distances to the nearest charging locations and selecting the nearest one to which to direct the stranded EV and/or by verifying and reserving a charging location for the stranded EV, (4) minimizing the time required for the rescue vehicle to recharge its charging system's batteries, such as by coordinating the exchange of fully charged battery modules for discharged modules onboard the rescue vehicle, (5) minimizing the fuel consumed by the rescue vehicle and time to respond in assisting a stranded vehicle, such as by keeping rescue vehicles near areas with high incidence of EV rescue events, (6) increasing rescue vehicle or energy storage device service lifetime and reliability, such as by monitoring the characteristics of the charging systems and scheduling maintenance, (7) minimizing charging equipment costs by increasing its utilization, (8) minimizing rescue vehicle downtime due to maintenance or refueling, (9) minimizing strain of rescue vehicle operators, such as by sending notifications of required maintenance and/or by allowing operators to override commands sent from a control center, and (10) increasing ease of use of rescue vehicle-transported charging systems, such as by displaying important information and automating maintenance decisions.

[0190] In some embodiments a first-level rescue vehicle controller is used to report status information to a rescue vehicle operator, and potentially also report this information to a second-level controller and/or provide charging system control commands to ensure safe and efficient operation of a service vehicle. (See FIG. **23** for a diagrammatic view of the hierarchy of controllers.)

[0191] In this embodiment, as shown in FIG. **15**, the rescue vehicle controller monitors vehicle location, vehicle system status, charging system status (step **1500**) and reports alerts and system status information to the vehicle operator (step **1502**) and, optionally, to a second level of controllers located in a control center (step **1504**). Alerts include system-safety-related alerts. Safety-related alerts may involve exceedances of electric fault indication, equipment temperature, vibration, current draw, high or low voltage and other indicators related to system safety. If the system controller detects a safety-related issue it will alert the vehicle operator and the control center controller to take appropriate action (step **1506**). Depending on the nature of the alert the controller may command the system to cease charging operations and/or safe the system (step **1508**), and report the status to the vehicle to the vehicle operator and, in some cases, a control center (step **1510**). The controller will also recommend appropriate actions to the vehicle operator which may include instructions about how to get the vehicle off a freeway and or maintenance actions to take (step **1512**).

[0192] In another embodiment the first-level system controller monitors vehicle system status and communicates this to vehicle operator and the second-level control center controller. This may include vehicle fuel status. The first-level controller working with the control center controller could recommend refueling at a specific location or recommend alternative locations prior to commencing another EV charging session. Alternatively it can recommend taking actions to correct a system overheating indication.

[0193] FIG. **15** is a process flowchart showing an example of a process performed by a first-level controller on a vehicle according to an embodiment of the invention to optimize and coordinate safety and maintenance instructions. Optional paths are indicated by dashed lines.

[0194] In another embodiment the rescue vehicle may receive alerts or unfavorable rescue vehicle operational data from a control or operational center (step **1514**). For example, this may include unfavorable trend data from a fleet of rescue vehicles or data that the control center has analyzed and believes action is warranted. The rescue vehicle may be put on alert and asked to monitor certain vehicle systems or types of activities and may be instructed concerning certain remedial actions to take. The rescue vehicle may be pulled from operations and either safed at its current location or advised to relocate to a new location which may have repair or replacement capability. Optimum routing information may be provided to the rescue vehicle operator as part of this communication.

[0195] In one embodiment the second-level controller analyzes vehicle system trends, safety or critical operational alerts, and analyzes maintenance records may recommend maintenance proactively (in preference to reacting to system failures after the fact) to minimize unplanned downtime for the rescue vehicle or its EV charging system. In the case of safety critical alerts or emergent action required, the second level controller may alert and/or command the rescue vehicle to take certain actions to keep the rescue vehicle and or its operations safe. It may follow these actions with a closed loop system to ensure the vehicle is safe and that no further safety or mission-critical actions or support is required. If support is deemed to be required, the rescue vehicle may initiate a support request or the second level controller may recommend support. In either case, the second-level controller may review available assets and send appropriate requests for support and provide a closed loop follow up to ensure required support has been provided and the situation has been remedied.

[0196] FIG. **16** is a process flowchart showing an example of this process performed by a second-level controller or control center according to an embodiment of the invention to optimize and coordinate safety and maintenance instructions. The second-level controller monitors the vehicle, vehicle's location, and charging system status for individual rescue vehicles (step **1600**), and when a potential defect or problem is detected in the rescue vehicle (step **1602**), a report is sent to the rescue vehicle operator (step **1604**) with that information, and the operator is given directions to repair, refuel, go to a service location, etc. (step **1606**).

[0197] The rescue vehicle controller in some embodiments is designed to safely operate without communication with the control center controller in the event of a lapse of communication connectivity or control center unavailability for any other reason. The first-level system performance may degrade in this case as insight into customer rescue requests becomes stale. Operations will continue to be conducted based on the rules based software and firmware on the onboard system controller which includes a comprehensive operational set of rules. This ensures safe operation with potential for appropriate local overrides by the rescue vehicle operator. In a period of interrupted communications with a control center system, data may be stored on board for later communication to the control center when communication links are reestablished. Relevant information from the control center from other pertinent sources may be updated manually, such as, for example, location and vehicle status data for the next customer that may have been received through an alternate communication path.

[0198] Communication paths include onboard cellular transceiver or transmitter systems, radio-based systems, personal cell phone systems, land line telephone communication systems, and the like. Additionally, voice and/or data communication may be relayed to a rescue vehicle through another rescue vehicle or other associated vehicles to and from a control center, operational center, or operating entity.

[0199] FIG. **17** is a process flowchart showing an example of a process performed by a first-level controller or vehicle controller according to an embodiment of the present invention that is used when there is a communication disruption between a first-level controller and its source of instructions. The first-level controller monitors a vehicle communication system link to a second-level controller (step **1700**) and if a communication disruption is detected (step **1702**), alternate communication links are polled and a new connection through other channels is attempted (step **1704**). If a communication link is reestablished, status and alert information is exchanged between the levels of controllers for the time that the communication disruption took place (step **1706**) and normal operations are resumed (step **1708**). If a link is not reestablished in step **1704**, the first-level controller stores available vehicle data and operates under a vehicle-stored protocol (step **1710**) and continues attempting to reconnect the communication link (step **1712**). When the communication link resumes (step **1714**), the stored data is sent to the second-level controller, and any alert information from the second-level controller that was not transmitted to the vehicle in that time is sent (step **1716**).

[0200] In another embodiment the vehicle controller provides recommendations as to how much charge is required to get the EV off of a roadway and to one or more EV charging stations (e.g., in kilowatt-hours). In this manner the amount of charge provided by a rescue vehicle is tailored to the need of the particular EV being assisted. Here the controller identifies nearby charging station location options and recommends one or more of the options to the rescue vehicle operator, along with instructions regarding how much charge to dispense to the EV battery, and then provides driving instructions to the EV operator that direct him or her to the selected location. In some embodiments the controller may also communicate information to the selected charging station regarding the EV operator's arrival time and make a reservation for a charging session, if possible. A discounted rate could also be applied for using the roadside assistance service in finding a vehicle charging customer.

[0201] FIG. **18** is a process flowchart showing an example of a process performed by a first- and second-level controller according to an embodiment of the present invention that optimizes charge provided to a disabled EV. At the start, the second-level controller dispatches a selected rescue vehicle to a disabled or depleted EV (step **1800**). This may include sending dispatch information to the service vehicle that comprises the location of the EV and other identifying information about the EV, such as the EV's state of charge, the model of the EV, charging standards supported by the EV, the length of time that the EV has been in need of charge, the EV operator's identification information, a license plate number, customer number, and other EV information that assists the service vehicle operator or first-level controller to provide effective or efficient service.

[0202] The first level controller evaluates EV charging location options given traffic and related factors (step **1802**) and determines the best available charging location (step **1804**). For example, the first level controller may determine the best route that the EV driver would follow to reach a charging location due to traffic, the range of the EV, the change in elevation between the EV and the dedicated charging location, whether the EV would be compatible with the charging equipment at the charging location, the price of recharging the EV at the charging station, the expected average rate of energy consumption of the EV between the location of the EV and the charging station location, the distance between the EV and the charging location, and other factors relevant to selecting the most efficiently accessed and utilized charging point. Additionally, a charging station may be selected based on the proximity of the charging location to an intended destination of the EV or proximity of the charging location to a path that would be used to reach the intended destination. For example, a charging location that is in a direction toward the EV's home garage may be preferred over a charging location that is in the opposite direction, even if the charging location in the opposite direction is closer to the distressed EV. Likewise, if a charging location is close to the route the EV driver would use to reach his intended destination, it may be preferred over charging locations in other directions even if the other locations are closer at the time the EV is charged by the service vehicle.

[0203] In the execution of step **1804**, functions may be performed in parallel by the second-level controller to improve or confirm the decision making of the first-level controller, since the second level controller will typically have more information available, including but not limited to the location of other service vehicles, replacement battery module locations for the service vehicle, other distressed EVs in the range of the service vehicle, and more. Thus, in steps **1806** and **1808** the second-level controller monitors and supports the first level controller. Additionally, the first-level controller determines an amount of charge to provide to the EV, preferably including a safety factor, and the second-level controller may support the service vehicle in this action such as by approving a point-of-sale transaction that takes place between the EV and the service vehicle (steps **1810** and **1812**). The first- or second-level controller may then reserve a charging station for the disabled EV (if the charging station supports reservations compatible with the first-level controller) (step **1814**), and the service vehicle provides directions and/or reservation information to the EV (step **1816**). Such reservation process may include electronically reserving a charging station for the EV or gathering charging station reservation availability information to be given to an occupant of the EV. Charging station reservation availability information is information that allows the EV occupant to make his own reservation or alternatively may define how long a reservation will remain available to the EV. The service vehicle is connected to the EV and provides an optimized amount of charge from its onboard charging system so that the EV can safely reach the charging station (step **1818**). At this time, if a second-level controller communication link is available, the second-level controller validates the payment and the recommendation determined by the first-level controller (step **1820**). Finally, the first-level controller may confirm the arrival of the EV at the charging location and that charge has been restored, such as through an internet- or cellular-network-based LAN or WAN messaging confirmation sent to or from the EV (step **1822**). Alternatively, the service vehicle may accompany the EV to the charging station. The second-level controller validates that the EV has been served and logs status information about the EV and/or service vehicle such as the remaining charge in the charging equipment of the service vehicle, the fuel level of the service vehicle, and other service-related metrics (step **1824**).

[0204] In this embodiment, with a sufficient communications link between the first- and second-level controllers, the second-level controller may replicate the steps performed by the first-level controller in near real-time. When the first-level controller experiences degraded performance, the second-level controller may actively provide recommendations and commands to the service vehicle in lieu of the first-level controller.

[0205] In some embodiments, a first-level rescue vehicle controller interacts with a second-level controller or operational center or control center and receives commands and/or status update information from the second level controller or operational control center. The rescue vehicle receives information regarding (1) future customers requiring rescue or other support, (2) availability of recharging capacity for its onboard battery-driven EV recharger, (3) optimum location and routing for the rescue vehicle to be refueled or repaired, (4) optimum routing to other planned stops, (5) information regarding rescheduling of operations, and (6) off-normal events and alerts including trend data regarding its onboard systems and recommended actions.

[0206] In another embodiment shown in the flowchart of FIG. **19**, pairing information for a rescue vehicle and recharging mission is evaluated at an operations or control center. The controller determines that a rescue vehicle has the requisite equipment and capacity to charge the stranded vehicle for a potential mission and selects that vehicle for performing that mission (step **1900**). Once selected, the rescue vehicle receives a rescue request including location and job information from a control or operational center located at a fixed (or potentially mobile) location (step **1902**). Optimum routing from his current location to the rescue location is provided. In some variations of this embodiment, the rescue vehicle operator may have to first decide to accept or override the request (step **1904**). In these embodiments, the second-level controller reassigns the task to another rescue vehicle if the vehicle operator rejects or overrides the instruction (step **1906**).

[0207] The second-level controller then monitors the rescue vehicle location its status, including point-of-sale information when the rescue vehicle performs some charging (step **1908**), as the rescue vehicle controller communicates its location and vehicle status information to the control center controller while the rescue vehicle is en route and performing rescue operations (step **1910**). The command center controller updates its database, and rerouting information and status information may be provided to the rescue vehicle while in transit or at the service location (step **1912**).

[0208] In some other embodiments, the rescue vehicle is sent instructions to deviate from currently planned or known operations and to proceed to a new operational assignment. For example, this may include performing rescue related operations or other operations as assigned from the control or operational center, such as, for example, delivering battery modules to another rescue vehicle or transferring battery modules between a charging location and another service vehicle.

[0209] FIG. **20** shows some other embodiments of routing rescue vehicles and the interaction between first-level controllers and second-level controllers. In steps **2000** to **2010**, a rescue vehicle receives a recommendation from an operational control center that its onboard energy storage battery capacity is depleted or needs to be changed out. The rescue vehicle may receive a command to rendezvous with a battery resupply vehicle and change out some number of depleted or partially depleted energy storage battery modules. Routing information may be provided to optimize time spent and expense. In some embodiments, these steps instead define a rendezvous or exchange instruction for the service vehicle to exchange one or more battery modules with a battery module storage location or another service vehicle instead of exchanging with a resupply vehicle.

[0210] In another embodiment, a rescue vehicle may receive a recommendation to proceed to an energy storage battery module resupply station specially designed to accommodate battery modules from rescue vehicle charging systems, as shown in steps **2012** through **2016**. Optimum routing information may be provided from the rescue vehicle's current location to the resupply station. The onboard charging system batteries are swapped out for fully-charged battery modules, and the rescue vehicle is provided information requisite to proceed on other rescue missions.

[0211] In another embodiment, the rescue vehicle controller monitors a rescue vehicle's location and the availability of energy storage on the vehicle and reports this information to the vehicle operator and to the second-level/control center controller. The rescue vehicle controller receives recommendations from the control center controller relative to changing out batteries or charging up existing batteries. Based on actual status, customer requests and other factors, the control center controller may reserve a battery for the rescue vehicle's charging system at an energy storage swap out station and recommend the rescue vehicle to proceed to that location after an EV rescue operation is completed. In this case, the rescue vehicle operator will review the recommendation and may accept or override it. Alternatively, the control center controller may recommend to the first-level controller that one or more battery modules be delivered by a vehicle battery delivery truck based on location, battery availability, anticipated EV battery charging service needs, and other factors. The vehicle operator may be allowed to either accept or override this recommendation. In some of these embodiments, the primary objective of this process is to maximize vehicle rescue timeliness while also maximizing equipment utilization and minimizing operational costs over time.

[0212] In another embodiment the rescue vehicle receives instructions regarding an optimum time to refuel and is given routing instructions to a nearby refueling station, as shown in steps **2018** through **2024**. The consumables referenced in these steps may include battery modules, charging devices, vehicle parts, and other components used in vehicle service operations. Instructions to the vehicles may be modified by including consideration for current traffic in the area near the service vehicle, queuing at a refueling station, and other relevant routing considerations.

[0213] In another embodiment the control center controller may recommend that a rescue vehicle take time out to refuel at a specific location in preparation for other planned or probabilistic activity. Optimized routing information may be developed and pushed to the rescue vehicle along with other related instructions. Similarly, the second-level controller may recommend other onboard consumables or other operational equipment to be repaired or replaced when such action is most cost-effective.

[0214] In the process depicted in FIG. **21**, a second-level controller optimizes to actions of a fleet of EV-charging rescue vehicles. Here, the second-level/control center controller receives status-related information and requests from a fleet of rescue vehicles and other sources (step **2100**) and optimizes rescue vehicles' performance across a service area, determining maintenance needs and schedules of rescue vehicles in the fleet, minimizing response times between receiving EV charging requests and performing EV charging, and otherwise optimizing fleet asset utilization (step **2102**). In this embodiment the second-level control center controller is designed to optimize rescue vehicle fleet or system performance at a higher level than an individual rescue vehicle controller. The control center controller receives customer rescue requests and optimizes rescue vehicles' response to the requests based on availability of the rescue vehicles, their respective locations, and the condition of other assets across a designated service area in combination with the suitability and readiness of their systems.

[0215] In this embodiment the second-level controller may recommend optimization actions as to when and where to utilize specific rescue vehicles. It may match availability of GPS-based asset location communicated to it from the onboard rescue vehicle systems with status information for onboard systems, customer requests, routing information, traffic information, status of on board fuel, refueling options, energy storage recharge battery status, and location of battery replacement options and other relevant information. It may then assign specific rescue vehicles to specific job assignments. It may use a closed loop system to verify that requisite actions are taken or recommend subsequent actions to address residual operational needs, if such needs exist. Optimization criteria may include response time, safety optimization, customer satisfaction factor optimization, vehicle utilization optimization, cost optimization, probabilistic impact to planned or unplanned but probable operations, and other factors.

[0216] In some embodiments, the second-level controller distributes tasks to rescue vehicles and ensures that all necessary tasks are accepted by reassigning tasks that are not accepted by rescue vehicle operators (steps **2104** and **2106**). After tasks are accepted and completed, the success of the tasks is validated and new assets are given assignments as required by the second-level controller (step **2108**).

[0217] Third-level controllers are another hierarchical tier of controls used to optimize staging and prepositioning of assets in a large area, primarily managing and advising multiple local regional control centers and their rescue vehicle fleets. In the embodiment shown in FIG. **22**, the third level of controllers is implemented at a regional level. The controller implementing this process may be non-real-time server-based controller designed to optimize top level and system wide needs. It may be co-located with a second level controller in a control center or may be associated with a separate server and/or location. The third-level controller aggregates operational needs for replacement parts and systems of the tiers of controllers and fleets below it (step **2200**). For example, it may aggregate energy storage battery failure information across the country or around the world and recommend new parameters for battery reordering or reusing based on widespread failure rates. The controller may aggregate failure data and identify equipment and systems having unusually high failure rates or undesirable reliability characteristics for further review. This may also include other components such as inverters or chargers that are associated with rescue vehicles. The third-level controllers may also coordinate changing out system-level assets across a region. This may include eliminating specific rescue vehicles or a class of rescue vehicles having a poor history of safety issues and reassigning other assets to replace them from areas of lower demand. The third-level controller's data compilations and analysis serve to provide a basis for bulk ordering and implementation of critical components and systems (steps **2202** and **2204**).

[0218] Another task suited for these controllers is the aggregation of critical requirements for operational support to meet certain future needs such as a surging of assets to support a large near-term temporary localized need for EV charging services. For example, a World Series baseball game could require mobilizing special EV charging support vehicles for a few days in a localized area around a stadium or in a city, where the support vehicles are drawn from a regional or global inventory of assets. The third-level controller would recognize assets managed by different second-level controllers that could be used to meet the temporary charging needs that arise in this situation and identify how to resume normal operations afterward.

[0219] FIG. **23** provides an overview of the hierarchy of controllers at the first, second, and third levels as described previously. This figure sets forth that the first-level controller or controllers operate in real-time control onboard a rescue/service vehicle to provide real-time control of aspects of the service vehicle and its charging equipment, the second-level controller or controllers operate in real-time (or near real-time) from a central control or operational center to optimize assets across an area, region, or globally, distribute vehicle assignments, and schedule vehicle service/maintenance and EV assistance services, and the third-level controller or controllers are located in central control or operational centers and provide business management optimization across the entire system and coordinate special needs of regions or areas that are managed on a day-to-day basis by first- and second-level controllers.

[0220] Miscellaneous Definitions and Scope Information

[0221] Battery modules are described herein as a preferable means for storing and transporting electrical energy, but other equivalent means for storing energy may be used, such as, for example, electrochemical batteries, compressed gas storage, pumped hydro storage, flywheel energy storage, capacitive energy storage, superconductive magnetic energy storage, fuel cell energy storage, combinations thereof, and other similar devices for energy storage known in the art. If the modules are battery-based, the battery types may include rechargeable or non-rechargeable chemistries and compositions, such as, for example, lead-acid, alkaline, secondary lead acid, lithium-ion, sodium (zebra), nickel-metal hydride, nickel cadmium, combinations thereof, and other energy storage chemistries known in the art. Energy storage devices such as these may be comprised of small or large numbers of cells, capacities, voltages, amperages, and other battery properties. They may be configured in unitary or modular designs and may follow standardized guidelines or customized specifications.

[0222] Some methods and systems of the embodiments of the invention disclosed herein may also be embodied as a computer-readable medium containing instructions to complete those methods or implement those systems. The term "computer-readable medium" as used herein includes not only a single physical medium or single type of medium, but also a combination of one or more tangible physical media and/or types of media. Examples of a computer-readable medium include, but are not limited to, one or more memory chips, hard drives, optical discs (such as CDs or DVDs), magnetic discs, and magnetic tape drives. A computer-readable medium may be considered part of a larger device or it may be itself removable from the device. For example, a commonly-used computer-readable medium is a universal serial bus (USB) memory stick that interfaces with a USB port of a device. A computer-readable medium may store computer-readable instructions (e.g. software) and/or computer-readable data (i.e., information that may or may not be executable). In the present example, a computer-readable medium (such as memory) may be included to store instructions for the controller to operate the heating of the ESD and historical or forecasted temperature data for the ESD or its surroundings.

[0223] The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0224] In addition, it should be understood that the figures described above, which highlight the functionality and advantages of the present invention, are presented for example purposes only and not for limitation. The exemplary architecture of the present invention is sufficiently flexible and configurable, such that it may be utilized in ways other than that shown in the figures. It will be apparent to one of skill in the art how alternative functional, logical or physical partitioning, and configurations can be implemented to implement the desired features of the present invention. Also, a multitude of different constituent module or step names other than those depicted herein can be applied to the various partitions. Additionally, with regard to flow diagrams, operational descriptions and method claims, the order in which the steps are presented herein shall not mandate that various embodiments be implemented to perform the recited functionality in the same order unless the context dictates otherwise.

[0225] Although the invention is described above in multiple various exemplary embodiments and implementations, it should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described, but instead can be applied, alone or in various combinations, to one or more of the other embodiments of the invention, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments.

[0226] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing: the term "including" should be read as meaning "including, without limitation" or the like; the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof; the terms "a" or "an" should be read as meaning "at least one," "one or more" or the like; and adjectives such as "typical," "conventional," "traditional," "normal," "standard," "known" and terms of similar meaning should not be construed as limiting the time described to a given time period or to an item available as of a given time, but instead should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Likewise, where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.

[0227] A group of items linked with the conjunction "and" should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as "and/or" unless expressly stated or context dictates otherwise. Similarly, a group of items linked with the conjunction "or" should not be read as requiring mutual exclusivity among that group, but rather should also be read as "and/or" unless expressly stated or context dictates otherwise. Furthermore, although items, elements or component of the invention may be described or claimed in the singular, the plural is contemplated to be within the scope thereof unless limitation to the singular is explicitly stated. The presence of broadening words and phrases such as "one or more," "at least," "but not limited to" or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent.

[0228] Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their accompanying description should not be construed as mandating a particular architecture or configuration.

[0229] Further, the purpose of the Abstract is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers, and practitioners in the art who are not familiar with patent or legal terms or phraseology to determine quickly from a cursory inspection the nature and essence of the technical disclosure of the application. The Abstract is not intended to be limiting as to the scope of the present invention in any way.

What is claimed is:

1. A network for providing energy to discharged batteries of electric vehicles (EVs), the network comprising:

a service vehicle transporting electric vehicle (EV) charging equipment, transporting a first-level controller, and capable of transporting battery modules removably mounted to the service vehicle, wherein the battery modules are configured as a source of electrical energy, the electrical energy transferable to an EV using the EV charging equipment; and

a storage location storing battery modules compatible with the EV charging equipment of the service vehicle, wherein the battery modules are manually exchangeable between the storage location and the service vehicle, such that a removably mounted battery module on the service vehicle is replaced by a battery module stored by a storage location.

2. The network of claim **1**, further comprising:

a resupply vehicle configured to deliver battery modules between a storage location and a service vehicle.

3. The network of claim **2**, wherein the resupply vehicle comprises an alternator or generator, the alternator or generator configured to charge a battery module while the battery module is delivered by the resupply vehicle.

4. The network of claim **1**, where the service vehicle may remotely reserve one or more battery modules at the storage location.

5. The network of claim **4**, further comprising:

a scheduling controller at the storage location programmed to reserve battery modules for rescue vehicles based on an emergency state of service required.

6. The network of claim **1**, further comprising:

a charging apparatus at the storage location, the charging apparatus configured to charge the battery modules at the storage location.

7. The network of claim **6**, wherein a charging controller at the storage location charges the battery modules sequentially.

8. The network of claim **6**, wherein a charging controller at the storage location charges the battery modules simultaneously.

9. The network of claim **6**, wherein a charging controller is configured to prevent charging battery modules if charging would exceed a demand threshold for the storage location.

10. The network of claim **6**, wherein the charging apparatus is an electric vehicle supply equipment (EVSE) having an EV charging connector, and the battery modules comprise a charging port configured to receive the EV charging connector.

11. The network of claim **1**, wherein the storage location is a repositionable mobile unit.

12. The network of claim **11**, wherein the mobile unit is repositioned to a location having a temporary need for battery modules.

13. The network of claim **11**, wherein the mobile unit is connectable to a utility distribution grid in such a manner that the battery modules of the mobile unit are charged by the utility distribution grid.

18. The network of claim **1**, the service vehicle further comprising:

an onboard controller device configured to monitor and report status conditions of the EV charging equipment and battery modules of the service vehicle and configured to communicate operational assignments for the service vehicle.

19. The network of claim **1**, the service vehicle further comprising:

an onboard controller device configured to monitor and report status conditions of the EV charging equipment and battery modules of the service vehicle and configured to indicate a status condition of battery modules at the storage location or on another vehicle.

20. The network of claim **1**, the service vehicle further comprising:

an onboard controller device configured to monitor and report status conditions of the EV charging equipment and battery modules of the service vehicle and configured to indicate a status of the battery modules and the charging equipment to a network operations center.

21. The network of claim **1**, the service vehicle further comprising:

an onboard controller device configured to monitor and report status conditions of the EV charging equipment and battery modules of the service vehicle and configured to control operation of the EV charging equipment and the battery modules.

22. The network of claim **1**, wherein the service vehicle is assigned to a service location, and the service vehicle transports a number of battery modules roughly proportional to the distance between the service location and the storage location.

23. A system comprising:

a first-level controller onboard a service vehicle, the first-level controller providing real-time control and alerts for the service vehicle and charging equipment transported by the service vehicle within an assigned area;

a second-level controller at a control center, the second-level controller configured to:

communicate with the first-level controller to aggregate real-time control and alert data, and

provide optimized service vehicle assignments, schedules, or alerts for one or more service vehicles in a region, the region comprising a plurality of areas assigned to the service vehicles; and

a third-level controller at a control center, the third-level controller configured to communicate with the second-level controller to provide charging service management optimization across the region.

24. The system of claim **23**, wherein the second-level controller provides service vehicle assignments, schedules, or alerts in real-time or near real-time.

25. The system of claim **23**, wherein the service management optimization across the region includes recommending preventative maintenance actions, reassignment of assets, ordering of equipment, scheduling of deliveries, and providing information to the first-level controller and the second-level controller.

26. The system of claim **23**, wherein the third-level controller temporarily stages a service vehicle in a region having temporary need for service vehicles.

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