DEFROSTING

BY
Ramesh Paranjpey
Fellow Life member ASHRAE/ISHRAE
Website: http://ramesh-paranjpey.com
Mail Id: ramesh.paranjpey@gmail.com
Cell : +9198223 98220

1

DEFROSTING-VARIOUS MEHHODS

Many Industrial Refrigeration Systems require “Defrost”. It is paramount to both proper system function and regulating energy efficient operation to ensure Defrost Cycles operate properly.

There are different types of “Defrosts” depending on the system’s Product Load, Operating Characteristics, and Equipment. Different “Defrost” methods have unique “Pros and Cons” to be considered when selecting equipment and/or operating a system.

2

DEFROSTING-WHEN?

The evaporator surface cools, water in the cold room attracts moisture from the air. This moisture settles & condenses on the evaporator surface, and when the surface temperature is below 0^{0}C frost is formed & needs to be removed.

3

WHY DEFROSTING IS ESSENTIAL?

1. Evaporator performance deteriorates, as frost acts as resistance to heat flow
2. Increases pressure drop across the coil, leads to higher fan power
3. If frost is not removed, evaporator becomes ineffective leading to compressor damage, due to unevaporated liquid returning to compressor
4. Fan blade gets damaged
5. Leaks in coil can develop
6. From drain pan water will spill over on the product
7. Cold room temperature is not maintained leading to product spoiling
8. Leads to lower evaporating temperature, lower C.O.P. value for the installation in general, means increasing power consumption
9. ‘Snowing’ as the result of excessively high air speeds through the coil block

4

EVAPORATOR COIL ICING –OR-EXCESSIVE CONDENSATE REMOVAL-REASONS

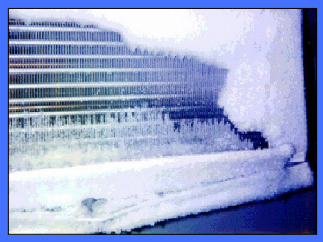
- Coils running at too low a temperature
- Defrost system defective
- Storage RH is too high
- Inadequate air flow
- Coil design incorrect -high fin density, small tubing, more than required depth
- Defective insulation-Air leakage through doors-holes

5

HEAVILY FROSTED COIL



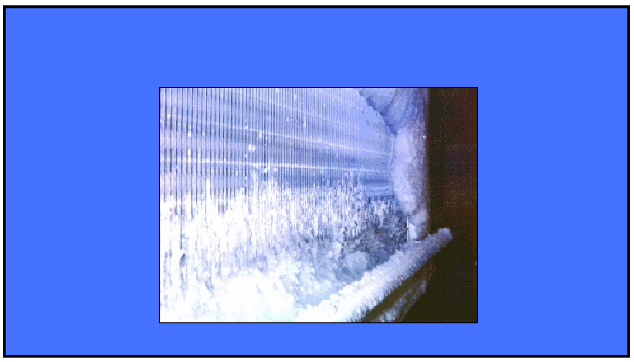
6



7



8

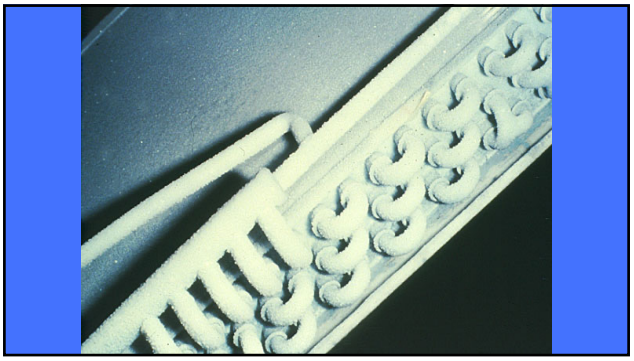


9

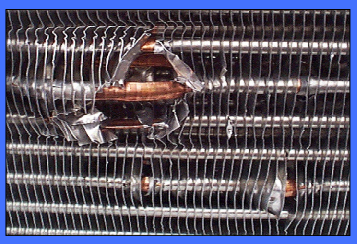
NO DEFROST FOR PLATE FREEZER



10



11



12



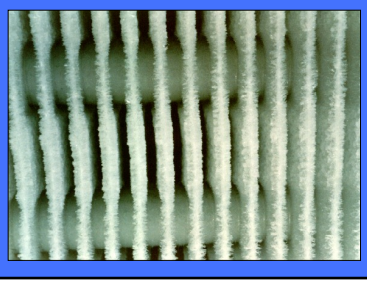
13



14

COIL FROST

- Frost building
- Defrost systems



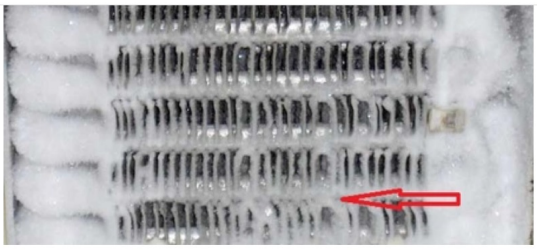
15

COST OF ICE-Rs.12.0 to Rs.16.0 per KG



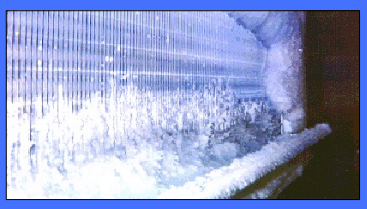
16

COIL DAMAGE –DUE TO ICE BUILD UP



17

ICE BUILD UP IN DRAIN PAN



The drain in the drain pan carries melting ice from the coil to the sewer, and this drain line can get clogged, causing water to pool and freeze in the drain pan forming ice, sometime even ice slab.

18

DEFROSTING

- Defrosting as the name suggests should be activated when frost is formed and do not wait till ice is formed on the coil surface
- .
- The total energy required to form the ice and defrost it again is estimated to be nearly **1.5 kW/Kg** of ice (IIAR condenser magazine May 2010 issue).
- One can thus estimate, based on condensate water amount collected as to how much extra energy and money one is spending.

19

DEFROSTING PHASES

1. Heating up of coil & frost
2. Melting of frost
3. Further heating of coil & water dripping/removal of frost from the coil

20

DEFROSTING LOAD

Energy required to produce one lb. of frost/ice on the coil in BTU	
Latent heat of condensation	1076
Sensible heat to reduce vapour from 42^{0}F room to 32^{0}F	10
Sensible heat of frost (32^{0}F to-15^{0}F)	23
Latent heat of frost/ice	144
Total BTU to produce 1Lb. frost	1253

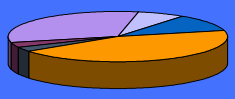
21

DEFROSTING LOAD

Heat required to defrost One Lb. frost/ice on coil in BTU		
Raise frost from -15^{0}F to 32^{0}F temperature	24	
Latent heat of frost	144	
Inefficiency of defrost (20%) (144x4)	576	
Raise water temperature from 32^{0}F to 42^{0}F	10	
SUB TOTAL		754
Sublimation (generally 16%)-0.16x754	121	
Evaporation (generally 14%) o.14x754	106	
Sub Total		227
Total defrost heat required		981
Total heat required to from 1 Lb. of frost and defrost	981+1253	2244 BTU(0.66kW)
Cost in Rupees@ 8Rs per kWh		Rs 5.28 per hr.

22

DEFROST ENERGY DISTRIBUTION



Refrigerant evaporation (3%)
Energy loss to cold room (32%)
Temperature rise cooler (7%)
Heating of frost (3%)
Melting down of frost (44%)
Temperature rise of melting water (11%)

23

DEFROSTING SYSTEMS

1. Off cycle- air Defrost method
2. Electric defrost systems
3. Water defrost systems
4. Hot gas defrost systems
5. Reverse cycle defrost
6. (Hot air/ & brine defrost-rarely used)

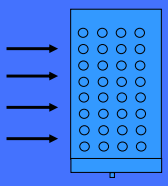
24

WHEN TO USE FORCED AIR CIRCULATION DEFROST ?

1. Room temperatures above 0 °C
2. Evaporating temperatures up to -4 °C maximum
3. Mostly small cold rooms for meat and agricultural produce

25

FORCED AIR CIRCULATION SYSTEMS-OFF CYCLE DEFROST



- $P_{forced\ air} = P_{fan\ motor}$
- defrost efficiency $\eta = Q_{melting\ water} / Q_{fan}$

26

OFF CYCLE -AIR DEFROST

1. The evaporator coils can be defrosted by simply turning off the refrigerant flow to the evaporator & pump out the liquid from the coil
2. Maintaining fans running and allowing room air to pass over the evaporator, thus melting of frost.
3. Drainage of melted water
4. It is of lowest cost and requires no additional controls or energy.
5. Can be used for positive temperature cold rooms as well as for blast freezers where loading/unloading of next batch allows enough time

27

ADVANTAGES-FORCED AIR CIRCULATION SYSTEMS

1. Requires only fan energy
2. No extra investments
3. Low surface temperatures
4. Control can be easily integrated into the cooling process
5. Melting energy is taken from the available air in the cold room, thus generating extra cold air.

28

DISADVANTAGES-FORCED AIR CIRCULATION SYSTEMS

1. Relatively long defrost periods.Slow process
2. Generally suitable for cold room temperatures above 0 °C
3. This method also does not help in removing accumulated oil in the cooler.

29

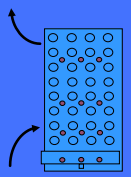
WHEN TO USE ELECTRIC DEFROST ?

1. No hot gas available

2. Forced air circulation not possible

30

ELECTRIC DEFROST



- $P_{elec} = V \times I = I^2 \times R$
- Defrost efficiency
- $\eta = Q_{melting\ water} / Q_{elec}$

31

ELECTRIC DEFROST

This is one of the popular methods for small size air coolers particularly for HFC/HCFC refrigerants.

The method can be applied to any cold room application operating at any temperature.

While manufacturing and assembling of coils; the dummy tubes are inserted in the coil blocks in a particular pattern and these tubes contain electrical heating elements.

32

ELECTRIC DEFROST DESIGN FEATURES

1. Contact between defrost heaters and fins & not tubes
2. Distribution of defrost heater elements
3. Drainage of melting water
4. Durability of heater elements
5. Defrost power
6. Surface temperatures
7. Temperature expansion of coil block

33

ADVANTAGES ELECTRIC DEFROST

1. Relatively low investments compared to hot gas defrost
2. Defrost system control is easy to integrate within the cooling process
3. Reliable
4. Breakdowns can be solved with relative ease
5. It does not interfere with the refrigerant circuit, and chances of liquid coming to compressor or hydraulic hammer are eliminated

34

DISADVANTAGES ELECTRIC DEFROST

1. Relatively long defrost periods
2. Use of expensive electric energy-Total power consumption goes up as many heater elements are required per coil block
3. Relatively low energetic yield
4. Relatively high surface temperatures
5. In general, for a cooler of 30 to 40 kW capacity, one requires heaters of nearly 18 kW including drain pan heating and if defrost is done 4 times a day for 30 minutes each cycle then the cost of defrosting alone is **36kWhxRs.8.0/kWh=290** Rupees/day or 8990Rs/per cooler per month.
6. High maintenance due to frequent failure of resistance heating elements & replacement of burnt heaters is also a tedious job.

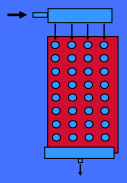
35

WHEN TO USE WATER DEFROST ?

1. Room temperature during defrost above 0 ^{o}C
2. Extended defrost periods are no problem
3. There are only small, open structured frost quantities
4. Mostly for installations with long cooling cycles

36

WATER DEFROST SYSTEMS



- $P_{water} = P_{pump}$

37

WATER DEFROST DESIGN FEATURES

1. Water distribution and water volumes over the coil block
2. Preventing splashing on and around the cooler
3. Drainage of melting water
4. Fouling due to water distribution system

38

ADVANTAGES WATER DEFROST

1. Requires only pump energy and sufficient water volume
2. Possibility to wash/ clean the coil surface
3. Low surface temperatures

39

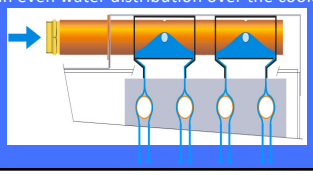
DISADVANTAGES WATER DEFROST

1. Relatively high investments
2. Relatively difficult to control
3. Extra attention is to be paid for cold room temperatures below 0 Deg.C

40

HELPMAN WATER DEFROST SYSTEM

- 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.



41

HELPMAN® WATER DEFROST

1. Required water flow is **0.6 m^3/h** per meter gutter length.
2. This flow will be reached with **0.03 bar** water pressure in the distribution line
3. 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.

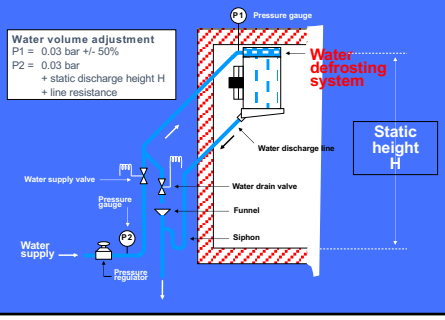
42

BOTTOM FEED WATER SUPPLY

1. Water pressure is reduced by a pressure regulator down to **0.03 bar +/-** allowed tolerance.
2. After completion of the defrosting process, the water supply line is closed and at the same time the drain line is opened. When the system is fully drained, the drain line will be closed again.
3. 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.

43

BOTTOM FEED WATER SUPPLY



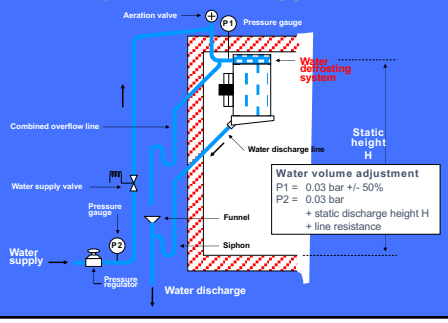
44

TOP FEED WATER SUPPLY

1. Water supply is identical to Bottom Feed System.
2. 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.
3. 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.
4. Both discharge lines are equipped with siphons to avoid freezing inside the cold room wall passages.
5. An automatic aerator at the top of the pipe alignment is required to enable draining.

45

TOP FEED WATER SUPPLY



46

HOT GAS DEFROST

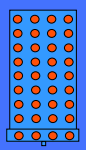
47

WHEN TO USE HOT GAS DEFROST ?

1. Forced air circulation not possible
2. Hot gas is available
3. Fast and even defrosting is required
4. Usually larger cooling systems with more than one cooler
5. (Heat pumps)

48

HOT GAS DEFROST SYSTEMS



- $P_{hot\ gas} = \phi_m \times \Delta h$
- Defrost efficiency

  $\eta = Q_{melting\ water} / Q_{hot\ gas}$

49

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

50

HOT GAS DEFROST

1. Hot gas defrost is the best alternative as heat source acts from within where as water/electrical defrost heat source is from outside.
2. During hot gas defrost cycle, evaporator acts as condenser giving up the heat and converting gas to liquid

51

HOT GAS DEFROST

1. Pressure around:4 to 5 bar
2. Defrost temp.: 12 10 13 ^{0}C [latent heat important]
3. Higher temperature: Lower latent heat more refrigeration quantity

   22 ^{0}C – 1178.22 kJ / kg

   5 ^{0}C – 1244.17 kJ / kg

   If 22 ^{0}C hot gas, means 5 % more quantity

52

HOT GAS DEFROST CONTD.

4. Return Defrost drain of intermediate vessel

53

HOT GAS DEFROST

1. The basic procedure in hot gas defrost method is to interrupt the supply of liquid refrigerant to evaporator, pump out the liquid to empty the evaporator, restrict the outlet by closing the valve, supply hot gas at high pressure to melt surface frost/ice formation.

2. During the operation the heat from hot gas is absorbed by the metal in the coil/plate and its temperature rises. Once the temperature is high enough, ice/frost on the surface melts and is drained off.

54

HOT GAS DEFROST SYSTEMS

5. At lower defrost pressures the defrosting takes slightly longer time say 20 to 30 minutes. However, with slightly extended defrost times at lower temperature, the overall defrost efficiency is much better than at higher temperature/pressures due to reduction of refrigeration requirements

6. If the temperature of hot gas is too high, the tendency of Tubes/plates is to steam. It also adds to refrigeration load.

7. Out of the total heat supplied by the hot gas, nearly 50% is used for heating the tube metal and balance 50% or even more is lost to space surrounding tubes/plates since the temperature of surrounding air is much lower than temperature of the unit.

.

55

HOT GAS DEFROST

8. Warmer temperatures will not necessarily improve defrost efficiency. This is because most of the defrost heat comes from latent heat of hot gas, rather than sensible heat. Following table will make the matter clearer: Ideal defrosting pressure should **be 6 to 7kg/cm2 maximum**

Temperature	Pressure	Latent heat
40^0F (4^0C)	58psig (4bar)	536 Btu/lb (1240kJ/kg)
50^0F (10^0C)	74psig (5bar)	527 Btu/lb (1220 kJ/kg)
60^0F (16^0C)	92psig (6bar)	518 Btu/lb (1200 kJ/kg)
70^0F (21^0C)	114psig (8bar)	508Btu/lb(1180kJ/kg)

From the above it can be seen that 70^0F (21^0C) defrost temperature would actually require 5% more hot gas than 40^0F (4^0C) to provide the same latent heat content.

56

HOT GAS DEFROST SYSTEMS

9.At lower defrost pressures the defrosting takes slightly longer time say 20 to 30 minutes. However, with slightly extended defrost times at lower temperature, the overall defrost efficiency is much better than at higher temperature/pressures due to reduction of refrigeration requirements.

10. A pressure regulator in the plant room is required to be installed on the hot gas defrost pipe **set at 6 to7 kg/cm2 max outlet pressure.**

11. Another advantage of this lower pressure is less liquid would condense in hot gas line

12. It should be remembered that at the most only 1/3 of all evaporators/freezers can be defrosted at a time to ensure availability of adequate hot gas for defrost generated due to load on other 2/3 working coolers/freezers. If only one or two coolers are operating and if one of it needs defrost then hot gas defrost system will not work as not enough hot gas is available for defrost.

57

HOT GAS DEFROST SYSTEM

1. **Pump out operation-** One should try to remove the liquid totally from evaporator before hot gas is admitted. Once this is done heat from hot gas is then applied directly to the frost instead being wasted in warming left over liquid refrigerant, besides creating damaging liquid hammer and pressure shocks.

2. **The soft hot gas defrost system-SDS-** It is designed to gradually increase the coil pressure as the defrost cycle is initiated. This is done by using small hot gas feed with 25 to 30% of the duty with solenoid valve and hand expansion valve adjusted to bring pressure up to 30 to 40 psig with in 3 to 5 minutes, before the main defrost valve opens.

58

HOT GAS DEFROST LINE SIZING

1. Hot gas pipe line sizing should be done to **3 times** the working capacity. It means for installation having 3 nos. 70 kW coolers each, the hot gas defrost line should be sized for 70x3=210 kW (50mm)

2. The main header from machine room to the production area should be sized for 2x70x3= 420 kW (80mm)

3. Defrost condensate return line from freezer should be sized one size higher than liquid supply line as this condensate line may contain return hot gas in addition to condensed liquid.

59

HOT GAS DEFROST LINE SIZES-IIAR Bulletin T163

Capacity Tons/kW	Line Size
8TR (28kW)	1" -(25mm)
20TR (70kW)	1-1/4" –(32mm)
30TR (105kW)	1-1/2"- (40mm)
58TR (200kW)	2" (50mm)
92TR (325kW)	2-1/2" 62.5mm
162TR (570kW)	3" (80mm)
328TR (1150kW)	4" (100mm)
594TR (2100kW)	5" (125m)
970TR (3400kW)	6" (150mm)

60

HOT GAS DEFROST

It is also necessary to Keep the defrost gas mains free of liquid- A condensate drainer needs to be installed to drain trapped condensed liquid in the hot gas defrost line. The hot gas tends to continuously condense during cold climate conditions if the pipe is running outside the building or in the cold space in processing areas. The liquid formed must be drained to low pressure liquid line or vessel. The defrost relief regulator setting or OFV setting should be around **5.0barg.**

61

DEFROSTING CONTROL SYSTEMS

1. Regulating defrost system
2. Positioning of temperature indicator(s)
3. Positioning of frost layer thickness indicator
4. Positioning Differential pressure switches befor and after the coil
5. Defrost time setup

62

ADVANTAGES HOT GAS DEFROST

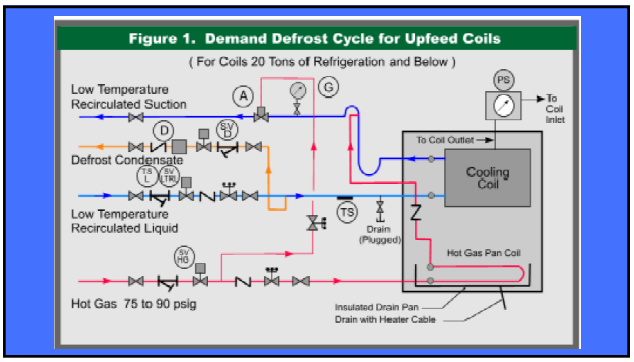
1. Relatively short defrost periods
2. Energy 'for free'
3. Reliable
4. Relatively low surface temperatures

63

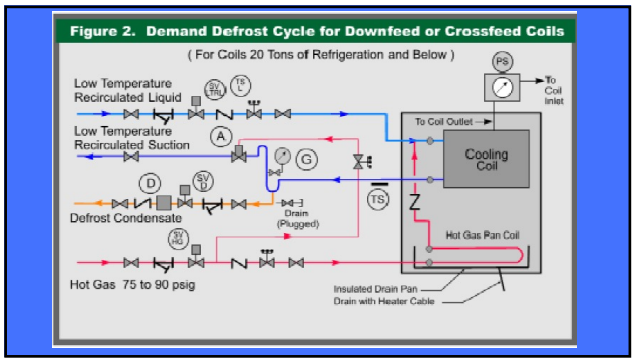
DISADVANTAGES HOT GAS DEFROST

1. Relatively high investments
2. Relatively difficult to integrate within the cooling process
3. Mostly for larger installation with more than one air cooler

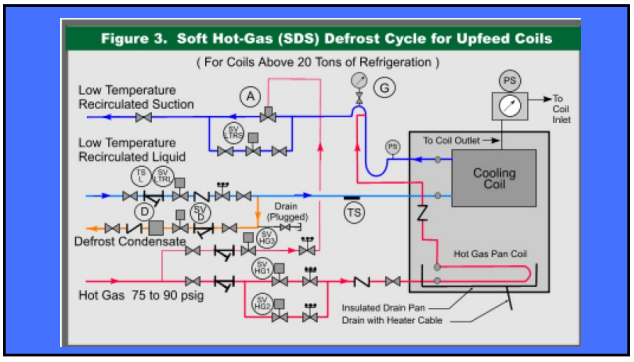
64


Figure 1. Demand Defrost Cycle for Upfeed Coils
(For Coils 20 Tons of Refrigeration and Below)
Low Temperature Recirculated Suction
Defrost Condensate
Low Temperature Recirculated Liquid
Hot Gas 75 to 90 psig
To Coil Outlet
Cooling Coil
Hot Gas Pan Coil
Drain (Plugged)
Insulated Drain Pan
Drain with Heater Cable
To Coil Inlet

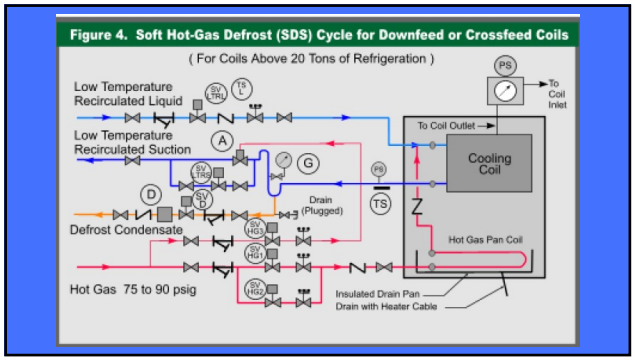
65


Figure 2. Demand Defrost Cycle for Downfeed or Crossfeed Coils
(For Coils 20 Tons of Refrigeration and Below)
Low Temperature Recirculated Liquid
Low Temperature Recirculated Suction
Defrost Condensate
Hot Gas 75 to 90 psig
To Coil Outlet
Cooling Coil
Hot Gas Pan Coil
Drain (Plugged)
Insulated Drain Pan
Drain with Heater Cable
To Coil Inlet

66

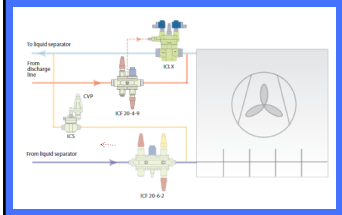

Figure 3. Soft Hot-Gas (SDS) Defrost Cycle for Upfeed Coils
(For Coils Above 20 Tons of Refrigeration)
Low Temperature Recirculated Suction
Low Temperature Recirculated Liquid
Defrost Condensate
Hot Gas 75 to 90 psig
To Coil Outlet
Cooling Coil
Hot Gas Pan Coil
Drain (Plugged)
Insulated Drain Pan
Drain with Heater Cable
To Coil Inlet

67


Figure 4. Soft Hot-Gas Defrost (SDS) Cycle for Downfeed or Crossfeed Coils
(For Coils Above 20 Tons of Refrigeration)
Low Temperature Recirculated Liquid
Low Temperature Recirculated Suction
Defrost Condensate
Hot Gas 75 to 90 psig
To Coil Outlet
Cooling Coil
Hot Gas Pan Coil
Drain (Plugged)
Insulated Drain Pan
Drain with Heater Cable
To Coil Inlet

68

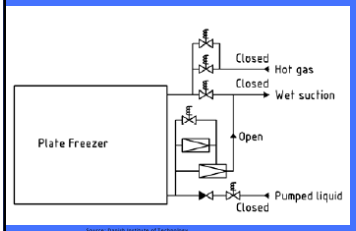
HOT GAS DEFROST-EFFICIENT STRATEGIES



- Evaporator becomes a condenser during the defrost sequence
- The latent heat of the ammonia while condensing melts away the ice around the pipes and fins
- The condensed liquid is expanded into the suction line
- For low temperature evaporators, it is highly recommended to connect the defrost condensate into the suction of a medium temperature system to minimize the energy required to compress the excess gas from the evaporator

69

HOT GAS DEFROST FOR PLATE FREEZERS

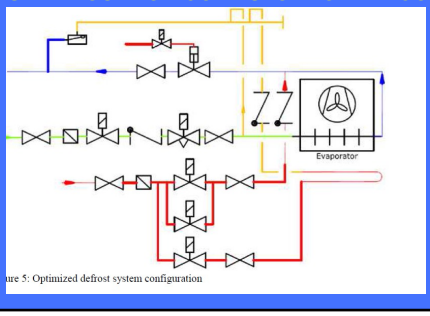


As there are flexible hoses involved:

- It is necessary to inject hot gas through the suction header
- Soft hot gas solenoid valve is recommended as flexible hoses may be vulnerable to bubble gas collapsing

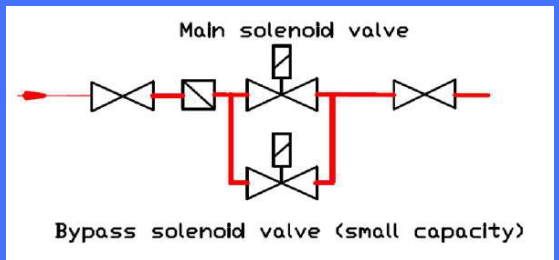
70

HOT GAS DEFROST FOR COLD STORAGE AIR COOLER



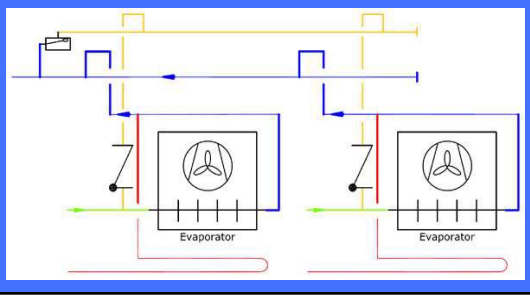
ure 5: Optimized defrost system configuration

71



72

FLOAT VALVES IN CONDENSING LINES WITH MULTIPLE EVAPORATORS. ONLY VALVES IN THECONDENSING LINES ARE INDICATED



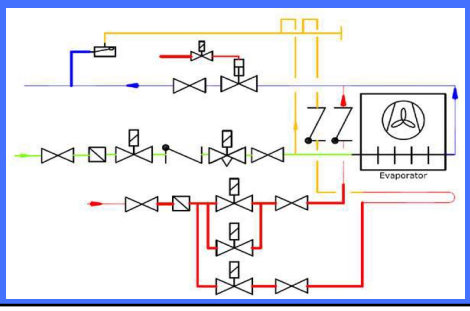
73

ICE MELTING ENERGY CALCULATIONS

Parameter	Value	Dimension
Fin spacing	10,00	mm
Ice Thickness	1,00	mm
Evaporator	100	kW
Weight	580	Kg
Frost density	300	kg/m3
Surface area	450	m2
Frost weight	135,00	Kg
Start temperature	-35	^{0}C
End temperature	5	^{0}C
Specific heat ice	2,1	kJ/kg*K
Specific heat water	4,2	kJ/kg*K
Specific melting heat	336	kJ/kg
Energy to heat the ice to 0^{0}C	9.922,50	kJ
Energy to melt the ice	45.360,00	kJ
Energy to heat up water to 5^{0}C	2.835,00	kJ
Total heat required to melt ice	58.117,50	kJ

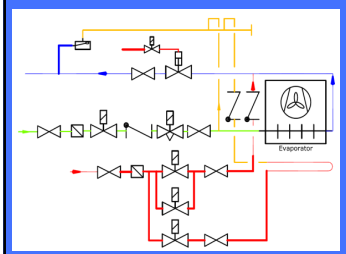
74

OPTIMIZED HOT GAS DEFROST SYSTEM



75

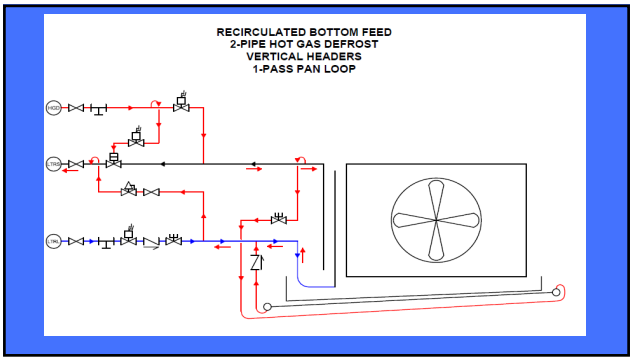
Separate hot gas defrost line for defrost pans



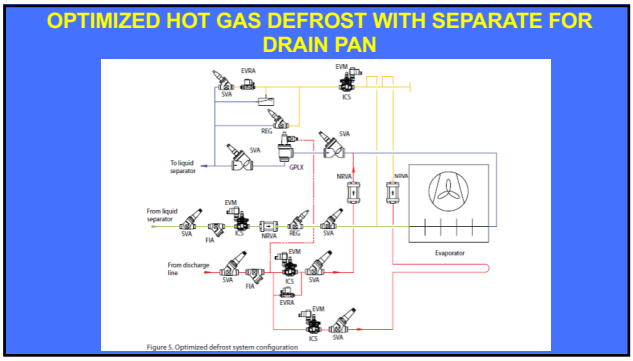
Having a separate valve station for the defrost pan:

- 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.

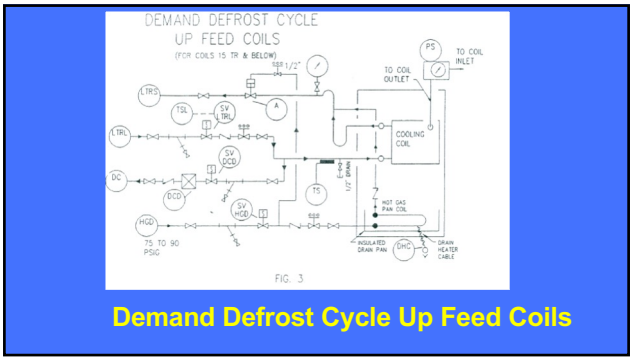
76


RECIRCULATED BOTTOM FEED
2-PIPE HOT GAS DEFROST
VERTICAL HEADERS
1-PASS PAN LOOP

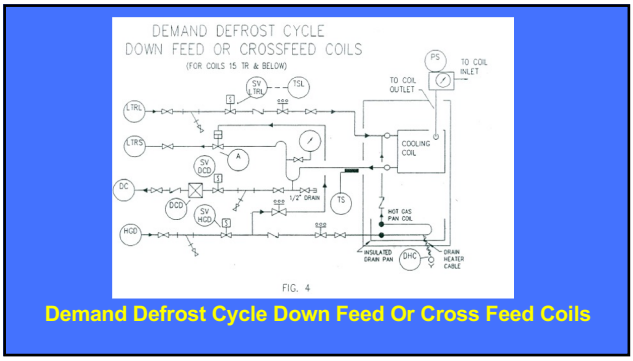
77


OPTIMIZED HOT GAS DEFROST WITH SEPARATE FOR DRAIN PAN
Evaporator
Figure 5. Optimized defrost system configuration

78


DEMAND DEFROST CYCLE
UP FEED COILS
(FOR COILS 15 TR & BELOW)
TO COIL OUTLET
TO COIL INLET
COOLING COIL
HOT GAS PAN COIL
INSULATED DRAIN PAN
DRAIN HEATER CABLE
75 TO 90 PSIG
FIG. 3
Demand Defrost Cycle Up Feed Coils

79


DEMAND DEFROST CYCLE
DOWN FEED OR CROSSFEED COILS
(FOR COILS 15 TR & BELOW)
TO COIL OUTLET
TO COIL INLET
COOLING COIL
HOT GAS PAN COIL
INSULATED DRAIN PAN
DRAIN HEATER CABLE
FIG. 4
Demand Defrost Cycle Down Feed Or Cross Feed Coils

80

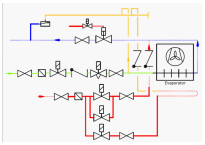
SUGGESTED FIN SPACING –RUN TIME-DEFROST FREQUENCY

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

81

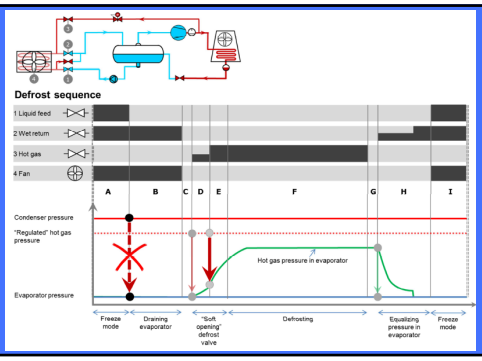
Separate hot gas defrost line for defrost pans



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.

82



83

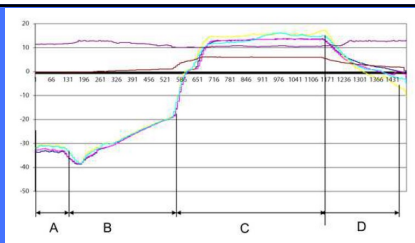
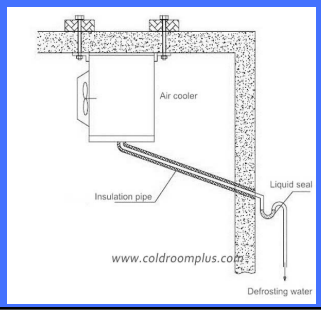


Figure 6: Defrost temperature graph
A: Liquid line solenoid valve is closed, fans are running and finally suction solenoid valve is closed
B: Bypass solenoid valve in the hot gas line is opened
C: Main solenoid valve in the hot gas line is opened
D: End of defrost, fans are running, suction solenoid opens. In the end of the process liquid feed resumes

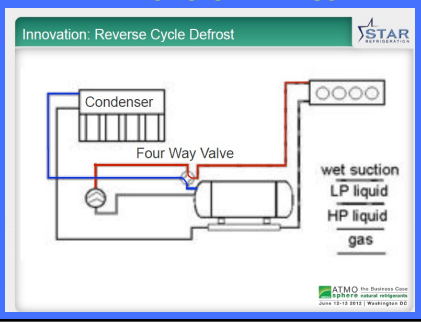
84

DRAIN LINE



85

REVERSE CYCLE DEFROST



86

POSSIBLE PROBLEMS DURING DEFROSTING

1. Stop defrosting cycle before completion
2. Insufficient defrost power available
3. Start of defrosting too late
4. Surface temperatures too high
5. Uneven defrost: refrigerant blow through
6. Splashing of cooler

87

Any Questions?

BY
Ramesh Paranjpey
Fellow Life member ASHRAE/ISHRAE
Website: http://ramesh-paranjpey.com
Mail Id: ramesh.paranjpey@gmail.com
Cell : +9198223 98220

88