Not Your Parent’s or Your Grandparent’s Heat Pump

From Load-Building Reverse Air Conditioners to Load-Reducing Heat Pumps
The Basics

- **COP** = Coefficient of Performance
  - Heating or cooling output/energy in (at given outdoor temperature)
- **HSPF** = Heating System Performance Factor = COP x 3.413.
  - Note HSPF also includes defrost and cycling losses
    - Avg COP of 2 x 3.413 = HSPF 6.8
    - Avg COP of 2.5 x 3.413 = HSPF 8.5
- Non-techies: the higher the number, the better
Bruce’s Introduction to Heat Pumps
The 1980’s
The Growth of Electric Heat

- Nation saw a 400% increase in the use of electric heat between 1950 and 1970

- 99.4% of new single-family homes in Seattle City Light’s territory were heated electrically by 1958
Hail the Reversing Valve

- So named because it “reverses the normal” flow of the refrigerant in an air conditioner
- Heat pumps are still called ‘reverse air conditioners’ in parts of the world
Live Better Electrically (LBL)

- LBL was launched in 1956
- A very successful consumer facing promotion of all things electric
  - Over 600 manufacturers, including General Electric and Westinghouse
  - Over 900 utilities
  - Coal companies, railroads and insulation companies
Promote Electric Heating!

- Tactics like the “Live Better Electrically Gold Medallion Home” promoted the use of electric heat
Newest guide for home buyers—the Live Better Electrically MEDALLION

This new Medallion assures you a home has been inspected by the local electric utility...meets modern standards for wiring, appliances and lighting. Look for the Medallion. It means a wonderful new way of life for you and your family!

What Sterling is to silver...that's what this Medallion is to a new home! It's the new national symbol of the finest in electrical living. Let these three top TV stars, speaking here for the electrical industry, tell how you save trouble, time, and money by choosing a home that wears the Live Better Electrically Medallion.

BETTY: In a Medallion home, you start right off with a modern electric range, plus at least 3 additional major appliances, maybe more. They're installed, ready to go to work the day you move in! Appliances are easier to pay for this way.

RONNIE: The lighting in every Medallion home is specially planned, too. It provides better light for better sight, plus new beauty for your home. You also get full horsepower. This means enough power, in every circuit, switch, and outlet to handle all the appliances you want to use.

FRAN: You'll be glad all your life, you bought a Medallion home. Read below what a few of the thousands of new Medallion home owners think of them. Then go see the Medallion homes in your neighborhood. Your electric utility will tell you where they are.

New Ideas for Better Living

The new Medallion is backed up by home builders, electric utilities, and electrical manufacturers (Frigidaire, General Electric, Hotpoint, Kelvinator, Thermador, Westinghouse, Whirlpool, and others). This year, utilities will award Medallions to 50,000 new homes—in every style and price range across the country. You'll see lots of new ideas in the Medallion homes on display now!
ELECTRIC HEATING. Many Medallion homes feature electric heating, too. These are awarded a special Gold Medallion. The all-electric heat pump, shown here in the home of Mr. and Mrs. William Isaac of Beverly Hills, California, provides year-round comfort from a single unit which automatically heats or cools as the weather requires.
Promotional Materials

- Save with a Heat Pump
- Reddy Kilowatt: Pump It Up!
- Reddy Kilowatt in the Heat Pump & the Mean Old Furnace
Things were going well

February 1959: “…consulting engineers and residential builders appear to be among the strongest champions of this combination heating and cooling equipment.” Major electric utilities also recognized “the load-leveling potential of widespread heat pump use and are actively promoting this highly efficient method of year-round air conditioning…”

But then…

June 1960: Recent designs and unfortunate installation and service practices are combining to cause trouble with some heat pumps — poor performance on heating at best, burned-out compressors at worst — according to a contractor-manufacturer who says he’s called ‘the guinea pig of the heat pump.’”
## Historic Heat Pump Performance

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Characteristic</th>
<th>Forced-Air Furnace</th>
<th>Zonal</th>
<th>Heat Pump</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of Homes</td>
<td>55</td>
<td>847</td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>Percent</td>
<td>5%</td>
<td>83%</td>
<td>12%</td>
</tr>
<tr>
<td></td>
<td>Average Size (sq.ft.)</td>
<td>2301</td>
<td>1789</td>
<td>2503</td>
</tr>
<tr>
<td></td>
<td>Average UA (Btu/F)</td>
<td>488</td>
<td>378</td>
<td>578</td>
</tr>
<tr>
<td></td>
<td>Average UA/sq.ft. (Btu/F)</td>
<td>0.212</td>
<td>0.211</td>
<td>0.231</td>
</tr>
<tr>
<td></td>
<td>Average Total Use (kWh/yr)</td>
<td>21,294</td>
<td>17,192</td>
<td>25,747</td>
</tr>
<tr>
<td></td>
<td>Average Total Use (kWh/sq.ft./yr)</td>
<td>9.7</td>
<td>11.4</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>Average Heating Use (kWh/yr)</td>
<td>9106</td>
<td>4822</td>
<td>8431</td>
</tr>
<tr>
<td></td>
<td>Average Heating Use (kWh/sq.ft./yr)</td>
<td>4.1</td>
<td>3.1</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Source: Bonneville's Super Good Cents Sub-Metering Project Data Set Through December 1990.
## Summary of Measured Annual Heating Performance

(Second Data Set) 2006-2007 winter

<table>
<thead>
<tr>
<th>Site</th>
<th>COP</th>
<th>“HSPF”</th>
<th>Target HSPF</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bend (410a)</td>
<td>1.4</td>
<td>4.8</td>
<td>9.0</td>
<td>Dropped out of program after 3 months of monitoring</td>
</tr>
<tr>
<td>Boise (410a)</td>
<td>2.2</td>
<td>7.4</td>
<td>8.6</td>
<td>Excessive defrost energy usage corrected late in monitoring period</td>
</tr>
<tr>
<td>Ashton (410a)</td>
<td>1.1</td>
<td>3.6</td>
<td>7.7</td>
<td>System oversized vs. heating load</td>
</tr>
<tr>
<td>Moses Lake (22)</td>
<td>2.7</td>
<td>9.3</td>
<td>9.1</td>
<td>Defective TXV on indoor unit replaced soon after initial installation</td>
</tr>
<tr>
<td>Deer Is (410a)</td>
<td>2.9</td>
<td>10.0</td>
<td>10.9</td>
<td></td>
</tr>
<tr>
<td>Shelton (410a)</td>
<td>2.4</td>
<td>8.2</td>
<td>10.2</td>
<td>Possible measurement problem (air mixing on return side).</td>
</tr>
<tr>
<td>Roseburg (410a)</td>
<td>2.4</td>
<td>8.2</td>
<td>10.3</td>
<td>Same unit as Bend; much better performance. Very limited heating data given system installed in late March.</td>
</tr>
</tbody>
</table>

Sources: Bob Davis / Ecotope, David Robison / Stellar Processes, 2008 ACEEE Summer Meeting
Good COP Bad COP

COP Comparison, Eugene

Temperature Bins, deg F

Heating COP

Sources: Bob Davis / Ecotope, David Robison / Stellar Processes, 2008 ACEEE Summer Meeting
Why Did Performance Suffer?

- Maybe if you build a heat pump as a reverse air conditioner with the goal of building winter load...
- … you’re not worried about cold climate efficiency.
# Heat Pump Developments: 1960-2010

<table>
<thead>
<tr>
<th>Issue</th>
<th>Old School</th>
<th>Sort of New School</th>
<th>New School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strip heat control</td>
<td>None</td>
<td>Lockouts</td>
<td>No</td>
</tr>
<tr>
<td>Defrost</td>
<td>Timed</td>
<td>On demand</td>
<td>Demand no strip heat</td>
</tr>
<tr>
<td>Refrigerant flow</td>
<td>Capillary Tube</td>
<td>Fixed Orifice/TXV</td>
<td>EEV</td>
</tr>
<tr>
<td>Compressor Efficiency</td>
<td>Hermetic/Piston</td>
<td>Scroll</td>
<td>Inverter</td>
</tr>
<tr>
<td>Duct Design</td>
<td>Good</td>
<td>Lousy</td>
<td>No Ducts</td>
</tr>
<tr>
<td>Fan</td>
<td>Belt Driven</td>
<td>Direct Drive/Shaded Pole</td>
<td>ECM <em>(only better with good ducts)</em></td>
</tr>
</tbody>
</table>
Cold Weather Heat Pumps. Many Styles

- Ductless
- Mini Ducted
- Full ducted systems
No Bad COP

COP with different outside air temperatures (pruned data)

Sources: Placeholder for sources if needed.
The Unknowns (Sizing)

- How best to size the systems for maximum efficiency
  - Traditional Around 30F
  - Can we go lower?
  - Can we design for the Winter design temperature (at least West of the Cascades)?

- Is the low output as important as the high output in order to prevent over cycling?
No Bad COP
Old School Sizing

Heat Pump Balance Point Chart

1st plot the heat loss 45,000 BTUs at 9°F

Heat Pump Capacity Ratings

2.5 ton
17°F = 15,000
47°F = 28,400

3 ton
17°F = 21,600
47°F = 34,200

3.5 ton
17°F = 26,200
47°F = 39,000

4 ton
17°F = 29,200
47°F = 47,000

2.5 ton BP = 37
3 ton BP = 33°F
3.5 ton BP = 28
4 ton BP = 25
25VNA024 BALANCE POINT WORK SHEET
(MINIMUM & MAXIMUM HEATING CAPACITIES)

OUTDOOR TEMPERATURE F (°C)

BUILDING HEAT LOSS, UNIT INTEGRATED HEATING CAPACITY, MBTU/H

0.00 5.00 10.00 15.00 20.00 25.00 30.00 35.00

KW

0.00 2.90 5.90 8.80

Minimum Capacities

Maximum Capacities

BASED ON INDOOR ENT. AIR AT 70°F (21.1°C)
The Unknowns (Data Collection)

- Most of the controllers are WI-FI enabled:
  - Can programs use this data for quality control and energy use analysis?
  - Can homeowners be nudged with data to better manage their systems?
The Unknowns (Standby loses)

- What are they?
  - What is the energy use and logic of heating the compressor?
  - Other
  - Significant saving potential Maybe as high 750kWh/year
The Unknowns (Ducts)

- Duct sizing, what capacity do we design for? Max air flow or somewhere in the middle?
- How much more important is duct insulation and duct sealing on these systems?
- Can we design for the Winter design temperature (at least West of the Cascades)?
The Unknowns (Defrost)

- May be more savings from intelligent defrost that from the gain in HSPF
  - Do we need the Aux heat to be on during defrost?
  - Can they just bring on 5 K of Aux heat?
  - At lower operating speeds do they defrost more or less than a standard heat pump
The Future Of Heat Pumps Is Now

Bruce Manclark
bruce.manclark@CLEAResult.com
This New, Hip Heat Pump Technology May Mean:

- A dramatic reduction in peak demand at the house level
  - Average strip heat according to RBSA is 12.2KW
- Dramatic reduction in energy use
  - High COPS
  - Less energy for defrost
  - No aux heat usage

BUT…. it all depends on better understanding of the technology and programs that mesh well in the real world and deliver real energy savings
Feedback: What did Bruce…

1. Get Wrong
2. Failed to Mention
3. Not understand the importance of?