2008 Title 24
Refrigerated Warehouse
CASE Initiative
Public Workshop
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Background Research

- Literature review
  - Utility efficiency programs
  - ASHRAE “Design Essentials for RWHs”
  - Purdue study for IARW
  - Pacific Northwest VFD Evaporator Fan Initiative
  - DEER measure cost study
  - Manufacturers’ data

- Contractor and designer telephone surveys

- DOE-2 simulations
Prototype Refrigerated Warehouse Simulations

- DOE-2.2R simulation program used
- Ammonia based system with screw compressors and evaporative condenser
- 92,000 SF
- Combination of freezer, cooler and shipping dock space
- See report for details
Areas Addressed

- Evaporators
- Condensers
- Compressors
- Lighting
- Insulation levels
- Under floor heat
- Defrost
Evaporator Fan VSD
Evaporator Fan VSD Analysis

- Used hourly “Time Dependent Valuation” costs,
  - 15 year measure life,
  - 3% real (net of inflation) discount rate
- Impact of over-sizing investigated
- Evaporator fan VSD costs of $577 per hp from the Northwest Energy Efficiency Alliance
  - Demonstrated energy savings
  - Reduced fruit mass loss in controlled atmosphere rooms
- Graph of savings (kWh/SF) and Benefit/Cost ratio versus over-sizing ratio
  - Greater over-sizing, greater savings
  - B/C ratio of 20 to 1 fairly constant for CV fans, above 10 for intermittent fans
Evaporator Fan VSD Energy Savings and Cost Effectiveness

- Energy Savings (kWh/SF)
- Benefit/Cost Ratio

Graph:
- Sizing Ratio
- Energy Savings (CV Fan)
- Energy Savings (Int Fan)
- Benefit Cost Ratio (CV Fan)
- Benefit Cost Ratio (Int Fan)
Compressors
VSD Compressor Analysis

- Used 15 year TDV to value energy cost savings
- Looked at VSD on 3 compressor parallel equal line
- Looked at VSD also on smallest compressor in 3 compressor parallel unequal line
- VSD costs from 2005 DEER Measure Cost Study @ $171/ton
VSD Trim Compressor Energy Savings and Cost Effectiveness

VSD Compressor Energy Savings and Cost Effectiveness

Energy Savings (kWh/SF)

BCR = 21.4

BCR = 1.7

VSD trim compr (parallel unequal) VSD trim compr (parallel equal)

Energy Savings

Benefit/Cost Ratio

0 5 10 15 20 25
0 1 2 3 4 5 6 7 8
Evaporative Condensers
Condenser Oversizing and Floating Head Pressure

- Used 15 year TDV to value energy cost savings
- Varied design approach temperature from 25°F to 13°F
- Condenser fan and pump power improved from 330 Btu/hr-watt to 400 Btu/hr-watt
- Minimum condensing temperature dropped from 85°F to 70°F
Oversized Evaporative Condenser and Floating Head Pressure

- Scenarios presented:
  - Fixed condensing temperature
  - 9°F wetbulb offset with VSD

- 2005 DEER Measure Cost Study used
  - $88 per ton @ 5°F reduction
  - $203 per ton @ 5°F reduction with VSD and wetbulb control
  - Scaled based on reduction modeled
Oversized Condenser Energy Savings and Cost Effectiveness

Design Condensing Approach Temperature

- Energy Savings (Fixed at 70 deg)
- BCR (Fixed @ 70deg)
- BCR (VSD and WB control)
- Energy Savings (VSD and WB control)
Shell Insulation

Freezer Floor Insulation

Insulated Panels
Insulation Energy And Economic Analysis

- Used 30 year “Time Dependent Valuation” costs
- Insulation incremental cost (R.S. Means)
  - Roof insulation
    - Polyisocyanurate @ R-7.1 per inch
    - $0.25 per SF – in.
  - Wall insulation
    - $0.63 per SF – in.
    - Polyurethane @ R-5 per inch
  - Floor insulation
    - Extruded polystyrene @ R-5 per inch
    - $0.32 per SF – in.
# Insulation Analysis

<table>
<thead>
<tr>
<th>Shell Component</th>
<th>Common Practice</th>
<th>ASHRAE Recommendation</th>
<th>CASE Recommendation</th>
<th>Benefit/Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freezer Ceiling</td>
<td>R-46</td>
<td>R-45 to R-50</td>
<td>R-49</td>
<td>Coastal (CZ 3)</td>
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<tr>
<td>Freezer Wall</td>
<td>R-32</td>
<td>R-35 to R-40</td>
<td>R-40</td>
<td>Central Valley (CZ 13)</td>
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<tr>
<td>Freezer Floor</td>
<td>R-30</td>
<td>R-27 to R-32</td>
<td>R-30</td>
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<tr>
<td>Cooler Ceiling</td>
<td>R-24 to R-40</td>
<td>R-30 to R-35</td>
<td>R-35</td>
<td></td>
</tr>
<tr>
<td>Cooler Walls</td>
<td>R-25</td>
<td>R-25</td>
<td>R-25</td>
<td></td>
</tr>
</tbody>
</table>

Note: BCR varies with refrigeration plant efficiency – efficient plant used.
Under Floor Heat

- Energy consumption for under floor heat
  - 2.0 Btu/hr-SF (-20°F freezer, R-30 insulation)
  - 0.6 W/SF (5.2 kWh/SF-yr)
  - 15 yr NPV TDV electricity costs for electric heat = $15.43 per SF

- Costs taken from R.S. Means
  - $2.26 per SF for glycol system
  - $2.04 per SF for electric system

- Benefit / Cost Ratio = 70+
Temperature Terminate Defrost

- Defrost needs vary by location within the facility, time of day and season
- Time on, time terminate defrost controls may be set for “worse case” conditions
- Time on, temperature terminate controls are standard practice
- Require additional temperature sensor at evaporator
- Case studies cited quick paybacks (< 1 year)
Energy Consumption Parametrics

![Energy Consumption Graph]

- **Base Building**: 27.5 kWh/yr
- **Evaporator**: 22.0 kWh/yr
- **Evap + compressor**: 18.0 kWh/yr
- **Evap + comp + condenser**: 16.0 kWh/yr
- **Evap + comp + cond + shell**: 15.0 kWh/yr
Overall Energy Savings Analysis

- Energy savings of about 12 kWh/SF and non-coincident peak demand savings of 1.4 W/SF
- Represents about 40% of annual consumption of prototype model
- Cost effective
Energy Savings Breakdown

- Evaporator: 51%
- Compressor: 34%
- Condenser: 12%
- Shell: 3%
Code Change Proposal

- Mandatory Measures
  - Lack of ACM for refrigerated warehouses precludes prescriptive approach

- New section in Standards
  - Section 120 – Mandatory Requirements for Refrigerated Warehouses

- Applies to freezers and coolers > 3000 SF
Proposed Code Provisions - Evaporators

- Require VSDs on evaporator fan motors
- Limits on evaporator fan motor power of 0.15 W/cfm
- Limit electric defrost
  - Exception based on system size
- Require temperature termination on defrost controls
Proposed Code Provisions - Compressors

- Require compressors and accessories supplied by manufacturers to operate at 70°F condensing
- Require VSD on at least one compressor per suction group
Proposed Code Provisions - Lighting

- Use same lighting provisions as for non-refrigerated warehouses
  - Max lighting power of 0.6 W/SF
  - Require bi-level lighting controls in storage spaces
Proposed Code Provisions - Condensers

- Require evaporative condensers on all ammonia systems
- Limits on condenser wetbulb approach temperature
  - 20°F at design conditions
- Limits on condenser fan and pump power
  - 400 Btu/hr-watt
- Require floating head pressure control to 70°F
- VSD on evaporative condenser fans controlled by wetbulb or load
Proposed Code Provisions – Insulation

- Minimum R-values for freezers
  - R-40 Wall
  - R-49 Ceiling
  - R-30 Floor

- Minimum R-values for coolers
  - R-25 Wall
  - R-35 Ceiling

- Limit on electric resistance under floor heating
  - Exception based on facility size
  - Resistance heat must be controlled off during summer on-peak periods
Discussion
Information and Contacts:

- Full CASE report available for download:
  www.energy.ca.gov/title24/2008standards/documents/
  2006-02-22+23_workshop/2006-02-15_DRAFT_REP_PG&E.PDF

- Please send written comments to:
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- Thank you very much!!