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Means & Methods for Metering Low Temperature Thermal Energy

Presenter: Connor Dacquay, P.E., GEOptimize

DESIGN TRACK - CEU CREDIT ELIGIBLE - 9:30 AM

Means & Methods for Metering Low Temperature Thermal Energy

Connor Dacquay, Dr. Eng, PE, CGD

connor@geoptimize.ca

1-204-996-8133

Overview

1. Hardware
2. Standards & Regulations
3. Software
4. Geothermal Energy as a Service (EaaS)

Learning Objectives

1. Learn how to measure a Btu
2. Understand factory and onsite calibration
3. Understand differences in a connection fee and consumption fee

British Thermal Unit (Btu)

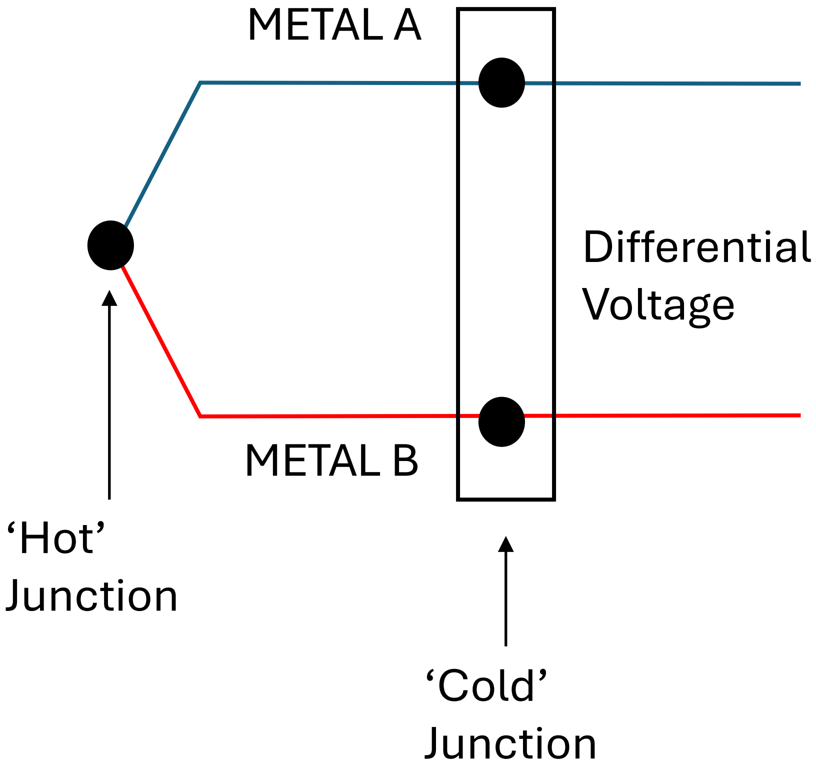
- $Q = c_p * M * \Delta T$
  - Q – heating or cooling capacity(Btu/hr)
  - c_p – specific heat of fluid (Btu/lb/°F)
  - M – mass of fluid per time (GPM)
  - ΔT – temperature difference between entering and leaving fluid (°F)

Temperature Sensors

- Thermocouple
- Resistance temperature detector (RTD)
- Thermistor

Thermocouple

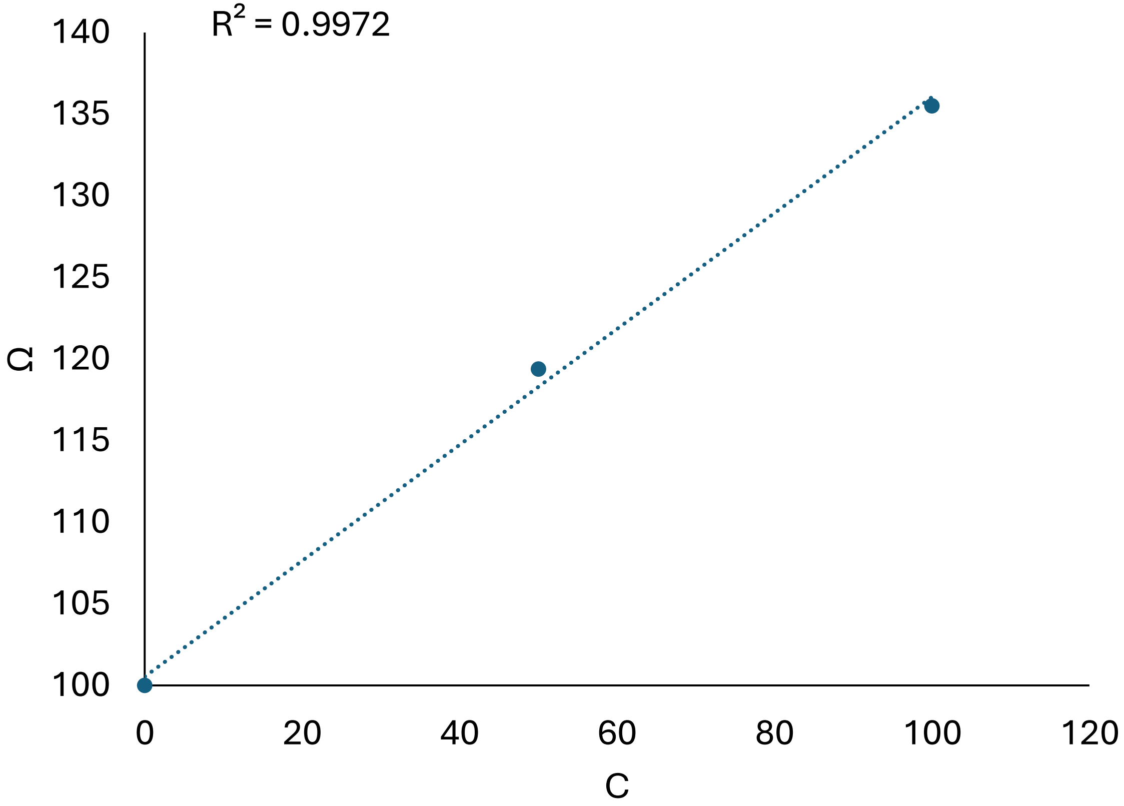
- Pros
  - Wide temperature range
  - Rugged & durable
  - Low cost
  - Quick response
- Cons
  - Lower accuracy (+/- 0.5 - 2°F)
  - Nonlinearity
  - Drift over time



Resistance Temperature Detector (RTD)

- Pros
  - High accuracy (+/- 0.055 - 0.5°F)
  - Linearity
  - Repeatability

- Cons
  - Narrow temperature range
  - Slower response time
  - Fragility
  - Higher cost



Flow Meters

- Ultrasonic
- Venturi
- Magnetic
- Turbine
- Oscillating Jet
- Vortex

Ultrasonic – Spool

- Pros
  - No pressure drop
  - Reliability
  - High accuracy (0.5% - 1%)

- Cons
  - Cost
  - Sensitivity to fluid characteristics
  - Pipe condition and installation environment

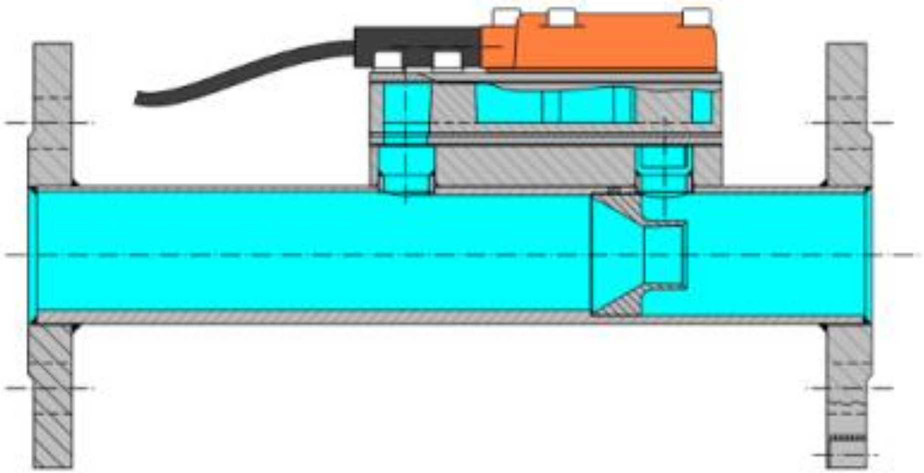
Ultrasonic – Clamp-on

- Pros
  - Nonintrusive
  - Easy installation
  - Low cost for large diameter pipe
- Cons
  - Lower accuracy (1% - 5%)
  - Require ultrasonic couplant
  - Pipe condition and installation environment

Venturi

- Pros
  - No moving parts
  - High reliability and low maintenance
  - Durability
  - Higher accuracy (0.5% - 1.5%)

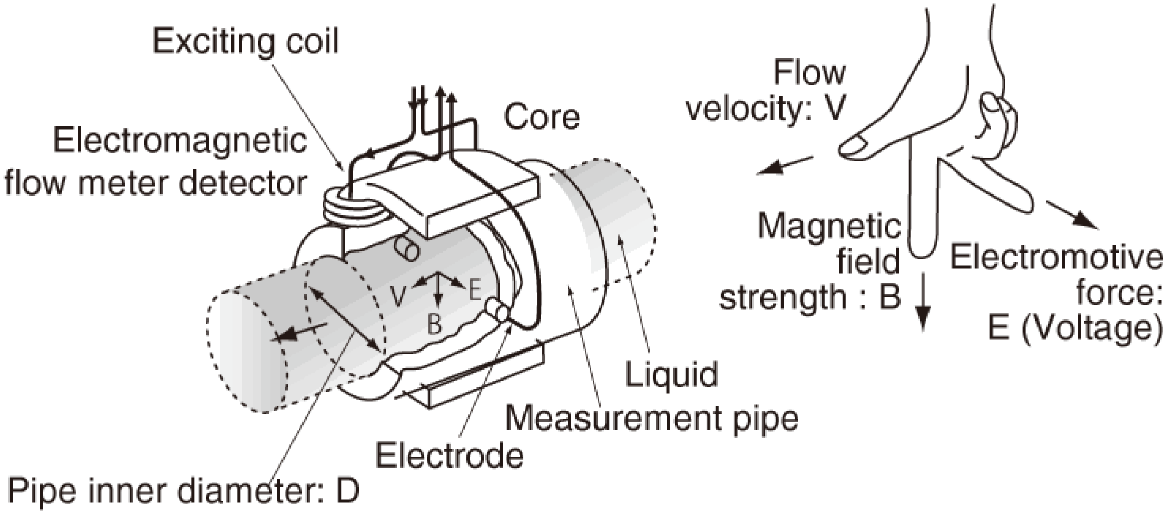
- Cons
  - Intrusive
  - Cost
  - Pressure drop



Magnetic

- Pros
  - No moving parts
  - High reliability and low maintenance
  - Higher accuracy (0.5% - 2%)

- Cons
  - Intrusive
  - Cost



Turbine

- Pros
  - Direct measurement of flow velocity
  - Simple design
  - Higher accuracy (0.5% - 1%)

- Cons
  - Intrusive
  - Cost
  - Moving parts
  - Pressure drop




European Standard EN1434

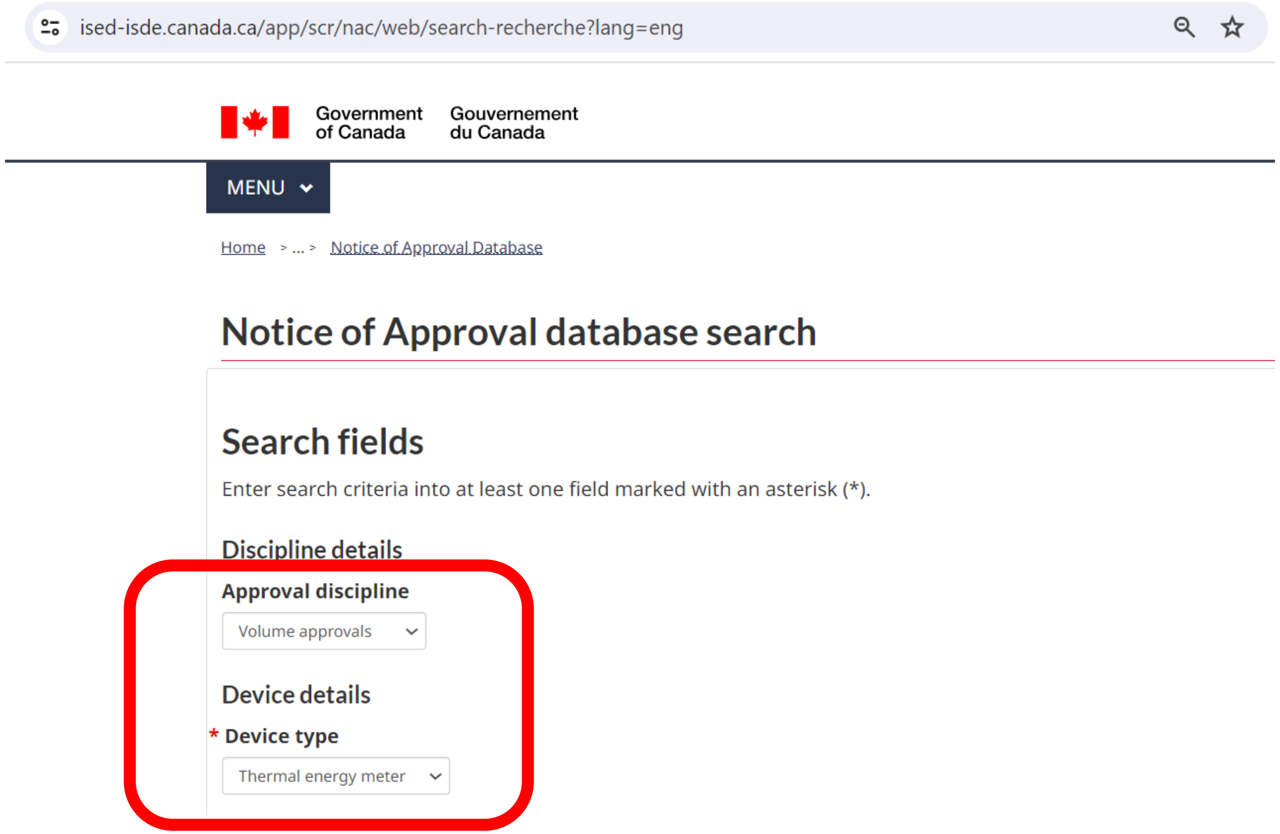
- CEN is the European Committee for Standardization
- EN1434 specifies requirements and test methods for “heat meters”
- Ensures the accuracy, reliability and compatibility of heat metering devices across Europe
- Created in 1997

Measurement Canada

- Government of Canada agency
- Primary mandate is to ensure the integrity and accuracy of measurement in the Canadian marketplace
- Regulates and enforces the accuracy of water, natural gas, electricity and Btu meters
- USA equivalent is National Institute of Standards & Technology (NIST)

Measurement Canada

- New thermal energy (Btu) meter division
- Currently 20 approved thermal energy meters
- Using an approved meter allows for legal trade of commodity
- A thermal energy meter for commercial use must be Class 1 or 2



Measurement Canada

Q/A

Measurement Canada

- Acceptance limits are the sum of error for each sub-assembly
- Total error based on the measurement equipment and test parameters
- $Error = Ef + Et + Ec$
  - $Ef = \left(2 + 0.02\frac{qp}{q}\right)$
  - $Et = \left(\frac{0.5+3\Delta\theta min}{\Delta\theta}\right)$
  - $Ec = \left(\frac{0.5+\Delta\theta min}{\Delta\theta}\right)$
- Typical total error +/- 2% - 4%

Innovation, Science and Economic Development Canada
Measurement Canada

Innovation, Sciences et Développement économique Canada
Mesures Canada

APPROVAL No. - N° D'APPROBATION
AV-2483C

NOTICE OF CONDITIONAL APPROVAL

Issued by statutory authority of the Minister of Industry (styled Innovation, Science and Economic Development) for the following device model(s):

AVIS D'APPROBATION CONDITIONNELLE

Émis en vertu du pouvoir statutaire du ministre de l'industrie (dénommé Innovation, Sciences et Développement économique) pour le(s) modèle(s) d'instrument suivant(s):

TYPE OF DEVICE

Thermal Energy Meter

TYPE D'APPAREIL

Compteur d'énergie thermique

APPLICANT / **REQUÉRANT**

ONICON Inc.
11451 Belcher Road South, Largo
Florida 33773, USA

MANUFACTURER / **FABRICANT**

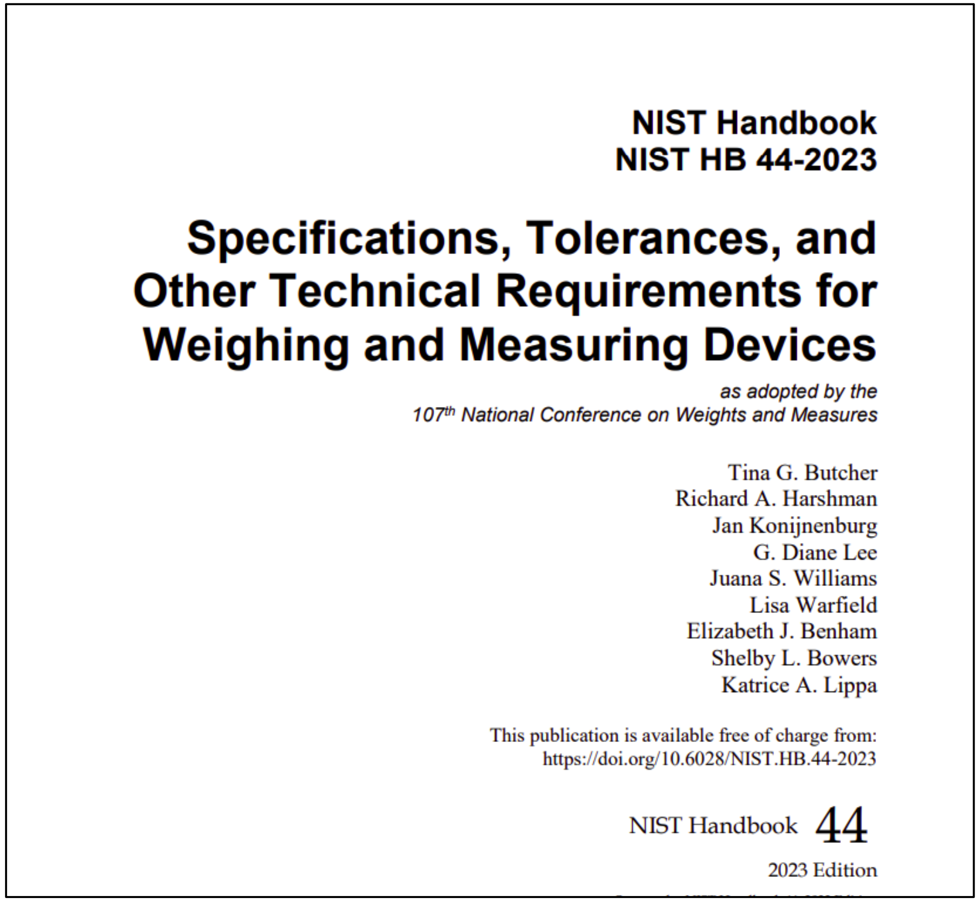
ONICON Inc.
11451 Belcher Road South, Largo
Florida 33773, USA

MODEL(S) | MODÈLE(S)

SYSTEM-22

Acceptance Tolerances

- Natural gas meters +/- 1.5%
- Water meters +/- 1.5%
- Electricity meters
    - Maintenance +/- 2%
    - Acceptance +/- 1%



NIST Handbook
NIST HB 44-2023

Specifications, Tolerances, and Other Technical Requirements for Weighing and Measuring Devices

as adopted by the
107th National Conference on Weights and Measures

Tina G. Butcher
Richard A. Harshman
Jan Konijnenburg
G. Diane Lee
Juana S. Williams
Lisa Warfield
Elizabeth J. Benham
Shelby L. Bowers
Katrice A. Lippa

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https://doi.org/10.6028/NIST.HB.44-2023

NIST Handbook 44

2023 Edition

Factory Calibration

- After Measurement Canada has approved a Btu meter, the manufacturer must prove each device has been calibrated to the standard
- Devices often have a higher accuracy than the minimum acceptable tolerance
- Calibration certificates come with every Btu meter ordered

ilac-MRA DANAK CAL Reg.No. 268 kamstrup

CALIBRATION CERTIFICATE

MC603

Certificate No.: 268-055-0000105

Ordered by: Kamstrup A/S

Address: Industrivej 28
8660 Skanderborg DENMARK

Make: Kamstrup A/S
Type: 603E21970000000
Serial No.: 80010870
Prog. No.: 448072100024241229510300000

Ambient temp.: 23 °C ± 5 °C
MDIR: EN 1434
Date of calibration: 2017-09-06
Calibrated by: ACH

Test	True T inlet [°C]	True T Outlet [°C]	True V [l]	True E [Wh]	Measured E [Wh]	**Error [%]**	Uncer-tainty [±%]	MPE [±%]
1	44,04	40,75	1.000,00	3.780,75	3.781,40	**0,02**	0,25	1,41
2	79,30	65,03	1.000,00	16.287,30	16.288,20	**0,01**	0,09	0,71
3	159,62	20,02	1.000,00	163.417,52	163.477,6(	**0,04**	0,02	0,52
4	15,09	18,39	1.000,00	3.824,46	3.832,80	**0,22**	0,24	1,41
5	6,03	20,02	1.000,00	16.257,78	16.254,10	**-0,02**	0,09	0,71

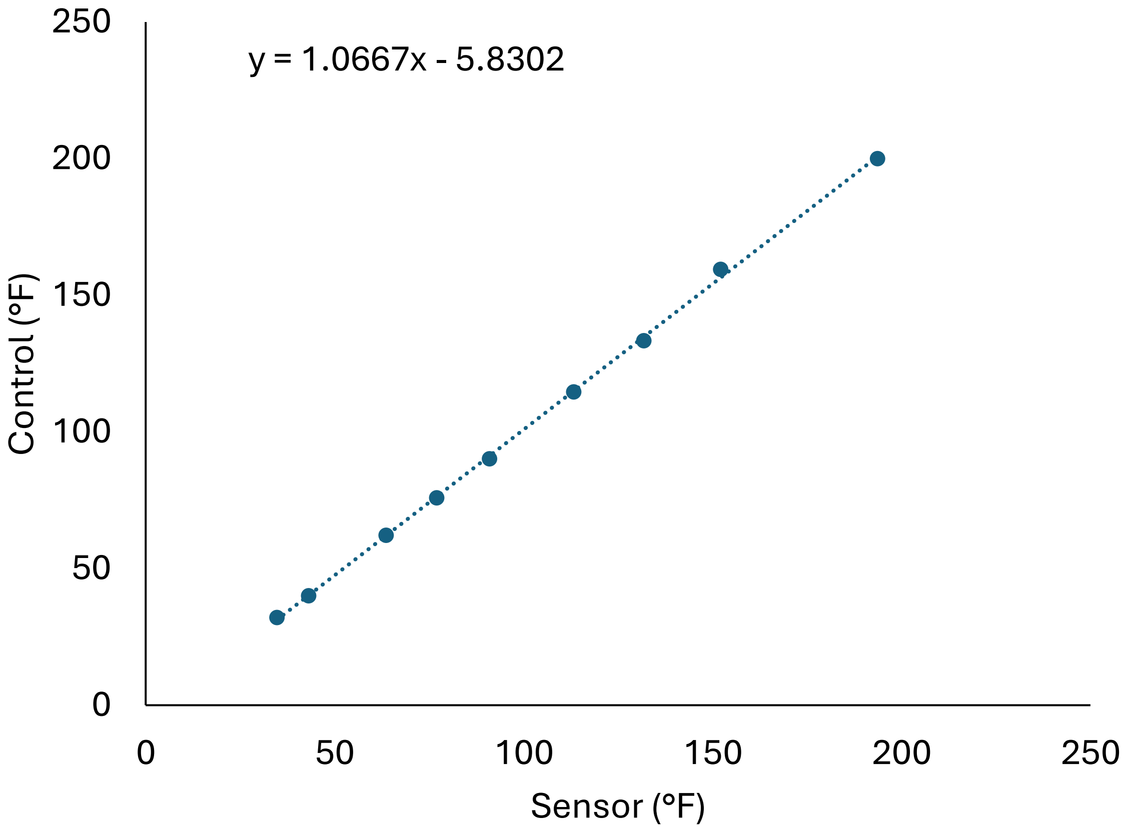
Reference: K000187

Calibration procedure: 5509-167

The reported expanded uncertainty of measurements is stated as the standard uncertainty of measurement multiplied by the coverage factor k=2, which for a normal distribution corresponds to a coverage probability of approximately 95 %. This certificate provides traceability of measurements to recognized national or international standards.

On-Site Recalibration

- Measure against a high accuracy control
- Ensure stable conditions
- Various measurements across the temperature and flow range
- Readings taken at the same time
- Frequency is dependent on application

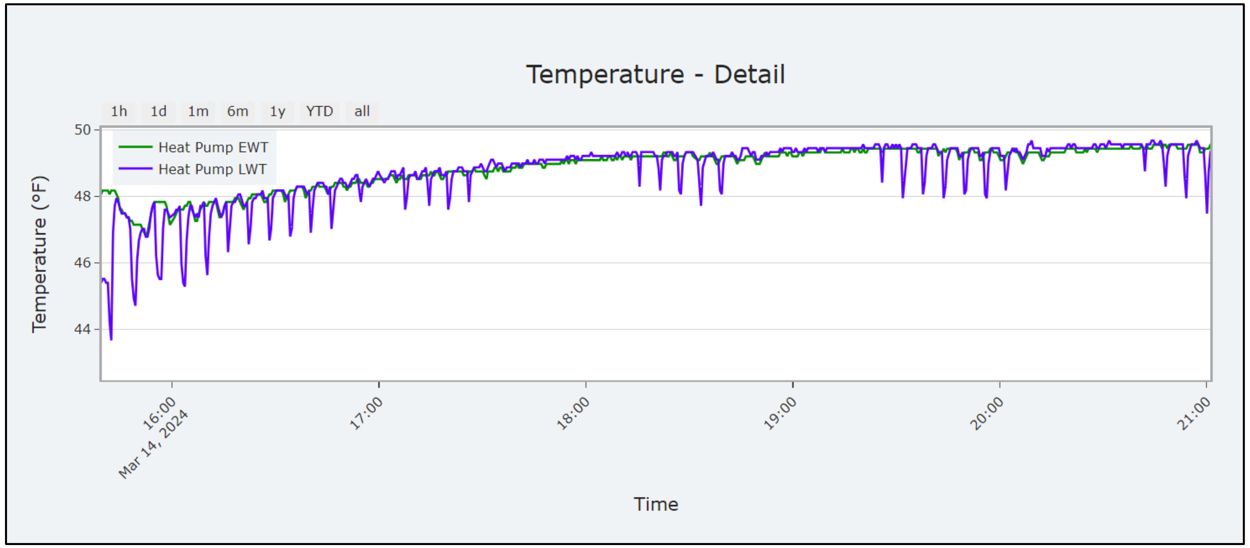


Calibration in Other Industries

- Aerospace
- Hospitals
- Nuclear power
- Pharmaceuticals
- Biotechnology
- Industrial processes

Small ΔT Considerations

- Thoughtful pumping strategies
- Calibration of temperature sensors
- For low load and small ΔT situation apply fixed fee past a certain threshold

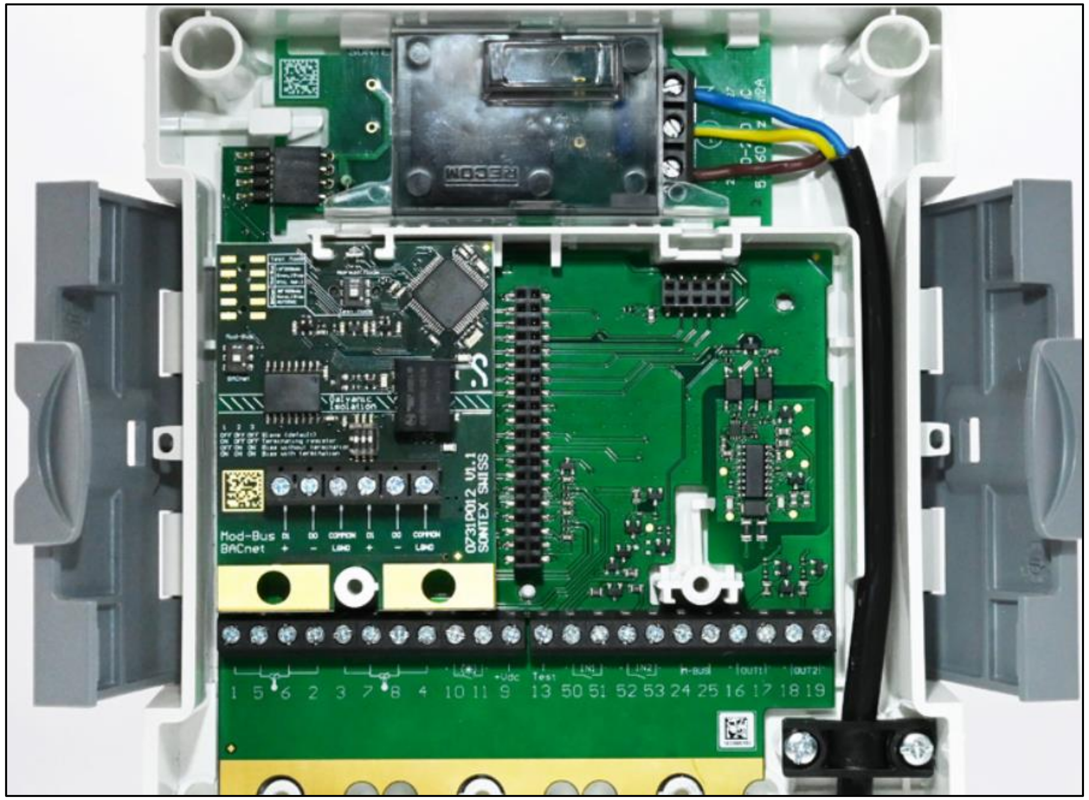


Hardware vs. Software

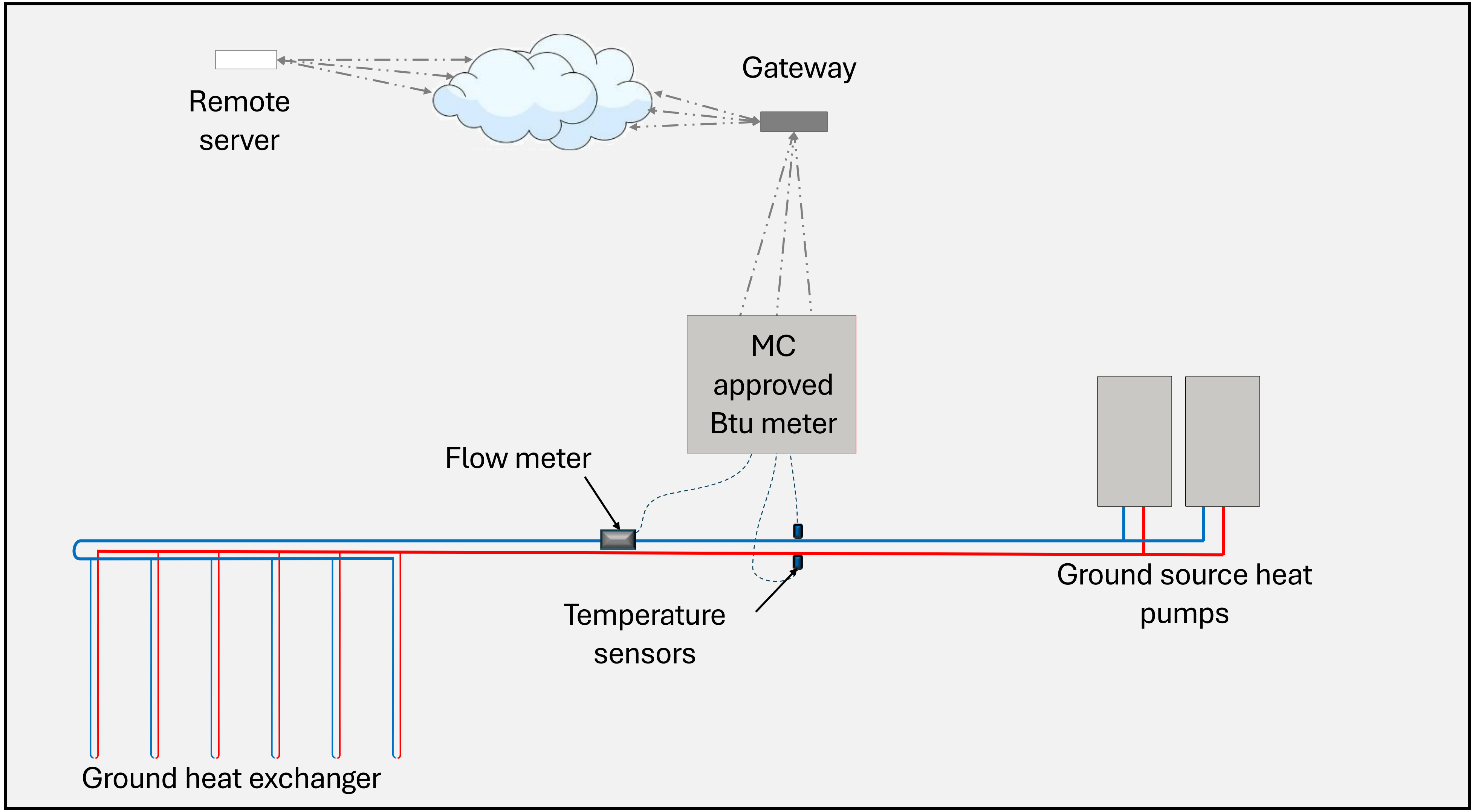
- Local storage limitations with physical Btu meters
- Software is needed for:
  - Long term data collection
  - Data organization and analysis
  - Graphical interpretation

Communication Interfaces

- BACnet and MODBUS are communication protocols
- MS/TP is for BACnet and RTU is for MODBUS
- Ethernet, RS232, and RS485 are communication methods for physical connection
- Wi-Fi enabled for wireless communication method



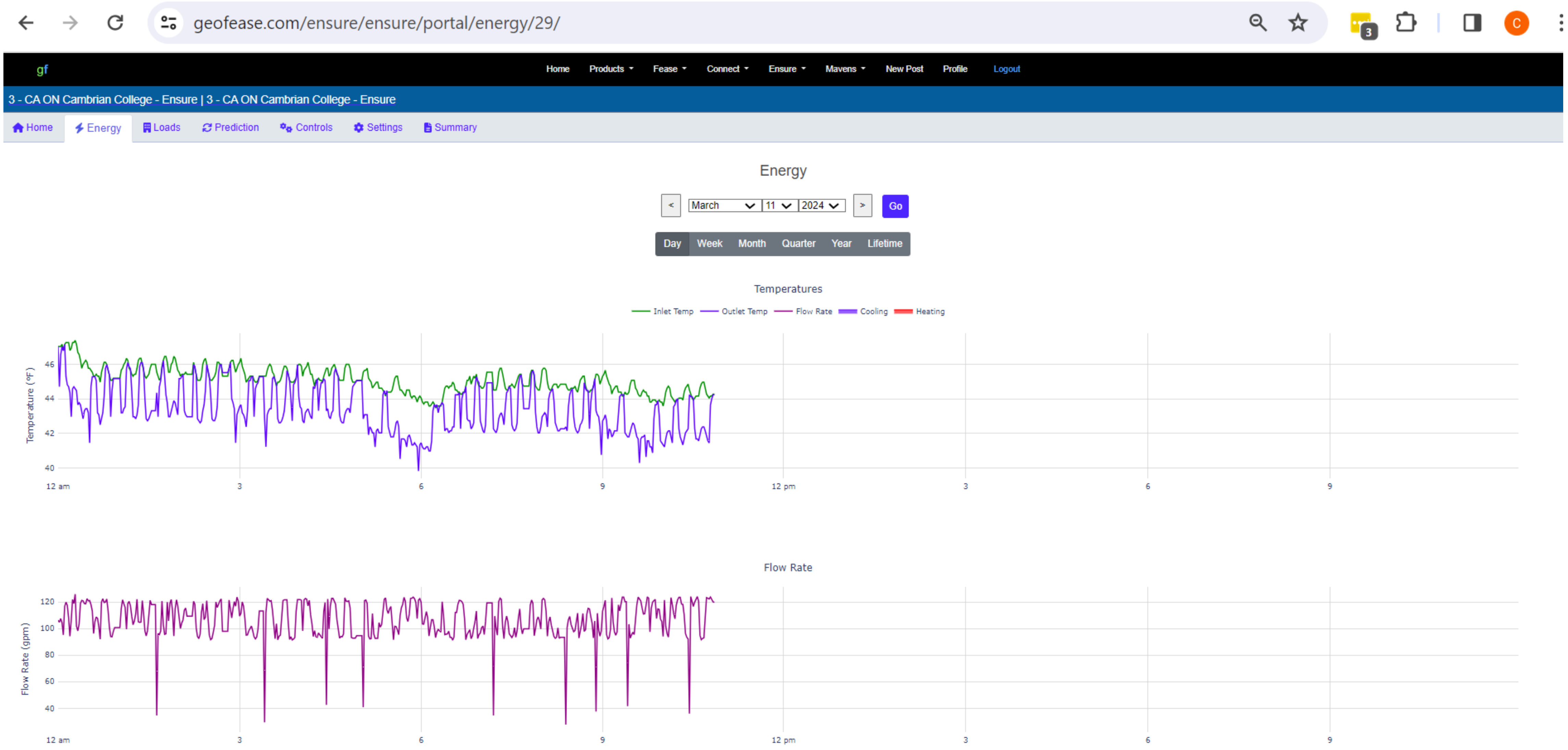
Communication Interfaces



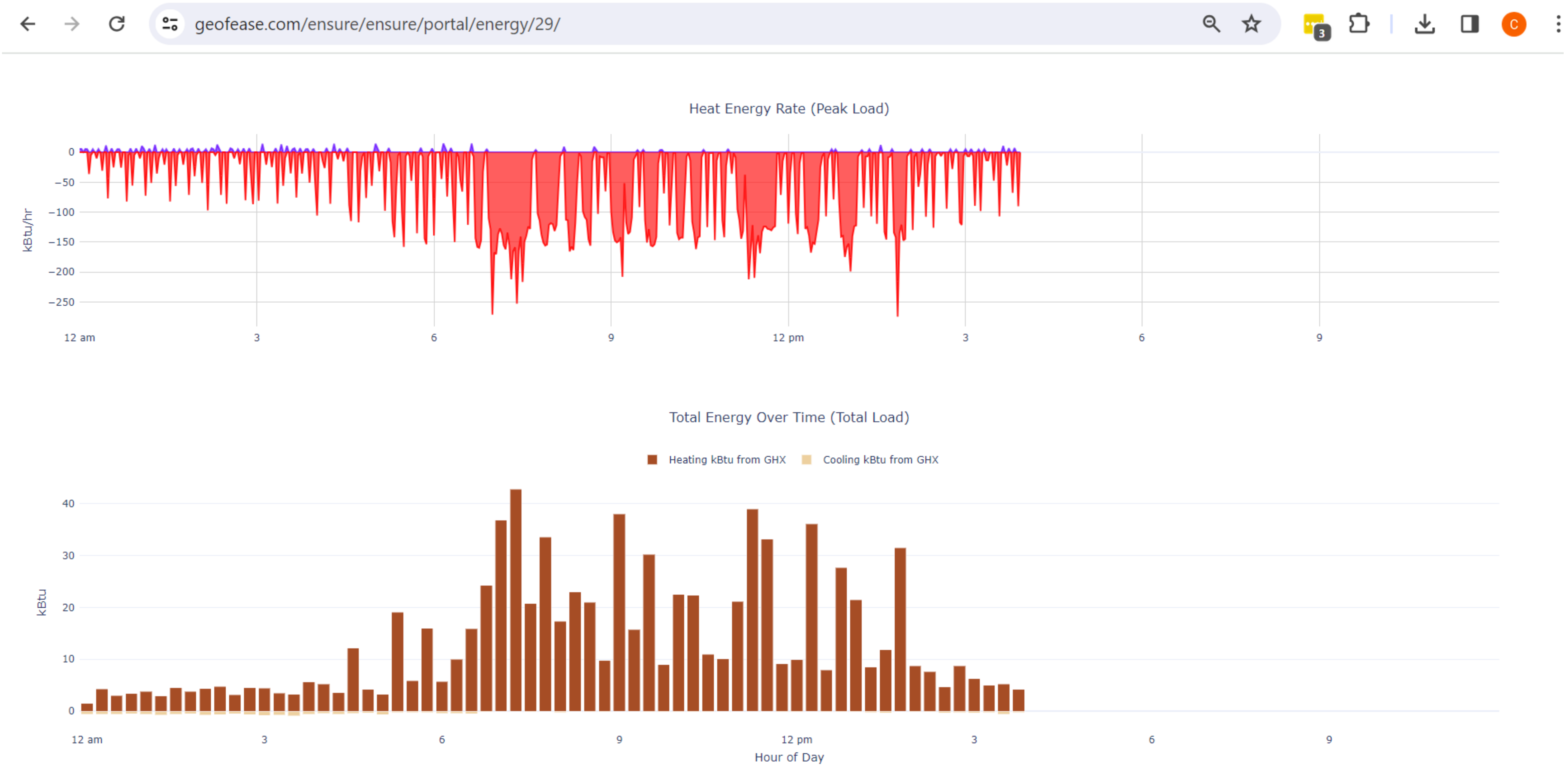
Software


geofease.com/ensure/ensure/portal/energy/29/
Temperature
Inlet Temp
Outlet Temp
Temperature (°F)
90
80
70
60
50
40
58.1 Inlet Temp
57.65 Outlet Temp
Nov 24, 2022
Jul 2021
Jan 2022
Jul 2022
Jan 2023
Jul 2023
Jan 2024
Time
Detailed View
Flow Rate
Flow Rate (gpm)
100
80
60
40
20
0
Jul 2021
Jan 2022
Jul 2022
Jan 2023
Jul 2023
Jan 2024
Time
Detailed View

Software


geofease.com/ensure/ensure/portal/energy/29/
gf
Home Products Fease Connect Ensure Mavens New Post Profile Logout
3 - CA ON Cambrian College - Ensure | 3 - CA ON Cambrian College - Ensure
Home Energy Loads Prediction Controls Settings Summary
Energy
March 11 2024 Go
Day Week Month Quarter Year Lifetime
Temperatures
Inlet Temp Outlet Temp Flow Rate Cooling Heating
Temperature (°F)
46 44 42 40
12 am 3 6 9 12 pm 3 6 9
Flow Rate
Flow Rate (gpm)
120 100 80 60 40
12 am 3 6 9 12 pm 3 6 9

Software



geofease.com/ensure/ensure/portal/energy/29/
Heat Energy Rate (Peak Load)
kBtu/hr
0
−50
−100
−150
−200
−250
12 am
3
6
9
12 pm
3
6
9
Total Energy Over Time (Total Load)
Heating kBtu from GHX
Cooling kBtu from GHX
kBtu
40
30
20
10
0
12 am
3
6
9
12 pm
3
6
9
Hour of Day

Software

geofease.com/ensure/ensure/portal/energy/29/

12 am 3 6 9 12 pm 3 6 9
Hour of Day

Energy Information			
Description	**Interval**	**Start**	**End**
Time Period	Day	00:00	23:59
	Minimum	**Maximum**	**Average**
Heat Pumps			
Inlet Temperature (°F)	44.3	48.7	46.9
Outlet Temperature (°F)	41.3	48.8	45.9
Delta T (°F)	-4.5	0.2	-1.0
Flow Rate (gpm)	25.5	131.9	104.3
Loads			
Cooling Peak (kBtu/hr)	0.0	14.8	1.2
Heating Peak (kBtu/hr)	0.0	274.8	53.0
Cooling Total (kBtu)	0.0	0.9	0.3
Heating Total (kBtu)	1.5	42.8	13.4

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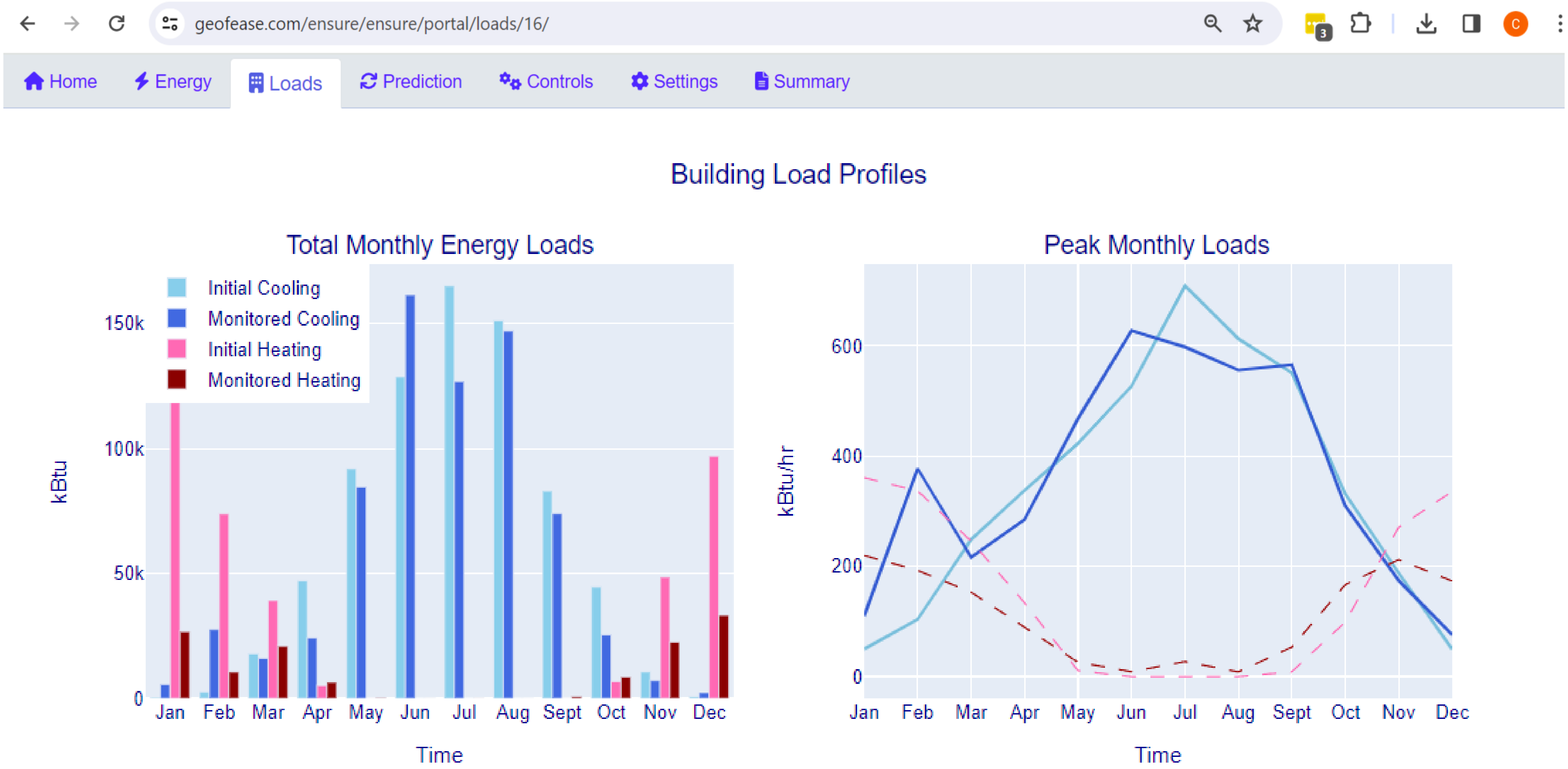
Software



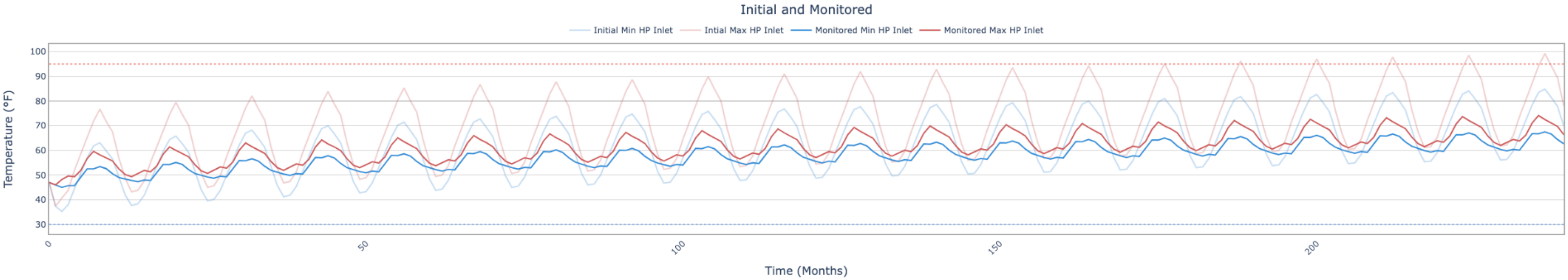
geofease.com/ensure/ensure/portal/loads/16/
Home
Energy
Loads
Prediction
Controls
Settings
Summary
Building Load Profiles
Total Monthly Energy Loads
Initial Cooling
Monitored Cooling
Initial Heating
Monitored Heating
kBtu
150k
100k
50k
0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Time
Peak Monthly Loads
kBtu/hr
600
400
200
0
Jan Feb Mar Apr May Jun Jul Aug Sept Oct Nov Dec
Time

Software

geofease.com/ensure/ensure/portal/prediction/16/

Home | Energy | Loads | Prediction | Controls | Settings | Summary

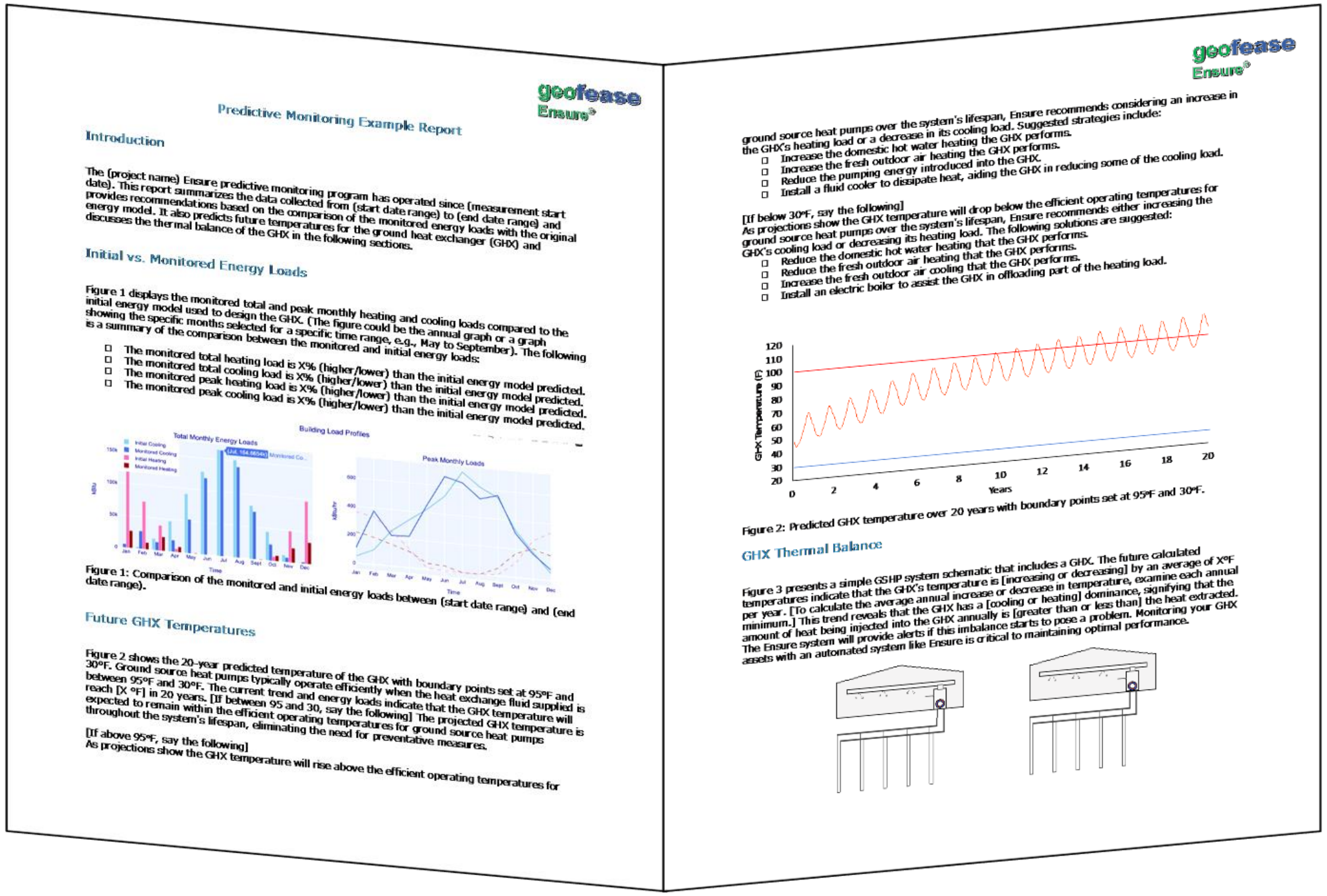
Prediction



Prediction Results		
Prediction Time	240 months	
Predicted Inlet Temperatures	*Minimum*	*Maximum*
Initial	35.2 °F	99.2 °F
Monitored	45.0 °F	74.1 °F

Software

- Automated reports for all stakeholders
  - Billing information summary
  - Summary of GHX performance
  - Recommendations for optimized operation



geofease Ensure®

Predictive Monitoring Example Report

Introduction

The (project name) Ensure predictive monitoring program has operated since (measurement start date). This report summarizes the data collected from (start date range) to (end date range) and provides recommendations based on the comparison of the monitored energy loads with the original energy model. It also predicts future temperatures for the ground heat exchanger (GHX) and discusses the thermal balance of the GHX in the following sections.

Initial vs. Monitored Energy Loads

Figure 1 displays the monitored total and peak monthly heating and cooling loads compared to the initial energy model used to design the GHX. (The figure could be the annual graph or a graph showing the specific months selected for a specific time range, e.g., May to September). The following is a summary of the comparison between the monitored and initial energy loads:

- The monitored total heating load is X% (higher/lower) than the initial energy model predicted.
- The monitored total cooling load is X% (higher/lower) than the initial energy model predicted.
- The monitored peak heating load is X% (higher/lower) than the initial energy model predicted.
- The monitored peak cooling load is X% (higher/lower) than the initial energy model predicted.

Figure 1: Comparison of the monitored and initial energy loads between (start date range) and (end date range).

Future GHX Temperatures

Figure 2 shows the 20-year predicted temperature of the GHX with boundary points set at 95°F and 30°F. Ground source heat pumps typically operate efficiently when the heat exchange fluid supplied is between 95°F and 30°F. The current trend and energy loads indicate that the GHX temperature will reach [X °F] in 20 years. [If between 95 and 30, say the following] The projected GHX temperature is expected to remain within the efficient operating temperatures for ground source heat pumps throughout the system's lifespan, eliminating the need for preventative measures.

[If above 95°F, say the following]
As projections show the GHX temperature will rise above the efficient operating temperatures for ground source heat pumps over the system's lifespan, Ensure recommends considering an increase in the GHX's heating load or a decrease in its cooling load. Suggested strategies include:

- Increase the domestic hot water heating the GHX performs.
- Increase the fresh outdoor air heating the GHX performs.
- Reduce the pumping energy introduced into the GHX.
- Install a fluid cooler to dissipate heat, aiding the GHX in reducing some of the cooling load.

[If below 30°F, say the following]
As projections show the GHX temperature will drop below the efficient operating temperatures for ground source heat pumps over the system's lifespan, Ensure recommends either increasing the GHX's cooling load or decreasing its heating load. The following solutions are suggested:

- Reduce the domestic hot water heating that the GHX performs.
- Reduce the fresh outdoor air heating that the GHX performs.
- Increase the fresh outdoor air cooling that the GHX performs.
- Install an electric boiler to assist the GHX in offloading part of the heating load.

Figure 2: Predicted GHX temperature over 20 years with boundary points set at 95°F and 30°F.

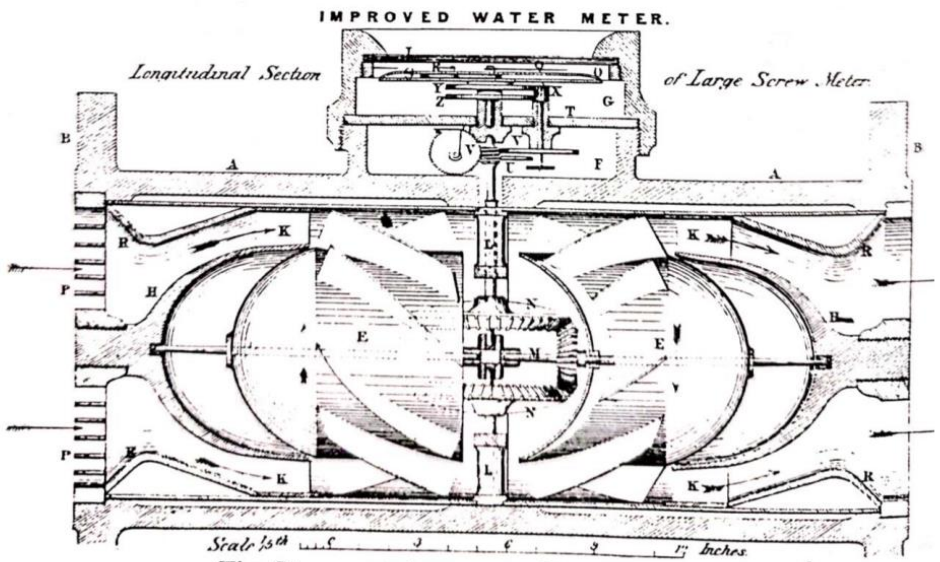
GHX Thermal Balance

Figure 3 presents a simple GSHP system schematic that includes a GHX. The future calculated temperatures indicate that the GHX's temperature is [increasing or decreasing] by an average of X°F per year. [To calculate the average annual increase or decrease in temperature, examine each annual minimum.] This trend reveals that the GHX has a [cooling or heating] dominance, signifying that the amount of heat being injected into the GHX annually is [greater than or less than] the heat extracted. The Ensure system will provide alerts if this imbalance starts to pose a problem. Monitoring your GHX assets with an automated system like Ensure is critical to maintaining optimal performance.

Q/A

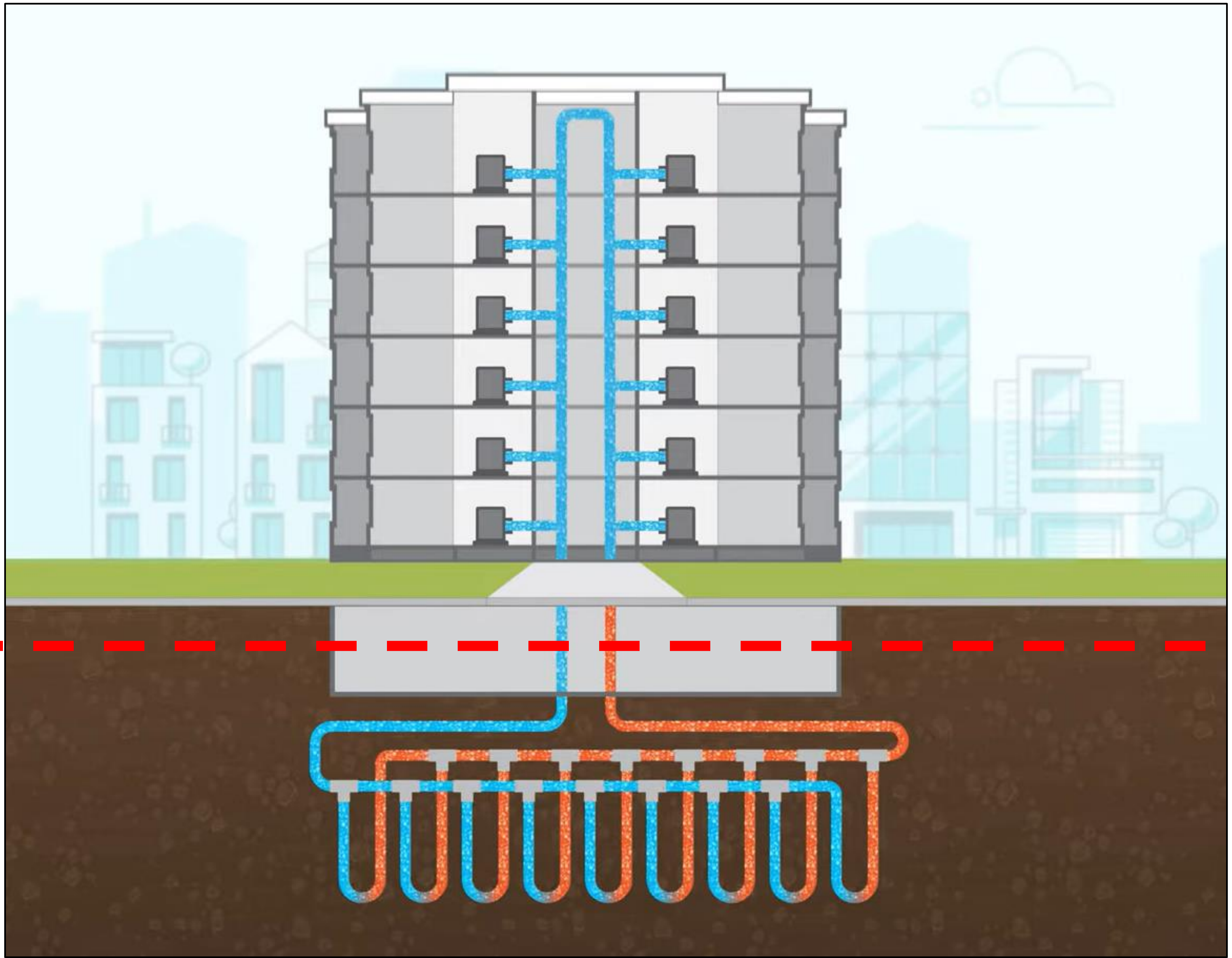
History of Water Measurement

- First recorded use of a water meter was in the 1850s
- First widespread installation of water meters for billing began in late 19th century in Europe
- Connection fee vs. consumption fee



The Siemens twin rotor turbine meter (1850)

Geothermal Energy as a Service (EaaS)



Whisper Valley, TX, USA

- 400+ homes with Enertech heat pumps
- 300 ft vertical boreholes
- 4 separate ambient loop systems
- Auxiliary cooling towers
- Future phases planned

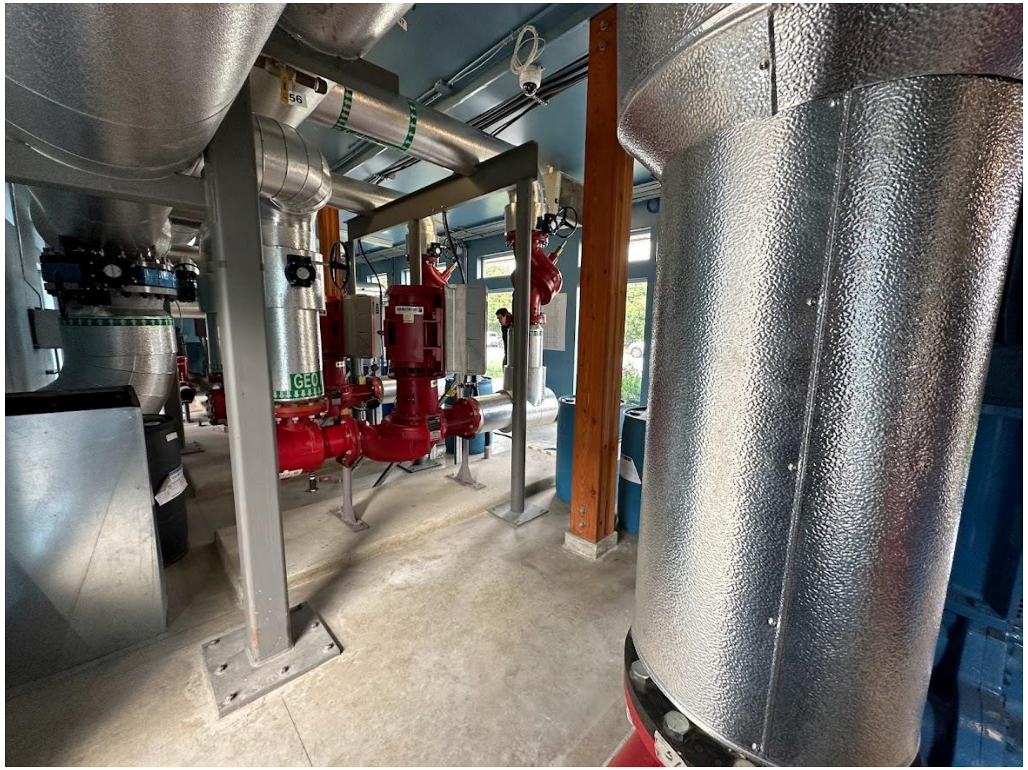
Richmond, BC, Canada

- 4 vertical GHX fields
- 2.2 miles of 20” supply/return lines
- 3 back-up natural gas boilers
- 2 back-up cooling towers
- 1,900,000 ft^2 of residential GFA
- 300,000 ft^2 of non-residential GFA

GARDEN CITY ROAD
McKIM WAY
Future Development
Future Development
Remy
STOLBERG STREET
CAMBIE ROAD
Future Development
DUBBERT STREET
ODLIN ROAD
Future Development
Mayfair Place
Future Development
Future Development
Fire Hall 3 & BC Ambulance
Future Development
GARDEN CITY ROAD
PREVIOUS DEVELOPMENT (NOT SERVICED BY ADEU)
Omega
Future Development
Jamatkhana Temple
Future Development
Geofield 1
DUBBERT STREET
Oxford Lane
PREVIOUS DEVELOPMENT (NOT SERVICED BY ADEU)
SmartREIT
Future Development
Satellite Energy Plant
Alexandra Court
MAY DRIVE
ODLIN ROAD
Energy Centre
Walmart
TOMICKI AVENUE
Geofield 2
Future Development
MAY DRIVE
ALEXANDRA ROAD
NO 4 ROAD

Richmond, BC, Canada

- Connection fee: 9.56 ¢/ft^2 of GFA
- Consumption fee: 0.7 ¢/kBtu
- Excess demand fee:
  - Btu/hr > 20.46 Btu/hr/ft^2 = 62.7 ¢/Btu/hr/ft^2
  - Baseline space heating/cooling and domestic hot water determined by an energy model



Geothermal EaaS New Ideas

- Connection fee + “surge-type pricing”
  - Heating and cooling dynamic billing based on GHX trend
- Heating dominate district loop
  - Heating 20 ¢/Btu
  - Cooling 20 ¢/Btu

Learning Objectives Q/A

What are the two types of sensors needed to measure Btu's?

- Temperature sensors and flow meters

What is the difference between factory and onsite calibration?

- Factory calibration occurs from the manufacturer when a device is created
- Onsite calibration occurs onsite periodically to eliminate sensor drift errors

What is the difference between a connection fee and consumption fee?

- Connection fee is a fixed fee for the service connection and a consumption fee is variable based on usage

Thank You!

- Connor Dacquay, Dr. Eng, PE, CGD
- 1-204-996-8133
- connor@geoptimize.ca

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