Energy & Store Development Conference

E+sd 2011

FOOD MARKETING INSTITUTE

Refrigeration 201

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September 2011

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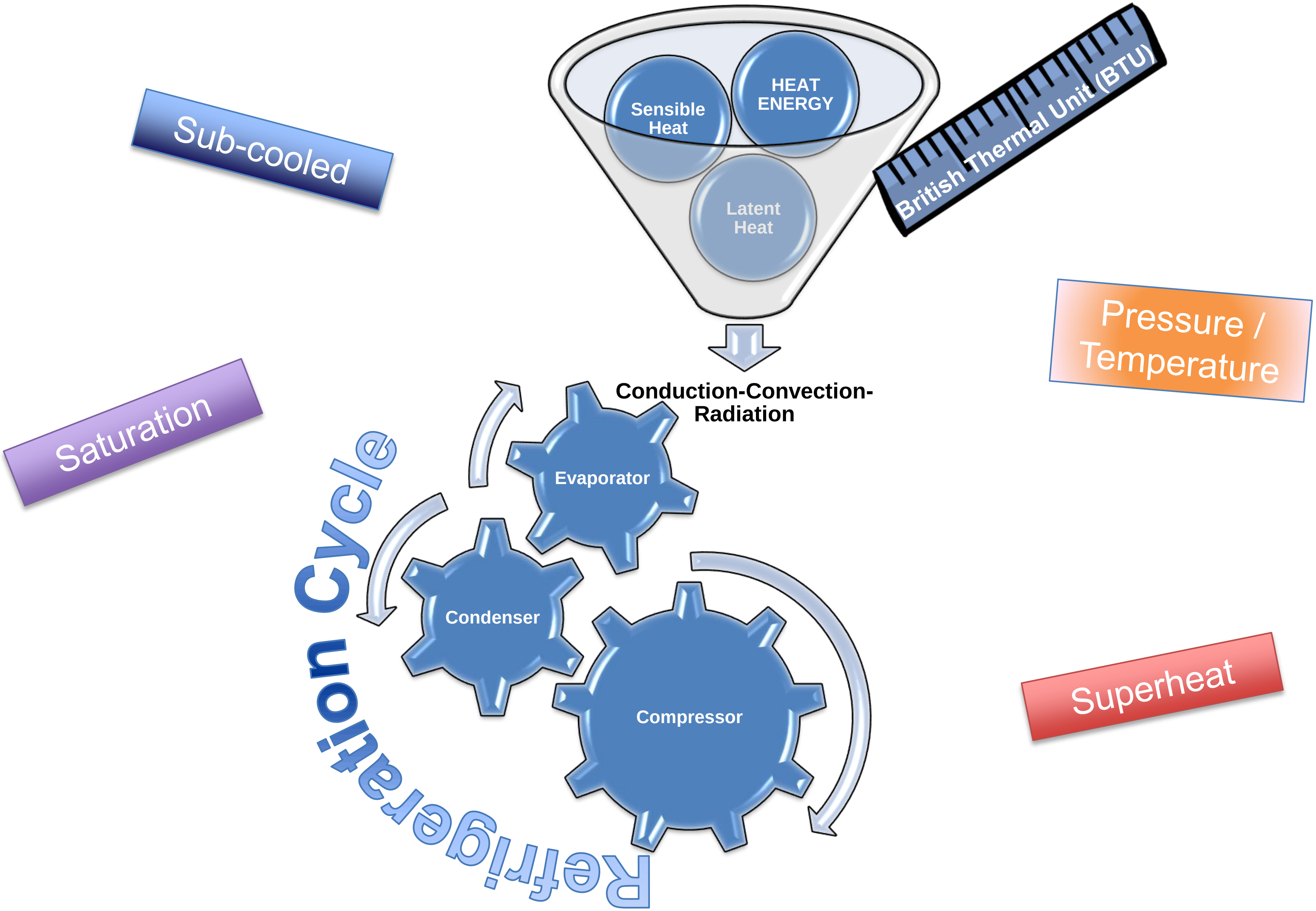
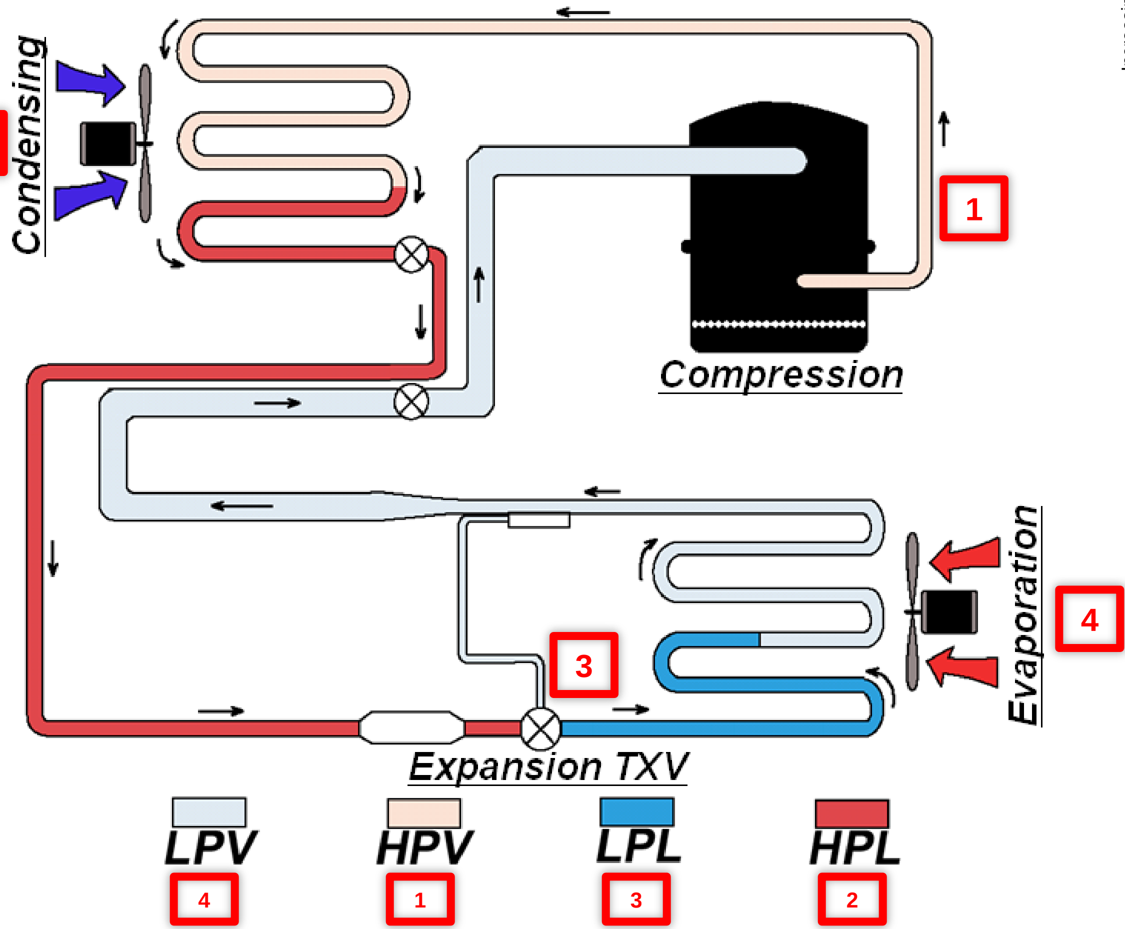
Key Learning's

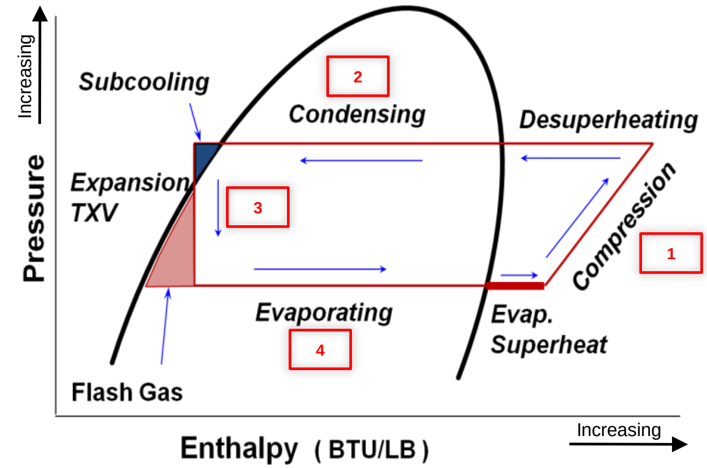
- Review of Refrigeration 101
- Basic understanding of more complex components of a refrigeration system
- Overview of more complex mechanical refrigeration systems
- Interaction of the mechanical system with the building
- Equipment planning and location

REFRIGERATION 101 REVIEW


Sub-cooled
Saturation
HEAT ENERGY
Sensible Heat
Latent Heat
British Thermal Unit (BTU)
Pressure / Temperature
Conduction-Convection-Radiation
Evaporator
Condenser
Compressor
Refrigeration Cycle
Superheat

Refrigeration Cycle



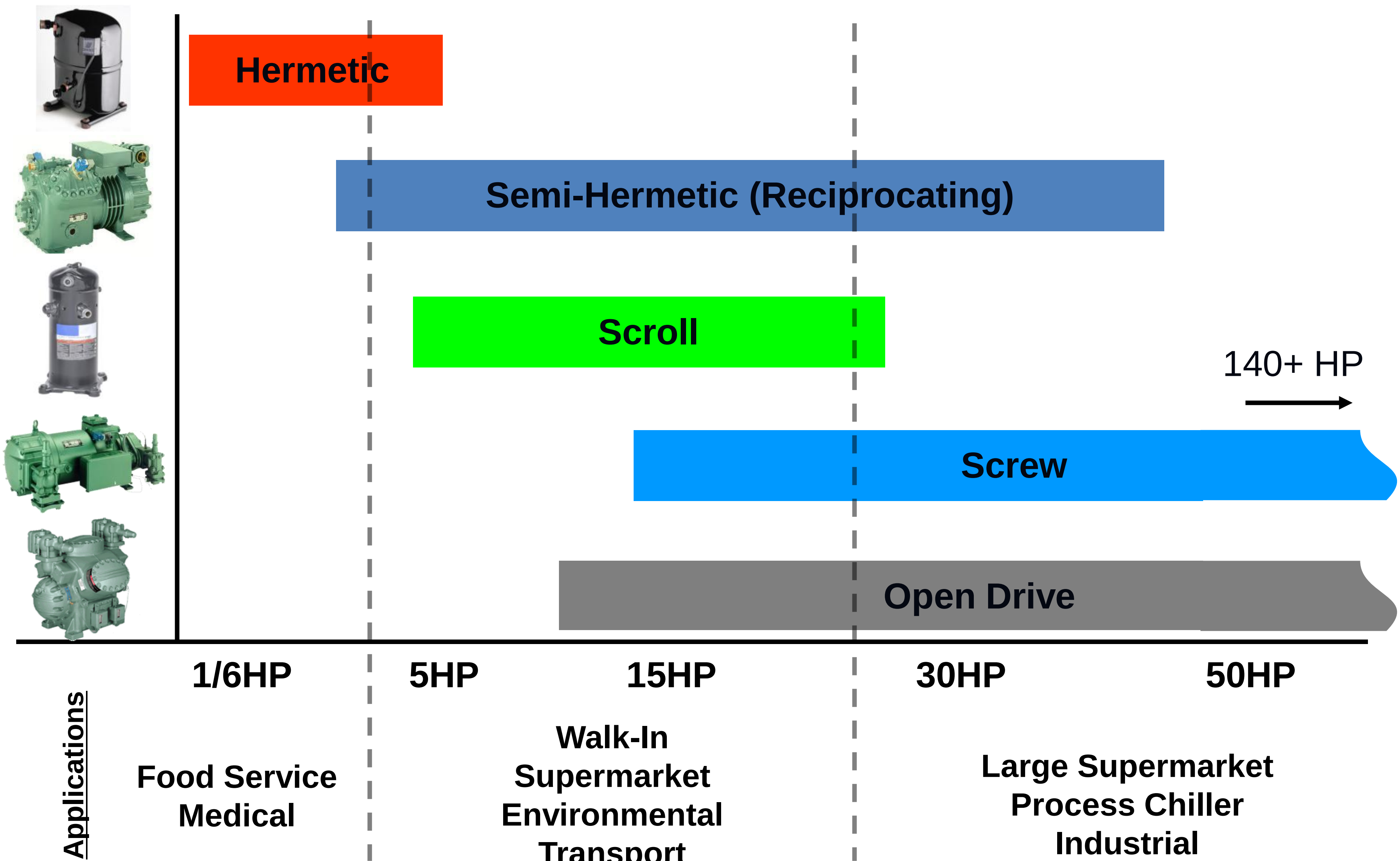


Vapor Compression Refrigeration Cycle

Enthalpy – measure of the heat energy of a substance.

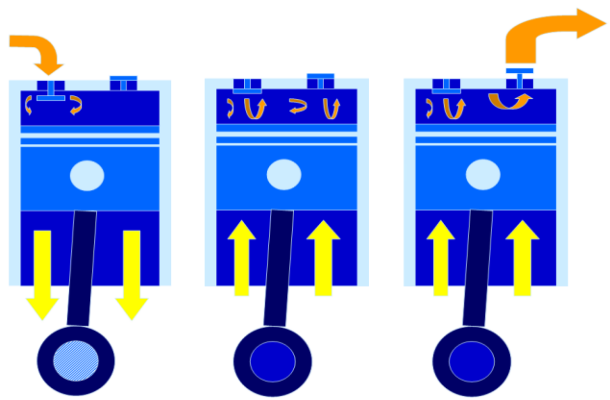
LPV - Low Pressure Vapor
HPV – High Pressure Vapor
LPL – Low Pressure Liquid
HPL – High Pressure Liquid

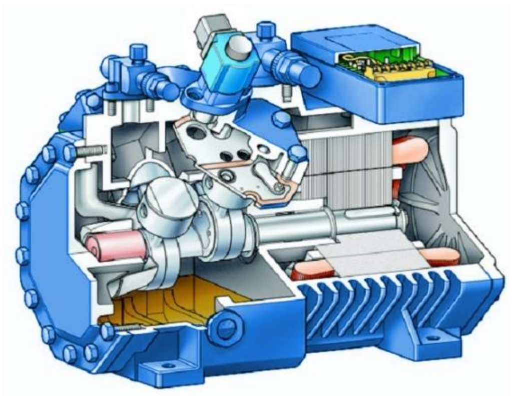
SYSTEM MAJOR COMPONENTS OVERVIEW



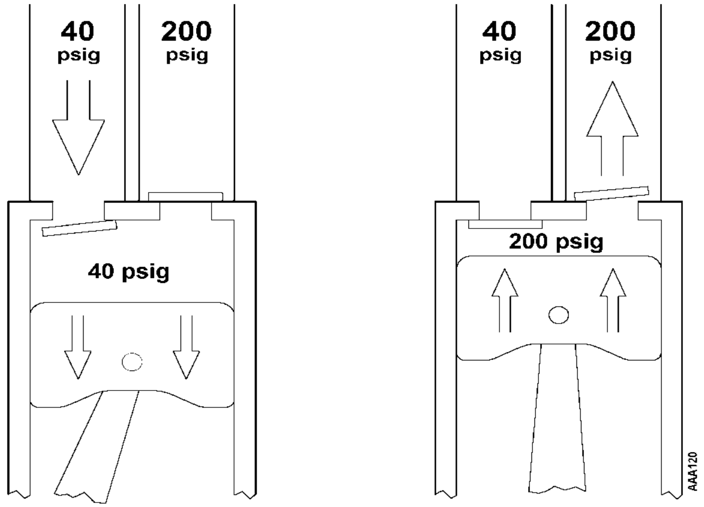
Select the proper compressor for the appropriate application

Reciprocating Compressor



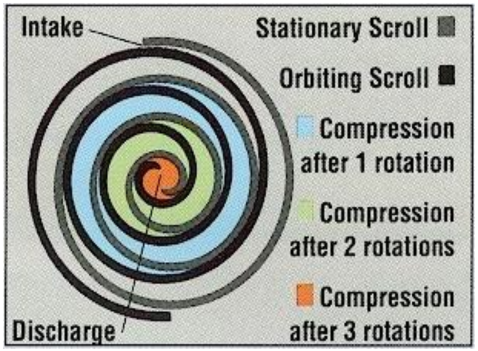


MEDIUM TEMP PRESSURES



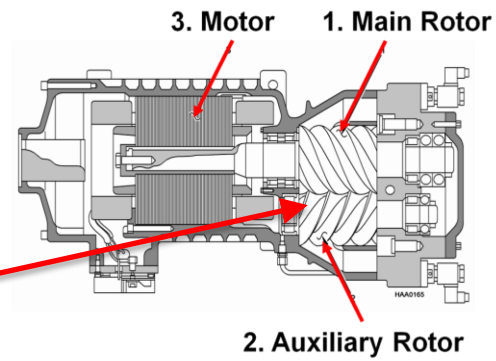
- Moving pistons compress refrigerant gas within cylinders.
- On the downstroke, the suction inlet valve is open as low pressure gas refrigerant is drawn into the cylinder.
- When the piston begins its upstroke, the suction inlet valve is closed and pressure increases.
- High pressure gas exits through the discharge port .

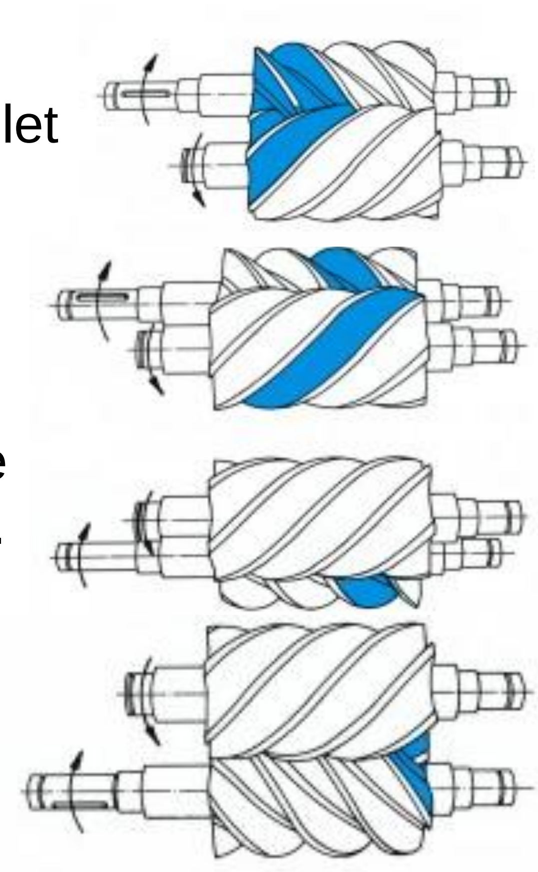
Scroll Compressor



- Rotation is critical on scroll compressors.
- An orbiting scroll moves in a circular motion within a second, fixed scroll.
- The gas entering the low pressure inlet is pressurized into continuously smaller areas until it exits through the discharge line.

Screw Compressor





Intake: the vapor passes through the inlet and into the void which is wide open at the suction end.

Compression: as the rotors contra-rotate, the inlet void closes, the volume is reduced and the pressure increases.

Discharge: compression is completed, final pressure achieved and the vapor is discharged.

Round Tube Plate Fin (RTPF) Air Cooled Condenser

- Coil comprised of:
  - copper tubes to transport refrigerant
  - aluminum fins to increase heat transfer capability
- Fans pull ambient air across coil section
- Heat is rejected to atmosphere
- Refrigerant changes from superheated vapor to sub-cooled liquid

MicroChannel Air Cooled Condenser

- Same operation as RTPF air cooled condenser
- Coil comprised of:
  - flattened aluminum tube with narrow channels
  - aluminum fins in between
- Reduced refrigerant charge
- Smaller size with less weight

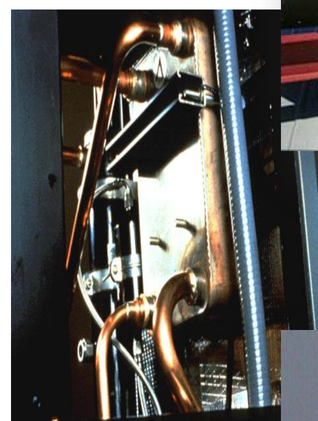
Evaporative Cooled Condenser

- Copper tubes transport refrigerant through coil slab
- Ambient air blown over coils
- Water from a sump is sprayed over the coils to increase heat removal

- Allows the condensing temperature to approach the wet bulb (WB) temperature of the ambient air versus the dry bulb (DB) temperature, which is normally higher.
- Increases system efficiency

Dry Fluid Cooler / Plate-to-Plate Condenser

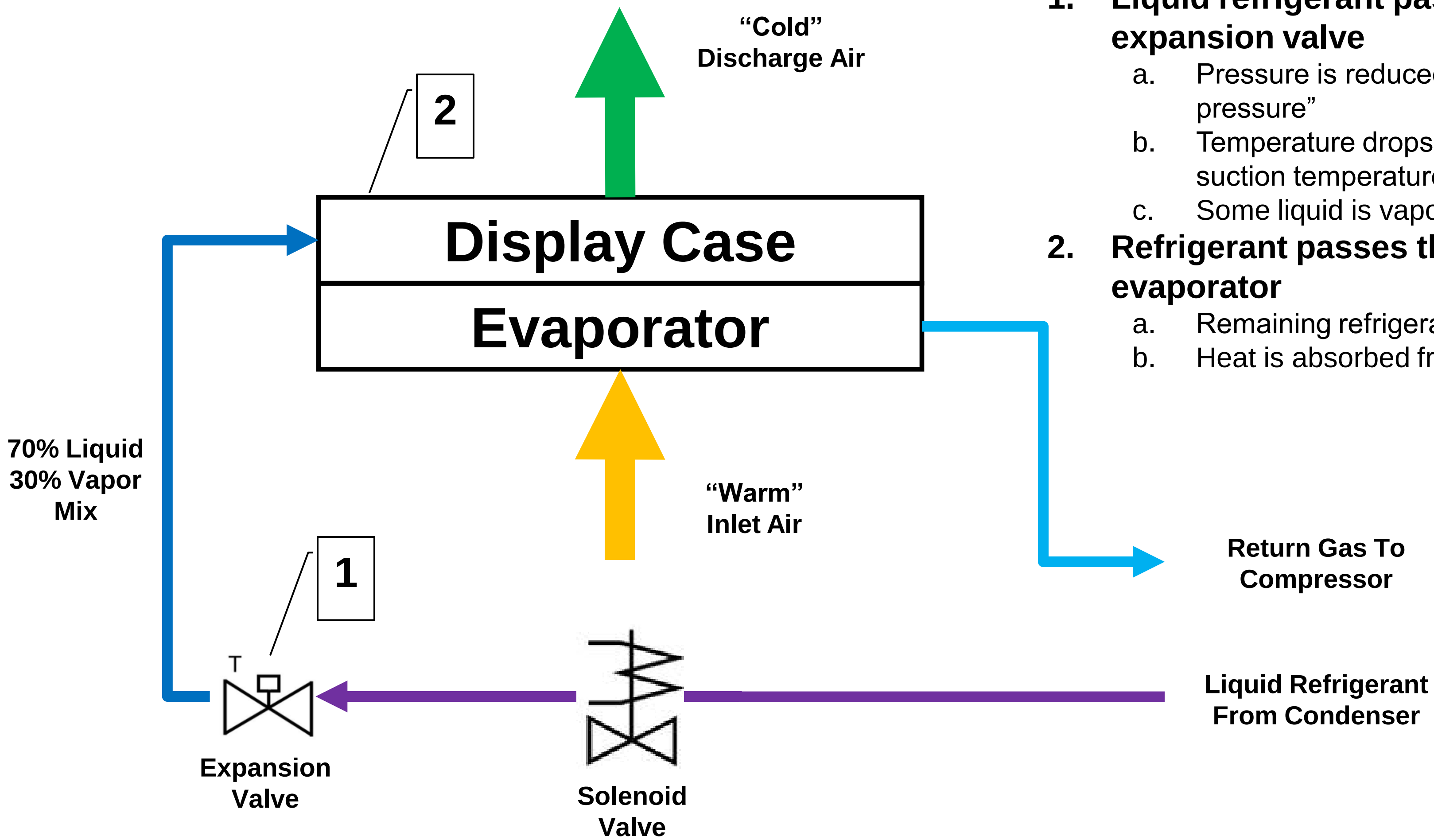
- Fan cooled coil assembly
- Draws ambient air across coil slab to remove heat from glycol mixture
- Glycol mixture used as condenser fluid for refrigeration system
- Refrigeration system uses heat exchanger (plate-to-plate shown) to condense compressor discharge gas
  - Located near compressors



Hybrid Fluid Cooler / Condenser

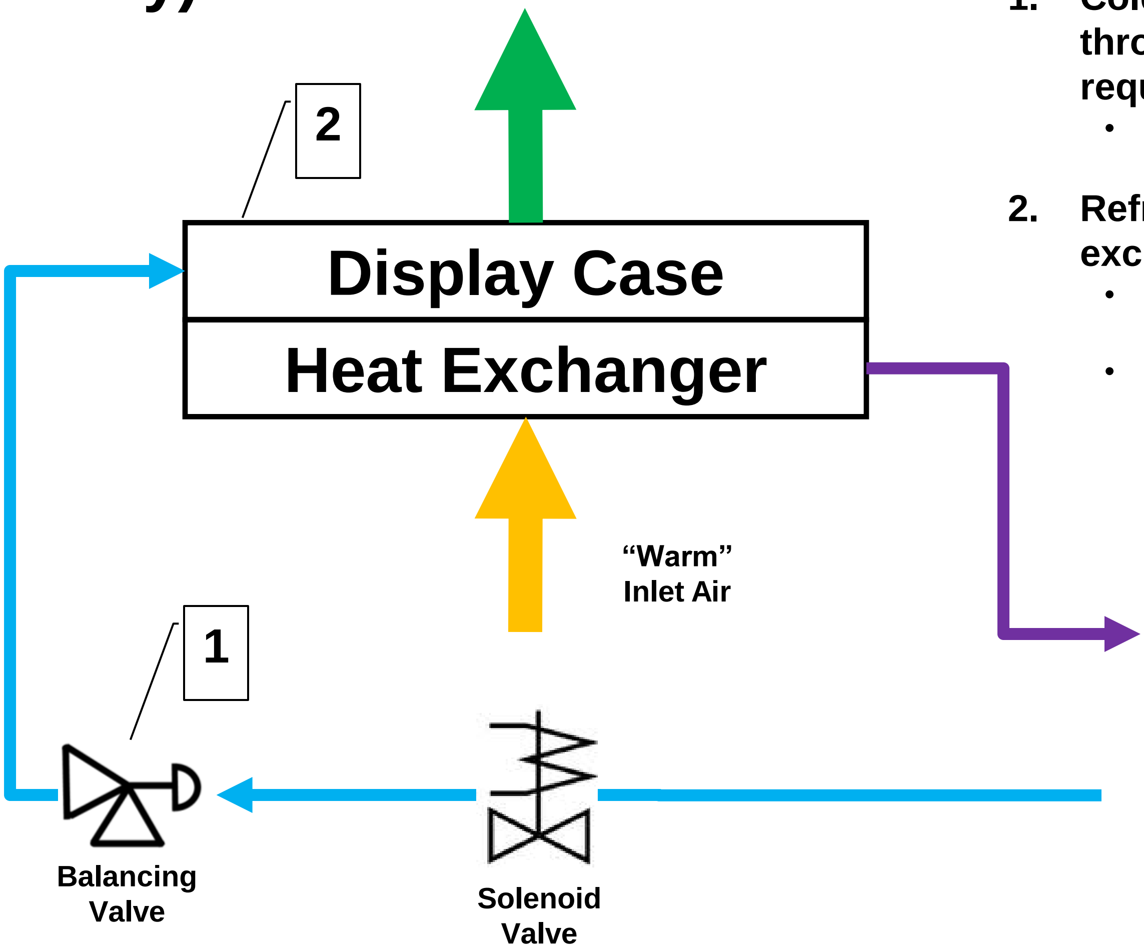
- Uses RTPF coil or microchannel coil
- Equipped with pre-cooling pads to cool incoming ambient air with water that is distributed over the cooling pads
- Air is drawn through the cooling pads and the heat exchangers
- Increases system efficiency

Display Case Operation (DX)



1. **Liquid refrigerant passes through expansion valve**
   a. Pressure is reduced to "evaporator pressure"
   b. Temperature drops to "saturated suction temperature"
   c. Some liquid is vaporized
2. **Refrigerant passes through evaporator**
   a. Remaining refrigerant "boils"
   b. Heat is absorbed from inlet air

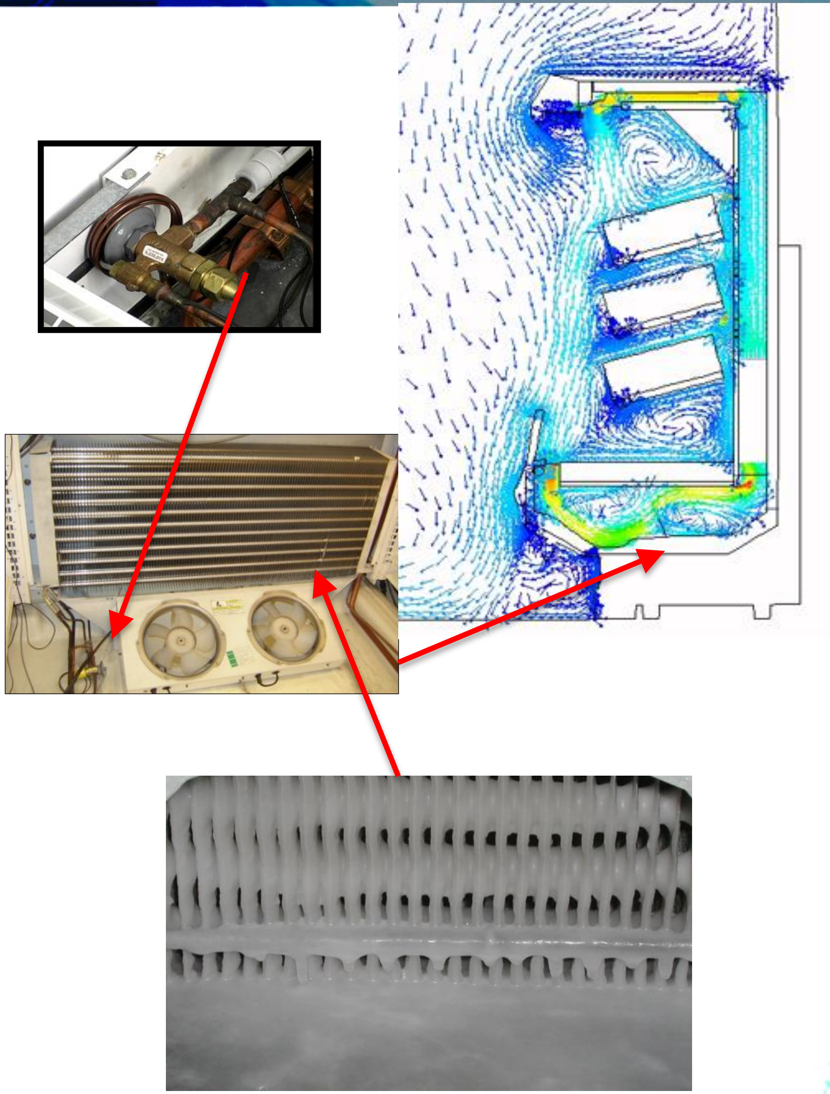
Display Case Operation (Secondary)



1. **Cold fluid (Glycol or CO_2) passes through Balancing Valve (when required)**
    - Flow is metered to the case requirements
2. **Refrigerant passes through heat exchanger**
    - Cold liquid absorbs heat from the inlet air
    - Liquid increases in temperature
        - Glycol does not "boil"
        - CO_2 partially "boils" – two phase mixture

Display Case Equipment

- Reduces the temperature of the air passing through it (sensible heat)
- Removes humidity (latent heat)
- Low pressure liquid refrigerant is boiled off into low pressure vapor
- Proper airflow though the evaporator coil is critical to its function
- Moisture from ambient air freezes on coil tubes. This frost or ice prevents proper air flow across the coil and air curtain velocities.
- Defrost is the removal of frost or ice from an evaporator coil
  - ***Off time*** – MT Coils
  - ***Electric*** – LT / MT Coils
  - ***Hot Gas*** – LT / MT Coils
  - ***Cool Gas*** – LT / MT Coils
  - ***Warm Fluid*** – MT Glycol Coils



◆ ***LT*** – Low temperature evaporator <= 0 F ◆ ***MT*** – Medium temperature evaporator <= 32 F

Case Temperature Control

Thermostatic Expansion Valve (TXV)

Electronic Expansion Valve (EEV)

- Expansion Valve (EV)
  - Regulates refrigerant flow
  - Maintains superheat at the evaporator outlet

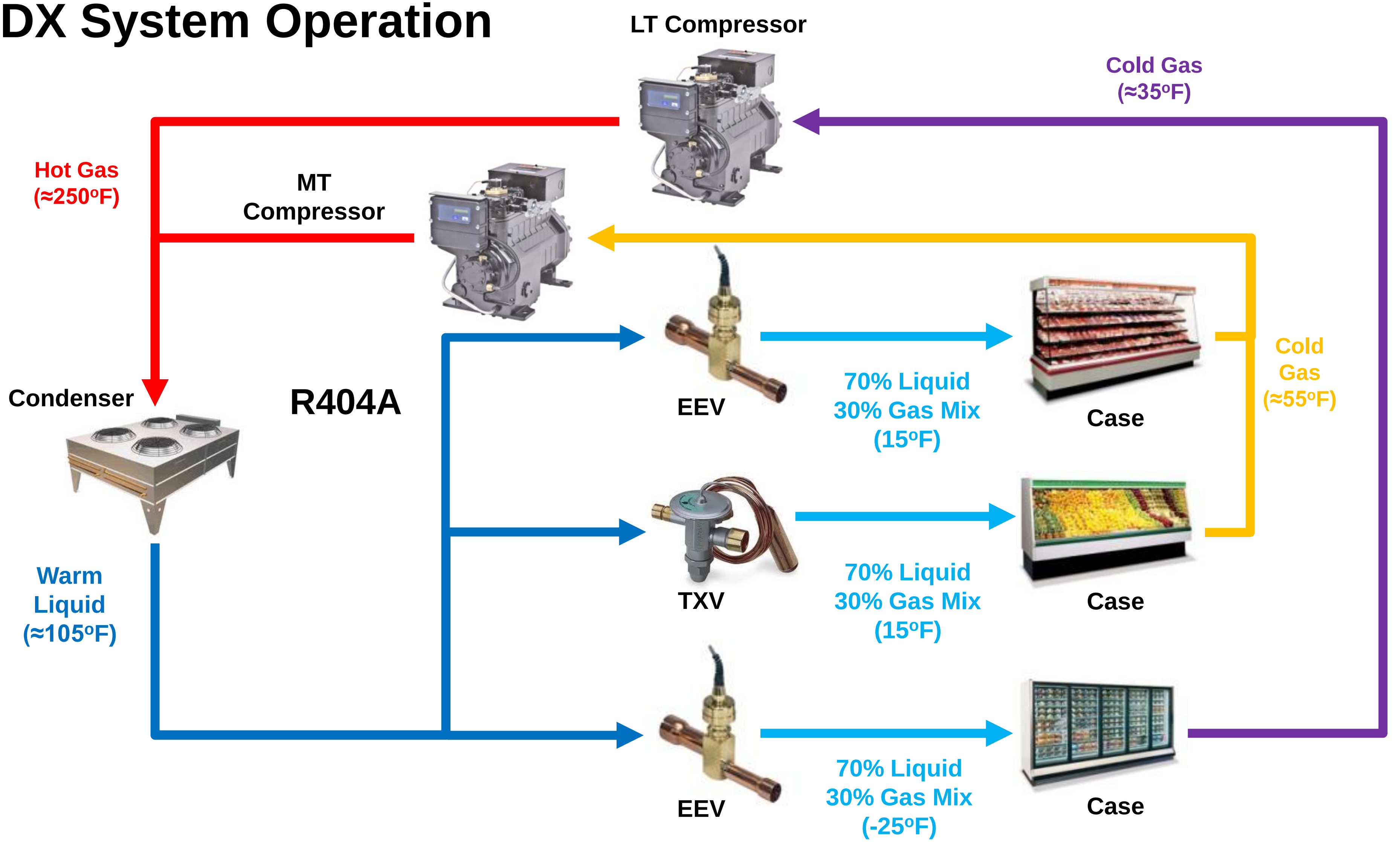
Mechanical EPR w/solenoid

Electronic EPR (EEPR)

- Evaporator Pressure Regulator (EPR)
  - Maintain accurate display case pressure and temperature
  - Allows multiple evaporator systems to operate at different temperatures when piped to a common suction group

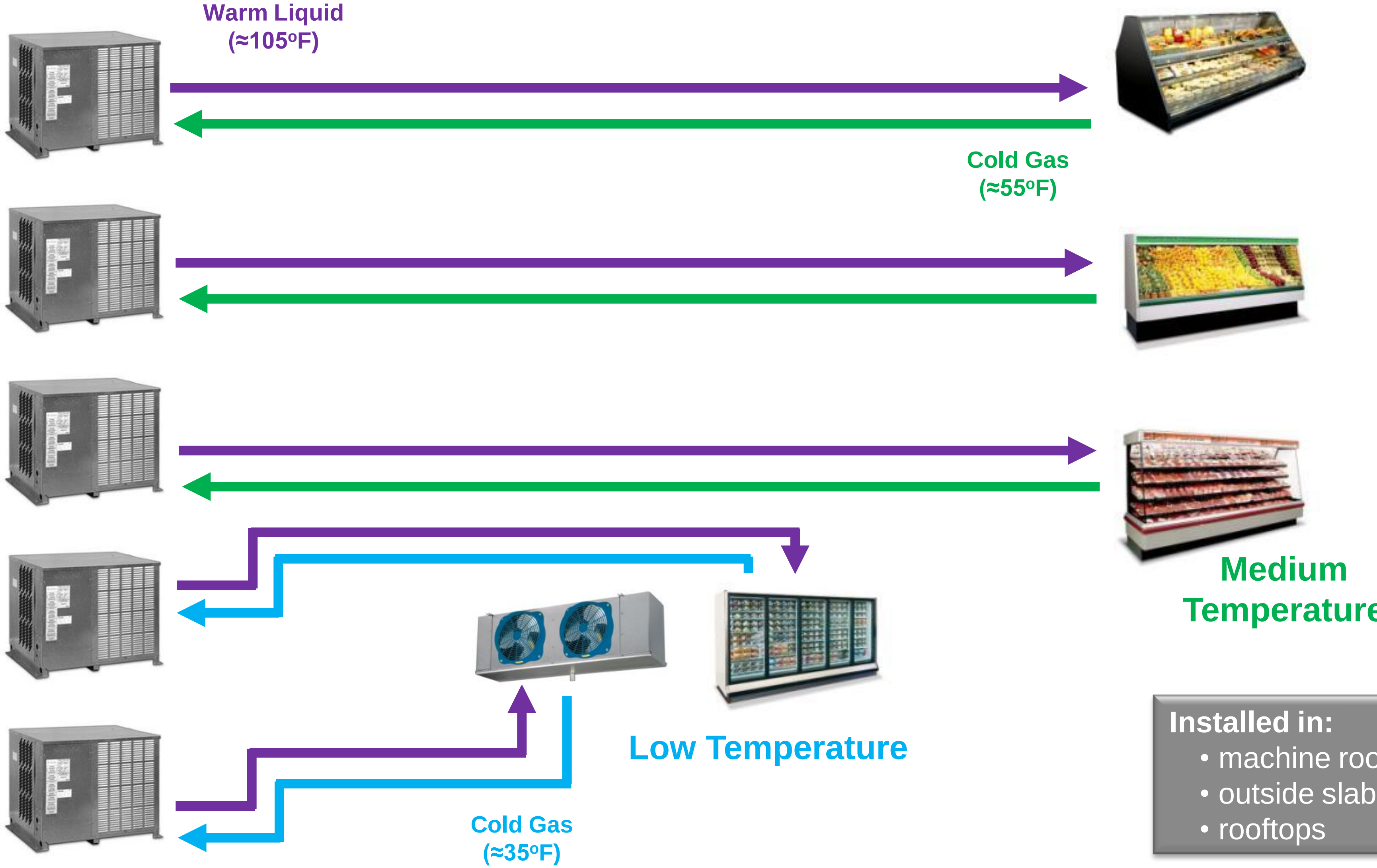
SYSTEM TYPES

DX System Operation



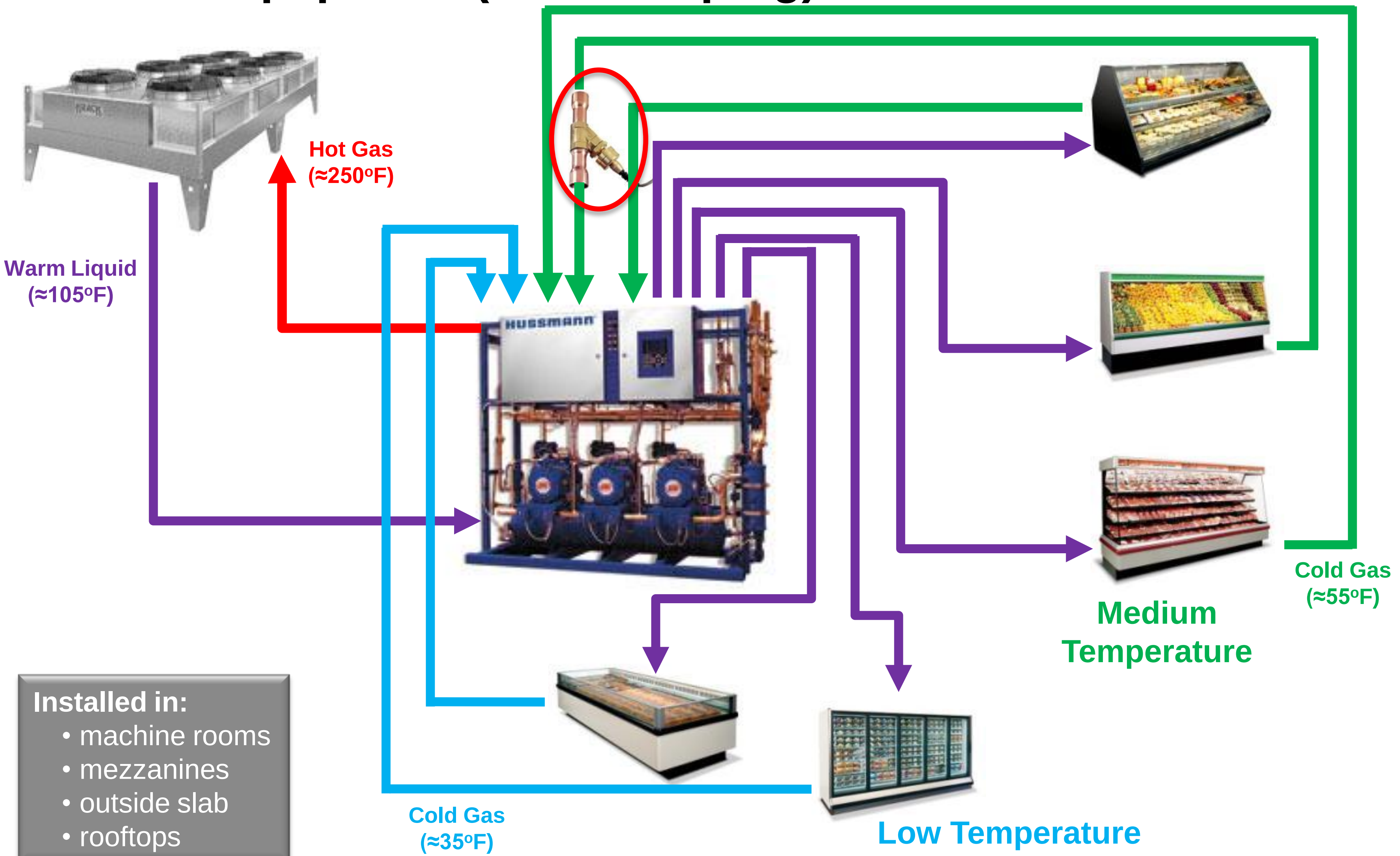
DX – Direct Expansion refrigeration system

DX Condensing Unit Equipment

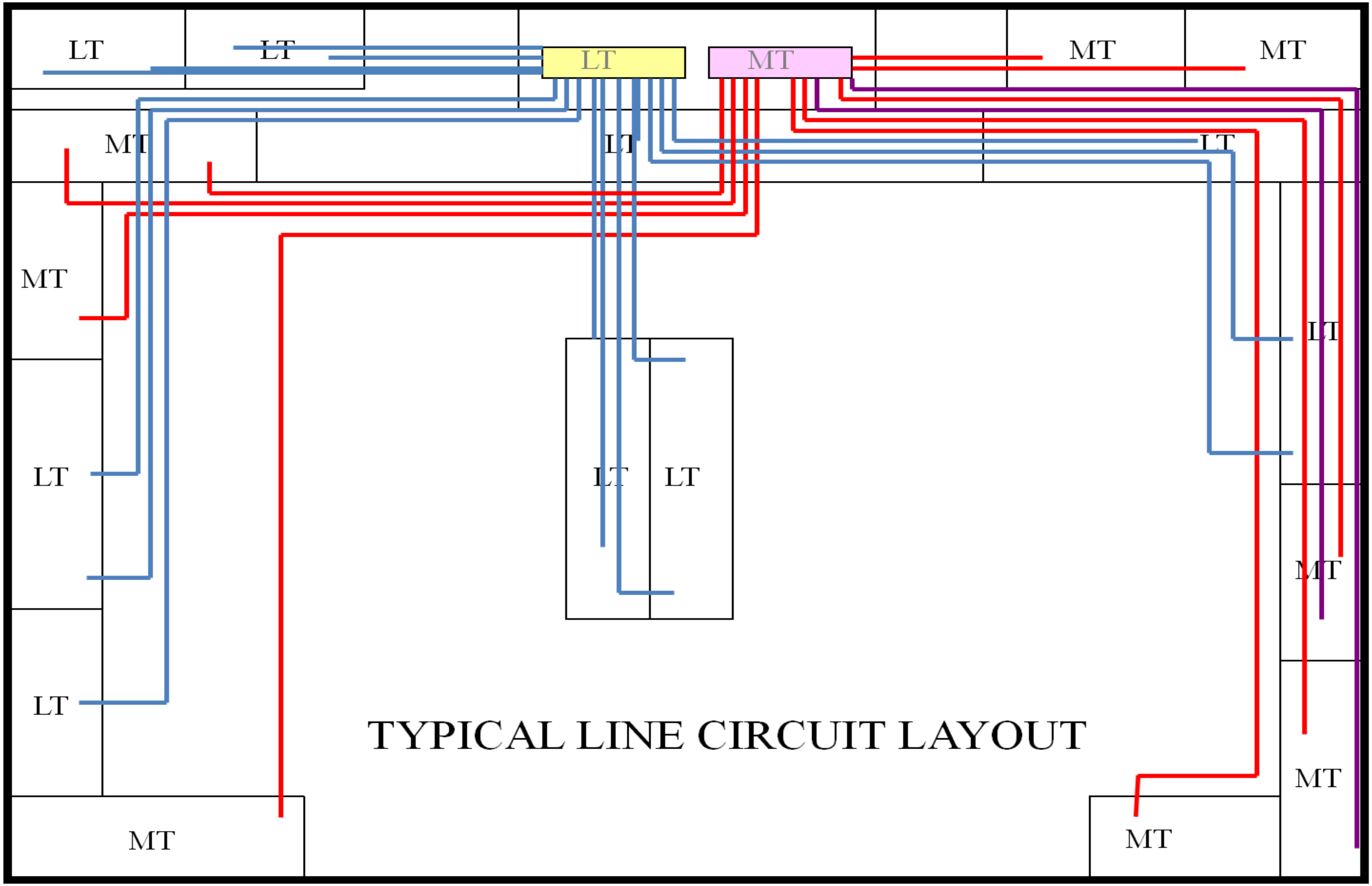


Installed in:
- machine rooms
- outside slab
- rooftops

DX Rack Equipment (Circuit Piping)



Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops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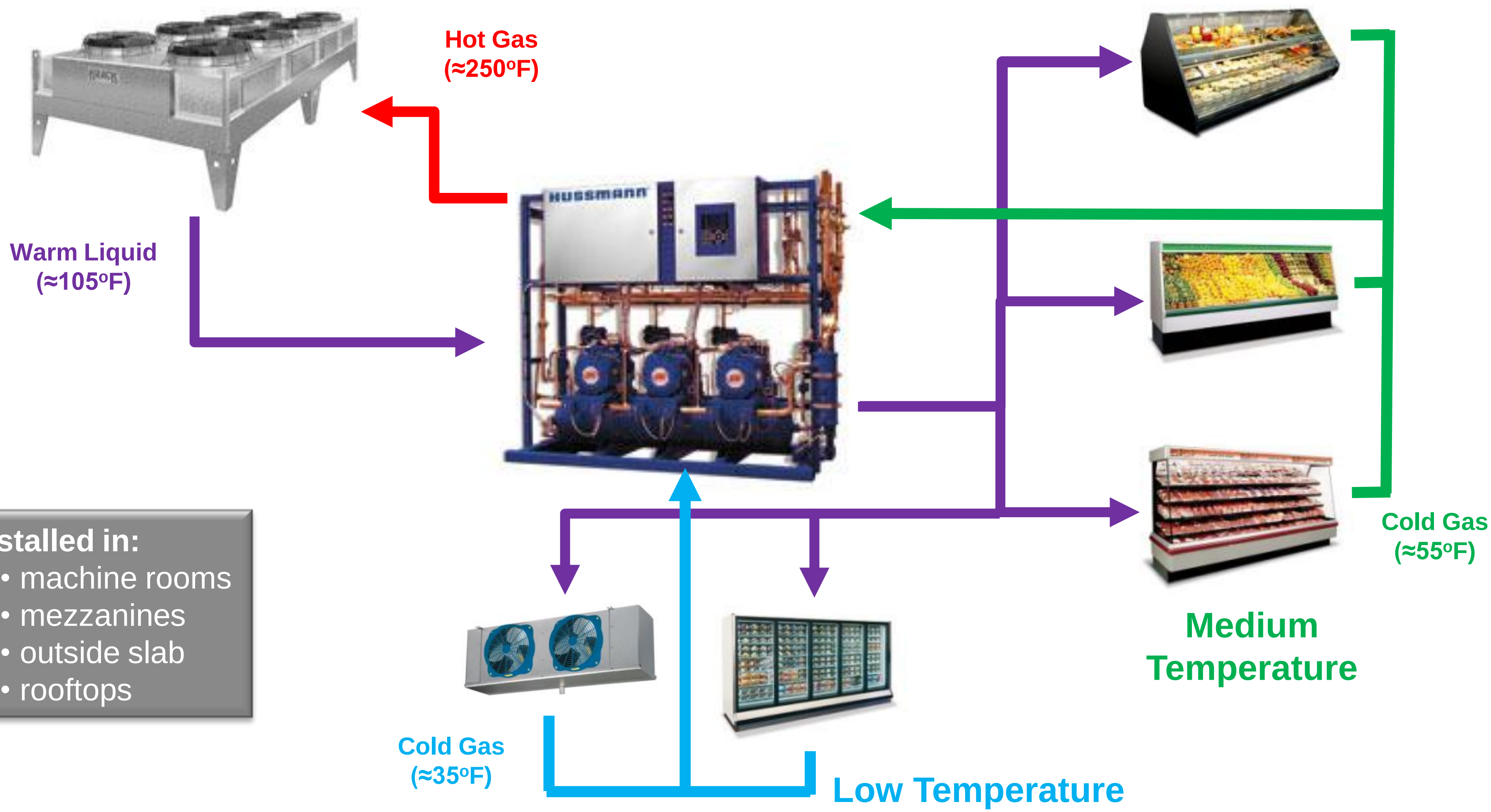
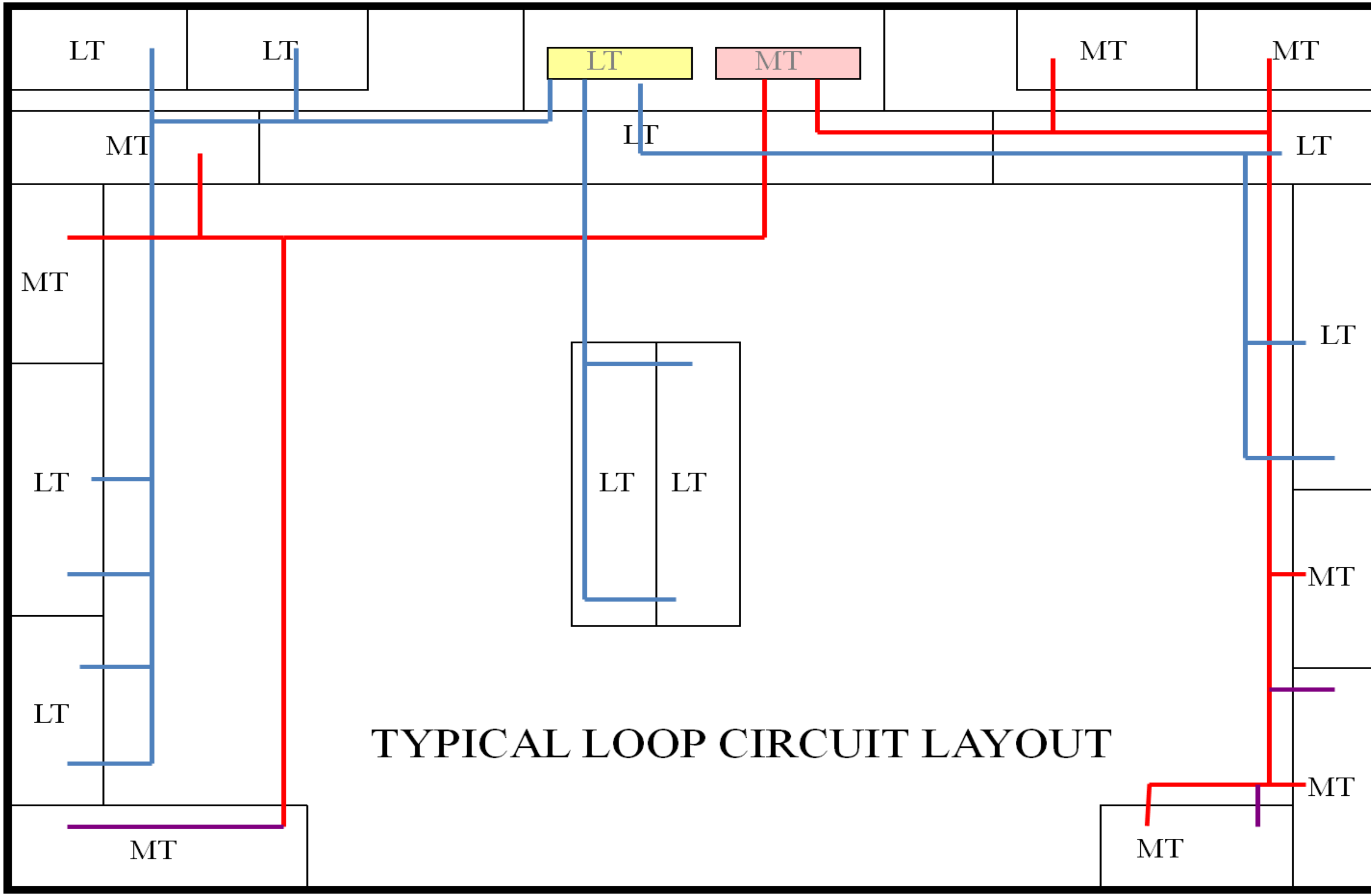
TYPICAL LINE CIRCUIT LAYOUT

DX Rack Equipment (Loop Piping)



Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

Lower refrigerant charge than circuit piping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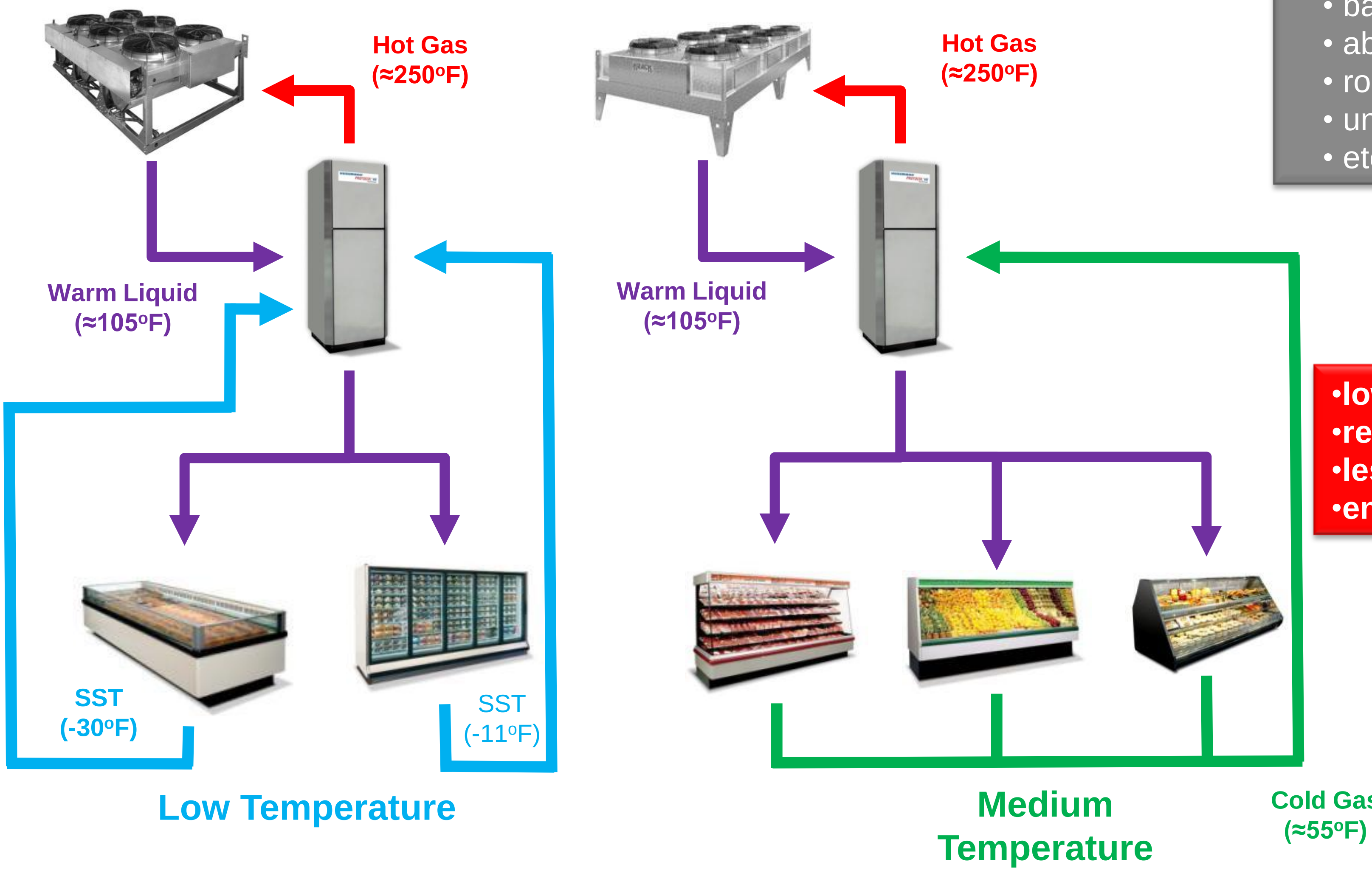
TYPICAL LOOP CIRCUIT LAYOUT

Distributed DX Equipment (Loop)

Installed in:
- back hallways
- above walk-ins
- rooftops
- under racking
- etc

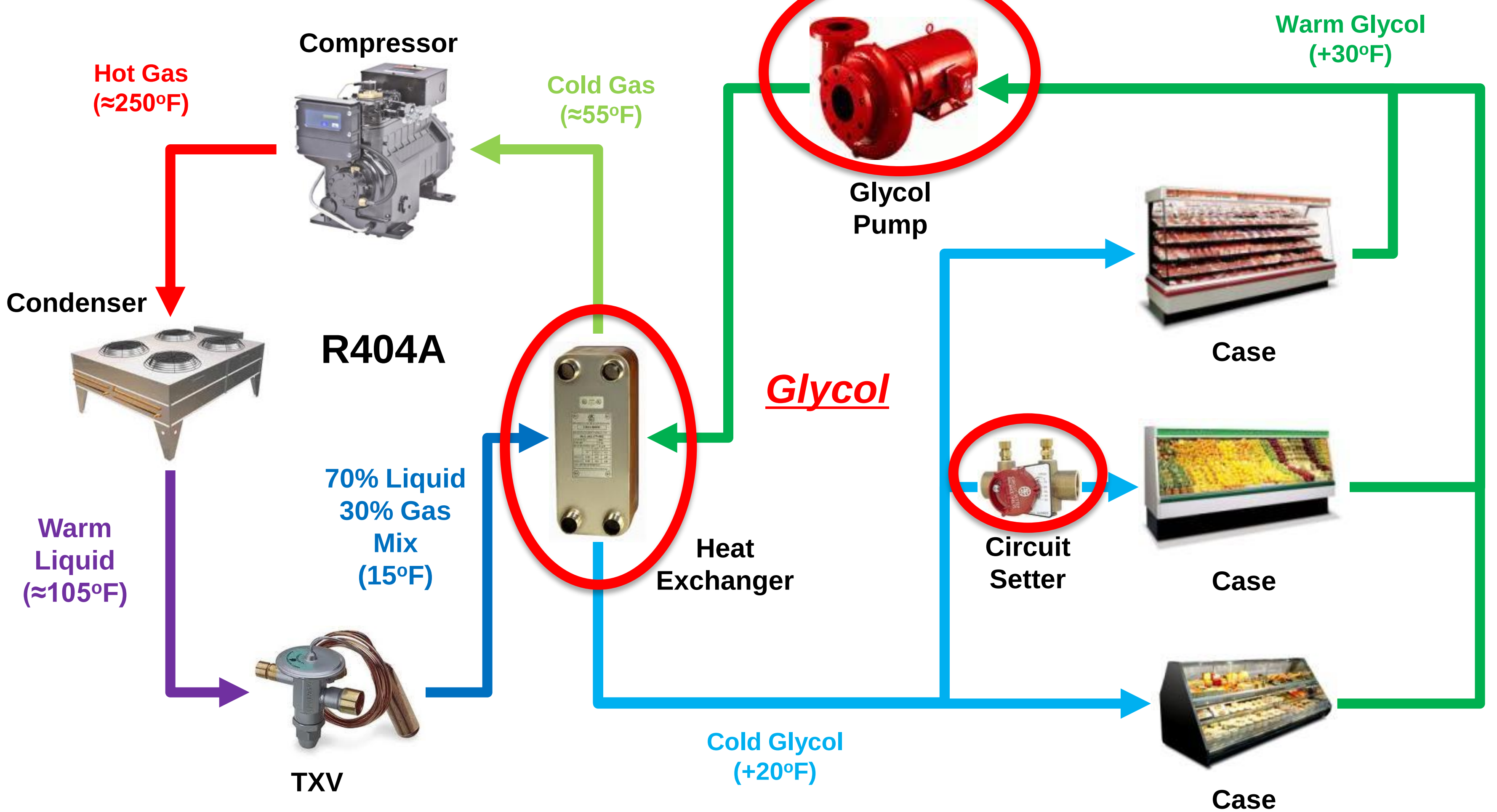


- **low charge**
- **reduced leaks**
- **less copper**
- **energy efficient**

Distributed – Multiple small compressor units located close to their loads throughout the store

Secondary Glycol System Operation

* MT Only

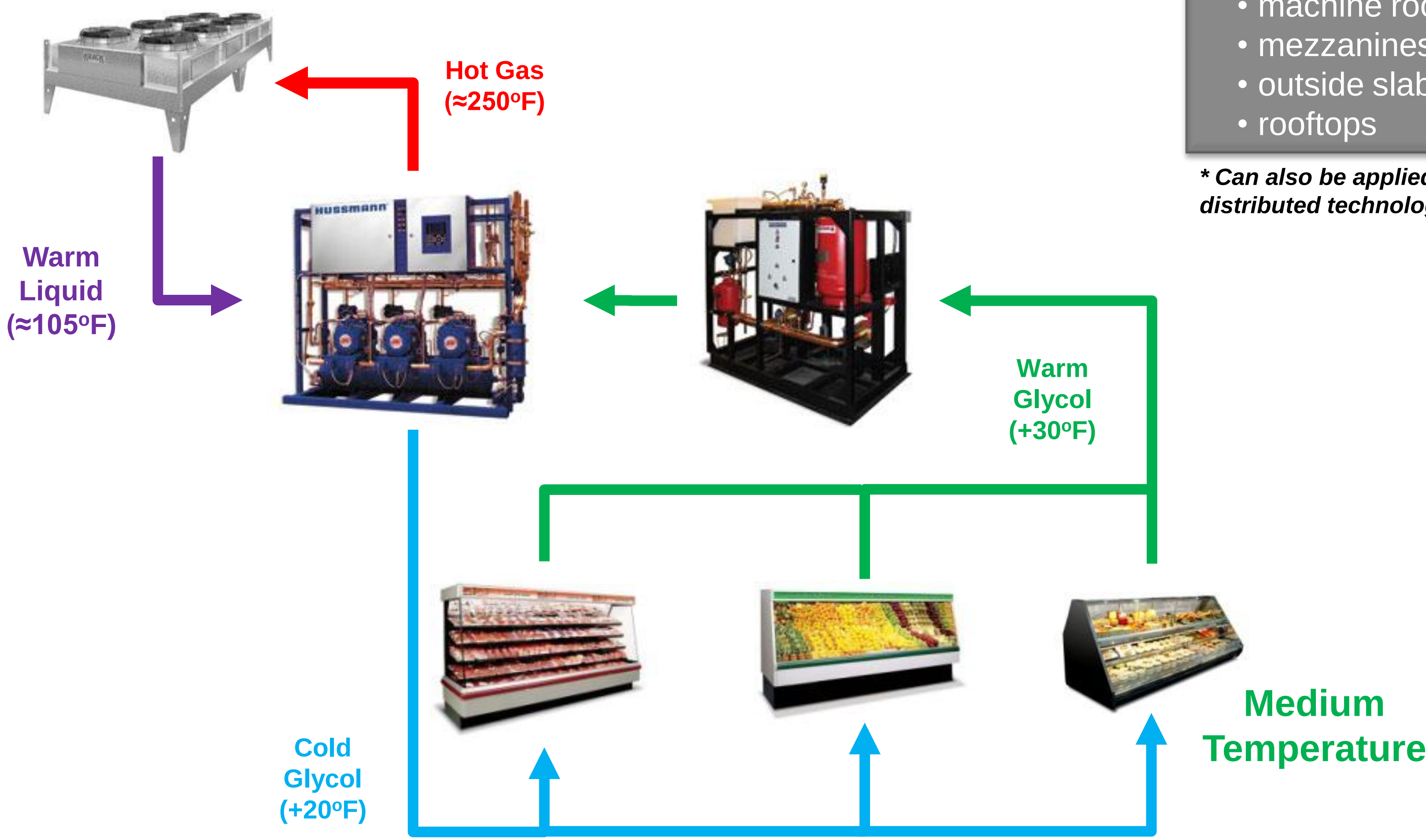


Secondary – Intermediate medium for heat transfer between cooling load and refrigerant

Secondary Glycol Equipment (Loop)

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops

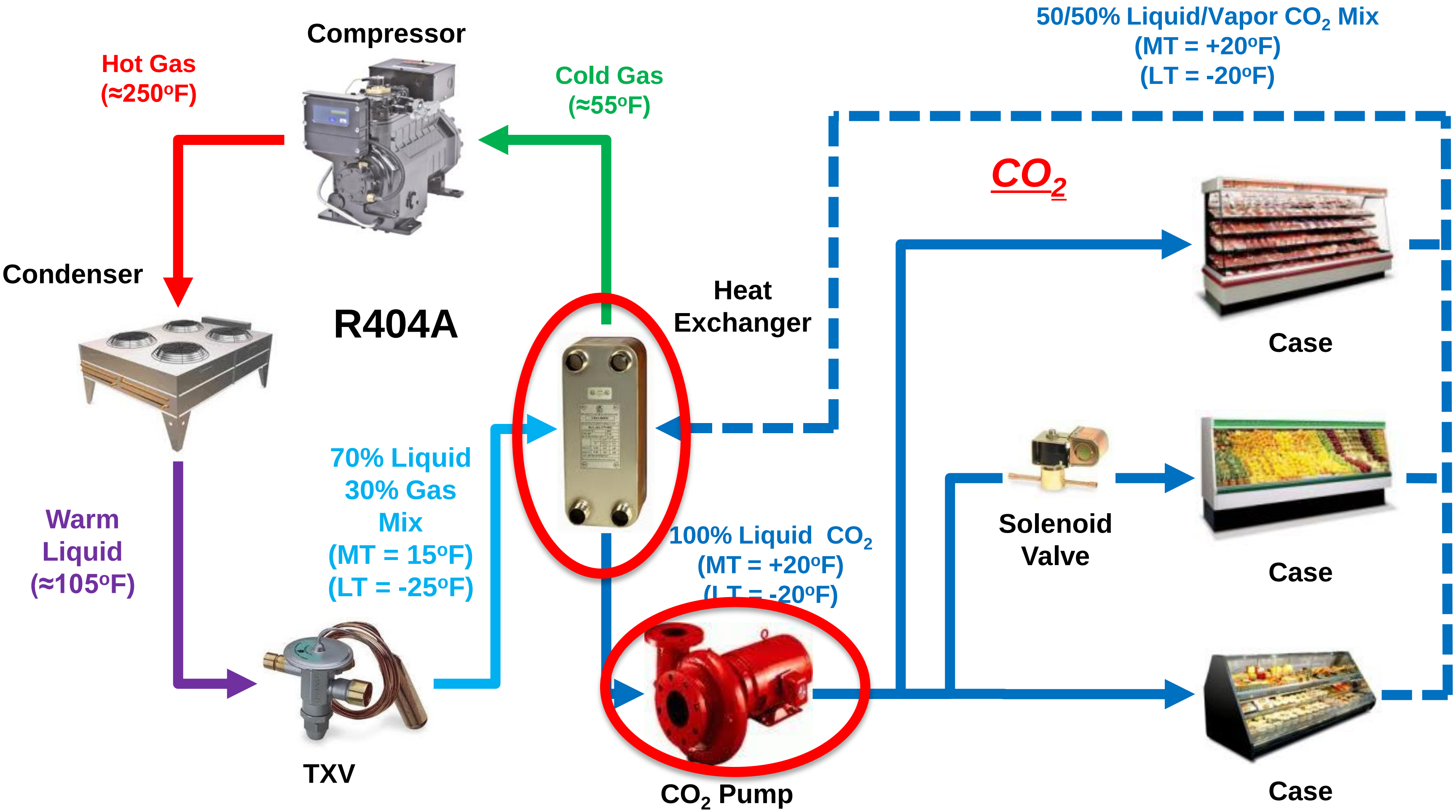
Can also be applied with distributed technology



◆ Low refrigerant charge ◆ Reduced leaks ◆ Less Copper

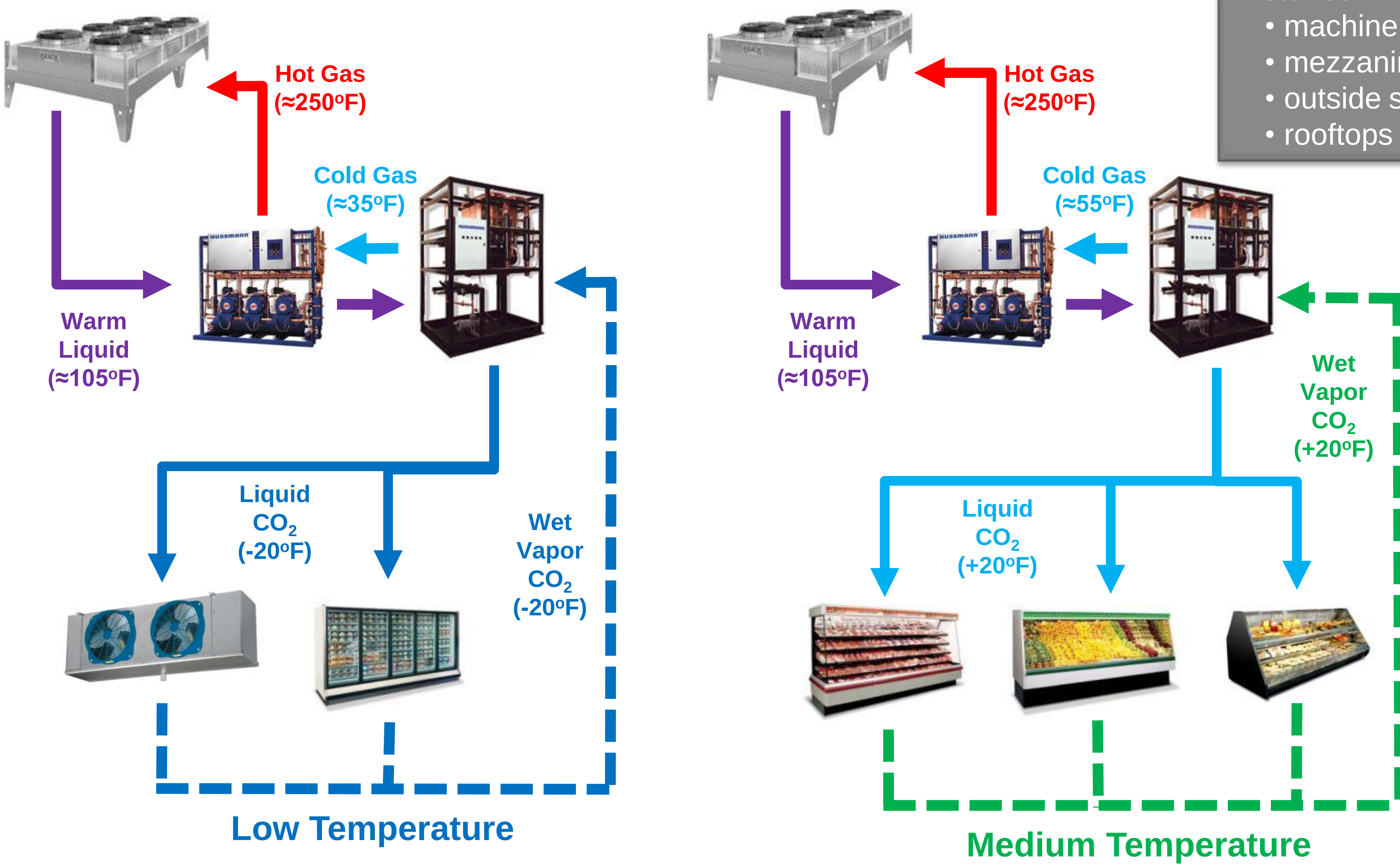
Secondary CO_2 System Operation

* LT and MT



Secondary CO_2 Equipment (Loop)

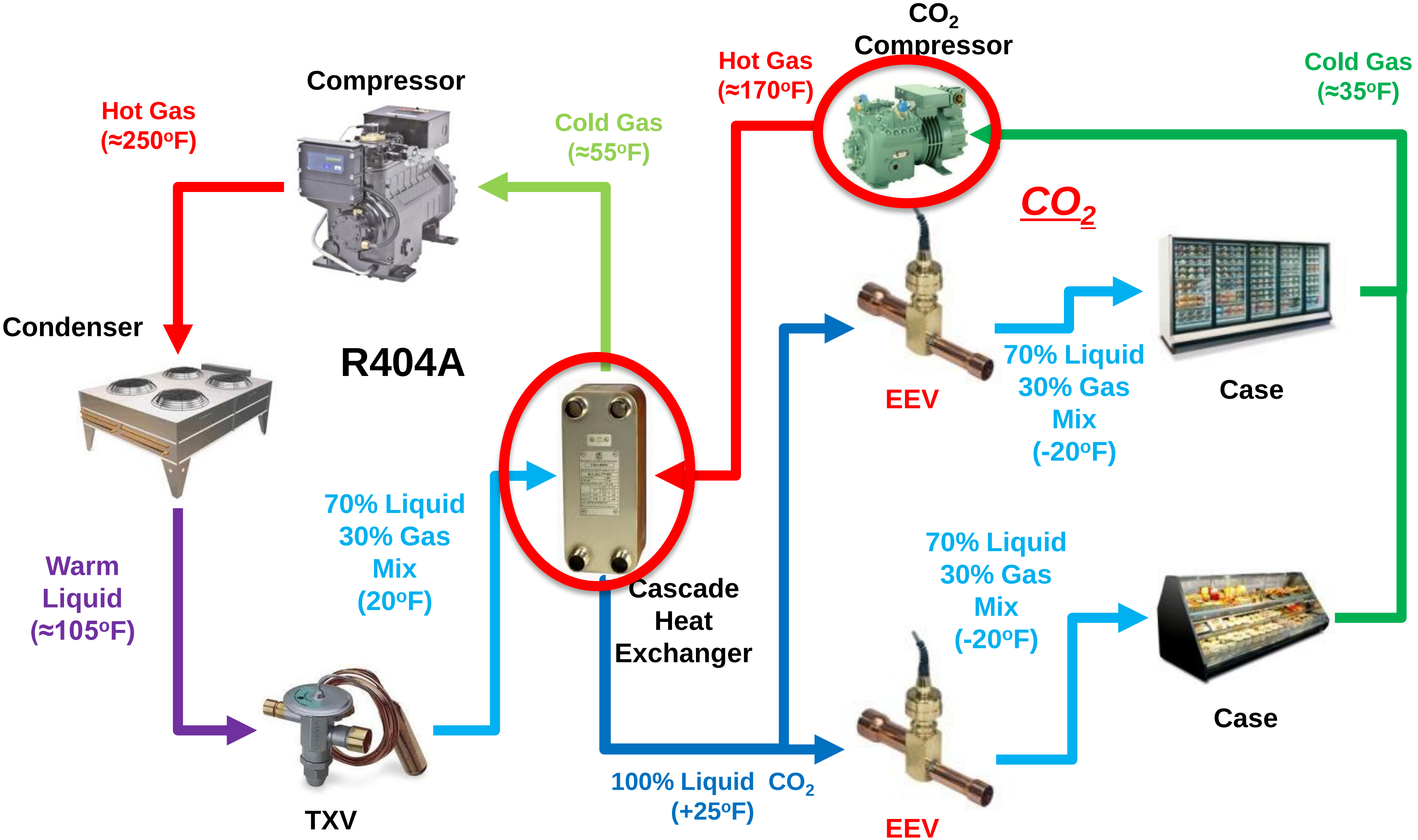
Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops



- Low refrigerant charge
- Reduced leaks
- less copper
- Uses natural CO_2

Cascade CO_2 DX System Operation

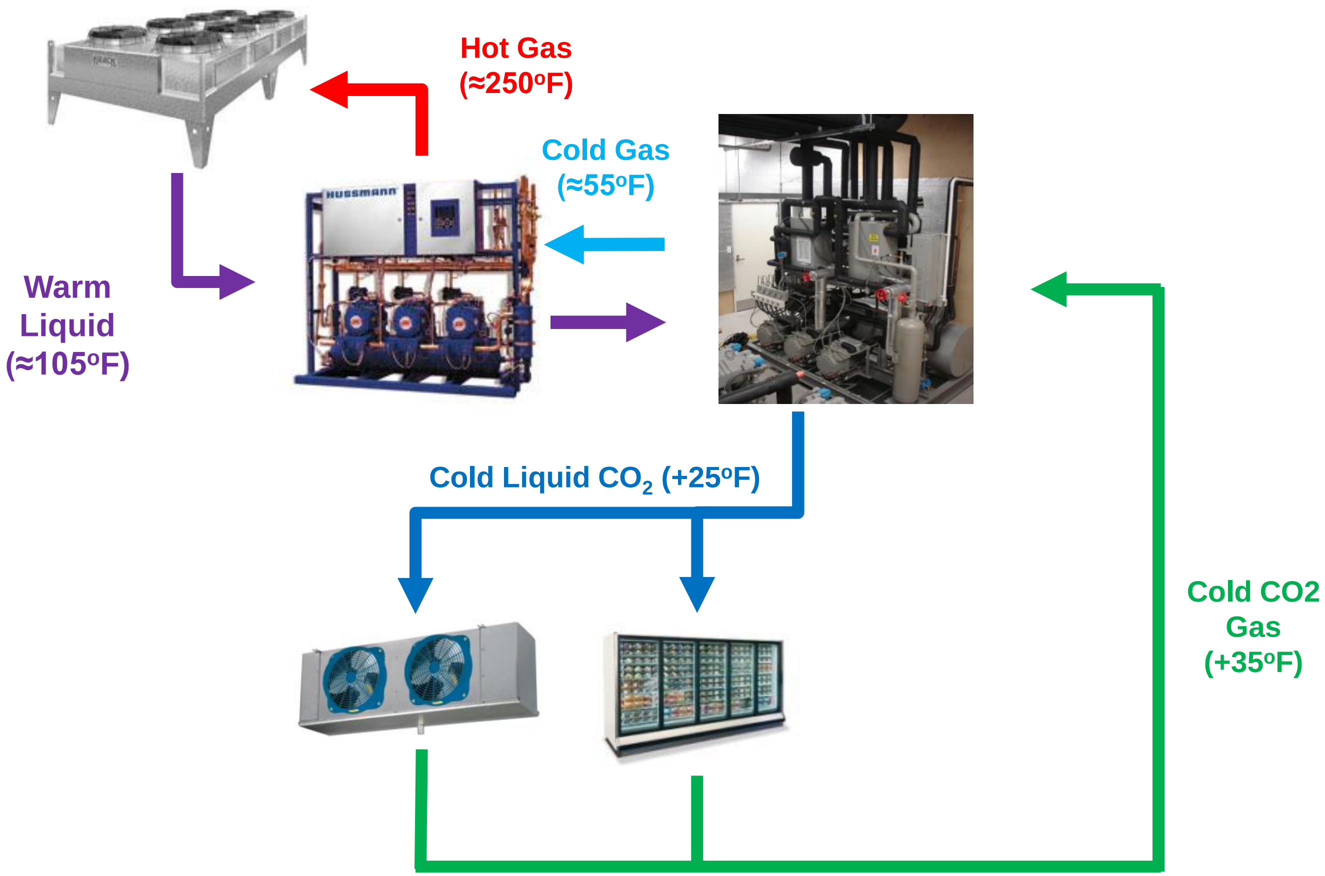
* LT Only



Cascade – Two independent refrigeration systems in series sharing a common heat exchanger

Cascade CO_2 DX Equipment

Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops



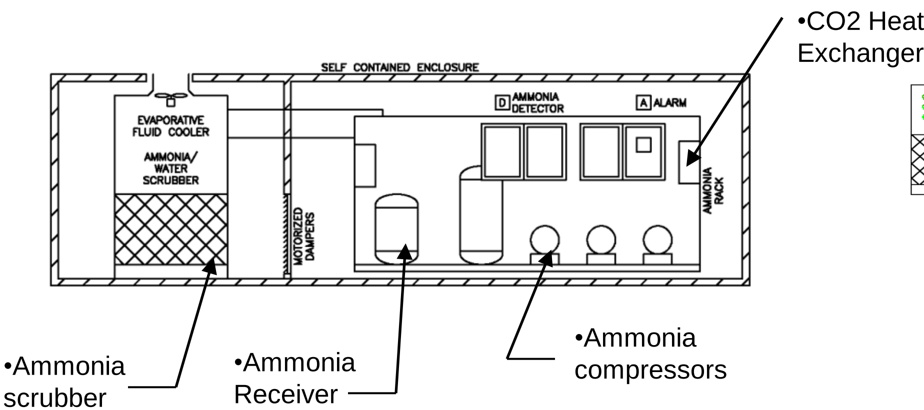
***Loop Piping Shown**

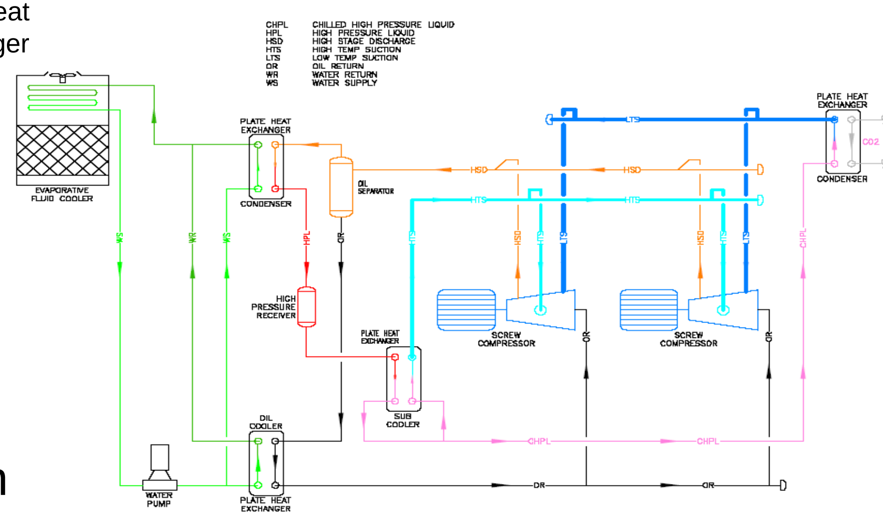
Low Temperature

- Low refrigerant charge
- Reduced leaks
- less copper
- Uses natural CO_2

Ammonia (NH3) Primary System

•Primary Refrigeration Enclosure *•Primary Refrigeration Loop*





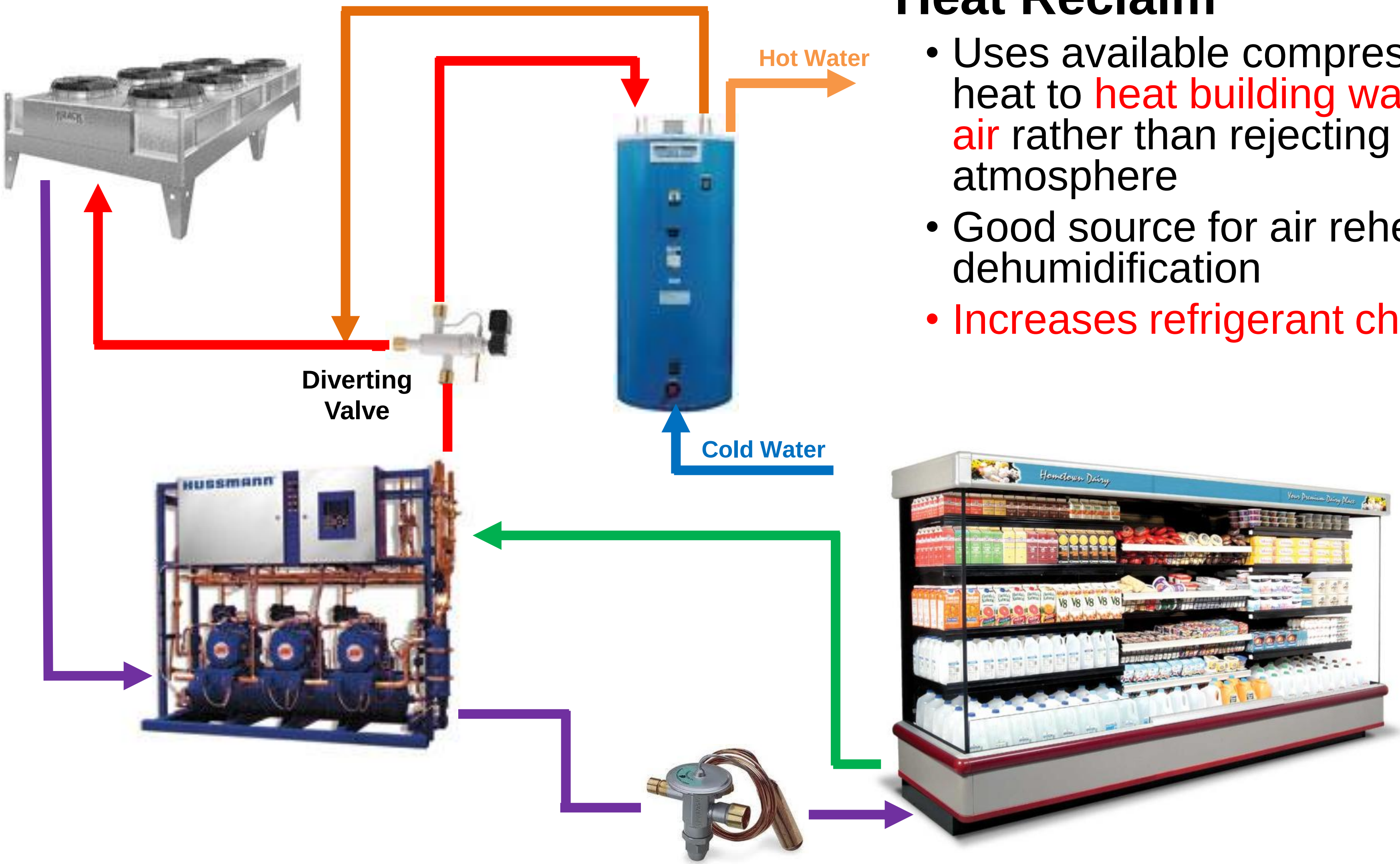
- Primarily used in industrial application
- Typically used with secondary systems
  - Example range of operation (-60°F to +60°F)
- Displaces use of HFC’s
- Can not be used with copper
- Use of water system for scrubbing in case of leak

◆ Low refrigerant charge ◆ Reduced leaks ◆ Natural refrigerant

SYSTEM & BUILDING INTERACTION


HUSSMANN
Hometown Dairy

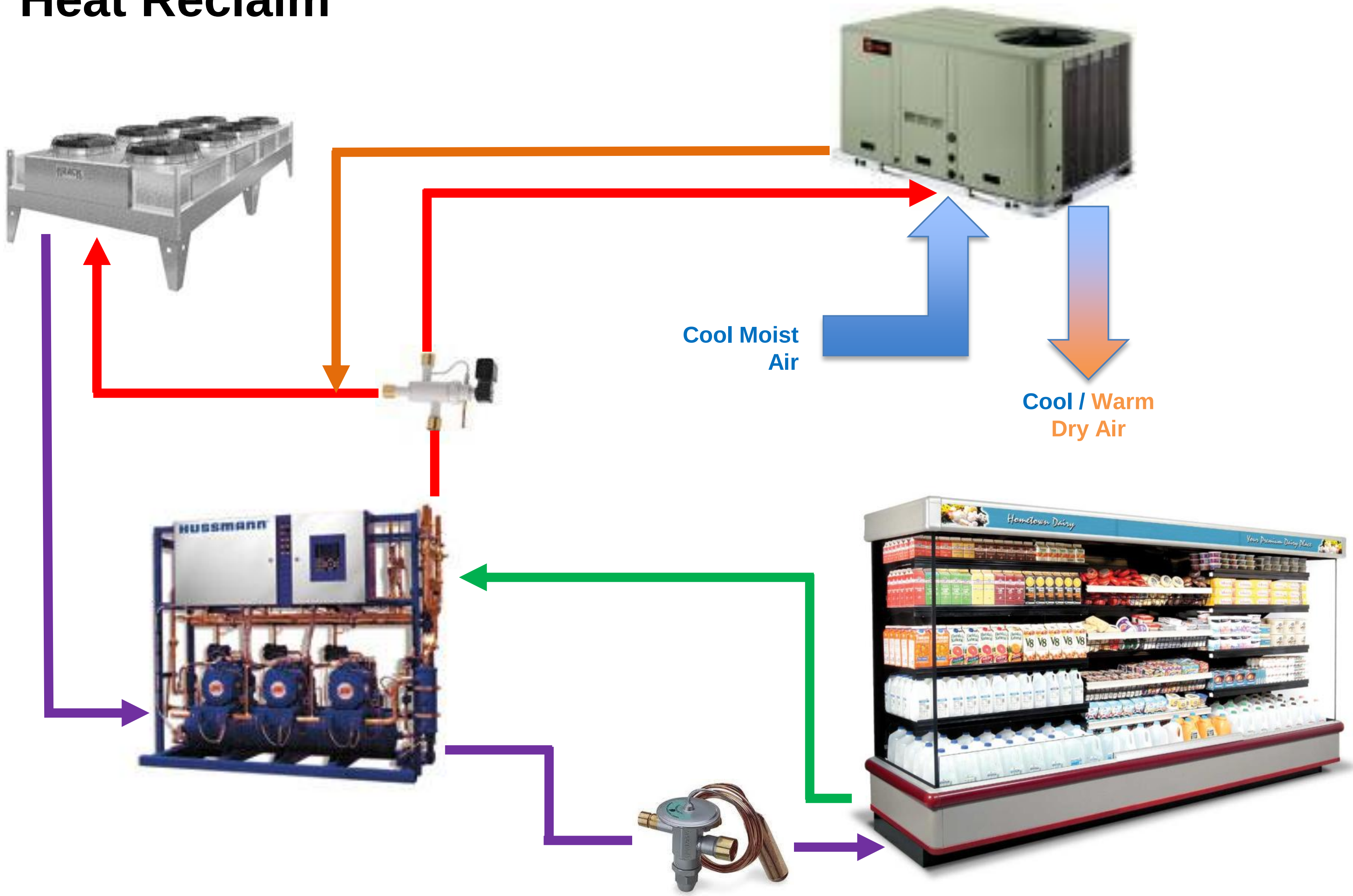
Water Heat Reclaim



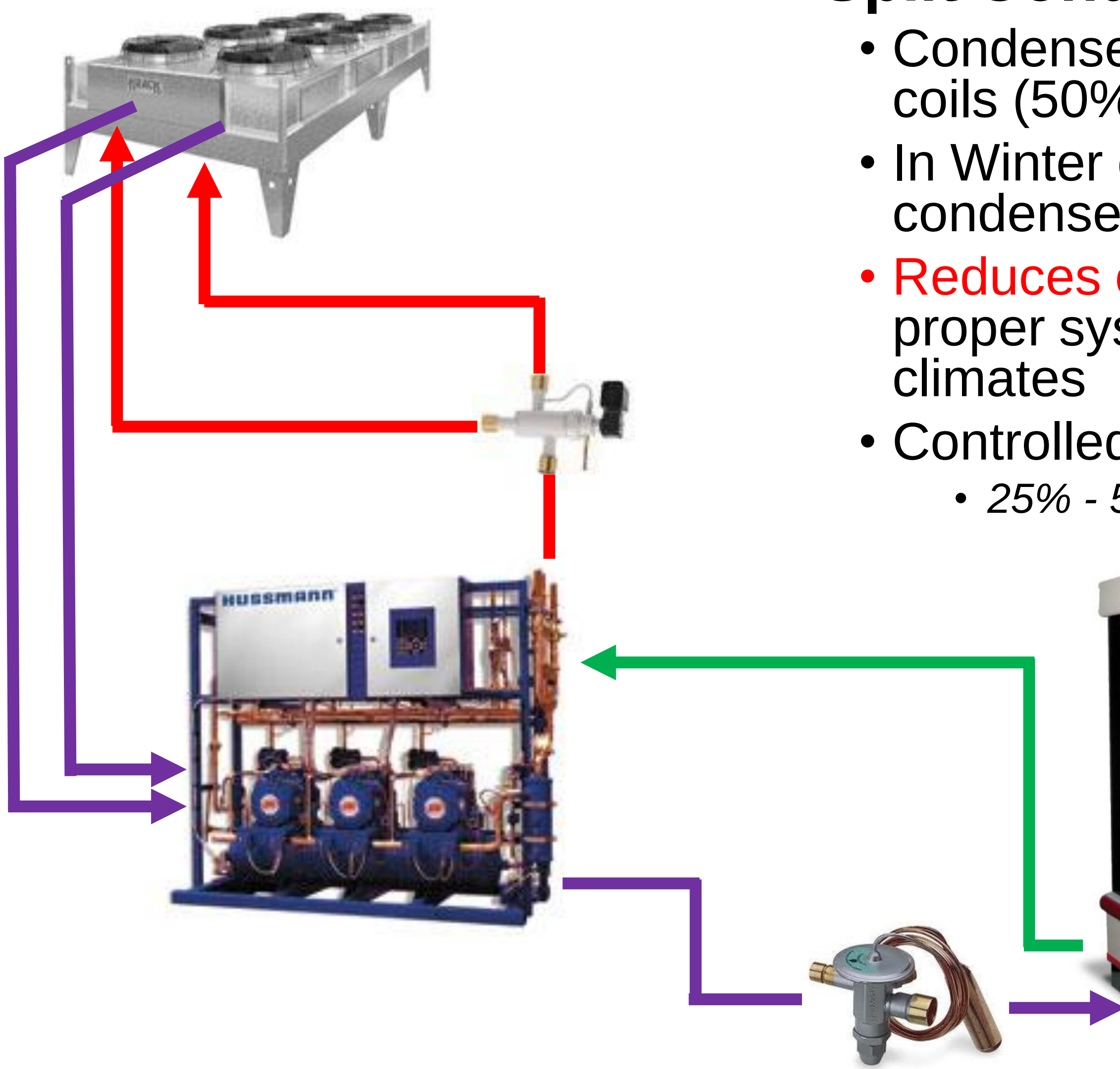
Heat Reclaim

- Uses available compressor heat to heat building water or air rather than rejecting to atmosphere
- Good source for air reheat or dehumidification
- Increases refrigerant charge

Air Heat Reclaim



Split Condenser



Split Condenser

- Condenser sized with two parallel coils (50% - 50%)
- In Winter operation, 50% of condenser is disabled
- Reduces capacity of condenser for proper system control in cold climates
- Controlled by ambient temp sensor
  - *25% - 50% - 50% split is also available*

Heat Reclaim & Split Condenser

** Water reclaim shown*
*** Can substitute with air if desired*

Condensers
•Enhances condenser performance

Suction groups
•Manages multiple compressor racks
•Optimizes compressor cycling and energy savings

Microprocessor Controller
•Central point of equipment control and monitoring
•Increases equipment life and energy with logical control algorithms
•Allows equipment monitoring, alarming and optimization

Controller boards
•Expandable I/O system
•Allows for multiple control and monitoring points

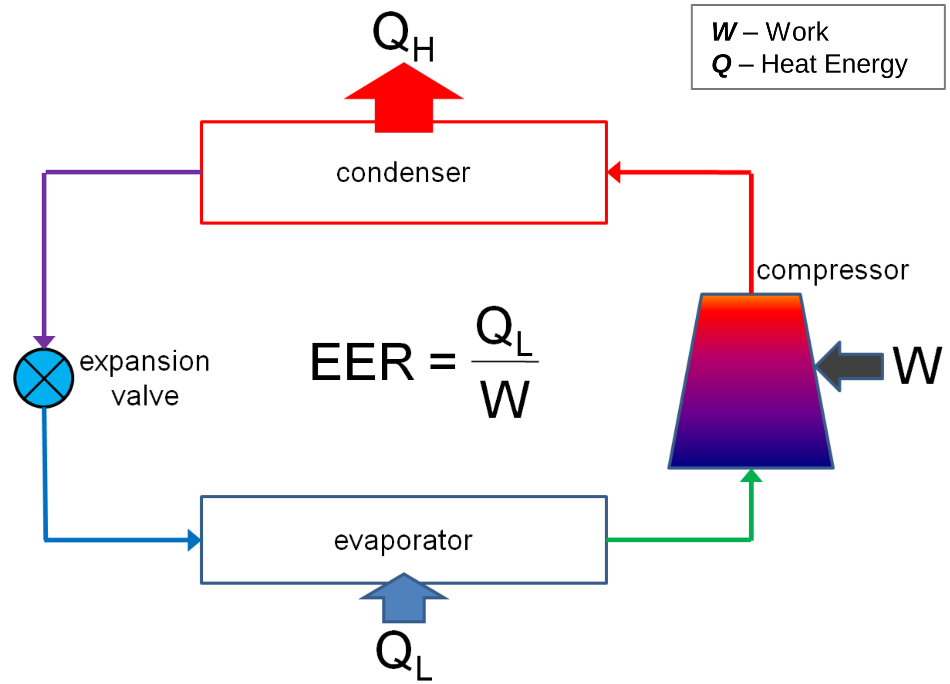
Circuits/display cases
•Flexible control options to choose from
•Supports multiples of cases and case types

Refrigerant leak detectors
•Immediate notification when leak occurs
•Program multiple set points

Tools Used by Engineers / Designers

ANALYSIS & COMPARISONS

Energy Analysis



- Energy Efficiency Ratio (**EER**)
  - Btu/hour per watt
- Coefficient of Performance (**COP**)
  - Unitless
- The amount of cooling divided by the power needed to do the cooling
- A higher value is better
  - it means less energy is used to do a given amount of cooling
- EER and COP depend on many factors
  - evaporating temperature
  - condensing temperature
  - size of condenser
  - type of compressor
  - etc

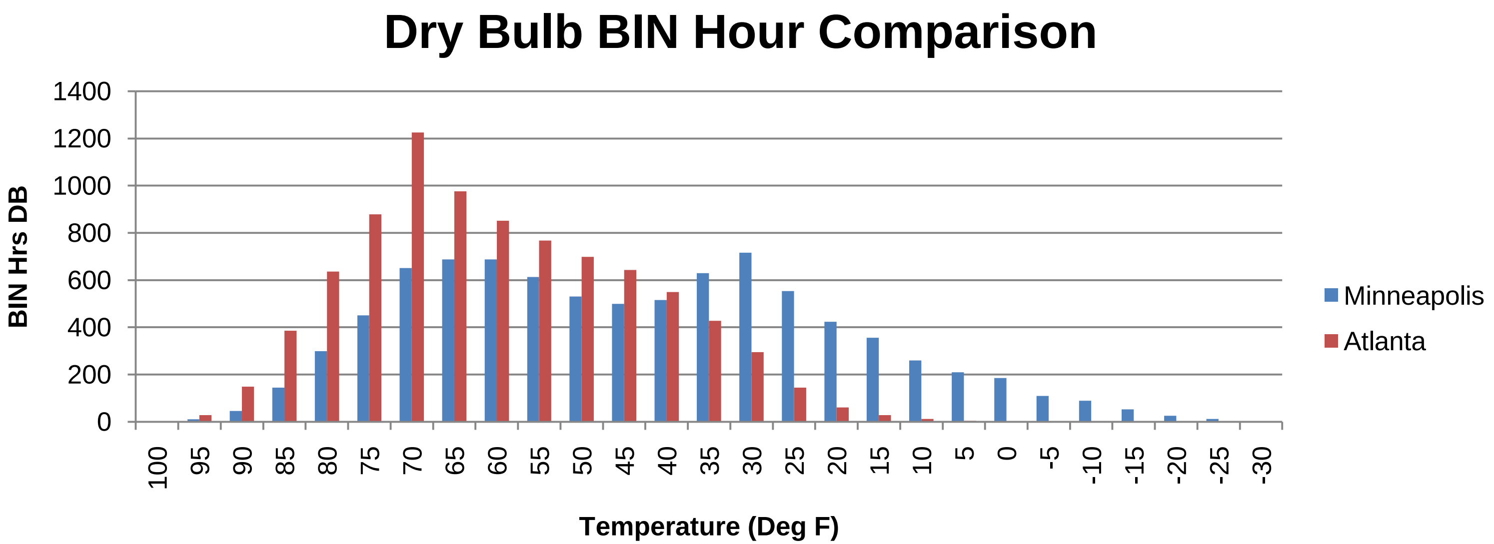
EER is heavily influenced by ambient temp:

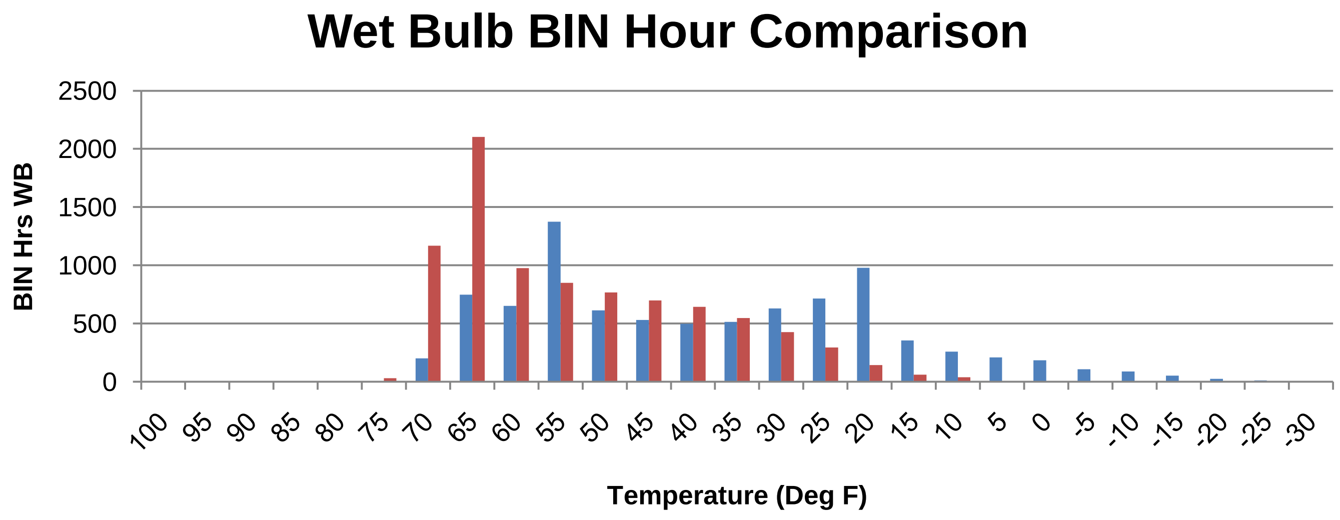
Hot day
- COP = 2
- EER = 7 Btu/hr/watt

Cold day
- COP = 5
- EER = 17 Btu/hr/watt

Energy use is less than half on cold days

Ambient Temperature Bin Hours





Technology Comparison






Approach	Central DX	Distributed DX	Distributed Glycol Secondary	Central Glycol Secondary	Liquid Recirc CO_2	Cascade CO_2
Equipment 1st Cost	**Baseline**	−	− −	− −	− −	−
Energy Efficiency	**Baseline**	+	−	− −	−	+
Refrigerant Charge	**Baseline**	+	+ +	+	+	+
Total Cost of Ownership	**Baseline**	+	−	−	− −	−
Carbon Footprint	**Baseline**	+	+	+	+	+
Service and Complexity	**Baseline**	+	−	−	+	−

+ Better than Baseline
− Worse than Baseline

U.S. ENVIRONMENTAL PROTECTION AGENCY GREENCHILL ADVANCED REFRIGERATION PARTNERSHIP





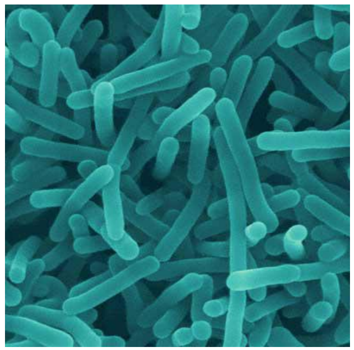



System Type	Possible Level Attainable
Distributed	Silver when air-cooled Gold when air-cooled with microchannel
Secondary Distributed	Gold when air-cooled condenser Platinum when water-cooled
MT Secondary Glycol	Silver with centralized LT DX Gold with other advanced LT
Secondary CO_2	Gold when used for both LT & MT Loads
LT CO_2 Cascade	Gold when combined with MT secondary glycol or secondary CO_2 MT
MT Glycol Compact Chiller	Platinum when water cooled and combined with LT CO_2

Application of any system type does not guarantee certification ability. Proper planning, equipment selection, application, placement, and refrigerant are required.

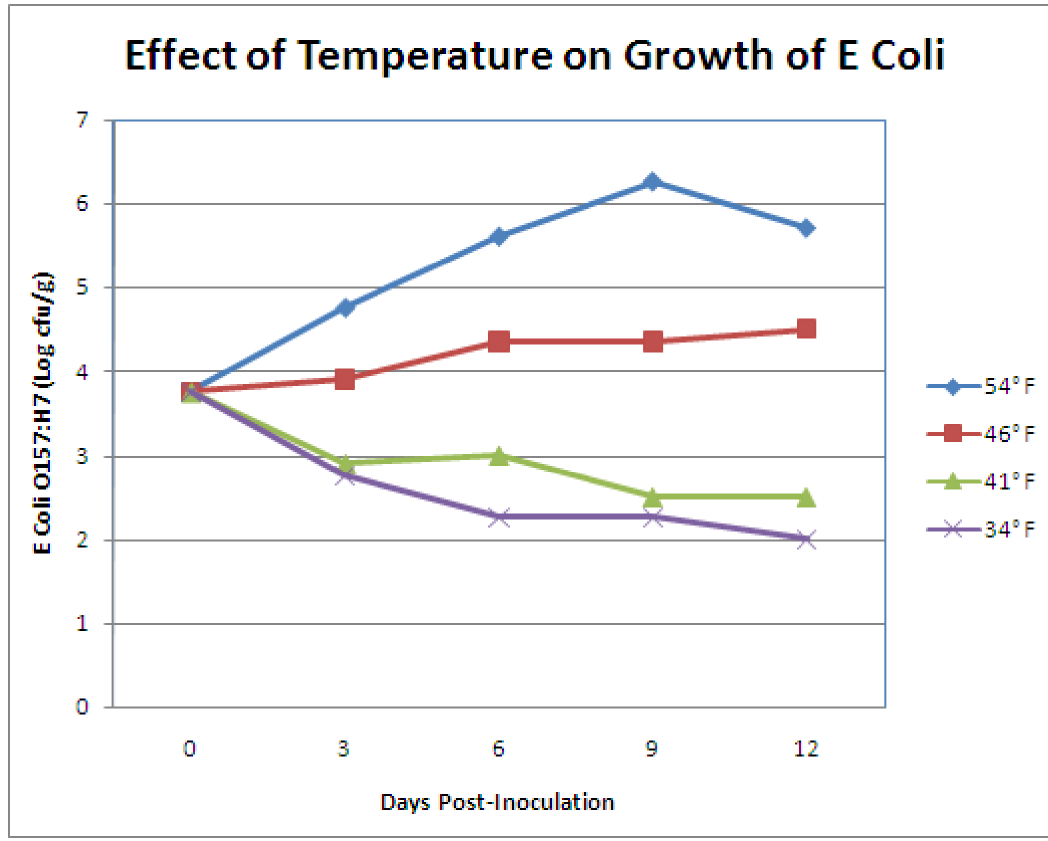
Risk Increases Significantly w/ Product Temp

•Salmonella



•Listeria

•E Coli on Beef



•Note: Y axis is 1000's of colony forming units per gram.
It only takes < 100 cells to cause illness

Why refrigeration is important - for the preservation and distribution of food…

Thank you for your attention!

Questions?

Travis D. Lumpkin, PE

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Hussmann