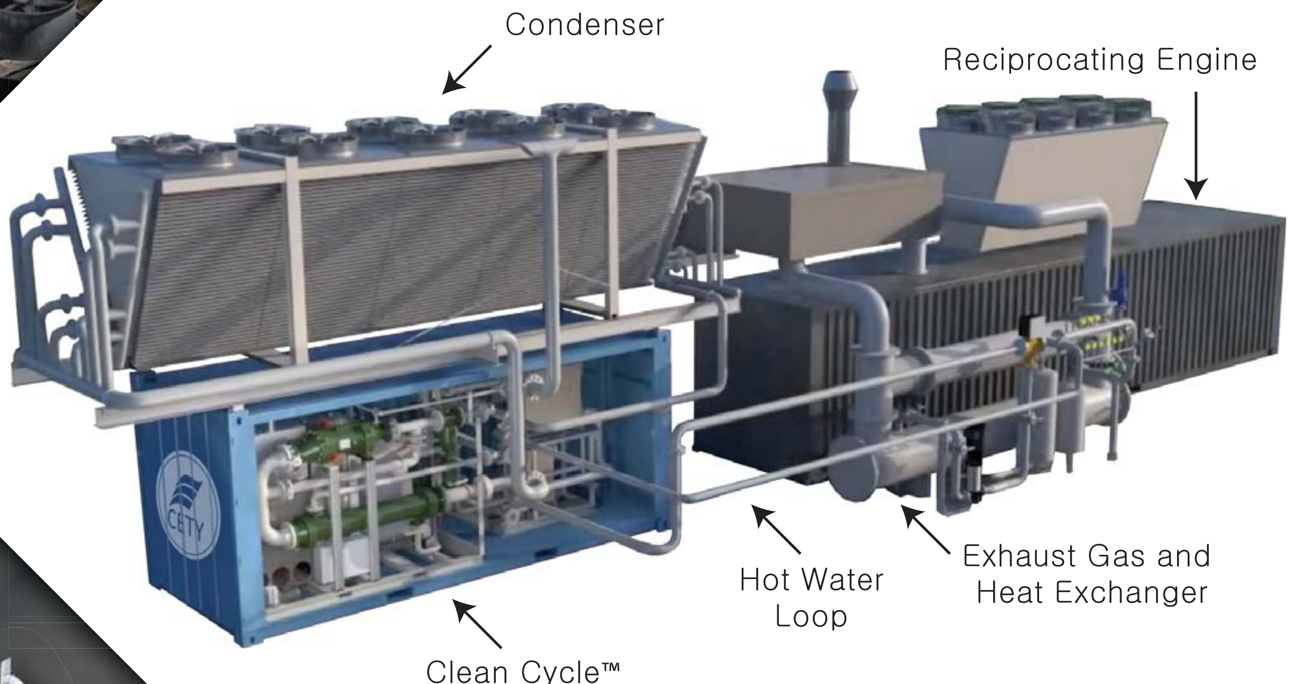
HEAT RECOVERY SOLUTIONS



CETY

A Clean Energy Technologies Inc. Company

http://heatrecoverysolutions.com/

Clean Cycle
Containerized Solution
Technical Specification Sheet

Description

The Clean Cycle has been designed with flexibility in mind so that a wide variety of heat sources can be tapped to generate electricity. Regardless of the heat source, if it can create hot water or steam at sufficient temperatures - typically through a heat exchanger - the Clean Cycle can generate electricity from it. The water or steam directed to the Clean Cycle is a closed loop, so no water consumption takes place. Similarly, the process by which the Clean Cycle generates electricity - called the Organic Rankine Cycle - requires no fuel, produces no emissions, and is closed loop.

Features

Turnkey package
Complete assembly requires only heat input, interconnection, and minor control integration to begin producing electricity.

Seamless grid integration
Electricity produced by the generator is conditioned with power electronics to match 50 or 60 hz at a power factor of 1 automatically.

Automatically controlled & remotely monitored
The unit adjusts to the heat provided to it, including automatic cut-in, load following, maximizing output, and automatic cut-out.

Low maintenance
Core generating equipment has no gearbox, no oils, no lubricants, no external rotating seals, and does not require manned operation; maintenance is typically performaned by existing on-site personnel.

Redeployable to other heat sources
The same package can be applied to reciprocating engine heat as well as biomass boiler heat or process heat.

Specifications

Rating	140kW gross electrical
Output	50 or 60hz, 3 phase 400-480V
Power factor	1. Built-in power electronics
Emissions	Zero
Refrigerant	R245fa, benign, non -flammable
Turbine	Single stage radial
Generator	Rare earth magnetic bearing
Cycle temperatures	25-144˚C, 77-291˚F
Cycle pressures	up to 25 bar
Heat exchangers	Brazed plate, on skid
Heat delivery	Pressurized water or steam
Cooling	Air cooled radiator standard. Water cooled options also available
Sound	85 decibels at 1 meter; about equal to a vacuum cleaner
Controls	Allen Bradley controller
Operation	Unmanned operation
Monitoring	Remotely monitored
Shipping	ISO 20ft container, redeployable

Certifications

The Clean Cycle meets strict international manufacturing standards.

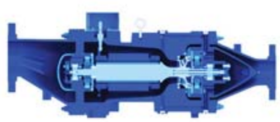
CE ASME PED TÜV SÜD ISO

HEAT RECOVERY SOLUTIONS

Key components of the Clean Cycle Solution

Deliver heat and the Clean Cycle will do the rest

The Clean Cycle containerized solution has been meticulously engineered to reliable produce power from a variety of different heat sources. The major components, listed below, are assembled to create an automated machine to generate electricity from nothing other than a hot water or steam loop.



Integrated Power Module (IPM)

The IPM is mounted on the Clean Cycle skid and is a fully enclosed, hermetically sealed module that includes an integrated turbine generator that sits on magnetic bearings. The turbine rotor vibration is dampened by controlling the magnetic field using a Magnetic Bearing Controller as it spins at 27,500 RPM. The turbine generator is self cooled, and there is no oil, lubricants, or gearbox required.

- Included on the Clean Cycle skid
- Self cooled... no oils or lubricants
- No scheduled maintenance
- Turbine speed... 27500 RPM
- Radial, single stage turbine

Clean Cycle Generator

The Clean Cycle is the heart of the containerized solution. The skid, pictured left, includes two brazed plate heat exchangers to transfer the heat from the water or steam to the refrigerant loop. From the heat exchangers, the refrigerant spins the turbine generator enclosed within the Integrated Power Module (IPM). The electricity is conditioned by on-board power electronics before being sent to the grid. The whole process is controlled by a central Controller & PLC.

- Includes... Turbine, generator, PLC, power electronics
- Dimensions... 12.5' x 4' x 7'
- Weight... 3863 kg (8500 lbs)
- Pressure rating... 25 bar
- Temperature... 144˚C (291˚F)

Container

The Clean Cycle arrives mounted in the 20ft ISO shipping container that it arrives in. The team has modified the container to have access doors, cut-outs for all necessary pipework to the heat source and condenser. It also has optional coating and salt screen with pressurization fan to prevent corrosion.

- Pre-cut doors & pipe access
- Clean Cycle arrives mounted inside
- Standard ISO shipping container
- Dimensions... 20' x 8' x 8.5'
- Weight... 3636 kg (8000 lbs)

Condenser

The standard air condenser uses fans to cool the vapor refrigerant to a liquid after it leaves the IPM. The condenser ships separately with a mounting kit so it can be placed on top of the containerized solution. An epoxy coating is optional for installations near salt water to prevent corrosion. If cooling water is available on site, an optional water cooled heat exchanger mounted inside the container can be used in place of the air condenser.

Air cooled condenser (standard)
- Dimensions... 30.5' x 8.5' x 9'
- Weight... 5113 kg (11250 lbs) dry
- Included... mounting kit & connection piping

Water cooled condenser (optional)
- Connects directly to Clean Cycle

Performance & recommendations

Clean Cycle units efficiently operate on a variety of heat input conditions including partial and fluctuating load. Units can be placed in parallel where sufficient heat is available for more than one Clean Cycle generator. This enables significant flexibility while maintaining reliability and consistency across the different units in the field.

The chart below on the right indicates the amount of pressurized water or steam to operate one Clean Cycle unit at full output. One Clean Cycle operates at full electrical output with 980 kWth (3.3MBTU) supplied to it. The chart on the bottom left shows how with more heat available, more Clean Cycle units are used, and more electricity is generated.

One Clean Cycle unit running at full output will produce 140 kW of electricity at the generator and result 119 kW exportable power from the Clean Cycle skid, after subtracting for auxilary power consumption. This is the net exportable power from the container for the water condensing version. For air condensing, approximately 6 kW will be consumed by the air blast condenser.

Page 4 includes additional information on the configuration of the water or steam loops used to deliver heat to the Clean Cycle. For additional questions related to output and performance, contact HRS at the number listed on page 7.

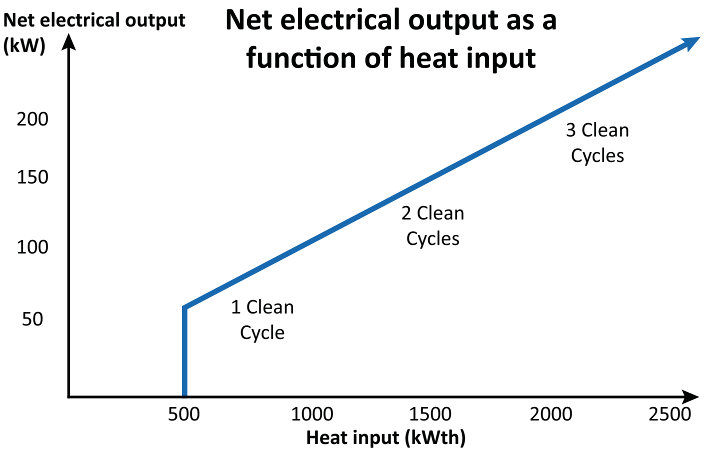


Chart assumes 155˚C pressurized water at 5.5 kg/s is delivered to the Clean Cycle unit(s) with ambient temperature of 25˚C

Heat delivery specifications for 1 unit at full output

Steam

Steam Supply bara	Steam Return bara	Flow Rate kg/s	Gross Power kW	Skid Power kW
>4.5	sat. condensate	0.43	140	119

Pressurized water

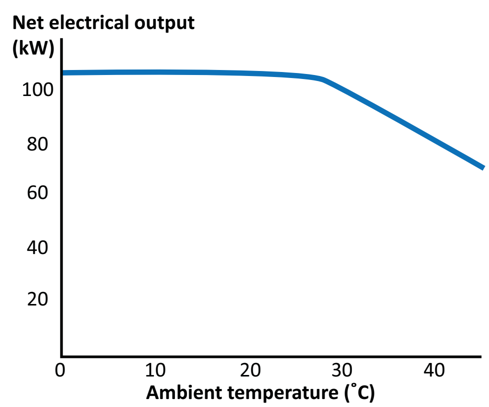
Inlet Temp °C	Outlet Temp °C	Flow Rate kg/s	Flow Rate GPM	Gross Power kW	Skid Power kW
150	127	8.6	149	140	119
155	120	5.5	96	140	119
160	114	4.2	73	140	119
165	109	3.5	60	140	119
170	104	3.0	51	140	119

Assumes water density @ 150C of 912kg/m3 and water Cp of 4.3kj/kg-k, and 25C ambient temperature

Design considerations

Ambient temperatures

If the Clean Cycle is using an air condenser, the net power output from the unit will vary slightly depending on the ambient air temperature. In cooler conditions, net output may increase, and in warm ambient conditions, net output may decrease. This is due to the internal cycle that the equipment operates under and the effect is shown in the chart on the right.

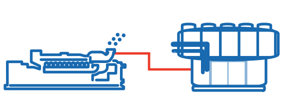


Peaking and variable heat loads

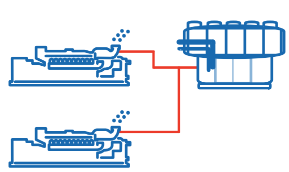
The Clean Cycle unit adjusts to variations in the quantity of heat supplied to it automatically. However, it is important to size the equipment for the heat condition that makes the most sense both technically and economically. For this reason, when performaning analysis it is recommended to look at heat source historical run data.

Flexible heat delivery configurations

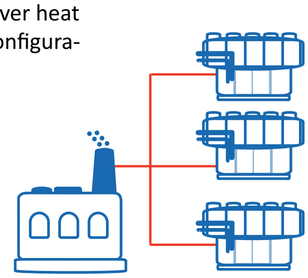
Water or steam loops can be configured in a number of different ways to deliver heat to one or multiple Clean Cycle units. Below are a few examples of different configura-tions, and the Clean Cycle scope remains the same in each.



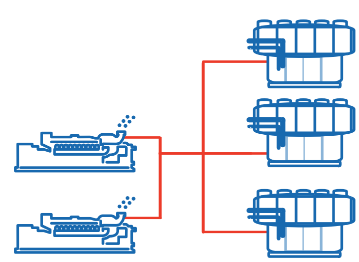
1 to 1
One heat source to one ORC... simple



2 to 1
The heat from two sources can be combined in a single water loop for one ORC



1 to 2+
One heat source can feed multiple ORC's using water loops in parallel



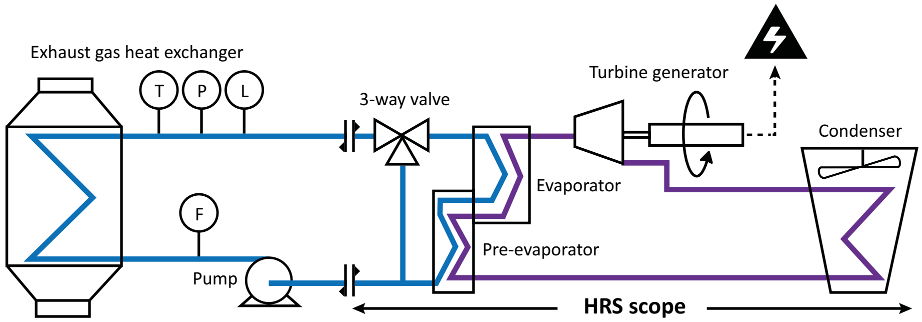
2+ to 2+
Mutliple heat sources, (e.g. engines) can run multiple ORC's to maximize output

Process flow diagrams

The process by which the Clean Cycle generates electricity is called the Organic Rankine Cycle. In this closed loop process, a liquid refrigerant (shown in purple below) is pressurized and exposed to heat, causing it to vaporize. The pressurized vapor expands across an integrated turbine generator, causing it to spin and generate electricity. After the vapor exits the turbine, it is condensed to a liquid and pumped back to the heat source so the process can begin again. The heat is delivered to the Clean Cycle from a heat source in steam or pressurized water loop (shown in blue below).

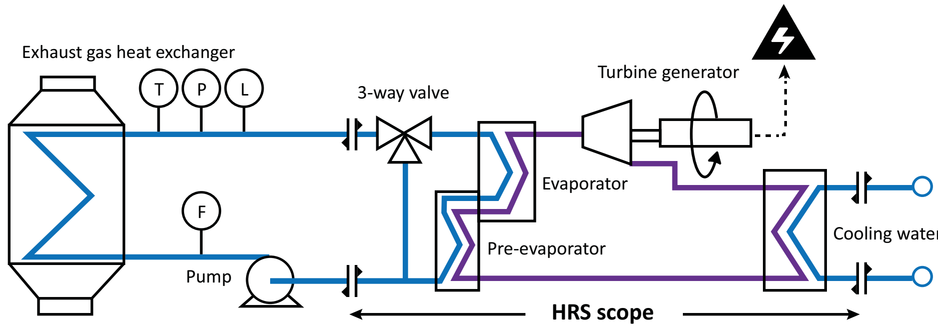
Air cooled condensing

Rows of fans blow air across coils of refrigerant to condense it from liquid to vapor. The condenser ships separately and is mounted on top of the Clean Cycle container.



Water cooled condensing

If fresh water is available for use near the installation, the Clean Cycle can be configured with a condensing heat exchanger packaged inside the container. Water can be pumped directly into the heat exchanger to condense the refrigerant. The advantage with water is there are no fluctuations with ambient temperatures, and parasitic losses are minimized.



Steam or hot water loop to deliver heat

To deliver heat from the heat source to the Clean Cycle, steam or pressurized hot water can be used. In both cases, the heat is delivered in 3 inch pipes according to the specifications listed on pages 5-6. In both cases, the Clean Cycle can automatically optimize the quantity of heat given to it with the 3 way valve pictured, and will start up, stop, and adjust according to the heat provided from the heat source. It is recommended that Temperature (T), Pressure (P), Water Level (L) and Flow (F) be measured in the water or steam loop to be able to make adjustments to meet the heat input specifications on pages 5-6.

Utilizing exhaust heat

Capturing and transferring the heat

The most common way to extract the heat energy from an exhaust stream is to use an exhaust gas heat exchanger, similar to the one pictured on the left. In this case, water is piped through the exhaust gas heat exchanger (pictured left), which transfers the exhaust heat to the water loop.

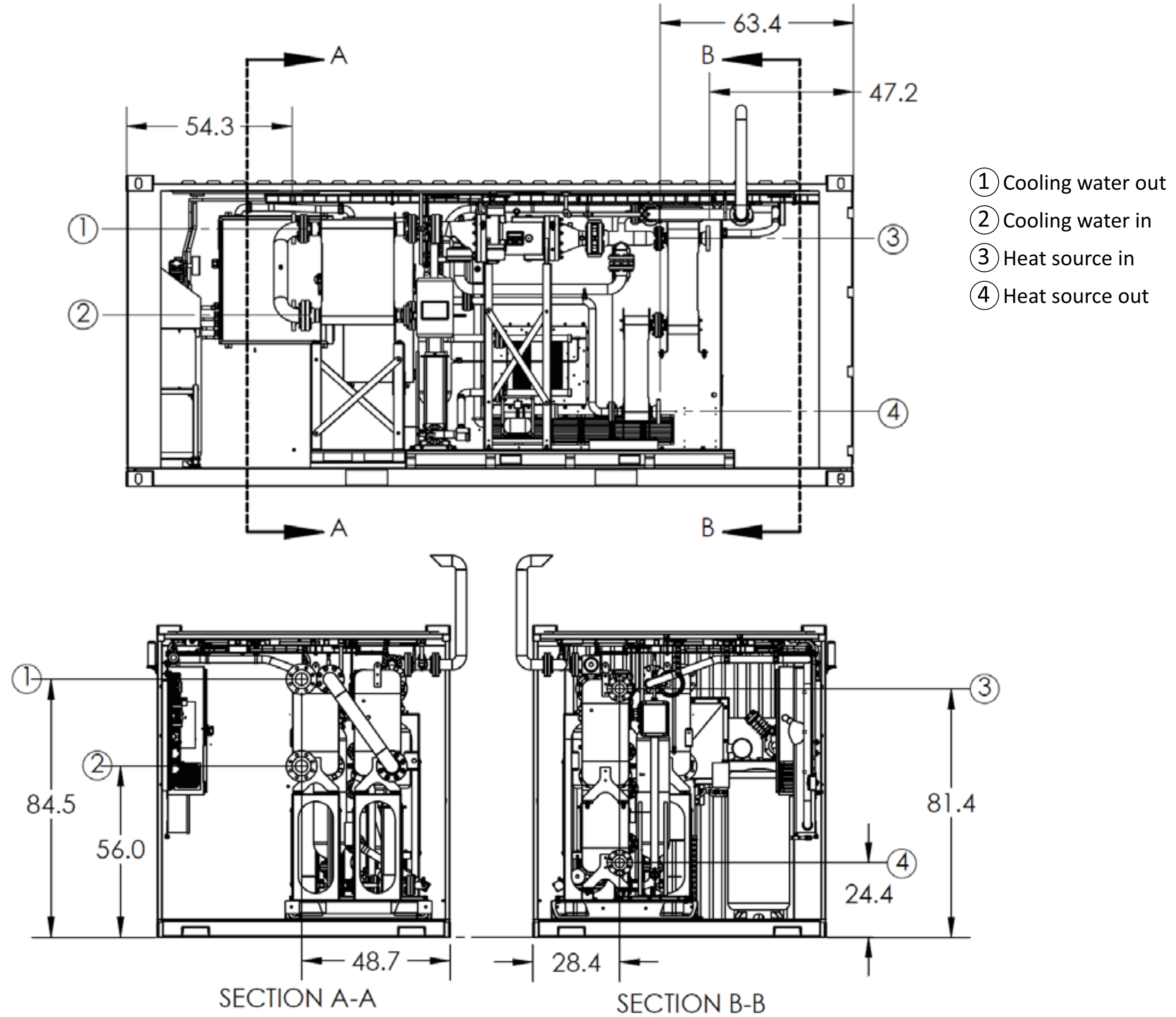
Protecting the heat source

Exhaust gas heat exchangers should be selected to extract the appropriate available amount of heat from the heat source, and ensure the protection of the heat source. This includes a bypass with diverting dampers, and sizing the heat exchanger so that it is within any backpressure limits that the heat source may have.

Quantifying the heat available

The usable heat in a medium can be calculated with a heat equation and can often be found on equipment specification sheets. The key pieces of information to understand quantity of heat are: 1) the medium of the heat source, 2) the mass flow rate, 3) the temperature. Heat Recovery Solutions can provide a quick heat source assessment for a project; just contact HRS at the email address listed on page 7 with items 1-3.

Dimensions and weights - water cooled



Connections

Pipework

Item	Type	Description
1. Cooling Water Outlet	4" 300# ANSI	To cooling source
2. Cooling Water Inlet	4" 300# ANSI	From cooling source
3. Hot Water Inlet	3" 300# ANSI	From heat source
4. Hot Water Outlet	3" 300# ANSI	To heat source

Electrical

Item	Type	Description
Electrical Connection	2/0 AWG 4-Conductor	To grid interconnection
GND	1/0 AWG Stranded	To site or new grounding point

Controls

Item	Type	Description
Internet	Ethernet Cable	Clean Cycle load, demand, status

A multitude of variables and data can be viewed via the ethernet connection

The Clean Cycle does not require other external control logic or inputs to operate

Installation

Civil work and logistics

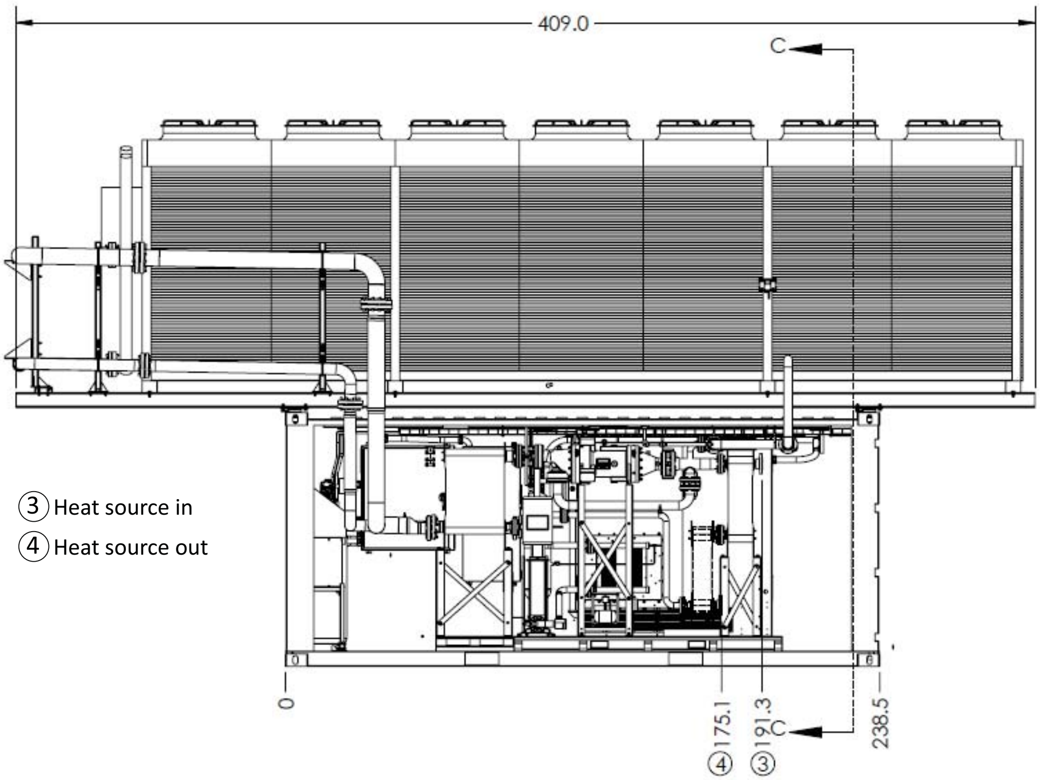
The Clean Cycle container arrives pre-assembled and is 8,000 lbs unfilled. Approximately 1,000 lbs of R245fa refrigerant should be filled once on-site and ready to operate in accordance with the pre-commissioning checklist.

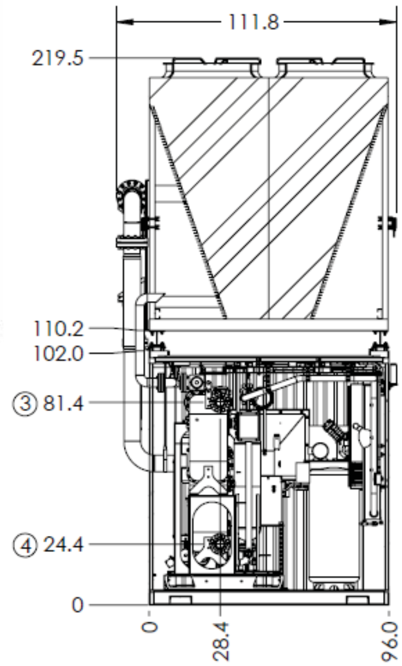
The site for the Clean Cycle container should be poured concrete or tamped gravel that is suitable for the weights and dimensions listed and secured. A crane is recommended for placing the unit.

Cooling with water

The flow rate for the fresh cooling water should be 1,893 liters per minute (500 gallons per minute) of fresh water delivered to flange connection #1 and out of #2 at temperatures below 30˚C (86˚F). Cooling water only needs to be circulated when the Clean Cycle unit is operating.

Dimensions and weights - air cooled





SECTION C-C
SCALE 1 : 50

Dimensions

Pipework

Item	Type	Description
Hot Water Inlet	3" 300# ANSI	From heat source
Hot Water Outlet	3" 300# ANSI	To heat source

Electrical

Item	Type	Description
Electrical Connection	2/0 AWG 4-Conductor	To grid interconnection
GND	1/0 AWG Stranded	To site or new grounding point

Controls

Item	Type	Description
Internet	Ethernet Cable	Clean Cycle load, demand, status

A multitude of variables and data can be viewed via the ethernet connection
The Clean Cycle does not require other external control logic or inputs to operate

Connections

Civil work and logistics

The Clean Cycle container arrives pre-assembled and is 19,000 lbs unfilled. Approximately 1,300 lbs of R245fa refrigerant should be filled once on-site and ready to operate in accordance with the pre-commissioning checklist.

The site for the Clean Cycle container should be poured concrete or tamped gravel that is suitable for the weights and dimensions listed and secured. A crane is recommended for placing the unit.

Cooling with air

The air blast condenser arrives in a separate shipment and is to be mounted on top of the Clean Cycle container. The Clean Cycle container shipment will include the appropriate mounting kit and associated piping and control connections to connect the two.

Heat Recovery Solutions

About

Heat Recovery Solutions is a composed of a team of entrepreneurs that have been involved with the Clean Cycle product from it's inception. The business includes engineering, sales, operations and manufacturing all under one roof in Southern California. The HRS team has the in-house knowledge and toolsets readily available to quickly assess and provide feedback on a particular heat source to begin a project and start realizing the environmental and economic benefits from heat to power projects.

Clean Cycle units move down the assembly line at the headquarters and manufacturing center for Heat Recovery Solutions.

The Clean Cycle Solution

Since the first installation in 2009, the growing fleet of Clean Cycle units has exceeded 1 million operating hours worldwide. The Clean Cycle remains a leader in the waste heat to power industry and has demonstrated reliable performance and savings to customers wanting to get more from their heat sources throughout the world.

Projects can be finished from inquiry to commissioning in a matter of months due to the pre-fabricated solution that HRS delivers and because detailed feasibility and grid integration studies are not required. Contact HRS using the details listed below, or visit the website for additional information.

2 Clean Cycle units installed on diesel engines on a Pacific Island.

HEAT RECOVERY SOLUTIONS

More information is available online:
www.heatrecoverysolutions.com

For inquiries, contact HRS directly:
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