

Design Considerations for Underfloor Heating Systems

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What is *Frost Heave Protection*?

- As soil drops below freezing, moisture in the soil will migrate into large ice crystals
- These crystals, or lenses, will form under the floor causing the floor to heave up
- *Frost Heave Protection* is an implementation of a method to prevent lenses from forming
- Underfloor heating is the most common method in refrigerated warehouses

Why is it Needed?

-20 freezer without FHP



1 Year



Why is it Needed?

3 Years



6 Years



Why is it Needed?

10 Years



If you had ground water a 20 feet below the surface, you most likely would be replacing your floor.

How Much Heat is Necessary?

$$Q = U A \Delta T$$

- The magic is in “U”
- Ballou (ASHRAE, 1981) offered 0.036 Btu/ft² hr F
 - 6 inches of concrete at 5 [F ft² hr/Btu] and 6 inches of insulation at 30 [F ft² hr/Btu] plus vapor barrier, sand, etc.

How Much Heat is Necessary?

Assume

- $U = 0.036 \text{ Btu/ft}^2\text{-hr-F}$
- Soil Temp = 50°F

Range

- $1\text{-}3 \text{ Btu/ft}^2\text{-hr}$

Freezer Temp [F]	Heat [Btu/ft ² -hr]
20	1.00
10	1.33
0	1.67
-10	2.00
-20	2.33
-30	2.67
-40	3.00

Better Methods

- Performed an extensive literature search
 - Very little found in English
 - Small amount in German
- *Parametric Analysis and Development of a Design Tool for Foundation Heat Gain for Coolers*
 - by Chuangchid & Krarti, *ASHRAE Transactions* from Minneapolis meeting
 - Provides an empirical fit to models developed by the interzone temperature profile estimation (ITPE) method

ITPE Method

Simplified Model 2, Denver

Freezer Temp [F]	Hand Calc [Btu/ft ² hr]	ITPE [Btu/ft ² hr]
20	1.00	0.90
10	1.33	1.16
0	1.67	1.42
-10	2.00	1.68
-20	2.33	1.95
-30	2.67	2.20
-40	3.00	2.47

Rules of Thumb and Reality

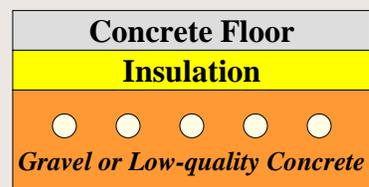
- For a -20°F Freezer in Denver, CO
 - $Q = U A \Delta T \Rightarrow 2.33 \text{ Btu/ft}^2 \text{ hr}$
 - ITPE Simplified Model 2 $\Rightarrow 1.95 \text{ Btu/ft}^2\text{-hr}$
 - Rule of thumb says 3 Btu/ft²-hr
- Most design for 2-3 Btu/ft²-hr or more
 - Realistically, more is better
 - Control based on ground temperature can taper back the amount of heat

What Is The Standard System?

**NOTHING
IS
STANDARD!**

Types of Protection Systems

- Large, porous gravel
- Electric Resistance
- Natural Ventilation
- Forced Ventilation
- Pumped Fluid



No Active Heating

- The floor is poured on top of a bed of large, porous gravel
- The large gaps prevent moisture from diffusing together and forming ice lenses
- Typically used under roads and pipelines
- Not recommended for warehouses or any permanent cold slab of any size

Electric Resistance

- Electric heat trace threaded through conduit embedded in the floor
- Very fast installation
- Easy thermostatic control of heat trace
- Easy maintenance
 - Circuits can be checked to verify operation
 - New heat trace threaded through conduit on failure



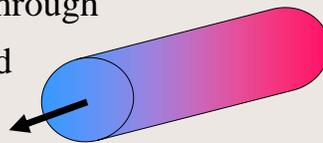
Electric Resistance



- Energy costs can be **EXTREMELY** high
 - Make sure sufficient capacity is installed to only use off-peak electricity
 - Hope utility does not change rate structure
- Recommended on small systems only (walk-in freezers)
 - Has been used on very large warehouse where electric rates are favorable to minimize construction time

Natural Ventilation

- Density difference between warm (outside) air and cold air in the system drives air movement
- Many different methods
 - Elevated floor
 - Ductwork/pipes straight through
 - Ductwork/pipes in U-bend
 - Concrete block channels



Natural Ventilation

- Design advice
 - Ductwork should be at least 8 in. diameter
 - Less than 120 ft in length
(less if there is a U-bend)
 - The ductwork must be pitched to allow for condensate to drain
- Use reliable materials, it will need to last 40+ years

Natural Ventilation

- Typical problems
 - Ductwork becomes plugged by debris or rodent nests
 - Ice plugging
 - Condensate freezes in duct
 - Increase pressure drop, reduces air flow
 - More ice forms until it is completely plugged
 - Air follows the path of least resistance, not the arrows on a construction diagram

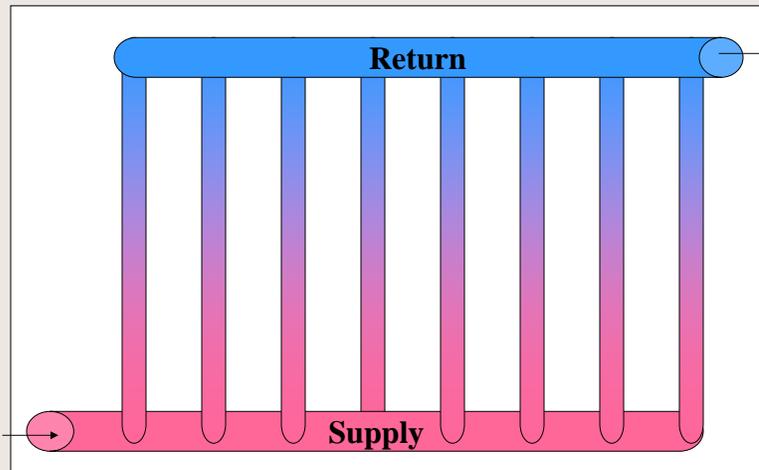
Forced Ventilation

- Air is forced through the ductwork
- Many different sources of fresh air
 - Outside air
 - Engine room air
 - Exhaust air from office (moisture problems)
 - Heated outside air
 - Heat recovery from hot gas
 - Forced air furnace
 - “Recycled” air in a closed system
 - Or any combination of above

Forced Ventilation

- Design advice
 - Ductwork usually 4 to 8 in diameter
 - Size and length dependent upon fan size
 - The ductwork should still be pitched in direction of airflow for condensate drainage
- Forced ventilation sees many of the same problems as natural ventilation
- Provides better temperature control

Forced Ventilation



Pumped Fluid

- Warm oil, glycol or other fluid is pumped through circuit(s) embedded below the floor
- Fluid is usually heated by hot gas
- The circuits are often overlapped
 - Redundancy in case a circuit is plugged or breaks
- Most reliable method of ensuring heat at reasonable operating expense

Pumped Fluid

- Design advice
 - Ethylene glycol is the most common working fluid
 - Tubing usually 1 in dia. spaced 4 to 5 ft OC
 - Size and length dependant upon pump size, but typically not longer then 1,200 ft
 - PE 3408 from geothermal industry is often used

Conclusions

	Installation Cost	Operating Cost	Risk of Failure
Electric	Low	High	Low
Nat. Vent	Medium to High	Low	High
Forc. Vent	Medium to High	Medium to High	Medium
Glycol	Medium	Low to Medium	Low

Weber, J.F., ASHRAE Transactions, 1981

Conclusions

- Many factors affect your choice
 - Weather conditions
 - Soil conditions
 - Groundwater level
- If a mistake is made in sizing or operation, refrigerated warehouse floors are very expensive to replace
 - Modern floors must be perfect for automated pickers
 - It can take years to rid a facility of frost heaved soil