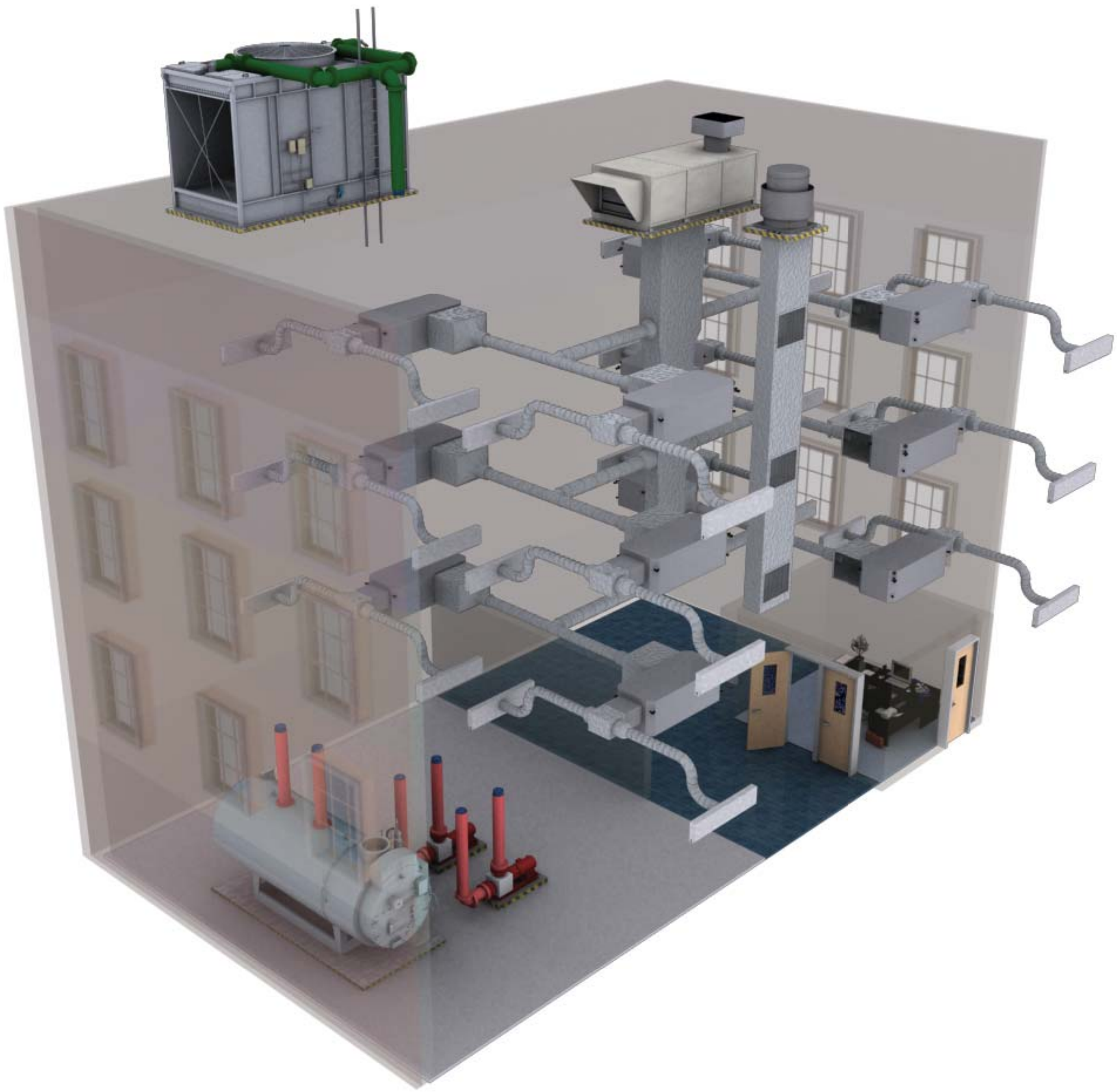
Trane Engineers Newsletter Live

Energy-Saving Strategies for Water-Source and Ground-Source Heat Pump Systems

Presenters: Mick Schwedler, Paul Solberg, John Murphy, Jeanne Harshaw (host)



Agenda

Energy-Saving Strategies for WSHP/GSHP Systems

Presenters: Mick Schwedler, Paul Solberg, John Murphy, Jeanne Harshaw (host)

This ENL will discuss HVAC system design and control strategies that can save energy in water-source heat pump (WSHP) and ground-source heat pump (GSHP) systems. Topics include the latest technologies being used in heat pumps, design and control of the water distribution loop and dedicated outdoor-air system, ground-source systems, and a review of the requirements in ASHRAE Standard 90.1 that apply to WSHP/GSHP systems.

Viewer learning objectives

1. *Identify the differences between distributed and centralized heat pump systems*
2. *Understand the latest technologies being used in heat pumps (compressors, fans)*
3. *Learn about various design and control strategies that can save energy in WSHP/GSHP systems*
4. *Learn how to design and control a dedicated OA system as part of a WSHP/GSHP system*
5. *Understand how the requirements of ASHRAE Standard 90.1 apply to WSHP/GSHP systems*

Welcome, agenda, introductions

Overview of a water-source heat pumps

- a) Value of heat pumps
- b) High-level description of WSHP (cooling vs. heating mode)

Brief comparison of distributed vs. centralized heat pump systems

- a) Advantages and drawbacks of distributed heat pump systems
- b) Advantages and drawbacks of centralized heat pump systems (refer to 2011 ENL for more info)

Overview of a distributed, water-source heat pump system

- a) High-level description of WSHP system components
- b) Overview advantages of WSHP systems
- c) Overview challenges of WSHP systems

Latest technologies being used in heat pumps

- a) Compressor technologies and capacity modulation technologies (cycling vs. two-stage vs. Digital scroll vs. variable-speed)
- b) Fan technologies (coordinated fan/compr control)
- c) ASHRAE 90.1 requirements

Dedicated outdoor-air system

- a) Air distribution options: direct to space vs. to the unit inlet (list advantages & drawbacks of each)
- b) Brief review of cold vs. neutral discussion and control strategies
- c) ASHRAE 90.1 requirements: Demand-controlled ventilation
- d) Brief discussion of various equipment types
- e) ASHRAE 90.1 requirements: Exhaust-air energy recovery

Water distribution loop, including heat rejection, heat addition, and controls

- a) High-level description of water distribution loop components
- b) Waterside economizing

Ground-source systems (brief discussion of advantages and drawbacks of each)

Presenter biographies

Mick Schwedler | manager, applications engineering | Trane

Mick has been involved in the development, training, and support of mechanical systems for Trane since 1982. With expertise in system optimization and control (in which he holds patents), and in chilled-water system design, Mick's primary responsibility is to help designers properly apply Trane products and systems. To do so, he provides one-on-one support, writes technical publications, and presents seminars.

A recipient of ASHRAE's Distinguished Service and Standards Achievement Awards, Mick is the immediate past Chair of SSPC 90.1, which was responsible for writing ANSI/ASHRAE/IESNA 90.1-2010, a prerequisite for LEED. He also contributed to the ASHRAE GreenGuide and is a member of theUSGBC Education Events Committee. Mick earned his mechanical engineering degree from Northwestern University and holds a master's degree from the University of Wisconsin Solar Energy Laboratory.

Paul Solberg | applications engineer | Trane

A mechanical engineer from the University of Wisconsin at Platteville, Paul is a 35-year veteran of Trane. He specializes in compressor and refrigeration systems, and has authored numerous Trane publications on these subjects, including application manuals, engineering bulletins, and *Engineers Newsletters*. Paul served in the technical service and applications engineering areas at various manufacturing locations, where he developed particular expertise supporting split systems, small packaged chillers, rooftop air conditioners, and other unitary products.

Paul is the Vice Chair of ASHRAE Standard 147 *"Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems"*, a voting member of TC 8.7 VRF, and is involved in other ASHRAE technical committees.

John Murphy | applications engineer | Trane

John has been with Trane since 1993. His primary responsibility as an applications engineer is to aid design engineers and Trane sales personnel in the proper design and application of HVAC systems. As a LEED Accredited Professional, he has helped our customers and local offices on a wide range of LEED projects. His main areas of expertise include energy efficiency, dehumidification, dedicated outdoor-air systems, air-to-air energy recovery, psychrometry, and ventilation.

John is the author of numerous Trane application manuals and *Engineers Newsletters*, and is a frequent presenter on Trane's Engineers Newsletter Live series. He also is a member of ASHRAE, has authored several articles for the ASHRAE Journal, and has been a member of ASHRAE's "Moisture Management in Buildings" and "Mechanical Dehumidifiers" technical committees. He was a contributing author of the *Advanced Energy Design Guide for K-12 Schools* and the *Advanced Energy Design Guide for Small Hospitals and Health Care Facilities,* a technical reviewer for the *ASHRAE Guide for Buildings in Hot and Humid Climates*, and a presenter on ASHRAE's "Dedicated Outdoor Air Systems" webcast.

Energy-Saving Strategies for Water-Source and Ground-Source Heat Pump Systems

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GBCI CMP

Heat Pumps Course ID: 0090007858

Approved for 1.5 GBCI hours for LEED professionals

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learning objectives

After today's program you will be able to:

- Identify differences between distributed and centralized heat pump systems
- Understand the latest technologies being used in heat pumps (compressors, fans)
- Learn about various design and control strategies that can save energy in WSHP/GSHP systems
- Understand how the requirements of ASHRAE Standard 90.1 apply to WSHP/GSHP systems

Agenda

- Value of heat pumps
- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed water-source heat pump systems
    - Latest technologies used in heat pumps
    - Dedicated outdoor-air system for ventilation
    - Water distribution loop design and control
    - Ground-source systems
- ASHRAE 90.1 requirements specific to WSHP/GSHP systems

Today's Presenters

Mick Schwedler
Manager, Applications Engineering

Paul Solberg
Applications Engineer

John Murphy
Applications Engineer

Agenda

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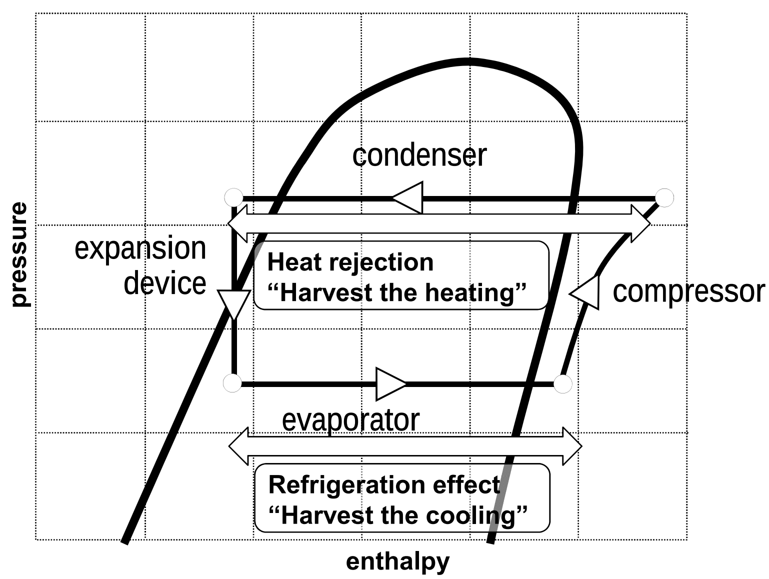
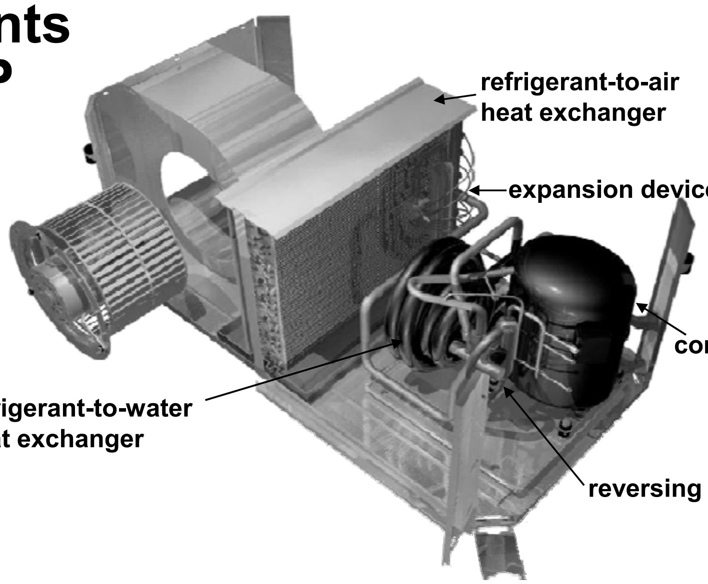
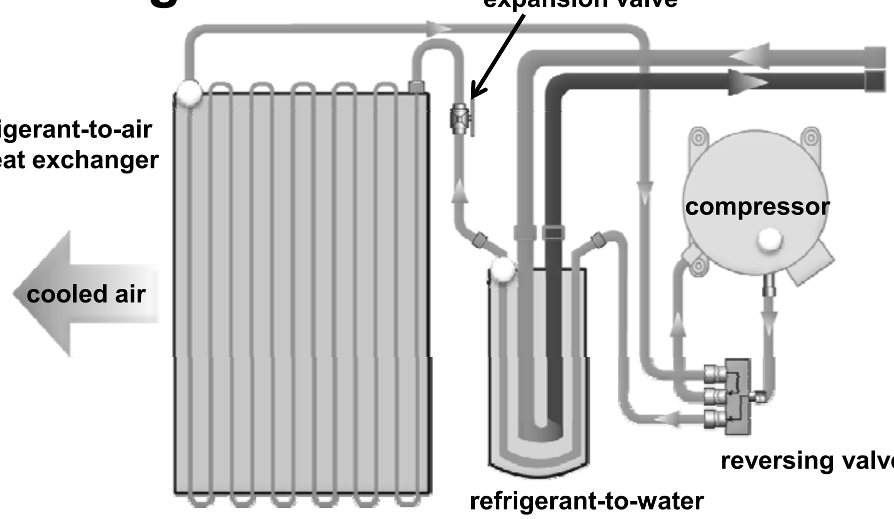
The Value of Heat Pumps



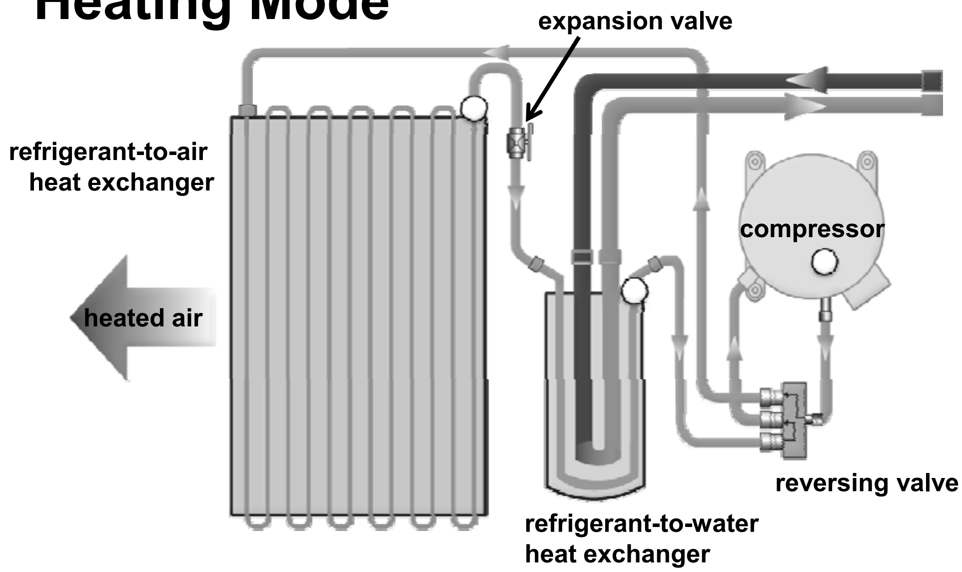
Components of a WSHP



water-source heat pump:
Cooling Mode



water-source heat pump:
Heating Mode



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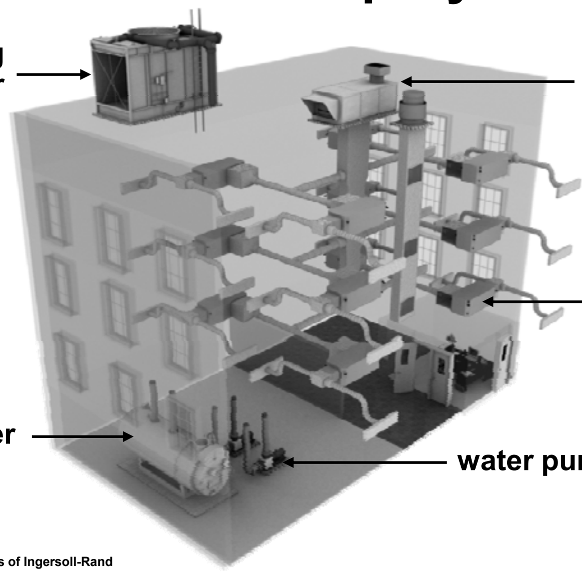
Distributed Heat Pump System



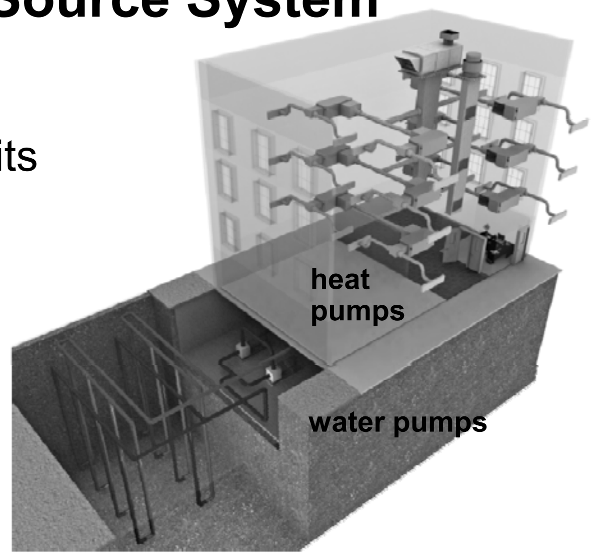
Distributed System

Advantages
- Limited floor space requirements
- Easy to self-service
- Isolated impact of equipment failure
- Capacity can be added
- Simple piping design

Disadvantages
- In-space service and maintenance
- Distributed service and maintenance
- Acoustics
- Use dedicated outdoor air systems
- Limited air cleaning options

Distributed Ground-Source System

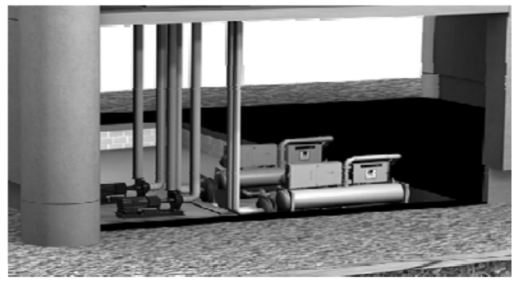
- WSHPs
- Dedicated outdoor air units
- Optional fluid cooler
- Water pumps
- Ground heat exchanger



Central Ground-Source System

Central Ground-Source System

- Heat recovery chillers (chiller/heaters) provide heating and cooling
  - Hydronic four pipe
- System choice
  - Central air handlers
  - Radiant
  - Fan coils



Central Ground-Source System

Advantages

- Service and maintenance occurs in an equipment room
- Service and maintenance is centralized
- Acoustics (equipment away from space)
- Air economizer integrates into air distribution system
- Efficient cascading of simultaneous energy streams
- Air cleaning flexibility

Disadvantages

- Requires MER space
- Requires a chiller technician to service the central plant
- Redundancy must be designed
- Capacity addition

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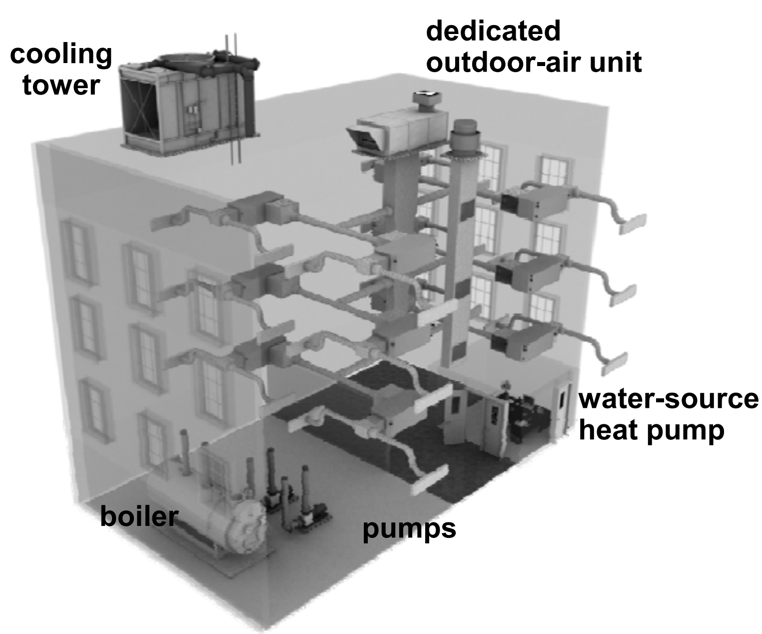
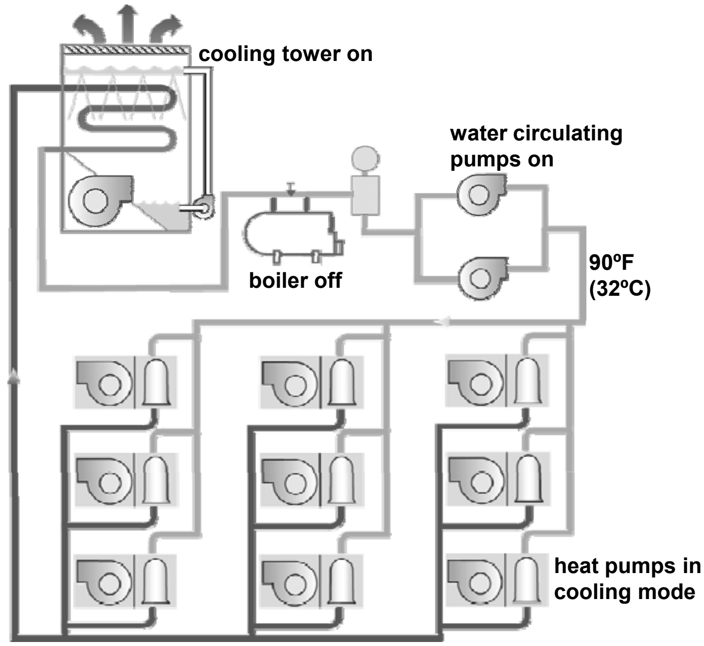
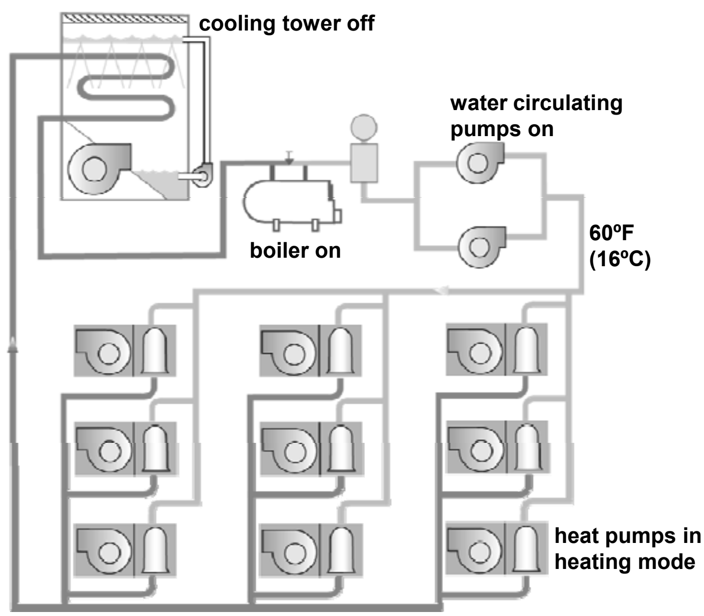
Typical WSHP System



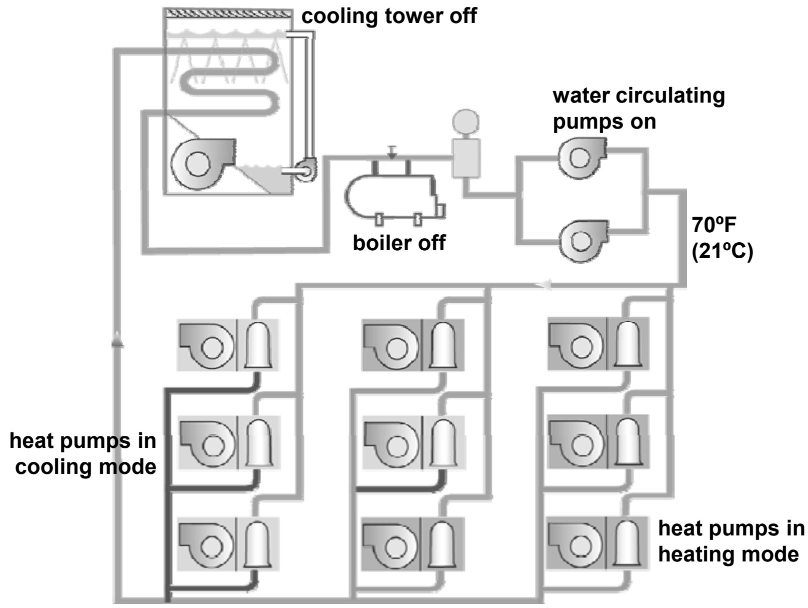
System Operation During Warm Weather



System Operation During Cold Weather



System Operation During Mild Weather

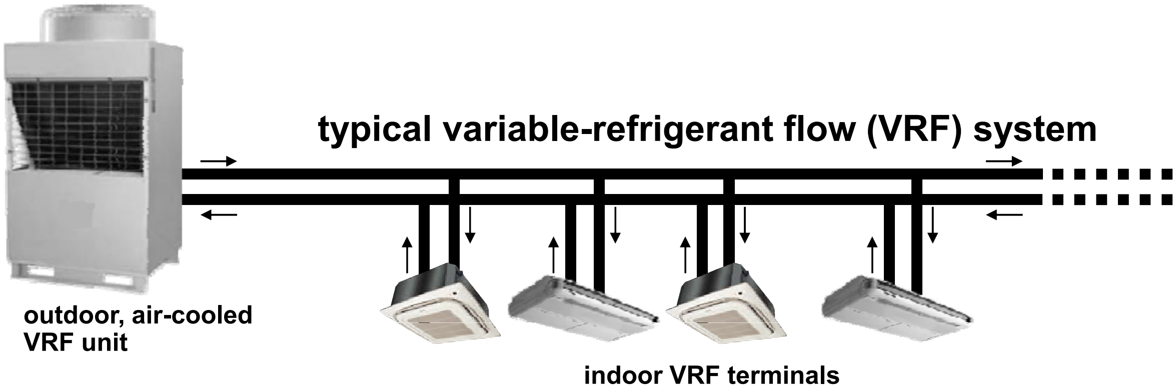


Distributed WSHP System

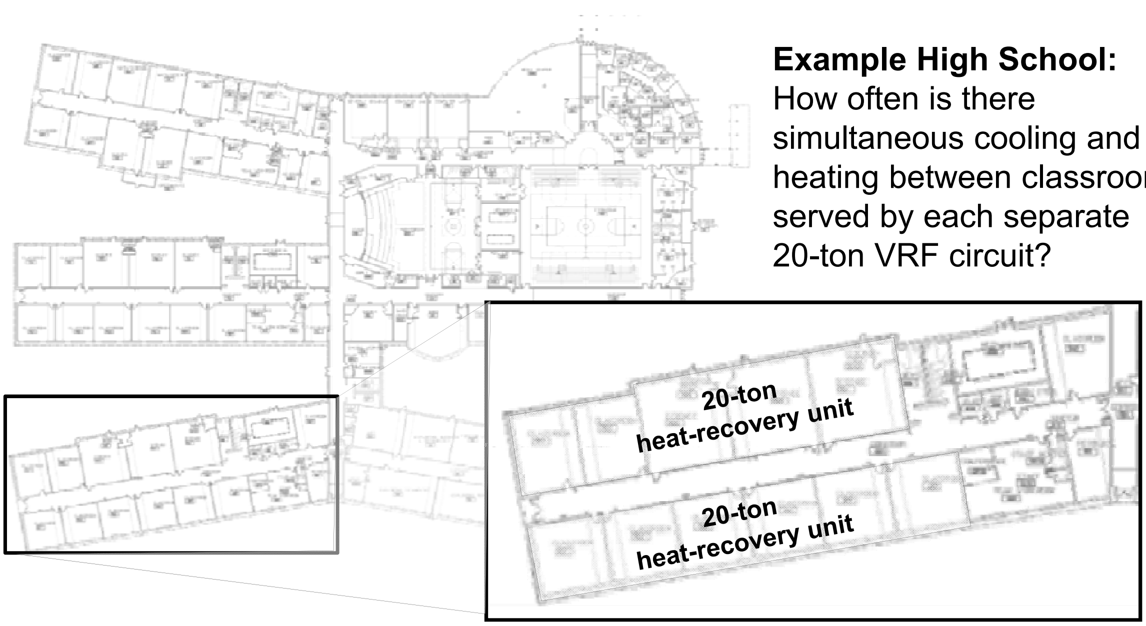
Typical benefits

- Opportunity to save energy
  - Heat recovery when some WSHPs operate in cooling mode while others operate in heating mode
  - Heat pumps have a high COP during heating mode
  - Water-cooled condensing during cooling mode
  - Can be used in a ground-coupled system

All Heat Recovery Is Not Equal



Example High School:
How often is there simultaneous cooling and heating between classrooms served by each separate 20-ton VRF circuit?



Distributed WSHP System

Typical benefits

- Opportunity to save energy
- Scalable capacity … add it as needed
- Opportunity for individual tenant metering
- Easy to install
- Limits impact of equipment failure

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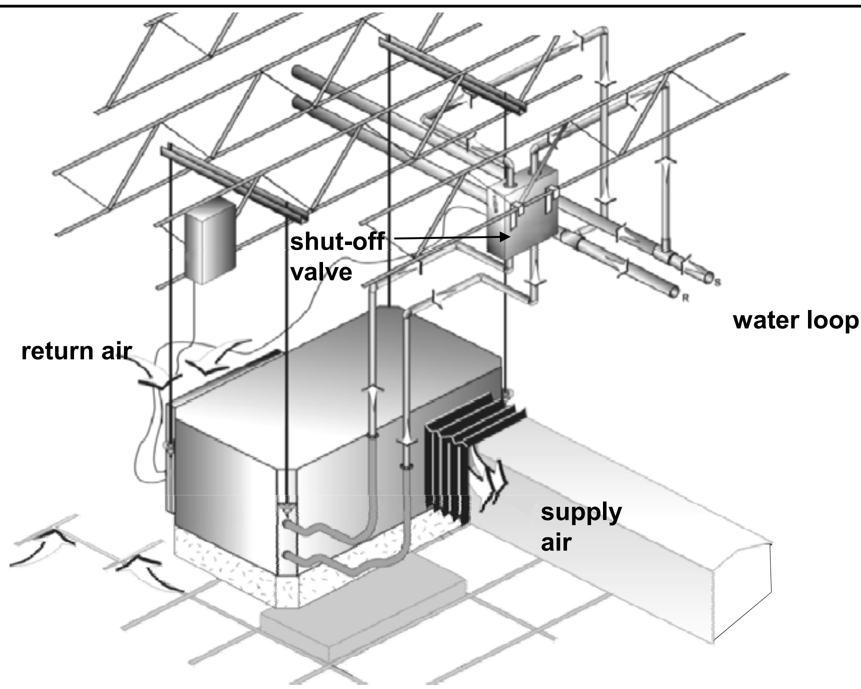

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Distributed WSHP System

Typical challenges/drawbacks

- Equipment is located in or near occupied spaces
- Distributed maintenance
- Separate ventilation system is typically required

Agenda

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- Basics of heat pumps
- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed water-source heat pump systems
  - Latest technologies used in heat pumps
  - Dedicated outdoor-air system for ventilation
  - Water distribution loop
  - Ground-source systems
- ASHRAE 90.1 requirements
- Summary

Small Tonnage Air Conditioning Compressors

- Compression technology
  - The method of compressing a refrigerant:
- Unloading strategy
  - The method of reducing the compressor capacity to match the coil load.
- How these affect WSHP efficiency

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Compression Technology Positive Displacement

- Rotary
- Scroll
- Reciprocating

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Reciprocating

Scroll Compressor

Rotary (Piston) Compressor

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Choosing Compression Technology

- Cost
- Durability
- Efficiency
  - Evaporator and condenser selection/utilization
  - Motor efficiency
  - Power factor
  - Compression efficiency (HGBP, digital release, etc.)
  - Frictional efficiency (aerodynamics, clean flow path, bearings, etc.)
  - Parasitic losses such as frequency drive efficiency

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Choosing Unloading Strategy

- On/off
- Hot Gas Bypass (HGBP)
- Digital
- Pocket unloading
- Multiple manifold
- Variable speed

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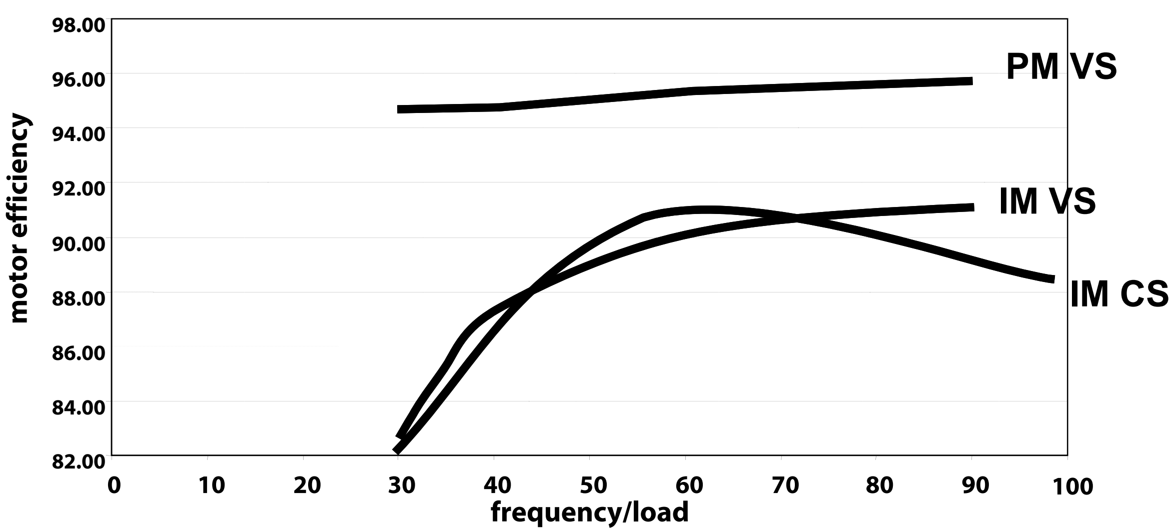
Motor Curves



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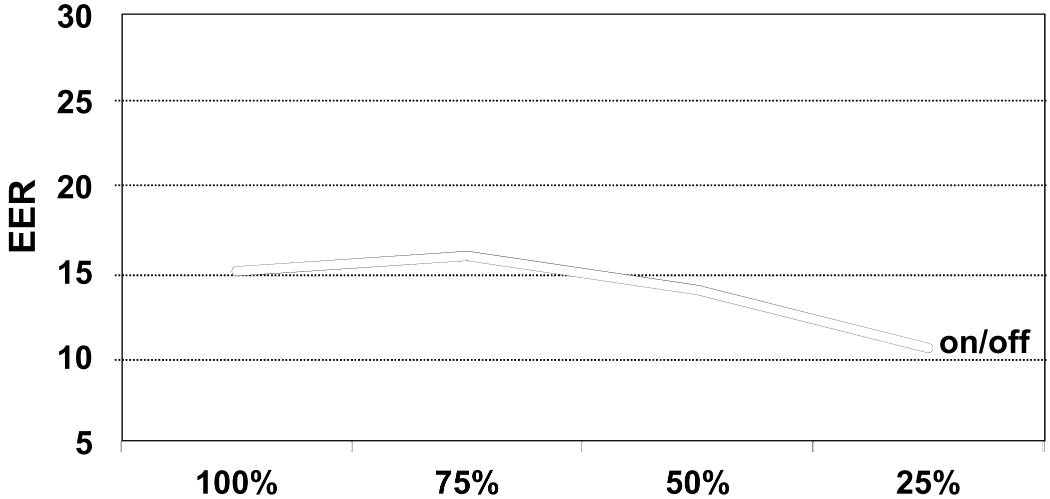
efficiency comparison
Compressor Unloading Modeled in a WSHP

- Compressor manufacturer operating maps
- ISO 13256-1 and AHRI 320 for WSHP conditions
- Examined AHRI 210/240 for variable capacity
  - Condenser flow set to 85ºF/95ºF at full load, fixed
  - Evaporator air at 80ºF/67ºF, fixed
  - 100% load: 85ºF EWT, fan flow 1600 cfm
  - 75% load: 75ºF EWT, fan flow 960/cfm
  - 50% load: 75ºF EWT, fan flow 800 cfm
  - 25% load: 75ºF EWT, fan flow 560 cfm

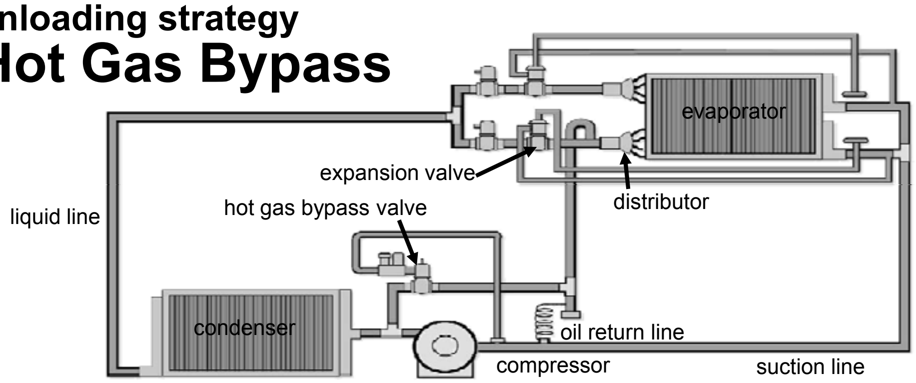
unloading strategy
On/Off

Capacity control	Coil Temp Control	Unit and Control Complexity	Total Cost
Poor	**Poor**	**Low**	**Low**

unloading strategy
On/Off

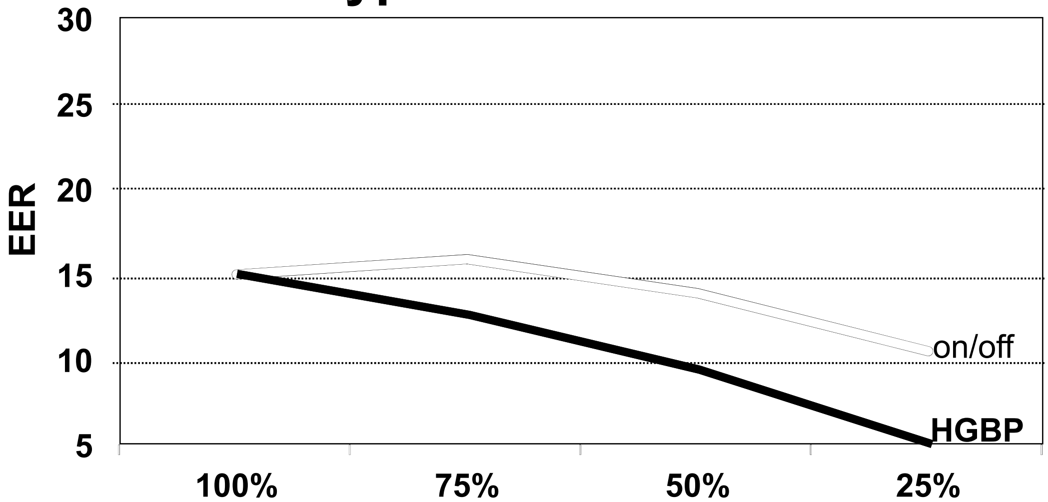


unloading strategy
Hot Gas Bypass



Capacity Modulation	Coil Temp Control	Unit and Control Complexity	Total Cost
EXC	**EXC**	**Med**	**Med**

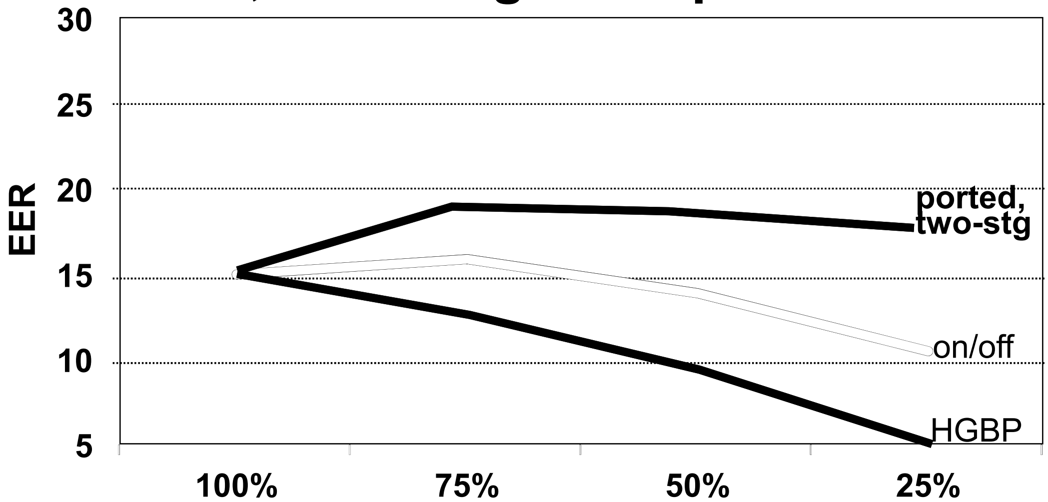
unloading strategy
Hot Gas Bypass



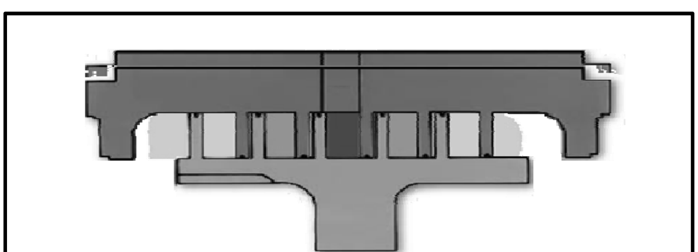
unloading strategy
Ported, Two-Stage Compressor

Capacity Modulation	Coil Temp Control	Unit and Control Complexity	Total Cost
Good	**Good**	**Low**	**Med**

unloading strategy
Ported, Two-Stage Compressor

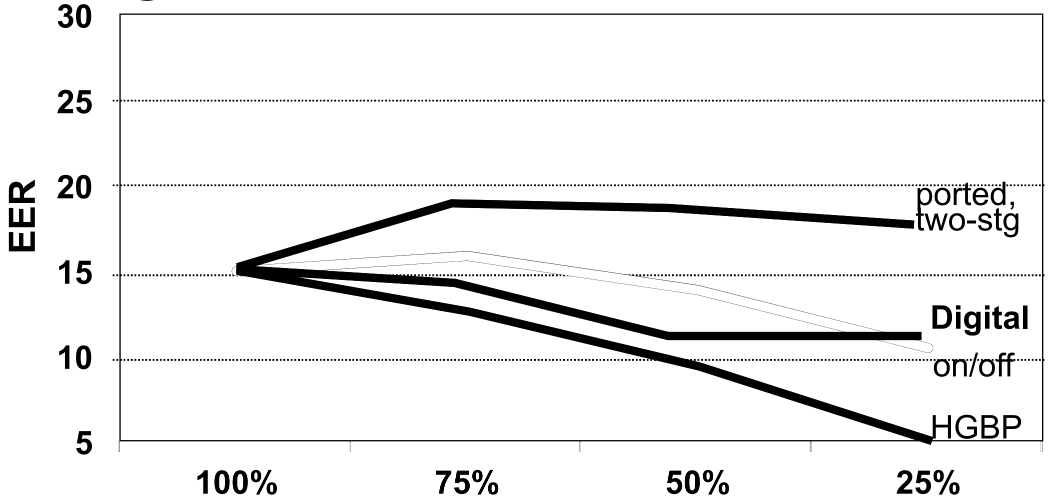


unloading strategy
Digital Scroll



Capacity Modulation	Coil Temp Control	Unit and Control Complexity	Total Cost
V Good	V Good	High	High

unloading strategy
Digital Scroll



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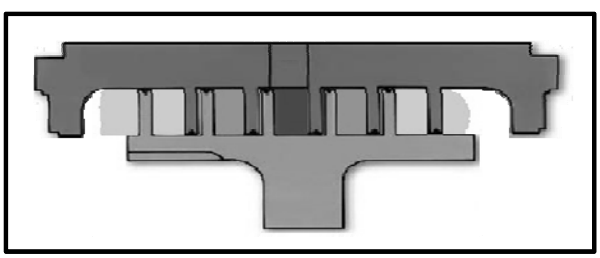
unloading strategy
Variable-Speed



Capacity Modulation	Coil Temp Control	Unit and Control Complexity	Total Cost
V Good	V Good	High	High

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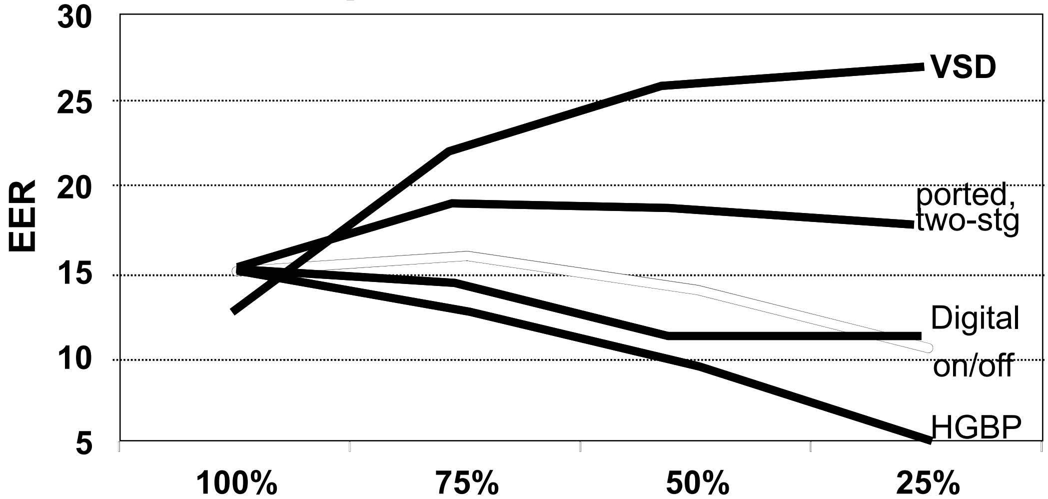
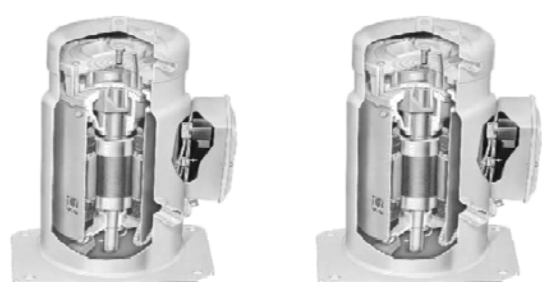
unloading strategy
Variable-Speed

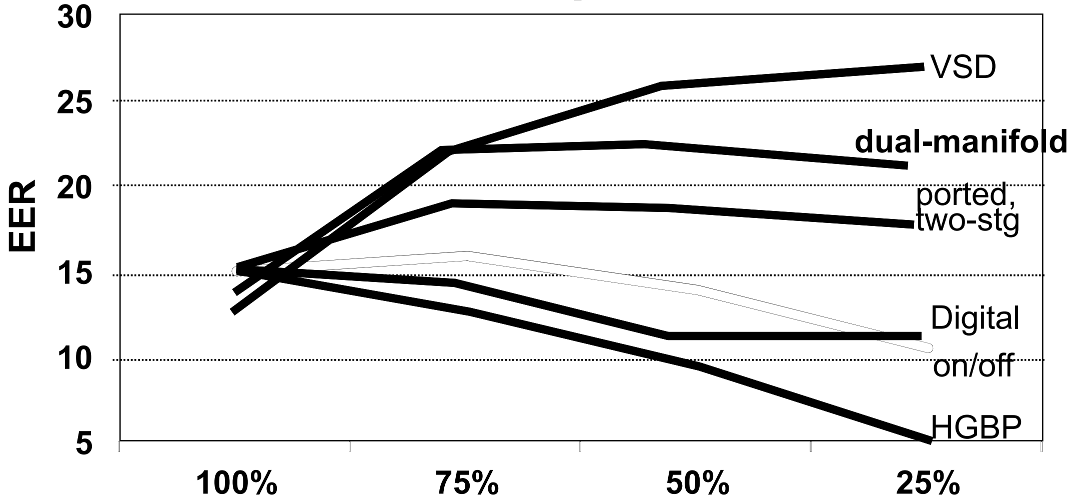


unloading strategy
Dual Manifold Compressor



Capacity Modulation	Coil Temp Control	Unit and Control Complexity	Total Cost
Good	Good	Low	Med

unloading strategy
Dual Manifold Compressor



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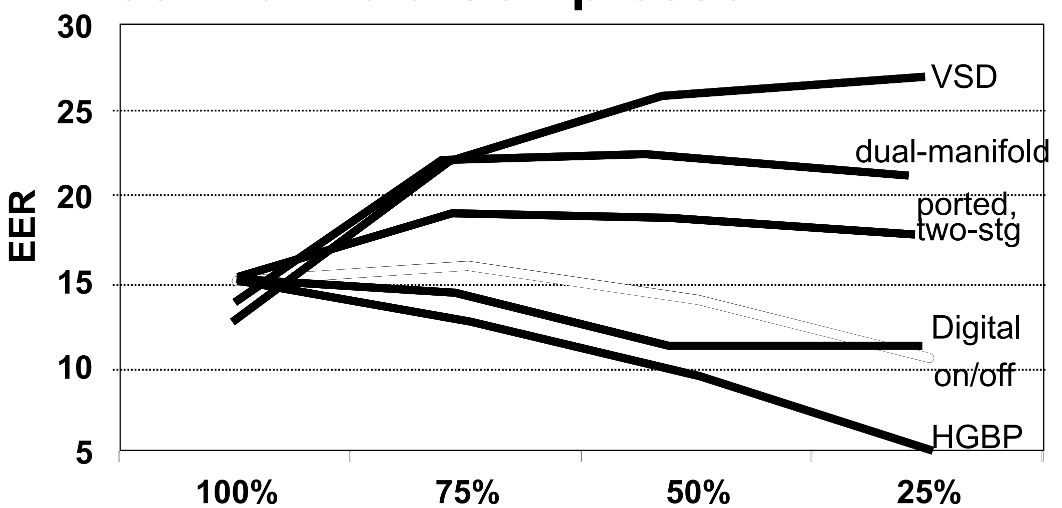
unloading strategy
Dual Manifold Compressor



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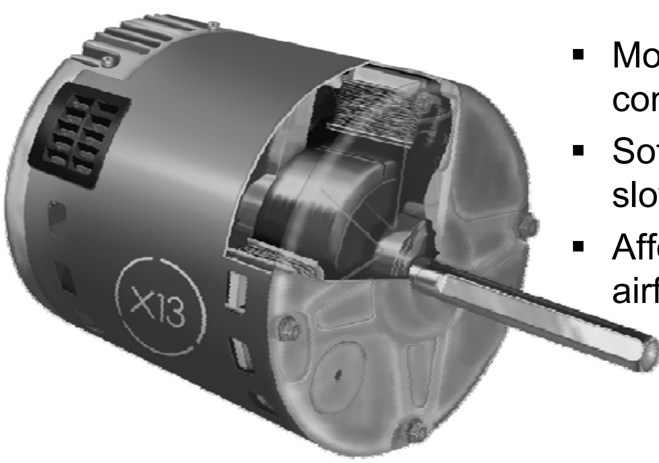
core technologies overview

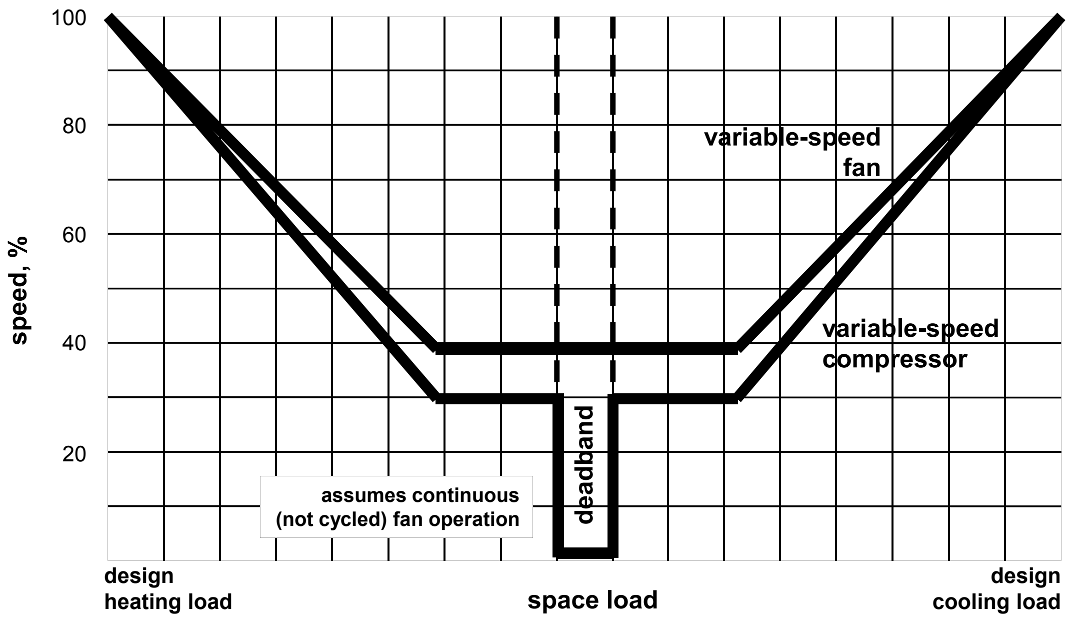
Comparison Summary

Unloading Strategy	Capacity Modulation	Coil Temp Control	Unit /Control Complexity	Total Cost	Efficiency
On/Off Comp	Poor	Poor	Low	Low	Fair
Hot Gas ByPass	Exc	Exc	Med	Med	V Poor
Ported	Good	Good	Low	Med	Good
Digital	V Good	V Good	High	High	Poor
Variable Speed	V Good	V Good	High	High	Exc
Manifold Compressors	Good	Good	Low	Med	V Good

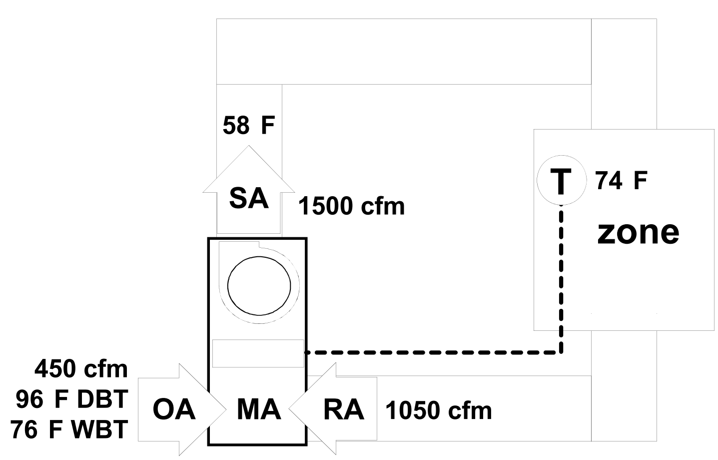
Electronically Commutated Motor (ECM)



- More efficient than most conventional motor technologies
- Soft start: ramps up and down slowly (less disruptive)
- Affords opportunity to vary airflow at part load



dehumidification performance
Full Load



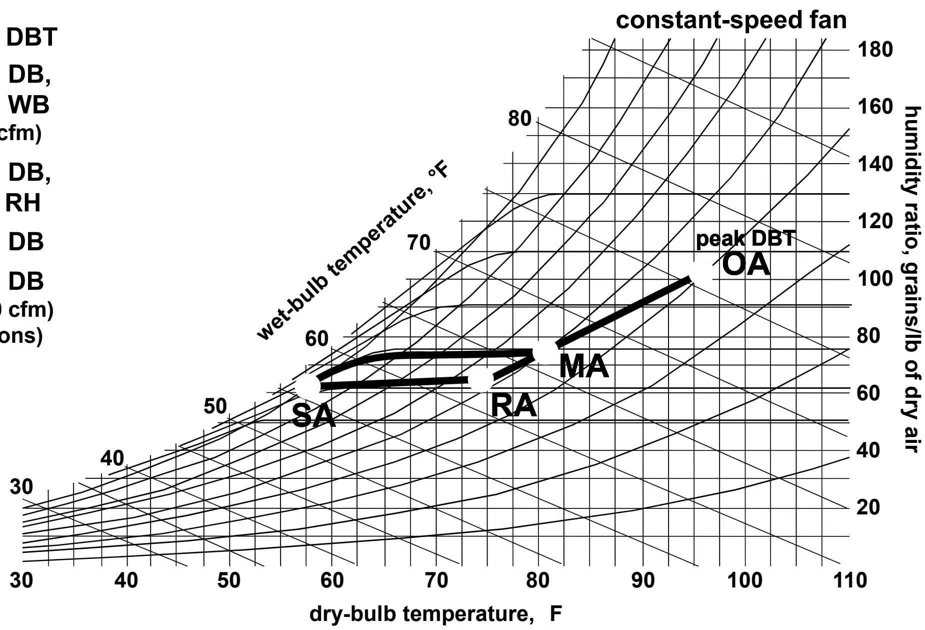
peak DBT

OA 96 F DB,
76 F WB
(450 cfm)

RA 74 F DB,
55% RH

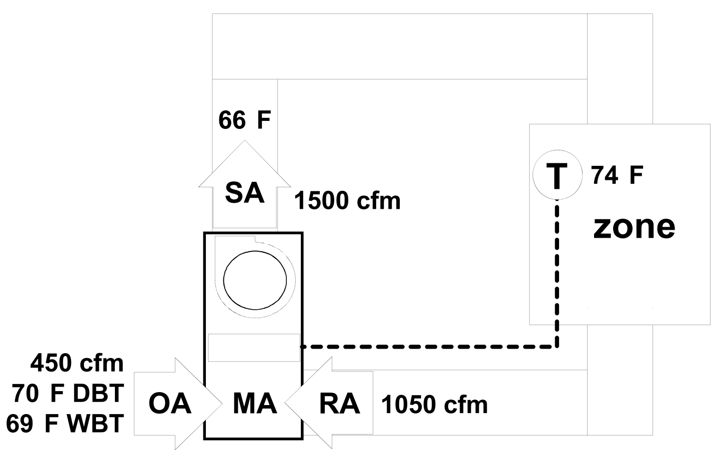
MA 81 F DB

SA 58 F DB
(1500 cfm)
(4.3 tons)



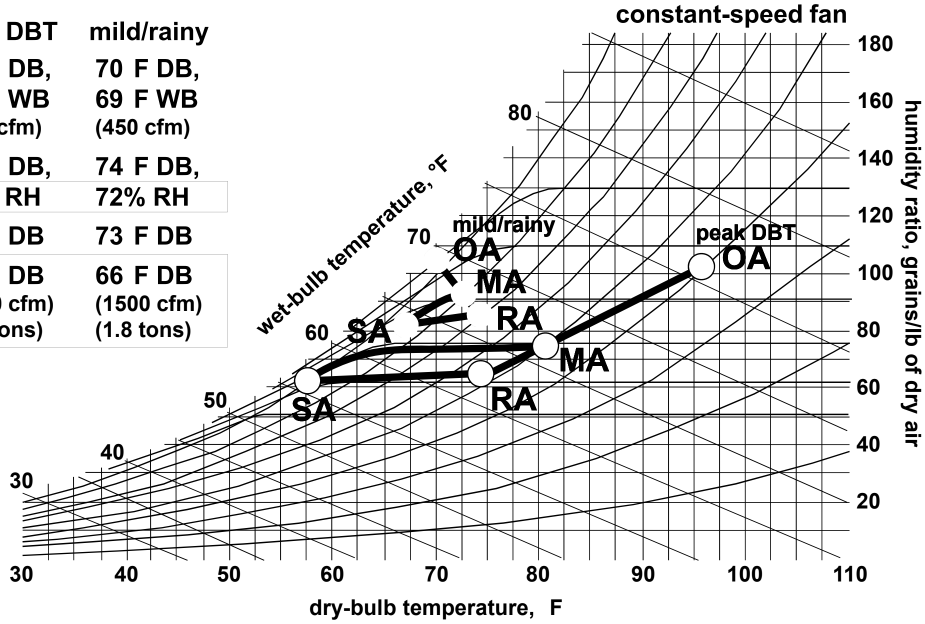
dehumidification performance

Part Load: Constant-Speed WSHP



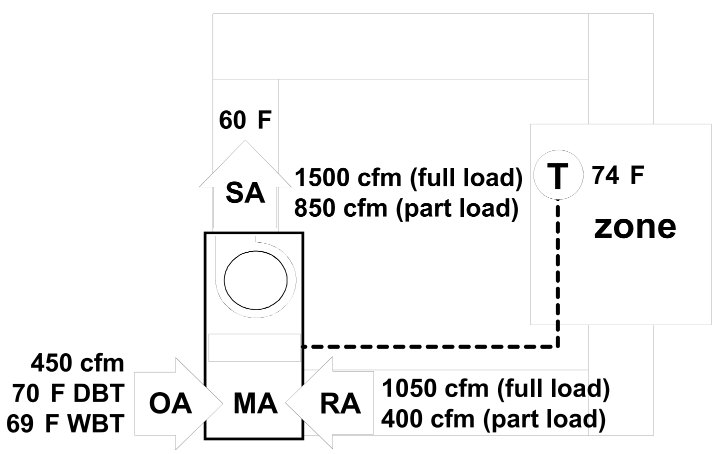
	peak DBT	mild/rainy
OA	96 F DB, 76 F WB (450 cfm)	70 F DB, 69 F WB (450 cfm)
RA	74 F DB, 55% RH	74 F DB, 72% RH
MA	81 F DB	73 F DB
SA	58 F DB (1500 cfm) (4.3 tons)	66 F DB (1500 cfm) (1.8 tons)

constant-speed fan

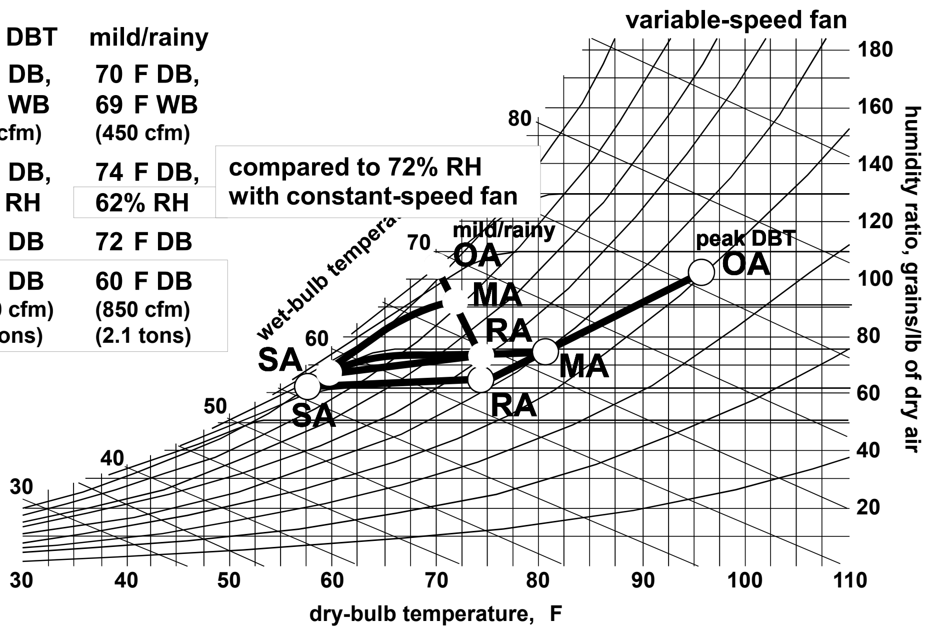


dehumidification performance

Part Load: Variable-Speed WSHP

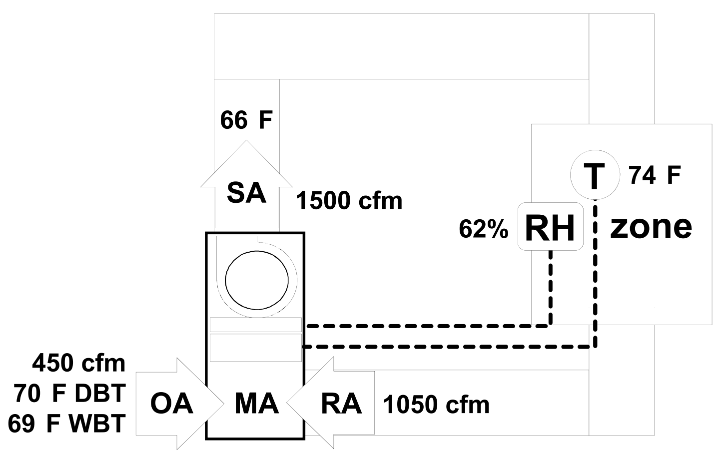


	peak DBT	mild/rainy
OA	96 F DB, 76 F WB (450 cfm)	70 F DB, 69 F WB (450 cfm)
RA	74 F DB, 55% RH	74 F DB, 62% RH
MA	81 F DB	72 F DB
SA	58 F DB (1500 cfm) (4.3 tons)	60 F DB (850 cfm) (2.1 tons)



dehumidification performance

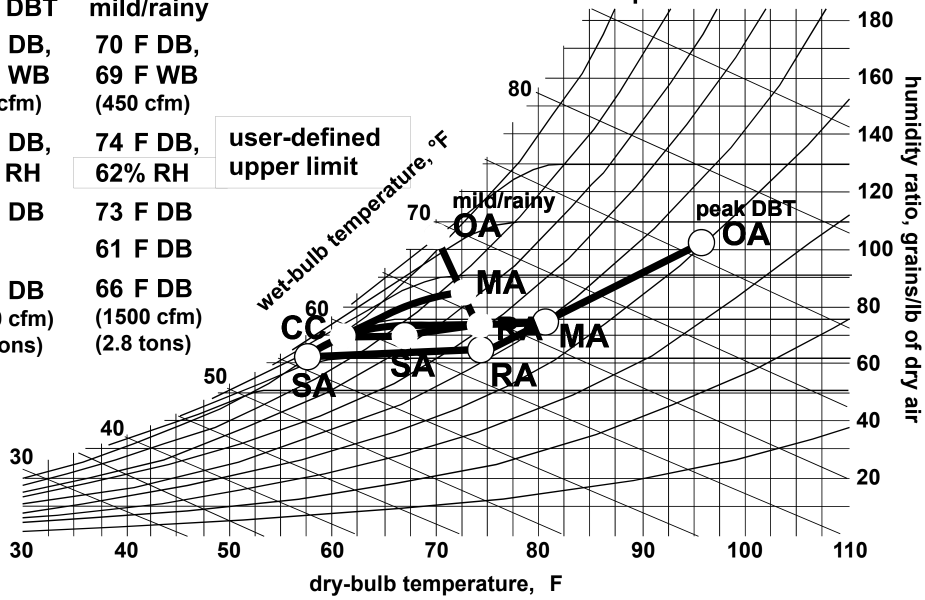
Part Load: Hot Gas Reheat



	peak DBT	mild/rainy
OA	96 F DB, 76 F WB (450 cfm)	70 F DB, 69 F WB (450 cfm)
RA	74 F DB, 55% RH	74 F DB, 62% RH
MA	81 F DB	73 F DB
CC		61 F DB
SA	58 F DB (1500 cfm) (4.3 tons)	66 F DB (1500 cfm) (2.8 tons)

user-defined upper limit

constant-speed fan w/ HGRH



mild, rainy day

Part-Load Example

	constant-speed WSHP	variable-speed WSHP	constant-speed WSHP with HGRH
zone humidity, %RH	72%	62%	62%
cooling load, tons	1.8	2.1	2.8
fan airflow, cfm	1500	850	1500

ASHRAE 90.1-2010 Mandatory Requirements

- Equipment Efficiency
  - Same as 90.1-2007
  - Water-to-Water requirements added
- Control
  - Auxiliary heat control (6.4.3.5)

Equipment Efficiency Table 6.8.1B

- Heat pump types
  - Water source
  - Ground water source
  - Ground Source
- Required efficiencies – must meet both
  - Cooling EER – at specified conditions
  - Heating COP – at specified conditions

ASHRAE 90.1-2010

Heat Pump Efficiencies 90.1-2010 / Addendum h (90.1-2013)

Type	Cooling Capacity (Btuh)	Clg EWT (ºF)	Clg EER	Htg (ºF)	Htg COP
Water source	<17,000	86	11.2 / **12.2**	68	4.2 / **4.3**
Water source	≥17,000 and <65,000	86	12.0 / **13.0**	68	4.2 / **4.3**
Water source	≥65,000 and <135,000	86	12.0 / **13.0**	68	4.2 / **4.3**
Ground water	<135,000	59	16.2 / **18.0**	50	3.6 / **3.7**
Ground loop (brine to air)	<135,000	77	13.4 / **14.1**	32	3.1 / **3.2**

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ASHRAE 90.1-2010

water-to-water

Heat Pump Efficiencies

Type	Cooling Capacity (Btuh)	Clg EWT (ºF)	Clg EER	Htg (ºF)	Htg COP
Water loop	<135,000	86	10.6	68	3.7
Ground water	<135,000	59	16.3	50	3.1
Ground loop (brine to water)	<135,000	77	12.1	32	2.5

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ASHRAE 90.1-2010

Heat Pump Auxiliary Heat Control

Section 6.4.3.5

- When electric resistance heat is integral to the heat pump, it must be locked out when the heat pump can satisfy load
  - User's Manual provides information on acceptable control methods
    - Example 6-X
    - Example 6-Y

ASHRAE 90.1-2010

Air System Design and Control

Section 6.5.3.1.1

Fan system power limitation:

- Applies to systems > 5 hp

Option	Constant volume	Variable volume
1) Nameplate hp	**hp ≤ CFMs x 0.0011**	**hp ≤ CFMs x 0.0015**
2) System bhp	**bhp ≤CFMs x 0.00094 + A**	**bhp ≤CFMs x 0.0013 + A**

Which fans' power apply to a WSHP system?
See example 6-DDD, ASHRAE 90.1-2010 User's Manual

example 6-DDD

User’s Manual for 90.1-2010

QUESTION: A wing of an elementary school building is served by eight WSHPs, each equipped with a ¾-hp fan motor and serving a single classroom. Ventilation air is supplied directly to each classroom by a dedicated outdoor-air system. Each classroom requires 500 cfm of outdoor air, so the DOAS delivers the total of 4000 cfm of conditioned outdoor air using a 5-hp fan. Does this system need to comply with section 6.5.3.1?

ANSWER: Each WSHP is a separate fan system because each has a separate cooling and heating source. The **power of the DOAS fan must be allocated to each heat pump** on a cfm-weighted basis.

ASHRAE 90.1-2010

example 6-DDD

User’s Manual for 90.1-2010

- DOAS delivers 500 cfm to each classroom
- ⅛ (500/400 cfm) of each DOAS fan power is added to the fan power for each WSHP
  - ⅛ of 5 hp= ⅝ hp
  - ¾ (heat pump) + ⅝ (DOAS) = 1 ⅜ hp
- Even with DOAS fan allocated, each heat pump “fan system” is less than the 5 hp threshold, so the system does not need to comply with the fan power limitation of Section 6.5.3.1

Agenda

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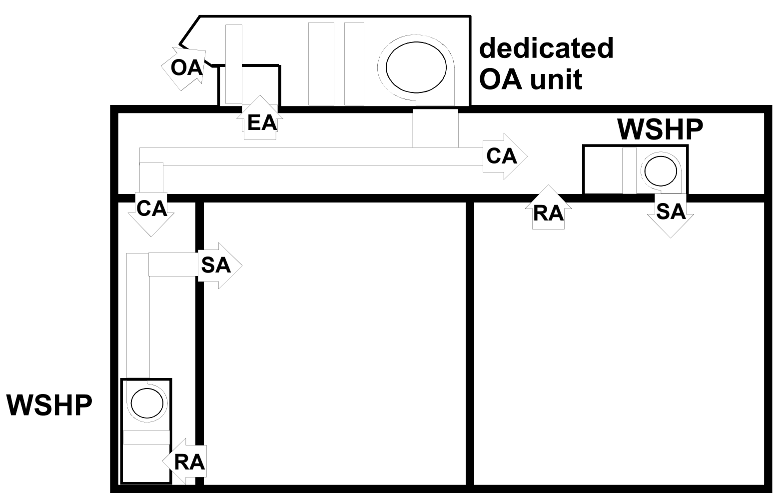
- Value of heat pumps
- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed water-source heat pump systems
  - Latest technologies being used in heat pumps
  - Dedicated outdoor-air system for ventilation
  - Water distribution loop design and control
  - Ground-source systems
- Summary

75

conditioned OA delivered

Near Inlet of Each WSHP



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conditioned OA delivered

Near Inlet of Each WSHP

Advantages

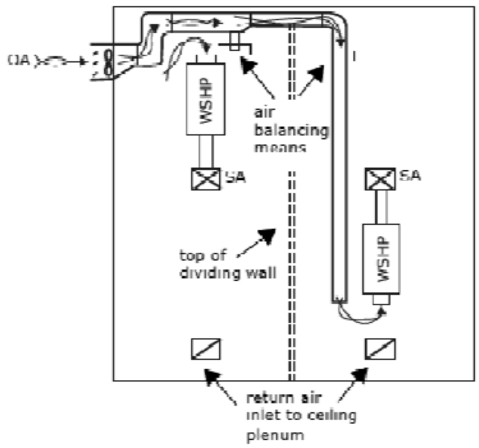
- Avoids cost and space to install additional ductwork and separate diffusers

conditioned OA delivered

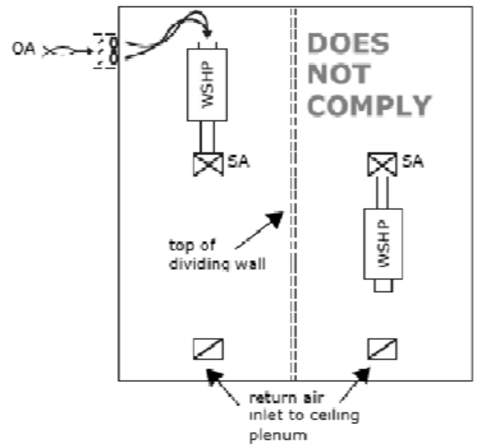
Near Inlet of Each WSHP

Drawbacks

- More difficult to ensure required OA reaches each zone (not ducted directly)
- Account for zone air distribution effectiveness (Ez) during heating season
- Local fan must operate continuously to provide OA during scheduled occupancy
  - or a VAV terminal should be used to ensure proper OA is delivered as WSHP fan speed changes
- Conditioned OA may not be able to be delivered at a cold temperature due to concerns over condensation



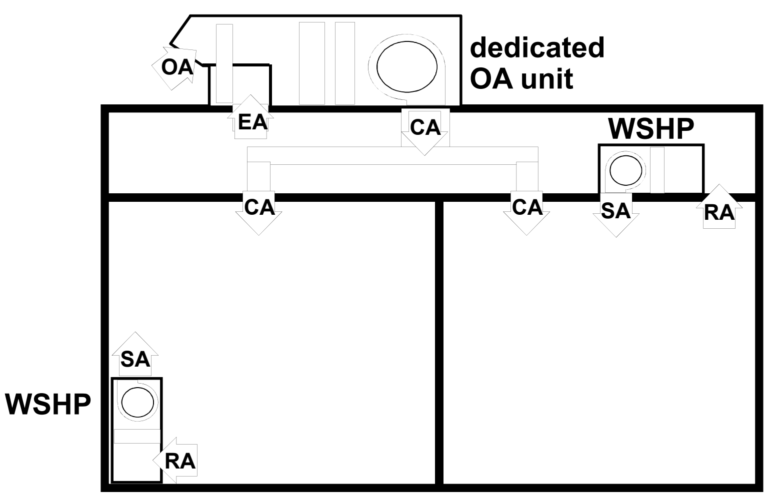
Correct plan of plenum system with discharge near terminal ends
Though the ducts are not connected to the terminal units, they discharge near them, with balancing means available to provide correct airflow to each.



Incorrect plan of plenum system
In this case, outdoor air ventilation is provided to one ventilation zone, but not the other. This could only meet the requirement if it could be shown that sufficient air gets to the remote system, perhaps by mixing between the zones.

ASHRAE 62.1-2010 User's Manual, Figures 5-D and 5-E

conditioned OA delivered
Directly to Each Zone



conditioned OA delivered
Directly to Each Zone

Advantages

- Easier to ensure required outdoor airflow reaches each zone (separate diffusers)
- Opportunity to cycle off (or vary speed of) the local fan because OA is not distributed through it
- Opportunity to downsize local WSHPs (if OA delivered cold)
- Allows dedicated OA system to operate during unoccupied periods without needing to operate local fans

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conditioned OA delivered
Directly to Each Zone

Drawbacks

- Requires installation of additional ductwork and separate diffusers
- May require multiple diffusers to ensure outdoor air is adequately dispersed throughout the zone

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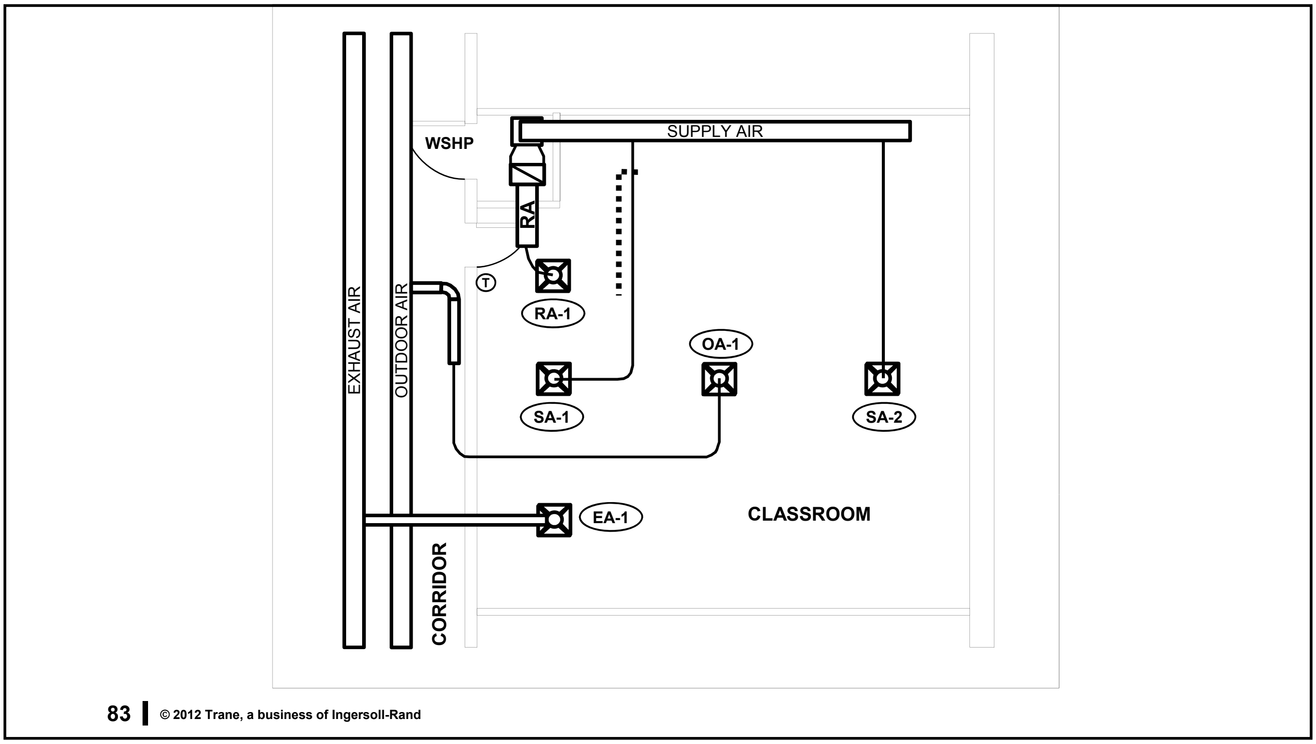
SUPPLY AIR
WSHP
RA
RA-1
OA-1
SA-1
SA-2
EXHAUST AIR
OUTDOOR AIR
EA-1
CLASSROOM
CORRIDOR
83
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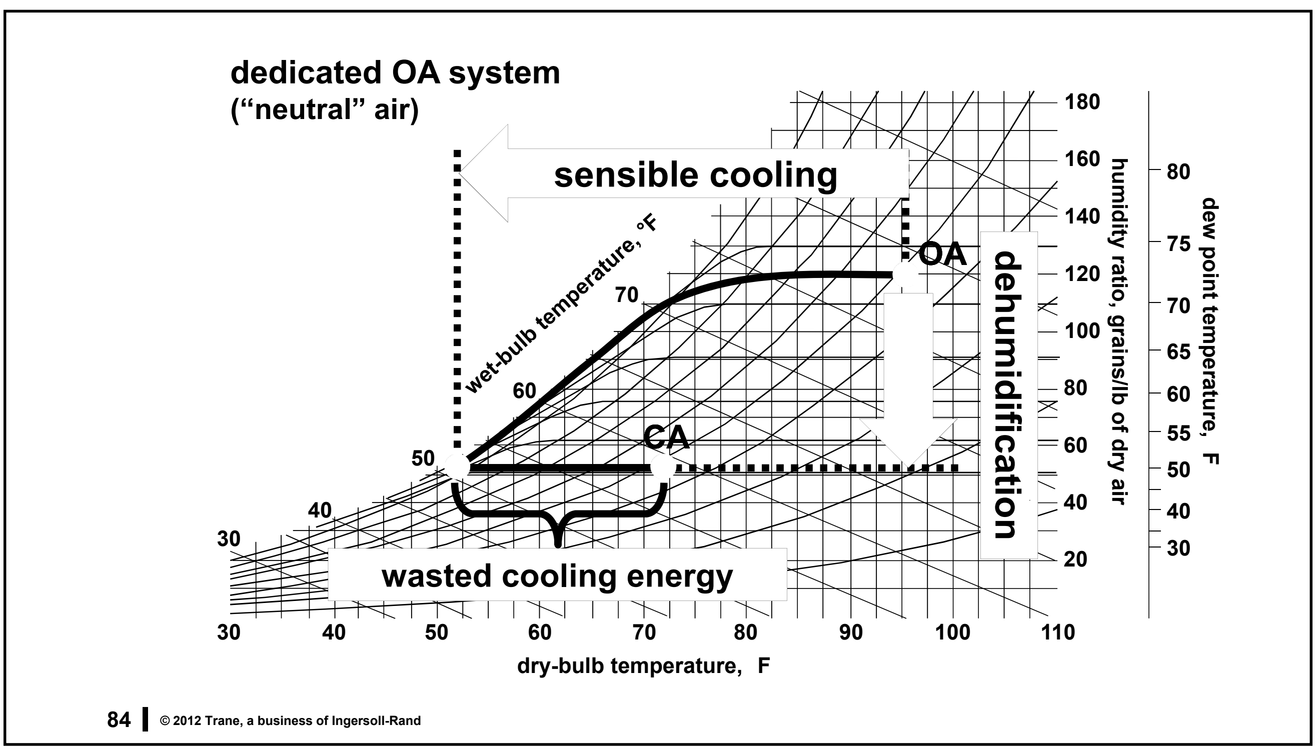
dedicated OA system
("neutral" air)
sensible cooling
wet-bulb temperature, °F
OA
CA
dehumidification
wasted cooling energy
humidity ratio, grains/lb of dry air
dew point temperature, F
dry-bulb temperature, F
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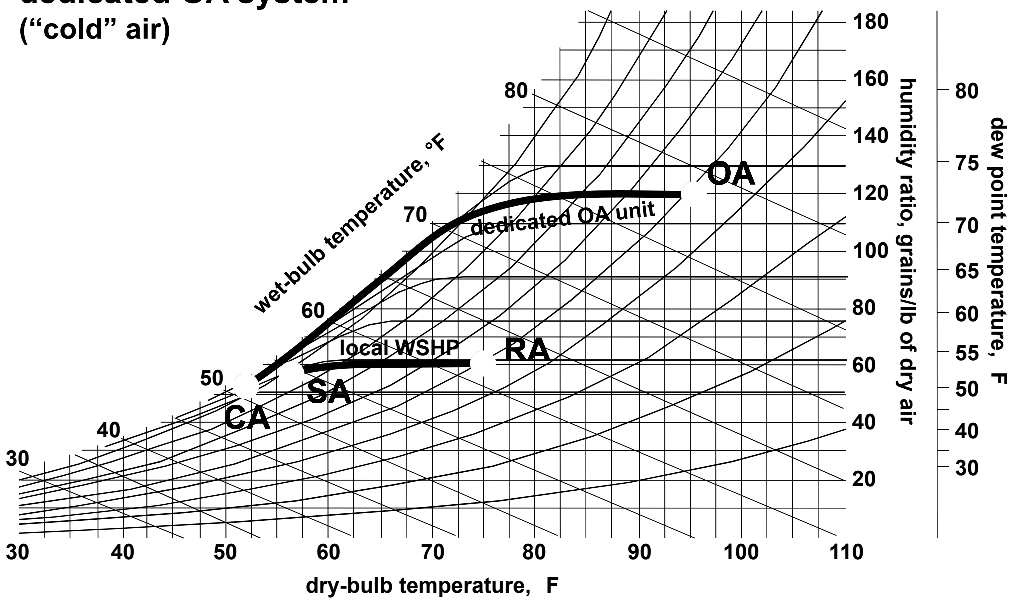
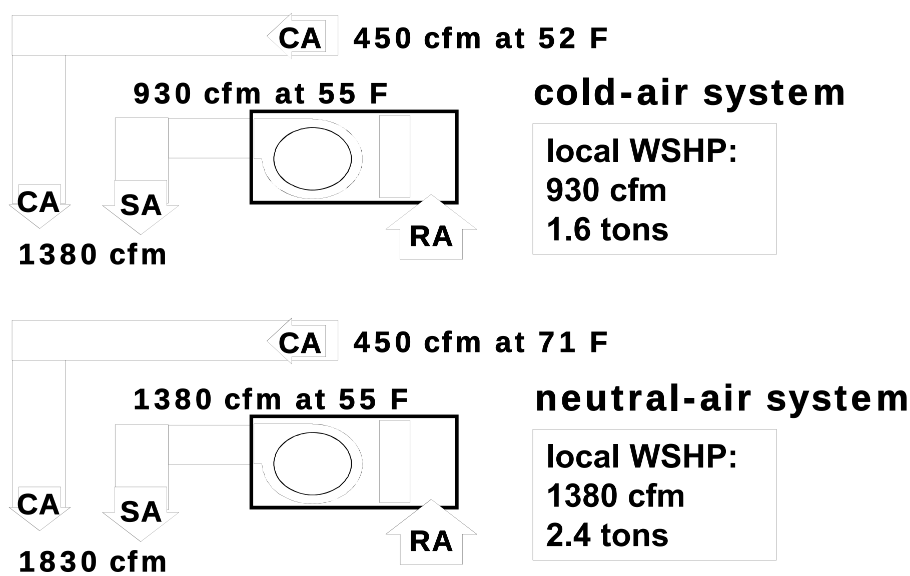
dedicated OA system
(“cold” air)



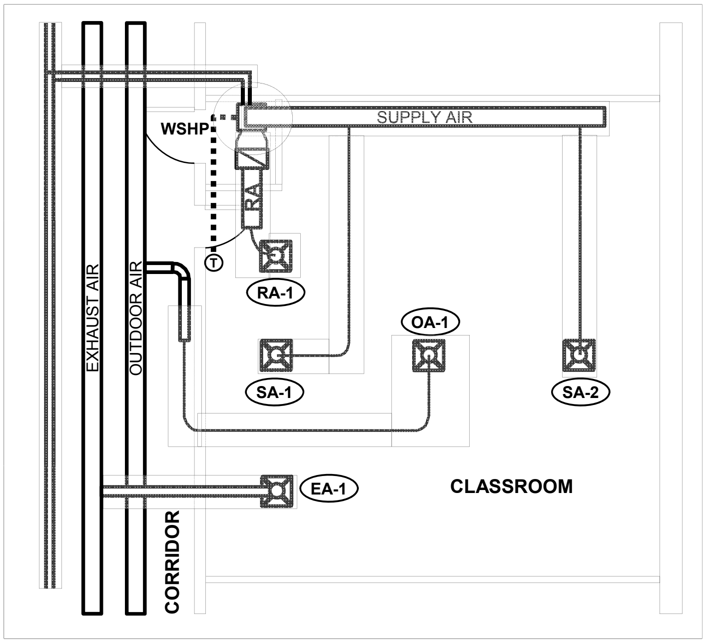


Cold versus Neutral

- Less overall cooling capacity
  - Sensible cooling provided by cold conditioned OA reduces required cooling capacity of local WSHPs
  - Cooling (dehumidification) capacity of the dedicated OA unit is the same in either case
- Less overall cooling energy
  - Sensible cooling provided by cold conditioned OA reduces cooling required from local WSHPs

Cold versus Neutral

- Less overall fan energy, if OA is delivered cold directly to spaces
  - Cold conditioned OA removes some of the space sensible cooling load, which reduces the airflow needed from local WSHPs
  - Airflow delivered by the dedicated OA unit is the same in either case
  - Opportunity to cycle off (or vary speed of) local fan



Increases installed cost

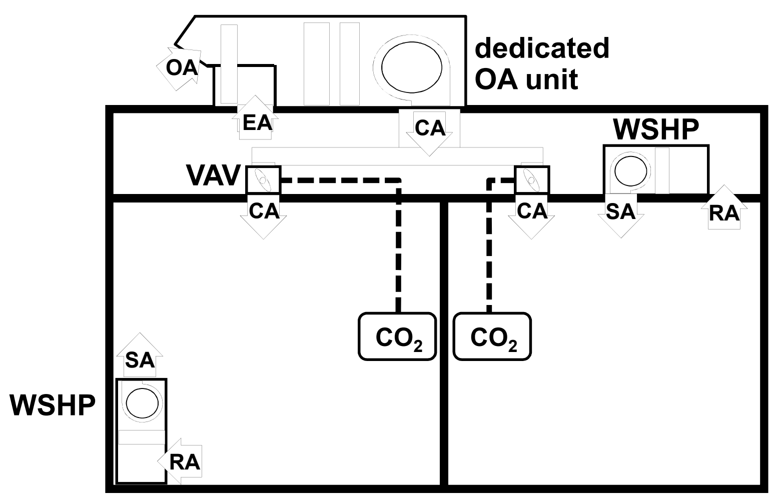
- Additional OA and EA ductwork and diffusers

Reduces installed cost

- Smaller WSHPs (typically)
- Smaller SA and RA ductwork and diffusers
- Smaller water pipes and circulating pumps
- Smaller electrical service

conditioned OA delivered cold, directly to each zone

What About Overcooling a Zone?



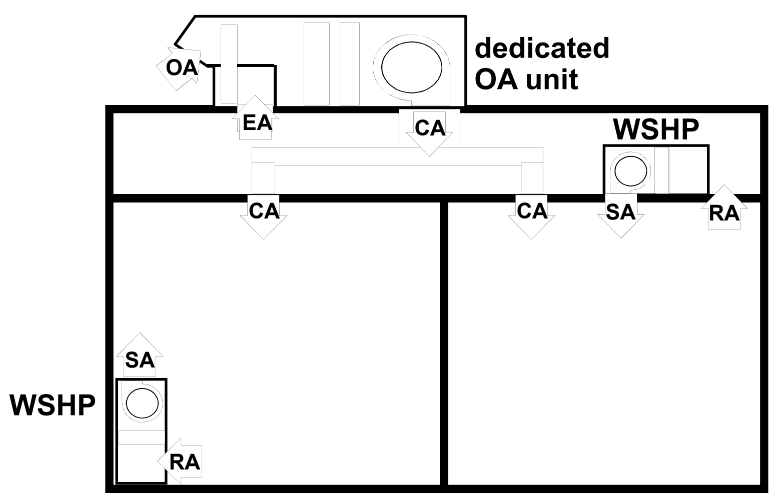
ASHRAE 90.1-2010

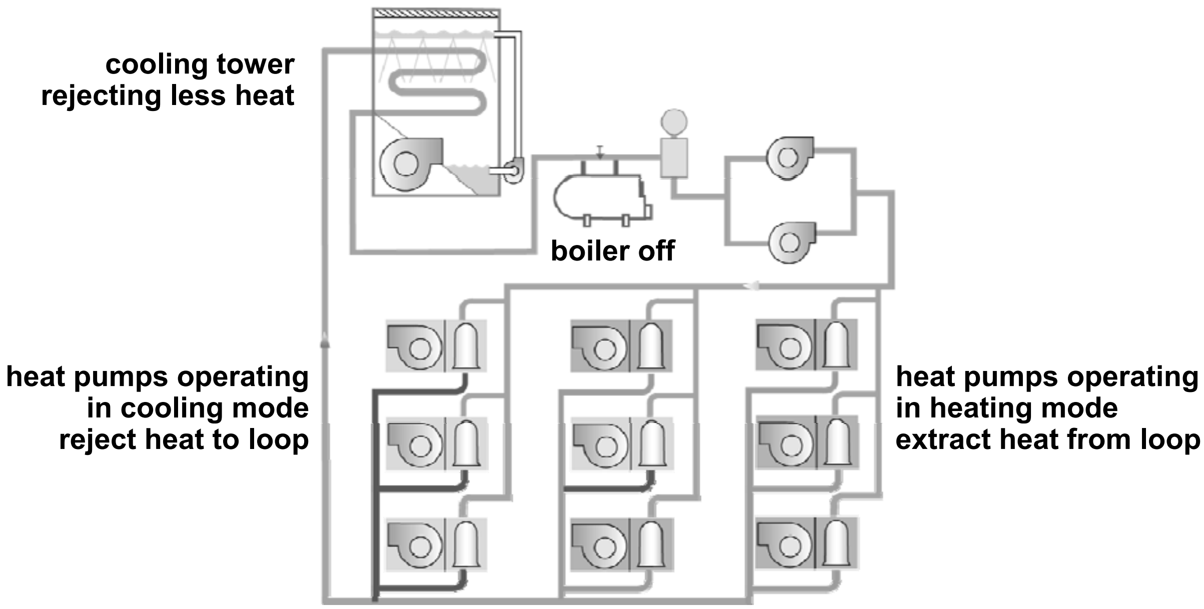
Demand-Controlled Ventilation (DCV)
Section 6.4.3.9

- Required at zone level if:
  - Larger than 500 ft²
  - Design occupant density greater than 40 people per 1,000 ft²
  - Served by systems with one or more of the following
    - An air-side economizer
    - Automatic modulating control of the outdoor air damper
    - A design outdoor airflow greater than 3,000 cfm

conditioned OA delivered cold, directly to each zone

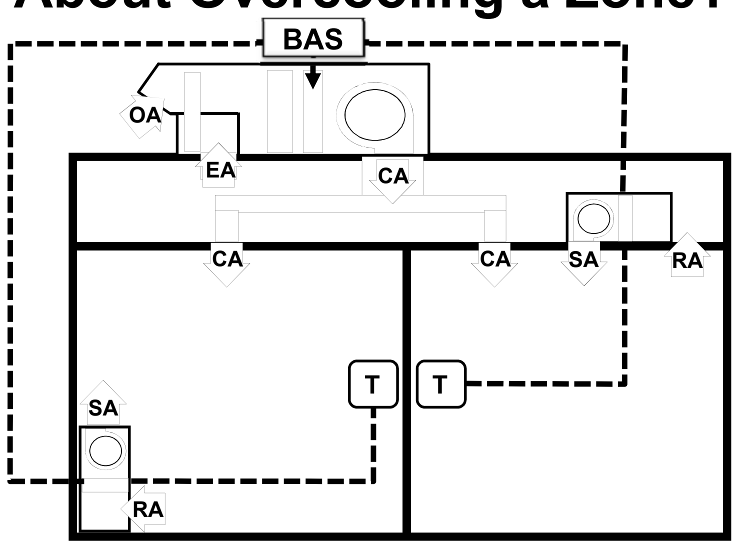
What About Overcooling a Zone?





conditioned OA delivered cold, directly to each zone

What About Overcooling a Zone?



conditioned OA delivered cold, directly to each zone

What About Overcooling a Zone?

- To avoid overcooling at part-load conditions:
  - Implement demand-controlled ventilation to reduce outdoor airflow as population changes
  - Allow the WSHP to operate in heating mode, likely improves overall system efficiency
  - Reheat dehumidified air in dedicated OA unit, but only when necessary (consider using recovery energy)

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Dedicated OA Equipment Types

- Packaged, air-cooled DX unit
- Packaged, water-cooled heat pump (connected to loop)
- AHU served by a standalone chiller
- AHU served by a water-to-water heat pump (connected to loop)

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Packaged, Air-Cooled DX Unit

Advantages
- Low installed cost
- Simple to design & install
- Can operate without water distribution loop operating

Drawbacks
- Less flexibility, fewer options
- Lower efficiency
- Typically installed outside

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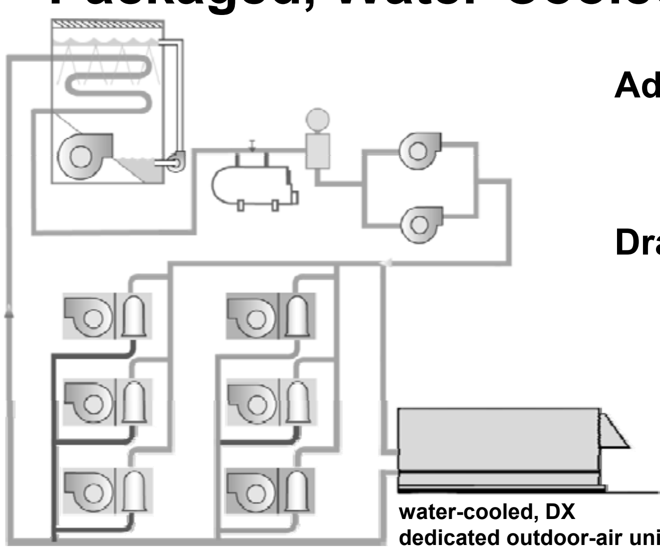
Packaged, Water-Cooled Heat Pump



Advantages
- Efficiency
- Simple to install

Drawbacks
- Selection impacted by other system components
- Freeze protection
- Less flexibility, fewer options

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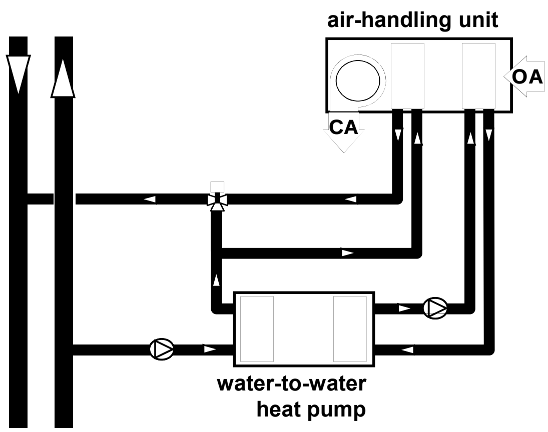
AHU and Water-to-Water Heat Pump



Advantages

- Efficiency
- Equipment can be distributed throughout building
- Lots of flexibility and options

Drawbacks

- Selection impacted by other system components
- Freeze protection

ASHRAE 90.1-2010

Energy Recovery

Section 6.5.6.1 CZ & % OA dependent

100% OA Units
A = Humid
B = Dry
C = Marine

Climate Zone (CZ)	**% *Outdoor air* at full design airflow rate**					
	≥ 30% and < 40%	≥ 40% and < 50%	≥ 50% and < 60%	≥ 60% and < 70%	≥ 70% and < 80%	≥ 80%
	Design Supply Fan airflow rate (cfm)					
3B, 3C, 4B, 4C, 5B	NR	NR	NR	NR	≥5000	≥5000
1B, 2B, 5C	NR	NR	≥26000	≥12000	≥5000	≥4000
6B	≥11000	≥5500	≥4500	≥3500	≥2500	≥1500
1A, 2A, 3A, 4A, 5A, 6A	≥5500	≥4500	≥3500	≥2000	≥1000	>0
7, 8	≥2500	≥1000	>0	>0	>0	>0

Agenda

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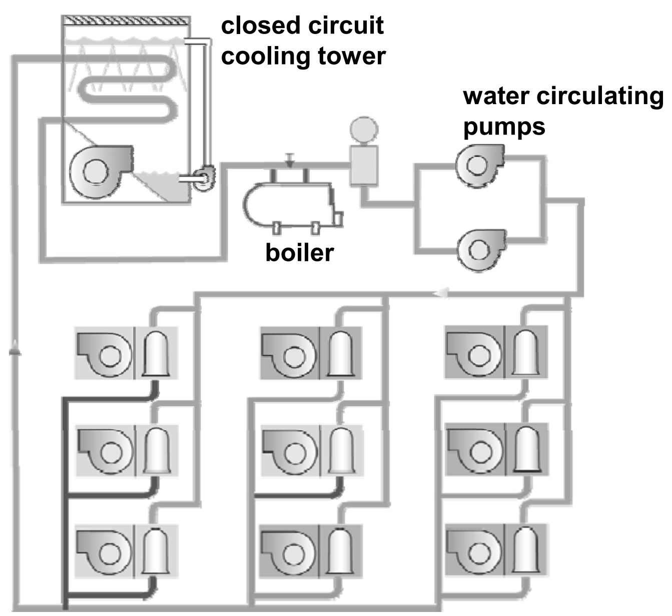
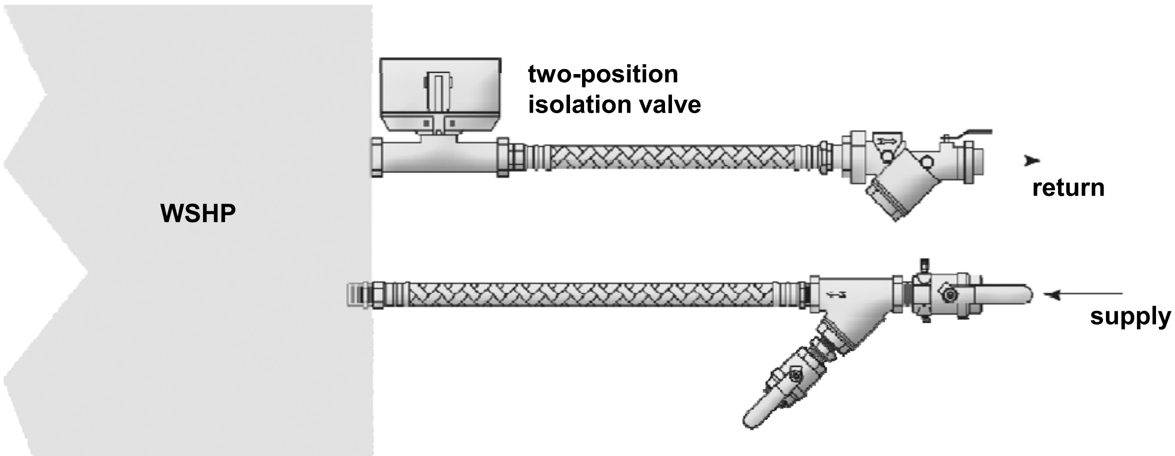
- Value of heat pumps
- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed water-source heat pump systems
  - Latest technologies being used in heat pumps
  - Dedicated outdoor-air system for ventilation
  - Water distribution loop design and control
  - Ground-source systems
- Summary

Water Distribution Loop



Isolation Valve for Variable Flow



ASHRAE 90.1-2010

Distribution Loop Design and Control
Section 6.5.6.1

- Automatic valve to shut off water flow when compressor is off (mandatory)
  - This makes all water source heat pumps variable flow – even if the water pumps are constant speed

ASHRAE 90.1-2010

Distribution Loop Design and Control

Section 6.5.4.1

- Pumps > 5 hp must have
  - Pump motor demand of no more than 30% at 50% of design water flow
    - Often met using variable speed drives

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ASHRAE 90.1-2010

condenser loop pumping

Variable Flow (isolation valve requirement)

- About how many tons is 5 hp?
  - Assumptions
    - 3 gpm/ton
    - 50 feet of pressure drop
    - 75% pump efficiency
  - hp/ton =
    [(3 gpm/ton) x 50 ft] / (3960 x 0.75) = 0.05 hp/ton
  - Tons = 5 hp / 0.05 hp/ton = 99 tons

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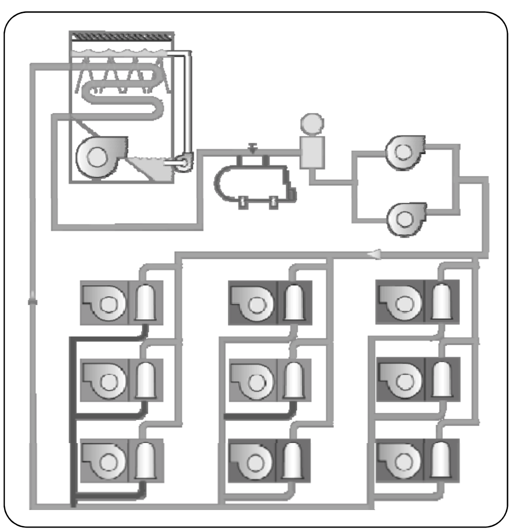
ASHRAE 90.1-2010

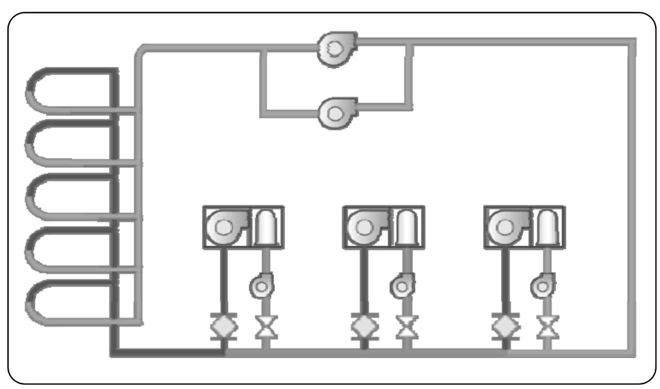
Distribution Loop Control

Sections 6.4.3.1.2 and 6.5.2.2.3

- 20ºF deadband between heat rejection and addition
  - Exception: Optimal loop temperature control
- Climate Zones 3-8, Bypass:
  - "All but minimal flow" around closed-circuit tower, or
  - All water around open-circuit tower (or heat exchanger)



centralized pumping



distributed pumping

Advantages of Centralized Pumping

- Fewer pumps to install and fewer connections, which reduces risk of water leaks
- Centralized pump maintenance, and fewer strainers to clean
- Larger pumps can typically be selected to better match the application, which can result in higher pump efficiency

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Advantages of Distributed Pumping

- Eliminates need to install an isolation valve at each heat pump (check valve may be required instead)
- Often eliminates need for pump capacity control to achieve variable flow
- If a pump fails, it only impacts one heat pump, rather than entire system

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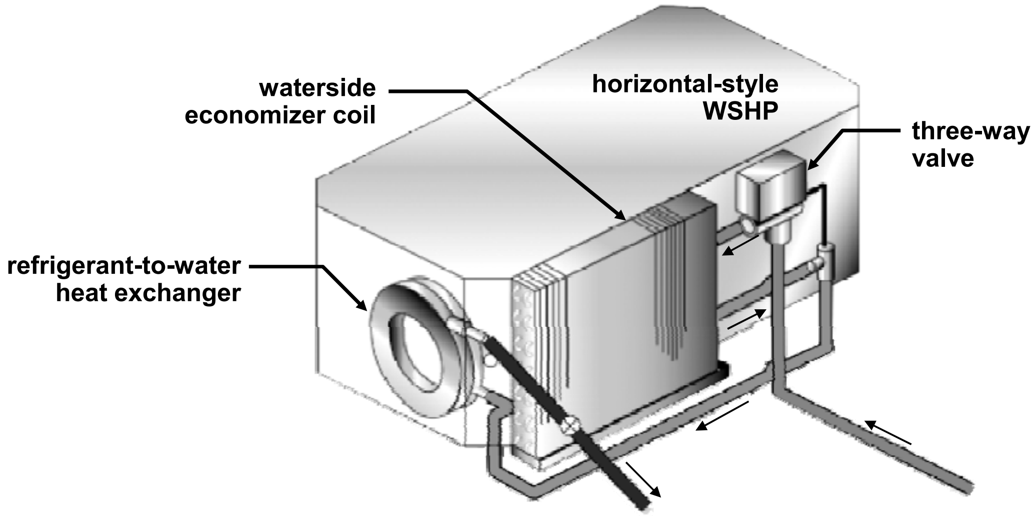
Waterside Economizer



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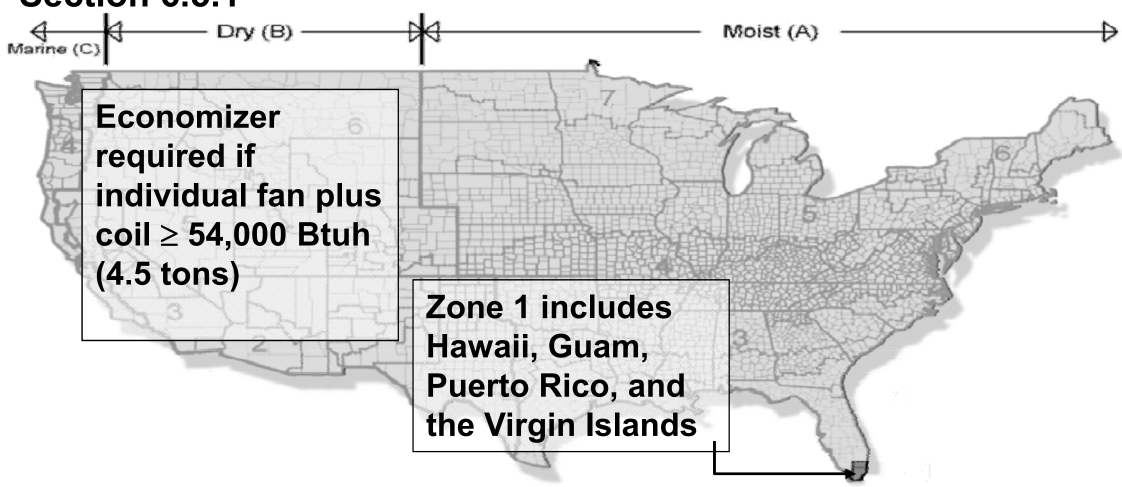
Economizers
Section 6.5.1



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90.1-2010 User's Manual Example 6-II

- *"…all but large (heat pumps) are exempted by Exception a and Table 6.5.1A. For this example…heat pumps below 4 ½ tons (54,000 Btu/h or 16 kW) would not have to have economizers"*

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ASHRAE 90.1-2010

Economizer for Heat Pumps 4.5 Tons and Larger

- Airside – very difficult for WSHP system with dedicated outdoor air unit
  - "Air economizers shall …provide up to 100% of the design supply air quantity as *outdoor air* for cooling"
  - OA ducting is generally sized for ventilation
- Options
  - Eliminate economizer by installing higher efficiency heat pump (Section 6.3.2)
  - Water economizer
  - Energy Cost Budget method (computer simulation)

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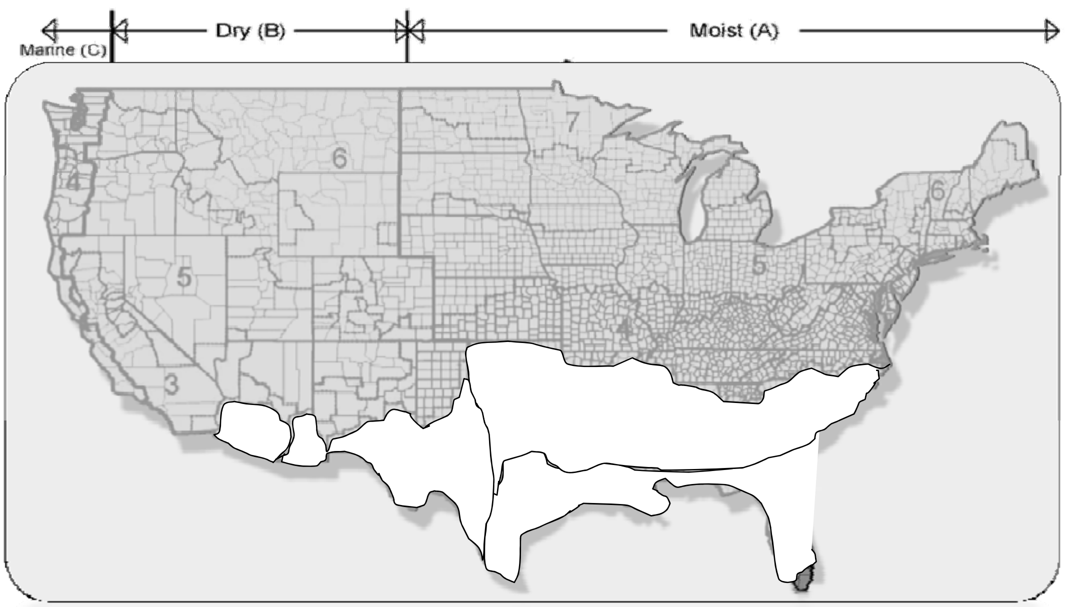
ASHRAE 90.1-2010

Efficiency Improvement Required to Eliminate an Economizer – Table 6.3.2

Climate Zone	Efficiency Improvement	5 ton WSHP EER Required to eliminate the economizer (Base is 12.0)
2A	17%	14.0
2B	21%	14.5
3A	27%	15.2
3B	32%	15.8
3C	65%	19.8
4A	42%	17.0
4B	49%	17.9
4C	64%	19.7
5A	49%	17.9
5B	59%	19.1
5C	74%	20.9
6A	56%	18.7
6B	65%	19.8
7	72%	20.6
8	77%	21.2

Economizer Elimination

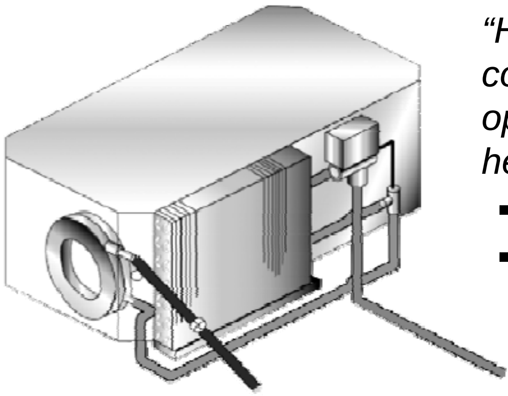
ASHRAE 90.1-2010



EER
14.0
14.5
15.2
15.8

ASHRAE 90.1-2010

Water Economizer
Section 6.5.1.4



- Economizer heating system impact

  "HVAC system design and economizer controls shall be such that economizer operation does not increase the building heating energy during normal operation."
  - Many multi-zone systems do not comply
  - How about water source heat pump systems?

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ASHRAE 90.1-2010

Water Economizer
90.1 User's Manual Example 6-LL

- States WSHP does not comply
- Calculations seemed to show example is incorrect
- Official interpretation has been requested
  - Answer has not been received yet
  - Once received, the interpretation will be communicated

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Energy Cost Budget (ECB) Method

- All mandatory requirements (e.g. equipment efficiency) must still be met
- Economizer requirement is prescriptive (not mandatory)
- It may be traded off using Section 11 computer simulation

Agenda

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- Summary

System Configurations

- Ground-source (closed loop)
  - Hybrid
- Ground-water (wells)
- Surface-water (ponds)

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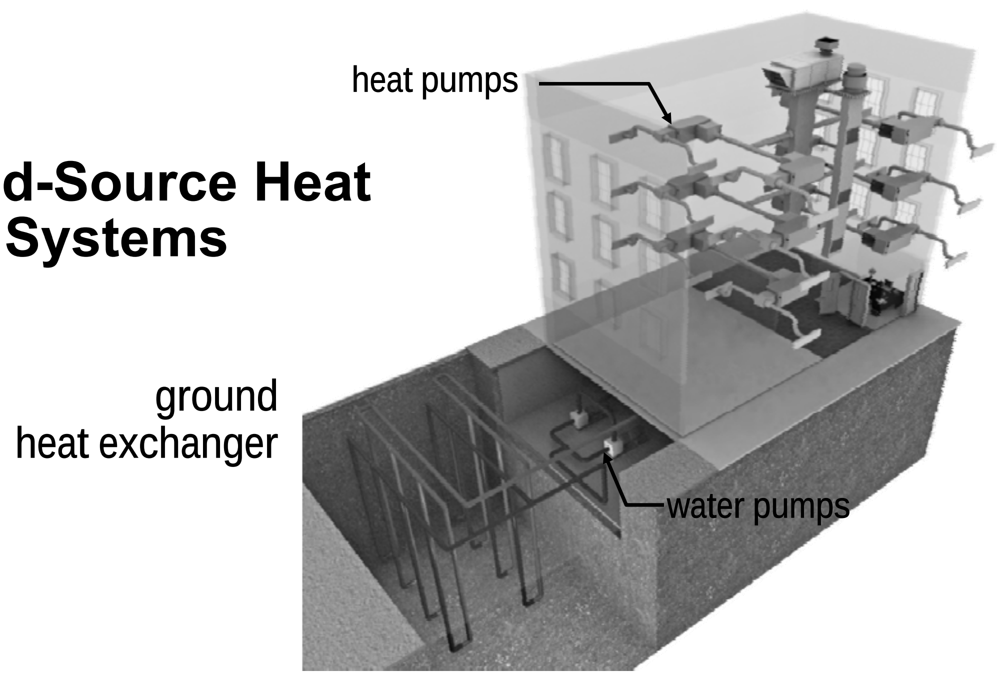
Ground-Source Heat Pump Systems



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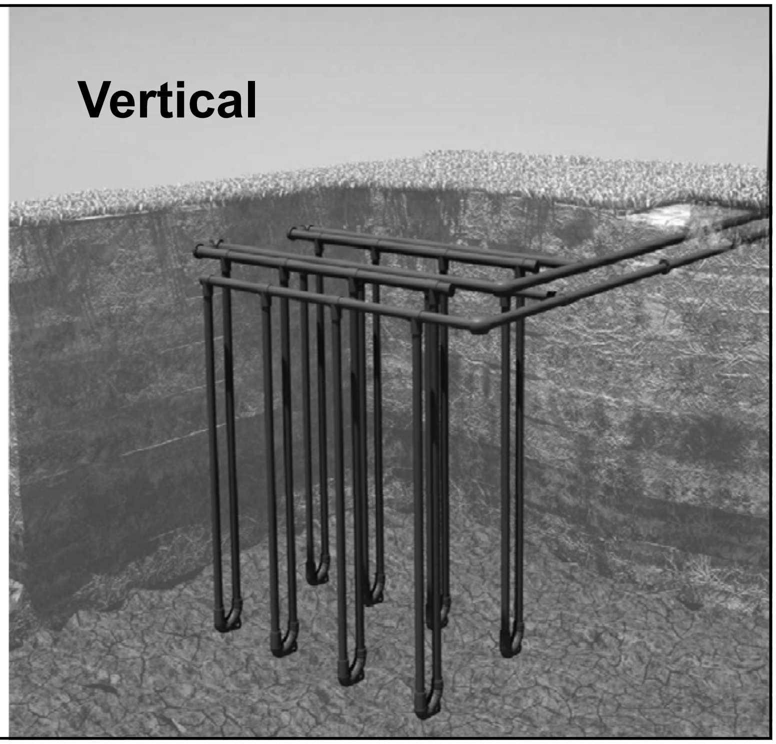
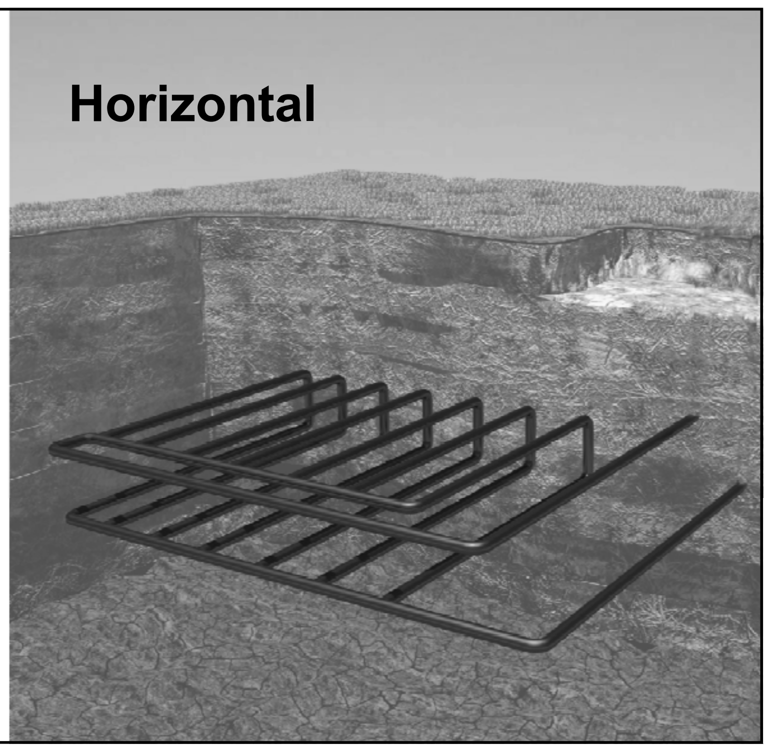
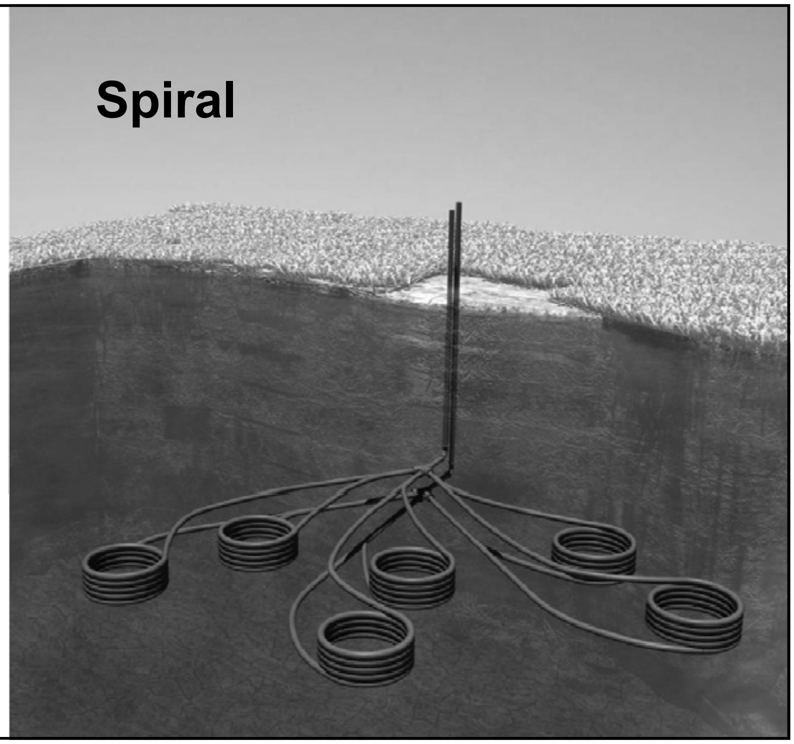
Ground Source Loop Types



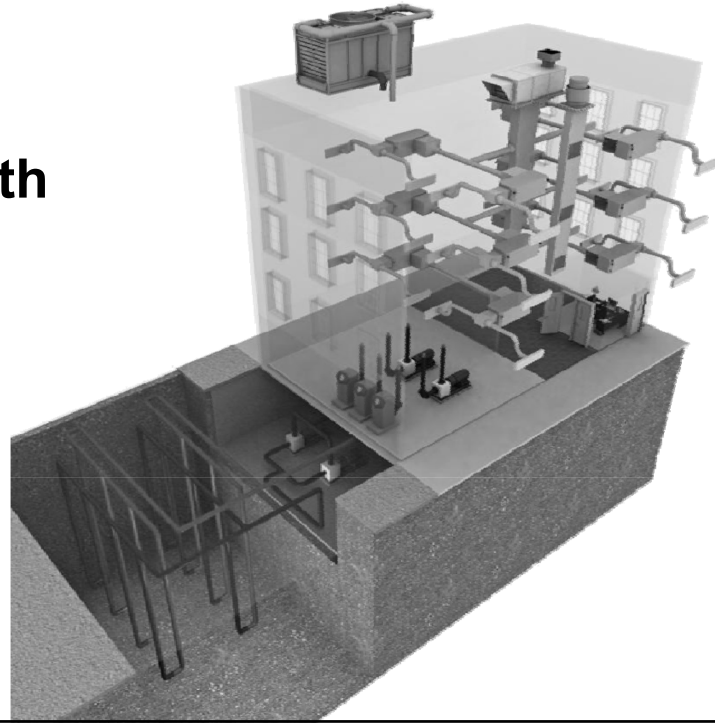
Ground Source Loop Types



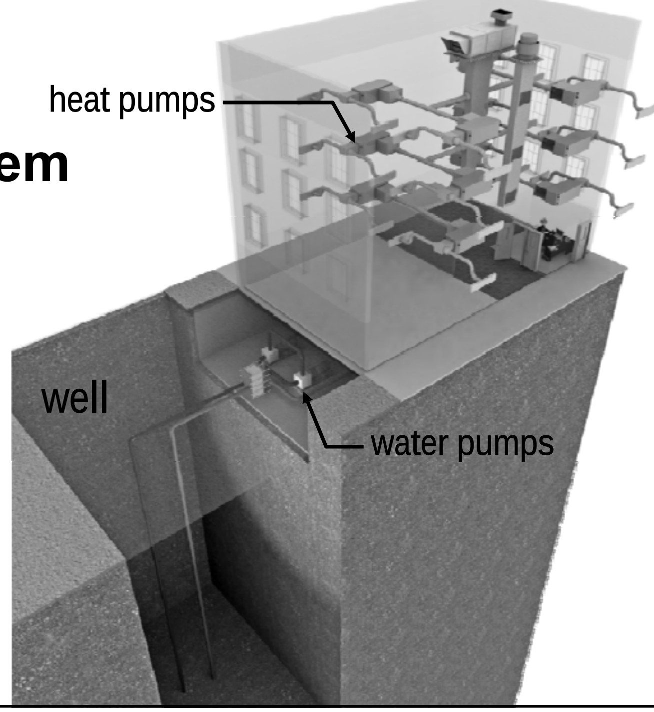
Ground Source Loop Types



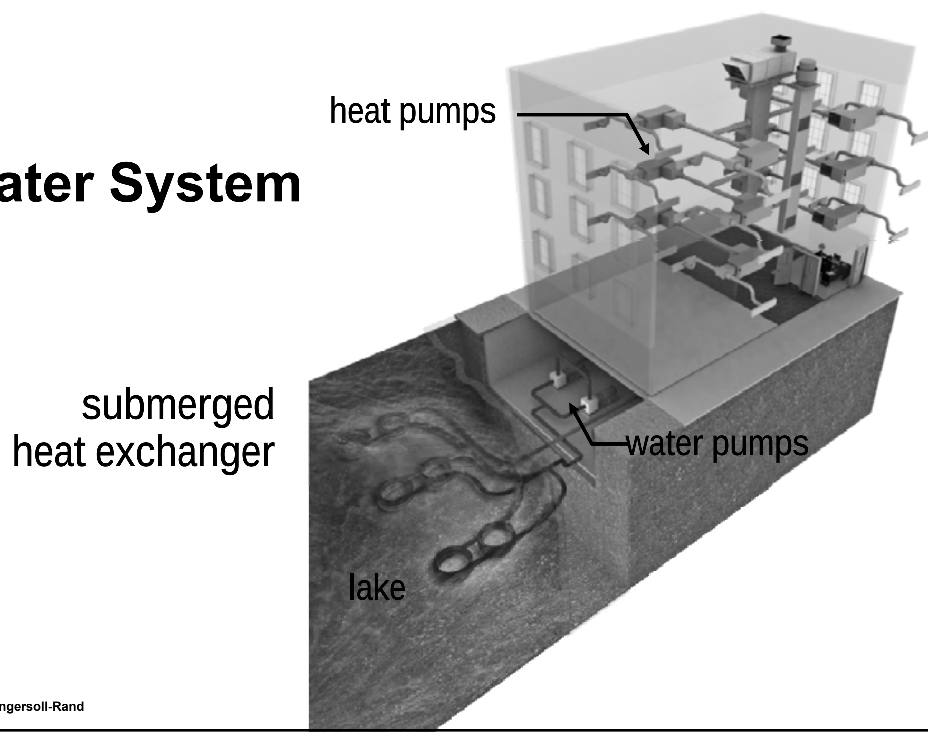
Hybrid System with Supplemental Heating or Heat Rejection



Ground-Water System (Well)



Surface-Water System



Agenda

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- Value of heat pumps
- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed water-source heat pump systems
  - Latest technologies being used in heat pumps
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  - Ground-source systems
- Summary

energy-saving strategies for WSHP and GSHP systems
Summary

- Distributed vs. centralized heat pump systems
- Energy-saving strategies for distributed WSHP systems
  - Investigate latest technologies used in heat pumps (variable-speed compressors, ECMs on fans)
  - Design dedicated outdoor-air systems to deliver conditioned OA directly to the zone at a cold temperature, when possible
  - Design water distribution loop for variable flow
  - Consider ground-source systems, when possible
- ASHRAE 90.1 requirements specific to WSHP/GSHP systems

references for this broadcast

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