Ammonia Refrigeration Piping Design & Installation

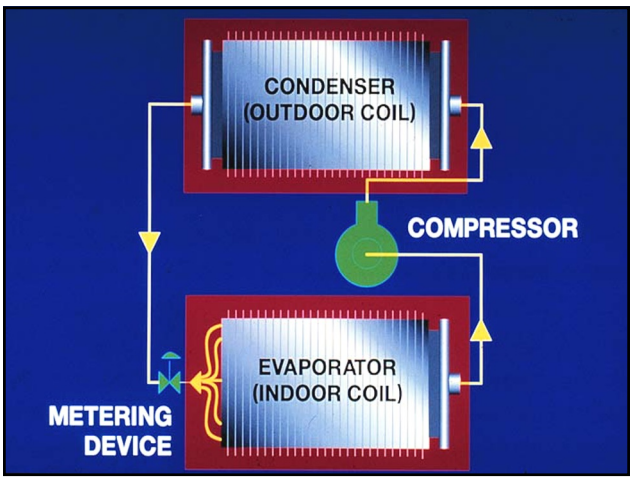
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Refrigerant Piping Design & Installation

Ref; Field erected Ammonia Refrigerant piping-part I & II cold chain ISHRAE Journal April-June 2023

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Refrigerant Piping Requirement

1. From compressor to oil separator-gas line
2. From Oil separator to condenser-Gas line
3. From Condenser to Receiver-liquid line
4. From receiver to expansion Device-liquid line
5. From expansion device to evaporator- liquid+ gas mixture
6. Wet return line- liquid+ gas mixture
7. Pump by pass line to wet return-liquid line
8. From evaporator or L.P. vessel to compressor-Gas line

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Refrigerant Piping Sizing Priorities In Descending Order

1. Suction Line sizing most important-min.pr.drop
2. Ammonia Pump inlet Line from LP vessel
3. Wet Return Line to LP vessel from evaporators
4. By pass line from pump discharge header to wet return line
5. High pressure liquid line
6. Condenser to Receiver Liquid line
7. High Pressure Discharge line

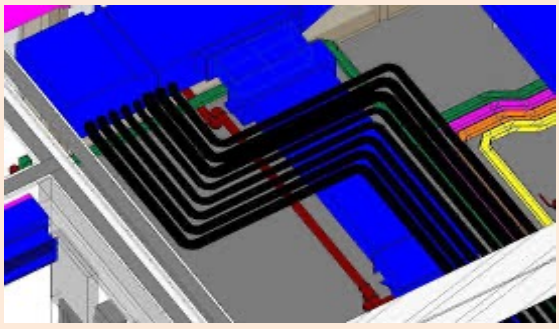
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Piping Design Goals

- Size for a 2°F Pressure Drop
- Suction Line
  - A. Evaporator to Compressor Oil Return
  - B. Prevent Evaporator Oil Drain
  - C. Dampen Vibration and Noise
  - D. Prevent Line Sweating
  - E. Prevent Unnecessary Heat Gain
- Hot Gas Line
  - A. Avoid Oil Trapping
  - B. Prevent Oil or Refrigerant Backflow
  - C. Dampen Vibration and Noise
- Liquid Line
  - A. Prevent Formation of Flash Gas
  - B. Prevent Heat Gain
- Condensate Line
  - A. Sewer Type Flow

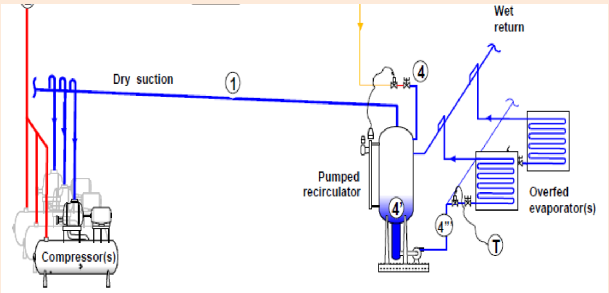
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Aesthetically good looing piping layout – Not Recommended



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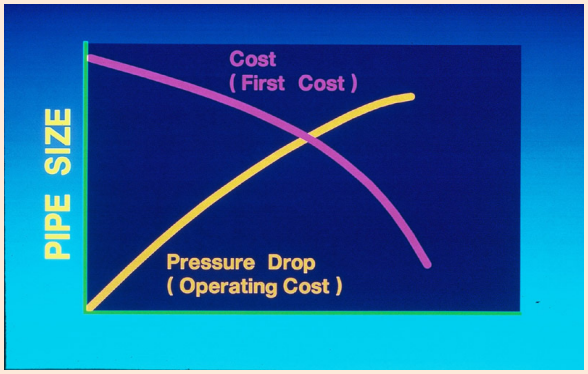
The piping should be done in accordance with refrigerant flow requirements and not from the point of aesthetics.



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Systems Using Ammonia (R – 717) and Other Immiscible Refrigerants Rely on Gravity, Rather than Velocity for Oil Return. Generous Sizing Saves Operating Costs for Such Systems.

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Optimum pipe sizing –compromise between first cost and pressure drop. Lower pressure drop means bigger pipe size & more cost, and the opposite

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Recommended Velocities For Line Sizing

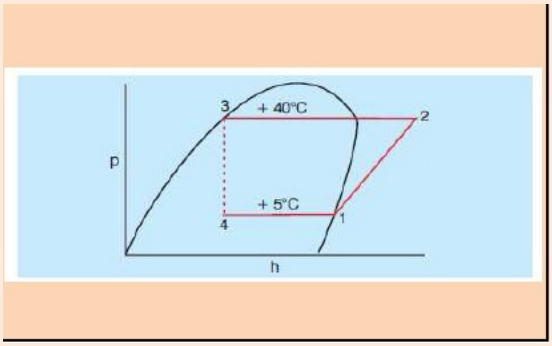
SIZE	From 25mm	To 300 mm
Compressor Suction Line	15m/s	18m/s
Wet Return To LP Vessel	12m/s	15m/s
Ammonia Pump Suction Line	0.3m/s	0.5m/s
Ammonia Pump Discharge Line	1.0 m/s	1.0m/s
Condenser to Receiver Line	0.3m/s	0.5m/s
Liquid Feed from main receiver	1m/s	1.5m/s
Compressor Discharge Line	18m/s	20m/s

Wet Return-One Size larger than calculated Suction Line or velocity reduced by √1/(circulation rate). It means ½ the velocity selected for dry suction-ASHRAE

1. Gas Line Velocity is higher than Liquid line as Density of liquid is higher hence more friction and gas density is lower hence less pressure drop
2. Smaller Diameters need to have low velocity, larger diameters can have higher velocities

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Pipe Line Sizing With P/H diagram Study-Mass Flow Calculations



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Mass Flow & Pipe Size Calculations

Basic Data

1. Capacity 100 kW(28.43 TR)
2. Condensing Temperature: +40^{0}C
3. Evaporating Temperature: +5^{0}C
4. No superheat or sub-cooling: 0^{0}C

Calculation for Pipe Diameter Selection:

1. From Ammonia Table properties: vapour enthalpy at compressor suction h_1= 1467.385 kJ/kg
2. Liquid Enthalpy at h_3=h_4=390.64 kJ/kg
3. Refrigerating Effect: h_1-h_3=1467.385-390.64=1076.745 kJ/kg
4. For 100 kW mass flow : 100/1076.745= 0.09287 kg/s
5. Specific volume of gas at point 1: 0.24321 m^3/kg
6. Volume flow rate required at compressor suction:0.09287x0.24321=0.022586m^3/s=81.31m^3/hr
7. Assuming suction line velocity as 12m/s, the pipe cross sectional area would be 0.001882m^2 or 1882 mm^2
8. Diameter of pipe would be:√1882 =43.38mm
9. Select nearest size as 50 NB

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Pipe Sizing – ASHRAE handbook Refrigeration

Table 2 Suction, Discharge Line, and Liquid Capacities in Kilowatts for Ammonia (Single- or High-Stage Applications)

Steel Nominal Line Size, mm	Suction Lines (Δt = 0.02 K/m) Saturated Suction Temperature, °C					Discharge Lines Δt = 0.02 K/m, Δp = 684.0 Pa/m Saturated Suction Temp., °C			Steel Nominal Line Size, mm	Liquid Lines	
	–40 Δp = 76.9	–30 Δp = 116.3	–20 Δp = 168.8	–5 Δp = 276.6	+5 Δp = 370.5	–40	–20	+5		Velocity = 0.5 m/s	Δp = 450.0
10	0.8	1.2	1.9	3.5	4.9	8.0	8.3	8.5	10	3.9	63.8
15	1.4	2.3	3.6	6.5	9.1	14.9	15.3	15.7	15	63.2	118.4
20	3.0	4.9	7.7	13.7	19.3	31.4	32.3	33.2	20	110.9	250.2
25	5.8	9.4	14.6	25.9	36.4	59.4	61.0	62.6	25	179.4	473.4
32	12.1	19.6	30.2	53.7	75.4	122.7	126.0	129.4	32	311.0	978.0
40	18.2	29.5	45.5	80.6	113.3	184.4	189.4	194.5	40	423.4	1469.4
50	35.4	57.2	88.1	155.7	218.6	355.2	364.9	374.7	50	697.8	2840.5
65	56.7	91.6	140.6	248.6	348.9	565.9	581.4	597.0	65	994.8	4524.8
80	101.0	162.4	249.0	439.8	616.9	1001.9	1029.3	1056.9	80	1536.3	8008.8
100	206.9	332.6	509.2	897.8	1258.6	2042.2	2098.2	2154.3	—	—	—
125	375.2	601.8	902.6	1622.0	2271.4	3682.1	3783.0	3884.2	—	—	—
150	608.7	975.6	1491.4	2625.4	3672.5	5954.2	6117.4	6281.0	—	—	—
200	1252.3	2003.3	3056.0	5382.5	7530.4	12 195.3	12 529.7	12 864.8	—	—	—
250	2271.0	3625.9	5539.9	9733.7	13619.6	22 028.2	22 632.2	23 237.5	—	—	—
300	3640.5	5813.5	8873.4	15568.9	21787.1	35 239.7	36 206.0	37 174.3	—	—	—

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Suction Line Selection Medium & High Temperature -

ASHRAE handbook -Refrigeration

Steel Nominal Line Size, mm	Saturated Suction Temperature, °C: –20 Δt = 0.005 K/m Δp = 42.2 Pa/m	–20 Δt = 0.01 K/m Δp = 84.4 Pa/m	–5 Δt = 0.005 K/m Δp = 69.2 Pa/m	–5 Δt = 0.01 K/m Δp = 138.3 Pa/m	+5 Δt = 0.005 K/m Δp = 92.6 Pa/m	+5 Δt = 0.01 K/m Δp = 185.3 Pa/m
10	0.91	1.33	1.66	2.41	2.37	3.42
15	1.72	2.50	3.11	4.50	4.42	6.37
20	3.66	5.31	6.61	9.53	9.38	13.46
25	6.98	10.10	12.58	18.09	17.79	25.48
32	14.58	21.04	26.17	37.56	36.94	52.86
40	21.99	31.73	39.40	56.39	55.53	79.38
50	42.72	61.51	76.29	109.28	107.61	153.66
65	68.42	98.23	122.06	174.30	171.62	245.00
80	121.52	174.28	216.15	308.91	304.12	433.79
100	249.45	356.87	442.76	631.24	621.94	885.81
125	452.08	646.25	800.19	1139.74	1124.47	1598.31
150	733.59	1046.77	1296.07	1846.63	1819.59	2590.21
200	1506.11	2149.60	2662.02	3784.58	3735.65	5303.12
250	2731.90	3895.57	4818.22	6851.91	6759.98	9589.56
300	4378.87	6237.23	7714.93	10973.55	10 810.65	15 360.20

Note: Capacities are in kilowatts of refrigeration resulting in a line friction loss per unit equivalent pipe length (Δp in Pa/m), with corresponding change in saturation temperature per unit length (Δt in K/m).

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Suction line Selection –Low Temperature

ASHRAE handbook

Table 1 Suction Line Capacities in Kilowatts for Ammonia with Pressure Drops of 0.005 and 0.01 K/m Equivalent

Steel Nominal Line Size, mm	Saturated Suction Temperature, °C: –50 Δt = 0.005 K/m Δp = 12.1 Pa/m	–50 Δt = 0.01 K/m Δp = 24.2 Pa/m	–40 Δt = 0.005 K/m Δp = 19.2 Pa/m	–40 Δt = 0.01 K/m Δp = 38.4 Pa/m	–30 Δt = 0.005 K/m Δp = 29.1 Pa/m	–30 Δt = 0.01 K/m Δp = 58.2 Pa/m
10	0.19	0.29	0.35	0.51	0.58	0.85
15	0.37	0.55	0.65	0.97	1.09	1.60
20	0.80	1.18	1.41	2.08	2.34	3.41
25	1.55	2.28	2.72	3.97	4.48	6.51
32	3.27	4.80	5.71	8.32	9.36	13.58
40	4.97	7.27	8.64	12.57	14.15	20.49
50	9.74	14.22	16.89	24.50	27.57	39.82
65	15.67	22.83	27.13	39.27	44.17	63.77
80	28.08	40.81	48.36	69.99	78.68	113.30
100	57.95	84.10	99.50	143.84	161.77	232.26
125	105.71	153.05	181.16	261.22	293.12	420.83
150	172.28	248.91	294.74	424.51	476.47	683.18
200	356.67	514.55	609.20	874.62	981.85	1402.03
250	649.99	937.58	1107.64	1589.51	1782.31	2545.46
300	1045.27	1504.96	1777.96	2550.49	2859.98	4081.54

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Liquid Line Selection-Pump Circulation Systems

ASHRAE handbook-Refrigeration

Table 3 Liquid Ammonia Line Capacities in Kilowatts

Nominal Size, mm	Pumped Liquid Overfeed Ratio			High-Pressure Liquid at 21 kPa[a]	Hot-Gas Defrost[a]	Equalizer High Side[b]	Thermosiphon Lubricant Cooling Lines Gravity Flow[c]		
	3:1	4:1	5:1				Supply	Return	Vent
40	513	387	308	1544	106	791	59	35	60
50	1175	879	703	3573	176	1055	138	88	106
65	1875	1407	1125	5683	324	1759	249	155	187
80	2700	2026	1620	10 150	570	3517	385	255	323
100	4800	3600	2880	—	1154	7034	663	413	586
125	—	—	—	—	2089	—	1041	649	1062
150	—	—	—	—	3411	—	1504	938	1869
200	—	—	—	—	—	—	2600	1622	3400

Source: Wile (1977).
[a]Rating for hot-gas branch lines under 30 m with minimum inlet pressure of 724 kPa (gage), defrost pressure of 483 kPa (gage), and –29°C evaporators designed for a 5.6 K temperature differential
[b]Line sizes based on experience using total system evaporator kilowatts.
[c]From Frick Co. (1995). Values for line sizes above 100 mm are extrapolated.

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Ammonia Leakage Possible areas

Where Most leakages occur	
Flanges & joints	**23%**
Manually controlled stop valves	**20%**
Ammonia pumps	**12%**
Pressure relief vales	**9%**
Compressor shaft seals	**9%**
Oil drain pots & other drain points	**8%**
Piping	**7%**
While ammonia Charging	**5%**
Evaporators	**4%**
Sight Glass	**2%**

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Piping material & thickness

1. Piping/fittings as per ANSI B31.5-2022
2. Carbon Steel A53 Grade A or B, ERW or A106 grade A/B seamless- **A106 seamless pipes preferred**
3. Do not Use Galvanized Piping(Low Grade)
4. 1 ½" and smaller –Sch. 80
5. 2" to 6' Sch. 40
6. 8" to 12" sch 20
7. Sch 80 ≥ Sch 40 ≥ sch20
8. All Weld Fittings preferred-Avoid Threads/Flanges

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Pipe Specifications

1. Carbon Steel ASTM A53 Grade a or B, Type E or S-Welded
2. **Carbon Steel ASTM A106 Gr A or B –Seamless preferred**
3. Stainless Steel ASTM A312 Type 304,304L,316, 316L Type E or S
4. Carbon Steel (below -20Deg F) ASTM A333 Gr 1 or 6 Type E or S

Note-**E** means electric resistance welded, **S** means seamless

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Pipe Material-Low Temperature

- Carbon Steel(Low Temperature):ASTM A333-Grade 1 or 6
- Carbon Steel Pipe, ASTM A53 or A106 may be used below -20^{0}F(-28.9^{0}C) if it meets ASME B31.5-2013 Refrigeration Piping and Heat Transfer component requirements

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Pipe Material-Low Temperature

- ASME B31.5 allows use of carbon steel pipe material for use between -28.9^{0}C to -101.1^{0}C provided the most severe conditions are multiplied by 2.5 times in determining the thickness

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Example Calculations

- A53-GrA to be used for low temperature below -29^{0}C
- Design pressure -19.8 kg/cm^2
- Design Temperature –Minus 50^{0}C
- Liquid line -10" NB-OD 10.75" Sch. 20- Thickness 0.365"
- T=2.5xPD_0/2xSE=(2.5x19.8x14.22x10.75/2x13600)+ corrosion allowance
- T= 0.278+0.06=0.338"
- Actual Thickness of Sch20 =0.365"- Hence Safe

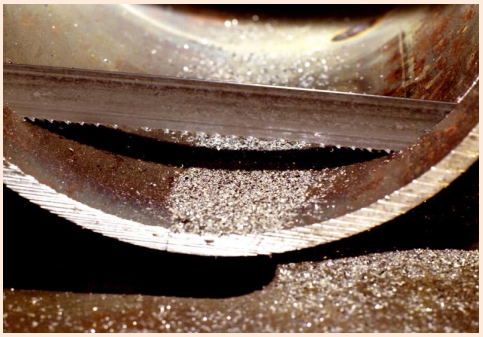
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Piping Accessories Material

- Fittings
- Carbon Steel ASTM A105
- Carbon Steel ASTM A234
- Carbon Steel(Low Temperature) ASTM A420
- Flanges
- Carbon Steel ASTM A105
- Carbon Steel ASTM A181
- Carbon Steel (Low Temperature) ASTM A707
- Bolting
- Cast Iron Flanges when used with ring gaskets, or when coupled to a raised face flange: ASTM A307 Grade B
- Carbon or Stainless-steel Flanges down to -55^{0}F –ASTM A193 Grade B7
- Low Temperature applications(-55^{0}F to -150^{0}F): ASTM A320 Grade L7
- Nuts: for above materials: ASTM A194

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Piping material lying at site should be internally and externally cleaned thoroughly to make them free of rust scale, sand or dirt prior to installation-Do not use hacksaw/use cutter for pipe cutting



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Welding Practices

1. Root run with **TIG-Tungsten Inert Gas(Argon)** for piping
2. Root run with **TIG(Argon) or MIG (Metal inert Gas)**for vessels
3. Welding by qualified welder certification level 3
4. Welding rods- Argon- High side-AWS-A5.18 ER70S-G, Low side –AWS –A5.28 ER70S-G
5. Electric Welding – AWS –A5.1 **E7018 preferred**, E7018 electrodes are widely used for welding pressure vessels, boilers, and high-stress industrial structures because of their low-hydrogen properties and high crack resistanceDo not use structural welding rods 6013
6. Remove valve internals & controls, strainers Solenoid coils etc. before welding

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Piping Accessories Material

- Fittings
- Carbon Steel ASTM A105
- Carbon Steel ASTM A234
- Carbon Steel(Low Temperature) ASTM A420
- Flanges
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Good Welding Joint



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Compressor Piping-ASHRAE Handbook

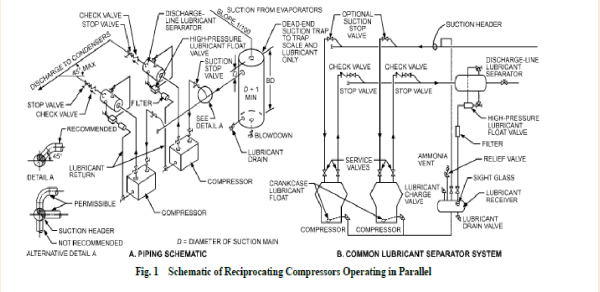


Fig. 1 Schematic of Reciprocating Compressors Operating in Parallel

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Compressor Piping

Important points to note:

1. The NRV should be after oil separator and not after compressor-The reason being, the reciprocating compressor discharge gas pulsations are dampened in the oil separator, if the NRV is placed between the compressor and oil separator the NRV is subjected to these pulsations and it many times chatters, or likely to get damaged earlier than expected. Many people argue that placing it immediately after compressor prevents liquid condensation during standstill state. This argument is incorrect as there is no liquid in the discharge side and the density of Ammonia refrigerant is so high that when converted to the liquid the quantity is insignificant and it would accumulate in the oil separator bottom and not on the compressor top. The discharge line from compressor to oil separator is also very short.

2. Depending on NRV design, keep NRV in horizontal line-The reason being in a horizontal position, the gravity is not acting on NRV parts, if in a vertical location, the parts are acted on by two forces, one is gravity and the other is the discharge gas, both are opposite to each other and can lead to vibrations, noise, damage to parts.

3. Provide independent oil separator for each compressor-many installations I have observed where there is a single common oil separator and the combined discharge header is connected to this oil separator. This is not a good practice; each compressor has its own characteristic and quantity of oil migration along with discharge gas varies for each machine. It is always a good practice to have independent oil separator for each compressor.

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Compressor Piping

4. Oil separator oil drain should be above oil return level of compressor- The pressure in the oil separator and the compressor is many times same, the oil returns by gravity and hence there should be sufficient head available between oil return point of oil separator and the incoming point of oil return on the compressor crankcase. Also, it is a good practice to drain oil manually when the installation is new and check the oil quality instead of automatically returning to the compressor crank case. The oil is normally not clean in the initial stages and till such time that one is fully convinced that the oil getting accumulated in the separator is clean, the automatic oil return should not be connected and used., as otherwise the contaminants would enter the compressor and may create problems.

5. Connect individual discharge and suction pipe to the header from the top in a sloping manner, the slope being in the direction of flow , or easier is to connect from the top in a reverse 'J' pipe like gent's umbrella handle

6. Check alignment of motor with compressor in all 3 arises

7. Hook up suction and discharge piping without any force needed while inserting bolts in the flanges- I have observed in many installations that when bolts joining the flanges of compressor and the discharge pipe are loosened, the alignment is not perfect, this happens due to the fact that during welding there is a shrinkage and the alignment gets disturbed. The normal practice is pulling the pipe with force and then inserting the bolts, this should be avoided as it imposes undue stress on compressor and may lead to additional vibrations.

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Compressor Piping

8. Always use a stop valve after the NRV in the discharge pipe leading to the common header. This is required because if NRV gets stuck, one should be able to attend the same without stopping the entire plant. The stop valve of the particular compressor can be closed and the NRV can then be attended.

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Vibration free operation-pipes connected with perfect flange matching without applying any pressure



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Vibration free operation



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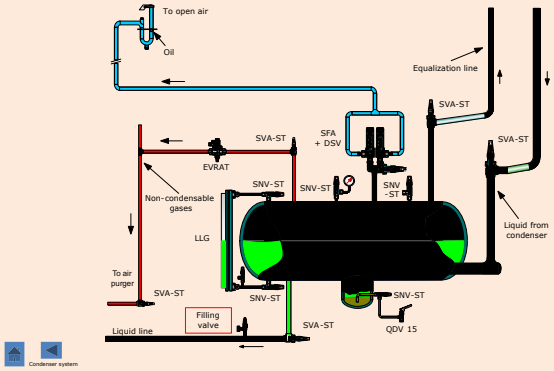
Receiver Mounted in the machine room



Liquid outlet pipe from the top with a tube immersed in the liquid, If receiver is mounted near evaporative condenser on roof top, the liquid outlet should be taken from the bottom

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Receiver system – pipingg principle



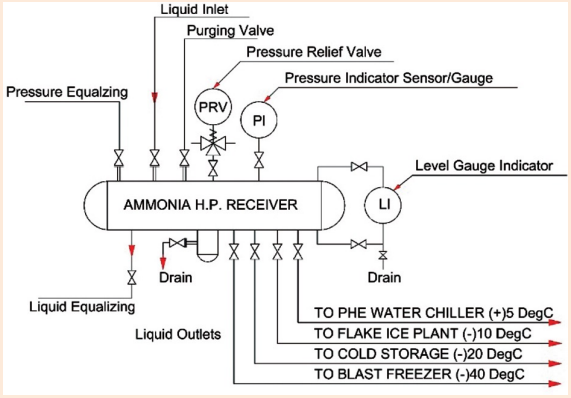
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Receiver Piping

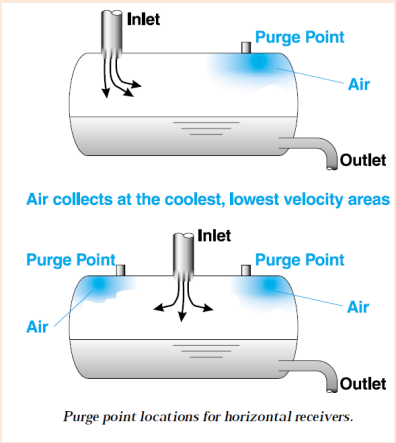
Normally it is a practice to take a common liquid header from the receiver with single outlet and then take different tapings from this common header to the various utilities for expansion at required temperatures.
It is observed in many plants, that when you take certain utility on line, let us say you start the freezing operation when other systems like ice plant, cold storages are operating, due to sudden increase in demand of the blast freezer, the major part of liquid gets diverted temporarily to this freezer and the other working utilities are starved of liquid for few minutes.
It is suggested to take as may outlets as required by the various utilities and size these liquid lines to meet the refrigeration load of each utility so that the each line is smaller, ammonia quantity is reduced and fear of one utility starving temporarily is avoided.

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Receiver Piping



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Purge point locations for horizontal receivers.

Receiver Purge Points- Away from inlet as much as possible

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Receiver spray header-if receiver outside exposed to sun radiation



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Evaporative condenser piping



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Evaporative condenser piping

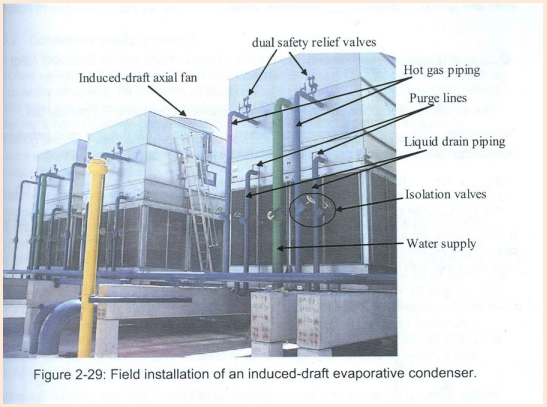


Figure 2-29: Field installation of an induced-draft evaporative condenser.

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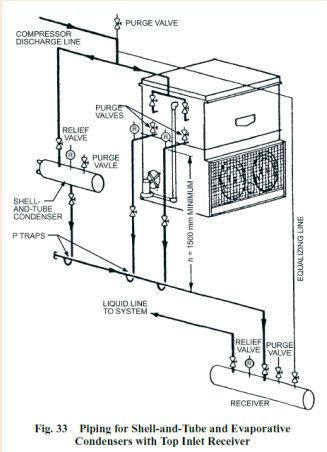


Fig. 33 Piping for Shell-and-Tube and Evaporative Condensers with Top Inlet Receiver

Evaporative Condenser Piping with Top inlet Receiver

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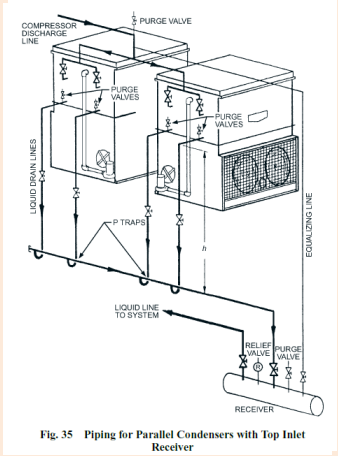
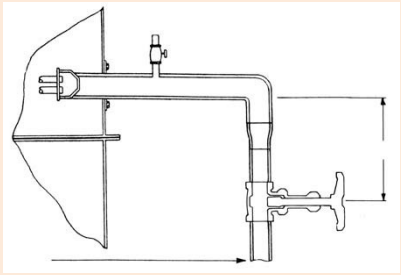


Fig. 35 Piping for Parallel Condensers with Top Inlet Receiver

Piping for Parallel running of evaporative condensers

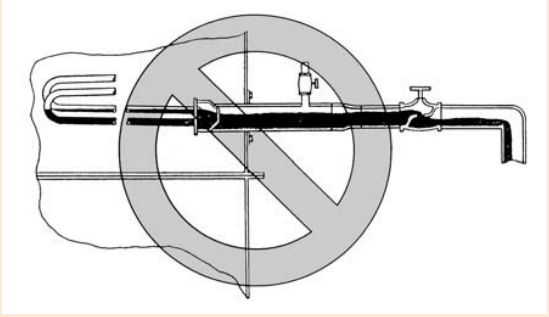
44

Install liquid line Valves in Vertical Line



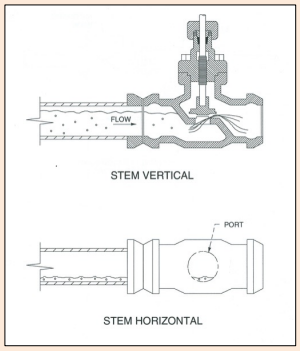
45

Incorrect Valve Installation for Liquid Lines



46

Liquid Hold-up Valve Position

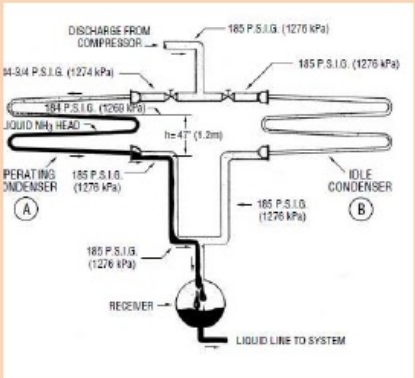


INCORRECT

CORRECT

47

Evap. Cond.-Incorrect Piping Arrangement



48

Correct Piping with Gas Equalizer pipe

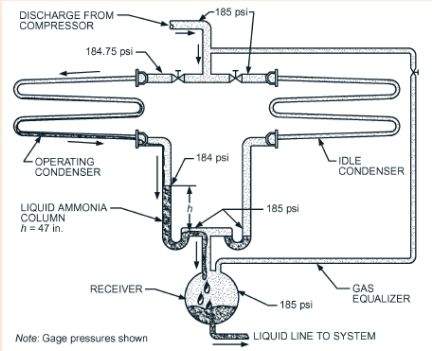
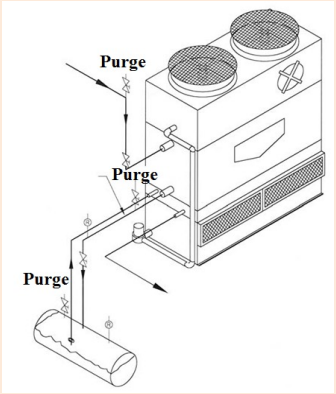


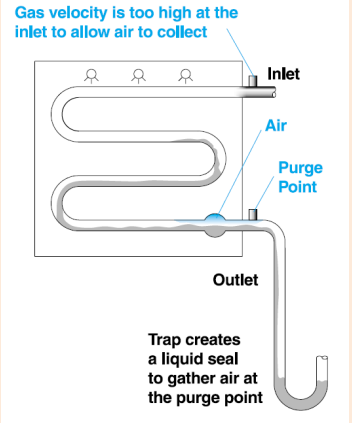
Fig. 31 Two Evaporative Condensers with Trapped Piping to Receiver

49

Purge Points Evaporative condensers On Liquid Outlet



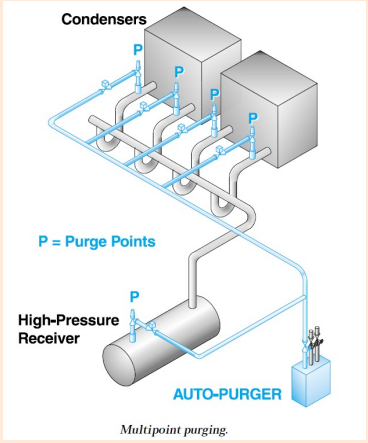
50



Purge point location for an evaporative condenser.

Evaporative Condenser Purge Piping Always on outlet pipe

51

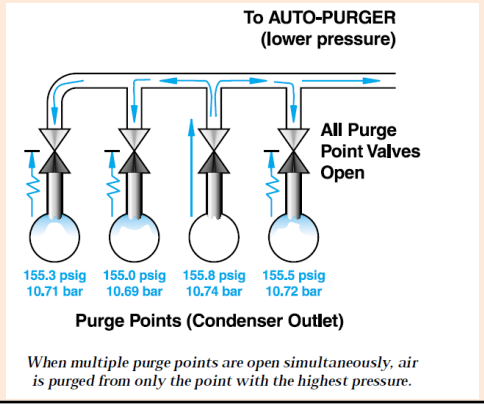


Multipoint purging.

Multiple Condenser Purge Piping

52

Multiple Condensers –Purge one at a time



53

Low Pressure Vessel & piping



54

L.P. Receiver Package



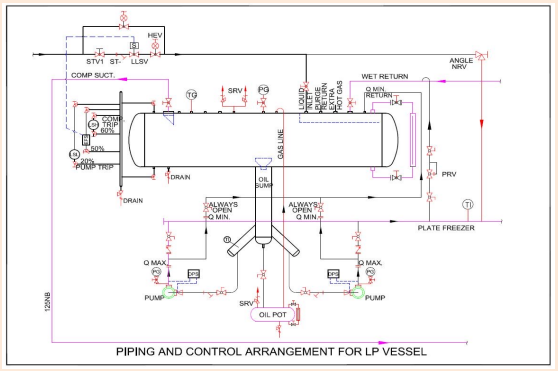
55

L.P. Vessel Assembly



56

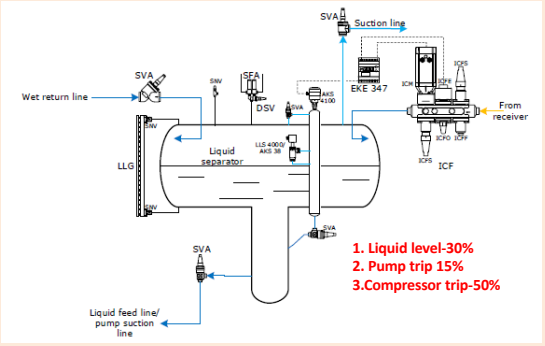
L. P. Vessel piping



PIPING AND CONTROL ARRANGEMENT FOR LP VESSEL

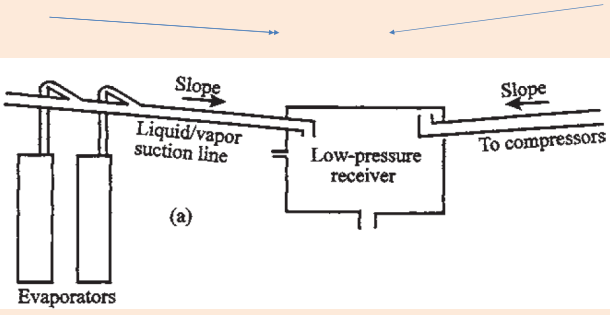
57

L.P. Vessel Piping



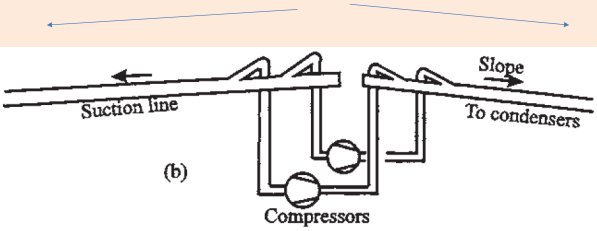
58

L.P. Vessel piping arrangement-slope towards L.P. vessel from both sides



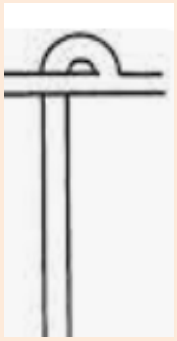
59

Compressor Piping slopes



60

Compressor piping from Suction header



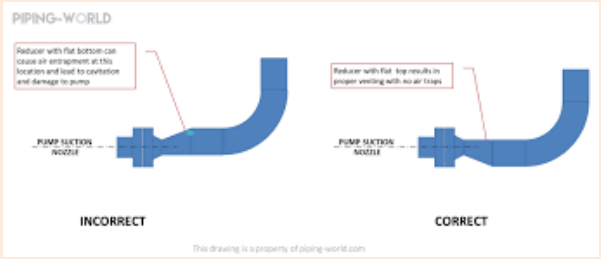
61

Recommended Sizes For Down Leg to Pump

Approx. Pump Flow Rate	5m³/hr	12m³/hr	15m³/hr	35m³/hr	70m³/hr
Pump Suction Size-mm	32	50	50	80	100
Down Leg Size-mm	80	100	125	150	250

62

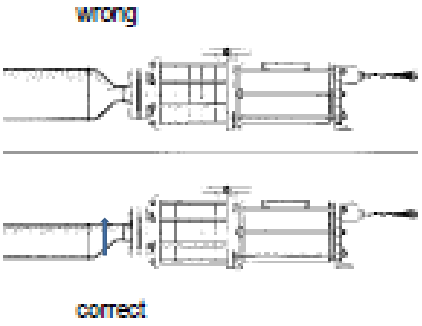
Pump inlet Reducer Installation



63

63

Reducer At Ammonia Pump Inlet



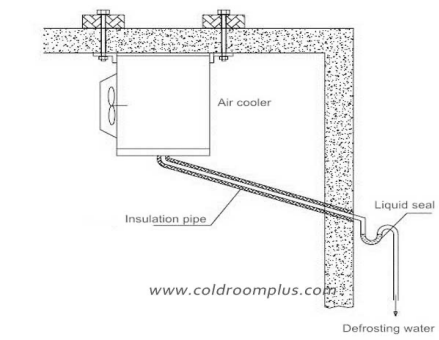
64

Piping valves

- Use ball valves
  1. Wet return line / suction line/Pump inlet line
  2. Keep minimum pressure drop
  3. Ensures higher operating compressor suction pressure
  4. Energy savings

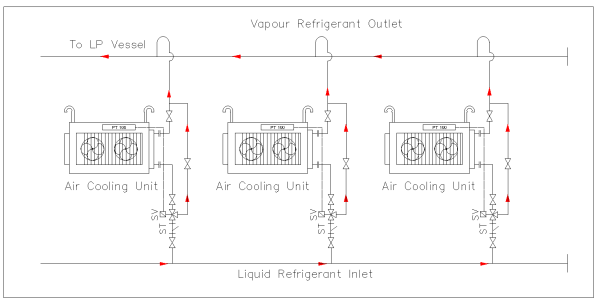
65

Air cooler drain piping with liquid seal-Ensures outside air does not flow inside due to pressure difference



66

Multiple Air Cooler piping & Controls



67

AIR COOLER PIPING OUTSIDE THE BUILDING ON TERRACE



68



69

Hot Gas Defrost Arrangement and piping

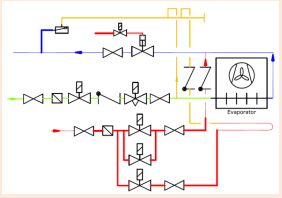
70

HOT GAS LINE SIZING AS RECOMMENDED BY 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)

71

Separate hot gas defrost line for defrost pans

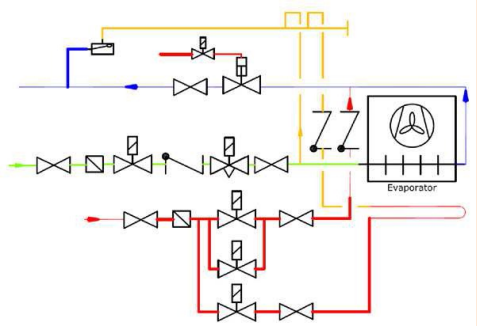


Having a separate valve station for the defrost pan:

- 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.

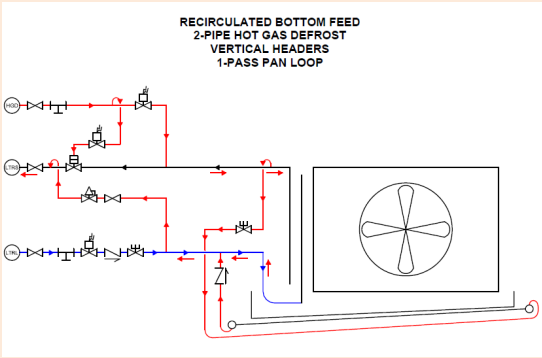
72

Optimized hot gas defrost



73

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



74

OPTIMIZED HOT GAS DEFROST WITH SEPARATE FOR DRAIN PAN

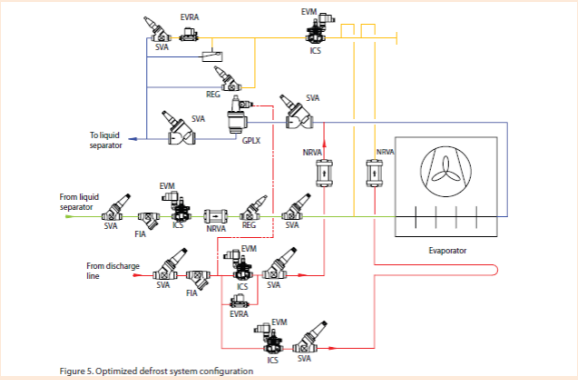


Figure 5. Optimized defrost system configuration

75

Hot Gas Defrost-Pump Out Phase

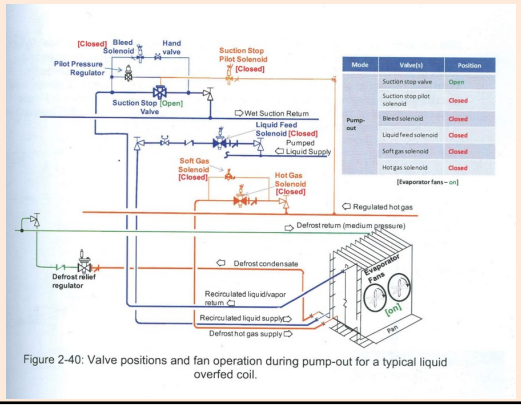


Figure 2-40: Valve positions and fan operation during pump-out for a typical liquid overfed coil.

76

Hot Gas Defrost-Soft Gas Phase

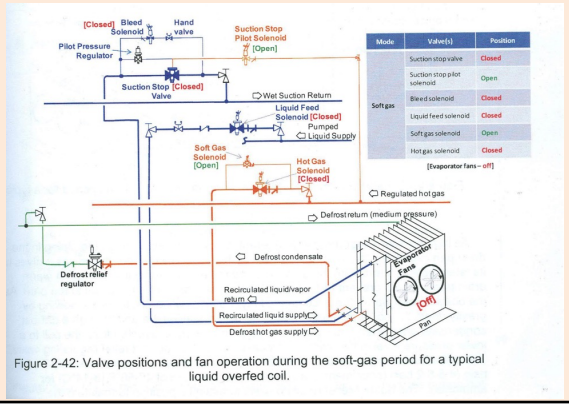


Figure 2-42: Valve positions and fan operation during the soft-gas period for a typical liquid overfed coil.

77

Hot Gas Defrost Phase

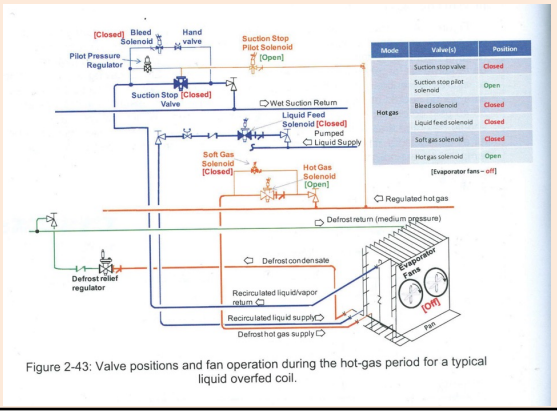


Figure 2-43: Valve positions and fan operation during the hot-gas period for a typical liquid overfed coil.

78

End of Defrost- Condensate Bleed Phase

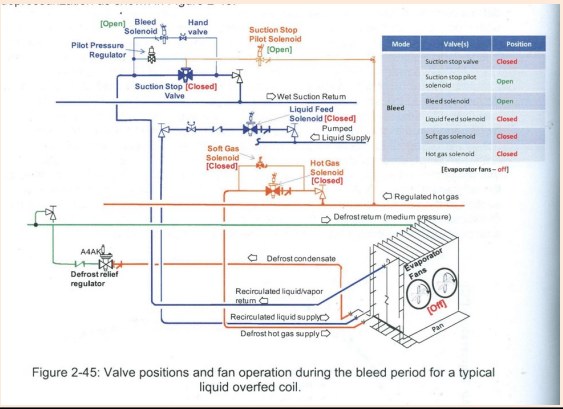


Figure 2-45: Valve positions and fan operation during the bleed period for a typical liquid overfed coil.

79

Defrost Ends-Re chill Phase

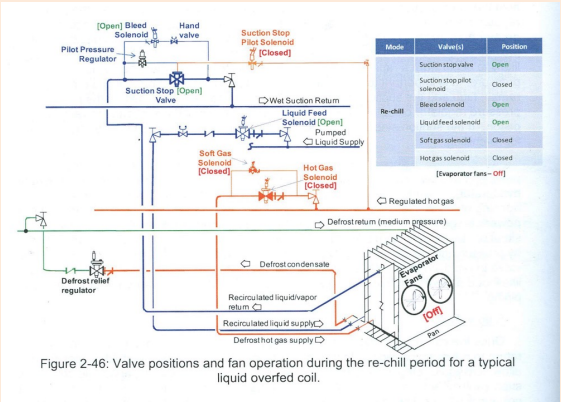


Figure 2-46: Valve positions and fan operation during the re-chill period for a typical liquid overfed coil.

80

Time Dependant Energy Flow During Defrost

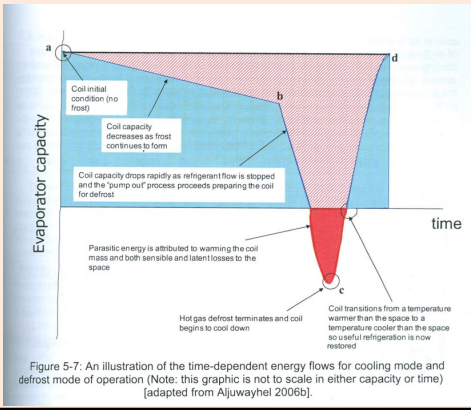
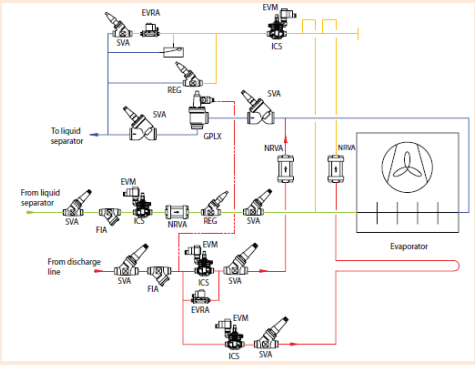


Figure 5-7: An illustration of the time-dependent energy flows for cooling mode and defrost mode of operation (Note: this graphic is not to scale in either capacity or time) [adapted from Aljuwayhel 2006b].

81

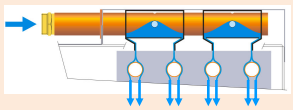
Hot gas for Drain Pan



82

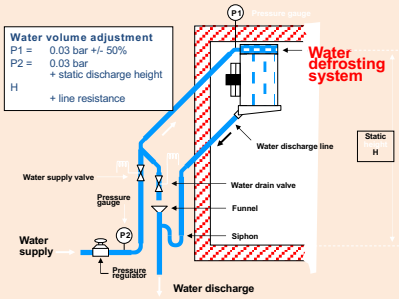
Water defrost

- 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.



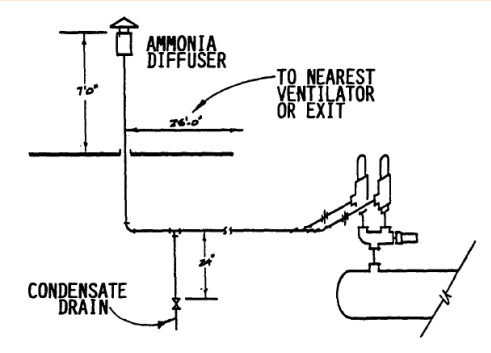
83

Bottom feed water supply



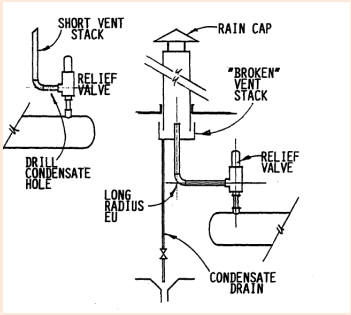
84

Safety Valve Piping Arrangement



85

Safety Valve Piping Arrangement

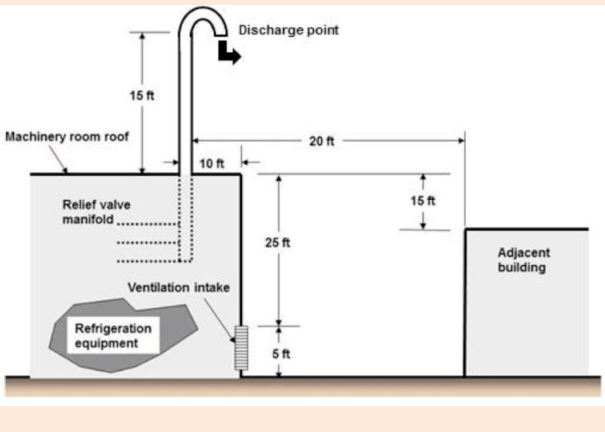


86

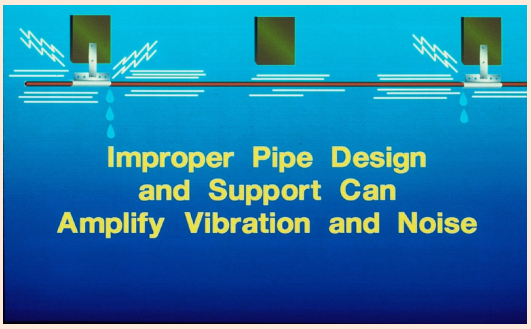
Safety Valve Piping outlets



87

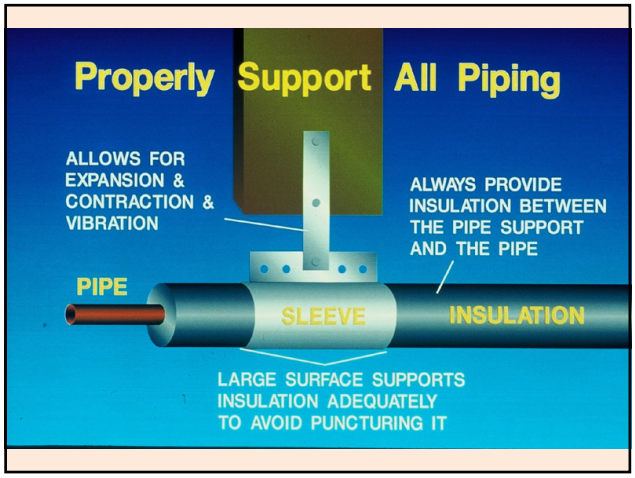


88

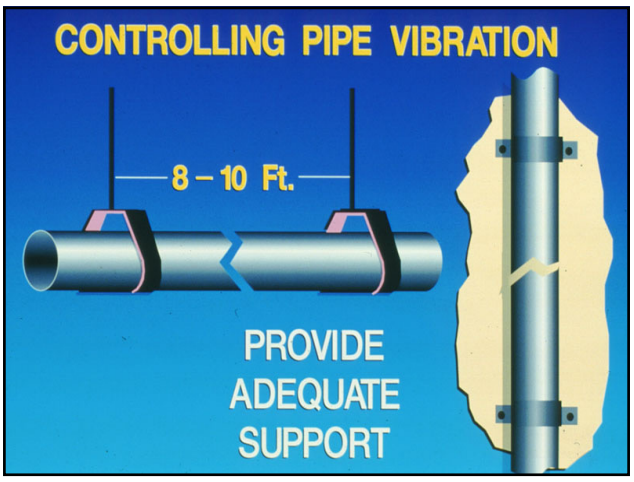


The distance between two lines should be at least 3 times the thickness over insulation & 4 times over the flange joints

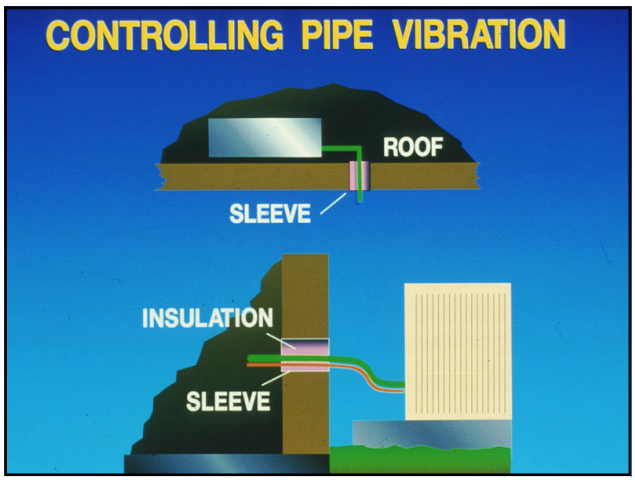
89



90



91



92

Pipe Support Spacing

Pipe Diameter-inch	Maximum Span-ft	Minimum rod Diameter-Inch
Up to 1	7	3/8
1 ¼	9	3/8
2	10	3/8
2 ½	11	½
3	12	½
4	14	5/8
5	16	5/8
6	17	¾
8	19	7/8
10	22	7/8
12	23	7/8
14	25	1
16	27	1
18	28	1 ¼
20	30	1 1/4

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THERMAL LINEAR EXPANSION OF COPPER TUBING AND STEEL PIPE (inches per 100 feet)

Temperature Range (F)	Copper Tubing	Steel Pipe
50	.56	.37
100	1.12	.76
150	1.69	1.15
200	2.27	1.55
250	2.85	1.96
300	3.45	2.38
350	4.05	2.81
400	4.65	3.25
450	5.27	3.70
500	5.89	4.15

Allow About 20mm expansion/contraction for every 30m of piping

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Stop Valves

1. Weld able-must show Flow Direction and Size
2. A420 material For Low Temperature
3. Forged Steel or Wrought Iron Steel for High Temperature



Dimension: DN 15 - DN 150

Pressure: PS 25 bar

Connection: DIN, ANSI, Metric

Types: Cap / Hand wheel
Angel / Straight

Material: Steel

STC full fill the same high quality and safety requirements as all other Danfoss products. The test procedures for strength pressure test and internal / external leakage tests are identical for SVA and STC valves.

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Use Angle Valve instead Globe valve plus bend-Reduced pressure drop, less welding



ANGLE VALVE GLOBE VALVE BEND

96

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HYDRAULIC SHOCK

Condensation-induced hydraulic shock (CIHS) is defined as a short-duration pressure spike in the liquid phase of a two-phase piping system. It is caused when a moving liquid--often called slug flow--advances into a section of piping with no outlet, thereby creating a volume of trapped gas that condenses as the slug flows in. This reduces the volume of the trapped gas to the point where the gas is totally condensed, and the slug flow comes to a sudden stop. The change in momentum of the liquid slug when its velocity goes to zero causes a pressure spike in the liquid phase of the fluid, which can then create noise or vibration, or even cause a rupture of piping.

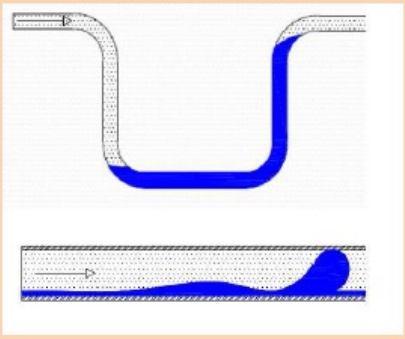
97

Hydraulic Shock/water Hammer-Why?

1. Damaging Hydraulic Shocks are often Condensation induced
2. Occur in low temperature applications during onset or termination of defrost
3. Normally occur in two phase suction line-wet return line-due to liquid slugs
4. During initiation of defrost hot gas rushes in low side and relieved at termination
5. When gas flow is large it scoops up liquid from wet return line
6. Wet return header closed without exit gas gets compressed even more
7. When pressure rises the gas gets condensed and draws liquid in to the suction behind it and the liquid hits the close end cap
8. The slugs then develop pressures of even up to 52 bar and damage seamless pipes even up to 400 mm diameter.

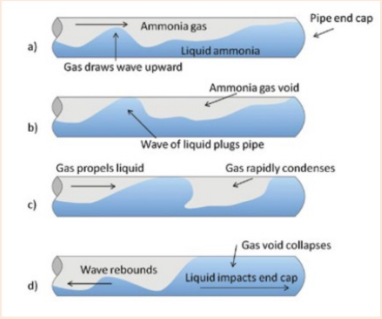
98

Liquid Hammer-Liquid Trap



99

HYDRAULIC SHOCK



100

100



26th June 2020

101



102

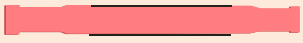
A Pipe ruptured due to liquid hammer



103

Avoid Locked refrigerant





EVR/A

NRV/A

104

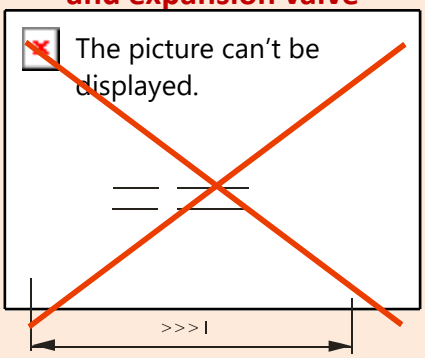
How to place solenoid and check valve
Check valve –downstream of solenoid valve to avoid liquid trap

EVR/A

NRV/A

105

Long distance between solenoid and expansion valve



106

Piping Practices to decrease hydraulic shocks

1. Hot gas piping-No traps, if traps unavoidable then provide liquid drains
2. The evaporator must be fully drained before admitting hot gas, giving any liquid slugs free flow through evaporator to suction piping
3. Especially important for evaporators with vertical suction header and bottom feed
4. Evaporator shut off valves with stem horizontal
5. Wet suction should contain no traps
6. Evaporator outlet connection from top of wet return header
7. Wet suction and branches-No dead end or closed valves
8. Do not overcharge or undercharge LP vessel
9. Draining a vessel puts gas in liquid line
10. Overfilling puts liquid in gas lines
11. Use soft gas defrost with smaller solenoid in parallel to equalize pressures for larger plants both in liquid and hot gas defrost lines to evaporator

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Key Lessons summarized to avoid liquid stroke/liquid hammer:

1. For the design of ammonia system, avoid grouping multiple, large capcity evaporators to a single set of controls, provide separate controls to each evaporator
2. Program the defrost control sequence to automatically depressurize or empty the coil after defrosting, prior to opening the suction stop valve to restart cooling cycle
3. Avoid manual interruption of evaporators while in defrost mode and equip controls to ensure only authorized and trained personnel are present.
4. Before staring hot gas defrost, ensure that entire quantity of liquid refrigerant has ben pumped out from the evaporator coil before admitting hot gas, especially after low load period or after power outages.
5. Connect all outlet pipes from evaporator coils to wet return with reverse 'U' connection, like gent's umbrella handle , to ensure liquid is not entering the from the wet return line into the evaporator which is getting defrosted.

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Piping Practices To Decrease Hydraulic Shocks

1. Hot gas piping-No traps, if traps unavoidable then provide liquid drains
2. The evaporator must be fully drained before admitting hot gas, not giving any liquid slugs, free flow for hot gas through evaporator to suction piping
3. Especially important for evaporators with vertical suction header and bottom feed
4. Evaporator shut off valves with stem horizontal
5. Wet suction should contain no traps
6. Evaporator outlet connection from top of wet return header
7. Wet suction and branches-No dead end or closed valves
8. Do not overcharge or undercharge LP vessel
9. Use soft gas defrost with smaller solenoid in parallel to equalize pressures for larger plants both in liquid and hot gas defrost lines to evaporator

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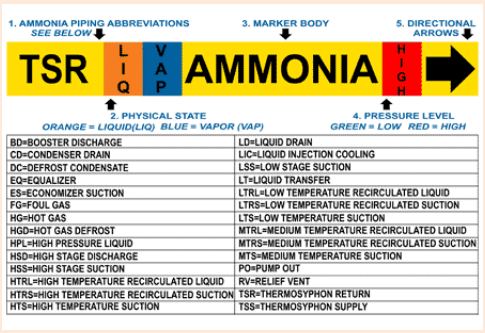
REFRIGERANT PIPING COLOR CODE

SR.NO.	DESCRIPTION	SCOPE	COLOUR CODE
1	HP Hot gas	High Stage Discharge	Red
		Booster Discharge	
2	HP liquid refrigerant	Receiver to Economizer	Orange
		Economizer to Intercooler	
3	LP liquid refrigerant	Intercooler to LP Vessel	Light green
4	LP refrigerant vapor	High Stage Suction	Dark green
		Booster Suction	
5	Liquid/vapor mixture of refrigerant		Purple
6	Oil Circuit	Both Booster & High Stage	Black

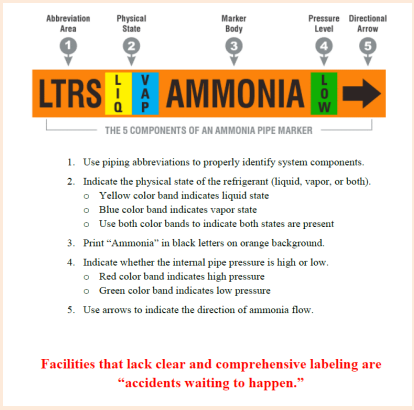
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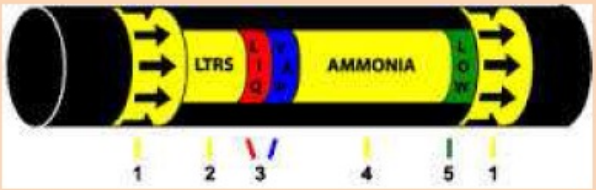
1. Use piping abbreviations to properly identify system components.
2. Indicate the physical state of the refrigerant (liquid, vapor, or both).
   - Yellow color band indicates liquid state
   - Blue color band indicates vapor state
   - Use both color bands to indicate both states are present
3. Print "Ammonia" in black letters on orange background.
4. Indicate whether the internal pipe pressure is high or low.
   - Red color band indicates high pressure
   - Green color band indicates low pressure
5. Use arrows to indicate the direction of ammonia flow.

Facilities that lack clear and comprehensive labeling are "accidents waiting to happen."

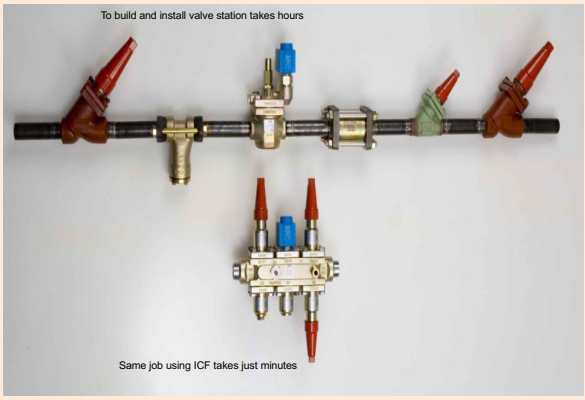
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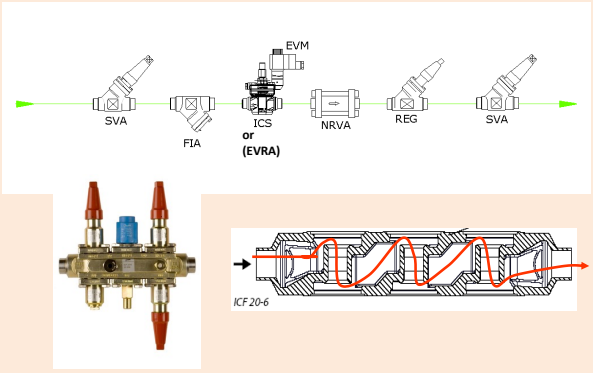
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Two welding joints instead of 12 Numbers

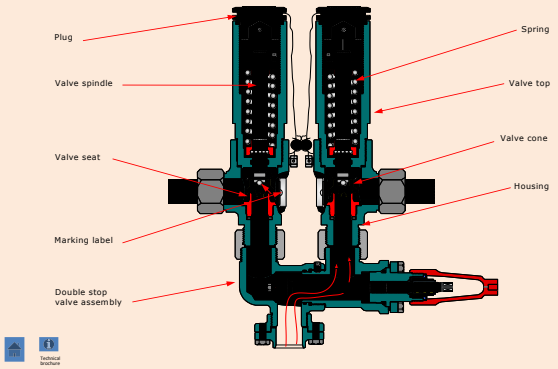
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USE COMPOSITE VALVES

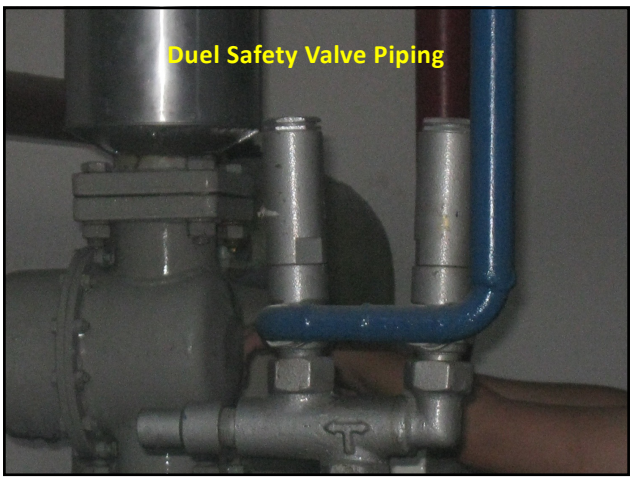


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Double Stop Valve - type DSV and Double Safety Valve - type SFV

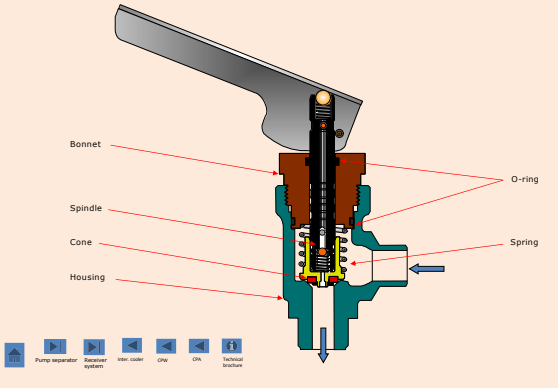


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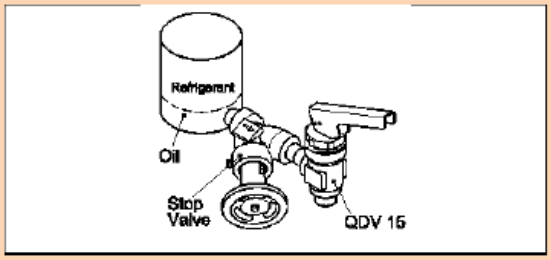
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Quick closing oil drain valve – type QDV 15



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QUICK CLOSING OIL DRAIN VALVE



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CONCLUSION

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Do not use flange joints, use welding joints wherever possible



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GOOD PIPING PRACTICES

1. PIPING TO SLOPE IN DIRECTION OF FLOW(except L.P. vessel)
2. PROVIDE LOOPS –THERMAL CONTRACTION/EXPANSION
3. VIBRATION ELIMINATORS-PROPER PENETRATION
4. PIPING INSULATION SLEEVES
5. OIL SEPARATOR ABOVE CRANKCASE LEVEL
6. ALL HIGH POINTS-VENT VALVES-PURGING
7. LIQUID LINE-VALVES IN VERTICAL LINES-
8. ECCENTRIC REDUCERS
9. BACKSEATING TYPE VALVES
10. GLOBE VALVES STEMS HORIZONTAL
11. VALVES INSTALLED TO CLOSE AGAINST FLOW OR PRESSURE
12. LONG STEM VALVES- FOR INSULATED LINES

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GOOD PIPING PRACTICES

13. SUCTION BRANCHES FROM TOP
14. LIQUID BRANCHES FROM BOTTOM
14. HOT GAS BRANCHES FROM TOP
16. SEAL CAPS NOT IN USE- DRAIN/PURGE/CHARGING
17. SAFETY VALVE DISCHARGE –15 FT. ABOVE GROUND
18. DRAIN/VENT CAPS WITH SMALL DRILLED HOLE
19. NO SHUFF OF VALVE BEFORE SAFETY VALVE IF PROVIDED IN LOCKED OPEN POSITION
20. VALVES APPROACHABLE FROM FLR/FIXED PLATFORM
21. WATER TANK /SPRAY IN PLANT ROOM- AMMONIA
22. TREATMENT OF PIPING BEFORE INSULATION

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IMPORTANT TIPS WHILE DOING THE PIPING TO AVOID AMMONIA ACCIDENTS:

1. Do not use flanged joints in piping wherever possible, use welded joints
2. Use proper slopes in the direction of flow, so that oil accumulates at desired places, except in pump circulation systems where piping to slope towards LP vessel.
3. Use safety relief valves of proper capacity and outlet piping to be taken above15ft. and 20 ft. Above human occupied areas
4. Ensure liquid traps are avoided in piping, since liquid is non-compressible, the piping would burst when ambient temperature rises
5. Avoid hydraulic shocks and vibrations in piping, wet rerun lines, during defrosting by proper designing

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IMPORTANT TIPS WHILE DOING THE PIPING TO AVOID AMMONIA ACCIDENTS

6.Provide bends, loops in long lines to take care of expansion/contraction due to temperature changes.

7. Use quick drain shutoff valves for oil draining. Consider using a spring -loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that migrates into system components) as an emergency stop valve.

8. Provide air purgers, especially in plants operating in negative pressures

9.Remove water from the system periodically

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IMPORTANT TIPS WHILE DOING THE PIPING TO AVOID AMMONIA ACCIDENTS

10. Operate equipment within the design parameters as recommended by manufacturer.

11. Provide regular maintenace practice and prepare schedule for each item including valves, pumps safety relief valves etc.

12. Provide sufficient training to operators and make them familiar with oerating and maintenace procedures

13. Provide safe access to all operating valves and controls in addition to all equipment

14.Provide valve numbering so as convey information by plant operator to procurment agency as to which valve has gone defective and needs replacement

15. Cap all valves whch do not need daily opening/closing.

16. Use proper supports to all piping with L-bracket, U channel, and hangers are typical .Ensure supporting structure like roofs are capable of supporting loads of filled pipes

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Thank you
Any Questions ??

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