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(54) **LOCOMOTIVE REPOWER**

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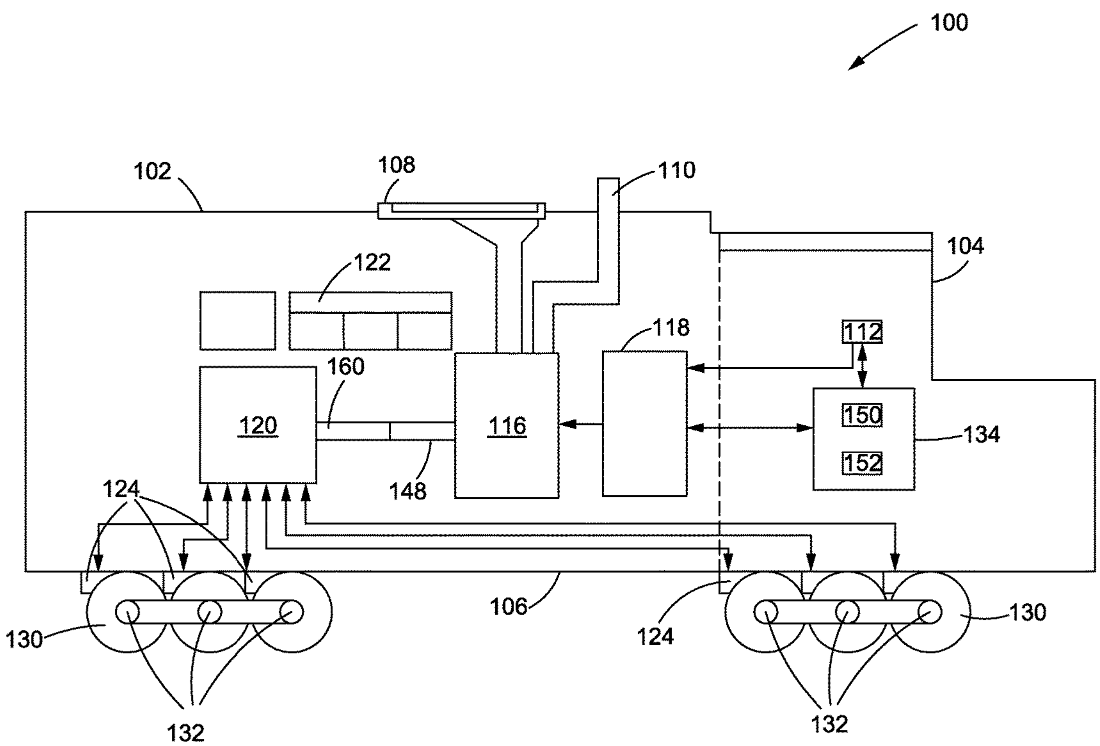
(57) **ABSTRACT**

A method for repowering a locomotive, a repower kit and a repowered locomotive is disclosed. The method may comprise replacing the 4-stroke engine with a 2-stroke, engine, and replacing the first engine controller with a second engine controller. The second engine controller may be configured to regulate operation of the second engine. The second engine controller and the second engine, in combination, may be adapted to meet at least Tier 0 emission standards for locomotives when repowered. Pre-existing traction motors may be configured to utilize power that results from operation of the second engine.



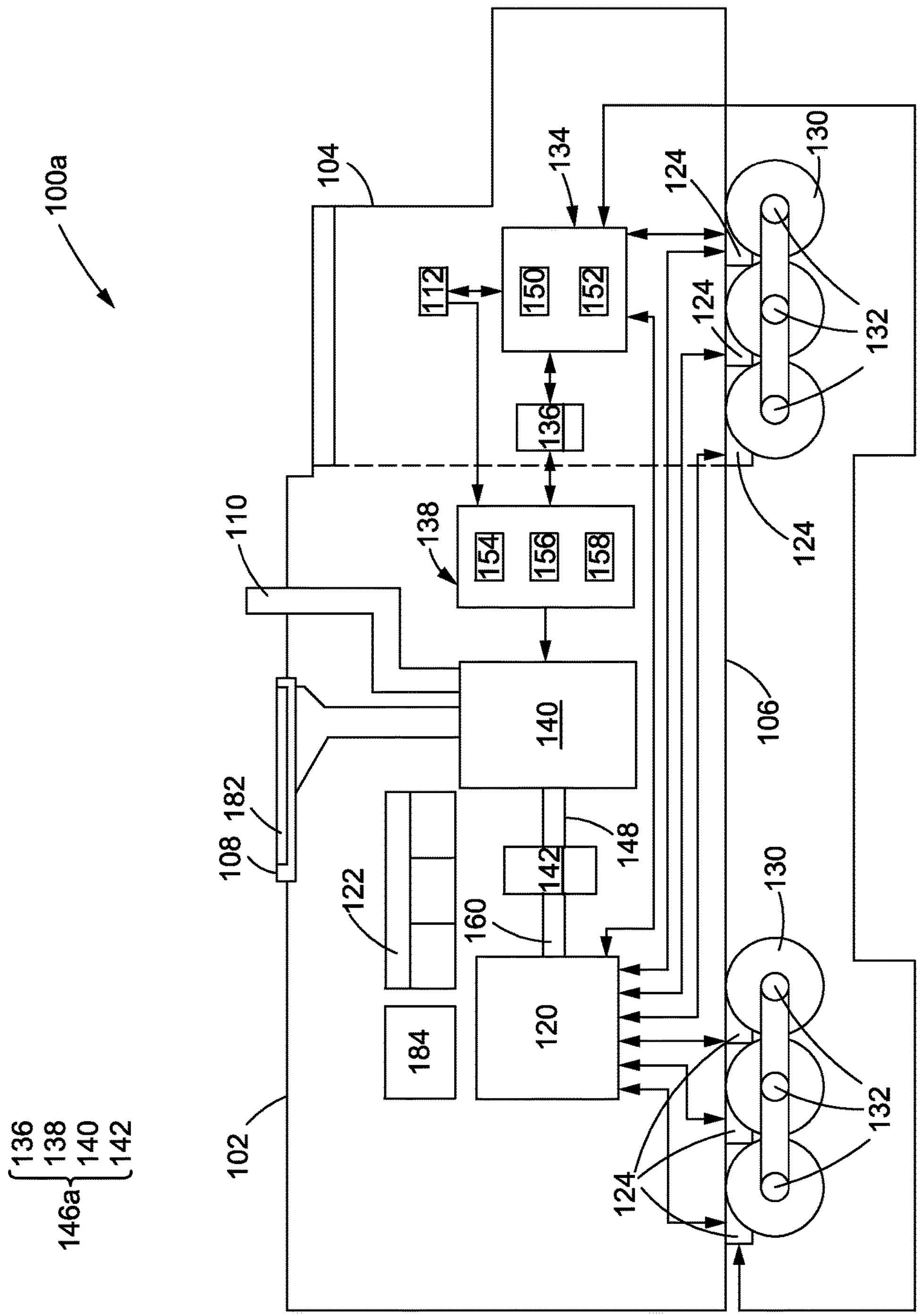

100a
104
134
124
130
112
150
152
132
136
110
138
154
156
158
140
106
182
108
148
142
122
160
120
184
102
146a
136
138
140
142

FIG. 1

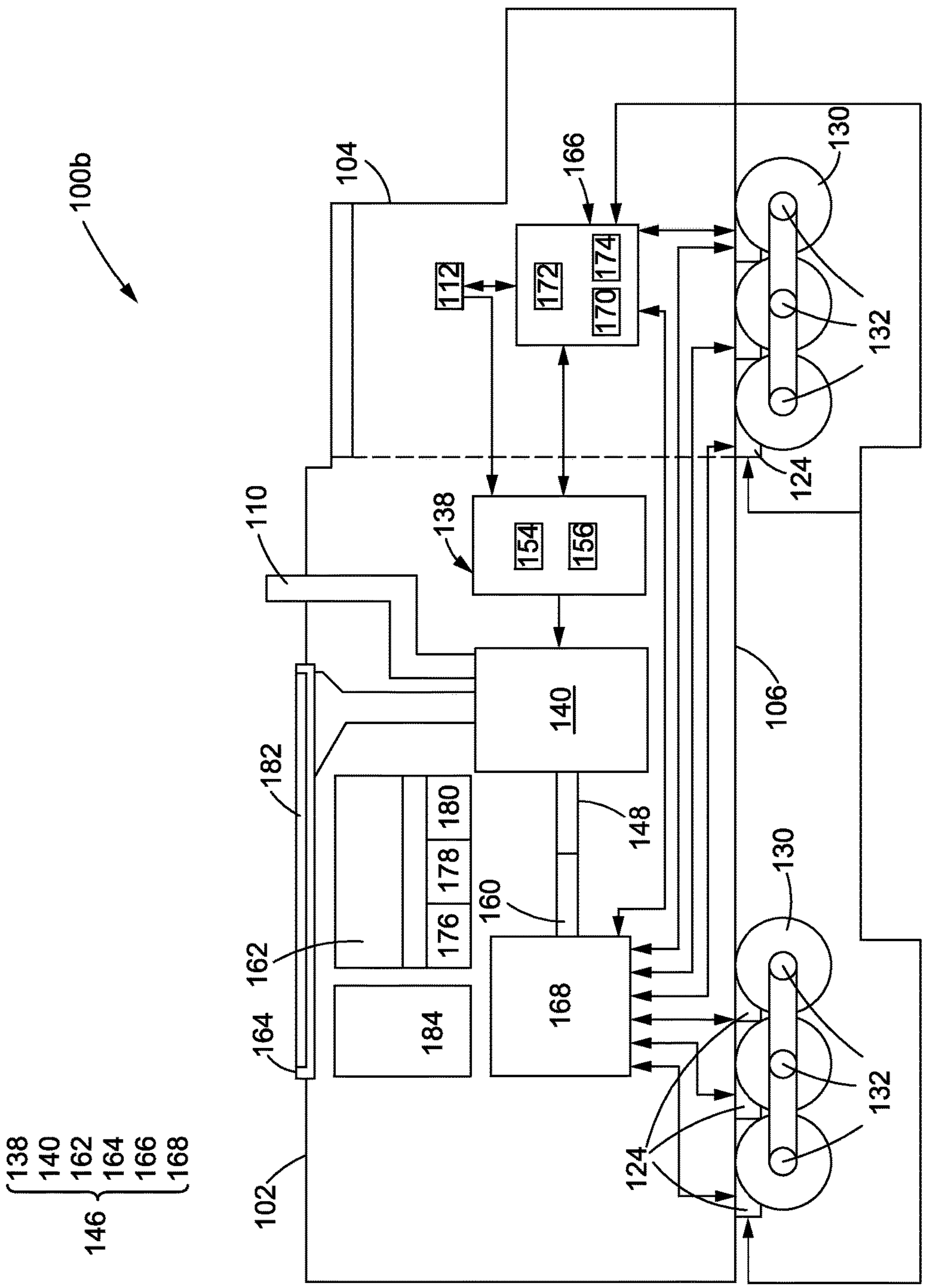

100b
104
166
130
112
172
174
170
132
124
110
138
154
156
140
106
182
148
180
178
176
160
162
168
164
184
102
146
138
140
162
164
166
168

FIG. 2

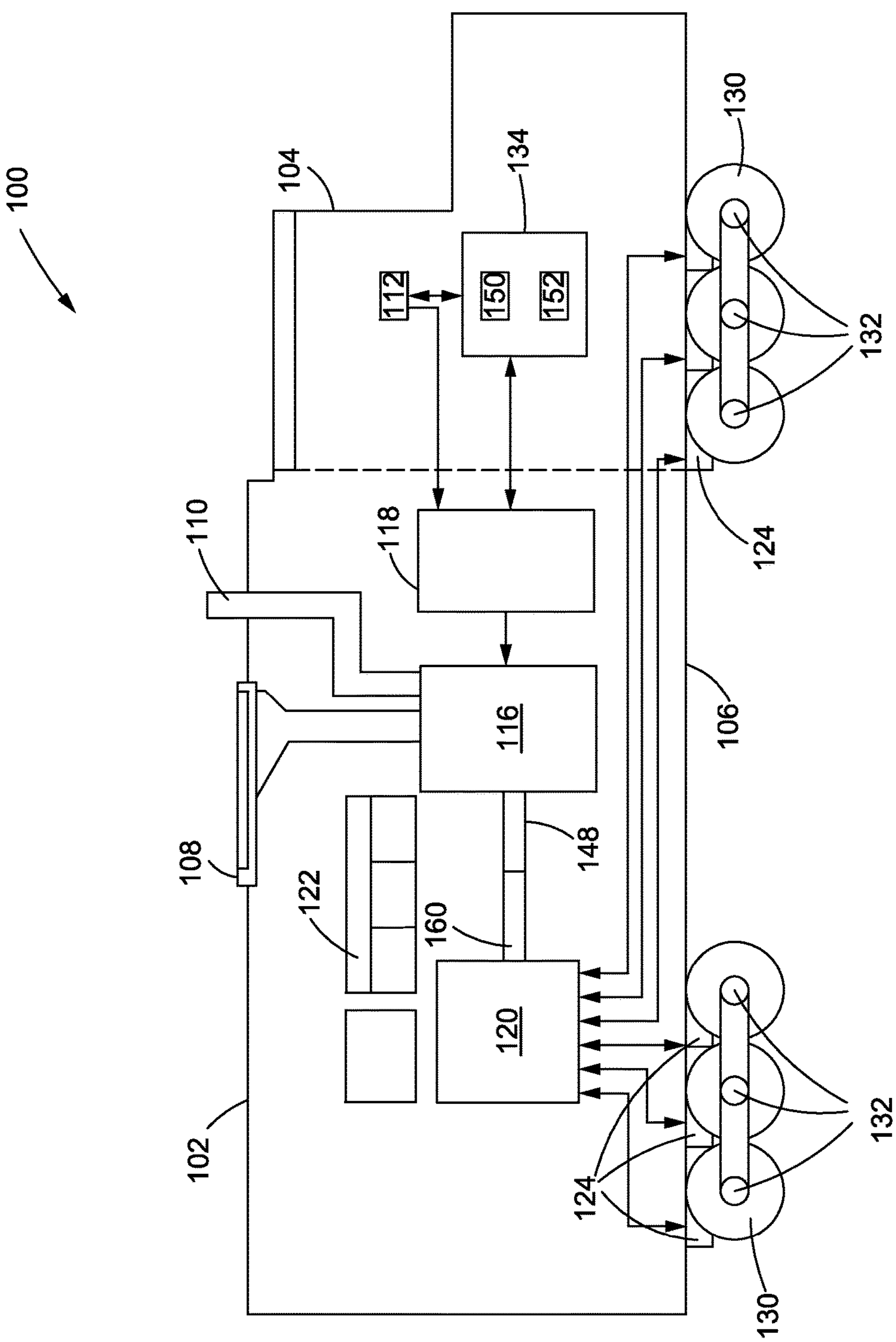

100
104
134
112
150
152
130
132
110
118
124
116
106
108
122
148
160
120
102
124
132
130

FIG. 3

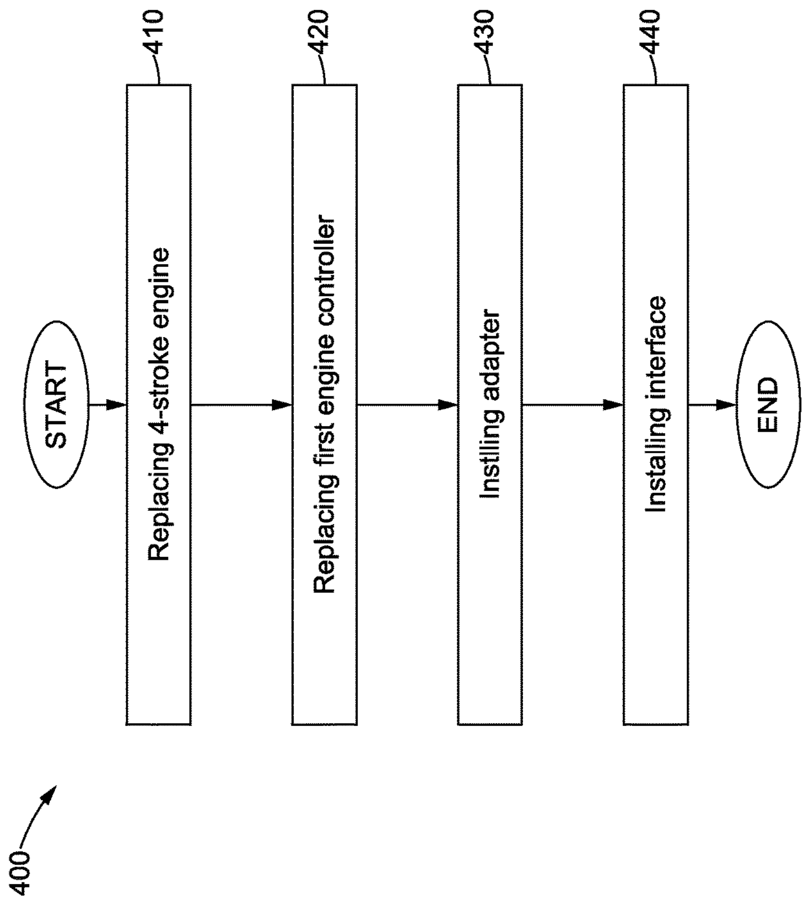

START
Replacing 4-stroke engine
Replacing first engine controller
Instlling adapter
Installing interface
END
410
420
430
440
400

FIG. 4

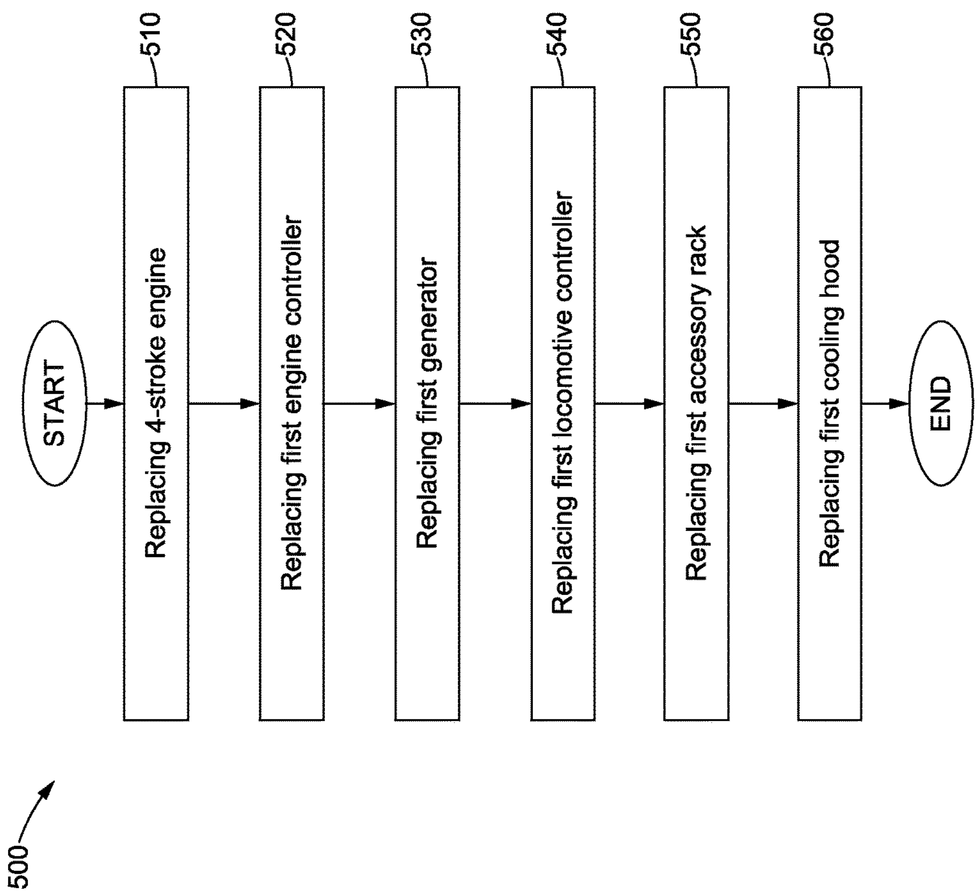

500
START
510
Replacing 4-stroke engine
520
Replacing first engine controller
530
Replacing first generator
540
Replacing first locomotive controller
550
Replacing first accessory rack
560
Replacing first cooling hood
END

FIG. 5

LOCOMOTIVE REPOWER

TECHNICAL FIELD

[0001] The present disclosure generally relates to method and apparatus for repowering of locomotives to meet emissions criteria by replacing the existing 4-stroke diesel engine with a two-stroke diesel engine.

BACKGROUND

[0002] Certain locomotives currently powered by a 4-stroke diesel engine, when repowered/rebuilt, do not meet current Environmental Protection Agency (EPA) emission requirements for repowered/rebuilt engines. There is no cost effective emission compliance solution available. As a result, such locomotives that have an engine failure must be retired to storage until they can be dismantled and sold for parts or otherwise disposed of.

[0003] U.S. Pat. No. 8,820,247 issued on Sep. 2, 2014 (the '247 patent) discloses a method of enabling the rebuilding of a locomotive by replacing the existing 2-stroke diesel engine with a 4-stroke diesel engine, while retaining the generator. The disclosure addresses the physical connection of the new 2-stroke engine to the existing generator. A different solution is required for repowering of other types of locomotives than that disclosed in the '247 patent.

SUMMARY OF THE DISCLOSURE

[0004] In accordance with one aspect of the disclosure, a method for repowering a locomotive is disclosed. The locomotive, prior to being repowered, may include a first traction motor, a 4-stroke engine, and a first engine controller configured to regulate operation of the 4-stroke engine. The method may comprise replacing the 4-stroke engine with a second engine installed in the locomotive, the second engine a 2-stroke engine, and replacing the first engine controller with a second engine controller. The second engine controller may be configured to regulate operation of the second engine. The second engine controller and the second engine, in combination, may be adapted to meet at least Tier 0 emission standards for the locomotive when repowered. The first traction motor may be configured to utilize power that results from operation of the second engine.

[0005] In accordance with another aspect of the disclosure, a repower kit for a locomotive is disclosed. The locomotive may include a first traction motor, a 4-stroke engine, a first engine controller, a first generator compatible with the 4-stroke engine, and a first locomotive controller configured to generate and transmit engine control signals to the first engine controller. The first engine controller may be configured to regulate operation of the 4-stroke engine based on the engine control signals received from the first locomotive controller. The repower kit may comprise a second engine not compatible with the first generator, the second engine a 2-stroke engine replacement for the 4-stroke engine, and a second engine controller configured to regulate operation of the second engine, the second engine controller and the second engine, in combination, adapted to meet at least Tier 0 emission standards for the locomotive when repowered. The second engine controller is a replacement for the first engine controller.

[0006] In accordance with a further aspect of the disclosure, a repowered locomotive is disclosed. The locomotive, prior to repowering may include a first traction motor, a 4-stroke engine, a first engine controller, a first generator compatible with the 4-stroke engine, and a first locomotive controller. The first locomotive controller is configured to generate and transmit engine control signals to the first engine controller. The first engine controller is configured to regulate operation of the 4-stroke engine. The repowered locomotive may comprise a second engine installed in the locomotive instead of the 4-stroke engine, and a second engine controller installed in the locomotive instead of the first engine controller. The second engine may be a 2-stroke engine. The second engine controller may be configured to regulate operation of the second engine. The second engine controller and the second engine, in combination, may be adapted to meet at least Tier 0, Tier 1 or Tier 2 emission standards for the locomotive when repowered.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a schematic illustrating an exemplary embodiment of a repowered locomotive constructed in accordance with the teachings of this disclosure;

[0008] FIG. **2** is a schematic illustrating an alternative exemplary embodiment of a repowered locomotive;

[0009] FIG. **3** is schematic illustrating an exemplary locomotive prior to repowering;

[0010] FIG. **4** is flowchart illustrating blocks of an exemplary method for repowering a locomotive, in accordance with the teachings of this disclosure; and

[0011] FIG. **5** is flowchart illustrating blocks of an exemplary method for repowering a locomotive, in accordance with the teachings of this disclosure.

DETAILED DESCRIPTION

[0012] This disclosure related to methods and repower kits that enable cost effective repowering of a locomotive **100**. FIGS. **1**-**2** are schematic illustrations of exemplary repowered locomotives **100***a*, **100***b*.

[0013] FIG. **3** illustrates, an exemplary schematic of the locomotive **100** prior to being repowered according to the methods disclosed herein. The locomotive **100** may include a car body portion **102** and a cab portion **104** disposed on a base **106**. The cab portion **104** may be suitable to accommodate an operator. The car body portion **102** includes a first cooling hood **108** and engine exhaust outlet **110** (for emissions).

[0014] Prior to repowering, the locomotive **100** may include a throttle **112** and a first locomotive controller **134**. The throttle **112** and the first locomotive controller **134** may be disposed inside the cab portion **104**. Such locomotive **100** may further include a 4-stroke engine **116**, a first engine controller **118**, a first generator **120** and an first accessory rack **122**. In addition, such locomotive **100** also includes a plurality of first traction motors **124** and a plurality of wheels **130**, each mounted on an axle **132**. The 4-stroke engine **116** in the locomotive **100**, prior to repowering, may be a 12-cylinder or a 16-cylinder 4-stroke diesel engine. Some of these engines may have a power output range of up to about 3200-4400 horsepower.

[0015] The first engine controller **118** utilized in the locomotive **100** (prior to repowering) is in operative communication with both the 4-stroke engine **116** and the first locomotive controller **134**. The first engine controller **118** is configured to regulate the operation of the 4-stroke engine

116 based on engine control signals generated by and received from the first locomotive controller **134**. The engine control signals are generated by the first locomotive controller **134** based on throttle input. In some embodiments, the throttle input may be received by the first locomotive controller **134** from the throttle **112**. Alternatively, the throttle input may be received by the first engine controller **118** and then transmitted (by the first engine controller **118**) to the first locomotive controller **134**. The locomotive **100** may also include the first accessory rack **122** configured to position and support oil cooling equipment and various filter housings.

[0016] Referring now to the drawings, and with specific reference to FIG. **1**, there is shown one embodiment of a repowered locomotive **100***a* in accordance with the present disclosure and generally referred to by reference numeral **100***a*. In the embodiment illustrated in FIG. **1**, the repowered locomotive **100***a* may comprise the throttle **112**, the first locomotive controller **134**, an interface **136**, a second engine controller **138**, a second engine **140**, an adapter **142**, the first generator **120**, and one or more first traction motors **124**. The repowered locomotive **100***a* may further comprise the first accessory rack **122** and the first cooling hood **108**. In this embodiment, the newly installed elements are the interface **136**, the second engine controller **138** (as a replacement for the first engine controller **118**), the second engine **140** (as a replacement for the 4-stroke engine **116**) and the adapter **142**. The repowered locomotive **100***a* retains the preexisting elements of the first locomotive controller **134**, the first generator **120** and the first traction motors **124**. The repowered locomotive **100***a* may retain the pre-existing throttle **112**, or may include a like throttle **112** with the same throttle-setting scheme as used in the locomotive **100** prior to repowering. The repower kit **146***a* for this embodiment may include the second engine controller **138**, the second engine **140**, the interface **136** and the adapter **142**.

[0017] The throttle **112** is a user input device having a finite number of power settings, typically referred to as "notches." In one embodiment, the throttle **112** may have eight (8) forward throttle-settings, in addition to idle and reverse settings. Each of the forward throttle-settings has an associated range of available horsepower that may be provided at that respective throttle-setting by the first generator **120** to the first traction motors **124**. Movement of the throttle **112** from one notch to another will change the (second) engine speed (for example, revolutions per minute (RPM)), thereby allowing the first generator **120** to produce the desired range of horsepower (indicated by the notch) to be delivered to the first traction motors **124**.

[0018] In one embodiment of the repowered locomotive **100***a*, the throttle **112** may be in operative communication with the first locomotive controller **134**. The throttle **112** may transmit to the first locomotive controller **134** the throttle input associated with the selected throttle-setting (notch). In some embodiments, the throttle **112** may be in operative communication with the second engine controller **138**. In such an embodiment, the throttle **112** may transmit to the first locomotive controller **134** the throttle input via the second engine controller **138**.

[0019] The second engine **140** replaces the 4-stroke engine **116** installed in the locomotive **100** prior to repowering. When installed, the second engine **140** is in operative communication with the second engine controller **138**, and is operatively connected to the first generator **120** via the adapter **142**. In an embodiment, the second engine **140** is a 2-stroke diesel engine that has pistons (not shown) that operate on a diesel cycle. The second engine **140** is configured to combust a gaseous fuel and to generate a mechanical output, for example the rotation of a crank shaft **148**. The rotation of the crank shaft **148** (of the second engine **140**) drives the first generator **120** to produce electric power. As is known in the art, the fuel/air mixture in the second engine **140** may be adjusted by the second engine controller **138** to control the rotational speed (revolutions per minute (RPM)) of the second engine **140** and the combustion temperature and injection timing may be adjusted to control the emissions. The second engine **140** may operate under the control of the second engine controller **138** as commanded by the first locomotive controller **134**.

[0020] The first locomotive controller **134** may be in operable communication with the interface **136**, the second engine controller **138** (via the interface **136**), the first generator **120** and the first traction motors **124**. The first locomotive controller **134** may also be in operable communication with the throttle **112** or the adapter **142** or various sensors (not shown). The first locomotive controller **134** may include a processor **150** and a memory component **152**. The processor **150** may be a microprocessor or other processor as known in the art. The processor **150** may execute instructions and generate control signals for processing a signal(s) or data indicative of throttle input, engine RPM, engine temperature, injection timing, generator operation, first traction motor **124** operation, the electricity supplied to or consumed by the first traction motors **124**, torque output of the first traction motors **124**, or the like. Such instructions that are capable of being executed by a computer may be read into or embodied on a computer readable medium, such as the memory component **152** or provided external to the processor **150**. In alternative embodiments, hard wired circuitry may be used in place of, or in combination with, software instructions to implement a control method. The first locomotive controller **134** is not limited to one processor **150** and memory component **152**. The first locomotive controller **134** may be several processors **150** and memory components **152**. The first locomotive controller **134** may retrieve from the memory component **152** the data required for processing operations or calculations.

[0021] The first locomotive controller **134** may be configured to generate engine control signals based on the throttle input associated with the selected throttle-setting. The first locomotive controller **134** may be further configured to transmit the engine control signals (via the interface **136**) to the second engine controller **138** to operate/regulate the second engine **140**. For example, such engine control signals may regulate the fuel/air mixture in the second engine **140** (as is known, the fuel/air mixture may be adjusted to control the RPM of the second engine **140**), the combustion temperature, the injection timing, or the like. More specifically, the first locomotive controller **134** may transmit the engine control signals to the interface **136** for conversion into a compatible format for the second engine controller **138**. The interface **136** may then pass the engine control signals, so converted/formatted, to the second engine controller **138**. In addition, the first locomotive controller **134** may generate and transmit generator control signals to the first generator **120** that, when implemented by the first generator **120** in conjunction with the RPM of the second engine **140**, will provide the desired horsepower to the first traction motors **124**.

[0022] The interface **136** is in operative communication with the first locomotive controller **134** and the second engine controller **138**. In some embodiments, the interface **136** may also be in operative communication with one or more second engine sensors (not shown). Because the second engine controller **138** is not compatible with the first locomotive controller **134**, the interface **136** is configured to format signals and/or data exchanged between the two (the second engine controller **138** and the first locomotive controller **134**) so that the receiving element can read/understand the transmitted signal/data/instructions. For example, the interface **136** is configured to enable the second engine controller **138** to regulate the operation of the second engine **140** based on the engine control signals generated by the first locomotive controller **134**. This includes, but is not limited to, formatting/processing of the engine control signals received from and generated by the first locomotive controller **134**, transmitting those engine control signals (as formatted or otherwise processed by the interface **136**) to the second engine controller **138**, as well as receiving signals or data from the second engine controller **138** (or in some scenarios, second engine sensors), formatting/processing such signals/data so that the first locomotive controller **134** can read such signals/data and transmitting such signals/data (as formatted/processed by the interface **136**) to the first locomotive controller **134**. In one embodiment, data received by the first locomotive controller **134** (via the interface **136**) from the second engine controller **138** (or in some scenarios, second engine sensors) may be indicative of whether the second engine **140** is producing the engine speed, or the like commanded by the first locomotive controller **134** via the engine control signals. Some data received by the first locomotive controller **134** (via the interface **136**) from the second engine controller **138** (or in some scenarios, second engine sensors) may be indicative of the combustion temperature and injection timing for the second engine **140**.

[0023] The second engine controller **138** is in communication with the second engine **140** and with the first locomotive controller **134** via the interface **136**. In some embodiments, the second engine controller **138** may be in communication with the throttle **112** and may receive throttle input (associated with the selected throttle-setting (notch)) from the such throttle **112**; the second engine controller **138** may transmit such throttle input to the first locomotive controller **134** via the interface **136**.

[0024] The second engine controller **138** may include a processor **154** and a memory component **156**. The processor **154** may be a microprocessor or other processor as known in the art. The processor **154** may execute instructions and generate control signals for processing a signal(s) indicative of regulating or controlling the fuel/air mixture in the second engine **140**, the speed of the second engine **140**, the combustion temperature, the injection timing for the second engine **140**, or the like. Such instructions that are capable of being executed by a computer may be read into or embodied on a computer readable medium, such as the memory component **156** or provided external to the processor **154**. In alternative embodiments, hard wired circuitry may be used in place of, or in combination with, software instructions to implement a control method. The second engine controller **138** is not limited to one processor **154** and memory component **156**. The second engine controller **138** may be several processors **154** and memory components **156**.

[0025] The second engine controller **138** is configured to regulate operation of the second engine **140** based on engine control signals received from the first locomotive controller **134**.

[0026] The EPA defines exhaust emission standards. Table 1 below defines the EPA exhaust emission standards applicable to locomotives that are propelled by engines with total rated horsepower (hp) of 750 kilowatts (kW) (1006 hp) or more.

TABLE 1

(portion of) EPA Locomotive Exhaust Emissions Standards

Duty cycle	Tier	Year	NO_x (g/bhp-hr) [d]	PM (g/bhp-hr) [e]
Line-haul	0	1973-1992 [a]	8.0	0.22
Line-haul	1	1993-2004 [a,b]	7.4	0.22
Line-haul	2	2005-2011 [a]	5.5	0.10
Switch	0	1973-2001	11.8	0.26
Switch	1	2002-2004 [c]	11.0	0.26
Switch	2	2005-2010 [c]	8.1	0.13

[a] Line-haul locomotives subject to the Tier 0 through Tier 2 emission standards must also meet switch standards of the same tier.
[b] Tier 0 standards apply for 1993-2001 locomotives not originally manufactured with a separate loop intake air cooling system.
[c] Tier 1 and Tier 2 switch locomotives must also meet line-haul standards of the same tier.
[d] nitrogen oxides (NOx) in grams per brakehorsepower-hour (g/bhp-hr).
[e] particulate matter (PM) in in grams per brakehorsepower-hour (g/bhp-hr).

[0027] Tier 0 emission standards apply to locomotives **100** manufactured between 1973-1992 when they are repowered or rebuilt. Tier 1 emission standards apply to locomotives **100** manufactured between 1993-2004 when they are repowered or rebuilt. In some embodiments, locomotives **100** may be repowered to meet Tier 2 emission standards. Line-haul locomotives are those powered by an engine with a maximum rated power (or a combination of engines having a total rated power) greater than 2300 hp. Switch locomotives are those powered by an engine with a maximum rated power (or a combination of engines having a total rated power) of 2300 hp or less. Line-haul locomotives subject to the Tier 0 through Tier 2 emission standards must also meet switch standards of the same tier, per the above EPA emission standards of Table 1. In addition, Tier 1 and Tier 2 switch locomotives must also meet line-haul standards of the same tier.

[0028] The second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 0 level or less for NOx emissions and Tier 0 level or less for PM emissions. In some embodiments, the second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 1 level or less for NOx emissions and Tier 1 level or less for PM emissions. In other embodiments, the second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 2 level or less for NOx emissions and Tier 2 level or less for PM emissions. As illustrated in Table 1 above, the applicable exhaust emissions standard depends on the tier for which the repowered locomotive **100***a*/**100***b* qualifies.

TABLE 2

Emission reduction benefits from repowering of locomotives 100 to repowered locomotives 100a/100b.

	NOx	PM
EPA Switcher duty cycle		
% reduction: Unregulated to Tier 0+	9%	19%
% reduction: Unregulated to Tier 2+	38%	59%
EPA Line Haul Duty Cycle		
% reduction: Unregulated to Tier 0+	54%	50%
% reduction: Unregulated to Tier 2+	68%	77%

[0029] Table 2 illustrates emission reduction benefits from operation of locomotives **100** prior to repowering to operation of the repowered locomotives **100***a*/**100***b*.

[0030] In the embodiment of FIG. **1**, the second engine controller **138** may include an engine management module **158**. The throttle **112** and the first locomotive controller **134** may be configured to accommodate a different throttle-setting scheme for horsepower than the desired throttle-setting scheme for the second engine controller **138** and second engine **140** when (the second engine **140**) used in conjunction with the first generator **120**. To adjust for this mismatch, the engine management module **158** may be configured to selectively adjust a first value of an engine control signal (more specifically, data contained in the engine control signal) for requested engine speed (the first value based on a first throttle-setting scheme compatible with the throttle **112** and the first locomotive controller **134**) to a second value for requested engine speed, the second value part of a desired second throttle-setting scheme which the second engine controller **138** and the second engine **140** are desired to support when used to drive the first generator **120**. To obtain the second value, the engine management module **158** may map the first value to the second value using, for example, a look-up table, algorithm, or the like. Control of the second engine **140** is based on the second value.

[0031] The first generator **120** is compatible with the preexisting 4-stroke engine **116** but is not compatible with the 2-stroke engine that replaces the 4-stroke engine **116** in the repowered locomotive **100***a*. Hence, the first generator **120** is operatively connected to the second engine **140** via the adapter **142**. The adapter **142** is configured to operatively couple the second engine **140** to the first generator **120** to enable the second engine **140** to drive the first generator **120**. For example, in one embodiment, the adapter **142** may couple the crank shaft **148** of the second engine **140** to a drive shaft **160** of the first generator **120**.

[0032] The first generator **120** may be an induction generator, a permanent magnet generator, a synchronous generator, a switched reluctance generator, or any other appropriate generator for a locomotive application. The first generator **120** is operatively connected to one or more first tractions motors **124** and is configured to produce electrical power and to deliver at least a portion of the electrical power produced to the one or more first traction motors **124**.

[0033] Each first traction motor **124** is coupled to an axle **132**. A plurality of wheels **130** are mounted to the axle **132**. The first traction motor **124** is configured to receive electrical horsepower from the first generator **120** (power that results from the operation of the second engine **140**) and to use that electrical horsepower to drive the axle **132** and to provide propelling force to the locomotive **100***a*, **100***b*. The first traction motor **124** may also be used to provide dynamic braking to the locomotive **100***a*, **100***b*.

[0034] FIG. **2** illustrates an alternative embodiment of a repowered locomotive **100***b*. In this embodiment, the repowered locomotive **100***b* may comprise the throttle **112**, a second locomotive controller **166**, a second engine controller **138**, a second engine **140**, a second generator **168**, and one or more (pre-existing) first traction motors **124**. The repowered locomotive **100***b* may further comprise an second accessory rack **162** and a second cooling hood **164**. In this embodiment, the newly installed elements are the second locomotive controller **166** (as a replacement for the first locomotive controller **134**), the second engine controller **138** (as a replacement for the first engine controller **118**), the second engine **140** (as a replacement for the 4-stroke engine **116**) and the second generator **168** (as a replacement for the first generator **120**). The repowered locomotive **100***b* retains the preexisting first traction motors **124**. The repowered locomotive **100***b* may also retain the pre-existing throttle **112**, or may include a like throttle **112** with the same throttle-setting scheme as used in the locomotive **100** prior to repowering. The repower kit **146***b* for this embodiment may include the second locomotive controller **166**, the second engine controller **138**, the second engine **140** and the second generator **168**. In the repower kit **146***b* for this embodiment, the repower kit **146***b* may include the second accessory rack **162** and the second cooling hood **164**.

[0035] The throttle **112**, in this embodiment, is the same as in the embodiment of FIG. **1**, except that movement of the throttle **112** from one notch to another will change the engine speed (for example, (RPM)) of the second engine **140**, thereby allowing the second generator **168** to produce the desired range of horsepower (indicated by the notch) to be delivered to the first traction motors **124**. Similar to the embodiment of FIG. **1**, the throttle **112** may be in operative communication with the second locomotive controller **166** (the replacement for the first locomotive controller **134**) and may transmit to the second locomotive controller **166** the throttle input associated with the selected throttle-setting (notch). In some embodiments, the throttle **112** may be in operative communication with the second engine controller **138**. In such an embodiment, the throttle **112** may transmit to the second locomotive controller **166** the throttle input via the second engine controller **138**.

[0036] The second engine **140** of the embodiment of FIG. **2** is the same as that of FIG. **1**, except that, when installed, the second engine **140** is operatively connected to the second generator **168** instead of the first generator **120**. Thus, the rotation of the crank shaft **148** (of the second engine **140**) drives the second generator **168** to produce electric power. The second engine **140** may operate under the control of the second engine controller **138** as commanded by the second locomotive controller **166** (the replacement for the first locomotive controller **134**).

[0037] The second locomotive controller **166** may be in operable communication with the second engine controller **138**, the second generator **168** and the first traction motors **124**. The second locomotive controller **166** may also be in operable communication with the throttle **112** or various sensors (not shown). The second locomotive controller **166** may include a processor **170** and a memory component **172**. The processor **170** may be a microprocessor or other processor as known in the art. The processor **170** may execute instructions and generate control signals for processing a signal(s) or data indicative of throttle input, engine RPM, engine temperature, injection timing, second generator **168** operation, first traction motor **124** operation, the electricity supplied to or consumed by the first traction motors **124**, torque output of the first traction motors **124**, or the like. Such instructions that are capable of being executed by a computer may be read into or embodied on a computer readable medium, such as the memory component **172** or provided external to the processor **170**. In alternative embodiments, hard wired circuitry may be used in place of, or in combination with, software instructions to implement a control method. The second locomotive controller **166** is not limited to one processor **170** and memory component **172**. The second locomotive controller **166** may be several processors **170** and memory components **172**. The second locomotive controller **166** may retrieve from the memory component **172** the data required for processing operations or calculations.

[0038] The second locomotive controller **166** may be configured to generate engine control signals based on the throttle input associated with the selected throttle-setting. The second locomotive controller **166** may be further configured to transmit the engine control signals to the second engine controller **138** to operate/regulate the second engine **140**. For example, such engine control signals may regulate the fuel/air mixture and speed (RPM) in the second engine **140**, the combustion temperature, the injection timing, or the like. The second locomotive controller **166** may include a motor management module **174** configured to enable the second locomotive controller **166** to control the second generator **168** to provide power compatible with the electrical characteristics of the first traction motors **124**. For example the motor management module **174** may be configured to control electrical loading in the first traction motors **124** related to optimization of tractive effort and control of heat generation. In addition, the second locomotive controller **166** may generate and transmit generator control signals to the second generator **168** that, when implemented by the second generator **168** in conjunction with the RPM of the second engine **140**, will provide the desired horsepower to the first traction motors **124**.

[0039] The second locomotive controller **166** may receive data from the second engine controller **138** (or in some scenarios, second engine sensors) that is indicative of whether the second engine **140** is producing the engine speed, or the like as commanded via the engine control signals. Some data received from the second engine controller **138** (or in some scenarios, second engine sensors) may be indicative of the combustion temperature and injection timing for the second engine **140**.

[0040] In some embodiments, the second engine controller **138** may be in communication with the throttle **112** and may receive throttle input (associated with the selected throttle-setting (notch)) from the such throttle **112**; the second engine controller **138** may transmit such throttle input to the second locomotive controller **166**.

[0041] The second engine controller **138** may include a processor **154** and a memory component **156**. The processor **154** may be a microprocessor or other processor as known in the art. The processor **154** may execute instructions and generate control signals for processing a signal(s) indicative of regulating or controlling the fuel/air mixture in the second engine **140**, the speed of the second engine **140**, the combustion temperature, the injection timing for the second engine **140**, or the like. Such instructions that are capable of being executed by a computer may be read into or embodied on a computer readable medium, such as the memory component **156** or provided external to the processor **154**. In alternative embodiments, hard wired circuitry may be used in place of, or in combination with, software instructions to implement a control method. The second engine controller **138** is not limited to one processor **154** and memory component **156**. The second engine controller **138** may be several processors **154** and memory components **156**.

[0042] The term "computer readable medium" as used herein in this disclosure refers to any non-transitory medium or combination of media that participates in providing instructions to the processor(s) **150**, **154**, **170** for execution. Such a medium may comprise all computer readable media except for a transitory, propagating signal. Common forms of computer-readable media include, for example, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, or any other medium from which a computer processor **150**, **154**, **170** can read.

[0043] The second engine controller **138** is configured to regulate operation of the second engine **140** based on engine control signals received from the second locomotive controller **166**. The second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 0 level (of the emission standards) or less for NOx emissions and Tier 0 level (of the emission standards) or less for PM emissions. In some embodiments, the second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 1 level (of the emission standards) or less for NOx emissions and Tier 1 level (of the emission standards) or less for PM emissions. In other embodiments, the second engine controller **138** and the second engine **140**, in combination, may be adapted to generate Tier 2 level (of the emission standards) or less for NOx emissions and Tier 2 level (of the emission standards) or less for PM emissions. As illustrated in Table 1, the applicable exhaust emissions standard depends on the tier for which the repowered locomotive **100***a*/**100***b* qualifies. In some embodiments, the repowering of the locomotive **100** may be done so as to meet a higher tier emission standard (lower emissions) than otherwise required. For instance, a repowered locomotive **100** subject to a Tier 0 standard may be repowered to meet a Tier 2 standard.

[0044] The second generator **168** may be an induction generator, a permanent magnet generator, a synchronous generator, a switched reluctance generator, or any other appropriate generator for a locomotive application. The second generator **168** is operatively connected to one or more first tractions motors **124** and is configured to produce electrical power and to deliver at least a portion of the electrical power produced to the one or more first traction motors **124**.

[0045] The first traction motors **124** of FIG. **2** are the same as those of FIG. **1** except that the first traction motors **124** are configured to receive electrical horsepower from the second generator **168**.

[0046] The second accessory rack **162** is different than the first accessory rack **122** and is configured to position and support on the base **106** an oil cooler **176**, oil filter housing **178** for the second engine **140** and a field filter housing **180**.

[0047] The second cooling hood **164** has a larger dimensioned air intake **182** area than the first cooling hood **108**. In some embodiments, the second cooling hood **164** may be configured to accommodate a larger radiator **184** that that used before repowering. The larger air intake area is configured to provide a less restrictive airflow to the radiator(s) **184**.

INDUSTRIAL APPLICABILITY

[0048] Referring now to FIG. **4**, an exemplary flowchart is illustrated showing sample blocks which may be followed in a first method **400** of repowering the locomotive **100**. The method **400** may be practiced with more or less than the number of blocks shown and is not limited to the order shown.

[0049] In block **410**, the method **400** includes replacing the 4-stroke engine **116** with a second engine **140** installed in the locomotive **100***a*. As discussed earlier herein, the second engine **140** is a 2-stroke engine.

[0050] In block **420**, the method **400** includes replacing the first engine controller **118** with the second engine controller **138**. The second engine controller **138** is configured to regulate the operation of the second engine **140** when powering the locomotive **100***a*.

[0051] In block **430**, the method **400** further includes installing an adapter **142** between the second engine **140** and the first generator **120**, the adapter **142** configured to operatively couple the second engine **140** to the first generator **120** to enable the second engine **140** to drive the first generator **120**. The first generator **120** is not compatible with the second engine **140**

[0052] In block **440**, the method **400** further includes installing an interface **136** between the second engine controller **138** and the first locomotive controller **134**. The interface **136** is configured to enable the second engine controller **138** to regulate the operation of the second engine **140** based on engine control signals generated by the first locomotive controller **134**, the second engine controller **138** not otherwise compatible with the first locomotive controller **134**.

[0053] In operation of the first embodiment of the repowered locomotive **100***a*, the throttle **112** receives the throttle input associated with the selected throttle-setting. In one embodiment, the throttle input may be transmitted to the first locomotive controller **134** for processing. The first locomotive controller **134** may generate the engine control signal based on the received throttle input. The first locomotive controller **134** may transmit via the interface **136** the engine control signal to the second engine controller **138**. The second engine controller **138** may, in some embodiments, process the engine control signal (data contained in the engine control signal) by mapping (or the like) of a first (data) value to a second (data) value, and then operate/regulate the second engine **140** based on the engine control signal. In embodiments, this may be the second value of the engine control signal (the mapped, or the like, value). Such operation/regulation may include, but is not limited to, controlling the engine speed, the fuel/air mixture, combustion temperature and injection timing. The first locomotive controller **134** may also transmit generator control signals to the first generator **120** to control operation of the first generator **120**. When implemented, the engine control signal results in the second engine **140** driving the first generator **120**. The second engine **140** is operatively connected to the first generator **120** by an adapter **142** that allows the second engine **140** to drive the first generator **120** at a speed that provides the desired horsepower to the first traction motors **124**.

[0054] Referring now to FIG. **5**, an exemplary flowchart is illustrated showing sample blocks which may be followed in a second method **500** of repowering the locomotive **100**. The method **500** may be practiced with more or less than the number of blocks shown and is not limited to the order shown.

[0055] In block **510**, the method **500** includes replacing the 4-stroke engine **116** with a second engine **140** installed in the locomotive **100***b*. As discussed earlier herein, the second engine **140** is a 2-stroke engine.

[0056] In block **520**, the method **500** includes replacing the first engine controller **118** with the second engine controller **138**. The second engine controller **138** configured to operate/regulate the operation of the second engine **140** when powering the locomotive **100***b*.

[0057] In block **530**, the method **500** further includes replacing the first generator **120** with a second generator **168** in the locomotive **100***b*.

[0058] In block **540**, the method **500** further includes replacing the first locomotive controller **134** with a second locomotive controller **166**. The second locomotive controller **166** may include a motor management module **174** configured to enable the second locomotive controller **166** to control the second generator **168** to provide electric power compatible with the electrical characteristics of the (pre-existing) first traction motor(s) **124**. The second locomotive controller **166** is configured to generate and transmit engine control signals to the second engine controller **138** to operate the 2-stroke engine.

[0059] In block **550**, the method **500** further includes replacing the first accessory rack **122** with a second accessory rack **162**.

[0060] In block **560**, the method **500** further includes replacing the first cooling hood **108** with a second cooling hood **164**.

[0061] During operation of the second embodiment of the repowered locomotive **100***b*, the throttle **112** receives the throttle input associated with the selected throttle-setting. In an embodiment, the throttle input may be transmitted to the second locomotive controller **166** for processing. The second locomotive controller **166** may generate the engine control signal based on the received throttle input. The second locomotive controller **166** may transmit the engine control signal to the second engine controller **138**. The second engine controller **138** may then operate/regulate the second engine **140** based on the engine control signal. Such operation/regulation may include, but is not limited to, controlling the engine speed, the fuel/air mixture, combustion temperature and injection timing. The first locomotive controller **134** may also transmit generator control signals to the second generator **168** to control operation of the second generator **168**. When implemented, the engine control signal results in the second engine **140** driving the second generator **168** at a speed that provides the desired horsepower to the first traction motor(s) **124**. The second cooling hood **164** is utilized to provide less restrictive airflow to the radiators **184** for the second engine **140**.

[0062] The features disclosed herein may be particularly beneficial for use with repowering of the locomotive **100**. The ability to provide a cost effective solution to repower the locomotive **100** allows these locomotives to continue to be utilized while meeting current required EPA emissions levels.

What is claimed is:

1. A method for repowering a locomotive, the locomotive, prior to being repowered, including a first traction motor, a 4-stroke engine, and a first engine controller configured to regulate operation of the 4-stroke engine, the method comprising:

replacing the 4-stroke engine with a second engine installed in the locomotive, the second engine a 2-stroke engine;

replacing the first engine controller with a second engine controller, the second engine controller configured to regulate operation of the second engine, the second engine controller and the second engine, in combination, adapted to meet at least Tier 0 emission standards for the locomotive when repowered,

wherein the first traction motor is configured to utilize power that results from operation of the second engine.

2. The method of claim **1**, wherein the 4-stroke engine is either a twelve cylinder or a sixteen cylinder engine.

3. The method of claim **2**, wherein the second engine controller and the second engine, in combination, are further adapted to meet at least Tier 1 emission standards for the locomotive when repowered.

4. The method of claim **1**, wherein the locomotive, prior to being repowered, further includes a first generator and a first locomotive controller, the first generator compatible with the 4-stroke engine and configured to produce electric power when driven by the 4-stroke engine and to supply at least a portion of the electric power to the first traction motor, the first locomotive controller configured to generate and to transmit engine control signals to the first engine controller, the method further comprising:

installing an adapter between the second engine and the first generator, the adapter configured to operatively couple the second engine to the first generator to enable the second engine to drive the first generator, the first generator not compatible with the second engine; and

installing an interface between the second engine controller and the first locomotive controller, the interface configured to enable the second engine controller to regulate the operation of the second engine based on engine control signals generated by the first locomotive controller, the second engine controller not compatible with the first locomotive controller.

5. The method of claim **4**, wherein the engine control signals are generated in response to a throttle input received by the first locomotive controller, the throttle input associated with a horsepower to be supplied by the first generator.

6. The method of claim **4**, wherein the locomotive is either a line-haul locomotive or a switch locomotive.

7. The method of claim **1**, wherein the locomotive, prior to being repowered, further includes a first generator and a first locomotive controller, the first generator compatible with the 4-stroke engine and configured to produce electric power when driven by the 4-stroke engine and to supply at least a portion of the electric power to the first traction motor, the first locomotive controller configured to generate and to transmit engine control signals to the first engine controller, the method further comprising:

replacing the first generator with a second generator in the locomotive; and

replacing the first locomotive controller with a second locomotive controller, the second locomotive controller including a motor management module configured to enable the second locomotive controller to control the second generator to provide electric power compatible with the electrical characteristics of the first traction motor, the second locomotive controller configured to generate and transmit engine control signals to the second engine controller to operate the second engine.

8. The method of claim **7** further comprising replacing a first accessory rack with a second accessory rack, wherein the locomotive, prior to being repowered, further includes the first accessory rack.

9. A repower kit for a locomotive that includes a first traction motor, a 4-stroke engine, a first engine controller, a first generator compatible with the 4-stroke engine, and a first locomotive controller configured to generate and transmit engine control signals to the first engine controller, the first engine controller configured to regulate operation of the 4-stroke engine based on the engine control signals received from the first locomotive controller, the repower kit comprising:

a second engine not compatible with the first generator, the second engine a 2-stroke engine replacement for the 4-stroke engine; and

a second engine controller configured to regulate operation of the second engine, the second engine controller and the second engine, in combination, adapted to meet at least Tier 0 emission standards for the locomotive when repowered, the second engine controller a replacement for the first engine controller.

10. The repower kit of claim **9**, wherein the 4-stroke engine is either a twelve cylinder or a sixteen cylinder engine.

11. The repower kit of claim **9**, wherein the second engine controller and the second engine, in combination, are further adapted to meet at least Tier 1 or Tier 2 emission standards for the locomotive when repowered.

12. The repower kit of claim **9**, further including:

an adapter configured to operatively couple the second engine to the first generator to enable the second engine to drive the first generator; and

an interface configured to enable the second engine controller to regulate the operation of the second engine based on the engine control signals generated by the first locomotive controller.

13. The repower kit of claim **12**, wherein locomotive is either a line-haul locomotive or a switch locomotive.

14. The repower kit of claim **9**, further including:

a second generator different than the first generator; and

a second locomotive controller including a motor management module configured to enable the second locomotive controller to control the second generator to provide power compatible with the electrical characteristics of the first traction motor, the second locomotive controller configured to generate and transmit engine control signals to the second engine controller to operate the 2-stroke engine.

15. The repower kit of claim **14**, further including a second accessory rack as a replacement for a first accessory rack, wherein the locomotive, prior to being repowered, further includes the first accessory rack.

16. The repower kit of claim **14**, further including a second cooling hood as a replacement for a first cooling hood, wherein the locomotive, prior to being repowered, further includes the first cooling hood.

17. A repowered locomotive, which prior to repowering included a first traction motor, a 4-stroke engine, a first engine controller, a first generator compatible with the 4-stroke engine, and a first locomotive controller configured to generate and transmit engine control signals to the first engine controller, the first engine controller configured to regulate operation of the 4-stroke engine, the repowered locomotive comprising:

a second engine installed in the locomotive instead of the 4-stroke engine, the second engine a 2-stroke engine; and

a second engine controller installed in the locomotive instead of the first engine controller, the second engine controller configured to regulate operation of the second engine, the second engine controller and the second engine, in combination, adapted to meet at least Tier 0, Tier 1 or Tier 2 emission standards for the locomotive when repowered.

18. The repowered locomotive of claim **17** further including:

an adapter between the second engine and the first generator, the adapter configured to operatively couple the second engine to the first generator to enable the second engine to drive the first generator; and

an interface between the second engine controller and the first locomotive controller, the interface configured to enable the second engine controller to regulate the operation of the second engine based on the engine control signals generated by the first locomotive controller, the second engine controller not compatible with the first locomotive controller.

19. The repowered locomotive of claim **17** further comprising:

a second generator different than the first generator; and

a second locomotive controller configured to generate and transmit engine control signals to a second engine controller to operate the 2-stroke engine, the second locomotive controller including a motor management module, the motor management module configured to enable the second locomotive controller to control the second generator to provide power compatible with the electrical characteristics of the first traction motor.

20. The repowered locomotive of claim **19**, further including a second accessory rack as a replacement for a first accessory rack, wherein the locomotive, prior to being repowered, further included the first accessory rack.

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