

# Cold Storage Warehouse Dock Parametric Study



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## Topics

- ◆ Objective
- ◆ Modeling loads
  - Infiltration
  - Desiccant operation
- ◆ Effects of dock temperature setpoint and addition of desiccant dehumidifier
- ◆ Effects of infiltration and defrost
- ◆ Conclusions

## Objective

- ◆ Develop a modeling tool for freezer and dock loads associated with dock operation
- ◆ Investigate effect of infiltration, defrost and dock setpoint on total refrigeration system energy use
- ◆ Investigate effect of adding a desiccant dehumidifier to the dock

## Refrigerated dock function

- ◆ The most obvious function is to facilitate the staging and transfer of stored goods
- ◆ What about from the refrigeration perspective?
  - “Protects” the freezer from infiltration by allowing for removal of humidity at a higher temperature level
  - “Protects” the employees from dangerous snow and ice at the freezer/dock door
    - ◆ Assisted by a well designed and operated freezer door

## Simulation of the Loads

### ◆ Weather

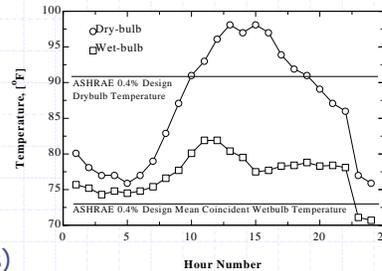
- NOAA surface observations of temperature and wetbulb

### ◆ Dock

- People
- Equipment (fans, forks, lights)
- Infiltration (ambient load and freezer credit)
- Transmission
- Defrost

### ◆ Freezer (incremental)

- Load from dock plus door heat (to avoid snow/frost)
- Defrost associated with latent load from dock



## Infiltration

### ◆ Ambient air that enters the conditioned space

- Uncontrolled
- Unconditioned

### ◆ Importance in refrigerated spaces

- Largest source of humidity (i.e. frost)
- Not as much of a problem now in WI

## Infiltration through an unprotected door

- ◆ The amount of air flow through a doorway as a function of only temperature difference is impressive
  - Truck bay door 10' wide x 9' high
  - Dock 35F/86%, Ambient 91F/73F<sup>1</sup> wetbulb
  - Results in:<sup>2</sup>
    - ◆ equivalent of 80 ft/min velocity through the door
    - ◆ 36 tons sensible, 32 tons latent
    - ◆ In other words, 1.1 ton-hrs per minute of open door

<sup>1</sup> ASHRAE 0.4% Design conditions for Minneapolis

<sup>2</sup> No influence of pressure difference from wind, etc.

## Freezer infiltration

- ◆ 10' wide x 14' high
- ◆ Usually have a protective device
  - Strip curtain, air curtain, or both
- ◆ Doorway effectiveness,  $\eta$ 
  - Fraction of unprotected doorway air exchange that is protected from exchange
  - In other words, multiply the unprotected doorway exchange by  $(1 - \eta)$  to determine the estimated protected doorway air exchange

# Freezer doorway effectiveness

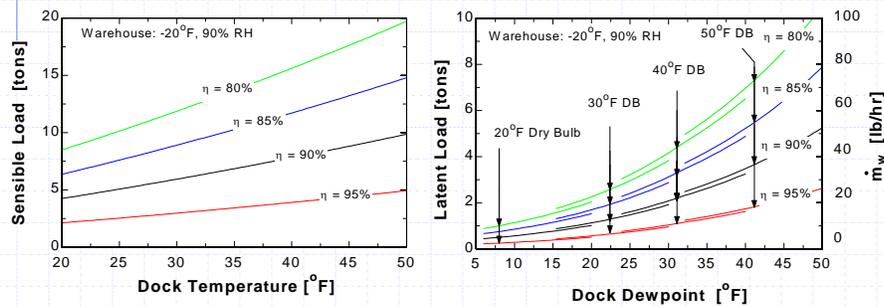
Strip curtain	82-94%
Vertical air curtain	49-80%
Dual horizontal air curtain	65-78%
Fast sliding doors	78-93%

Values taken from:

Downing, C.C., W.A. Meffert, 1993, "Effectiveness of cold-storage door infiltration protective devices," *ASHRAE Transactions*, vol. 99, part 2, pp. 356-366.

# Freezer loads

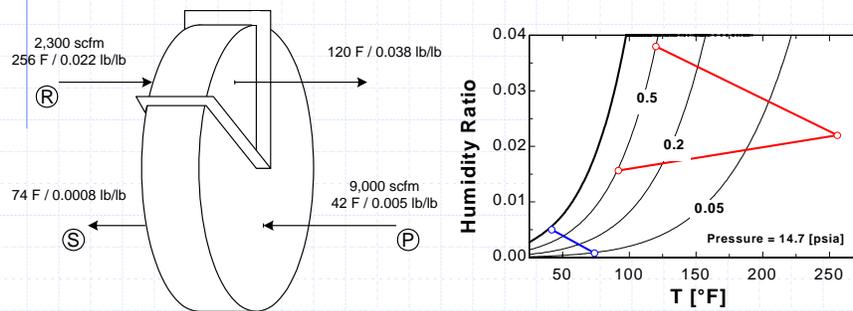
- ◆ Plots of sensible and latent load on freezer as a function of door effectiveness and dock conditions



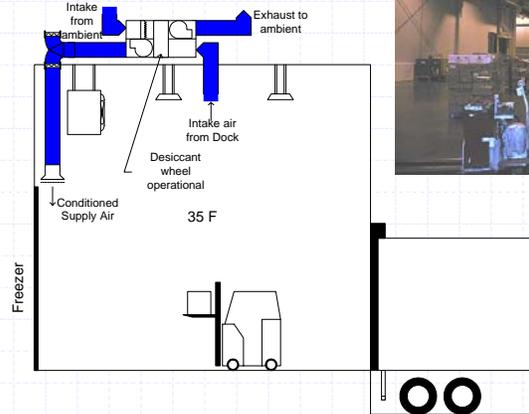
## How do desiccants dehumidify?

- ◆ Adsorption of water vapor from humid air on the surface of the desiccant (solid type)
- ◆ A "heat-activated water pump"
  - Use heat source to regenerate (drive-off moisture) the desiccant
  - Adsorbs water vapor from humid air on the surface of the desiccant (gives off heat similar to condensation)
- ◆ Humid air is dehumidified and heated

## Schematic and Psychrometric Representation of Desiccant



## Desiccant System Schematic



## Dock Details

- ◆ Located in Minneapolis, MN
- ◆ Dock setpoint of 35F
- ◆ Attached to a -20F warehouse
- ◆ 8,000 ft<sup>2</sup> of dock per freezer door ( $\eta = 85\%$ )
- ◆ 900 ft<sup>2</sup> of dock per truck bay door (open 2 minutes per hour)



## Design Day Energy Use

### ◆ Mechanical-refrigeration only

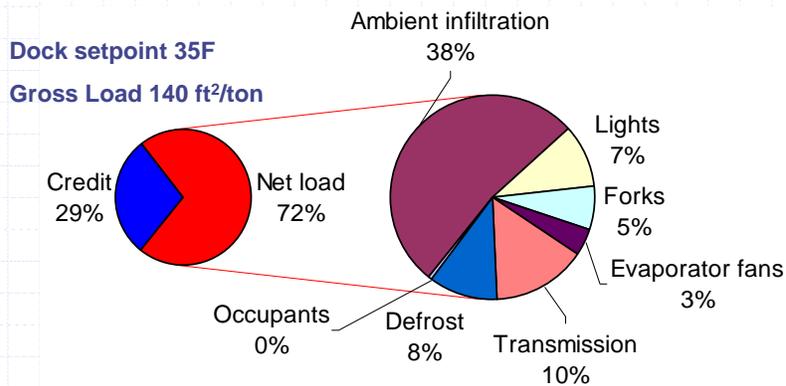
- Freezer load: 4.7 ton-hr/ft<sup>2</sup> of door/SHR = 0.85
- Peak dock load 200 ft<sup>2</sup>/ton
- 0.33 kWh/ft<sup>2</sup> per design day
- \$0.016/ft<sup>2</sup> per design day<sup>1</sup>

### ◆ With desiccant (flow rate 0.56 cfm/ft<sup>2</sup> of dock)

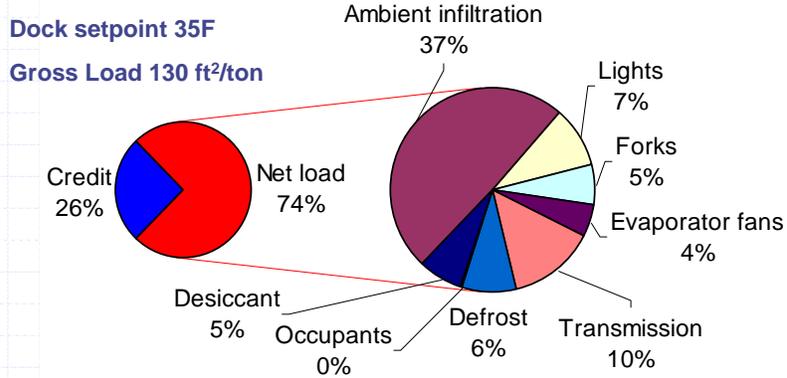
- Freezer load: 4 ton-hr/ft<sup>2</sup> of door/SHR = 0.98
- Peak dock load 175 ft<sup>2</sup>/ton
- 0.35 kWh/ft<sup>2</sup> and 0.007 therms/ft<sup>2</sup> per design day
- \$0.019/ft<sup>2</sup> per design day<sup>1</sup>

<sup>1</sup> Assume \$0.05/kWh and \$0.25/therm

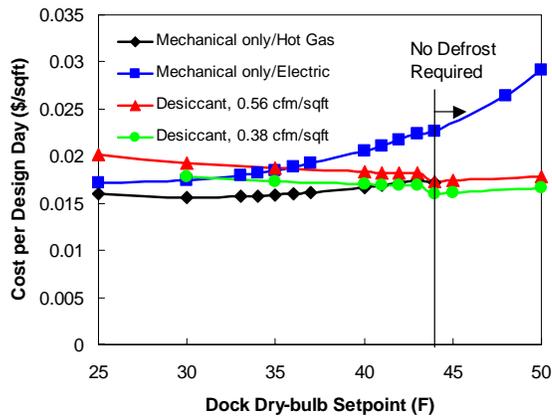
## Mechanical-only Load Breakdown



# Desiccant Load Breakdown



# Effect of Dock Setpoint



Note: "Hot Gas" and "Electric" refer to the method of applying dock/freezer door heat to avoid frost, etc.

## Effects of Ambient Infiltration

### ◆ 50% decrease in ambient infiltration

- Mechanical Refrigeration-only
  - ◆ Nearly 50% reduction in dock load
  - ◆ Only 10% reduction in freezer load
  - ◆ 25% reduction in design day energy use and cost
- With 0.56 cfm/ft<sup>2</sup> desiccant
  - ◆ Approximately 40% reduction in dock load
  - ◆ Negligible change in freezer load
  - ◆ 17% reduction in design day energy use and cost

Note: all parametric reductions are for 35F dock setpoint.

## Effects of Freezer Infiltration

### ◆ 67% decrease in freezer infiltration

- Mechanical Refrigeration-only
  - ◆ 40% increase in dock load
  - ◆ 60% reduction in freezer load
  - ◆ 25% reduction in design day energy use and cost
- With 0.56 cfm/ft<sup>2</sup> desiccant
  - ◆ 40% increase in dock load
  - ◆ 60% reduction in freezer load
  - ◆ 16% reduction in design day energy use and cost

## Effects of Defrost Load

- ◆ Double the energy associated with defrost
  - Mechanical Refrigeration-only
    - ◆ 16% increase in dock load
    - ◆ Negligible effect on freezer load
    - ◆ 9% increase in design day energy use and cost
  - With 0.56 cfm/ft<sup>2</sup> desiccant
    - ◆ 10% increase in dock load
    - ◆ Negligible effect on freezer load
    - ◆ 6% reduction in design day energy use and cost

## Conclusions

- ◆ Infiltration
  - Ambient
    - ◆ Large effect on dock load
  - Dock/freezer
    - ◆ Large effect on both dock and freezer load
- ◆ Mechanical refrigeration-only
  - 33-35F dock setpoint is near optimum
- ◆ Desiccant opportunities
  - Benefits from higher setpoint in the dock
  - Proper sizing important

## Future work

### ◆ General

- Optimum dock temperature determination as a function of ambient conditions.

### ◆ Freezer door

- Dock/freezer air exchange conditions that result in “no frost” condition in the freezer.
- Methods for control of door heat addition to prevent freezer frost.

### ◆ Desiccant

- Investigate sizing of desiccant system.
- Investigate siting of desiccant system inlets and outlets.
- Investigate alternative control of desiccant system.