Capstone Turbine Corporation • 21211 Nordhoff Street • Chatsworth • CA 91311 • USA
Telephone: (818) 734-5300 • Facsimile: (818) 734-5320 • Website: www.microturbine.com

Application Guide -

Model C60 Integrated CHP (ICHP)

This document presents application information for the Capstone C60 MicroTurbine with the Integrated CHP (ICHP) heat recovery module option.

Introduction

Capstone MicroTurbines are prime power generators, producing high quality, commercial-grade electric power. The C60 ICHP System offers an energy dense, small footprint, with clean exhaust and co-generation capabilities with complete control at the customer's fingertips. These characteristics allow for low installed cost, quick start-up and low maintenance costs. When applications require, Capstone manufactures heat recovery modules that meet ASME standards.

MicroTurbines can be used to produce power in parallel with a power grid (Grid Connect), to work as a Stand Alone generator, or to provide Dual Mode functionality. Due to this versatility, Capstone's C60 ICHP Systems can be applied in a variety of applications, and multiple units can be controlled as a MultiPac. They are currently used to provide continuous power to hotels, grocery stores, oil-field processing equipment, schools and office buildings, reliable off-grid power to data centers, telecom equipment and protected manufacturing processes.

This document describes the application of MicroTurbines and external equipment in a variety of power applications.

Table of Contents

Summary

The C60 Integrated CHP System (C60 ICHP) is an integrated single package that includes a high-pressure natural gas C60 MicroTurbine with a hot water heat exchanger mounted on the top. The C60 ICHP system is available in Grid Connect or Dual Mode versions, and includes an exhaust diverter and factory-installed modem.

The hot water thermal output depends on the position of the diverter (full heat recovery, full bypass, or any intermediate position), the temperature and flow of the exhaust gas from the MicroTurbine, and the inlet water temperature and water flow. The exhaust temperature and flow of the MicroTurbine depend on the ambient temperature, elevation above sea level, and electric power output. There is a minimum heat transfer to the hot water heat exchanger of about 10,000 BTU/hr (3kWt), regardless of diverter position and electric power output. This is due to a combination of conducted heat from the exhaust ducting and small amounts of exhaust leakage into the heat exchanger core. This requires continuous water flow whenever the microturbine is operating.

The nominal rated output at full heat recovery is 375,000 BTU/hr (110kWt) of hot water with the MicroTurbine operating at full 60kW electrical power output under ISO conditions, inlet water temperature of 140 °C (60 °F), and water flow of 40 gpm (2.5 l/s).

The following table provides general guidelines for how each of these variables impact the hot water thermal output:

Table 1. Thermal Output Variables

Variable	Change in Variable	Change in Thermal Output
Engine Power Output	Increase	Increase
Ambient Temperature	Increase	Increase (assuming constant power)
Hot Water Inlet Temp	Decrease	Increase
Water Flow Rate	Increase	Increase
Elevation	Increase	No Change (assuming constant power)

Detailed performance data is provided in the “Thermal Performance Curves” section below.

The C60 ICHP System provides flexibility to operate in several thermal and electrical modes, accepts analog and discrete control inputs, and provides discrete output signals. The MicroTurbine’s integral microprocessor control system reads and displays inlet and outlet water temperatures, and adjusts thermal or electrical output based on these measured temperatures or external analog control signals. The user can set modes of operation and read selected thermal information from the front panel or remotely using Capstone Remote Monitoring Software version 60C-CRMS-S (single unit) or 60C-CRMS-M (Multi Unit).

The system is UL listed to 2200 and 1741, and meets IEEE 519. The heat recovery system incorporates several safety features to prevent equipment damage, including an integral high temperature switch to shut down the MicroTurbine if heat exchanger core temperatures become too high, and a pressure relief valve to protect the core from excessive pressures. In addition, the integral control system performs several self-checks during startup, and monitors current draw from the diverter actuator to confirm proper operation.

Modes of Operation

There are three basic thermal operating (CHP) modes, as summarized in the table below:

Table 2. CHP Operating Modes

CHP Mode	**Grid Connect**	**Stand Alone**	**Description**
Thermal Priority	X	▨	The diverter is locked in the full heat recovery position. Electric power is automatically adjusted to control thermal output using measured water inlet, outlet or external temperature control signal. Temperature setpoint and feedback are controlled by the Master. This mode cannot be used in Stand Alone mode. If a Dual Mode unit has been set up to operate in Thermal Priority mode, it will automatically switch to Electric Priority mode when switched to Stand Alone operation, and switch back to Thermal Priority in Grid Connect mode.
Electric Priority (with Thermal Tracking)	X	X	In Grid Connect mode, electric power is controlled either as a fixed setpoint or using one of several electric load following schemes. In Stand Alone mode, the electric output is controlled by the connected load. The diverter is automatically adjusted to try to maintain the measured water inlet, outlet or external temperature control signal. Maximum available heat recovery will depend on the electric output.
Thermal Bypass	X	X	The diverter is locked in the full bypass position. A minimum amount of heat will still be recovered, but will not depend strongly on the electric power level. This is the default mode.

The most stable thermal tracking is achieved when the unit is grid connected and operating in the Thermal Priority mode. This method also keeps thermal and electric outputs in proportion, thereby preserving the total system efficiency. This may be important if specific overall system efficiencies must be maintained.

If electric output has higher value than thermal output, Electric Priority may be the best operating mode. When the electric power output is fixed in Grid Connect operation, the exhaust diverter will provide stable thermal tracking and will move to a stationary intermediate position when thermal loads are constant.

When the MicroTurbine is set to electrically load follow in Grid Connect mode, or when operating in Stand Alone mode, it may be forced to make constant electric power output adjustments as loads change. This will result in the exhaust diverter constantly adjusting its position to try to maintain the programmed thermal output. Therefore, when operating in Electric Priority mode under these load changing conditions, thermal output control may not be as stable as when set for a fixed electric output in Grid Connect mode. The system also may not be able to provide the expected thermal output, since electric power will be determined by load changes.

Another application consideration for operation in Stand Alone mode is the need for the water flow to be maintained. This may require that a pump or other flow controls be powered by the turbine output power.

Several C60 ICHP systems can be tied together using the Capstone MultiPac Cable Kits, allowing information to be shared between systems. The CHP modes and electric MultiPac operating modes are set independently, which provides application flexibility. However, not all possible combinations can be used. When a system is set to operate in Thermal Priority CHP Mode, it requires that the Master define the electrical output for the entire MultiPac group. Therefore, the thermal requirement will be measured, and setpoint tracking done, only by the Master. When MultiPac operation is enabled for a group that has been set to operate in Thermal Priority CHP Mode, the Local C60 ICHP systems are automatically programmed to reference the Master's temperature measurement and setpoint. If this is a Dual Mode unit, the same Master temperature measurement and Master setpoint will be used in Stand Alone mode. The table below summarizes how the systems are allowed to operate under different MultiPac scenarios. First choose the desired CHP Mode for grid connect operation - the corresponding CHP Mode for Stand Alone operation is then given in the table.

Unit Type	Grid Connect Operation			Stand Alone Operation	
	CHP Mode	Temperature Measurements and Setpoints		CHP Mode	Temperature Measurements and Setpoints
Grid Connect 60C-HG4-XXXX	Thermal Priority	Master Only		▨	▨
	Electric Priority with Thermal Tracking	Master or Local		▨	▨
Dual Mode 60C-HD4-XXXX	Thermal Priority	Master Only	⟺	Electric Priority with Thermal Tracking	Master Only
	Electric Priority with Thermal Tracking	Master or Local	⟺	Electric Priority with Thermal Tracking	Master or Local

MultiPac Operating Modes (MultiPac Enabled)

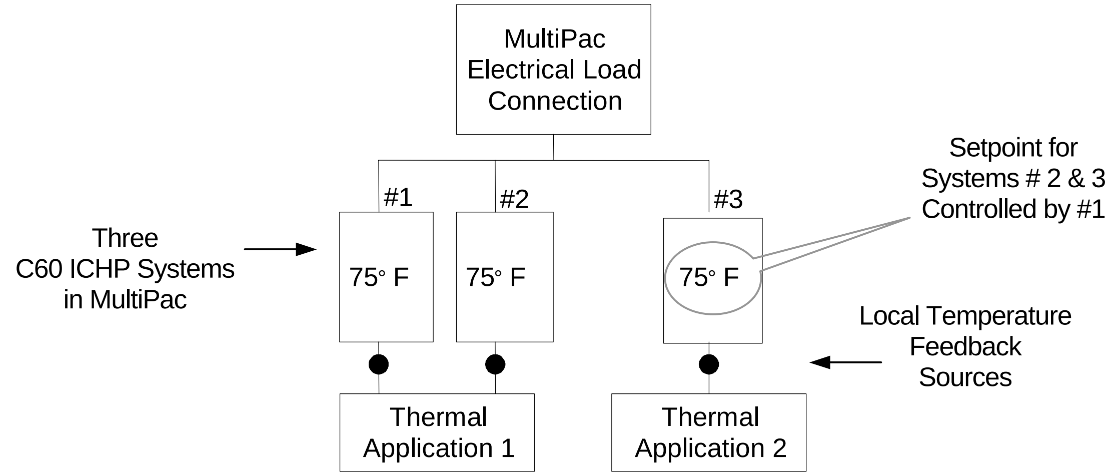
In the case that the MultiPac is disabled, it is still possible to read and set parameters for each system in the group using CRMS software, provided they are communicating through the MultiPac communications cable and the PC with CRMS software is connected to unit # 1.

The two examples below illustrate difference applications where the C60 ICHP Systems are MultiPac-enabled with one Master and two Local units:

Example 1 presents an instance where two separate applications using the same MultiPac output power require the same temperature setpoint but unique feedback sources.

Mode: Electrical Priority (Grid Connect or Stand Alone operation)
Settings: CHP Setpoint source – Master
CHP Feedback source – Local

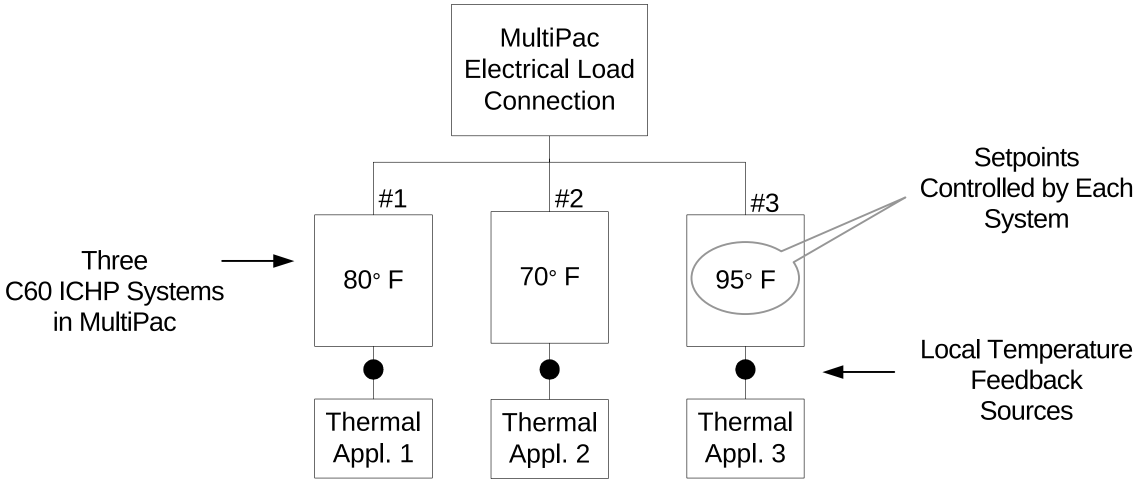
Scenario: Master controls water temperature setpoint for the entire MultiPac, but each C60 ICHP uses its own temperature feedback source. Note that each C60 ICHP System can be set to use its own inlet RTD, outlet RTD, or an external temperature sensor for its temperature feedback source.



Example 2 presents an instance where three separate applications using the same MultiPac output power require unique temperature setpoints and temperature feedback sources.

Mode: Electrical Priority (Grid Connect or Stand Alone operation)
Settings: CHP Setpoint source – Local
CHP Feedback source – Local

Scenario: Each C60 ICHP System uses its own temperature feedback source and temperature setpoint to control the output water temperature. Note that each C60 ICHP System can be set to use its own inlet RTD, outlet RTD, or an external temperature sensor for its temperature feedback source.



The C60 Integrated CHP System Technical Reference (410043) provides additional details on how to set up the C60 ICHP Systems to enable each of these MultiPac modes.

WARNING	Excessive water temperatures may result in personal injury and/or equipment damage. Follow good engineering practice in the design and installation of any hot water circuit, and consider the unique operating characteristics of the Capstone C60 Integrated CHP System as noted below.

The C60 ICHP System is designed to protect itself from excessive temperatures and pressures. However, it is the responsibility of the person(s) designing and installing the system to assure that resulting temperatures and pressures do not cause a safety hazard or damage other equipment. Several points should always be considered:

1. As a general precaution, the Over Temperature limits for each C60 ICHP System should be set to cause shutdown of the system when outlet water temperatures go above the safety and/or equipment damage levels for the specific application. Refer to the C60 ICHP System Technical Reference (410043) for setting these Over Temperature limits.

2. Temperatures should be monitored at points in the water circuit where excessive temperature may cause a safety hazard or damage equipment. Consideration should be given to automatically adjust power output, or even shut down the associated C60 ICHP Systems, if safe operating limits are exceeded.

3. For any MultiPac application where the Master is providing the temperature feedback signal, care should be taken to assure that this temperature signal is proper for the hot water output of all other C60 ICHP systems that are MultiPac-enabled under all possible operating scenarios. For example, if the water circuit for one of the Local C60 ICHP Systems is different than the water circuit for the Master, temperature feedback signals from the Master could result in continued heat addition from the Local C60 ICHP System that could result in safety and/or equipment damage issues. For water circuits that have taken this into account during normal intended operation, the potential for a water circuit to be inadvertently put into an unsafe condition must be considered (such as from valve and/or water pump failure or manual adjustment of valves or pumps).

4. For any MultiPac application where the Master is providing either the temperature feedback signal or the temperature setpoint for the entire MultiPac, the consequences of failure of the Master must be considered. The Capstone MultiPac logic is set up to control operation of the Local C60 ICHP units. Note that in Electric Priority mode, the Local C60 ICHP units will continue to provide hot water output at the last setpoint issued from the Master, which may provide more hot water than required. Means to avoid this situation must be included in the total system control scheme, such as by interlocking the Master with the Local units to cause them to shut down in the case of a failure of the Master.

   The following table describes the impact on local MultiPac-enabled units if the MultiPac Master fails:

CHP Mode	GC	SA	Impact on Local MultiPac-enabled Units if Master Fails
Thermal Priority	X	▨	Local units will shut down
Electric Priority	X	X	Local units will continue operating at the last commanded setpoint
Thermal Bypass	X	X	Local units will continue operating

Major System Components

Figure 1 shows the major elements in the C60 ICHP system heat recovery module. The MicroTurbine components provide the same functionality and control as the standard Capstone C60 high pressure natural gas system. The CHP system adds the following major elements:

1. Gas to Water Heat Exchanger – An efficient heat exchanger core is provided to extract energy from the MicroTurbine exhaust. It uses counter flow of exhaust and water to provide the maximum heat transfer. Standard construction is copper tubes with copper fins on the exhaust gas side.
2. Exhaust Gas Diverter – An exhaust gas diverter plate controls the amount of waste exhaust heat that passes through the heat exchanger. In the bypass position, nearly all of the MicroTurbine's exhaust is directed straight out, avoiding contact with the heat exchanger. Only a small amount (approximately 10,000 BTU/hr, or 3kWt) of the MicroTurbine's waste heat is transmitted into the water in the heat exchanger through conduction in the heat exchanger assembly and convection due to small amounts of exhaust leakage past the diverter. When moved to the full heat recovery position, the diverter forces most of the MicroTurbine exhaust through the heat exchanger. The diverter is also able to operate at intermediate positions, allowing part of the exhaust to flow across the heat exchanger. The diverter is driven by a linear actuator, which is controlled by the internal system logic and can modulate to provide "Thermal Tracking" independently of electric power output.
3. Linear Actuator – The linear actuator controls the diverter position, and receives its input command from the CHP Control Board. The actuator is rated for the high temperatures it may encounter near the heat exchanger and exhaust ducting.
4. CHP Control Board – Most of the CHP system inputs and outputs are monitored and controlled with the CHP control board assembly. This control board is an intelligent I/O module able to convert analog signals to digital values and communicate them to the MicroTurbine's main CPU using the Capstone internal RS 485 communications bus. It is also a power supply for the linear actuator, providing the current to drive the diverter between bypass and recovery positions.
5. Water Temperature Sensors – Resistive thermal device (RTD) sensors are mounted to the water inlet and outlet connections of the heat exchanger, and are read by the CHP Control Board. These measured water temperatures can also be read from the C60 MicroTurbine display.
6. Flow Switch – A water flow switch is provided on the heat exchanger outlet to confirm proper system operation. Its contact output is wired into the CHP Control Board. The flow switch will close its contacts to indicate water flow above about 1.3 l/s (20 gpm). If no flow is detected (flow switch contact open), the CHP Control Board will signal a fault condition, and the C60 MicroTurbine will shut down to prevent or limit over temperature damage to the heat exchanger core.
7. Safety Relief Valve – A pressure relief valve is installed at the water outlet to prevent damage to the heat exchanger core due to unexpected high pressure. The relief valve is set for 125 psi.

8. Thermostat – The system may also include a thermally activated switch to indicate over temperature of the heat exchanger core. If the temperature limit is reached, the switch contact will open, causing the CHP Control Board to signal a fault condition and shut down the MicroTurbine.
9. Optional Shutoff Valve and Pressure Sensor (External) – The CHP Control Board will accept a digital input from a pressure switch, and provide a 0.5A, 24Vdc output signal to control a shutoff valve. The terminals on the CHP Control Board have a jumper installed at the factory. Opening this jumper connection will cause a fault condition and shut down the MicroTurbine. To use the external pressure switch input, the jumper must be removed and pressure switch wired as a normally closed contact.
10. UCB Analog Inputs (not shown) – Terminal J14 in the UCB provides for analog control and measurement inputs. Three 0 to 5Vdc (4 to 20mA) inputs are provided. These can be defined during commissioning to represent electric power output control, external water temperature measurement (for thermal control), and water flow measurement.
11. UCB Control Output (not shown) – One of the six UCB digital output relay contacts can be used as control output for turning a water pump on and off. The 5Vdc output becomes active at lightoff (exhaust gas detected), and inactive at shutdown (no exhaust gas detected). This output will become inactive immediately in case of an E-stop command to the system.
12. Heat Recovery Unit Drain (not shown) – A drain connection is provided to allow excess moisture from condensation during start/stop sequences or small water leaks in the heat exchanger core or associated connections. The drain is capable of water flow rates of 0.13 l/s (2 gpm), and should be piped to a suitable building drain location.

NOTE: Refer to C60 Integrated CHP System Technical Reference (410043) for more details.

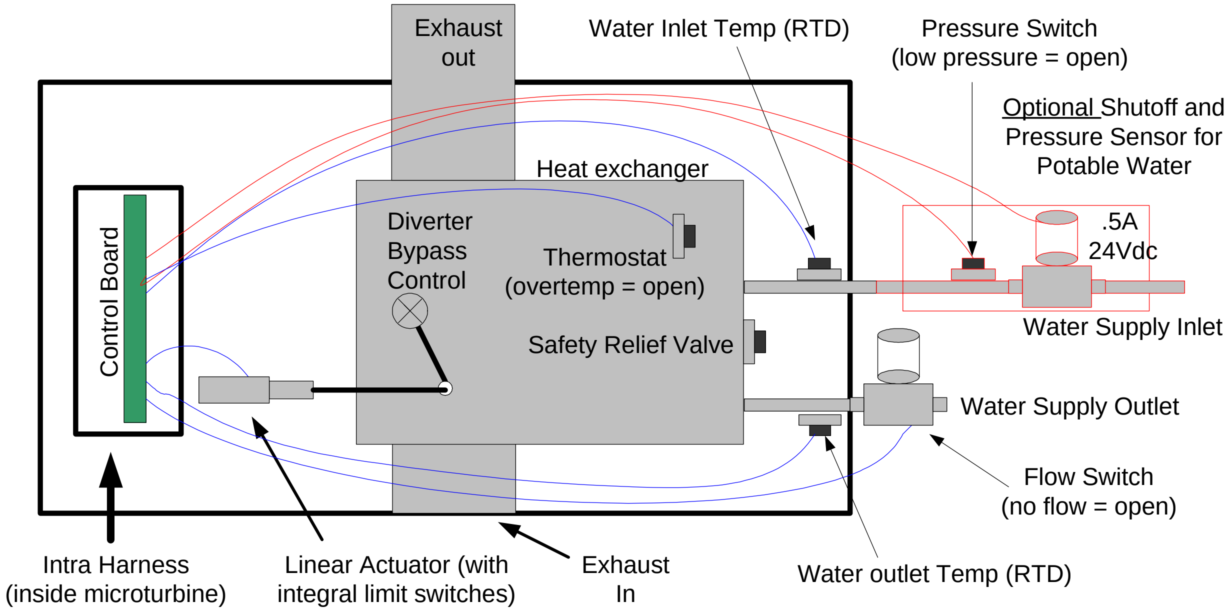


Figure 1 - Heat Recovery Module

Heat Exchanger Water Connections

In general, connections should be made to the C60 Integrated CHP System according to sound engineering practice and local building codes for hot water heaters. Galvanic isolation is suggested to prevent premature erosion of the heat exchanger and associated connections whenever any metals other than copper are part of the total water circuit (note that the heat exchanger is not warranted against such electro-chemical attack). Typically, shutoff valves would be added at the inlet and outlet to the heat recovery unit to facilitate maintenance. The C60 ICHP system includes a safety relief valve that must be connected to a suitable water drain. There is also a water drain for collecting condensation or water leaks from the heat exchanger core. This drain should also be plumbed to a suitable building drain. Refer to the Model C60 Integrated CHP System Technical Reference (410043) for more details on these thermal connections.

Water Specifications

The Capstone heat recovery module has been designed for operation with water and water/glycol mix (see Figure 2 for water flow requirements). Table 3 provides water quality requirements for reliable system operation. A water/glycol mix is also acceptable up to 50 percent glycol. It is strongly recommended that no other fluids or water flow rates be used directly in the heat recovery module, as corrosion or erosion may result which are not covered by Capstone's standard warranty. A suitable intermediate heat exchanger should be used to isolate the Capstone heat recovery module from chlorinated swimming pool water, salt water, or any other fluid not meeting the specification in Table 3.

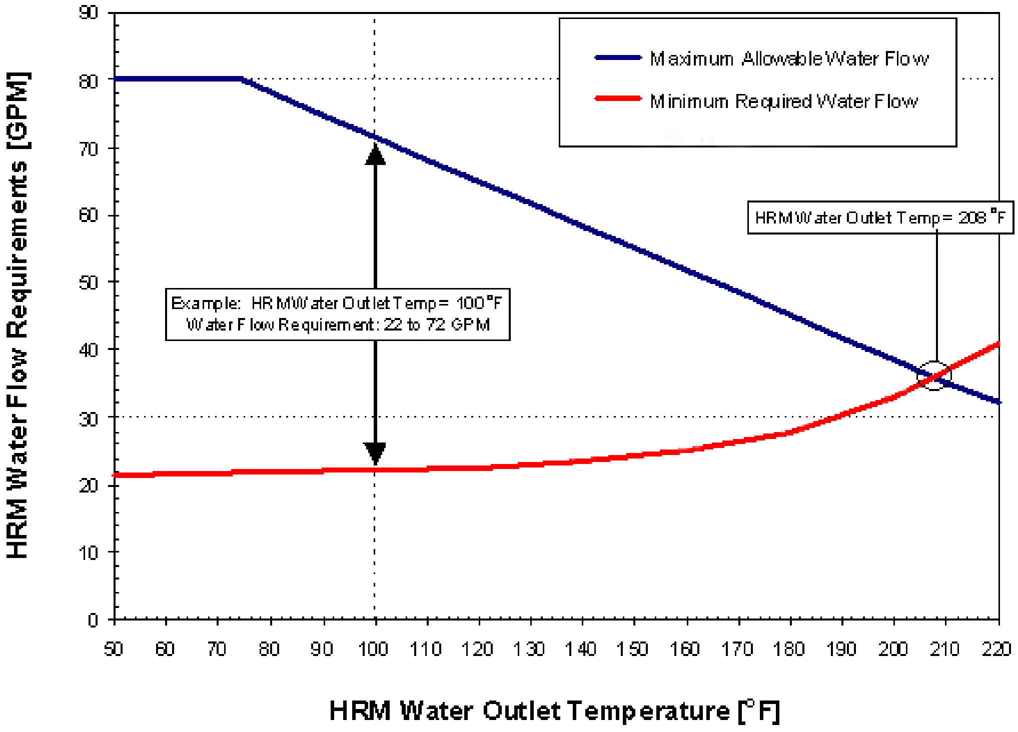


Figure 2. HRM Water Flow Requirements

When using water/glycol mixtures, the application must consider the lower heat transfer and higher pumping losses for the chosen fluid mix.

Keep in mind the ambient temperatures for each application. For water, the minimum ambient temperature should not go below 1.7 °C (35 °F). There is no freeze protection in the system, and therefore the heat recovery module and associated piping can be damaged if proper application is not followed. Damage due to freezing is not covered in Capstone's standard warranty.

Table 3. Water Quality Requirements

Item	Limits
pH (25C)	6.5 - 8.5
Electrical Conductivity (micS/cm)	800 or less
M Alkalinity (ppm)	100 or less
Chloride ion (mg Cl/l)	200 or less
Sulfuric acid (mg SO4/l)	200 or less
Total hardness (mg CaCO3/l)	200 or less
Total iron (mg Fe/l)	1.0 or less
Sulfur ion (mg S/l)	not detected
Ammonium ion (mg NH/l)	1.0 or less
Silica in ion state (mg SiO/l)	50 or less

Thermal Performance Curves

Thermal power output depends on several factors:

- ✓ Electric Power Output – The higher the electric output, the more thermal energy available in the exhaust gas, both in terms of temperature and mass flow rate,
- ✓ Ambient Temperature – For a given electric power output, higher ambient temperature also results in higher available exhaust energy,
- ✓ Water Inlet Temperature – As the water inlet temperature to the heat recovery system is lowered, more energy can be extracted from the MicroTurbine exhaust gas,
- ✓ Water Flow Rate – Within the allowable water flow rates, there is only a small variation in captured thermal energy due to changes in water flow rate. Slower flow rates mean higher water outlet temperatures, and thus slightly less captured thermal energy,
- ✓ Elevation –Thermal output de-rating is in proportion to the electric power de-rating at all ambient temperatures.
- ✓ Exhaust Backpressure – Increasing backpressure due to exhaust ducting results in minimal thermal output change.

The information in this section provides a means to calculate the expected thermal output under various conditions. While the expected tolerance range for thermal output at any given point is rather large (at most ±10%), the total system efficiency will have less variation since lower electrical efficiency means higher available exhaust energy, and vice versa. There is also a strong variation in expected thermal output depending on ambient temperatures and electric power output. Therefore, it is suggested that the thermal output be calculated as simply as possible for estimating performance and making economic projections. A procedure for estimating the electric and thermal output is given below. Table 4 at the end of this section summarizes the steps described below, and can be referred to as needed.

The starting point for estimating typical thermal output is to select the ambient temperature(s) at which the system is expected to operate. The Capstone product specifications are based on ISO conditions of 15 °C (59 °F) and sea level elevation, since this is the basis of electrical rating for the MicroTurbine. However, the system may be most needed at other temperatures. For example; for building heating an ambient of 35 to 40 °F may be most meaningful, while for application with an absorption chiller a 95 °F ambient may be a better basis for rating. Second, the typical inlet water temperature needs to be selected for the specific application.

Figure 3 shows the electric output and thermal outputs for several inlet water temperatures for a single C60 Integrated CHP system operating at full power and sea level elevation.

For example: using inlet water temperature of 140 °F at 60 °F ambient, the typical thermal output is 110kW. To convert to BTU/hr, multiplying by 3,413 BTU/kWh (i.e. 110kW ≅ 375,000 BTU/hr). At 40 °F ambient, the typical thermal output is 99kW (338,000 BTU/hr). At 90 °F, typical thermal output is 120kW (410,000 BTU/hr), and electric output is 56kW.

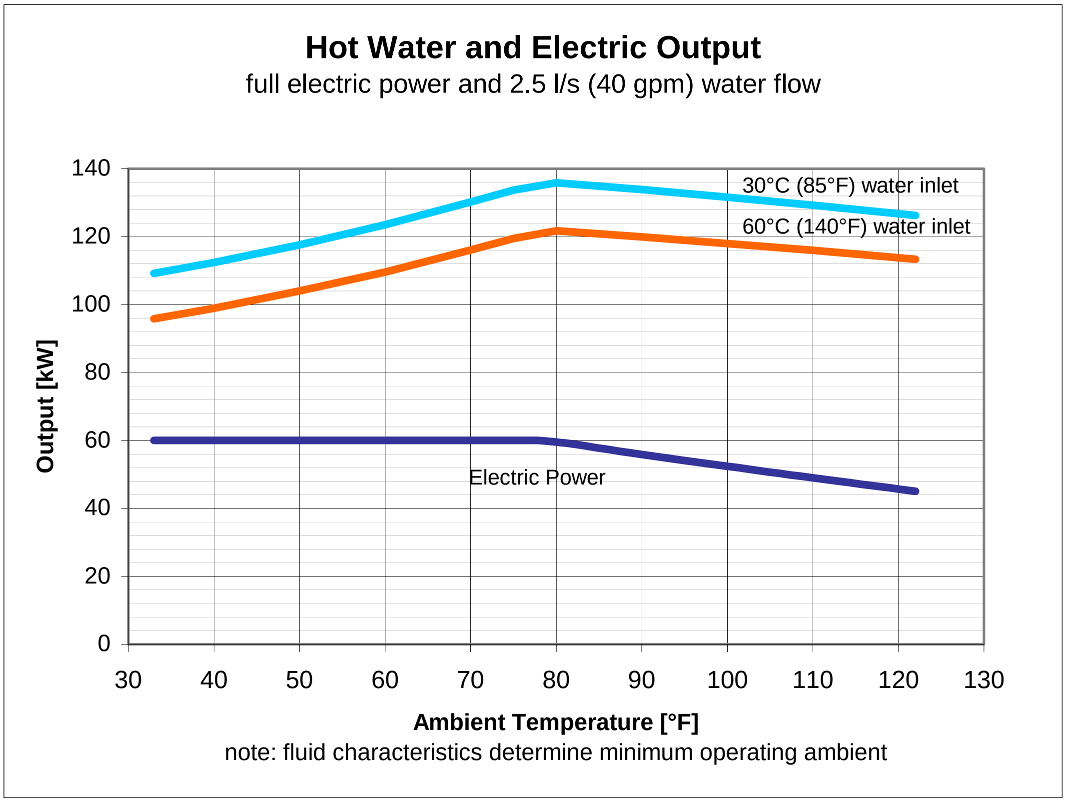


Figure 3 – Electric and Thermal Output vs. Ambient Temperature at Full Electric Power and Sea Level Elevation

Elevation above sea level has the effect of de-rating the maximum power output, both electric and thermal. The de-rating factor is provided in the C60 Performance Technical Reference (410005), and is slightly more than three percent per 1,000 feet above sea level. For example, using the 90 °F example above and elevation of 1,000 feet, the outputs would each be reduced by about three percent to 54.3kW electric and 116.5kW (398,000 BTU/hr) thermal.

For ambient temperatures above 80 °F, the electric power output will be reduced about .25% for each inch water column backpressure. Thermal output will not change significantly. Since maximum allowable backpressure is only 5 inches water column (after the integrated CHP heat recovery module), the maximum change in electric power output is only 1.25% for ambient temperatures above 80 °F with no change in the thermal output. Therefore correcting output values due to system backpressure may not provide significant improvement in accuracy of the calculated outputs. If a correction for backpressure is desired, the method described here can be used. For the 90 °F and 1,000 foot elevation example above with 5 inch water column backpressure, the 54.3kW electric becomes 53.6kW. The 116.5kW (398,000 BTU/hr) thermal output remains the same.

There is a small variation in the predicted thermal output depending on water flow rate. Figure 4 provides this correction factor for several different inlet water temperatures. As can be seen in this figure, the correction is at most only slightly more than two percent from the typical values for 2.5 l/s (40 gpm) above. Therefore, it is suggested to use this correction factor only for low flow rates combined with low inlet water temperatures.

For example, using the 140 °F inlet water temperature example above, at 20 gpm (1.3 l/s) the correction factor is slightly above the 130 °F curve shown in Figure 4, about .985 (or 1.5% lower than predicted for 40 gpm). Therefore, the predicted thermal output at 90 °F ambient with 20 gpm water flow changes from, 116.5kW (398,000 BTU/hr) to 115kW (392,000 BTU/hr).

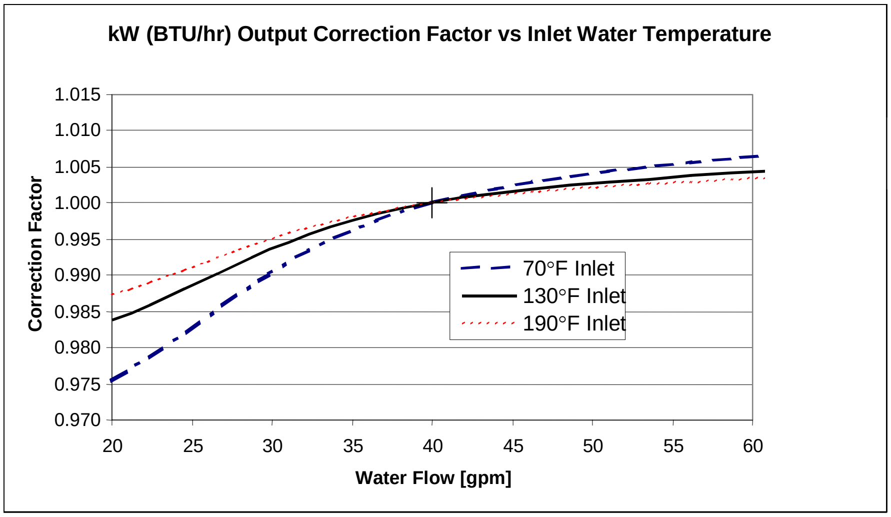


Figure 4 – Correction Factor for Thermal Output vs Water Flow

Once the net thermal output has been calculated for the selected ambient and inlet water temperatures (and corrected if needed for water flow rate and elevation), the water outlet temperature can be easily calculated using the equation below. The specific heat capacity and density of water are both relatively constant over the allowable temperature range of 70 to 220 °F, and their product is within ± .7% using a 160 °F nominal inlet water reference temperature. Therefore, the following simple equation is a highly accurate method for estimating the temperature rise for any water-based heat recovery system when the thermal input is known:

$$\text{Temperature Rise } [^{\circ}\text{F}] = 6.9 \text{ X } \frac{\text{Thermal Output [kW]}}{\text{Water Flow [gpm]}}$$

Continuing to use the 90 °F ambient temperature example above for 140 °F inlet water temperature, the thermal output of 115kW at 20 gpm water flow provides a temperature rise of 39.7 °F.

While the previous calculations have been based on the full power output from Figure 3, the effect of partial load operation can also be estimated if necessary. The operating scheme for the MicroTurbine is to try to maintain turbine outlet temperature by varying turbine speed (and therefore exhaust mass flow) as power requirements change. If turbine efficiency remained constant as power output decreased, a linear relationship for thermal output would follow; that is, if the MicroTurbine were operating at half power, the thermal output would likewise be half its full power output.

This is almost the case down to about 50% power output for the C60 MicroTurbine, so as a first approximation simply ratio the thermal with the electric output. For less than 50% electric power output, the ratio of thermal output to electrical output will increase. However, a conservative thermal output can be estimated by using the same thermal to electric output ratio for all power levels.

The following table provides a guide process and example for calculating maximum thermal and electric power output and associated water temperature rise for a given application:

Table 4. Electric and Thermal Output Calculations

Steps	Rule	Example*
1. Estimate maximum electric and thermal output for given ambient and inlet water temperature	Use Figure 3	56kW electric 120kW thermal
2. Correct for Elevation	Electric output de-rated per C60 Performance Technical Reference (410005) Thermal de-rating in proportion to Electric de-rating	3% electric de-rating 3% thermal de-rating
3. Correct for Backpressure	Electric Output de-rated .25% per inch WC above 80° F ambient	1.25% electric de-rating
4. Correct for Water Flow	Use Figure 4	1.5% thermal de-rating
5. Total Electric and Thermal Output Corrections	Sum Electric and Thermal Correction Factors from Steps 2 - 4	4.25% electric de-rating 4.5% thermal de-rating
6. Correct Electric and Thermal Outputs	Correct initial estimates from Step 1 using Step 5	53.6kW electric 115kW Thermal
7. Estimate Temperature Rise for given Water Flow	Use equation: 6.9 times Thermal Output [kW] divided by Water Flow [gpm]	39.7° F

NOTE: * 90 °F Ambient, 140 °F inlet water, 20 gpm, 1,000 foot elevation, 5 inch WC backpressure

The above analysis is for water. The system can accept up to 50% water glycol mix, with slight change in the captured heat and water temperature rise. As an example, a 30% propylene glycol mix was analyzed for a 140 °F inlet temperature and 32 gpm water flow with the following results (exhaust input energy constant):

Water – 409,000 BTU/hr and temperature rise of 25.6 °F

30% Glycol – 397,000 BTU/hr and temperature rise of 26.4 °F

Water System Curves

The C60 ICHP heat exchanger is designed for low water pressure drop. Figure 5 provides the pressure drop, in feet of water head, versus water flow rate.

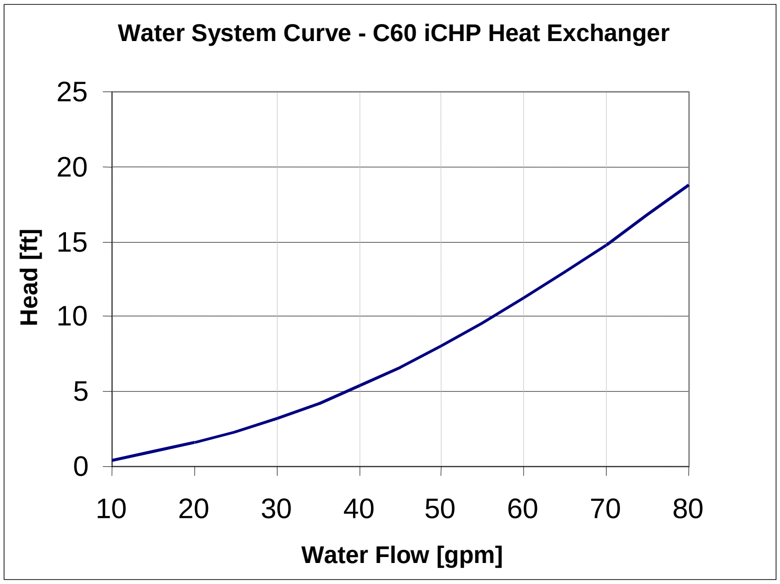


Figure 5 – Heat Exchanger Water Pressure Drop

Choose a pump suitable for the total water system drop, including the heat exchanger, associated piping, and any intermediate heat exchanger or other water circuit equipment. Figure 6 provides an example of how to size a pump for a given water circuit. For the example given, the selected pump will provide 52 gpm water flow.

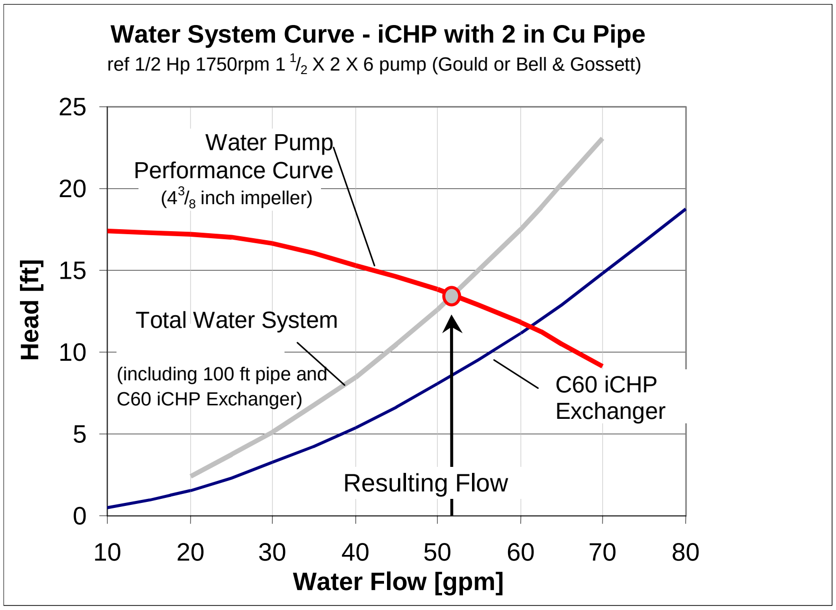


Figure 6 – Example System Curve

Exhaust Ducting Requirements

The C60 ICHP system package has been designed for indoor or outdoor application. An outdoor exhaust flapper is included as standard, so for most outdoor applications no additional exhaust ducting will be required. For indoor application, or outdoor applications requiring duct extensions, suitable insulated exhaust ducting will be required.

Several factors must be considered when designing suitable exhaust ducting:

1. Backpressure – Exhaust ducting must be pressure rated, and properly sealed to avoid buildup of toxic exhaust fumes. The C60 ICHP system's MicroTurbine will provide positive exhaust flow under normal operation. However, the exhaust system must limit backpressure to no more than 5 inches of water column under all operating conditions. Nominal exhaust flow rate at full power is 425 l/s or 900 standard cubic feet per minute (scfm). This is roughly 1,700 cfm when adjusted for temperature. The exhaust outlet of the C60 ICHP system is 10-inch diameter. Guidance for backpressure calculations is available from ducting manufacturers. If the system design includes a backflow damper (ref item 5 below), use 0.7 inches of water column as the estimated forward pressure drop across the damper.

2. Temperature Rating – At full power and without heat recovery, the nominal exhaust temperature of the C60 ICHP is less than 600 °F. However, during transient conditions and/or high ambient temperature operation, the exhaust can reach 700 °F. Therefore, exhaust ducting must be rated for at least 700 °F. In addition, sufficient thermal insulation should be provided to avoid hazards to personnel or buildings due to contact with high temperature exhaust ducting. As a reference, double wall stainless steel ducting with 2 to 4 inch ceramic fiber insulation is a general-purpose solution. However, specifics of the application must be considered when designing a proper installation.

3. Condensation – While the exhaust system needs to be capable of the maximum temperature noted above, normal heat recovery operation reduces the exhaust temperature considerably. Therefore, the potential for condensation of moisture in the exhaust must be considered in any ducting system. For short runs to direct exhaust outside (for example through a single story roof or to elevate slightly the point of exhaust in an outdoor installation), and when the ICHP system is not switched on and off frequently, it may not necessary to make any accommodation for condensation. However for any other application, it is suggested that the exhaust ducting include means to capture any condensation and direct it away from the top of the ICHP system exhaust. Figure 7 shows a typical exhaust arrangement using an offset with drain.

4. Weight – The C60 Integrated CHP System can accept a maximum load on the 10-inch exhaust outlet of 25 lbs. When designing any exhaust ducting arrangement, suitable supporting means must be included to avoid damage to the heat exchanger structure of the C60 ICHP. Using an offset, as shown in Figure 7, is one way to avoid high loading.

5. Common Exhaust Ducting – Exhaust from several MicroTurbines cannot be brought to a common duct system without considering the impact of reverse exhaust flow. If one MicroTurbine is not operating, exhaust from the common duct will flow back into the non-operating unit. This condition will elevate temperatures in the non-operating unit, causing potentially expensive equipment damage. If the non-operating unit is located indoors (or other area with restricted ventilation), toxic exhaust fumes can build up, causing a safety hazard for anyone in the area. Therefore, means to prevent backflow must be provided for in the exhaust ducting system design. One method to avoid reverse flow is to add an exhaust fan so that the common exhaust duct is always at negative gauge pressure. High temperature induction type exhaust fans are suitable for the potentially high exhaust temperatures, and must be interlocked with the MicroTurbines to assure that no MicroTurbine is operating if the fan is not. An alternative is to use a suitable exhaust backflow damper. Capstone offers backflow dampers with a maximum reverse flow of 0.1%, which are designed to prevent over-temperature damage to a non-operating MicroTurbine. The total system design must still consider the impact that even this small amount of reverse flow exhaust may have on any enclosed location. Currently, the largest backflow damper offered by Capstone has an 8 inch diameter. The exhaust duct can be reduced to 8 inches for the damper as well as downstream ducting, provided exhaust pressure calculations are performed to ensure compliance with the maximum allowable 5 inches water column backpressure at the C60 ICHP exhaust.

(Complete Ducting and Support Structure not shown)

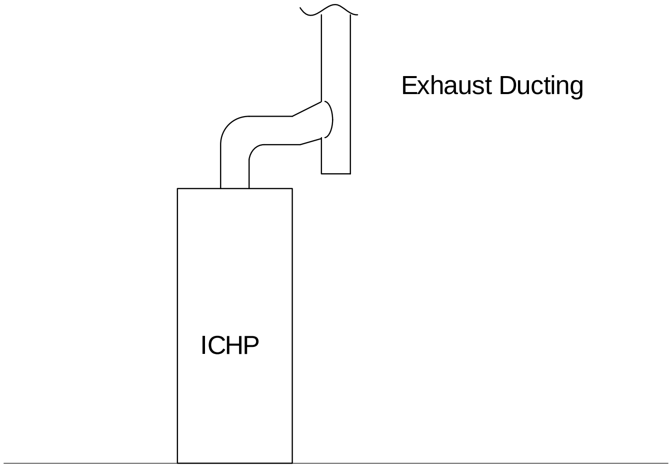


Figure 7 – Exhaust Ducting with Offset for Condensation

Application Examples

This section presents several application examples.

Boiler Feedwater Preheat

The simplest application is to use the C60 ICHP system as a pre-heater for boiler feedwater return. Figure 8 shows an example. One way to control this installation is to have the C60 ICHP track its inlet water temperature, with a setpoint slightly lower than the Boiler's control setpoint. When the building load requires heat, the C60 ICHP system will be the first system to respond, with the boiler only turning on if the CHP system cannot supply sufficient heat.

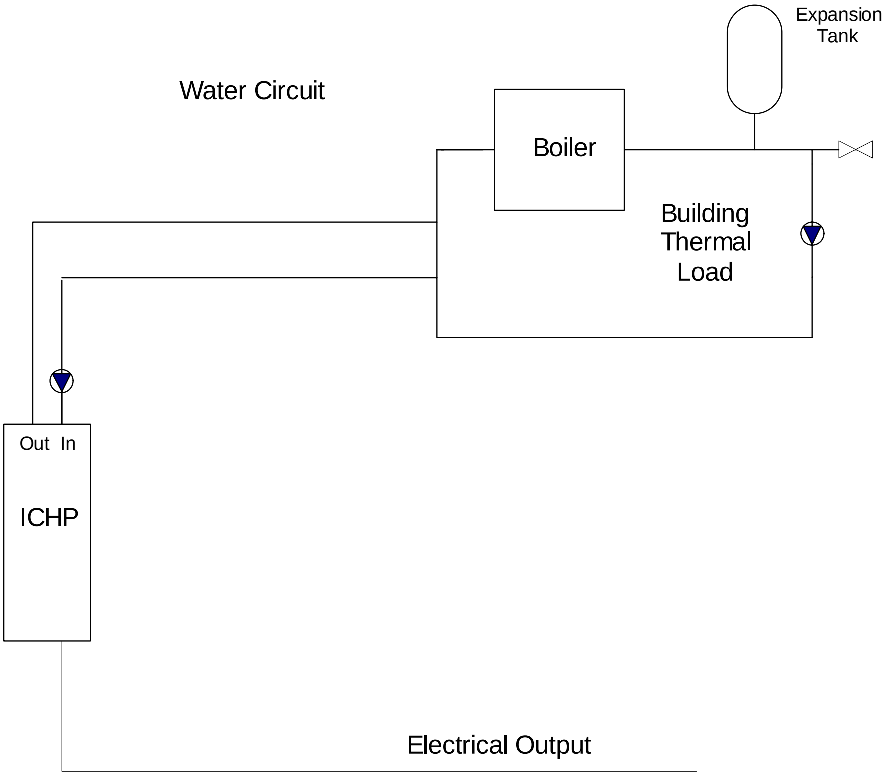


Figure 8 – Boiler Feedwater Preheat Application Example

Use of Intermediate Heat Exchanger

For applications where the building water circuit is not compatible with the C60 ICHP system's copper heat exchanger material, an intermediate heat exchanger can be used to isolate the two water circuits as shown in Figure 9. This example shows how temperature can be controlled at an external point – in this case at the inlet to the intermediate heat exchanger.

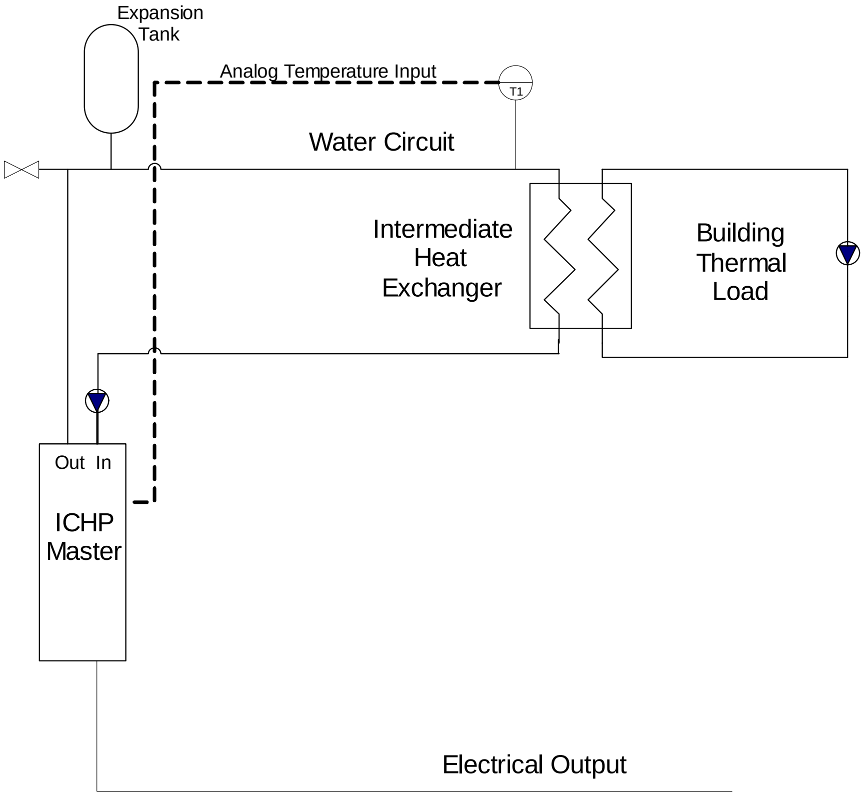


Figure 9. Intermediate Heat Exchanger Application Example

Absorption Chiller

Combining the C60 ICHP system with absorption chillers provides high efficiency cooling for buildings or processes. The example in Figure 10 shows two C60 ICHP systems feeding their hot water output to a single hot-water-fired chiller. In this example, the chiller provides a 4-20 mA (or 0 to 5Vdc) control signal or an external temperature sensor input to both C60 ICHP systems to regulate their thermal output. Each ICHP system will then adjust its respective thermal output to try to match the control signal or external temperature setpoint. In this way, the chiller is acting as the master to control thermal input to meet changing building thermal load requirements. Note that means must be included in the water circuity to assure that the water flow in each C60 ICHP heat exchanger remains within the 20 to 60 gpm useable range (in this example, separate pumps are used for each C60 ICHP System).

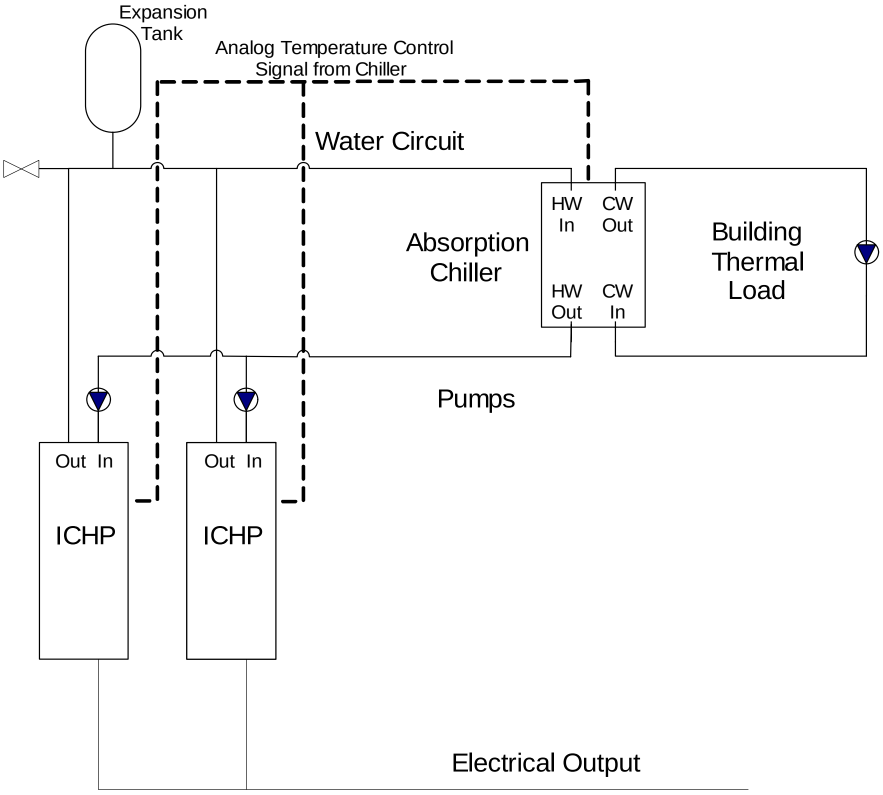


Figure 10. Absorption Chiller Application Example

Related Documentation

The following table lists applicable Capstone documentation.

Document No.	Document Title
400000	Capstone MicroTurbine Users Manual
410005	Capstone Model C60 Performance Technical Reference
410043	Capstone Model C60 Integrated CHP System Technical Reference
460025	Capstone C60 Integrated CHP System Product Specification

Capstone Technical Information

If questions arise regarding ICHP operation for your Capstone MicroTurbine, please contact Capstone Turbine Technical Support for assistance and information.

Capstone Technical Support
Toll Free Telephone: (877) 282-8966
Service Telephone: (818) 407-3600 • Fax: (818) 734-1080
E-mail: service@capstoneturbine.com

Capstone Technical Support (Japan)
Service Telephone: (818) 407-3700 • Fax: (818) 734-1080
E-mail: servicejapan@capstoneturbine.com