MEASUREMENT AND VERIFICATION PLAN

FOR

CHP SYSTEM AT
CONCORD APARTMENTS

Draft
June 2012

Submitted to:

New York State Energy Research and Development Authority
17 Columbia Circle
Albany, NY 12203-6399

Submitted by:

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1. Introduction

Concord Court Apartments is an affordable housing complex that contains 156 units. The brick building was built in 1973 and stands 6 stories tall. The CHP system being installed at the facility includes one (1) 100-kW InVerde 100 cogen unit provided by Tecogen. The InVerde unit includes a natural gas-fired reciprocating V8 engine, water cooled permanent magnet generator, jacket water and exhaust heat recovery systems, and self-contained inverter in a sound attenuating enclosure. The unit can provide 100 kW of continuous power, 125 kW of peak power, and 700 MBtu/h of thermal output as hot water.

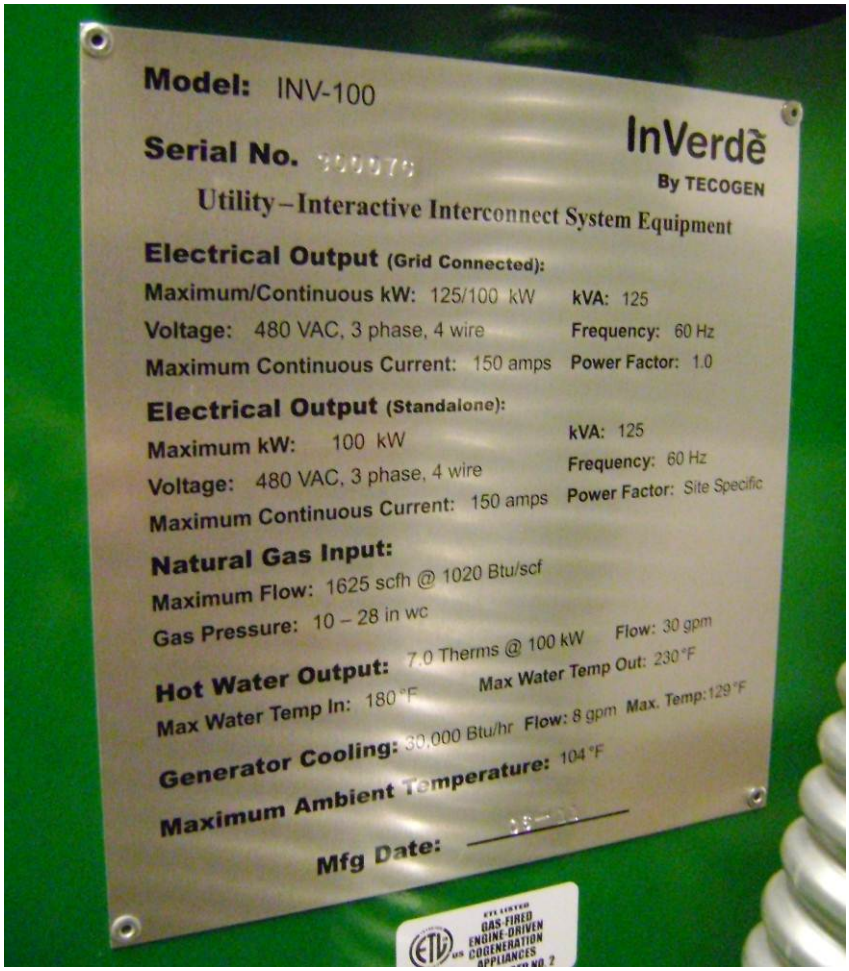
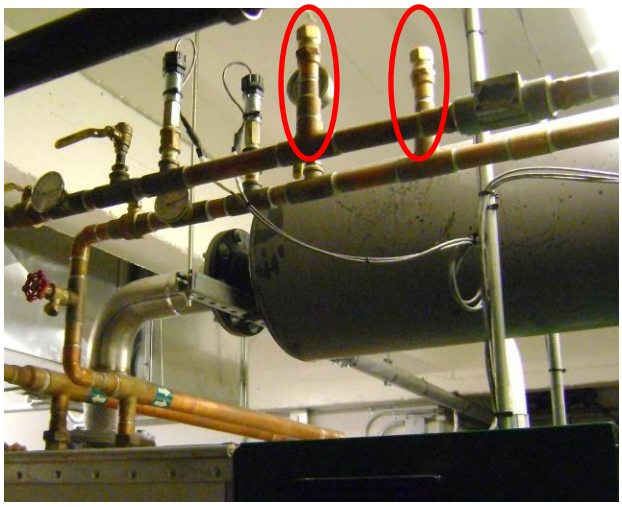


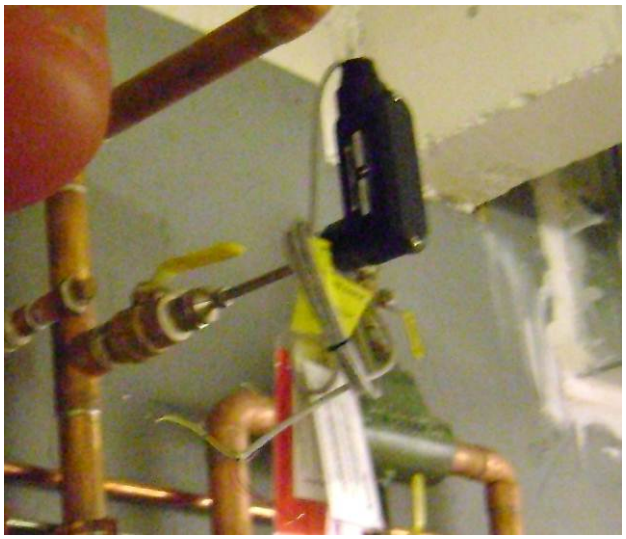
Figure 1. Photo of Tecogen InVerde 100 unit nameplate

The CHP system contains three (3) separate water loops; one for DHW heating, boiler heating, and a generator cooling loop. The DHW heating loop includes a HX for DHW loads and a dump radiator to remove excess heat. The boiler heating loop feeds the boilers directly and the generator cooling loop flows directly to a cooling radiator.



Boiler Loop - thermowells

Boiler Loop - flow meter



DHW / Dump Radiator Loop - flow meter

Natural Gas Meter

Figure 2. Photos of CHP System and Meters

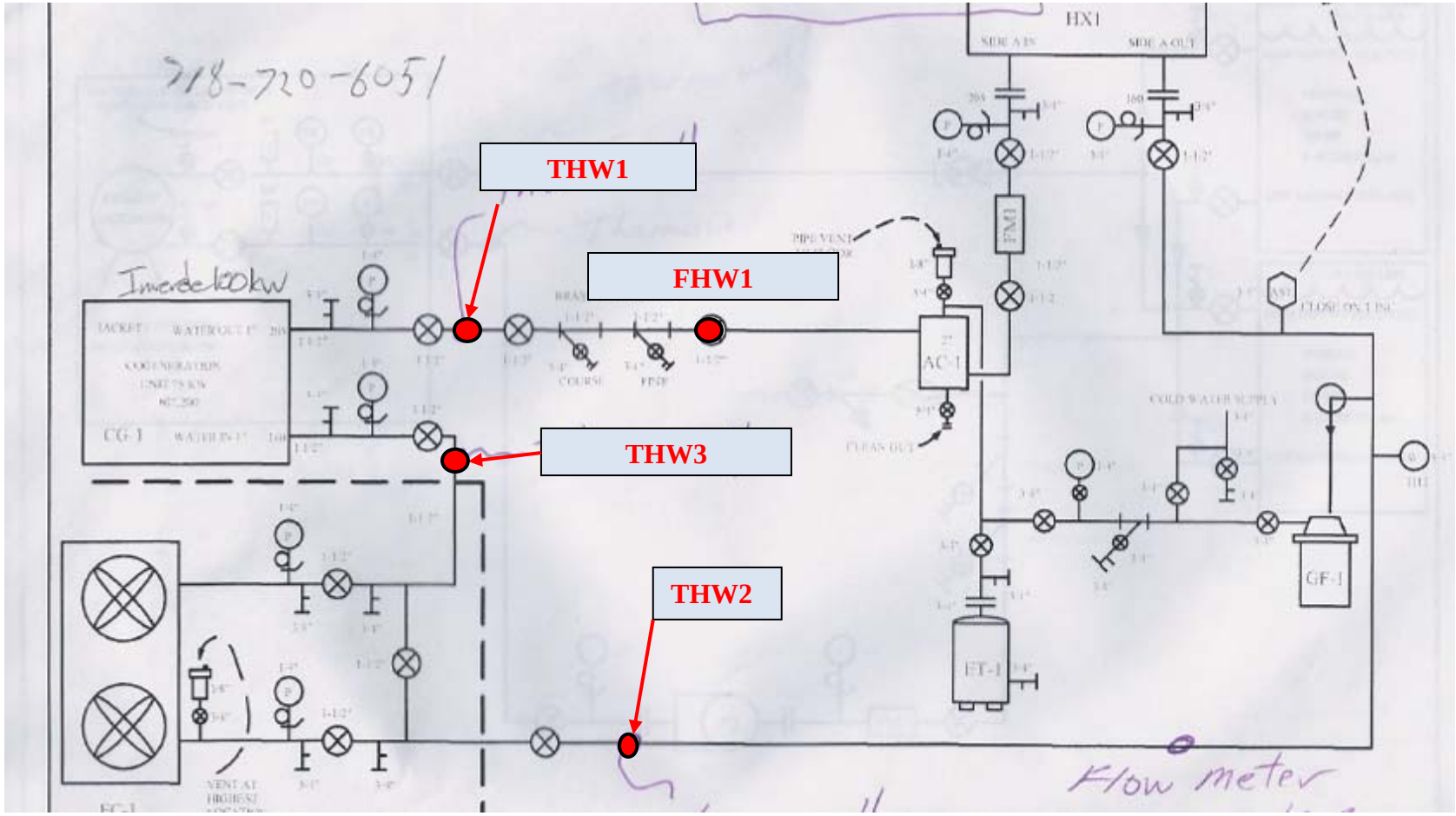


Figure 3. DHW Heating Loop Schematic with Installed Sensor Locations

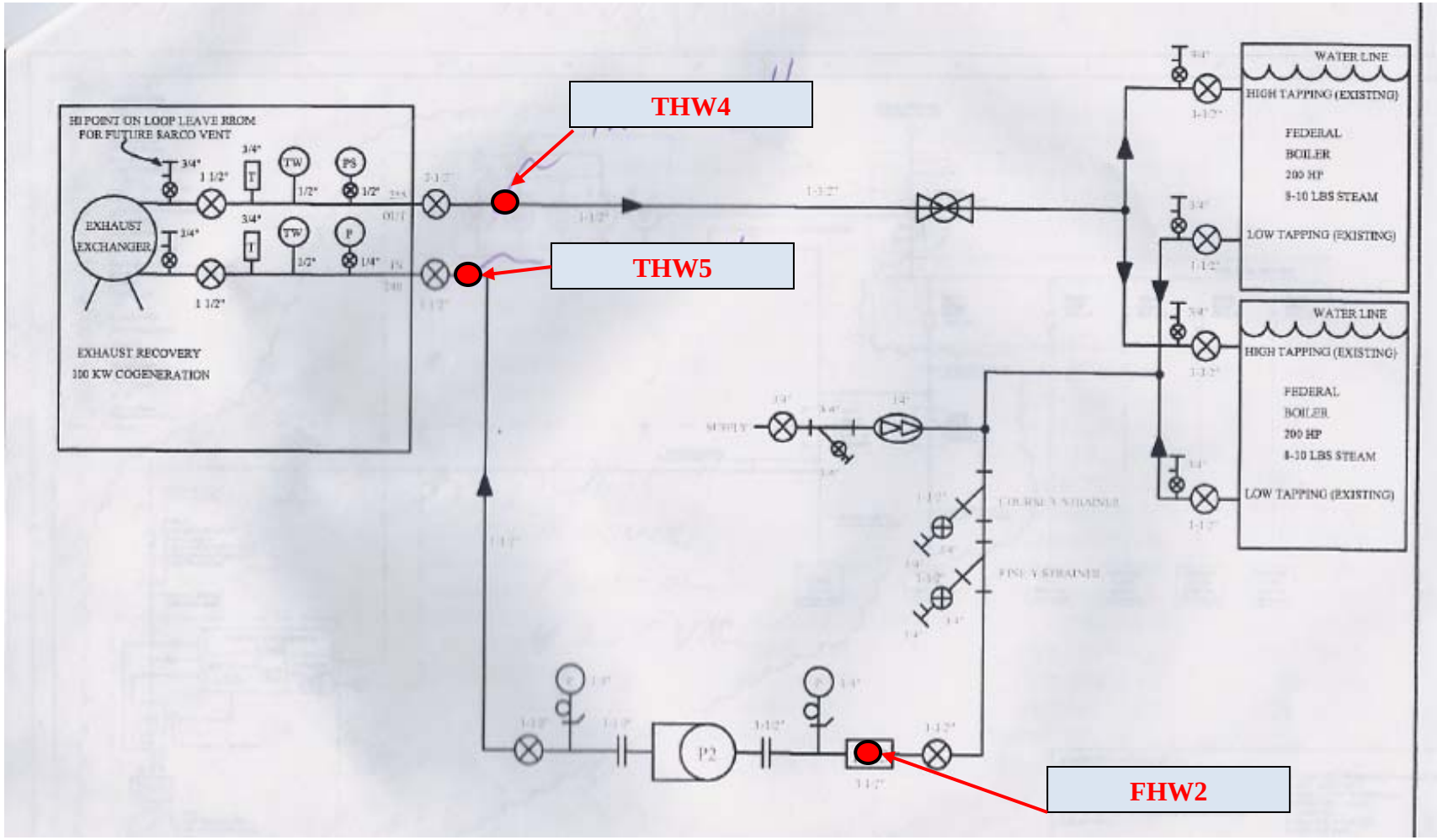


Figure 4. Boiler Loop Schematic with Installed Meter Locations

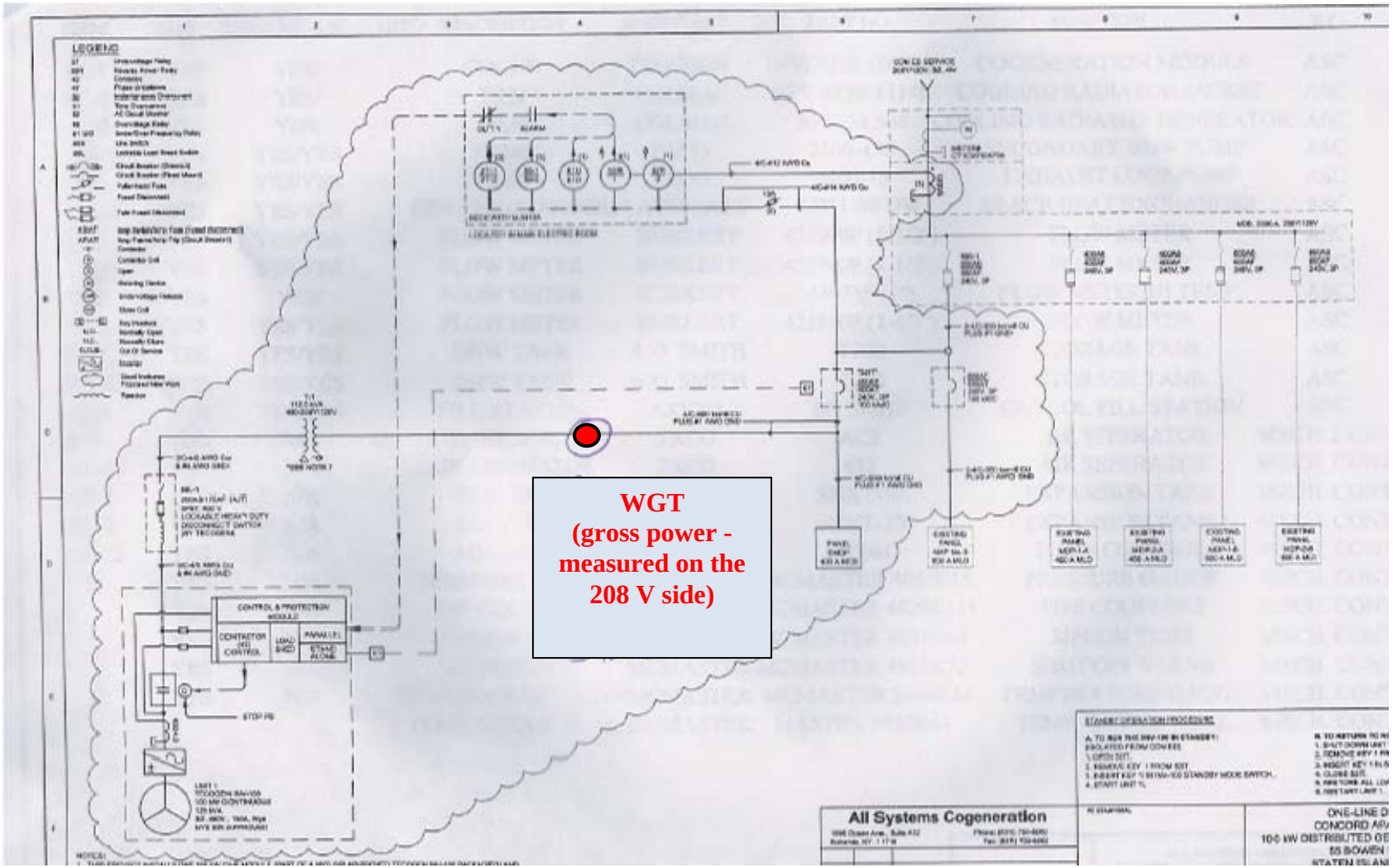


Figure 5. Electrical One-Line with Installed Meter Location

2. Monitoring System

A monitoring system has been installed to measure the performance of the CHP system. The system is based around an Obvius AcquiSuite datalogger. CDH provided all of the equipment required for the monitoring system and the temperature sensors. The site provided the flow meters, gas meter, power meters, and thermowells. Both recovered heat loops, DHW and space heating, are 1 ½ inch copper piping. The monitored points recommended to quantify performance are listed in Table 1.

Table 1. Monitored Data Points

Logger Channel	Data Point	Description	Eng Units	Instrument / Transducer	Output
1	WGT	Net Generator Power	kWh	Wattnode: WNC-3Y-208-P	Pulse
2	FG	Natural Gas to Generator	cf	Roots: Series B	Pulse
3	FHW1	DHW Loop Flowrate	gal	Onicon F-1111	4-20 mA
4	FHW2	Boiler Loop Flowrate	gal	Onicon F-1111	4-20 mA
5	THW1	Cogen Loop Temp - Supply	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
6	THW2	Cogen Loop Temp - Space Heating	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
7	THW3	Cogen Loop Temp - Dump (return)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
8	THW4	Cogen Loop Temp - Boiler (supply)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
EXP1	THW5	Cogen Loop Temp - Boiler (return)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
-	QU	Usefull Recovered Heat	Mbtu	-	Calculated
-	QR	Rejected Recovered Heat	MBtu	-	Calculated
-	QSH	Recovered Heat - Boiler	MBtu	-	Calculated
-	QDHW	Recovered Heat - DHW	MBtu	-	Calculated

The amount of heat used for DHW is calculated across the one heat exchanger in the system **(FHW1, THW1, THW2).** The heat provided to the boiler for space heating is calculated from the other loop **(FHW2, THW4, THW5)**. The total useful thermal output of the system is calculated by adding together the calculated DHW and space heating values **(QDHW, QSH)**. The rejected recovered heat is calculated from the DHW loop using the temperatures on either side of the dump radiator **(FHW1, THW2, THW3)**.

The net generator output is directly measured **(WGT)**. All the parasitic loads (cogen loop pumps, dump radiator fan, and dump radiator pumps) are powered separately. One-time power measurements were used to determine that the systems parasitic loads **(WP)** sum to 11 kW. A natural gas meter **(FG)** was provided by the facility, and will measure the total gas input to the unit.

Sensor Details

- ***Temperature***. 6" Veris 10k Type 2 thermistors are used the measure temperature. They are installed in 6" thermowells provided by CDH.

- ***Water Flow***. Onicon F-1111 insertion, paddle wheel style flow meters are installed in the 1" full port ball valves provided to the site. The flow meters were installed on the return side of the Tecogen unit (so temperatures will remain below 185F).

- ***Gas Flow***. A Roots Series B, rotary style gas meter is installed in line to the CHP unit.

- ***Power***. A Wattnode: WNC-3Y-208 was provided by the facility and measures the net power output of the CHP generator.

Data Logging System

CDH installed an Obvius AcquiSuite datalogger in its own enclosure in the mechanical room. The datalogger records readings at 1-minute intervals so that the thermal calculations below can accurately determine "BTUs". CDH installed a phone stick in order to share Tecogen's existing phone line for the CHP unit. The data logger is able to hold approximately 30 days of recorded data if communications are lost.

The data are downloaded from the datalogger at least once a day via the phone line and loaded into a database at CDH. The data is checked for validity and then posted to the NYSERDA CHP Integrated Data System web site.

3. Data Analysis

Heat Recovery Rates

The heat recovery rates will be calculated using the 1-minute data from the logger and then averaged or summed into 15-minute data.

Total Useful Heat Recovery:

$$QU_{avg} = k \cdot \frac{1}{N} \sum_{j=1}^{N} FHW1_j \cdot (THW1_j - THW2_j) + \sum_{j=1}^{N} FHW2_j \cdot (THW4_j - THW5_j)$$

DHW: $$QU_{avg} = k \cdot \frac{1}{N} \sum_{j=1}^{N} FHW1_j \cdot (THW1_j - THW2_j)$$

Boiler: $$QU_{avg} = k \cdot \frac{1}{N} \sum_{j=1}^{N} FHW2_j \cdot (THW4_j - THW5_j)$$

Rejected Heat Recovery: $$QU_{avg} = k \cdot \frac{1}{N} \sum_{j=1}^{N} FHW1_j \cdot (THW2_j - THW3_j)$$

Where N = 15 when converting from 1-minute to 15-minute data. K is the product of density and specific heat. The boiler loop fluid is water, while the DHW loop is expected to be water with 20% glycol. In this instance, the factor *k* is equal to:

20% glycol:	k_{gly}	= 473 Btu/h·gpm·°F at 180ºF
pure water:	k_{water}	= 487.8 Btu/h·gpm·°F at 180ºF

If necessary, CDH will use a hygrometer to estimate the glycol concentration.

Other Calculated Quantities

The gross power from the system **(WG)** can be estimated from the one-time readings with a handheld power meter for the parasitic loads. The parasitic loads include: cogen loop pumps, load pumps, and radiator fans and were measured at 11 kW.

WG = WGT + WP

The fraction of parasitic losses (which is typically 3-5%) is defined as

$$f_{para} = \frac{WP}{WGT}$$

The net total efficiency of the CHP system, based on the lower heating value of the fuel, will be defined as:

$$TE_{net} = \frac{QU \cdot \Delta t + 3412 \cdot (WGT)}{0.9 * HHV_{gas} \cdot FG}$$

where:

QU_{avg}	-	Useful heat recovery (Btu/h)
WGT	-	Net Generator output (kWh)
FG	-	Generator gas consumption (Std CF)
Δt	-	0.25 hour for 15-minute data
HHV_{gas}	-	Higher heating value for natural gas (1032 Btu per CF) and 0.9 is the conversion from HHV to LHV

The total efficiency (TE) can be calculated for any time interval. Other efficiency metrics are also of interest.

Table 2 below summarizes the other efficiency metrics that will be determined:

Table 2. Summary of Efficiency Calculations

	NET (using measured net power)	**GROSS (using generator output)**
Electrical Efficiency (EE)	$\frac{3412 \cdot (WGT)}{HHV_{gas} \cdot FG}$	$\frac{3412 \cdot (WG)}{HHV_{gas} \cdot FG}$
Thermal Efficiency (THE)	$\frac{QU \cdot \Delta t}{HHV_{gas} \cdot FG}$	
Total Efficiency (TE)	$\frac{QU \cdot \Delta t + 3412 \cdot (WGT)}{HHV_{gas} \cdot FG}$	$\frac{QU \cdot \Delta t + 3412 \cdot (WG)}{HHV_{gas} \cdot FG}$

Notes: 1) All values must be over same time interval.

2) The difference between net and gross efficiency can also be related by a factor of: $1\text{-}f_{para}$

Appendix A

Data Sheets

Wattnode

Onicon F-1111

Veris 10k Type 2 thermistor

Roots Series B

Continental Control Systems

WattNode® Logger

AC Power Measurement for LonWorks®

The WattNode® Logger for LonWorks® is a networked, multi-function digital energy meter with internal logging. The WattNode Logger offers true RMS power, energy and demand metering, plus individual phase measurements of voltage, current, power factor, reactive power and energy, and line frequency. The WattNode Logger can log 24,000+ measurement records in non-volatile memory. Typical applications include energy monitoring, sub metering, demand management and stand-alone electrical system data logging.

Networking for LonWorks is easy. A simple twisted-pair connection links all devices together into a LonWorks network. Measurements are transmitted over the network as Standard Network Variable Types (SNVTs).

Logging is provided for all important measurements at user-selectable intervals from 1 minute to 12 hours. At a 15-minute interval, it can log for 250 days. Logging is possible in a networked or stand-alone mode. An LNS plug-in downloads the data to a PC file in CSV format.

Ease Of Use and economy of installation were key design criteria. The WattNode Logger's compact size permits installation inside of most electrical service panels and junction boxes. Detachable screw terminals make wiring a snap. The WattNode Logger is line-powered and requires no separate power source.

Accuracy of the WattNode Logger is 0.5% nominal. Even with leading or lagging power factor and chopped or distorted wave forms, the WattNode Logger measures true RMS power. This makes it ideal for monitoring motors and pumps controlled by variable speed drives or loads with switching power supplies.

The Complete Line of WattNode Logger models measures 1, 2, or 3 phases in 2, 3, or 4 wire configurations with nominal voltages from 120 to 600 VAC at 50/60 Hz. Operation from 5 to 5000 Amps is possible by selecting from our line of safe, low-voltage output, current transformers.

kWH
kVAR
Volts
Peak Demand
Demand
kW
PF
Frequency
Amps
Logging

c UL us LISTED

LonMark® 3.4

- **Multiple Measurements**
  kW, kWh, Demand, kVAR, kVARh, PF, Amps, Volts, Frequency
- **Bidirectional Metering**
  Enables net metering solution for PV or wind turbine sites
- **LonWorks Network Ready**
  Simple twisted-pair network installation, Internet accessible
- **LonMark Version 3.4 Certified**
  Easy to integrate using an open, interoperable device
- **Measures 1ϕ, 2ϕ, 3ϕ Circuits**
  Flexible for various applications
- **Line Powered**
  No external power supply required
- **Compact Size**
  Fits inside of standard power panels and junction boxes

Continental Control Systems LLC
3131 Indian Road, Suite A
Boulder, CO 80301 USA
(303) 444-7422 Fax (303) 444-2903
sales@ccontrolsys.com
www.ccontrolsys.com

Toll-Free
(888) 928-8663

Specifications

WattNode® Logger

AC Power Measurement for LonWorks®

Quantities Measured

Energy: Real and reactive
Power: Real and reactive, per phase and sum
Voltage: Per phase volts
Current: Per phase amps
Frequency
Power Factor: Per phase and average
Demand: Block or sliding window
Peak Demand: Value and time

Quantities Logged

Date & Time
Net Energy (A, B, C & Sum)
Reactive Energy (Sum)
Positive Energy (Sum)
Real and Reactive Power (A, B, C & Sum)
Voltage, Current & Power Factor (A, B, C)
Demand

Measurement Configuration

Three phase: 3-wire or 4-wire
Single phase: 2-wire or 3-wire

LonWorks Interoperability

40 network variables SNVTs
LonMark Version 3.4

User Controlled Inputs

Set CT size in amps
Set demand window type and period
Reset peak demand to zero
Set time of day

Accuracy

0.5% nominal (see manual for details)
Time: ± 2 minutes a year (battery backed)

Electrical

Operating Voltage Range: 80% - 115% of nominal
Power Line Frequency Range: 50 to 60 Hz

Environmental

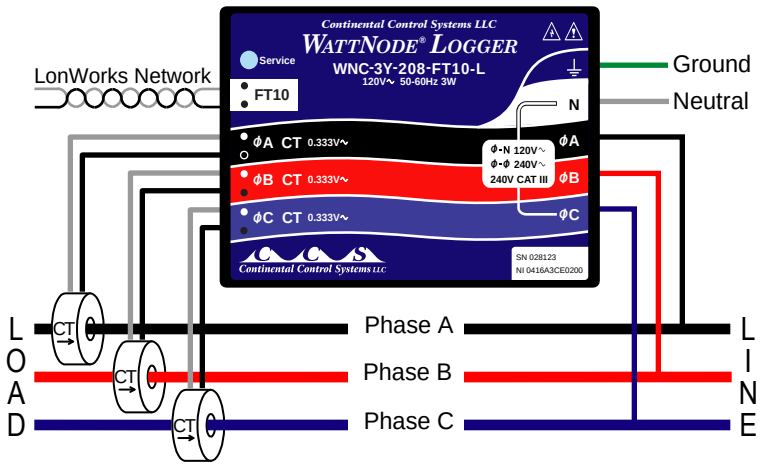
Temperature: -30° C to 55° C
Humidity: 5 to 90% RH (noncondensing)

Mechanical

Enclosure: High impact, UL rated, ABS plastic
Size: 3.3" x 5.6" x 1.5" (includes mounting tabs)
Connectors: Detachable screw terminals (22-12 AWG)

MADE IN THE USA

(888) 928-8663



Models

Model	VAC Line To Neutral	VAC Line To Line	Phases	Wires
WNC-3Y-208-FT10-L	120	208-240	3*	4
WNC-3Y-400-FT10-L	230	400	3*	4
WNC-3Y-480-FT10-L	277	480	3*	4
WNC-3Y-600-FT10-L	347	600	3*	4
WNC-3D-240-FT10-L	N/A	208-240	3	3
WNC-3D-400-FT10-L	N/A	400	3	3
WNC-3D-480-FT10-L	N/A	480	3	3

**Can be used to measure 1, 2 or 3 phase circuits.*

Opening Current Transformers (Split Core)

Model	Inside Diameter	Rated Amps
CTS-0750	0.75"	5, 15, 30, 50, 70, 100, 150, 200
CTS-1250	1.25"	70, 100, 150, 200, 250, 300, 400, 600
CTS-2000	2.00"	600, 800, 1000, 1200, 1500
CTB	Bus Bar	600, 800, 1200, 2000, 3000 (custom)

Toroidal Current Transformers (Solid Core)

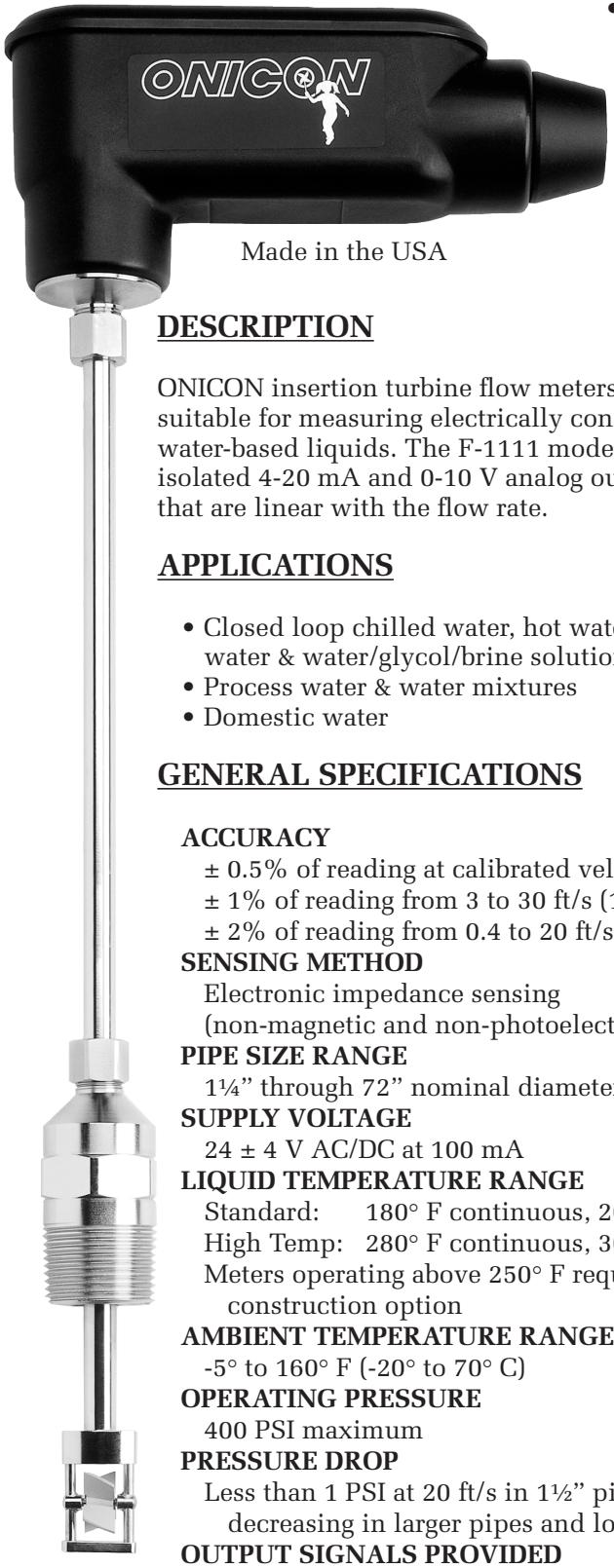
Model	Inside Diameter	Rated Amps
CTT-0300	0.30"	5, 15, 20, 30
CTT-0500	0.50"	15, 20, 30, 50, 60
CTT-0750	0.75"	30, 50, 70, 100
CTT-1000	1.00"	50, 70, 100, 150, 200
CTT-1250	1.25"	70, 100, 150, 200, 250, 300, 400

Current Transformer Output Voltage: 0 - 0.333 VAC @ rated current

Continental Control Systems
3131 Indian Road, Suite A
Boulder, CO 80301
(303) 444-7422 Fax (303) 444-2903
sales@ccontrolsys.com
www.ccontrolsys.com

• F-1111 SINGLE TURBINE •
INSERTION FLOW METER
ISOLATED ANALOG OUTPUT

ONICON INCORPORATED



Made in the USA

DESCRIPTION

ONICON insertion turbine flow meters are suitable for measuring electrically conductive water-based liquids. The F-1111 model provides isolated 4-20 mA and 0-10 V analog output signals that are linear with the flow rate.

APPLICATIONS

- Closed loop chilled water, hot water, condenser water & water/glycol/brine solutions for HVAC
- Process water & water mixtures
- Domestic water

GENERAL SPECIFICATIONS

ACCURACY
± 0.5% of reading at calibrated velocity
± 1% of reading from 3 to 30 ft/s (10:1 range)
± 2% of reading from 0.4 to 20 ft/s (50:1 range)

SENSING METHOD
Electronic impedance sensing
(non-magnetic and non-photoelectric)

PIPE SIZE RANGE
1¼" through 72" nominal diameter

SUPPLY VOLTAGE
24 ± 4 V AC/DC at 100 mA

LIQUID TEMPERATURE RANGE
Standard: 180° F continuous, 200° F peak
High Temp: 280° F continuous, 300° F peak
Meters operating above 250° F require 316 SS construction option

AMBIENT TEMPERATURE RANGE
-5° to 160° F (-20° to 70° C)

OPERATING PRESSURE
400 PSI maximum

PRESSURE DROP
Less than 1 PSI at 20 ft/s in 1½" pipe, decreasing in larger pipes and lower velocities

OUTPUT SIGNALS PROVIDED
Analog Outputs (isolated)
Voltage output: 0-10 V (0-5 V available)
Current output: 4-20 mA
Frequency Output
0 – 15 V peak pulse, typically less than 300 Hz

(continued on back)

CALIBRATION

Every ONICON flow meter is wet calibrated in our flow laboratory against primary volumetric standards that are directly traceable to N.I.S.T. A certificate of calibration accompanies every meter.

FEATURES

Unmatched Price vs. Performance - Custom calibrated, highly accurate instrumentation at very competitive prices.

Excellent Long-term Reliability - Patented electronic sensing is resistant to scale and particulate matter. Low mass turbines with engineered jewel bearing systems provide a mechanical system that virtually does not wear.

Industry Leading Two-year "No-fault" Warranty - Reduces start-up costs with extended coverage to include accidental installation damage (miswiring, etc.) Certain exclusions apply. See our complete warranty statement for details.

Simplified Hot Tap Insertion Design - Standard on every insertion flow meter. Allows for insertion and removal by hand without system shutdown.

OPERATING RANGE FOR COMMON PIPE SIZES 0.17 TO 20 ft/s

±2% accuracy begins at 0.4 ft/s

Pipe Size (Inches)	Flow Rate (GPM)
1 ¼	0.8 - 95
1 ½	1 - 130
2	2 - 210
2 ½	2.5 - 230
3	4 - 460
4	8 - 800
6	15 - 1,800
8	26 - 3,100
10	42 - 4,900
12	60 - 7,050
14	72 - 8,600
16	98 - 11,400
18	120 - 14,600
20	150 - 18,100
24	230 - 26,500
30	360 - 41,900
36	510 - 60,900

1500 North Belcher Road, Clearwater, FL 33765 • Tel (727) 447-6140 • Fax (727) 442-5699
www.onicon.com • sales@onicon.com

F-1111 SPECIFICATIONS cont.

MATERIAL

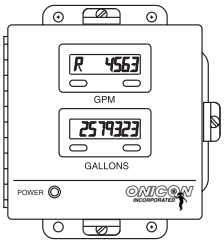
Wetted metal components:
- Standard: Electroless nickel plated brass
- Optional: 316 stainless steel

ELECTRONICS ENCLOSURE
- Standard: Weathertight aluminum enclosure
- Optional: Submersible enclosure

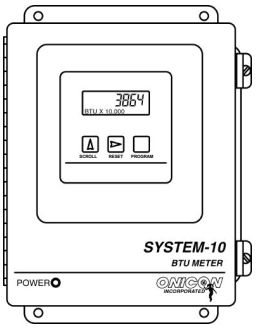
ELECTRICAL CONNECTIONS

4-wire minimum for 4-20 mA or 0-10 V output
Second analog output and/or frequency output requires additional wires
- Standard: 10' of cable with ½" NPT conduit connection
- Optional: Indoor DIN connector with 10' of plenum rated cable

ALSO AVAILABLE



Display Modules



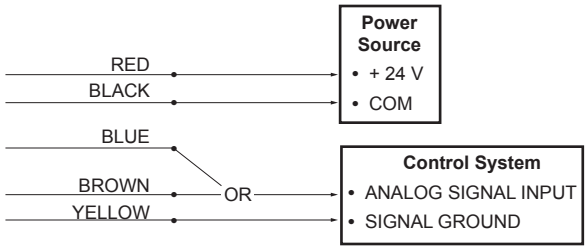
Btu Measurement Systems

F-1111 Wiring Information

WIRE COLOR	DESCRIPTION	NOTES
RED	(+) 24 V AC/DC supply voltage, 100 mA	Connect to power supply positive
BLACK	(-) Common ground (Common with pipe ground)	Connect to power supply negative
GREEN	(+) Frequency output signal: 0-15 V peak pulse	Required when meter is connected to local display or Btu meter
BLUE	(+) Analog signal: 4-20 mA (isolated)	Use yellow wire as (-) for these signals. Both signals may be used independently.
BROWN	(+) Analog signal: 0-10 V (isolated)	
YELLOW	(-) Isolated ground	Use for analog signals only

F-1111 Wiring Diagram

Flow meter into control system (no display or Btu meter)

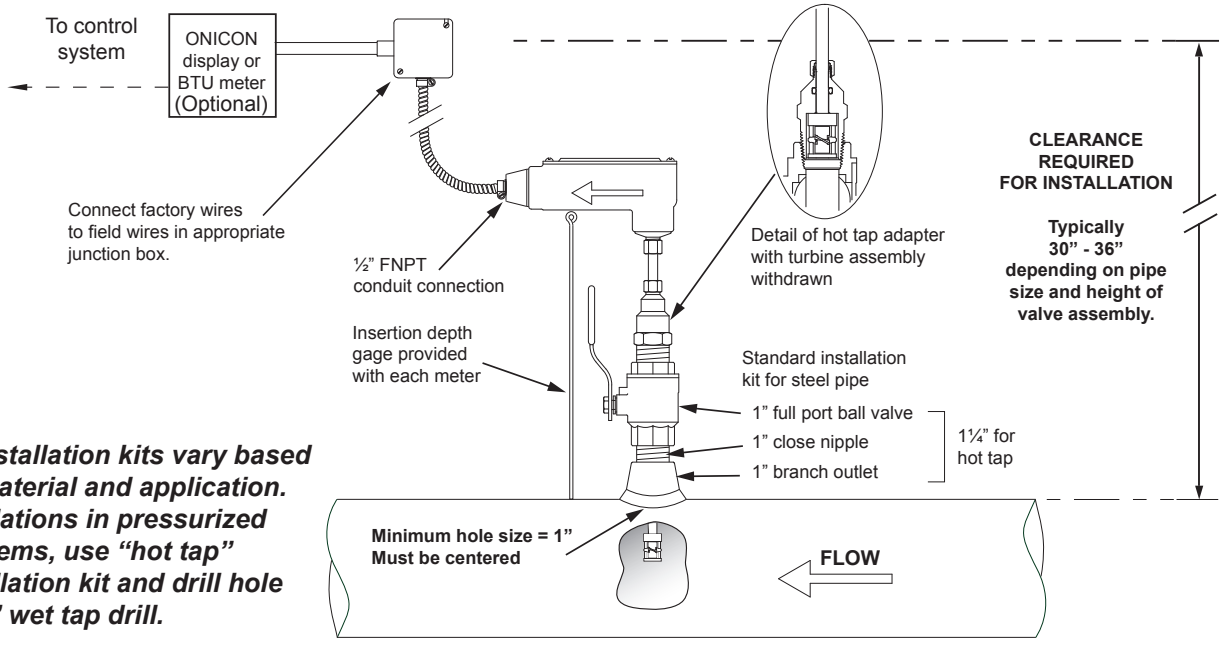


NOTE: ***1. Black wire is common with the pipe ground (typically earth ground).***
2. Frequency output required for ONICON display module or Btu meter, refer to wiring diagram for peripheral device.

Typical Meter Installation

(New construction or scheduled shutdown)

- Acceptable to install in vertical pipe
- Position meter anywhere in upper 240° for horizontal pipe



NOTE: Installation kits vary based on pipe material and application. For installations in pressurized (live) systems, use "hot tap" 1¼" installation kit and drill hole using a 1" wet tap drill.

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www.onicon.com • sales@onicon.com

Immersion Temperature Sensors

Corrosion Resistant Stainless Steel Probe

5 Year Warranty

APPLICATIONS

- Tanks
- Pipes
- Chillers

FEATURES

- Cost-effective high accuracy thermistors/RTDs
- Corrosion resistant stainless steel probe design
- 1/2" NPT threads standard
- Variety of enclosures include duct mount, service entry body, threaded, and water resistant
- Thermowells available

DESCRIPTION

These immersion probe type temperature sensors are both highly accurate and cost effective. Installation could not be easier. The sensor is encased in a corrosion-resistant stainless steel probe for durability, with a choice of service entry body, indoor junction box, or threaded enclosures. A variety of RTD or thermistor sensor options and probe lengths are available for maximum application versatility.

Class	Pt RTD		THERMISTOR									
Type	**100 Ohm**	**1000 Ohm**	**2.2k**	**3k**	**10k** Type 2	**10k** Type 3	**10k** Dale	**10k** 3A221	**10k** "G" US	**20k**	**20k** "D"	**100k**
Accuracy	±0.3°C	±0.3°C	±0.2°C	±0.2°C	±1.0°C	±0.2°C	±0.2°C	±1.1°C	±0.2°C	Consult	Consult	Consult
	0.0385 curve	0.0385 curve	0/70°C	0/70°C	-50/150°C	0/70°C	-20/70°C	0/70°C	0/70°C	Factory	Factory	Factory
Temp. Response*	PTC	PTC	NTC	NTC	NTC	NTC	NTC	NTC	NTC	NTC	NTC	NTC

*PTC: Positive Temperature Coefficient
*NTC: Negative Temperature Coefficient

STANDARD RTD AND THERMISTOR VALUES (Ohms Ω)

°C	°F	100 Ohm	1000 Ohm	2.2k	3k	10k Type 2	10k Type 3	10k Dale	10k 3A221	10k "G" US	20k	20k "D"	100k
-50	-58	80.306	803.06	154,464	205,800	692,700	454,910	672,300	-	441,200	1,267,600	-	-
-40	-40	84.271	842.71	77,081	102,690	344,700	245,089	337,200	333,562	239,700	643,800	803,200	3,366,000
-30	-22	88.222	882.22	40,330	53,730	180,100	137,307	177,200	176,081	135,300	342,000	412,800	1,770,000
-20	-4	92.160	921.60	22,032	29,346	98,320	79,729	97,130	96,807	78,910	189,080	220,600	971,200
-10	14	96.086	960.86	12,519	16,674	55,790	47,843	55,340	55,252	47,540	108,380	122,400	553,400
0	32	100.000	1000.00	7,373	9,822	32,770	29,588	32,660	32,639	29,490	64,160	70,200	326,600
10	50	103.903	1039.03	4,487	5,976	19,930	18,813	19,900	19,901	18,780	39,440	41,600	199,000
20	68	107.794	1077.94	2,814	3,750	12,500	12,272	12,490	12,493	12,260	24,920	25,340	124,900
25	77	109.735	1097.35	2,252	3,000	10,000	10,000	10,000	10,000	10,000	20,000	20,000	100,000
30	86	111.673	1116.73	1,814	2,417	8,055	8,195	8,056	8,055	8,194	16,144	15,884	80,580
40	104	115.541	1155.41	1,199	1,598	5,323	5,593	5,326	5,324	5,592	10,696	10,210	53,260
50	122	119.397	1193.97	811.5	1,081	3,599	3,894	3,602	3,600	3,893	7,234	6,718	36,020
60	140	123.242	1232.42	561.0	747	2,486	2,763	2,489	2,486	2,760	4,992	4,518	24,880
70	158	127.075	1270.75	395.5	527	1,753	1,994	1,753	1,751	1,990	3,512	3,100	17,510
80	176	130.897	1308.97	284.0	378	1,258	1,462	1,258	1,255	1,458	2,516	2,168	12,560
90	194	134.707	1347.07	207.4	-	919	1,088	917	915	1,084	1,833	1,542	9,164
100	212	138.506	1385.06	153.8	-	682	821	679	678	816.8	1,356	1,134	6,792
110	230	142.293	1422.93	115.8	-	513	628	511	509	623.6	1,016	816	5,108
120	248	146.068	1460.68	88.3	-	392	486	389	388	481.8	770	606	3,894
130	266	149.832	1498.32	68.3	-	303	380	301	299	376.4	591	456	3,006

To compute Linitemp Temperature:

2-Wire version (1µA/°C)
µA reading - 273.15=Temperature in °C
3-Wire version (10mV/°C)
mV reading/10 - 273.15 = Temperature in °C

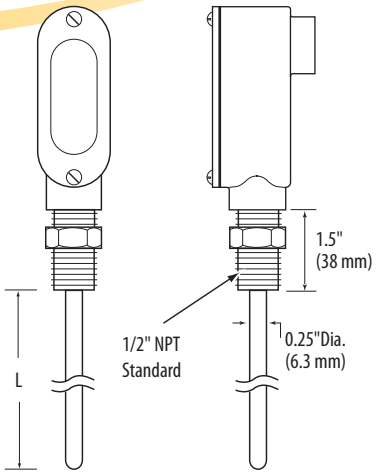
SPECIFICATIONS

Wiring		22AWG; 2-wire:RTD Thermistor, 4-20mA; 3-wire: Voltage output models
Probe		Stainless Steel
Test Pressure		200psi
Linitemp:		
Input Power		5 to 30VDC
Output		1µA/°C or 10mV/°C
Operating Temperature		-25° to 105°C (-13° to 221°F)
Accuracy	Calibration Error:	1.5°C (35°F) typical; 2.5°C (37°F) max. at 25°C (77°F)*
	Error over Temperature:	1.8°C typical (35°F); 3.0°C (34°F) max. over 0° to 70°C (32° to 158°F) range
		2.0°C (35°F) typical, 3.5°C (38°F) max. over -25° to 105°C (-13° to 221°F) range

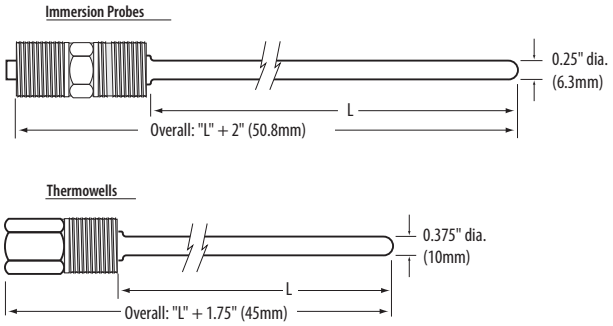
Room temperature error documented on each unit.

DIMENSIONAL DRAWINGS

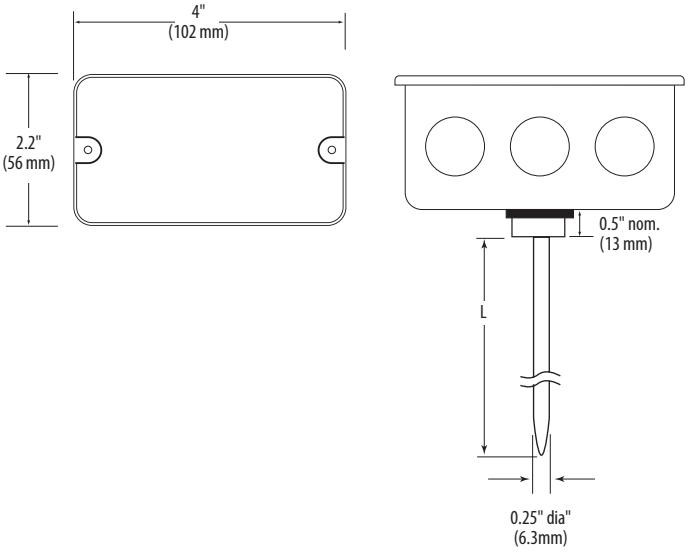
TIG Model



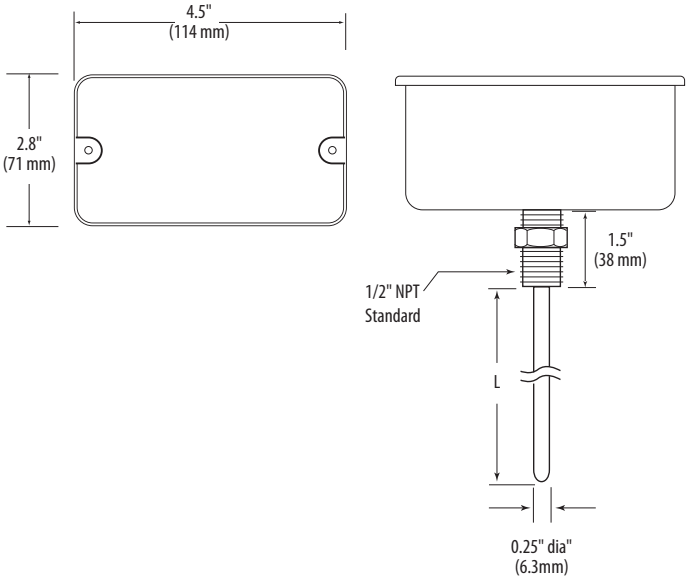
TIH Model



TID Model



TIW Model



TEMPERATURE

ORDERING INFORMATION

	Enclosure	Immersion Probe Length "L"	Thermowell	Sensor Type	Cal Certificate	Threads
TI	☐	☐	☐	☐	☐	☐
	D = Duct **G** = Service Entry Body **H** = Threaded NPT Only **W** = Water resistant housing	**A** = 2 1/2" (64mm) **B** = 4" (102mm) **C** = 6" (152mm) **D** = 8" (203mm) **E** = 12" (305mm)	**0** = None **1** = Add Thermowell	**B** = 100R Platinum, RTD **C** = 1k Platinum, RTD **D** = 10k T2, Thermistor **E** = 2.2k, Thermistor **F** = 3k, Thermistor **G** = 10k CPC, Thermistor **H** = 10k, T3, Thermistor **J** = 10k Dale, Thermistor **K** = 10k w/11k shunt,Thermistor **M** = 20k NTC, Thermistor **N** = 1800 ohm, Thermistor **P** = 10mV/°C, Linitemp **R** = 10k US, Thermistor **S** = 10k 3A221, Thermistor **T** = 100k, Thermistor **U** = 20k "D", Thermistor	*OPTIONS* **0** = None **1** = 1 point Cal validation **2** = 2 point Cal validation	*OPTIONS* **Blank** = NPT **A** = BSPT **B** = DIN 2999

Thermowell Sizing

Probe Length		Thermowell Length
A	(2 1/2") (64mm)	1 1/2" (38mm)
B	(4") (102mm)	3" (76mm)
C	(6") (152mm)	5" (127mm)
D	(8") (203mm)	7" (178mm)
E	(12") (305mm)	11" (279mm)

Example:

TI	D	B	1	D	2	A

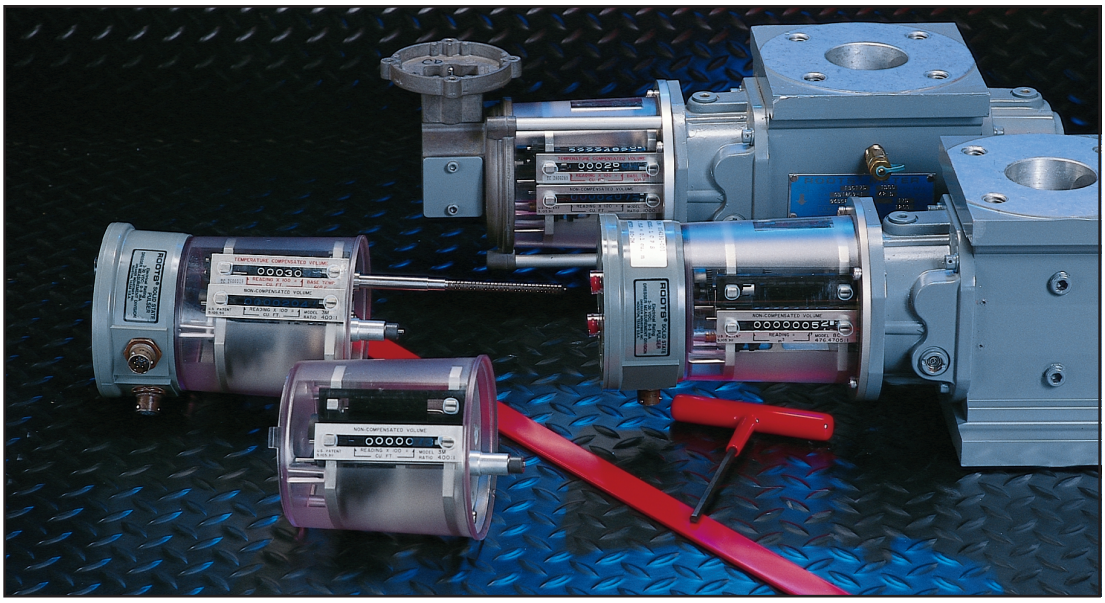
NOTE:
For 4-20mA transmitter output, order any TI with the 100Ω platinum RTD and accessory AA10xx

ACCESSORIES

Thermowells (AA22, AA24, AA25, AA33)

DRESSER
Measurement

ROOTS® Meter Series B3
Featuring Life-Lubed Accessory Units



ROOTS® meter Series B3 are designed to provide accurate gas measurement over widely fluctuating flow, pressure and temperature conditions.

Series 3 and Series 2(TQM) accessory units are interchangeable with Series B basic meter bodies.

Available Types Include:

- CTR - Non-Compensated Counter
- CD - Non-Compensated Counter with Instrument Drive
- TC - Temperature Compensated Counter
- TD - Temperature Compensated Counter with Instrument Drive
- CTR or TC with Solid State Pulser - Low Frequency pulse output
- CEX - Counter (CTR) with High Frequency Transmitter/Pulser

Series B meter bodies are also available with the integral electronic ROOTS® VTC temperature compensator or the ROOTS® IMC volume, pressure and temperature corrector.

PRODUCT DATA

ROOTS Meters & Instruments

DRESSER

ROOTS® SERIES B3

Full Range of Sizes:
12 meter sizes offer a complete range of rotary meters for commercial and industrial metering applications. Select the correct meter size for cost effectiveness and accurate measurement.

Standardized Flanges:
Sizes 8C through 5M have a 6-3/4" (171 mm.) flange-to-flange dimension for standardization in the meter set design. As loads change, meter sizes can be easily interchanged, saving the cost of re-piping.

Accurate Low Flow Performance:
Low start/stop rates extend the rangeability (gas measured) over wider range of flow conditions.

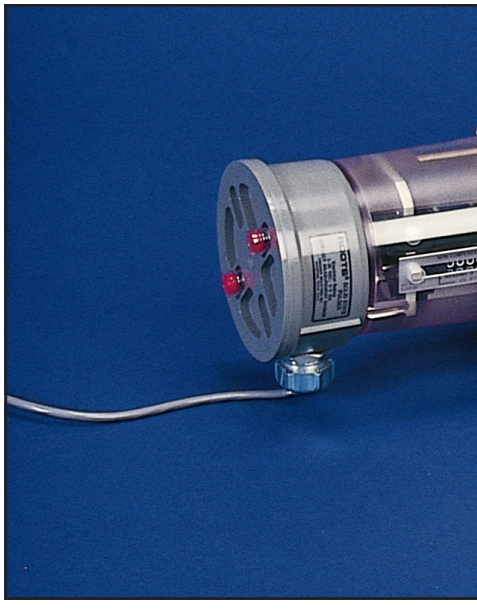
Low Pressure Differentials:
Reducing the maximum operating speed provides lower pressure differentials for low pressure applications, as well as extending the meter's life-expectancy.

SERIES 3 ACCESSORY UNITS

Oil-Free Design:
Series 3 accessories feature high quality and long-term reliability with an oil-free, permanently lubricated design. Oil is not required for the Polymer bushings and pre-lubricated, shielded ball bearings. Permanent lubrication equates to easier installation and less maintenance.

Durable, Weather Resistant Cover:
Optical Quality Lexan® covers on Series 3 accessories offer optional Ultraviolet protection while the cylindrical design allows the unit to easily shed rain, snow, ice, and dirt. The single piece cover design provides added protection against leakage under extreme conditions.

Solid State Pulser Installation Is A Snap:
ROOTS® meters with factory installed Solid State Pulsers are the low cost solution for your AMR requirements. With magnets installed, the pulser assembly literally snaps onto the cover without removing the meter from service. Pulser-ready meters are an economical factory option.



Non-Moving Odometer Masking System:
A unique and versatile odometer masking design using opaque or semi-transparent covers offers configurable, trouble-free masking.

Universal Instrument Drive Assembly:
One size fits all with the Series 3 Instrument Drive Assembly. Inventory costs are reduced by stocking one ID Assembly.

General Information

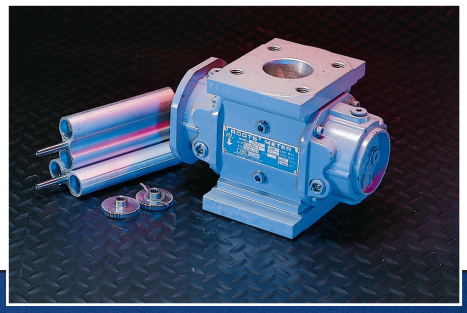
The ROOTS® meter Series B3 is a positive displacement, rotary type gas meter designed for continuously measuring and indicating the accurate measurement of gas in a pipeline. ROOTS® meters are suitable for handling most types of clean, dry, common gases at either constant or varying flow rates. Meters of standard construction are not directly suitable for handling acetylene, biogas or sewage gas. Contact the factory for information on specially constructed meters made of materials directly compatible with these and other gases.

Volumetric accuracy of the ROOTS® meter is permanent, non-adjustable, and is not affected by low or varying line pressure. Series B meters may be used satisfactorily for pressure ranging from a few ounces to full MAOP. Displaced volume measurement is completely independent of the gas specific gravity, temperature, and pressure.

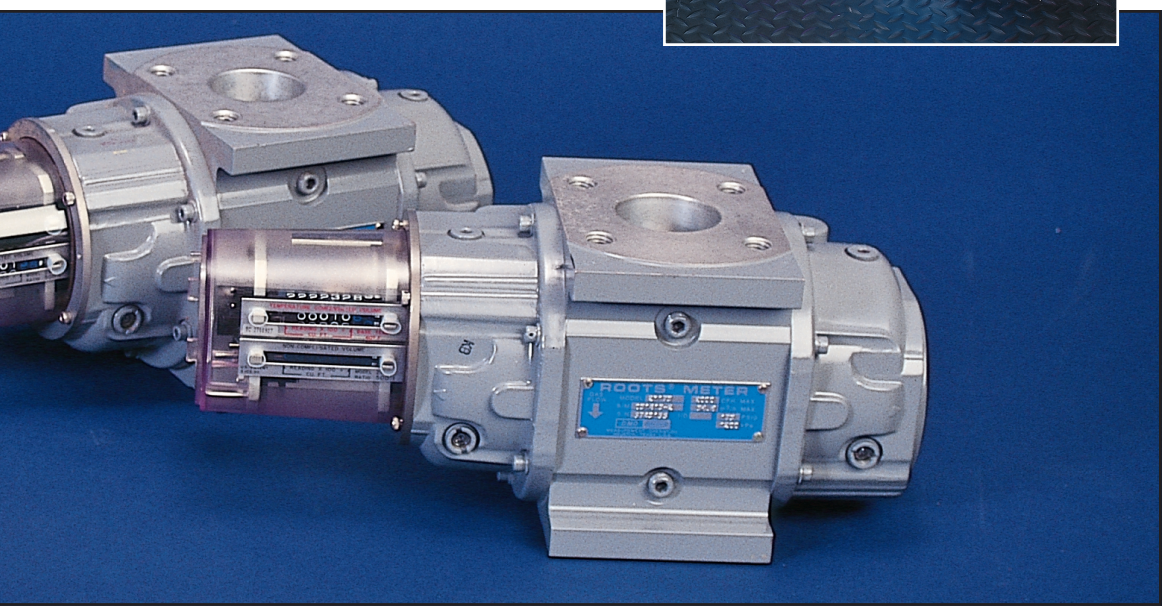
ROOTS® meters are manufactured in accordance with ANSI/ASC-B109.3 for Rotary Type Gas Displacement Meters. ROOTS® meter series B sizes 8C through 56M have flanged inlet and outlet connections conforming dimensionally with ANSI/ASME standards. Sizes 8C through 2M are available with 1-1/2” NPT connections, upon special request. The meter operating temperature range is from -40°F to +140°F (-40°C to +60°C).

ROOTS® meters series B have a Maximum Allowable Operating Pressure (MAOP) rating of 175 psig (1200 kPa). Every meter is static pressure tested at the factory at twice its MAOP and leak tested at 125 percent of MAOP in accordance with ASME Boiler Pressure Vessel Codes. Other pressure ratings are available. Consult Factory.

ROOTS® Series B meter bodies accept a wide range of Series 3 accessories for all metering applications.



Counter Pulser & TC Versions



ROOTS® SERIES B3

Meter Specifications

SERIES B3	Units	8C175	11C175	15C175	2M175	3M175	5M175	7M175	11M175	16M175	23M175	38M175	56M175
Base Rating	acfh	800	1100	1500	2000	3000	5000	7000	11000	16000	23000	38000	56000
Max. Operating Pressure	psig	175	175	175	175	175	175	175	175	175	175	175	175
Rangeability +/- 1%		26:1	31:1	40:1	68:1	76:1	120:1	67:1	124:1	116:1	40:1	90:1	53:1
Rangeability +/- 2%		46:1	58:1	78:1	126:1	139:1	215:1	115:1	227:1	223:1	60:1	110:1	109:1
Start Rate	cfh	2.79	2.3	1.94	1.9	2.1	1.2	5.33	3.88	3.24	23	27	40
Stop Rate	cfh	2.03	1.74	1.57	1.1	1.8	0.8	3.39	3.23	1.89	18	20	29
Flow Rate, 0.5" w.c., Gas	cfh	800	1100	1500	2000	2580	3975	5400	7300	9950	14800	20600	23000
Differential, 100% Flow	in.w.c.	0.26	0.356	0.459	0.495	0.64	0.733	0.984	1.07	1.27	1	1.5	1.8
Drive Rate, CD/TD	cf/rev	10/100	10/100	10/100	10/100	10/100	10/100	10/100	10/100	100/1000	100/NA	100/NA	100/NA
Min. CTR Reading	cf	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2	2	2	2
Nominal Pipe Size	in.	2	2	2	2	2	3	3	4	4	6	6	8
Flange/Flange Dim.	in.	6-3/4	6-3/4	6-3/4	6-3/4	6-3/4	6-3/4	9-1/2	9-1/2	9-1/2	16	18	21
Oil Capacity: Side Inlet	oz.	0.8	0.8	0.8	1.25	1.25	1.25	3.4	3.4	3.4	40.2	40.2	40.2
Oil Capacity: Top Inlet	oz.	3	3	3	7.6	7.6	7.6	21.85	21.8	21.8	154	154	154

Meter Sizing

Model	8C175*	11C175*	15C175*	2M175	3M175	5M175	7M175	11M175	16M175	23M175	38M175	56M175
Base Rating (ACFH)	**800**	**1100**	**1500**	**2000**	**3000**	**5000**	**7000**	**11000**	**16000**	**23000**	**38000**	**56000**
Metering Pressure (PSIG)	**Corrected Capacity at Metering Pressure - MSCFH**											
1	0.8	1.2	1.6	2.1	3.1	5.2	7.3	11.5	16.7	24	39.7	58.5
5	1.1	1.5	2	2.6	4	6.6	9.2	14.5	21.1	30.3	50	73.8
25	2.1	2.9	4	5.4	8	13.4	18.7	29.4	42.8	61.5	101.7	149.8
60	4	5.6	7.6	10.1	15.2	25.3	35.4	55.6	80.8	116.2	191.9	282.9
100	6.2	8.5	11.7	15.5	23.3	38.8	54.4	85.4	124.3	178.6	295.1	434.9
150	8.9	12.3	17	22.3	33	56	78	123	179	256.7	424.1	625
175	10.3	14.1	19	25.7	39	64	90	141	206	295.7	488.6	721.5
200	11.7	16	21.9									

*Available with 200 PSIG Rating.

To select proper meter size, use Minimum Operating Pressure and Maximum Instantaneous Hourly Flow Rate.

Complete Data Sheets are available for each meter size. Request Data Sheet by meter model.

DRESSER Measurement

Dresser Measurement
2135 Hwy 6 South
Houston, Texas, USA TX 77077
Email: DMD_Roots@dresser.com

Dresser, Inc.
PH: 281 966 4300
FX: 281 966 4307
Website: www.dresser.com

S:B3
Rev. 6/01

Addendum – Concord

Concord Court Apartments
55 Bowen St.
Staten Island, NY 10304

Site Contact
Jose – Site Supervisor – 516-305-2335
Rick @ All Systems Cogen – 631-750-6060
Joe Gilligan @ All Systems Cogen – 631-891-8123

- CDH was on site February 9, 2012 to install the Obvius datalogger, thermistors, and terminate wiring.
- CDH on site March 9, 2012 to verify sensors.
- Thermowells not fully in flow, causing inaccurate temperature readings.
- CDH on site April 19, 2012 to replace 4" thermistors with 6" thermistors.
- CDH on site July 24, 2013 to replace broken 4" THW4 thermistor with new 6" thermistor.
- CDH on site May 20, 2014 to replace broken 6" THW5 thermistor with new surface mount thermistor.

Obvius Phone #: 718-720-6051 *2

Summary

The site provided the gas meter, power meter, and flow meters while CDH Energy provided the thermistors and thermowells. All Systems Cogen did the mechanical and electrical installation work. CDH provided and installed the data logger and terminated all the sensor wiring.

Monitored Data Points

Logger Channel	Data Point	Description	Eng Units	Instrument / Transducer	Output
1	WGT	Net Generator Power	kWh	Wattnode: WNC-3Y-208-P	Pulse
2	FG	Natural Gas to Generator	cf	Roots: Series B	Pulse
3	FHW1	DHW Loop Flowrate	gal	Onicon F-1111	4-20 mA
4	FHW2	Boiler Loop Flowrate	gal	Onicon F-1111	4-20 mA
5	THW1	Cogen Loop Temp - Supply	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
6	THW2	Cogen Loop Temp - Space Heating	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
7	THW3	Cogen Loop Temp - Dump (return)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
8	THW4	Cogen Loop Temp - Boiler (supply)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
EXP1	THW5	Cogen Loop Temp - Boiler (return)	^{0}F	Veris 10k Type 2 Thermistor	4-20 mA
-	QU	Usefull Recovered Heat	Mbtu	-	Calculated
-	QR	Rejected Recovered Heat	MBtu	-	Calculated
-	QSH	Recovered Heat - Boiler	MBtu	-	Calculated
-	QDHW	Recovered Heat - DHW	MBtu	-	Calculated

Procedure

- Power measurements were made with a Fluke 39 handheld meter from phase to phase (p-p).
    - Generator power measurements were taken in the 480 VAC disconnect upstream of the transformer (gross power), and in the 208 VAC panel (net power) where the Wattnode CT's are located (downstream of the transformer).
    - Parasitic loads can be calculated as the difference between the gross and net power measurements.

- Temperatures were measured using a Fluke 51-II and a surface probe.
    - All temperatures were measured from the surface of the copper piping.

- Both hot water loop flows were verified using a Portaflow ultrasonic flowmeter, mounted on a straight section of the return piping.

- Natural gas use was verified by counting pulses received by the data logger.

Verification Data – November 18, 2011

Generator Power:

The Wattnode CT's are 400 A CT's, and are installed in the 208 VAC cogen disconnect in the cogen room. The CT's are downstream of the 480 V to 208 V transformer, and are measuring the net generator power. The disconnect panel is on the far right hand side of the cogen room. The generators net power was verified at the CT location, and the gross power was verified in the 480 V Disconnect, also located in the cogen room.

Net Power - 208 VAC Panel - Fluke 39

Phase	Amps
A	161
B	161
C	161
Avg :	***161***

Phase	kW
A to B	27
B to C	28
Total :	***55***

Aquisuite Display

54 kW

Gross Power @ 480 VAC Panel

64 kW

Gross Power - 480 VAC Panel - Fluke 39

Phase	Amps
A	76.3
B	76.2
C	76.3
Avg :	***76.3***

Phase	kW
A to B	31
B to C	35
Total :	***66***

Aquisuite Display

55.7 kW

Engine Display

67 kW

Temperatures:

The DHW heating loop supply temperature (jacket water loop) was at a fairly constant temperature.

THW1 (6")	Obvius (°F)	Fluke (°F)
	187.4	186.8
	189.3	188.2
	192	200
Avg:	*189.6*	*191.7*

The temperature after the DHW heat exchanger and after the dump radiator (THW2 & THW3) was fluctuating on approximately 45 second intervals, in response to the load side pump turning on and off. When the pump turned off, the DHW loop temperature would increase until the pump turned back on. The variation in Obvius vs. Fluke measurements is due to the varying time constant between the two measuring methods, the fact the thermowells are longer than the thermistors inserted in them, and the fact that the thermowells are just barely immersed in the flow of the pipe. Upon changing the 4" thermistors to 6" thermistors, the time delay between the handheld Fluke temperature measurement and the data logger value, decreased.

THW2 (6")	Obvius (°F)	Fluke (°F)
	182.6	197
	146	138.3
	136	122.5
Avg:	154.9	152.6

THW3 (6")	Obvius (°F)	Fluke (°F)
	143	143.2
	164	144
	144	135
Avg:	150.3	140.7

The temperatures on the boiler heating loop (exhaust heat exchanger loop) were very constant. However there was a noticeable difference in the Obvius temperature vs. the Fluke temperature. The temperatures in the database will be adjusted in accordance with the on-site verification.

THW4	Obvius (°F)	Fluke (°F)
	192.4	190.3
	192.5	190.6
Avg:	192.45	190.45

THW5	Obvius (°F)	Fluke (°F)
	182.4	179.6
	182.5	179.8
Avg:	182.45	179.7

Flows:

The flow for the DHW loop (FHW1) was verified using the strap on ultrasonic flow meter. According to the verification data there is a slight difference between the flows, so the measured flow will be adjusted in the data base according to the on-site verification.

FHW1

Obvius (gpm)	Portaflow (gpm)
21	25
20.9	24.5
14.2	15.6
13.1	15.2
14.1	16.2
12.8	14.6
10.8	13
10.3	13.1
19.5	24.8
8.5	10.1
8	10.3
13.9	***16.6***

Avg:

The Obvius was receiving accurate readings from the Onicon flow meter because the boilers weren't running at the time of verification. As a result the water was well below the saturation point, so there were no vapor bubbles in the piping. The data for FHW2 will be adjusted according to the difference in gpm's measured.

FHW2

Obvius (gpm)	Portaflow (gpm)
25.3	27.4
25.5	27.5
25.7	27.5
25.5	***27.5***

Avg:

Verification Data – July 24, 2013

While on site installing replacement thermistor for THW5, all temperatures were verified again.

THW1	Fluke (°F)	Obvius (°F)
	191.5	191.98
	188.9	192.78
	187.5	191.2
Avg:	*190.2*	*192.4*

THW2	Fluke (°F)	Obvius (°F)
	142.1	141.6
	142.6	147.5
	141.5	146.3
Avg:	*142.1*	*145.1*

THW3	Fluke (°F)	Obvius (°F)
	145.8	145.5
	133.5	139.1
	140.3	142.7
Avg:	*139.9*	*142.4*

THW4	Fluke (°F)	Obvius (°F)
	196.9	199.9
	196.8	199.4
Avg:	*196.85*	*199.65*

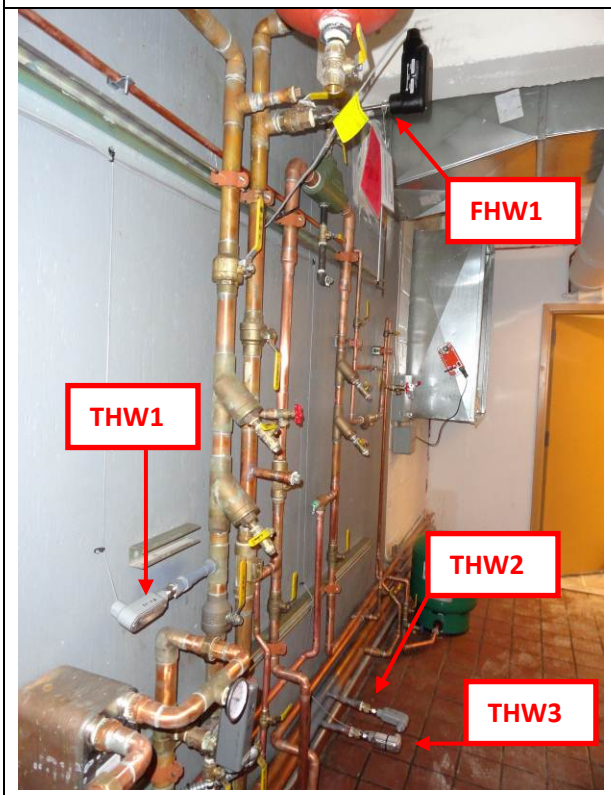
THW5*	Fluke (°F)	Obvius (°F)
	182.4	191.4
	184.3	191.2
	184.7	191.2
	182.5	191.2
	185.5	191.2
	184.3	189.7
Avg:	*184.9*	*190.45*

* New THW5 data adjusted based on this field calibration.

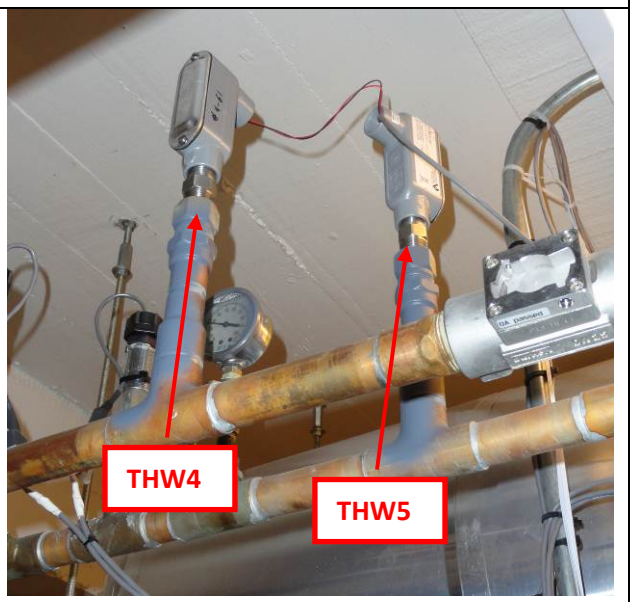
Site Photos

CDH enclosure and datalogger

Boiler heating loop flowmeter – FHW2



DHW heating and dump radiator loop sensor locations



Boiler heating loop supply and return temperature sensors

Gas meter

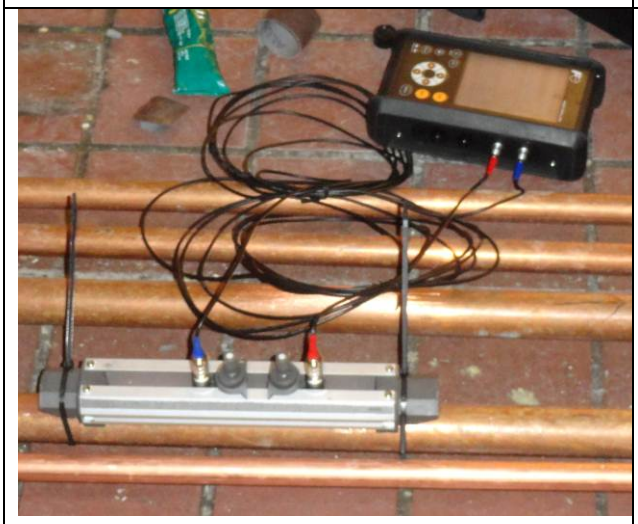
Cogen disconnect (far left) and CT location

Beckwith panel (bottom) and Wattnode panel (top)

Wattnode inside enclosure

480 V Disconnect – Gross power measurement location

208 V breaker panel (left), 208 V feeder panel (center), and 208 V disconnect (right) – Net power measured in center panel.



FHW1 verification location

FHW2 verification location