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(54) **Waste heat recovery system**

(57) In one embodiment, a waste heat recovery system (10) includes a Rankine cycle system (14) that circulates a working fluid that absorbs heat from exhaust gas. The Rankine cycle system (14) includes an evaporator (36) that may transfer sensible heat from the exhaust gas to the working fluid to produce cooled exhaust gas. The Rankine cycle system (14) also includes an economizer (30) that may transfer latent heat from the exhaust gas to the working fluid. The economizer (30) is a carbon steel heat exchanger with a corrosion resistant coating (52).

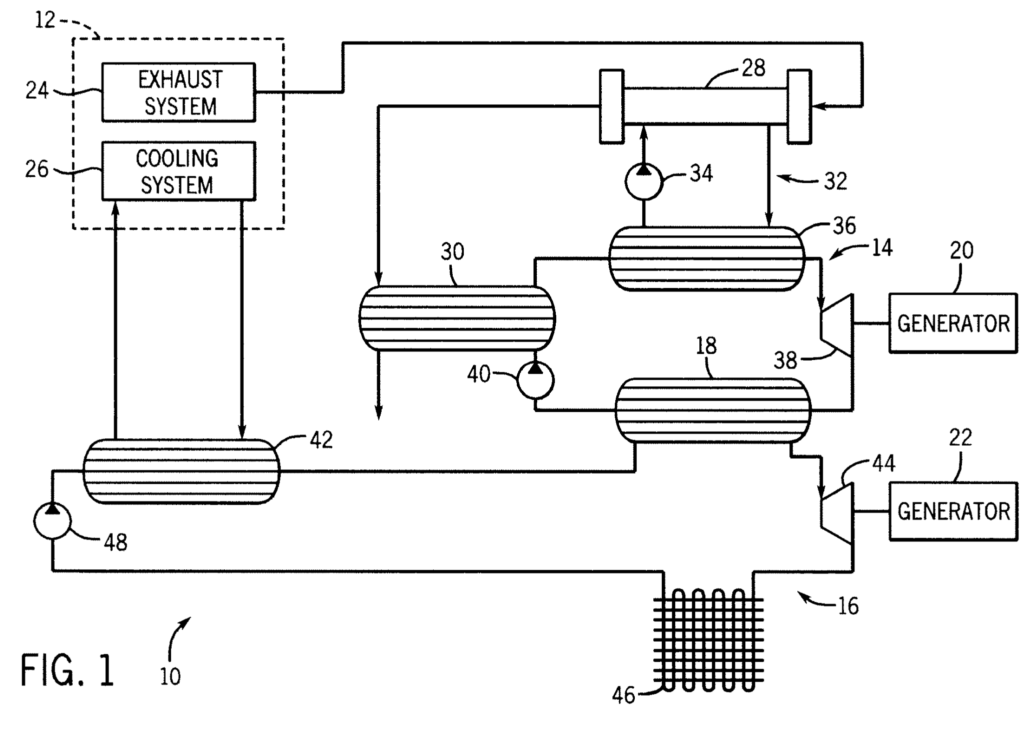

FIG. 1

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Description

[0001] The subject matter disclosed herein relates generally to waste heat recovery systems, and more specifically, to systems for recovering waste heat from exhaust gas.

[0002] In general, power generation systems, such as combustion engines, may produce exhaust gas in addition to power. A bottoming Rankine cycle may be employed to recover waste heat from the exhaust gas as well as from other heat sources, such as the cooling system. The power output of the bottoming Rankine cycle may generally increase the more that the exhaust gas is cooled. However, the temperature to which the exhaust gas may be cooled may be limited by corrosive elements in the exhaust gas. For example, exhaust gas may include sulfur that may mix with water upon condensation of the exhaust gas to produce sulfuric acid. Accordingly, to inhibit corrosion in certain bottoming Rankine cycles, the exhaust gas may not be cooled below the dew point and/or to temperatures that may produce condensation of the exhaust gas.

[0003] In one embodiment, a waste heat recovery system includes an exhaust system that generates exhaust gas and a Rankine cycle system for circulating a working fluid. The Rankine cycle system includes an evaporator configured to transfer sensible heat from the exhaust gas to the working fluid to produce cooled exhaust gas and an economizer configured to transfer latent heat from the exhaust gas to the working fluid. The economizer includes a carbon steel heat exchanger with a corrosion resistant coating.

[0004] In another embodiment, a waste heat recovery system includes an exhaust system that generates hot exhaust gas, a first Rankine cycle system for circulating a first working fluid, a second Rankine cycle system for circulating a second working fluid and configured to transfer heat from an engine heat source to the second working fluid, and a shared heat exchanger common to the first and second Rankine cycle systems and configured to transfer heat from the first working fluid to the second working fluid to condense the first working fluid and to evaporate the second working fluid. The first Rankine cycle system includes an evaporator configured to transfer sensible heat from the hot exhaust gas to the first working fluid to produce cooled exhaust gas and an economizer configured to transfer latent heat from the cooled exhaust gas to the working fluid. The economizer includes a carbon steel heat exchanger with a corrosion resistant coating.

[0005] In yet another embodiment, a waste heat recovery system includes an exhaust system that generates hot exhaust gas and a Rankine cycle system for circulating a working fluid. The Rankine cycle system includes an evaporator configured to transfer heat from the hot exhaust gas to the working fluid to at least partially vaporize the working fluid and to produce cooled exhaust gas, a condenser configured to receive and to condense the vaporized working fluid, and an economizer configured to transfer heat from the cooled exhaust gas to the condensed working fluid to at least partially condense the cooled exhaust gas. The economizer includes a carbon steel heat exchanger with a silica coating.

[0006] Various features, aspects, and advantages of the present invention 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:

FIG. 1 is a diagrammatical representation of an embodiment of a waste heat recovery system; and

FIG. 2 is a cross-sectional view of a portion of the economizer shown in FIG. 1.

[0007] One or more specific embodiments of the present invention 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.

[0008] When introducing elements of various embodiments of the present invention, 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.

[0009] The present disclosure is directed to techniques for recovering waste heat from exhaust gas. In accordance with certain embodiments, a waste heat recovery system may include a pair of organic Rankine cycle (ORC) systems arranged in a cascade configuration. The high temperature ORC system may recover waste heat from exhaust gas, and the low temperature ORC system may recover waste heat from another heat source, such as an engine cooling system. The high temperature ORC system may include a working fluid economizer designed to recover latent heat from condensing water in the exhaust gas in addition to sensible heat. Specifically, the economizer may allow the exhaust gas to be cooled below the dew point of the exhaust gas, which may increase the power output of the waste heat recovery system. To inhibit corrosion that may occur during condensation of the exhaust gas, the economizer may be constructed of carbon steel with a corrosion resistant coating. The coating may facilitate decreased manufacturing and/or capital costs by allowing low cost carbon steel to be employed rather than more expensive stainless steel.

[0010] FIG. 1 depicts a waste heat recovery system 10 that may employ a carbon steel economizer with a corrosion resistant coating. The waste heat recovery system 10 may recover heat from a heat generation system, such as an engine 12. In certain embodiments, the engine 12 may be part of a power generation system and may run on fuels such as biogas, natural gas, landfill gas, coal mine gas, sewage gas, or combustible industrial waste gases, among others. Further, although the engine 12 is depicted as a combustion engine, in other embodiments, any suitable heat generation system that produces exhaust gas may be employed, such as a gas turbine, micro-turbine; reciprocating engine, or geothermal, solar thermal, industrial, or residential heat sources.

[0011] The waste heat recovery system 10 includes a pair of ORC systems 14 and 16 arranged in a cascade configuration with a shared heat exchanger 18 that transfers heat between the ORC systems 14 and 16. Each ORC system 14 and 16 may include a closed loop that circulates a working fluid through a Rankine cycle within the ORC system 14 and 16. Specifically, the high temperature ORC system 14 may circulate a first working fluid, and the low temperature ORC system 16 may circulate a second working fluid. According to certain embodiments, the first and second working fluids may include organic working fluids. However, in other embodiments, steam may be employed as the first and/or second working fluid. Further, in certain embodiments, the first working fluid may have a condensation temperature above the boiling point of the second working fluid. According to certain embodiments, the first working fluid may include cyclohexane, cyclopentane, thiophene, ketones, aromatics, or combinations thereof. The second working fluid may include propane, butane, fluoro-propane, pentafluoro-butane, pentafluoro-polyether, oil, or combinations thereof, among others. Further, in certain embodiments, the first and/or second organic working fluids may include a binary fluid such as cyclohexane-propane, cyclohexane-butane, cyclopentane-butane, or cyclopentane-pentafluoro propane, among others.

[0012] Each ORC system 14 and 16 may be coupled to a generator 20 and 22 that converts heat recovered from the engine 12 to electricity. Specifically, the high temperature ORC system 14 may recover heat from an exhaust system 24 of the engine 12, and the low temperature ORC system 16 may recover heat from another heat source of the engine 12, such as the engine cooling system 26.

[0013] The first ORC system 14 may recover heat from the exhaust system 24 through a heat exchanger 28 and an economizer 30. The heat exchanger 28 and the economizer 30 may allow the first ORC system 14 to recover heat from the exhaust gas at two different temperatures. Specifically, the heat exchanger 28 may transfer heat from the hot exhaust gas existing the exhaust system 24 to the first ORC system 14 to produce cooled exhaust gas. The cooled exhaust gas may then be direct to the economizer 30, which transfers heat from the cooled exhaust gas to the first ORC system 14.

[0014] In certain embodiments, the exhaust gas may exit the exhaust system at a temperature of approximately 400 to 500 °C, may be cooled to a temperature of approximately 150 to 200 °C in the heat exchanger 28, and may be cooled to a temperature of approximately 100 to 110 °C in the economizer 30. More specifically, the exhaust gas may exit the exhaust system at a temperature of approximately 427 °C, may be cooled to a temperature of approximately 180 °C by the heat exchanger 28, and may be cooled to a temperature of approximately 104 °C by the economizer 30. In yet another example, the heat exchanger 28 may reduce the temperature of the exhaust gas by approximately 200 to 300 °C, and the economizer 30 may reduce the temperature of the exhaust gas by approximately 80 to 90 °C.

[0015] In certain embodiments, the heat exchanger 28 may recover primarily sensible heat from the exhaust gas, and the economizer 30 may recovery primarily latent heat from the exhaust gas. In other words, the exhaust gas flowing through the heat exchanger 28 may be cooled to reduce its temperature while the exhaust gas remains in the gaseous phase, while the exhaust gas flowing through the economizer 30 may be all or partially condensed to produce liquid phase exhaust gas.

[0016] The heat exchanger 28 may transfer heat from the exhaust gas to the first ORC system 14 through a thermal oil loop 32 in heat transfer communication with the first working fluid. Specifically, as the exhaust gas flows through the heat exchanger 28, the exhaust gas may heat the thermal oil flowing within the thermal oil loop 32. For example, in certain embodiments, the exhaust gas may heat the thermal oil from a temperature of approximately 160 °C to a temperature of approximately 280 °C. A pump 34 may circulate the thermal oil within the thermal oil loop 32, and the heated thermal oil exiting the heat exchanger 28 may enter an evaporator 36 of the first ORC system 14. As the heated oil flows through the evaporator 36, the heated thermal oil may transfer heat to the first working fluid flowing within the first ORC system 14. In other embodiments, the thermal oil loop 32 may be replaced by another closed loop circulating any suitable type of heat transfer fluid for transferring heat from the exhaust gas to the first working fluid.

[0017] Within the evaporator 36, the first working fluid may absorb heat from the thermal oil and may be evaporated and/or superheated. In certain embodiments, the first working fluid may be heated to a temperature of approximately 225°C. Upon exiting the evaporator 36, the vapor phase working fluid may then flow to an expander 38 where the fluid may be expanded to drive the generator 20. In certain embodiments, the expander may be a radial expander, axial expander, impulse type expander, or high temperature screw type expander, among others.

Within the expander 38, the first working fluid may be expanded to produce a low temperature and pressure vapor.

[0018] From the expander 38, the first working fluid may enter the shared heat exchanger 18 as a low temperature and pressure vapor. Within the shared heat exchanger 18, the first working fluid may transfer heat to the second working fluid flowing through the shared heat exchanger 18 within the second ORC system 16. Specifically, the first working fluid may transfer heat to the second working fluid and condense into a liquid. The liquid phase first working fluid may then flow through a pump 40 that circulates the first working fluid within the first ORC system 14.

[0019] From the pump 40, the first working fluid may flow through the economizer 30 where the first working fluid may be heated by the exhaust gas flowing through the economizer 30. As noted above, the exhaust gas flowing through the economizer 30 may be partially or completely condensed to transfer latent heat to the first working fluid. Within the economizer 30, the heat from the exhaust gas may be transferred to the first working fluid to preheat the first working fluid before the first working fluid enters the evaporator 36. In certain embodiments, the preheating within the economizer 30 may improve the efficiency of the waste heat recovery system 10 by allowing additional heat to be extracted from the exhaust gas. The first working fluid may then return to the evaporator 36 where the cycle may begin again.

[0020] Through the shared heat exchanger 18, the first working fluid flowing within the first ORC system 14 may transfer heat to the second working fluid flowing within the second ORC system 16. Specifically, as the second working fluid flows through the shared heat exchanger 18, the second working fluid may absorb heat from the first working fluid and may evaporate. The vapor phase second working fluid may then enter an expander 44 and expand to drive the generator 22. In certain embodiments, the expander 44 may be a radial expander, axial expander, impulse type expander, or high temperature screw type expander, among others. The second working fluid may exit the expander 44 as a low temperature and pressure vapor.

[0021] From the expander 44, the vapor phase second working fluid may flow through an air-to-liquid heat exchanger 46 where the second working fluid may be condensed by air flowing across the air-to-liquid heat exchanger 46. In certain embodiments, the air-to liquid-heat exchanger may include a motor with a fan that draws ambient air across the air-to-liquid heat exchanger. The condensed second working fluid may then enter a pump 48 that circulates the second working fluid within the second ORC system 16.

[0022] From the pump 48, the second working fluid may flow through a preheater 42 that may heat the second working fluid. The preheater 42 may circulate a fluid from a heat source within the engine 12. For example, the preheater 42 may circulate heated cooling fluid from the cooling system 26 of the engine 12. The temperature of the fluid entering the preheater 42 from the engine 12 may generally be lower than the temperature of the exhaust gas entering the heat exchanger 28 and the economizer 30. For example, in certain embodiments, the fluid from the engine 12 may enter the preheater 42 at a temperature of approximately 80 to 100 °C. Within the preheater 42, the fluid may transfer heat to the second working fluid to cool the fluid from the engine 12. For example, in certain embodiments, the fluid from the engine 12 may exit the preheater 42 at a temperature of approximately 30 °C. The cooled fluid may then be returned to the engine 12. In other embodiments, the preheater may receive fluid from one or more heat sources within the engine 12 instead of, or in addition to, the cooling system 26. For example, the pre-heater 42 may receive fluid from gas turbines and/or intercoolers.

[0023] Regardless of the heat source, the preheater 42 may transfer heat from the engine 12 to the second working fluid. In certain embodiments, the second working fluid may partially evaporate to form a liquid-vapor mixture. However, in other embodiments, the second working fluid may remain in a liquid phase. Upon exiting the preheater 42, the second working fluid may return to the shared heat exchanger 18 where the cycle may begin again.

[0024] The cascade arrangement of the first and second ORC systems 14 and 16 may generally allow an increased heat recovery over a larger temperature range. For example, the first ORC system 14 may allow recovery of heat in higher temperature ranges, such as approximately 400 to 500 °C while the second ORC system 16 facilitates recovery of heat in lower temperature range, such as approximately 50 to 100 °C. Further, the inclusion of the economizer 30 in the first ORC system 14 may allow additional heat in an intermediate temperature range, such as approximately 150 to 250 °C, to be recovered from the exhaust gas. For example, rather than recovering heat solely through the heat exchanger 28, additional heat in an intermediate temperature range also may be recovered through the use of the economizer 30. In certain embodiments, the additional heat recovered by the economizer 30 may provide a power increase of approximately twenty percent when compared to ORC systems without an economizer. Further, as will be discussed below with respect to FIG. 2, the economizer 30 may be constructed of carbon steel and coated with a corrosion resistant coating. The coating may allow carbon steel, rather than stainless steel, to be employed for the economizer, which may reduce manufacturing and/or capital costs.

[0025] As may be appreciated, additional equipment such as pumps, valves, control circuitry, pressure and/or temperature transducers or switches, among others may be included within the waste heat recovery system 10. Furthermore, the types of equipment included within the waste heat recovery system 10 may vary. For example, according to certain embodiments, the heat exchangers

18, 28, 30, 36, and 42 may include shell and tube heat exchangers, fin and tube heat exchangers, plate heat exchangers, plate and shell heat exchangers, or combinations thereof, among others.

[0026] FIG. 2 is a cross-sectional view taken through the economizer 30 illustrating a surface 50 of the economizer that includes a corrosion resistant coating 52. In general, the coating 52 may be applied to surfaces 50 of the economizer that are exposed to the exhaust gas. For example, in a shell and tube heat exchanger where the exhaust gas flows through the shell portion, the coating 52 may be applied to the exterior surfaces of the tubes and the interior surface of the shell. In another example where the exhaust gas flows across tubes circulating a working fluid within a fin and tube heat exchanger, the coating 52 may be applied to the external surfaces of the tubes, to the fins, and to the interior surfaces of the enclosure surrounding the fin and tube heat exchanger. In a further example where the exhaust gas flows through the tubes of a shell and tube heat exchanger, the coating 52 may be applied to the interior surfaces of the tubes.

[0027] The coating 52 may be designed to inhibit corrosion that may occur during condensation of the exhaust gas. The coating 52 may include a silicon dioxide (silica) coating that provides a barrier layer to inhibit corrosion to the surface 50 of the economizer 30. In certain embodiments, the coating 52 may inhibit corrosion by contaminants in the exhaust gas, such as sulfur that may react with water upon condensation to form sulfuric acid that may corrode and/or pit the surface 50. Further, in addition to corrosion resistant properties, the coating 52 may exhibit hydrophobic, oleophobic, and/or antistatic properties. According to certain embodiments, the coating 52 may include a nanoparticle coating of colloidal silica with particles ranging in size from approximately one to five nanometers. However, in other embodiments, the size of the nanoparticles may vary.

[0028] The coating may be applied by any suitable manufacturing process, such as spray coating, dipping, or flooding. For example, in certain embodiments, the external surfaces of the tubes and/or fins may be spray coated to apply the coating. The coating may then be cured upon startup of the engine 12 or through a separate curing step where the coating 52 may be exposed to high temperatures. In another example, the heat exchanger may be flooded with the coating and then drained to allow the coating to adhere to surfaces of the economizer 30. Further, in other embodiments, the coating 52 also may be applied to other heat exchangers within the waste heat recovery system 10. For example, the coating 52 may be applied to surfaces of the heat exchanger 28.

[0029] This written description uses examples to disclose the invention, including the preferred 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 languages of the claims.

[0030] Various aspects and embodiments of the present invention are defined by the following numbered clauses:

1. A waste heat recovery system, comprising:

    an exhaust system that generates exhaust gas; and

    a Rankine cycle system for circulating a working fluid and comprising:

        an evaporator configured to transfer sensible heat from the exhaust gas to the working fluid to produce cooled exhaust gas; and

        an economizer configured to transfer latent heat from the exhaust gas to the working fluid, wherein the economizer comprises a carbon steel heat exchanger with a corrosion resistant coating.

2. The waste heat recovery system of clause 1, wherein the corrosion resistant coating comprises a silica coating.

3. The waste heat recovery system of any preceding clause, wherein the corrosion resistant coating exhibits at least one of hydrophobic, oleophobic, or antistatic properties.

4. The waste heat recovery system of any preceding clause, wherein the working fluid comprises an organic working fluid.

5. The waste heat recovery system of any preceding clause, wherein the Rankine cycle system comprises an expander configured to expand the working fluid evaporated by the evaporator to drive a generator.

6. The waste heat recovery system of any preceding clause, wherein the Rankine cycle system comprises a condenser configured to condense the working fluid.

7. The waste heat recovery system of any preceding clause, wherein the evaporator is configured to at least partially evaporate and/or to superheat the working fluid.

8. The waste heat recovery system of any preceding clause, comprising an exhaust gas heat exchanger configured to transfer the sensible heat from the ex-

haust gas to an intermediate fluid in heat transfer communication with the working fluid.

9. A waste heat recovery system, comprising:

an exhaust system that generates hot exhaust gas;
a first Rankine cycle system for circulating a first working fluid and comprising:

an evaporator configured to transfer sensible heat from the hot exhaust gas to the first working fluid to produce cooled exhaust gas; and
an economizer configured to transfer latent heat from the cooled exhaust gas to the working fluid, wherein the economizer comprises a carbon steel heat exchanger with a corrosion resistant coating;

a second Rankine cycle system for circulating a second working fluid and configured to transfer heat from an engine heat source to the second working fluid; and
a shared heat exchanger common to the first and second Rankine cycle systems and configured to transfer heat from the first working fluid to the second working fluid to condense the first working fluid and to evaporate the second working fluid.

10. The waste heat recovery system of any preceding clause, wherein the first and second working fluids comprise organic working fluids, and wherein the first working fluid has a condensation temperature above a boiling point of the second working fluid.

11. The waste heat recovery system of any preceding clause, wherein the engine heat source comprises an engine cooling system.

12. The waste heat recovery system of any preceding clause, wherein the second Rankine cycle system comprises a preheater configured to transfer heat from the heat source to the second working fluid to at least partially evaporate the second working fluid prior to directing the second working fluid to the shared heat exchanger.

13. A waste heat recovery system, comprising:

an exhaust system that generates hot exhaust gas; and
a Rankine cycle system for circulating a working fluid and comprising:

an evaporator configured to transfer heat from the hot exhaust gas to the working fluid to at least partially vaporize the working fluid and to produce cooled exhaust gas;
a condenser configured to receive and to condense the vaporized working fluid; and
an economizer configured to transfer heat from the cooled exhaust gas to the condensed working fluid to at least partially condense the cooled exhaust gas, wherein the economizer comprises a carbon steel heat exchanger with a silica coating.

14. The waste heat recovery system of any preceding clause, wherein the working fluid comprises cyclohexane.

15. The waste heat recovery system of any preceding clause, wherein the silica coating comprises silica nanoparticles disposed on surfaces of the heat exchanger exposed to the cooled exhaust gas.

16. The waste heat recovery system of any preceding clause, wherein the carbon steel heat exchanger comprises a carbon steel shell configured to receive the cooled exhaust gas and carbon steel tubes configured to receive the working fluid and wherein the corrosion resistant coating is disposed on an interior surface of the carbon steel shell and on an exterior surface of the carbon steel tubes.

17. The waste heat recovery system of any preceding clause, comprising a thermal oil loop for circulating thermal oil between the evaporator and an exhaust gas heat exchanger configured to receive the hot exhaust gas and transfer heat from the hot exhaust gas to the thermal oil.

18. The waste heat recovery system of any preceding clause, comprising an exhaust gas heat exchanger configured to receive the hot exhaust gas and transfer heat from the hot exhaust gas to an intermediate fluid in thermal communication with the working fluid.

19. The waste heat recovery system of any preceding clause, wherein the evaporator is configured to transfer sensible heat from the hot exhaust gas to the working fluid, and wherein the economizer is configured to transfer latent heat from the cooled exhaust gas to the working fluid.

20. The waste heat recovery system of any preceding clause, comprising a gas engine configured to combust biogas to generate the hot exhaust gas.

Claims

1. A waste heat recovery system (10), comprising:

an exhaust system (24) that generates exhaust gas; and
a Rankine cycle system (14) for circulating a working fluid and comprising:

an evaporator (36) configured to transfer sensible heat from the exhaust gas to the working fluid to produce cooled exhaust gas; and
an economizer (30) configured to transfer latent heat from the exhaust gas to the working fluid, wherein the economizer comprises a carbon steel heat exchanger with a corrosion resistant coating (52).

2. The waste heat recovery system (10) of claim 1, wherein the corrosion resistant coating (52) comprises a silica coating.

3. The waste heat recovery system (10) of any preceding claim, wherein the corrosion resistant coating (52) exhibits at least one of hydrophobic, oleophobic, or antistatic properties.

4. The waste heat recovery system (10) of any preceding claim, wherein the working fluid comprises an organic working fluid.

5. The waste heat recovery system (10) of any preceding claim, wherein the Rankine cycle system (14) comprises an expander (38) configured to expand the working fluid evaporated by the evaporator (36) to drive a generator (20).

6. The waste heat recovery system (10) of any preceding claim, wherein the Rankine cycle system comprises a condenser (18) configured to condense the working fluid.

7. The waste heat recovery system (10) of any preceding claim, wherein the evaporator (36) is configured to at least partially evaporate and/or to superheat the working fluid.

8. The waste heat recovery system (10) of any preceding claim, comprising an exhaust gas heat exchanger (28) configured to transfer the sensible heat from the exhaust gas to an intermediate fluid in heat transfer communication with the working fluid.

9. A waste heat recovery system (10), comprising:

an exhaust system (24) that generates hot exhaust gas;
a first Rankine cycle system (14) for circulating a first working fluid and comprising:

an evaporator (36) configured to transfer sensible heat from the hot exhaust gas to the first working fluid to produce cooled exhaust gas; and
an economizer (30) configured to transfer latent heat from the cooled exhaust gas to the working fluid, wherein the economizer (30) comprises a carbon steel heat exchanger with a corrosion resistant coating (52);

a second Rankine cycle system (16) for circulating a second working fluid and configured to transfer heat from an engine heat source (12) to the second working fluid; and
a shared heat exchanger (18) common to the first and second Rankine cycle systems (14,16) and configured to transfer heat from the first working fluid to the second working fluid to condense the first working fluid and to evaporate the second working fluid.

10. The waste heat recovery system of claim 9, wherein the second Rankine cycle system (16) comprises a preheater (42) configured to transfer heat from the heat source (12) to the second working fluid to at least partially evaporate the second working fluid prior to directing the second working fluid to the shared heat exchanger (18).

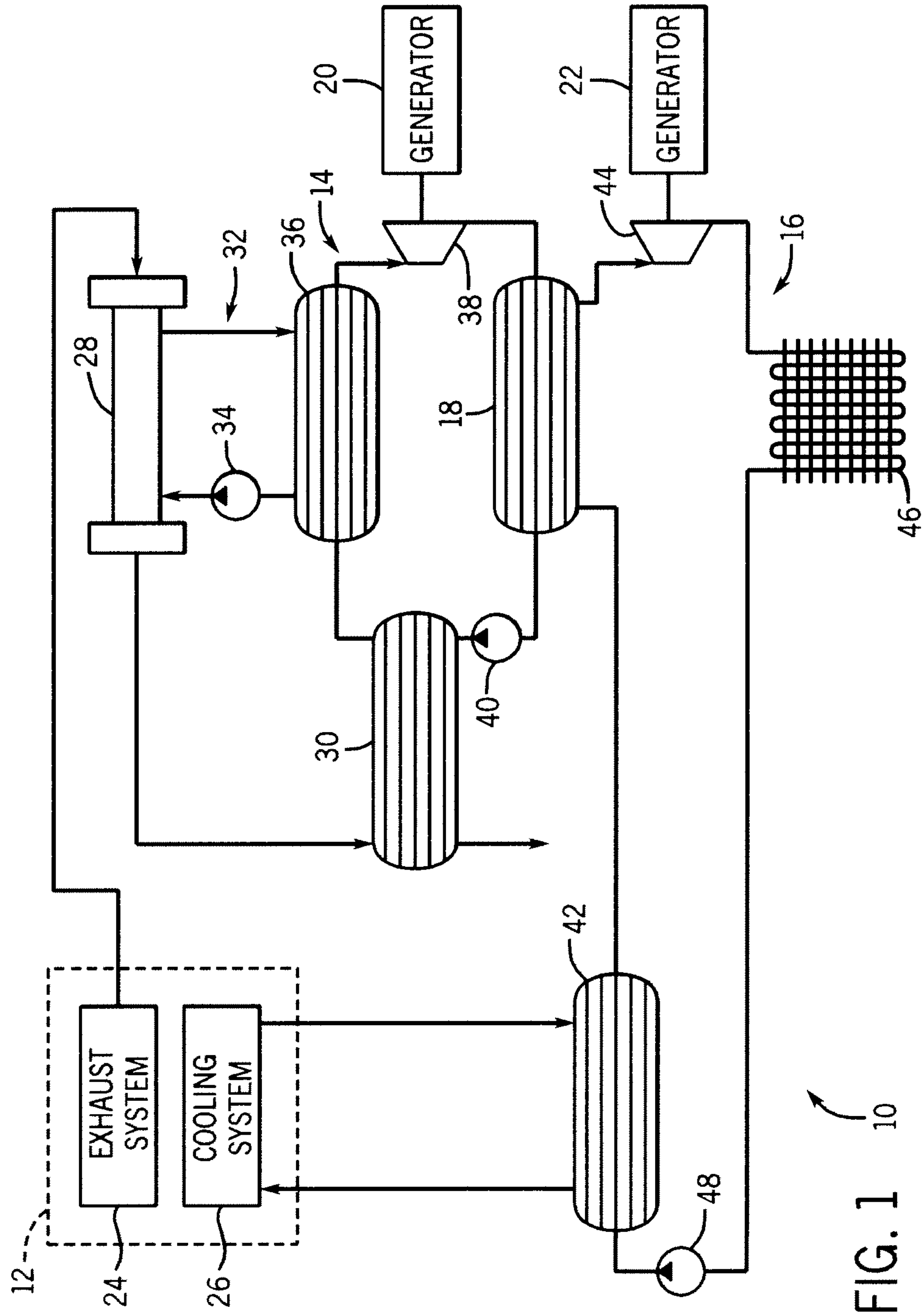
GENERATOR
GENERATOR
EXHAUST SYSTEM
COOLING SYSTEM
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FIG. 1

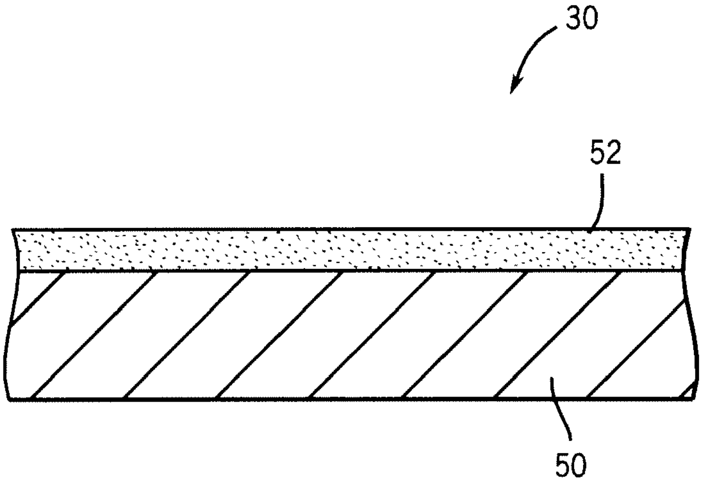

FIG. 2