Commercial Refrigeration
Temperature & Defrost
Control and Optimization

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Commercial Refrigeration: The unmet energy challenge

**SUPERMARKET**
- Refrigeration: 50%
- Lighting
- Cooling
- Miscellaneous

**WAREHOUSE**
- Refrigeration: 52%
- Lighting
- Other

**RESTAURANT**
- Refrigeration: 28%
- Cooking equipment
- Lighting
- Cooling
- Miscellaneous
Traditional Temperature Controls

- Pressure Controls
  - Provides Indirect Temperature Control

- Thermostat
  - Return/Discharge Air Temp
  - Evaporator Coil Temp
  - Product Temp
Advanced Temperature Control
Multiplex Rack Systems

- **Evaporator Pressure Regulator (EPR)**
  - EPR = Steady Suction P = Steady Air Temp
  - Good for stable load conditions

- **Electronic Suction Regulator**
  - Controlled by microprocessor controls
  - Flexible control (pressure or temp)
  - Responds to varying load conditions for improved temperature control
Advanced Temperature Control
Single Compressor Systems

• Hot Gas Bypass
  • Can Provide Excellent Temperature Control
  • Comes at an Energy Penalty
**Advanced Temperature Control**

**Single Compressor Systems**

- Utilize microprocessor controls to improve overall system performance
- Reduced Room Temp Differential Between Cut-In & Cut-Out
- Compressor Short Cycle Protection (Minimum Runtime & Off-time)
- Evaporator Fan Management
  - **Variable Speed Evaporator Fans**
    - Should be part of overall system design
    - Likely requires other variable capacity components (EEVs, Variable Speed Compressor, etc.)
    - Can be cost prohibitive for smaller applications
  - **Two Speed Evaporator Fans**
    - Provides energy savings during refrigeration off-cycle
    - Typically requires specific motor design
  - **Off-Cycle Fan Management**
Off-Cycle Fan Management Provides Improved Temp Control & Energy Savings

Latent energy recovery through evaporator fan cycling, compressor stays off.
Free Cooling – Latent Energy Recovery

- Proper fan control during operation provides “free cooling” by sublimating frost to chill room

~ 1200 BTUs per Pound
Factors Affecting Frost Buildup

- Air Temp
- Humidity
- Coil Temp
  - Including variations due to refrigerant flow
- Fin Spacing
- Air movement (high velocity vs. low velocity)

Light Frost Accumulation Improves Heat Transfer of the Coil
Common Methods of Defrost

• Air Defrost (Off-Time)
• Hot Gas Defrost
• Electric Defrost
Air Defrost Techniques
(Space Temps ≈ 36°F & Above)

• **Natural Off-Time**
  o Requires oversized refrigeration system
  o Space Temperature control always active
  o No guarantee the coil is defrosted

• **Pressure/Temperature constant cut-in/cut-out**
  o Initiates off-cycle/defrosts in response to drop in suction temp/pressure
  o Provides indirect space temperature control
  o Does provide feedback regarding defrost effectiveness
  o Can be difficult to dial-in
  o System issues & load variations can “fool” the controls

• **Forced Defrost**
  o Independent of Temperature Control
  o Fixed Time or Temperature Terminated
Hot Gas Defrost

• Typically Fastest Means of Defrost

• Melts Frost from Inside-Out

• Heat is Provided by Refrigeration System

• Higher Up Front Cost for Added Piping & Controls
Hot Gas Defrost Techniques

- **Reverse Flow**
  - Typically on Rack Systems
  - Hot Gas is directed from Compressor Discharge or Liquid Receiver to Outlet of Evaporator
  - Gas flows backwards through Evap and condensed liquid is directed to liquid line/header
Hot Gas Defrost Techniques

• Three Pipe
  o Dedicated Hot Gas line to the evaporator inlet
  o Must have a means of dealing with condensed liquid exiting the evap during defrost

• Reverse Cycle
  o Single Compressor System
  o Reversing Valve Shifts Flow of Refrigerant Condenser↔Evaporator
Electric Defrost

• Simple to Operate & Maintain

• Typically longer to Defrost than Hot Gas since heat has to travel from heaters to frost
  o Surface Mounted Heaters
  o Heater Elements Inserted into Coil

• Uses External Heat Source for Defrost Heat

• Up to 80% of Heat Load can be transferred to Refrigerated Space
Electric Defrost Techniques

• **Time Initiated**
  o Typically set for “worst case” and seldom adjusted
  o Can be Time or Temperature Terminated

• **Runtime Defrost Schemes**

• **Adaptive Defrost Schemes**
  o Reactive
  o Proactive
Proactive Defrost Constantly Monitors System Performance

Temperature
- Actual Room Temp
- Coil Surface Temp

Temperature Difference Between Actual Room & Coil Surface
- $TD_1$
- $TD_2$
- Defrost Needed

Cooling
- ON
- OFF

Defrost
- ON
- OFF

Time

$TD_1$: Difference between actual room temperature and coil surface temperature - Normal Operation
$TD_2$: Difference between actual room temperature and coil surface temperature - Indicating Defrost
Walk-In Freezer (Before)

7 day graph with defrost timeclock set to (4) 30 minute defrosts/day
Walk-In Freezer (After)

As Few As 3 Defrosts in 1 Week
Electric Defrost Heater Control

80% additional room heat gain (radiation + convection) due to high heater temperature

High coil temperature drives “fog” into the room, can create ice build up problems
Consequences of Fogging
Advanced Defrost Heater Control

Only 20% additional heat gain (radiation + convection) due to heater temperature
Ensures lower coil temperature, less energy usage, decreased product heating
Results of Improved Defrost Control

Before - June 15, 2012

After - July 22, 2012
Defrost Termination

• Defrost Termination On Time
  o No guarantee coil is defrosted
  o Doesn’t prevent addition of unnecessary heat into refrigerated space

• Defrost Termination on Temperature
  o Fixed Temperature Setting vs. Adjustable
  o Adjustable Defrost Termination Location vs. Fixed
  o More than 1 Defrost Termination Location?
Coil Temperature Reaching 80°F
Improved Defrost Termination