ELECTRATHERM DOE CHP ENERGY PORTFOLIO REVIEW

Southwest Research Institute, June 7-9th 2022

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ElectraTherm
BY BITZER GROUP

BACKGROUND - ORC

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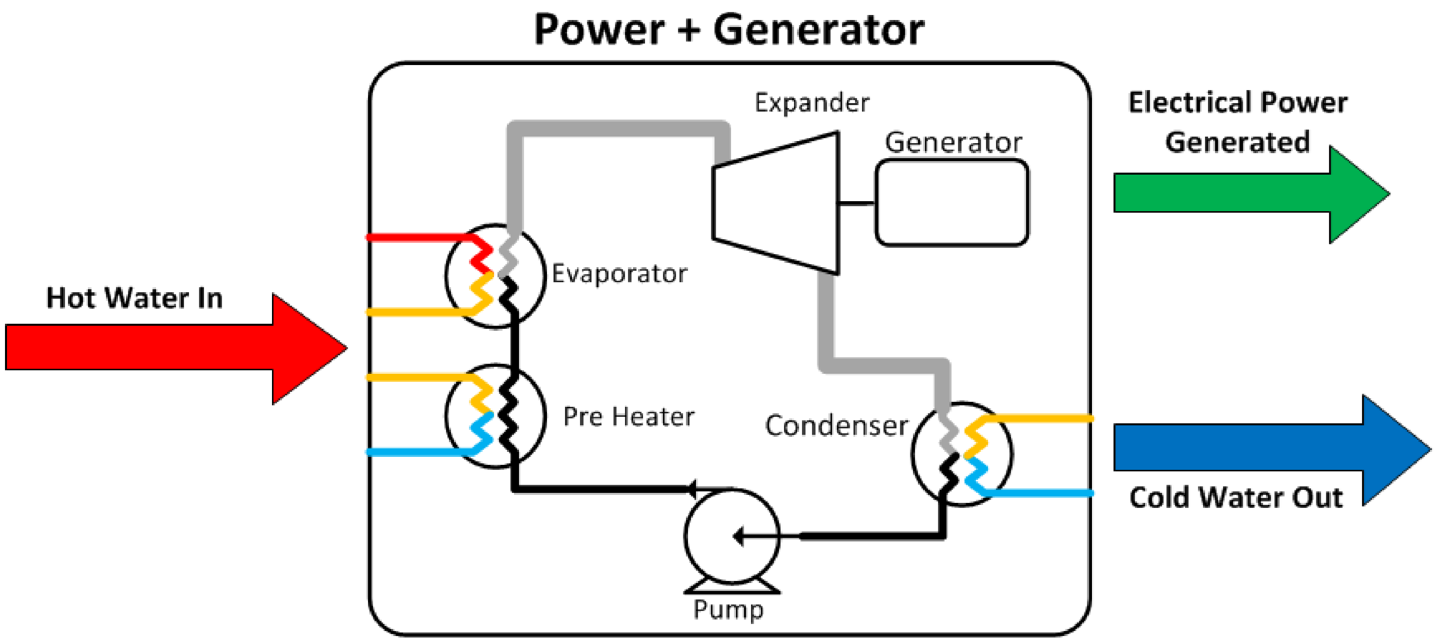
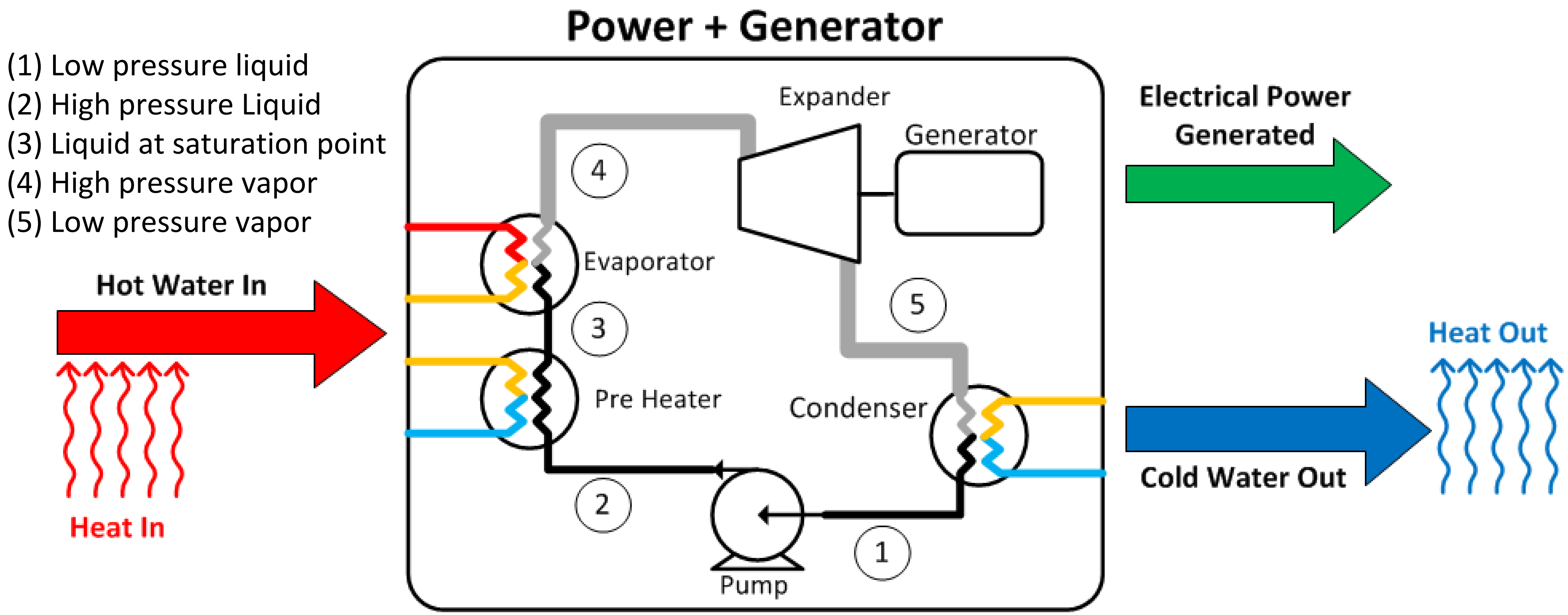
Similar to Steam Cycle with a Lower Temperature Working Fluid



The Organic Rankine Cycle (ORC) is a thermodynamic cycle which uses an organic fluid to convert low-temperature heat into mechanical work. That mechanical work is converted into electricity.

BACKGROUND - ORC

Similar to Steam Cycle with a Lower Temperature Working Fluid



BACKGROUND - CHP

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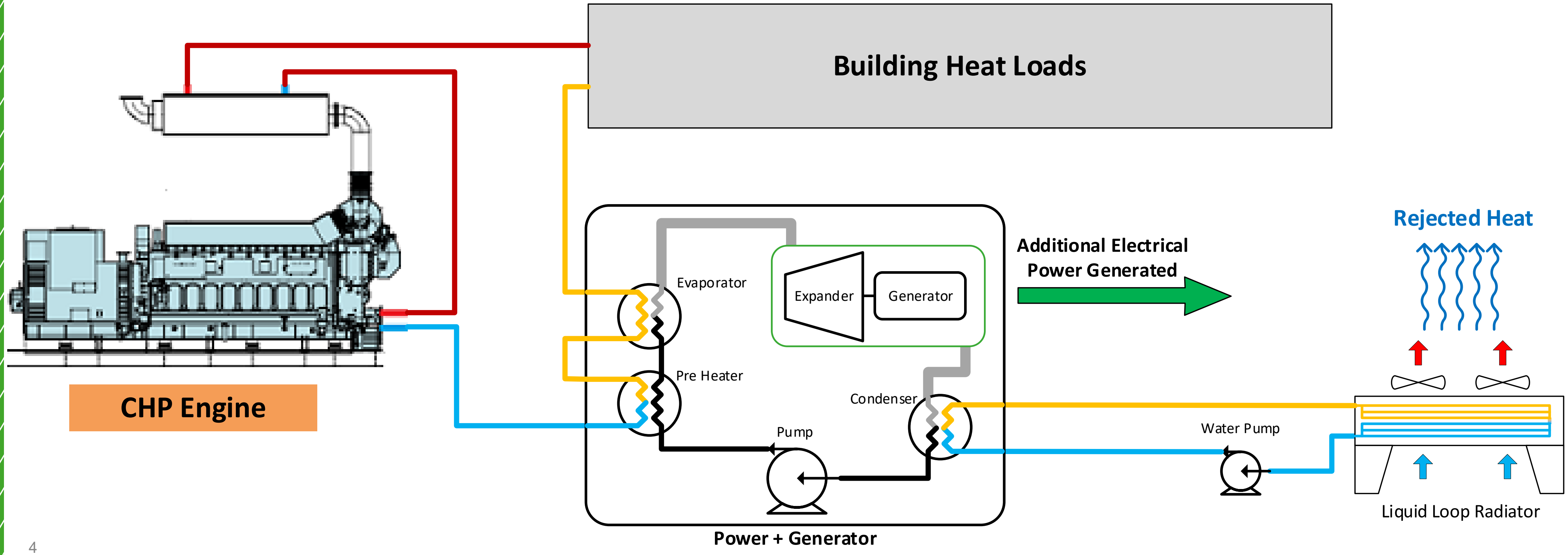
ElectraTherm ORC commonly used as a Bottoming Cycle

// CHP generated more heat than the building needs

// Extra power generated for the site

// Return temperature guaranteed for engine

// Rejected heat is lost



Rejected heat is a loss to the system, limiting the additional power generated and efficiency gains

BACKGROUND - CHP

ElectraTherm ORC used as a Bottoming Cycle

// ORC runs when building is not using all the heat

// Extra power generated, no extra engine cooling needed

BACKGROUND – CHP + ORC

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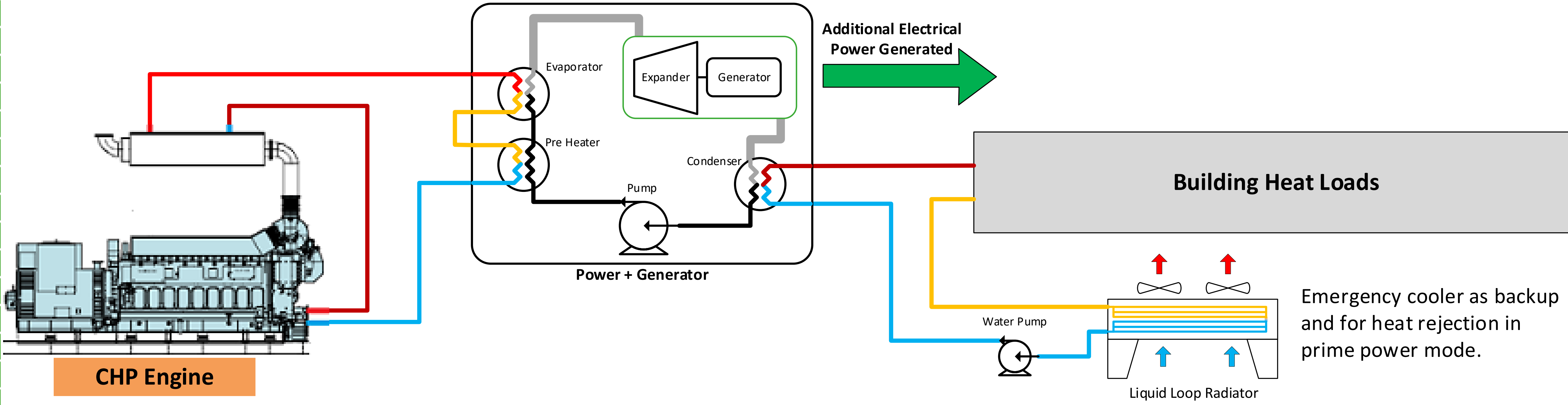
ElectraTherm High Temp ORC – Flexible CHP

// Higher temperature ORC – primary heat from the Engine

// Extra power generated for the site

// Cold side of the ORC elevated to be useful for the building

// Potential for additional power generation when building heat demand is low

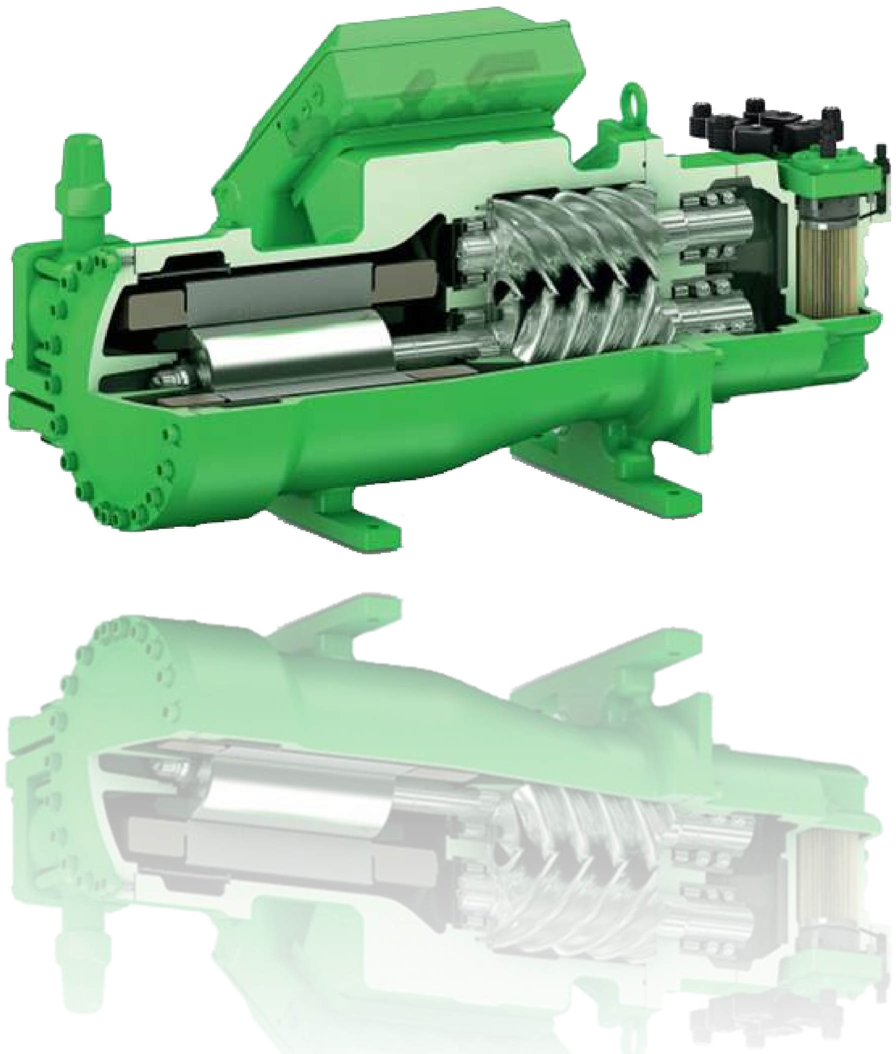


Emergency cooler as backup and for heat rejection in prime power mode.

BACKGROUND – EXPANDER

Maximum temperature determined by ORC Maximum Allowable Working Pressure

M.A.W.P set by the pressure rating of the expander.



Conversion to Semi-Hermetic Expander

// Integrated generator

// No shaft seal needed

// Higher case pressure rating = Higher temperature ORC circuit

BACKGROUND – CONTROLS FLEXIBILITY

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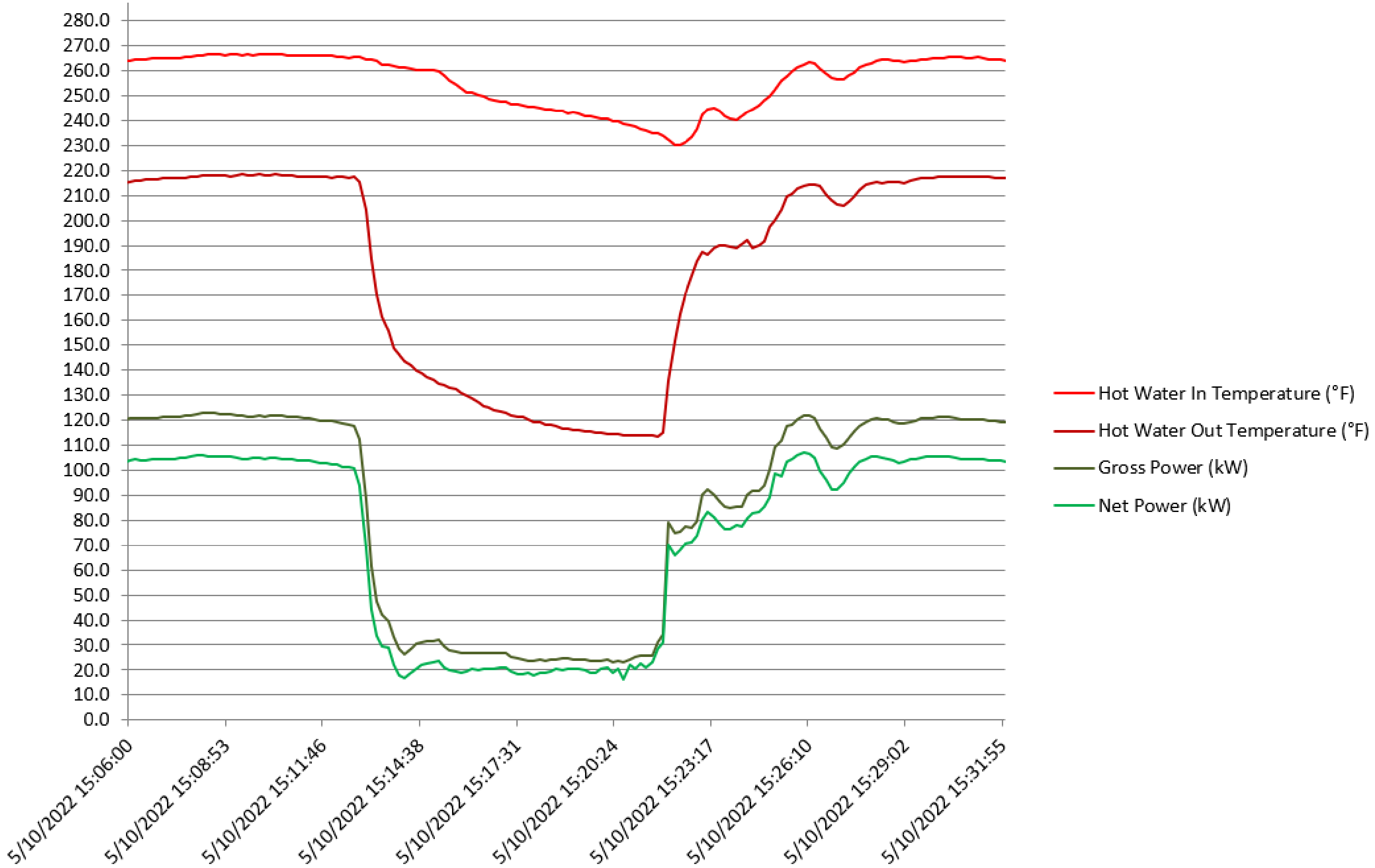
Automatic controls allow for load following

// New expander has much faster response – controls tuning / improvement

// ORC can stay connected through large changes in temperature and flow

// Allows for uninterrupted transitions between heating, prime power, or different load conditions



ACCOMPLISHMENTS

Budget Period 1 Summary

- ✓ New working fluid chemical compatibility study
- ✓ High temperature ORC design complete
- ✓ Prototype unit running at a commercial test site
- ✓ Thermodynamic Model Validated

ACCOMPLISHMENTS – THERMODYNAMIC MODEL VALIDATION

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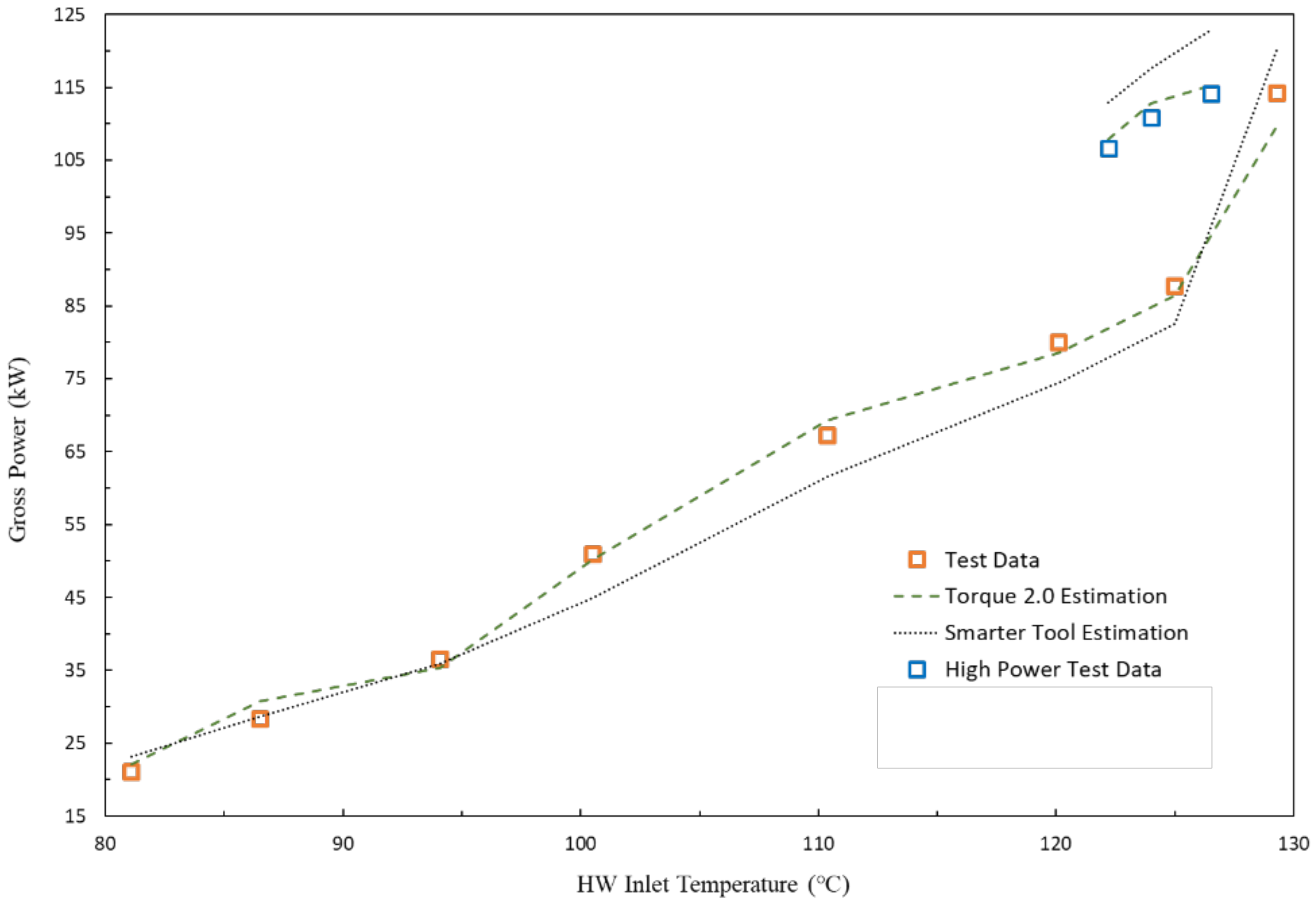

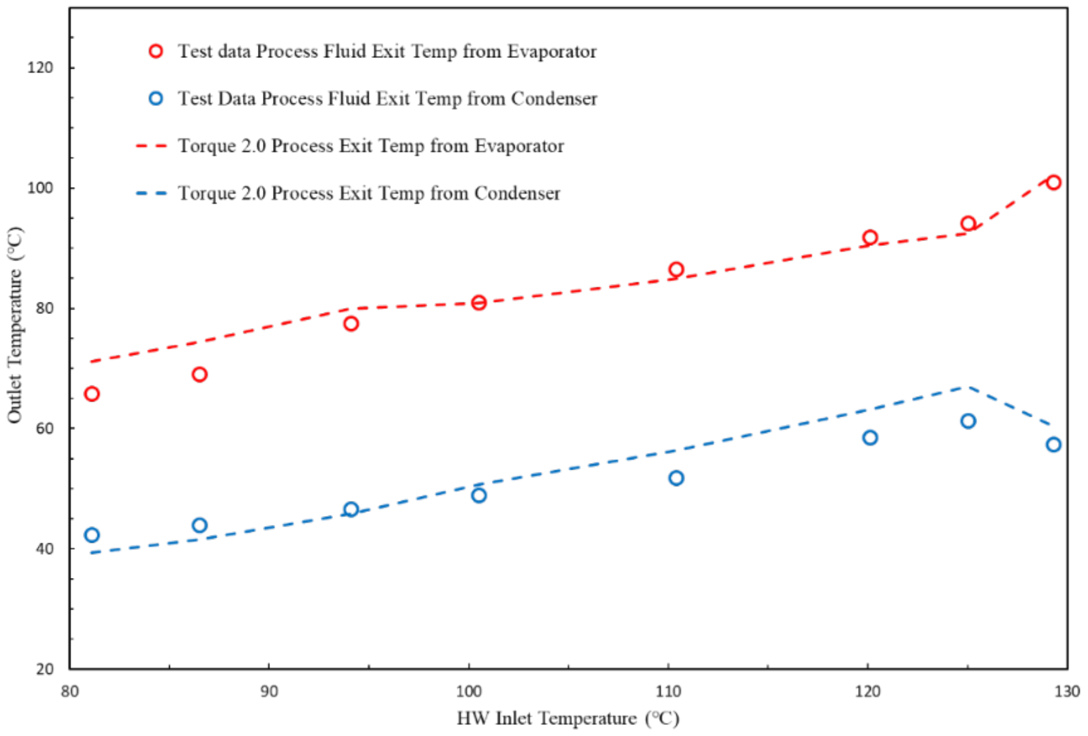

MODELING SOFTWARE UPDATE

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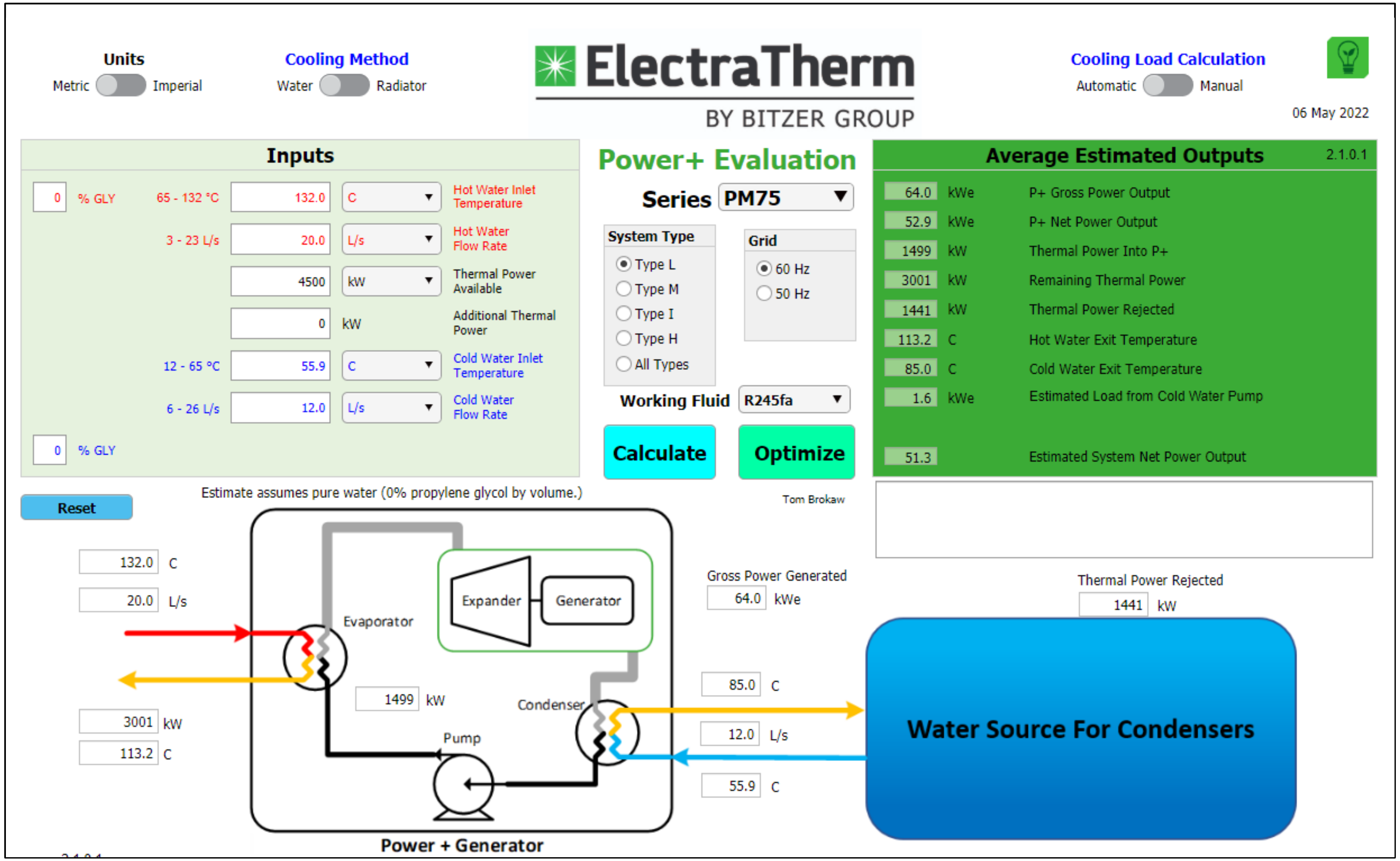
Estimating Software

- // Quick calculation of power output based on heat source conditions
- // Full heat balance provided
- // Water (CHP) or air on OCR cold side



MODELING SOFTWARE UPDATE

ElectraTherm
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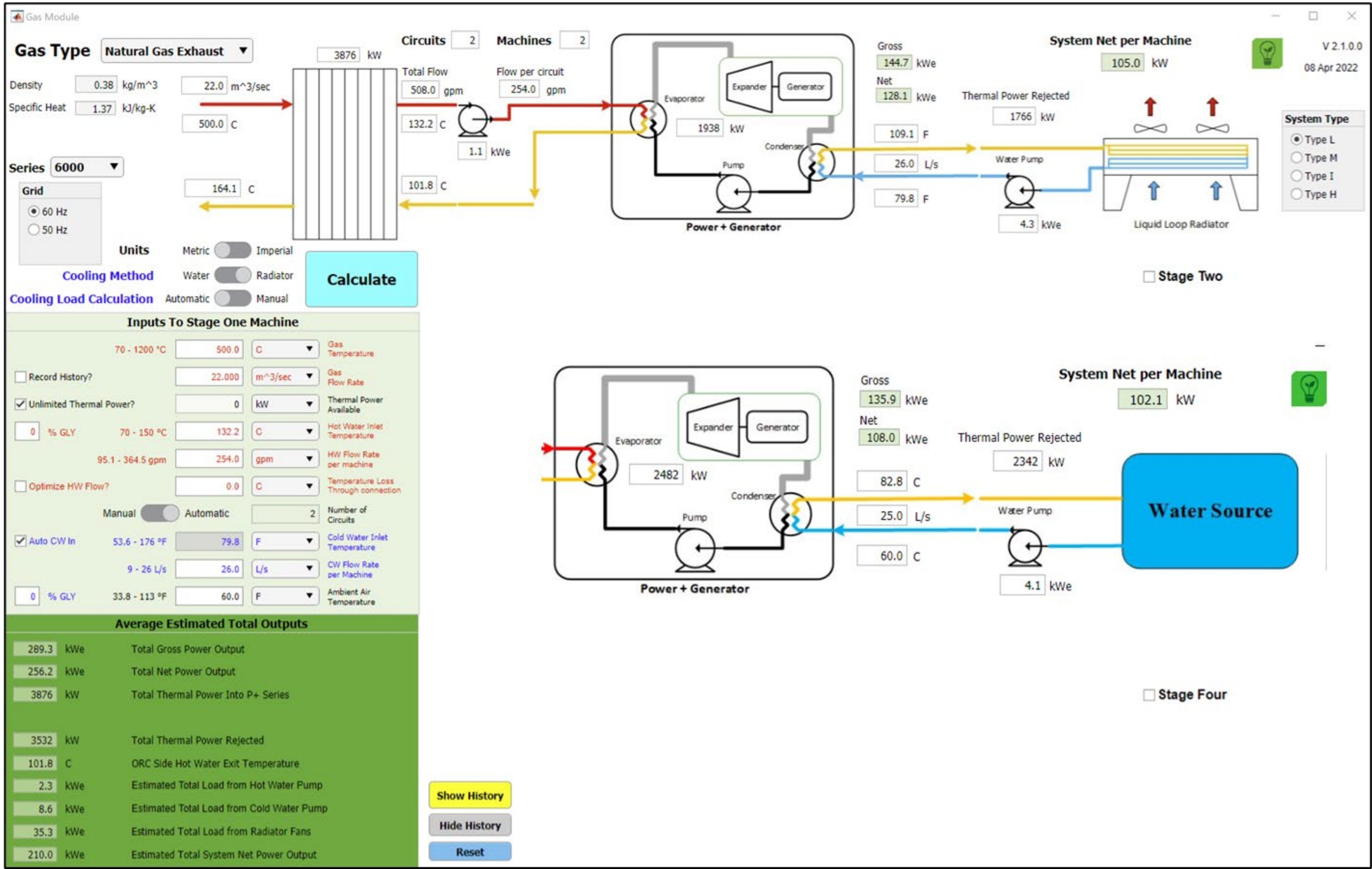
Gas Module

- // Allows for: Air, Natural Gas Exhaust, Steam, and Custom Fluid
- // Evaluation of parallel and series operation
- // Defines requirements for interface heat exchanger
- // Water (CHP) or air on OCR cold side



ACCOMPLISHMENTS

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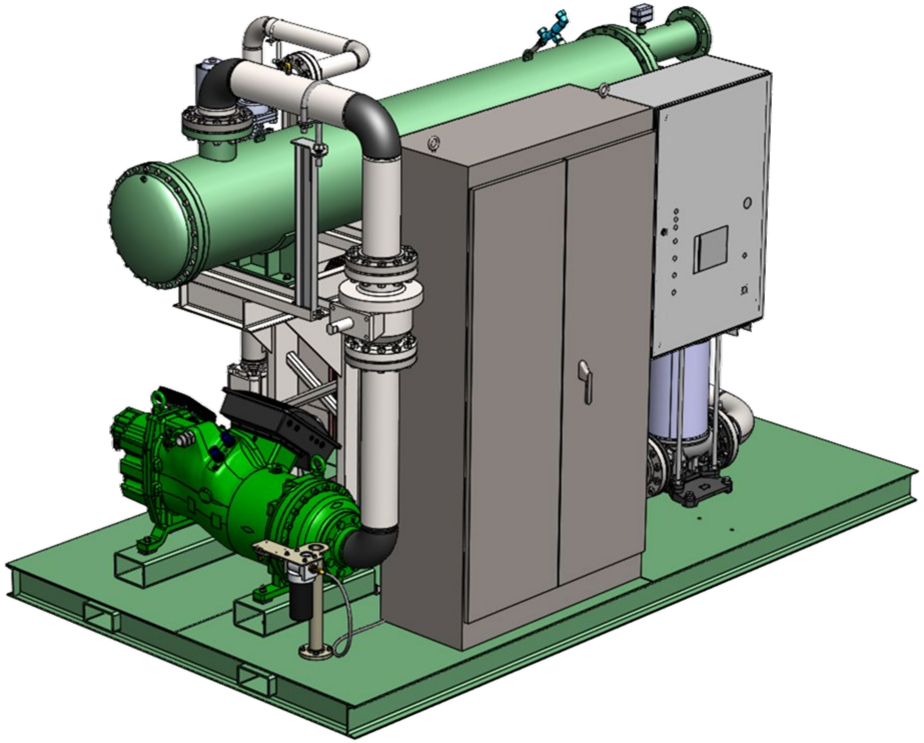
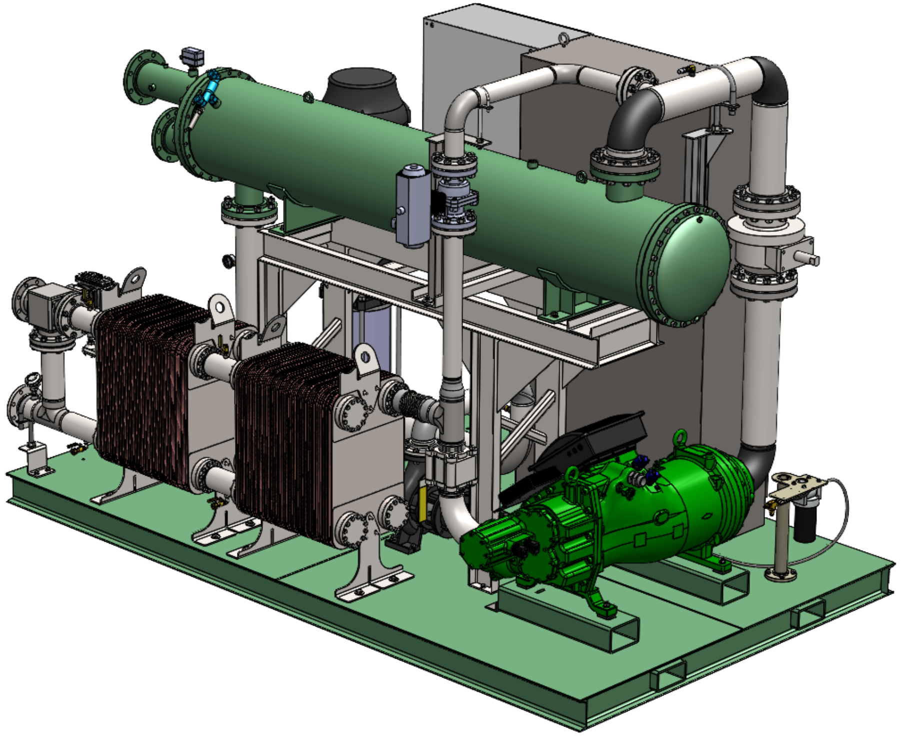
Budget Period 2 Summary

- ✓ Next Generation ORC design complete
- Next Gen ORC Construction complete
- Engine Configuration and BOP design complete
- Successful modeling of CHP – ORC system capable of meeting program goals





ACCOMPLISHMENTS

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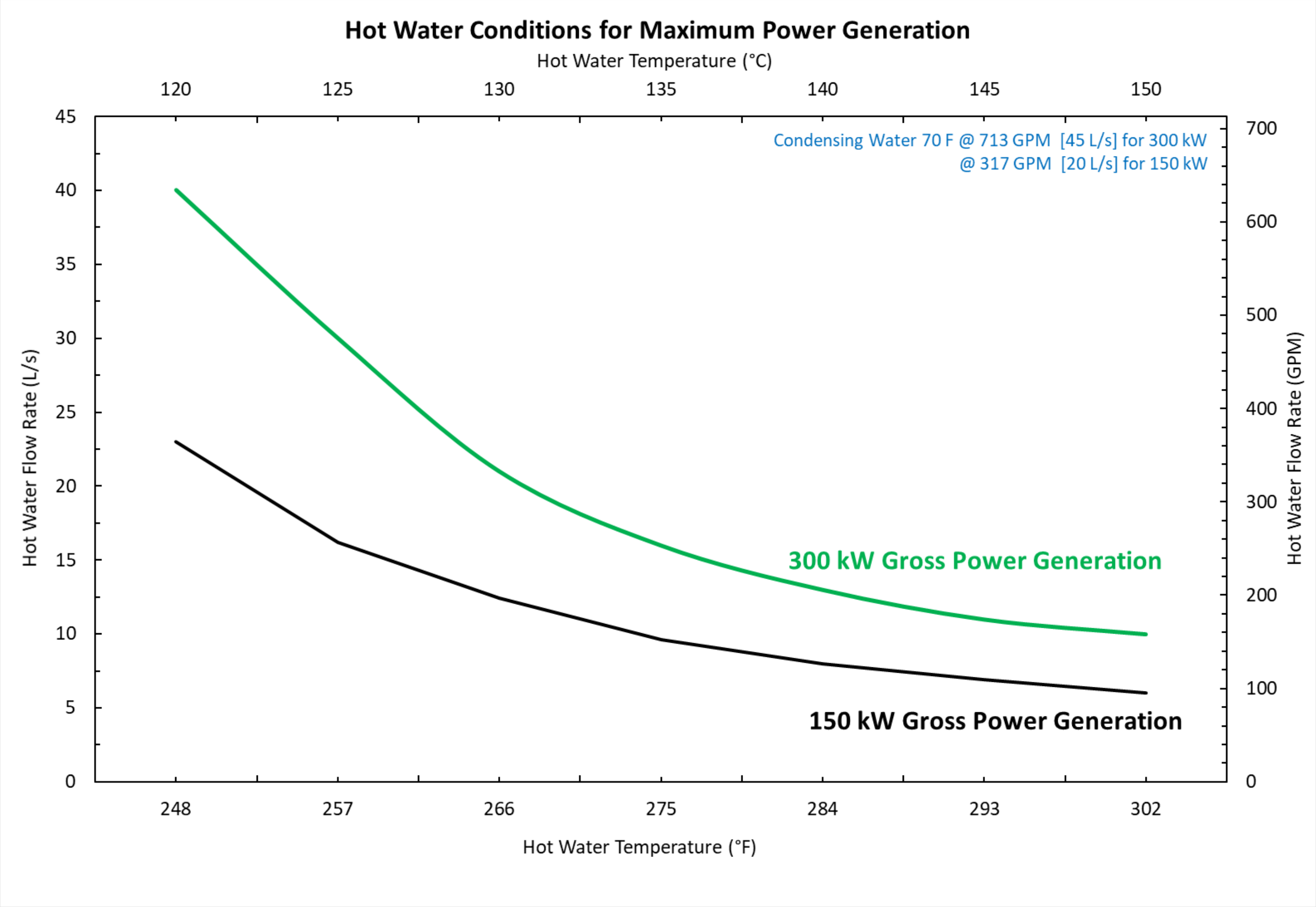
Budget Period 2 Summary

✓ **Next Generation ORC design complete**

Projected output curves based on Thermodynamic system model



ACCOMPLISHMENTS

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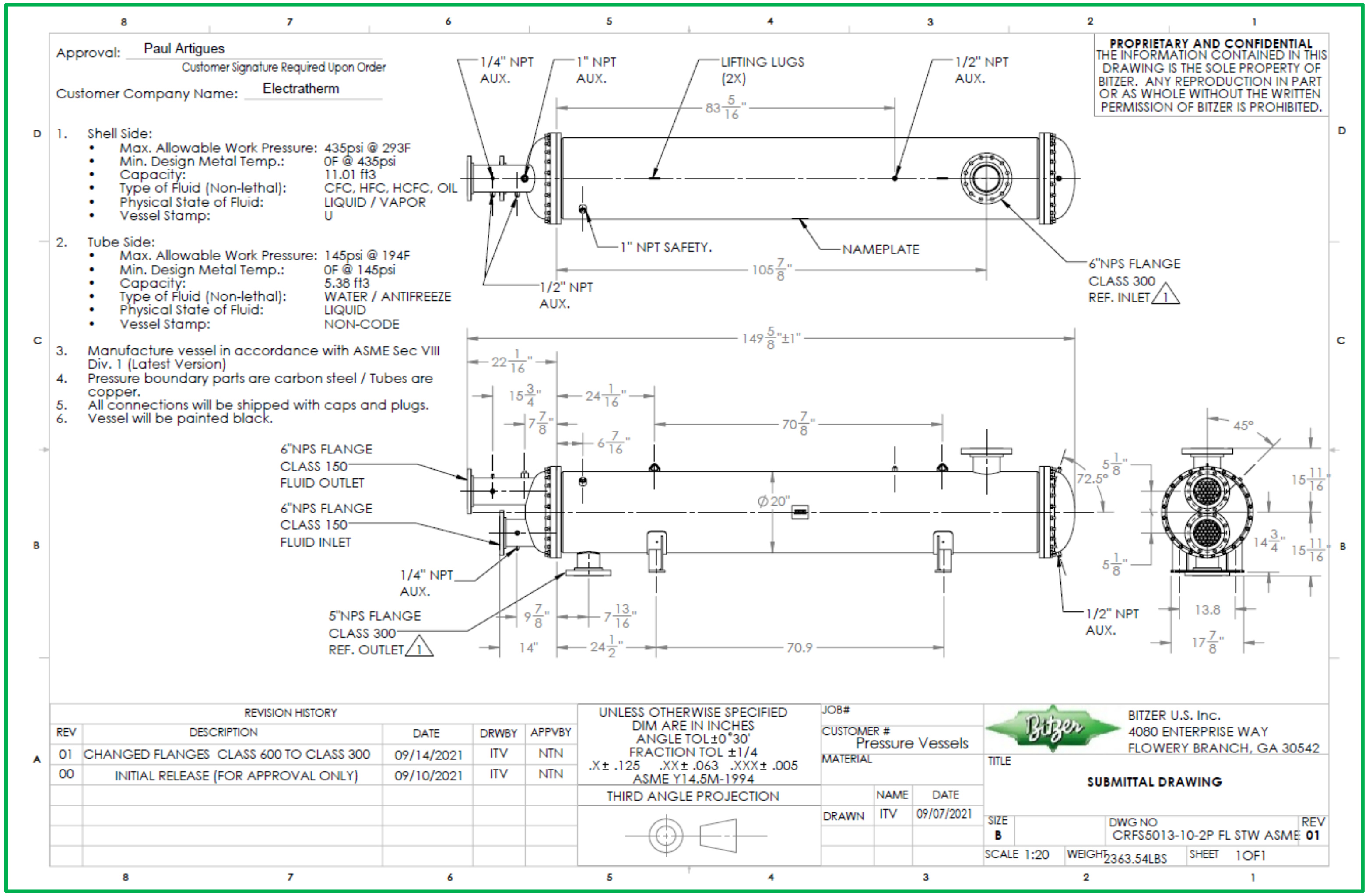
Budget Period 2 Summary

✓ **Next Generation ORC design complete**



Shell and Tube Condenser

// Lower pressure drop on the working fluid side

// Less subcooling

// Simplified piping design

ACCOMPLISHMENTS – MODELING OF CHP – ORC SYSTEM

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CHP Test Case

- // 10MW Cogeneration Unit
- // Meets DOE Targets for Electrical Efficiency
- // Does not meet targets for total CHP Efficiency
- // Sufficient heat in the exhaust that can be used with Next Gen ORC

JMS 920 GS-N.L			
% of Rated Output		Energy input (LHV)	Electrical output
100%	kW	22,703	10,377
	Efficiency		45.7%
50%	kW	12,315	5,189
	Efficiency		42.1%

Cogeneration Unit

JMS 920 GS-N.L

no special Grid Code

920

Electrical output	10377 kW el.
Thermal output	6088 kW

ACCOMPLISHMENTS – MODELING OF CHP – ORC SYSTEM

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CHP Test Case

// 4.3MW of heat available in the Exhaust

// Maximum ORC Power when building heat is not needed

// Lower power but usable heat when the building needs it

Thermal energy balance

Energy input	kW	22.703
CAC Charged air cooler (Intercooler)	kW	3.713
Lube oil	kW	1.176
Jacket water	kW	1.199
Exhaust gas cooled to 180 °C	kW	3.036
Exhaust gas cooled to 100 °C	kW	4.383
Surface heat	kW	369

Exhaust gas data

Exhaust gas temperature at full load	°C [8]	355
Exhaust gas temperature at bmep= 18 [bar]	°C	~ 395
Exhaust gas temperature at bmep= 12 [bar]	°C	~ 432
Exhaust gas mass flow rate, wet	kg/h	56.463
Exhaust gas mass flow rate, dry	kg/h	52.994
Exhaust gas volume, wet	Nm³/h	44.591
Exhaust gas volume, dry	Nm³/h	40.275
Max.admissible exhaust back pressure after engine	mbar	60

HWT In (C)	HWF (L/s)	HWT Out (C)	Heat Extracted (kW)	CWT In (C)	CWF (L/s)	CWT Out (C)	Heat Rejected (kW)	Gross (kW)
150	40	125	4000	32	55	47	3450	300
		127.5	3547	55		70	3180	232
		128.1	3447	60		74	3104	216
		129.5	3241	68		85	2927	194

ACCOMPLISHMENTS – MODELING OF CHP – ORC SYSTEM

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CHP Test Case

- // Combining the power and heat rejected by the ORC
- // DOE targets are now met for Electric efficiency and CHP efficiency
- // Potential to have added flexibility and power output when the building does not need all the heat

JMS 920 GS-N.L								
% of Rated Output		Energy input (LHV)	Electrical output	CAC HT & CAC LT	Lube oil	Jacket water	Total recoverable thermal	Total CHP Efficiency
100%	Engine kW	22,703	10,377	3,713	1,176	1,199	6,088	
	ORC kW		232				3,180	
	Efficiency		45.7%				40.8%	86.5%
50%	Engine kW	12,315	5,189	1,261	1,011	837	3,109	
	ORC kW		160				2,192	
	Efficiency		43.4%				43.0%	86.5%

Any Questions?

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