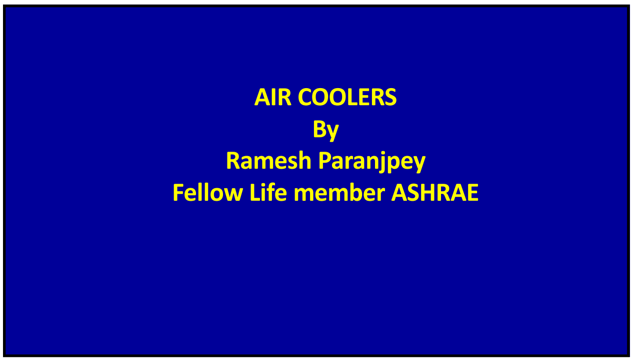
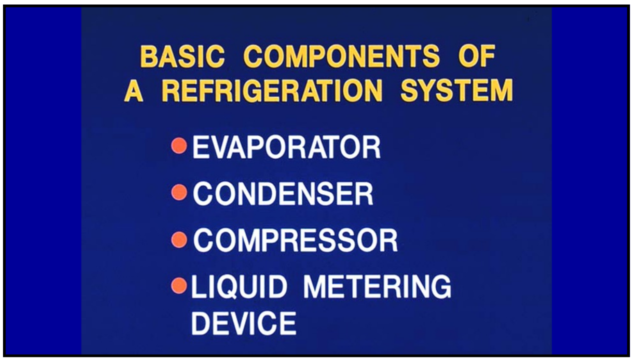
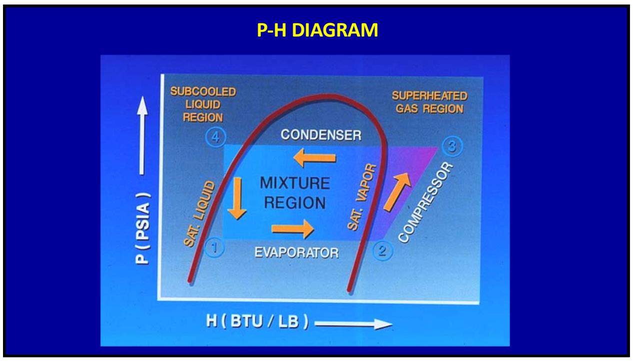


AIR COOLERS
By
Ramesh Paranjpey
Fellow Life member ASHRAE

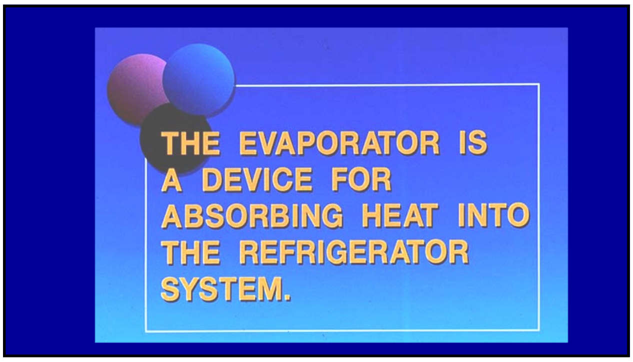


BASIC COMPONENTS OF A REFRIGERATION SYSTEM

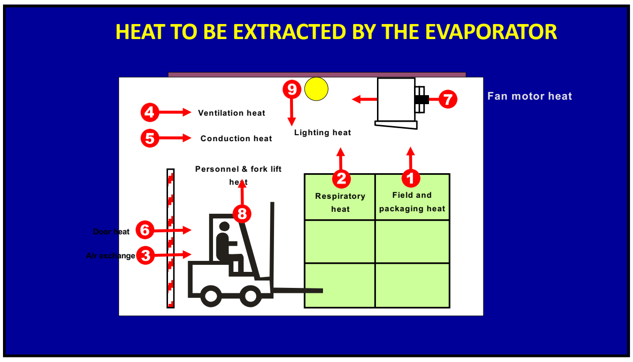
- EVAPORATOR
- CONDENSER
- COMPRESSOR
- LIQUID METERING DEVICE



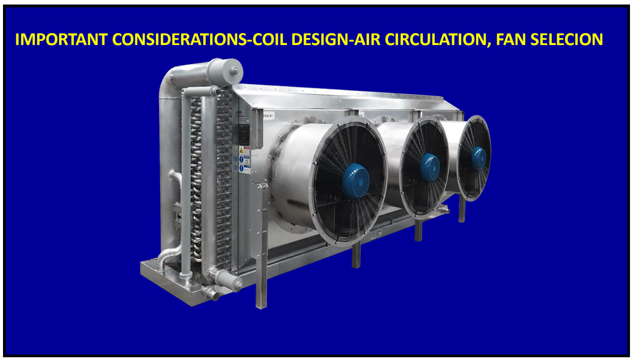
P-H DIAGRAM



THE EVAPORATOR IS A DEVICE FOR ABSORBING HEAT INTO THE REFRIGERATOR SYSTEM.

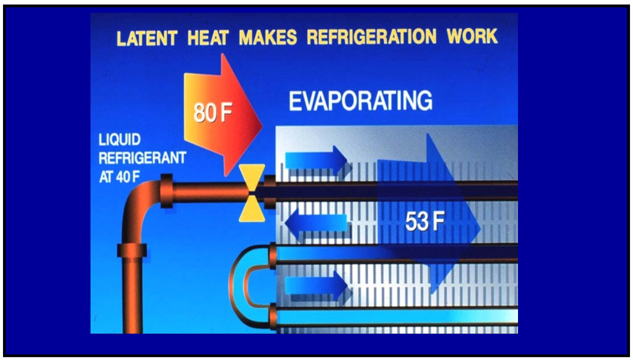


HEAT TO BE EXTRACTED BY THE EVAPORATOR

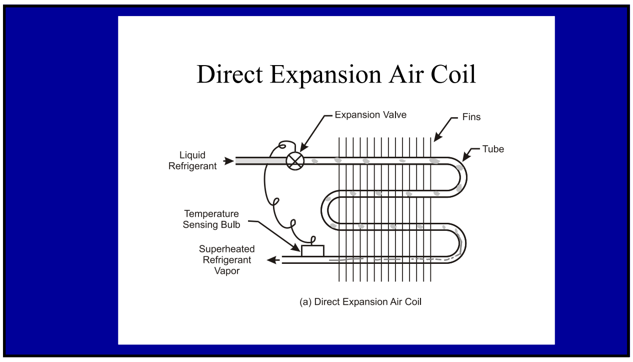


IMPORTANT CONSIDERATIONS-COIL DESIGN-AIR CIRCULATION, FAN SELECION

AIR COOLERS IN COLD STORAGE

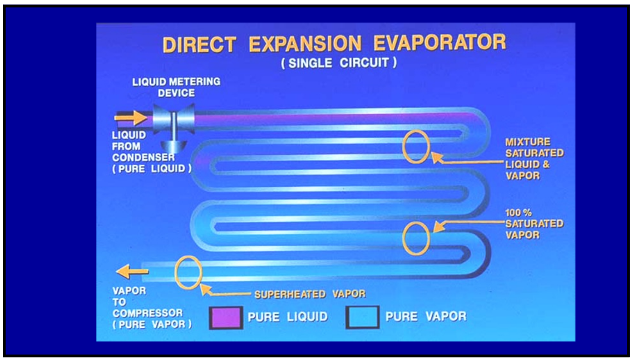


LATENT HEAT MAKES REFRIGERATION WORK



Direct Expansion Air Coil

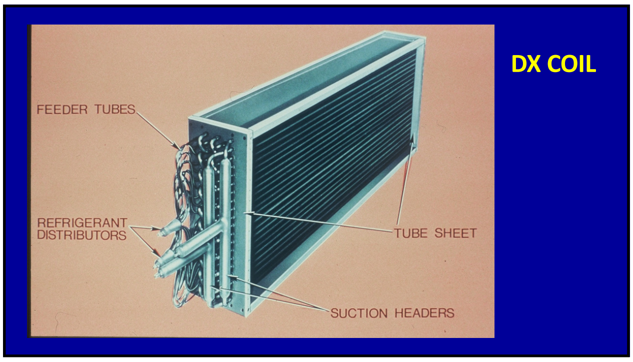
(a) Direct Expansion Air Coil



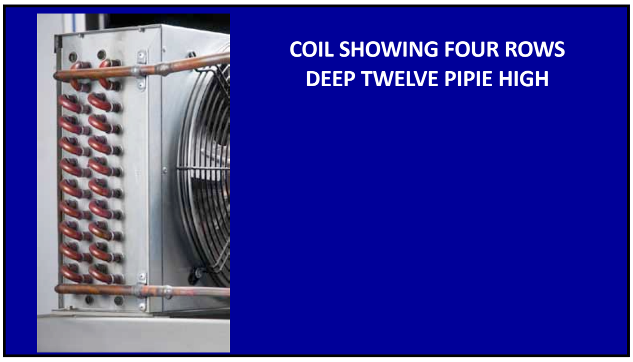
DIRECT EXPANSION EVAPORATOR

(SINGLE CIRCUIT)

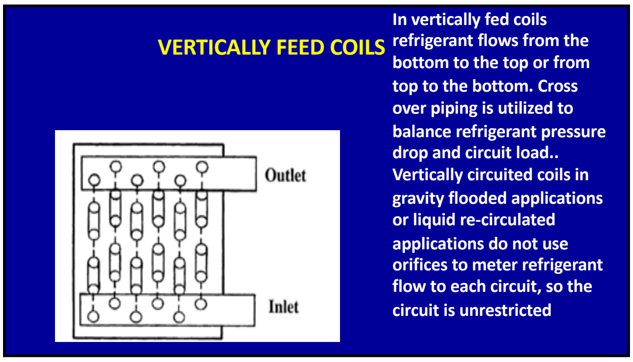
OLD – BUNKER SYSTEM



DX COIL

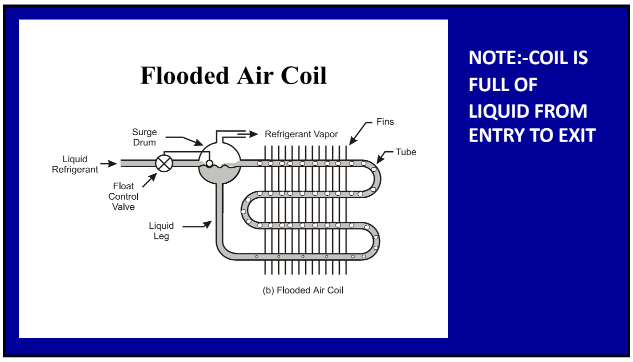


COIL SHOWING FOUR ROWS DEEP TWELVE PIPIE HIGH

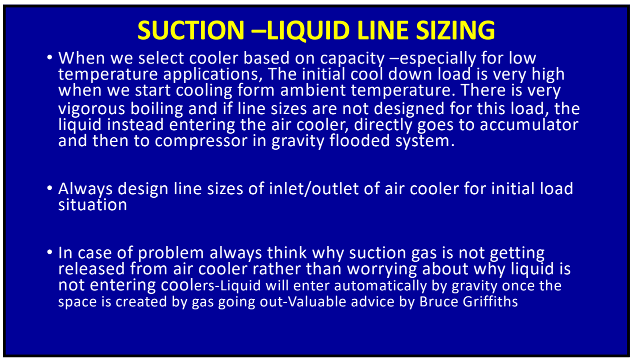


VERTICALLY FEED COILS

In vertically fed coils refrigerant flows from the bottom to the top or from top to the bottom. Cross over piping is utilized to balance refrigerant pressure drop and circuit load.. Vertically circuited coils in gravity flooded applications or liquid re-circulated applications do not use orifices to meter refrigerant flow to each circuit, so the circuit is unrestricted

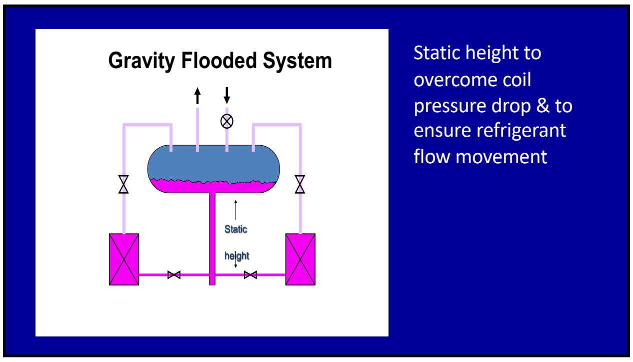


NOTE:-COIL IS FULL OF LIQUID FROM ENTRY TO EXIT

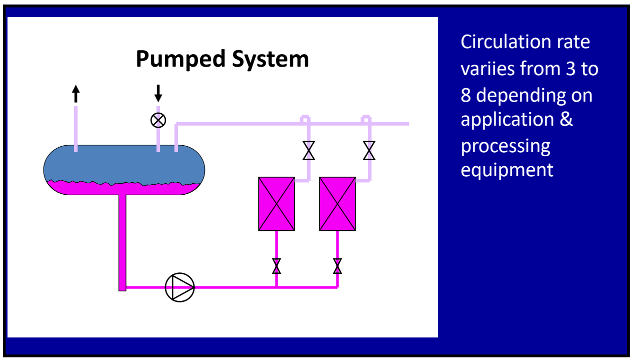


SUCTION –LIQUID LINE SIZING

- When we select cooler based on capacity –especially for low temperature applications, The initial cool down load is very high when we start cooling form ambient temperature. There is very vigorous boiling and if line sizes are not designed for this load, the liquid instead entering the air cooler, directly goes to accumulator and then to compressor in gravity flooded system.
- Always design line sizes of inlet/outlet of air cooler for initial load situation
- In case of problem always think why suction gas is not getting released from air cooler rather than worrying about why liquid is not entering coolers-Liquid will enter automatically by gravity once the space is created by gas going out-Valuable advice by Bruce Griffiths

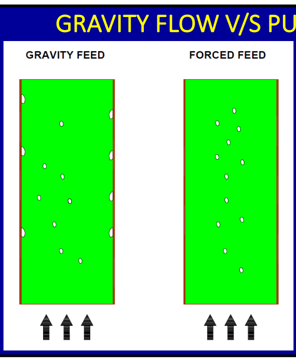


Static height to overcome coil pressure drop & to ensure refrigerant flow movement



Circulation rate variies from 3 to 8 depending on application & processing equipment

GRAVITY FLOW V/S PUMPED FLOW



IN PUMP CIRCULATONSYSTEM GAS BUBBLES ARE ENRAPPED IN EXCESS LIQUID FLOW, WALLS ARE ALWAYS IN CONTACT WITH LIQUID HENCE BETTER HEAT TRANSFER

KEY POINTS FOR SELECTING RIGHT SIZE EVAPORATOR

- Material of Construction
- Tube diameter/fin thickness/Fin Pitch
- Selection of temperature difference
- Fin Pitch-Square or Triangular
- Coil capacity selection-Based on TD1 or LMTD or MTD
- Air Flow Direction-Blow Through or Draw Through
- Air cooler surface area which includes fin area or only coil internal volume/length of coil without headers?
- Coil face velocity at the air outlet
- External static pressure available
- No of rows deep more or coil face area more ?-inlet/out connection sizes
- Defrost system-Hot gas/water/electrical heaters/reverse cycle or on/**off**

KEY POINTS FOR SELECTING RIGHT SIZE EVAPORATOR

- **Material of Construction**

1. Stainless steel tubes, casing as well as drain pan & and Al fins
2. Entire construction in Aluminium
3. C.S. Tubes with hot deep galvanizing and aluminium fins
4. Any other material to suit surrounding conditions and refrigerant

CHOICE OF MATERIAL

1. Hot Dip Galvanized Steel (Steel/Zn)- (SA179)
2. 304 S.S. Tubes with Aluminium Fins (SST/Al)- (SA249)
3. 3003 Gr. Aluminum Tubes with Aluminum Fins (Al/Al)- (SA210)

MATERIAL PROPERTIES

Metal	Density Lbs/cft.	Thermal conductivity Btu/sq.ft^{o}F/ft.	Specific heat Btu/lb. ^{o}F	Tensile strength kJ	Allowable Temperature ^{o}F
C.S.(SA179)	490	26	0.107	47	-20 to +500
304L S.S. (SA249)	501	9.4	0.120	70	-320 to +320
3003 Al(SA210)	16.5	117	0.215	14	-452 TO +300

Advantages Aluminium Coolers

1. Light weight-30% lighter
2. Heat transfer-Better-30% more compact
3. Cost-30% Cheaper

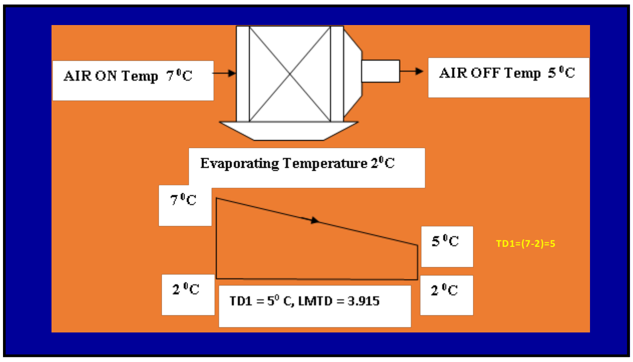
Disadvantages:

1. Cannot be repaired at site
2. Delicate-not yet popular

Ref: Colmac Coill-USA

HEAT TRANSFER EQUATION

- Q= U * A * LMTD or A=Q÷(U*LMTD)
- TD1 is method is based on the difference between the air temperature entering the evaporator coil (room Temperature)and the corresponding temperature of the saturated suction pressure of the refrigerant measured at the outlet of the evaporator.
- -Selection by DT1 gives adequate and bigger air cooler compared to LMTD and hence should be used.
- High humidity requirements will require coils with large surface areas and must be run at low TD's.
- Low humidity requirements will require coils with smaller surface
- areas and greater TD's.



AIR ON Temp 7⁰C

AIR OFF Temp 5⁰C

Evaporating Temperature 2⁰C

7⁰C

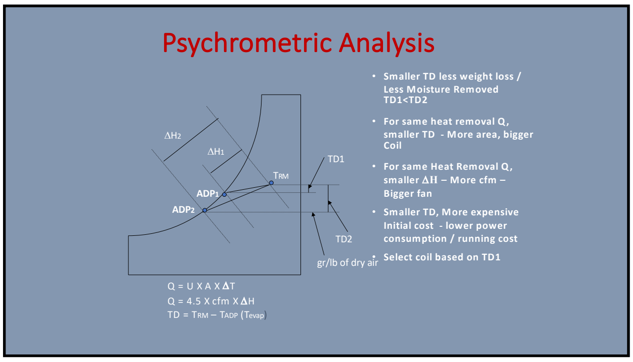
5⁰C

TD1=(7-2)=5

2⁰C

TD1 = 5⁰ C, LMTD = 3.915

2⁰C



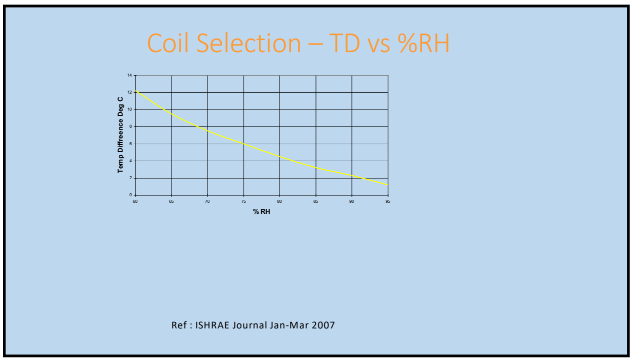
Psychrometric Analysis

- Smaller TD less weight loss / Less Moisture Removed TD1<TD2
- For same heat removal Q, smaller TD - More area, bigger Coil
- For same Heat Removal Q, smaller ΔH – More cfm – Bigger fan
- Smaller TD, More expensive Initial cost - lower power consumption / running cost
- Select coil based on TD1

$Q = U \times A \times \Delta T$

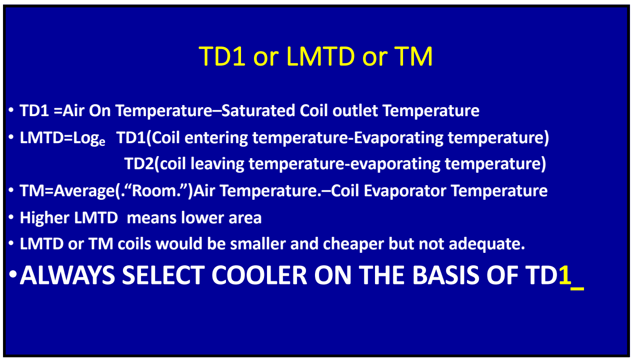
$Q = 4.5 \times cfm \times \Delta H$

$TD = T_{RM} - T_{ADP} (T_{evap})$



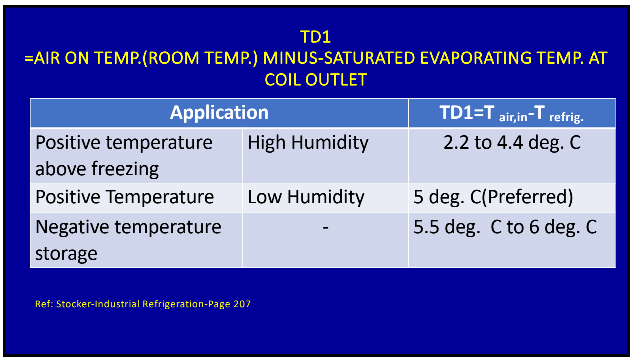
Coil Selection – TD vs %RH

Ref : ISHRAE Journal Jan-Mar 2007



TD1 or LMTD or TM

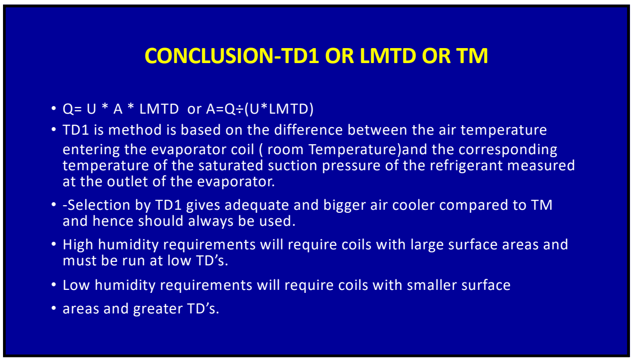
- **TD1 =Air On Temperature–Saturated Coil outlet Temperature**
- **LMTD=Log$_e$ TD1(Coil entering temperature-Evaporating temperature)**
  TD2(coil leaving temperature-evaporating temperature)
- **TM=Average(."Room.")Air Temperature.–Coil Evaporator Temperature**
- **Higher LMTD means lower area**
- **LMTD or TM coils would be smaller and cheaper but not adequate.**
- **ALWAYS SELECT COOLER ON THE BASIS OF TD1_**



TD1
=AIR ON TEMP.(ROOM TEMP.) MINUS-SATURATED EVAPORATING TEMP. AT COIL OUTLET

Application		TD1=$T_{air,in}$-$T_{refrig.}$
Positive temperature above freezing	High Humidity	2.2 to 4.4 deg. C
Positive Temperature	Low Humidity	5 deg. C(Preferred)
Negative temperature storage	-	5.5 deg. C to 6 deg. C

Ref: Stocker-Industrial Refrigeration-Page 207



CONCLUSION-TD1 OR LMTD OR TM

- Q= U * A * LMTD or A=Q÷(U*LMTD)
- TD1 is method is based on the difference between the air temperature entering the evaporator coil (room Temperature)and the corresponding temperature of the saturated suction pressure of the refrigerant measured at the outlet of the evaporator.
- -Selection by TD1 gives adequate and bigger air cooler compared to TM and hence should always be used.
- High humidity requirements will require coils with large surface areas and must be run at low TD's.
- Low humidity requirements will require coils with smaller surface
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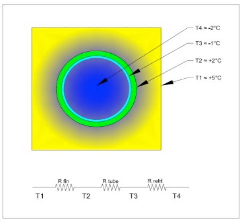
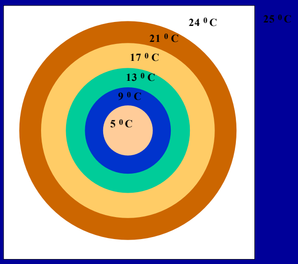
Cross Section of Typical Fin



AO-EXTERNAL AREA

AI-INTERNAL AREA

Tube Volume and Tube external area more Effective & important than fin area-IF-A_0/A_I LESS, MORE EEFFECTIVE IS THE COIL

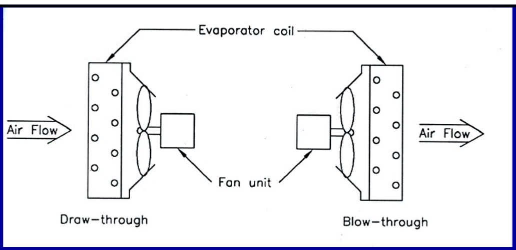


CROSS SECTION OF PLATE FIN COIL

AREA SELECTION

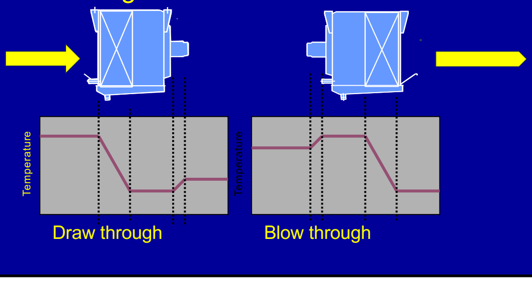
- Air cooler Area-Which area to be considered?
- surface area which includes fin area or coil internal volume/length of coil without headers?
- Always Check coil internal volume –Coil which has maximum internal volume is the more efficient selection & do not be mislead by coil surface area

- **AIR FLOW DIRECTION-**
- **DRAW THROUGH OR BLOW THROUGH**

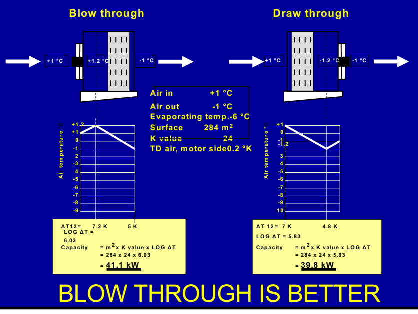


Draw through or blow through evaporator – fan configurations

BLOW THROUGH OR DRAW THROugh



BLOW-THROUGH & DRAW THROUGH AIR COOLERS



Air in +1 °C
Air out -1 °C
Evaporating temp.-6 °C
Surface 284 m²
K value 24
TD air, motor side0.2 °K

ΔT1,2= 7.2 K 5 K
LOG ΔT = 6.03
Capacity = m²x K value x LOG ΔT
= 284 x 24 x 6.03
= **41.1 kW**

ΔT 1,2= 7 K 4.8 K
LOG ΔT = 5.83
Capacity = m²x K value x LOG ΔT
= 284 x 24 x 5.83
= **39.8 kW**

BLOW THROUGH IS BETTER

BLOW THROUGH

- Wide air outlet surface
- Equal air distribution through the coil
- Micro turbulence in the coil because of the fan turbulence resulting in better heat exchange
- Frostbuilding visual
- No condensation on inside of fanplate
- Lower chill factor because lower air velocity

MAIN DIFFERENCE

- **DRAW THROUGH**

- Relatively high air velocity on outlet of the cooler
- Relatively much turbulence because of the fan

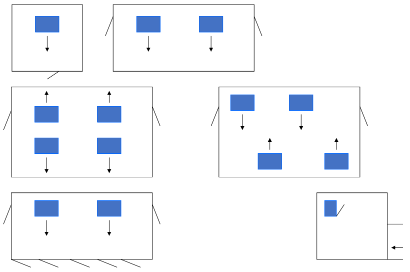
- **BLOW THROUGH**
- Relatively low air velocity on outlet of the cooler
- Relatively less turbulence because of the fan

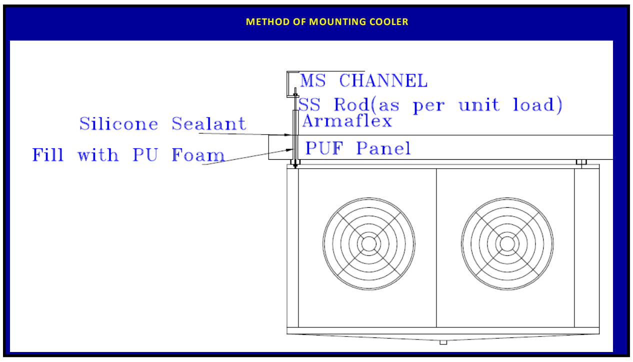
ADVANTAGES AND DISADVANTAGES OF BLOW THROUGH/DRAW THROUGH UNITS

1. Blow through has higher efficiency
2. The air distribution pattern is less effective due to coil resistance
3. Blow through design has lower discharge velocity as entire coil is in the air path.-Throw of 11to 13 m possible
4. For longer discharge and more uniform air distribution draw through design preferred with 33m throw or more.
5. Draw through design uses normally propeller fans
6. Centrifugal or propeller fans can be used for blow through design, depending on depth of coil, fin spacing

ALUMINUM COOLERS

RECOMMENDED COOLER PLACEMENT





METHOD OF MOUNTING COOLER

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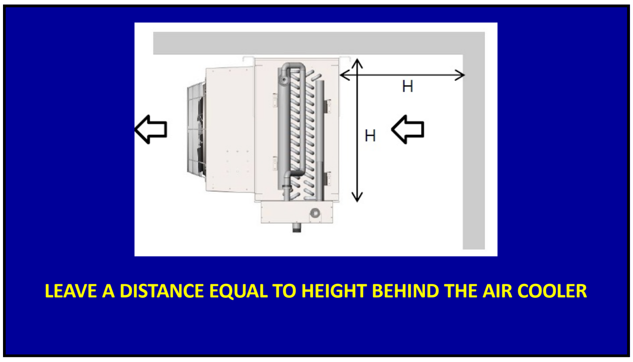


LEAVE A DISTANCE EQUAL TO HEIGHT BEHIND THE AIR COOLER

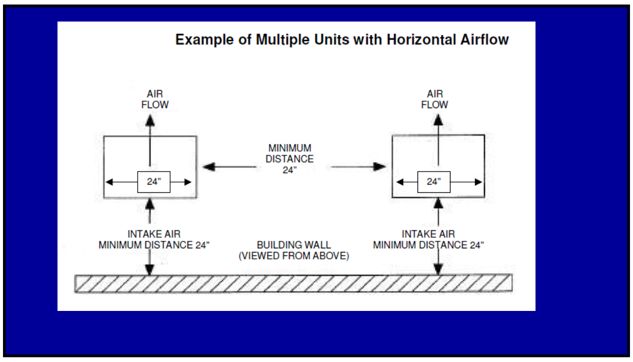
44

CEILING MOUNTED EVAPORATOR

45

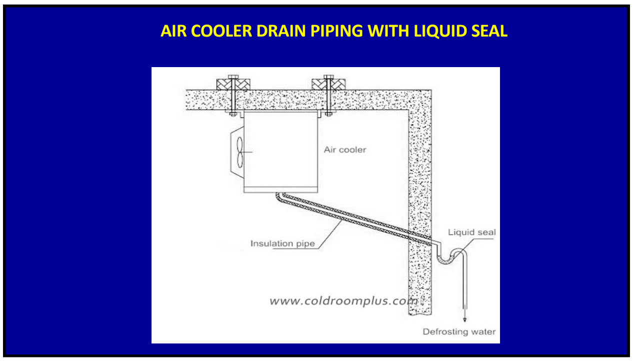
CEILING HUNG EVAPORATOR

46



Example of Multiple Units with Horizontal Airflow

47



AIR COOLER DRAIN PIPING WITH LIQUID SEAL

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AIR COOLER PIPING OUTSIDE THE BUILDING ON TERRACE

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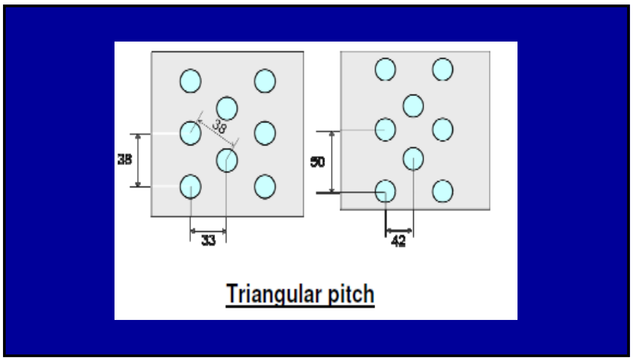
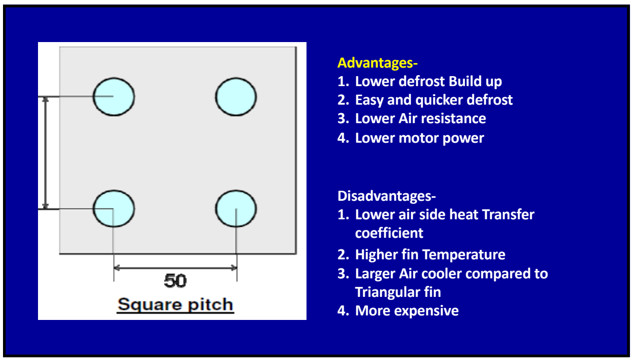


Triangular pitch

50



Square pitch

Advantages-
1. Lower defrost Build up
2. Easy and quicker defrost
3. Lower Air resistance
4. Lower motor power

Disadvantages-
1. Lower air side heat Transfer coefficient
2. Higher fin Temperature
3. Larger Air cooler compared to Triangular fin
4. More expensive

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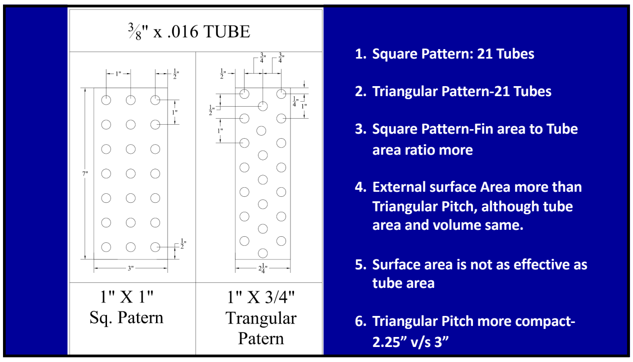
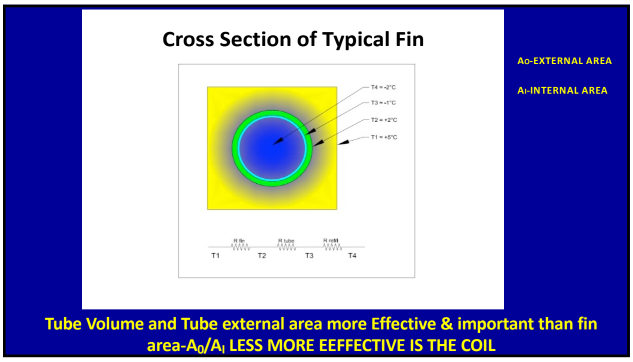


1. Square Pattern: 21 Tubes
2. Triangular Pattern-21 Tubes
3. Square Pattern-Fin area to Tube area ratio more
4. External surface Area more than Triangular Pitch, although tube area and volume same.
5. Surface area is not as effective as tube area
6. Triangular Pitch more compact- 2.25” v/s 3”

52



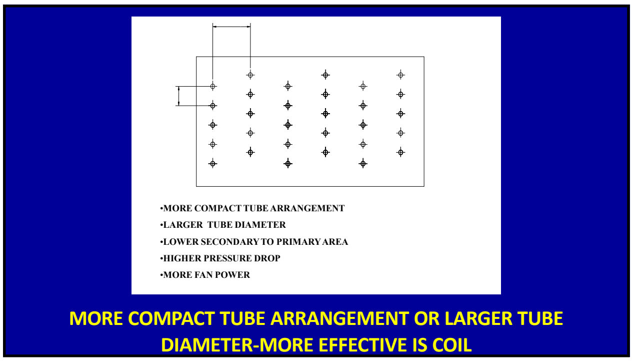
Cross Section of Typical Fin

A_O-EXTERNAL AREA

A_I-INTERNAL AREA

Tube Volume and Tube external area more Effective & important than fin area-A_0/A_I LESS MORE EEFFECTIVE IS THE COIL

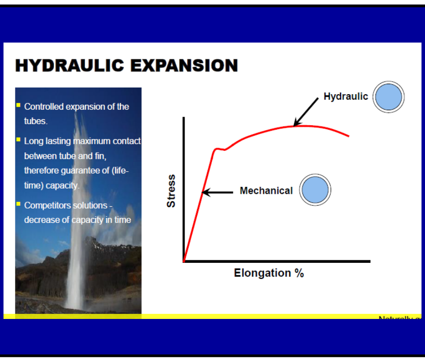
53



- MORE COMPACT TUBE ARRANGEMENT
- LARGER TUBE DIAMETER
- LOWER SECONDARY TO PRIMARY AREA
- HIGHER PRESSURE DROP
- MORE FAN POWER

MORE COMPACT TUBE ARRANGEMENT OR LARGER TUBE DIAMETER-MORE EFFECTIVE IS COIL

54



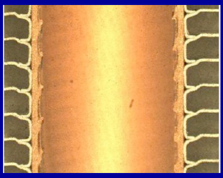
HYDRAULIC EXPANSION

- Controlled expansion of the tubes.
- Long lasting maximum contact between tube and fin, therefore guarantee of (life-time) capacity.
- Competitors solutions - decrease of capacity in time

1. Stainless Steel needs to be elongated beyond its yield point during expansion.
2. If that is done , it does not come to its original shape.
3. As per Kelvion Goedhart , in mechanical expansion this is not achieved.
4. The tubes are subject to thermal stress of low temp during cooling and high temp while defrosting

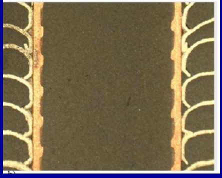
Hence over a period of time the bonding between tubes and fins gets loosened & eventually loosing capacity – in case of mechanical expansion

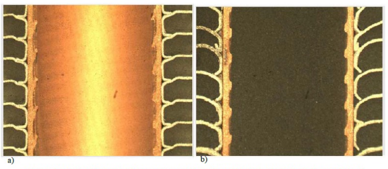
HYDRAULIC EXPANSION-
Better contact



The pressure expansion process provides superior consistency in tube/fin bond

Mechanical expansion



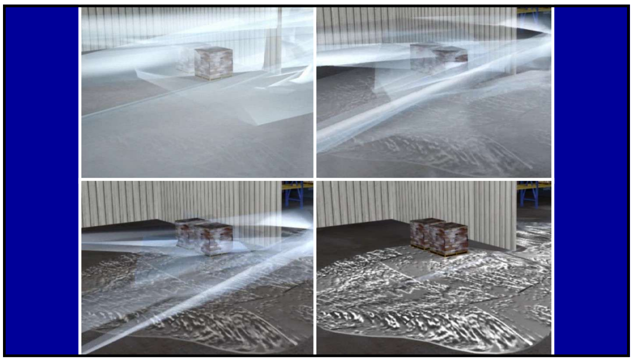


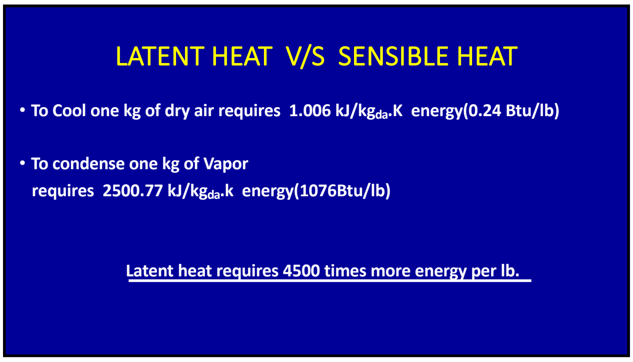
a) b)

Figure 3: a) Tube-Fin Contact for pressure expanded coil; and b) mechanically (bullet) expanded coil

Based on a series of physical measurements, visual inspections, and coil tests, the new pressure expansion method shows significant improvements and potential over more traditional mechanical expansion processes. Measurements of tube diameter show that pressure expanded coils have a more consistent expanded diameter than their mechanicallyexpanded counterparts.

DEFROSTING COILS

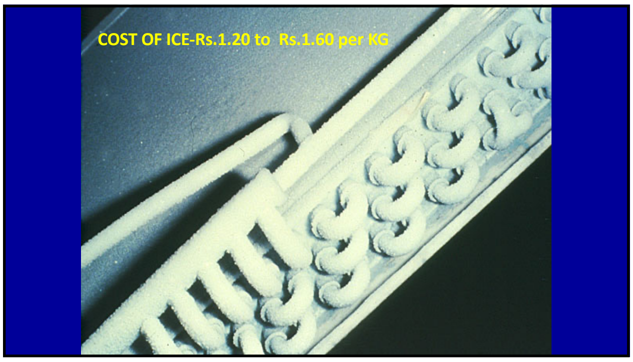




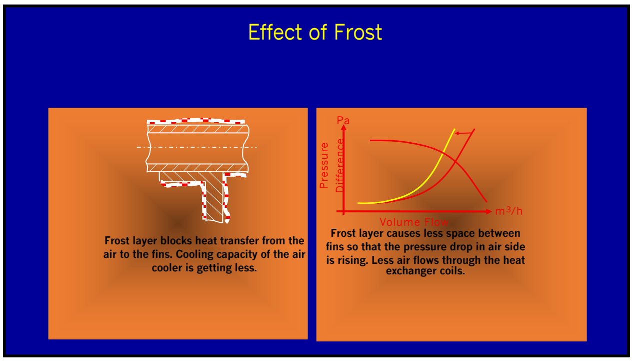
LATENT HEAT V/S SENSIBLE HEAT

- To Cool one kg of dry air requires 1.006 kJ/kg_{da}.K energy(0.24 Btu/lb)
- To condense one kg of Vapor requires 2500.77 kJ/kg_{da}.k energy(1076Btu/lb)

Latent heat requires 4500 times more energy per lb.



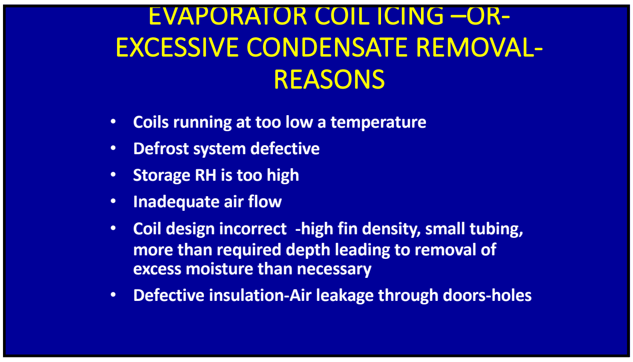
COST OF ICE-Rs.1.20 to Rs.1.60 per KG



Effect of Frost

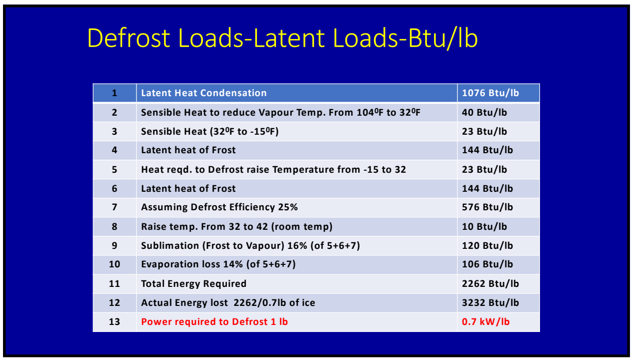
Frost layer blocks heat transfer from the air to the fins. Cooling capacity of the air cooler is getting less.

Frost layer causes less space between fins so that the pressure drop in air side is rising. Less air flows through the heat exchanger coils.



EVAPORATOR COIL ICING –OR- EXCESSIVE CONDENSATE REMOVAL-REASONS

- Coils running at too low a temperature
- Defrost system defective
- Storage RH is too high
- Inadequate air flow
- Coil design incorrect -high fin density, small tubing, more than required depth leading to removal of excess moisture than necessary
- Defective insulation-Air leakage through doors-holes



Defrost Loads-Latent Loads-Btu/lb

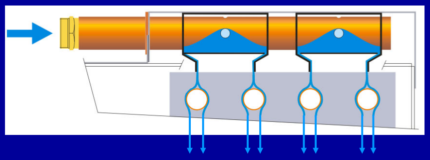
1	Latent Heat Condensation	1076 Btu/lb
2	Sensible Heat to reduce Vapour Temp. From 104⁰F to 32⁰F	40 Btu/lb
3	Sensible Heat (32⁰F to -15⁰F)	23 Btu/lb
4	Latent heat of Frost	144 Btu/lb
5	Heat reqd. to Defrost raise Temperature from -15 to 32	23 Btu/lb
6	Latent heat of Frost	144 Btu/lb
7	Assuming Defrost Efficiency 25%	576 Btu/lb
8	Raise temp. From 32 to 42 (room temp)	10 Btu/lb
9	Sublimation (Frost to Vapour) 16% (of 5+6+7)	120 Btu/lb
10	Evaporation loss 14% (of 5+6+7)	106 Btu/lb
11	Total Energy Required	2262 Btu/lb
12	Actual Energy lost 2262/0.7lb of ice	3232 Btu/lb
13	Power required to Defrost 1 lb	0.7 kW/lb

DEFROST LOADS-LATENT LOADS-BTU/0.7LB FROM COIL

		kWh
1	To produce Frost	0.21 kWh
2	To Defrost Frost	0.09 kWh
3	To remove Defrost Heat	0.16 kWh
4	Total power	0.46 kWh
6	Power required to remove 1 lb of Frost	0.46/0.7=0.66 kWh

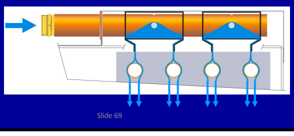
HELPMAN® WATER DEFROST SYSTEM

P_{water} = 0.03 bar



HELPMAN® WATER DEFROST

- Water is lead to gutters, located lengthwise above the cooler coil. One gutter per two tube rows.
- Water distribution openings in the gutter bottom plate ensure an even water distribution over the cooler tubes



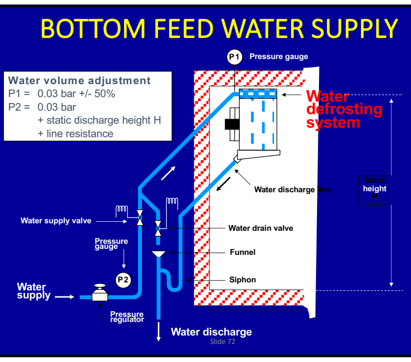
HELPMAN® WATER DEFROST

- Required water flow is 0.6 m^3/h per meter gutter length. This flow will be reached with 0.03 bar water pressure in the distribution line *(+/- 30%, this means a 50% pre-pressure tolerance).*
- If too much water is supplied, part of the water flows to the wrong places and could splash outside the cooler casing. This may affect the defrosting process and will cause solid ice on undesirable locations.

BOTTOM FEED WATER SUPPLY

- Water pressure is reduced by a pressure regulator down to 0.03 bar +/- allowed tolerance.
- After completion of the defrosting process, the water supply line is closed and at the same time the water drain line is opened. When the system is fully drained, the drain line will be closed again.
- The water discharge line is equipped with a siphon (air trap) to avoid freezing of the discharge line where is passes through the cold room wall.

BOTTOM FEED WATER SUPPLY



Water volume adjustment
P1 = 0.03 bar +/- 50%
P2 = 0.03 bar
+ static discharge height H
+ line resistance

TOP FEED WATER SUPPLY

- Water supply is identical to Bottom Feed System.
- During defrost, a part of the added water will be lead to the sewer through the combined overflow drain line to avoid freezing of the pipe section inside the cold room.
- After completion of the drefrosting process, the water supply line is closed and the system will be drained directly using the combined overflow drain line.
- Both discharge lines are equipped with siphons to avoid freezing inside the cold room wall passages.
- An automatic aerator at the top of the pipe alignment is required to enable draining.

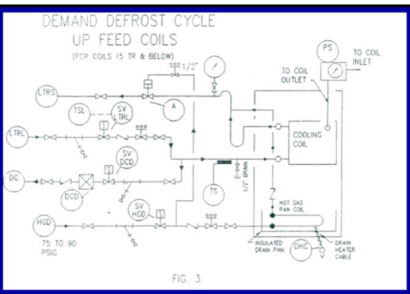


FIG. 3

Demand Defrost Cycle Up Feed Coils

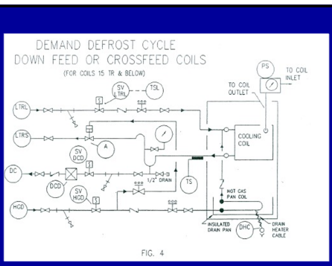


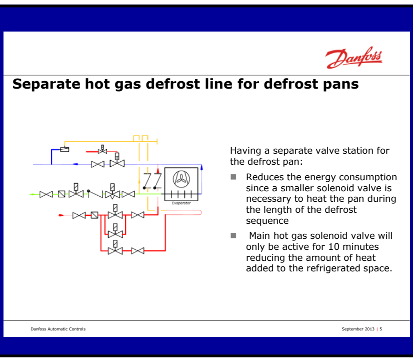
FIG. 4

Demand Defrost Cycle Down Feed Or Cross Feed Coils

SUGGESTED FIN SPACING –RUN TIME-DEFROST FREQUENCY

SHR= S.H./(S.H.+L.H)	Fin Spacing	Design Running Time	Defrost Frequency-Nos. per day
0.65	2	14	9
0.75	3	16	8
0.85	4	16	6
0.95	4	18	2

As sensible Heat increases less defrost Frequency and closer fin spacing



Separate hot gas defrost line for defrost pans

Having a separate valve station for the defrost pan:

- Reduces the energy consumption since a smaller solenoid valve is necessary to heat the pan during the length of the defrost sequence
- Main hot gas solenoid valve will only be active for 10 minutes reducing the amount of heat added to the refrigerated space.

Danfoss Automatic Controls

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AIR COOLER WITH A FLAP WHICH CLOSES DURING DEFROSTING

At normal cooling operation: (shut up i.e. textile opens and defrost flap is open.)

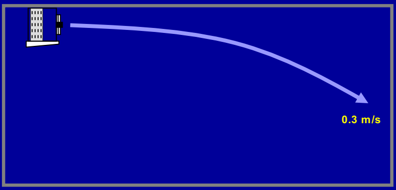
At defrosting operation: (shut up i.e. textile fall down and closes the defrost flap. Therefore, heat (which is generate during defrosting) will not enter into the room. This arrangement help to improve the defrost efficiency and saves energy too.

Above pictures are just for understating.

FAN CLOSING
CLOATH DUCT FLAP,
DURING DEFROST TO
AVOID WARM AIR
COMING TO ROOM

PROPER AIR CIRCULATION- AIR THROW & AIR SPREAD IMPORTANCE

How is Air Throw defined

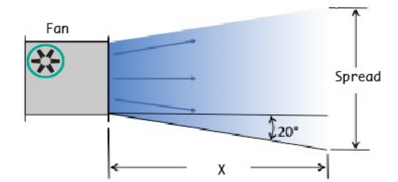


Most sources recommend a theoretical air speed of 0.3 m/s at the end of the room. This is pure theory, however, because any airflow of less than 0.5 m/s is dispersed and becomes impractical to measure.

Calculating the range

Empirical equation: $\text{Air throw} = A \times V_{eo}^2 \times \frac{1.2}{W_s}$

A = Correction factor, pressure/suction (depending on fan type and cooler design)
V_{eo} = Air speed at the evaporator outlet (m/s)
W_s = specific weight of the air

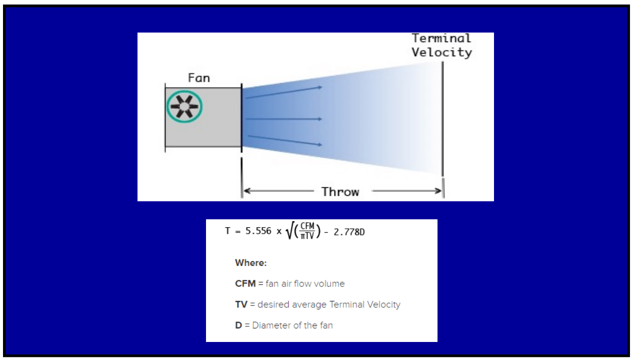


$S = D + .36X$

Where:

D = Diameter of the fan

X = Distance from the fan outlet



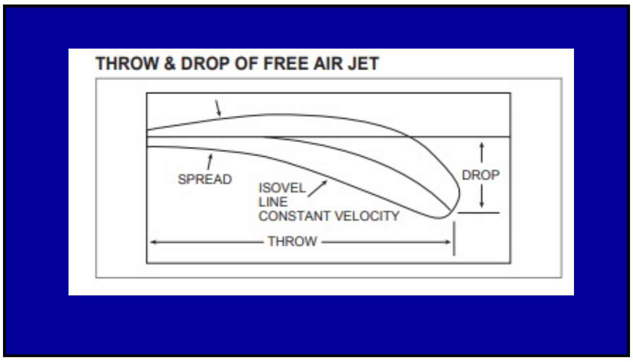
$$T = 5.556 \times \sqrt{\left(\frac{CFM}{\pi TV}\right)} - 2.778D$$

Where:

CFM = fan air flow volume

TV = desired average Terminal Velocity

D = Diameter of the fan



THROW & DROP OF FREE AIR JET

AIR DISTRIBUTION BASICS

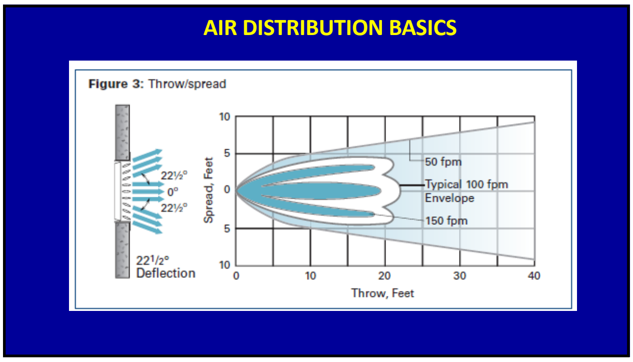
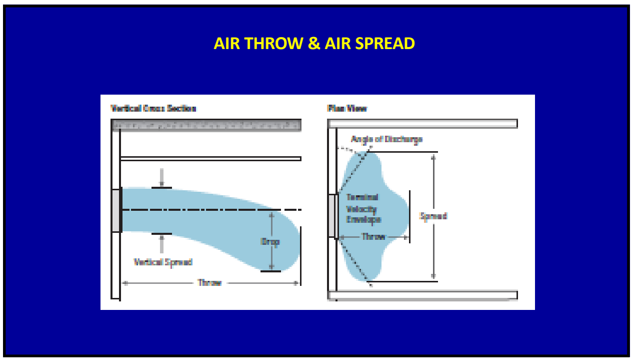
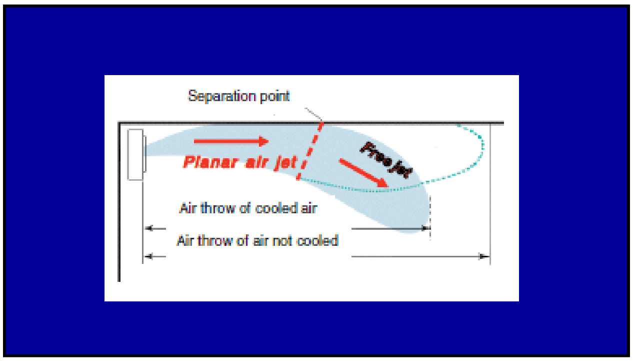


Figure 3: Throw/spread

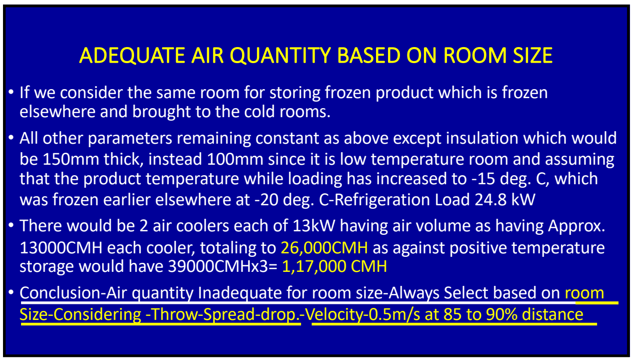
AIR THROW & AIR SPREAD





STANDARD POTATO COLD STORAGE-2000MT

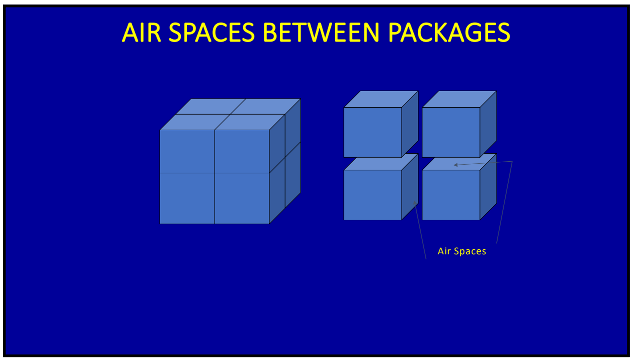
- Chamber Size each -21m Lx16m Wx13.7m H Volume 4603 m^3, floor Area=226 m^2
- (Refrigeration load -85.32kW)-NHB DOCUMENT
- In each room normally there would be three air cooler units, each of 33kW, and air quantity of each is approx.39000 CMH, for 3 coolers it would be 1,17,000 CMH



ADEQUATE AIR QUANTITY BASED ON ROOM SIZE

- If we consider the same room for storing frozen product which is frozen elsewhere and brought to the cold rooms.
- All other parameters remaining constant as above except insulation which would be 150mm thick, instead 100mm since it is low temperature room and assuming that the product temperature while loading has increased to -15 deg. C, which was frozen earlier elsewhere at -20 deg. C-Refrigeration Load 24.8 kW
- There would be 2 air coolers each of 13kW having air volume as having Approx. 13000CMH each cooler, totaling to 26,000CMH as against positive temperature storage would have 39000CMHx3= 1,17,000 CMH
- Conclusion-Air quantity Inadequate for room size-Always Select based on room Size-Considering -Throw-Spread-drop.-Velocity-0.5m/s at 85 to 90% distance

AIR SPACES BETWEEN PACKAGES

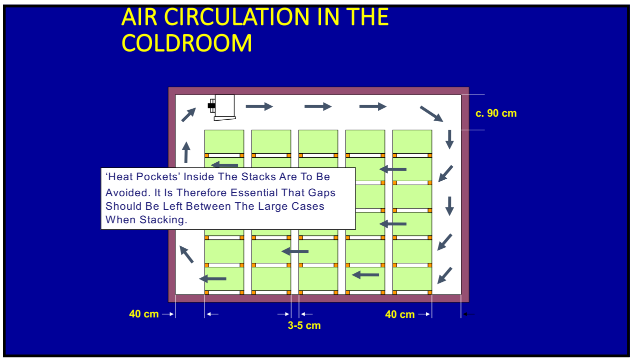


INCORRECT USE OF SPACE

Product stacked haphazardly in aisles due to a lack of suitable racking space.

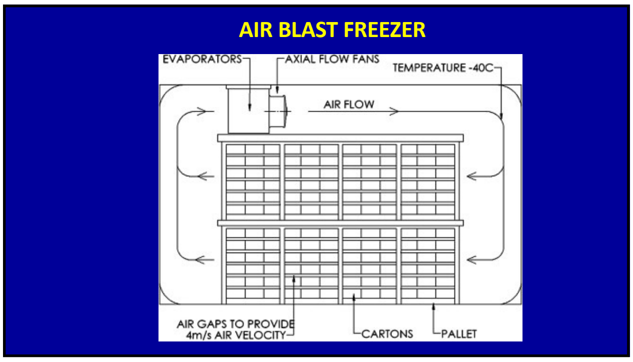
NO PROPER AIR CIRCULATION ON PRODUCT

AIR CIRCULATION IN THE COLDROOM

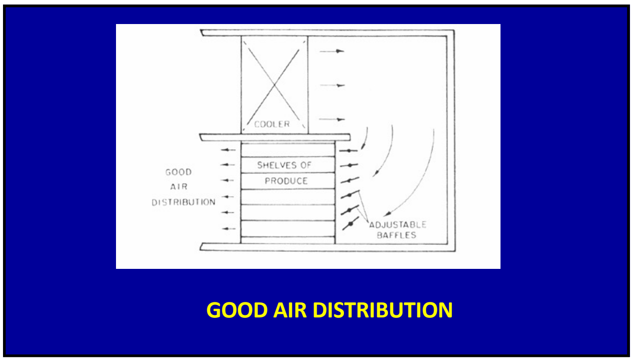


'Heat Pockets' Inside The Stacks Are To Be Avoided. It Is Therefore Essential That Gaps Should Be Left Between The Large Cases When Stacking.

AIR BLAST FREEZER



AIR BLAST FREEZER



GOOD AIR DISTRIBUTION

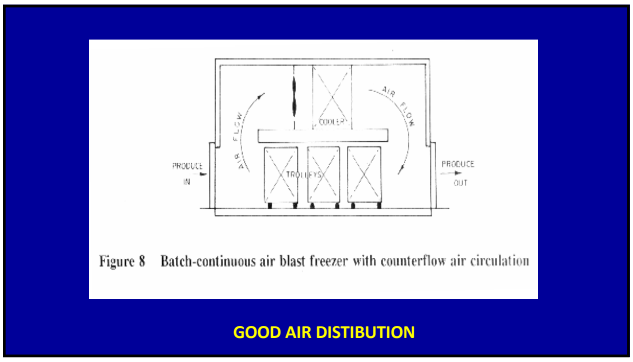
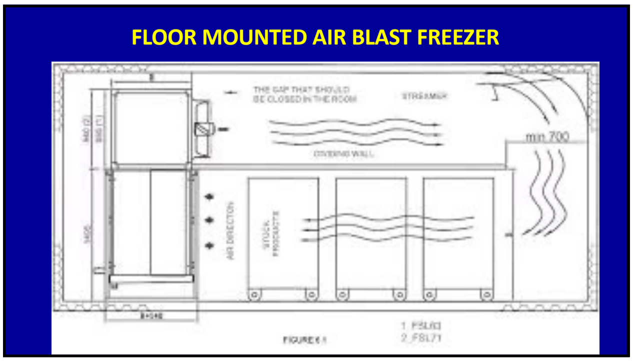


Figure 8 Batch-continuous air blast freezer with counterflow air circulation

GOOD AIR DISTIBUTION



FLOOR MOUNTED AIR BLAST FREEZER

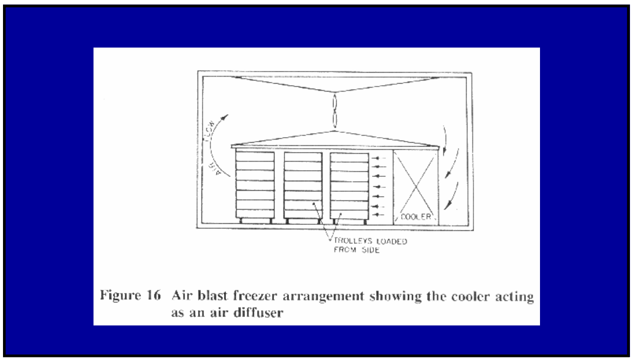
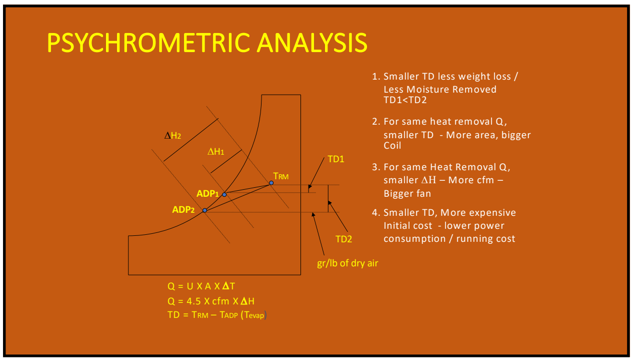


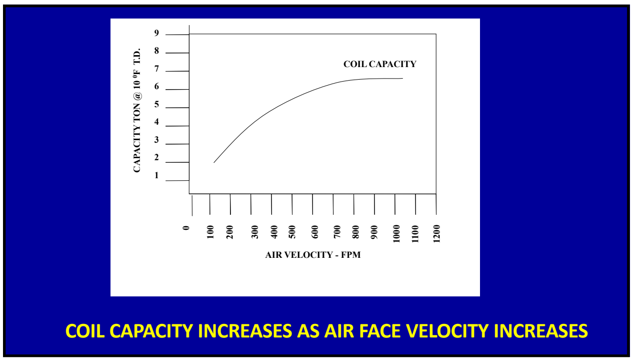
Figure 16 Air blast freezer arrangement showing the cooler acting as an air diffuser



PSYCHROMETRIC ANALYSIS

1. Smaller TD less weight loss / Less Moisture Removed TD1<TD2
2. For same heat removal Q, smaller TD - More area, bigger Coil
3. For same Heat Removal Q, smaller ΔH – More cfm – Bigger fan
4. Smaller TD, More expensive Initial cost - lower power consumption / running cost

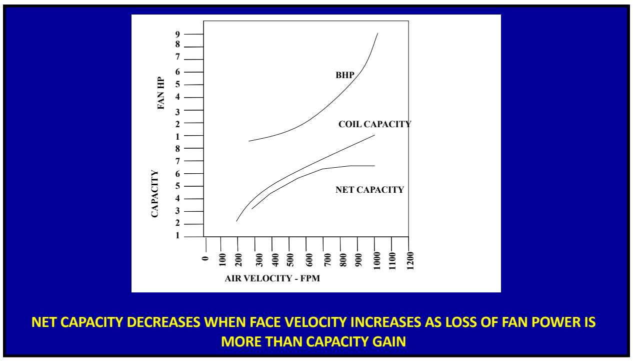
$Q = U \times A \times \Delta T$
$Q = 4.5 \times cfm \times \Delta H$
$TD = T_{RM} - T_{ADP}\ (T_{evap})$



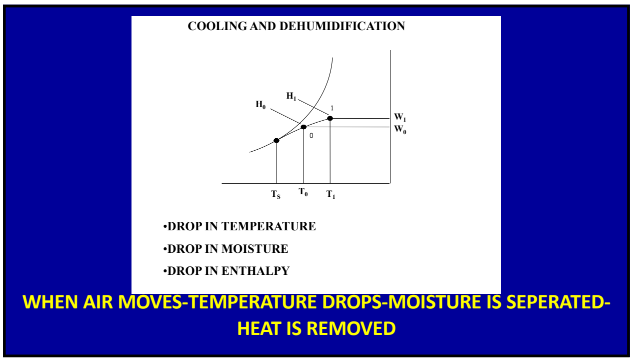
COIL CAPACITY INCREASES AS AIR FACE VELOCITY INCREASES

FAN LAWS

1. Volume flow:- $q_{v2} = q_{v1} \times \left(\frac{n_2}{n_1}\right)^1 \times \left(\frac{d_2}{d_1}\right)^3$
2. Pressure:- $p_2 = p_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{d_2}{d_1}\right)^2 \times \left(\frac{\rho_2}{\rho_1}\right)^1$
3. Absorbed power:- $P_{R2} = P_{R1} \times \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{d_2}{d_1}\right)^5 \times \left(\frac{\rho_2}{\rho_1}\right)^1$



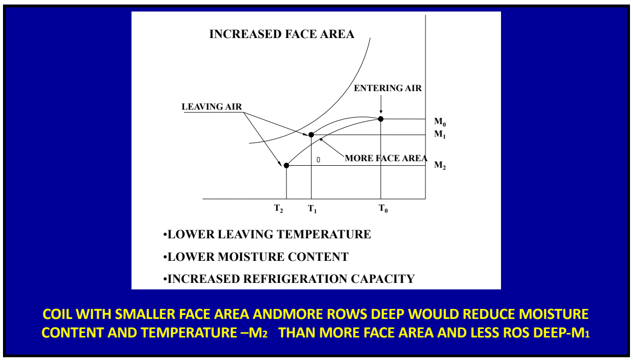
NET CAPACITY DECREASES WHEN FACE VELOCITY INCREASES AS LOSS OF FAN POWER IS MORE THAN CAPACITY GAIN



COOLING AND DEHUMIDIFICATION

- DROP IN TEMPERATURE
- DROP IN MOISTURE
- DROP IN ENTHALPY

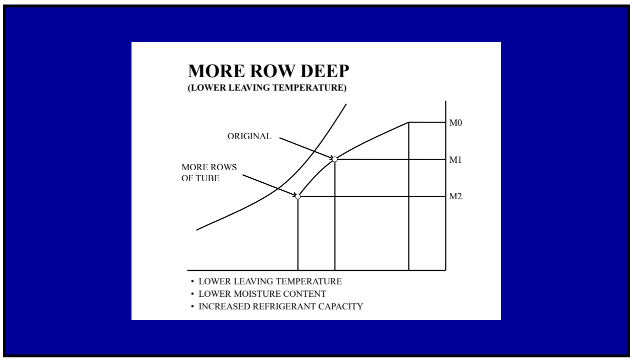
WHEN AIR MOVES-TEMPERATURE DROPS-MOISTURE IS SEPERATED-HEAT IS REMOVED



INCREASED FACE AREA

- LOWER LEAVING TEMPERATURE
- LOWER MOISTURE CONTENT
- INCREASED REFRIGERATION CAPACITY

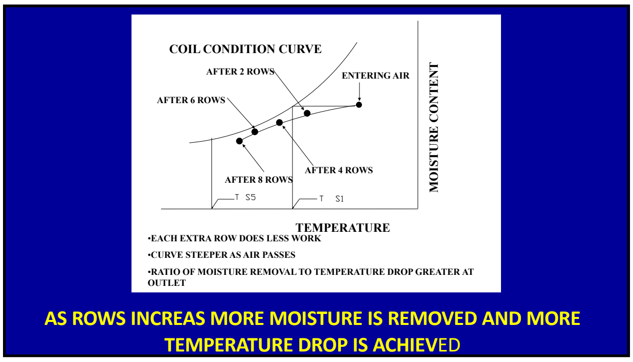
COIL WITH SMALLER FACE AREA ANDMORE ROWS DEEP WOULD REDUCE MOISTURE CONTENT AND TEMPERATURE –M_2 THAN MORE FACE AREA AND LESS ROS DEEP-M_1



MORE ROW DEEP

(LOWER LEAVING TEMPERATURE)

- LOWER LEAVING TEMPERATURE
- LOWER MOISTURE CONTENT
- INCREASED REFRIGERANT CAPACITY



- EACH EXTRA ROW DOES LESS WORK
- CURVE STEEPER AS AIR PASSES
- RATIO OF MOISTURE REMOVAL TO TEMPERATURE DROP GREATER AT OUTLET

AS ROWS INCREAS MORE MOISTURE IS REMOVED AND MORE TEMPERATURE DROP IS ACHIEVED

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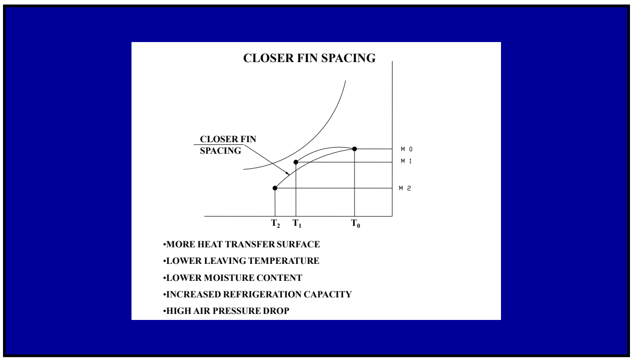

- MORE HEAT TRANSFER SURFACE
- LOWER LEAVING TEMPERATURE
- LOWER MOISTURE CONTENT
- INCREASED REFRIGERATION CAPACITY
- HIGH AIR PRESSURE DROP

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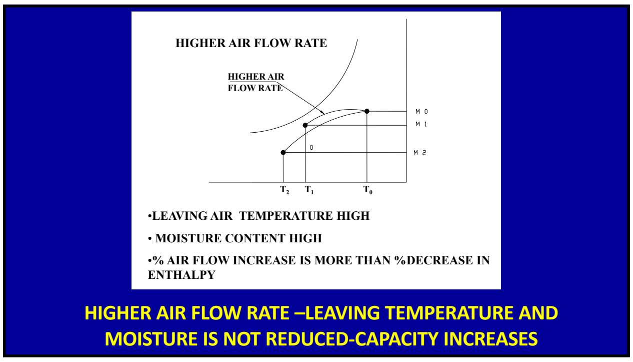

- LEAVING AIR TEMPERATURE HIGH
- MOISTURE CONTENT HIGH
- % AIR FLOW INCREASE IS MORE THAN %DECREASE IN ENTHALPY

HIGHER AIR FLOW RATE –LEAVING TEMPERATURE AND MOISTURE IS NOT REDUCED-CAPACITY INCREASES

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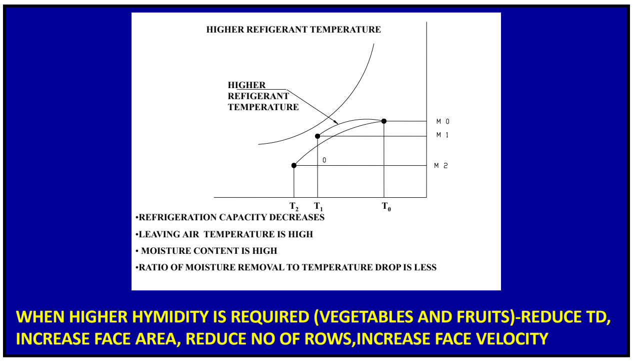

- REFRIGERATION CAPACITY DECREASES
- LEAVING AIR TEMPERATURE IS HIGH
- MOISTURE CONTENT IS HIGH
- RATIO OF MOISTURE REMOVAL TO TEMPERATURE DROP IS LESS

WHEN HIGHER HYMIDITY IS REQUIRED (VEGETABLES AND FRUITS)-REDUCE TD, INCREASE FACE AREA, REDUCE NO OF ROWS,INCREASE FACE VELOCITY

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QUESTIONS?
Ramesh Paranjpey
Fellow Life member ASHRAE
Cell No.+9120-9822398220
Mail: Ramesh.paranjpey@gmail.com
Web:http://ramesh-paranjpey.com

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