Energy & Store Development Conference

E+sd 2011

FOOD MARKETING INSTITUTE

Refrigeration 201

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September 2011

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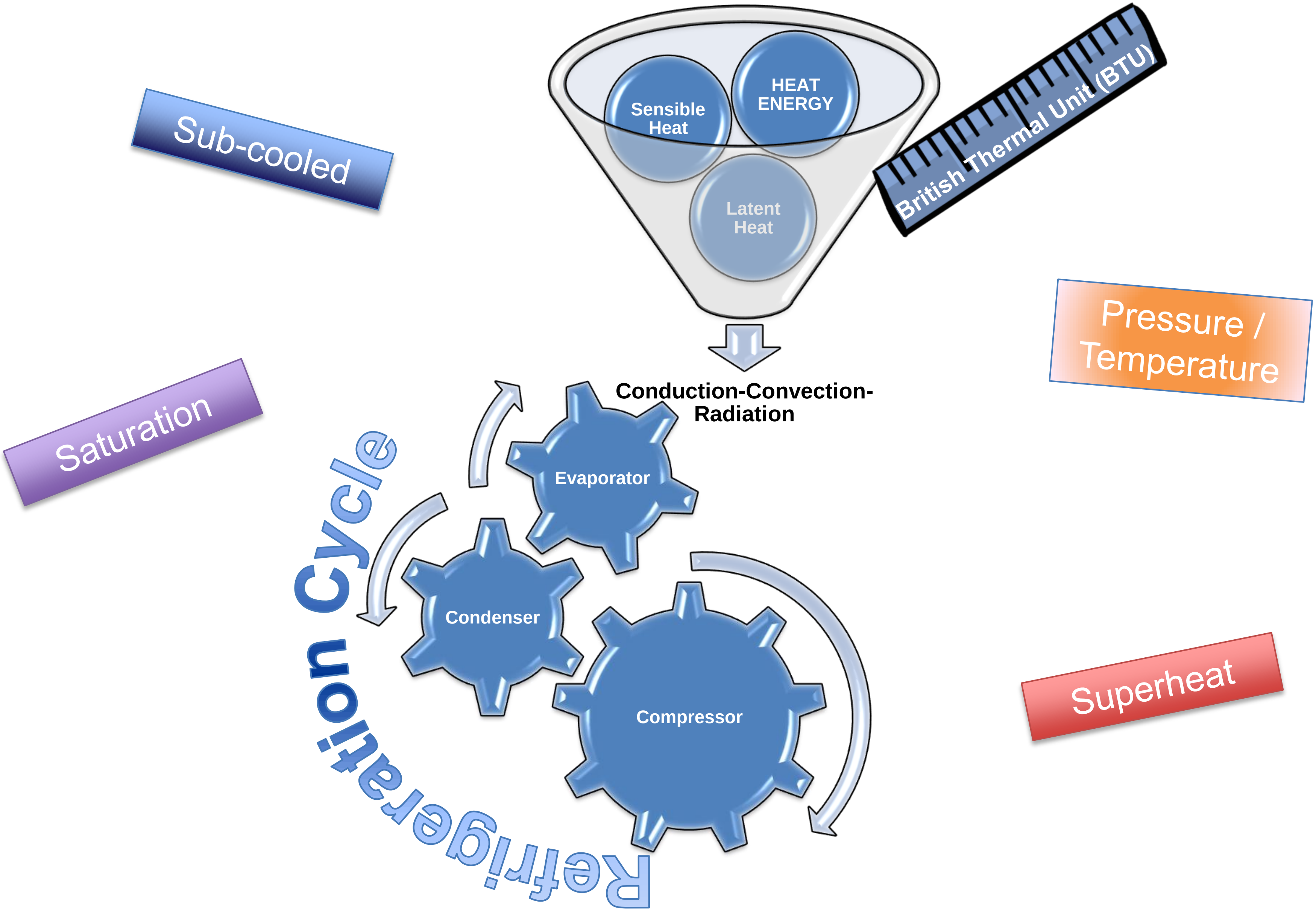
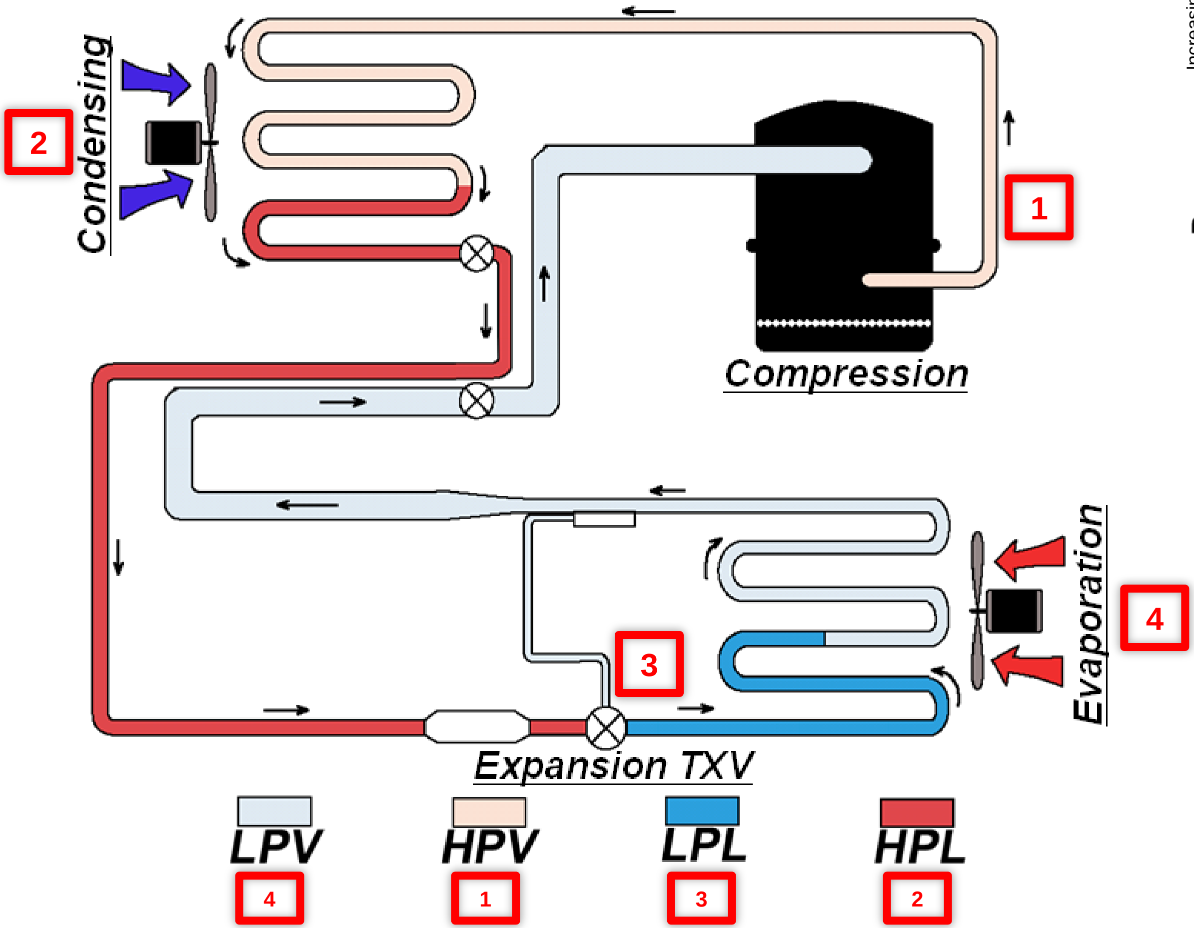
Key Learning's

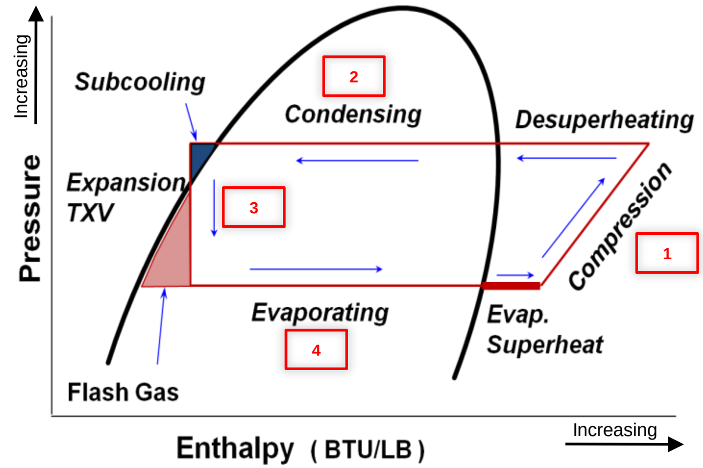
- Review of Refrigeration 101
- Basic understanding of more complex components of a refrigeration system
- Overview of more complex mechanical refrigeration systems
- Interaction of the mechanical system with the building
- Equipment planning and location

REFRIGERATION 101 REVIEW


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

Refrigeration Cycle



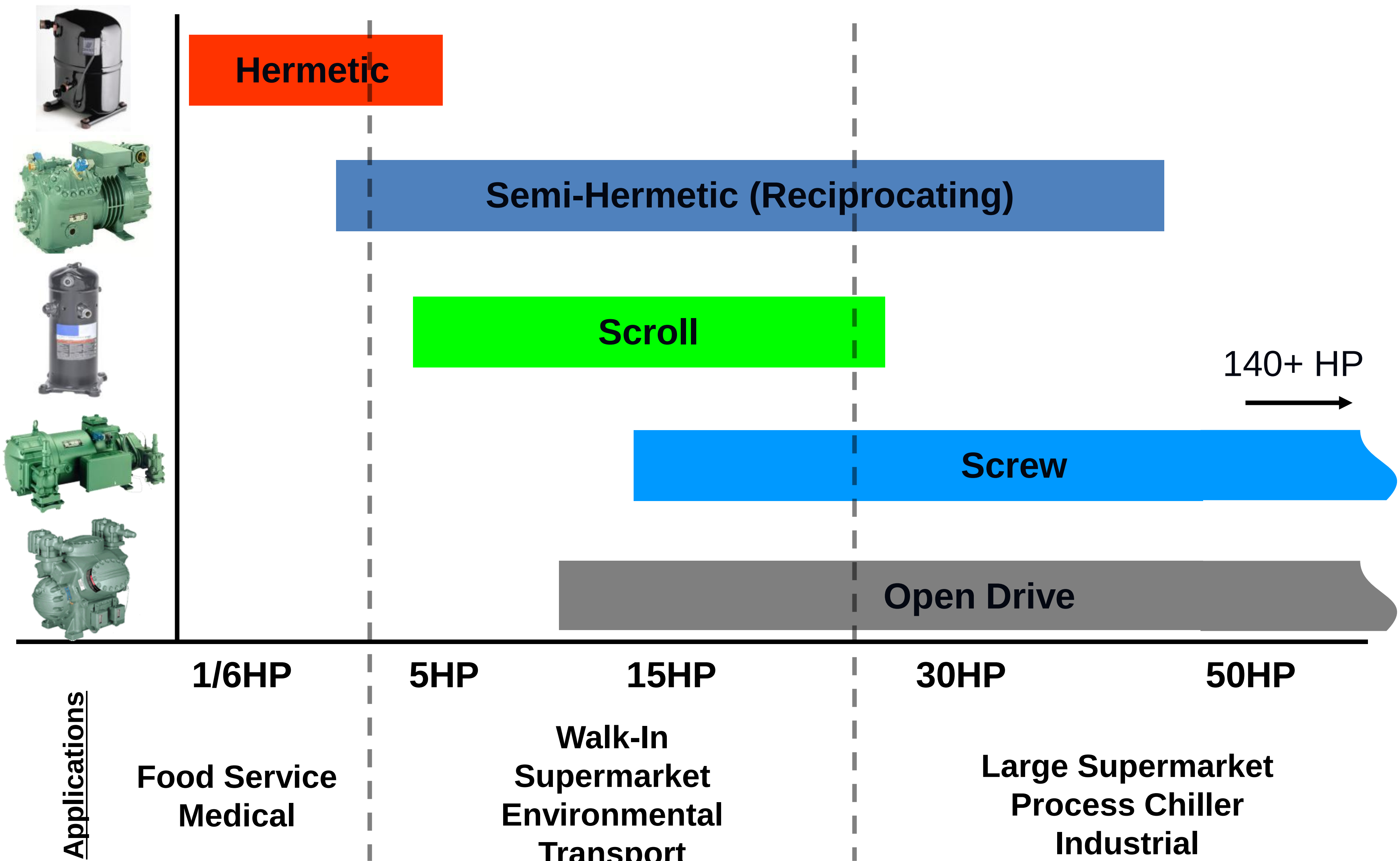


Vapor Compression Refrigeration Cycle

Enthalpy – measure of the heat energy of a substance.

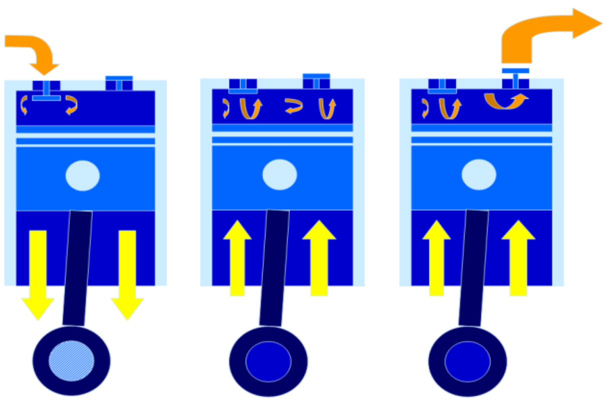
LPV - Low Pressure Vapor
HPV – High Pressure Vapor
LPL – Low Pressure Liquid
HPL – High Pressure Liquid

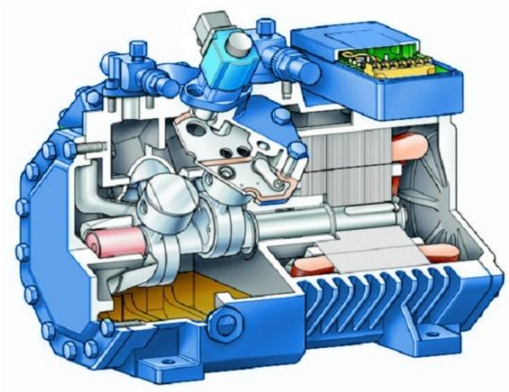
SYSTEM MAJOR COMPONENTS OVERVIEW



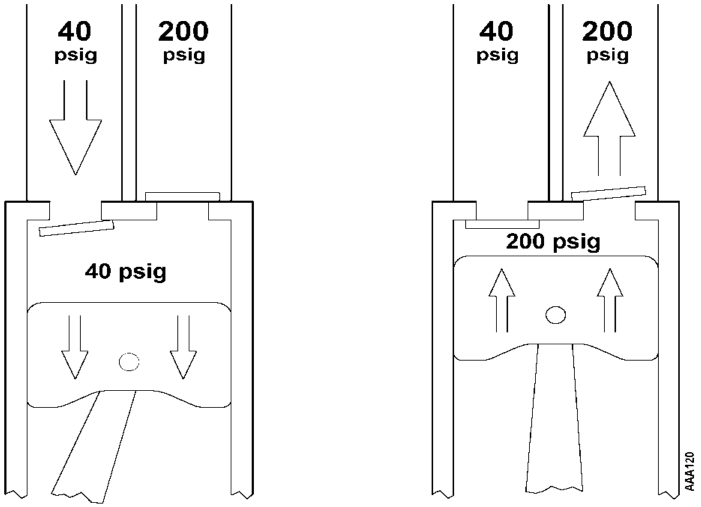
Select the proper compressor for the appropriate application

Reciprocating Compressor



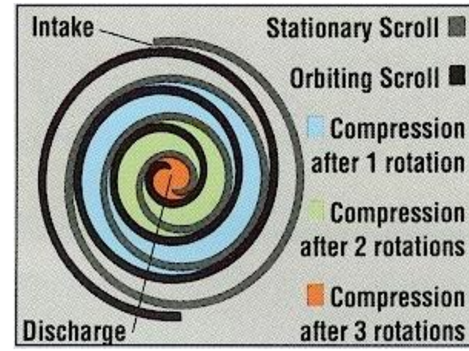


MEDIUM TEMP PRESSURES



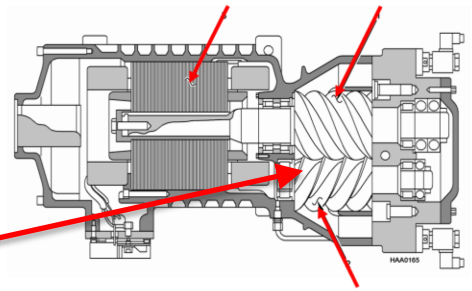
- Moving pistons compress refrigerant gas within cylinders.
- On the downstroke, the suction inlet valve is open as low pressure gas refrigerant is drawn into the cylinder.
- When the piston begins its upstroke, the suction inlet valve is closed and pressure increases.
- High pressure gas exits through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

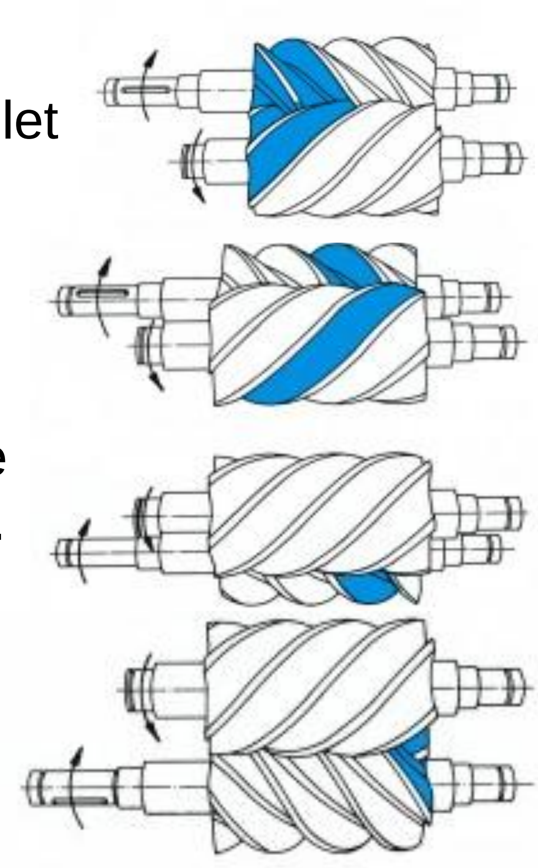
Scroll Compressor



- 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.

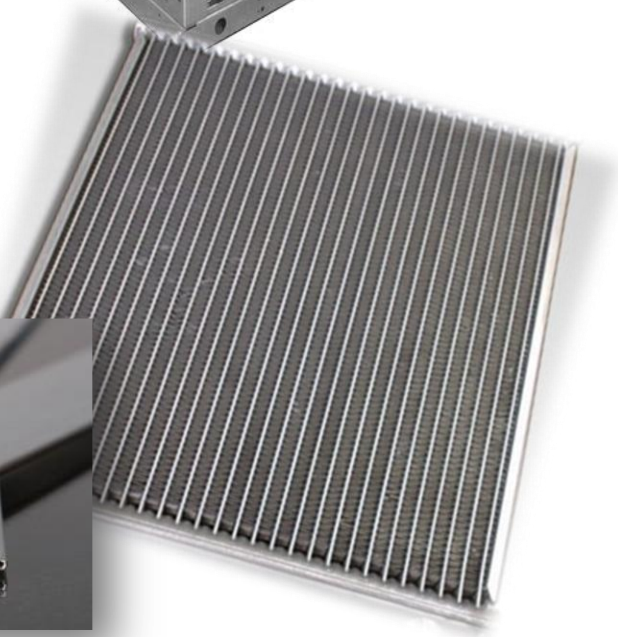
Discharge: compression is completed, final pressure achieved and the vapor is discharged.

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

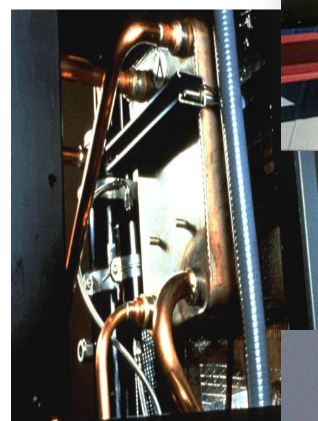


Evaporative Cooled Condenser

- 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

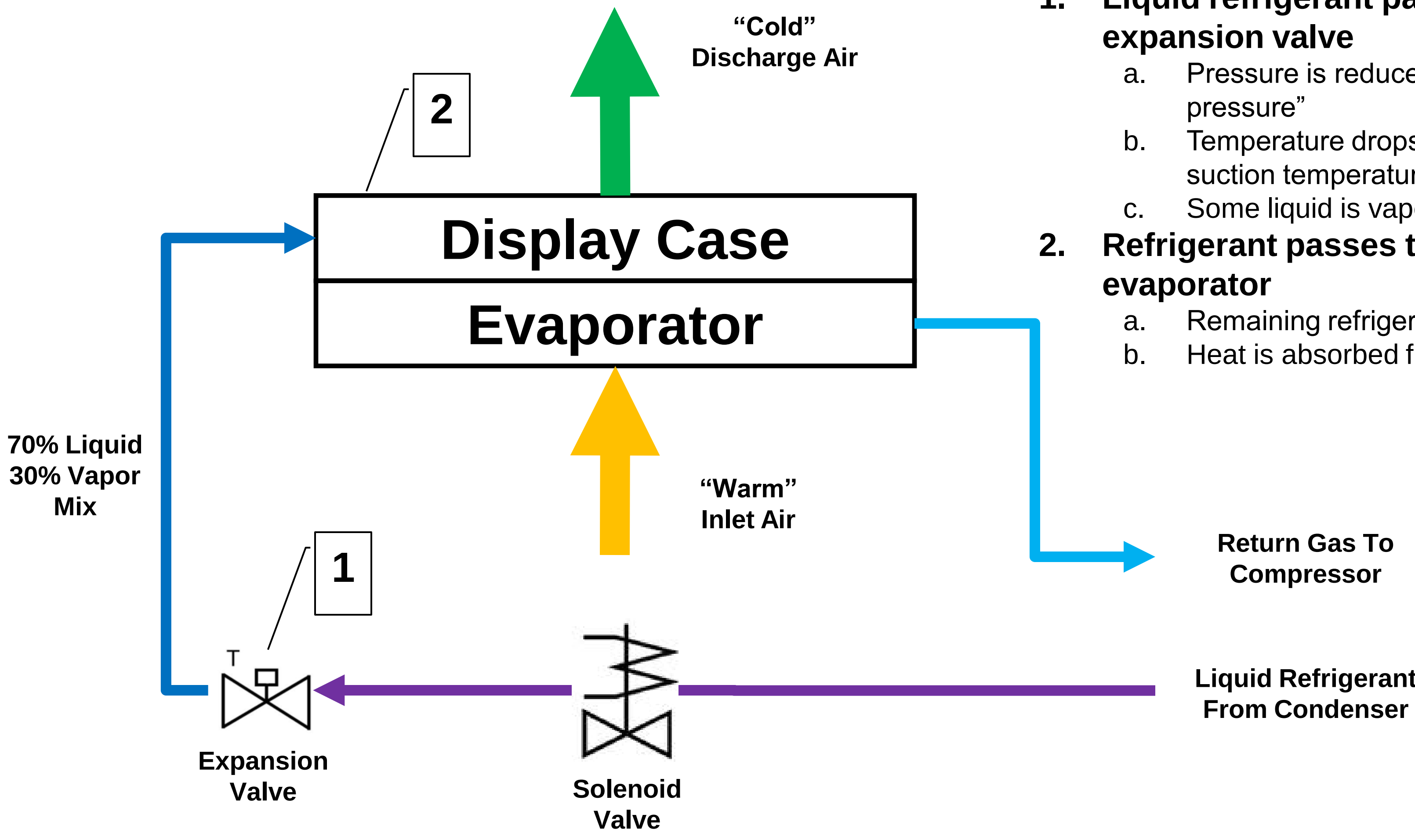
- Fan cooled coil assembly
- Draws ambient air across coil slab to remove heat from glycol mixture
- Glycol mixture used as condenser fluid for refrigeration system
- Refrigeration system uses heat exchanger (plate-to-plate shown) to condense compressor discharge gas
    - Located near compressors



Hybrid Fluid Cooler / Condenser

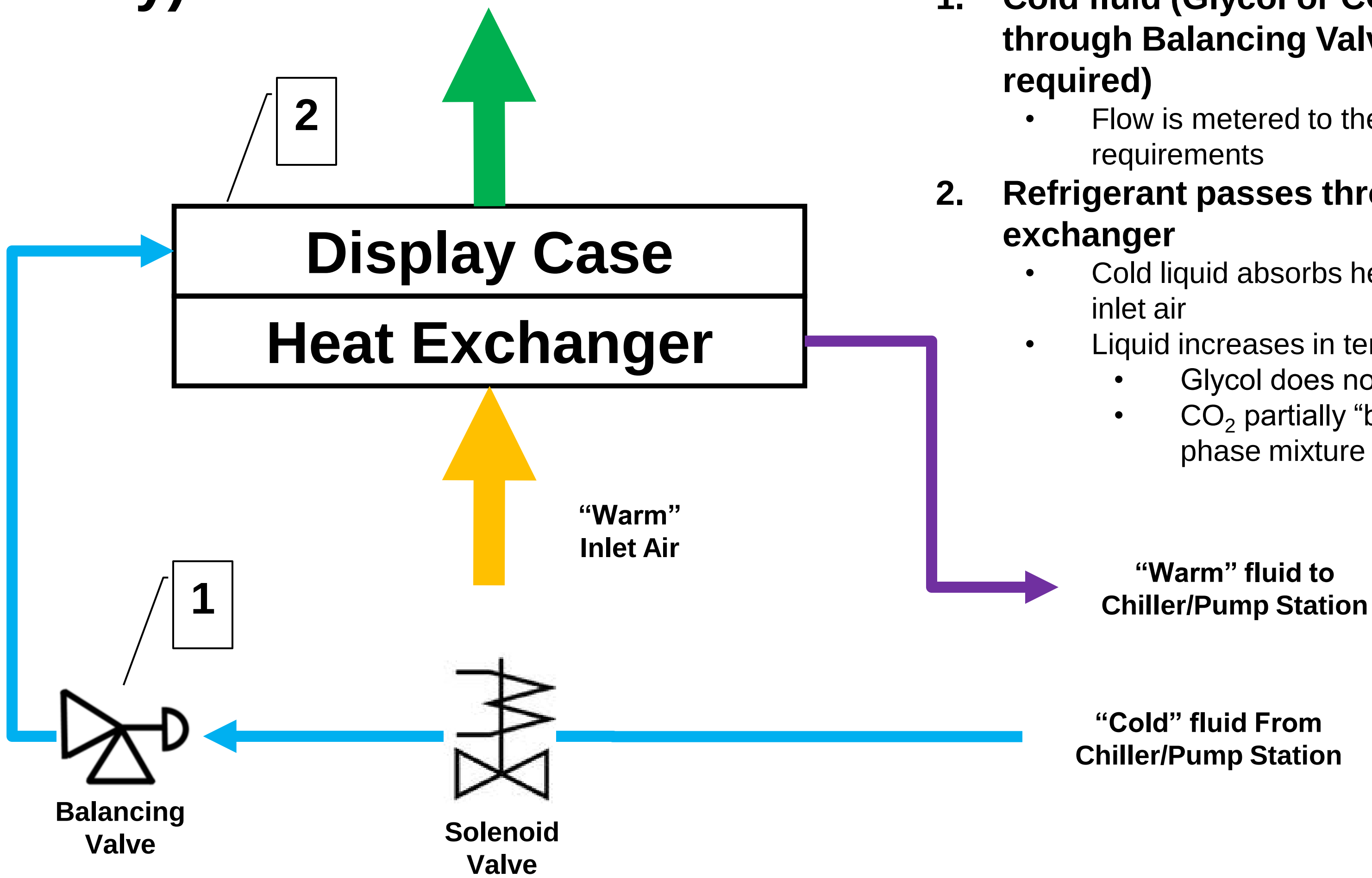
- Uses RTPF coil or microchannel coil
- Equipped with pre-cooling pads to cool incoming ambient air with water that is distributed over the cooling pads
- Air is drawn through the cooling pads and the heat exchangers
- Increases system efficiency

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

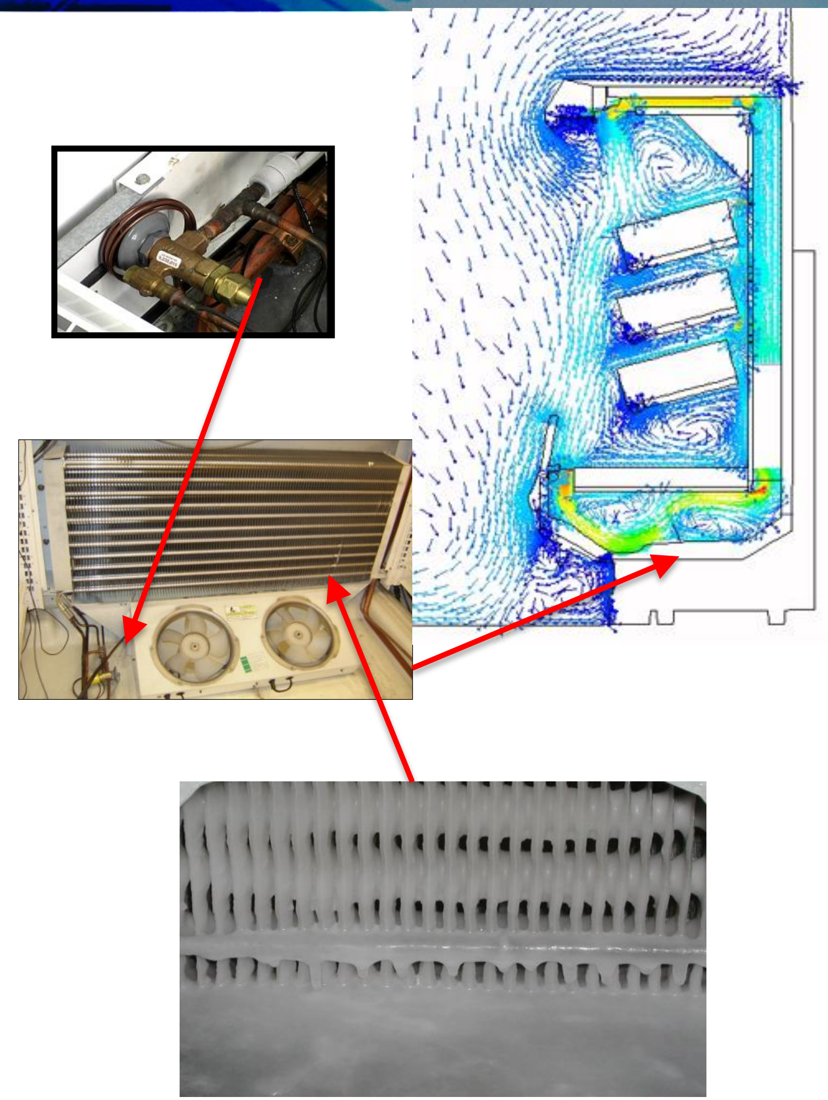
Display Case Operation (Secondary)



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)

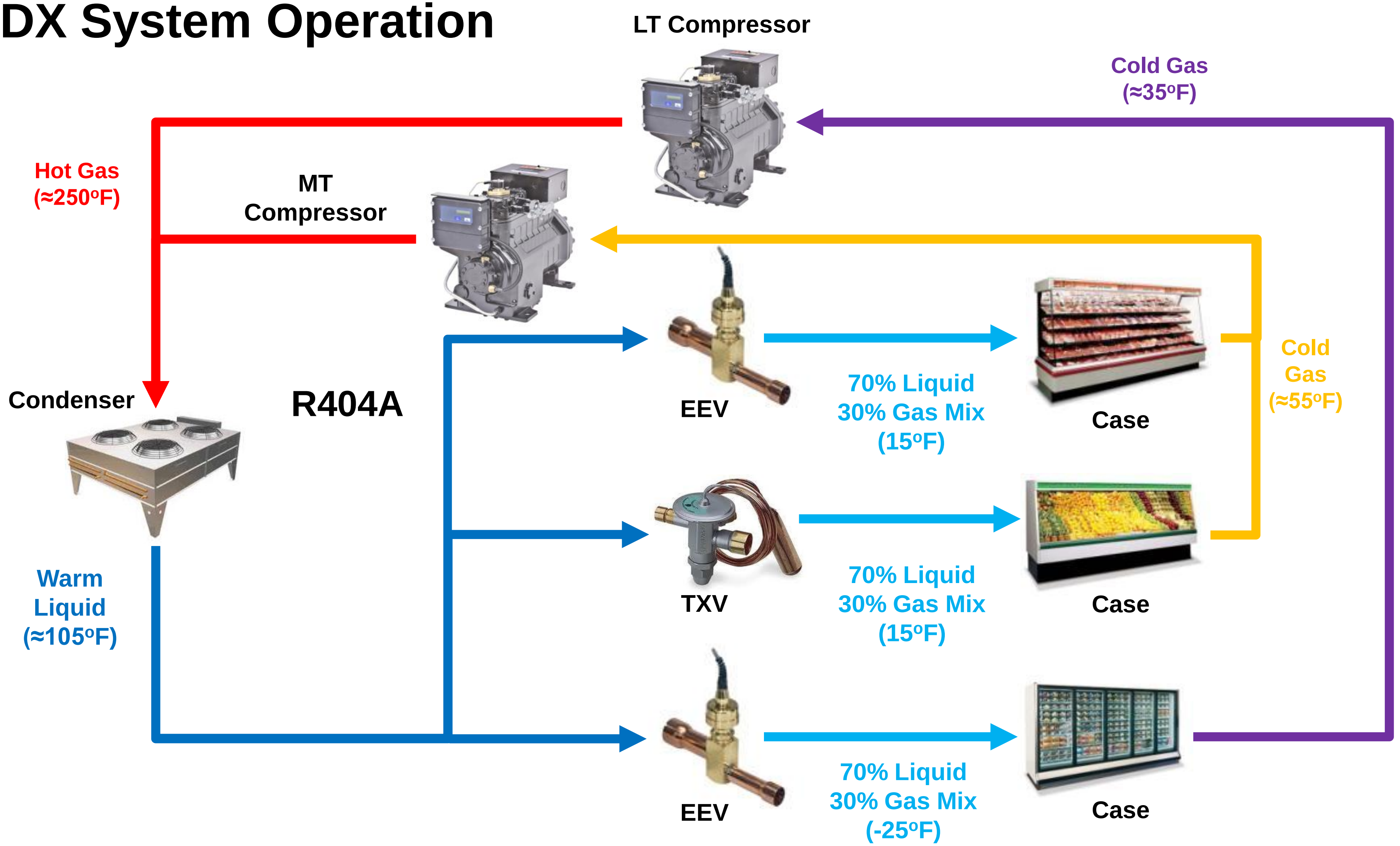
Mechanical EPR w/solenoid

Electronic EPR (EEPR)

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

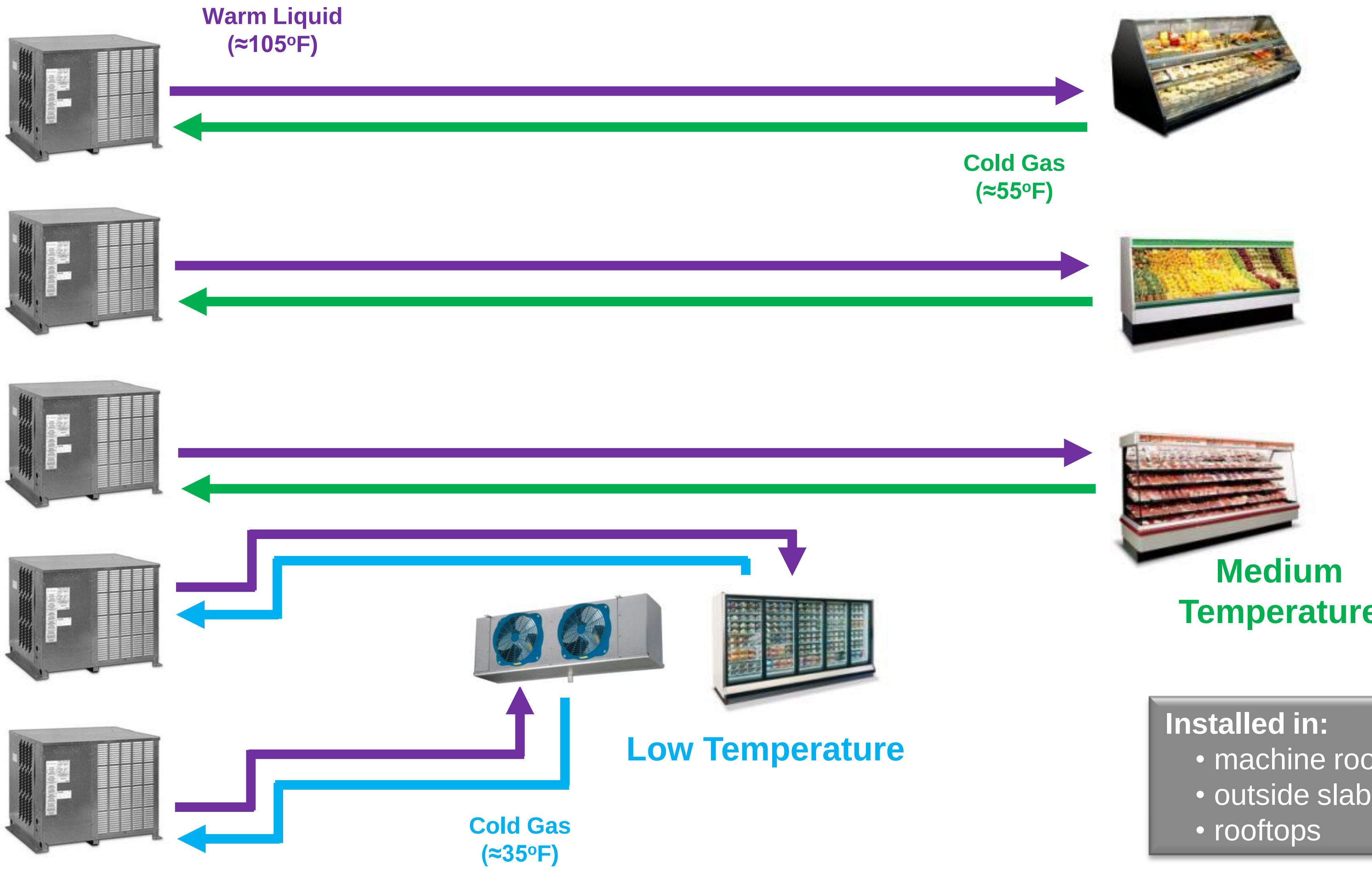
SYSTEM TYPES

DX System Operation



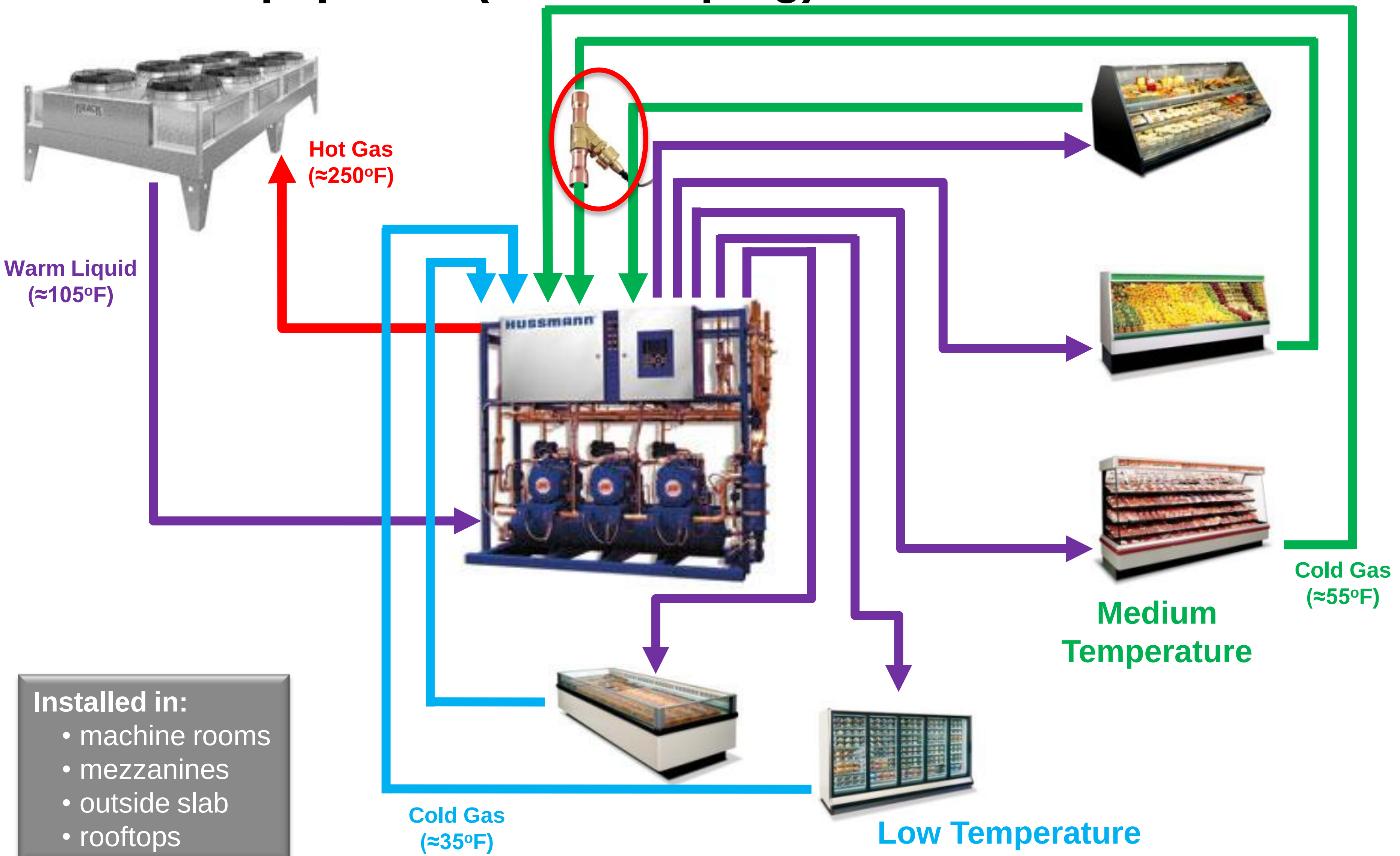
DX – Direct Expansion refrigeration system

DX Condensing Unit Equipment

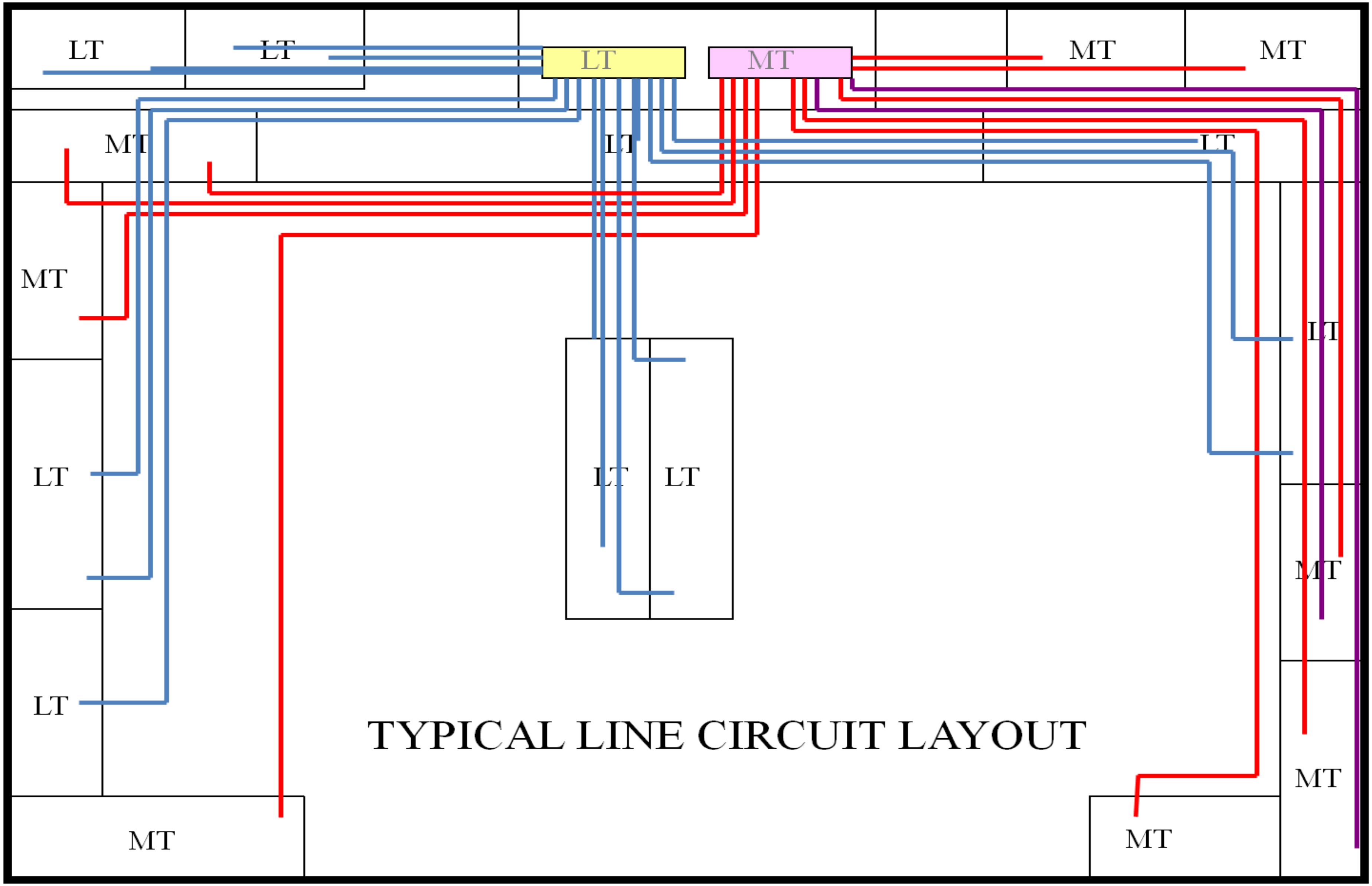


Installed in:
- machine rooms
- outside slab
- rooftops

DX Rack Equipment (Circuit Piping)



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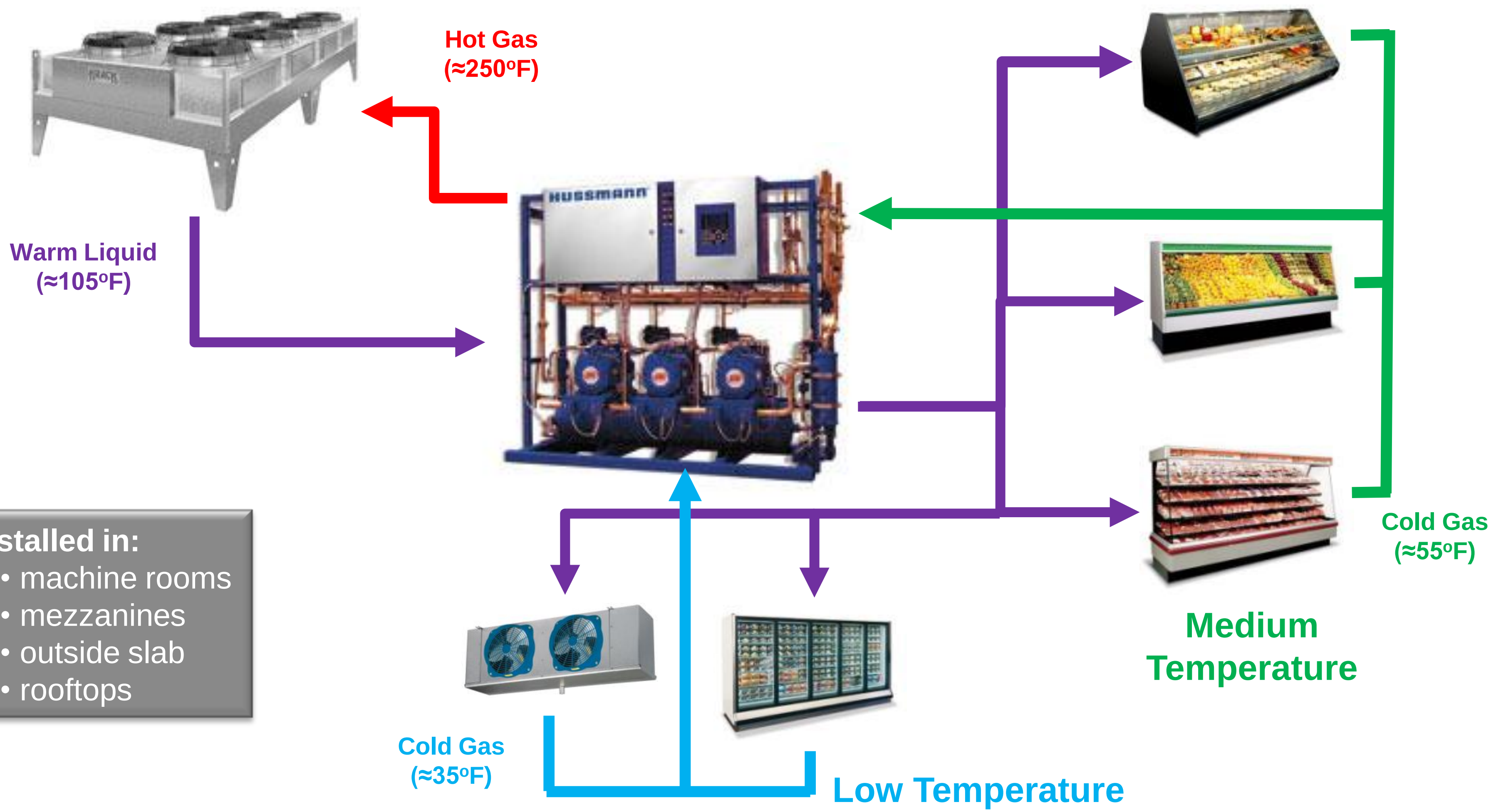
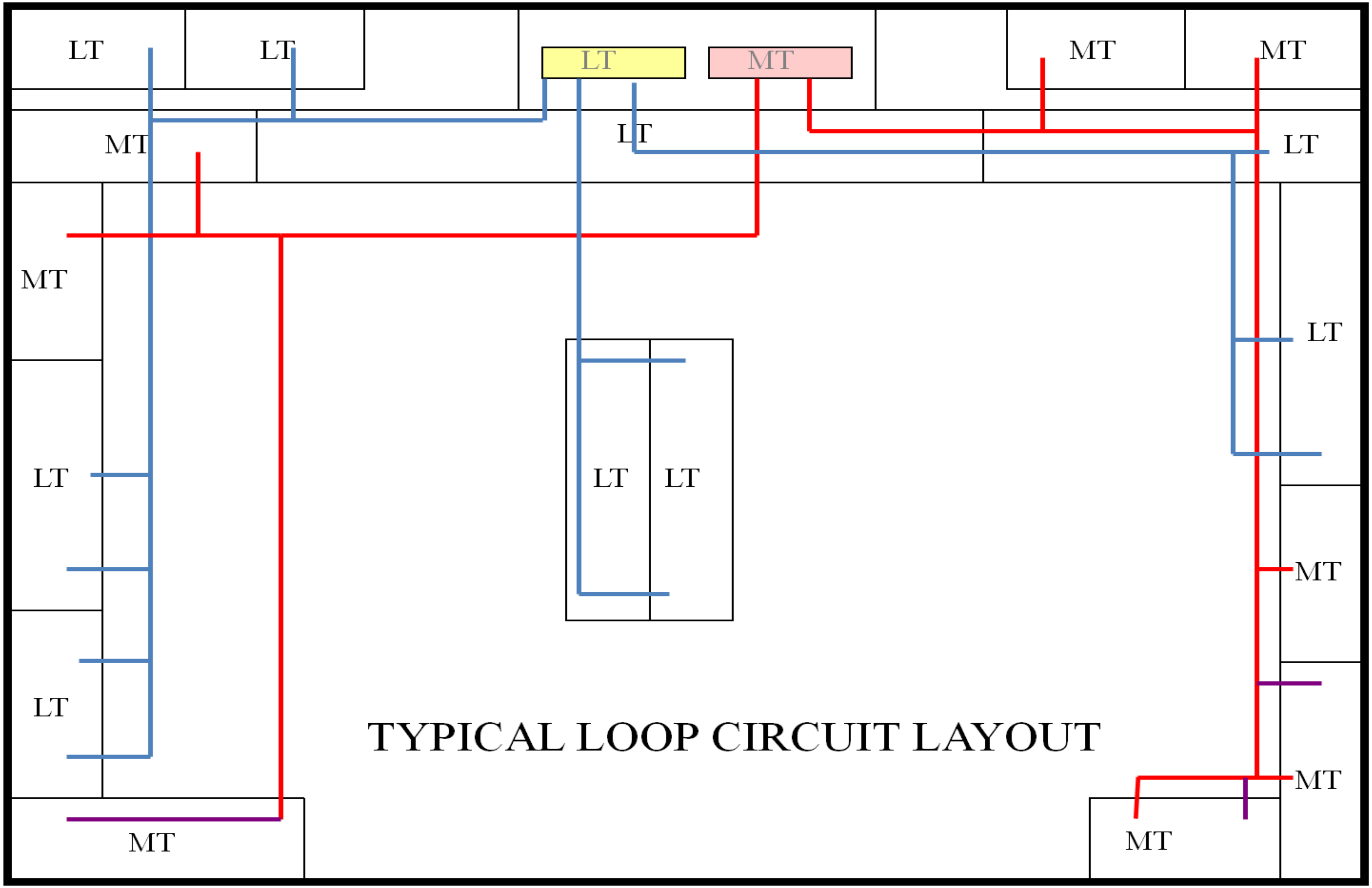
TYPICAL LINE CIRCUIT LAYOUT

DX Rack Equipment (Loop Piping)



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

Lower refrigerant charge than circuit piping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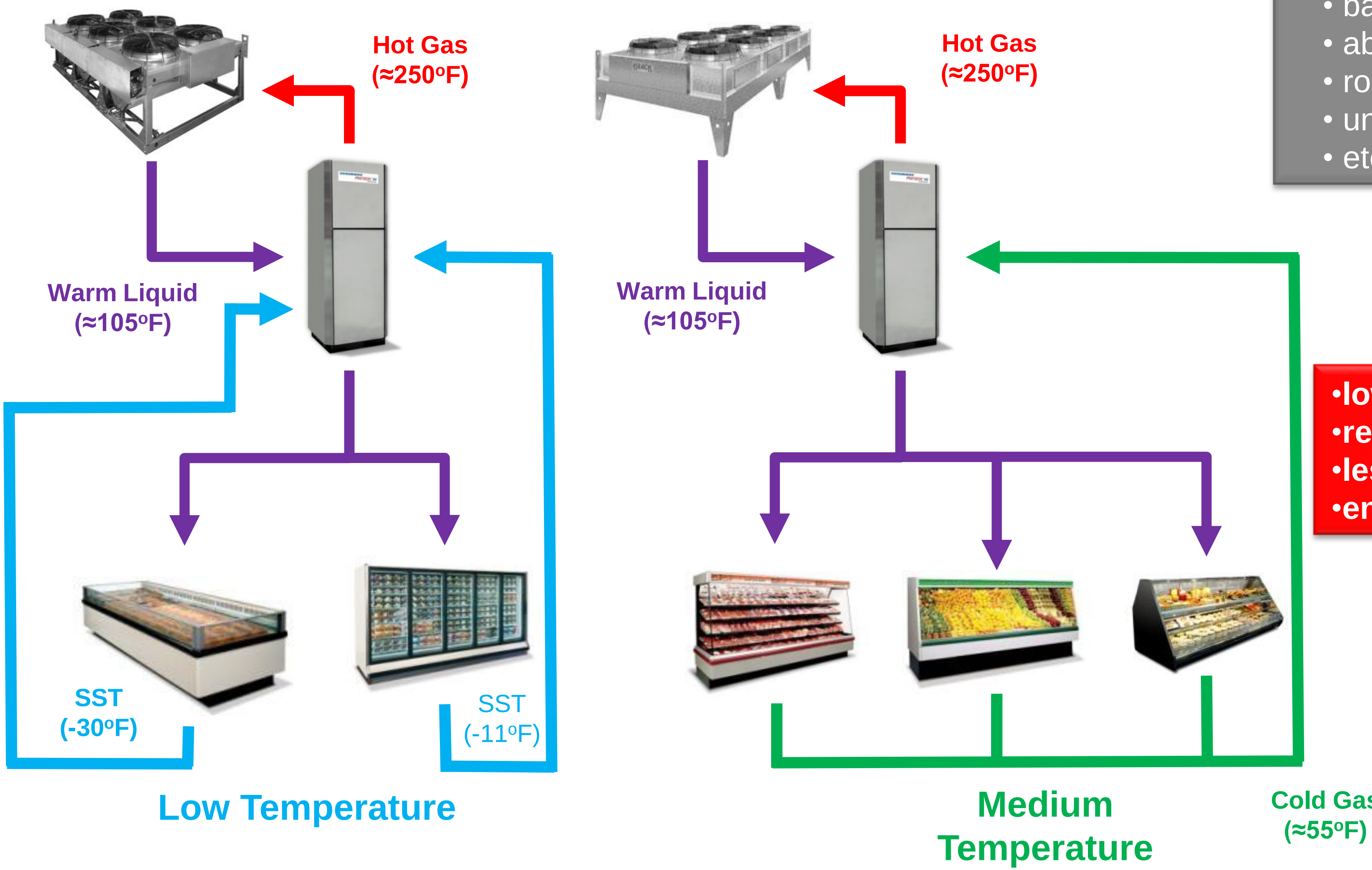
TYPICAL LOOP CIRCUIT LAYOUT

Distributed DX Equipment (Loop)

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

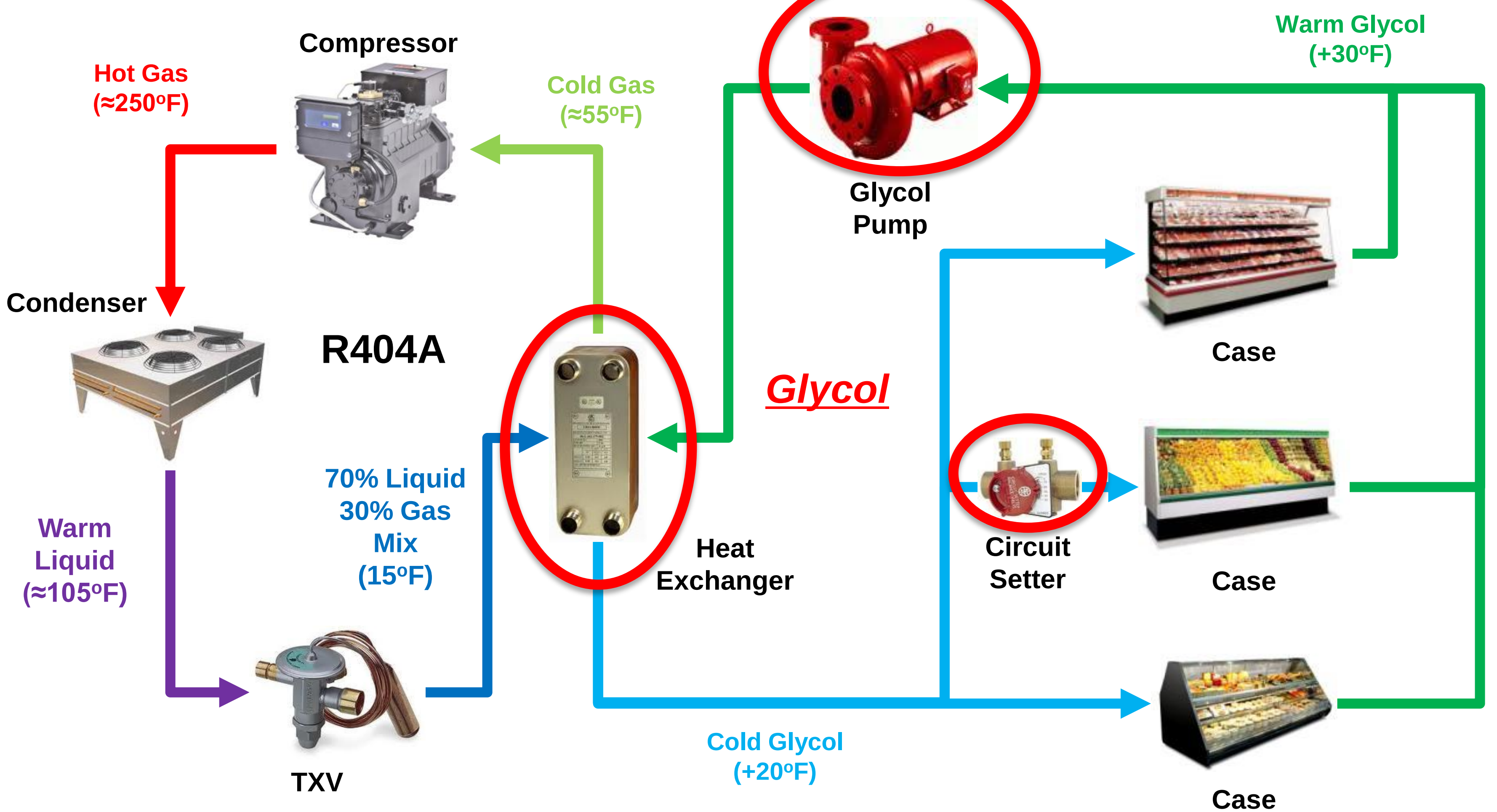


- **low charge**
- **reduced leaks**
- **less copper**
- **energy efficient**

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

Secondary Glycol System Operation

* MT Only

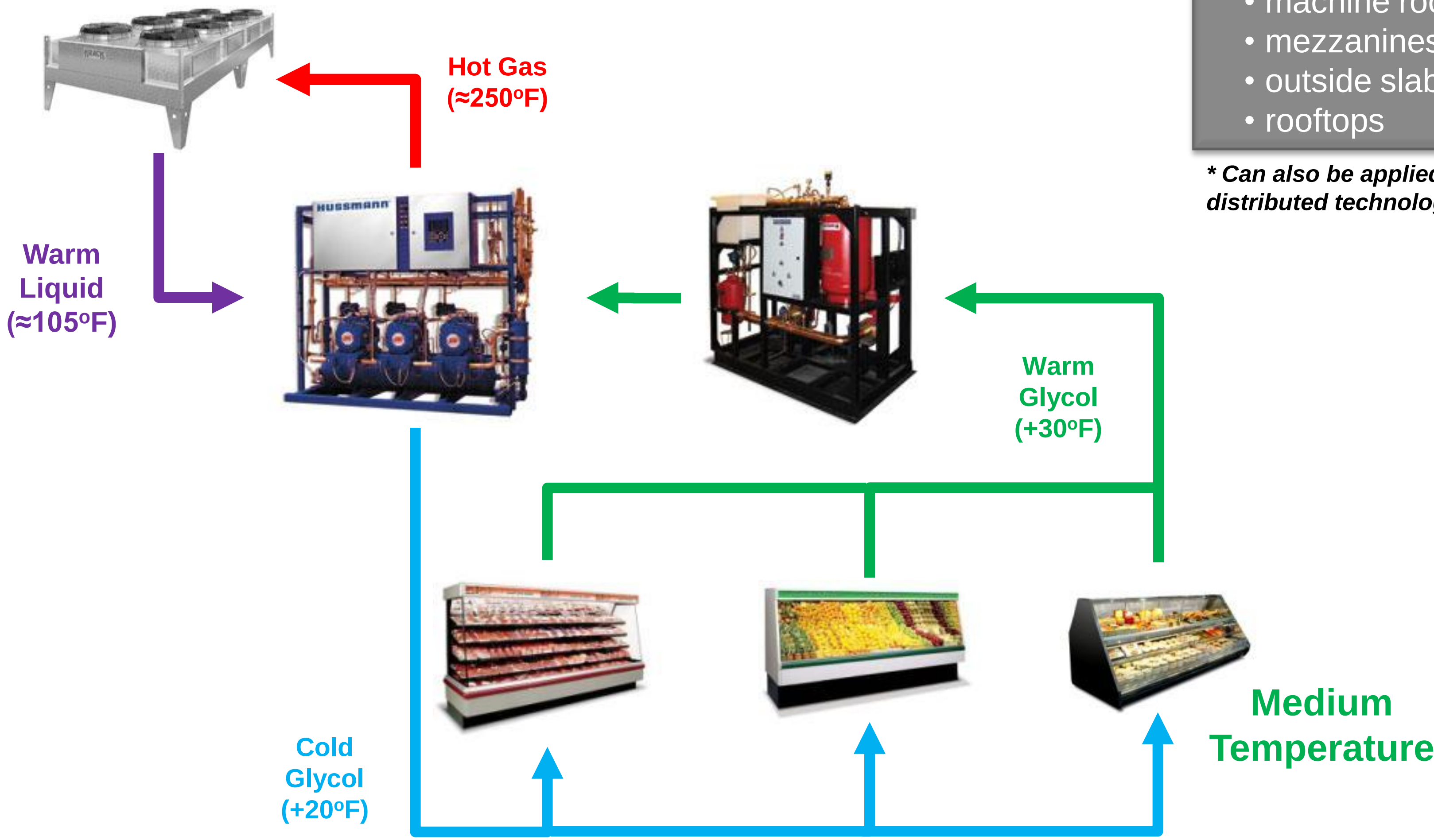


Secondary – Intermediate medium for heat transfer between cooling load and refrigerant

Secondary Glycol Equipment (Loop)

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

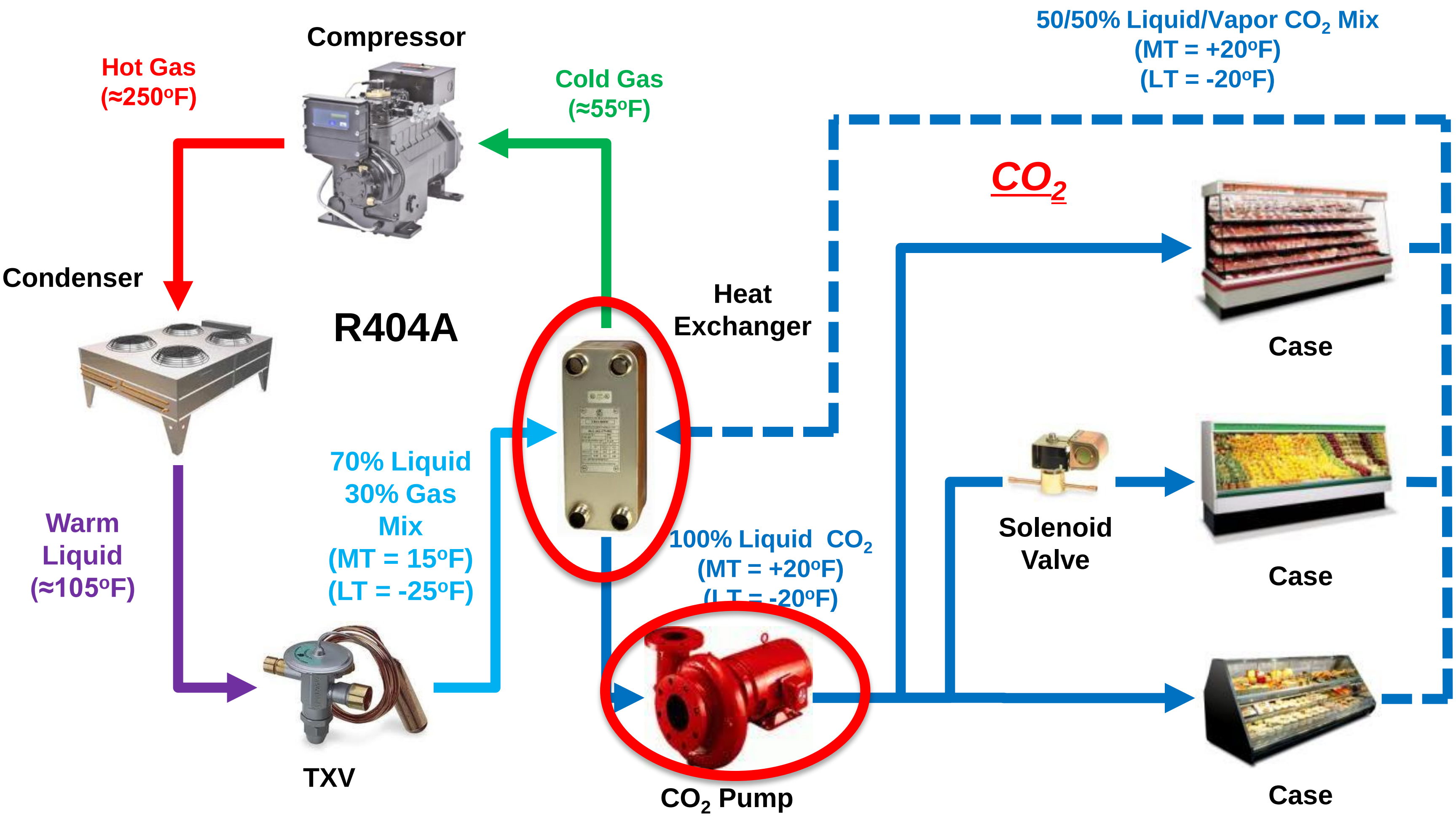
Can also be applied with distributed technology



- **Low refrigerant charge**
- **Reduced leaks**
- **Less Copper**

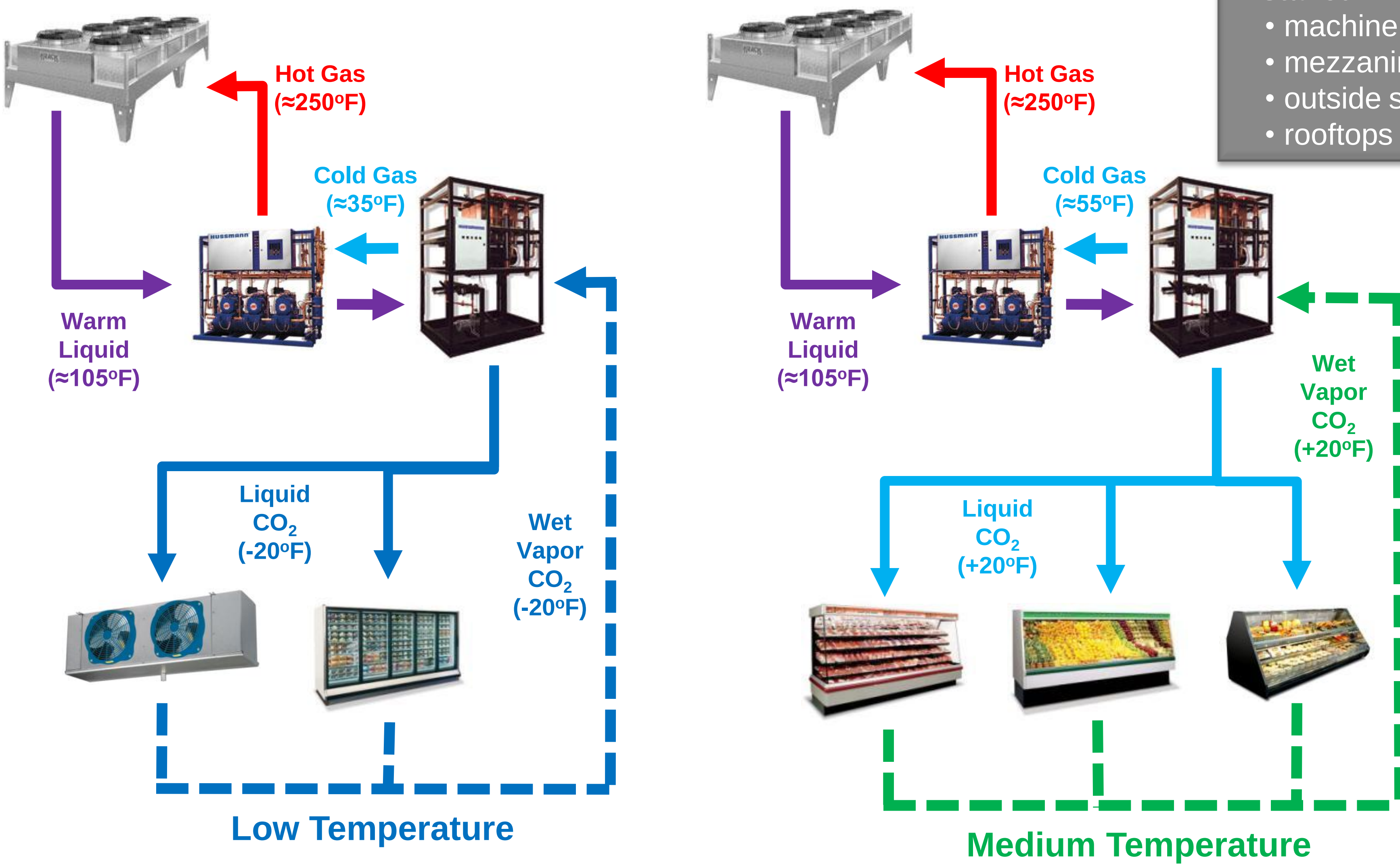
Secondary CO_2 System Operation

* LT and MT



Secondary CO_2 Equipment (Loop)

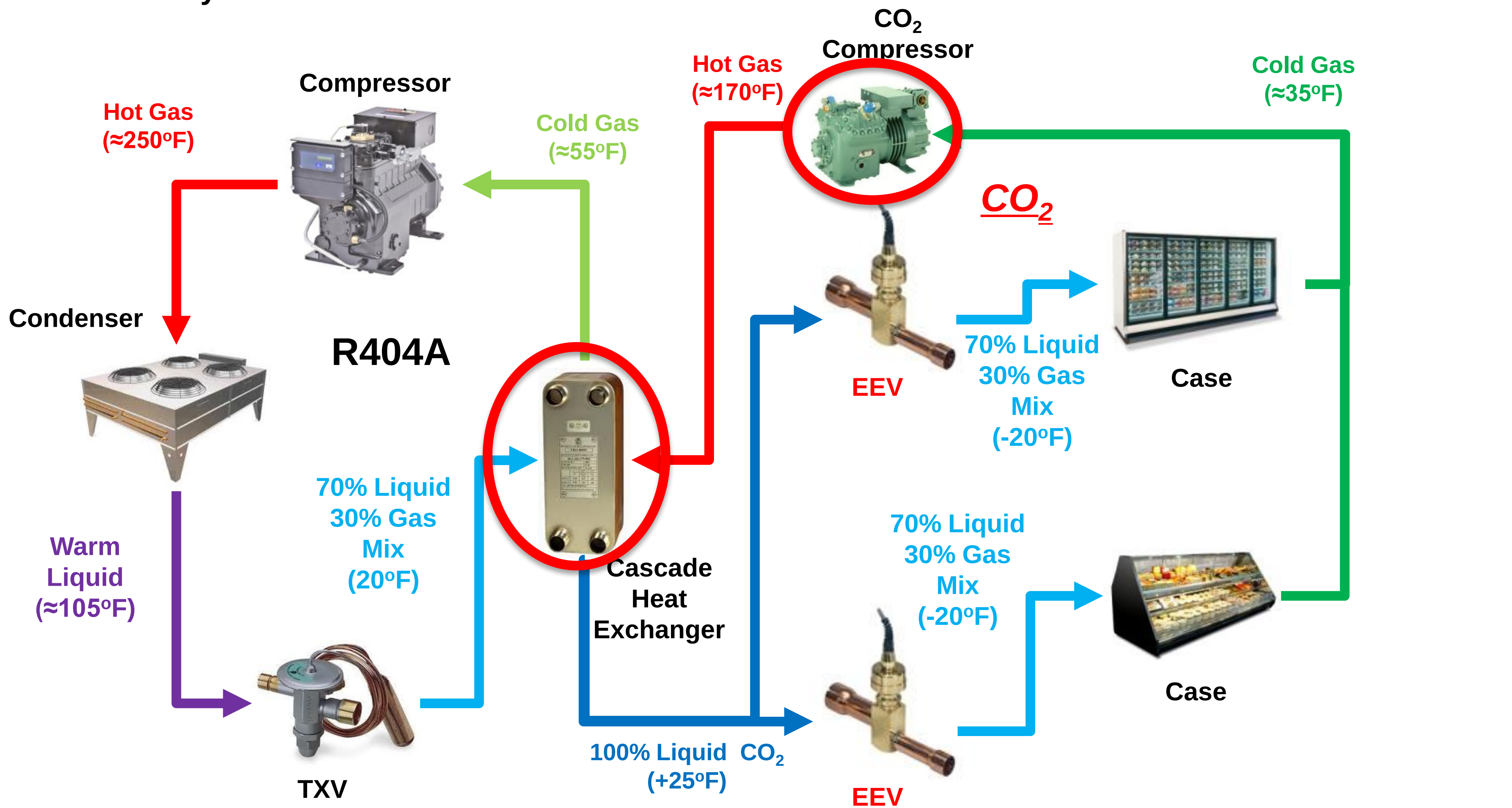
Installed in:
- machine rooms
- mezzanines
- outside slab
- rooftops



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

Cascade CO_2 DX System Operation

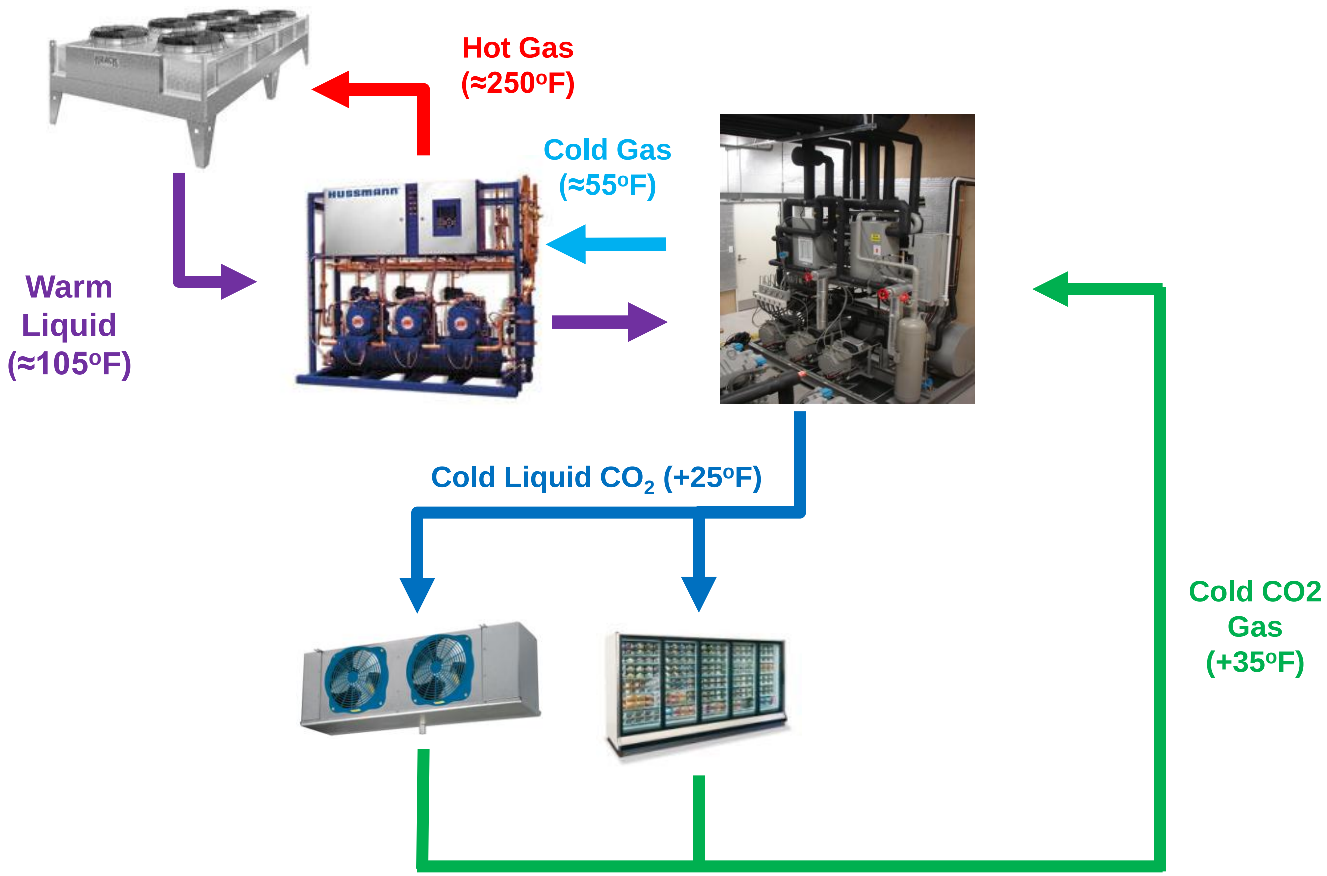
*** LT Only**



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



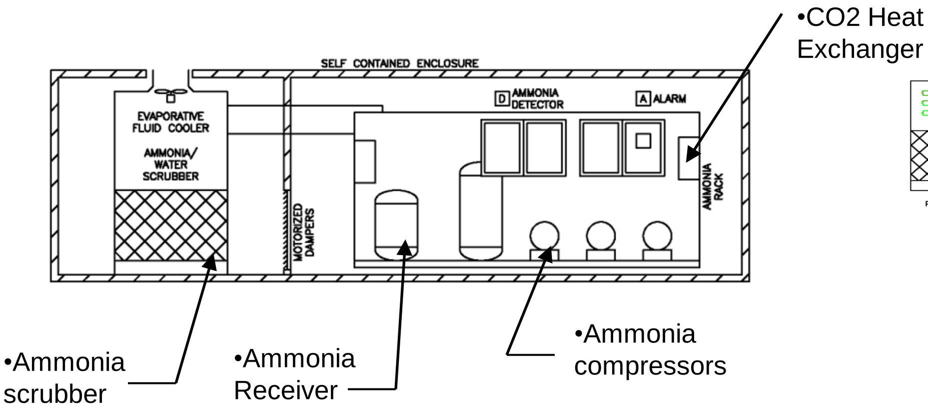
*** Loop Piping Shown**

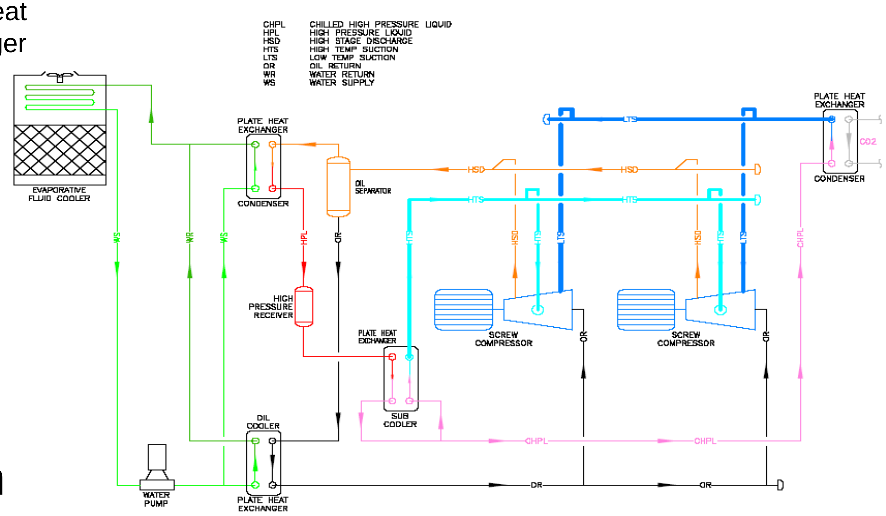
Low Temperature

◆ **Low refrigerant charge** ◆ **Reduced leaks** ◆ **less copper** ◆ **Uses natural CO_2**

Ammonia (NH3) Primary System

- *Primary Refrigeration Enclosure*
- *Primary Refrigeration Loop*





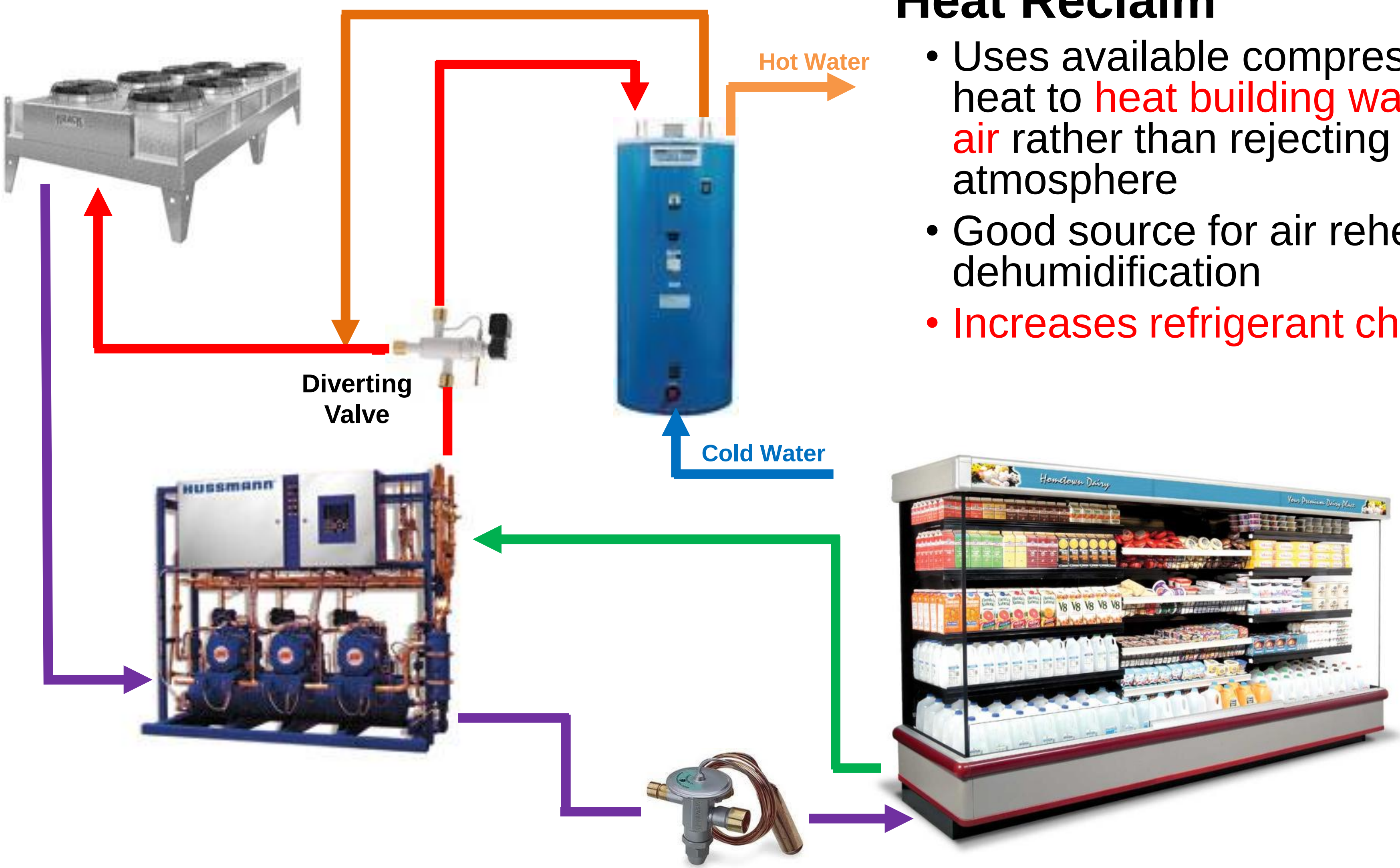
- Primarily used in industrial application
- Typically used with secondary systems
  - Example range of operation (-60°F to +60°F)
- Displaces use of HFC's
- Can not be used with copper
- Use of water system for scrubbing in case of leak

◆ Low refrigerant charge ◆ Reduced leaks ◆ Natural refrigerant

SYSTEM & BUILDING INTERACTION


HUSSMANN
Hometown Dairy

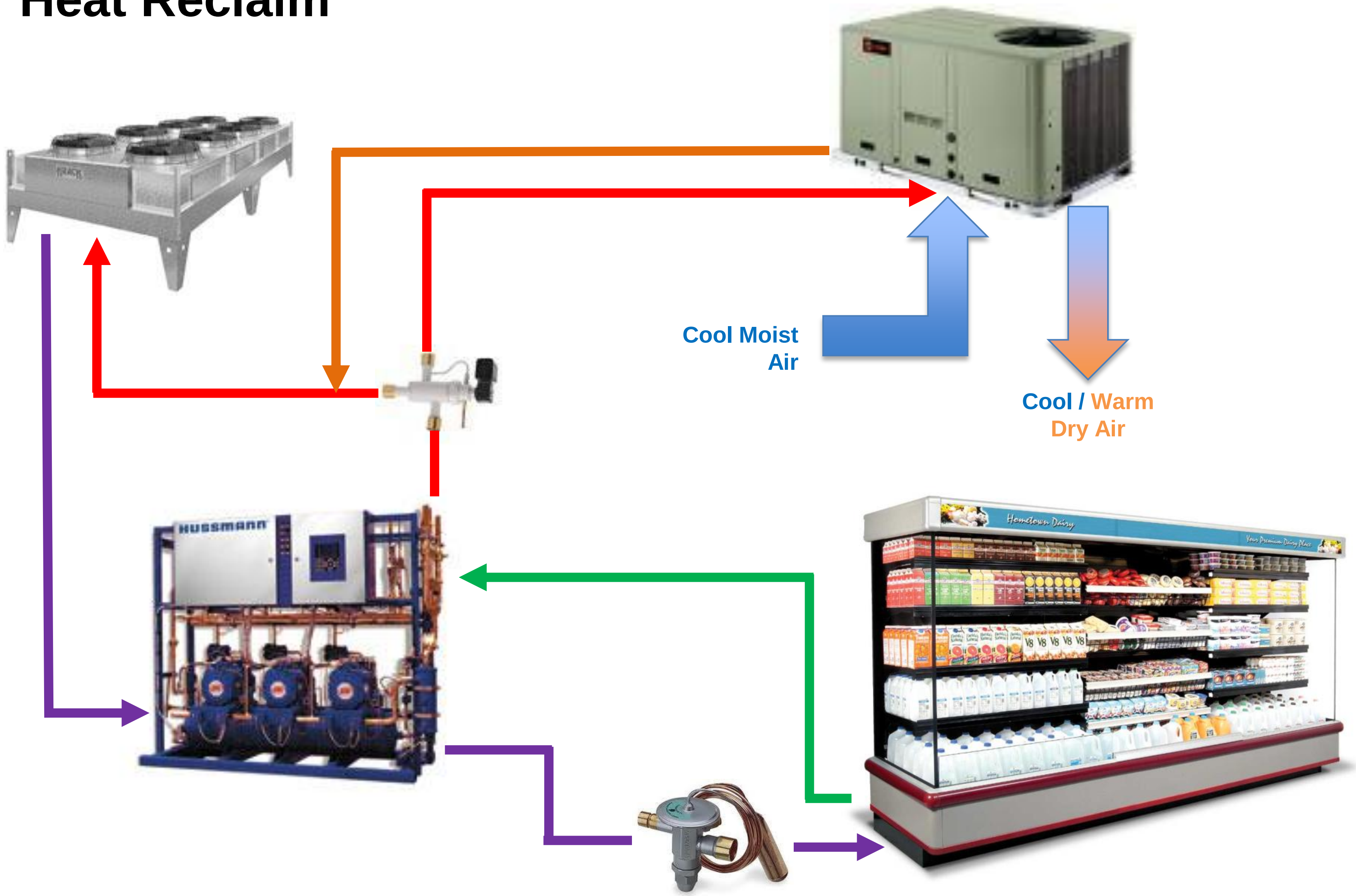
Water Heat Reclaim



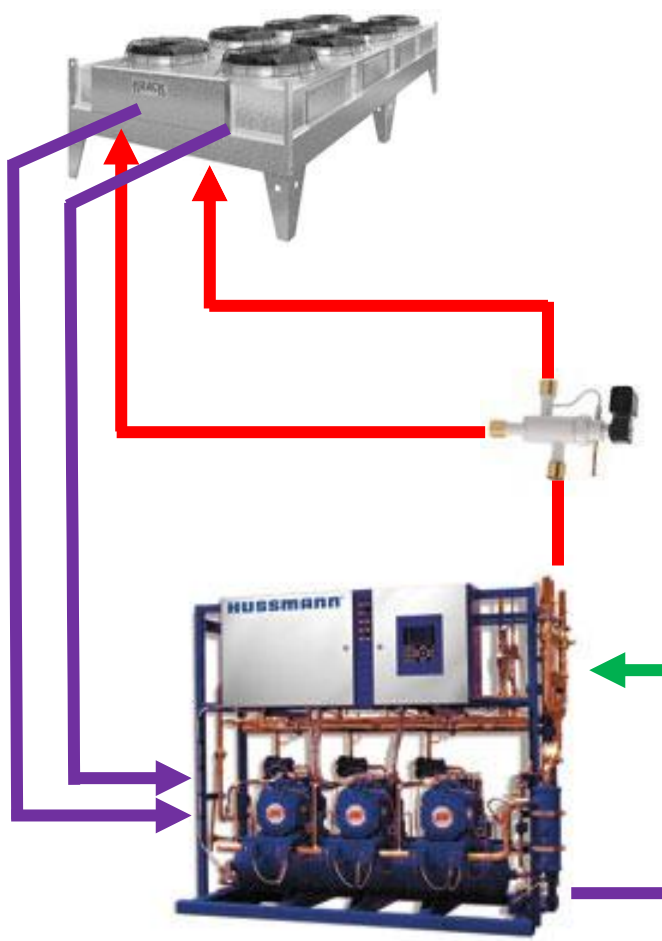
Heat Reclaim

- 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

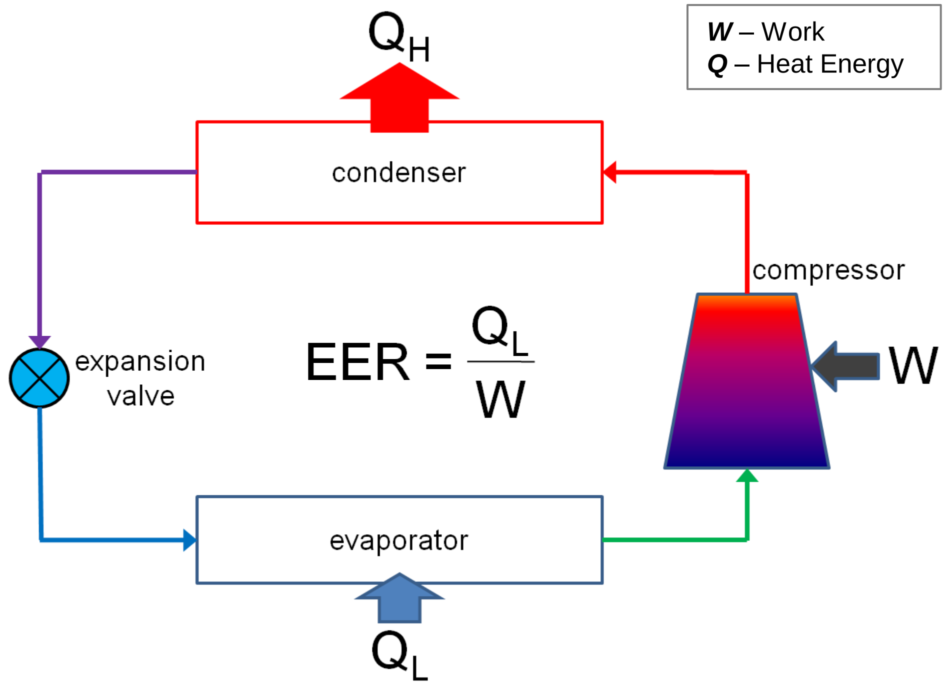
- Immediate notification when leak occurs
- Program multiple set points

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



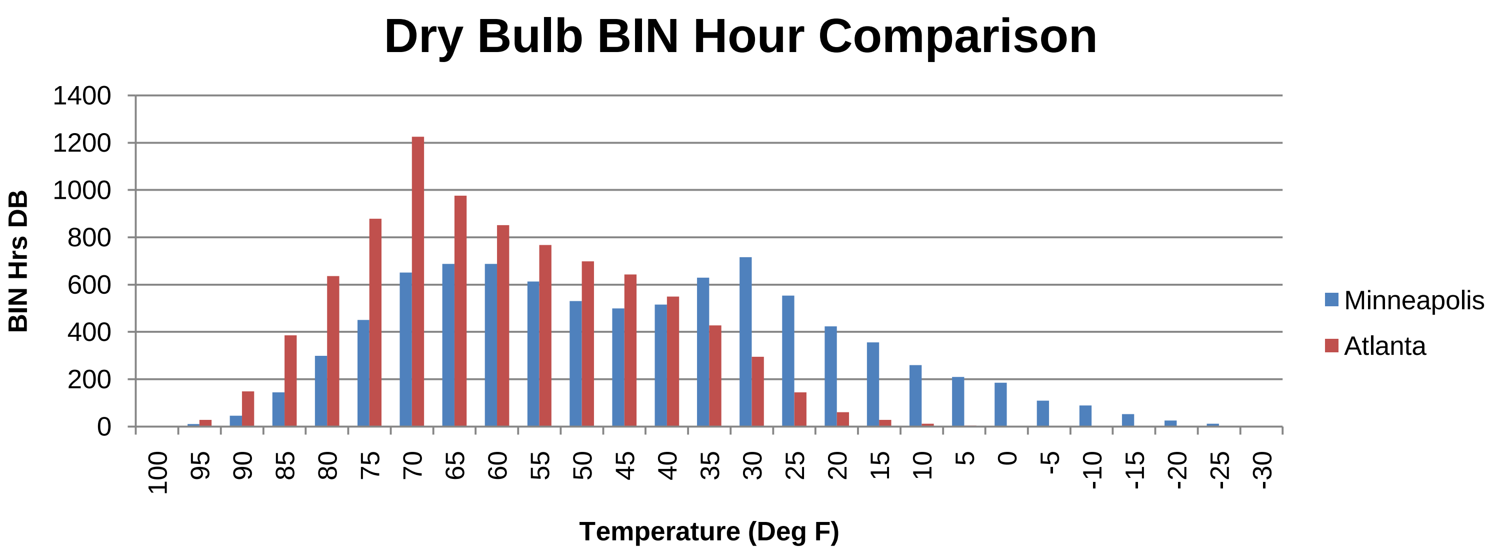
EER is heavily influenced by ambient temp:

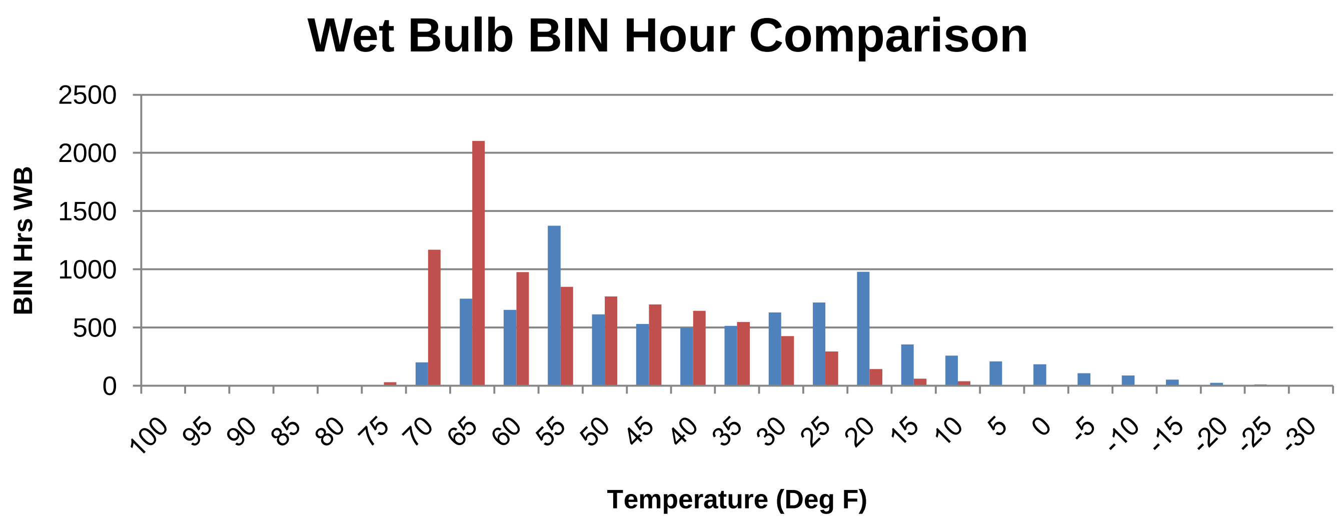
Hot day
- COP = 2
- EER = 7 Btu/hr/watt

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



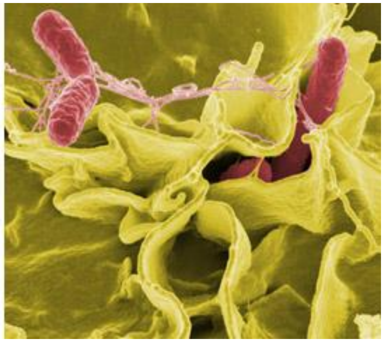




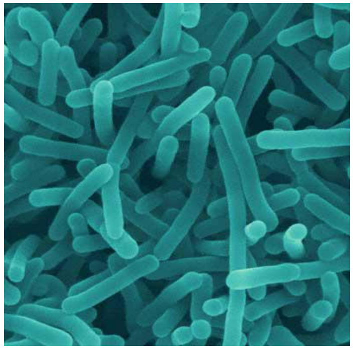

System Type	Possible Level Attainable
Distributed	Silver when air-cooled Gold when air-cooled with microchannel
Secondary Distributed	Gold when air-cooled condenser Platinum when water-cooled
MT Secondary Glycol	Silver with centralized LT DX Gold with other advanced LT
Secondary CO_2	Gold when used for 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

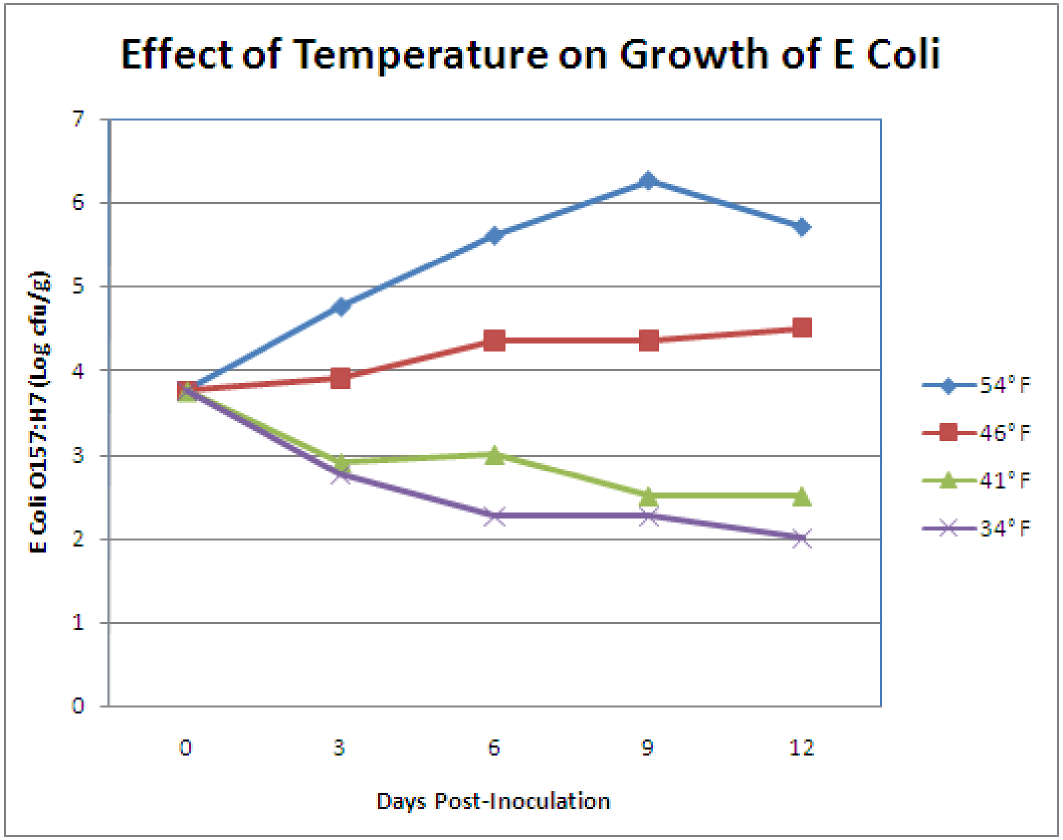


•Salmonella



•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