Design Evolution for HVAC Systems
What We Know

- Ductless Heat Pumps
  - Reliable
  - Efficient
  - Energy saving
  - Can be aesthetically pleasing
  - Give homeowners high levels of satisfaction

Having my DHP installed was as easy as falling off a log!
DHP Cold Weather Performance

This looks scary, let's focus first on the scale on the left and legend at the bottom.
How Hot Would You Like Your Supply Air?

Warm air produced at low outdoor air temps – we’ll take it!
What We Have Learned

• **Important Considerations**
  - Sizing and selection
  - Placement
  - Homeowner education
  - Sizing and selection
  - There are BIG differences between models with same nominal size

Heating cooling loads must be calculated

Detailed capacity must be known
The Present and Future of New Construction

- Stringent energy codes and legislated code cycles following in the wake of above-code programs
- Growing market demand for more energy-efficient and sustainable homes
- Heating and cooling loads dropping sharply in new homes *(Yes, I said cooling)*
- Existing technology limitations are giving way to highly efficient emerging technologies and practices
The Nature of Equipment Selection

• The goal of sizing HVAC equipment is to find the *best match* between the house and the equipment.

• Optimal size is the best match, or balance, between the load of the house and the capacity of the HVAC equipment.

• Modern, efficient homes are creating a dichotomy in which the loads don’t match well with traditional, ducted equipment.
Heating Load Inputs: It’s Pretty Simple

This is the old Greek formula: $UA\Delta T$

Limited range in new construction

Almost all new homes are best matched to 40k systems

Duct Multiplier

ACH

Square Footage and R-U Values

Selection Process

5 choices for gas

40K 60K 80K 100K 120K

It’s an educated guess
Heating Load Inputs: It’s Pretty Simple

This is the old Greek formula: $UA \Delta T$

Limited range in new construction

It’s an educated guess

This range is better, but still not good for lower load homes

A few more choices for HPs

24K 30K 36K 42K 48K 60K
NEEA Performance Home Pilot

- ~40 pilot homes across two phases, distributed across the region
- Full verification and commissioning
- 13 months of continuous metering data with extensive metering array
  - Environmentals (temperature, RH, VOCs)
  - HRV performance
  - Hot water consumption and performance
  - Heating/cooling systems performance
- Detailed cost data and interviews identify challenges and barriers for builders
Heat Loss: It’s All About R-values

House size does matter, but not nearly as much as whether or not it’s insulated.
Loads Getting Lower

• What kind of loads are we looking at for new above-code homes?
  • <8,000 – 36,000 BTU/hr. design heat load
    • Upper end of range characterized by large homes in cold climates
  • Homes in NEEA’s pilot range from <8,000 to 18,000 BTU/hr.
Equipment Selection: Where We’re Headed

This is the old Greek formula: \( UA \Delta T \)

Limited range in new construction

It’s an educated guess

Lowering UA, Removing duct multiplier, lowering ACH

24K 30K 36K 42K 48K 60K

Need more appropriate options

Selection Process

Square Footage and R-U Values

Duct Multiplier

ACH
Great! Simpler inputs into load calcs, but DARN, now we need new selections of heat pump capacities.
DHP: Point-Source

- Considerations
  - How to heat remote rooms
    - Backup heat in bedrooms may be a good idea
  - Home geometry and floor plan influence heat distribution
Central Questions About the Lack of Central Heating

• First Question:
  • Will humans be thermally comfortable in the absence of a central heating system?

• Second Question:
  • Are humans thermally comfortable in homes with central heat?
If Central Systems are Better, Please Explain the Following....
Heat delivery looks pretty awesome up to 15 feet and still useful up to 30 feet.
House has low UA. Very tight. 12K ductless heat pump and low-efficiency HRV. About 900 kWh/year for space heat.
Sizing Variable Capacity Units

- When sizing variable capacity heat pumps, the *minimum* capacity is nearly as important as the *maximum* capacity
  - When the house load drops below *minimum* capacity, performance drops from severe short-cycling
  - A look at the max/min capacity at 47° F can be an indicator of how the unit will perform in these conditions
  - We call this the unit’s “turn-down ratio”. It varies greatly by model.
- Look for a unit with at least a 4:1 ratio between its maximum and minimum capacity at 47° F
If this house had part load needs of around 3,000 Btu/hr for much of the year, which of these systems would meet that without short cycling?
Comparison of Nominal 2-ton DHP Models

Same question, would a larger system solve that problem?
Check out the turn down ratios at 47°F, 30°F, and 15°F. It’s over 4:1 at 47°F.
Sizing Variable Capacity Units

Don’t panic, look at outdoor temps (around 50°C). Look at power usage in gray and green spikes. Lots of cycling, 400 watts when on.
Sizing Variable Capacity Units

New control algorithms via an updated control board. See the peak watts and length of runs. Far less cycling and only using 15-20 watts.
Boise DHP – Low Output Sizing

Check out total hours where this system will short cycle. With a 2.5:1 turndown, it's 3300 hours. It's cut in half for a 6:1 turndown ratio!
Seattle DHP – Low Output Sizing

In Seattle, short cycling total hours can be cut again by almost half by upgrading a 2.5:1 ratio to 6:1.

Design load: 15 K@27F; Nom size 18K

7 K low output

3 K low output

4375 hrs

2810 hrs

In Seattle, short cycling total hours can be cut again by almost half by upgrading a 2.5:1 ratio to 6:1.
DHP System Design

- Use an appropriate number of indoor heads
  - In most homes, one head per floor is enough:
  - An optimal system often consists of:
    - 1 DHP in the main living area, +1 smaller unit in the master suite
    - 1 DHP in the main living area, +1 ducted mini-split serving bedrooms
    - 1 DHP in the main living area, plus small electric resistance heaters in the bedrooms
    - If using ER heaters, use smaller units (750w), control with digital wall T-stats
DHP System Design

• Orient heads to take advantage of throw and mixing
  • Place in largest, most open areas
  • Orient to blow down central hallways
• In rooms with high ceilings, place DHP ≤ 8’ off the floor to minimize stratification effects
• Don’t leave units set in “Auto” mode
Home Geometry and DHP Performance

- Master bedroom in single-story home
- Five surfaces exposed to exterior
- 65 sq. ft. of glazing (26 percent of floor area)
- Design heat load around 2,700 BTU/hr. for this room alone
POP QUIZ

Q: How much 70° F air must you deliver to keep this room comfortable?
A: Too much.

Avoid creating thermal peninsulas unless you have an active conditioning strategy to meet the load. Room-by-room loads *still* matter.
Using Auxiliary Distribution

- Room-by-room loads matter and must be met
- In remote rooms, the heat gained through internal surfaces and delivered via distribution must outweigh the heat loss
- Delivering air at or near room temperature may not be enough to keep the space conditioned
- Supplemental backup heat doesn’t transform a low-load home into an energy hog
It’s Not a Ductless Purity Test. It’s OK to Transfer Air by Other Means

SPECIFICATION

Volts: 120
Hertz: 60
Amps: 0.50 maximum
Watts: 25
CFM: 75
RPM: 1,800

Air has a low heat capacity.

Example 75°F warm room

70°F cool room

100 CFM

1.08 X 100 CFM X 5°F = 540/BTUS/hr.
Using Auxiliary Distribution

- So, can I use an HRV or transfer fan to heat rooms?
  - What room-to-room temp difference are you okay with?
  - Without a high-efficiency HRV, you will be cooling during the heating season
  - Ventilation air typically can’t meet room loads alone
  - They only *recovered* and/or move heat. They doesn’t make heat.
Ducted Mini-Split Design

- Select equipment with at least a 4:1 ratio between its maximum capacity and minimum capacity at 47f
- Place and orient indoor heads to allow for future maintenance/service
  - Closets and dropped ceiling are good options
  - Locate ducts and equipment in conditioned space
Ducted Mini-Split Design

- Good duct design is key
  - Adhere to manufacturer's guidance – some specify ducting limitations for their units, others just provide static pressures for the fan
  - Do a real duct design – follow Manual D guidance or use the “Easy Ducts” process
  - Design and install to minimize restriction
  - Use grilles that will throw and mix well
- Use with a wall-mounted T-stat
  - Locate T-stat appropriately
  - Make sure controls reflect the necessary settings
Ducted Mini-Split Design

Shoemaker 201 10x4" (5' throw), center fins directed toward wall.

6" duct, 27 cfm.
Ducted Mini-Split Design

“FUNCTION 42 and Other Settings”

- Setting the unit to sense temperature at the T-stat:
  - Function 42 has to be set to “01” and the t-stat icon has to appear on the screen
  - “High Insulation” setting needs to be activated
Using an HRV to Ventilate and Distribute into Bedrooms

- HRV Ratings: Which Three-Letter Acronym Matters?

**Sensible Recovery Efficiency (SRE):**
- The efficiency including the energy use of the system.
- This value is used principally to predict and compare energy performance.

**Apparent Sensible Effectiveness (ASE):**
- The efficiency not including the electrical energy used by the system.
- This value is useful principally to predict final delivered air temperature.

We recommend high-ASE HRVs as it relates to delivered air temperature. People WILL shut off HRVs that blow cold air on them!
About that ASE…

Use HRVs with high ASEs (over 85%, ideally) to deliver proper air temp.
Conclusions

- Net Zero, low load, above code homes, are no longer a niche market in the Northwest
- Low loads don’t make the home “comfort invincible”
- The best system in the world does nothing if it isn’t used properly—
  - Homeowners must be educated on the operation of systems in their homes
Advice to Homeowners

- Leave interior doors open
- Clean filters
- Check drain pains
- NEVER use auto mode
- Don’t make big changes in the set points
Thank you

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