



Fundamentals of Refrigeration

Refrigerant Piping



What you will Learn in this Lesson

- Piping design basics
- Equivalent length
- Liquid, suction and discharge line sizing
 - Correcting for non standard conditions
 - Double suction risers
- Hot gas bypass sizing
- Matching condensing units

Piping Objectives

- **Transfer heat!**
- Carry refrigerant between components in a system smoothly and consistently, at a minimal pressure drop.
- Limit the amount of materials and refrigerant in the system (Control Cost & Keep it Simple S).
- Oil management.
- Control refrigerant movement and migration.
- Protect the compressor
 - Liquid will not compress!
 - Oil is required for lubrication!
 - Refrigerant is a solvent!
 - Provide motor cooling

Piping Design Basics

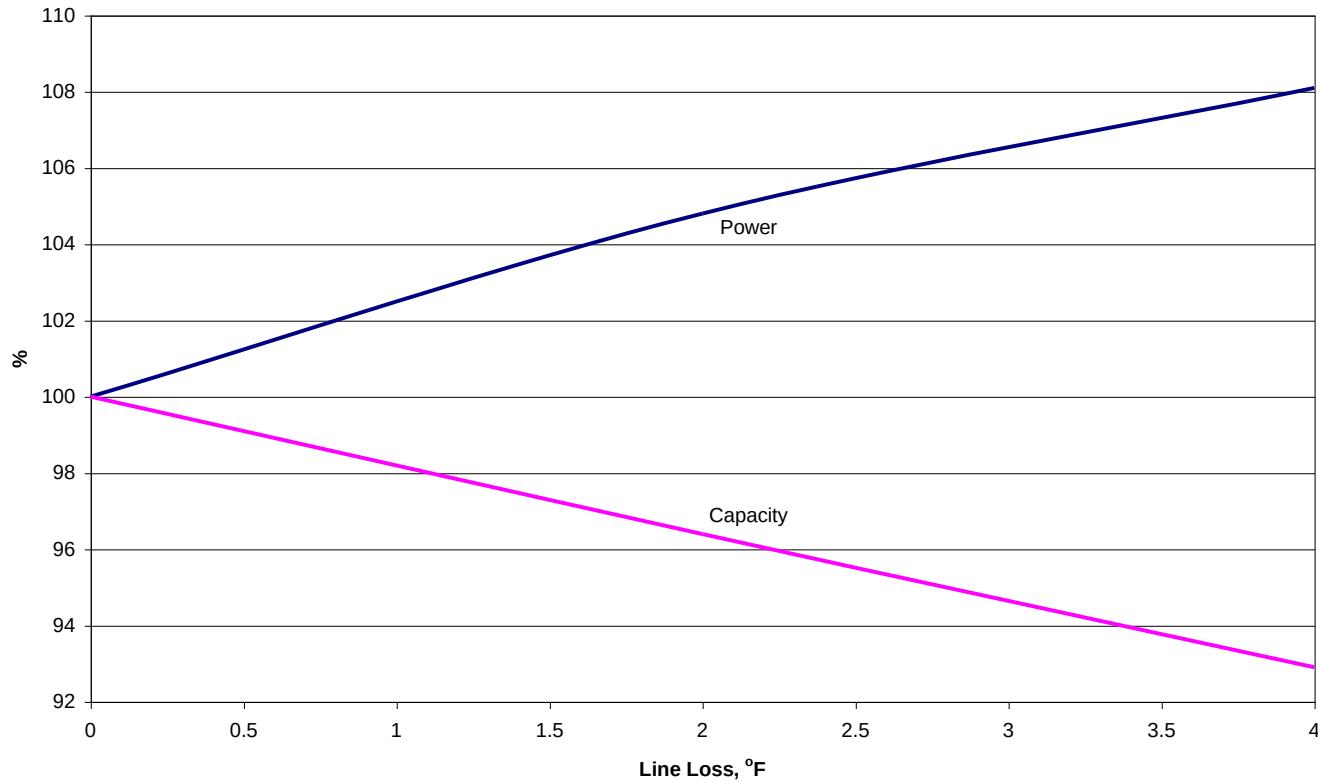
- Good piping design balances:
 - Initial cost, pressure drop & system reliability
- A good design needs to:
 - Return oil return back to compressor
 - Deliver (only) liquid refrigerant to the expansion device
 - Minimize capacity loss
 - Minimize refrigerant charge

Pressure Drop and Temperature Change

- Pressure and temperature are closely related
- Pressure losses lead to temperature drops which leads to increase compressor work
 - Inefficiency
- Condensing units are sized as;
 - 25 tons at 45 °F SST
 - Assume a 2 °F suction line loss so the evaporator must deliver 25 tons of cooling at 47 °F SST
- Even though the pressure loss is causing the temperature drop it is common to refer to line losses as **“2°F”**

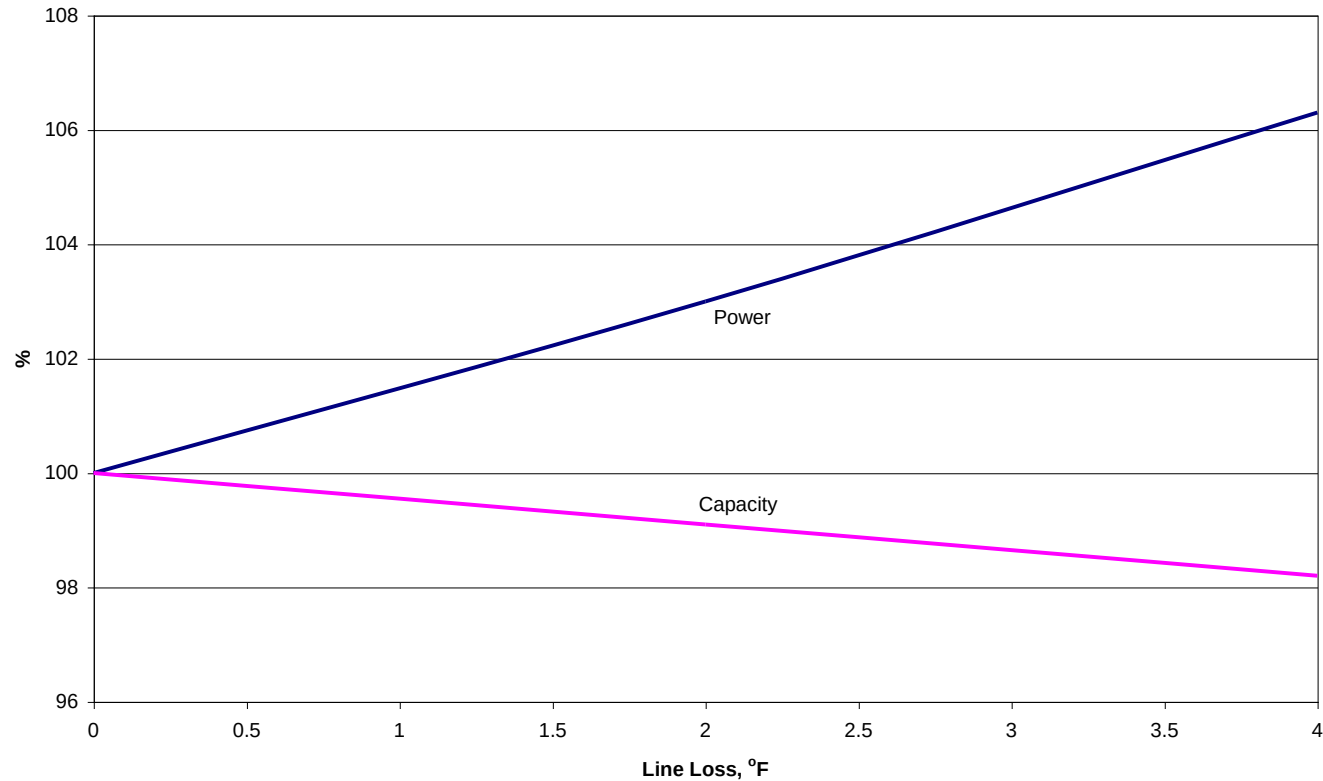
Capacity and Performance vs. PD

Approximate Effect of Gas Line Pressure Drops on R-22 Compressor Capacity & Power
Suction Line



Capacity and Performance vs. PD

Approximate Effect of Gas Line Pressure Drops on R-22 Compressor Capacity & Power
Discharge Line



Piping Design Basics

- Minimize change to less than 2°F per line
- Temperature versus pressure drop

Refrigerant	Suction Pressure Drop		Discharge Pressure Drop		Liquid Pressure Drop	
	F (C)	PSI (kPa)	F (C)	PSI (kPa)	F (C)	PSI (kPa)
R-22	2 (1.1)	2.91 (20.1)	1 (0.56)	3.05 (21.0)	1 (0.56)	3.05 (21.0)
R-407C	2 (1.1)	2.92 (20.1)	1 (0.56)	3.30 (22.8)	1 (0.56)	3.50 (24.1)
R-410A	2 (1.1)	4.50 (31.0)	1 (0.56)	4.75 (32.8)	1 (0.56)	4.75 (32.8)
R-134a	2 (1.1)	1.93 (13.3)	1 (0.56)	2.20 (15.2)	1 (0.56)	2.20 (15.2)

Piping Design Basics

- Maintain minimum velocities for proper oil return (rule of thumb)
 - 500 fpm – horizontal suction & hot gas lines
 - 1000 fpm – suction & hot gas risers
 - < 300 fpm – liquid lines (avoid liquid hammering when solenoid closes)
- Refrigerant grade copper tubing
 - Type L and K are approved for ACR applications
 - Type M is not, wall is too thin
- Proper support (expansion, vibration, weight)
- Avoid installing underground
- Test refrigerant lines for leaks

Liquid Lines

- Connects condenser to evaporator
- Carries liquid refrigerant to TX valve
- Must be designed to avoid liquid flashing
 - Subcooling or static head
- If condenser below evaporator – must have enough subcooling to avoid flashing
- Size Lines for 2-3 °F pressure drop
- Don't oversize or refrigerant charge will go up unnecessarily
 - Oil charge will have to go up as well

Liquid Lines

- As liquid refrigerant is lifted from bottom to top
 - Pressure drops
 - If liquid refrigerant was saturated – will flash
- Subcooling must offset pressure drop
- Should have 4-6 °F subcooling at TX valve for proper operation

Refrigerant	Pressure Drop PSI/ft (kPa/m) Riser
R-22	0.50 (11.31)
R-407c	0.47 (10.63)
R-410a	0.43 (9.73)
R-134a	0.50 (11.31)

Liquid Lines

- Field Supplied
 - Solenoid
 - TX valve
 - ASC (HGBP)
 - Liquid line filter drier
- Slope liquid line 1/8" per foot in direction of refrigerant flow
- Flood back design will add
 - Head pressure control valves
 - Receiver

Suction Lines

- Connects evaporator to compressor
- Carries low pressure refrigerant gas
- Size lines for 2-3 °F pressure drop
- Must be sized to move oil through system
 - Oil flows on bottom of piping
 - Pushed along by refrigerant gas
- Pitched 1/8" per foot in direction of refrigerant flow
 - Oil return

Suction Lines

- Piping design must avoid liquid refrigerant flow to compressor (slugging)
 - During off periods refrigerant gas can condense into liquid and pool or flow into compressor
 - During start up the liquid refrigerant will be drawn into the compressor
- Use inverted traps

Discharge Lines

- Connects compressor to condenser
 - Sometimes called “hot gas” line
- Carries hot, high pressure refrigerant gas
- Size lines for 2-3 °F pressure drop
- Must be sized to move oil through system
 - Oil flows on bottom of piping
 - Pushed along by refrigerant gas
- Pitched 1/8” per foot in direction of refrigerant flow
 - Oil return

Discharge Lines

- Piping design must avoid liquid refrigerant flow to compressor (slugging)
 - During off periods refrigerant gas can condense into liquid and pool or flow into compressor
- If condenser above compressor
 - Inverted trap or check valve at condenser to prevent liquid flowing back to compressor

Multiple Refrigeration Circuits

- Anything much bigger than 50 tons will likely have 2 circuits
- Possible to have a single refrigeration circuit with multiple evaporators
- NOT possible to have multiple refrigeration circuits connected to a single circuit evaporator

Equivalent Lengths

- Need to calculate pressure drop through piping, fittings and accessories
- Tables are provided that give fitting and accessory pressure drops in terms of equivalent feet of straight pipe
- For example
 - Refer to table 4
 - A 2 1/8" 90° long elbow has the same pressure drop as 3.3 feet of 2 1/8" pipe.

Line Sizing - General

- Tables provide capacity for different pipe sizes
- Based on
 - Refrigerant
 - SST and SDT
 - 100ft pressure drop
- Correction factors for other conditions
- Graphs that plot velocity vs. capacity for various pipe sizes

Line Sizing – System Design Requirements

- Circuit capacities at full and minimum loads
- Refrigerant to be used
- Suction and discharge saturated conditions
- Circuit pump down capacity
- Measured line set length
- Elevation changes and locations
- Ambient operation range
- Sound levels acceptable for the application

Line Sizing – System Design Requirements

- Load stability
- Circuit and piping components
- Total equivalent length of piping runs
- Environment of pipe routing
- Tie-in details to equipment
- Equipment mounting
- Variable or constant evaporator air/water flow
- Staging control type and sensor location
- Pump down controls right for application
- Gas velocities adequate for oil return at minimum loads

Line Sizing – System Design Requirements

- Underground piping is not recommended. May cause migration and condensing when not desired. Limits service access and can cause corrosion
- Install reducers and piping transitions so that oil return is not impeded
- Piping supports and hangers per code and system requirements
- Piping insulation per code and application needs
- Refrigerant migration effects may require accessories or control modifications
- Hot gas bypass evaluated for effects on oil and refrigerant management (10% typical min. load limit)

Sizing Liquid Lines

- Oil return not an issue
 - Oil is mixed into liquid refrigerant
- Avoiding refrigerant flashing ***is critical***
 - If condenser above evaporator – refrigerant column weight will stop flashing
 - If condenser below evaporator – lifting refrigerant will cause flashing
 - Solution is subcooling to offset pressure drop
- Maximum 300 fpm to avoid liquid hammer
- Maintain 2-3 F pressure drop
- Maintain 4-6 F subcooling at TX Valve

Sizing Suction Lines

- Oil return a critical issue
 - Oil is in liquid form on bottom of tube
 - Gaseous refrigerant ***must push oil back to compressor***
 - 500 fpm horizontal pipe
 - 1000 fpm in risers
- Maintain 2-3 F pressure drop
- Manage risk from slugging liquid refrigerant into compressor
 - Issue on startup after system has been off for a while

Risers & Oil Traps

- Should be made with u-bend or street elbows to limit width.
- *Not required at top of riser if slope is maintained.
- May be required every 15-25' of rise.
- Verify riser velocity adequate for oil return based on ASHRAE tables. May require line size change for vertical or in rare cases double risers.

Oil Return In Suction And Discharge Risers

- Unloading capability
 - AS unit unloads – velocity drops!
 - Check risers to verify minimum capacity allows acceptable oil return
- If necessary – smaller pipe diameter for riser
- Worst case, double suction risers can be used

Double Suction Risers

- More common when suction pressure drops are critical
- Modern air conditioning applications don't need double risers
 - Strongly recommended systems designed without double risers
- Sum of two risers is sized for full capacity
- Smaller riser sized for minimum capacity
- Challenges:
 - Can hold a significant amount of oil
 - Large amount of oil “blown” through piping
 - Add oil separator or suction accumulator

Double Risers

- Use only if down sizing risers is not an option.
- May require use of suction accumulator, oil separator, and/or oil level control system.
- Trap only the larger line.
- Size smaller line for minimum load.
- Size larger line for full load less smaller line capacity.
- Keep depth and width of trap to a minimum.

Sizing Discharge Lines

- Provide no more than a 2 to 3°F ΔP
- Over sizing:
 - Increases initial cost of project
 - Results in insufficient refrigerant gas velocity
- Under sizing:
 - Reduces compressor capacity
 - Increases compressor work
- Sloped 1/8 inch per foot in direction of refrigerant flow
- Add traps to bottom of risers
- Use invert trap if condenser above compressor
- Use mufflers with reciprocating compressors

TX Valve Installation

- Valve must be sized for actual operating conditions, not nominal rating.
- Confirm minimum turn-down adequate for circuit unloading.
- Remote bulb and external equalizer must be installed properly.

TX Valve installation

- Smaller systems – Internally equalized
- Larger systems – Externally equalized
 - Greater than 2 psi across evaporator, or
 - If distributor is used
- TX valves and distributors
 - Installed in vertical pipes

TX Valve Installation

- Sensing bulb at top (12 o'clock) for lines under 7/8 inch
- At 4 or 8 o'clock for larger line sizes
- Bulb secured to suction line and insulated, unless in leaving air stream
- Equalization line downstream of bulb; refer to manufacture's installation instructions
- Bulb and equalization line should NOT be installed in a trap

HGBP Line Requirements

- Sized using discharge gas line sizing tables
- Best to under size HGBP lines
 - Rule of thumb: one line size smaller than the recommended discharge table line size
- Keep HGBP lines as short as possible
- HGBP valve and solenoid located as close to discharge line as possible
- Line pressure drop small relative to pressure drop across valve
- Pitched 1/8 inch per foot in direction of refrigerant flow
- Insulate to prevent refrigerant vapor from condensing

HGBP Valves

- Used with distributor type DX coils – Externally equalized
- Oversizing may cause:
 - System inversion
 - Loss of oil management
 - Prevent the compressor from cycling off (over heating)
 - Poor efficiency
- Selection based on:
 - Refrigerant type
 - Minimum allowable evaporator temperature at reduced load
 - Typically 32 to 34°F for chillers & 26 to 28°F for air conditioners
 - Minimum compressor capacity
 - Minimum system capacity
 - Approximately 10% of system capacity
 - Condensing temperature at minimum load – typically 80°F

HGBP Valves

- $HGBP_{\text{valve}} = \text{Min. Compressor Capacity} - \text{Min. System Capacity}$

Direct Acting Discharge Bypass Valve Capacities (tons)

Capacities based on discharge temperatures 50°F above isentropic compression, 25°F superheat at the compressor, 10°F sub-cooling, and includes both the hot gas bypassed and liquid refrigerant for desuperheating, regardless of whether the liquid is fed through the system thermostatic expansion valves or an auxiliary desuperheating thermostatic expansion valve.

Refrigerant	Valve Type	Adjustment Range (psig)	Minimum Allowable Evaporator Temperature At The Reduced Load (°F)					
			26			20		
			Condensing Temperature (°F)					
			80	100	120	80	100	120
22	ADRI-1-1/4 ADRIE-1-1/4	0/55	0.34	0.044	0.56	0.41	0.52	0.66
		0/75	0.50	0.64	0.81	0.50	0.65	0.81
		0/100	0.42	0.54	0.67	1.41	0.53	0.66
	ADRS-2 ADRSE-2	0/30	-	-	-	-	-	-
		0/80	2.77	6.57	4.50	2.79	3.59	4.53
	ADRP-3 ADRPE-3	0/30	-	-	-	-	-	-
		0/80	7.69	9.90	12.5	7.92	10.2	12.8
	ADRHE-6	0/30	-	-	-	-	-	-
		0/80	7.69	9.90	12.5	7.92	10.2	12.8

Hot Gas Bypass Valves

- Recall HGBP valve starts to open 6 °F above SST (26 °F)
- By time SST reaches 26 °F;
 - HGBP valve will be passing 10 tons of refrigerant from discharge line to inlet of evaporator

Pump Down

- Some systems designed with recycling or a one-time pump down cycle
 - Condensers sized to hold refrigerant charge
 - Cooling not required, solenoid valve in liquid line closes
 - Compressor operates until suction pressure is below cutout
 - Suction pressure switch opens, the compressor stops
 - One-time pump down systems stay off until need for cooling
- Advantages:
 - Most or all of refrigerant in evaporator is removed
 - Prevents refrigerant migration
 - Maintenance accessibility
- Long piping arrangements may increase volume above condenser capacity
 - Add receiver to store extra refrigerant

Piping Insulation

- Suction lines should be insulated with vapor proof insulation
 - Suction lines are cold, 40°F (condensation)
 - Heat added to the refrigerant, increases superheat, reducing system efficiency
- Rubrutex is the most common form of refrigerant line insulation
- Liquid lines are generally insulated
 - Warm to hot (110°F for air-cooled)
 - If hot enough to pose a safety risk, add insulation
- Discharge lines are generally not insulated
 - May be very hot, in excess of 150°F
 - Insulation may be warranted as a safety consideration
- HGPD lines should be insulated

Refrigerant Line Installation

- Need to be secured to minimize vibration
 - Reciprocating compressor, in particular, cause vibration
 - Steel braided flexible refrigerant lines
- Discharge mufflers used to minimize gas pulsations
- Protect refrigerant lines that rub solid objects or pass through walls
- Piping should be protected from mechanical damage
 - Route out of way or protect in a chase
 - Burying lines should be avoided

Low Ambient Operation

- Fan cycling
 - Staging condenser fans on and off based on ambient
- Fan speed control
 - Use fan speed controller to modulate air flow through condenser
 - Usually based on head pressure

Low Ambient Operation

- Condenser flood back design
 - Head pressure control valve restricts flow from condenser
 - Liquid refrigerant floods condenser, reducing heat rejection capacity
 - Receiver required during warmer weather
 - Size at 80% of capacity while containing entire system charge
 - Excellent at providing head pressure control in cold climates
 - Increase initial cost, add complexity, increase installation time, increase refrigerant charge

End of Lesson

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