Heat Pumps & Electrification in Commercial Buildings

Heat Pumps, VRFs, and Best Practices

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Rhode Island Energy™
a PPL company

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Code Compliance Enhancement Initiative

- Free Energy Code Technical Support is available by calling **1-855-343-0105**

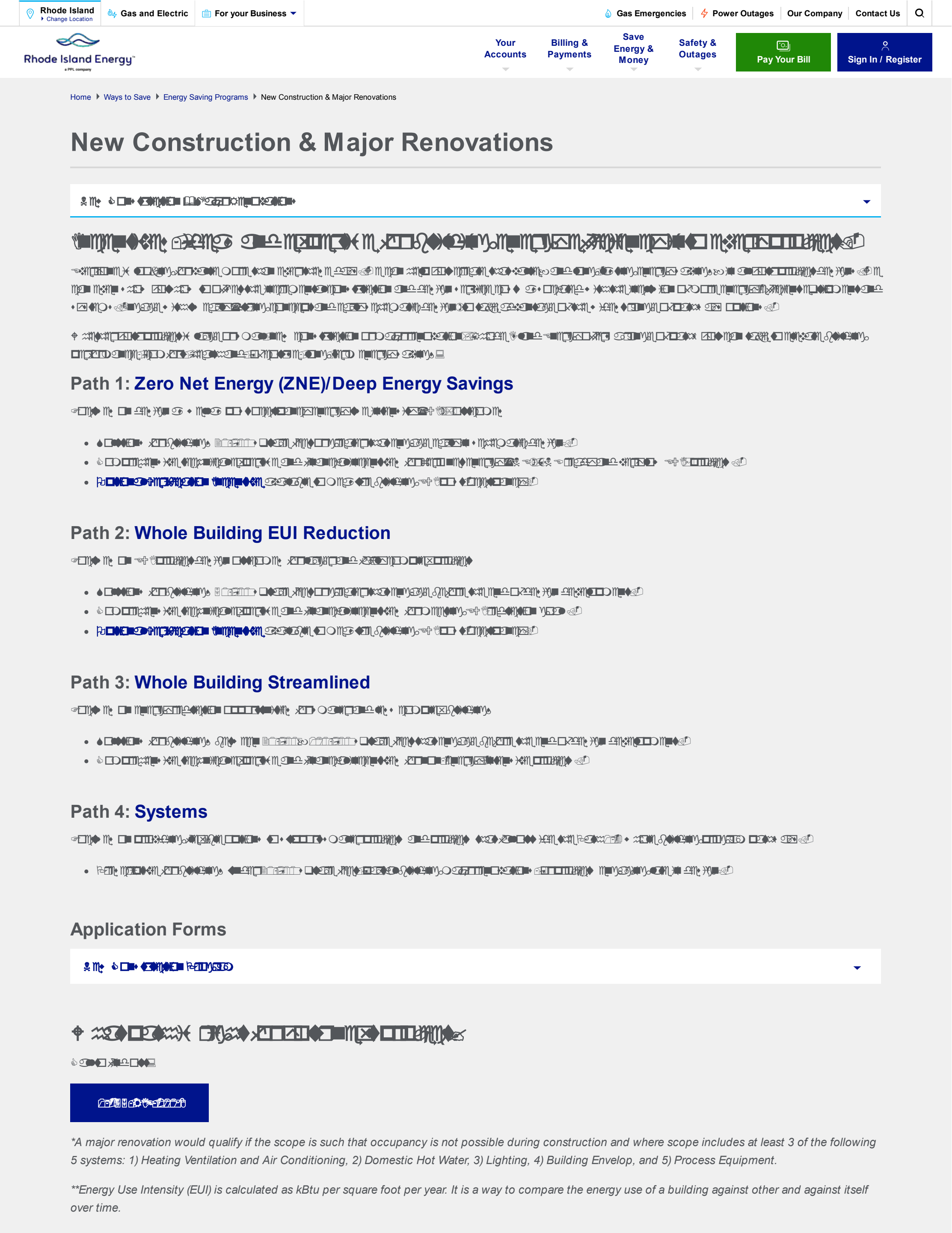
- The Rhode Island Energy Code Technical Support Initiative aims to:
    - Improve energy conservation code compliance through educating code officials and industry professionals
    - Establish higher compliance by offering a competitive stretch code
    - Take on an active role in the policy and advocacy 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**



Disclaimer

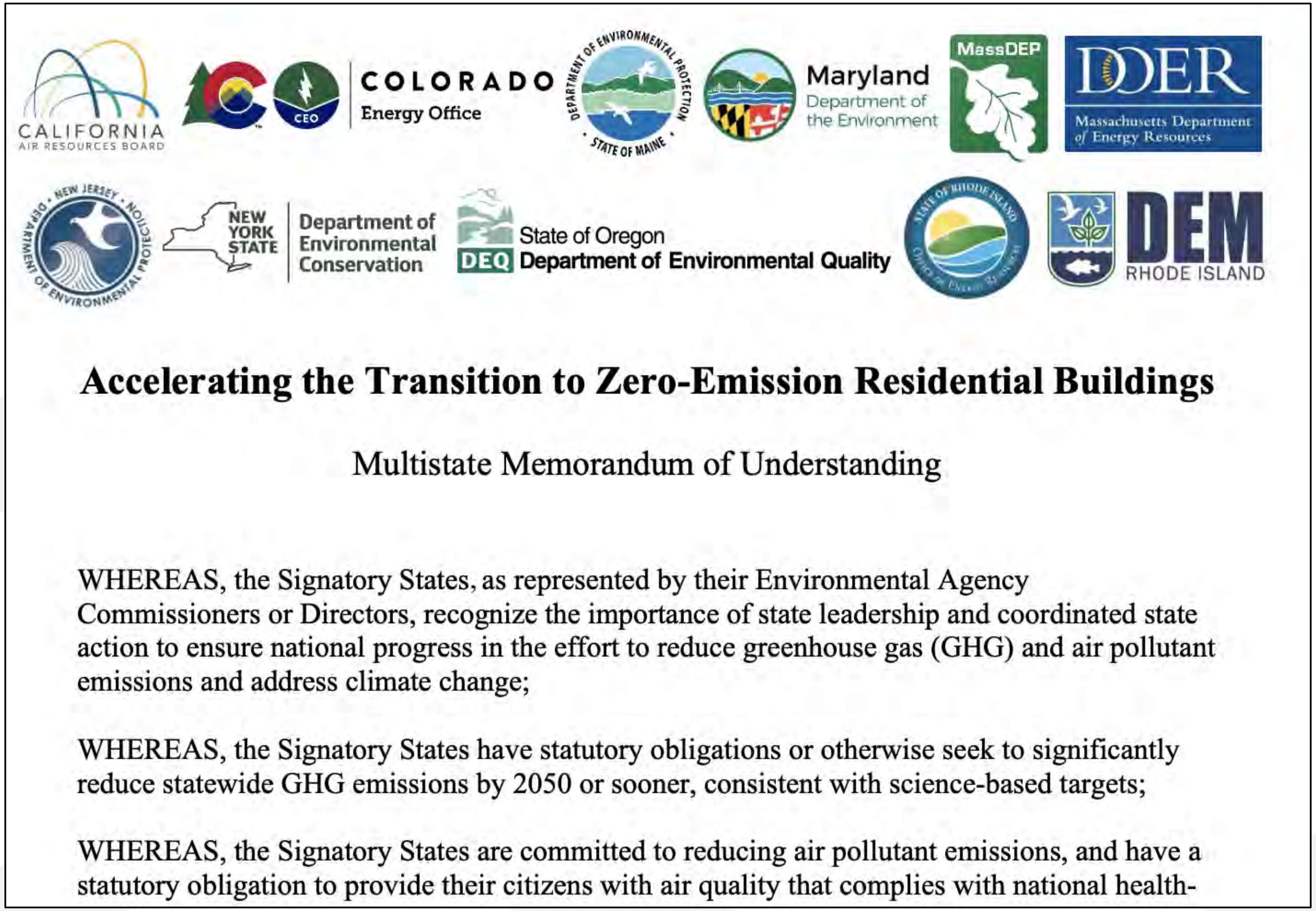
These trainings are being offered through the support of Rhode Island Energy, and in cooperation with the Rhode Island Building Code Commission. The Energy Code Technical Support staffs are not code officials, and the information provided through the program is not a formal interpretation of the code. 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	Look at four different applications of heat pump systems in high performance projects
Learning Objective 3	Learn to evaluate heat pump performance and efficiency
Learning Objective 4	Review current RI code requirements related to heat pumps
Learning Objective 5	Look at the role of heat pump technology in current trends for electrification in commercial buildings

Heat Pump Zeitgeist

"The Inflation Reduction Act of 2022 (IRA) is the largest ever climate investment by the Federal Government in American history, projected to reduce greenhouse gas (GHG) by 31% to 44% below the 2005 levels by 2030. The IRA will also bring energy bill relief to U.S. households by incentivizing the adoption of more efficient, all-electric appliances. Importantly, the IRA recognizes the key role of highly efficient, variable-capacity heat pumps… " – Mitsubishi Electric



Accelerating the Transition to Zero-Emission Residential Buildings

Multistate Memorandum of Understanding

WHEREAS, the Signatory States, as represented by their Environmental Agency Commissioners or Directors, recognize the importance of state leadership and coordinated state action to ensure national progress in the effort to reduce greenhouse gas (GHG) and air pollutant emissions and address climate change;

WHEREAS, the Signatory States have statutory obligations or otherwise seek to significantly reduce statewide GHG emissions by 2050 or sooner, consistent with science-based targets;

WHEREAS, the Signatory States are committed to reducing air pollutant emissions, and have a statutory obligation to provide their citizens with air quality that complies with national health-

Source: https://media.wbur.org/wp/2024/02/buildings-mou-final-with-signatures.pdf

Terminology

- **Air Conditioner -** "*Vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere.*" *(Source: Wikipedia)*

- **Heat Pump –** same as an Air Conditioner, but can heat in addition to cool, typically due to the addition of a "reversing valve", to switch the direction of refrigerant

- **Mini Split** – the simplest type of heat pump "system", common in residential buildings; less common in commercial buildings

- **Variable Refrigerant Flow (VRF) -** reduces compressor motor speed with an electrical inverter, to match the heating/cooling load (better than simple ON/OFF)

- **Dedicated Outside Air System (DOAS) –** Decouples ventilation from heating/cooling. A small air handler which simply provides tempered ventilation air to heat pump heating/cooling systems ("100% outside air" -no recirculation); often incorporates energy recovery

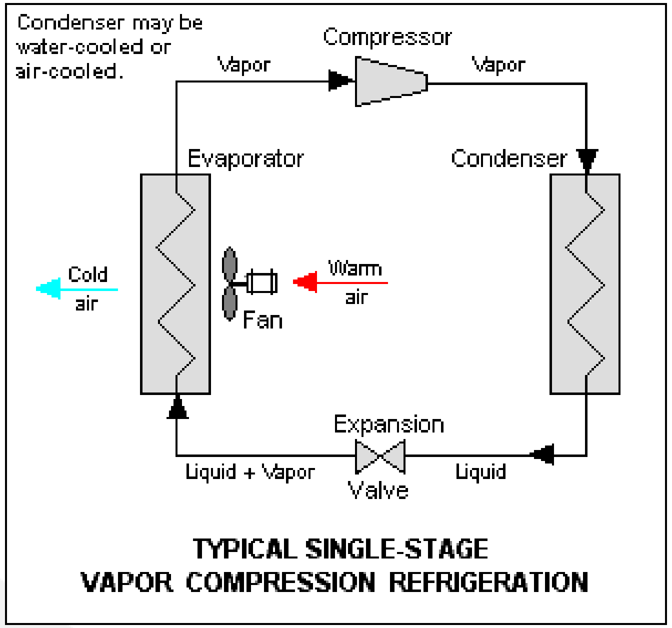
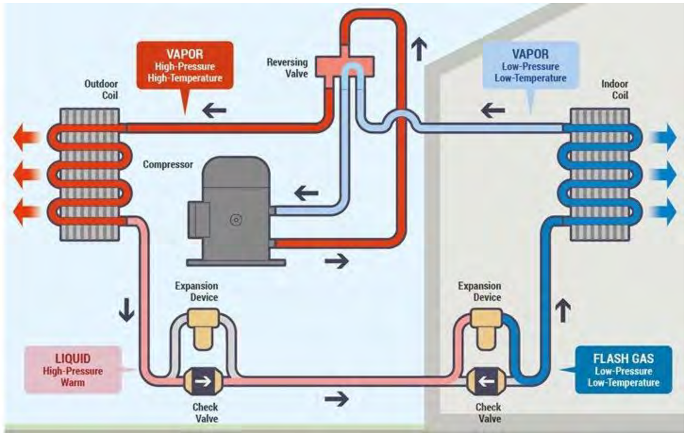


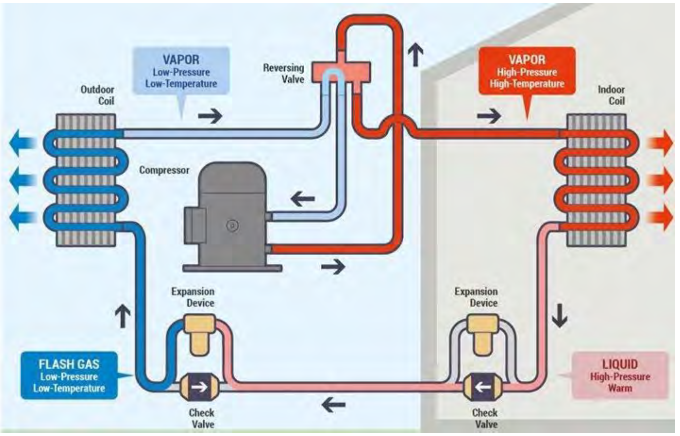
Image source: https://en.wikipedia.org/wiki/Vapor-compression_refrigeration

Overview of Commercial Heat Pump Operation



Cooling Mode:

- Move heat from indoors to outdoors
- Use the cold indoor evaporator coil to collect indoor heat, and reject it to the hot outdoor condenser coil (coil is much hotter than the hottest summer day)



Heating Mode:

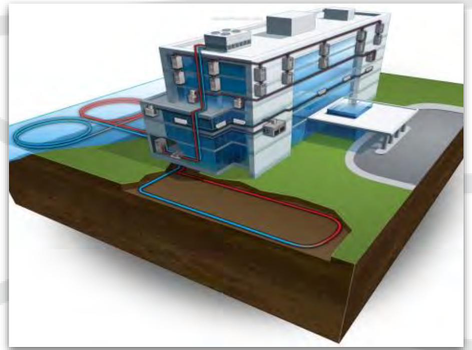
- Move heat from outdoors to indoors
- Use the cold outdoor evaporator coil to collect outdoor heat (yes, it's a really cold coil!), and reject it via the hot indoor condenser coil

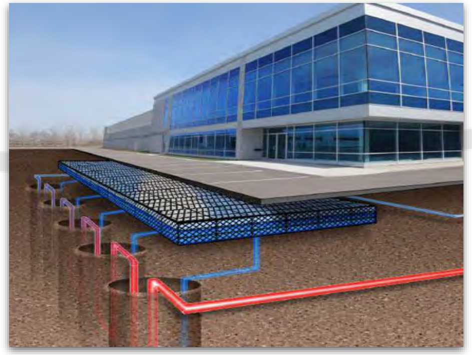
Image source: https://www.hvacrschool.com/wp-content/uploads/2020/11/HP-System.jpg

Types of Heat Pump Systems

- **Air Source Heat Pump**
  - Rejects heat to (cooling mode) or harvest heat from (heating) the outdoor air

- **Water Source Heat Pump**
  - Rejects heat to or harvests heat from a piped water loop
  - Higher initial cost, controls complexity, and energy savings
  - Possible destinations for this "piped water loop" :
    - cooling towers for cooling mode
    - boilers for heating mode
    - geothermal loops for both heating and cooling modes (most common)
  - Can avoid potential problems with heating mode associated with low temperature outdoor air
- "Air Source" or "water source" terminology is vague -- it does not specify the indoor mode of heat transfer to the refrigerant, i.e. air or water





Types of Heat Pump Systems

- More descriptive terminology: the conventional order of the phrase is [OUTDOOR FLUID]-to-[INDOOR FLUID]
  - **Air-to-Air Heat Pump**
  - **Water-to-Air Water Heat Pump**
  - **Water-to-Water Heat Pump**
  - **Air-to-Water Heat Pump**
    - Not commonly used since large hydronic heating/cooling systems would typically justify cost of using a water-source
    - Example: Air-Source Heat Pump Domestic Hot Water heater

Equipment Types

Ceiling Cartridge Units

Wall Cassette Units

Fan Coil Units

Air Handling Units

Rooftop Units

MUA or DOAS Units

Domestic Hot Water Heaters

Additional Technologies

- Features available for some heat pump system types (must be specified)
  - Low outdoor air temperature provisions (varies by manufacturer)
  - Multiplex several indoor units (often cartridge units) connected to a single outdoor unit (typically for air-to-air systems only)
  - Heat recovery for banked or “multiplexed” indoor units
  - Improved filtration - Higher capacity air-side fans in fan coil units and air handling units, rated for higher MERV filters (COVID-era advancement)
  - BACnet compatible controls integration
  - Advanced control systems that can include sub-metering modules for tenant-paid utilities

Evaluate Heat Pump Performance & Efficiency

- Heat pump efficiency is 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), Energy Efficiency Ratio (EER), and Integrated Energy Efficiency Ratio (IEER)
- The higher the better (your mileage may vary!)
  - 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
  - IERR: Nearly the same as SEER, but for larger equipment
  - Coefficient of Performance (COP) is the peak heat output divided by the peak electricity 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

Application Consideration (1 of 2)

- Water source systems may be easier to expand, than air-source systems, if sufficient capacity is provided
- Seasonal variation in monthly energy use and cost
  - Heat pump conversions in existing multifamily often result in a shift from rent-included winter heat, to individually tenant-billed heating costs
  - Tenants in multi-family buildings can face their peak electric bills in winter
  - If replacing a heating-only system, the newly available cooling can result in higher electric use in summer
- Energy and GHG/carbon performance
  - Detailed analysis requires grid fuel mix data
  - Replaces on-site combustion

Application Consideration (2 of 2)

- Central vs. Distributed equipment
  - 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
    - Accepting the risk of refrigerant leaks during equipment's life, especially if refrigerant is located within the building envelope
- Provide neutral mechanical ventilation air independent of heat pump cycling

Maintenance Considerations

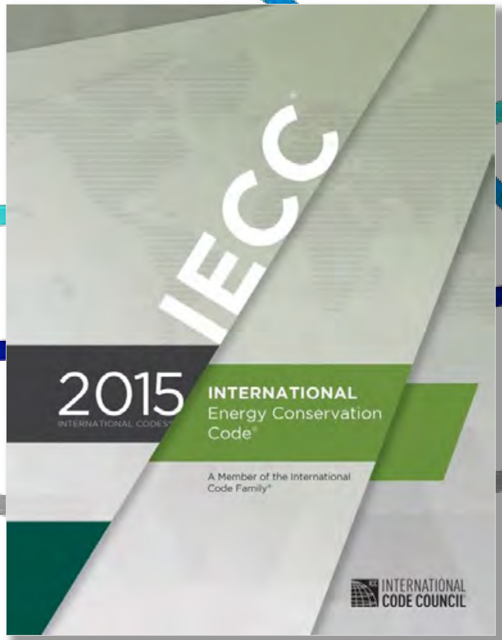
- Snow stands - 18” minimum height
- Combiner boxers & indoor units accessible for service
- Locate indoor units so they can “gravity drain”; minimize quantity of condensate lift pumps
  - Provide access to condensate drain piping
- Air-to-Air Systems:
  - Defrost cycle - adjust settings to address cold draft complaints in heating season
  - Undue compressor failures may indicate refrigerant & oil contamination from improper install

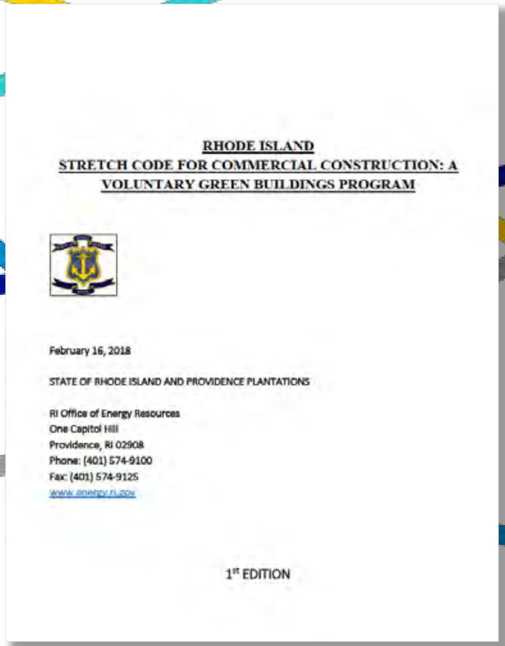
Integration & Control Challengers

- 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 BAS 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 BAS
- Ensure meaningful graphics, historical trend data, & alarms are provided
- Monitor BACnet connection faults & address

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

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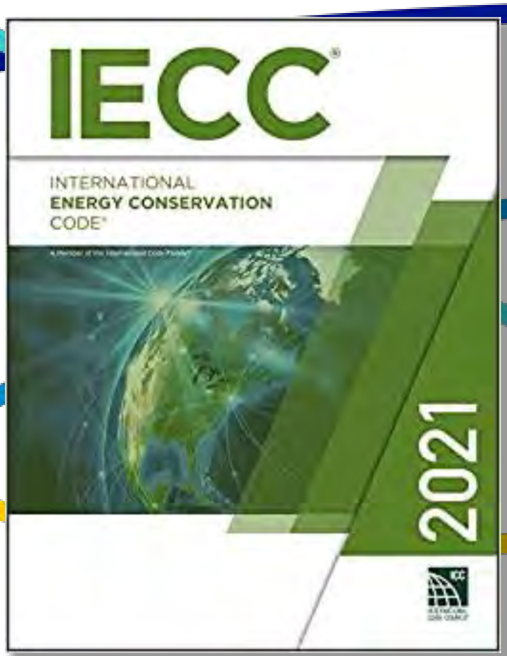


Heat Pump Efficiency Ratings in the Code

TABLE C403.3.2(2)
MINIMUM EFFICIENCY REQUIREMENTS: ELECTRICALLY OPERATED UNITARY AND APPLIED HEAT PUMPS

EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY OR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[a]
Air cooled (cooling mode)	< 65,000 Btu/h[b]	All	Split System	14.0 SEER	AHRI 210/240
			Single Package	14.0 SEER	
Through-the-wall, air cooled	≤ 30,000 Btu/h[b]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	
Single-duct high-velocity air cooled	< 65,000 Btu/h[b]	All	Split System	11.0 SEER	
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 12.0 IEER	AHRI 340/360
		All other	Split System and Single Package	10.8 EER 11.8 IEER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.6 EER 11.6 IEER	
		All other	Split System and Single Package	10.4 EER 11.4 IEER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 10.6 IEER	
		All other	Split System and Single Package	9.3 EER 9.4 IEER	
Water to Air: Water Loop (cooling mode)	< 17,000 Btu/h	All	86°F entering water	12.2 EER	ISO 13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86°F entering water	13.0 EER	
	≥ 65,000 Btu/h and	All	86°F entering water	13.0 EER	

RI Energy Rebates for Heat Pumps

Water/Evaporatively-Cooled Air Conditioners and Heat Pumps										
Equipment Type	Unit Type	Sub Category	Size Category	Tier	Full Load Cooling Efficiency (EER)		Seasonal/ Part Load Cooling Efficiency (SEER/IEER)		Heating Efficiency (COP)	Minimum Customer Sales Price Discount ($/Ton)*
Water-Cooled	Water Source HP	Split System and Single Package	ANY	1	14.0		-	and	4.6	$37.50
				2	17.0		-	and	4.6	$100
Water-Cooled	Ground Source Closed Loop HP	Split System and Single Package	ANY	1	15.0		-	and	3.4	$75
Water-Cooled	Ground Source Open Loop HP	Split System and Single Package	ANY	1	19.0		-	and	4.0	$75
Water Cooled or Evaporatively-Cooled	AC	Split System and Single Package	< 65 kBtuh (<5.4 tons)	1	13.5	and	14.0		-	$25
Water Cooled or Evaporatively-Cooled	AC	Split System and Single Package	≥ 65 kBtuh and < 240 kBtuh (≥ 5.4 Tons and < 20 Tons)	1	13.0	and	15.5		-	$25
Water Cooled or Evaporatively-Cooled	AC	Split System and Single Package	≥ 240 kBtuh (≥ 20 Tons)	1	12.5	and	14.5		-	$20

RI Energy Custom Incentives for New Construction

New Construction Services

Rhode Island Energy™
a PPL company

Overview

Rhode Island Energy's New Construction Commercial, Industrial, and Institutional (non-residential) program consists of four main areas of activity:

1. New building projects wherein no structure or site footprint presently exists
2. Addition or expansion of an existing building or site footprint
3. Projects that require design and selection of new systems based on the needs of new or modified space functions
4. Training and assistance to meet building energy codes

The program is designed to promote and support high-performance building design, equipment selection, and building operation. The services help lower a building's operating and maintenance costs throughout its life cycle; increase comfort, health, and productivity for building occupants;

Process from Start to Finish:

1. Contact Rhode Island Energy
2. Present Conceptual Design
3. Provide Schematic Design
4. Design Development
5. Submit Construction Documents
6. Begin Construction
7. Verify Work is Completed

Services (See details on reverse side)

Owner Financial Incentives

These incentives encourage owners to invest in energy efficiency as a major goal in their new buildings. Financial incentives are available to owners when the efficiency of their building exceeds the minimum building energy code threshold.

Case Studies Overview

- Brook Street Dormitories
  - Conventional scalable air-to-air multiplexed heat pumps
  - DOAS ventilation
  - **Typical design for a small commercial all-electric heat pump system**
- MLK School
  - Geothermal with distributed small water-to-air heat pump fan coil units
  - DOAS ventilation
- Tobin School
  - Hybrid:
    - Geothermal with water-to-air heat pumps serving larger centralized AHU coils
    - and air-to-air, multiplexed VRF heat pump system with DOAS ventilation
- King Open School
  - Geothermal with central water-to-water heat pump plant
  - HW/CHW serves active chilled beams and DOAS ventilation
- **All but Brook Street Dormitories include photovolatiacs, and show aggressive net zero energy goal approaches**

Case Study- Brook Street Dormitories

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

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

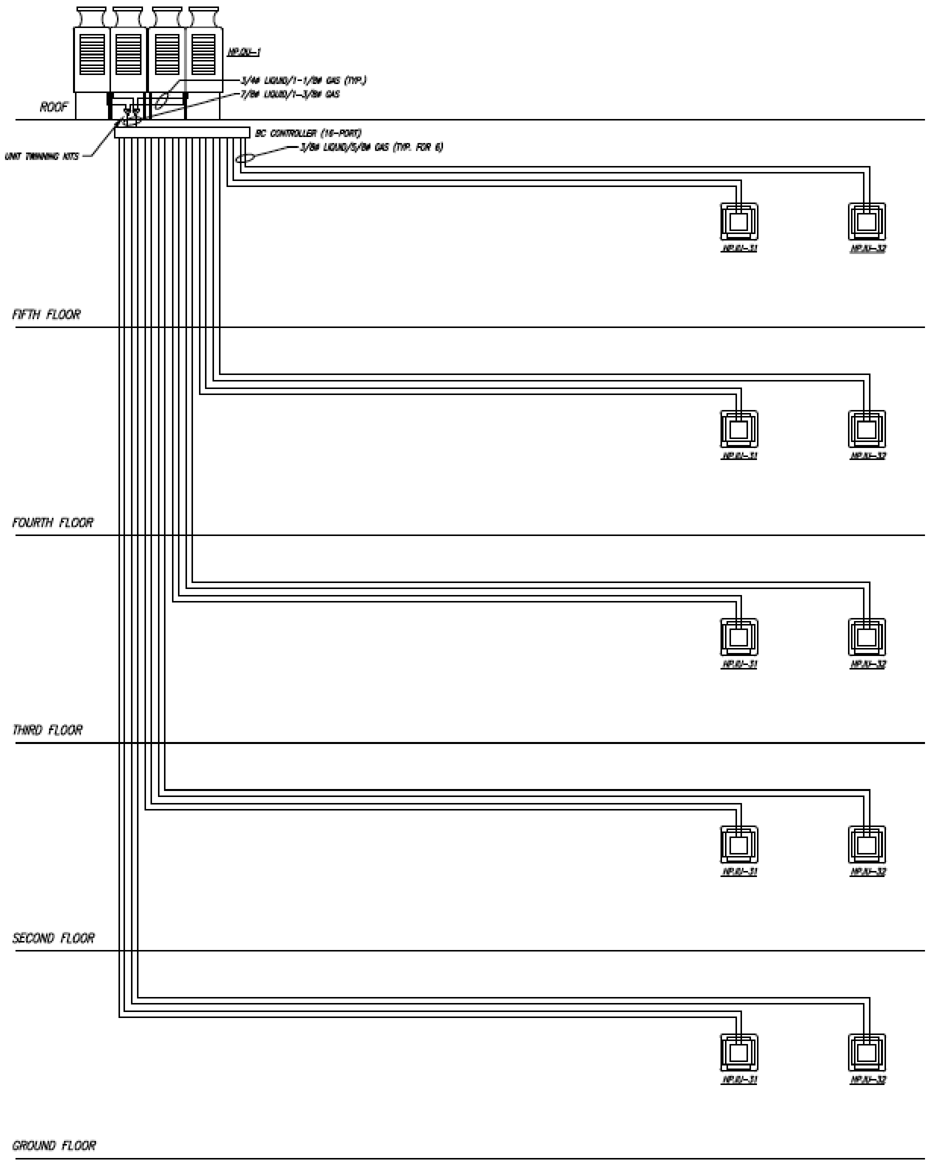
Heat Pump Types and Locations:

- Air-to-air multiplexed VRF
- VRF outdoor air units located on the roof
- DOAS units provide ventilation air

Heat Pump Functionality:

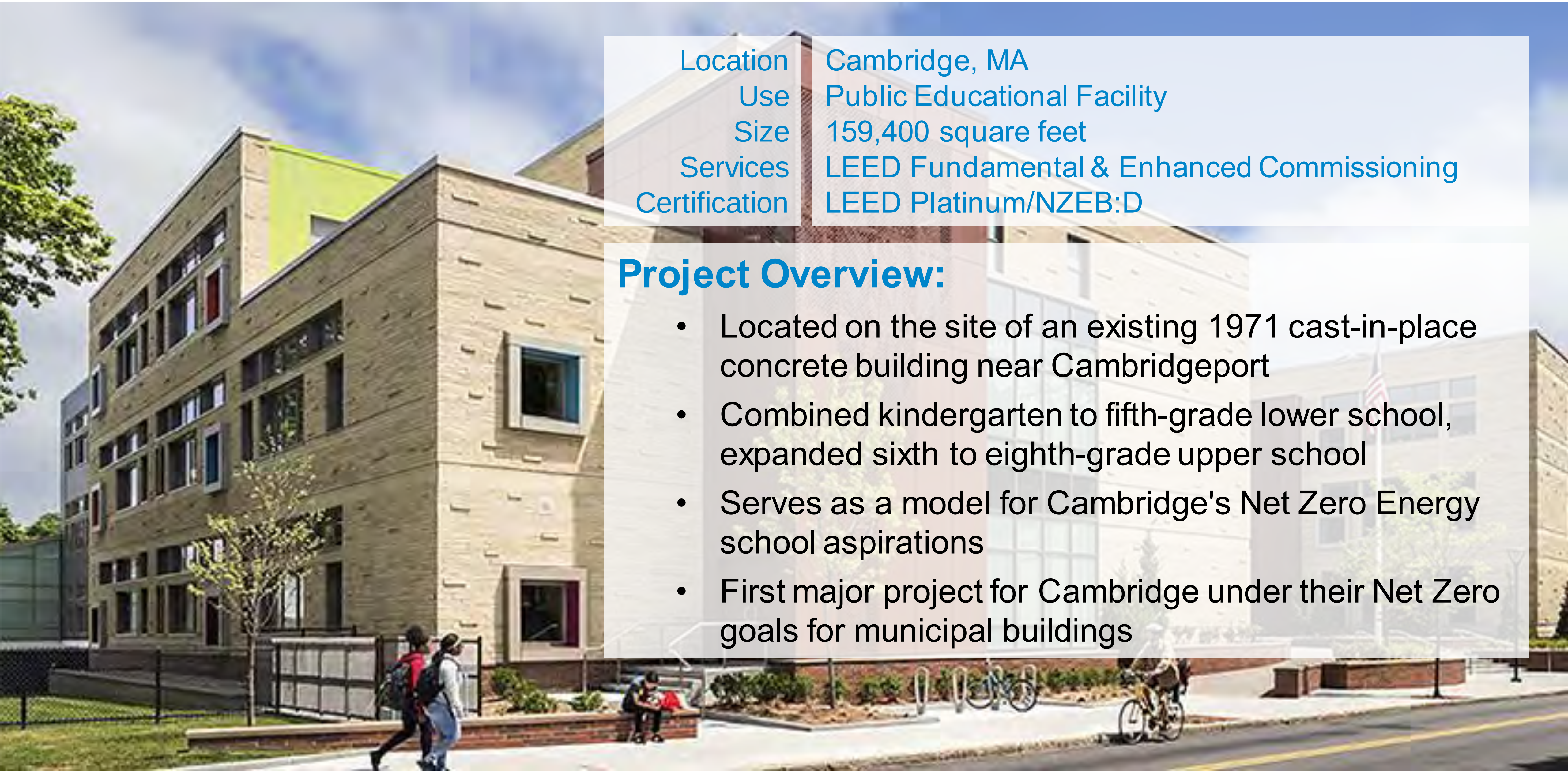
- Spilt system
  - Heating
  - Cooling
  - Heat Recovery

Case Study- Brook Street Dormitories



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

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:

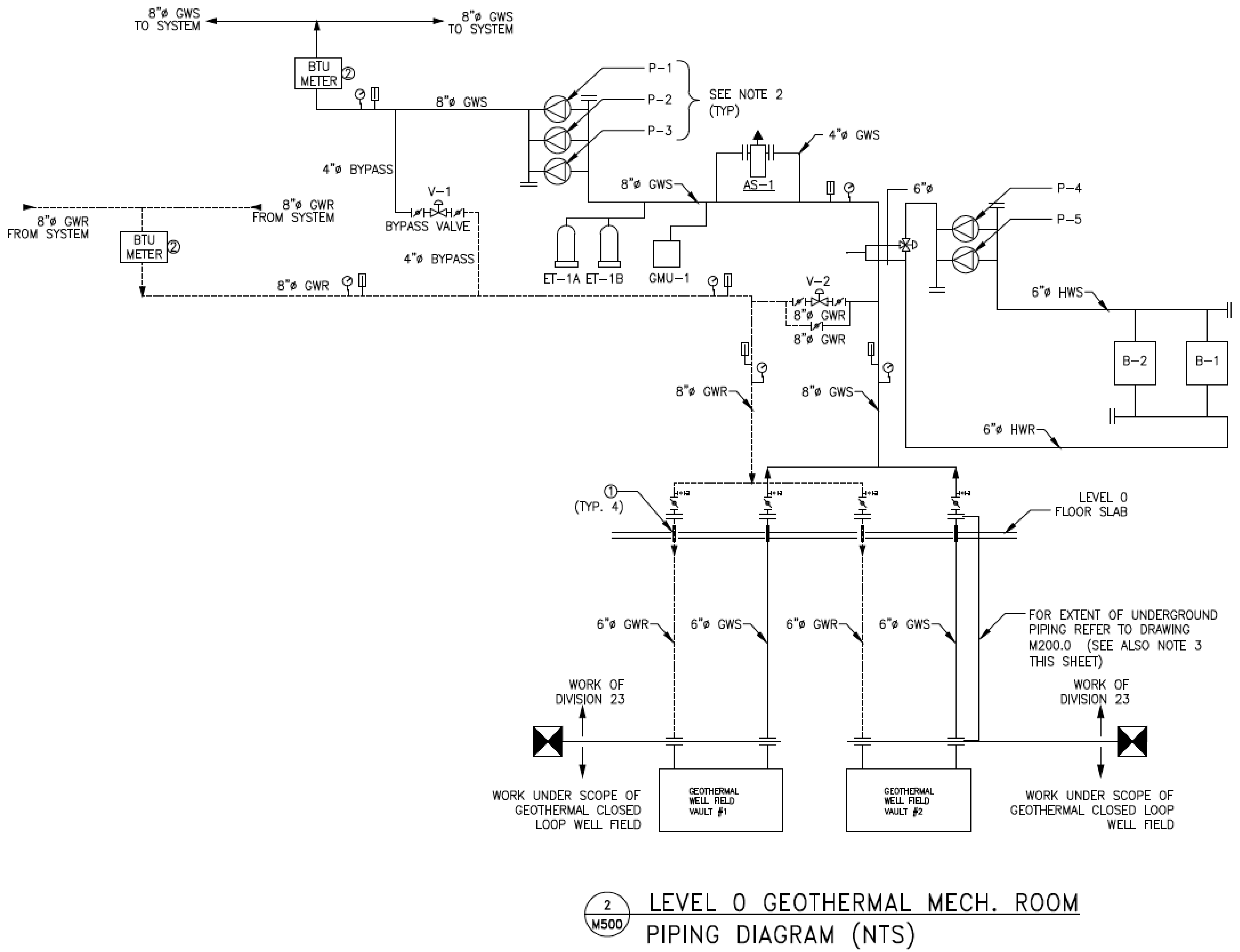
- Located on the site of an existing 1971 cast-in-place concrete building near Cambridgeport
- Combined kindergarten to fifth-grade lower school, expanded sixth to eighth-grade upper school
- Serves as a model for Cambridge's Net Zero Energy school aspirations
- First major project for Cambridge under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

Case Study- MLK School

Ground Source Distributed System:

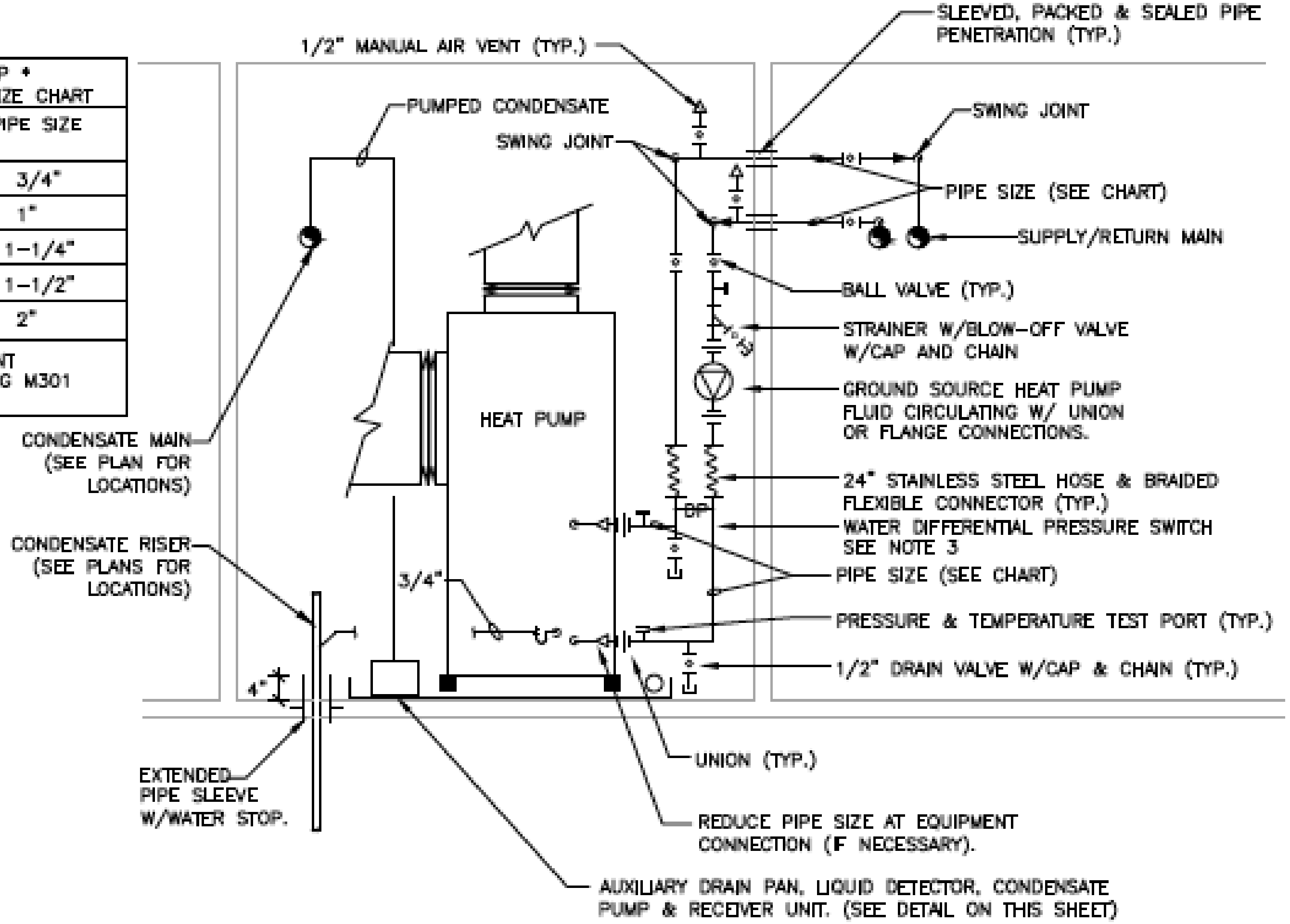
- 101 distributed water-to-air heat pumps
- Classrooms are equipped with vertical floor mounted heat pumps located in equipment closets accessible from the corridor
- Core workrooms, teacher lounges, and gymnasiums are served by horizontal heat pumps
- Ventilation air: DOAS units include energy recovery wheels, can provide supplemental cooling/heating
- Geothermal wells supply ground source water to all heat pumps
- 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	

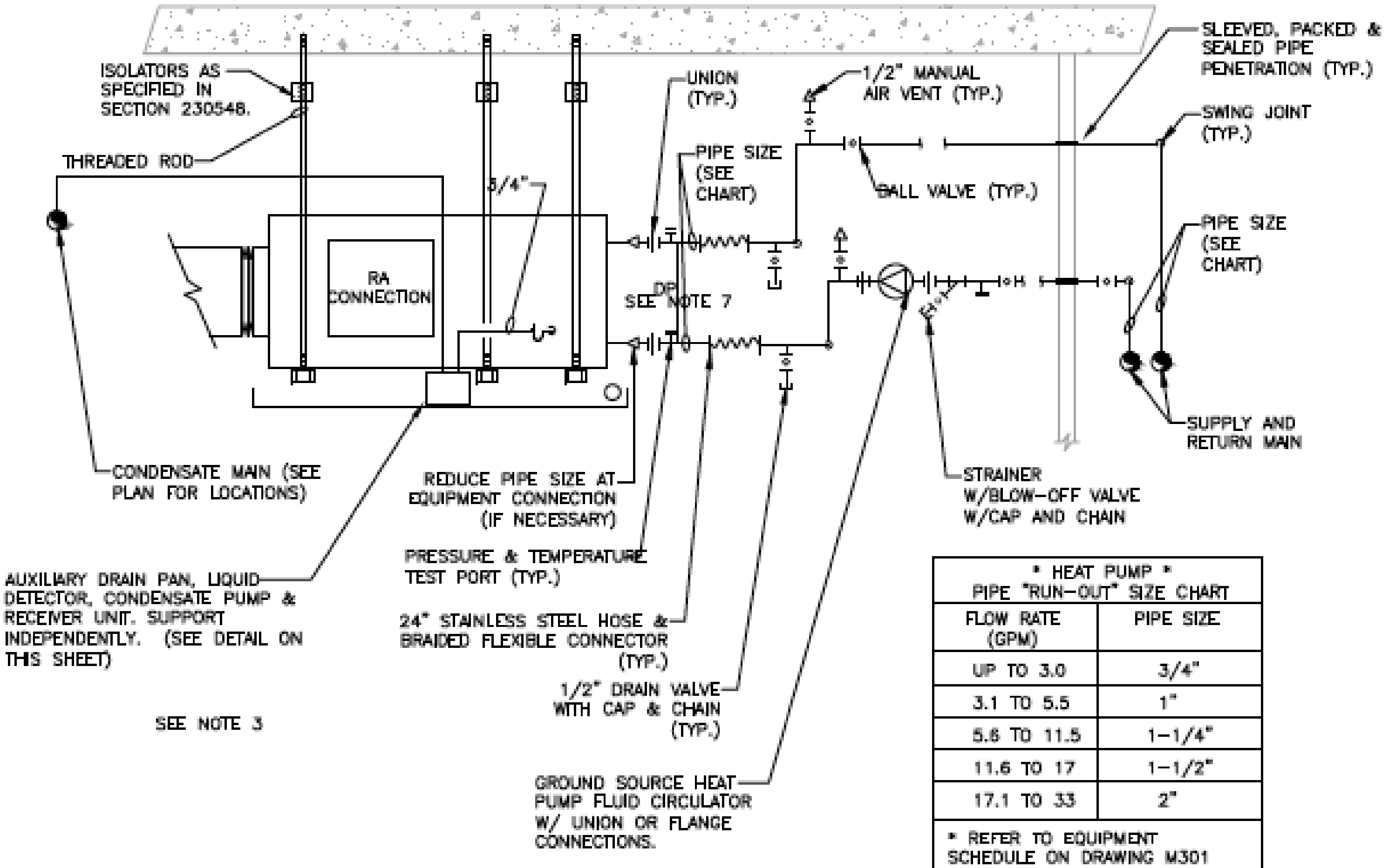


NOTES:

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



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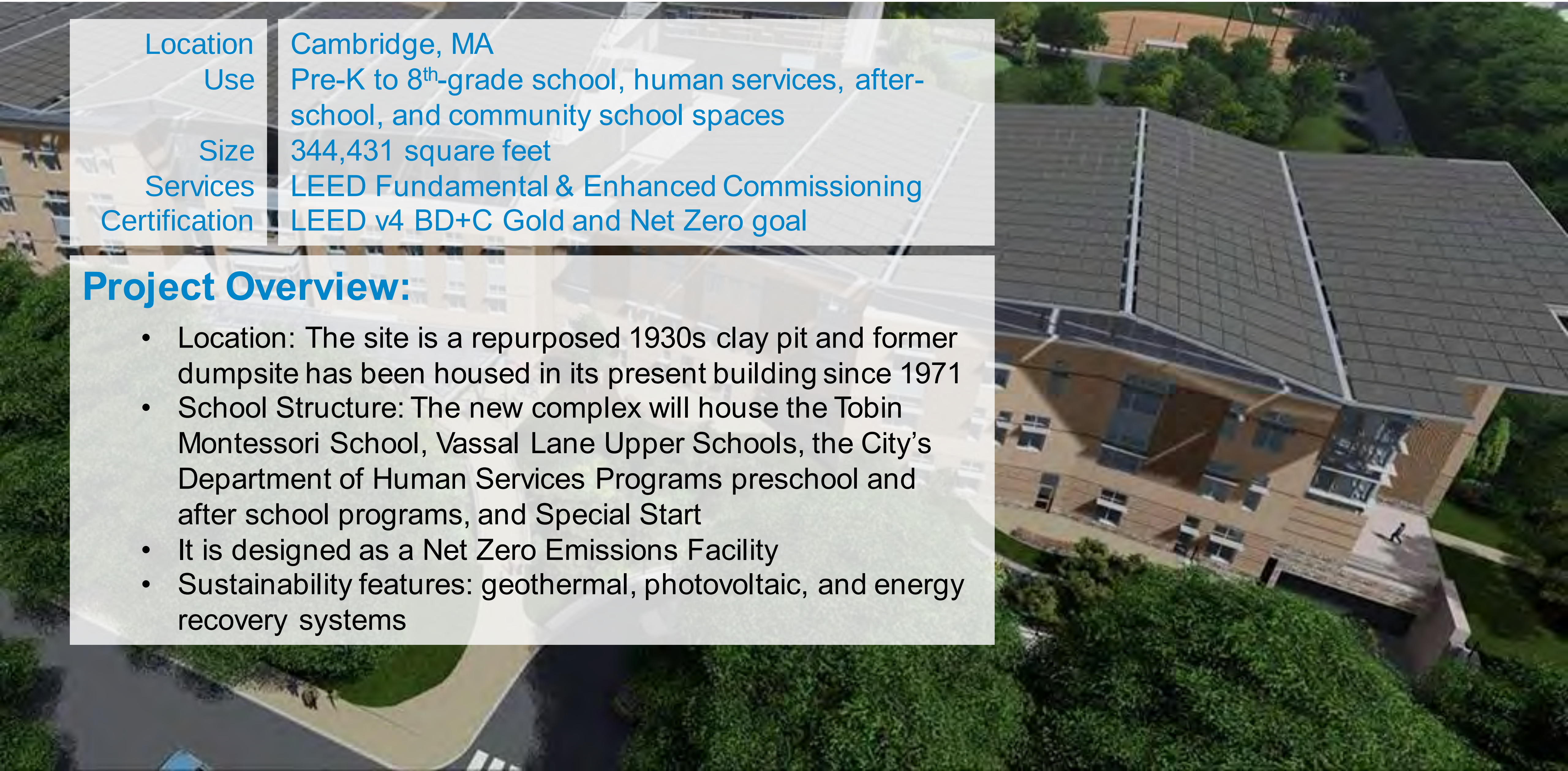
17.1 TO 33	2"
* REFER TO EQUIPMENT SCHEDULE ON DRAWING M301 FOR FLOW RATES	

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. PROVED 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 – Tobin Montessori/Vassal Lane Upper Schools



Location	Cambridge, MA
Use	Pre-K to 8th-grade school, human services, after-school, and community school spaces
Size	344,431 square feet
Services	LEED Fundamental & Enhanced Commissioning
Certification	LEED v4 BD+C Gold and Net Zero goal

Project Overview:

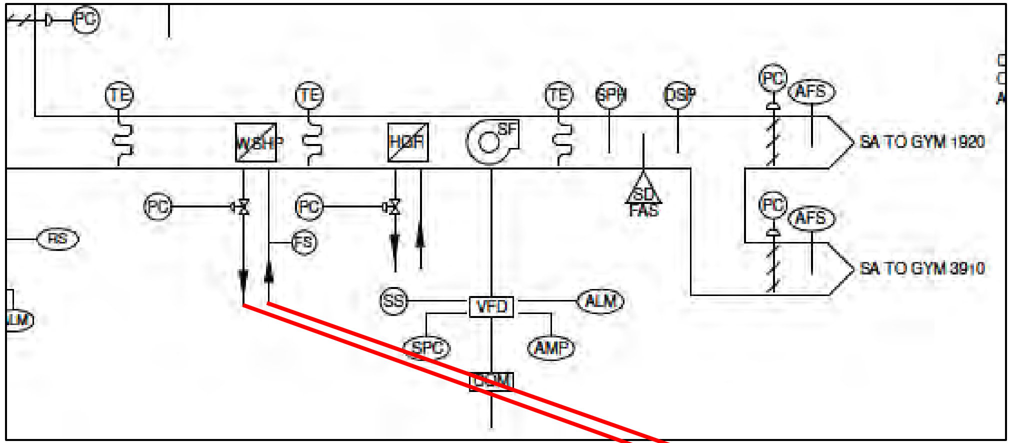
- Location: The site is a repurposed 1930s clay pit and former dumpsite has been housed in its present building since 1971
- School Structure: The new complex will house the Tobin Montessori School, Vassal Lane Upper Schools, the City’s Department of Human Services Programs preschool and after school programs, and Special Start
- It is designed as a Net Zero Emissions Facility
- Sustainability features: geothermal, photovoltaic, and energy recovery systems

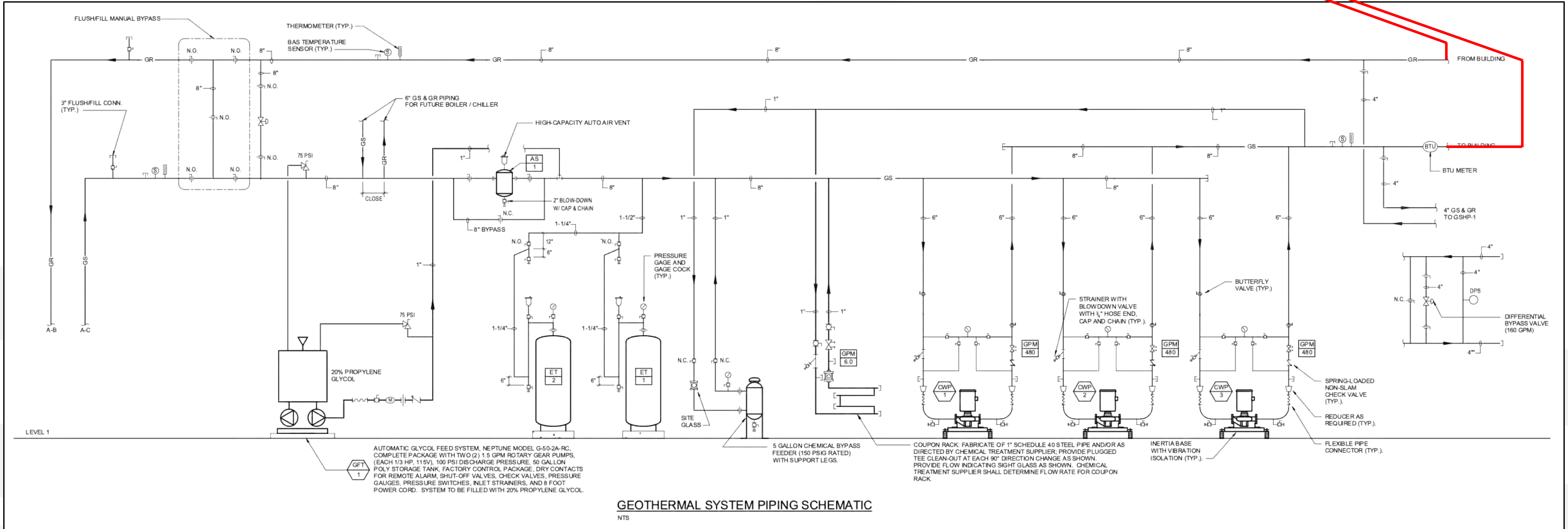
Case Study – Tobin Montessori/Vassal Lane Upper Schools

Hybrid System: Ground-Source Geothermal Heat Pump, and Variable Refrigerant Flow (VRF) Air Source Heat Pump

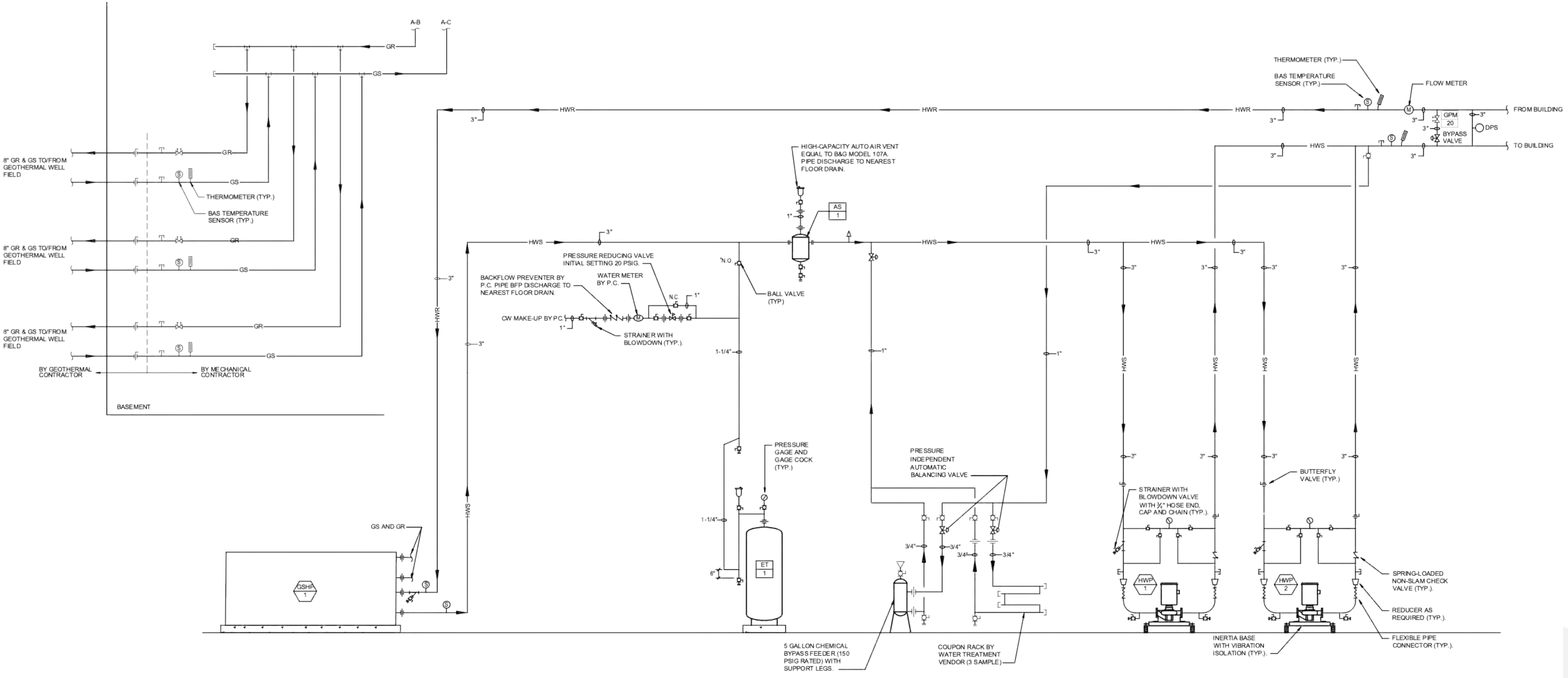
- A ground-source geothermal heat pump system will provide ground water to the air handlers' heat pump coils (water-to-air heat pump), for the gymnasium, auditorium, cafeteria, and general circulation spaces.
  - The geothermal well field will consist of 75 to 90 geothermal wells
  - One dedicated water-to-water heat pump will produce hot water for unit heaters and VAV box reheat coils
- A separate "VRF" system (air-to-air heat pumps) serves academic and office areas.

Case Study – Tobin Montessori/Vassal Lane Upper Schools





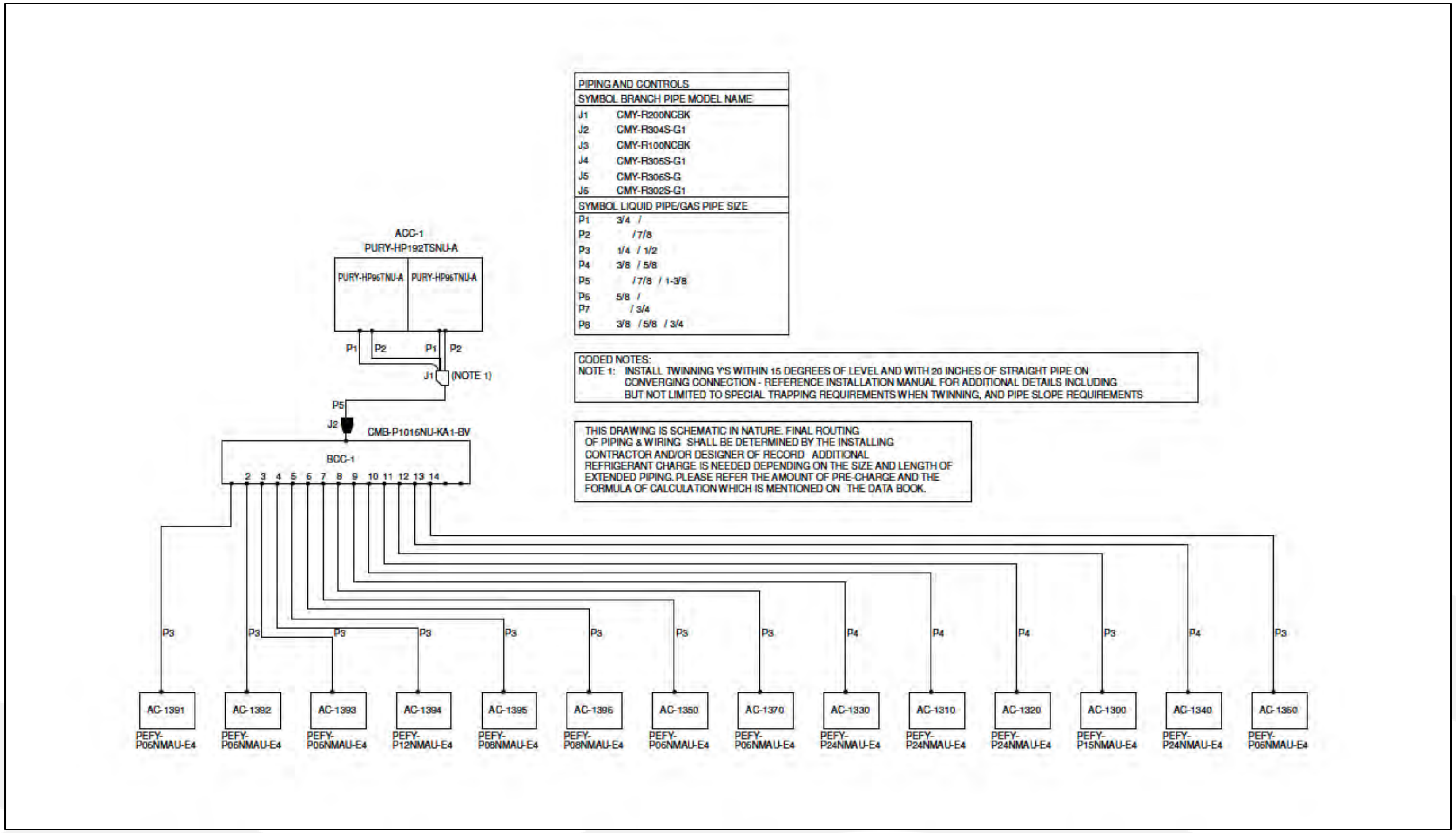
Case Study – Tobin Montessori/Vassal Lane Upper Schools



HOT WATER SYSTEM PIPING SCHEMATIC

NTS

Case Study – Tobin Montessori/Vassal Lane Upper Schools



Above is only one example of the 19 air-to-air VRF systems in the Tobin project.

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 (HW, CHW)
- Heating and cooling by central geothermal plant consisting of eight 85-ton water-to-water heat pump chillers.
  - These heat pump modules serve AHUs/chilled beams/etc., providing hot water, chilled water, and heat recovery (via the source water loop)
  - Heat Recovery - the heat pump submittal states, *"If the chilled water (evaporator) or hot water (condenser) is not required for the building load, it will be diverted within the module and sent to the source (sink)."*
- The system is supplied with ground source "condenser" water from 190 closed loop geothermal wells, organized into 38 circuits
- 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

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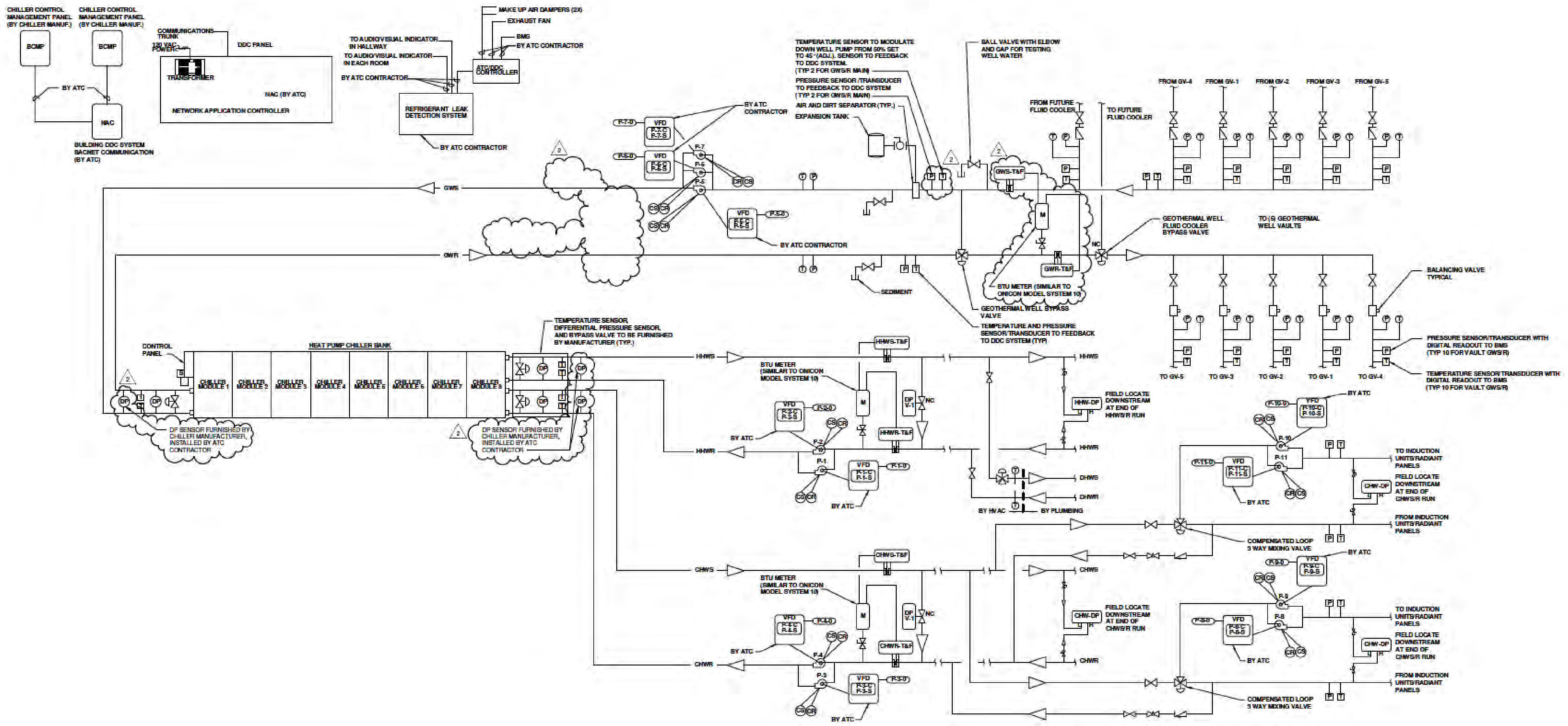

Learning Objectives:

Learning Objective 1 — Understand the differences between the most common types of commercial heat pump systems

Learning Objective 2 — Look at four different applications of heat pump systems in high performance projects

Learning Objective 3 — Learn to evaluate air source heat pump performance and efficiency

Learning Objective 4 — Review current RI code requirements related to heat pumps

Learning Objective 5 — Look at the role of heat pump technology in current trends for electrification in commercial buildings

Questions?





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