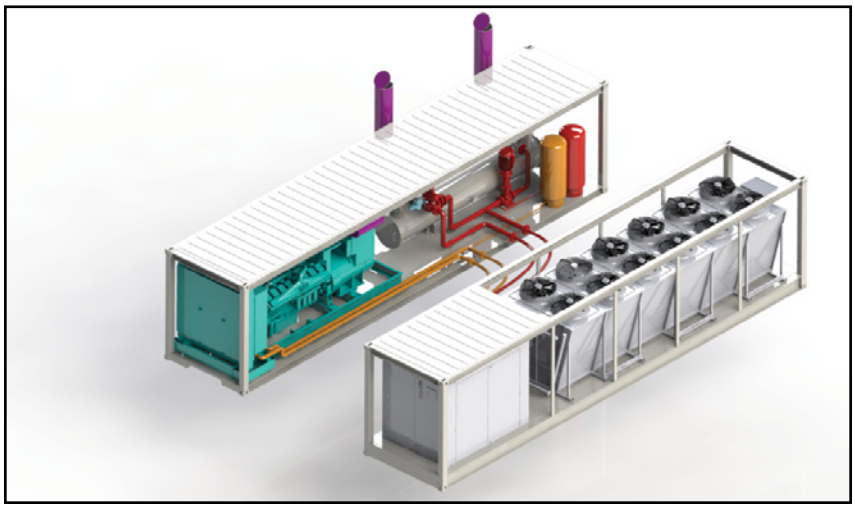


The DOD-funded ORC integration and replacement project that will deploy later this year is comprised of two 40 ft. (12 m) ISO shipping containers.

Utilizing Waste Heat For Power

Advanced engine cooling with economic payback; DOD project demonstrates up to 12% increase in fuel efficiency

Continuous duty gen-sets provide base-load power generation in diverse applications around the globe. However, high fuel costs and engine maintenance are pain points felt by operators. A low-maintenance path to significant fuel savings and lower emissions is what the U.S. Department of Defense (DOD) had in mind when they approached ElectraTherm to integrate the company's Green Machine waste heat to power (WHP) generator with a 1.1 MW Cummins KTA-50 generator.

ElectraTherm specializes in small-scale, distributed power generation from waste heat, utilizing Organic Rankine Cycle (ORC) and proprietary technologies to generate power from low temperature heat ranging from 77° to 116°C. The company's WHP technology converts various sources of heat into power, including internal combustion engines, small geothermal, biomass, concentrated solar and process heat. To date, ElectraTherm said it has deployed 42 units worldwide, with a cumulative 250 000 operating hours and over 97% availability.

ElectraTherm's primary market is waste heat from stationary internal combustion engines. Typical sites for these engines include prime power production in remote areas, island and developing nations, biogas gen-sets including landfill and waste water treatment plants, natural gas compression stations and renewable biofuels. With the typical engine running at about 35% efficiency, there is considerable waste heat between the jacket water and the exhaust that ElectraTherm converts into emissions-free/fuel-free electricity.

ElectraTherm's Green Machine generator operates using a closed-loop ORC, where hot water is the fuel. Hot water from the engine enters a heat exchanger to excite (pressurize) the non-flammable, nontoxic working fluid, driving the twin-screw expander and generator to create electricity. The company said its twin-screw expander is unique in its configuration, lubrication and specifications, but the core technology is based on decades of proven compressor technology.

The twin-screw expander has a rotational speed of 1800 to 4900 r/min, considerably less than turboexpanders, according to ElectraTherm. Unlike high-speed turboexpanders, screw expanders are robust units that tolerate "wet" dual-phase flow.

"This allows a very robust and cost-effective design for the Green Machine that can tolerate perturbations in both temperature and flow with turn down ratios of 6:1 available on demand," said John Fox, CEO of ElectraTherm, Inc. "This is particularly advantageous in low temperature waste heat streams such as engine jacket water. Our Green Machine design is simplified and eliminates lubrication reservoirs, oil coolers, pumps and land filters, creating a simple, robust and efficient system with fewer parasitic loads and maintenance requirements."

The Green Machine acts as the engine's radiator, so the engine-driven radiator fans can actually be disconnected (or eliminated completely for a new installation), allowing more work to be performed by the engine to generate additional electricity. In effect, the engine's waste heat becomes a source of cost savings by displacing the radiator's capital cost and parasitic load.

Between the DOD project and the machines currently running in the field, ElectraTherm said it increases fuel efficiency up to 12%, depending on engine size and configuration, and site conditions while featuring simple installation, mobility and low maintenance.

There are multiple benefits to integrating an ORC heat to power generator with an engine gen-set: the additional electrical output from the conversion of the waste heat to electricity with no additional fuel consumption or emissions, and the reduction or elimination of the parasitic load from the engine cooling fans. In hot climates or seasonally high ambient conditions, which often coincide with peak demand, the engine's derate can be reduced due to the added cooling effect of the ORC, thereby increasing the power output of the engine. "The additional benefits from

decreasing the engine's de-rate period or the amount of de-rate will, of course, vary with ambient conditions.

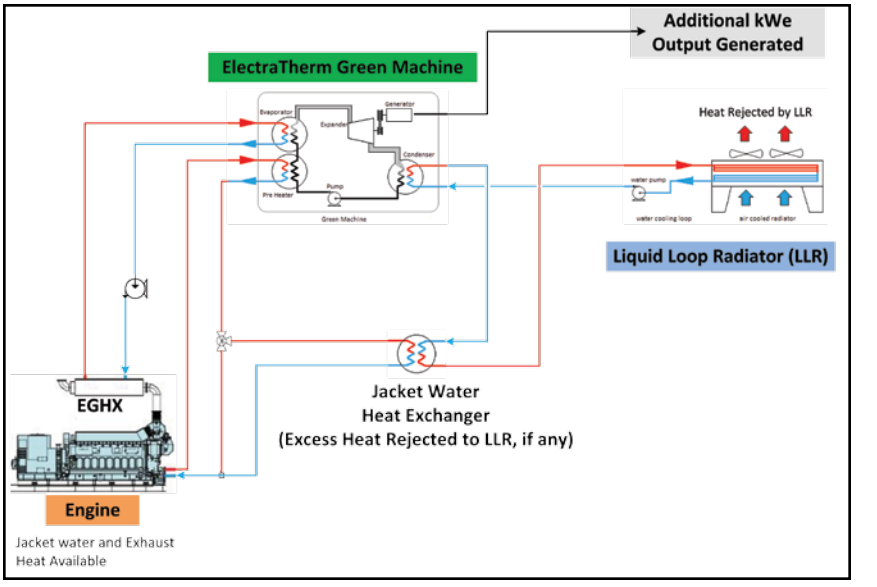
"Our first project with the DOD was to simulate various engine models and ORC integration schemes and fully test those configurations on ElectraTherm's test cell," Fox said. "A matrix was developed consisting of five engine models and two engine configurations over different ambient conditions for waste heat capture: jacket water only and jacket water boosted with exhaust energy for higher ORC efficiencies and output."

Fox said the next step was to develop a higher output, fully integrated ORC specific to a 1.1 MW Cummins KTA-50 engine for DOD deployment. The ORC and all balance of plant will be packaged in 12 m ISO shipping containers for ease of deployment and mobility throughout the world. Funding for this second project came from the DOD's Environmental Security Technology Certification Program (ESTCP) through Southern Research Institute (SRI), which is independently monitoring the performance and fuel efficiency gains.

The Cummins gen-set, engine controls, switch gear and exhaust gas heat exchanger will all be housed in a combined heat and power (CHP) module packaged under ElectraTherm's direction by Denver, Colorado, U.S.A.-based Cummins Rocky Mountain. The ORC module will contain the Green Machine and associated controls, liquid loop radiator (combined radiator for the engine and ORC) and the corresponding balance of plant (piping, pumps and expansion tank, etc.).

Fox said the system would be tested with the Mobile Utilities Support Equipment (MUSE) group at the Port Hueneme, California, U.S.A., Navy facility for fuel efficiency testing by SRI and then shipped to Guantanamo Bay for a full year of performance monitoring.

"This project forced our engineering team to take a hard look at whether we need both the engine radiator and ORC radiator," Fox said. "All ORCs need condensing and all engines need cooling — could it be done with one radiator, eliminating approximately US$75 000 in capital cost for an engine this size? The answer is yes. This was accomplished with an intermediate heat exchanger to optimize the return temperature to the engine and a bypass to ensure the engine cooling remained operating even when the ORC is not running. The impact to the overall installed cost for an ORC can now be reduced by 20 to 30%."



The engine radiator is replaced by the Green Machine ORC and its condenser, a liquid-loop radiator, which captures both the engine jacket water and exhaust for maximum electrical output. A secondary loop is configured between the engine and the condenser for the ORC, and this loop controls the return temperature of the jacket water to the engine.

ElectraTherm said it currently manufactures a 35 kW unit (3600 model) that fits with 500 kW gen-sets, and a 65 kW unit (4400 model) that fits with 800 kW engines. The company's project with the DOD is the first 110 kW unit (6500 model), and is well suited for 1 to 2 MW engines.

"Our gen-set integration has been very successful," Fox said. "Applications include single and multiple engines utilizing jacket water heat alone as well as jacket water combined with exhaust heat. We have integrated into engines models such as Jenbacher, Deutz and MWM engines in Europe, as well as Cat and Waukesha engines in North America.

"As we deploy our units in varied global applications, we are discovering new opportunities. We have looked at the large number of stationary engines associated with natural gas compression, where engine heat is typically unused. A prospective customer is investigating the potential to remove the shaft-driven radiators from their existing gas compression engines, which would enable usage of approximately 56 kW of parasitic load from the engine and allow more power for additional compression. Also, the ORC-generated electricity can be converted to use more compression via an electric compressor. More compression means more gas throughput, which equates to increased revenue. Particularly in emissions-capped areas where another engine cannot be easily added, this is a great way to increase plant throughput without additional emissions, thereby keeping the station under existing permitted levels."

Fox said that distributed WHP systems for stationary engines are not yet well known or mainstream, but the technology is field proven and the economics are now attractive. "Our various packaged solutions are making it easier to economically capture waste heat and make emissions-free and fuel-free power from sources that already exist," Fox said. "We are excited about the introduction of the radiator with a payback."