Paper Outline

1. Challenge of Load Calculation Compliance
   1. Customer Preferences
      1. Run time vs. energy savings
   2. Determining customer preferences
      1. Stated vs. revealed preferences
   3. Installer Preferences
      1. Models vs. Experience
      2. Fear of callback
2. Data Sources
   1. Runtime data
      1. Amp clamps
      2. Indoor temperature data
   2. Model Data
      1. Modeled Cooling Load
         1. Wrightsoft with manual J Inputs
            1. Models were updated and verified including test-out improvements (blower door and duct leakage), T-stat set-points and internal loads.
   3. Manufacturer data
      1. ACCA Capacity Calculator
         1. Manual S inputs: OAT of 100, IAT of 75, indoor wet bulb of 63 and default equipment CFM.
         2. Multiplied total capacity by SHR at 75 IAT.
         3. Some variation here, but not a lot.
         4. If in-field performance of equipment is less than manufacturer capacity, we should assume that the actual load is biased downward.
   4. Weather Data
      1. Weather Underground
      2. On-site data
   5. Customer data
      1. Thermostat Operation.
         1. Staging is controlled differently depending on the thermostat, but this shouldn’t have a major effect. If equipment runs in low stage for over an hour (ex. Hansen), we’ll assume that it’s meeting the load.
      2. Maintaining Indoor Temps
3. Methodology
   1. Runtimes + Model + Manufacturer
      1. Core Methodology
         1. A study of extremes. In order to analyze performance we want to know, we need to look at performance under extreme conditions.
         2. Hourly sample of runtimes at extreme conditions. Each observation is assumed to be independent.
            1. Assumption: 98 degree OAT at 11 AM will have a lower impact than a 98 degree OAT at 5 PM given solar radiation.
      2. Example
      3. Display of Data
4. Results
   1. Table of Observations

|  |  |  |
| --- | --- | --- |
| OAT | Count of Obs. | % CL |
| 98 | 54 | 76 |
| 99 | 22 | 80 |

* 1. **Chart: Scatterplot for All**
  2. **Chart: Residual Plot**
  3. **Table: Average variance, by degree, for each job**

1. Exceeding Equipment Capacity
   1. Once we go over an hour of runtimes, we do not know what the cooling load is.
   2. Observations that hit 100% of the equipment capacity.
      1. What is the relative percentage for these jobs?
      2. Using indoor temperature data- did it maintain temp?
      3. **LINE CHART:** Indexed temperature data at t=0 for all values. Color Coded by whether temp increases or not.
         1. Pittard
         2. Hemmingway
         3. Cruz
         4. Flores
2. Customer Operation Quirks
   1. Izard- Upstairs system is off, load for downstairs?
   2. Laxx- Turned down from 77 to 75
   3. Gonzalez- Turned on only when he gets home
3. Conclusions
   1. The risks- even if 95% of the rightly-sized systems perform well, the 5% will still be enough to impress upon the HVAC contractor to upsize.
   2. Things done differently
      1. Logging AC runtimes in unprecedented. We expect this data to become more available in the future with the expansion of IT.
      2. Collecting more system performance data, rather than using Lennox data.
      3. Collecting more data on OAT on-site rather than Weather Underground.
      4. More information from occupants, although we can’t know everything. Knowing what other appliances they are running in their home is possible to know. But knowing whether they leave a window open or not isn’t feasible.
4. Appendix
   1. Customers: Brick- data from 7/13-7/28
   2. Weather Data
      1. CDD during study for last 30 years
      2. 1% temperatures during study compared to last 30 years
   3. Energy Usage
   4. Energy Costs
   5. Histogram of Runtimes
   6. Exceeding 1 hr runtimes- did interior temperatures increase?
   7. Calculating output of variable capacity equipment using Manual S
      1. Compressor kilowatt draw, total cooling capacity and sensible heat ratio data was gathered from Lennox equipment data. This data was collected at three different points: minimum, intermediate and maximum capacity at an 85, 95 and 100 degree OAT.
      2. Compressor kW was converted to Amps and check against logger data. Minimum/maximum amp draw matched compressor kW minimum and maximum.
      3. Sensible cooling capacity was calculated.
      4. A scatterplot was constructed with amps as the independent variable and capacity as the dependent. A line of best fit was drawn to between the three data points within R^2 of .99.
         1. *capacity =6.5248+1.8831x*
      5. Amp data from the logger was plugged into the equation to get equipment capacity.
      6. Using variable capacity equipment allows us to measure loads more precisely even when equipment is running for multiple hours because it is not just “on” or “off” but load-matching.
      7. Variable capacity equipment loads frequently did not correlate with outdoor air temperatures. They tended to start later, did not reach their daily maximum capacity until after outdoor temperatures began to drop, and would run continuously much later into the night, often past midnight.
         1. While this may have something to do with thermostat adjustment, it also fits with the idea that houses “hold heat.” Variable capacity adjusts to the “hold heat” theory.
            1. There are some days that have large jumps in amperage, other days we get more continuous runtimes (7/17).
      8. In order to get a better idea of the correlation, maximum hourly equipment output was matched to hottest hourly OAT, 2nd maximum matched to 2nd hottest, etc.