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(54) **SYSTEM AND METHOD FOR INJECTING CONDENSATE IN CYLINDER OF A RECIPROCATING ENGINE**

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(57) **ABSTRACT**

A system includes a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store condensate collected from the EGR system. The condensate injection system also includes a pump fluidly coupled to the condensate tank. The condensate injection system also includes an injector fluidly coupled to the pump. The injector is configured to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

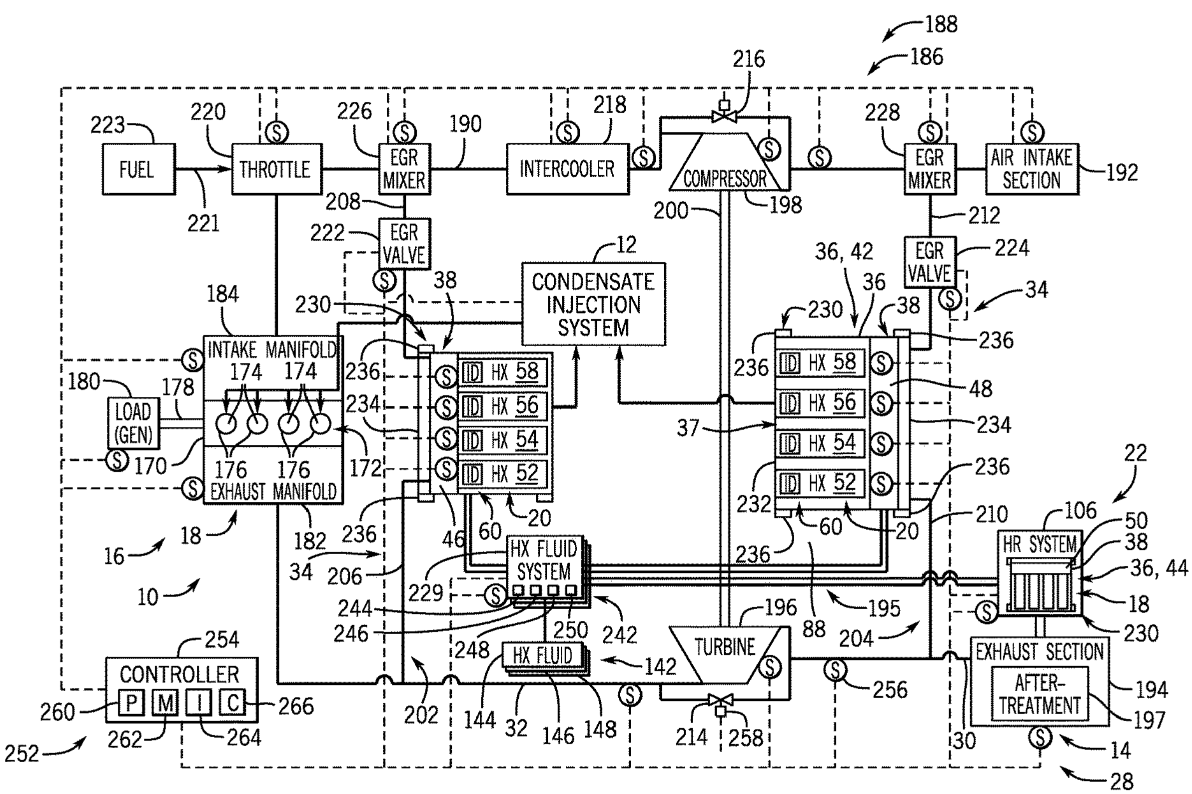
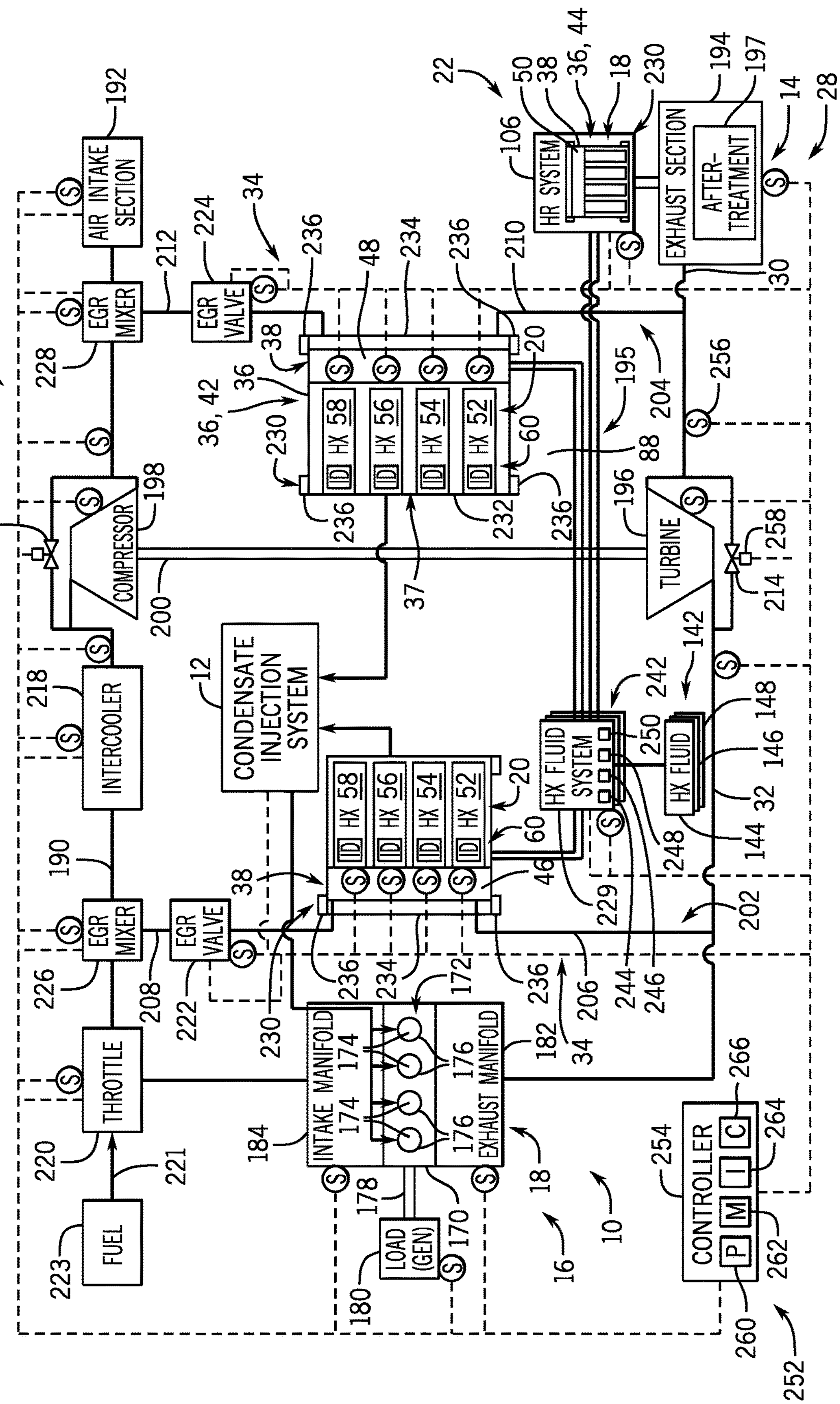
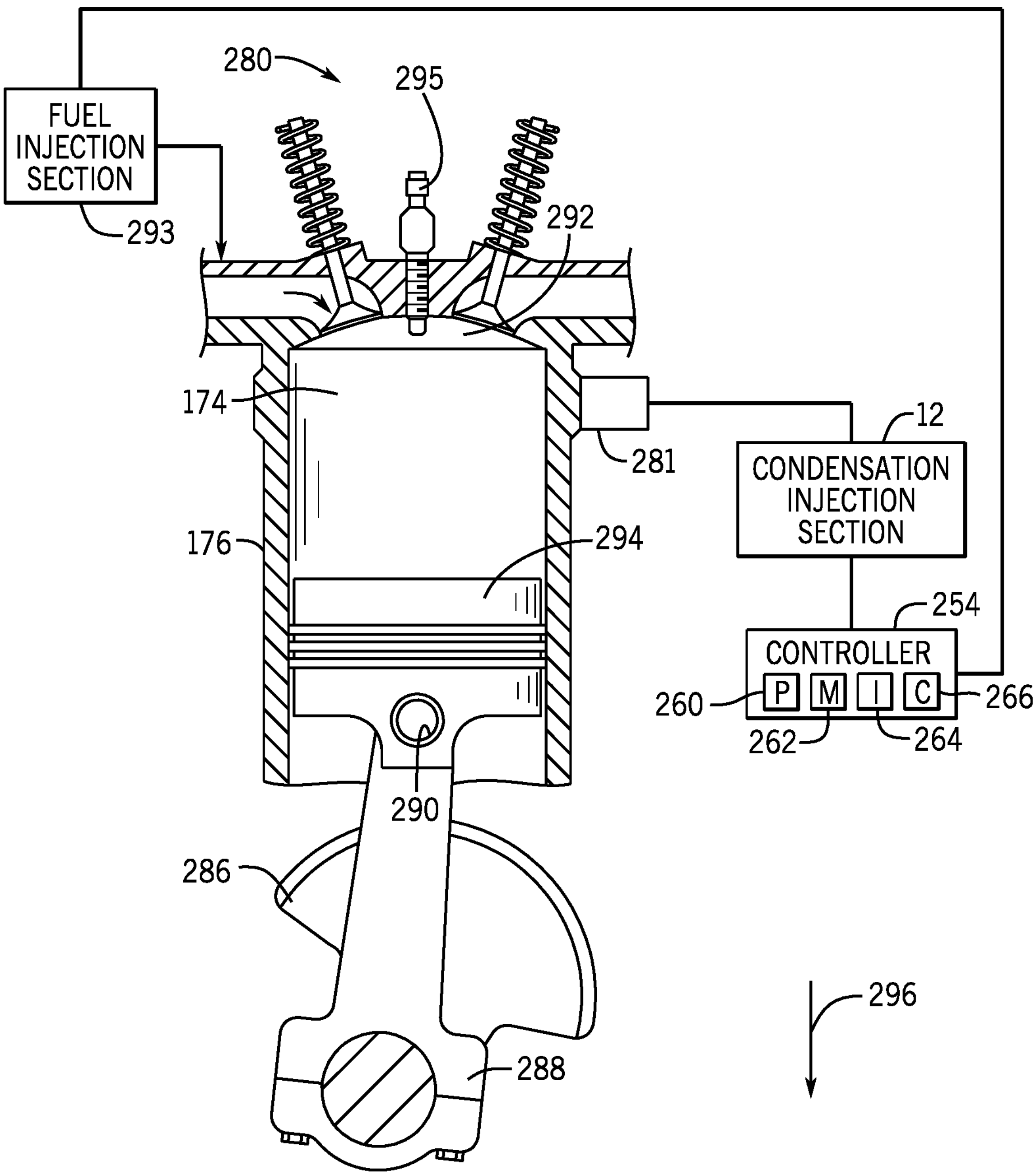


FIG. 1


AIR INTAKE SECTION
EGR MIXER
EGR VALVE
COMPRESSOR
INTERCOOLER
THROTTLE
FUEL
CONDENSATE INJECTION SYSTEM
HX 58
HX 56
HX 54
HX 52
ID
INTAKE MANIFOLD
EXHAUST MANIFOLD
LOAD (GEN)
TURBINE
HR SYSTEM
EXHAUST SECTION
AFTER-TREATMENT
HX FLUID SYSTEM
HX FLUID
CONTROLLER
P
M
I
C
S


280
295
FUEL
INJECTION
SECTION
293
292
174
281
12
CONDENSATION
INJECTION
SECTION
176
294
254
CONTROLLER
P
M
I
C
260
262
264
266
290
286
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288

FIG. 2

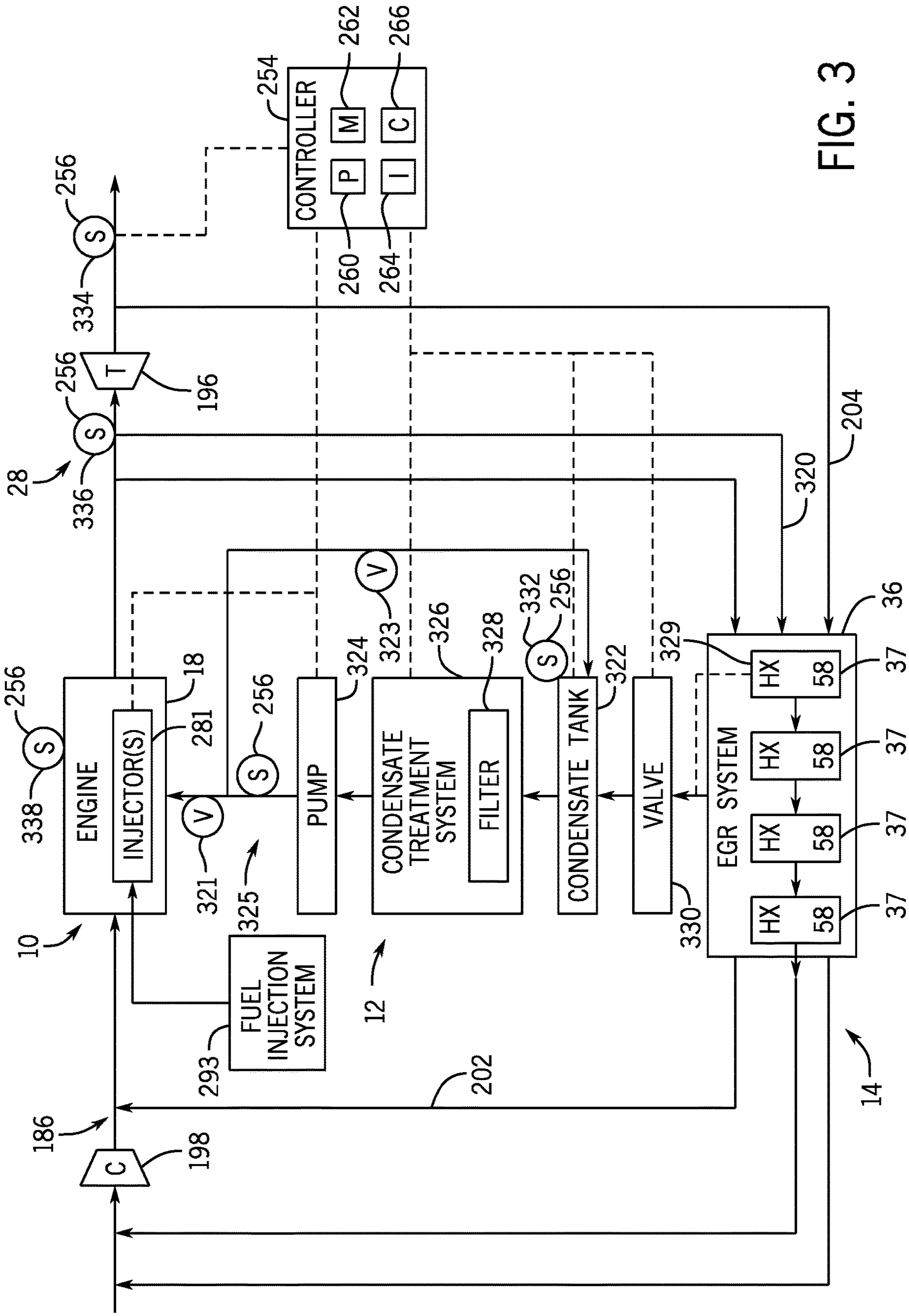
CONTROLLER
P
M
I
C
ENGINE
INJECTOR(S)
PUMP
CONDENSATE TREATMENT SYSTEM
FILTER
CONDENSATE TANK
VALVE
EGR SYSTEM
HX
58
FUEL INJECTION SYSTEM
S
V
T
C
10
12
14
18
28
36
37
186
196
198
202
204
254
256
260
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FIG. 3

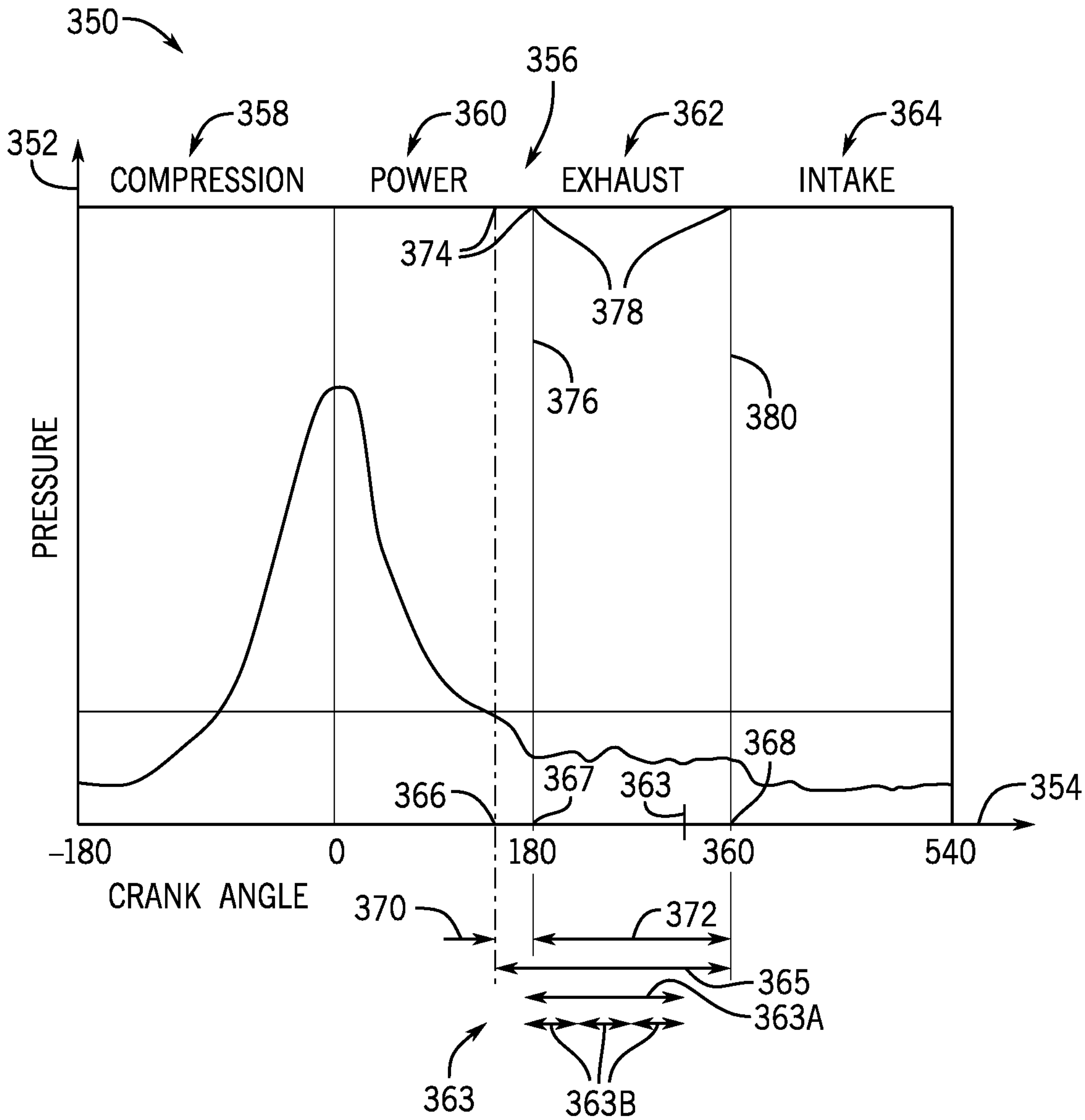
350
352
358
COMPRESSION
360
POWER
356
362
EXHAUST
364
INTAKE
374
378
376
380
PRESSURE
368
367
363
366
354
-180
0
180
360
540
CRANK ANGLE
370
372
365
363A
363
363B

FIG. 4

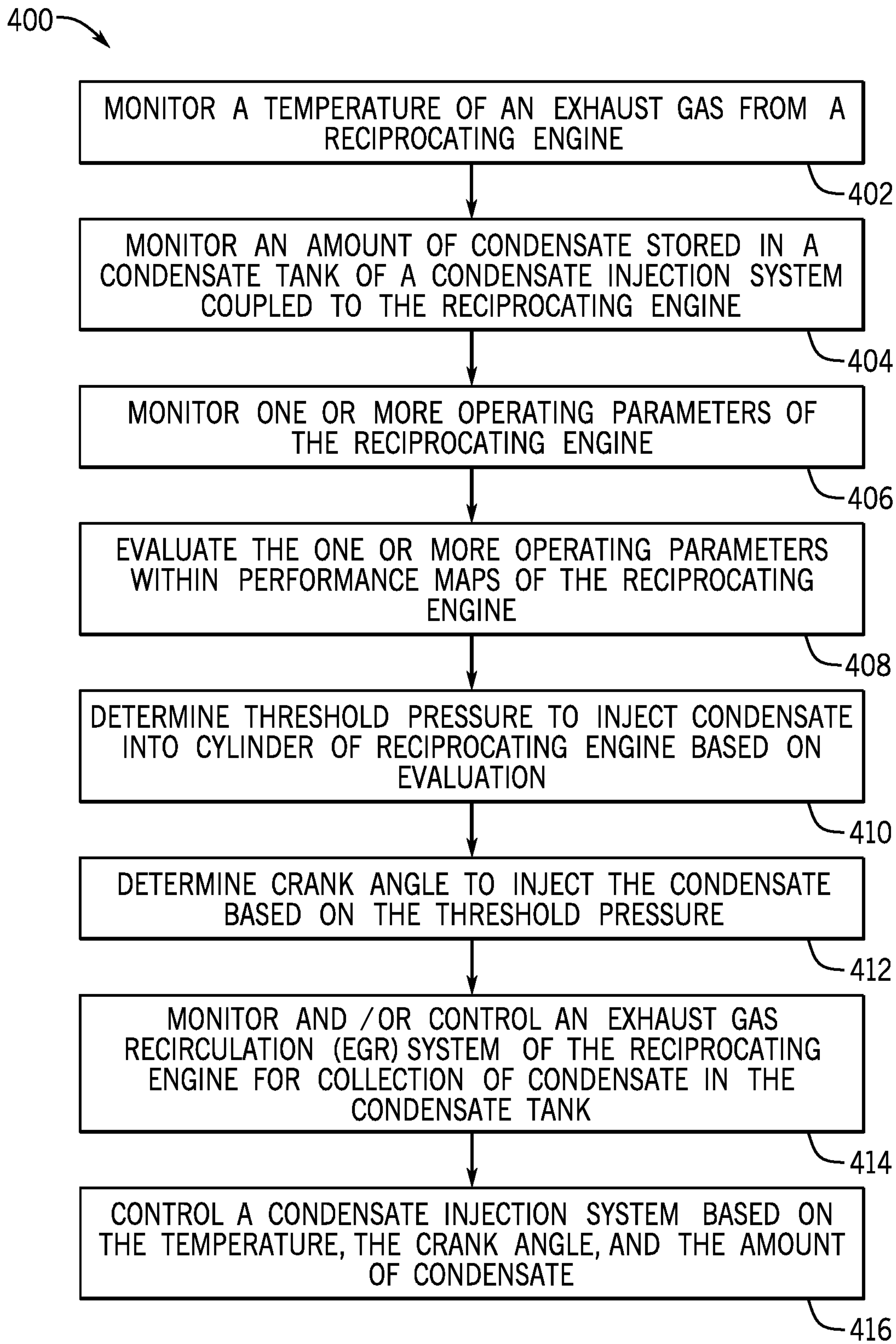
400
MONITOR A TEMPERATURE OF AN EXHAUST GAS FROM A RECIPROCATING ENGINE
402
MONITOR AN AMOUNT OF CONDENSATE STORED IN A CONDENSATE TANK OF A CONDENSATE INJECTION SYSTEM COUPLED TO THE RECIPROCATING ENGINE
404
MONITOR ONE OR MORE OPERATING PARAMETERS OF THE RECIPROCATING ENGINE
406
EVALUATE THE ONE OR MORE OPERATING PARAMETERS WITHIN PERFORMANCE MAPS OF THE RECIPROCATING ENGINE
408
DETERMINE THRESHOLD PRESSURE TO INJECT CONDENSATE INTO CYLINDER OF RECIPROCATING ENGINE BASED ON EVALUATION
410
DETERMINE CRANK ANGLE TO INJECT THE CONDENSATE BASED ON THE THRESHOLD PRESSURE
412
MONITOR AND /OR CONTROL AN EXHAUST GAS RECIRCULATION (EGR) SYSTEM OF THE RECIPROCATING ENGINE FOR COLLECTION OF CONDENSATE IN THE CONDENSATE TANK
414
CONTROL A CONDENSATE INJECTION SYSTEM BASED ON THE TEMPERATURE, THE CRANK ANGLE, AND THE AMOUNT OF CONDENSATE
416

FIG. 5

SYSTEM AND METHOD FOR INJECTING CONDENSATE IN CYLINDER OF A RECIPROCATING ENGINE

BACKGROUND

[0001] The subject matter disclosed herein relates to reciprocating engines and associated heat exchangers.

[0002] A combustion system may include an exhaust gas recirculation (EGR) system configured to recirculate exhaust gas from an exhaust to an intake of a reciprocating engine. The EGR system may produce condensate due to a cooling of the exhaust gas via a set of heat exchangers. The condensate is expelled via a drainage system from the combustion system, such that the condensate is a byproduct of operating the combustion system. Accordingly, a need exists to reduce the amount of condensate outputted via a drainage system.

BRIEF DESCRIPTION

[0003] Certain embodiments commensurate in scope with the originally claimed subject matter are summarized below. These embodiments are not intended to limit the scope of the claimed subject matter, but rather these embodiments are intended only to provide a brief summary of possible forms of the subject matter. Indeed, the subject matter may encompass a variety of forms that may be similar to or different from the embodiments set forth below.

[0004] In certain embodiments, a system includes a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store condensate collected from the EGR system. The condensate injection system also includes a pump fluidly coupled to the condensate tank. The condensate injection system also includes an injector fluidly coupled to the pump. The injector is configured to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

[0005] In certain embodiments, a system includes a controller having a processor, a memory, and instructions stored on the memory and executable by the processor to control a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store condensate collected from the EGR system. The condensate injection system also includes a pump fluidly coupled to the condensate tank. The condensate injection system also includes an injector fluidly coupled to the pump. The controller is configured to control the injector to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

[0006] In certain embodiments, a method includes controlling, via a controller, a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store a condensate collected from the EGR system. The condensate injection system also includes a pump fluidly coupled to the condensate tank. The condensate injection system also includes an injector fluidly coupled to the pump. Controlling includes commanding the injector to inject the condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. **1** is a diagram of an embodiment of a combustion system having a condensate injection system coupled to a recirculation line of an engine system;

[0009] FIG. **2** is a schematic view of an embodiment of a piston-cylinder assembly having an injector coupled to the condensate injection system;

[0010] FIG. **3** is a diagram of an embodiment of the combustion system of FIG. **1**, further illustrating the condensate injection system coupled to the recirculation line and a reciprocating engine of the combustion system;

[0011] FIG. **4** is an embodiment of a graph mapping an internal pressure and a crank angle during an engine cycle of the piston-cylinder assembly of FIG. **2**; and

[0012] FIG. **5** is a flow chart showing an embodiment of a process for controlling the condensate injection system of FIG. **2**.

DETAILED DESCRIPTION

[0013] One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0014] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0015] The disclosed embodiments provide systems and methods for injecting condensate (e.g., water condensed from water vapor in the exhaust gas) collected from a heat exchanger assembly (e.g., exhaust cooling system, EGR cooler system) into a combustion chamber of a piston-cylinder assembly of a reciprocating engine, via a condensate injection system, during a portion of the engine cycle of the reciprocating engine. In particular, the portion of the engine cycle may include an end portion of a power stroke (e.g., combustion stroke) and an exhaust stroke of the engine cycle. Additionally, a controller may be configured to control the condensate injection system based on one or more signals received from one or more sensors disposed throughout the combustion system.

[0016] For example, the controller may be configured to monitor a temperature of an exhaust gas disposed in an exhaust system of the combustion system. If the temperature of the exhaust gas decreases below a lower temperature threshold or increases above a higher temperature threshold, then the controller may be configured to decrease or increase the amount of condensate into the combustion chamber, respectively. By controlling the amount of condensate injected into the combustion cylinder based on the exhaust temperature, the controller may be configured to regulate the temperature of the exhaust gas between the lower and higher temperature thresholds. Furthermore, the controller may be configured to monitor an amount of condensate stored in a condensate tank of the condensate injection system. In particular, the controller may be configured to control the amount of condensate injected into the combustion chamber and/or the amount of condensate produced by the heat exchanger assembly based on the monitored amount of condensate in the condensate tank. For example, the controller may be configured to increase the consumption of condensate (e.g., via injection) and/or decrease the production of condensate in response to the amount of condensate in the condensate tank exceeding a high threshold. Additionally or alternatively, the controller may be configured to decrease the consumption of condensate (e.g., via injection) and/or increase the production of condensate in response to the amount of condensate in the condensate tank falling below a low threshold. Furthermore, the controller may be configured to monitor one or more parameters of the reciprocating engine for determining when to inject the condensate into the combustion chamber. For example, the controller may be configured to utilize one or more maps (e.g., lookup tables of various parameters) of the combustion system to determine one or more parameters that are not measured directly (e.g., internal pressure of the combustion chamber). The controller may be configured to determine a crank angle corresponding to a starting point and/or end point of the engine cycle for condensate injection based on the one or more parameters determined via the maps.

[0017] FIG. **1** is a diagram of an embodiment of a combustion system **10** having a condensate injection system **12** coupled to a recirculation line **14** of an engine system **16**. The engine system **16** may include a reciprocating engine **18** having a heat exchange system **20** (e.g., EGR cooling system) and an exhaust system **22**. As discussed below, the condensate injection system **12** is configured to receive condensate (e.g., water condensed from water vapor in exhaust gas **30**) from the heat exchange system **20**, store the water in one or more condensate tanks, and supply the condensate to combustion chambers of the reciprocating engine **18** during an end portion of a power stroke and/or an exhaust stroke. Thus, the condensate injection system **12** is configured to control a temperature in the combustion chamber and the discharging exhaust gas **30**, while also reducing or eliminating waste of the condensate. The temperature control may be used to help control exhaust emissions and protect downstream equipment (e.g., turbocharger, valves, etc.) from excessive temperatures in the exhaust gas **30**. In certain embodiments, the condensate injection system **12** may rely only on the condensate for injection into the combustion chambers of the reciprocating engine **18** without any additional supply of water. However, in some embodiments, the condensate injection system **12** may supplement the condensate with a separate water supply for injection into the combustion chambers of the reciprocating engine **18**. For example, the condensate injection system **12** may selectively supplement the condensate with the separate water supply when the condensate is insufficient to meet demands. Additional details of the condensate injection system **12** are discussed below.

[0018] The reciprocating engine **18** may include a four-stroke engine having a four-stroke cycle (e.g., intake stroke, compression stroke, power/expansion stroke, exhaust stroke). In certain embodiments, the reciprocating engine **18** may include a two-stroke engine or a five-stroke engine. The reciprocating engine 18 may also include any number of combustion chambers, pistons, and associated cylinders (e.g., 1-24) in one cylinder bank (e.g., inline) or multiple cylinder banks (e.g., left and right cylinder banks) of a V, W, VR (a.k.a. Vee-Inline), or WR cylinder bank configuration. For example, in certain embodiments, the reciprocating engine 18 may include a large-scale industrial reciprocating engine having 6, 8, 12, 16, 20, 24 or more pistons reciprocating in cylinders. In some such cases, the cylinders and/or the pistons may have a diameter of between approximately 13.5-31 centimeters (cm). In certain embodiments, the cylinders and/or the pistons may have a diameter outside of the above range. The fuel utilized by the reciprocating engine 18 may be any suitable gaseous fuel, such as natural gas, associated petroleum gas, hydrogen (H_2), propane (C_3H_8), biogas, sewage gas, landfill gas, coal mine gas, butane (C_4H_{10}), ammonia (NH_3) for example. The fuel may also include a variety of liquid fuels, such as gasoline, diesel, methanol, or ethanol fuel. The fuel may be admitted through either a high pressure (blow-through) fuel supply system or low pressure (draw-through) fuel supply system or direct injection. In certain embodiments, the fuel may be admitted via port fuel injection (PFI). In certain embodiments, the reciprocating engine **18** may utilize spark ignition. In other embodiments, the reciprocating engine **18** may utilize compression ignition.

[0019] The exhaust system **22** may include one or more exhaust circuits **28** between the reciprocating engine **18** and the corresponding heat exchange system **20**. The exhaust circuits **28** may be configured to route one or more flows of exhaust gas **30** between the reciprocating engine **18** and the heat exchange system **20**. For example, the reciprocating engine **18** may output and route a flow of the exhaust gas **30** along an exhaust line **32** to the heat exchange system **20** and recirculate the exhaust gas **30** from the heat exchange system **20** back into the reciprocating engine **18** via one or more exhaust gas recirculation (EGR) circuits **34**.

[0020] The heat exchange system **20** coupled to the exhaust circuit **28** may include one or more heat exchanger assemblies **36**, wherein each of the heat exchanger assemblies **36** includes a plurality of the heat exchanger modules **37** coupled to one of a plurality of distribution manifolds **38**. For example, the heat exchanger assemblies **36** may include heat exchanger assemblies **40**, **42**, and **44**, wherein each of the heat exchanger assemblies **36** includes one of the distribution manifolds **38** (e.g., distribution manifolds **46**, **48**, and **50**). Each of the heat exchanger assemblies **36** may include any number of the heat exchanger modules **37** disposed in a series arrangement, a parallel arrangement, or a combination thereof. For example, in certain embodiments, the heat exchanger modules **37** for each of the heat exchanger assemblies **36** having one of the distribution manifolds **38** may include heat exchangers (e.g., EGR coolers) **52**, **54**, **56**, and **58**. Although four heat exchangers **52**, **54**, **56**, and **58** are shown, any number of heat exchangers (e.g., up to an Nth heat exchanger) may be disposed in each of the heat exchanger assemblies **36**. The heat exchangers **52**, **54**, **56**, and **58** may be arranged in series, in parallel, or a combination thereof. In certain embodiments, the heat exchangers **52** and **54** may be first stage heat exchangers (e.g., arranged in parallel), the heat exchanger **56** may be a second stage heat exchanger, and the heat exchanger **58** may be a third stage heat exchanger. However, the heat exchanger modules **37** may be arranged in any number of stages, each stage having 1, 2, 3, or more heat exchangers arranged in parallel with one another.

[0021] The illustrated heat exchanger assemblies **40**, **42**, and **44** each have one of the distribution manifolds **46**, **48**, and **50** having a plurality of the heat exchanger modules **37**, such as the heat exchangers **52**, **54**, **56**, and **58**. The heat exchanger assemblies **40**, **42**, and **44** may have the same or different configuration of the heat exchanger modules **37** and the distribution manifolds **38**, such as the same or different numbers of the heat exchanger modules **37**, the same or different numbers of sections making up the distribution manifolds **38**, or any combination thereof. Each of the distribution manifolds **38** may represent a single one-piece distribution manifold (e.g., single cast manifold), a multi-piece distribution manifold (e.g., sectional cast manifold) having different manifold portions removably coupled together, or individual conduits coupling together the heat exchanger modules **37** as a multi-conduit distribution manifold.

[0022] In the illustrated embodiment, each heat exchanger assembly **36** includes a plurality of the heat exchanger modules **37**, such as a series arrangement of the heat exchangers **52**, **54**, **56**, and **58**, coupled to at least one of the distribution manifolds **38**. The heat exchanger modules **37** are also coupled to the exhaust line **32** and the EGR circuit **34** of the exhaust system **22** through the at least one distribution manifold **38**. A flow of the exhaust gas **30** may be configured to flow from the reciprocating engine **18** through the exhaust line **32** into one of the distribution manifolds **38**, through the heat exchanger modules **37**, back through one of the distribution manifolds **38**, and then through the EGR circuit **34** for recirculation into an intake of the reciprocating engine **18**. In some embodiments, at least part or all of the exhaust gas **30** may not flow back into the reciprocating engine **18** via the EGR circuit **34**. For example, at least part of the exhaust gas **30** may not enter the heat exchanger assembly **36** and flow downstream into one of the exhaust gas waste heat recovery systems **106** and/or discharge into the environment.

[0023] Each distribution manifold **38** may be configured to circulate the exhaust gas **30** from the reciprocating engine **18** through each of the heat exchanger modules **37**, such as in a series arrangement and/or a parallel arrangement, while also circulating one or more heat exchange fluids **142** through the distribution manifold **38** and the heat exchanger modules **37**. For example, the heat exchange fluids **142** may include heat exchange fluids **144**, **146**, and **148**. The heat exchange fluids **142** may include one or more liquids, such as condensate, antifreeze liquids or additives, coolants, or any combination thereof. For example, the heat exchange fluids **142** may include a main engine fluid and an auxiliary fluid. For example, the main engine fluid may flow to, from, and through the reciprocating engine **18**, such that the main engine fluid may be configured to provide cooling of the reciprocating engine **18**. Similarly, the auxiliary fluid may pass to and from one or more auxiliary systems, such that the auxiliary fluid may provide cooling. The auxiliary systems may be related and/or unrelated to the reciprocating engine **18**, but the auxiliary systems may be outside or separate from the reciprocating engine **18**. For example, auxiliary systems may include other power plant equipment, and the auxiliary fluid may be described as a balance of plant (BoP) fluid (e.g., BoP auxiliary coolant)). Again, for each heat exchanger assembly **36**, the distribution manifold **38** may be configured to route inputs and outputs of both the exhaust gas **30** and the heat exchange fluids **142** (e.g., the main engine fluid and/or the auxiliary fluid) through each of the heat exchanger modules **37**.

[0024] Accordingly, the heat exchanger assemblies **36** may transfer heat between the exhaust gas **30** and one or more of the heat exchange fluids **142**, such as the main engine fluid and the auxiliary fluid. The heat exchanger modules **37** may be gas liquid heat exchangers, which are configured to transfer heat between the exhaust gas **30** and the liquid of the heat exchange fluids **142**. In some embodiments, each of the heat exchanger modules **37** may be a plate heat exchanger, a brazed plate heat exchanger, and/or a gas-to-liquid plate heat exchanger.

[0025] In the illustrated embodiment, the heat exchanger assemblies **36** are disposed in three different locations throughout the exhaust system **22**, as indicated by heat exchanger assemblies **40**, **42**, and **44**. However, the exhaust system **22** may include only one or two of the heat exchanger locations (e.g., heat exchanger assemblies **40**, **42**, and **44**). The reciprocating engine **18** includes an engine block **170** having a plurality of piston-cylinder assemblies **172**, each having a piston **174** disposed within a cylinder **176**. Each piston **174** may be configured to reciprocate within the cylinder **176** in response to combustion in a combustion chamber of the engine block **170**, thereby driving rotation of a crankshaft coupled to a shaft **178** driving a load **180** (e.g., an electric generator). Additionally, the reciprocating engine **18** includes an exhaust manifold **182** and an intake manifold **184**. The intake manifold **184** is coupled to an intake circuit **186** of an intake system **188**, while the exhaust manifold **182** is coupled to the exhaust circuit **28** of the exhaust system **22**. The intake circuit **186** includes one or more intake lines **190** extending between an air intake section **192** and the intake manifold **184**, thereby supplying air into the reciprocating engine **18**. For example, the air intake section **192** may include an air intake duct, air filters, or other features to process the air coming into the intake system **188**.

[0026] The exhaust system **22** has one or more exhaust lines **32** extending between an exhaust section **194** and the exhaust manifold **182**. For example, the exhaust section **194** may include a silencer, an after-treatment **197** (e.g., three-way catalyst), a discharge duct, or other equipment to facilitate discharge of the exhaust gas into the environment. As noted above, the exhaust system **22** also may include one or more EGR circuits **34** (e.g., recirculation line **14**) to facilitate exhaust gas recirculation between the exhaust circuit **28** and the intake circuit **186**. For example, the EGR circuits **34** may include EGR lines **199** disposed upstream and/or downstream of a turbocharger **195**, which includes a turbine **196** disposed along the exhaust line **32**, a compressor **198** disposed along the intake line **190**, and a shaft **200** coupling together the turbine **196** and the compressor **198**. The turbocharger **195** is driven by exhaust gas passing through the exhaust line **32** and through the turbine **196**, which in turn rotates the shaft **200** coupled to the compressor **198**. The compressor **198** operates to compress an airflow from the air intake section **192** flowing along the intake line **190** into the intake manifold **184**.

[0027] As noted above, the EGR circuits **34** may include EGR lines **199** both upstream and downstream of the turbocharger **195**. For example, the EGR circuits **34** may include EGR circuits **202** and **204** disposed at different positions upstream and downstream relative to the turbocharger **195**. In the illustrated embodiment, the EGR circuit **202** has EGR lines **206** and **208** coupled to the respective exhaust line **32** and the intake line **190**, wherein the EGR lines **206** and **208** also couple to one of the heat exchanger assemblies **36** (e.g., the heat exchanger assembly **40**). Similarly, the EGR circuit **204** has EGR lines **210** and **212** coupled to the respective exhaust line **32** and the intake line **190**, wherein the EGR lines **210** and **212** also couple to one of the heat exchanger assemblies **36** (e.g., the heat exchanger assembly **42**). In the illustrated embodiment, the EGR circuit **202** may be described as a high pressure EGR circuit, due to its location upstream from the turbine **196**, whereas the EGR circuit **204** may be considered a low pressure EGR circuit based on its position downstream from the turbine **196**. The exhaust system **22** may include one or more of the heat recovery systems, such as the exhaust gas waste heat recovery system **106** having one of the heat exchanger assemblies **36** (e.g., the heat exchanger assembly **44**).

[0028] The combustion system **10** may include a variety of components along the exhaust system **22** and the intake system **188**. As discussed above, the turbine **196** of the turbocharger **195** is disposed along the exhaust line **32** of the exhaust system **22**. The turbocharger **195** also may include a bypass valve or waste gate valve **214** configured to open and close to vary a bypass of exhaust gas around the turbine **196**. The exhaust section **194** also may include various components, such as the silencer, after-treatment **197**, or other exhaust gas treatment components.

[0029] Similarly, the intake system **188** may include a bypass valve **216** configured to open and close to vary a bypass flow of air intake around the compressor **198**. The intake circuit **186** of the intake system **188** may include an intercooler **218** configured to control the temperature of the air intake and a throttle **220** configured to control the flow of the air intake and fuel **221** from a fuel supply **223** into the intake manifold **184**. For example, the intercooler **218** may be a heat exchanger configured to transfer heat away from the intake air after compression in the compressor **198**, thereby cooling the compressed air to a suitable temperature prior to intake into the reciprocating engine **18** via the intake manifold **184**. The throttle **220** also may be configured to control the fluid flows (e.g., air, recirculate exhaust gas, and fuel) into the intake manifold **184** downstream from the intercooler **218**. The air intake section **192**, as discussed above, may include air filters, intake ducts, or other equipment to properly intake and route the air flow into the reciprocating engine **18**.

[0030] Each of the EGR circuits **202** and **204** may be configured to recirculate an exhaust gas **30** being discharged along the exhaust line **32** into the intake line **190** for return into the intake manifold **184** of the reciprocating engine **18**. Each of the EGR circuits **202** and **204** includes an EGR valve, such as EGR valves **222** and **224**, configured to regulate the flow of exhaust gas **30** back into the reciprocating engine **18** through the respective circuits **202** and **204**. Downstream from the EGR valves, the EGR circuits **202** and **204** may include an EGR mixer, such as EGR mixers **226** and **228**. The EGR mixers **226** and **228** are configured to mix the EGR flow (e.g., the exhaust gas) with the incoming air from the air intake section **192**. The EGR mixers **226** and **228** mix the exhaust gas and air prior to delivery into the reciprocating engine **18** via the intake manifold **184**. The EGR mixer **226** mixes the exhaust gas and air downstream from the compressor **198** of the turbocharger **195**, whereas the EGR mixer **228** mixes the exhaust gas in the air upstream from the compressor **198** of the turbocharger **195**.

[0031] In certain embodiments, the combustion system **10** may include only one or both of the EGR circuits **202** and **204** and the respective heat exchanger assemblies **36**. Each of the heat exchanger assemblies **36**, such as the heat exchanger assemblies **40** and **42**, may be configured to transfer heat away from the exhaust gas **30** and into one or more heat exchange fluids **142** of a heat exchanger fluid system **229**. For example, as discussed above, the heat exchange fluids **142** may include a main engine fluid and/or an auxiliary fluid. The heat exchanger assemblies **36** transfer heat away from the exhaust gas into the heat exchange fluids **142** of the heat exchanger fluid system **229**, thereby cooling the exhaust gas prior to recirculating the exhaust gas back into the intake manifold **184** of the reciprocating engine **18**. The heat exchanger fluid system **229** may include one or more components **242**, such as components **244**, **246**, **248**, and **250**, such as fluid pumps, valves, filters, sensors, or any combination thereof. The heat exchanger assemblies **36** (e.g., heat exchanger assemblies **40** and **42**) may be described as EGR cooling systems, such as multi-stage EGR cooling systems that provide EGR cooling in a plurality of stages.

[0032] As discussed above, each of the heat exchanger assemblies **36** (e.g., heat exchanger assemblies **40** and **42**) includes a plurality of the heat exchanger modules **37**, such as heat exchangers **52**, **54**, **56**, and **58**, disposed in series and/or parallel along the EGR circuit **202** or **204**. The heat exchanger modules **37** are coupled to one of the distribution manifolds **38**, which in turn couples with the EGR lines **206** and **208** of the EGR circuit **202** or the EGR lines **210** and **212** of the EGR circuit **204**. In the EGR circuit **202**, the EGR line **206** directs the exhaust gas from the exhaust line **32** into the manifold **38**, while the EGR line **208** receives a discharge of the exhaust gas from the distribution manifold **38** and returns the exhaust gas into the intake line **190**. The EGR circuit **204** has the EGR line **210** coupled to an intake of the distribution manifold **38**, while the EGR line **212** couples to a discharge of the distribution manifold **38** and returns the exhaust gas to the intake line **190**. Similarly, the exhaust gas waste heat recovery system **106** has one of the heat exchanger assemblies **36** (e.g., heat exchanger assembly **44**) coupled to the exhaust section **194** to facilitate waste heat recovery using the heat exchanger modules **37**. The heat exchanger assembly **44** of the exhaust gas waste heat recovery system **106** may include any number of the heat exchanger modules **37** in series, in parallel, or a combination thereof, in a similar manner as the heat exchanger modules **37** in the EGR circuits **202** and **204**.

[0033] In each of the heat exchanger assemblies **36**, the manifold **38** and the heat exchanger modules **37** may be coupled together and supported by a support system **230**. For example, the support system **230** may include a horizontal support, slab or table **232**, a vertical support or backrest **234**, and a plurality of legs **236**. The horizontal support **232** may be configured to support the heat exchanger modules **37**, the vertical support **234** may be configured to support the distribution manifold **38**, and the legs **236** are coupled to the horizontal support **232** and extend to the ground to support the entire support system **230** at a vertical distance above the ground. However, a variety of support systems **230** may be used to support each of the heat exchanger assemblies **36**.

[0034] In certain embodiments, the combustion system **10** may include a control system **252** having a controller **254** coupled to a plurality of sensors **256** and actuators **258** distributed about the combustion system **10**. For example, the sensors **256**, designated as “S,” may be coupled to the combustion system **10** at various locations along the exhaust system **22**, the intake system **188**, the EGR circuit **202**, the EGR circuit **204**, the turbocharger **195**, the reciprocating engine **18**, and the heat exchanger assemblies **36**. Each of these sensors **256** may be configured to obtain feedback associated with one or more parameters of an exhaust gas in the exhaust system **22**. For example, the sensors **256** may be used to monitor a temperature of the exhaust gas output via the exhaust system **22**. Additionally or alternatively, the sensors **256** may be configured to monitor a parameter indicative of an amount of emissions (e.g., emission gases) in the exhaust gas output via the exhaust system **22**. The actuators **258** may include valve actuators, such as valve actuators for the waste gate **214** and the bypass valve **216**, pump actuators for the heat exchanger fluid system **229**, valve actuators for the EGR valves **222** and **224**, or any combination thereof.

[0035] The sensors **256** monitor and, in certain embodiments, retain in memory the parameters along with other information associated with the exhaust system **22**. The sensors **256** may include physical sensors and/or virtual sensors, which are configured to measure certain parameters based on input data. The monitored parameters may include a temperature, a pressure, a flow rate, a leakage, a composition of the fluid, a vibration, a time, reciprocating engine metrics, or any combination thereof.

[0036] The parameters monitored by the sensors **256** may be further characterized as set forth below. At least some or all of the monitored parameters may correspond to a measured temperature, a measured pressure, a measured flow-rate, or a combination thereof of the exhaust gas passing through the exhaust system **22**. The measured temperature may include an exhaust gas temperature, a main fluid temperature, and/or an auxiliary fluid temperature, wherein the respective temperatures may include temperatures measured at the inlets and the outlets and changes in temperatures between the inlets and the outlets of the exhaust system **22**. For exhaust gas temperatures, the exhaust gas temperatures may include EGR exhaust gas temperatures, heat recovery (HR) exhaust gas temperatures (e.g., in the exhaust gas waste heat recovery system **106**), or any combination thereof. Similarly, the measured pressure may include an exhaust gas pressure, a main fluid pressure, and/or an auxiliary fluid pressure, wherein the respective pressures may include pressures measured at the inlets and the outlets and changes in pressures between the inlets and the outlets (e.g., pressure drops) of the exhaust gas system **22**. Similarly, the measured flow rate may include an exhaust gas flow rate, a main fluid flow rate, and/or an auxiliary fluid flow rate, wherein the respective flow rates may include flow rates measured at the inlets and the outlets and changes in flow rates between the inlets and the outlets of the exhaust system **22**.

[0037] In certain embodiments, the sensors **256** may be configured to monitor a measured composition of the exhaust gas passing through the exhaust system **22**. For example, the measured composition of the exhaust gas may include a humidity or condensate content in the exhaust gas, a particulate or soot content in the exhaust gas, a carbon dioxide (CO_2) content in the exhaust gas, an oxygen (O_2) content in the exhaust gas, a nitrogen oxide (NOx) content in the exhaust gas, a sulfur oxide (SOx) content in the exhaust gas, or any combination thereof.

[0038] In certain embodiments, the controller **254** may include a processor **260**, a memory **262**, instructions **264** stored on the memory and executable by the processor, and communication circuitry **266** configured to communicate with the sensors distributed throughout the combustion system **10**. As discussed herein, the controller **254** may be configured to control the condensate injection system **12** to inject the condensate, via an injector, into each combustion chamber **292** (see FIG. **2**) of the reciprocating engine **18** during a portion of the engine cycle of the reciprocating engine **18**. In certain embodiments, the controller **254** may be configured to control the condensate injection system **12** in response to the feedback received from the sensors **256**. The controller **254** may use local and/or remote computer systems and storage, web-based interfaces, cloud-based interface, apps on smart devices (e.g., smart phones, tablet computers, etc.), or any suitable use interface. In certain embodiment, the controller **254** may implement a cloud-based platform used for asset management of the reciprocating engines **18**, such as myPlant, provided by Innio of Jenbach, Tyrol, Austria.

[0039] FIG. **2** is a schematic view of an embodiment of a piston-cylinder assembly **280** having an injector(s) **281** coupled to the condensate injection system **12**. In certain embodiments, the injector(s) **281** may include direct injectors that may use wall-guided direction injection, air-guided direct injection, spray-guided direct injection, or a combination thereof. As shown, the piston-cylinder assembly **280** includes a piston **174** disposed within a cylinder **176** (e.g., an engine cylinder) of the engine system. The piston **174** is attached to a crankshaft **286** via a connecting rod **288** and a pin **290**. The crankshaft **286** converts the reciprocating linear motion of the piston **174** into a rotating motion. As the piston **174** moves, the crankshaft **286** rotates to power the load **180** (shown in FIG. **1**), as discussed herein. As shown, a combustion chamber **292** is positioned adjacent to the top land **294** of the piston **174**. The condensate injection system **12** injects condensate into the combustion chamber **292** via the injector(s) **281**. In certain embodiments, the injector(s) **281** may additionally inject fuel into the combustion chamber **292** of the piston **174**. Alternatively, one injector(s) **281** may be used for the injection of fuel into the combustion chamber **292** and a separate injector(s) **281** may be used for the injection of condensate into the combustion chamber **292**. In certain embodiments, a separate fuel injection system **293** may inject fuel into the combustion chamber **292** via fuel injector(s) **295**. As shown, the fuel injection system **293** may be controlled via the controller **254**. In operation, combustion of the fuel with the air in the combustion chamber **292** cause the piston **174** to move in a reciprocating manner (e.g., back and forth) in the axial direction **296** within the cylinder **176**. During operations, when the piston **174** is at the highest point in the cylinder **176**, it is in a position called top dead center (TDC). When the piston **174** is at its lowest point in the cylinder **176**, it is in a position called bottom dead center (BDC). For a four-stroke engine, the piston **174** is positioned at TDC twice during the four-stroke cycle, and is positioned at BDC twice during the four-stroke cycle. The two TDC positions include top dead center firing (TDCF), and top dead center gas exchange (TDCGE) or top dead center exchange (or alternatively, TDCE). As the piston **174** moves from top to bottom or from bottom to top, the crankshaft **286** rotates one half of a revolution. Each movement of the piston **174** from top to bottom or from bottom to top is called a stroke.

[0040] As shown, the controller **254** is communicatively coupled to the condensate injection system **12** and configured to control the condensate injection system **12**, which is coupled to the injector(s) **281**. The controller **254** may be configured to control the condensate injection system **12** to inject the condensate, via the injector(s) **281**, into a combustion chamber **292** of the reciprocating engine **18** during a portion of the engine cycle of the reciprocating engine **18**. The portion of the engine cycle is described in further detail herein.

[0041] FIG. **3** is a diagram of an embodiment of the combustion system **10** of FIG. **1**, further illustrating the condensate injection system **12** coupled to the recirculation line **14** (e.g., EGR circuits **202**, **204**, and **320**) and the reciprocating engine **18** of the combustion system **10**. As shown, the condensate injection system **12** includes a condensate tank **322** configured to collect and store condensate from the recirculation line **14**. The condensate injection system **12** also includes a pump **324** (e.g., electric motor driven pump) coupled to the condensate tank **322**. In certain embodiments, the condensate injection system **12** may include a condensate treatment system **326** disposed between the condensate tank **322** and the pump **324** and, in certain embodiments, the condensate treatment system **326** may have one or more filters **328**. For example, the filters **328** may include a media filter, a centrifugal separator, a gravity separator, or any combination thereof. The condensate treatment system **326** also may include other treatment systems, such as a biological treatment system (e.g., an ultraviolet light treatment system). In certain embodiments, the condensate treatment system **326** includes a reverse osmosis (RO) system, a deionized (DI) system, a distilled water system, and/or a pH balancing/neutralizer system. The condensate injection system **12** also includes one or more injectors **281** coupled to one or more cylinders and fluidly coupled to the pump **324** of the reciprocating engine **18**, and configured to inject condensate (e.g., and fuel) into one or more combustion chambers during a portion of the engine cycle of the reciprocating engine **18**. In certain embodiments, each injector **281** may include a common injection flow path for selectively injecting the condensate and the fuel at different times, or separate injection flow paths (e.g., coaxial or parallel offset flow paths) for separately injecting the condensate and the fuel at the different times. Each injector **281** may include one or more fluid injection orifices, nozzles, or atomizers to inject a spray (e.g., atomized spray) of the condensate or the fuel. In certain embodiments, the fuel may be injected into the reciprocating engine **18** via the fuel injection system **293**. In certain embodiments, the condensate injection system **12** may include a check valve **321** disposed between the pump **324** and the injector(s) **281** to prevent backflow should the injector(s) open when cylinder pressure exceeds condensate pump pressure. In certain embodiments, the condensate injection system **12** may include a pressure relief valve **323**, back to the condensate tank, as a way to mitigate excess pressure in the condensate fluid circuit **325** in the event that the injector(s) **281** fail to open.

[0042] For the condensate injection via the injector **282**, the portion of the engine cycle includes at least part of a combustion stroke (e.g., power stroke) and/or an exhaust stroke of the engine cycle. In certain embodiments, the combustion stroke spans from TDCF to 180 degrees after TDCF (e.g., aTDCF). Additionally, in certain embodiments, the exhaust stroke spans from 180 degrees aTDCF to TDCGE (or alternatively, TDCE).

[0043] As shown, the recirculation line **14** may include the heat exchanger assembly **36** (e.g., exhaust cooling system or EGR cooler system) having heat exchanger modules **37** (e.g., heat exchangers **52**, **54**, **56**, and **58**) configured to cool the exhaust gas **30**. In certain embodiments, the condensate tank **322** may be coupled to one or more of the heat exchanger modules **37** (e.g., condensing heat exchangers), wherein the heat exchanger modules **37** are configured to condense water vapor in the exhaust gas **30** and discharge condensate to the condensate tank **322**. In certain embodiments, the heat exchanger modules **37** of the heat exchanger assembly **36** may include one or more non-condensing heat exchangers, one or more condensing heat exchangers, and/or one or more reheat heat exchangers arranged in a sequence (e.g., multiple stages). For example, heat exchangers **52** and **54** may be non-condensing heat exchangers (e.g., first EGR cooler stage), the heat exchanger **56** may be a condensing heat exchanger, and the heat exchanger **58** may be a reheat heat exchanger. However, any arrangement of non-condensing, condensing, and/or reheat heat exchanger modules **37** may be used for the heat exchangers **52**, **54**, **56**, and **58**. In certain embodiments, the condensate tank **322** may be coupled to the one or more condensing heat exchangers via an outlet (e.g., condensate drain conduit **329**) disposed in each of the condensing heat exchangers. Additionally or alternatively, a valve **330** may be disposed between the heat exchanger assembly **36** and the condensate tank **322** and configured to regulate the amount of condensate collected in the condensate tank **322**. Collectively a condensate fluid circuit (e.g., condensate flow path) **325** extends from the heat exchanger assembly **36** to the injectors **281** of the reciprocating engine **18**, wherein the condensate fluid circuit **325** includes the valve **330**, the condensate tank **322**, the condensate treatment system **326**, the pump **324**, and various connecting fluid conduits. Although the illustrated embodiment shows condensate being collected from the heat exchanger assembly **36**, it should be understood that the condensate may be additionally or alternatively collected from other locations, including the waste heat recovery system **106** shown in FIG. **1**.

[0044] As discussed herein, the heat exchanger assembly **36** may be coupled to the reciprocating engine **18**. For example, the heat exchanger assembly **36** may be coupled to the intake circuit **186** and the exhaust circuit **28**. As shown, the recirculation line **14** may include EGR circuits **202**, **204**, or **320**. As discussed herein, the EGR circuit **202** may couple to the intake circuit **186** downstream of the compressor **198** and may also couple to the exhaust circuit **28** upstream of the turbine **196**. The EGR circuit **204** may couple to the intake circuit **186** upstream of the compressor **198** and may also couple to the exhaust circuit **28** downstream of the turbine **196**. The EGR circuit **320** may couple to the intake circuit **186** upstream of the compressor **198** and may also couple to the exhaust circuit **28** upstream of the turbine **196**.

[0045] In the illustrated embodiment, the combustion system **10** includes a sensor **256** (e.g., tank level sensor **332**) coupled to the condensate tank **322**. The sensor **332** (e.g., photo detector, float switches, proximity sensor, camera) may be configured to send a signal to the controller **254** indicative of an amount of condensate in the condensate tank **322**. For example, the sensor **332** may be configured to send the signal to the controller **254** based on the condensate in the condensate tank **322** falling below a threshold level (e.g., threshold amount). In certain embodiments, the controller **254** may be configured to control the condensate injection system **12** based on receiving the signal from the sensor **332**. For example, the controller **254** may be configured to control the heat exchanger assembly **36**, the pump **324**, the valve **330**, the injector(s) **281**, or a combination thereof, based on the signal received from the sensor **332**. In certain embodiments, the controller **254** may be configured to decrease a throughput of the pump **324** and/or a parameter associated with the injector(s) **281** (e.g., controlling an amount of condensate injected into the reciprocating engine **18**, injection duration) based on the sensor **332** indicating that the amount of condensate in the condensate tank **322** is below a threshold level. For example, the controller **254** may be configured to adjust a ratio of a first duration of time during which the injector(s) **281** inject condensate to a second duration of time during which the injector(s) do not inject condensate.

[0046] In certain embodiments, the controller **254** may be configured to control the condensate injection (e.g., via the injector(s) **281**) and/or control the heat exchanger assembly **36** to maintain a substantially constant level (e.g., within upper and lower thresholds) of condensate in the condensate tank **322**. For example, the controller **254** may be configured to increase a rate of condensate injected into the cylinder via the injector(s) **281** based on an amount of condensate in the condensate tank **322** exceeding a threshold (e.g., high threshold) amount. Additionally or alternatively, the controller **254** may be configured to decrease a rate of condensate injected into the cylinder via the injector(s) **281** based on an amount of condensate in the condensate tank **322** falling below a threshold (e.g., low threshold) amount. In certain embodiments, the controller **254** may be configured to adjust a temperature of the heat exchanger assembly **36** and/or a rate of condensate collection in the condensate tank **322** from the heat exchanger modules **37**. In certain embodiments, the controller **254** may be configured to adjust a rate of a drainage of excess condensate to an external drain system. For example, in response to the amount of condensate in the condensate tank **322** exceeding a threshold (e.g., high threshold), the controller **254** may be configured to redirect condensate collected from the heat exchange assembly **36** to the external drain system.

[0047] In the illustrated embodiment, the combustion system **10** includes a sensor **256** (e.g., sensor **334**) coupled to the exhaust system **22**. In certain embodiments, the controller **254** may be configured to determine a temperature of the exhaust gas in the exhaust system **22** based on a signal received from the sensor **334**. In certain embodiments, the sensor **334** may include a plurality of sensors disposed in the after-treatment **197** of the exhaust section **194**, an inlet of the turbine **196**, a cylinder head outlet port of a cylinder **176** of the engine **18**, or a combination thereof (see FIG. **1**). The control system **254** may be configured to control the condensate injection based on the determined temperature of the exhaust gas in the exhaust system **22**. For example, the controller **254** may be configured to decrease an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature of the exhaust gas falling below a threshold (e.g., low threshold) temperature. Additionally or alternatively, the controller **254** may be configured to increase an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature of the exhaust gas exceeding a threshold (e.g., high threshold) temperature.

[0048] In certain embodiments, the combustion system **10** includes a sensor **256** (e.g., sensor **336**) coupled to the combustion system **10** upstream of the turbine **196** proximate to an inlet of the turbine **196**. In certain embodiments, the controller **254** may be configured to determine a temperature of the inlet of the turbine **196** based on a signal received from the sensor **336**. The control system **254** may be configured to control the condensate injection based on the determined temperature of the inlet of the turbine **196**. For example, the controller **254** may be configured to decrease an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature of the inlet of the turbine **196** falling below a threshold (e.g., low threshold) temperature. Additionally or alternatively, the controller **254** may be configured to increase an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature of the inlet of the turbine **196** exceeding a threshold (e.g., high threshold) temperature.

[0049] In certain embodiments, the combustion system **10** includes one or more sensors **256** (e.g., one or more sensors **338**) coupled to one or more cylinders **176** of the engine **18**. In certain embodiments, one or more sensors **338** may include one or more port thermocouples. The one or more port thermocouples may be coupled to one or more cylinders **176** of the engine **18** and may be configured to output a signal indicative of a temperature of individual cylinders **176** and/or an average temperature of the cylinders **176**. Additionally or alternatively, the one or more sensors **338** may include in-cylinder pressure transducers disposed on one or more of the cylinders **176**. The one or more in-cylinder pressure transducers may be configured to output a signal indicative of a pressure of the individual cylinders **176** and/or an average pressure of the cylinders **176**. Additionally or alternatively, the one or more sensors **338** may include one or more knock sensors configured to estimate an in-cylinder pressure trace (e.g., pressure reconstruction). The controller **254** may be configured to determine a temperature and/or pressure of one or more cylinders **176** of the engine **18** based on receiving the signal from the one or more sensors **338**. The control system **254** may be configured to control the condensate injection based on the determined temperature and/or pressure of the one or more cylinders **176**. For example, the controller **254** may be configured to decrease an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature and/or pressure of the one or more cylinders **176** falling below a threshold (e.g., low threshold) temperature and/or pressure. Additionally or alternatively, the controller **254** may be configured to increase an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined temperature and/or pressure of the one or more cylinders **176** exceeding a threshold (e.g., high threshold) temperature and/or pressure.

[0050] In certain embodiments, the combustion system **10** may include one or more sensors **256** (e.g., one or more sensors **340**) disposed between the pump **324** and the engine **18**. The one or more sensors **340** may include one or more pressure sensors configured to measure an outlet pressure of the condensate in the fluid circuit **325** prior to injection of the condensate into the engine **18**. The controller **254** may be configured to determine a pressure of the condensate disposed between the pump **324** and the engine **18** based on receiving the signal from the one or more sensors **340**. The control system **254** may be configured to control the condensate injection based on the determined pressure of the condensate. For example, the controller **254** may be configured to decrease an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined pressure of the condensate falling below a threshold (e.g., low threshold) pressure. Additionally or alternatively, the controller **254** may be configured to increase an amount of condensate (e.g., via the injector(s) **281**) injected into the combustion chamber based on the determined pressure of the condensate exceeding a threshold (e.g., high threshold) pressure.

[0051] FIG. **4** is an embodiment of a graph **350** mapping an internal pressure **352** and a crank angle **354** of a four-stroke engine cycle **356** of the piston-cylinder assembly **280** of FIG. **2**. As shown, the four-stroke engine cycle **356** includes a compression stroke **358** (e.g., compression stage), a power stroke **360** (e.g., power stage, combustion stroke, combustion stage), an exhaust stroke **362** (e.g., exhaust stage), and an intake stroke **364** (e.g., intake stage). The crank angle **354** ranges from −180 degrees (e.g., at a beginning of the compression stroke **358**) to 540 degrees (e.g., at an end of the intake stroke **364**). As shown, the internal pressure **352** of a cylinder of the reciprocating engine peaks between the end of the compression stroke **358** and the beginning of the power stroke **360**. In the illustrated embodiment, the TDCF of the four-stroke cycle is located at 0 crank angle degrees, and the TDCGE (or alternatively, TDCE) of the four-stroke cycle is located at 360 crank angle degrees.

[0052] In certain embodiments, the controller **254** may be configured to instruct the condensate injection system **12** to injection condensate at one or more intervals **363** during a portion **365** (e.g., a condensate injection window, boundary, or range) of the four-stroke engine cycle **356** at least partially or entirely during the power stroke **360** and/or the exhaust stroke **362**. In certain embodiments, the portion **365** may be described as a maximum acceptable window (e.g., crank angle window) suitable for condensate injection, while the condensate injection at the one or more intervals **363** may occur during all or part of the maximum acceptable window. As shown in the illustrated embodiment, the portion **365** of the four-stroke engine cycle **356** during which the condensate injection system **12** may be configured to inject condensate into the combustion chamber **292** of the piston-cylinder assembly **280** of the reciprocating engine **18** may occur between a first point **366** (e.g., first limit or boundary) and a second point **368** (e.g., second limit or boundary) along the four-stroke engine cycle **356**. In the illustrated embodiment, the portion **365** of the four-stroke engine cycle **356** includes portions **370** and **372** of the four-stroke engine cycle **356**, wherein the portion **370** occurs during the power stroke **360** and the portion **372** occurs during the exhaust stroke **362**. For example, the portion **370** may be an end portion of the power stroke **360** and the portion **372** may be all or part of the exhaust stroke **362**. Accordingly, in the illustrated embodiment, the portion **370** extends from the first point **366** during the power stroke **360** to a transition point **367** between the power stroke **360** and the exhaust stroke **362**, while the portion **372** extends from the transition point **367** to the second point **368**. In certain embodiments, the second point **368** may be a transition point between the exhaust stroke **362** and the intake stroke **364**, or the second point **368** may be prior to the transition point during the exhaust stroke **362**.

[0053] In certain embodiments, the first point **366** may be defined by an offset from an end-of-combustion (EOC) defined by mass fraction burned (MFB) by the Rassweiler and Withrow method. In certain embodiments, the MFB may fall between 0 and 1, and may be described as a Wiebe function curve based on initial pressure and volume (e.g., at ignition), final pressure and volume (e.g., at end of combustion), a polytropic index relating cylinder pressure and volume, and pressure and volume during combustion. In certain embodiments, the EOC is defined as at least 80, 85, 90, or 95 percent of MFB. In certain embodiments, the second point **368** may be during an end portion of the exhaust stroke **362**. For example, the second point **368** may occur prior to the opening of an intake valve opening **363** (IVO) of a cylinder of the engine. The IVO may be as early as 30 crank angle degrees before TDCGE (or alternatively, TDCE).

[0054] The portion **365** of the four-stroke engine cycle **356** bounded by the first and second points **366** and **368** defines an acceptable condensate injection window, during which the controller **254** can instruct the condensate injection system **12** to inject the condensate for the one or more intervals **363**. In certain embodiments, the one or more intervals **363** may include a single interval **363**A spanning all or part of the portion **365** or a plurality of intervals **363** (e.g., 2, 3, 4, 5, 6, 7, 8, 9, 10, or more intervals) spanning all or part of the portion **365**. The one or more intervals **363** (e.g., **363**A and **363**B) may start directly at or after the first point **366** during the power stroke **360** or the exhaust stroke **362**, and the one or more intervals **363** (e.g., **363**A and **363**B) may stop directly at or before the second point **368** during the power stroke **360** or the exhaust stroke **362**. Furthermore, the controller **254** can instruct the condensate injection system **12** to vary the number and duration of the intervals **363** (e.g., **363**A and **363**B), the starting point of the intervals **363**, the stopping point of the intervals, or any combination thereof, depending on the exhaust gas **30** temperature, the level of available condensate, the exhaust gas emissions, the fuel composition, combustion parameters, or any combination thereof.

[0055] In certain embodiments, the portion **370** of the power stroke **360** includes a first crank angle window **374** from the crank angle **354** at the first point **366** before an end **376** of the power stroke **360** (e.g., transition point **367**) to the crank angle **354** at the end **376** of the power stroke **360**. In certain embodiments, the first crank angle window **374** may be equal to, less than, or greater than at least 5, 10, 15, or 20 degrees. Similarly, the crank angle **354** at the first point **366** may be equal to, less than, or greater than at least 5, 10, 15, or 20 degrees, before the end **376** of the power stroke **360**. The portion **372** of the exhaust stroke **362** includes a second crank angle window **378** spanning from the crank angle **354** at the end **376** of the power stroke **360** (e.g., transition point **367**) to the crank angle **354** at the second point **368**. As discussed above, the crank angle **354** of the second point **368** may be directly at or before an end **380** of the exhaust stroke **362** (e.g., transition point between the exhaust stroke **362** and the intake stroke **364**). For example, the crank angle **354** of the second point **368** may be equal to, less than, or greater than at least 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, or 90 degrees before the end **380** of the exhaust stroke **362**. Thus, the second crank angle window **378** may be a remaining range of crank angles between the end **376** of the power stroke **360** and the second point **368**, such as equal to, less than, or greater than at least 270, 280, 290, 300, 310, 320, 330, 340, 350, or 355 degrees. For example, in certain embodiments, the portion **365** of the four-stroke engine cycle **356** available for condensate injection may include at least 50, 60, 70, 80, 90, 95, 99, or 100 percent of the exhaust stroke **362**, and less than 5, 10, 15, 20, 25, 30, 35, 40, 45, or 50 percent of the power stroke **360** (e.g., directly before the end **376** of the power stroke **360**). For example, in certain embodiments, the portion **365** of the four-stroke engine cycle **356** available for condensate injection may include approximately 50 to 100, 60 to 100, 70 to 100, 80 to 100, or 90 to 100 percent of the exhaust stroke 362, and 0 to 50, 0 to 40, 0 to 30, 0 to 20, or 0 to 10 percent of the power stroke **360**. In certain embodiments, the portion **365** may exclude the intake stroke **364** and the compression stroke **358**, such that condensate injection does not occur during the intake stroke **364** and the compression stroke **358**. As noted above, first and second crank angle windows **374** and **378** define the portion **365** available for condensate injection in terms of the crank angle **354**, wherein the controller **254** is configured to inject condensate into the combustion chamber **292** at one or more intervals **363** during all or part of the first and/or second crank angle windows **374** and **378**. Thus the one or more intervals **363** (e.g., **363**A and **363**B) may be defined based on the crank angle **354**. In certain embodiments, the each of the one or more intervals **363** (e.g., **363**A and **363**B) of condensate injection may occur over a change in crank angles **354** of equal to, less than, or greater than at least 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, or 200 degrees.

[0056] The portions **365**, **370**, and **372** may also be described relative to TDCF and TDCGE. As shown, the first point **366** is disposed between TDCF and a transition point **367** that occurs **180** degrees after aTDCF. In certain embodiments, the first point **366** may have a crank angle **354** equal to, less than, or greater than at least 160, 165, 170, or 175 degrees aTDCF. The portion **372** of the exhaust stroke **362** includes a second crank angle window **378** spanning from the crank angle **354** at the transition point **367** to a second point **368** located at TDCGE (or alternatively, TDCE). In certain embodiments, the second point **368** may be equal to, less than, or greater than at least 5, 10, 15, 20, 30, 40, 50, 60, 70, 80, or 90 degrees before TDCGE (e.g., bTDCGE). Thus, the second crank angle window **378** may be a remaining range of crank angles between the transition point **367** and the second point **368**. In certain embodiments, the second point **368** may be located at least 270, 280, 290, 300, 310, 320, 330, 340, 350, or 355 degrees aTDCF. In certain embodiments, the portion **365** may exclude the intake stroke **364** and the compression stroke **358**, such that condensate injection does not occur during the intake stroke **364** and the compression stroke **358**. That is, the portion **365** may exclude crank angles **354** that occur between 360 degrees and 540 degrees aTDCF, and between TDCF and 180 degrees before TDCF (e.g., bTDCF).

[0057] In certain embodiments, the combustion system **10** may include a fuel injection system coupled to the injector **281** or proximate to the injector **281**. The controller **254** may be configured to control the fuel injection system to inject a fuel (e.g., hydrocarbon-based fuel, hydrogen, etc.) through the injector **281** into the combustion chamber **292** at a suitable fuel injection timing during an additional portion of the four-stroke engine cycle **356** (e.g., during the intake stroke **364**). In certain embodiments, the additional portion of the four-stroke engine cycle **356** during which the fuel is injected into the combustion chamber **292** and the portion **365** of the four-stroke engine cycle **356** during which condensate is injected into the combustion chamber **292** are different from one another. In certain embodiments, the controller **254** is configured to control the condensate injection system **12** to inject the condensate to quench post-combustion reactions and reduce undesirable emissions (e.g., CO, NOx, SOx, etc.). Methods for determining the time at which the condensate is injected into the combustion chamber **292** is described in more detail herein.

[0058] FIG. **5** is a flow chart showing an embodiment of a process **400** for controlling the condensate injection system **12** of FIG. **2**. In block **402** of the process **400**, the controller **254** may be configured to monitor a temperature of an exhaust gas from a reciprocating engine. For example, the controller **254** may be configured to receive a signal (e.g., feedback) from a sensor (e.g., thermocouple, resistance temperature detector [RTD], etc.) configured to provide a signal indicative of a temperature of exhaust gas in the exhaust system of the combustion system. Additionally, the controller **254** may be configured to determine if the monitored exhaust gas temperature decreases below a low threshold temperature and/or increases above a high threshold temperature.

[0059] In block **404**, the controller **254** may be configured to monitor an amount of condensate stored in the condensate tank of the condensate injection system coupled to the reciprocating engine. For example, the controller **254** may be configured to receive a signal (e.g., feedback) from a sensor (e.g., resistive/float fuel sensor, capacitive fuel sensor, etc.) configured to determine an amount (e.g., level) of condensate stored in the condensate tank. Additionally, the controller **254** may be configured to determine if the condensate in the condensate tank decreases below a low threshold amount. Additionally or alternatively, the controller **254** may be configured to determine if the condensate in the condensate tank increases above a high threshold amount of condensate.

[0060] In block **406**, the controller **254** may be configured to monitor one or more operating parameters of the reciprocating engine. For example, a position sensor (e.g., magnetic pickup or hall-effect) may be coupled to the crankshaft of the reciprocating engine and configured to send a signal (e.g., feedback) indicative of a crank angle to the controller **254**. In response to receiving the signal, the controller **254** may be configured to determine a crank angle of the crankshaft of the reciprocating engine.

[0061] In block **408**, the controller **254** may be configured to evaluate the one or more parameters within performance maps (e.g., lookup tables) associated with the reciprocating engine. For example, the controller **254** may be configured to utilize the performance maps in conjunction with one or more known parameters (e.g., fuel index, intake manifold absolute pressure, engine speed, ignition timing, etc.) to provide parameters that are not directly measured (e.g., internal pressure of combustion chamber). In certain embodiments, performance maps may be utilized for standard and non-standard conditions (e.g., less than commercial quality natural gas, less than full engine speed, etc.). For example, non-standard conditions may be approximated by using a corresponding offset from the standard condition.

[0062] In block **410**, the controller **254** may be configured to determine a threshold pressure to inject condensate into a cylinder of the reciprocating engine based on the evaluation of the one or more parameters. For example, the controller **254** may be configured to determine the threshold pressure by setting the threshold pressure to be lower than the pressure at which the condensate is injected into the combustion chamber of the cylinder.

[0063] In block **412**, the controller **254** may be configured to determine a crank angle to inject the condensate based on the threshold pressure. For example, the controller **254** may be configured to use a graph similar to the graph **350** shown in FIG. **4** mapping internal pressure of the combustion chamber to the crank angle of the crank shaft. For example, the controller **254** may be configured to determine the starting point of the portion of the engine cycle during which condensate is injected into the combustion chamber based on the determined threshold internal pressure of the combustion chamber.

[0064] In block **414**, the controller **254** may be configured to monitor and/or control the heat exchanger assembly (e.g., EGR cooler system) of the reciprocating engine for collection of condensate in the condensate tank. In certain embodiments, the controller **254** may be configured to adjust the amount of condensate produced by the heat exchanger assembly such that the amount of condensate stored in the condensate tank remains between a low threshold amount and a high threshold amount. For example, the controller **254** may be configured to increase the temperature of the heat exchanger assembly (e.g., decrease condensate production) based on the amount of condensate in the condensate tank exceeding a high threshold. Additionally or alternatively, the controller **254** may be configured to decrease the temperature of the heat exchanger assembly (e.g., increase condensate production) based on the amount of condensate in the condensate tank falling below a low threshold. In certain embodiments, the controller **254** may be configured to control the amount of condensate produced by the heat exchanger assembly via controlling a temperature of the heat exchanger assembly.

[0065] In block **416**, the controller **254** may be configured to control the condensate injection system based on the monitored temperature, the crank angle, and the amount of condensate in the condensate tank. For example, the controller **254** may be configured to control a flow rate, a pressure, an injector configuration, or a combination thereof based on the monitored exhaust gas temperature, the crank angle of the crankshaft, the amount of condensate in the condensate tank, or any combination thereof.

[0066] Technical effects of the disclosed embodiments include using condensate (e.g., water) collected from the EGR system to regulate the temperature of the cylinder head exhaust port and/or turbine inlet temperature associated with combustion. For example, a controller may be configured to monitor a temperature of an exhaust gas disposed in an exhaust system of the combustion system. If the temperature of the exhaust gas decreases below a lower temperature threshold or increases above a higher temperature threshold, then the controller may be configured to decrease or increase the amount of condensate (e.g., collected from the EGR) into the combustion chamber, respectively. By controlling the amount of condensate injected into the combustion cylinder based on the exhaust temperature, the controller may be configured to regulate the temperature of the exhaust gas between the lower and higher temperature thresholds. Additionally, injecting condensate adds exhaust mass flow to the turbine.

[0067] The subject matter described in detail above may be defined by one or more clauses, as set forth below.

[0068] A system includes a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store condensate collected from the EGR system. The condensate injection system also includes a pump fluidly coupled to the condensate tank. The condensate injection system also includes an injector fluidly coupled to the pump. The injector is configured to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

[0069] The system of the preceding clause, including the reciprocating engine, wherein the engine cycle includes a four-stroke engine cycle comprising an intake stroke, a compression stroke, the power stroke, and the exhaust stroke.

[0070] The system any preceding clause, including the EGR system coupled to the reciprocating engine.

[0071] The system of any preceding clause, wherein the EGR system includes an exhaust cooling system having a plurality of EGR coolers configured to cool an exhaust gas being recirculated from an exhaust manifold to an intake manifold of the reciprocating engine, wherein a condensate drain conduit is coupled to the exhaust cooling system and the condensate tank.

[0072] The system of any preceding clause, including a controller having a processor, a memory, and instructions stored on the memory and executable by the processor to control the condensate injection system to inject the condensate through the injector into the combustion chamber during the first portion of the engine cycle.

[0073] The system of the preceding clause, wherein the condensate injection system comprises includes a condensate treatment system including a reverse osmosis system, a deionized system, a distilled water system, a pH balancing system, or a combination thereof; a check valve disposed between the injector and the pump; a pressure relief valve; or a combination thereof.

[0074] The system of any preceding clause, including one or more sensors configured to obtain feedback associated with one or more parameters of an exhaust gas, wherein the controller is configured to control the condensate injection system to inject the condensate in response to the feedback.

[0075] The system of any preceding clause, including a fuel injection system coupled to the injector, wherein the controller is configured to control the fuel injection system to inject a fuel through the injector into the combustion chamber during a second portion of the engine cycle, and the first and second portions of the engine cycle are different from one another.

[0076] The system of any preceding clause, wherein the first portion of the engine cycle excludes an intake stage and a compression stage.

[0077] The system of any preceding clause, wherein the injector is configured to inject the condensate into the combustion chamber at one or more intervals during all or part of the first portion of the engine cycle, wherein the first portion includes an end portion of the power stroke and all or part of the exhaust stroke between first and second points along the engine cycle.

[0078] The system of any preceding clause, wherein the first portion includes a crank angle window, the end portion includes a first crank angle window from a first crank angle at least 20 degrees before a first end of the power stroke to a second crank angle at the first end of the power stroke, and the second end portion includes a second crank angle window from a third crank angle at the first end of the power stroke to a fourth crank angle at or before a second end of the exhaust stroke.

[0079] A system includes a controller having a processor, a memory, and instructions stored on the memory and executable by the processor to control a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store condensate collected from the EGR system, a pump fluidly coupled to the condensate tank, and an injector fluidly coupled to the pump. The controller is configured to control the injector to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

[0080] The system of the preceding clause, wherein the controller is configured to obtain first feedback from a first sensor indicative of a temperature of an exhaust gas disposed in an exhaust system of the reciprocating engine. The controller is also configured to control the condensate injection system based on the first feedback.

[0081] The system of any preceding clause, wherein controlling the condensate injection system includes decreasing an amount of the condensate injected into the combustion chamber based on the temperature of the exhaust gas falling below a low threshold temperature, increasing the amount of the condensate based on the temperature exceeding a high threshold temperature, or any combination thereof.

[0082] The system of any preceding clause, wherein the controller is configured to obtain second feedback from a second sensor indicative of an amount of the condensate in the condensate tank. The controller is also configured to obtain third feedback from a third sensor indicative of one or more operating parameters of the reciprocating engine. The controller is also configured to control the condensate injection system based on the first feedback, the second feedback, or any combination thereof.

[0083] A method includes controlling, via a controller, a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine. The condensate injection system includes a condensate tank configured to store a condensate collected from the EGR system, a pump fluidly coupled to the condensate tank, and an injector fluidly coupled to the pump. Controlling includes controlling the injector to inject the condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine. The first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

[0084] The method of the preceding clause, wherein controlling the condensate injection system includes monitoring a temperature of an exhaust gas from the reciprocating engine. Controlling the condensate injection system also includes monitoring an amount of the condensate stored in the condensate tank of the condensate injection system.

[0085] The method of any preceding clause, wherein controlling the condensate injection system includes evaluating the one or more operating parameters within performance maps of the reciprocating engine, determining a threshold pressure to inject the condensate into a cylinder of the reciprocating engine based on evaluation of the one or more operating parameters, and determining a crank angle to inject the condensate based on the threshold pressure.

[0086] The method of any preceding clause, wherein controlling the condensate injection system includes monitoring the EGR system of the reciprocating engine for a collection of the condensate in the condensate tank, controlling the EGR system of the reciprocating engine for the collection of the condensate in the condensate tank, or a combination thereof.

[0087] The method of any preceding clause, wherein controlling the condensate injection system includes obtaining feedback from a sensor indicative of the amount of the condensate in the condensate tank, and controlling the amount of the condensate in the condensate tank based on the feedback.

[0088] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

[0089] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for [perform]ing [a function] . . . " or "step for [perform]ing [a function] . . . ", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112 (f).

1. A system, comprising:

a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine, wherein the condensate injection system comprises:

a condensate tank configured to store condensate collected from the EGR system;

a pump fluidly coupled to the condensate tank; and

an injector fluidly coupled to the pump, wherein the injector is configured to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine, and the first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

2. The system of claim **1**, comprising the reciprocating engine, wherein the engine cycle comprises a four-stroke engine cycle comprising an intake stroke, a compression stroke, the power stroke, and the exhaust stroke.

3. The system of claim **2**, comprising the EGR system coupled to the reciprocating engine.

4. The system of claim **1**, wherein the EGR system comprises an exhaust cooling system having a plurality of EGR coolers configured to cool an exhaust gas being recirculated from an exhaust manifold to an intake manifold of the reciprocating engine, wherein a condensate drain conduit is coupled to the exhaust cooling system and the condensate tank.

5. The system of claim **1**, comprising a controller having a processor, a memory, and instructions stored on the memory and executable by the processor to control the condensate injection system to inject the condensate through the injector into the combustion chamber during the first portion of the engine cycle.

6. The system of claim **5**, wherein the condensate injection system comprises:

a condensate treatment system comprising a reverse osmosis system, a deionized system, a distilled water system, a pH balancing system, or a combination thereof;

a check valve disposed between the injector and the pump;

a pressure relief valve;

or a combination thereof.

7. The system of claim **6**, comprising one or more sensors configured to obtain feedback associated with one or more parameters of an exhaust gas, wherein the controller is configured to control the condensate injection system to inject the condensate in response to the feedback.

8. The system of claim **5**, comprising a fuel injection system coupled to the injector, wherein the controller is configured to control the fuel injection system to inject a fuel through the injector into the combustion chamber during a second portion of the engine cycle, and the first and second portions of the engine cycle are different from one another.

9. The system of claim **1**, wherein the first portion of the engine cycle excludes an intake stage and a compression stage.

10. The system of claim **1**, wherein the injector is configured to inject the condensate into the combustion chamber at one or more intervals during all or part of the first portion of the engine cycle, wherein the first portion includes an end portion of the power stroke and all or part of the exhaust stroke between first and second points along the engine cycle.

11. The system of claim **10**, wherein the end portion includes a first crank angle window from a first crank angle at least 20 degrees before a first end of the power stroke to a second crank angle at the first end of the power stroke, and a second portion of the engine cycle includes a second crank angle window from a third crank angle at the first end of the power stroke to a fourth crank angle at or before a second end of the exhaust stroke.

12. A system, comprising:

a controller having a processor, a memory, and instructions stored on the memory and executable by the processor to control a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine, wherein the condensate injection system comprises a condensate tank configured to store condensate collected from the EGR system, a pump fluidly coupled to the condensate tank, and an injector fluidly coupled to the pump, wherein the controller is configured to:

control the injector to inject condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine, wherein the first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

13. The system of claim **12**, wherein the controller is configured to:

obtain first feedback from a first sensor indicative of a temperature of an exhaust gas disposed in an exhaust system of the reciprocating engine; and

control the condensate injection system based on the first feedback;

wherein the first feedback is indicative of the temperature of the exhaust gas at a cylinder head port of the reciprocating engine, an inlet of a turbine of the reciprocating engine, or an after-treatment system of the reciprocating engine.

14. The system of claim **13**, wherein controlling the condensate injection system comprises:

decreasing an amount of the condensate injected into the combustion chamber based on the temperature of the exhaust gas falling below a low threshold temperature;

increasing the amount of the condensate based on the temperature exceeding a high threshold temperature; or any combination thereof.

15. The system of claim **13**, wherein the controller is configured to:

obtain second feedback from a second sensor indicative of an amount of the condensate in the condensate tank;

obtain third feedback from a third sensor indicative of one or more operating parameters of the reciprocating engine; and

control the condensate injection system based on the first feedback, the second feedback, or any combination thereof.

16. A method, comprising:

controlling, via a controller, a condensate injection system configured to fluidly couple to a combustion chamber of a reciprocating engine and an exhaust gas recirculation (EGR) system of the reciprocating engine, wherein the condensate injection system comprises a condensate tank configured to store a condensate collected from the EGR system, a pump fluidly coupled to the condensate tank, and an injector fluidly coupled to the pump, wherein controlling comprises:

controlling the injector to inject the condensate into the combustion chamber during a first portion of an engine cycle of the reciprocating engine, wherein the first portion of the engine cycle includes at least part of a power stroke and/or an exhaust stroke of the engine cycle.

17. The method of claim **16**, wherein controlling the condensate injection system comprises:

monitoring a temperature of an exhaust gas from the reciprocating engine; and

monitoring an amount of the condensate stored in the condensate tank of the condensate injection system.

18. The method of claim **17**, wherein controlling the condensate injection system comprises:

evaluating the one or more operating parameters within performance maps of the reciprocating engine;

determining a threshold pressure to inject the condensate into a cylinder of the reciprocating engine based on evaluation of the one or more operating parameters; and

determining a crank angle to inject the condensate based on the threshold pressure.

19. The method of claim **18**, wherein controlling the condensate injection system comprises:

monitoring the EGR system of the reciprocating engine for a collection of the condensate in the condensate tank;

controlling the EGR system of the reciprocating engine for the collection of the condensate in the condensate tank;

or a combination thereof.

20. The method of claim **19**, wherein controlling the condensate injection system comprises:

obtaining feedback from a sensor indicative of the amount of the condensate in the condensate tank; and

controlling the amount of the condensate in the condensate tank based on the feedback.

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