CASCADED ORGANIC RANKINE CYCLE SYSTEM

BACKGROUND

The present disclosure relates generally to Organic Rankine Cycle (ORC) systems and, more particularly, to a cascaded organic Rankine cycle.

The Organic Rankine Cycle (ORC) is a vapor power cycle with an organic fluid refrigerant instead of water/steam as the working fluid. The working fluid is heated in an "evaporator/boiler" by a source of waste or low quality heat. The fluid starts as a liquid and ends up as a vapor.

The high-pressure refrigerant vapor expands in the turbine to produce power. The low-pressure vapor exhausted from the turbine is condensed then sent back to the pump to restart the cycle.

The simple rankine cycle used for power generation follows the process order: 1) Adiabatic pressure rise through a pump; 2) Isobaric heat addition in a preheater, evaporator and superheater; 3) Adiabatic expansion in a turbine; and 4) Isobaric heat rejection in a condenser, although other cycle modifications are possible such as the addition of a vapor-to-liquid recuperator.

Typical cascaded organic Rankine cycle systems are disclosed in WO2009045196 and WO2011005374 whilst US20100122534 discloses a Rankine cycle system including a recuperator intended to increase system efficiency.

Furthermore, it is known from US 4085593 that the transitioning of fluids into superheated phases is desirable for power generation when the working fluid is expanded through the turbine.

Such thermal energy generation need not necessarily come from conventional engines but may be derived from solar power, (see for example the disclosure contained within US20100295306).

A main thermodynamic irreversibility in organic Rankine cycles is caused by the large temperature difference in the evaporator between the temperature of the waste heat stream and the boiling refrigerant. The higher the waste heat stream temperature the greater this irreversibility becomes.

One way to reduce this loss is to cascade two thermodynamic cycles together where a cycle operating at higher temperatures rejects heat to a cycle operating at lower temperatures.

Other systems employ 'counter flow' heat exchangers such as the one disclosed in WO2010080861 whereby streams of fluid flow in opposite directions through the heat exchanger thus causing it to operate at a higher efficiency than systems with heat exchangers wherein the streams flow in the same direction.

Other losses such as those caused by mechanical stress may also be reduced through the use of a counter flow heat exchanger (US6241953) and greater overall heat transfer efficiency may be achieved through the use of a saturated heating fluid (US7487955).

Although the aforementioned cited prior art addresses some of the efficiency issues associated with systems incorporating the Rankine cycle, increased efficiency of such systems is still desirable.

SUMMARY

A cascaded Organic Rankine Cycle (ORC) system according to an exemplary aspect of the present disclosure includes a bottoming cycle in thermal communication with a topping cycle through a condenser/evaporator in which a bottoming cycle working fluid is first evaporated and then superheated and a topping cycle working fluid is first desuperheated and then condensed such that a percentage of total heat transfer from the topping cycle fluid that occurs during a saturated condensation is equal to or less than a percentage of total heat transfer to the bottoming cycle fluid that occurs during a saturated evaporation.

CLAIMS

What is claimed is:

1. A method of operating a cascaded Organic Rankine Cycle (ORC) system in which a bottoming cycle is in thermal communication with a topping cycle comprising:

superheating a working fluid in the topping cycle;

expanding the working fluid over a turbine in the topping cycle such that the working fluid leaving the turbine is still superheated;

circulating the working fluid from the turbine in the topping cycle into a condenser/evaporator;

circulating a working fluid in the bottoming cycle into the condenser/evaporator for heat exchange with the working fluid of the topping cycle, the working fluid in the bottoming cycle being superheated in the condenser/evaporator;

during the heat exchange in the condenser/evaporator, maintaining a percent of total heat transfer from the working fluid in the topping cycle that occurs during saturated condensation to be less than a percent of total heat transfer to the working fluid in the bottoming cycle that occurs during saturated evaporation.

2. The method as recited in claim 1, further comprising:

utilizing Siloxane MM as the working fluid in the topping cycle; and

utilizing R245fa as the working fluid in the bottoming cycle.

3. The method as recited in claim 1, comprising expanding the working fluid in the bottoming cycle over a turbine in the bottoming cycle and circulating the working fluid in the bottoming cycle from the turbine into a recuperator.

4. The method as recited in claim 3, comprising using the working fluid that is circulated into the recuperator from the turbine in the bottoming cycle to preheat the working fluid in the bottoming cycle at a location downstream from a pump in the bottoming cycle and prior to circulation into the condenser/evaporator such that the

percent total heat transfer from the working fluid in the topping cycle that occurs during saturated condensation is within 10% of the percent of total heat transfer to the working fluid in the bottoming cycle that occurs during saturated evaporation.

5. The method as recited in claim 1, comprising superheating the working fluid in the topping cycle using boiler in the topping cycle.

6. The method as recited in claim 5, comprising superheating the working fluid in the topping cycle in the boiler using an oil circuit.