CO_2 Heat Pump Water Heater For Residential Pools Field Study ***Final Draft*** Metering Plan

Prepared by:
Ecotope, Inc.

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Introduction

This project seeks to answer the technical questions associated with using a Sanden CO_2-refrigerant system as an integral part of a residential swimming pool heating system. The test site is located near Spokane, WA and currently utilizes an electric-resistance pool heater. The Sanden system will have nominal capacity of about 15,000 Btu/hr and is a packaged heat pump that will be sited adjacent to the pool's mechanical room. Ecotope, Inc. was asked to assist Bonneville Power Administration with this project based on extensive experience with M&V and with similar heat pump water heater systems.

The project will assess the heating contribution from the Sanden, calculate an in-situ COP (including the electric resistance boiler contribution), and access the data logging platform remotely via cellular connection. Bonneville Power Administration has already collected several months of data for the pre-existing heating system, including flow rates of the main circulation pump and water temperature measurements. The new system design will incorporate a parallel heating loop (so that adjustments will not affect the existing pool function) but after the system is fine-tuned, the intention is that a direct comparison of before/after COP can be made.

The project will also document various challenges to the system design (which will be original), system installation, and system fine-tuning. The intent is to gather enough data and installation experience to inform future projects of this sort.

This metering plan describes the data collection process for each platform, including the sensors required, data logging platform, and metering interval. Additional details related to the project's success are also outlined.

Project Scope

This study will measure, in real time, operating temperatures and flows at various points in the system, as well as measure true (RMS) power of the heat pump, back-up heat system (where applicable), and circulation pump energy. The metering systems will be left in place for at least six months so that seasonal effects can be assessed. Initial installation of the new system and M&V components is expected to take place in October, 2016. All metering equipment will be installed by Ecotope personnel in concert with licensed, bonded plumbers and electricians. Bonneville and Ecotope each curate a large inventory of metering gear and will coordinate provision of this gear to the installers.

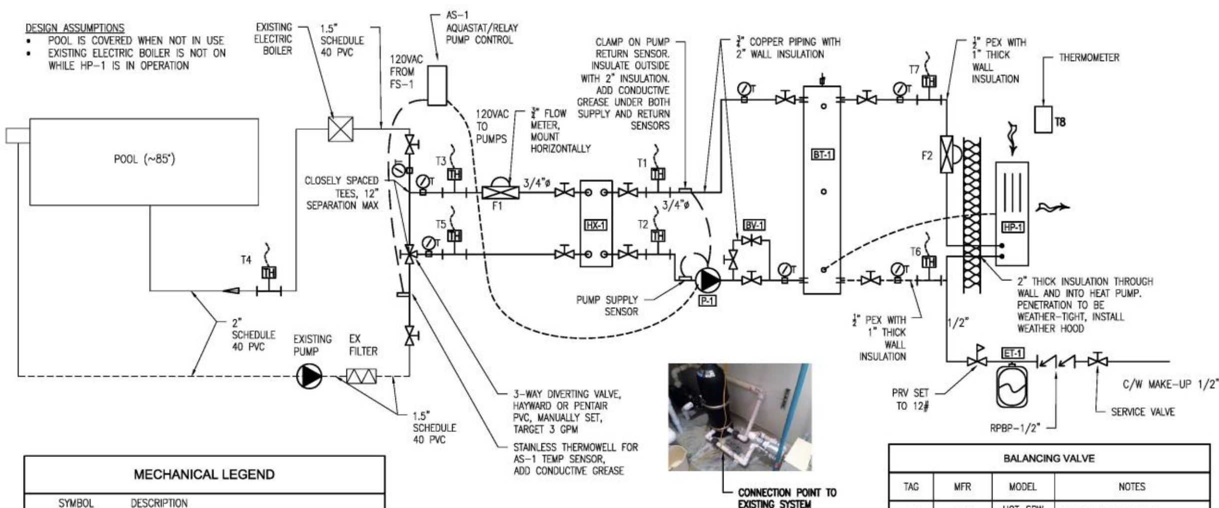
General Equipment and Metering Notes

The data logging platform for this project will be the Onset Computing RX3003. This durable logger has a 4G cellular data connection (four to six daily data uploads to a secure site) and supports up to 15 data channels via RJ plugs. Temperatures will be measured with Onset sensors or Onset A/D converters connected to Veris wettable thermistors. Pool water flow will be measured with an EKM stainless steel meter that provides pulse output to Onset pulse adapters. Water flow in the Sanden loop will be measured with a Minol Minomess 130 flow meter with pulse output. Electricity usage will be measured with a combination of split-core current transformers, Continental Control System WattNodes, and Onset pulse adapters. This is a wired system, so each site will require installation of extension wire (CAT5 or CAT6). Readings will be taken every 10 seconds and averaged over each minute.

Metering Schematic

The Sanden system is a packaged unit (nominal capacity 15,000 Btu/hr) that is installed outside the house, near the pool mechanical room. The system gathers heat from outside air via the refrigeration cycle and transfers this heat to an indirect storage tank (BB-80 on Figure 1) located inside the house. This tank then feeds hot water to the swimming pool loop via a flat plate heat exchanger (HX-1); a variable speed circulating pump (P-1) controls the rate of heat transfer. Downstream of the heat exchanger, the water can be further heated as necessary by the existing electric boiler before it enters the pool. An existing pump feeds pool water through a pool filter; this system will remain and adjustment of the current flow rate may be needed through use of a diverting valve to optimize system performance. (The existing heating/filtration system will interface with the new Sanden loop via a 3-way diverting valve, which can be manually adjusted.)

The data collection scheme (next page) currently includes 15 measured points. See the following section, which includes a discussion of COP calculation, for more insight.



BASIS OF DESIGN:

THE SANDEN CO2 HEAT PUMP WATER HEATER PILOT WILL AIM TO HEAT A SMALL INDOOR SWIMMING POOL WITH A CO2 BASED HEAT PUMP WATER HEATING SYSTEM. THE EXISTING POOL PUMP AND POOL HEATING SYSTEM SHALL REMAIN IN PLACE. THE PROPOSED RETROFIT SHALL PLUG INTO THE EXISTING SUPPLY PIPING BETWEEN THE FILTER AND RESISTANCE HEATER AS SHOWN IN THE SCHEMATIC. PIPING SHALL CONNECT TO PRIMARY LOOP ASSUMING CLOSELY SPACED TEES (12" SEPARATION MAX).

THE SANDEN CO2 HEAT PUMP IS ONLY RATED AT 15,000 BTU/HR (4.4 KW) OUTPUT, THE EXISTING ELECTRIC BOILER IS RATED AT 18 KW.

THE CO2 HEAT PUMP PLANT SHALL USE A BOILER BUDDY STORAGE TANK AS THE CONTROL TANK FOR CYCLING CONTROL OF THE SANDEN CO2 HEAT PUMP. THE BOILER BUDDY INCLUDES 3 THERMOWELLS, THE SANDEN SENSOR SHALL BE LOCATED IN THE BOTTOM THERMOWELL AND PACKED IN WITH CONDUCTIVE GREASE PER INSTALLATION REQUIREMENTS. THE LOAD SIDE OF THE BOILER BUDDY SHALL PIPE THROUGH A FLAT PLATE HEAT EXCHANGER AS SHOWN. THE HEAT EXCHANGER PUMP (PUMP-1) IS A VARIABLE SPEED PUMP AND SHALL BE SETUP TO CONTROL FLOW RATE BASED ON DISCHARGE WATER SUPPLY TEMPERATURE (100°F) TO THE BOTTOM OF THE BOILER BUDDY TANK. INSTALL BOTH TEMP SENSORS FOR ALTERNATE DELTA T CONTROL FOR FUTURE. THE PIPE SENSORS THAT ARE PART OF THE PUMP CONTROLS SHALL BE MOUNTED ON CONDUCTIVE PIPING USING ZIP-TIES PROVIDED, ADD CONDUCTIVE GREASE UNDER SENSORS AND INSULATE PIPE AROUND SENSORS WITH SLEEVE. BOTH PUMP-1 CONTROL MODES SHALL BE SETUP FOR THIS PILOT TEST. A BYPASS CIRCUIT SETTER IS PROVIDED IN CASE WE NEED ADDITIONAL PRESSURE FOR THE LOW FLOW SCENARIOS.

THE POOL SIDE OF THE HEAT EXCHANGER PIPING IS POOL WATER AND FLOW IS ASSUMED TO USE THE PRIMARY EXISTING POOL CIRCULATION PUMP. A DIVERTING VALVE SHALL BE SETUP ON THE INTAKE SIDE OF THE HEAT EXCHANGER POOL LOOP AND SHALL MANUALLY DIVERT ROUGHLY 3 GPM OF THE PRIMARY POOL WATER FLOW THROUGH THE HEAT EXCHANGER. FIELD MEASUREMENTS AND OBSERVATIONS MAY REQUIRE ADJUSTING FLOWS.

ALL PEX PIPING SHALL BE INSULATED WITH 1" THICK WALL INSULATON. ALL COPPER PIPING SHALL BE INSULATED WITH 2" THICK WALL INSULATION. ALL POOL WATER PIPING AND COMPONENTS SHALL BE SELECTED TO BE SUITABLE FOR USE WITH POOL WATER.

MECHANICAL LEGEND

SYMBOL	DESCRIPTION
	PUMP
	SERVICE VALVE
	PRESSURE REDUCING VALVE
	REDUCED PRESSURE BACKFLOW PREVENTION VALVE
	TEMPERATURE GAUGE (PERMANENT)
	AIR DIRECTION
	IMMERSION THERMISTOR (RESEARCH)
	FLOW METER
	DIRECTION OF FLOW
HP-1	EQUIPMENT TAG
	LINE VOLTAGE LOW VOLTAGE
	EXPANSION TANK

EXPANSION TANK

TAG	MFR	MODEL	NOTES
ET-1	AMTROL	THERMXTROL ST-8	

M&V POINTS

ITEM NUMBER	DESCRIPTION	MEASUREMENT
T1	HX-HP SUPPLY TEMP	WATER TEMPERATURE (DEG F)
T2	HX-HP RETURN TEMP	WATER TEMPERATURE (DEG F)
T3	EB INPUT TEMP	WATER TEMPERATURE (DEG F)
T4	POOL INPUT TEMP	WATER TEMPERATURE (DEG F)
T5	HX-POOL RETURN TEMP	WATER TEMPERATURE (DEG F)
T6	HEAT PUMP INPUT TEMP	WATER TEMPERATURE (DEG F)
T7	HEAT PUMP OUTPUT TEMP	WATER TEMPERATURE (DEG F)
T8	OUTSIDE AIR TEMP	AIR TEMPERATURE (DEG F)
T9	POOL ROOM TEMP	AIR TEMPERATURE (DEG F)
RH1	POOL ROOM RELATIVE HUMIDITY	MASS PER UNIT VOLUME (%)
F1	POOL SIDE LOOP WATER USAGE	GALLONS PER MINUTE (GPM)
F2	SANDEN WATER LOOP FLOW	GALLONS PER MINUTE (GPM)
E1	HEAT PUMP ELECTRICITY USAGE	RMS ENERGY, SINGLE PHASE 208 VAC
E2	ER HEATER ELECTRICITY USAGE	RMS ENERGY
E3	VARIABLE SPEED PUMP (P-1) ELECTRICITY USAGE	RMS ENERGY, SINGLE PHASE 115VAC

BALANCING VALVE

TAG	MFR	MODEL	NOTES
BV-1	B&G	CB-1/2S LF	CIRCUIT SETTER. USED FOR ADDITIONAL PRESSURE IN LOW FLOW SCENARIOS

BALANCING VALVE

TAG	MFR	MODEL	NOTES
F1	EKM	HOT-SPW M-075	MOUNT HORIZONTALLY
F2	MINOL	MINOMESS 130	

HEAT EXCHANGER

TAG	MFR	MODEL	LOAD (BTU/H)	FLUID FLOW RATE (HP SIDE/POOL SIDE)	PRESSURE DROP (HP SIDE/POOL SIDE)	NOTES
HX-1	KELVION	MPN5X12-6	15,000	0.6/3 GPM	0.3/3.2 PSI	

PUMP

TAG	MFR	MODEL	DESIGN FLOW (GPM)	DESIGN HEAD PRESSURE (FT)	VOLTAGE/ PHASE	NOTES
P-1	TACO	00E SERIES VT2218	0.6	5	115/1	

AQUASTAT

TAG	MFR	MODEL	MAX TEMP (°F)	MIN TEMP (°F)	VOLTAGE	NOTES
AS-1	JOHNSON CONTROLS	PENN A419	212	-30	120	

STORAGE TANK

TAG	MFR	MODEL	CAPACITY (GALLONS)	NUMBER OF SENSOR WELLS	NOTES
BT-1	HOT WATER PRODUCTS INC	BB-50	50	3	

HEAT PUMP WATER HEATER

TAG	MFR	MODEL	HEAT CAPACITY (BTU/H)	VOLTAGE /PHASE	NOTES
HP-1	SANDEN	GUS-A45HPA	15,000	208/1	

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PROJECT
SANDEN POOL HEATING
SPOKANE, WASHINGTON

DATE 9/7/16
REVISIONS

SHEET TITLE
SANDEN POOL HEATER SCHEMATIC - 95% CD

SHEET NO.
M1.0

Table 1. Test Points of Sanden System

Test point (see diagram)	Sensor Type	Sensor	Location	Notes
T1	Water temp	Onset A/D plus Veris wettable thermistor	HX-1 supply temperature (heat pump side)	Output from BT-1
T2	Water temp	Onset A/D plus Veris wettable thermistor	HX-1 return temperature (heat pump side)	Return to BT-1
T3	Water temp	Onset A/D plus Veris wettable thermistor	EB inlet temperature	
T4	Water temp	Onset A/D plus Veris wettable thermistor	Pool inlet temperature	Downstrm of EB
T5	Water temp	Onset A/D plus Veris wettable thermistor	Return leg from pool	
T6	Water temp	Onset A/D plus Veris wettable thermistor	Sanden water loop input (return) temperature	
T7	Water temp	Onset A/D plus Veris wettable thermistor	Sanden water loop output temperature	
T8	Air temp	Onset A/D plus Veris wettable thermistor	Sanden evaporator entering air temperature	Shield from sun and rain
T9	Air temp	Onset smart sensor	Pool room temp	
RH1	Relative humidity	Onset temp/RH sensor	Pool room RH	
F1	Flow	EKM HOT SPWM-075	Flow of heated water downstream from flat plate heat exchanger	Stainless meter, ¾" fitting, pulse output (use Onset pulse adapter)
F2	Flow	MInol Minomess 130	Sanden water loop flow	Pulse output (use Onset pulse adapter)
E1	RMS energy	Dent or Magnelab split core CT (50 A)	In electrical panel or at mech room subpanel; Sanden heat pump circuit	Wire as 120 vac device (cross conductors through single CT); use one channel of CCS WattNode (3P output). Requires Onset pulse adapter.
E2	RMS energy	Dent or Magnelab split core CT (100 A)	In electrical panel or mech room subpanel; hot water boost heater.	Wire as 120 vac device (cross conductors through single CT); use one channel of CCS WattNode. (3P output). Requires Onset pulse adapter.
E3	RMS energy	Dent or Magnelab split core CT (50 A)	Heat exchanger circ pump (P-1 on schematic) In electrical panel or may have to pick up at pump.	120 vac device; use one channel of CCS WattNode. (3P output). Requires Onset pulse adapter.

Discussion of Coefficient of Performance Calculation and Data Points

The selection of test points, both temperature and flow, enable calculation of system COP over various time intervals. The contribution of both the Sanden and existing electric boiler are part of the calculation.

COP = Energy Out / Energy In = Q_{out} / Q_{in}

$Q_{in} = Q_{in,Sanden} + Q_{in,electric\_boiler\ (EB)}$

$Q_{out} = Q_{out,HX} + Q_{out,EB}$

$Q_{out,HX} = m_1 c_p (T3-T5)$ [where m1 equals mass flow from heat exchanger and cp is heat capacity of water]

$m_1 = FM1 * \rho$ [F1 is flow through the HX flow meter; ρ is density of water]

$Q_{out,HX} = Q_{in,HX} = Q_{out,Sanden}$

$COP_{Sanden} = Q_{out,Sanden} / Q_{in,Sanden}$

$Q_{out,EB} = m_2 c_p (T4-T3)$

$m_2 = FM3 * \rho$ [note that this is an optional flow measurement; there is no third flow meter in Figure 1 – we can do without it we note the following relationship:]

$Q_{out,EB} = Q_{in,electric\_boiler}$ [this is true because COP of EB = 1]

COP = Energy Out / Energy In = Q_{out} / Q_{in}

$= (Q_{out,HX} + Q_{out,EB}) / (Q_{in,Sanden} + Q_{in,electric\_boiler})$

$= [m_1 c_p (T3-T5) + m_2 c_p (T4-T3)] / (Q_{in,Sanden} + Q_{in,electric\_boiler})$

$= (m_1 c_p (T3-T5) + Q_{in,electric\_boiler}) / (Q_{in,Sanden} + Q_{in,electric\_boiler})$

Note that this ignores the pump energy, but we know this energy from measuring the heat exchanger pump and can either use a constant number for the main pump or add it to the measured heat exchanger pump channel. The main pump and the heat exchanger pump are likely water cooled, which means they add heat to the system. If we deem this to be significant, this would be accounted for in the COP calculation by adding these values to both the numerator and denominator.

Further note that measurement points T6 and T7 could also be viewed as optional, but they provide insight into what is going on with the plumbing lines coming directly from and going directly to the Sanden. Also, the Sanden loop flow rate will be directly measured. Having these readings will be useful in making fine adjustments to the heat exchanger pump flow rate and also to the Sanden itself.

Site Visit Chronology

Ecotope expects at least four site visits will be needed. One visit, to do an initial evaluation of the site, occurred in early May, 2016. The remainder of the visits will focus on system installation and troubleshooting.

The second (primary) visit will require at least three days to install the new Sanden system and all M&V components. Ecotope plans to engage a plumber who has already installed a Sanden system and also plans to work with the site owner to prepare the site for installation (scope out position of outdoor unit plus make provisions for wall penetrations and placement of new gear in the pool mechanical room). Ecotope will provide sufficient plumbing fittings to facilitate a relatively quick installation of wettable thermistors and water flow meter(s). The installation of electrical M&V components will take about a half day of electrician work (with oversight), including checking of sensor functionality.

An additional visit is expected to fine-tune the system after initial data streams are reviewed. Ecotope plans to be on site for this work and coordinate the visit with BPA so they can also attend; it may be necessary to have the plumber attend this visit. If more fine-tuning is needed based on review of field data, Ecotope plans to coordinate with BPA so that they can return to the site to make further adjustment.

A final site visit will be needed to remove M&V equipment; depending on BPA's desire to keep monitoring systems in place, this visit might be in mid/late 2017. Ecotope may not need to attend the final visit; this will be determined in consultation with BPA.

Trade Notes

Ecotope will arrange for hiring of all trades and will supervise their work on site. Ecotope has allowed for two plumber re-visits to the site after the initial installation for possible adjustments. Subtrades will arrange for mechanical and electrical permits and inspections.

Appendix A: Data Logging Component List

Onset Computer Corp. RX3003 data logger (contains on-board 4G antenna with AT&T data plan); accepts up to 15 inputs

Onset 12-bit temperature sensor, model S-THB-M002

Onset Computing pulse input adapter, model S-UCC-M006

Continental Controls True RMS WattNode, wye config, nominal 208 volts, 3 pulse output

Dent Instruments or Magnelab split core current transformers (333 mVDC output at full reading)

EKM stainless steel flow meter: ¾" NPT, designed for hot water usage. Model HOT-SPWM-075.

Minol Minomess 130 brass flow meter, ¾" NPT, pulse output

Appendix B: Data Logging Field Form

Device	Serial Number	Notes
RX3003		Device keycode:
WattNode	N/A	Specify model of W/N:
T1 (HX supply temp) Label: HX_hot_T		
T2 (HX return temp) Label: BB_return_T		
T3 (Elec boiler inlet temp) Label: EB_inlet_T		
T4 (Pool inlet temp) Label: Pool_inlet_T		
T5 (Pool return temp) Label: Pool_return_water_T		
T6 (Sanden inlet temp) Label: Sanden_loop_inlet_T		
T7 (Sanden delivery temp) Label: Sanden_loop_delivery_T		
T8 (Outside air temp) Label: OAT		Actually more accurately is Sanden evaporator entering air temp
T9 (Pool room temp/RH) Label: Pool_room_T (2^{nd} channel is RH)		
Pulse adapter (Sanden power/energy) Label: Sanden_energy		CT size: Criss-cross? Y N
Pulse adapter (electric boiler) Label: elec_boiler_energy		CT size: Criss-cross? Y N
Pulse adapter (HX pump) Label: Hx_pump_energy		
Pulse adapter (hot water flow from HX) Label: Hx_flow		CT size:
Pulse adapter (Sanden loop water flow) Label: Sanden_flow		CT size:

Notes: