Air Source Heat Pump Best Practices

Types, Tips, & Tricks

Presenter

Stephen C. Turner

PE, LEED AP

President

STEPHEN TURNER INC.
Building Better Performance

317 Hope Street
Providence, RI 02906
401.273.1935
stephen@sturnerinc.com
www.buildingcommissioning.com

Code Compliance Enhancement Initiative

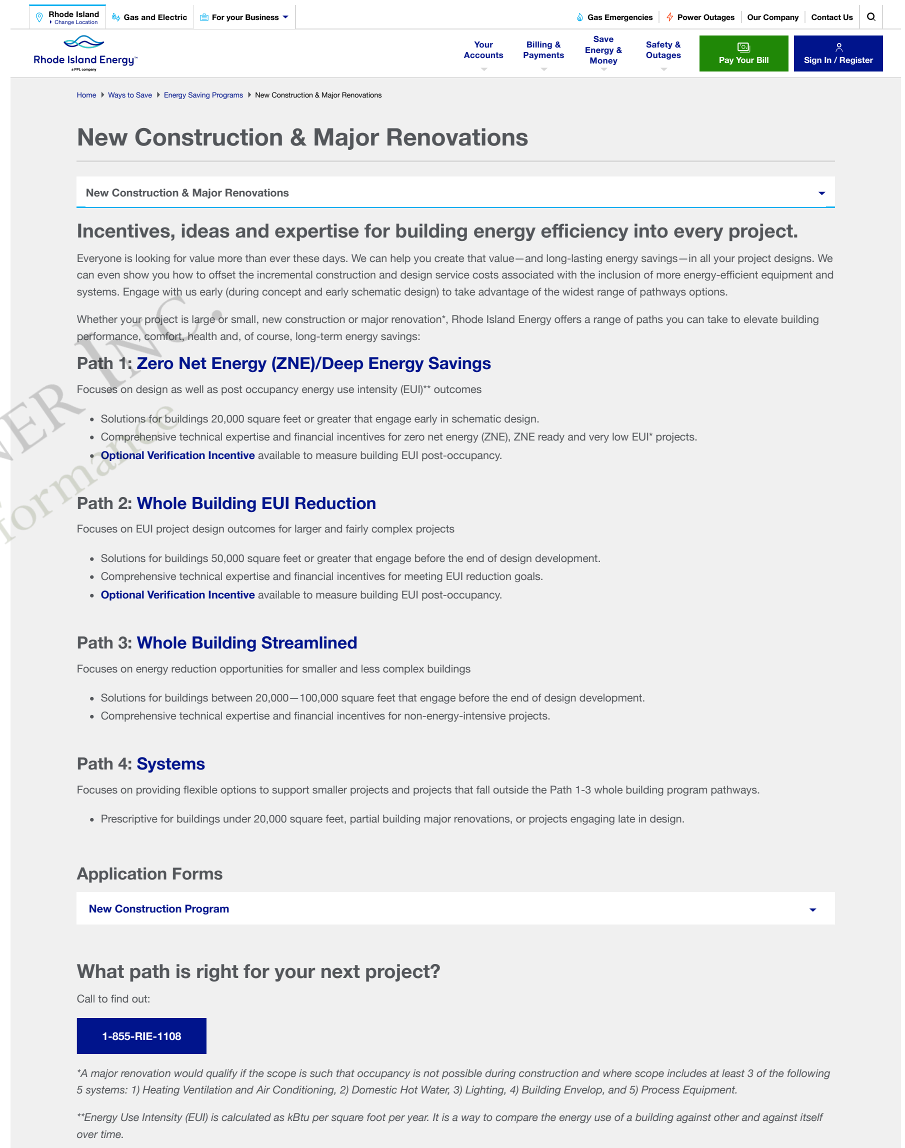
- Free Energy Code Technical Support is available by calling **1-855-343-0105**
- The Rhode Island Energy Code Technical Support Initiative aims to:
  - Improve energy conservation code compliance through educating code officials and industry professionals
  - Establish higher compliance by offering a competitive stretch code
  - Take on an active role in the policy and advocacy of matters related to energy code

RI Energy Rebate

Energy efficiency incentives and rebates continue to be available for New construction and major renovation projects.

Visit https://www.rienergy.com/RI-Business/Energy-Saving-Programs/New-Construction-Major-Renovations

Or call **1-855-RIE-1108**


Rhode Island · Change Location | Gas and Electric | For your Business

Gas Emergencies | Power Outages | Our Company | Contact Us

Rhode Island Energy™ a PPL company

Your Accounts | Billing & Payments | Save Energy & Money | Safety & Outages | Pay Your Bill | Sign In / Register

Home › Ways to Save › Energy Saving Programs › New Construction & Major Renovations

New Construction & Major Renovations

New Construction & Major Renovations

Incentives, ideas and expertise for building energy efficiency into every project.

Everyone is looking for value more than ever these days. We can help you create that value—and long-lasting energy savings—in all your project designs. We can even show you how to offset the incremental construction and design service costs associated with the inclusion of more energy-efficient equipment and systems. Engage with us early (during concept and early schematic design) to take advantage of the widest range of pathways options.

Whether your project is large or small, new construction or major renovation*, Rhode Island Energy offers a range of paths you can take to elevate building performance, comfort, health and, of course, long-term energy savings:

Path 1: Zero Net Energy (ZNE)/Deep Energy Savings

Focuses on design as well as post occupancy energy use intensity (EUI)** outcomes

- Solutions for buildings 20,000 square feet or greater that engage early in schematic design.
- Comprehensive technical expertise and financial incentives for zero net energy (ZNE), ZNE ready and very low EUI* projects.
- **Optional Verification Incentive** available to measure building EUI post-occupancy.

Path 2: Whole Building EUI Reduction

Focuses on EUI project design outcomes for larger and fairly complex projects

- Solutions for buildings 50,000 square feet or greater that engage before the end of design development.
- Comprehensive technical expertise and financial incentives for meeting EUI reduction goals.
- **Optional Verification Incentive** available to measure building EUI post-occupancy.

Path 3: Whole Building Streamlined

Focuses on energy reduction opportunities for smaller and less complex buildings

- Solutions for buildings between 20,000—100,000 square feet that engage before the end of design development.
- Comprehensive technical expertise and financial incentives for non-energy-intensive projects.

Path 4: Systems

Focuses on providing flexible options to support smaller projects and projects that fall outside the Path 1-3 whole building program pathways.

- Prescriptive for buildings under 20,000 square feet, partial building major renovations, or projects engaging late in design.

Application Forms

New Construction Program

What path is right for your next project?

Call to find out:

1-855-RIE-1108

**A major renovation would qualify if the scope is such that occupancy is not possible during construction and where scope includes at least 3 of the following 5 systems: 1) Heating Ventilation and Air Conditioning, 2) Domestic Hot Water, 3) Lighting, 4) Building Envelop, and 5) Process Equipment.*

***Energy Use Intensity (EUI) is calculated as kBtu per square foot per year. It is a way to compare the energy use of a building against other and against itself over time.*

Disclaimer

These trainings are being offered through the support of Rhode Island Energy, and in cooperation with the Rhode Island Building Code Commission. The Energy Code Technical Support staffs are not code officials, and the information provided through the program is not a formal interpretation of the code. Your local code official is responsible for the enforcement of the code and the Rhode Island Building Code Commission is the governing body responsible for interpretations of the code.

Learning Objectives:

Learning Objective 1	Understand the differences between the most common types of commercial heat pump systems
Learning Objective 2	Analyze pros and cons for different types of heat pump systems and understand how to select the right type of heat pump system for a specific application
Learning Objective 3	Learn to evaluate air source heat pump performance and efficiency
Learning Objective 4	Grasp the primary application, operating, and maintenance considerations
Learning Objective 5	Understand the integration and control challenges for ASHP

Overview of Commercial Heat Pumps

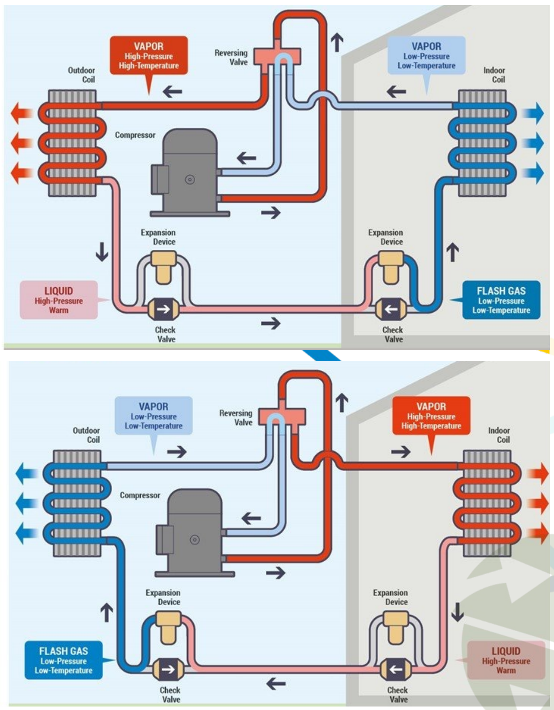


Image source: https://www.hvacrschool.com/wp-content/uploads/2020/11/HP-System.jpg

- In **cooling mode**:
  - Use the evaporator to remove heat from a space, airstream, or hydronic circuit
- In **heating mode**:
  - Use the condenser to add heat to a space, airstream, or hydronic circuit
  - Depending on whether heat pumps are air or water source, the heat is rejected or derived from the outdoor air or a pumped fluid
  - Includes heat of compression in addition to extracted heat from source

Rebates widely available

Electrification reduces renewal of fossil fuel infrastructure

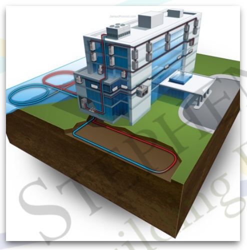
Common types of commercial heat pump systems

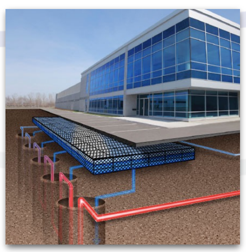
Air to Air	Water Source	Water to Water
• Air source heat pumps reject heat to (cooling mode) or extract heat from (heating) outdoor air • Utilize refrigerant to either heat or cool the space via the reversing valve • The reversing valve changes the direction of the refrigerant to either disperse heat or remove heat from the indoor space. • Air source heat pumps previously were not suited for colder climates, but recent advances has made them more reliable in such climates	• Water source heat pumps reject heat to (cooling mode) or extract heat from (heating) a pumped source loop • May use motorized valves to alter the water flow through the heat pump to change modes • Can avoid the problems with heating mode associated with low temperature outdoor air • Can use a variety of water sources, including cooling towers for cooling mode, boilers for heating mode, geothermal loops for both modes, or other water sources	• Water to water heat pumps also reject heat to (cooling mode) or extract heat from (heating) a pumped source loop • Water to water heat pumps utilize hydronic heating systems to deliver heat to the conditioned spaces • Typically use motorized valves to alter the water flow through the heat pump to change modes • Can use the same range of water sources as water source heat pumps

System Types

Simple Air-to-Air
- VRF
- Multiplexed VRF

Water-to-Air
- Central or Distributed

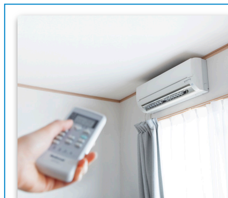




Water-to-Water
- Ground Source Heat Pump

Equipment Types

Ceiling Cartridge Units



Wall Cassette Units

Fan Coil Units

Air Handling Units

Rooftop Units

MUA or DOAS Units

Domestic Hot Water Heaters

Overview of Commercial Heat Pumps

Additional technologies for enhanced performance in some systems:

- Multiplex several indoor units (often cartridge units) connected to a single outdoor unit (typically air to air systems only)
- Low outdoor temperature, high heating capacity versions of some systems
- Variable Refrigerant Flow (VRF) for continuously modulating capacity control
- Desuperheating coil for dehumidification reheat on air side (air to air or water to air systems only)
- Higher capacity air-side fans in fan coil units and air handling units to handle better air filters
- BACnet compatible controls integration
- Advanced control systems that can include sub-metering modules for tenant-paid utilities

Pros and Cons of Each System

Air to Air

Pros
- Flexible application
- DHW available
- Rebates available
- Require only OEM automatic controls
- Lower first costs

Cons
- Filtration limitations (evolving)
- Virtual metering complexity
- OEM controls limitations: not compatible with standard room thermostats
- Integration results with Building Automation Systems vary

Water Source

Pros
- Lower energy costs from high system efficiency
- Doesn't rely on fossil fuel
- Rebates available
- Higher efficiency (doesn't depend on outdoor air temperature)

Cons
- Higher first costs
- Virtual metering complexity
- Need access to water source at a reasonable, consistent temperature
- Require more non-OEM automatic controls than air source heat pumps

Water to Water

Pros
- Same pros as water source heat pumps
- Produces heating hot water for different methods of heating
- Often highest efficiency option

Cons
- Same cons as water source heat pumps
- Highest first costs

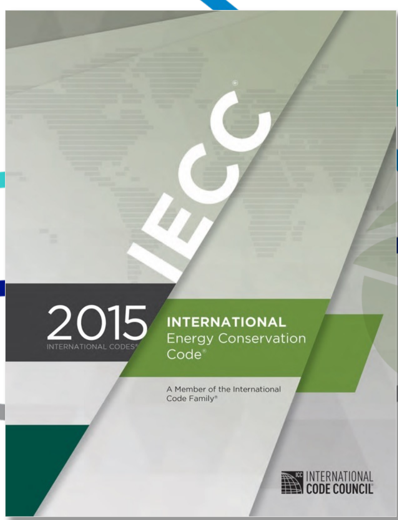
Evaluate air source heat pump performance & efficiency

- Air source heat pumps are rated several ways; code requirements are expressed in SEER for small unitary equipment or COP for larger systems
- Other ratings include Heating Seasonal Performance Rating (HSPR), EER, and IEER (Integrated Energy Efficiency Ratio)
- The higher the better (your mileage may vary!)
  - Code requires 14 SEER; EnergyStar requires 16 SEER; VRF units are often rated at 18 SEER or higher
  - Seasonal Energy Efficiency Ratio (SEER): ratio of cooling or heating energy output from a unit in BTU per hour to the power input required to operate the unit in watts, adjusted for seasonal operating conditions and varying loads
  - Coefficient of Performance (COP) is the output divided by the input, where both are expressed in the same units

Primary Unit	Conversion Unit
1 COP	3.5 EER
1 kW/Ton	3.5 COP
12 EER	1 kW/Ton

Current Commercial Code Versions

- SBC-8 RI State Energy Conservation Code
  - SBC-8-2021, adopted in 2022, references the 2018 IECC with RI Amendments
- 2017 RI Stretch Code for Commercial Construction



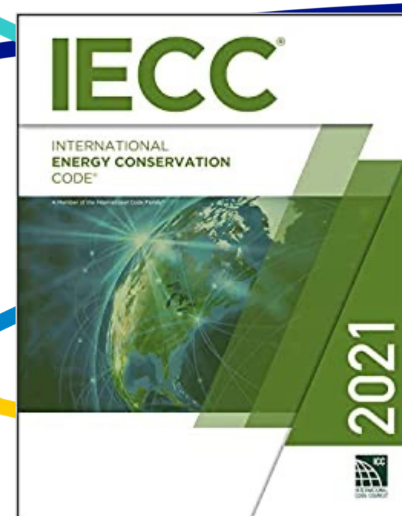
RHODE ISLAND
STRETCH CODE FOR COMMERCIAL CONSTRUCTION: A VOLUNTARY GREEN BUILDINGS PROGRAM

February 16, 2018

STATE OF RHODE ISLAND AND PROVIDENCE PLANTATIONS

RI Office of Energy Resources
One Capitol Hill
Providence, RI 02908
Phone: (401) 574-9100
Fax: (401) 574-9125
www.energy.ri.gov

1st EDITION



IECC 2021 TABLE C403.3.2(3) MINIMUM EFFICIENCY REQUIREMENTS

TABLE C403.3.2(2)
ELECTRICALLY OPERATED AIR-COOLED UNITARY HEAT PUMPS—MINIMUM EFFICIENCY REQUIREMENTS[c, d]

EQUIPMENT TYPE	SIZE CATEGORY	HEADING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 66,000 Btu/h	All	Split system, three phase and applications outside US single phase[b]	14.0 SEER before 1/1/2023 14.3 SEER2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
			Single package, three phase and applications outside US single phase[b]	14.0 SEER before 1/1/2023 13.4 SEER2 after 1/1/2023	
Space constrained, air cooled (cool-ing mode)	≤ 30,000 Btu/h	All	Split system, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.7 SEER2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
			Single package, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 11.7 SEER2 after 1/1/2023	
Single duct, high velocity, air cooled (cooling mode)	< 65,000	All	Split system, three phase and applications outside US single phase[b]	12.0 SEER before 1/1/2023 12.0 SEER2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
Air cooled (cooling mode)	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric resistance (or none)	Split system and single package	11.0 EER 12.2 IEER before 1/1/2023 14.1 IEER after 1/1/2023	AHRI 340/360
		All other		10.8 EER 12.0 IEER before 1/1/2023 13.9 IEER after 1/1/2023	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric resistance (or none)		10.6 EER 11.6 IEER before 1/1/2023 13.5 IEER after 1/1/2023	
		All other		10.4 EER 11.4 IEER before 1/1/2023 13.3 IEER after 1/1/2023	
	≥ 240,000 Btu/h	Electric resistance (or none)		9.5 EER 10.6 IEER before 1/1/2023 12.5 IEER after 1/1/2023	
		All other		9.3 EER 10.4 IEER before 1/1/2023 12.3 IEER after 1/1/2023	
Air cooled (heating mode)	< 65,000 Btu/h	All	Split system, three phase and applications outside US single phase[b]	8.2 HSPF before 1/1/2023 7.5 HSPF2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
			Single package, three phase and applications outside US single phase[b]	8.0 HSPF before 1/1/2023 6.7 HSPF2 after 1/1/2023	

TABLE C403.3.2(2)—continued
ELECTRICALLY OPERATED AIR-COOLED UNITARY HEAT PUMPS—MINIMUM EFFICIENCY REQUIREMENTS[c, d]

EQUIPMENT TYPE	SIZE CATEGORY	HEADING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Space constrained, air cooled (heating mode)	≤ 30,000 Btu/h	All	Split system, three phase and applications outside US single phase[b]	7.4 HSPF before 1/1/2023 6.3 HSPF2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
			Single package, three phase and applications outside US single phase[b]	7.4 HSPF before 1/1/2023 6.3 HSPF2 after 1/1/2023	
Small duct, high velocity, air cooled (heating mode)	< 65,000 Btu/h	All	Split system, three phase and applications outside US single phase[b]	7.2 HSPF before 1/1/2023 6.1 HSPF2 after 1/1/2023	AHRI 210/240—2017 before 1/1/2023 AHRI 210/240—2023 after 1/1/2023
Air cooled (heating mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (cooling capacity)	All	47°F db/43°F wb outdoor air	3.30 COP_H before 1/1/2023 3.40 COP_H after 1/1/2023	AHRI 340/360
			17°F db/15°F wb outdoor air	2.25 COP_H	
	≥ 135,000 Btu/h and < 240,000 Btu/h (cooling capacity)		47°F db/43°F wb outdoor air	3.20 COP_H before 1/1/2023 3.30 SOP_H after 1/1/2023	
			17°F db/15°F wb outdoor air	2.05 COP_H	
	≥ 240,000 Btu/h (cooling capacity)		47°F db/43°F wb outdoor air	3.20 COP_H	
			17°F db/15°F wb outdoor air	2.05 COP_H	

Application Consideration (1 of 2)

- Water source systems may be easier to expand if sufficient capacity is provided
- Seasonal variation in monthly energy use and cost
  - Tenants in multi-family buildings can face peak electric bills in winter
  - If replacing heating-only system, newly available cooling can increase electric use in summer
- Energy and GHG/carbon performance
  - Detailed analysis requires grid fuel mix data
  - Replaces on-site combustion
- Metering and cost assignment (utility & maintenance costs)

Application Consideration (2 of 2)

- Central vs. Distributed equipment
  - Central equipment can be air-to-air, water-to-air, or water-to-water
  - Distributed equipment can support sub-metering and utility cost-shifting to tenants
- Refrigerant piping vs. hydronic piping
  - Hydronic piping & water leak risks can be eliminated with air-to-air systems
  - Refrigerant piping requires:
    - Careful documentation of as-built piping for manufacturer to calculate exact refrigerant charge
    - Conscientious nitrogen purging during any brazing/soldering of fittings

Operating Considerations

- Air-to-Air & water source: avoid deep unoccupied setbacks
- Provide neutral mechanical ventilation air independent of heat pump cycling
- Use setpoint, deadband or mode lock to reduce winter cooling calls (& vv.)
- Multiplexed systems:
  - Spaces with more than 1 indoor unit controlled from a single thermostat, properly programmed, & lead unit identified
  - Document how simultaneous heating and cooling calls on the same combiner box & outdoor unit are handled
  - Colorized drawings or other records to understand indoor/outdoor unit pairings

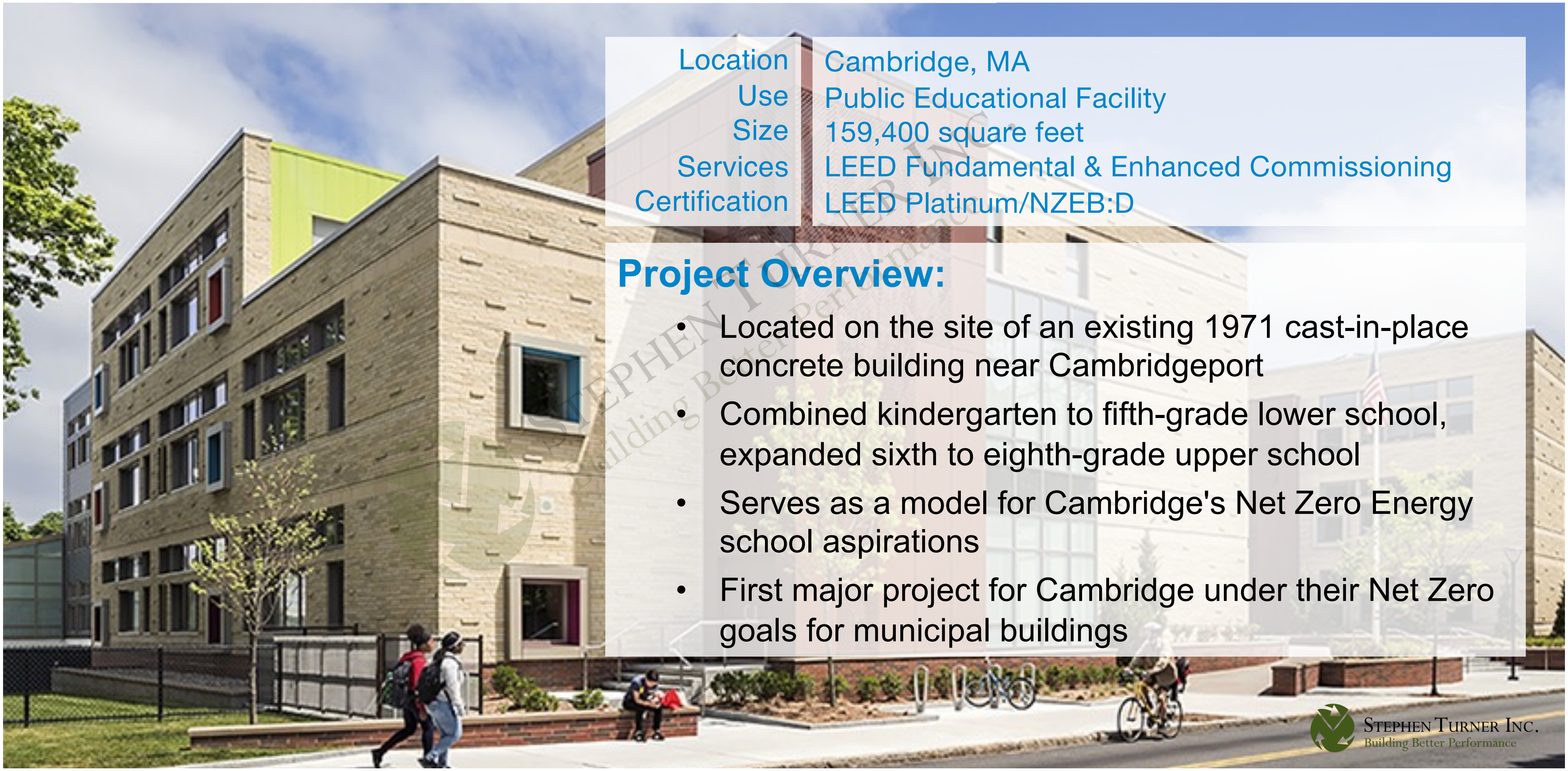
Maintenance Considerations

- 18” minimum snow stands
- Combiner boxers & indoor units accessible for service
- Indoor units located to minimize condensate lift pumps
  - Provide access to condensate drain piping
- Wireless thermostats tethered to protect against loss where appropriate
- Understand system limitations for air filter pressure drop & select compatible replacements (or regular cleaning for “lint filters”)
- Air-to-Air Systems:
  - Adjust defrost cycle settings to address cold draft complaints in heating season
  - Undue compressor failures may indicate refrigerant & oil contamination from improper install

Integration & Control Challengers

- When integrated with building automation system, this BACnet integration must be planned, executed, and maintained with care
- Establish & document unique, logical unit and point names, especially on larger installations
- Understand how BACnet commands for mode and setpoint interact with local user commands on OEM thermostats
- Plan whether unoccupied schedules will be programmed individually or commanded from the building automation system
- Ensure meaningful graphics, historical trend data, & alarms are provided
- Monitor BACnet connection faults & address

Case Study- MLK School



Location	Cambridge, MA
Use	Public Educational Facility
Size	159,400 square feet
Services	LEED Fundamental & Enhanced Commissioning
Certification	LEED Platinum/NZEB:D

Project Overview:

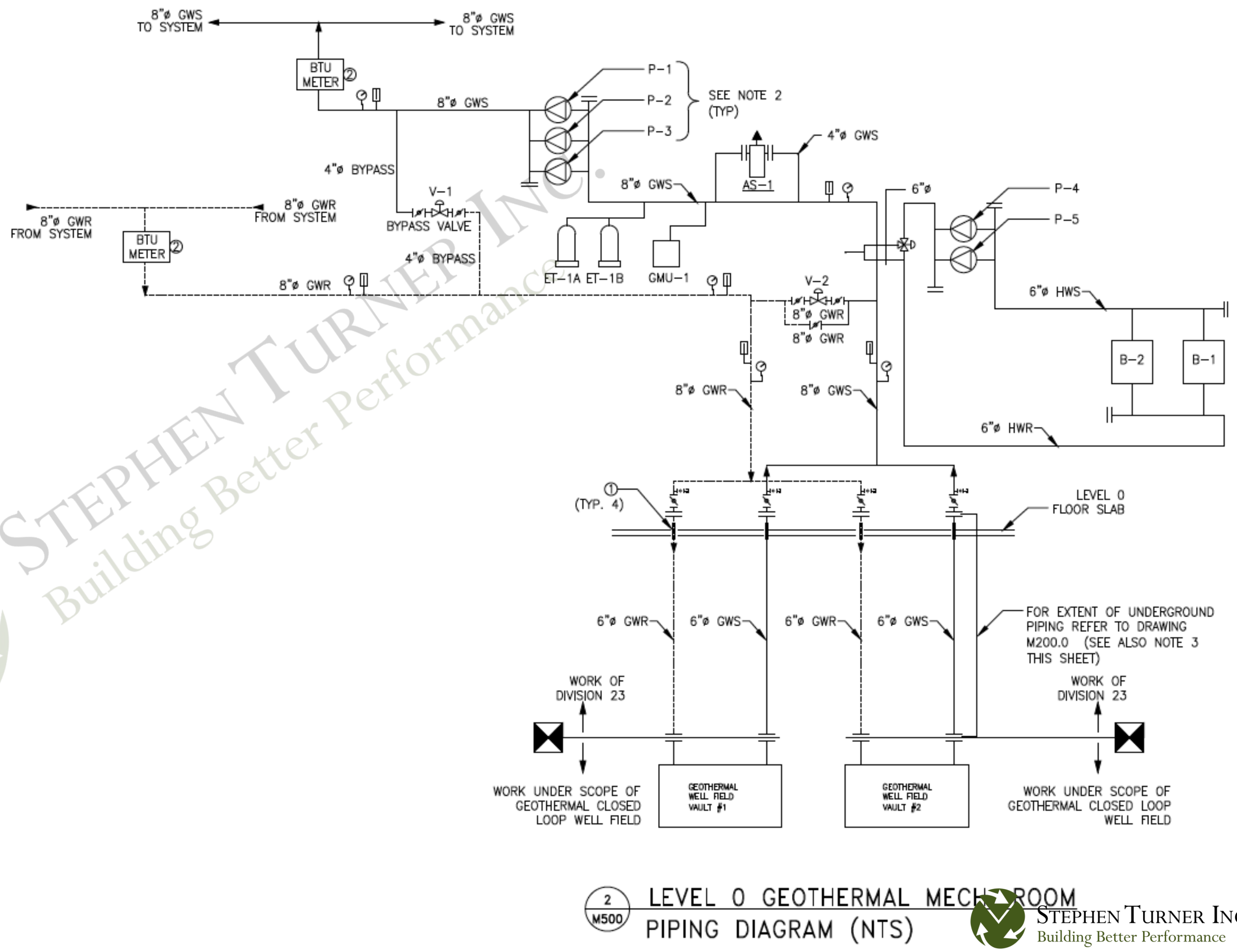
- Located on the site of an existing 1971 cast-in-place concrete building near Cambridgeport
- Combined kindergarten to fifth-grade lower school, expanded sixth to eighth-grade upper school
- Serves as a model for Cambridge's Net Zero Energy school aspirations
- First major project for Cambridge under their Net Zero goals for municipal buildings

Case Study- MLK School

Ground Source Distributed System:

- 101 water-to-air heat pumps
- Classrooms are equipped with vertical floor mounted heat pumps located in equipment closets accessible from the corridor
- Core workrooms, teacher lounges, and gymnasiums are served by horizontal heat pumps
- Several large DOAS units
- Geothermal wells supply ground source condenser water routed to the building, serving all heat pumps
- Classroom heat pumps include OEM controls; reversible refrigerant cycle to provide heating & cooling
- DOAS units include energy recovery wheels to provide neutral air to some spaces, others provide full heating and cooling
- Dedicated constant speed circulating pumps are utilized for pumping at each heat pump unit.
- Each heat pump is equipped with a trapped condensate drain line, drained to the nearest indirect waste
- Condensate lift pumps where gravity drainage is not possible

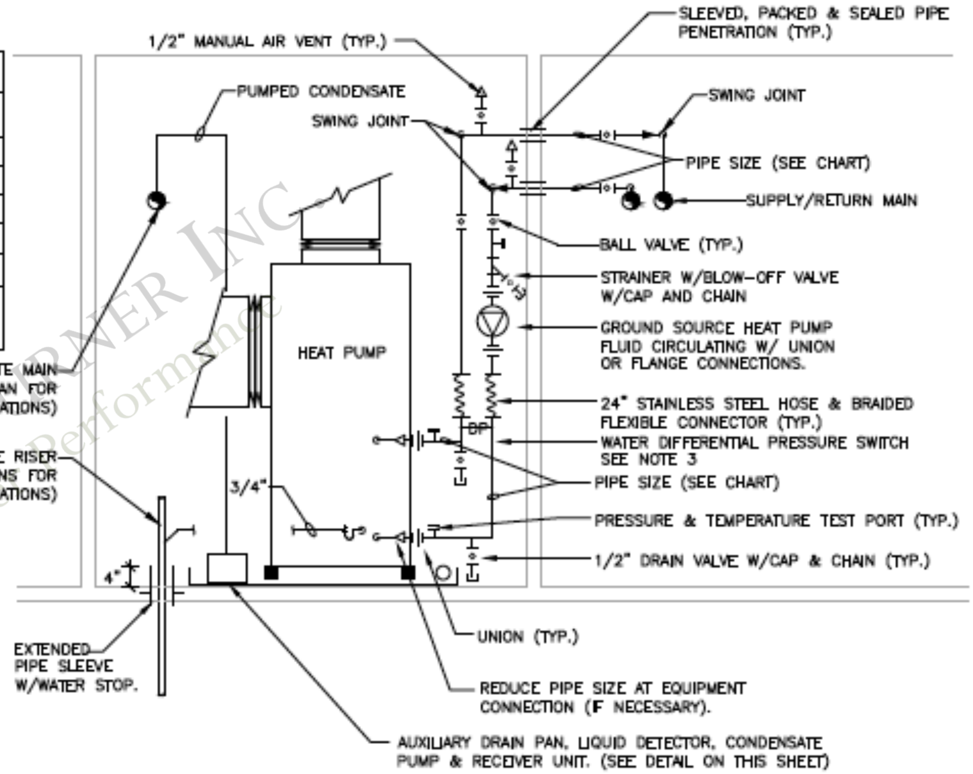
Case Study- MLK School



Case Study- MLK School

* HEAT PUMP * PIPE "RUN-OUT" SIZE CHART	
FLOW RATE (GPM)	PIPE SIZE
UP TO 3.0	3/4"
3.1 TO 5.5	1"
5.6 TO 11.5	1-1/4"
11.6 TO 17	1-1/2"
17.1 TO 33	2"

* REFER TO EQUIPMENT SCHEDULE ON DRAWING M301 FOR FLOW RATES

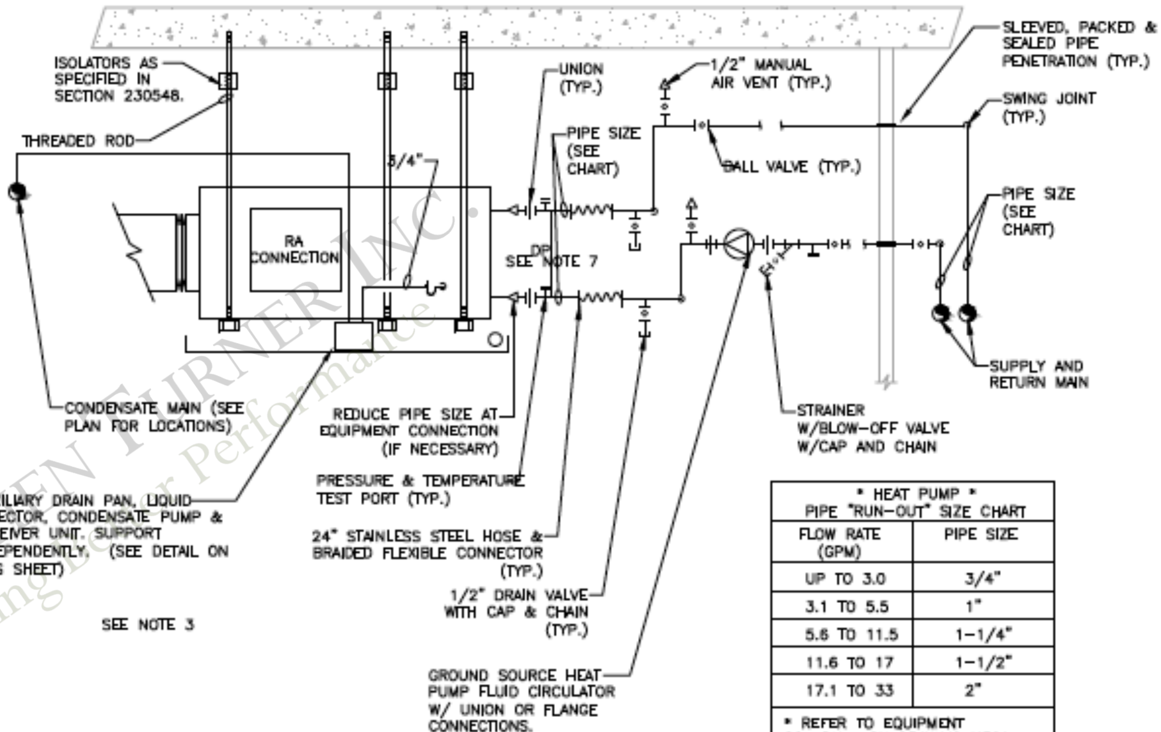


NOTES:

1. PITCH CONDENSATE (1" PER 10 FEET) DOWN TO EITHER CONDENSATE RISER OR TO RECEIVER UNIT AS APPLICABLE
2. CONDENSATE DRAIN PIPING SHALL BE COPPER. PROVED WITH PLUGGED TEE FITTINGS TO PERMIT CLEANOUT.
3. PROVIDE WATER DIFFERENTIAL PRESSURE SWITCH ACROSS SUPPLY AND RETURN FOR EACH HEAT PUMP AS SPECIFIED IN 230993.

9 / M400 VERTICAL WATER-TO-AIR GROUND SOURCE HEAT PUMP PIPING DETAIL

Case Study- MLK School



* HEAT PUMP * PIPE "RUN-OUT" SIZE CHART	
FLOW RATE (GPM)	PIPE SIZE
UP TO 3.0	3/4"
3.1 TO 5.5	1"
5.6 TO 11.5	1-1/4"
11.6 TO 17	1-1/2"
17.1 TO 33	2"

* REFER TO EQUIPMENT SCHEDULE ON DRAWING M301 FOR FLOW RATES

NOTES:

1. DRAIN PAN SHALL BE AT LEAST 4-INCHES LARGER THAN HEAT PUMP IN ALL DIRECTIONS. SUPPORT DRAIN PAN ASSEMBLY FROM STRUCTURE ABOVE INDEPENDENTLY OF THE HEAT PUMP.
2. SUPPORT HEAT PUMP FROM STRUCTURE ABOVE USING THREADED ROD ATTACHED TO MANUFACTURER FURNISHED CONTRACTOR INSTALL BRACKETS (TYP. 6).
3. PITCH CONDENSATE (1" PER 10 FEET) DOWN TO EITHER CONDENSATE RISER OR TO RECEIVER UNIT AS APPLICABLE
4. CONDENSATE DRAIN PIPING SHALL BE COPPER. PROVIDE WITH PLUGGED TEE FITTINGS TO PERMIT CLEANOUT.
5. EACH HEAT PUMP SHALL BE PROVIDED WITH BOTH A SUPPLY AND RETURN AIR SOUND ATTENUATORS. REFER TO PLANS FOR TYPE OF ATTENUATOR (ELBOW OR STRAIGHT) AND EFFECTIVE LENGTH.
6. PROVIDE WITH SEISMIC BRACING AS SPECIFIED.
7. PROVIDE WATER DIFFERENTIAL PRESSURE SWITCH ACROSS SUPPLY AND RETURN FOR EACH HEAT PUMP AS SPECIFIED IN 230993.

3 / M400 HORIZONTAL WATER-TO-AIR GROUND SOURCE HEAT PUMP PIPING DETAIL

Case Study- King Open School

Location	Cambridge, MA
Use	Education & Community Space
Size	273,000 square feet
Services	LEED Fundamental & Enhanced Commissioning
Certification	LEED v4 BD+C Silver and Net Zero goal

Project Overview:

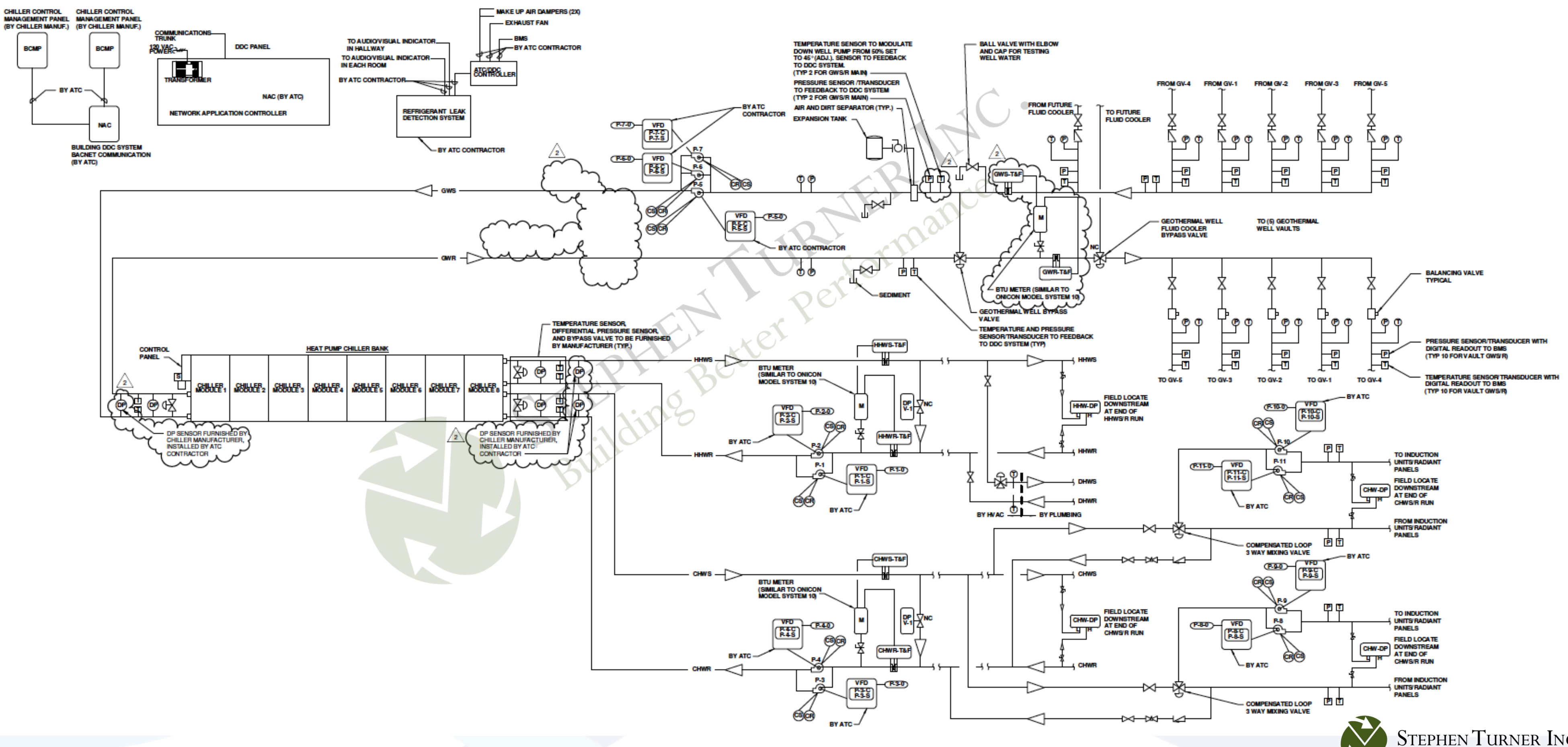
- Location: Existing site of a 1971 cast-in-place concrete building.
- School Structure: Combined kindergarten through fifth-grade lower school and expanded sixth through eighth-grade upper school.
- Model for Cambridge's Net Zero Energy school aspirations.
- Extensive sustainability features: geothermal, photovoltaic, and energy recovery systems.
- Advocated for Net Zero goals and ensured at least LEED for Schools Silver certification.

Case Study- King Open

Geothermal Heating and Cooling Plant:

- Fully Hydronic Distribution
- Heating and cooling by central geothermal plant consisting of eight 85-ton water-to-water heat pump chillers.
    - These heat pump modules serve the facility, providing hot water, chilled water, and heat recovery
- These modules can operate in heating mode, cooling mode, or heat recovery mode based on the building's requirements
- The system is supplied with ground source condenser water from 190 closed loop geothermal wells, organized into 38 circuits with 5 bores per circuit
- Ground loop circuit manifolds are situated in 5 separate vaults, each connected to the building via 6" supply and return piping
- A master controller determines building-side loads and controls the staging of central water-to-water heat pump modules on or off, with plans to add a redundant master controller
- The modules are equipped with scroll compressors, two independent refrigerant circuits each for heat recovery, and use R410A refrigerant

Case Study- King Open



Case Study- Brook Street Dormitories

Location	Providence, RI
Use	Brown University Dormitory
Size	80,590SF & 50,490SF

Project Overview:

- The Brook Street Residence Halls project aimed to achieve the United States Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) version 4 silver rating for New Construction.
- This aligns with Brown University's sustainability strategy, focusing on reducing greenhouse gas emissions by eliminating fossil fuel use and cutting energy usage to 25-50% below state code requirements.
- On-site fossil fuel burning is excluded from consideration for this project, emphasizing a commitment to limiting environmental impact.

Case Study- Brook Street Dormitories

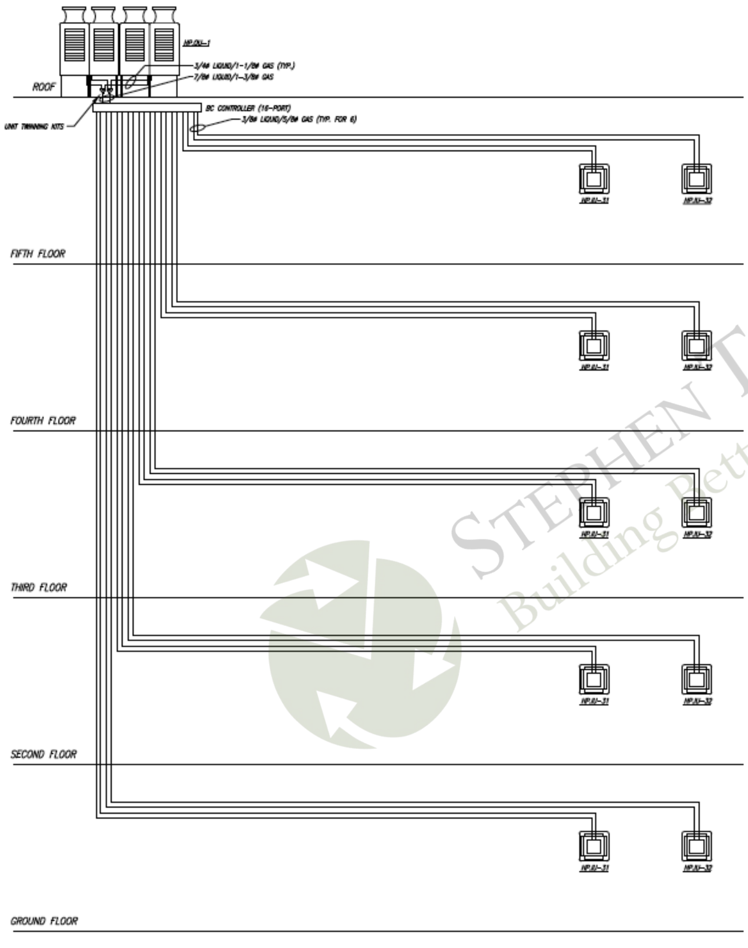
Heat Pump Types and Locations:

- Air Source Multiplexed
- Outdoor air units located on the roof

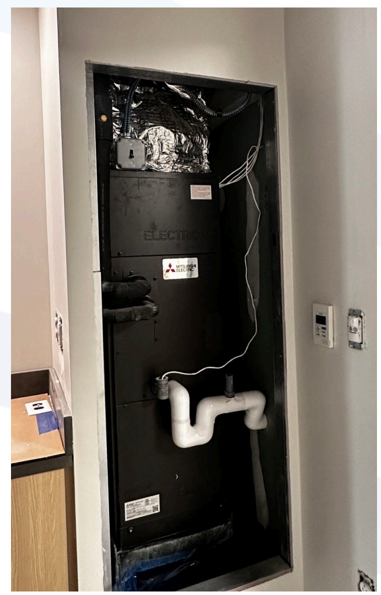
Heat Pump Components and Functionality:

- Spilt system
  - Heating
  - Reheat
  - Cooling

Case Study- Brook Street Dormitories



SYSTEM HP.OU-1 WITH CONNECTED INDOOR UNITS
NO SCALE

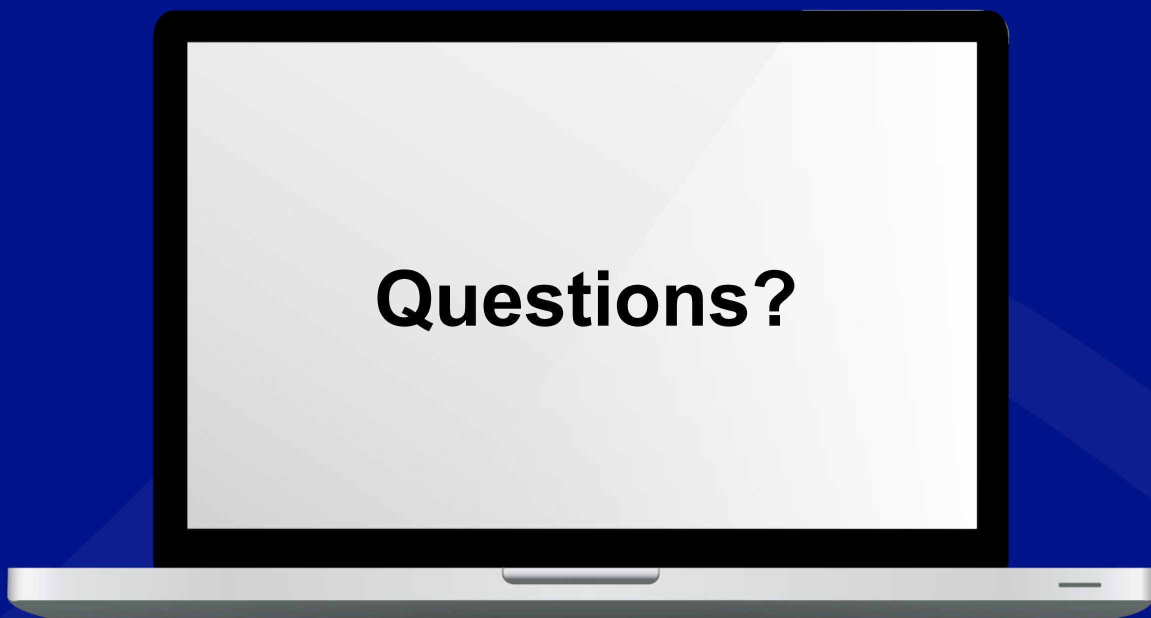


Case Study- Brook Street Dormitories

FLOOR	ROOM #	ROOM NAME	HP INDOOR UNITS	HP OUTDOOR UNIT	BRANCH CONTROLLER	ADDRESS	PROPOSED EQUIP. TAG FOR HP INDOOR UNIT	UNIT SENSOR (ZN-T, RZN-T, RA-T) BEING USED FOR THE HEATING / COOLING CONTROL	EBB	UH/CUH	EF / RTERV EXH
1	100	LOBBY	HPI-100			CC-1.13	OU-3.HPI-100				
1	100A	LOBBY LOUNGE							EBB-3 (3)		
1	100A	CORRIDOR (NORTH)									RTERV-2 EXHAUST
1	100B	ELEVATOR LOBBY									
1	100C	VESTIBULE								CUH-2	
1	100D	CORRIDOR (SOUTH)									RTERV-1 EXHAUST
1	101	WATER SERVICE / HWH								UH-2	RTERV-2 EXHAUST
1	101A	PUMP ROOM							EBB-1		RTERV-2 EXHAUST
1	102	ELECTRICAL	TCHP.IU-3			CC-2.33	TCHP.OU-3.IU-3				
1	103A	W.C.							EBB-1		RTERV-2 EXHAUST
1	103B	W.C.							EBB-1		RTERV-2 EXHAUST
1	104	ELECTRICAL EM ROOM									EF-2
1	105	TRASH								UH-1	RTERV-2 EXHAUST
1	106	ELECTRICAL GENERATOR ROOM									
1	107	MEETING ROOM MD	HPI-107			CC-1.14	OU-3.HPI-107		EBB-3		
1	109	CREATIVE SPACE	HPI-109			CC-1.15	OU-3.HPI-109		EBB-3 (2)		
1	111	SUITE LIVING	HPI-111			CC-2.22	OU-10.HPI-111				
1	111A	BED									
1	111B	BED									
1	111C	BATH									RTERV-1 EXHAUST
1	112	RES LIFE SUITE	HPI-112			CC-2.21	OU-10.HPI-112				
1	112A	BED									
1	112B	BED									
1	112C	BATH									RTERV-1 EXHAUST
1	113	KITCHEN	HPI-113			CC-2.20	OU-10.HPI-113				RTERV-1 EXHAUST
1	114	SUITE LIVING	HPI-114			CC-2.19	OU-10.HPI-114				

Heat Pump – Summary

Learning Objective 1	Understand the differences between the most common types of commercial heat pump systems
Learning Objective 2	Analyze pros and cons for different types of heat pump systems and understand how to select the right type of heat pump system for a specific application
Learning Objective 3	Learn to evaluate air source heat pump performance and efficiency
Learning Objective 4	Grasp the primary application, operating, and maintenance considerations
Learning Objective 5	Understand the integration and control challenges for ASHP


Questions?