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(54) **HYBRID LIGHT TOWER**

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(21) Appl. No.: **19/054,338**

(22) Filed: **Feb. 14, 2025**

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H02J 7/16	(2006.01)

(52) **U.S. Cl.**

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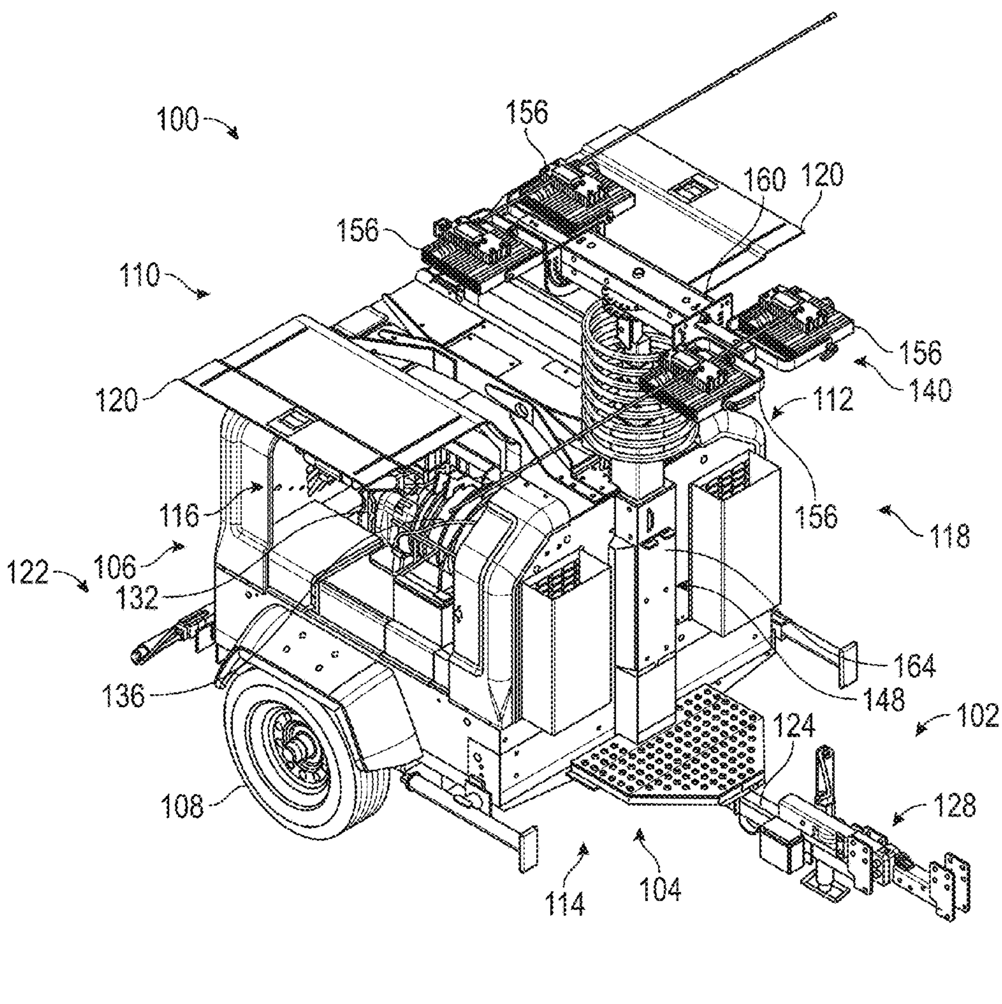
(57) **ABSTRACT**

A hybrid light tower includes an engine, a mast, a generator configured to be driven by the engine, a battery coupled to the generator, a light assembly having a light, and a controller in communication with the battery, the engine, and the light assembly. The controller is configured to operate in a hybrid mode where the controller is configured to monitor a cell voltage of the battery, determine if the cell voltage of the battery is below a charging threshold, upon determining that the cell voltage of the battery is below the charging threshold, start the engine and charge the battery in a constant current mode, while charging in the constant current mode, determine if the cell voltage is above a constant voltage threshold, and upon determining that the cell voltage is above a constant voltage threshold, charge the battery in a constant voltage mode.



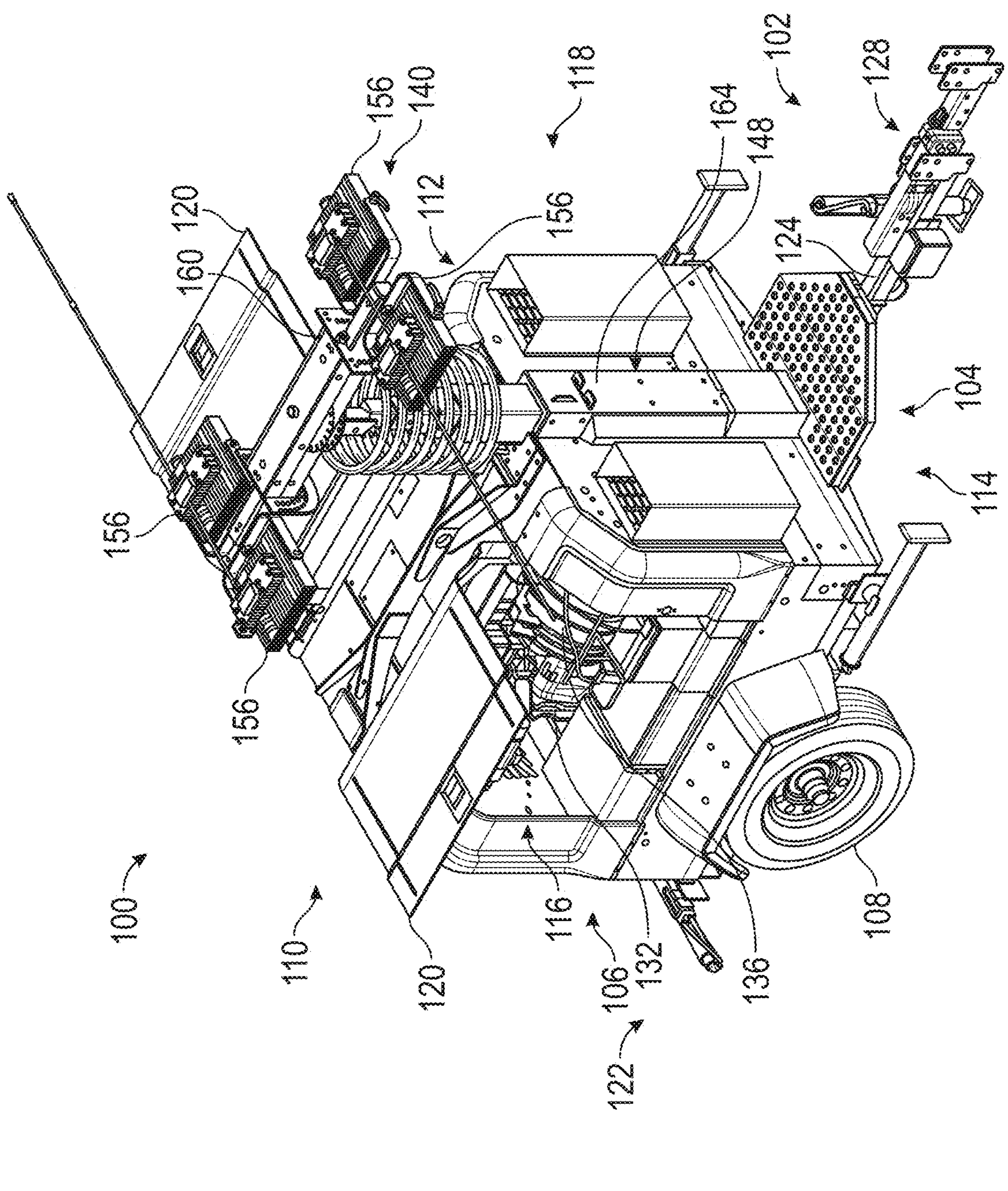

100
110
120
116
106
132
136
108
122
156
156
160
120
156
140
112
156
118
164
148
102
128
124
104
114

FIG. 1

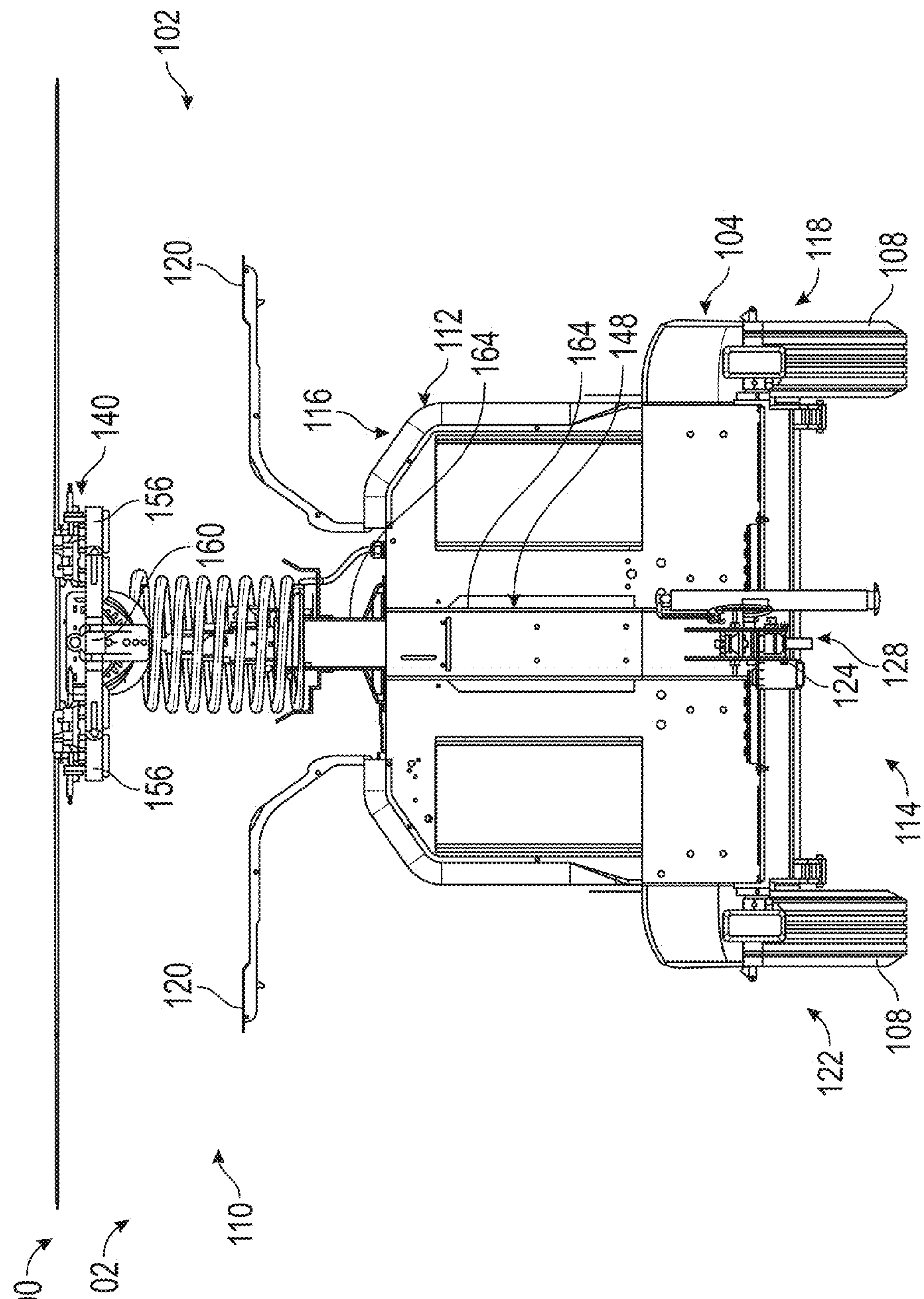

102
120
104
118
108
112
164
116
164
148
140
156
160
128
124
156
114
120
108
122
110
100
102

FIG. 2

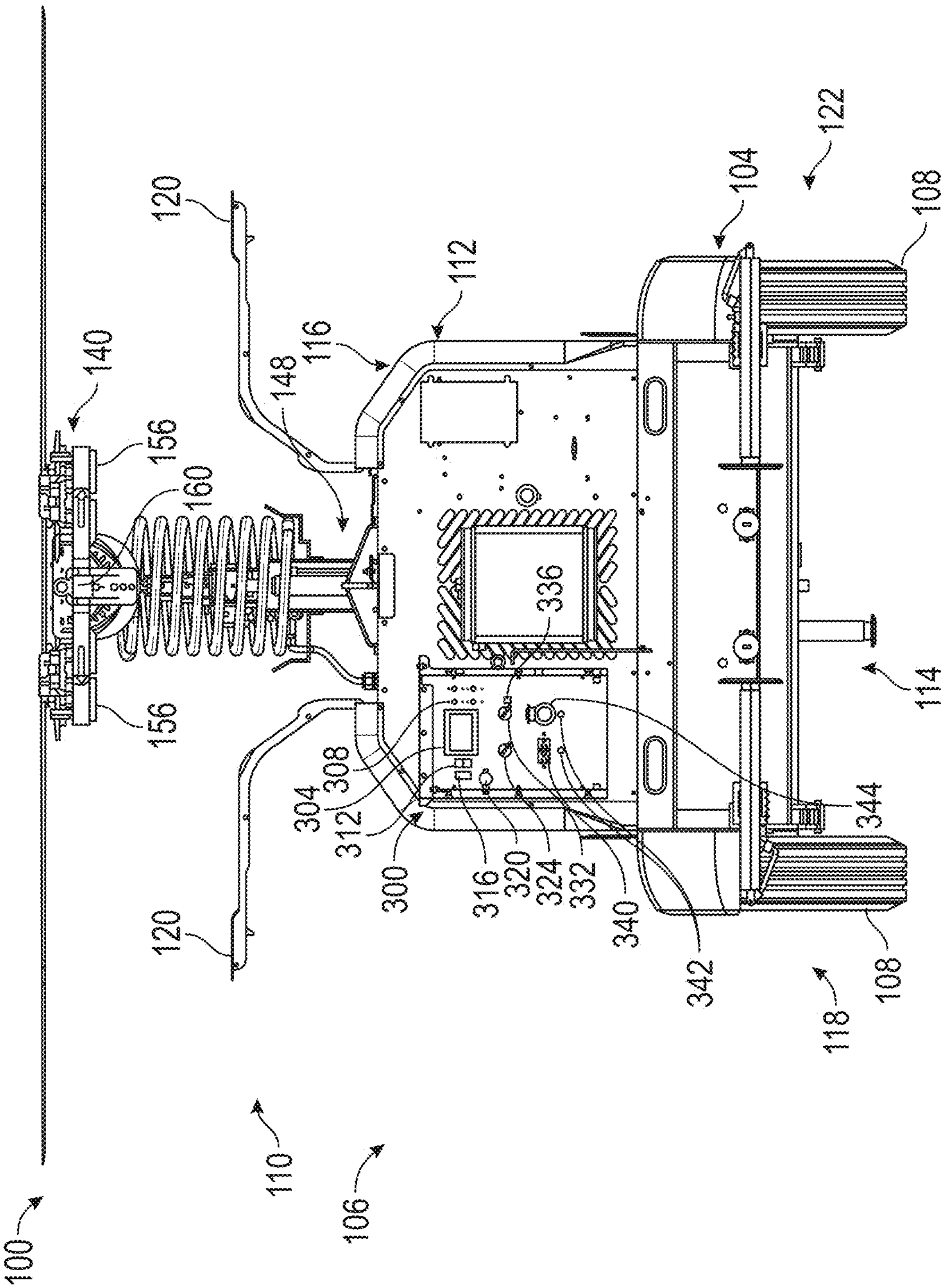

100
106
110
120
120
140
156
156
160
148
116
112
104
122
108
108
118
114
300
304
308
312
316
320
324
332
336
340
342
344

FIG. 3

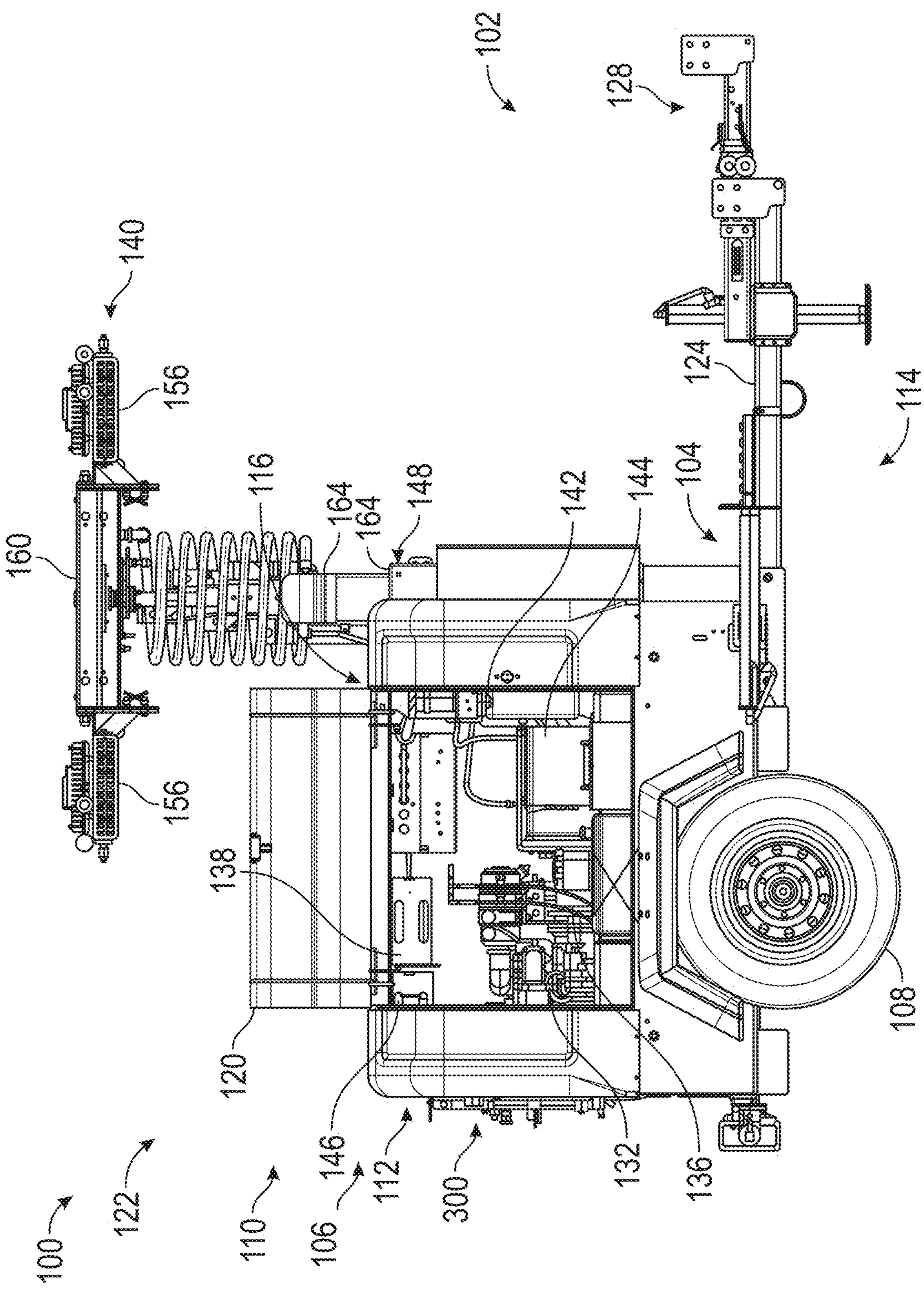

100
102
104
106
108
110
112
114
116
120
122
124
128
132
136
138
140
142
144
146
148
156
156
160
164
164
300

FIG. 4

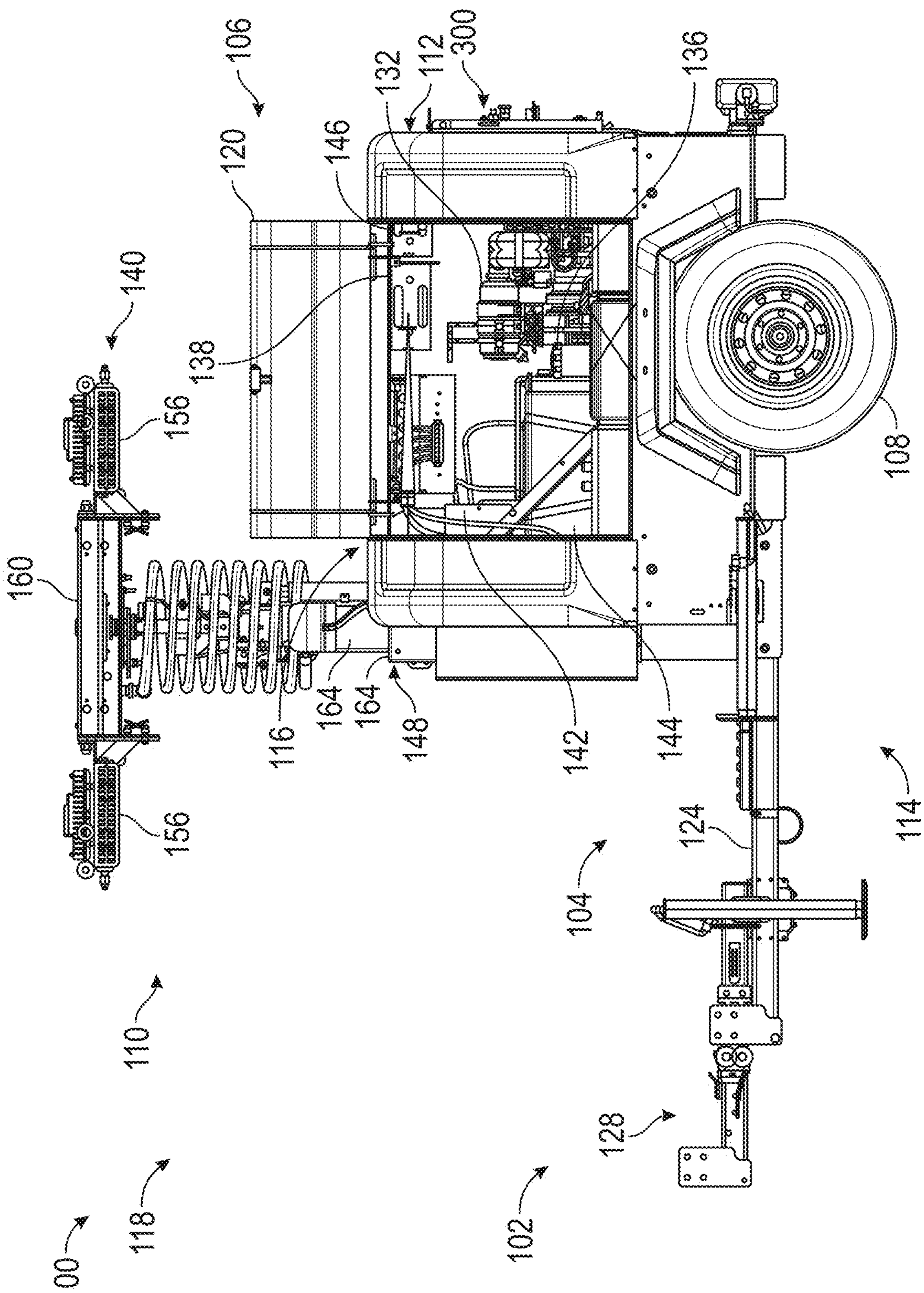

106
120
146
132
112
300
136
140
138
156
160
116
164
164
148
142
144
108
156
124
114
104
110
128
118
102
100

FIG. 5

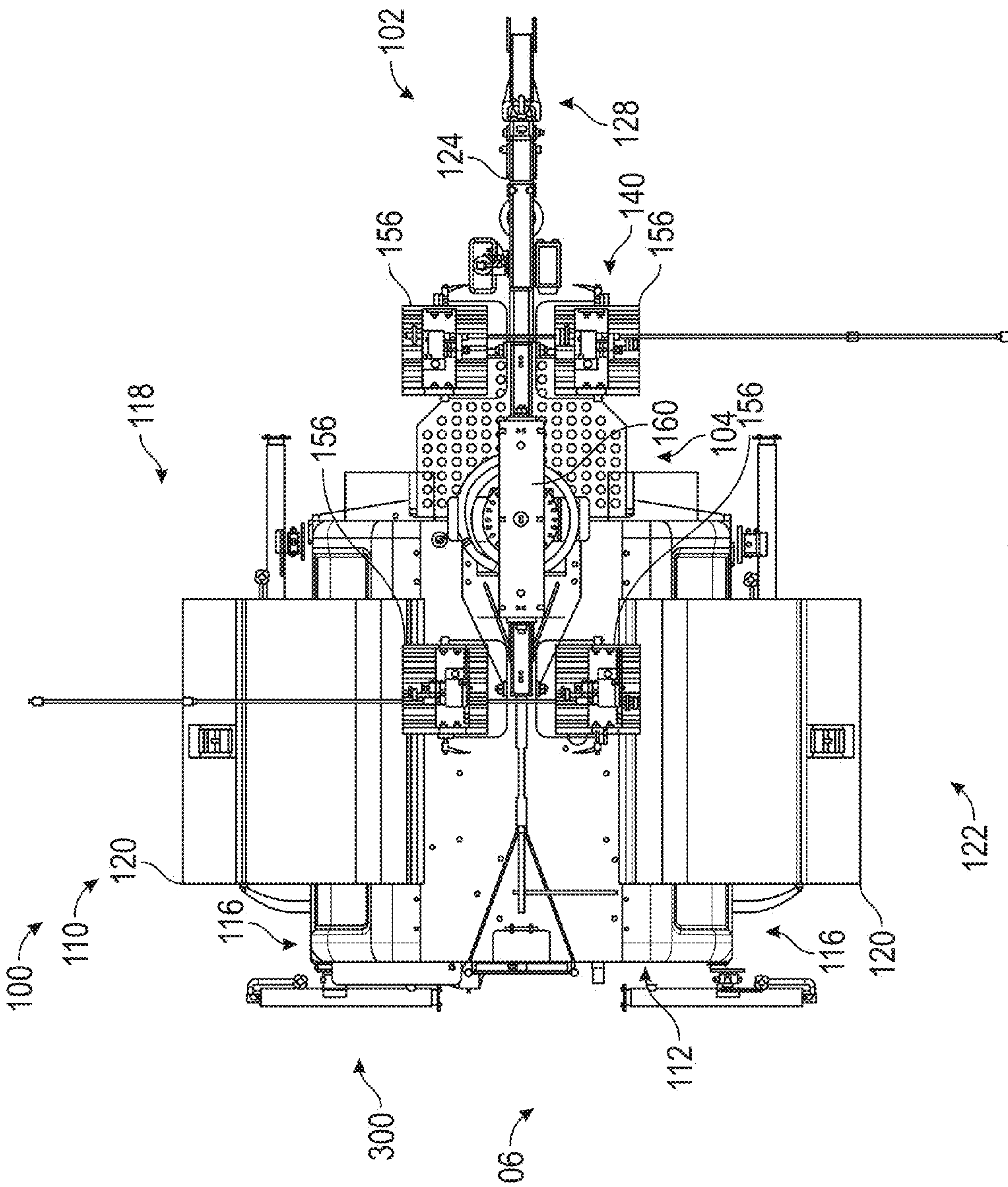

102
128
124
140
156
156
118
156
160
104
156
100
110
120
116
116
120
122
112
300
106

FIG. 6

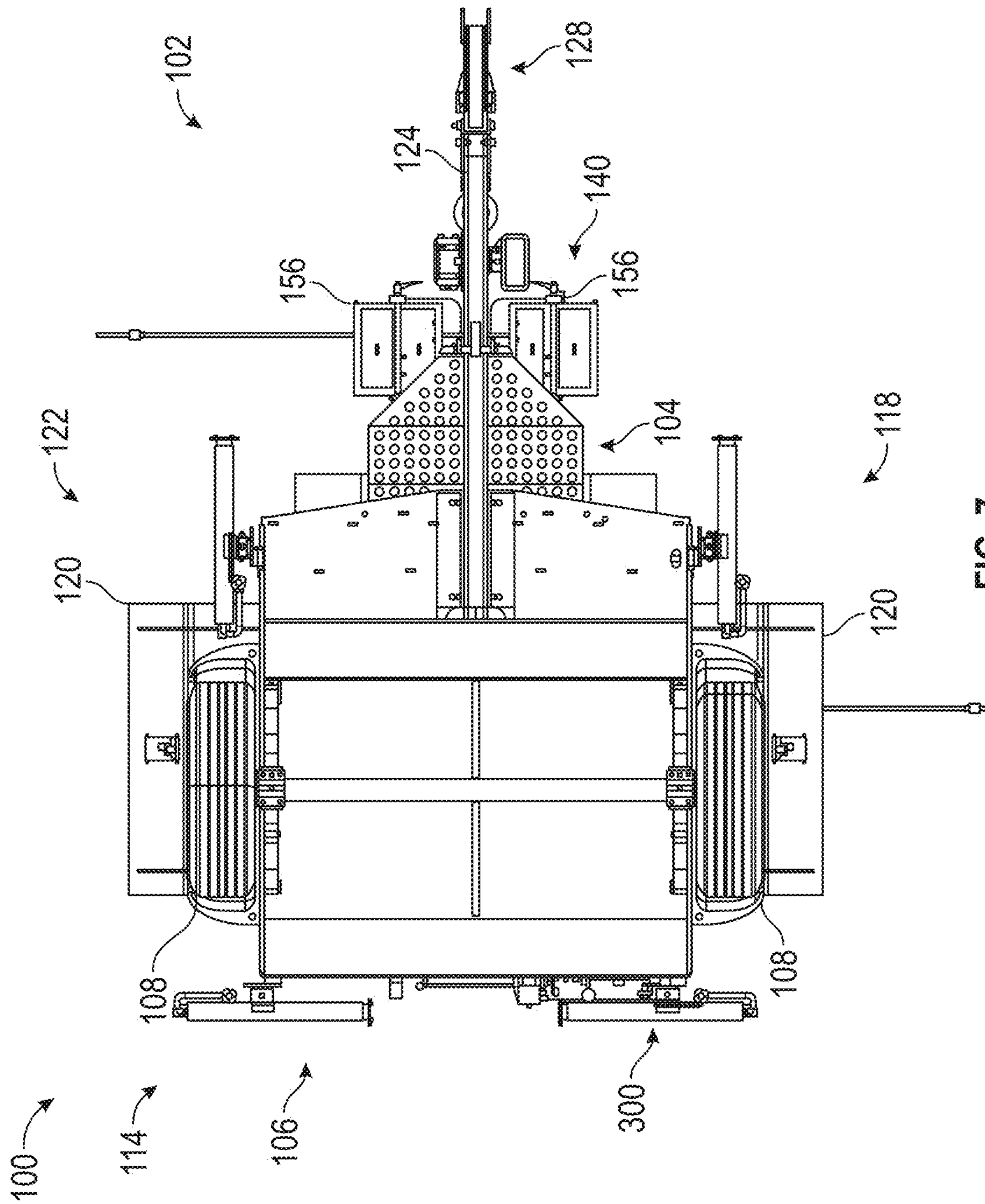

102
128
124
140
156
156
122
104
118
120
120
108
108
100
114
106
300

FIG. 7

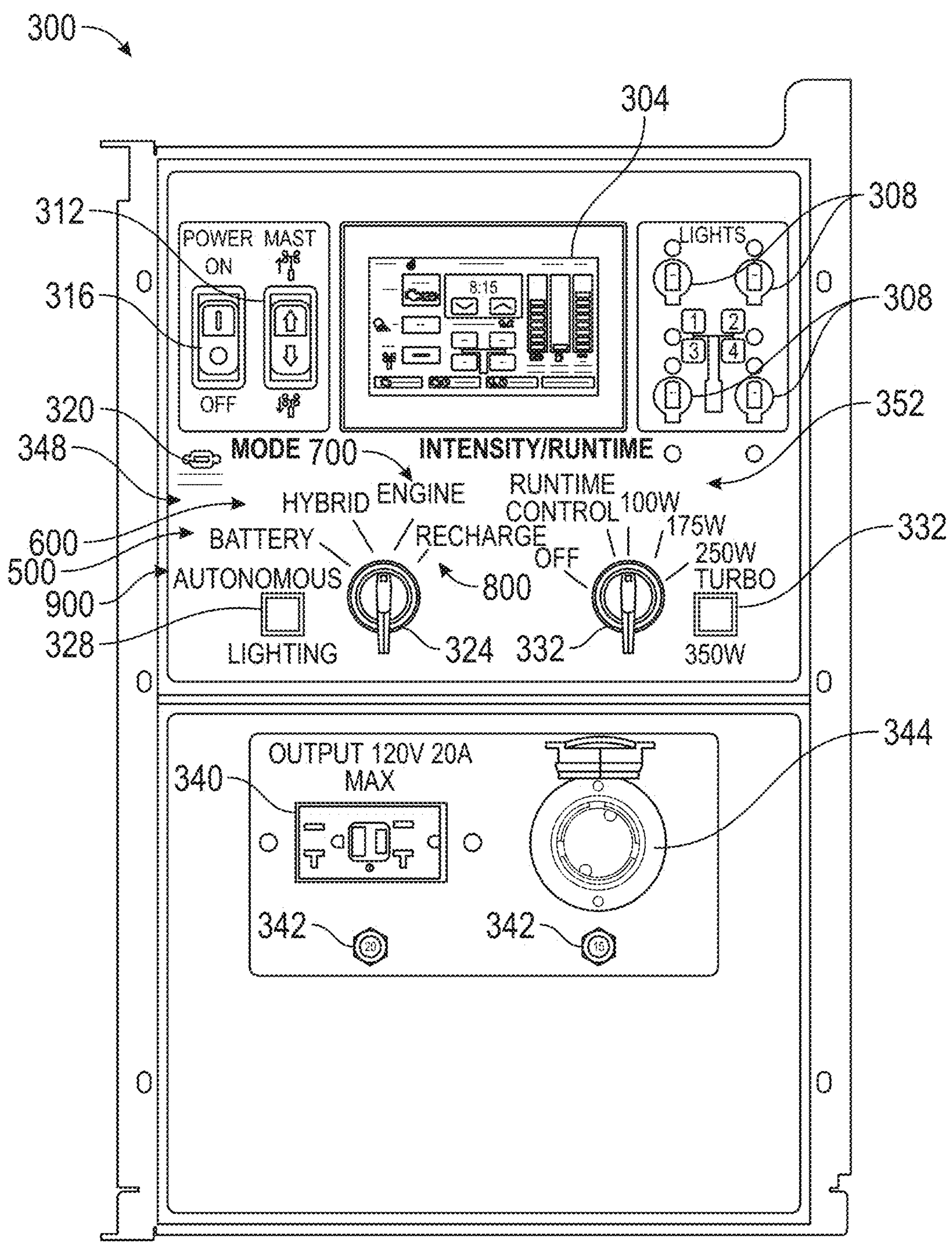

300
304
308
308
312
316
POWER
ON
OFF
MAST
LIGHTS
8:15
1
2
3
4
320
348
352
MODE
700
INTENSITY/RUNTIME
HYBRID
ENGINE
BATTERY
RECHARGE
AUTONOMOUS
LIGHTING
RUNTIME
CONTROL
100W
175W
250W
OFF
TURBO
350W
600
500
900
328
800
324
332
332
OUTPUT 120V 20A
MAX
340
344
342
342

FIG. 8

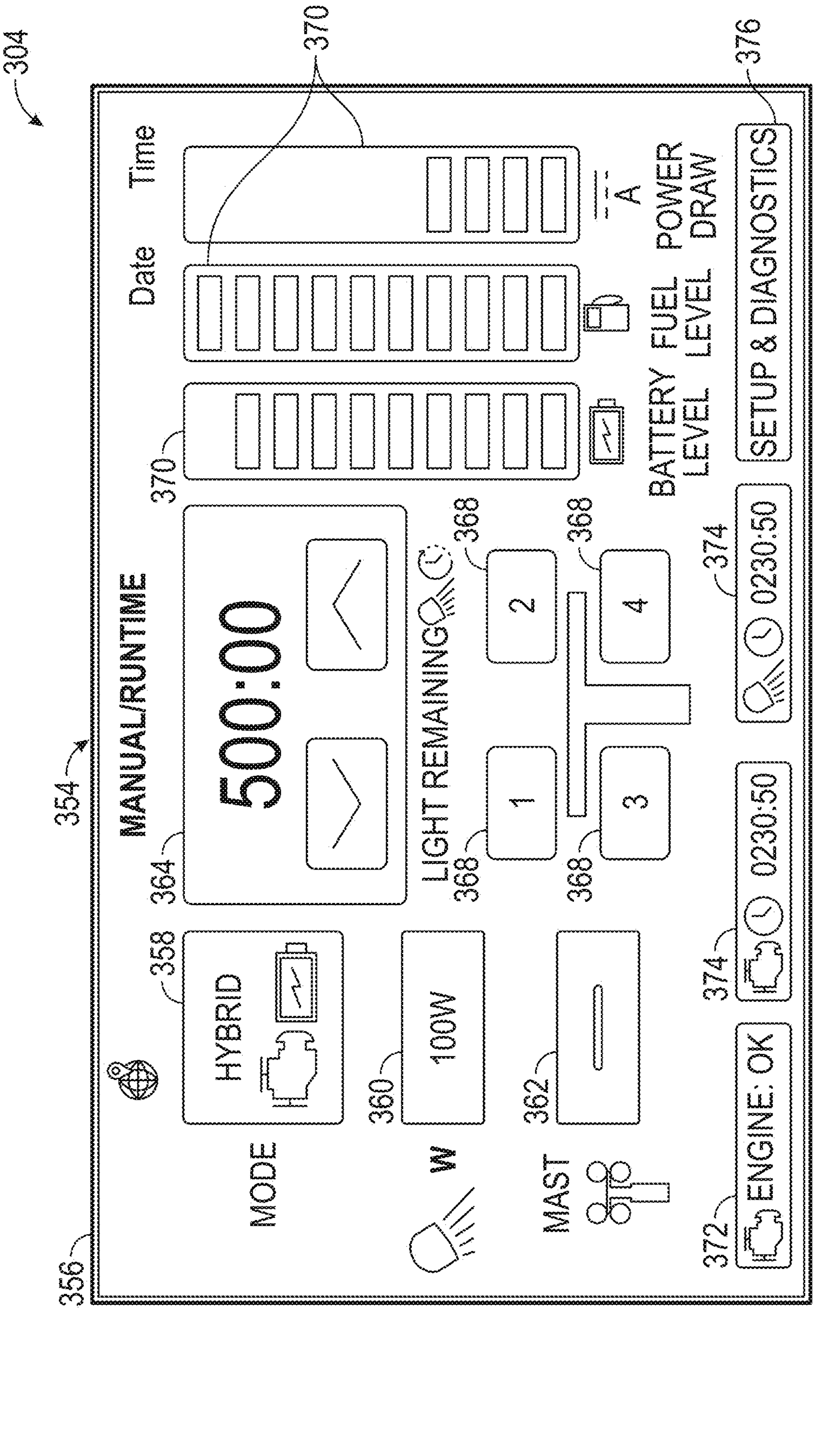

304
354
MANUAL/RUNTIME
356
MODE
358
HYBRID
360
W
100W
362
MAST
364
500:00
LIGHT REMAINING
368
1
2
3
4
370
Date
Time
BATTERY LEVEL
FUEL LEVEL
A
POWER DRAW
372
ENGINE: OK
374
0230:50
0230:50
376
SETUP & DIAGNOSTICS

FIG. 9

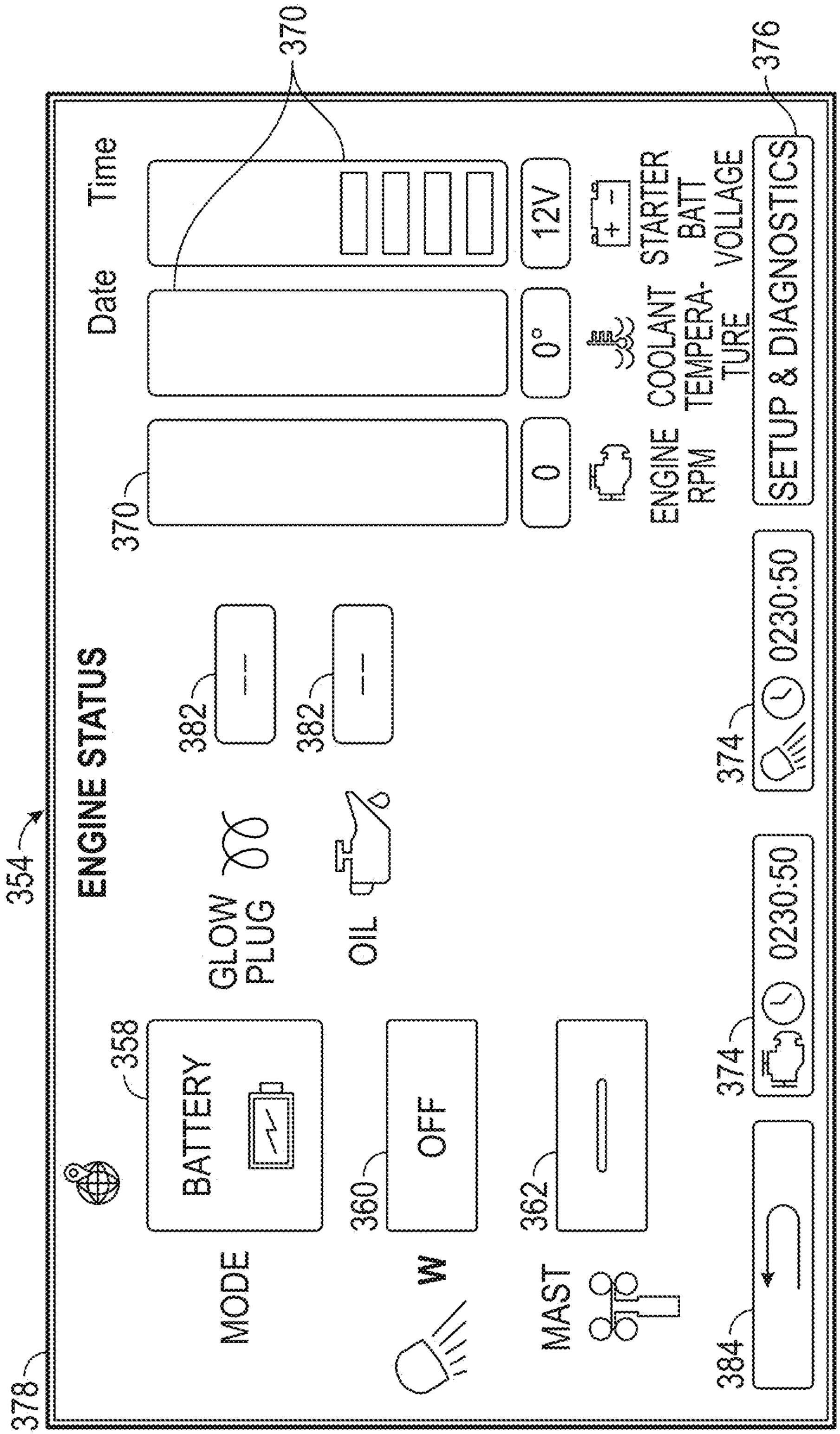

304
354
ENGINE STATUS
MODE
BATTERY
358
W
OFF
360
MAST
362
GLOW
PLUG
OIL
382
—
382
—
Date
Time
370
370
0
0°
12V
ENGINE
RPM
COOLANT
TEMPERA-
TURE
STARTER
BATT
VOLLAGE
SETUP & DIAGNOSTICS
376
374
0230:50
374
0230:50
384
378

FIG. 10

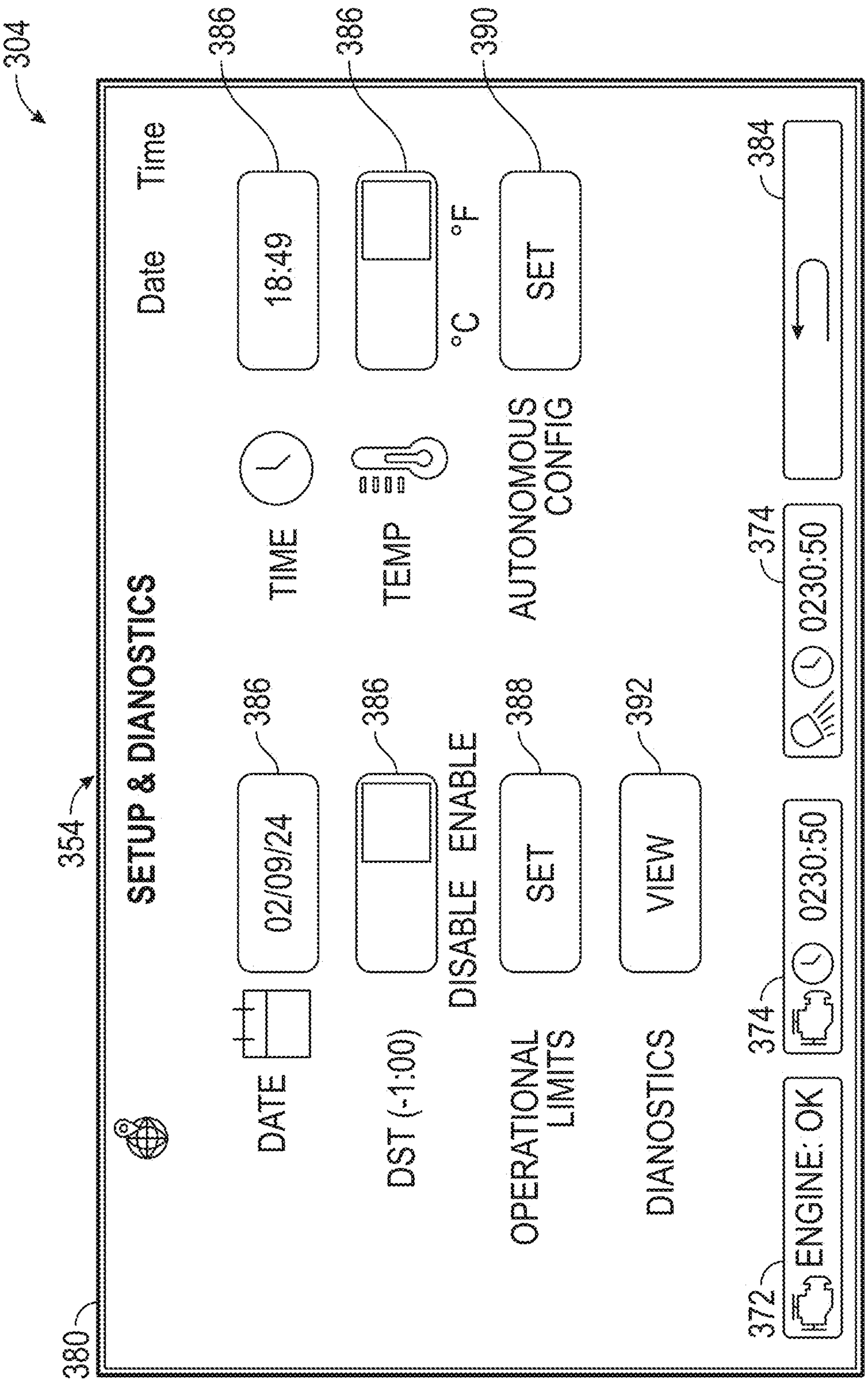

304
354
380
SETUP & DIANOSTICS
Date
Time
DATE
02/09/24
386
TIME
18:49
386
DST (-1:00)
DISABLE ENABLE
386
TEMP
°C
°F
386
OPERATIONAL LIMITS
SET
388
AUTONOMOUS CONFIG
SET
390
DIANOSTICS
VIEW
392
ENGINE: OK
372
0230:50
374
0230:50
374
384

FIG. 11

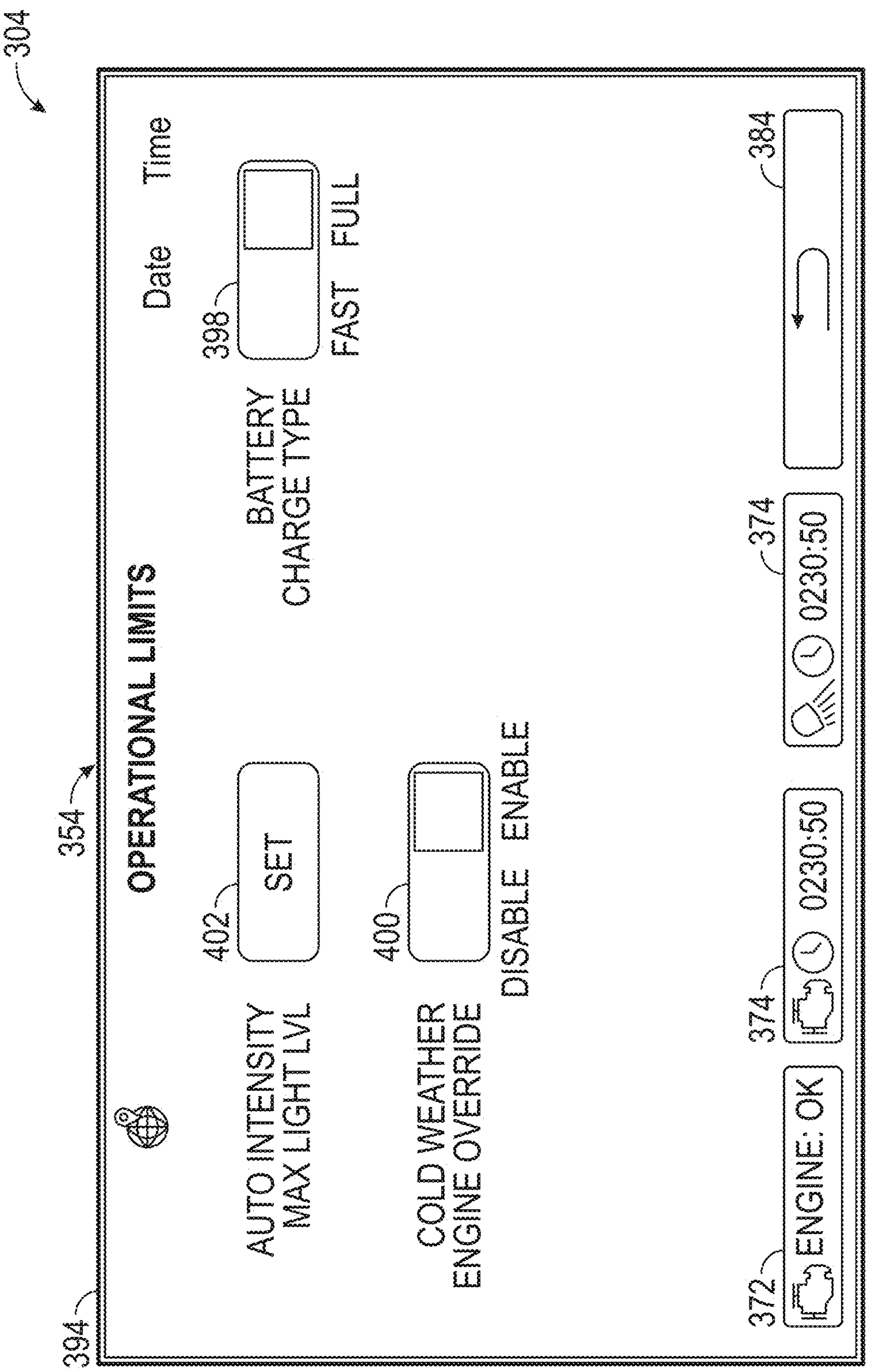

304
354
OPERATIONAL LIMITS
Date
Time
AUTO INTENSITY
MAX LIGHT LVL
402
SET
BATTERY
CHARGE TYPE
398
FAST
FULL
COLD WEATHER
ENGINE OVERRIDE
400
DISABLE
ENABLE
372
ENGINE: OK
374
0230:50
374
0230:50
384
394

FIG. 12

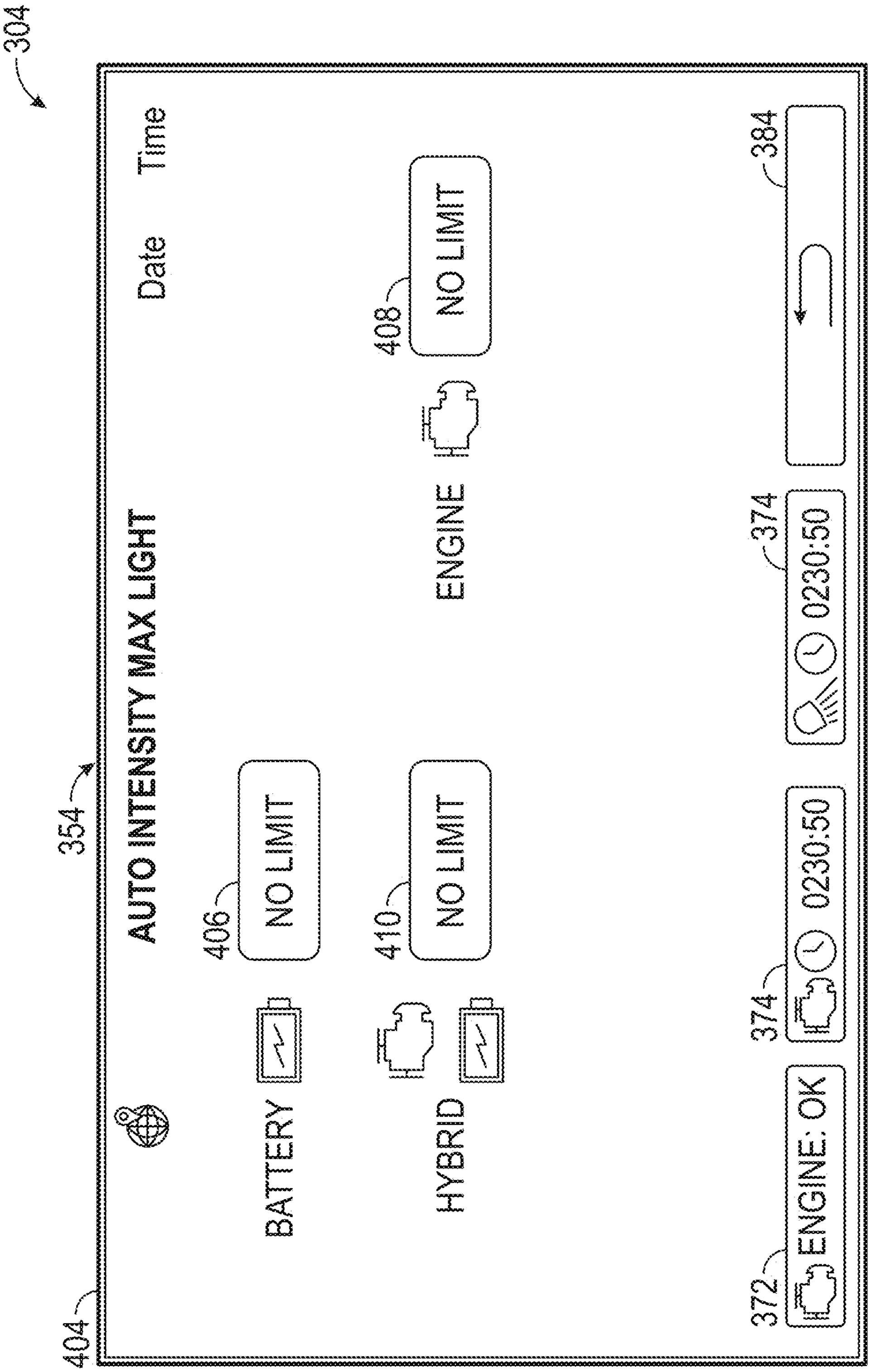

304
354
AUTO INTENSITY MAX LIGHT
Date
Time
BATTERY
406
NO LIMIT
HYBRID
410
NO LIMIT
ENGINE
408
NO LIMIT
372
ENGINE: OK
374
0230:50
374
0230:50
384
404

FIG. 13

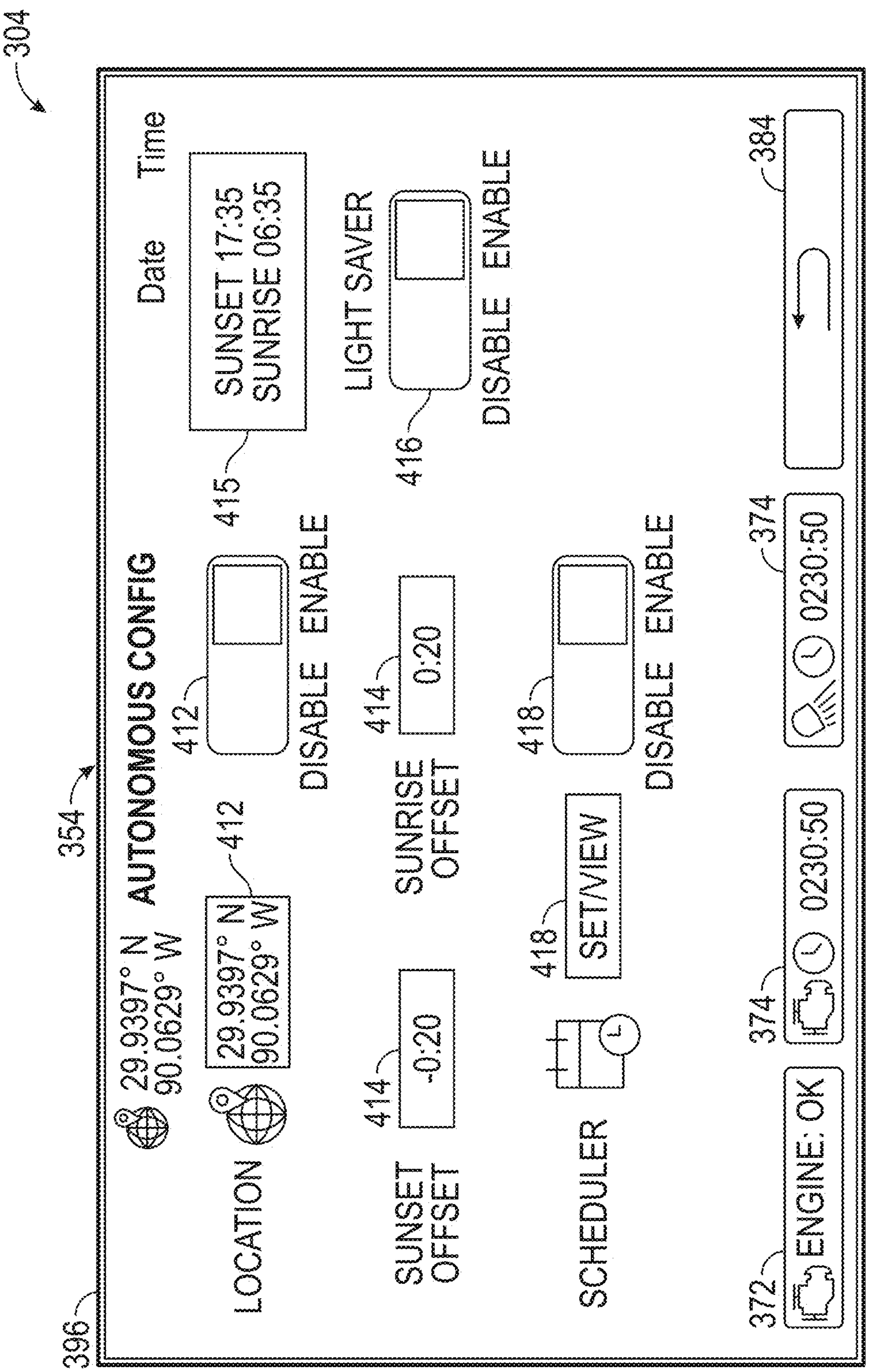

304
354
396
AUTONOMOUS CONFIG
29.9397° N
90.0629° W
LOCATION
29.9397° N
90.0629° W
412
412
DISABLE ENABLE
415
SUNSET 17:35
SUNRISE 06:35
Date
Time
SUNSET OFFSET
414
-0:20
SUNRISE OFFSET
414
0:20
LIGHT SAVER
416
DISABLE ENABLE
SCHEDULER
418
SET/VIEW
418
DISABLE ENABLE
372
ENGINE: OK
374
0230:50
374
0230:50
384

FIG. 14

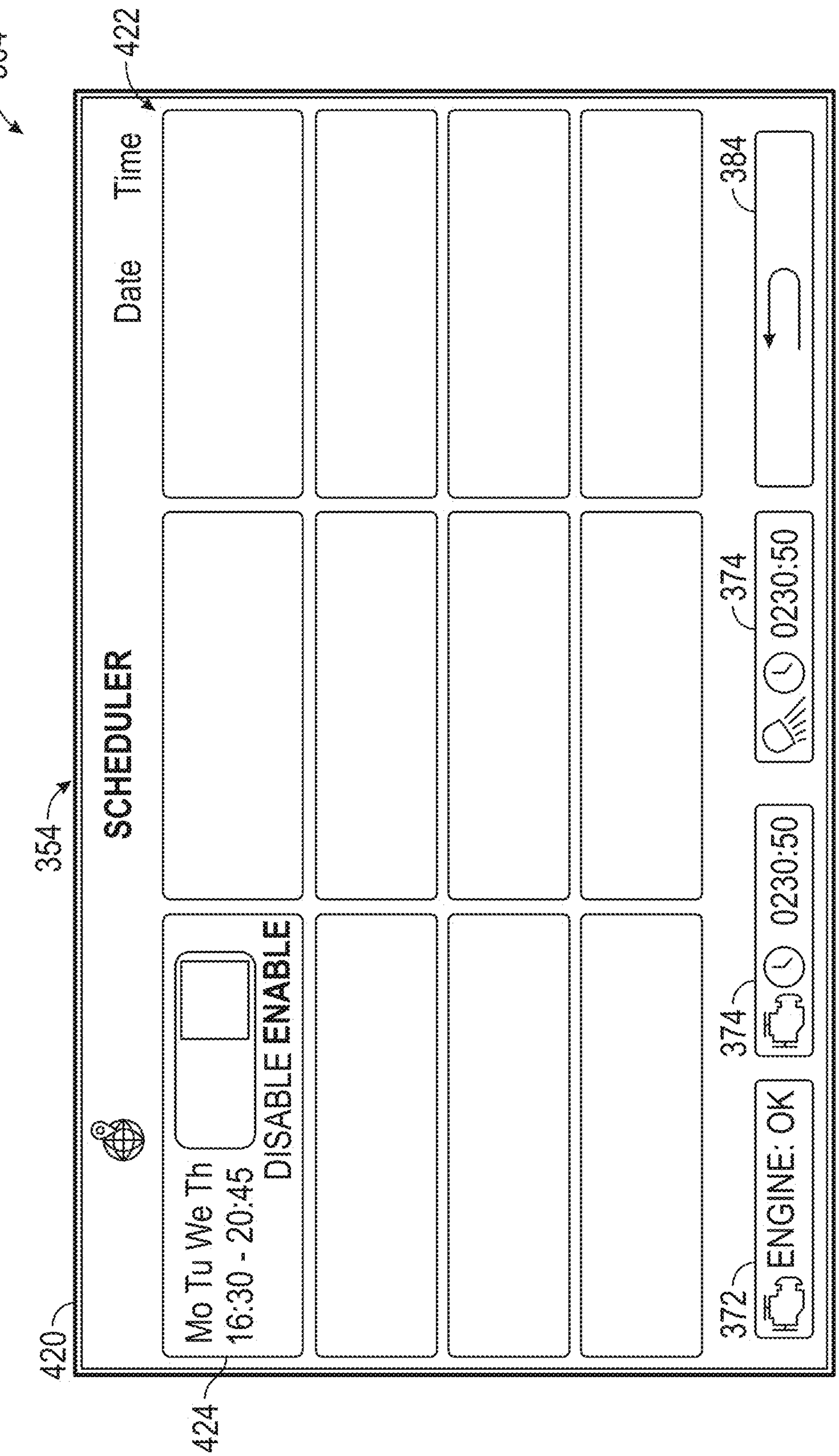

304
422
354
SCHEDULER
Date
Time
Mo Tu We Th
16:30 - 20:45
DISABLE ENABLE
420
424
372
ENGINE: OK
374
0230:50
374
0230:50
384

FIG. 15

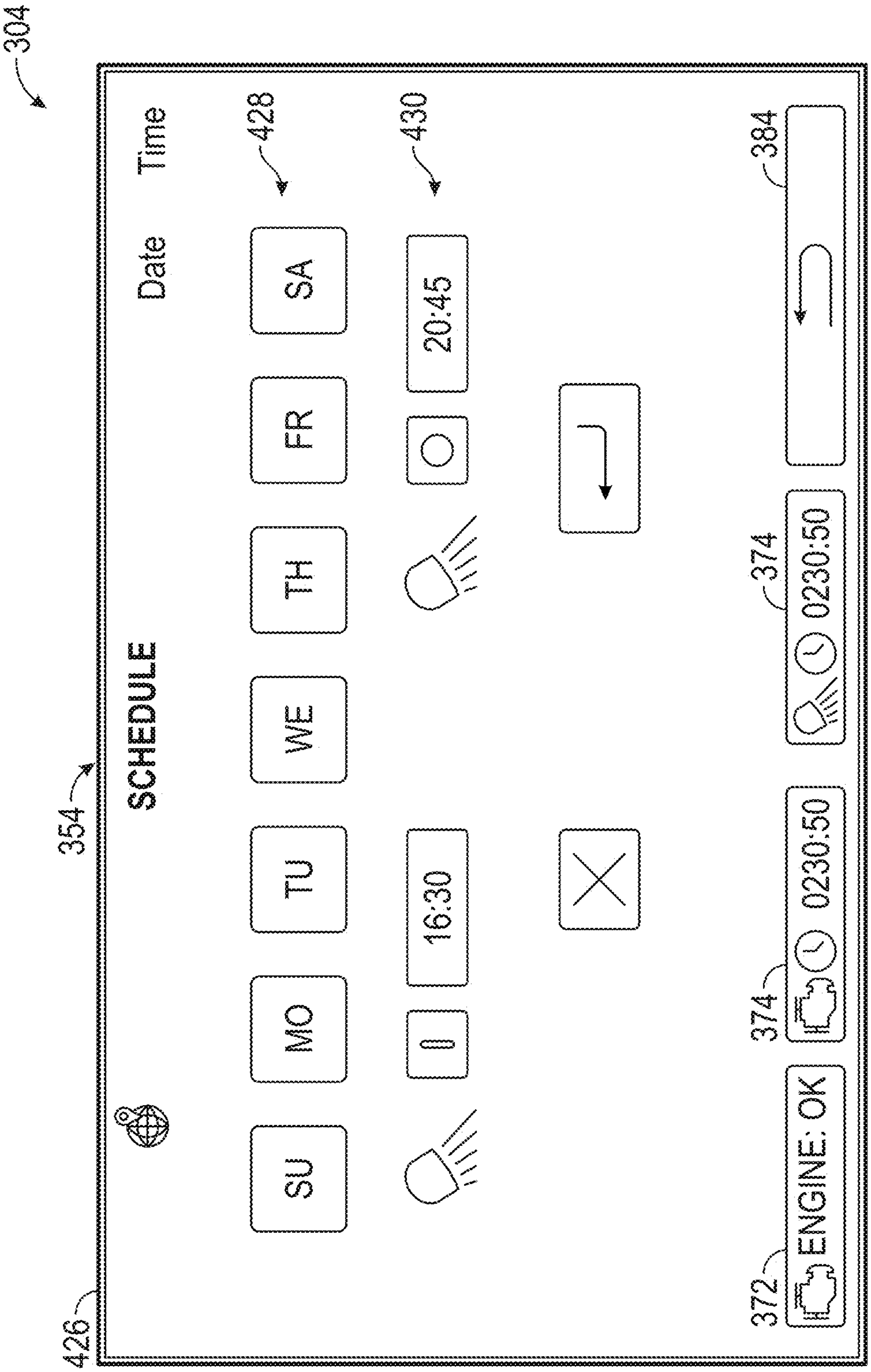

304
354
SCHEDULE
Date
Time
428
430
SU
MO
TU
WE
TH
FR
SA
16:30
20:45
ENGINE: OK
0230:50
0230:50
372
374
374
384
426

FIG. 16

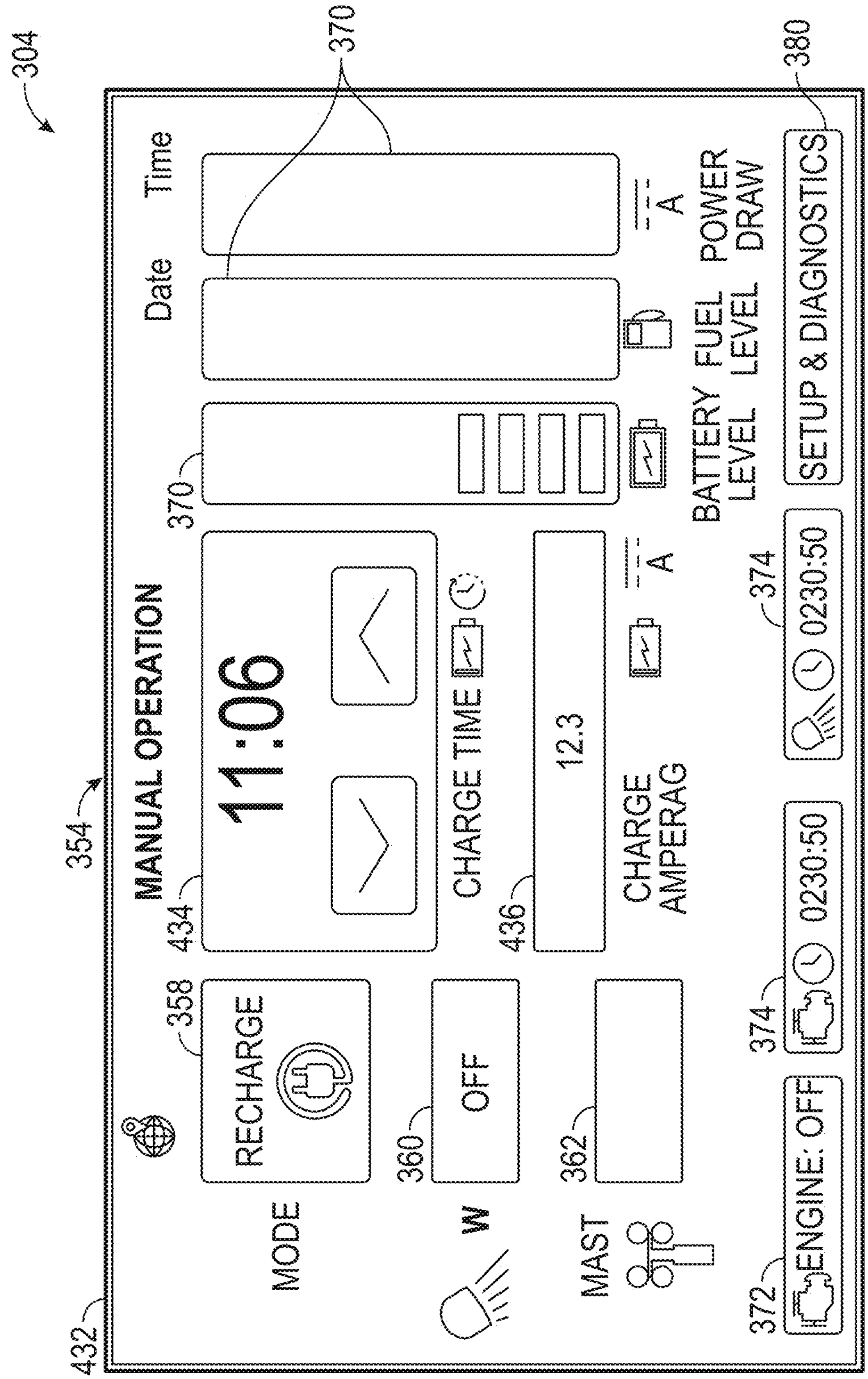

304
354
432
MANUAL OPERATION
MODE
RECHARGE
358
W
OFF
360
MAST
362
434
11:06
CHARGE TIME
436
12.3
CHARGE
AMPERAG
A
370
BATTERY
LEVEL
FUEL
LEVEL
POWER
DRAW
Date
Time
372
ENGINE: OFF
374
0230:50
374
0230:50
380
SETUP & DIAGNOSTICS

FIG. 17

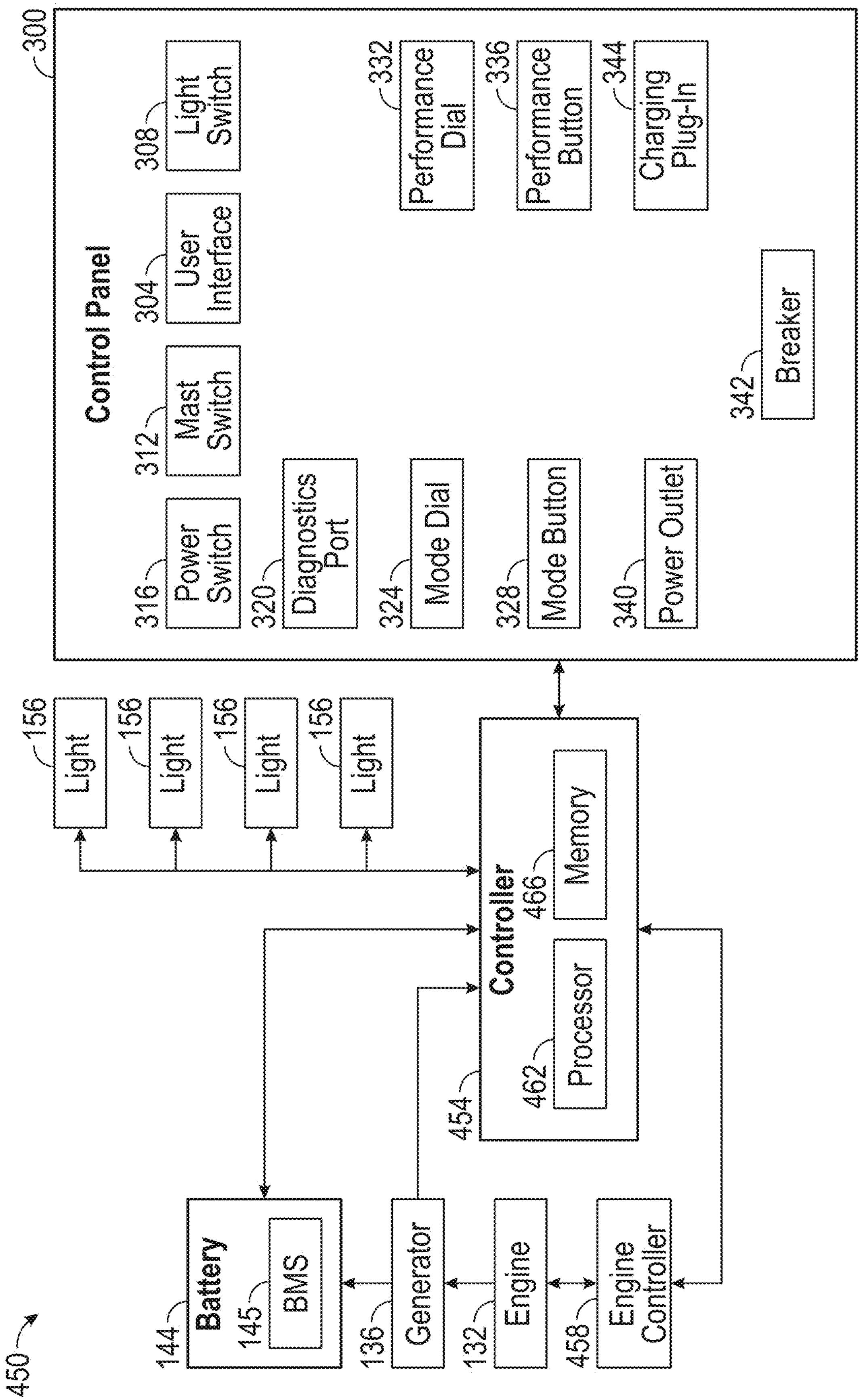

450
300
Control Panel
308 Light Switch
304 User Interface
312 Mast Switch
316 Power Switch
320 Diagnostics Port
324 Mode Dial
328 Mode Button
340 Power Outlet
332 Performance Dial
336 Performance Button
344 Charging Plug-In
342 Breaker
156 Light
156 Light
156 Light
156 Light
454 Controller
462 Processor
466 Memory
144 Battery
145 BMS
136 Generator
132 Engine
458 Engine Controller

FIG. 18

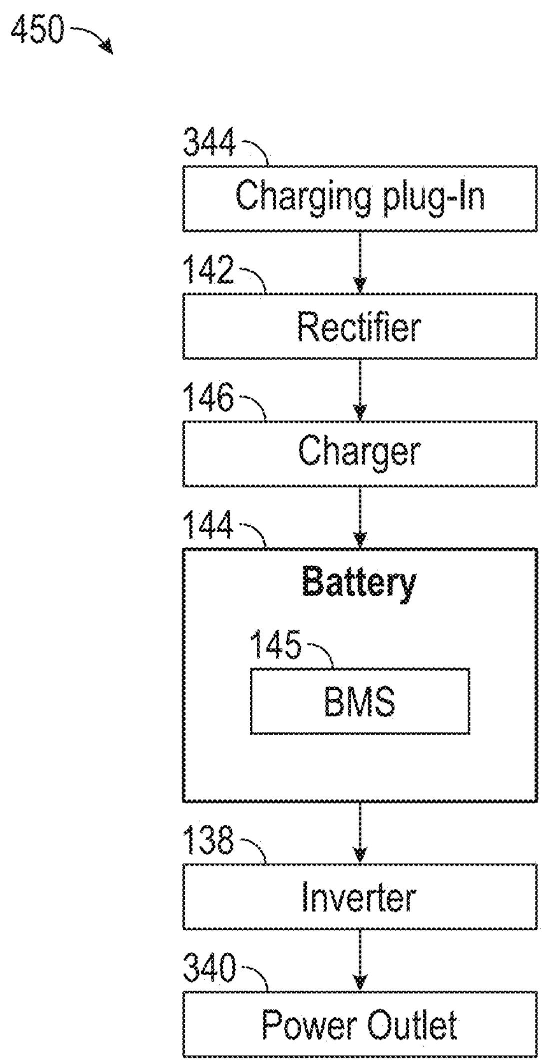
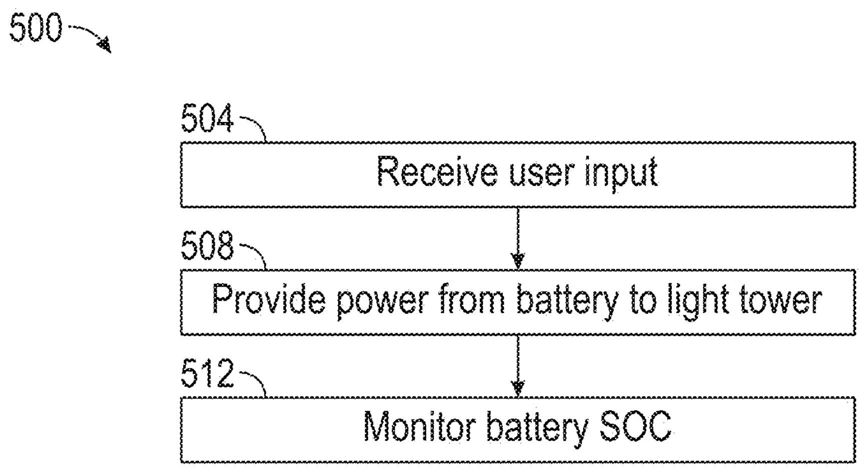
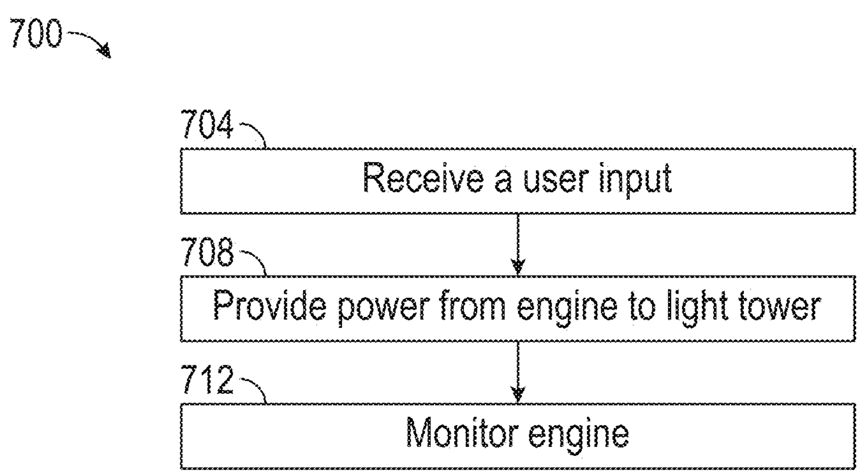

450
344
Charging plug-In
142
Rectifier
146
Charger
144
Battery
145
BMS
138
Inverter
340
Power Outlet

FIG. 19



500
504
Receive user input
508
Provide power from battery to light tower
512
Monitor battery SOC

FIG. 20



700
704
Receive a user input
708
Provide power from engine to light tower
712
Monitor engine

FIG. 21

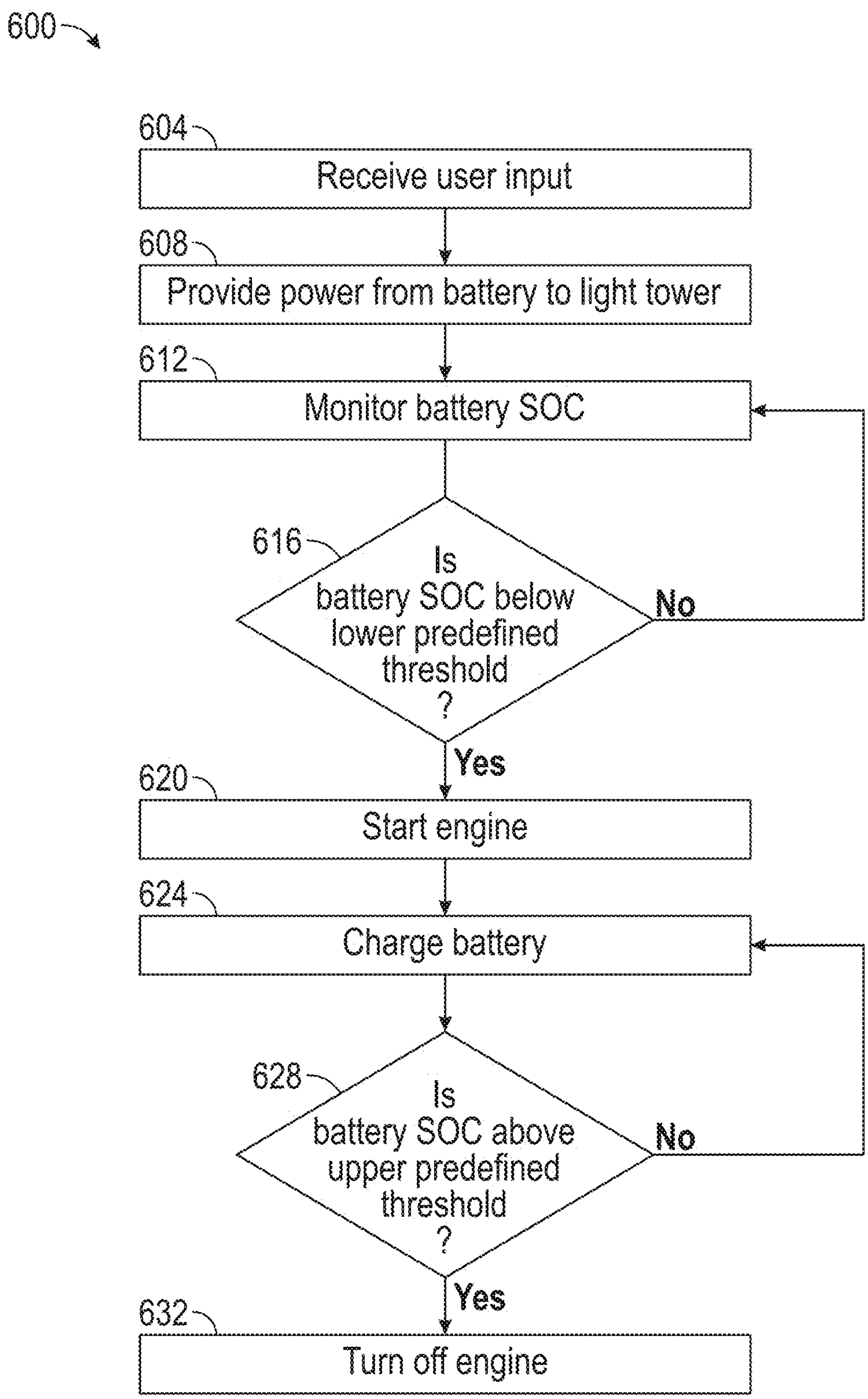

600
604
Receive user input
608
Provide power from battery to light tower
612
Monitor battery SOC
616
Is battery SOC below lower predefined threshold ?
No
Yes
620
Start engine
624
Charge battery
628
Is battery SOC above upper predefined threshold ?
No
Yes
632
Turn off engine

FIG. 22

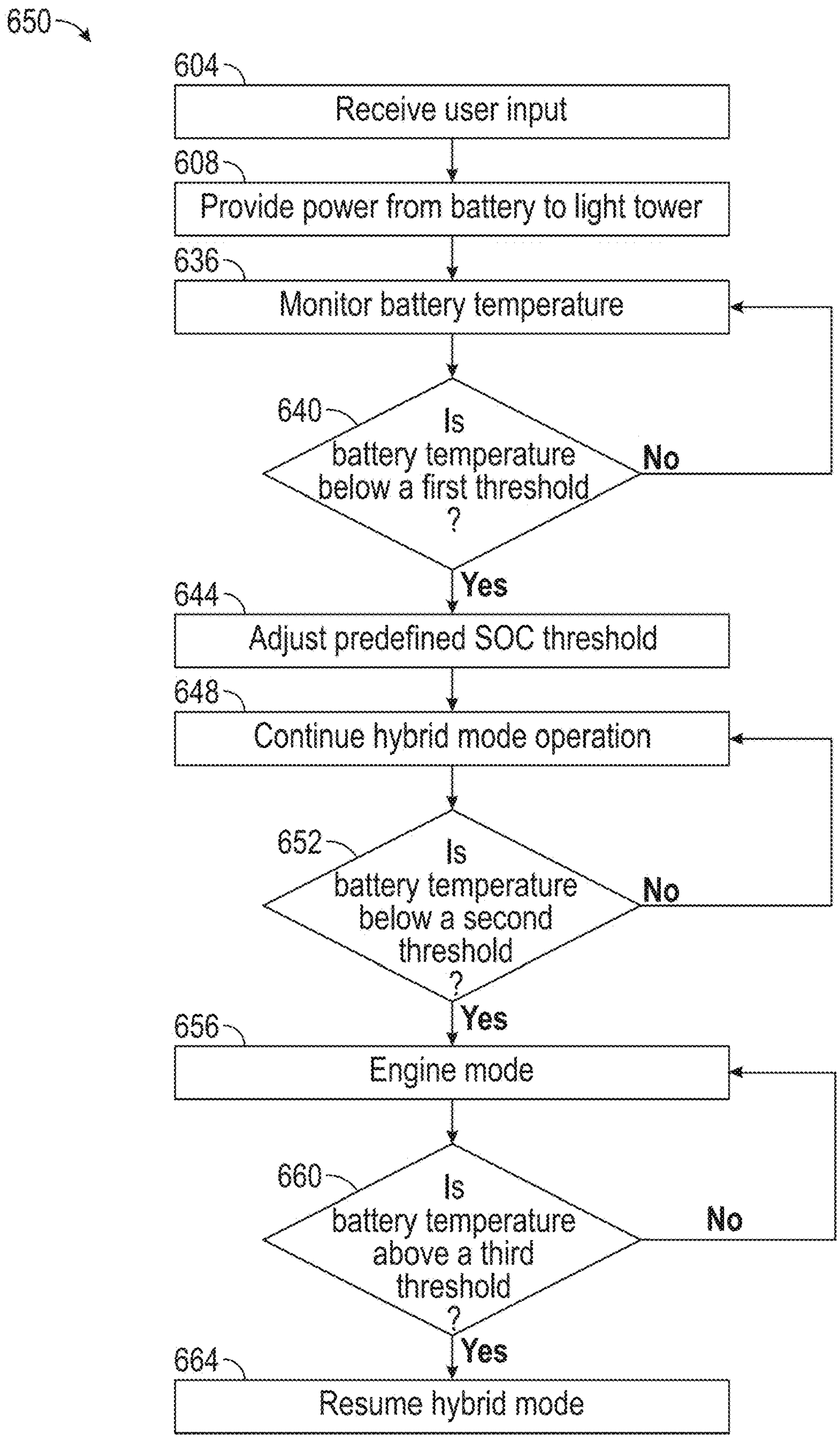

650
604
Receive user input
608
Provide power from battery to light tower
636
Monitor battery temperature
640
Is battery temperature below a first threshold ?
No
Yes
644
Adjust predefined SOC threshold
648
Continue hybrid mode operation
652
Is battery temperature below a second threshold ?
No
Yes
656
Engine mode
660
Is battery temperature above a third threshold ?
No
Yes
664
Resume hybrid mode

FIG. 23

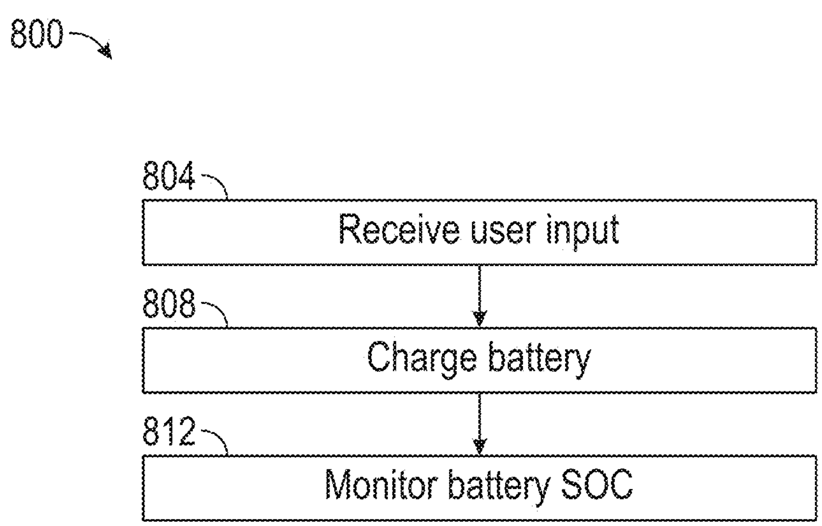

800
804
Receive user input
808
Charge battery
812
Monitor battery SOC

FIG. 24

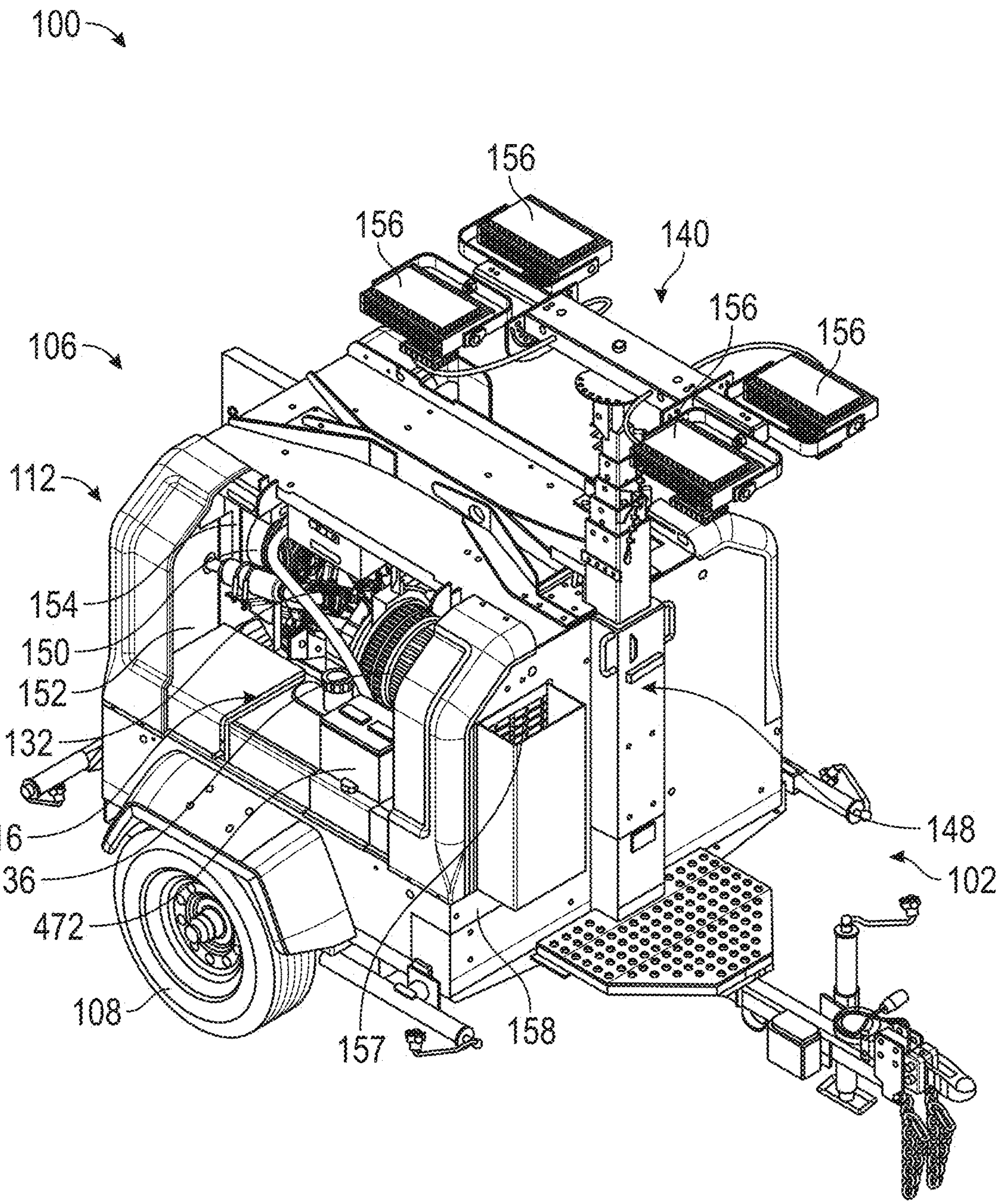

100
106
112
154
150
152
132
116
136
472
108
157
158
156
156
140
156
156
148
102

FIG. 25

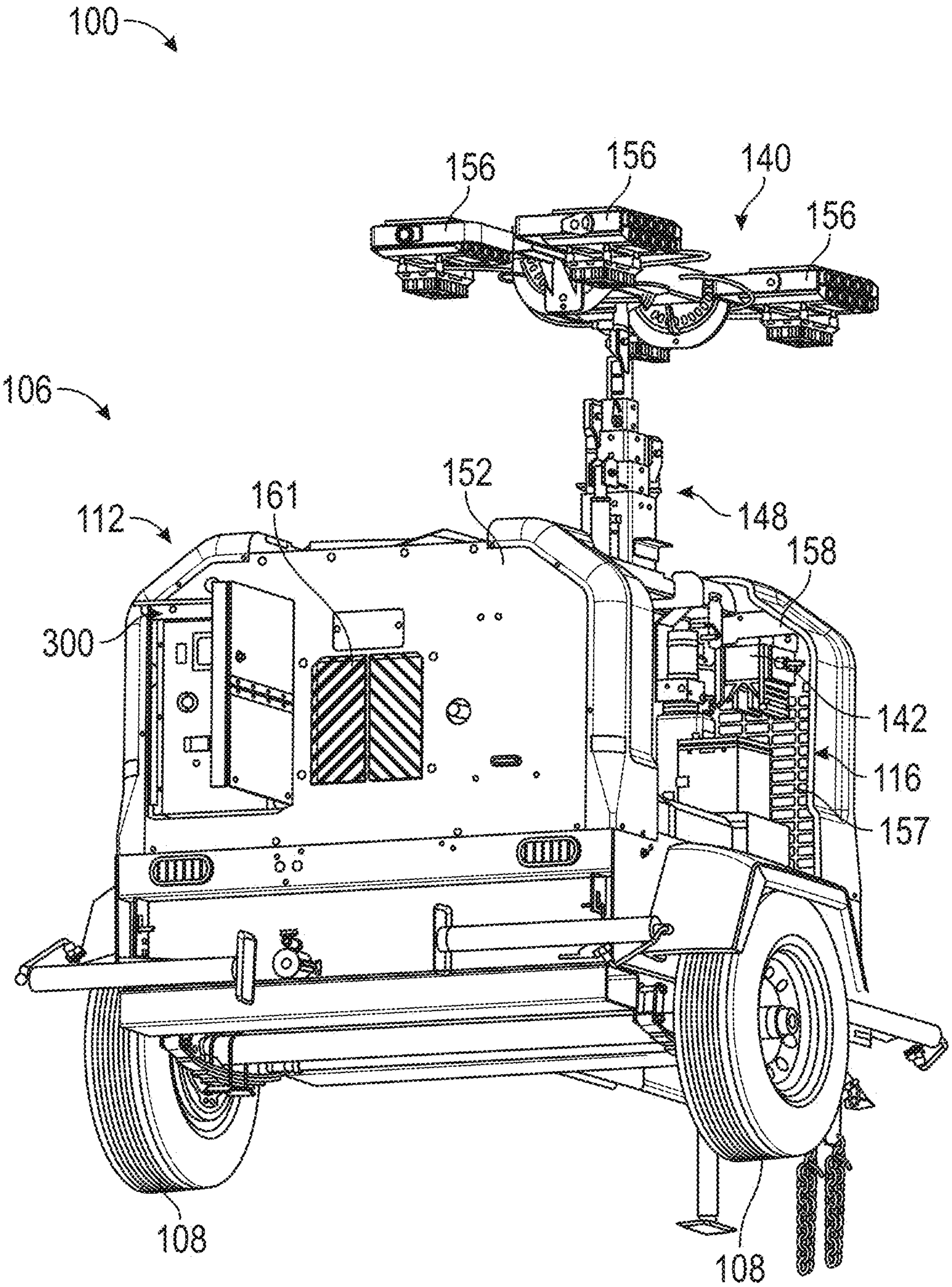

100
156
156
140
156
106
152
161
148
112
158
300
142
116
157
108
108

FIG. 26

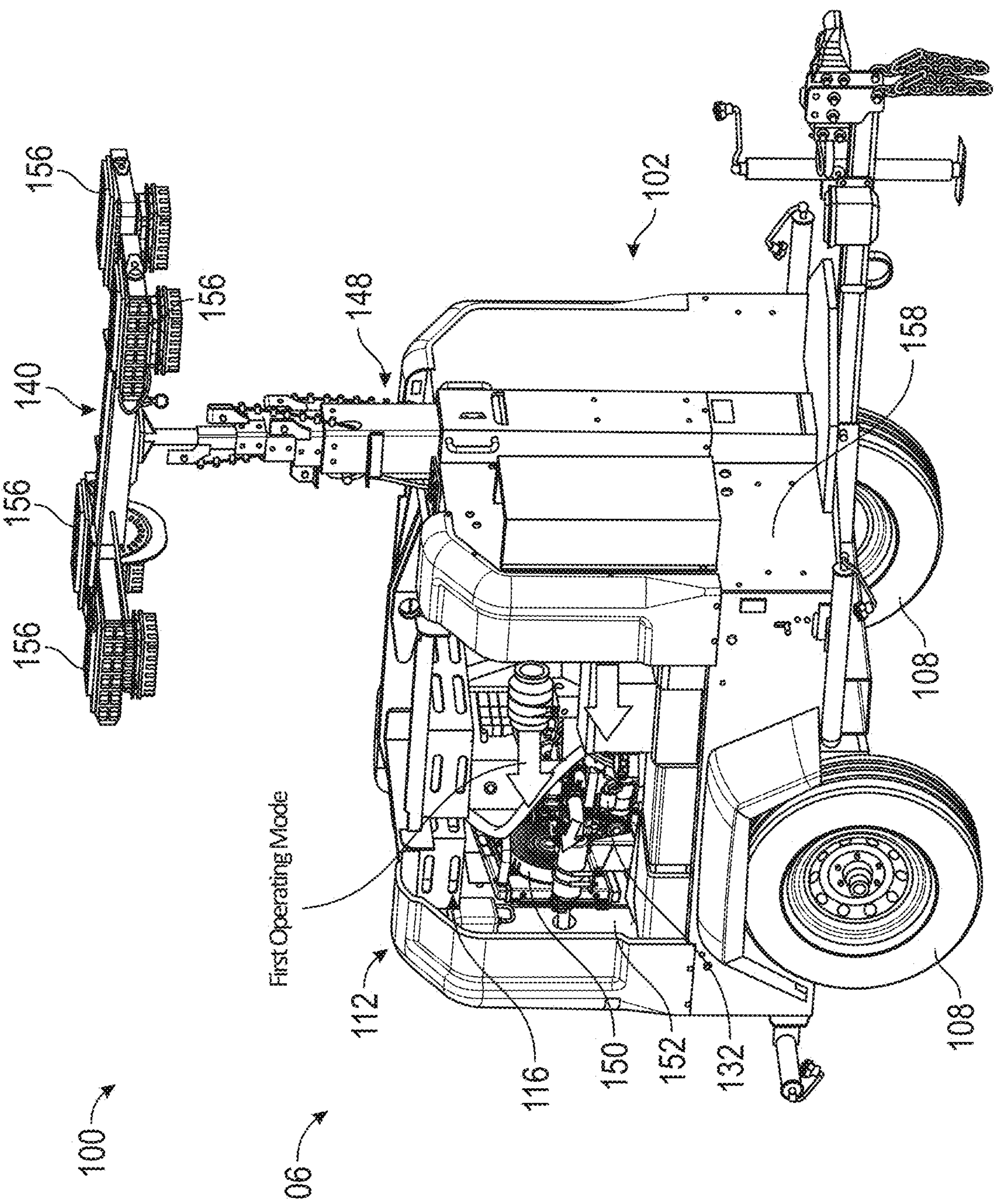

156
156
140
156
156
148
102
158
108
First Operating Mode
112
116
150
152
132
108
100
106

FIG. 27

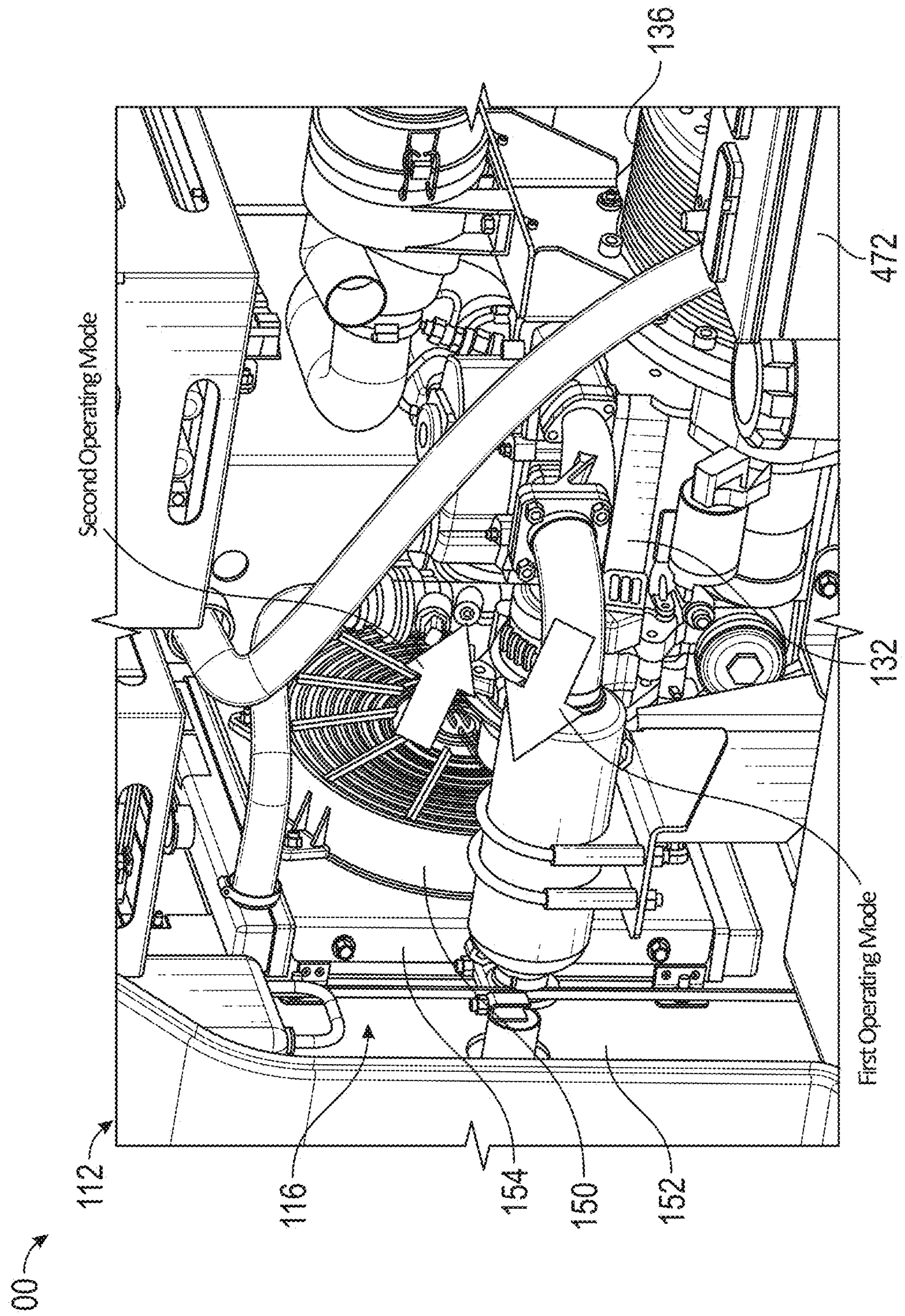

100
112
116
154
150
152
136
472
132
Second Operating Mode
First Operating Mode

FIG. 28

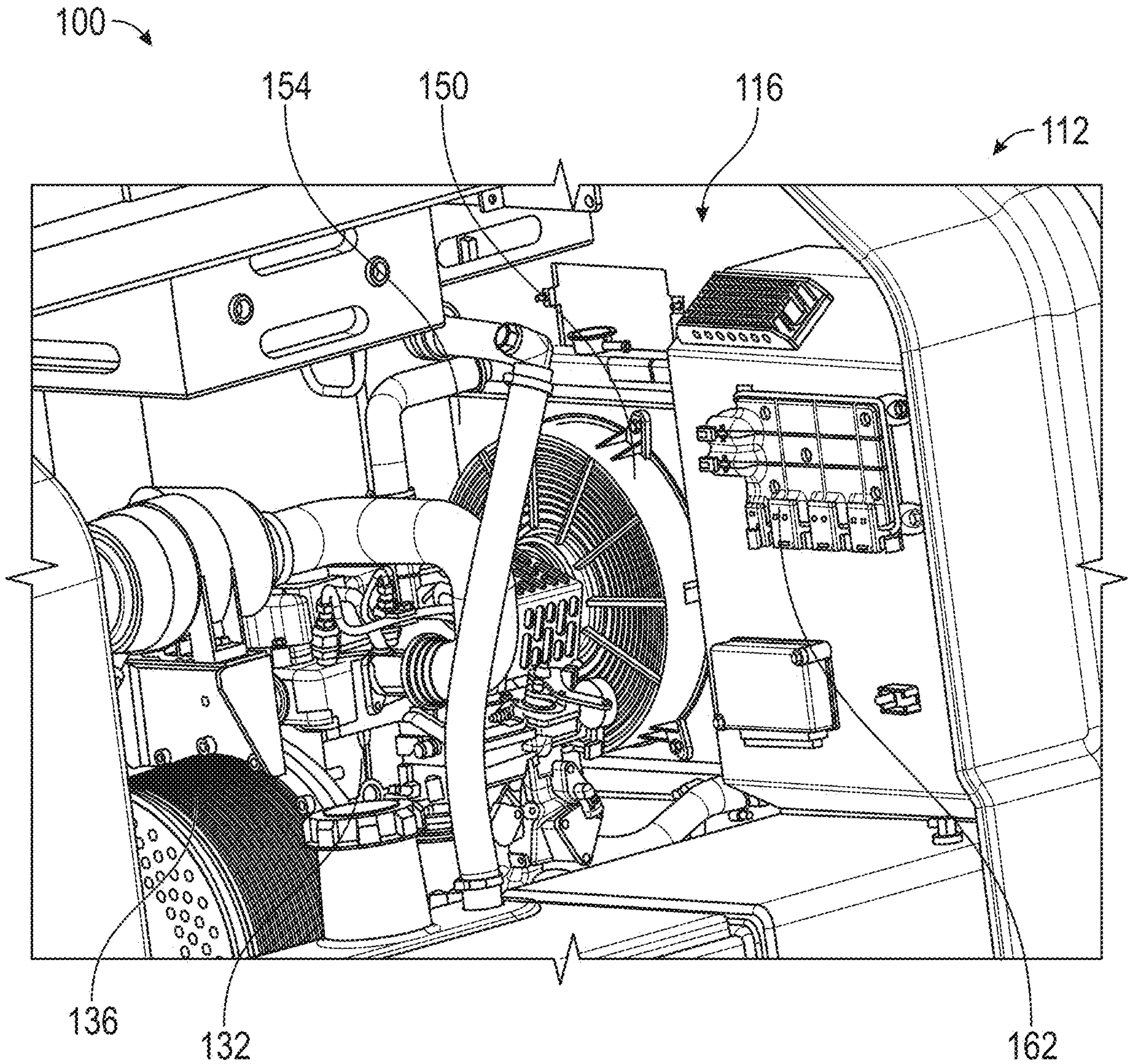


FIG. 29

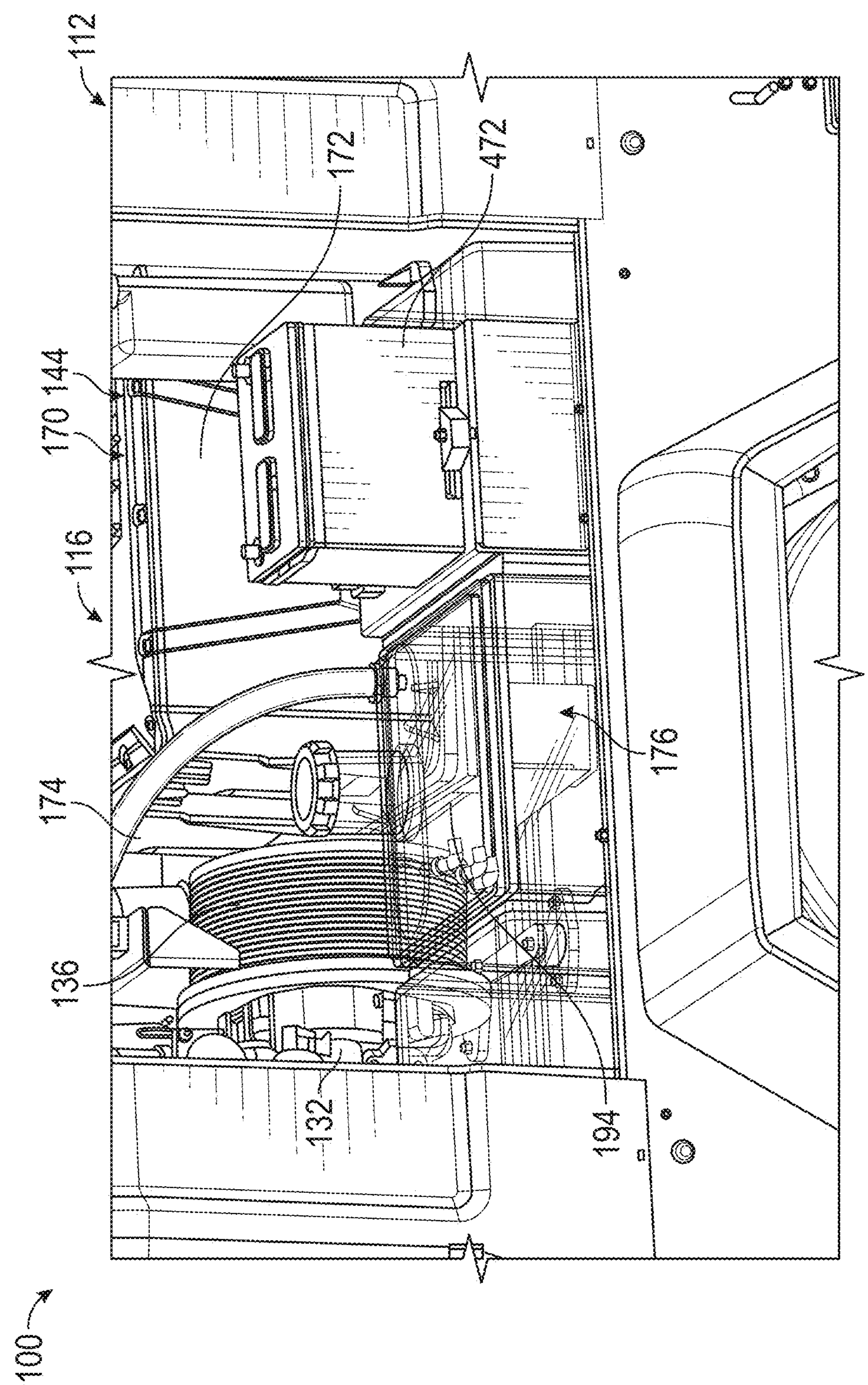


FIG. 30

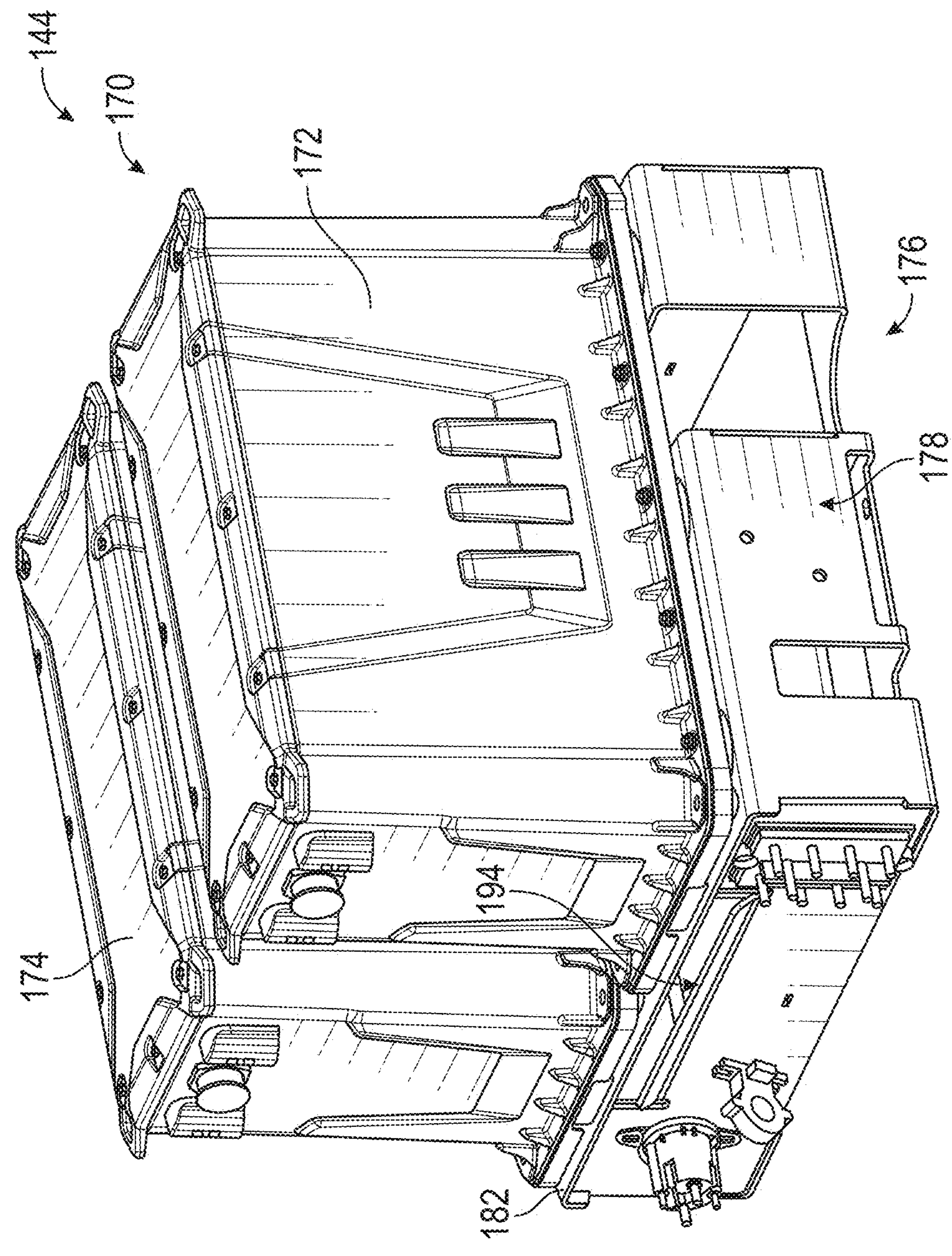


FIG. 31

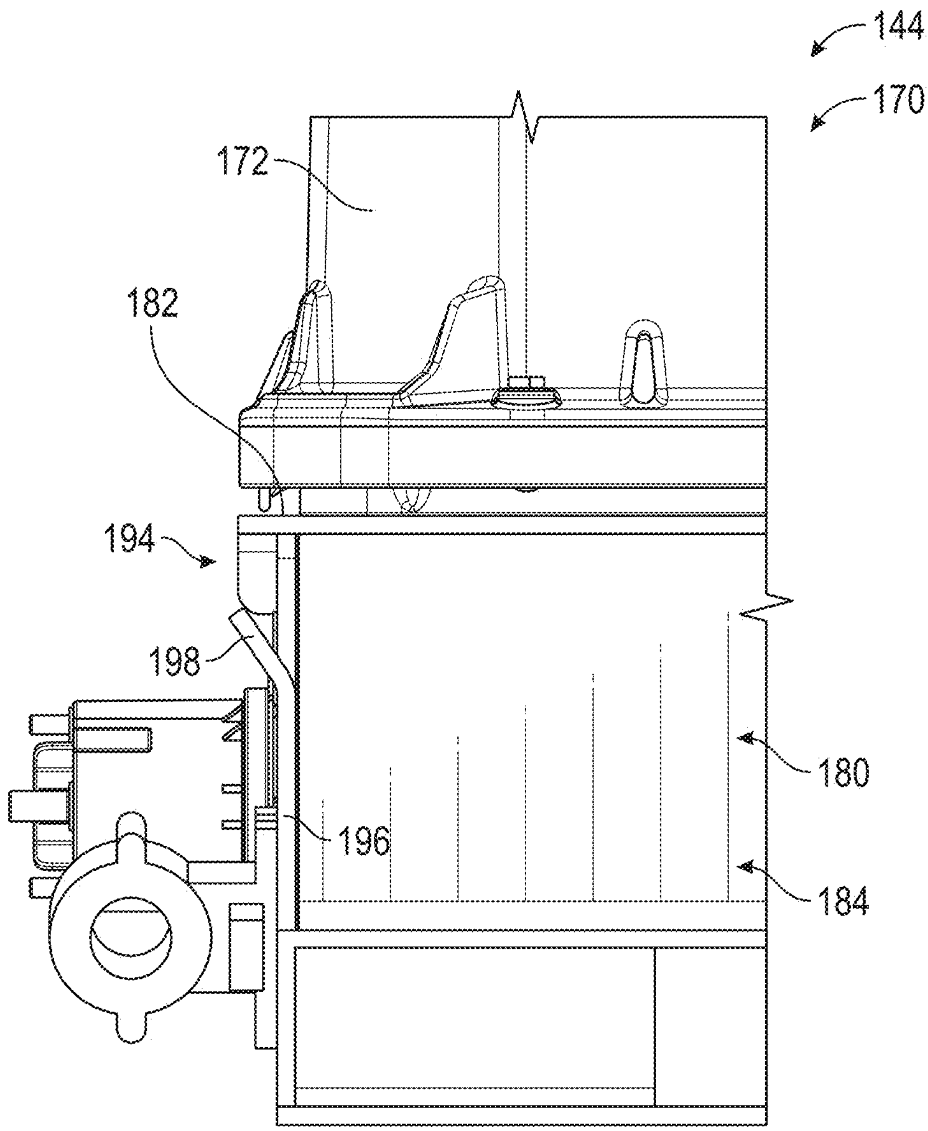


FIG. 32

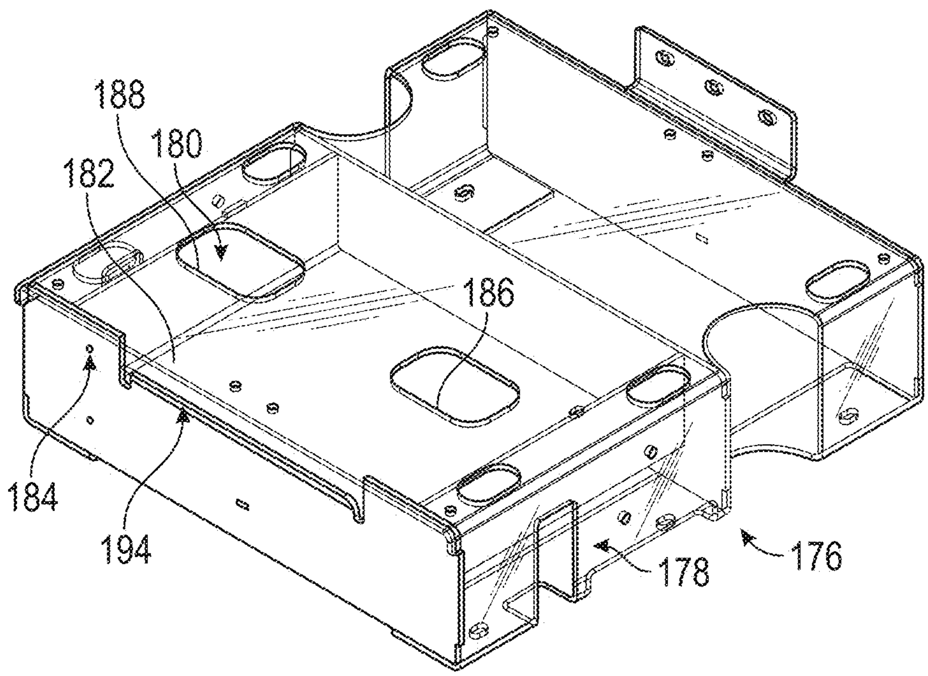


FIG. 33

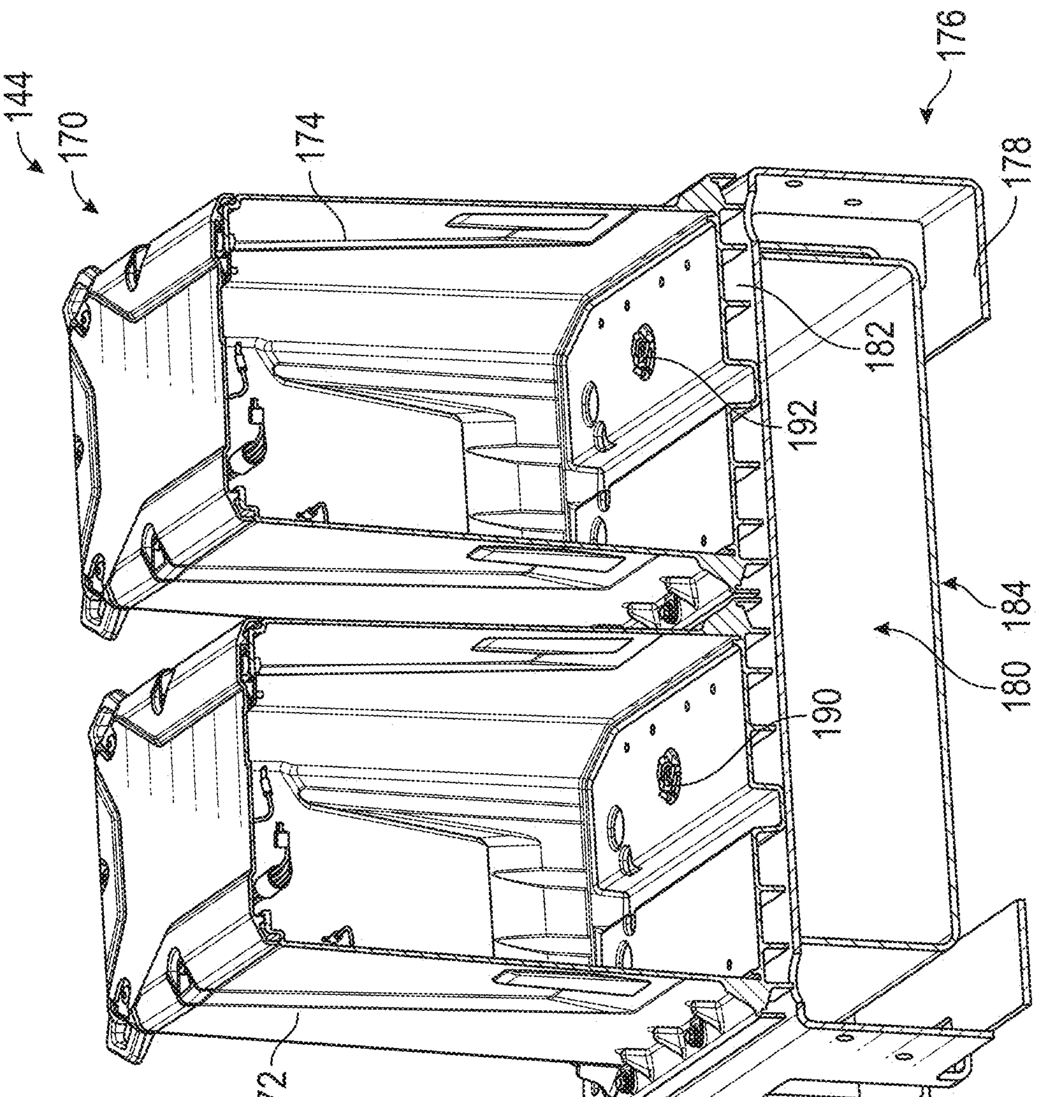


FIG. 34

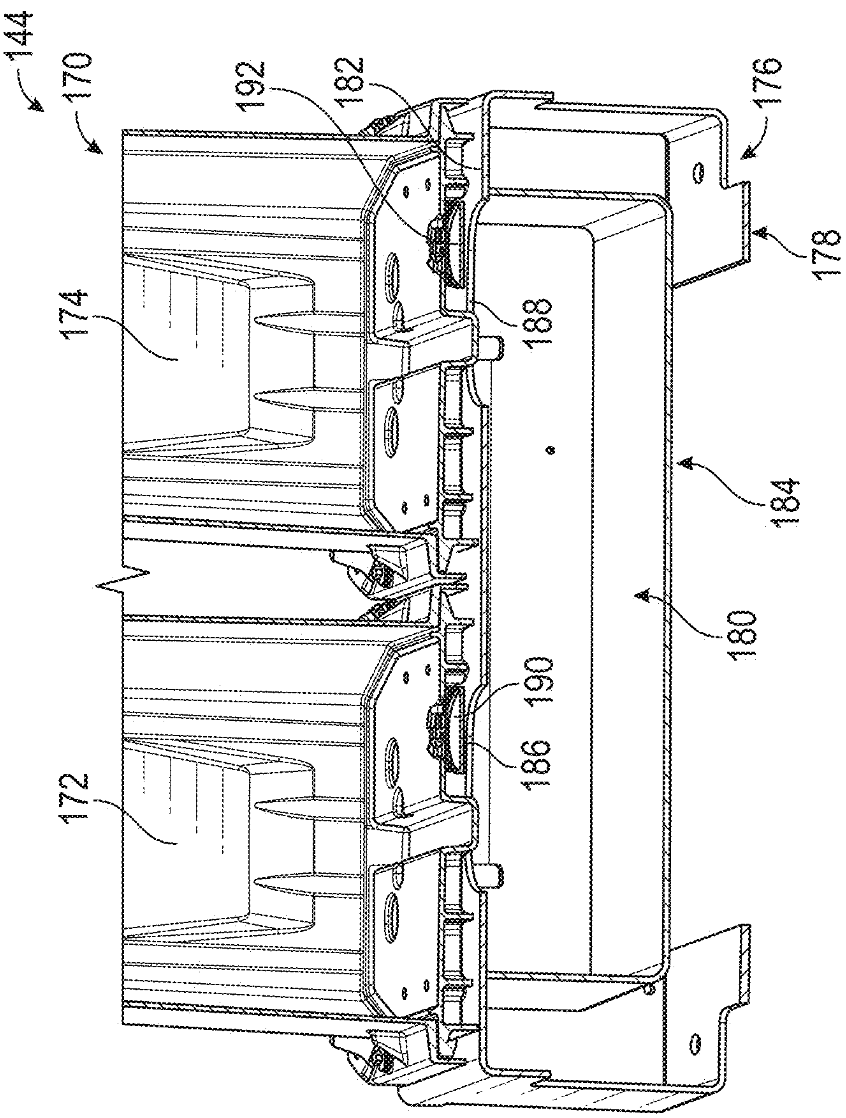


FIG. 35

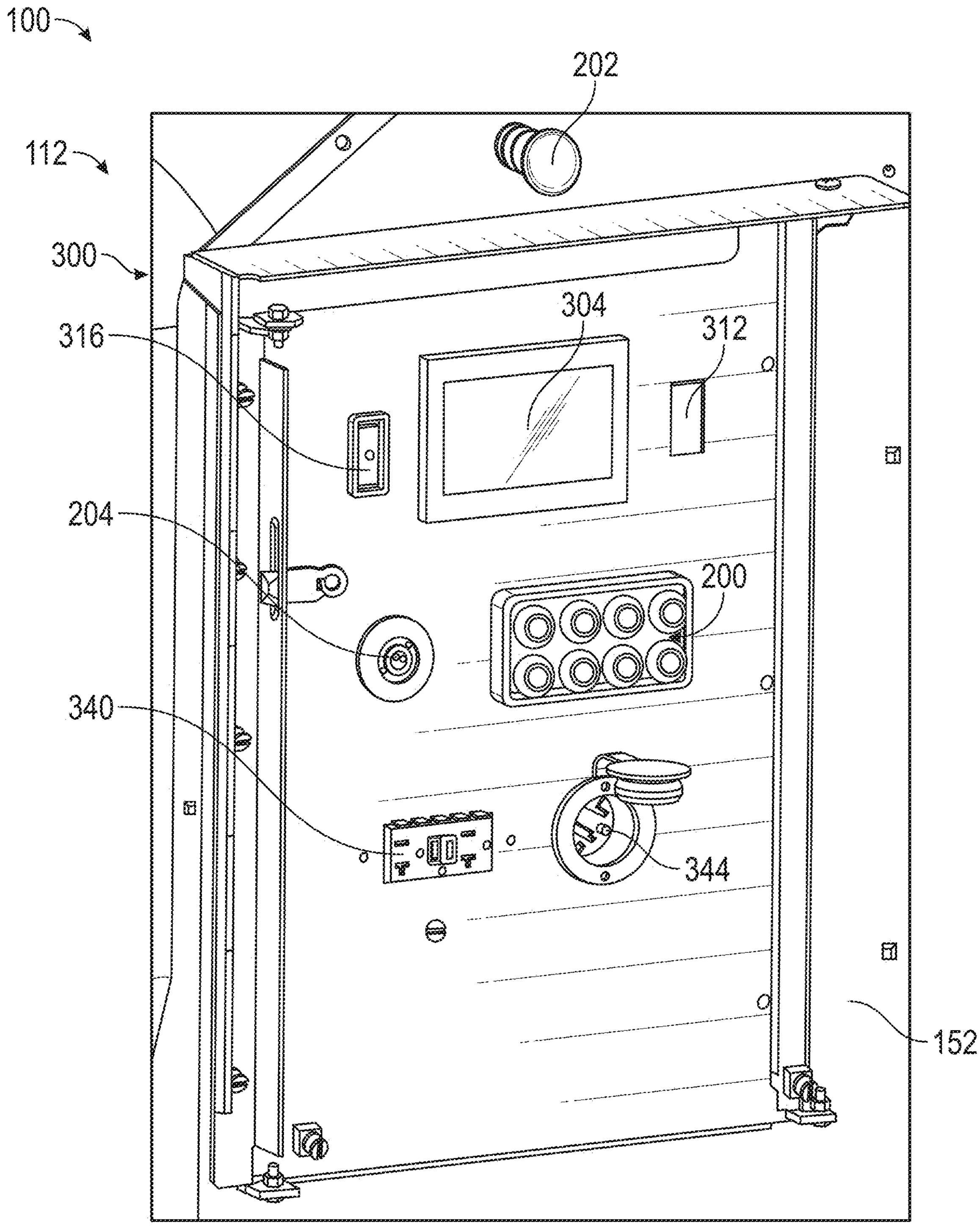


FIG. 36

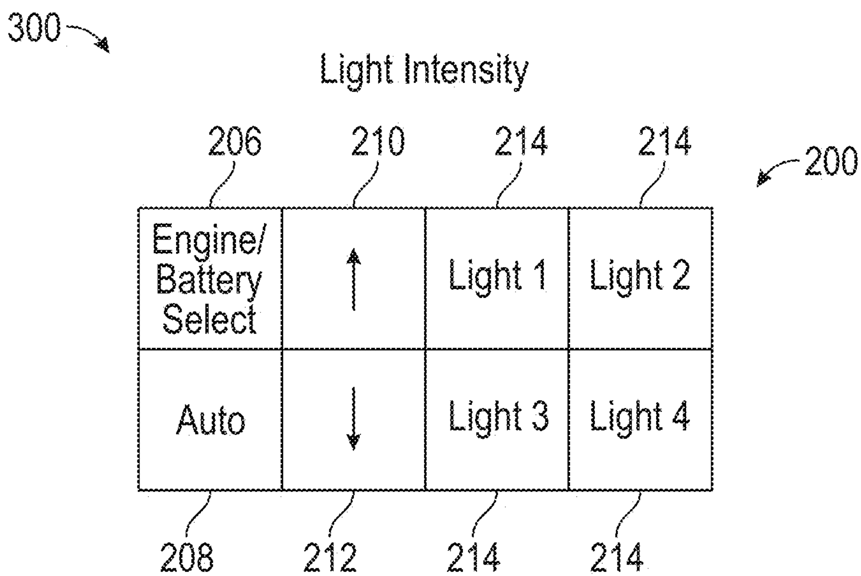

300
Light Intensity
206
210
214
214
200
Engine/ Battery Select
Light 1
Light 2
Auto
Light 3
Light 4
208
212
214
214

FIG. 37

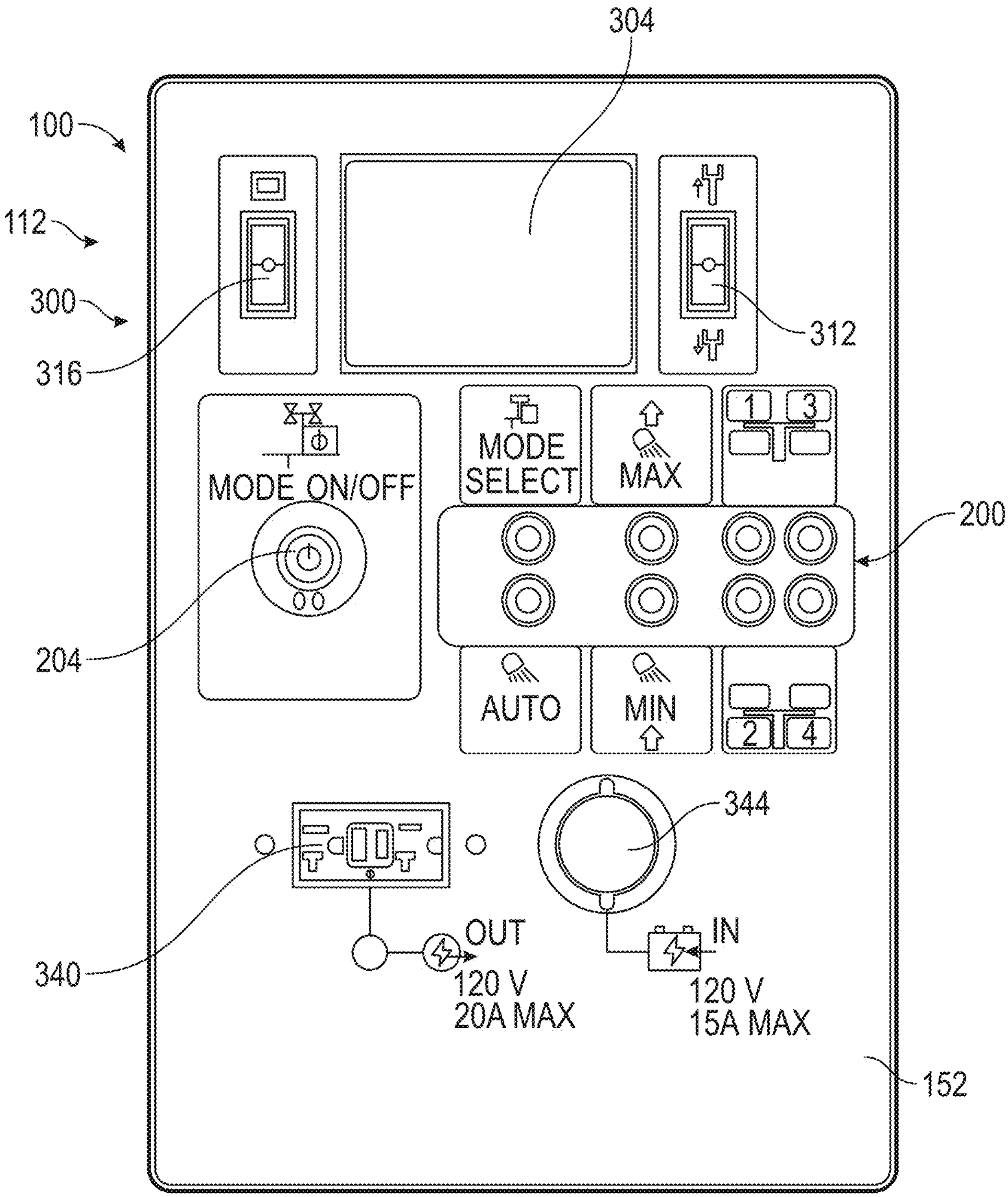

304
100
112
300
316
312
MODE ON/OFF
MODE SELECT
MAX
1
3
200
204
AUTO
MIN
2
4
344
340
OUT
120 V
20A MAX
IN
120 V
15A MAX
152

FIG. 38

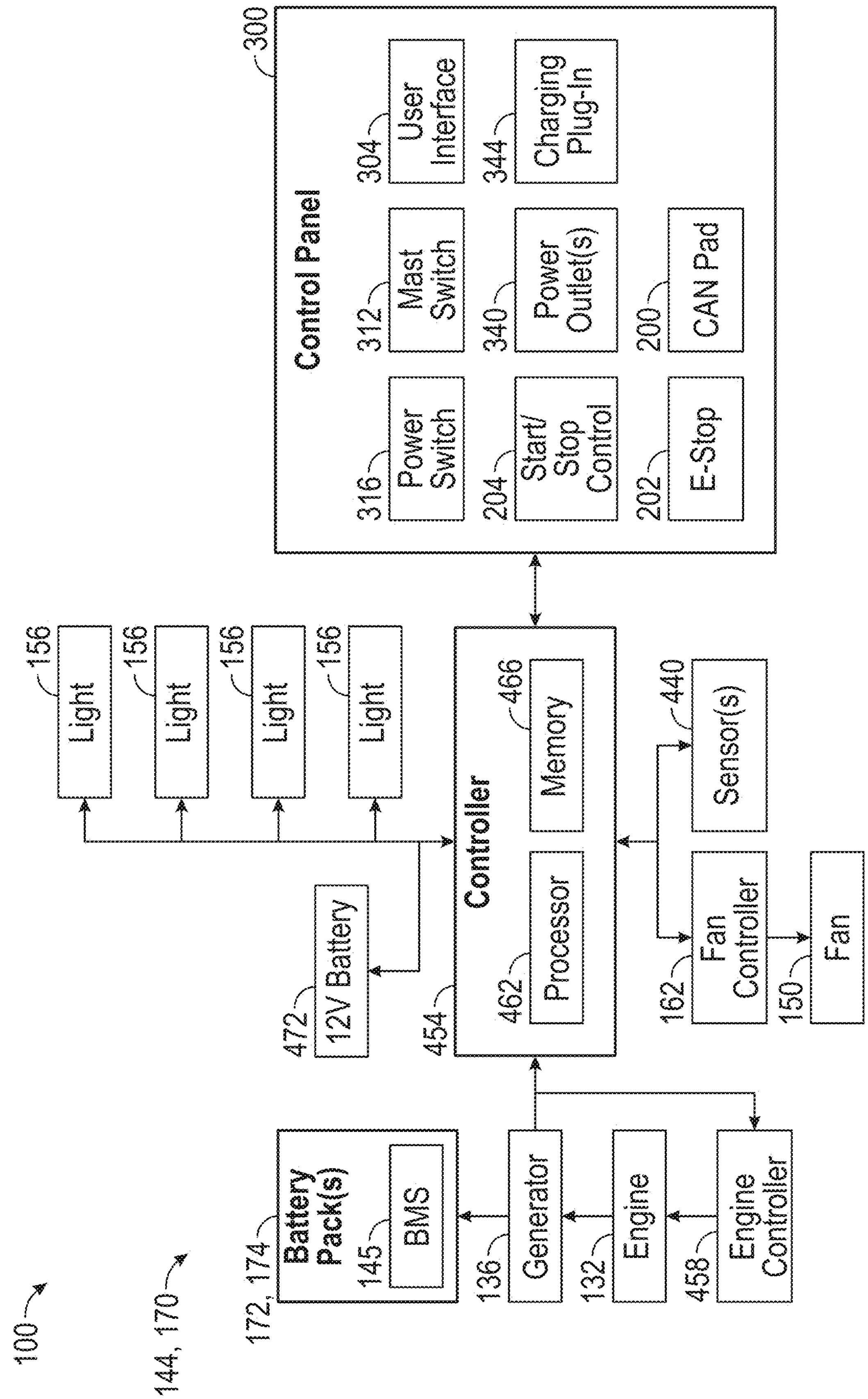

100
144, 170
172, 174
Battery Pack(s)
145
BMS
136
Generator
132
Engine
458
Engine Controller
472
12V Battery
454
Controller
462
Processor
466
Memory
156
Light
156
Light
156
Light
156
Light
162
Fan Controller
150
Fan
440
Sensor(s)
300
Control Panel
316
Power Switch
312
Mast Switch
304
User Interface
204
Start/ Stop Control
340
Power Outlet(s)
344
Charging Plug-In
202
E-Stop
200
CAN Pad

FIG. 39

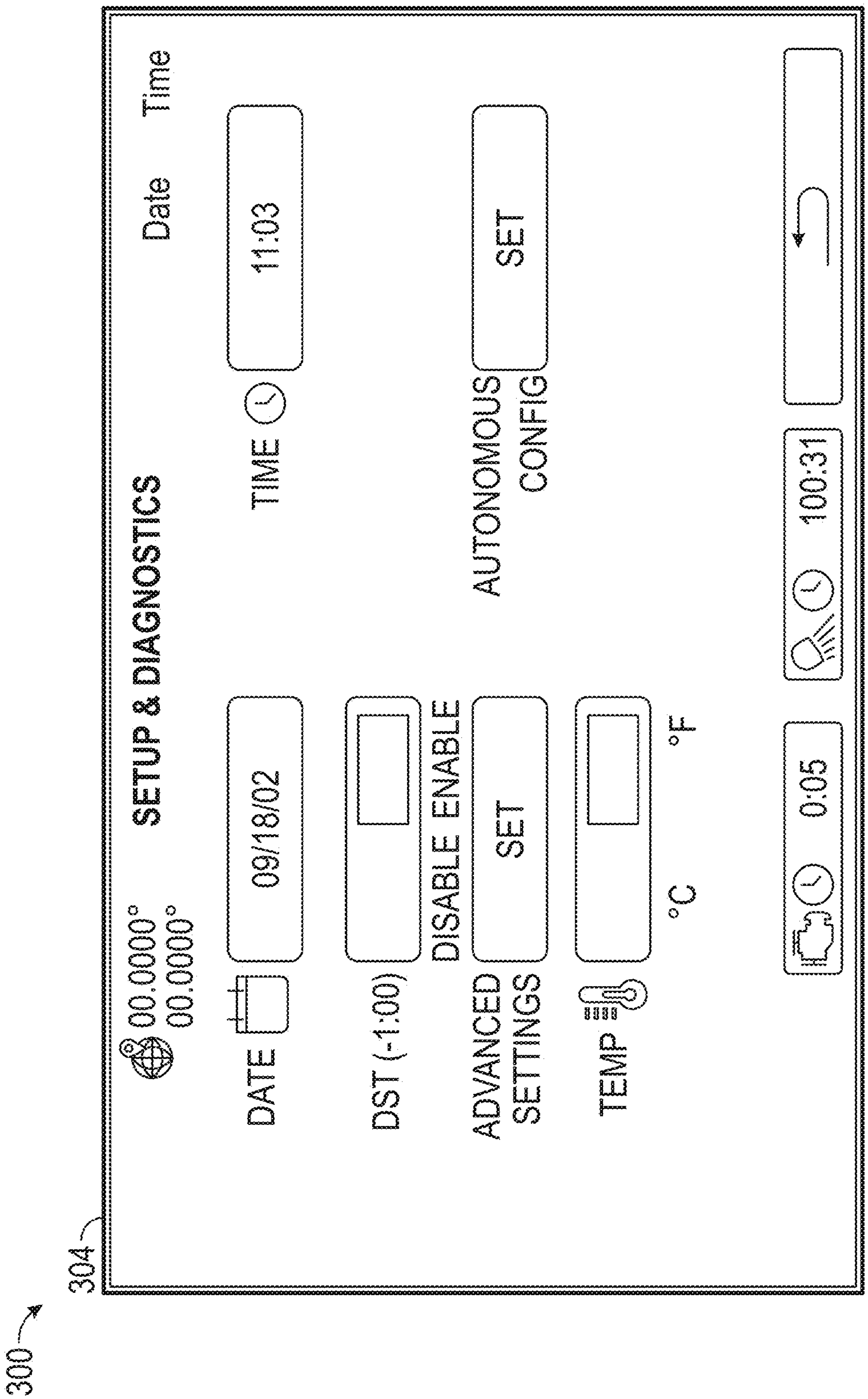

300
304
SETUP & DIAGNOSTICS
00.0000°
00.0000°
Date
Time
DATE
09/18/02
TIME
11:03
DST (-1:00)
DISABLE ENABLE
ADVANCED SETTINGS
SET
AUTONOMOUS CONFIG
SET
TEMP
°C
°F
0:05
100:31

FIG. 40

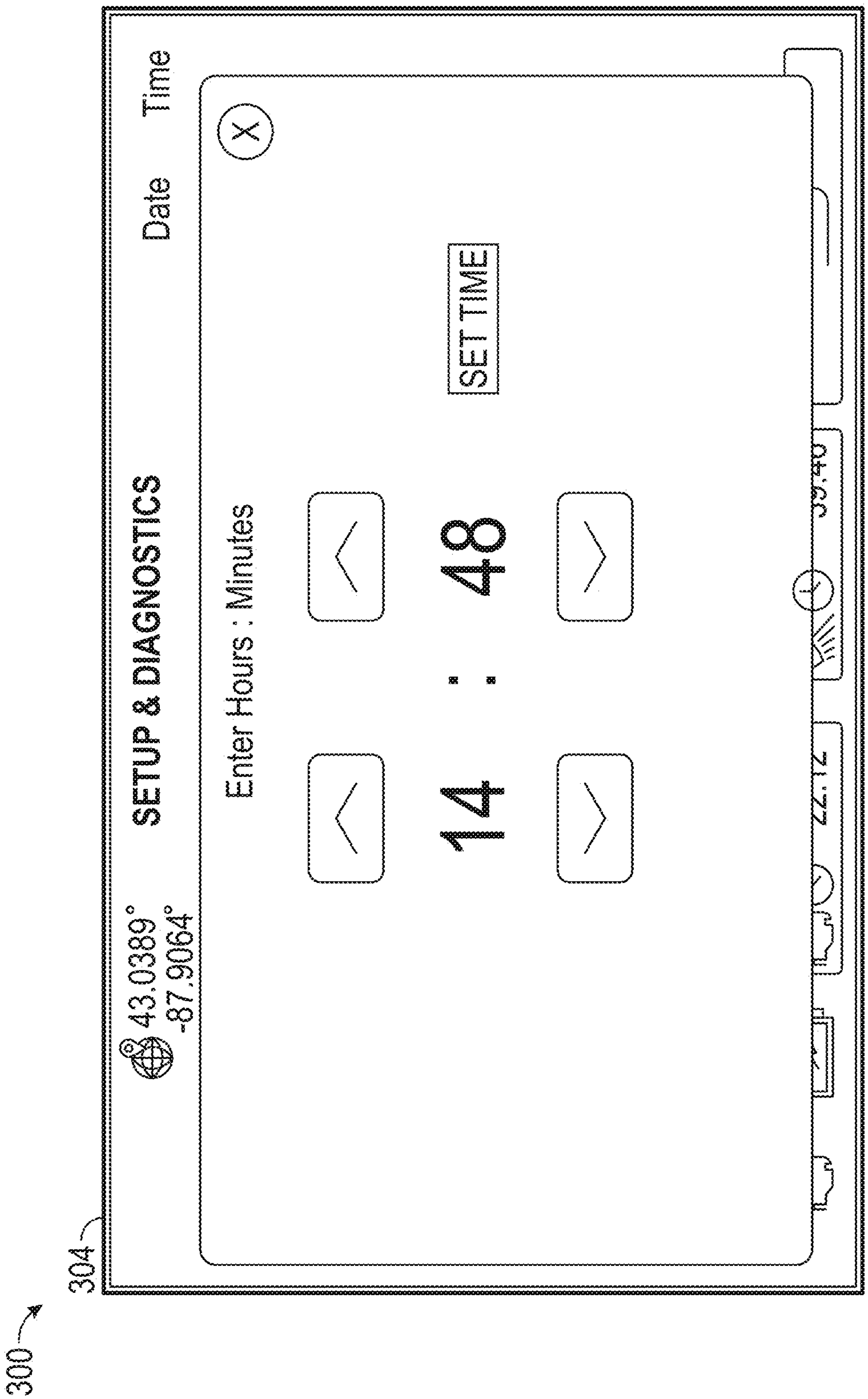

300
304
43.0389°
-87.9064°
SETUP & DIAGNOSTICS
Date
Time
Enter Hours : Minutes
14
:
48
SET TIME

FIG. 41

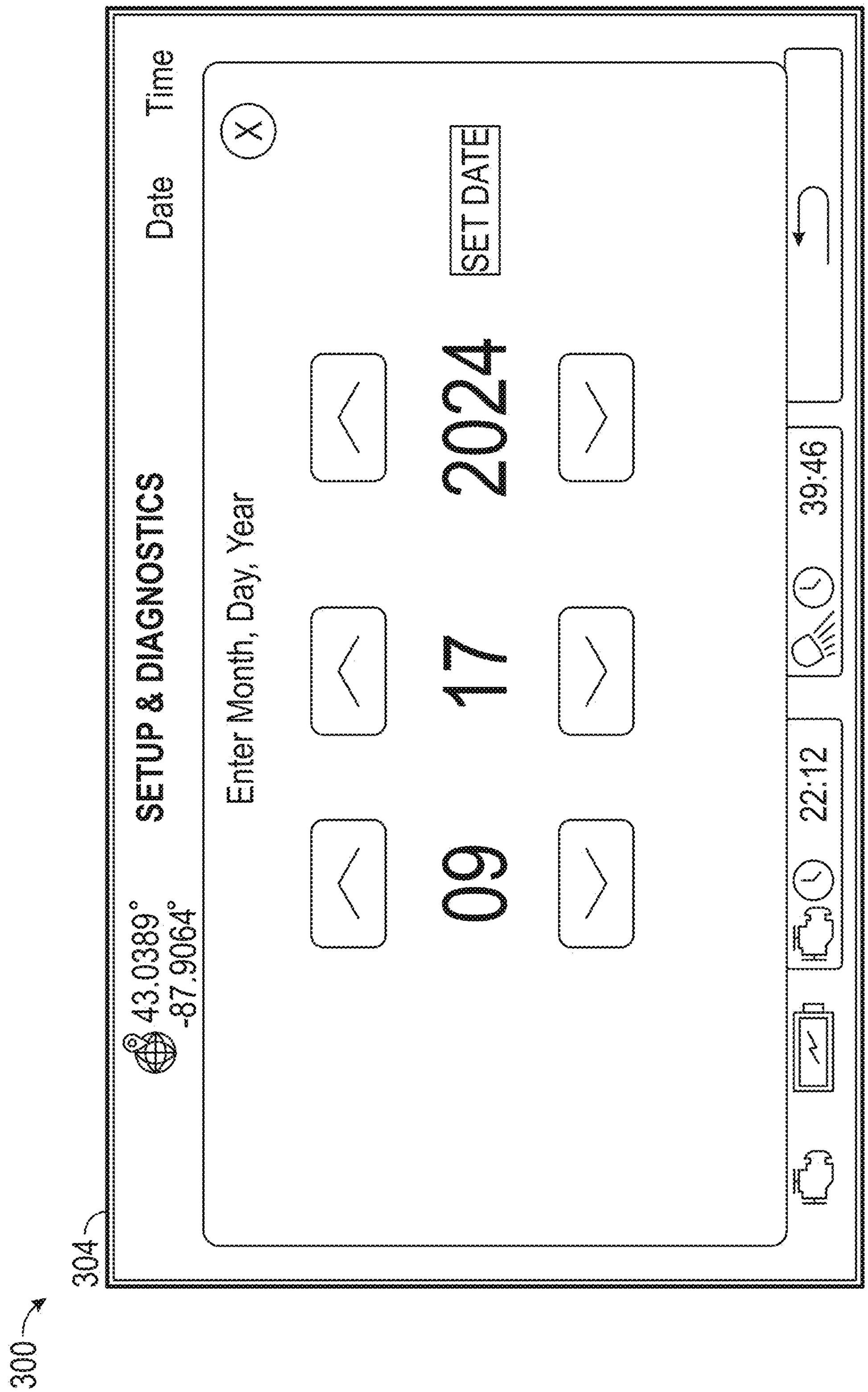

300
304
43.0389°
-87.9064°
SETUP & DIAGNOSTICS
Date
Time
Enter Month, Day, Year
09
17
2024
SET DATE
22:12
39:46

FIG. 42

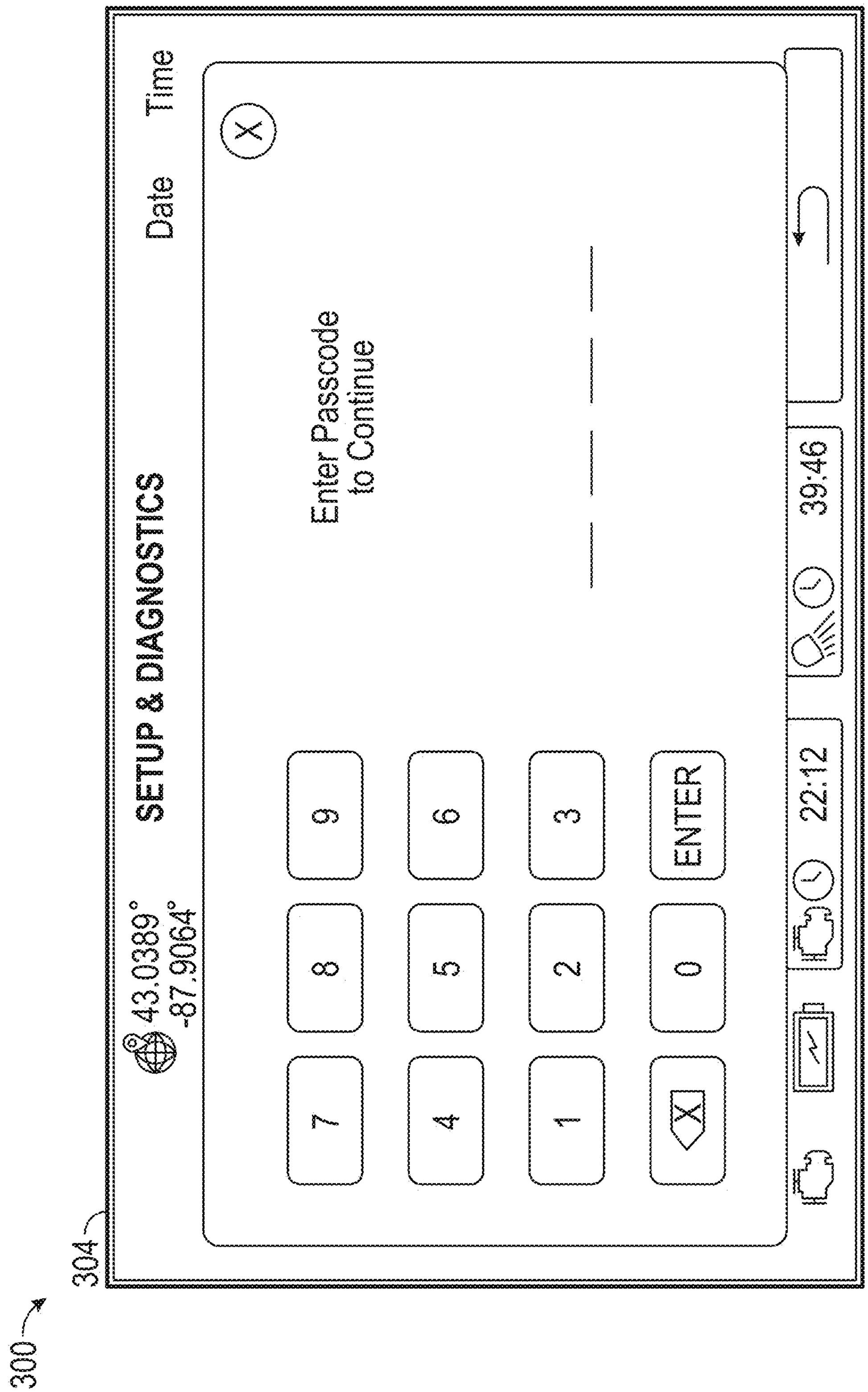

300
304
43.0389°
-87.9064°
SETUP & DIAGNOSTICS
Date
Time
Enter Passcode
to Continue
7
8
9
4
5
6
1
2
3
0
ENTER
22:12
39:46

FIG. 43

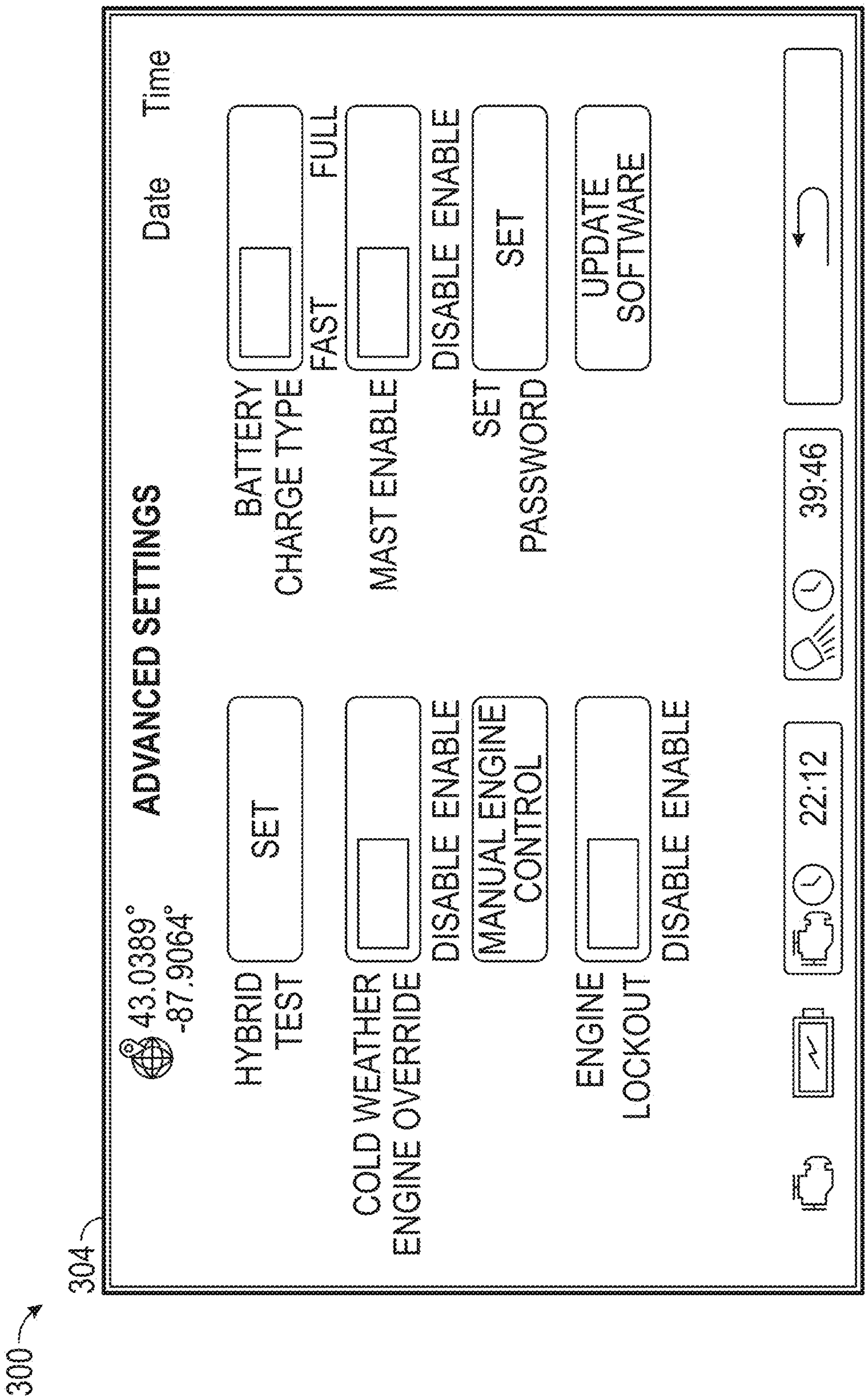

300
304
43.0389°
-87.9064°
ADVANCED SETTINGS
Date
Time
HYBRID TEST
SET
BATTERY CHARGE TYPE
FAST
FULL
COLD WEATHER ENGINE OVERRIDE
DISABLE ENABLE
MAST ENABLE
DISABLE ENABLE
MANUAL ENGINE CONTROL
SET PASSWORD
SET
ENGINE LOCKOUT
DISABLE ENABLE
UPDATE SOFTWARE
22:12
39:46

FIG. 44

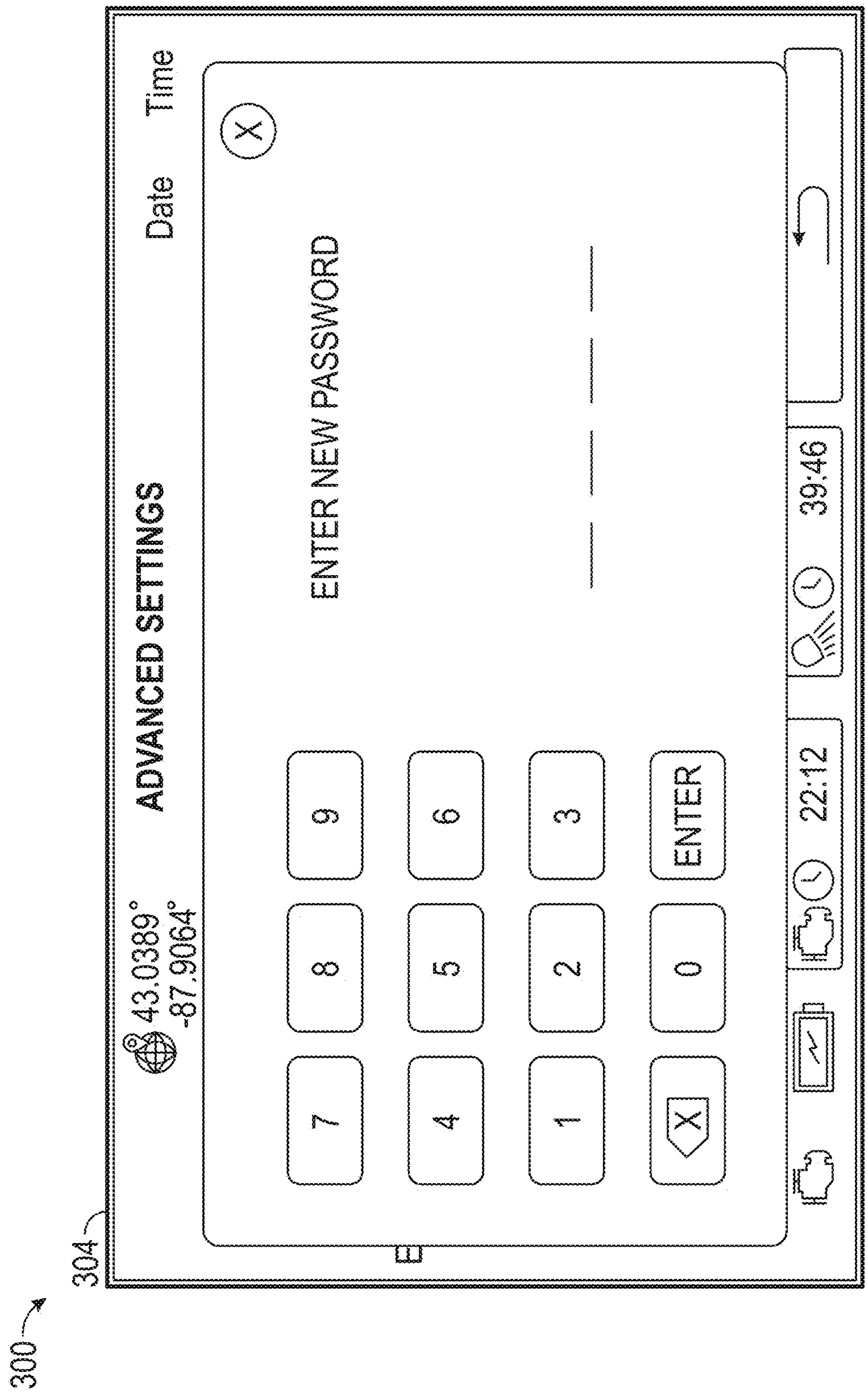

300
304
43.0389°
-87.9064°
ADVANCED SETTINGS
Date
Time
ENTER NEW PASSWORD
7
8
9
4
5
6
1
2
3
0
ENTER
22:12
39:46

FIG. 45

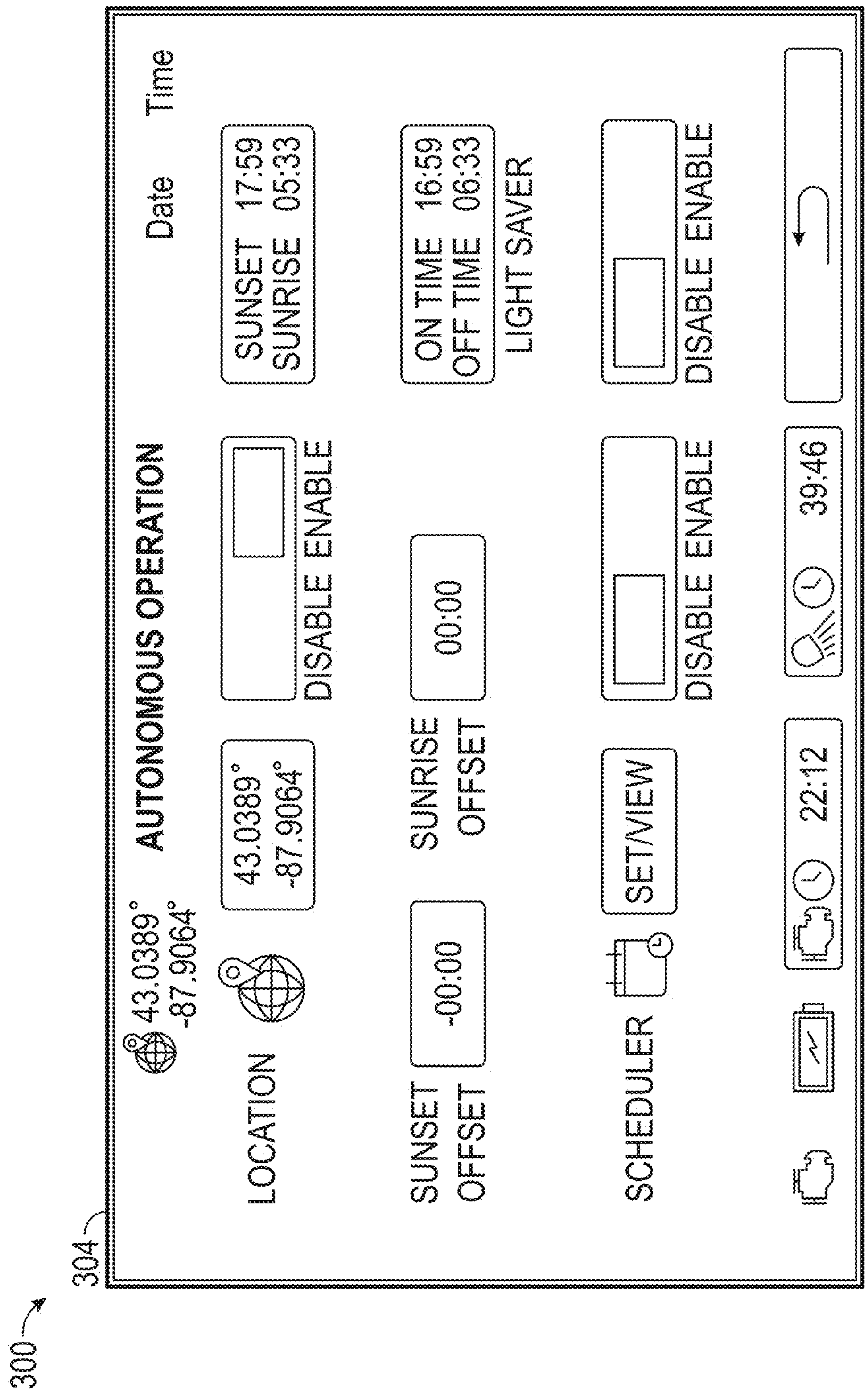

300
304
AUTONOMOUS OPERATION
Date
Time
43.0389°
-87.9064°
LOCATION
43.0389°
-87.9064°
DISABLE ENABLE
SUNSET 17:59
SUNRISE 05:33
SUNSET OFFSET
-00:00
SUNRISE OFFSET
00:00
ON TIME 16:59
OFF TIME 06:33
LIGHT SAVER
SCHEDULER
SET/VIEW
DISABLE ENABLE
DISABLE ENABLE
22:12
39:46

FIG. 46

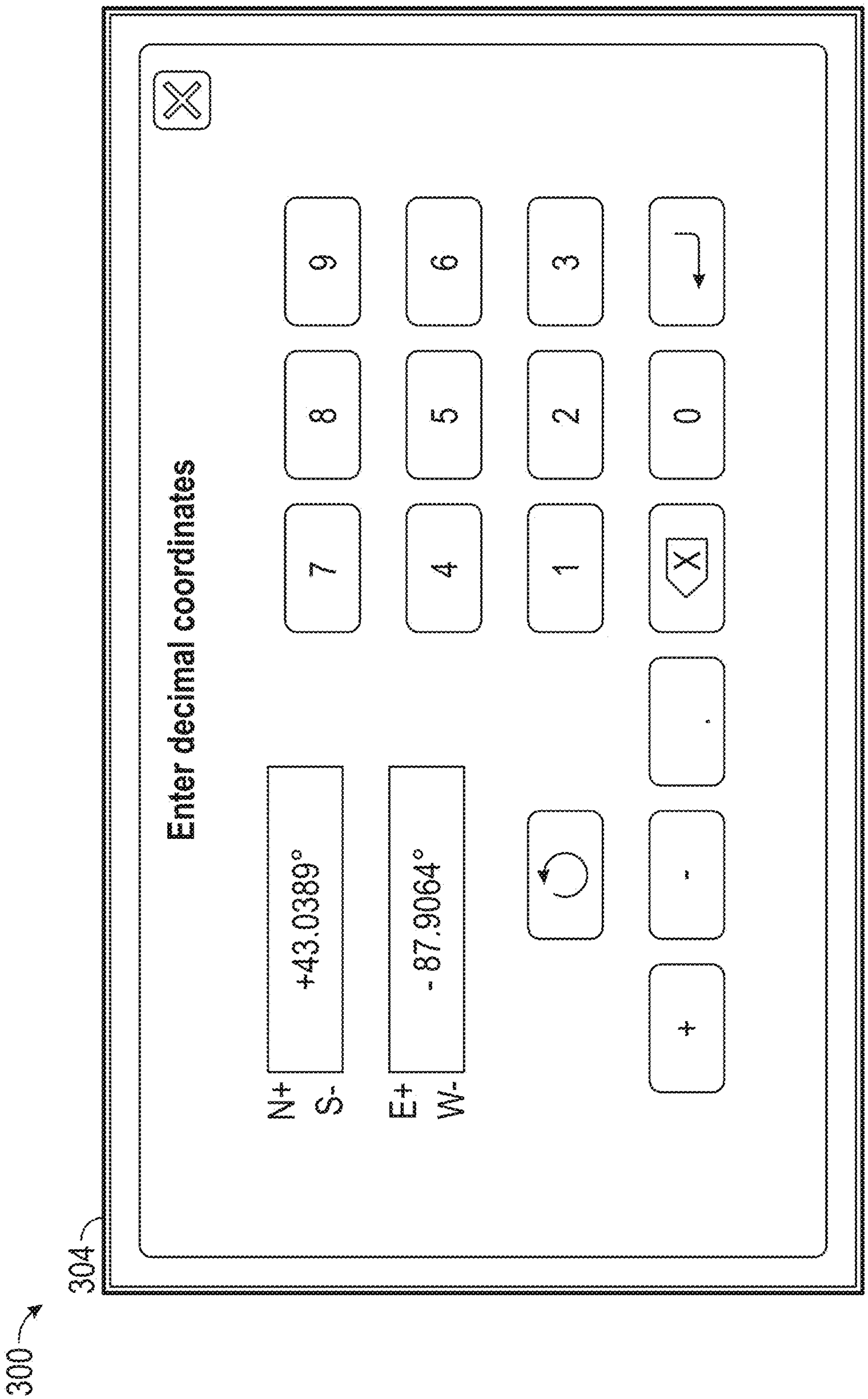

300
304
Enter decimal coordinates
N+
S-
+43.0389°
E+
W-
-87.9064°
7
8
9
4
5
6
1
2
3
0
+
-
.

FIG. 47

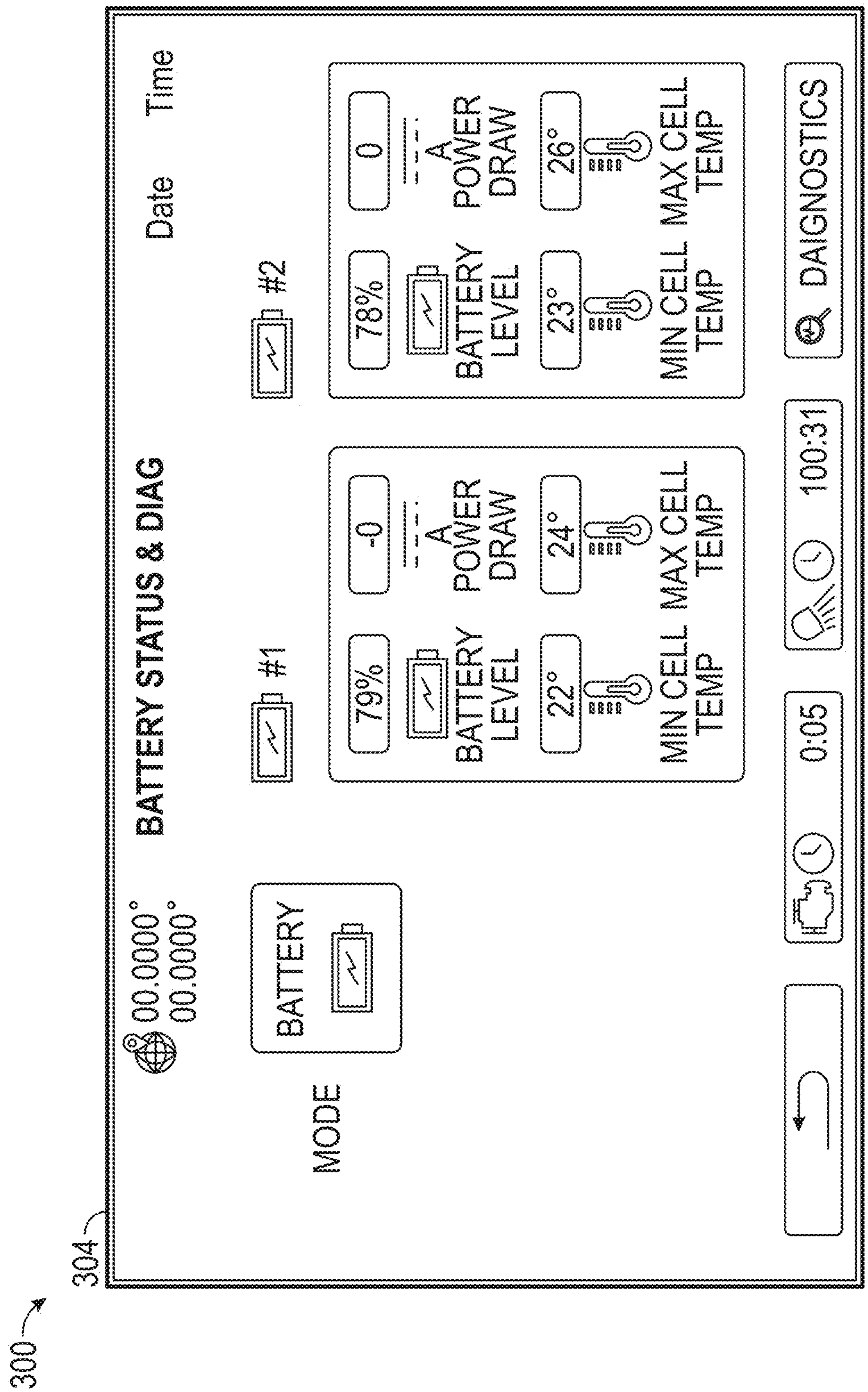

300
304
BATTERY STATUS & DIAG
Date
Time
00.0000°
00.0000°
MODE
BATTERY
#1
79%
BATTERY LEVEL
-0
A
POWER DRAW
22°
MIN CELL TEMP
24°
MAX CELL TEMP
#2
78%
BATTERY LEVEL
0
A
POWER DRAW
23°
MIN CELL TEMP
26°
MAX CELL TEMP
0:05
100:31
DAIGNOSTICS

FIG. 48

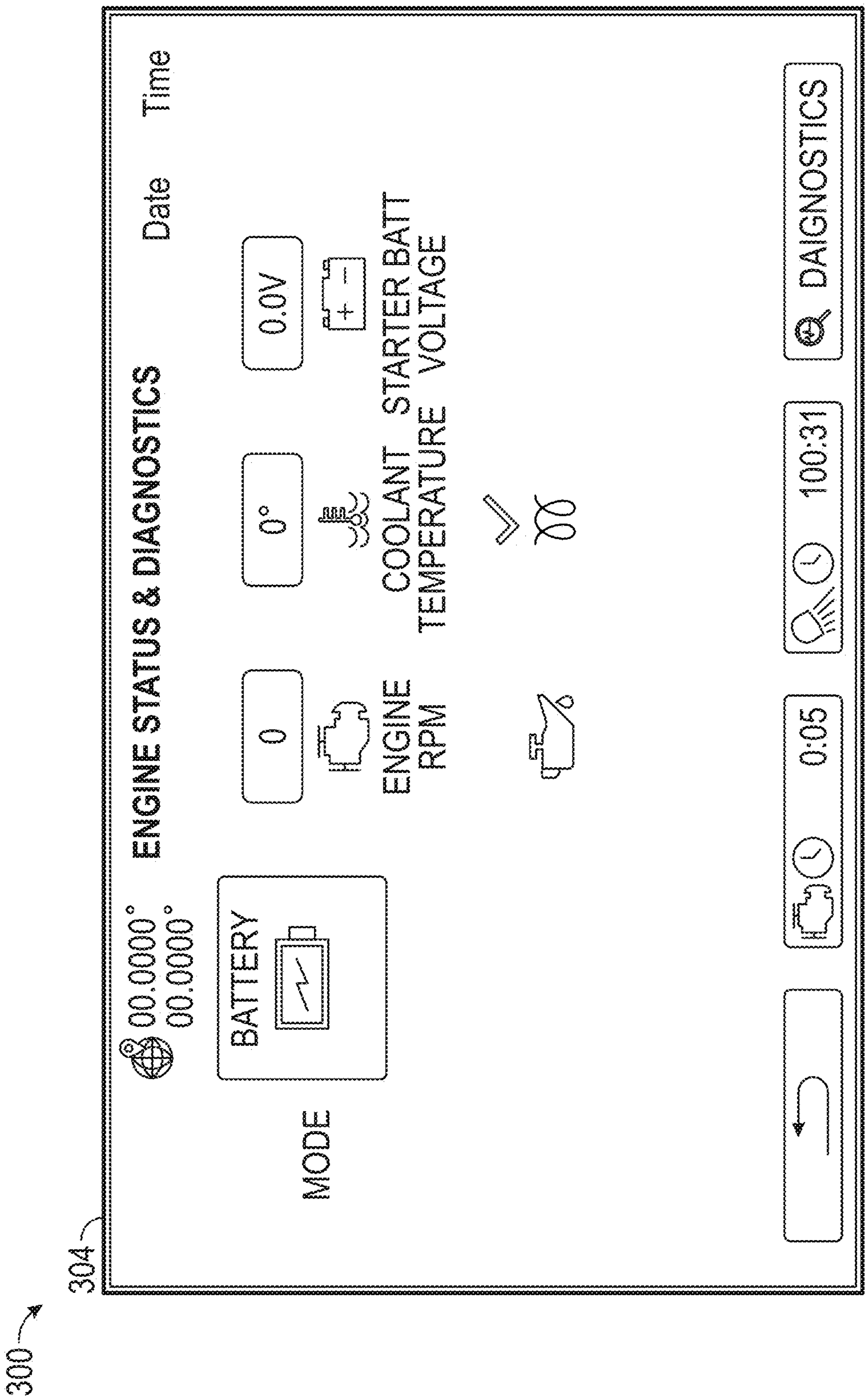

300
304
ENGINE STATUS & DIAGNOSTICS
Date
Time
00.0000°
00.0000°
BATTERY
MODE
0
ENGINE RPM
0°
COOLANT TEMPERATURE
0.0V
STARTER BATT VOLTAGE
0:05
100:31
DAIGNOSTICS

FIG. 49

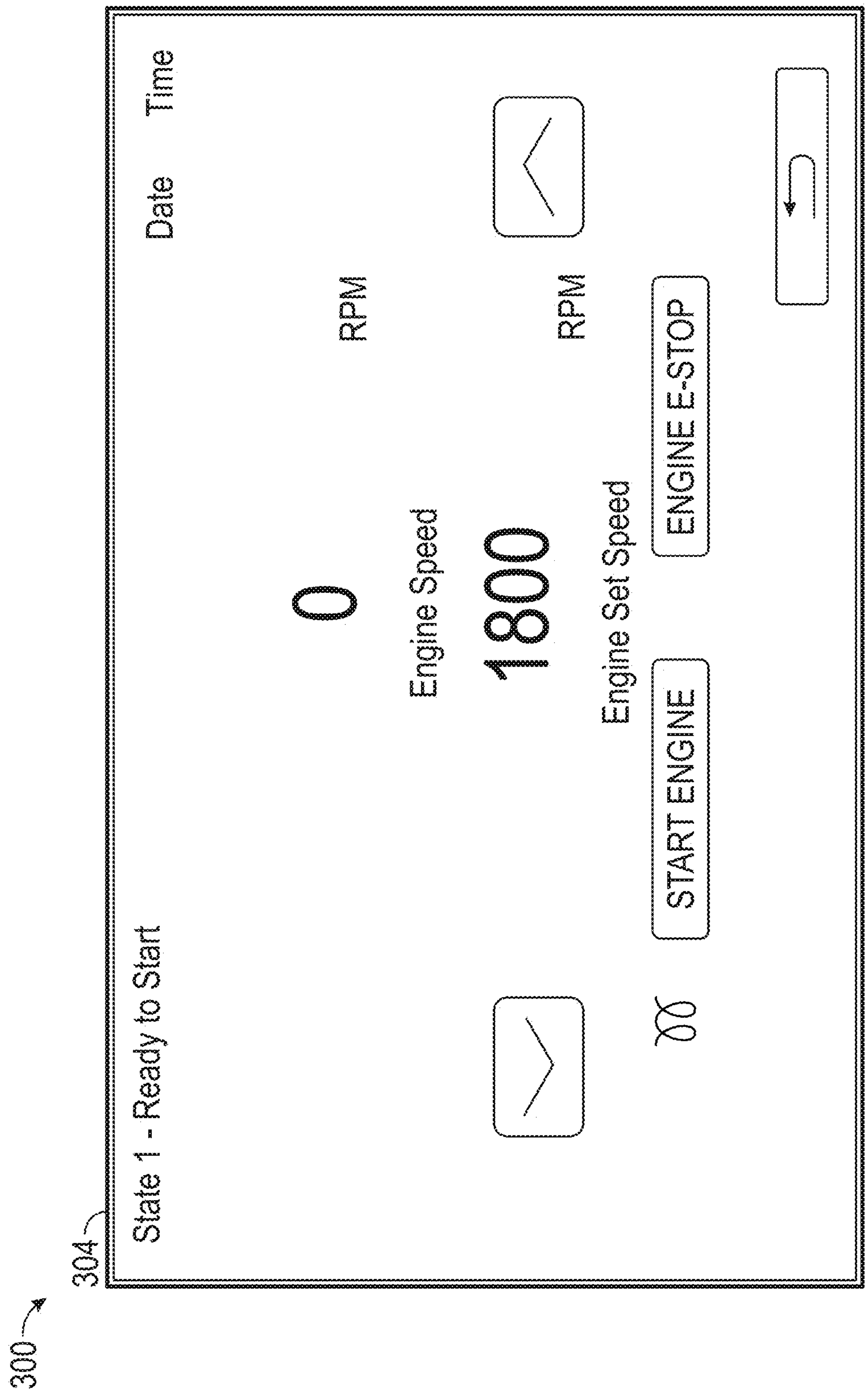

300
304
State 1 - Ready to Start
Date
Time
0
RPM
Engine Speed
1800
RPM
Engine Set Speed
START ENGINE
ENGINE E-STOP

FIG. 50

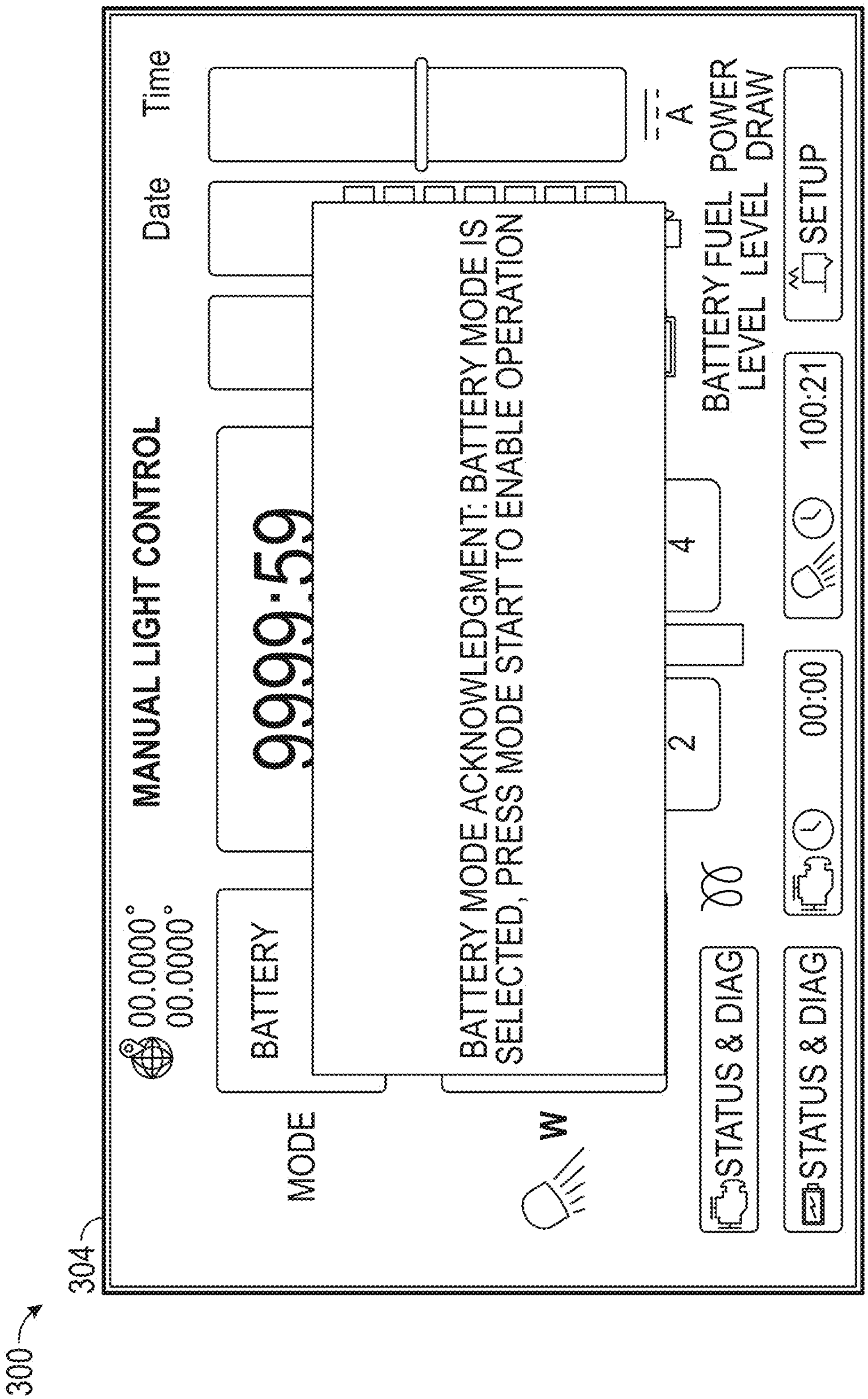

300
304
MANUAL LIGHT CONTROL
00.0000°
00.0000°
Date
Time
MODE
BATTERY
9999:59
W
BATTERY MODE ACKNOWLEDGMENT: BATTERY MODE IS SELECTED, PRESS MODE START TO ENABLE OPERATION
2
4
A
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 51

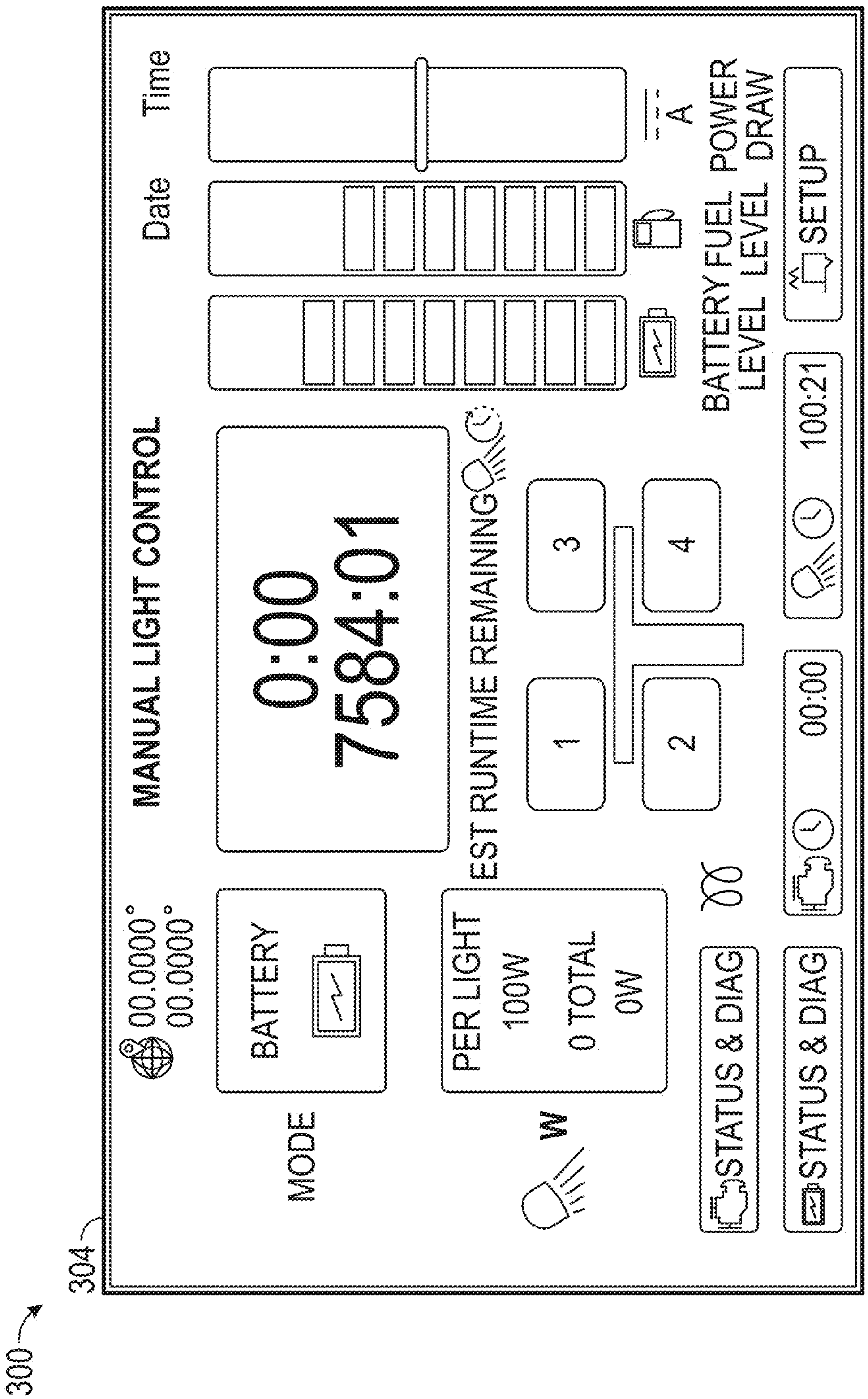

300
304
00.0000°
00.0000°
MANUAL LIGHT CONTROL
Date
Time
MODE
BATTERY
0:00
7584:01
EST RUNTIME REMAINING
W
PER LIGHT
100W
0 TOTAL
0W
1
2
3
4
A
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 52

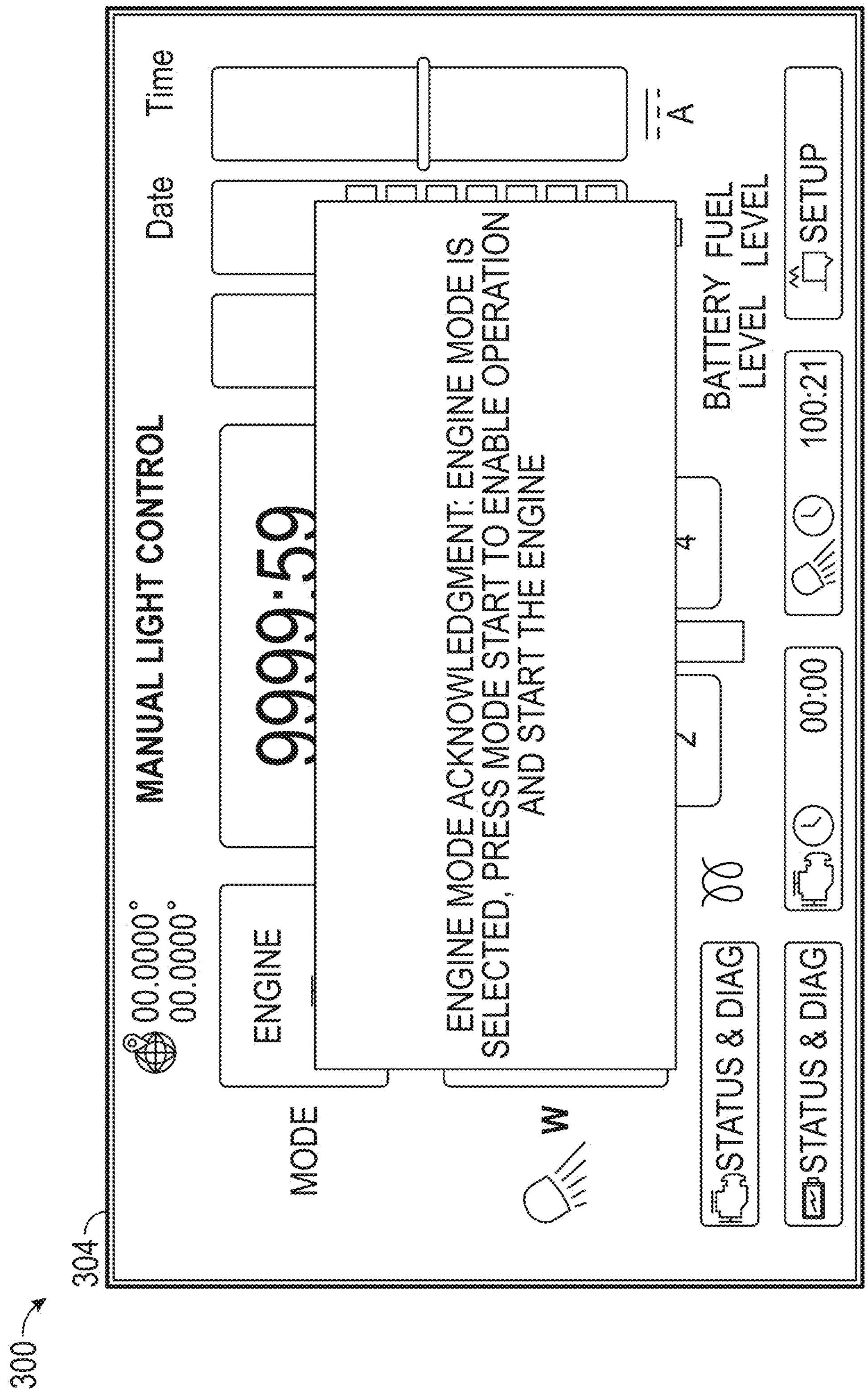

300
304
MANUAL LIGHT CONTROL
Date
Time
00.0000°
00.0000°
MODE
ENGINE
9999:59
W
2
4
ENGINE MODE ACKNOWLEDGMENT: ENGINE MODE IS SELECTED, PRESS MODE START TO ENABLE OPERATION AND START THE ENGINE
BATTERY LEVEL
FUEL LEVEL
A
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 53

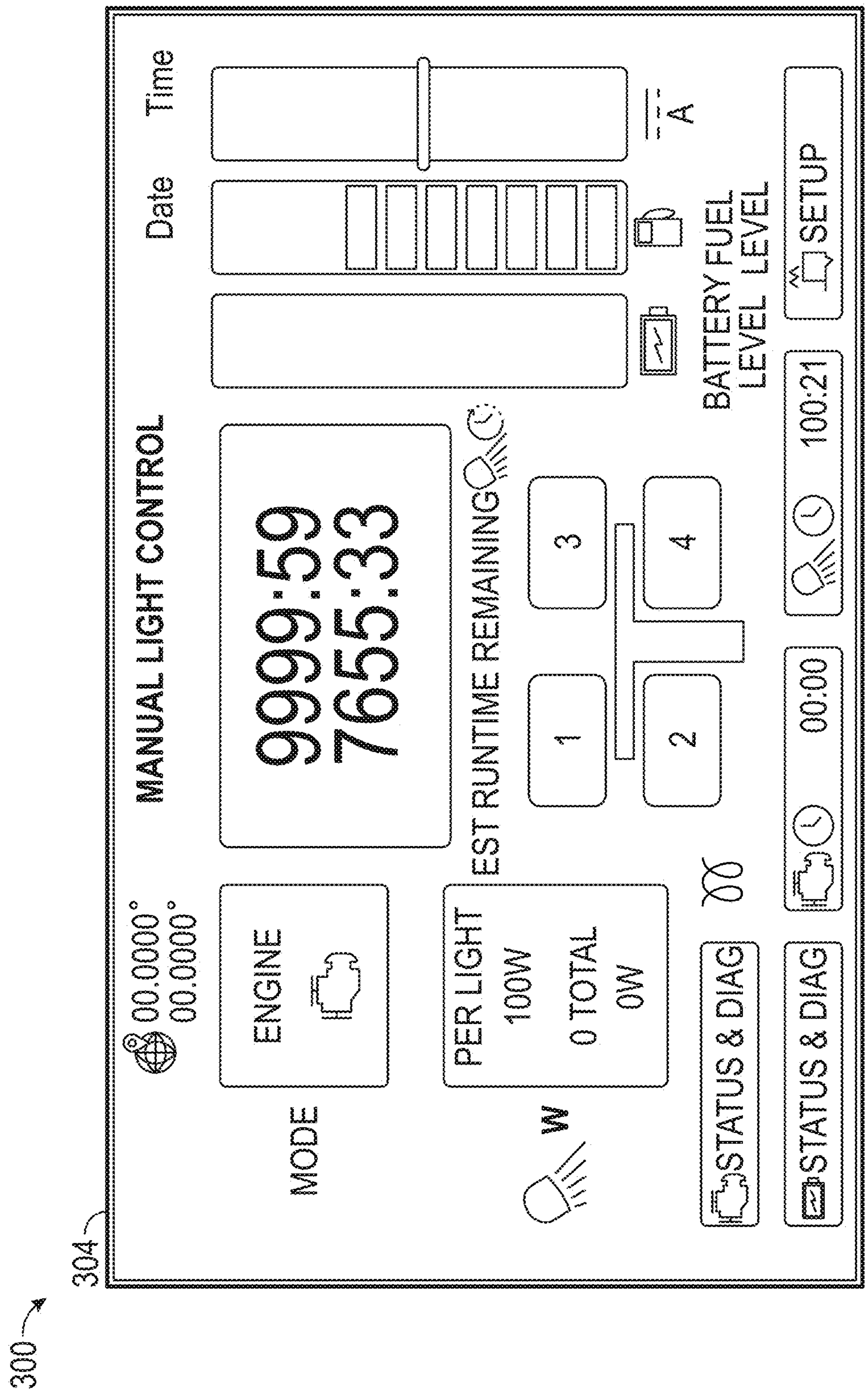

300
304
MANUAL LIGHT CONTROL
Date
Time
00.0000°
00.0000°
MODE
ENGINE
9999:59
7655:33
EST RUNTIME REMAINING
PER LIGHT
100W
0 TOTAL
0W
W
1
2
3
4
BATTERY LEVEL
FUEL LEVEL
A
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 54

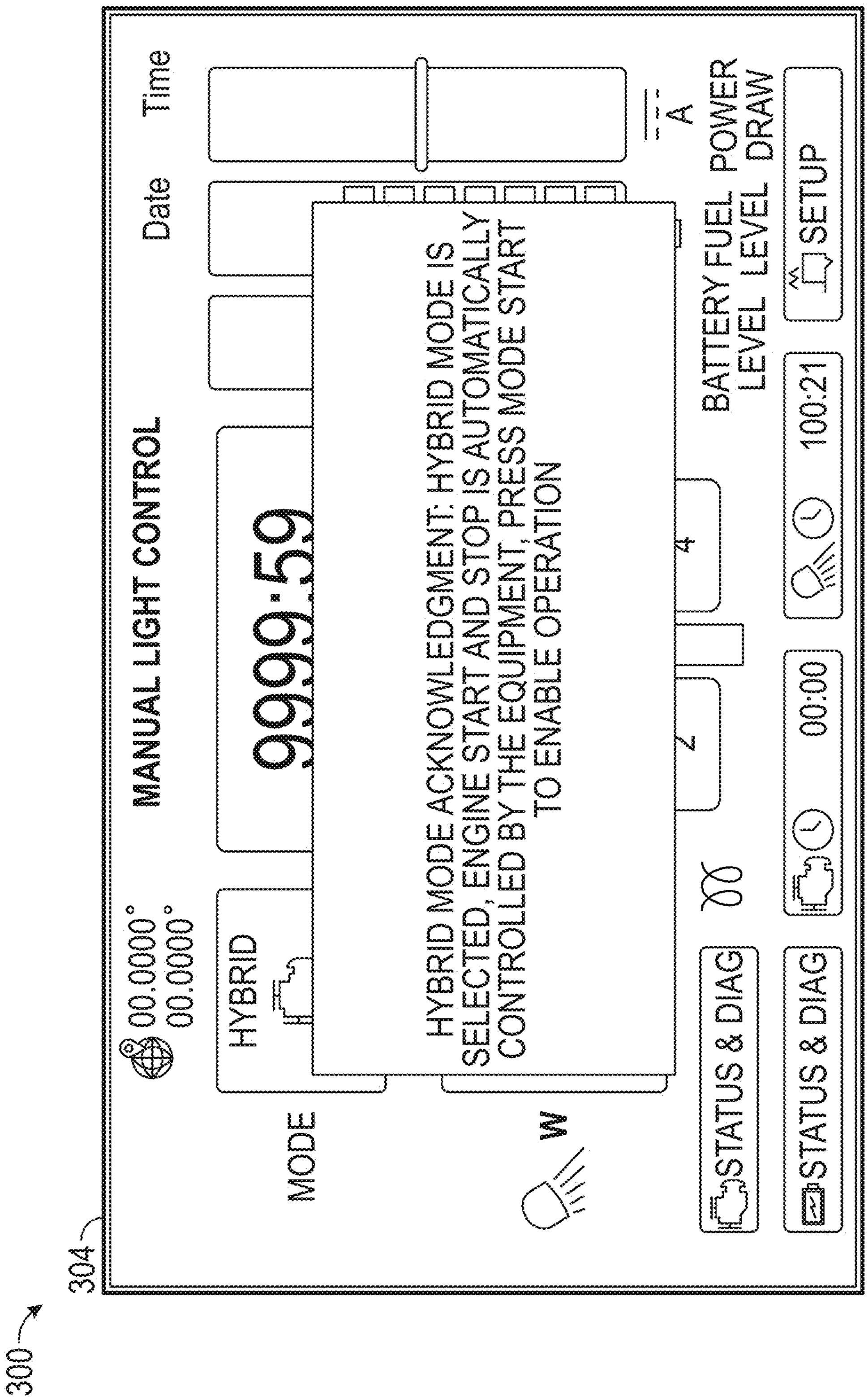

MANUAL LIGHT CONTROL
Date
Time
00.0000°
00.0000°
MODE
HYBRID
9999:59
W
HYBRID MODE ACKNOWLEDGMENT: HYBRID MODE IS SELECTED, ENGINE START AND STOP IS AUTOMATICALLY CONTROLLED BY THE EQUIPMENT, PRESS MODE START TO ENABLE OPERATION
2
4
A
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP
300
304

FIG. 55

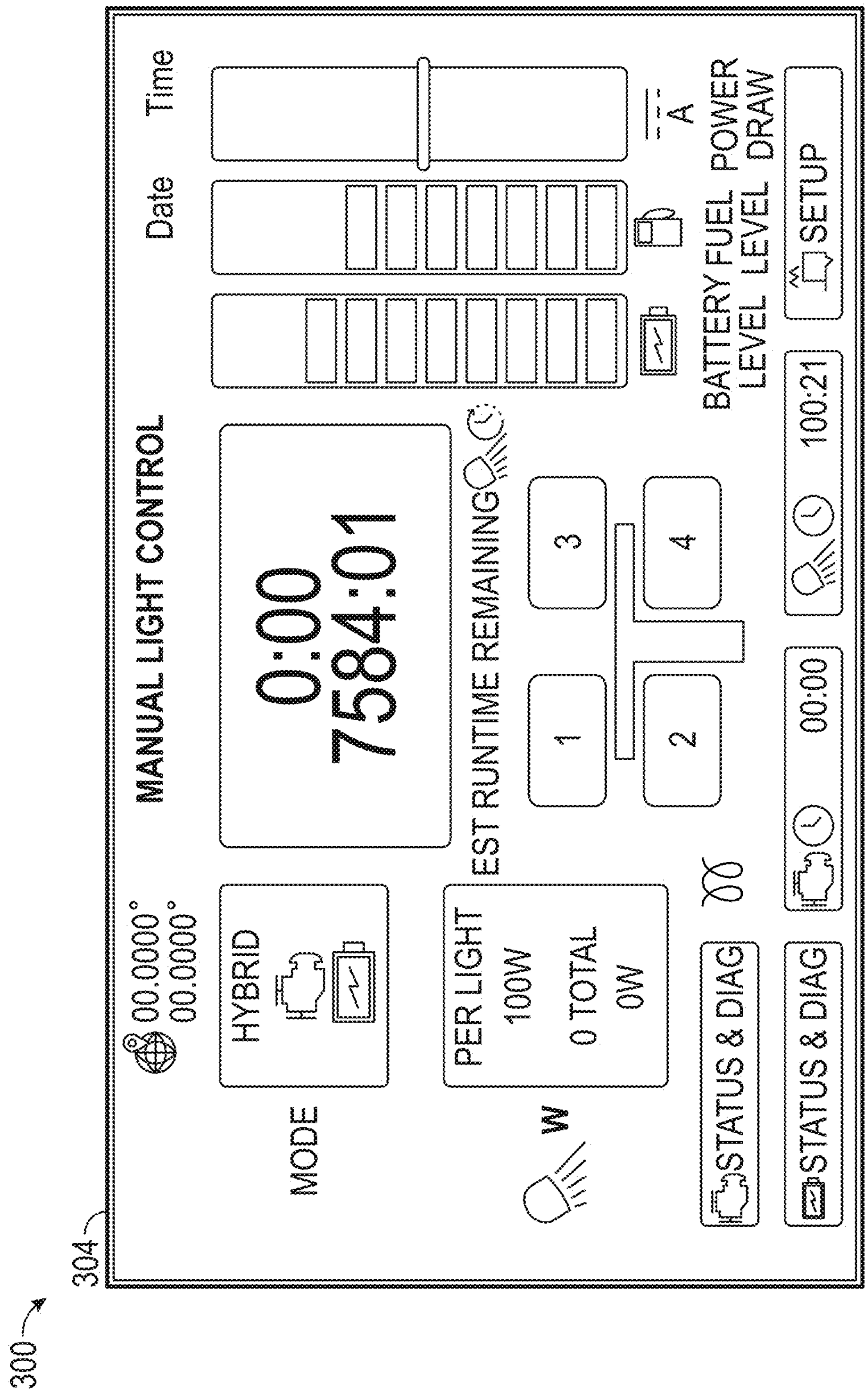

300
304
MANUAL LIGHT CONTROL
00.0000°
00.0000°
Date
Time
MODE
HYBRID
0:00
7584:01
EST RUNTIME REMAINING
PER LIGHT
100W
0 TOTAL
0W
W
1
2
3
4
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
A
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 56

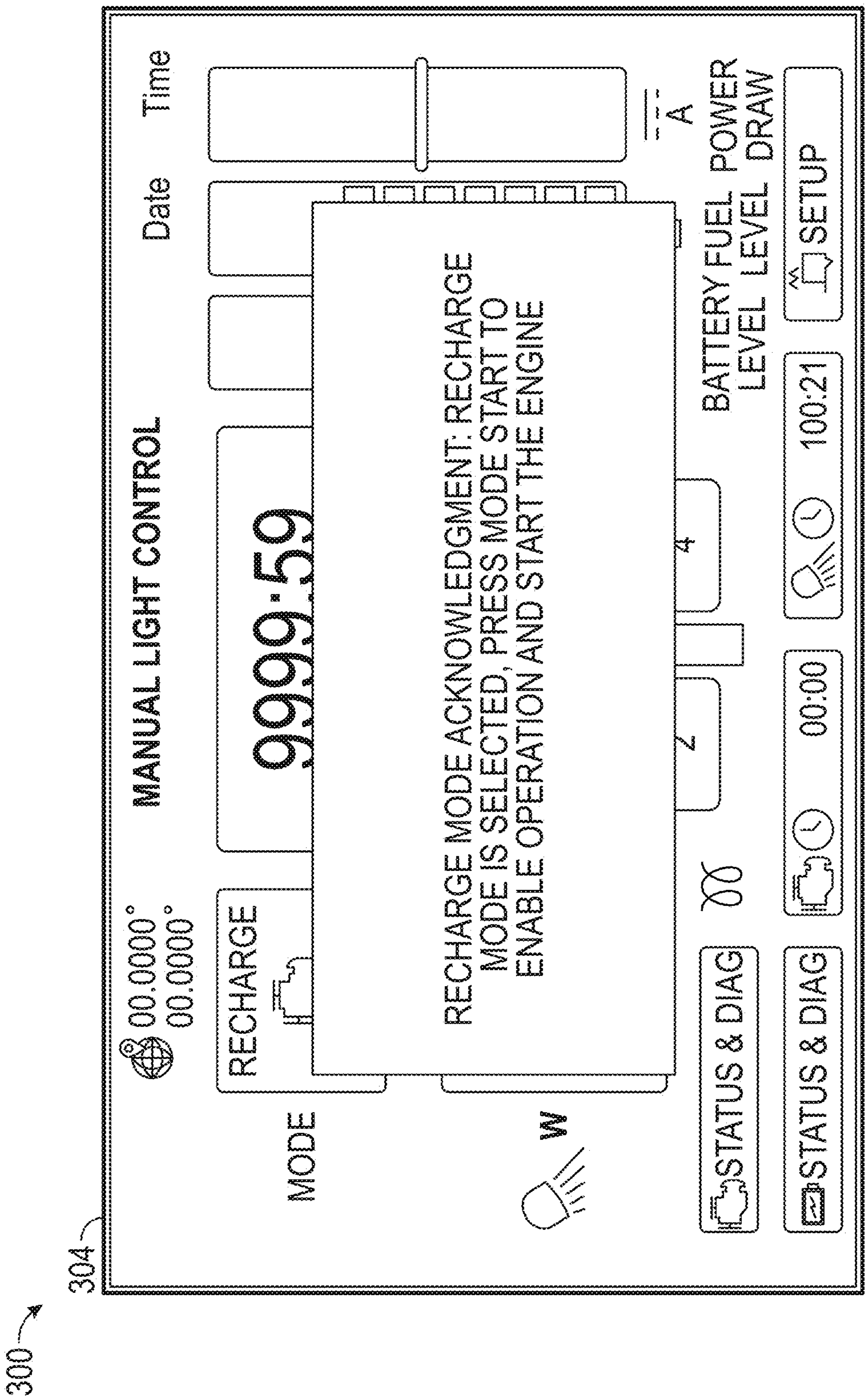

300
304
MANUAL LIGHT CONTROL
Date
Time
00.0000°
00.0000°
MODE
RECHARGE
W
9999:59
RECHARGE MODE ACKNOWLEDGMENT: RECHARGE MODE IS SELECTED, PRESS MODE START TO ENABLE OPERATION AND START THE ENGINE
2
4
A
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 57

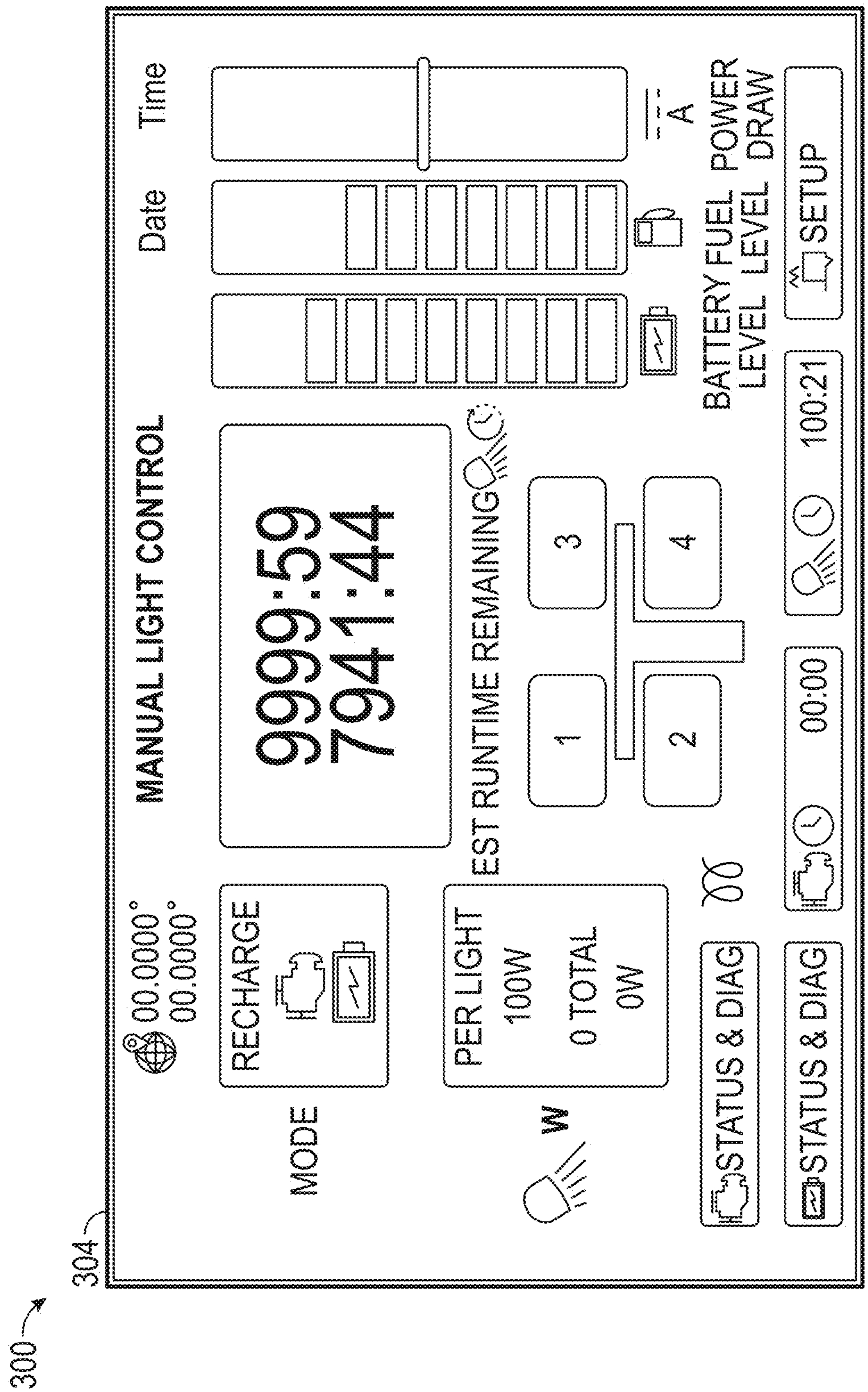

300
304
MANUAL LIGHT CONTROL
Date
Time
00.0000°
00.0000°
MODE
RECHARGE
9999:59
7941:44
EST RUNTIME REMAINING
W
PER LIGHT
100W
0 TOTAL
0W
1
2
3
4
A
BATTERY LEVEL
FUEL LEVEL
POWER DRAW
STATUS & DIAG
STATUS & DIAG
00:00
100:21
SETUP

FIG. 58

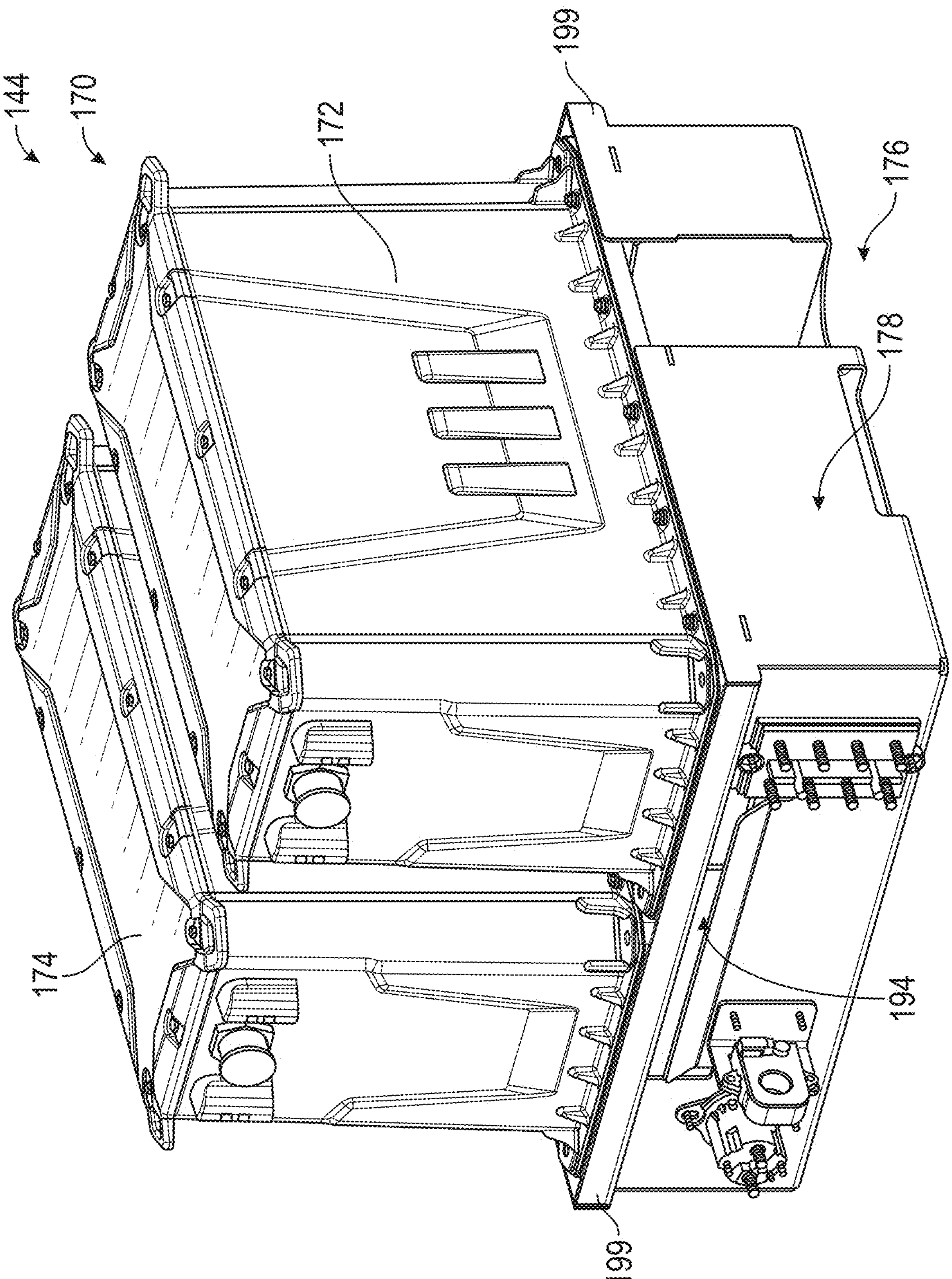


FIG. 59

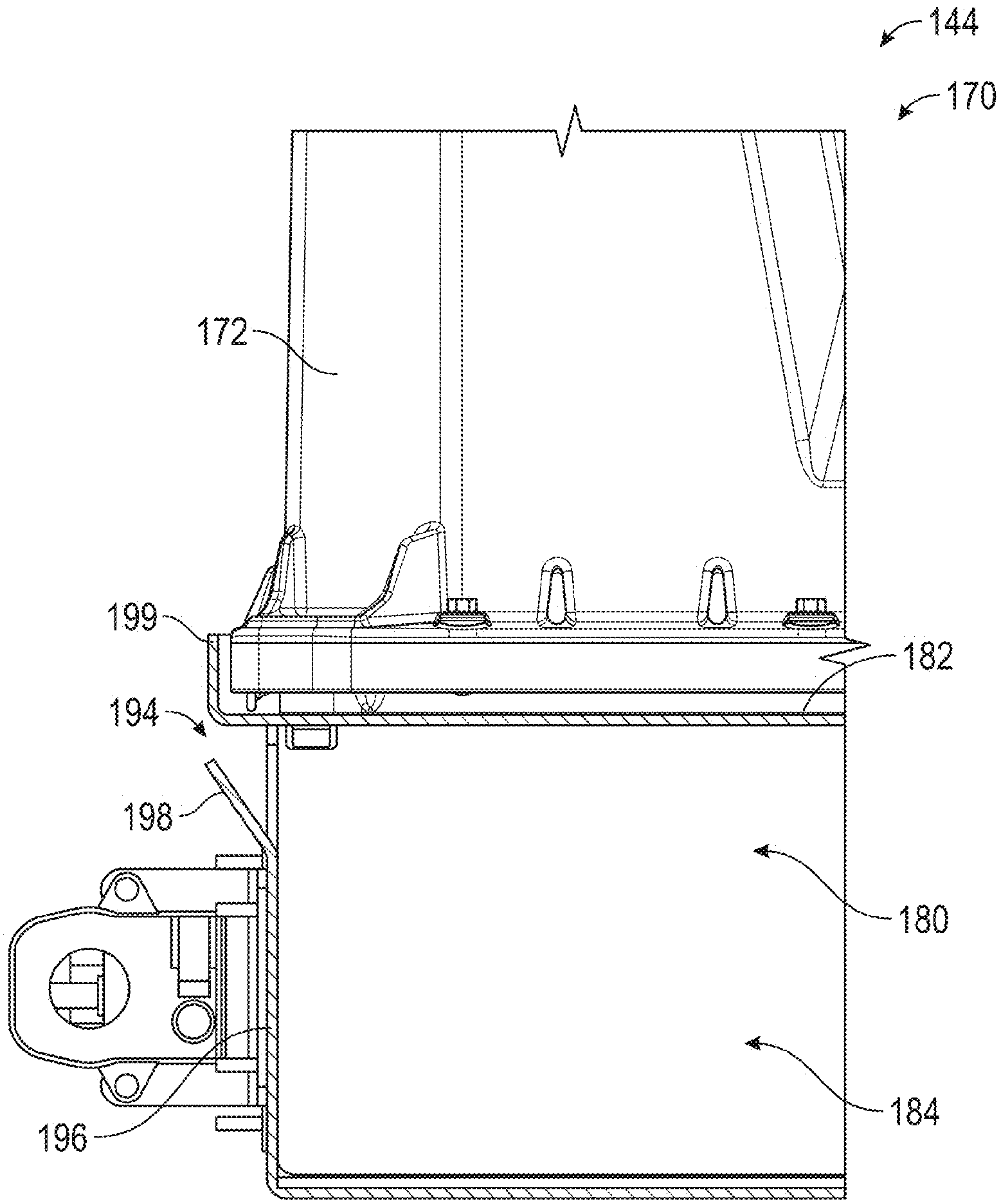


FIG. 60

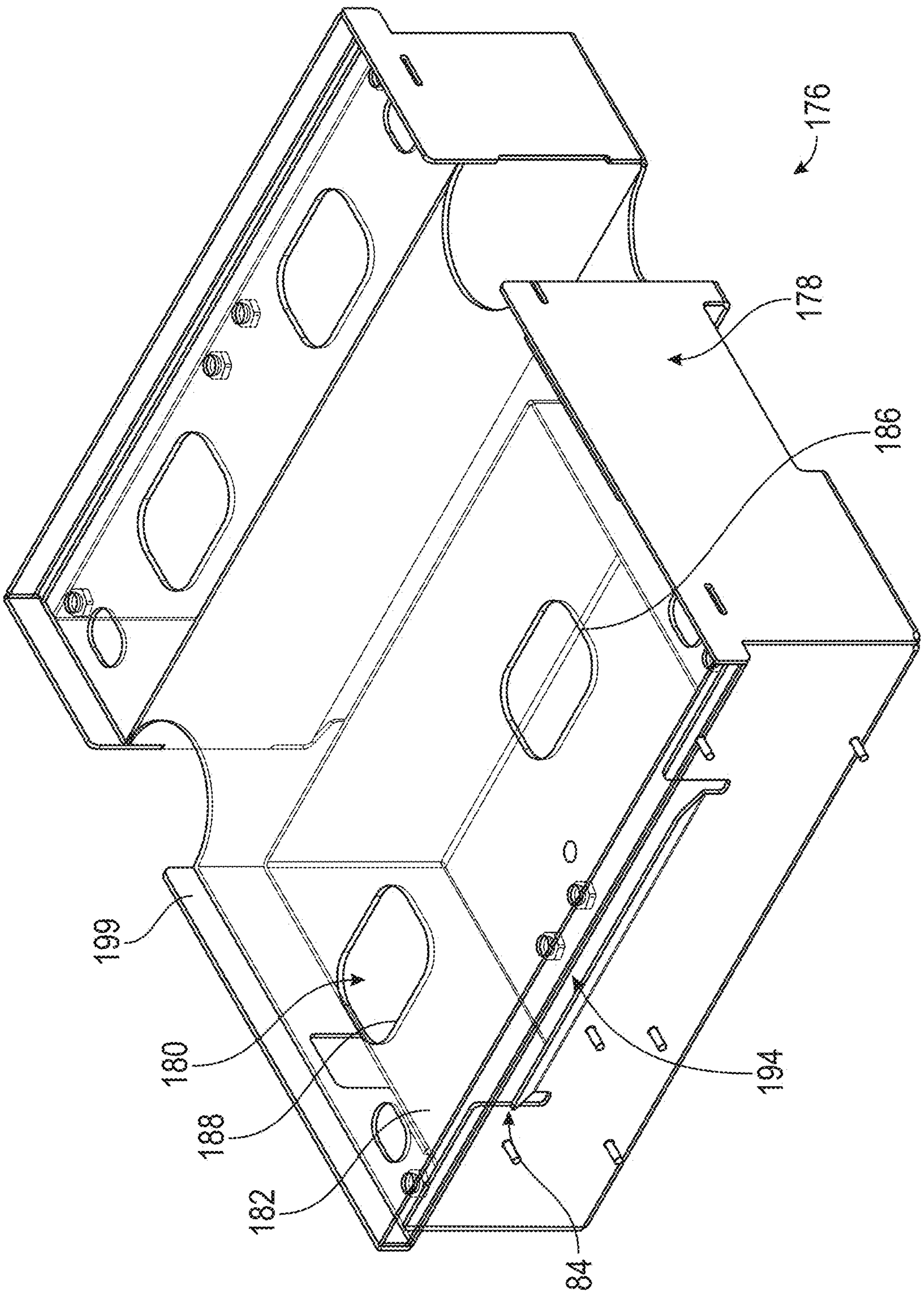


FIG. 61

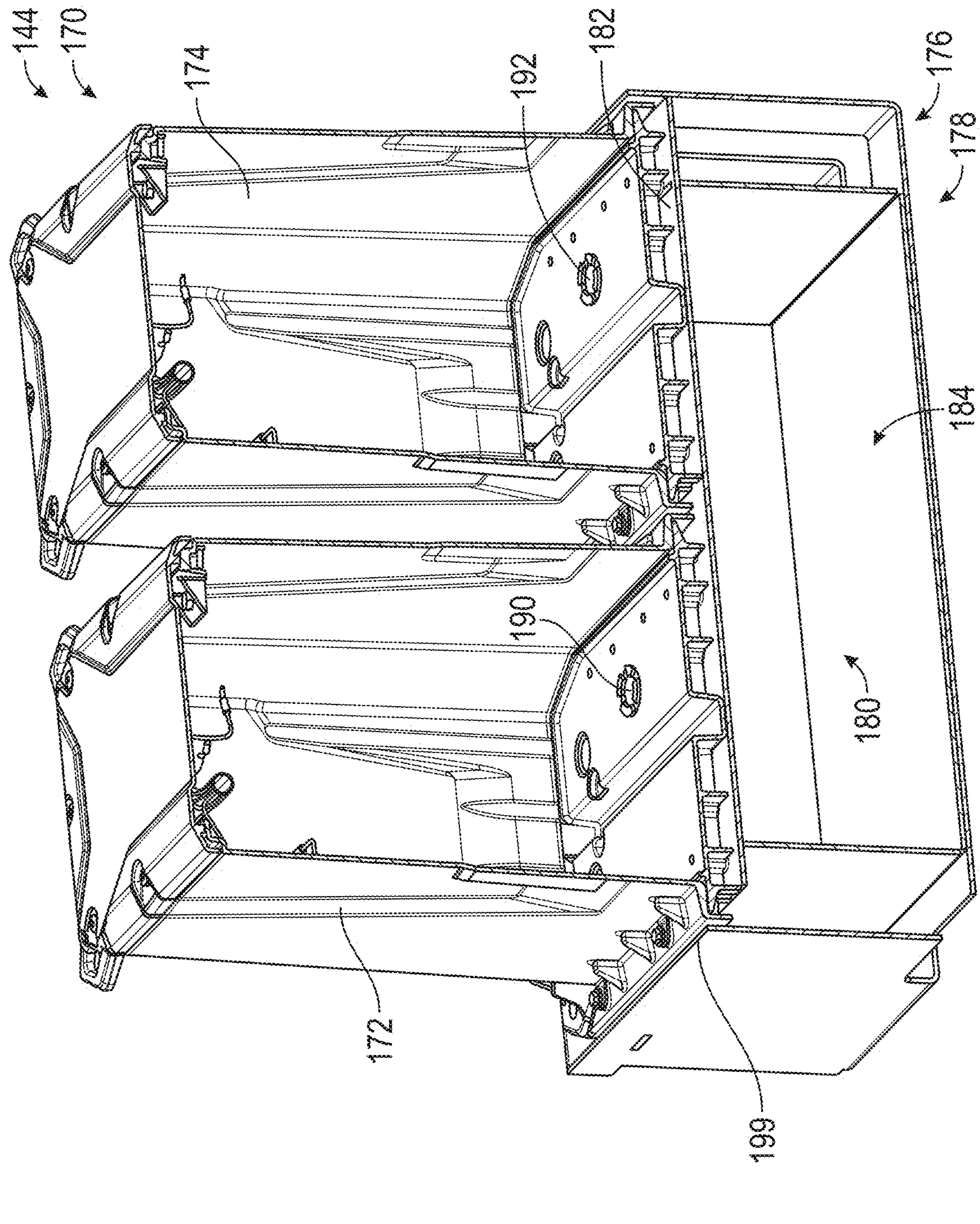


FIG. 62

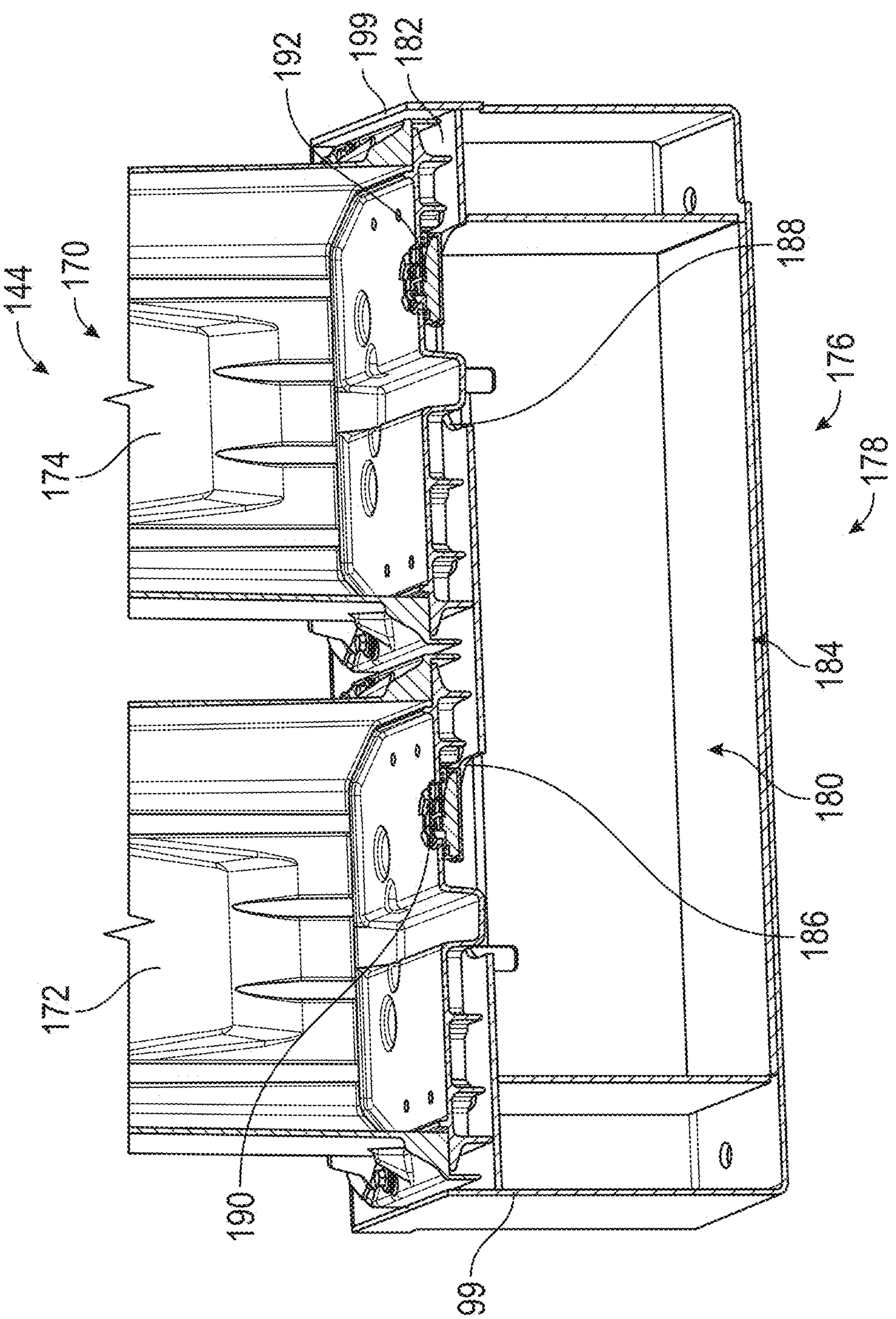


FIG. 63

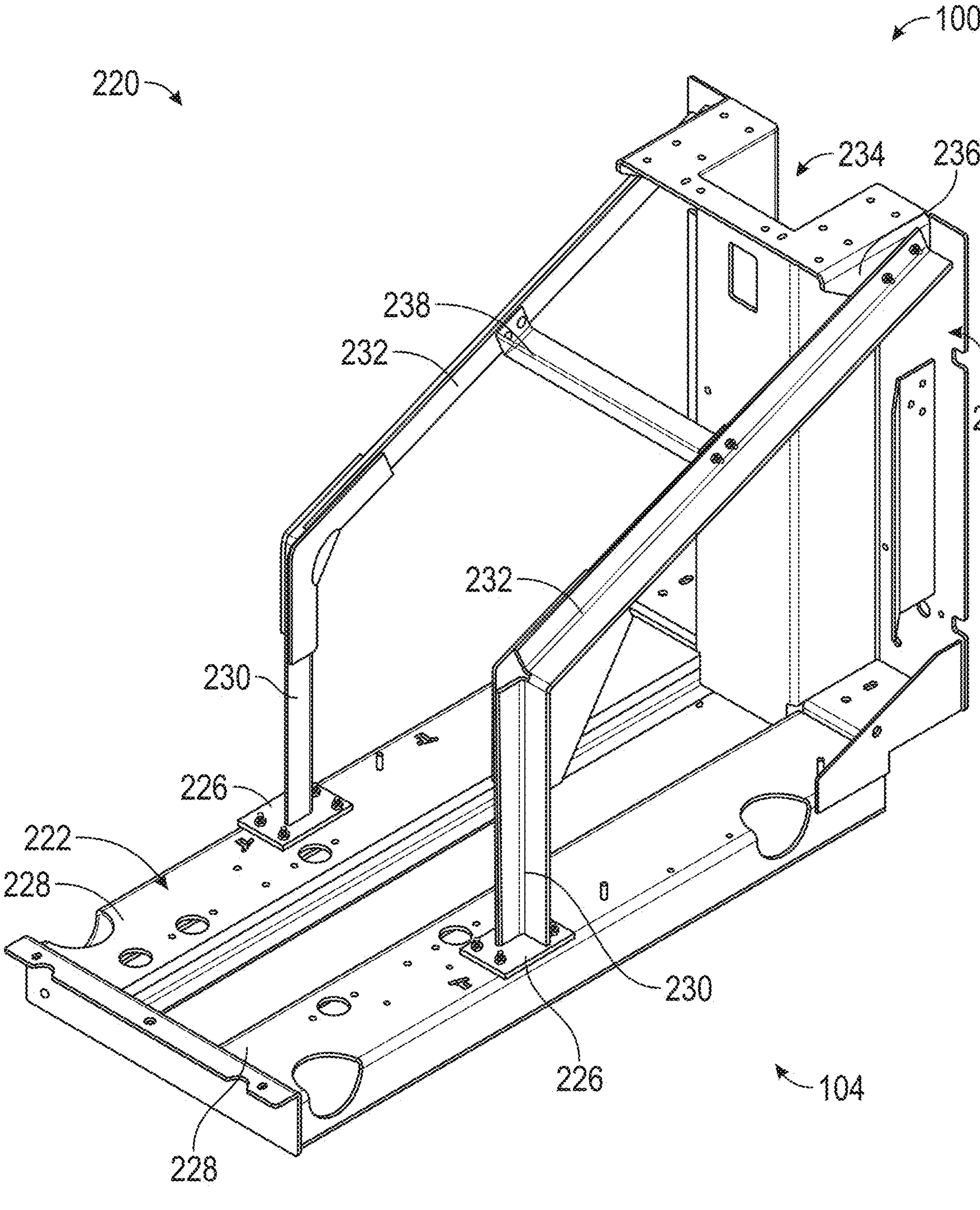


FIG. 64

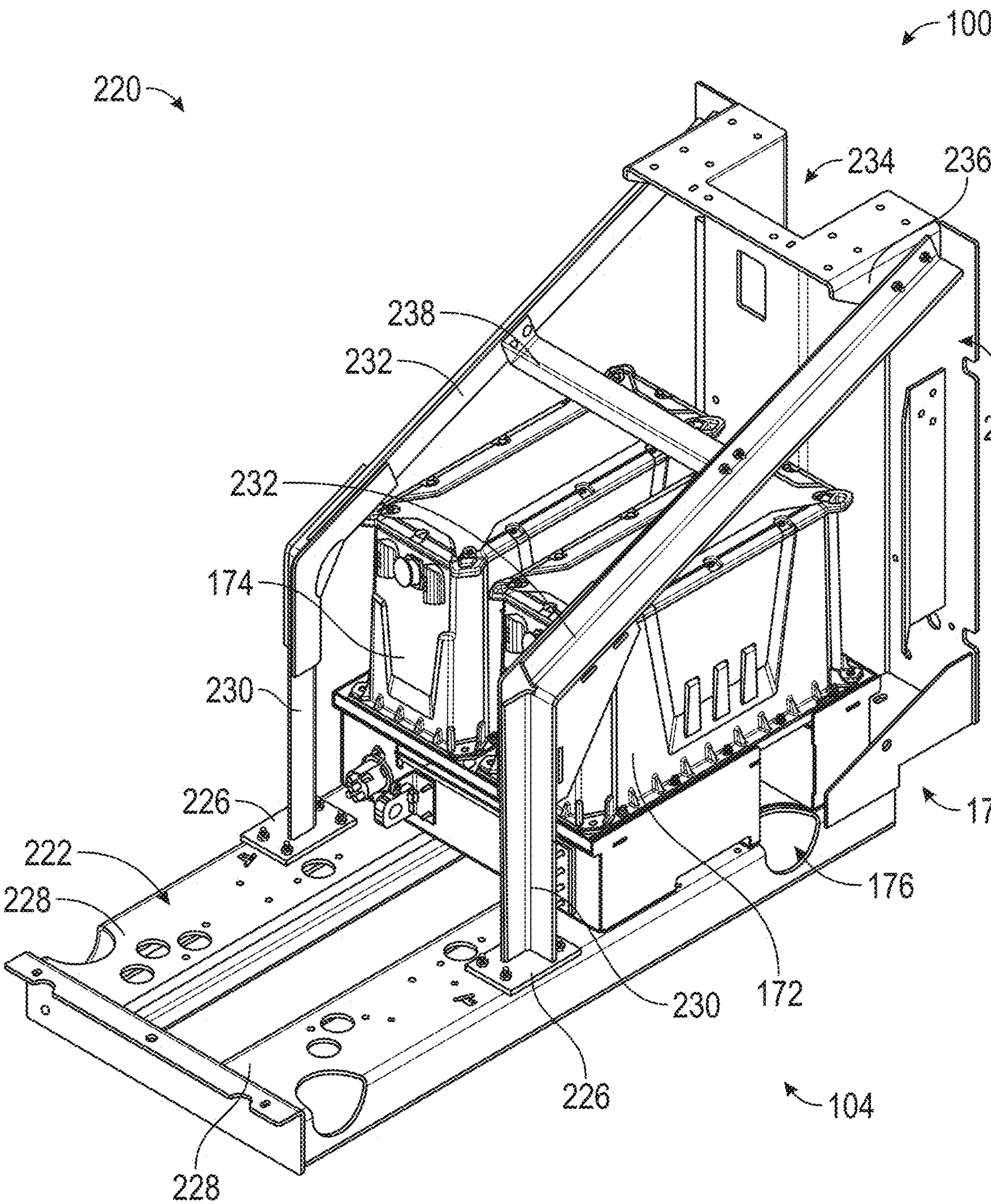

100
220
234
236
238
232
224
232
174
230
226
170
222
228
176
230
172
226
104
228

FIG. 65

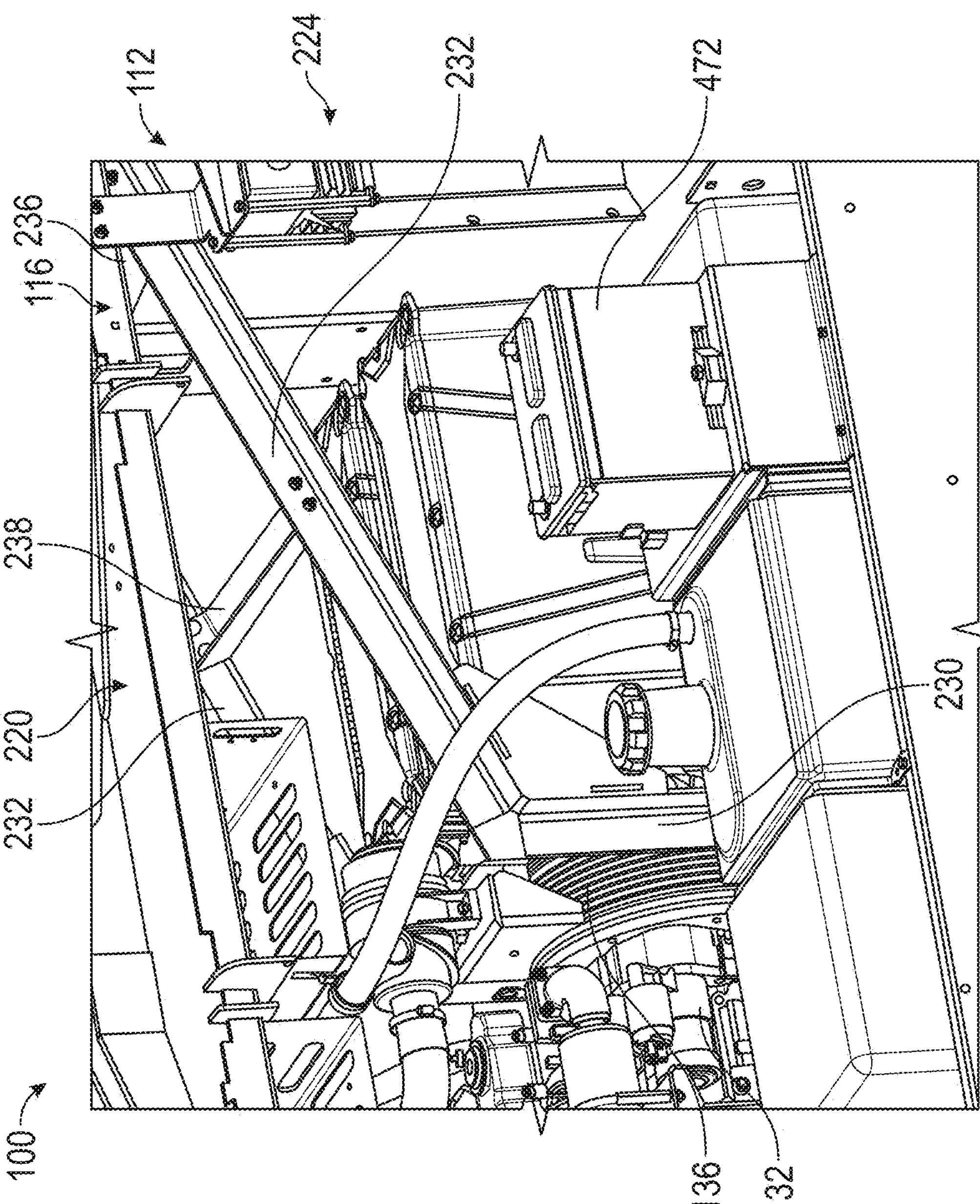


FIG. 66

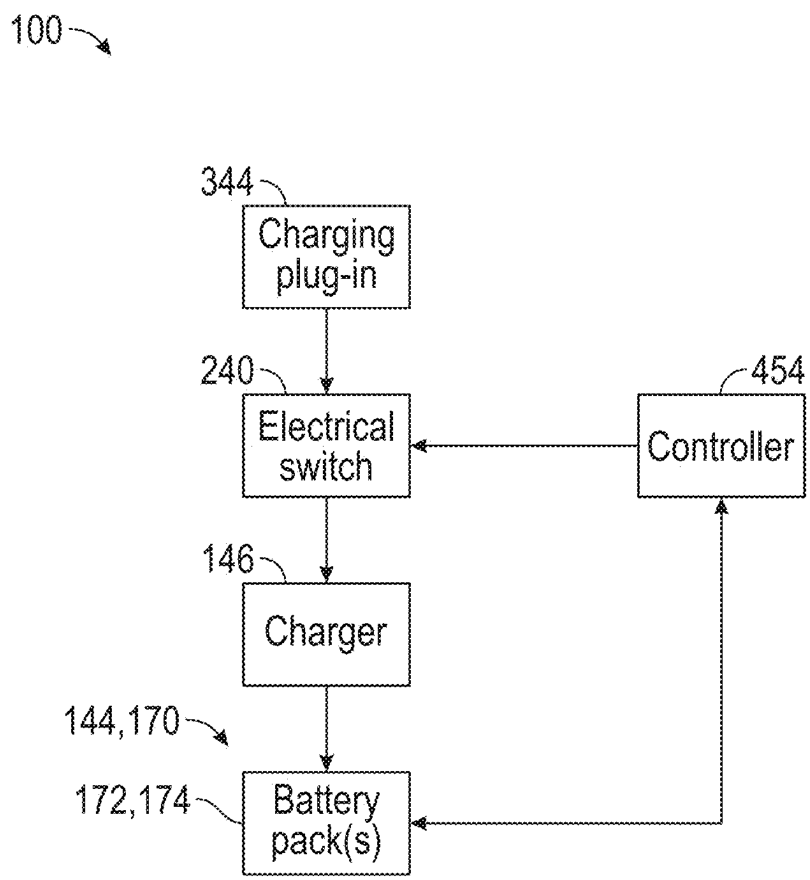

100
344
Charging plug-in
240
Electrical switch
454
Controller
146
Charger
144,170
172,174
Battery pack(s)

FIG. 67

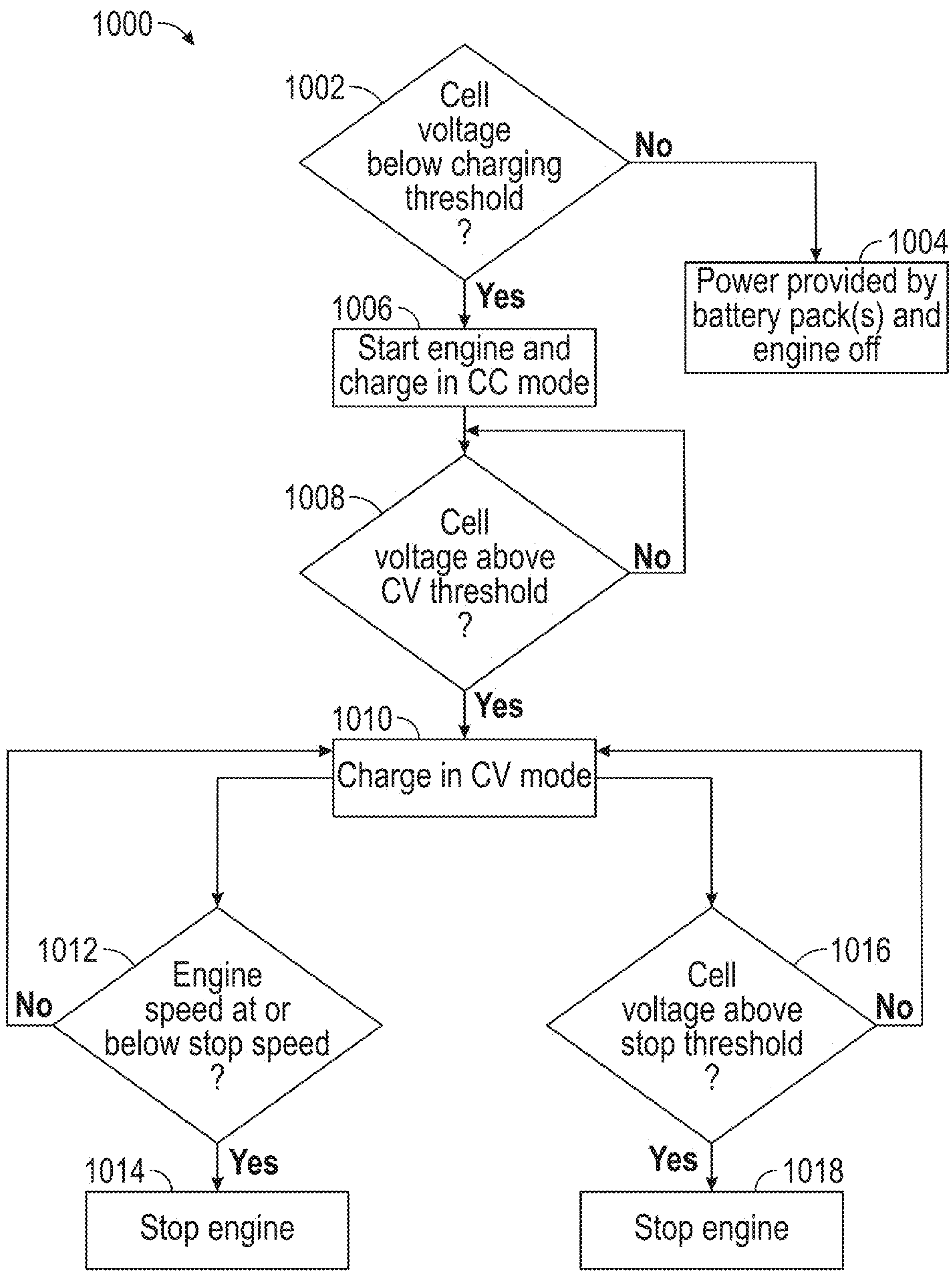

1000
1002
Cell voltage below charging threshold ?
No
1004
Power provided by battery pack(s) and engine off
Yes
1006
Start engine and charge in CC mode
1008
Cell voltage above CV threshold ?
No
Yes
1010
Charge in CV mode
1012
Engine speed at or below stop speed ?
No
1016
Cell voltage above stop threshold ?
No
Yes
1014
Stop engine
Yes
1018
Stop engine

FIG. 68

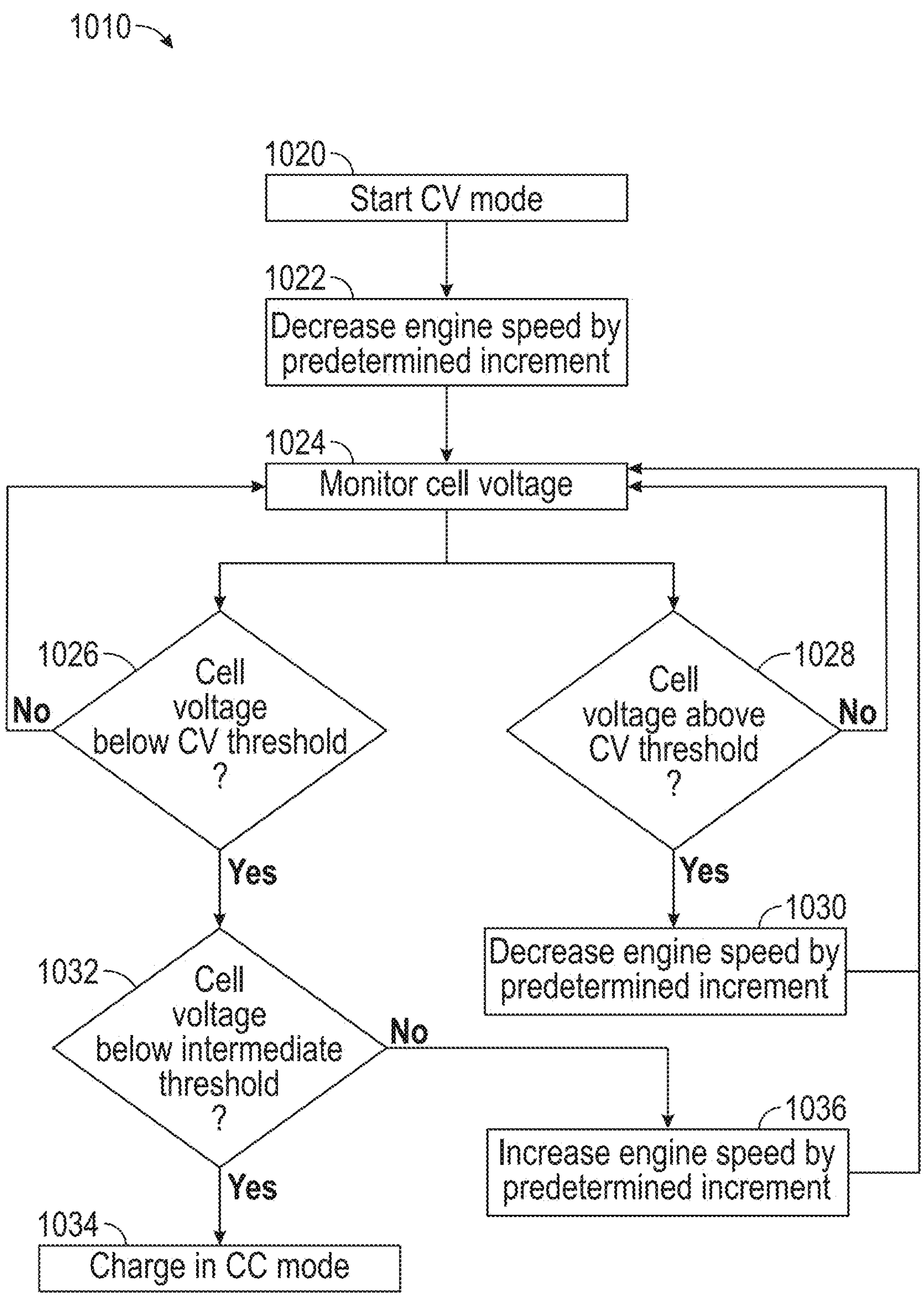

1010
1020
Start CV mode
1022
Decrease engine speed by predetermined increment
1024
Monitor cell voltage
1026
Cell voltage below CV threshold ?
No
Yes
1028
Cell voltage above CV threshold ?
No
Yes
1030
Decrease engine speed by predetermined increment
1032
Cell voltage below intermediate threshold ?
No
Yes
1036
Increase engine speed by predetermined increment
1034
Charge in CC mode

FIG. 69

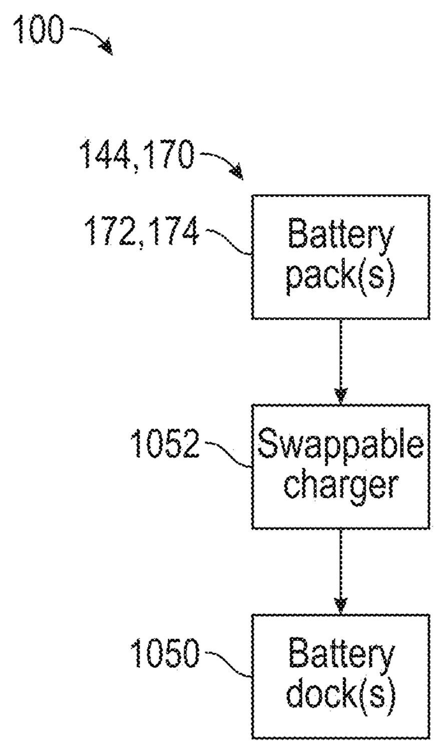

100
144,170
172,174
Battery pack(s)
1052
Swappable charger
1050
Battery dock(s)

FIG. 70

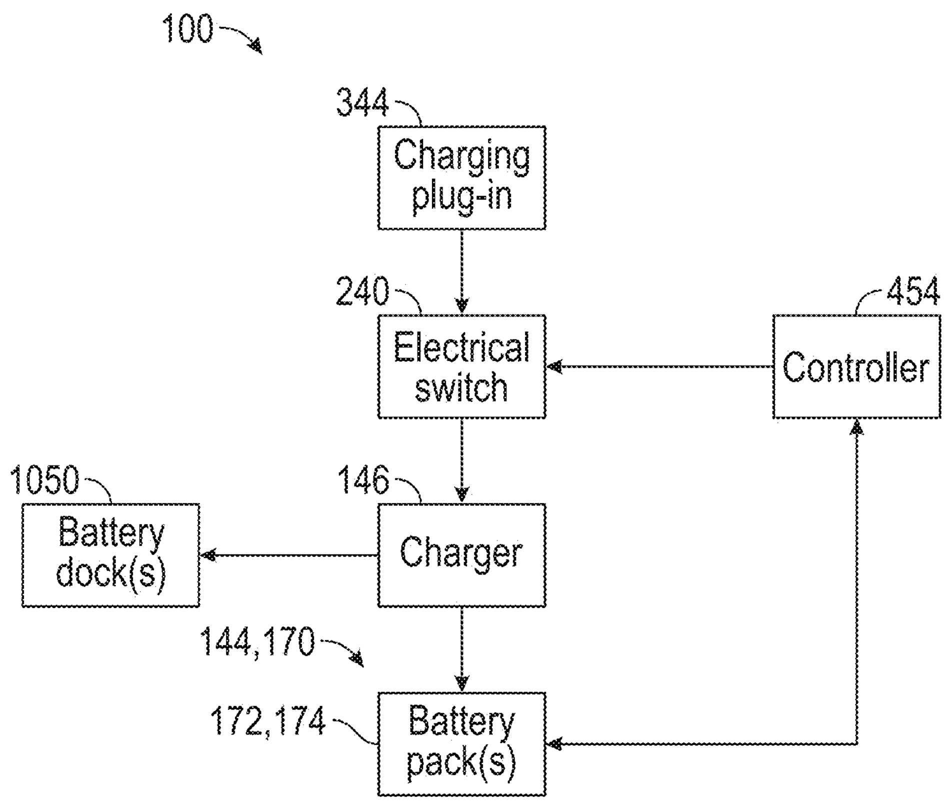

100
344
Charging plug-in
240
Electrical switch
454
Controller
1050
Battery dock(s)
146
Charger
144,170
172,174
Battery pack(s)

FIG. 71

HYBRID LIGHT TOWER

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/696,238, filed Sep. 18, 2024, and U.S. Provisional Patent Application No. 63/553,593, filed Feb. 14, 2024, each of which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Conventional portable light towers typically include one or more lights attached to a movable base.

SUMMARY

[0003] At least one embodiment relates to a hybrid light tower, including: an engine; a mast; a generator configured to be driven by the engine; a battery coupled to the generator; a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery or the generator; and a controller in communication with the battery, the engine, and the light assembly, wherein the controller is configured to operate in an engine mode where the generator supplies power to the light, a battery mode where the battery supplies power to the light, or a hybrid mode where the battery supplies power to the light, in the hybrid mode, the controller is configured to: monitor a state of charge (SOC) of the battery; determine if the SOC of the battery is below a lower threshold; if the SOC of the battery is below the lower threshold, start the engine and charge the battery via the generator until the SOC of the battery reaches an upper threshold; and upon the battery reaching the upper threshold, stop the engine.

[0004] At least one embodiment relates to a hybrid light tower, including: a housing defining an enclosure; an engine arranged within the enclosure; a mast; a generator configured to be driven by the engine and arranged within the enclosure; a battery pack arranged within the enclosure and mounted on a mounting assembly that includes an outer frame and an internal exhaust chamber, wherein the outer frame includes an exhaust cutout and the battery pack includes a vent formed in a bottom surface thereon, wherein the vent is positioned over the exhaust cutout a flow path is provided through the exhaust cutout and into the internal exhaust chamber, wherein the mounting assembly includes an external vent formed in an external wall thereof adjacent to a top surface of the outer frame and in fluid communication with the internal exhaust chamber; a light assembly coupled to the mast and including a light; and a controller in communication with the battery pack, the engine, and the light assembly, wherein the controller is configured to operate in an engine mode where the generator supplies power to the light, a battery mode where the battery pack supplies power to the light, or a hybrid mode where the battery pack supplies power to the light and the generator selectively charges the battery pack.

[0005] At least one embodiment relates to a hybrid light tower, including: a housing defining an enclosure; an engine arranged within the enclosure and including a coolant circuit; a mast; a generator configured to be driven by the engine and arranged within the enclosure; a battery pack arranged within the enclosure; a fan arranged within the enclosure; a light assembly coupled to the mast and including a light; and a controller in communication with the battery pack, the engine, the fan, and the light assembly, wherein the controller is configured to control a speed of the fan based on a coolant temperature within the coolant circuit and control a direction of the fan based on a battery cell temperature within the battery pack.

[0006] At least one embodiment relates to a hybrid light tower, including: an engine; a mast; a generator configured to be driven by the engine; a battery pack; a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery pack or the generator; and a controller in communication with the battery pack, the engine, and the light assembly, wherein the controller is configured to operate in an engine mode where the generator supplies power to the light, a battery mode where the battery pack supplies power to the light, or a hybrid mode where the battery pack supplies power to the light, in the hybrid mode, the controller is configured to: monitor a state of charge (SOC) of the battery pack; monitor a battery cell temperature of the battery pack; determine if the battery cell temperature is below a first temperature threshold; if the battery cell temperature is below the first temperature threshold, adjust a low SOC threshold from a first value to a second value that is higher than the first value; determine if the SOC of the battery pack is below the low SOC threshold; if the SOC of the battery pack is below the lower SOC threshold, start the engine and charge the battery pack via the generator until the SOC of the battery pack reaches an upper threshold; and upon the battery pack reaching the upper threshold, stop the engine.

[0007] In some aspects, the present disclosure relates to a hybrid light tower, including: a housing; an engine mounted within the housing; a mast; a generator mounted within the housing and configured to be driven by the engine; a battery mounted within the housing and electrically coupled to the generator; a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery or the generator; and a controller in communication with the battery, the engine, and the light assembly, wherein the controller is configured to operate in a hybrid mode where the controller is configured to: monitor a cell voltage of the battery; determine if the cell voltage of the battery is below a charging threshold; upon determining that the cell voltage of the battery is below the charging threshold, start the engine and charge the battery in a constant current mode; while charging in the constant current mode, determine if the cell voltage is above a constant voltage threshold; and upon determining that the cell voltage is above a constant voltage threshold, charge the battery in a constant voltage mode.

[0008] In some aspects, the present disclosure relates to a hybrid light tower, including: a housing; an engine mounted within the housing; a mast; a generator mounted within the housing and configured to be driven by the engine; a battery mounted within the housing and electrically coupled to the generator; a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery or the generator; a control panel including a charging plug-in; a charger arranged within the housing and electrically coupled to the battery; an electrical switch electrically coupled between the charging plug-in and the charger; and a controller in communication with the battery, the engine, the electrical switch, and the light assembly, wherein the controller is configured to selectively switch

between a battery mode and a hybrid mode, wherein the controller is configured to control the electrical switch so that: in the hybrid mode, the electrical switch is configured to prevent power transmission from the charging plug-in to the charger; and in the battery mode, the electrical switch is configured to allow power transmission from the charging plug-in to the charger.

[0009] In some aspects, the present disclosure relates to a hybrid light tower, including: a housing defining an enclosure; an engine arranged within the enclosure; a mast; a generator configured to be driven by the engine and arranged within the enclosure; a battery pack arranged within the enclosure and mounted on a mounting assembly that includes an outer frame and an internal exhaust chamber, wherein the outer frame includes an exhaust cutout and the battery pack includes a vent formed in a bottom surface thereon, wherein the vent is positioned over the exhaust cutout a flow path is provided through the exhaust cutout and into the internal exhaust chamber, wherein the mounting assembly includes an external vent formed in an external wall thereof adjacent to a top surface of the outer frame and in fluid communication with the internal exhaust chamber; a light assembly coupled to the mast and including a light; and a controller in communication with the battery pack, the engine, and the light assembly, wherein the controller is configured to operate in an engine mode where the generator supplies power to the light, a battery mode where the battery pack supplies power to the light, or a hybrid mode where the battery pack supplies power to the light and the generator selectively charges the battery pack.

[0010] This summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices or processes described herein will become apparent in the detailed description set forth herein, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements.

BRIEF DESCRIPTION OF THE FIGURES

[0011] The disclosure will become more fully understood from the following detailed description, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements, in which:

[0012] FIG. **1** is a perspective view of a light tower, according to an exemplary embodiment;

[0013] FIG. **2** is a rear view of the light tower of FIG. **1**;

[0014] FIG. **3** is a front view of the light tower of FIG. **1**;

[0015] FIG. **4** is a left side view of the light tower of FIG. **1**;

[0016] FIG. **5** is a right side view of the light tower of FIG. **1**;

[0017] FIG. **6**. is a top view of the light tower of FIG. **1**;

[0018] FIG. **7** is a bottom view of the light tower of FIG. **1**;

[0019] FIG. **8** is a control panel of the light tower of FIG. **1**;

[0020] FIG. **9** shows a user interface of the control panel of FIG. **8**;

[0021] FIG. **10** shows a user interface of the control panel of FIG. **8**;

[0022] FIG. **11** shows a user interface of the control panel of FIG. **8**;

[0023] FIG. **12** shows a user interface of the control panel of FIG. **8**;

[0024] FIG. **13** shows a user interface of the control panel of FIG. **8**;

[0025] FIG. **14** shows a user interface of the control panel of FIG. **8**;

[0026] FIG. **15** shows a user interface of the control panel of FIG. **8**;

[0027] FIG. **16** shows a user interface of the control panel of FIG. **8**;

[0028] FIG. **17** shows a user interface of the control panel of FIG. **8**;

[0029] FIG. **18** is a block diagram of a control system of the light tower of FIG. **1**;

[0030] FIG. **19** is a block diagram of the battery charging system of the control system of FIG. **18**;

[0031] FIG. **20** is a flow chart of a method of controlling the light tower of FIG. **1** in a battery mode;

[0032] FIG. **21** is a flow chart of a method of controlling the light tower of FIG. **1** in an engine mode;

[0033] FIG. **22** is a flow chart of a method of controlling the light tower of FIG. **1** in a hybrid mode;

[0034] FIG. **23** is a flow chart of a method of controlling the light tower of FIG. **1**;

[0035] FIG. **24** is a flow chart of a method of controlling the light tower of FIG. **1** in a recharge mode;

[0036] FIG. **25** is a front perspective view of a light tower, according to an exemplary embodiment;

[0037] FIG. **26** is a rear perspective view of the light tower of FIG. **25**;

[0038] FIG. **27** is side perspective view of the light tower of FIG. **25**;

[0039] FIG. **28** is a perspective view of an enclosure of the light tower of FIG. **25**;

[0040] FIG. **29** is a perspective view of an enclosure of the light tower of FIG. **25**;

[0041] FIG. **30** is a perspective view of an enclosure of the light tower of FIG. **25**;

[0042] FIG. **31** is a perspective view of a battery assembly of the light tower of FIG. **25**;

[0043] FIG. **32** is a cross-sectional view of the battery assembly FIG. **31**;

[0044] FIG. **33** is a perspective view of a mounting assembly of the battery assembly of

[0045] FIG. **31**, with an outer mounting box being transparent;

[0046] FIG. **34** is a cross-sectional view of the battery assembly FIG. **31**;

[0047] FIG. **35** is a cross-sectional view of the battery assembly FIG. **31**;

[0048] FIG. **36** is a perspective view of a control panel of the light tower of FIG. **25**;

[0049] FIG. **37** is a front view of a CAN panel of the control panel of FIG. **36**;

[0050] FIG. **38** is a front view of the control panel of the light tower of FIG. **25**;

[0051] FIG. **39** is a block diagram of a control system of the light tower of FIG. **25**;

[0052] FIGS. **40**-**58** show various screens on a user interface of the control panel of FIGS. **36** and **38**;

[0053] FIG. **59** is a perspective view of a battery assembly of the light tower of FIG. **25** including an upper flange;

[0054] FIG. **60** is a cross-sectional view of the battery assembly FIG. **59**;

[0055] FIG. **61** is a perspective view of a mounting assembly of the battery assembly of FIG. **59**, with an outer mounting box being transparent;

[0056] FIG. **62** is a cross-sectional view of the battery assembly FIG. **59**;

[0057] FIG. **63** is a cross-sectional view of the battery assembly FIG. **59**;

[0058] FIG. **64** is a perspective view of a frame and housing of the light tower of FIG. **25** including stabilizing brackets;

[0059] FIG. **65** is a perspective view of the frame and housing of FIG. **64** with the battery packs installed;

[0060] FIG. **66** is a perspective view of the enclosure of the light tower of FIG. **25** including the stabilizing brackets;

[0061] FIG. **67** is a schematic illustration of the light tower of FIG. **1** or FIG. **25** including an electrical switch between a charging plug-in and a charger;

[0062] FIG. **68** is a flowchart outlining the steps for controlling a light tower in a hybrid mode;

[0063] FIG. **69** is a flowchart outlining the steps for controlling a light tower in a constant voltage charging mode, during the hybrid mode of FIG. **68**;

[0064] FIG. **70** is a schematic illustration of the light tower of FIG. **1** or FIG. **25** including battery docks to support battery packs to be charged by a charger; and

[0065] FIG. **71** is a schematic illustration of the light tower of FIG. **1** or FIG. **25** including battery docks to support battery packs to be charged by a dedicated charger.

DETAILED DESCRIPTION

[0066] Before turning to the figures, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the figures. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

[0067] Referring to the FIGURES generally, the various exemplary embodiments disclosed herein relate to systems, apparatuses, and methods for a hybrid lighting system, or a plug-in hybrid lighting system. The lighting system includes a light tower having a base, an engine coupled to the base and configured to drive a generator, a battery pack coupled to the base, a mast extending from the base, one or more lights coupled to the mast a one or more wheels coupled to the base, and a control system coupled to the base. The battery pack is electrically coupled to both a charger and the generator, and includes a one or more lithium-ion battery cells that are configured to provide power to the lighting system.

[0068] The control system includes a controller operably coupled to the engine, the battery pack, and the lights. The control system is further operably coupled to an engine controller, a battery management system (BMS), and a control panel. The control panel includes a user interface, a power outlet, and a charging plug-in. A user may interact with the control panel to provide a user input and control an operational status of the light tower. In general, the engine, the generator, the battery pack, and the control of these components defines a hybrid power system and is used to supply electrical power to the lights. The hybrid power system provides several different operational modes including battery mode, hybrid mode, engine mode, and recharge mode. The incorporation of the hybrid power system enables the lighting system to have longer runtimes, for example, when compared to engine-only and battery-only lighting systems.

[0069] Referring now to FIGS. **1-7**, a portable lighting tower, hybrid lighting tower, a plug-in hybrid light tower, towable lighting tower, or lighting tower, shown as light tower **100** is shown, according to an exemplary embodiment. The light tower **100** includes a first or front portion **102**, a second or rear portion **106**, a third or top portion **110**, a fourth or bottom portion **114**, a first lateral or right portion **118**, and a second lateral or left portion **122**. The light tower **100** includes a chassis or base, shown as a frame **104**, one or more tractive elements, shown as wheels **108**, and a housing **112**.

[0070] According to an exemplary embodiment, the frame **104** is positioned along the bottom portion **114** and defines a longitudinal axis extending from the front portion **102** to the rear portion **106** of the light tower **100**. The frame **104** further includes an arm (e.g., a rail, a tongue, etc.), shown as frame arm **124**, extending outward (e.g., in a direction opposite the housing **112**) from the frame **104**. The longitudinal axis may be generally aligned with the frame arm **124** of the frame **104**. The frame arm **124**, may be detachedly coupled to a hitch (e.g., a tongue), shown as a hitch assembly **128**, which is positioned along the longitudinal axis defined by the frame **104**. In some embodiments, the hitch assembly **128** receives a hitch, ball, joint, etc., to allow a user to selectively reposition the light tower **100**. The wheels **108** are coupled to the frame **104** and lift the frame **104** off of the ground so that the light tower **100** is repositionable and movable. In the illustrated embodiments, the wheels **108** are positioned opposite each other on the right portion **118** and the left portion **122** and coaxially aligned along an axle. By way of example, the light tower **100** may be lowered onto or aligned with a hitch, where the user may then exert a push or pull force onto the light tower **100** to move the light tower **100** in a desired direction (e.g., via a vehicle, via a motored device, via a user, etc.).

[0071] The housing **112** is supported by the frame **104** of the light tower **100**. The housing **112** defines a chamber, housing, or enclosure **116** and includes one or more panels, shown as panels **120** disposed along the right portion **118** and the left portion **122**. The panels **120** are pivotably coupled to the housing **112** such that when the one or more panels **120** move upward (e.g., towards the top portion **110** of the light tower **100**), the enclosure **116** is accessible to a user. In some embodiments, the panels **120** are symmetrical about the longitudinal axis.

[0072] The light tower **100** further includes a hybrid power system. The hybrid power system includes a first driver, shown as engine **132**, positioned within the enclosure **116** of the housing **112**. The engine **132** may receive fuel (e.g., gasoline, diesel, etc.) from a fuel tank and combusts the fuel to generate rotational mechanical energy. The fuel tank may include a fuel level sensor positioned within the fuel tank, where the fuel level sensor provides a fuel status (e.g., level of the fuel in the fuel tank, etc.). The rotational mechanical energy from the engine **132** may then be supplied to one or more components (e.g., a generator, one or more lights, one or more electric motors, one or more controllers, etc.) of the light tower **100**.

[0073] The hybrid power train further includes a permanent magnet generator, shown as generator **136**, coupled to the engine **132**. The generator **136** is positioned within the enclosure **116** of the housing **112**. The generator **136** may further be driven by the engine **132**, where the generator **136** converts the rotational mechanical energy generated by the engine **132** into electrical energy. In some embodiments, the engine **132** and the generator **136** are formed as a single component (e.g., a motor/generator) and supported on the frame **104**. The electrical energy from the generator **136** may then be supplied to one or more components of the light tower **100**. By way of example, the generator **136** generates direct current (DC) power that may be supplied directly to an inverter **138** or a battery pack, shown as battery **144**. In some embodiments, the generator **136** generates alternating current (AC) power that is rectified by a rectifier **142** to DC power and provided to a light assembly **140** and/or to recharge the battery **144**, depending on the operating mode of the light tower **100**. In some embodiments, the inverter **138** converts DC power from the battery **144** to alternating current (AC) power that may then be supplied to a power outlet (e.g., power outlet **340**) to power a device connected to the light tower **100**. The battery **144** includes a battery management system (BMS) **145** and is also coupled to a charger **146** that recharges the battery **144** when the battery is below a maximum state of charge (SOC). The charger **146** converts AC power from a plug-in, shore power source (e.g., charging plug-in **344**) to DC power (e.g., via the rectifier **142** or a dedicated rectifier within the charger **146**) to charge the battery **144**.

[0074] The battery **144**, the engine **132**, the generator **136**, the inverter **138**, the rectifier **142**, and the charger **146** are enclosed within the enclosure **116** of the housing **112** and supported on the frame **104**. In some embodiments, the battery **144** is removably coupled to the frame **104** to allow the battery **144** to be changed with another battery **144** in case the battery **144** needs to be charged, no longer usable, or needs to be changed for various other reasons. In some embodiments, the battery **144** is removably coupled to the housing **112** through one or more fasteners (e.g., a bolt, screw, or other fastening agent). In some embodiments, the engine **132**, the generator **136**, the battery **144**, the inverter **138**, the rectifier **142**, or the charger **146** are at least partially enclosed within the housing **112**.

[0075] The frame **104** is coupled to an extendable or adjustable mast, shown as mast **148**. The mast **148** is moveable between a storage configuration and a deployed configuration. The mast **148** includes one or more light assemblies, shown as light assembly **140** arranged at a top end (e.g., an end opposite of the end which the mast **148** is coupled to the frame **104**) of the mast **148**. Each light assembly **140** includes one or more lights **156** and a moveable or adjustable frame, shown as frame **160**. By way of example, the one or more lights **156** may include one or more light emitting diodes (LED). In some embodiments, the one or more lights **156** may be incandescent lights. In general, the frame **160** allows the one or more lights **156** to be moved and adjusted. For example, the frame **160** may allow each one of the one or more lights **156** to be swiveled and/or rotated about the mast **148**, and moved in any direction (e.g., within the range of the frame **160**). In some embodiments, the frame **160** allows the one or more lights **156** to be tilted, turned, and/or moved. Tilting and turning the one or more lights **156** allows a user to position a beam of light as desired. In some embodiments, the mast **148** and/or the frame **160** may be mechanically controlled by one or more electric motors for tilting, turning, raising, or lowering the one or more lights **156**. The one or more electric motors may be controlled by a controller discussed further herein (e.g., in response to a user input and/or automatic controls based on other gathered signals from the light tower **100**).

[0076] In some embodiments, the mast **148** may be lowered and raised between the storage configuration and the deployed configuration. The mast **148** may include multiple mast sections or members **164** (e.g., a top member, one or more middle members, a bottom member) that telescope to raise and lower the mast **148**. For example, when lowering the mast **148**, the top member **164** lowers inside of the one or more middle members **164**, all of which lower inside of the bottom member **164**, and so on. In this way, the bottom member **164** may have the largest diameter, and the top member **164** may have the smallest diameter.

[0077] Referring specifically to FIGS. **3** and **8**, the light tower **100** includes a control panel **300** arranged along the rear portion **106** of the light tower **100** and coupled to the housing **112**. The control panel **300** is includes knobs, switches, dials, and buttons so that the user may more easily and conveniently interact with the control panel **300** using gloves. Any feature (e.g., knob, switch, dial, breaker, button, etc.) of the control panel **300** described herein may be configured alternatively as one or more knobs, switches, dials, breakers, or buttons. The control panel **300** includes one or more displays, shown as a user interface **304**, one or more light switches or breakers, shown as a light switch **308**, one or more mast switches, shown as a mast switch **312**, and a power switch **316**. In the illustrated embodiment, the light switch **308**, the mast switch **312**, and the power switch **316** are laterally spaced from the user interface **304**. The light switch **308** includes manual light breakers (e.g., on/off switches) to turn each of the one or more lights **156** on or off manually. The mast switch **312** can be moved by a user to raise or lower the mast **148**. The power switch **316** can be moved by the user to turn the light tower **100** on and off.

[0078] The control panel **300** further includes a port, shown as a diagnostic port **320**, a mode dial **324**, a mode button **328**, an intensity-runtime dial, shown as a performance dial **332**, and a performance button **336**. In some embodiments, the diagnostic port **320** is a USB-B port configured to connect a device (e.g., a sensor, a meter, a laptop, etc.) to retrieve diagnostics information of the light tower **100**. In the illustrated embodiment, the diagnostic port **320**, the mode dial **324**, the mode button **328**, the performance dial **332**, and the performance button **336** are spaced below the user interface **304**, the light switch **308**, the mast switch **312**, and the power switch. Additionally, the mode dial **324** is laterally spaced from the performance dial **332**. The mode button **328** is located proximately to the mode dial **324**, and the performance button **336** is located relative to the performance dial **332**, relative to one another.

[0079] The control panel **300** further includes one or more power outlets or ports, shown as a power outlet **340**, a charging plug-in **344**, and one or more breakers, shown as breakers **342**. In the illustrated embodiment, the power outlet **340** is laterally spaced from the charging plug-in **344**, both of which are located below the mode dial **324** and the performance dial **332**, respectively. In some embodiments, the power outlet **340** includes one or more 20 A, 120V outlets and one or more USB ports to provide power to an external device plugged in to the power outlet **340** by the user. In some embodiments, the charging plug-in **344** is electrically connected to the on-board battery charger **146** and configured to receive power from an external power source (e.g., wall power, shore power, etc.). The charging plug-in **344** allows for the light tower **100** to receive power (e.g., be plugged-in, or be a plug-in hybrid light tower) while the light tower **100** is turned on (in some operating modes) or turned off. Further, the breaker **342** is laterally spaced from breaker **342**, both of which are located below the power outlet **340** and the charging plug-in **344**.

[0080] Referring to FIG. **8**, the user may interact with the mode dial **324** and the mode button **328** to place the light tower **100** in one or more modes **348**. The one or more modes **348** includes a battery mode **500**, a hybrid mode **600**, an engine mode **700**, a recharge mode **800**, and an autonomous lighting mode, shown as autonomous mode **900**. The mode dial **324** can be rotated by the user to place the light tower **100** in the battery mode **500**, the hybrid mode **600**, the engine mode **700**, or the recharge mode **800**. The mode button **328** can be pressed by the user to place the light tower **100** in the autonomous mode **900**. In alternative embodiments, the autonomous mode **900** may be configured with the mode dial **324** and/or the battery mode **500**, the hybrid mode **600**, the engine mode **700**, or the recharge mode **800** may be initiated similarly to the mode button **328**.

[0081] Referring still to FIG. **8**, the user may interact with the performance dial **332** and the performance button **336** to specify one or more performance parameters **352** of the light tower **100**. The one or more performance parameters **352** include an intensity (e.g., 100 W, 175 W, 250 W, or 350 W), a runtime (e.g., a runtime control), or neither specified parameter (e.g., off). The performance dial **332** can be rotated by the user to specify the intensity or the runtime of the one or more lights **156**. The performance button **336** can be pressed by the user to specify a higher intensity (e.g., TURBO, 350 KW) for the one or more lights **156** than the intensity of the performance dial **332**. In alternative embodiments, the higher intensity may be configured with the performance dial **332** and/or the intensity or the runtime of the one or more lights **156** may be initiated similarly to the performance button **336**.

[0082] Referring to FIGS. **9-17**, the user interface **304** generally includes visual indicators, statuses, and settings based on inputs from the user. In some embodiments, the user interface **304** is one or more touch screens, graphical user interfaces, or other types of input devices that allow the user to input information and display information to a user. The user interface **304** may provide one or more screens that are indicated by a screen title or label **354** at the top of user interface **304**. The label **354** will change based on a selection from the user engaging with the user interface **304** and may reflect information indicative of one or more modes **348** or one or more performance parameters **352**.

[0083] Referring to FIG. **9**, the user interface **304** includes an overview display **356**. The overview display **356** provides the user information that includes a mode status **358**, an intensity status **360**, a mast status **362**, a runtime button or indicator **364**, one or more light statuses or buttons, shown as light indicator **368**, a one or more level indicators **370**, an engine status or button **372**, one or more runtime timers **374**, and a setup and diagnostics button, shown as settings button **376**. In alternative embodiments, the arrangement and positioning of the overview display **356** may vary from the illustrated embodiment.

[0084] The mode status **358** indicates the light tower **100** is in the one or more modes **348**. The mode status **358** changes based on a selection from the user by the mode dial **324** or the mode button **328**. The intensity status **360** indicates the one or more performance parameters **352** of the light tower **100**. The intensity status **360** changes based on a selection from the user by the performance dial **332** or the performance button **336** (e.g., 100 W, 175 W, 250 W, TURBO, etc.). The mast status **362** indicates information of the mast **148**. The mast status **362** changes based on a selection from the user by the mast switch **312**. The runtime indicator **364** includes one or more buttons that the user may touch to increase or decrease the runtime. The runtime indicator **364** provides the user information indicative of one or more of a total runtime, a desired runtime, an estimated runtime, or a current runtime. The light indicator **368** includes information indicative of a status of the one or more lights **156**. In some embodiments, the light indicator **368** responds to the user engaging with the light switch **308** and provides the status of the one or more lights **156** (e.g., the light indicator **368** lights up if the corresponding light is on and the light indicator **368** becomes dark if the corresponding light is off). In alternative embodiments, the light indicator **368** includes one or more buttons that correspond to the one or more lights **156**. The user may touch the one or more buttons to turn change the status of the one or more lights **156**. The one or more buttons also provide an indication of the status of the one or more lights **156** (e.g., the button lights up if the corresponding light is on and the button becomes dark if the corresponding light is off). The one or more level indicators **370** include information indicative of a level or status of the battery **144** (e.g., a battery level, a start batt voltage, a coolant temperature, the engine **132** (e.g., a fuel level, an engine rpm), or a power draw of the light tower **100**. The engine status button **372** provides the user a visual indication of the engine status (e.g., "OK," "OFF," etc.). The user may touch the engine status button **372** to learn more about the engine status, and the user interface **304** will respond by changing from the current display to an engine status display **378**. The one or more runtime timers **374** include information indicative of a runtime the engine **132** has been on or running or a runtime the one or more lights **156** have been on or running. In some embodiments, the one or more runtime timers **374** include a runtime of the battery **144**, the generator **136**, or another component of the light tower **100**. The settings button **376** allows the user to navigate from the overview display **356** or the current display to a setup and diagnostics display, shown as settings display **380**.

[0085] Referring to FIG. **10**, the user interface **304** further includes the engine status display **378**. In some embodiments, the engine status display **378** includes substantially similar features (e.g., the mode status **358**, the one or more level indicators **370**, etc.) as the overview display **356**. The engine status display **378** further includes one or more engine parameters **382** (e.g., glow plug, oil, temperature, rpm, etc.), and a return button **384** that allows the user to return to a previous display.

[0086] Referring to FIG. **11**, the user interface **304** further includes the settings display **380**. In some embodiments, the settings display **380** includes substantially similar features (e.g., the engine status button **372**, the one or more runtime timers **374**, the return button **384**, etc.) as the overview display **356** and the engine status display **378**. The settings display further includes one or more setting inputs **386**, an operational limits button **388**, an autonomous configuration button **390**, and a diagnostics button **392**. The user can press one or more setting inputs **386** to enter in information regarding a date, time, daylight savings time, temperature units, etc. The user can press the operational limits button **388** to set the operational limits of the light tower **100**, and the user interface **304** will respond by changing from the settings display **380** to an operational limits display **394**. The user can press the autonomous configuration button **390** to configure settings of the autonomous mode **900**, and the user interface **304** will respond by changing from the settings display **380** to an autonomous configuration display **396**. The user can press the diagnostics button **392** to view diagnostic information of the light tower **100**.

[0087] Referring to FIG. **12**, the user interface **304** further includes the operational limits display **394**. In some embodiments, the operational limits display **394** includes substantially similar features as the overview display **356**, the engine status display **378**, or the settings display **380**. The operational limits display **394** further includes a battery charge type button **398**, a cold weather engine override button, shown as override button **400**, and an intensity settings button **402**. The battery charge type button **398** allows the user to select a battery charge type (e.g., fast or full). In some embodiments, responsive to the user selecting a fast battery charge type, the battery **144** is charged to 80% SOC to minimize the amount of time the engine **132** is on in hybrid mode **600**. In some embodiments, responsive to the user selecting a full battery charge type, the battery **144** is charged to 95% SOC. The override button **400** allows the user to enable or disable an engine override in which the engine **132** overrides the battery **144** when the battery **144** temperature is below a certain threshold as described herein (e.g., see FIG. 23). The intensity settings button **402** can be pressed by the user to set a maximum intensity, and the user interface **304** will respond by changing from the operational limits display **394** to an intensity settings display **404**.

[0088] Referring to FIG. **13**, the user interface **304** includes the intensity settings display **404**. In some embodiments, the operational limits display **394** includes substantially similar features as the overview display **356**, the engine status display **378**, the settings display **380**, or the operational limits display **394**. The intensity settings display **404** includes a battery intensity setting **406**, an engine intensity setting **408**, and a hybrid intensity setting **410**. The battery intensity setting **406** can be pressed by the user to set a maximum intensity of the one or more lights **156** for the battery **144** in battery mode **500**. The engine intensity setting **408** can be pressed by the user to set a maximum intensity of the one or more lights **156** for the engine **132** in engine mode **700**. The hybrid intensity setting **410** can be pressed by the user to set a maximum intensity of the one or more lights **156** for the battery **144** and engine **132** in hybrid mode **600**.

[0089] Referring to FIG. **14**, the user interface includes the autonomous configuration display **396**. The autonomous configuration display **396** includes a location button **412**, one or more offset buttons **414**, a tracker, shown as calculation indicator **415**, a light saver button **416**, and a scheduler button **418**, which are used to input one or more parameters of the autonomous mode **900** of the light tower **100**. The user can press the location button **412** to input a coordinates indicative of a location of the light tower **100** and disable or enable coordinates of the location of the light tower **100**. In some embodiments, the coordinates provided are used to determine one or more calculated times that correlate to a sunrise or sunset (e.g., on or off). The one or more offset buttons **414** allow the user to enter an offset value corresponding to a time before or after sunset or sunrise. In some embodiments, the one or more offset buttons **414** allow for adjustments for the one or more lights **156** to turn on and off relative to actual calculated times. The calculation indicator **415** provides an estimated sunrise time and an estimated sunset time based on inputs to the one or more setting inputs (e.g., date and time) and the location button **412**. The light saver button **416** may be pressed to disable or enable a light saver. In some embodiments, enabling the light saver transitions the light intensity up and down to a target value (e.g., a maximum lighting value) during on or off events based on the calculated times and the offset values. The scheduler button **418** allows the user to set and/or view a schedule of the light tower **100** and navigates the user to a scheduler display **420**.

[0090] Referring to FIG. **15**, the user interface **304** includes the scheduler display **420**. The scheduler display **420** includes one or more schedule slots **422** for a user to select. In the illustrated embodiment, the one or more schedule slots **422** have an event **424**. The event **424** displays the dates and times of when the light tower **100** is scheduled to turn on. The user can interact with the event **424** to disable or enable the event **424** or edit the event **424** on the schedule display **426**, shown in FIG. **16**. The schedule display **426** includes day buttons **428** each of which can be pressed to include or remove the respective day from the schedule, and time buttons **430** for a user to indicate a time for the light tower **100** to turn on and a time for the light tower **100** to turn off.

[0091] Referring to FIG. **17**, the user interface **304** includes a recharge display **432**. The recharge display **432** includes substantially similar features as the overview display **356**. The recharge display **432** further includes a charge time indicator **434** and a charge amperage indicator **436**. The charge time indicator **434** provides the remaining charge time of the battery **144**. The charge amperage indicator **436** provides the amperage at which the battery **144** is being charged.

[0092] Referring to FIG. **18**, the light tower **100** includes a control system **450**. In general, the connections and arrows between blocks in the control system **450** of FIG. **18** may refer to an electrical coupling, a communicative coupling, an operable coupling, a physical coupling, and/or a combination of one or more these couplings. In some embodiments, some or all of the connections may represent a Controller Area Network (CAN). In some embodiments, the control system **450** The control system **450** includes the engine **132**, the generator **136**, the battery **144**, the BMS **145**, the one or more lights **156**, the control panel **300**, a controller **454**, and an engine controller **458**.

[0093] The controller **454** includes a processing circuit including a processor **462** and memory **466**. The processing circuit can be communicably connected to a communications interface such that the processing circuit and the various components thereof can send and receive data via the communications interface. The processor **462** can be implemented as a general purpose processor, an application specific integrated circuit ("ASIC"), one or more field programmable gate arrays ("FPGAs"), a group of processing components, or other suitable electronic processing components.

[0094] The memory **466** (e.g., memory, memory unit, storage device, etc.) can include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage, etc.) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present application. The memory **466** can be or include volatile memory or non-volatile memory. The memory **466** can include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present application. According to some embodiments, the memory **466** is communicably connected to the processor **462** via the processing circuit and includes computer code for executing (e.g., by the processing circuit and/or the processor **462**) one or more processes described herein.

[0095] The battery **144** may be charged by the generator **136**, which is powered from the engine **132**. The BMS **145** may be operably coupled to the controller **454**, where the BMS **145** may send and receive control signals. Specifically, the BMS **145** may be configured to monitor a status, utilization, etc., of the battery **144** and to provide an output command to the controller **454** indicating a status of the battery **144**. According to an exemplary embodiment, the controller **454** may send a command to the engine controller **458** for the engine **132** to output a specific power to the generator **136** based on feedback to the controller **454**. As shown in FIG. **19**, the battery **144** may be charged by the charger **146**, which outputs DC power from the rectifier **142**. The rectifier **142** converts the AC power supplied by the charging plug-in **344** to DC power to supply to the charger **146** for the battery **144**. In some embodiments, the rectifier **142** may supply DC power to the one or more lights **156**, the control panel **300**, the controller **454**, or other components of the light tower **100**. The inverter **138** may receive DC power supplied by the battery **144** and convert the DC power to AC power to supply to the power outlet **340**.

[0096] The engine **132** is operably coupled to the engine controller **458**. The engine controller **458** may further be operably coupled to the controller **454**, where the engine controller **458** may send and receive control signals. Specifically, the engine controller **458** may be configured to monitor a status, operating characteristics, utilization, etc., of the engine **132** and to provide an output command to the engine **132** based on feedback from the controller **454**. According to an exemplary embodiment, the controller **454** may provide a command to the engine controller **458** for a desired engine output (e.g., output speed, output power, and/or output torque, etc.). In some embodiments, the controller **454** may determine speed of the engine **132** that will meet a runtime requirement.

[0097] The controller **454** is configured to control the power to the one or more lights **156**. In some embodiments, the amount of light produced by each of the one or more lights **156** is dimmable based on the power received by each of the one or more lights **156**. Accordingly, a user may directly adjust the power supplied to the one or more lights **156** based on a variety of factors including required runtime, needed light, and/or time of day. As described further herein, the one or more lights **156** may also be adjusted (e.g., by controller **454**) without manual control.

[0098] In some embodiments, the controller **454** is configured to receive a user input from the control panel **300** and is communicably and electrically coupled to the user interface **304**, the light switch **308**, the mast switch **312**, the power switch **316**, the diagnostic port **320**, the mode dial **324**, the mode button **328**, the performance dial **332**, the performance button **336**, the power outlet **340**, the charging plug-in **344**, and the breaker **342**. The power switch **316** is communicably and/or electrically coupled to the controller **454** and/or the battery **144** to control power output to the light tower **100**. In one embodiment, the power switch **316**, is an on/off switch. When in an "on" position, components of the control system **450** (e.g., the one or more lights **156**, the controller **454**, etc.) receive power from the battery **144** (or another battery on the light tower **100**). When in an "off" position, the components of the control system **450** (e.g., the one or more lights **156**, the controller **454**, etc.) do not receive power from the battery **144**.

[0099] In some embodiments, the controller **454** receives the user input from the performance dial **332** and/or the performance button **336** of the control panel **300**. The user input from the performance dial **332** and/or the performance button **336** includes one or more performance parameters **352**, which include the intensity or the runtime. Responsive to receiving the user input that indicates the intensity (e.g., 100 W, 175 W, 250 W, 350 W, etc.) or the runtime (e.g., the runtime control), the controller **454** will calculate an amount of stored energy using a fuel level and a fuel economy, which is determined through a calculation and/or a look-up table based on one or more modes **348**, a current drawing from the rectifier **142**, and an engine speed. The stored energy represents an available energy output from the battery **144** and the engine **132**, so the controller **454** can determine a minimum and a maximum runtime available based on a minimum and a maximum intensity available for each of the one or more lights **156**. The controller **454** uses the calculation to adjust the runtime or the intensity up or down in the battery mode **500**, the hybrid mode **600**, the engine mode **700**, and the autonomous mode **900**. For the user input that indicates the intensity, a calculated runtime will appear on the runtime indicator **364**, the intensity status **360** will display a maximum total light level available for a selected intensity, and the light indicator **368** will display which of the one or more lights **156** are operating at the selected intensity. For the user input that indicates the runtime, a selected runtime will appear on the runtime indicator **364**, the intensity status **360** will display the maximum total light level available for a calculated intensity, and the light indicator **368** will display which of the one or more lights **156** are operating the calculated intensity.

[0100] In some embodiments, the controller **454** receives the user input from the user interface **304** of the control panel **300**. The user may configure and enable the autonomous mode **900** through the settings display **380**, the operational limits display **394**, the autonomous configuration display **396**, the intensity settings display **404**, the scheduler display **420**, and the schedule display **426**. The autonomous mode **900** may run in conjunction with or simultaneously to the battery mode **500**, the hybrid mode **600**, and the engine mode **700** of the light tower **100**. The controller **454** receives a date, a time, and a location from the control panel **300** and uses a solar calculator (e.g., NOAA Solar Calculator) to calculate the estimated sunrise time and the estimated sunset time to be displayed on the user interface **304** of the control panel **300**, so the user can input an offset to either the estimated sunrise time or the estimated sunset time to allow for adjustments of the estimated sunrise time and the estimated sunset time relative to an actual sunrise time and an actual sunset time.

[0101] Responsive to the light saver being enabled in autonomous mode **900**, the controller **454** will control the one or more lights **156** to transition the intensity up and down to a set target maximum lighting value in response to one or more events (e.g., indicated by the event **424** inputted one or more schedule slots **422**). The controller **454** uses the estimated sunrise time, the estimated sunset time, and the respective offset to determine the transition of the intensity. In some embodiments, the transition of the one or more lights **156** from off to a maximum intensity or a maximum intensity to off is based on the offset of the estimated sunrise time and the offset of the estimated sunset time. In such embodiments, the controller **454** transitions the one or more lights **156** at the estimated sunset time so the one or more lights **156** are at the maximum intensity by the offset of the estimated sunset time. Further, in such embodiments, the controller **454** transitions the one or more lights **156** at the estimated sunrise time so the one or more lights **156** are completely off by the offset of the estimated sunrise time. In some embodiments, the transition of the one or more lights **156** from off to a maximum intensity or a maximum intensity to off is based on the estimated sunrise time and the offset of the estimated sunset time. In such embodiments, the controller **454** begins the transition of the one or more lights **156** without the offset to the estimated sunset time so that the one or more lights **156** are at the maximum intensity by the actual sunset time. Further, in such embodiments, the controller **454** begins the transition of the one or more lights **156** without the offset to the estimated sunrise time so that the one or more lights **156** are completely off by the actual sunrise time.

[0102] Responsive to the scheduler being enabled in autonomous mode **900**, the controller **454** will turn the light tower **100** on and off based on a date and a time provided in the scheduler display **420** and the schedule display **426**. The user inputs the event **424** into the one or more schedule slots **422**. The user can specify one or more days, an on time, and an off time. The controller **454** will power the one or more lights **156** based on the events **424** inputted into the one or more schedule slots **422**. In some embodiments, one or more of the scheduler, the light saver, and the location may be enabled for the autonomous mode **900**.

[0103] In some embodiments, the controller **454** receives the user input from the mode dial **324** and/or the mode button **328** of the control panel **300**. The user input from the mode dial **324** and/or the mode button **328** includes one or more modes **348**, which include the battery mode **500**, the hybrid mode **600**, the engine mode **700**, the recharge mode **800**, and the autonomous mode **900**.

[0104] FIG. **20** shows a method of controlling the light tower **100** in the battery mode **500**. At process **504**, the controller **454** receives a user input. In some embodiments, the user input is provided by the control panel **300**. The user input may include a selection from the control panel **300** that includes at least the battery mode **500** from the mode dial **324**. The battery mode **500** limits the power supply so that power is only supplied by the battery **144** to the light assembly **140**. In some embodiments, the battery **144** may receive power from the charging plug-in **344**, while in the battery mode. In such embodiments, the battery **144** is charged by the charger **146** while the battery **144** is supplying power to the light assembly **140**. At process **508**, the battery **144** provides power to the light tower **100**. The battery **144** supplies power to the one or more lights **156**, the control panel **300**, the power outlet **340**, and the other components of the light tower **100**. At process **512**, the controller **454** monitors the SOC of the battery **144**. In some embodiments, the BMS **145** monitors the SOC of the battery **144** and communicates with the controller **454**. In some embodiments, the BMS **145** receives feedback using amperage and temperature to determine the runtime and communicates with the controller **454**. In some embodiments, the controller **454** determines the runtime of the light tower **100** using the SOC of the battery **144** and one or more performance parameters **352** and provides the runtime to the user interface **304** of the control panel **300**. In some embodiments, the controller **454** defines a low SOC threshold for the battery **144** that is based on a minimum battery cell temperature (e.g., if the minimum battery cell temperature is below a temperature threshold, the low SOC threshold is a first value, and if the minimum battery cell temperature is above the temperature threshold, the low SOC threshold is a second value that is lower than the first value). Once the controller **454** detects that the battery **144** reaches the low SOC threshold, the controller **454** turns off the lights **156** and the controller **454** waits for a user interaction to occur (e.g., change to recharge mode). In some embodiments, the controller **454** monitors a voltage of the battery **144** and/or a minimum battery cell voltage within the battery **144** to determine when to turn off the lights **156** and require charging of the battery **144**.

[0105] FIG. **21** shows a method of controlling the light tower **100** in the engine mode **700**. At process **704**, the controller **454** receives a user input. In some embodiments, the user input is provided by the control panel **300**. In some embodiments, the controller **454** provides the user input to the engine controller **458**. The user input may include a selection from the control panel **300** that includes at least the engine mode **700** from the mode dial **324**. The engine mode **700** supplies power to the light assembly **140** from the engine **132** and generator **136**. At process **708**, the engine **132** and the generator **136** provide power to the light tower **100**. In some embodiments, the engine controller **458** varies the engine speed and the engine load based on the user input (e.g., the runtime, the intensity, etc.) for the one or more lights **156**. At process **712**, the controller **454** monitors the engine **132**. The engine controller **458** monitors the fuel level, the speed, the load, etc., of the engine **132** and communicates with the controller **454**. In some embodiments, the controller **454** determines the runtime of the light tower **100** using the fuel level and one or more performance parameters **352** and provides the runtime to the user interface **304** of the control panel **300**.

[0106] FIG. **22** shows a method of controlling the light tower **100** in the hybrid mode **600**. At process **604**, the controller receives a user input. In some embodiments, the user input is provided by the control panel **300**. The user input may include a selection from the control panel **300** that includes at least the hybrid mode **600** from the mode dial **324**. In some embodiments, the controller **454** provides the user input to the engine controller **458** and the BMS **145**. At process **608**, the battery **144** provides power to the light tower **100**. In some embodiments, the battery **144** provides power to the light tower **100** based on the user input, similarly to the battery mode **500**. At process **612**, the controller **454** monitors the SOC of the battery **144**. In some embodiments, the BMS **145** monitors the SOC of the battery **144** and communicates with the controller **454**. At process **616**, the controller **454** determines if the SOC of the battery **144** is below a first or lower predefined threshold. Responsive to the controller **454** determining the battery **144** is above the lower predefined threshold, the controller **454** continues to monitor the SOC of battery **144**. Responsive to the controller **454** determining the SOC of the battery **144** is below the lower predefined threshold, at process **620**, the controller **454** starts the engine **132**. In some embodiments, the engine **132** is started with a 12V lead acid starting system or starter battery.

[0107] At process **624**, the battery **144** is charged. In some embodiments, controller **454** communicates with the engine controller **458** so the engine **132** drives the generator **136** to charge the battery **144**. The engine **132** supplies power to the battery **144**, the one or more lights **156**, and the other components of the light tower **100**. The engine controller **458** and the controller **454** communicate with the engine **132** to maximize the charge rate of the battery **144** to an upper SOC. At process **628**, the controller **454** determines if the SOC of the battery **144** is above a second or upper predefined threshold. Responsive to the controller **454** determining the battery **144** is below the upper predefined threshold, the controller **454** continues to charge the battery **144** with the engine **132** and the generator **136**. Responsive to the controller **454** determining the battery **144** is above the upper predefined threshold, at process **632**, the controller **454** turns off the engine **132**, and the battery **144** continues to supply power to the light assembly **140** based on the user input as in process **608**. In some embodiments, the voltage of the battery **144** and/or a minimum cell voltage of the battery **144** is used to control when the engine **132** starts and stops charging the battery **144**.

[0108] FIG. **23** shows a battery temperature monitoring method or process **650** of the light tower **100**. The method described in FIG. **23** may occur while the light tower **100** is operating in the battery mode **500** or in the hybrid mode **600**. The override button **400** enables the method of FIG. **23** as described herein. Similar to the method described in FIG. **22**, at process **604**, the controller receives a user input. At process **608**, the battery **144** provides power to the light tower **100**. At process **636**, the controller **454** monitors a temperature of the battery **144**. In some embodiments, the BMS **145** monitors the temperature of the battery and communicates with the controller **454**. At process **640**, the controller **454** determines if the temperature of the battery **144** is below a first threshold (e.g., first temperature threshold, first predefined threshold). In some embodiments, the first threshold is approximately 40° F.

[0109] Responsive to the controller **454** determining the temperature of the battery **144** is above the first threshold, the controller **454** continues to monitor the temperature of the battery **144**. Responsive to the controller **454** determining the temperature of the battery **144** is below the first threshold, at process **644**, the controller **454** adjusts a predefined SOC or SOC threshold (e.g., updated SOC threshold). In some embodiments the predefined SOC threshold is adjusted based on the lower predefined threshold from the hybrid mode **600**. In some embodiments, the controller **454** increases the predefined SOC threshold from a minimum SOC limit to an increased minimum SOC limit (e.g., 40%) to protect the battery **144**. At process **648**, the controller **454** continues in the battery mode **500** or the hybrid mode **600**. In the illustrated mode, the controller **454** continues in the hybrid mode **600** at process **648**. In some embodiments, the controller **454** continues in the battery mode **500** or the hybrid mode **600** using the predefined SOC threshold as the lower predefined threshold to charge the battery **144**.

[0110] At process **652**, the controller **454** determines if the temperature of the battery **144** is below a second threshold (e.g., second temperature threshold, second predefined threshold). Responsive to the controller **454** determining the temperature of the battery **144** is above the second threshold, the controller **454** continues in the hybrid mode **600**. Responsive to the controller **454** determining the temperature of the battery **144** is below the second threshold, at process **656**, the controller **454** switches to the engine mode **700**.

[0111] At process **660**, the controller **454** determines if the temperature of the battery **144** is below a third threshold (e.g., third temperature threshold, third predefined threshold). In some embodiments, the third threshold is greater than, less than, or equal to the first threshold. In some embodiments, the third threshold is greater than, less than, or equal to the second threshold. Responsive to the controller **454** determining the battery **144** is below the third threshold, the controller **454** continues in the engine mode **700**. Responsive to the controller **454** determining the battery **144** is above the third threshold, at process **664**, the controller **454** switches or resumes the hybrid mode **600** or the battery mode **500**.

[0112] FIG. **24** shows a method of controlling the light tower **100** in the recharge mode **800**. At process **804**, the controller **454** receives a user input. In some embodiments, the user input is provided by the control panel **300**. The user input may include a selection from the control panel **300** that includes at least the recharge mode **800** from the mode dial **324**. The recharge mode **800** allows the battery **144** to return to a maximum SOC (e.g., full charge). At process **808**, the battery **144** is charged. In some embodiments, the battery **144** may receive power from the charging plug-in **344** and is charged by the charger **146**.

[0113] In some embodiments, the battery **144** is charged based on the battery charge type selected by the user using the battery charge type button **398**. In some embodiments, responsive to the user selecting the fast battery charge type, the battery **144** is charged to 80% SOC to minimize the amount of time the engine **132** is on. In such embodiments, the battery **144** is charged only by a constant current, which draws more power and occurs faster. In some embodiments, responsive to the user selecting a full battery charge type, the battery **144** is charged to 95% SOC. In such embodiments, the battery **144** is charged by the constant current and a controlled voltage, which increases charging time. In some embodiments, the battery **144** is charged by a combination of constant current and constant voltage, as described herein.

[0114] FIGS. **25-30** show an exemplary embodiment of the light tower **100** including a fan **150**. In general, the light tower of FIGS. **25-30** is similar to the light tower **100** of FIGS. **1-18**, with like features identified using the same reference numerals, except as described herein or as apparent from the figures. In the illustrated embodiment, the light tower **100** includes the fan **150** arranged internally within the enclosure **116**. Specifically, the fan **150** is mounted on an internal surface of a rear wall **152** of the housing **112** adjacent to the rear portion **106**. The fan **150** may be positioned adjacent or coupled to a radiator **154** of the engine **132** so that the fan **150** directs airflow over the radiator **154** to provide cooling to a coolant circuit of the engine **132**.

[0115] In some embodiments, the fan **150** is configured to operate in a first operating mode where the fan **150** rotates in a first direction, and a second operating mode where the fan **150** rotates in a second direction opposite to the first direction. In the first operating mode, the fan **150** may draw fresh air through a vent or perforated portion **157** of a front wall **158** in the housing **112** (see, e.g., the arrows in FIG. **25** indicating the direction of airflow). The air drawn in through the perforated portion **157** of the front wall **158** flows into the enclosure **116** and initially travels over the rectifier **142**, which is coupled to an internal side of the front wall **158** (see, e.g., FIG. **26**). By having the air initially flow over the rectifier **142**, the rectifier **142** is provided with a maximum amount of cooling capacity available in the air flow and the cooling improves the efficiency of the rectifier **142**. From the rectifier **142**, the air flows over the engine **132**, then reaches the fan **150** as indicated by the arrows in FIG. **27**, and flows over the radiator **154**, which provides cooling to the engine **132** and the coolant circuit thereof. After flowing through the radiator **154**, the air exits the enclosure **116** and flow out of a vent or perforated portion **161** formed in the rear wall **152** (see, e.g., FIG. **26**). In the second operating mode, the fan **150** reverses direction and draws air through the perforated portion **161** so that the air flows over the radiator **154** (see, e.g., FIG. **28**). The heat from the radiator **154** warms the air, which can then be used to warm the enclosure **116** and the battery **144** therein during certain operating conditions, as will be described herein.

[0116] In some embodiments, the fan **150** is connected to a fan controller or power distribution module (PDM) **162** that controls the speed and direction of the fan **150**, for example, based on pulse-width modulation (PWM). In some embodiments, the fan controller **162** is in communication with the controller **454** and the controller **454** is configured to control the speed and direction of the fan **150** based on a temperature of a battery cell within the battery **144** (e.g., communicated from the BMS **145** to the controller **454**) and a coolant temperature within the coolant circuit of the engine **132** (e.g., communicated from the engine controller **458** to the controller **454**).

[0117] Turning to FIGS. **30-35**, the battery **144** is included in a battery assembly **170** that is mounted within the enclosure **116**. In the illustrated embodiment, the battery assembly **170** includes a first battery pack **172** and a second battery pack **174** (e.g., the battery **144** comprises the first battery pack **172** and the second battery pack **174** connected in parallel). In some embodiments, the battery **144** may include more or less than two battery packs. The first battery pack **172** and the second battery pack **174** are mounted and supported on a mounting assembly **176**. The mounting assembly **176** includes an outer frame or box **178** upon which the first battery pack **172** and the second battery pack **174** are supported and an internal exhaust chamber or enclosure **180**. For example, a bottom wall or surface of each of the first battery pack **172** and the second battery pack **174** is supported on an upper or top surface **182** of the outer frame **178**. The top surface **182** of the outer frame **178** elevates the first battery pack **172** and the second battery pack **174** above a floor within the enclosure **116** of the housing **112**, which creates space for the internal exhaust chamber **180** to be positioned between the top surface **182** and the floor of the housing **112**.

[0118] The internal exhaust or vent chamber **180** is formed by an internal frame or box **184** that is at least partially arranged within the outer frame **178**. The internal frame **184** includes an open top side. The outer frame **178** includes a first exhaust cutout **186** and a second exhaust cutout **188** that both extend through the top surface **182** (see, e.g., FIG. **33**). The first battery pack **172** includes a first vent **190** formed in a bottom wall thereof, and the second battery pack **172** includes a second vent **192** formed in a bottom wall thereof (see, e.g., FIGS. **34** and **35**). The first vent **190** is positioned over the first exhaust cutout **186** so that fluid flow is allowed through the first vent **190** and the first exhaust cutout **186**, and into the internal exhaust chamber **180** (see, e.g., FIG. **35**). Similarly, the second vent **192** is positioned over the second exhaust cutout **188** so that fluid flow is allowed to flow through the second vent **192** and the second exhaust cutout **188**, and into the internal exhaust chamber **180**. In some embodiments, in addition to the flow path into the internal exhaust chamber **180**, a bottom surface of the first battery pack **172** and the second battery pack **174** may be spaced from the top surface **182** of the outer frame **178** to provide an additional venting flow path.

[0119] The internal frame **184** includes an external vent **194** formed along an external wall **196** of the internal frame **184**. As shown in FIGS. **30-32**, the external vent **194** is formed by an angled portion **198** of the external wall **196** that is spaced from the top surface **182** to define a gap therebetween. The angled portion **198** extends outwardly (e.g., away from the internal exhaust chamber **180**) at an acute angle to urge potential exhaust or gas within the internal exhaust chamber **180** to flow upward and rise up into the flow path of the fan **150**.

[0120] FIGS. **36-38** illustrate an exemplary embodiment of the control panel **300** that includes a CAN panel **200**, an emergency stop (E-Stop) button **202**, and a start/stop control button **204**, in addition to the user interface **304**, the mast switch **312**, the power switch **316**, the power outlet **340**, and the charging plug-in **344**. In some embodiments, the CAN panel **200** replaces the functionality of the light switches **308**, the mode dial **324**, and the performance dial **332**. In the illustrated embodiment, the CAN panel **200** includes eight buttons or inputs that may be selectively pressed or selected by a user. Specifically, the CAN panel **200** includes a mode selector button **206**, an auto mode button **208**, an increase intensity button **210**, a decrease intensity button **212**, and a plurality of light control buttons **214** (see, e.g., FIG. **37**).

[0121] In general, the mode selector button **206** is configured to change or allow a user to select the operational mode of the light tower **100**. For example, pressing the mode selector button **206** may toggle through the various modes (e.g., battery mode **500**, hybrid mode **600**, engine mode **700**, recharge mode **800**), with each mode including a unique screen that is displayed on the user interface **304**. That is, rather than a user manually turning the mode dial **324** to select the operational mode, the user may press the mode selector button **206** and choose one of the operational modes by stopping when the desired mode is displayed on the user interface **304**. It should be appreciated that the control and operation of the light tower **100** in the battery mode (e.g., the battery mode **500**), the hybrid mode (e.g., the hybrid mode **600**), the engine mode (e.g., the engine mode **700**), and the recharge mode (e.g., the recharge mode **800**) remains the same, but the process of selecting the mode is governed by the mode selector button **206**. The CAN panel **200** is in communication with the controller **454**, which is configured to relay instructions from the CAN panel **200** to the engine controller **458**, the battery management system **145**, and/or the lights **156** (see, e.g., FIG. **38**). In some embodiments, the controller **454** is configured to require a secondary authorization or confirmation of a mode that is selected by the mode selector button **206**. For example, in response to a user selecting, via the mode selector button **206**, the hybrid mode, the engine mode, or the recharge mode, the controller **454** may require an input to the start/stop control button **204** to enable operation in the selected mode.

[0122] The auto mode button **208** may toggle the autonomous mode (e.g., the autonomous mode **900**) on and off. When the auto mode button **208** enables the autonomous mode, the lights **156** may be automatically controlled according to a set, programmed schedule or in reference to sunrise and sunset, as described herein. The increase light intensity button **210** and the decrease light intensity button **212** are configured to increase and decrease, respectively, a light intensity of all of the lights **156**. The controller **454** is configured to update an available runtime that is displayed on the user interface **304** in response to changes to the light intensity received by the increase light intensity button **210** and the decrease light intensity button **212**.

[0123] In the illustrated embodiment, the plurality of light control buttons **214** includes four buttons, one for each of the lights **156** in the light assembly **140**. In some embodiments, the CAN panel **200** may include more or less than four light control buttons **214** to correspond with the number of lights **156** in the light assembly **140**. Each of the light control buttons **214** is configured to control or toggle an on/off status of one of the lights **156** based on a user pressing the light control button **214**. The E-Stop button **302**, when pressed, is configured to shutdown the engine **132** and the controller **454** is configured to control shutdown of all remaining functions once the controller **454** detects that the E-Stop button **302** has been pressed.

[0124] Turning to FIG. **38**, the controller **454** is in communication with the generator **136**, the BMS **145**, the lights **156**, the fan controller **162**, the control panel **300**, one or more sensors **440**, and the engine controller **458**. In some embodiments, each of the first battery pack **172** and the second battery pack **174** includes a dedicated BMS that both communicate with the controller **454**. In some embodiments, the first battery pack **172** and the second battery pack **174** include a common BMS. Regardless of the particular BMS implementation, the controller **454** is configured to monitor performance and operating characteristics (e.g., SOC, charge current, discharge current, cell temperature, cell voltage, etc.) of the first battery pack **172** and the second battery pack **174** and attempt to maintain the SOC of the first battery pack **172** and the second battery pack **174** in a balanced stated (e.g., within a predetermined differential from one another). In some embodiments, if one of the first battery pack **172** or the second battery pack **174** needs to go offline and the contactor opens preventing the battery from being used, the controller **454** and/or the BMS **145** may instruct both of the first battery pack **172** and the second battery pack **174** to turn off together to maintain the SOC of the first battery pack **172** and the second battery pack **174** within the predetermined differential.

[0125] In some embodiments, the controller **454** is configured to operate one or more components of the light tower **100** in a light sleep mode or a deep sleep mode. In some embodiments, the controller **454** is configured to transition into the light sleep mode after not receiving an input from the control panel **300** for a predetermined waiting period (e.g., 1 minute, 2 minutes, 3 minutes, etc.), or after instructing the user interface **304** to display a notification for the predetermined waiting period. Once the conditions for entering light sleep mode are satisfied, the controller **454** is configured to turn of the display or screen of the user interface **304**, which reduces a power demand on a 12V battery **472** that, in some embodiments, provides power to the controller **454**, the CAN panel **200**, among other components within the light tower **100**. In some embodiments, the 12V battery **472** is charged via an alternator of the engine **132**, when the engine **132** is running, and charged by either a DC-to-DC battery charger that is powered by the battery **144**/the battery assembly **170** or an AC-to-DC battery charger that is powered by the inverter **138** (which is powered by the battery **144**/the battery assembly **170**).

[0126] In some embodiments, once the light sleep mode has been active for a predetermined sleep period (e.g., 1 hour, 1.5 hours, 2, hours, etc.), the power switch **316** is still in the on position, and the light assembly **140** is not operational (e.g., due to a missed secondary authorization, an interrupted charging condition that has not been resumed, or after running in battery mode and reaching the low SOC threshold), the controller **454** transitions into the deep sleep mode. In the deep sleep mode, the first battery pack **172** and the second battery pack **174** are shutdown, any lights associated with the CAN panel **200** are turned off, and the display or screen on the user interface **304** is turned off. In this way, for example, the power draw from the 12V battery **472** is significantly reduced in the deep sleep mode to maintain available power to allow the controller **454** to "wake up" in predetermined wake-up intervals (e.g., 2 hours, 4 hours, 6 hours, etc.) and broadcast the deep sleep status via telematics.

[0127] As described herein, the controller **454** is configured to define a low SOC threshold (e.g., the SOC threshold where the battery assembly **170** is allowed to drain down to before the engine **132** initiates charging the battery assembly **170** via the generator **136**), in both the battery and hybrid modes, that may be based on a battery cell temperature that is communicated to the controller **454** from the BMS **145**. In some embodiments, the BMS **145** communicates signals to the controller **454** relating to the maximum and minimum battery cell temperature for both the first battery pack **172** and the second battery pack **174**. In general, adjusting the low SOC threshold based on battery cell temperature prepares the battery assembly **170** for going offline and being stored for an extended period of time. In some embodiments, when operating in the hybrid mode (e.g. the hybrid mode **600**), when the minimum battery cell temperature of the battery assembly **170** (i.e., either the first battery pack **172** or the second battery pack **174**) is above a first temperature threshold, the low SOC threshold is set to a first value, and when the minimum battery cell temperature of the battery assembly **170** is below the first temperature threshold, the low SOC threshold is set to a second value that is greater than the first value. Once the low SOC threshold is set to the second value, the low SOC threshold may remain at the second value until the minimum battery cell temperature of the battery assembly **170** increases to a second temperature threshold that is greater than the first temperature threshold. Once the minimum battery cell temperature reaches the second temperature threshold, the low SOC threshold is set back to the first value. In some embodiments, if the minimum battery cell temperature drops below the first temperature threshold after the SOC has already dropped below the second value, the controller **454** instructs the engine controller **458** to initiate a full recharge cycle where the engine **132** powers the generator **136** to recharge the battery assembly **170**.

[0128] In general, when operating in the battery mode (e.g., the battery mode **500**) where engine/generator recharging is not an option, once the low SOC threshold is reached, the light assembly **140** is turned off and the controller **454** will transition to the light sleep mode and then the deep sleep mode pending user interaction. In some embodiments, when operating in the battery mode (e.g., the battery mode **500**), when the minimum battery cell temperature of the battery assembly **170** (i.e., either the first battery pack **172** or the second battery pack **174**) is above a first temperature threshold, the low SOC threshold is set to a first value by the controller **454**, and when the minimum battery cell temperature of the battery assembly **170** is below the first temperature threshold, the low SOC threshold is set to a second value that is greater than the first value. In some embodiments, the first temperature threshold in the battery mode is different than (e.g., less than) the first temperature threshold in the hybrid mode. In some embodiments, the first value of the low SOC threshold is the same for both the battery mode and the hybrid mode. In some embodiments, the second value of the low SOC threshold in the battery mode is different than (e.g., less than) the second value of the low SOC threshold in the hybrid mode.

[0129] In some embodiments, when operating in the battery mode and once the low SOC threshold is set to the second value, the low SOC threshold may remain at the second value until the minimum battery cell temperature of the battery assembly **170** increases to a second temperature threshold that is greater than the first temperature threshold. Once the minimum battery cell temperature reaches the second temperature threshold, the low SOC threshold is set back to the first value. In some embodiments, the second temperature threshold in the battery mode is the same as the second temperature threshold in the hybrid mode. In some embodiments, if the minimum battery cell temperature drops below the first temperature threshold and the SOC is already below the low SOC threshold, the controller **454** instructs the user interface **304** to display a notification informing a user to recharge the battery assembly **170** or select another operating mode (e.g., hybrid mode, recharge mode, etc.). If nothing changes in the operation of the light tower **100** after a predetermined waiting period (e.g., 1 minute, 2 minutes, 3 minutes, etc.), the controller **454** turns off the light assembly **140** and will transition to the light sleep mode and then the deep sleep mode. In some embodiments, during normal operating conditions in the battery mode (e.g., the SOC is above the low SOC threshold), the controller **454** may provide the notification informing a user to recharge the battery assembly **170** or select another operating mode a predetermined SOC value above the low SOC threshold (e.g., 5% above the low SOC threshold, 10% above the low SOC threshold, etc.).

[0130] In some embodiments, the controller **454** is configured to control a speed of the engine **132** during charging operations, via communication with the engine controller **458**, based on a current output from the generator **136** and the maximum charging current available from the battery assembly **170**. For example, the one or more sensors **440** may include a current sensor that measures a current output from the generator **136**. The current measured output from the generator **136** measured by the current sensor is a function of the load from the light assembly **140** and the inverter **138**. The current flowing into the battery assembly **170** (i.e., into the first battery pack **172** and the second battery pack **174**) is measured by the BMS **145** and communicated to the controller **454**. In addition, the BMS **145** also communicates the maximum charge current available for the battery assembly **170** to the controller **454**, which is based on, for example, the maximum and minimum battery cell temperatures of each of the first battery pack **172** and the second battery pack **174**.

[0131] In some embodiments, the generator **136** is restricted during operation to output a maximum generator current. This maximum generator current is used in combination with the current output from the generator **136** that is measured by the current sensor to determine a maximum charge available for each of the first battery pack **172** and the second battery pack **174**. For example, the difference between the maximum generator current and the sensed current output from the generator is averaged for the number of battery packs (e.g., divided by 2 in the exemplary embodiment including two battery packs). This value provides the maximum charge available per battery. In some embodiments, the controller **454** determines the minimum value of the two maximum charge currents for the battery assembly **170** provided by the BMS **145** (e.g., maximum charge current for the first battery pack **172** and the maximum charge current for the second battery pack **174**, which should be close due to the first battery pack **172** and the second battery pack **174** not varying much in temperature), and sets a target maximum charge rate for the battery assembly **170** at a predetermined margin or tolerance below this minimum value.

[0132] When determining the charge rate for the battery assembly **170**, the controller **454** compares the target maximum charge rate to the maximum charge available from the generator **136**. Specifically, if the target maximum charge rate is greater than or equal to the maximum charge available, then the charge rate is set to the maximum charge available. If the target maximum charge rate is less than the maximum charge available, then the charge rate is set to the target maximum charge rate. The current into the battery assembly **170** (e.g., the current flow into each of the first battery pack **172** and the second battery pack **172**) is measured either by a battery current sensor of the one or more sensors **440** and/or by the BMS **145**. If the current flowing into the first battery pack **172** or the second battery pack **174** is greater than the charge rate, the controller **454** instructs the engine **132** to decrease speed. If the current flowing into the first battery pack **172** and the second battery pack **174** is less than the charge rate, the controller **454** instructs the engine **132** to increase speed.

[0133] In some embodiments, the controller **454** is configured to control a speed of the engine **132** during engine mode operations, via communication with the engine controller **458**. In engine mode, the light assembly **140** and the inverter **138** are powered by the output of the generator **136** and no current is being used to charge the battery assembly **170**, which is offline. The maximum charge rate from the battery assembly **170** is, therefore, assumed to be zero when the battery assembly **170** is offline. Accordingly, the controller **454** is configured to control the speed of the engine **132** to match the current demand of the current sensor that monitors the loads required by the light assembly **140** and the inverter **138**.

[0134] As described herein and shown in FIG. **39**, the controller **454** is in communication with the fan controller **162**. In general, the controller **454** is configured to instruct the fan controller **162** to control a speed and direction of the fan **150** based, for example, of both the coolant temperature within the coolant circuit of the engine **132** and the battery cell temperature within the battery assembly **170**. In some embodiments, the coolant temperature may be used to control a speed of the fan **150**, with the fan **150** being off when the coolant temperature is below a low temperature threshold and the fan **150** at a first speed when the coolant temperature is above the low temperature threshold. The controller **454** may define various incremental step changes in fan speed as the coolant temperature increases above the low temperature threshold. For example, when the coolant temperature increases above a second temperature threshold, the fan **150** may increase to a second speed higher than the first speed, and when the coolant temperature increases above a third temperature threshold, the fan **150** may increase to a third speed higher than the second speed, and so on. In some embodiments, the battery cell temperature may be used to control a direction of the fan **150**. If the battery cell temperature is greater than or equal to a first temperature threshold, the controller **454** instructs the fan **150** to operate in the first operating mode where the fan **150** rotates in the first direction (see, e.g., FIGS. **25-28**). If the battery cell temperature is less than the first temperature threshold, the controller **454** instructs the fan **150** to operate in the second operating mode where the fan **150** rotates in the second direction (see, e.g., FIG. **28**). In the second operating mode, the fan **150** draws warm air from the radiator **154** to warm the enclosure **116** and the battery assembly **170**. Once the fan **150** is transitioned to the second operating mode, the controller **454** will maintain the fan **150** in the second operating mode until the battery cell temperature increases above a second temperature threshold that is greater than the first temperature threshold. When the battery cell temperature increases above the second temperature threshold, the controller **454** instructs the fan **150**, via the fan controller **162**, to transition back to the first operating mode.

[0135] FIGS. **40-58** show exemplary embodiments of various screens that may be displayed on the user interface **304** of the control panel **300**. For example, FIG. **40** shows a setup and diagnostic screen. FIG. **41** shows a time entry screen where the time of day may be entered into the controller **454**. FIG. **42** shows a date entry screen where the date may be entered into the controller **454**. FIG. **43** shows a passcode screen where a user is prompted to enter a password, for example, to access an advanced setting screen. FIG. **44** shows an advanced setting screen, and FIG. **45** shows a new password screen.

[0136] FIG. **46** shows an autonomous operation screen where the location and schedule of the light assembly **140** may be controlled or viewed in the autonomous mode. FIG. **47** shows a location screen where a geographic location may be entered into the controller **454**. FIG. **48** shows a battery status and diagnostic screen, and FIG. **49** shows an engine status and diagnostic screen. FIG. **50** shows an engine speed screen where a speed of the engine **132** may be manually controlled based on an input to the user interface **304**.

[0137] FIG. **51** shows a light control screen after a user selected, for example, via the CAN panel **200**, the battery mode and the user interface **304** prompts the user for secondary authorization to proceed with the battery mode (e.g., requiring the start/stop control button **204** to be pressed). FIG. **52** shows the light control screen after the secondary authorization occurs in battery mode. FIG. **53** shows a light control screen after a user selected, for example, via the CAN panel **200**, the engine mode and the user interface **304** prompts the user for secondary authorization to proceed with the engine mode (e.g., requiring the start/stop control button **204** to be pressed). FIG. **54** shows the light control screen after the secondary authorization occurs in engine mode. FIG. **55** shows a light control screen after a user selected, for example, via the CAN panel **200**, the hybrid mode and the user interface **304** prompts the user for secondary authorization to proceed with the hybrid mode (e.g., requiring the start/stop control button **204** to be pressed). FIG. **56** shows the light control screen after the secondary authorization occurs in hybrid mode. FIG. **57** shows a light control screen after a user selected, for example, via the CAN panel **200**, the recharge mode and the user interface **304** prompts the user for secondary authorization to proceed with the recharge mode (e.g., requiring the start/stop control button **204** to be pressed). FIG. **58** shows the light control screen after the secondary authorization occurs in recharge mode.

[0138] FIGS. **59-63** show an exemplary embodiment of the mounting assembly **176** for the battery assembly **170** including an upper flange **199**. In general, the mounting assembly **176** of FIGS. **59-63** is similar to the mounting assembly **176** of FIGS. **31-35**, with like features identified using the same reference numerals, except as described herein or as apparent from the figures. In the illustrated embodiment, the mounting assembly **176** includes the upper flange **199** extending around a periphery of the top surface **182**. Specifically, the upper flange **199** extends outwardly and away from the top surface **182** to form a lip that surrounds a base of the battery assembly **170** (e.g., surrounds the first battery pack **172** and the second battery pack **174**). In some embodiments, the upper flange **199** is formed along the sidewalls of the outer frame **178** (e.g., sides arranged perpendicular to the external wall **196** including the external vent **194**) by the external walls extending above the top surface **182** (see, e.g., FIGS. **62** and **63**). In some embodiments, the upper flange **199** is formed along the front and back sides of the outer frame **178** (e.g., side including the external wall **196** and the opposing side) as an integral feature with the top surface **182**.

[0139] FIGS. **64-66** show an exemplary embodiment of the frame **104** of the light tower **100** including stabilizing brackets **220**. In the illustrated embodiment, the light tower **100** includes two of the stabilizing brackets **220**. In some embodiments, the light tower **100** may include more of less than two of the stabilizing brackets **220**. In general, the stabilizing brackets **220** are coupled between a base **222** of the frame **104** and a sidewall **224** of the frame **104**, and provide structural stability and support for the battery assembly **170** and the light tower **100**, for example, during wind loading. Each of the stabilizing brackets **220** includes a base plate **226** coupled to and supported on the base **222**. In some embodiments, the base **222** includes a pair of separated frame rails **228**. In some embodiments, the base **222** is formed by a base plate or another structure.

[0140] Each of the stabilizing brackets **220** includes a first arm or linkage **230** that extends outwardly from the base plate **226**, and an angled arm or linkage **232** that extends from a junction between the first arm **230** and the second arm **232** to the sidewall **224**. In the illustrated embodiment, the first arm **230** extends generally perpendicularly from the base plate **226**, and the angled arm **232** extends from the junction between the first arm **230** and the second arm **232** at an acute angle (e.g., neither parallel to a top surface of the base **222** nor perpendicular to the top surface of the base **222**). For example, the second arm **232** may extend upwardly (e.g., away from the base **222**) as the second arm **232** extends from the junction between the first arm **230** and the second arm **232** to the sidewall **224**, so that an acute angle (e.g., between approximately 15 degrees and approximately 75 degrees) is formed between a plane that is parallel to the top surface of the base **222** and the second arm **232**.

[0141] In the illustrated embodiment, a distal end of each of the second arms **232** is coupled to the sidewall **224**. Specifically, each of the second arms **232** is coupled to an opposing side of a mast recess or cutout **234** formed in the sidewall **224**. The cutout **234** is dimensioned to receive at least a portion of the mast **148**, and the second arms **232** are coupled to the sidewall **224** on internal, opposing sides (e.g., within the enclosure **116** formed by the housing **112**) of the cutout **234**. In some embodiments, the sidewall **224** includes a mounting flange **236** that is coupled to and arranged outwardly from each of the internal, opposing sides of the walls that form the cutout **234**, and the distal end of each of the second arms **232** is coupled to the mounting flange **236**. By arranging the stabilizing brackets **220** in an area on the frame **104** where the mast **148** interfaces with the frame **104**, the stabilizing brackets **220** provide added stability in a location where the frame **104** may experience high loading (e.g., when the **148** is extended).

[0142] In the illustrated embodiment, a linkage or crossbar **238** is coupled between (e.g., directly coupled between) the second arms **232** of the stabilizing brackets **220**. The crossbar **238** is arranged at a location between the junction between the first arm **230** and the second arm **232**, and a distal end of the second arm **232**. When the battery assembly **170** is installed on the frame **104** (see, e.g., FIGS. **65** and **66**) and the mounting assembly **176** is supported on the frame **104**, the stabilizing brackets **220** extend over the battery assembly **170** and the crossbar **238** is arranged above the battery assembly **170**.

[0143] In some embodiments, the controller **454** may be configured to limit when the battery **144** and/or the battery assembly **170** is allowed to be charged via the charging plug-in **344** (e.g., charged by wall power or shore power) based on the operational mode of the hybrid power system. For example, the light tower **100** may include an electronic switch or relay **240** connected between the charging plug-in **344** and the charger **146** that is on-board the light tower **100** (e.g., within the housing **112** and the enclosure **116**), as shown in FIG. **67**. In some embodiments, the relay **240** may operate in a normally-closed state, where the relay **240** closes the circuit between the charging plug-in **344** and the charger **146** and enables power transmission therebetween. Accordingly, when the power switch **316** is in an off-state, where the light tower **100** is powered off and no power is being provided by the battery **144**, the battery assembly **170**, or the engine **132**, the relay **240** is configured to allow power transmission from the charging plug-in **344** and the charger **146**. Accordingly, when the charging plug-in **344** is connected to an external power source (e.g., wall power or shore power) and the power switch **316** is in an off-state, the battery assembly **170** is charged by electrical power provided by the external power source.

[0144] Once the power switch **316** is switched to an on-state and the controller **454** is powered on, the controller **454** is configured to instruct the relay **240** to transition to an open state, where the relay **240** opens the circuit between the charging plug-in **344** and the charger **146** and prevents power transmission therebetween. With the light tower **100** powered on and operating, the controller **454** is configured to prevent the relay **240** from transitioning to the closed state, unless the hybrid power system is operating in the battery mode (e.g., the battery mode **500**), where only the battery **144**/the battery assembly **170** is allowed to power the light assembly **140**. In other words, the controller **454** controls the state of the relay **240** and prevents power transmission between the charging plug-in **344** and the charger **146** in hybrid mode and engine mode. Once the controller **454** detects that the hybrid power system is operating in battery mode, the controller **454** is configured to instruct the relay **240** to transition to the closed state and allow the external power source, when connected to the charging plug-in **344**, to supply power to the charger **146** and charge the battery **144**/the battery assembly **170**. If the controller **454** detects that the hybrid power system is operating in battery mode and the battery **144**/the battery assembly **170** is being charged by the external power source (e.g., via signal(s) from the BMS **145**), the controller **454** is configured to prevent the hybrid power system from leaving battery mode. Accordingly, when in battery mode, the power switch **316** may need to transition to the off-state or the controller **454** may be required to detect that the battery **144**/the battery assembly **170** is not being charged by the external power source to change from the battery mode.

[0145] As described herein, in some embodiments, the charging of the battery **144**/the battery assembly **170** in hybrid mode (e.g., the hybrid mode **600**) may be based on voltage or cell voltage, rather than SOC. Specifically, the controller **454** may control operation of the engine **132** and the charging of the battery assembly **170** by the generator **136** based on the cell voltage communicated to the controller **454** from the BMS **145**, as shown in the process or method **1000** of FIG. **68**. With the hybrid power system operating in hybrid mode, the battery **144**/the battery assembly **170** is prioritized (i.e., used to power the light assembly **140**) and the controller **454** monitors a minimum cell voltage communicated from the BMS **145**. For example, the BMS **145** of each of the first battery pack **172** and the second battery pack **174** may communicate a minimum cell voltage, and the controller **454** may monitor these values to determine, at step **1002**, if the minimum cell voltage is below a charging threshold. If the minimum cell voltage is not below the charging threshold, the battery **144**/the battery assembly **170**

continues to provide power to the light assembly **140** and the engine **132** remains off at step **1004**.

[0146] In some embodiments, the charging threshold for the minimum cell voltage may vary as a function of battery temperature (e.g., a minimum cell temperature measured by the BMS **145**). Specifically, the charging threshold may define a first value when the battery temperature is above a temperature threshold, and define a second value when the battery temperature is below the temperature threshold, where the first value is less than the second value. In other words, the minimum cell voltage where charging is initiated may be higher when the battery temperature is below the temperature threshold. In some embodiments, once the battery temperature drops below the temperature threshold, the controller **454** does not increase the charging threshold back from the second value (e.g., higher value) to the first value (e.g., lower value) until the battery temperature rises above a second temperature threshold that is greater than the temperature threshold.

[0147] If the minimum cell voltage is at or below the charging threshold (e.g., for the corresponding battery temperature), the controller **454** instructs the engine **132** to start and the engine **132** charges the battery **144**/the battery assembly **170** in a constant current mode, at step **1006**. In the constant current mode, the controller **454** is configured to control a speed of the engine **132** based on the current output from the generator **136** and the maximum charging current available from the battery **144**/the battery assembly **170**. As described herein, in the constant current mode, the charge rate for the battery **144**/the battery assembly **170** is determined by the controller **454** comparing the target maximum charge rate to the maximum charge available from the generator **136**. If the target maximum charge rate is greater than or equal to the maximum charge current available, then the charge rate is set to the maximum charge current available. If the target maximum charge rate is less than the maximum charge available, then the charge rate is set to the target maximum charge rate. The current into the battery **144**/the battery assembly **170** is measured either by a battery current sensor of the one or more sensors **440** and/or by the BMS **145**. If the current flowing into the battery **144**/the battery assembly **170** is greater than the charge rate, the controller **454** instructs the engine **132** to decrease speed. If the current flowing into the battery **144**/the battery assembly **170** is less than the charge rate, the controller **454** instructs the engine **132** to increase speed.

[0148] While in the constant current mode, the controller **454** determines, at step **1008**, if a maximum cell voltage measured by the BMS **145** reaches or is equal to a constant voltage threshold. If the maximum cell voltage is below the constant voltage threshold, the engine **132** continues to charge the battery **144**/the battery assembly **170** in constant current mode. If the maximum cell voltage reaches or is equal to the constant voltage threshold, the controller **454** controls the engine **132** to charge the battery **144**/the battery assembly **170** in a constant voltage mode at step **1010**. In general, in the constant voltage mode, the controller **454** controls the speed of the engine **132** to maintain the maximum cell voltage of the battery **144**/the battery assembly **170** at the constant voltage threshold, or within a predetermined tolerance or margin of the constant voltage threshold. As the battery **144**/the battery assembly **170** are charged in the constant voltage mode, the speed of the engine **132** required to maintain the constant voltage threshold may continually decrease (assuming there are not increases in electrical load, for example, from increases in light intensity of the light assembly **140** or additional loads powered by the inverter **138**, which the constant voltage mode adapts to as described herein). The controller **454** is configured to determined, at step **1012**, if the speed of the engine **132** decreases to a point where it is equal to a stop speed. If the speed of the engine **132** is not at the stop speed, the charging continues in the constant voltage mode. If the speed of the engine **132** is at the stop speed, the controller **454** instructs the engine **132** to stop, at step **1014** and the battery **144**/the battery assembly **170** are charged and can again solely provide power to the light assembly **140**.

[0149] While in the constant voltage mode, the controller **454** also monitors the maximum cell voltage for any voltage spikes. If the controller **454** determines, at step **1016**, that the maximum cell voltage is above a stop threshold (e.g., a predetermined value above the constant voltage threshold), the controller **454** instructs the engine **132** to stop, at step **1018**, and the battery **144**/the battery assembly **170** are charged and can again solely provide power to the light assembly **140**.

[0150] Turning to FIG. **69**, the operational details of the constant voltage mode at step **1010** in the method **1000** (e.g., between initiation and stopping the engine **132**) are shown according to an exemplary embodiment. Once the constant voltage mode is started at step **1020**, the controller **454** is configured to decrease the speed of the engine **132**, at step **1022**, a predetermined increment (e.g., 5 RPM, 10 RPM, 15 RPM, 20 RPM, 25 RPM, 30 RPM, 35 RPM, 40 RPM, 45 RPM, 50 RPM) from the current value, and then monitor the cell voltage from the BMS **145** at step **1024**. Specifically, the controller **454** is configured to determine if the maximum cell voltage measured by the BMS **145** is a predetermined tolerance or margin below the constant voltage threshold at step **1026**, and determine if the maximum cell voltage measured by the BMS **145** is a predetermined tolerance or margin above the constant voltage threshold at step **1028**. In some embodiments, the predetermined margin for being above the constant voltage threshold may be different than the predetermined margin for being below the constant voltage threshold.

[0151] If the controller **454** determines that the maximum cell voltage is not the predetermined margin above the constant voltage threshold at step **1028**, the controller **454** continues to operate the engine **132** in constant voltage mode and continues to monitor the cell voltage at step **1024**. If the controller **454** determines that the maximum cell voltage is the predetermined margin above the constant voltage threshold at step **1028**, the controller **454** decreases the speed of the engine **132** by the predetermined increment, at step **1030**, and continues to monitor the cell voltage at step **1024**.

[0152] If the controller **454** determines that the maximum cell voltage is not the predetermined margin below the constant voltage threshold at step **1026**, the controller **454** continues to operate the engine **132** in constant voltage mode and continues to monitor the cell voltage at step **1024**. If the controller **454** determines that the maximum cell voltage is the predetermined margin below the constant voltage threshold at step **1026**, the controller **454** then determines, at step **1032**, if the maximum cell voltage decreased to an intermediate threshold that is more than the predetermined margin below the constant voltage threshold and greater than or equal to the charging threshold. If the maximum cell voltage is less than or equal to the intermediate threshold, the controller **454** switches back to the constant current mode (e.g., step **1006**) at step **1034**. If the maximum cell voltage is greater than the intermediate voltage, the controller **454** increases the speed of the engine **132** by the predetermined increment at step **1036**.

[0153] Accordingly, the controller **454** is configured to adapt to changes in load (e.g., increases and decreases in load) by controlling the speed of the engine **132**, while charging in the constant voltage mode, and the controller **454** will continue to charge in the constant voltage mode until the controller **454** determines that the charging requires switching back to the constant current mode or the speed of the engine **132** reaches the stop threshold (e.g., continuing to decrease via steps **1028** and **1032**).

[0154] In some embodiments, the light tower **100** may include one or more battery docks **1050** that are each configured to receive a swappable battery pack. The battery docks may receive electrical power from the battery **144**/the battery assembly **170** (see, e.g., FIG. **70**), or from the charger **146** (see, e.g., FIG. **71**), when the external power source is connected and allowed to provide power to the charger **146**, to facilitate charging the swappable battery packs connected to the respective battery docks **1050**. In some embodiments, the battery docks **1050** are coupled to and/or supported on an external-facing portion of the frame **104**. In some embodiments, the battery docks **1050** are coupled to and/or supported on an external-facing portion of the housing **112**. In some embodiments, the battery docks **1050** are mounted to and/or arranged within an internal-facing portion of the housing **112** (e.g., the battery docks **1050** are within the enclosure **116**). The swappable battery pack(s) and the battery dock **1050** may be in the form of the swappable battery pack and the dock assembly that are described in International Patent Application No. PCT/US2023/033002, filed on Sep. 18, 2023, which is incorporated herein by reference in its entirety.

[0155] In the exemplary embodiment where power from the battery **144**/the battery assembly **170** is used to charge the swappable battery pack(s) (see, e.g., FIG. **70**), the light tower **100** includes a dedicated swappable battery charger **1052**. In some embodiments, the swappable battery charger **1052** may be mounted on or within the housing **112**, and the swappable battery charger **1052** may receive DC power from the battery **144**/the battery assembly **170**, when available, and output DC power to the battery docks **1050** (e.g., when a swappable battery is connected to the battery dock **1050**).

[0156] It should be appreciated that while the hybrid power system (e.g., the engine **132**, the generator **136**, the battery **144**/the battery assembly **170**) and the control/operation thereof described herein are applied to the light tower **100**, the hybrid power system may be implemented to provide electrical power to other outdoor power equipment applications and/or chore products. For example, the hybrid power system may be applied to chore products, including outdoor power equipment, standby generators, portable jobsite equipment, or other appropriate uses. Outdoor power equipment may include lawn mowers, riding tractors, snow throwers, pressure washers, portable generators, tillers, log splitters, zero-turn radius mowers, walk-behind mowers, wide-area walk-behind mowers, riding mowers, standing mowers, golf carts, construction equipment, cleaning equipment, industrial vehicles such as forklifts, utility vehicles, etc. Portable jobsite equipment may include cleaning equipment, construction equipment, mobile industrial heaters, and portable light stands.

[0157] As utilized herein with respect to numerical ranges, the terms "approximately," "about," "substantially," and similar terms generally mean +/−10% of the disclosed values. When the terms "approximately," "about," "substantially," and similar terms are applied to a structural feature (e.g., to describe its shape, size, orientation, direction, etc.), these terms are meant to cover minor variations in structure that may result from, for example, the manufacturing or assembly process and are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

[0158] It should be noted that the term "exemplary" and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

[0159] The term "coupled" and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If "coupled" or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of "coupled" provided above is modified by the plain language meaning of the additional term (e.g., "directly coupled" means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of "coupled" provided above. Such coupling may be mechanical, electrical, or fluidic.

[0160] References herein to the positions of elements (e.g., "top," "bottom," "above," "below") are merely used to describe the orientation of various elements in the FIGURES. It should be noted that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

[0161] The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

[0162] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0163] Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

[0164] It is important to note that the construction and arrangement of the light tower **100** as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with any other embodiment disclosed herein.

What is claimed is:

1. A hybrid light tower, comprising:

a housing;

an engine mounted within the housing;

a mast;

a generator mounted within the housing and configured to be driven by the engine;

a battery mounted within the housing and electrically coupled to the generator;

a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery or the generator; and

a controller in communication with the battery, the engine, and the light assembly, wherein the controller is configured to operate in a hybrid mode where the controller is configured to:

monitor a cell voltage of the battery;

determine if the cell voltage of the battery is below a charging threshold;

upon determining that the cell voltage of the battery is below the charging threshold, start the engine and charge the battery in a constant current mode;

while charging in the constant current mode, determine if the cell voltage is above a constant voltage threshold; and

upon determining that the cell voltage is above a constant voltage threshold, charge the battery in a constant voltage mode.

2. The hybrid light tower of claim **1**, wherein the hybrid light tower includes a control panel, and wherein an engine mode, a battery mode, and the hybrid mode are user-selectable via the control panel.

3. The hybrid light tower of claim **2**, wherein the control panel includes a controller area network (CAN) pad includes a mode selector button configured to toggle between the engine mode, the battery mode, and the hybrid mode.

4. The hybrid light tower of claim **2**, wherein the control panel includes a charging plug-in configured to selectively receive power from an external power source and supply the power from the external power source to a charger.

5. The hybrid light tower of claim **4**, wherein the charger is mounted within the housing.

6. The hybrid light tower of claim **1**, wherein the controller is further configured to operate in an autonomous mode, wherein in the autonomous mode, the controller is configured to:

receive a time, a date, and a location;

determine a sunrise calculation and a sunset calculation from the time, the date, and the location;

receive a sunrise offset and a sunset offset; and

control the light based on the sunrise calculation, the sunrise offset, the sunset calculation, and the sunset offset.

7. The hybrid light tower of claim **1**, wherein the controller is configured to:

monitor a temperature of the battery;

determine if the temperature of the battery is above a temperature threshold;

if the temperature of the battery is above the temperature threshold, set the charging threshold to a first value;
determine if the temperature of the battery is below a temperature threshold; and
if the temperature of the battery is below the temperature threshold, set the charging threshold to a second value, wherein the first value is less than the second value.

8. The hybrid light tower of claim **1**, wherein the controller is configured to determine, in the constant current mode, a charge rate for the battery based on a current output from the generator and a maximum charging current available from the battery.

9. The hybrid light tower of claim **8**, wherein the controller is configured to:
decrease, in the constant current mode, a speed of the engine if a current flowing into the battery is greater than the charge rate a charge rate for the battery; and
increase, in the constant current mode, a speed of the engine if a current flowing into the battery is less than the charge rate a charge rate for the battery.

10. The hybrid light tower of claim **1**, wherein the controller is configured to stop the engine, in the constant voltage mode, when a speed of the engine is less than or equal to a stop speed.

11. The hybrid light tower of claim **1**, wherein the controller is configured to:
monitor, in the constant voltage mode, the cell voltage;
determine if the cell voltage is a predetermined margin above the constant voltage threshold;
upon determining that the cell voltage is the predetermined margin above the constant voltage threshold, decrease a speed of the engine by a predetermined increment;
determine if the cell voltage is a predetermined margin below the constant voltage threshold; and
upon determining that the cell voltage is the predetermined margin below the constant voltage threshold, increase the speed of the engine by the predetermined increment.

12. The hybrid light tower of claim **1**, wherein the battery is mounted on a mounting assembly that includes an outer frame having an external vent formed in an external wall thereof adjacent to a top surface of the outer frame.

13. The hybrid light tower of claim **1**, further comprising a fan arranged within the housing.

14. The hybrid light tower of claim **13**, wherein the controller is configured to control a direction of the fan based on a battery cell temperature within the battery.

15. A hybrid light tower, comprising:
a housing;
an engine mounted within the housing;
a mast;
a generator mounted within the housing and configured to be driven by the engine;
a battery mounted within the housing and electrically coupled to the generator;
a light assembly coupled to the mast and including a light, wherein the light is configured to be powered by the battery or the generator;
a control panel including a charging plug-in;
a charger arranged within the housing and electrically coupled to the battery;
an electrical switch electrically coupled between the charging plug-in and the charger; and
a controller in communication with the battery, the engine, the electrical switch, and the light assembly, wherein the controller is configured to selectively switch between a battery mode and a hybrid mode, wherein the controller is configured to control the electrical switch so that:
in the hybrid mode, the electrical switch is configured to prevent power transmission from the charging plug-in to the charger; and
in the battery mode, the electrical switch is configured to allow power transmission from the charging plug-in to the charger.

16. The hybrid light tower of claim **15**, wherein the control panel further includes a power switch, and wherein the electrical switch is configured to transition to a closed state and allow power transmission between the charging plug-in and the charger when the power switch is in an off state.

17. The hybrid light tower of claim **16**, wherein the controller is configured to transition the electrical switch to an open state and prevent power transmission between the charging plug-in and the charger when the power switch is in an off state and the controller is not in the battery mode.

18. A hybrid light tower, comprising:
a housing defining an enclosure;
an engine arranged within the enclosure;
a mast;
a generator configured to be driven by the engine and arranged within the enclosure;
a battery pack arranged within the enclosure and mounted on a mounting assembly that includes an outer frame and an internal exhaust chamber, wherein the outer frame includes an exhaust cutout and the battery pack includes a vent formed in a bottom surface thereon, wherein the vent is positioned over the exhaust cutout a flow path is provided through the exhaust cutout and into the internal exhaust chamber, wherein the mounting assembly includes an external vent formed in an external wall thereof adjacent to a top surface of the outer frame and in fluid communication with the internal exhaust chamber;
a light assembly coupled to the mast and including a light; and
a controller in communication with the battery pack, the engine, and the light assembly, wherein the controller is configured to operate in an engine mode where the generator supplies power to the light, a battery mode where the battery pack supplies power to the light, or a hybrid mode where the battery pack supplies power to the light and the generator selectively charges the battery pack.

19. The hybrid light tower of claim **18**, further comprising a frame on which the battery pack is supported within the housing, and a stabilizing bracket coupled between a base of the frame and a sidewall of the frame.

20. The hybrid light tower of claim **19**, wherein the stabilizing bracket includes a first arm extending generally perpendicularly to the base of the frame, and a second arm that extends toward the sidewall at an acute angle.

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