Ammonia Pump Circulation Systems- Important & Finer Points for consideration

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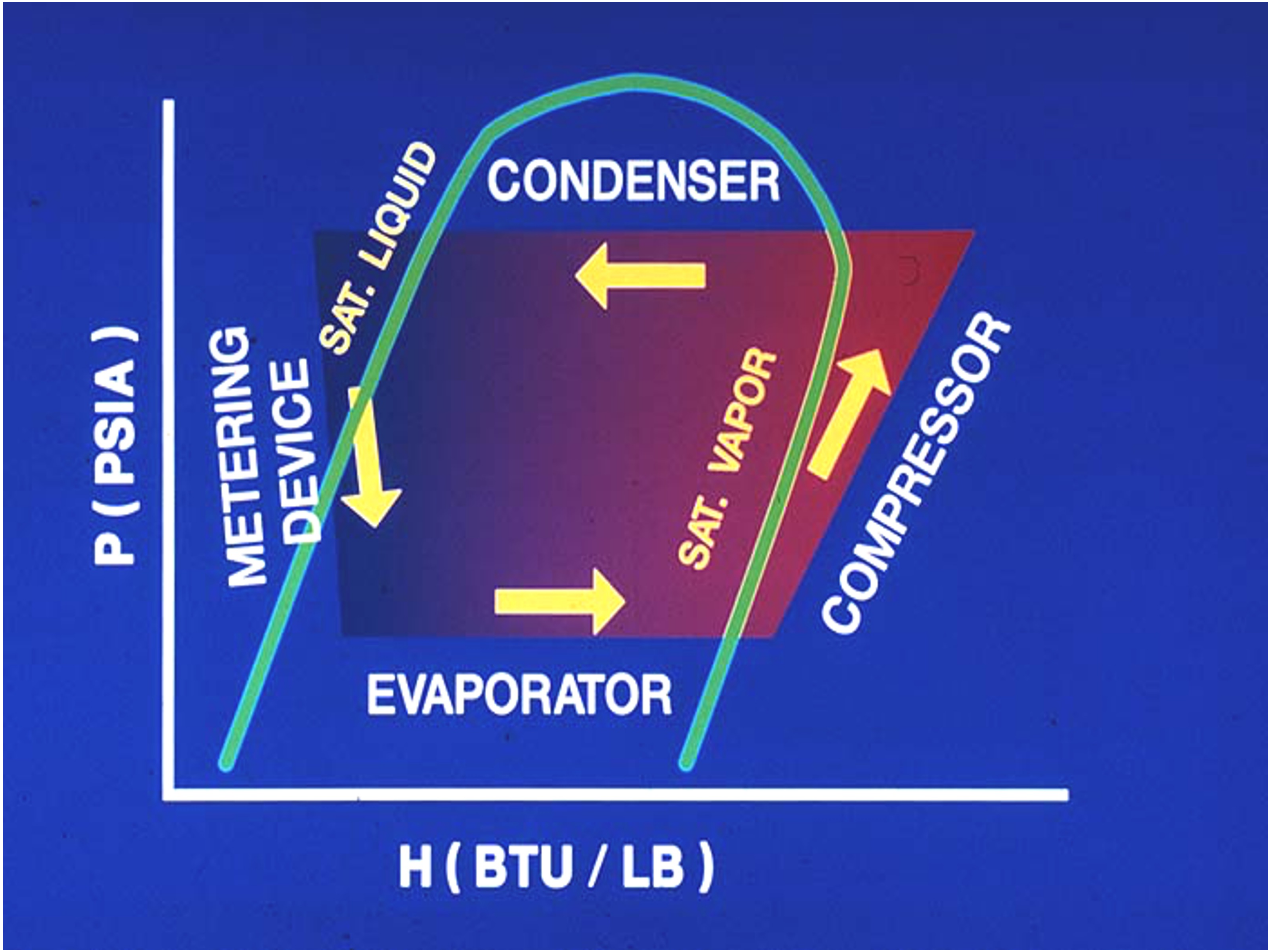
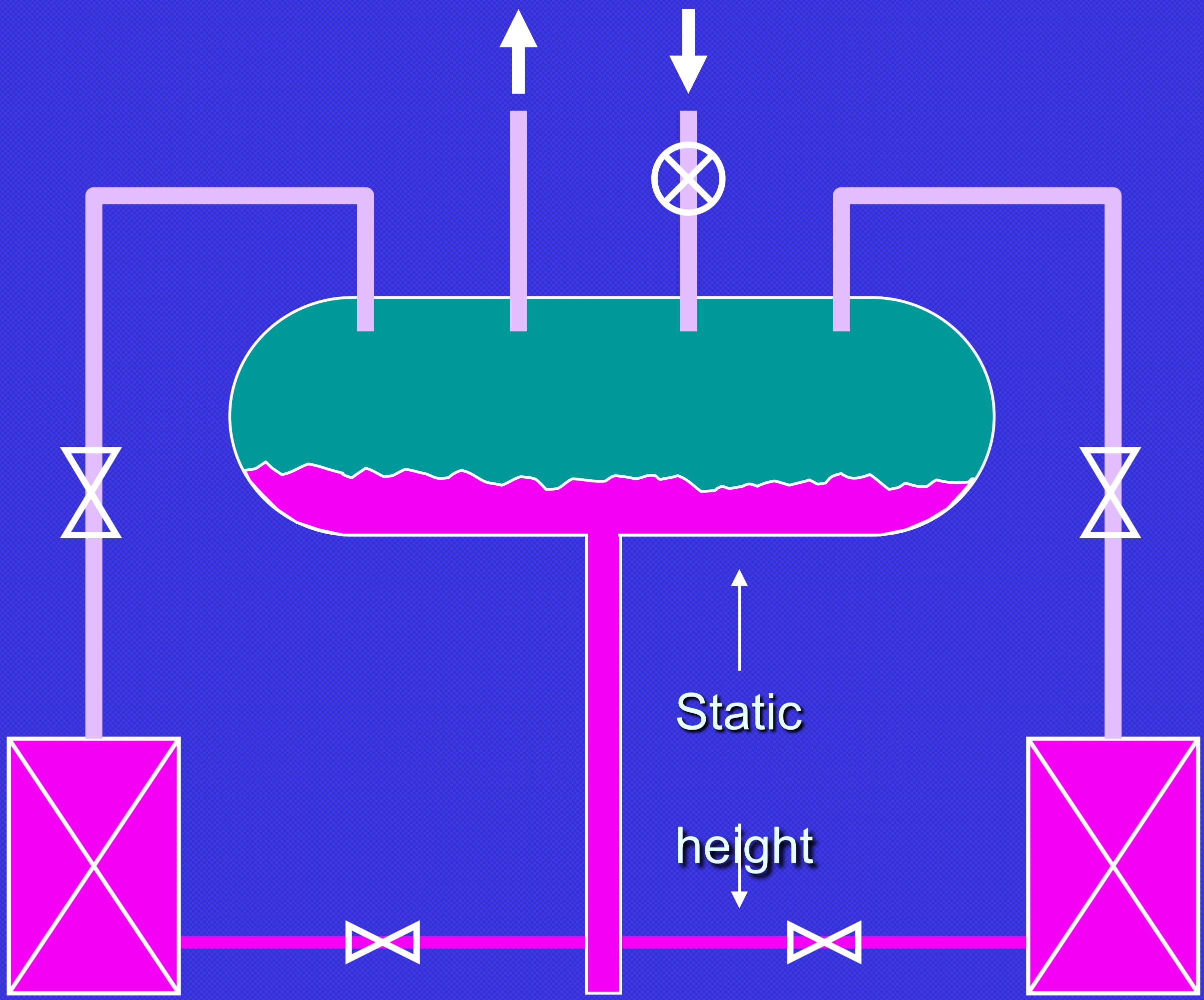
Basic Components of A Refrigeration System

- Evaporator
- Condenser
- Compressor
- Liquid Regulation Device-Hand Expansion Valve/Float Valve



P (PSIA)
CONDENSER
SAT. LIQUID
METERING DEVICE
SAT. VAPOR
COMPRESSOR
EVAPORATOR
H (BTU / LB)

Gravity Flooded System



Gravity Flooded System Characteristics

Mostly similar characteristics as pumped systems

No extra pump & pump energy necessary

Static pressure (liquid column) necessary to overcome the pressure drop in the coil, piping ,valves, controls

Normally flow rate is two times evaporation rate

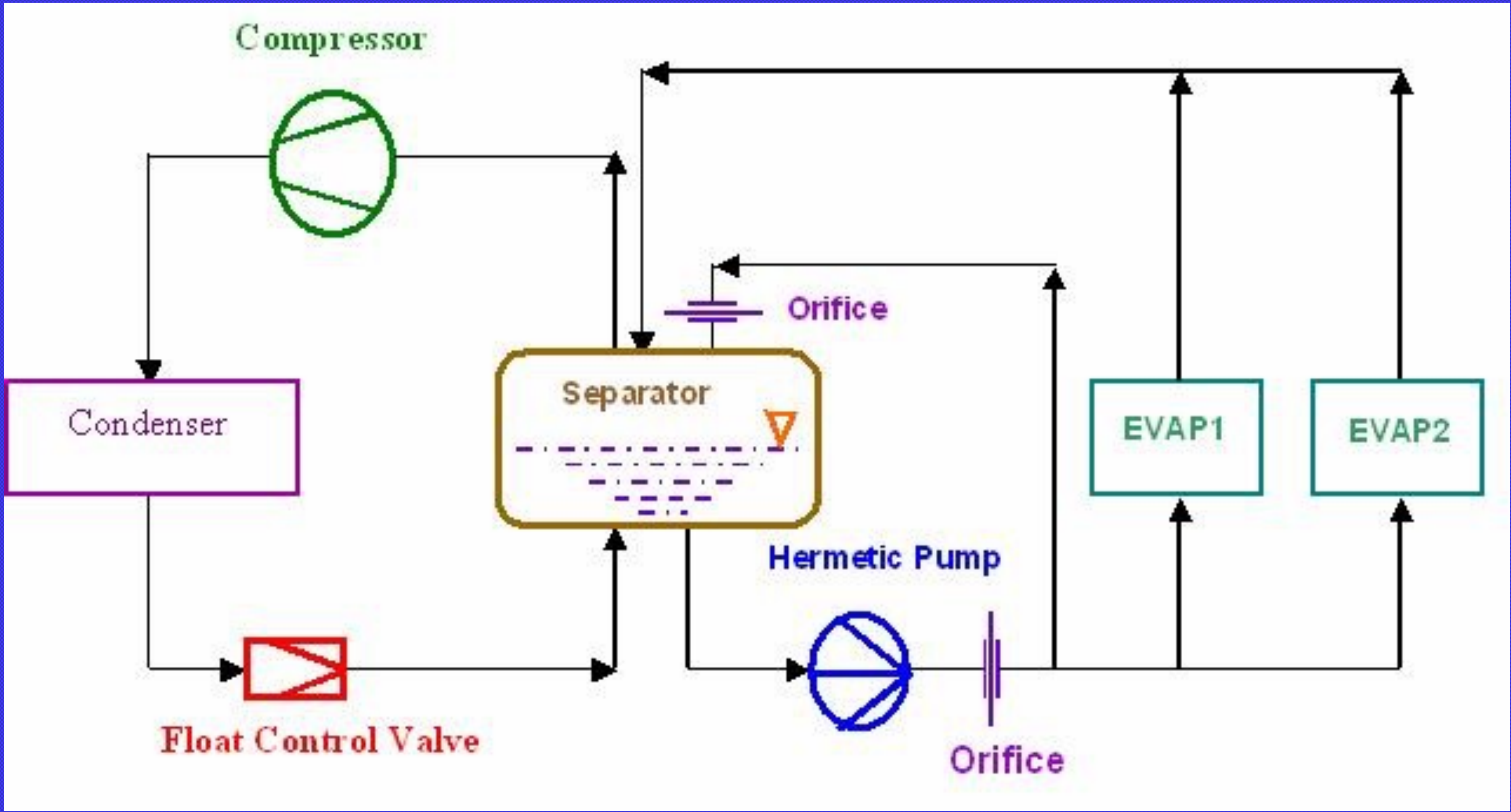
Force Feed Pump Circulation Systems

1. In the pumped system the low temperature liquid Ammonia, instead of going to the evaporator, is stored in the Low Pressure Vessel (like a storage tank) and then it is circulated with the help of pump to various air coolers/freezers
2. The excess unevaporated liquid and vapours formed due to the system load return to L.P. vessel instead going directly to the compressor.
3. So this becomes an additional component in the refrigeration system and forms independent circuit, de-coupled from compressor, condenser, & H.P. receiver, inter-stage cooler

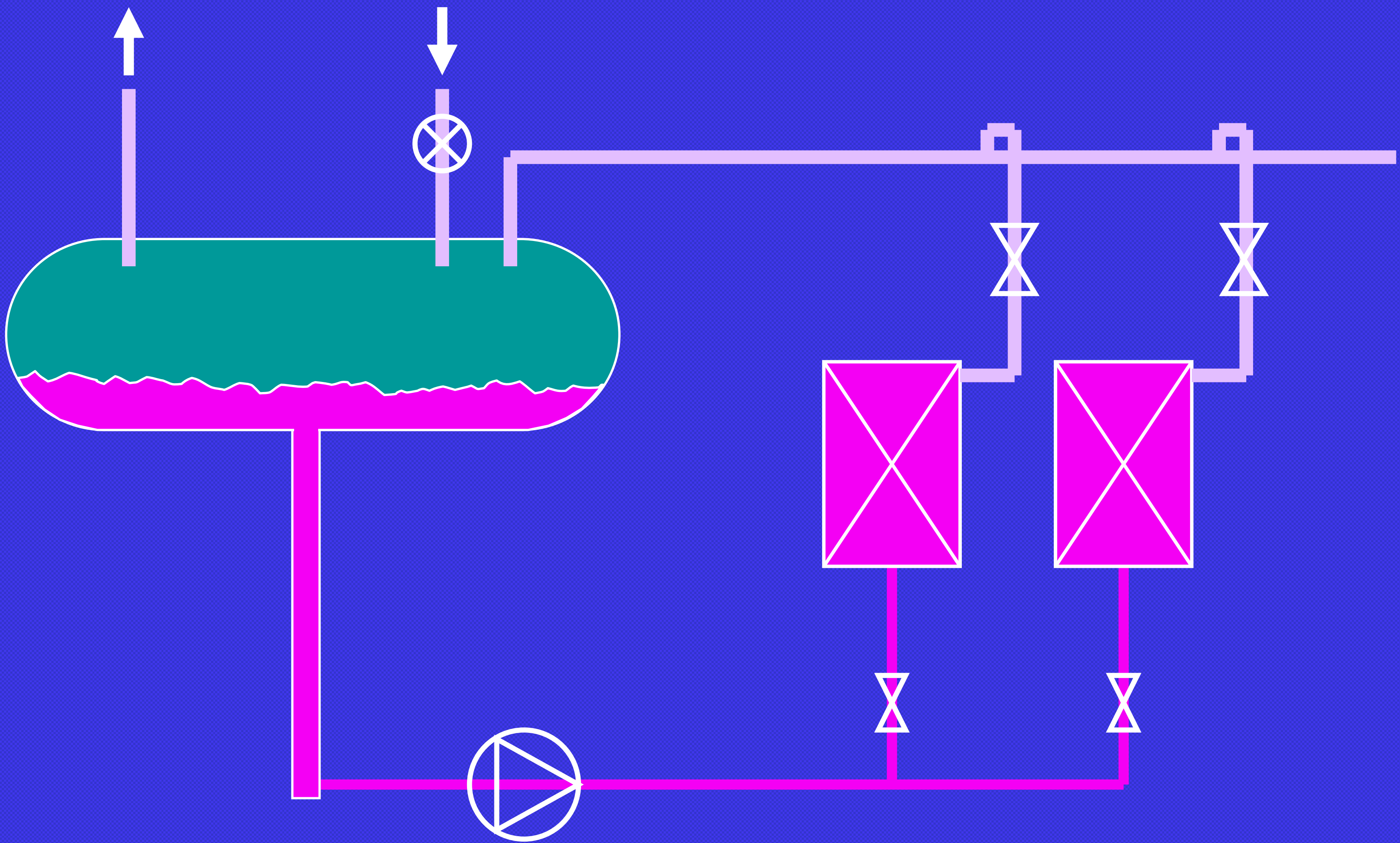
When to use Overfeed?

1. More than 3 to 4 freezers or cold rooms
2. More suited for low temperature applications
3. Processing area away from machine room
4. Better efficiency
5. Dependability/Reliability

System layout



Pumped System-Overfeed Systems



Difference Between Circulation rate & Over feed rate

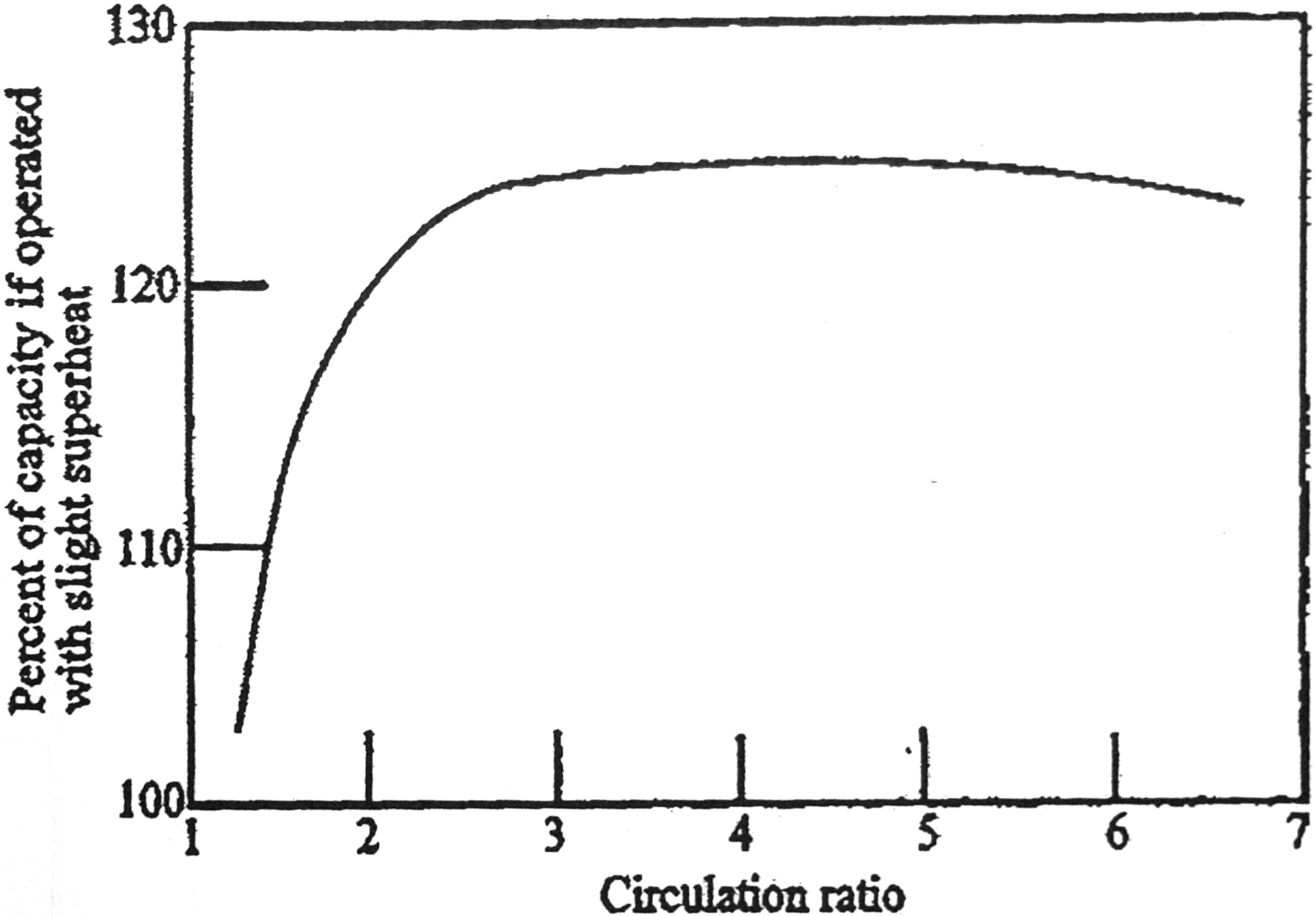
Circulation rate 4:1 =

Supply to freezer (4kg) Liquid/ Evaporation of (1 kg) Liquid in to Gas equal to load

OR

Overfeed rate 3:1 =

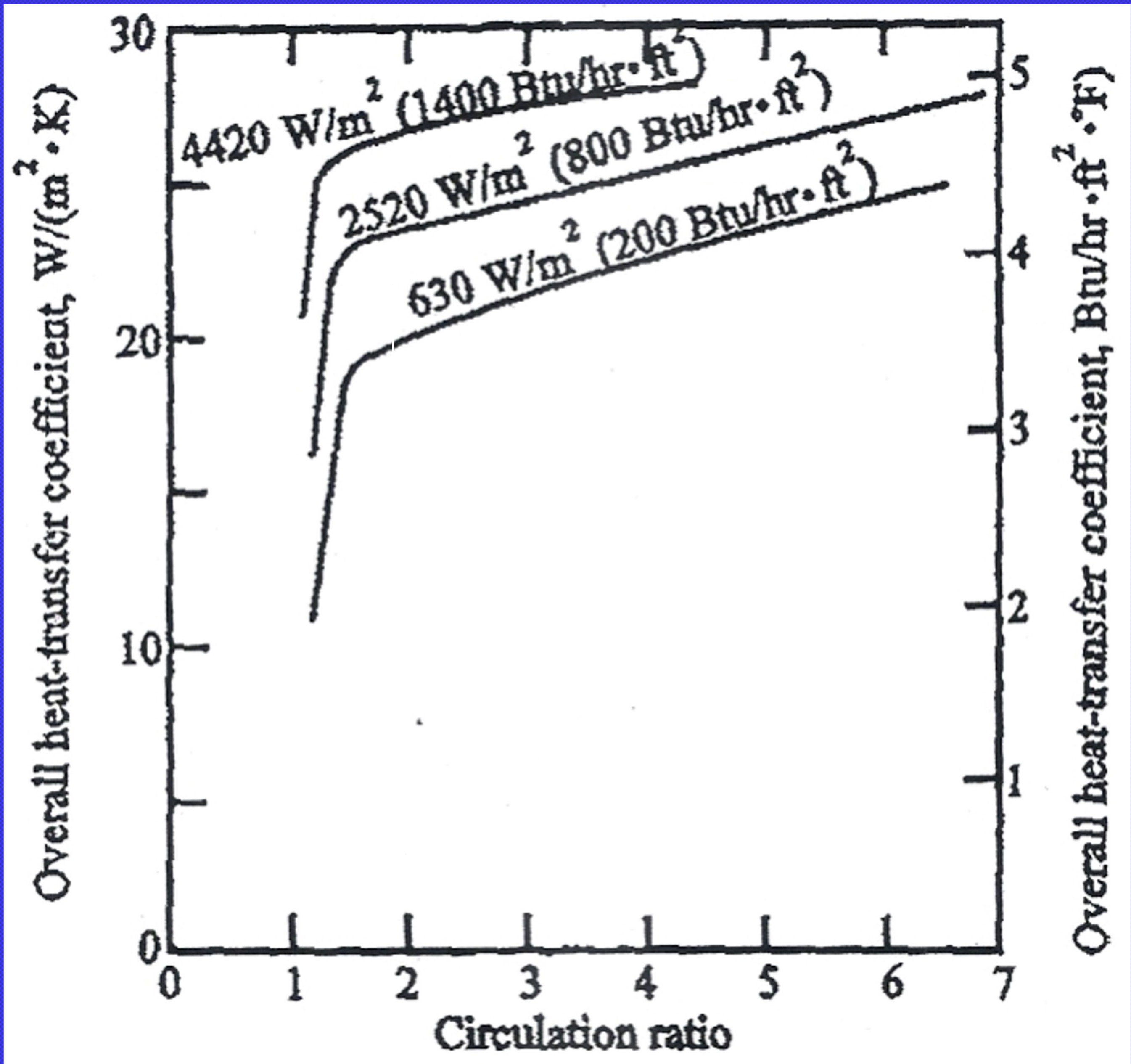
Liquid return (3 kg) / Evaporation (1 kg) Liquid into the Gas, means you have overfed evaporator with liquid 3 times more, circulation rate is one more than overfeed rate.



Ref: W.F. Stoecker

Effect of circulation ratio on the overall heat-transfer coefficient of an air-cooling coil[1].

Optimum circulation rate



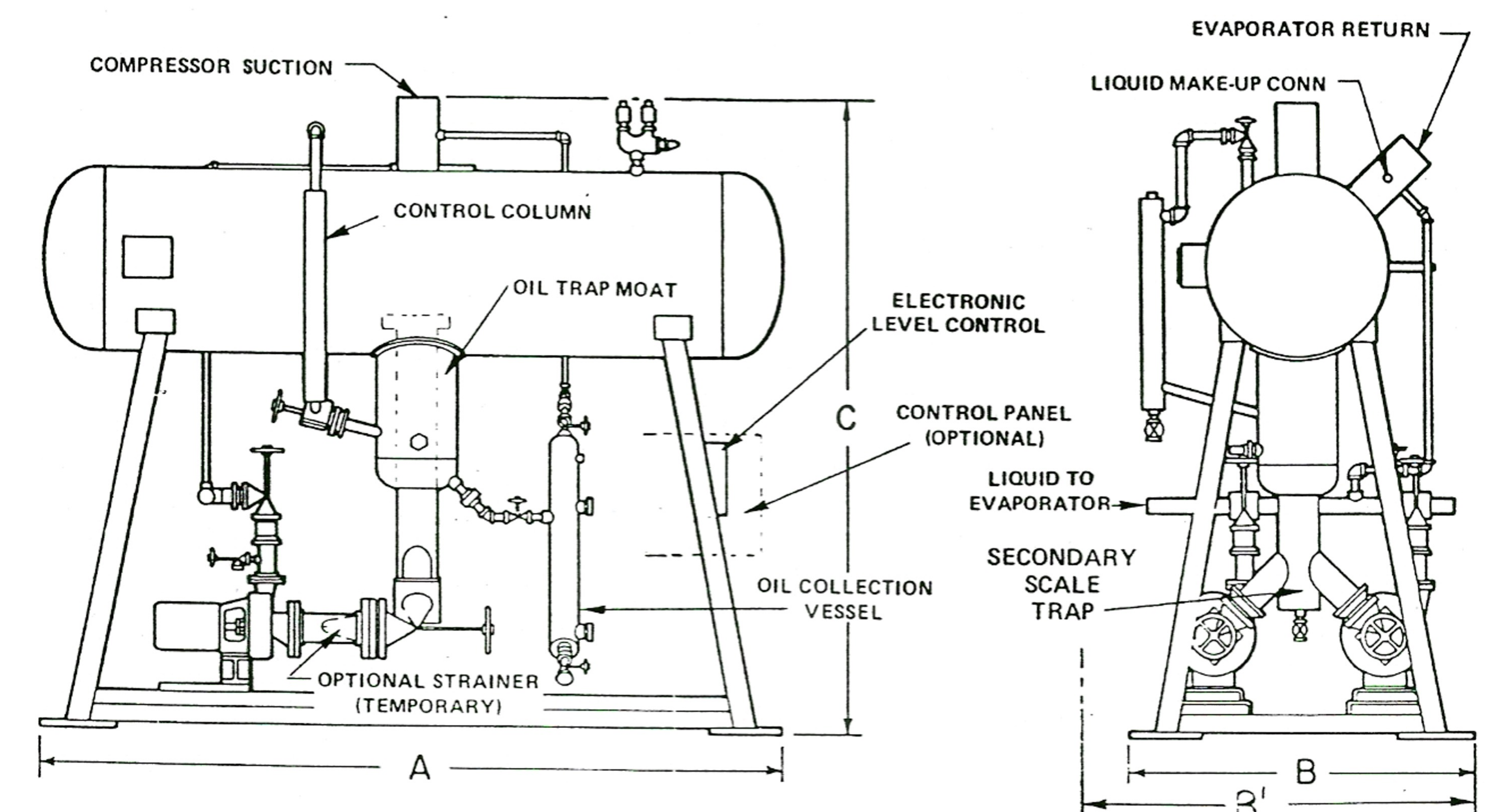
Ref: W.F. Stocker

Recommended Circulation Rates For Bottom Feed Evaporators

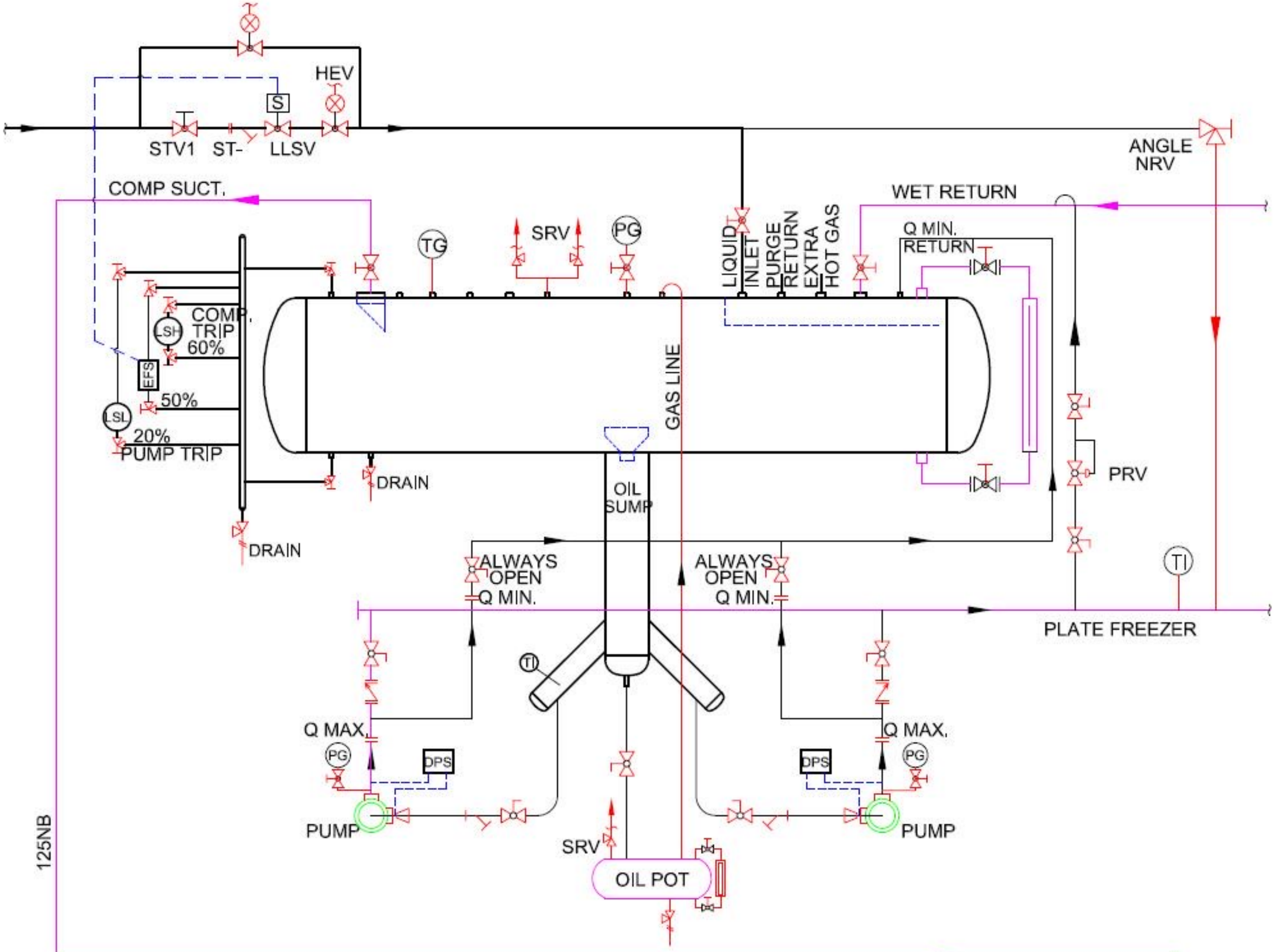
	CO_2	AMMONIA	R22
Blast freezers/ Air Coolers	1.2-2	3-4	2-3
Plate Freezers	5-10	7-14	5-12
Liquid Chillers	1.2-1.5	1.2-1.5	1.2-1.5

Excess rate means you are wasting Pumping energy

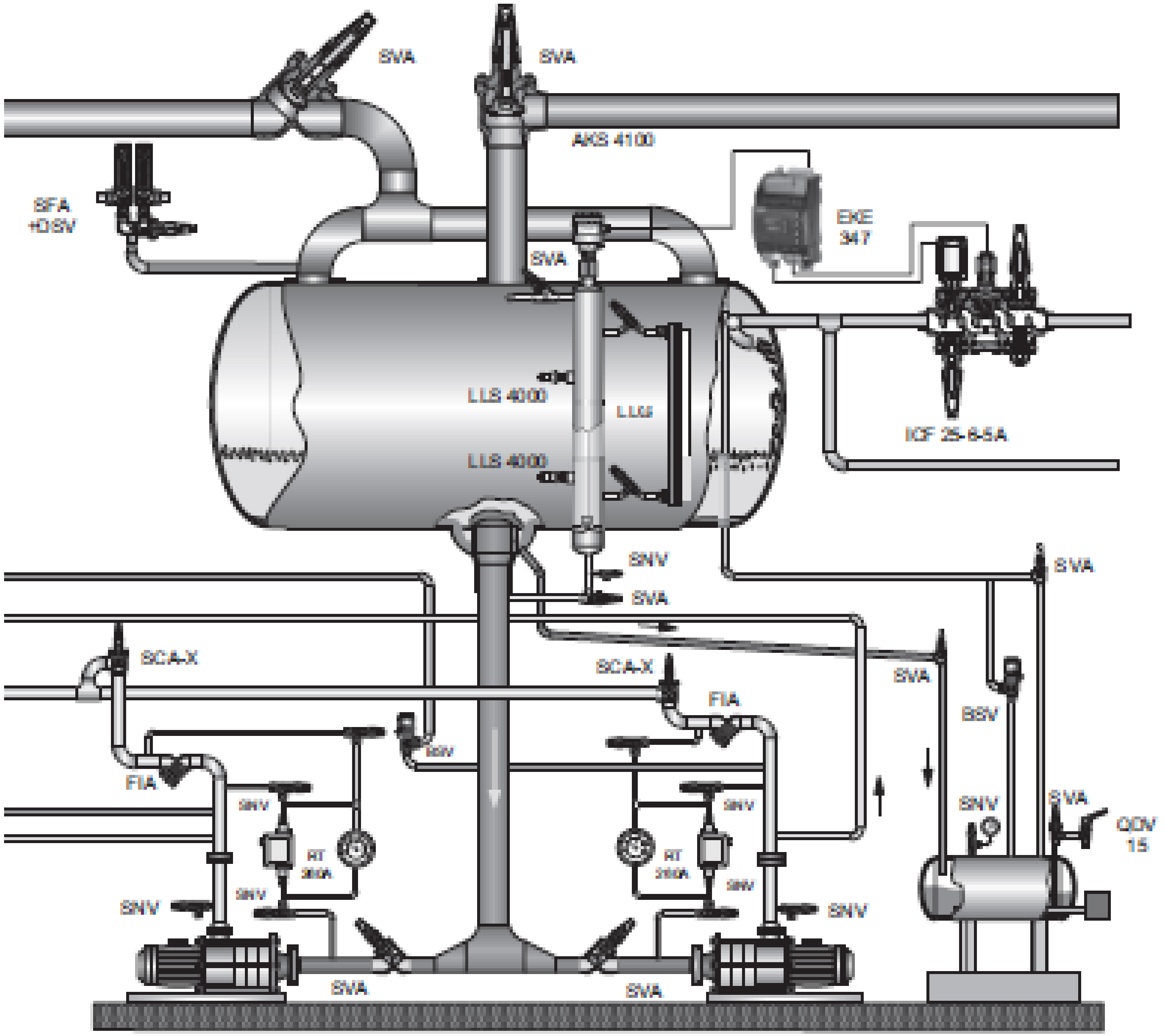
L.P. Receiver Package
Next Three Slides



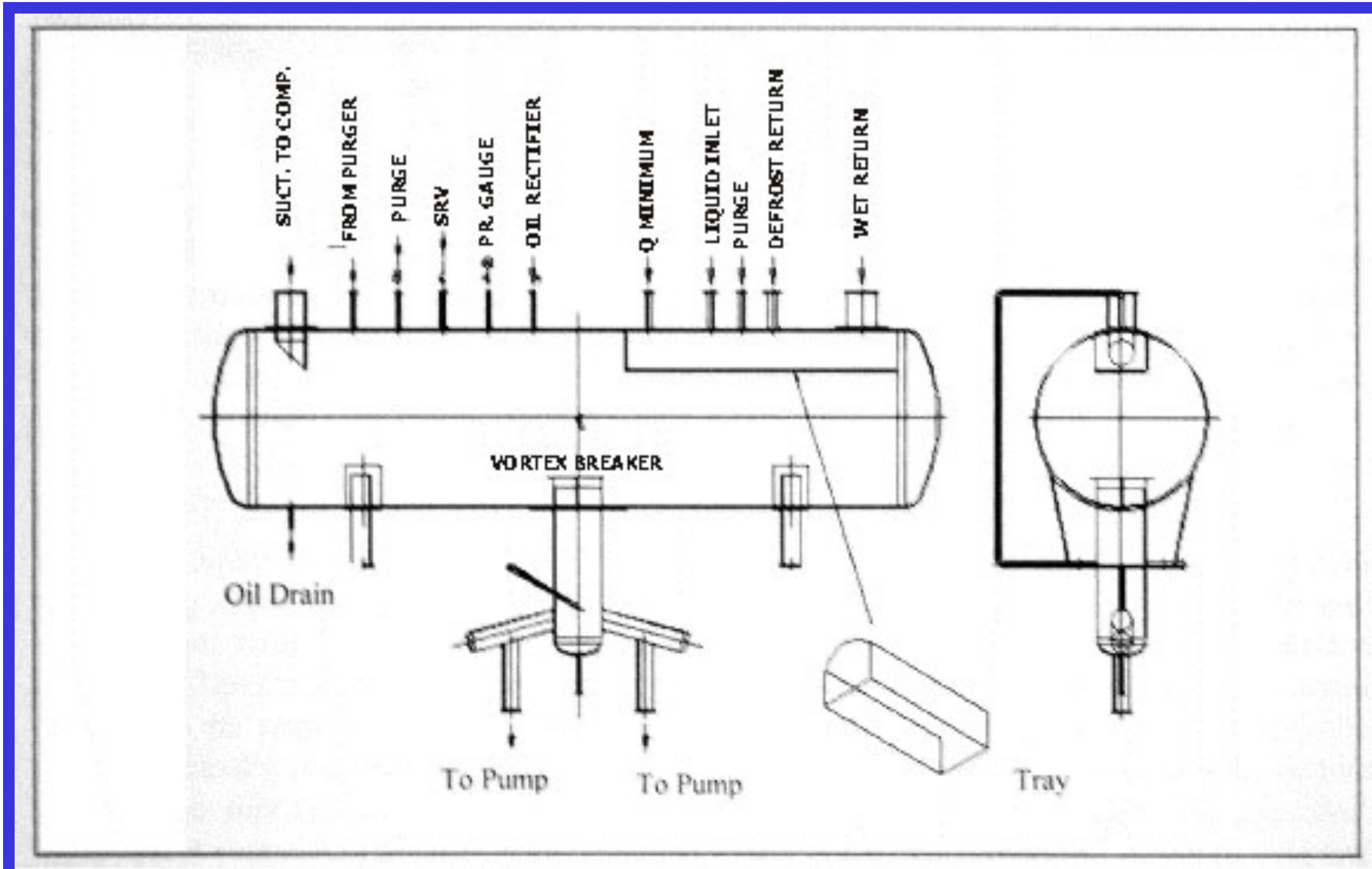
COMPRESSOR SUCTION
CONTROL COLUMN
OIL TRAP MOAT
ELECTRONIC
LEVEL CONTROL
C
CONTROL PANEL
(OPTIONAL)
OIL COLLECTION
VESSEL
OPTIONAL STRAINER
(TEMPORARY)
A
EVAPORATOR RETURN
LIQUID MAKE-UP CONN
LIQUID TO
EVAPORATOR
SECONDARY
SCALE
TRAP
B



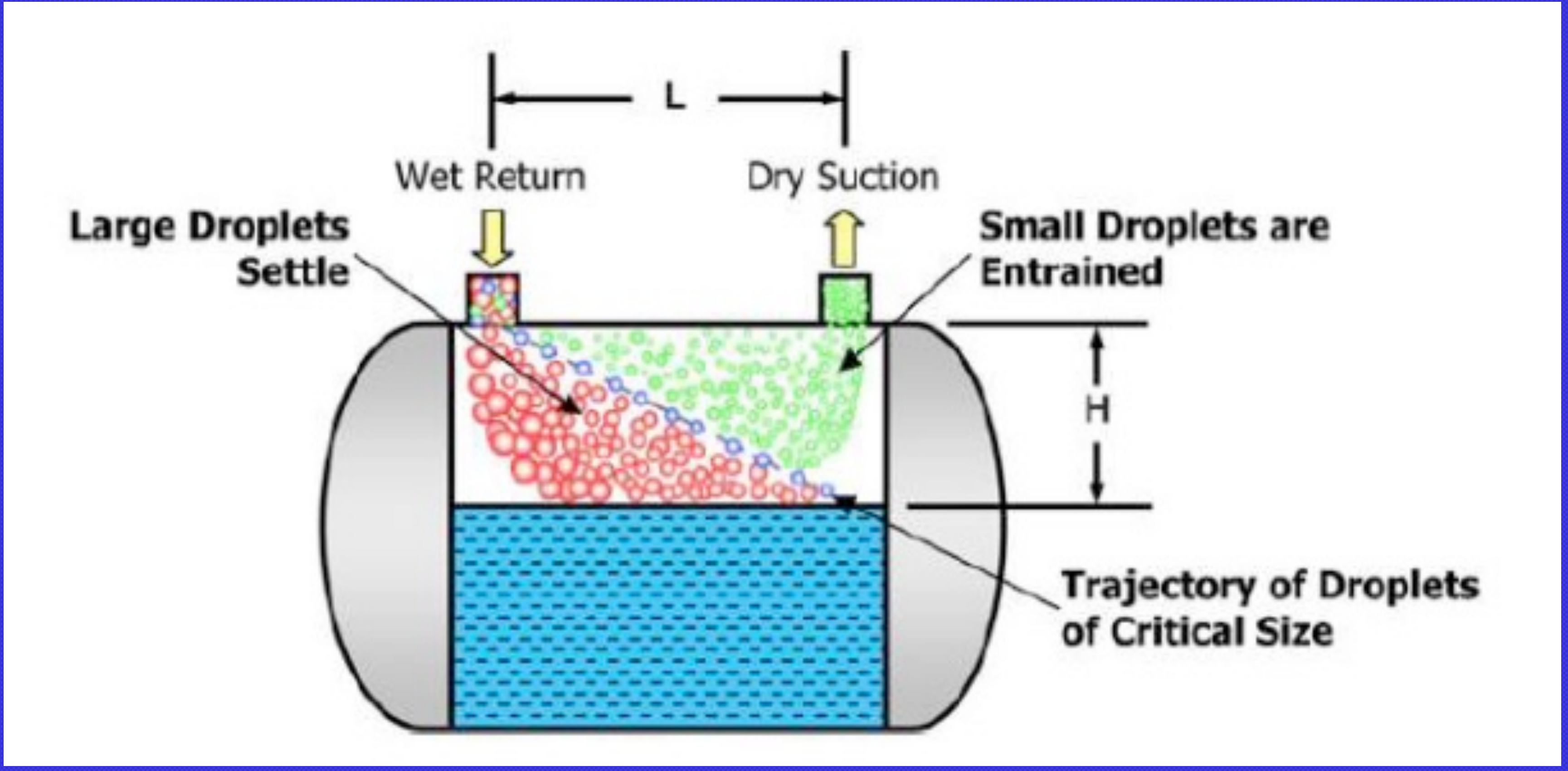
PIPING AND CONTROL ARRANGEMENT FOR LP VESSEL


SVA
SVA
AKS 4100
SFA
+DSV
EKE
347
SVA
LLS 4000
LLG
LLS 4000
ICF 25-6-5A
SNV
SVA
SVA
SCA-X
SCA-X
FIA
SVA
BSV
FIA
SNV
SNV
SVA
QDV
15
SNV
SNV
SVA
SVA

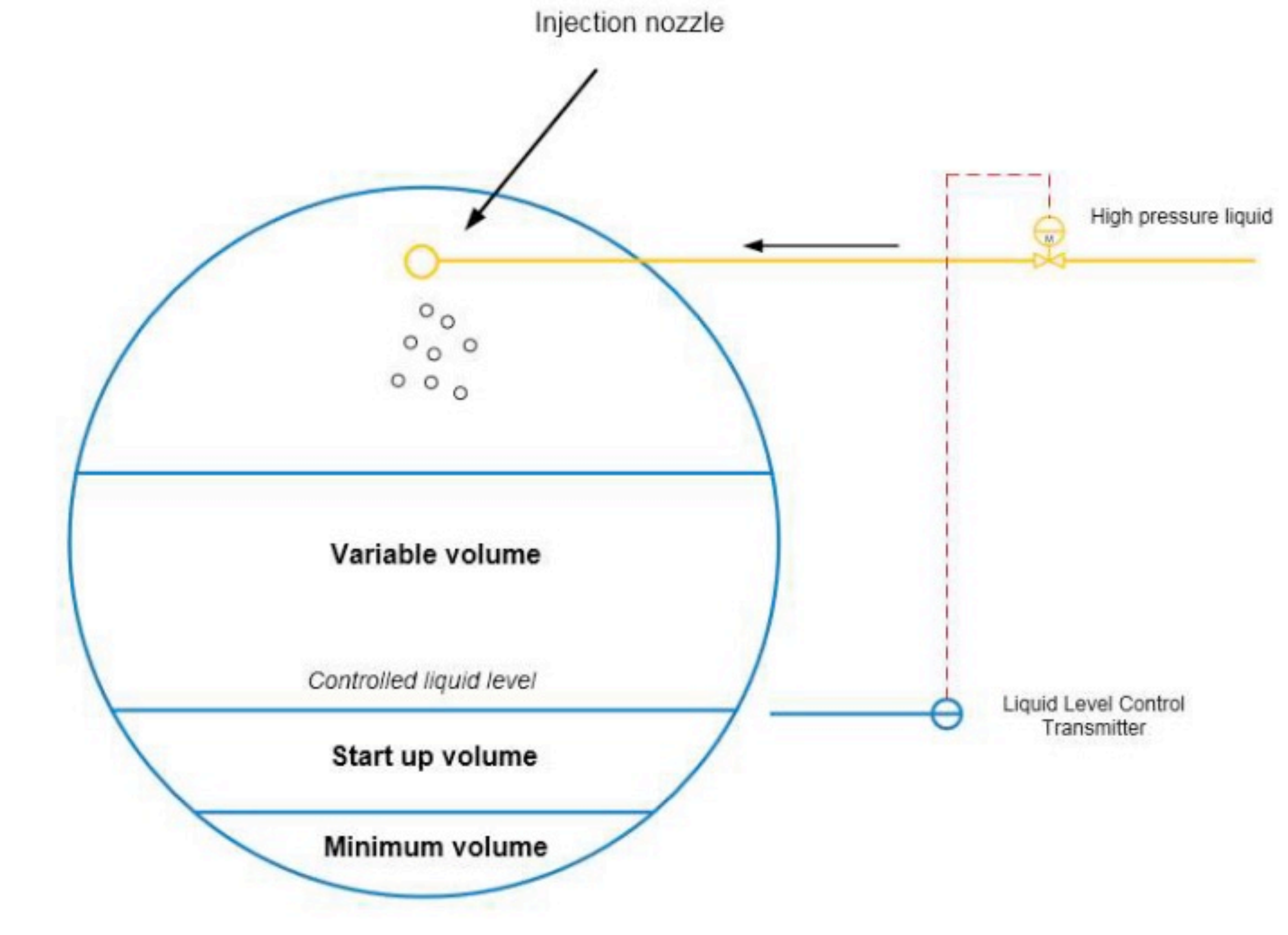
Design Details of Low Pressure Receiver



Low Pressure vessel details-Most Important Vessel



L
Wet Return
Dry Suction
Large Droplets Settle
Small Droplets are Entrained
H
Trajectory of Droplets of Critical Size


Injection nozzle
High pressure liquid
M
Variable volume
Controlled liquid level
Liquid Level Control
Transmitter
Start up volume
Minimum volume

Surge volume

the volume above working liquid level provided in the vessel, is known as surge volume and serves the purpose of accommodating liquid that might be forced out of evaporators during defrosting of one or more evaporators.

Another aspect needs to be considered is the liquid in the wet return line from evaporators to L.P. vessel, which may drain in the L.P. vessel if power shut down takes place and the liquid refrigerant pump becomes inoperative.

In normal circumstances the amount of liquid + vapour returning is same as pump circulation feed to evaporators, but when pump is not working, the extra liquid quantity gets added to vessel from the wet suction line and vessel design needs to take quantity to account in addition to defrost quantity.

Ballast Volume

1. The other important level on the lower side of the operating liquid level is the liquid required either during start up after a pump down cycle or if additional evaporators are taken on line for operation. During this period the liquid drawn from the vessel is at higher rate than it is returning to L.P. vessel.
2. The alarm indication for this minimum level should be provided making the operator aware about the falling liquid level.
3. The ballast volume is generally calculated for 5 minutes period meaning pump flow rate per minute multiplied by 5.

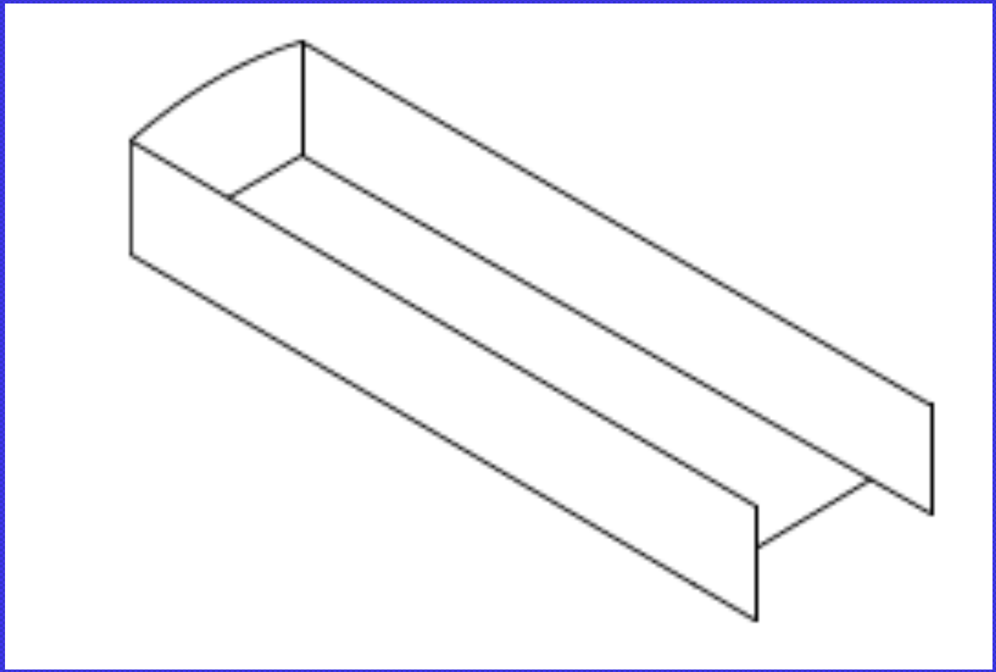
Liquid channel

While constructing L.P. vessel, provide a liquid channel inside the L.P. vessel, which is fully welded from all sides except open on one side as shown

All liquid connections should be brought/taken to this channel so that there is no risk of liquid going to the compressor

Be careful of locating pump bypass return line at correct place otherwise there would be pump pressure development problem. I have experienced this and have learned the hard way. Connect this in wet return rather than in the Liquid Channel

Liquid Channel

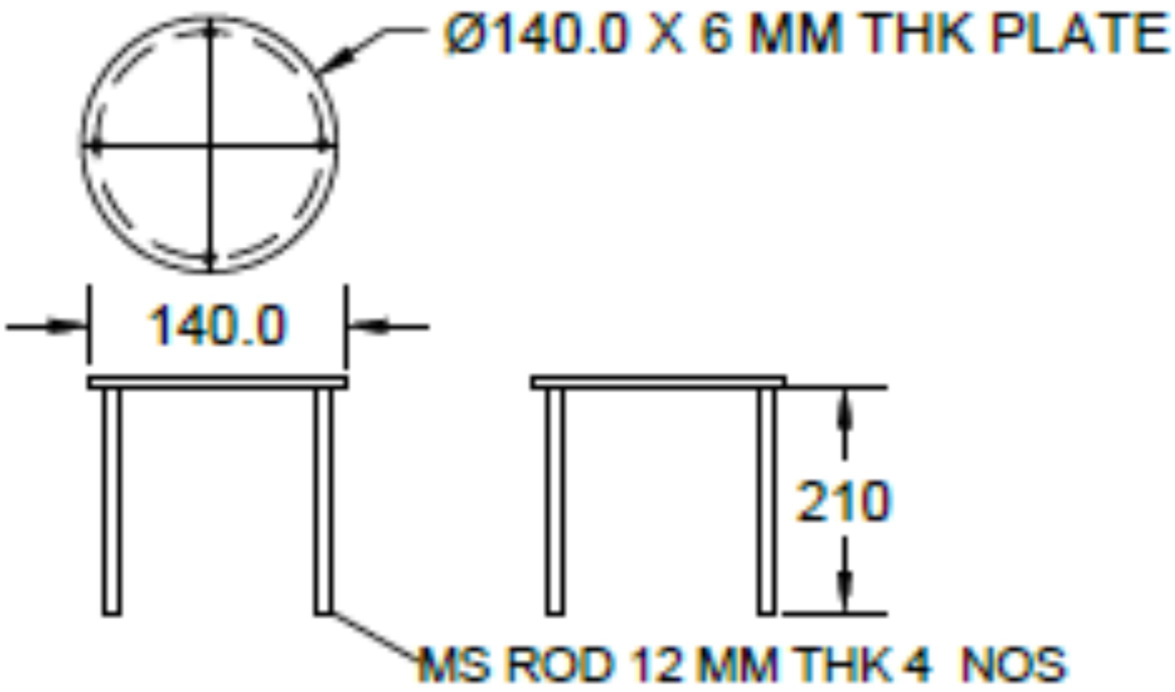


Length-750-800mm Long

Height -150mm

Width-200-250mm

Vortex Breaker



VERTEX BREAKER DEATAILS ' A'

Recommended Sizes For Down Leg to Pump

Approx. Pump Flow Rate	$5m^3/hr$	$12m^3/hr$	$15m^3/hr$	$35m^3/hr$	$70m^3/hr$
Pump Suction Size-mm	32	50	50	80	100
Down Leg Size-mm	80	100	125	150	250

Design Velocity Less than 0.3m/s

Adjustment of flow rate and Pressure –most Important

- Inlet / outlet temperature difference 1.5 ^{0}C to 2 ^{0}C max.
- Inlet pressure: Just enough to overcome freezer + wet return pipe line pressure+ valves, controls
- Higher temperature difference / Higher pressure means waste.
- - 32 ^{0}C liquid / 1 bar_a saturation
- - 32 ^{0}C liquid / 2 bar_a pr (- 18 ^{0}C saturation)
- 14 ^{0}C sub-cooling – Evaporator area wasted

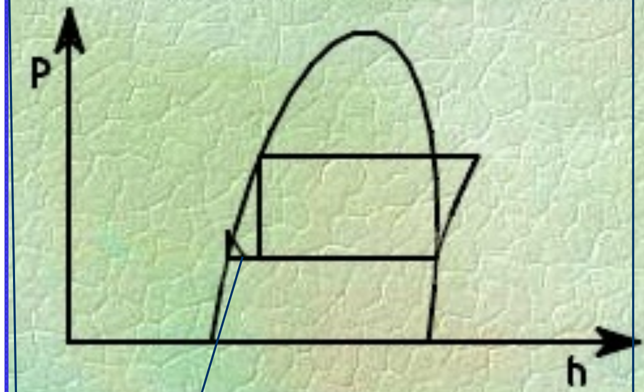
Optimum Liquid Levels To be maintained

1. Operating Level-25 to 30%

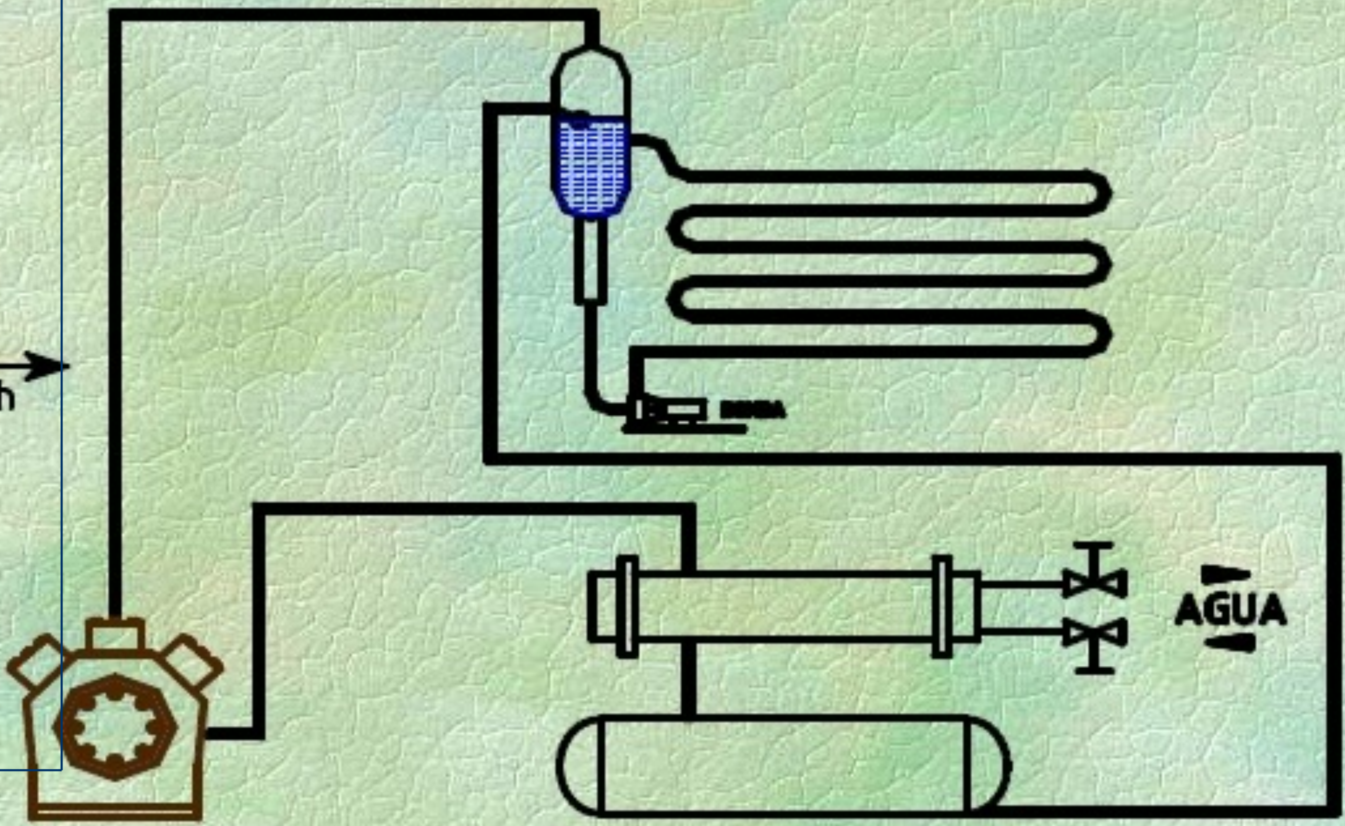
2. High level trip for compressor stop--50%

1. Low level trip for pump shut down-15 to 20%

Flow Control Methods
Recirculated Systems



P-H diagram showing increase in pressure due to pump



Ing. R. R. Aguiló & Asoc.

Adjustment of flow rateand Pressure –Very Important

- Inlet / outlet temperature difference 1.5 ^{0}C to 2 ^{0}C max.
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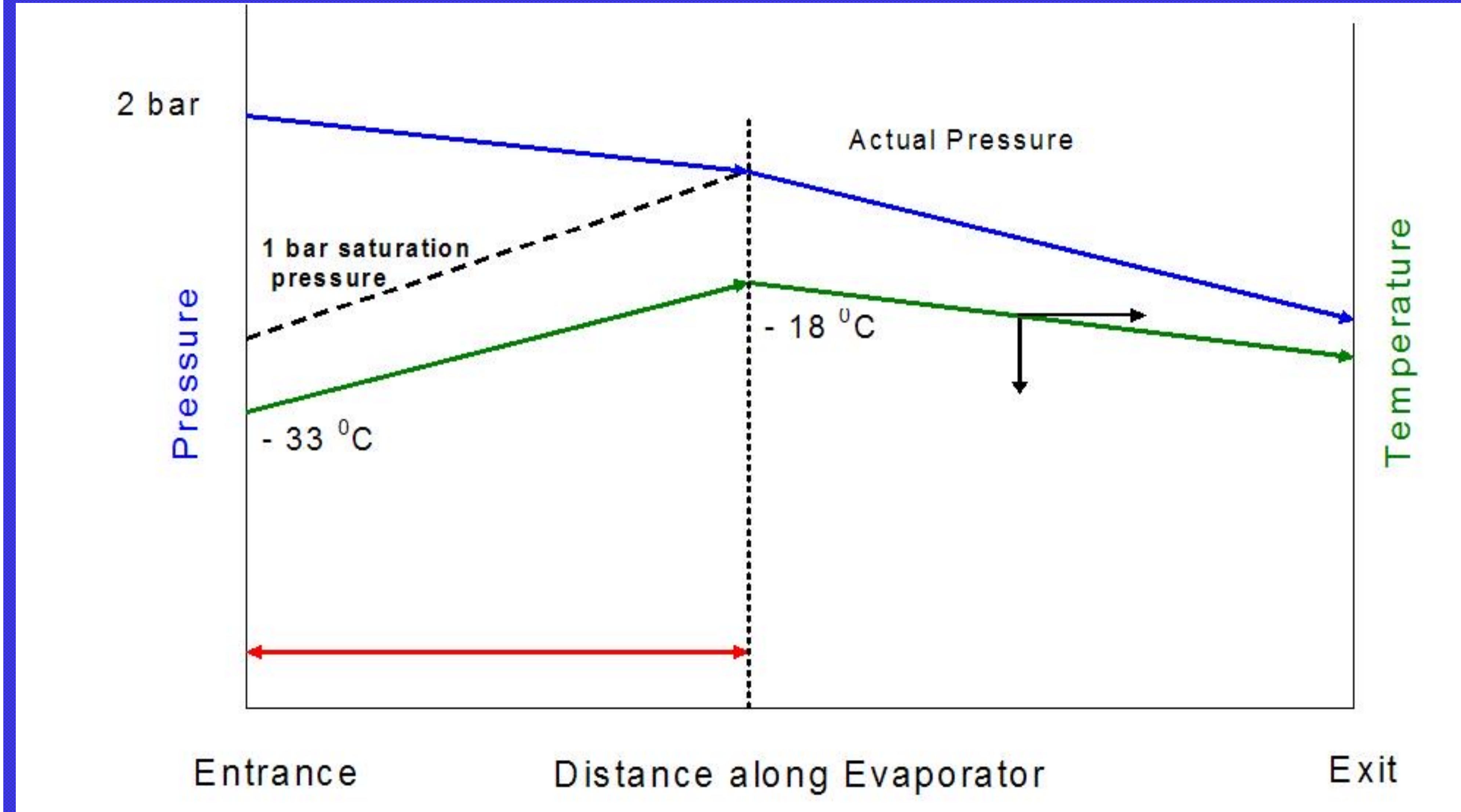
- - 32 ^{0}C liquid / 2 bar_a pr (- 18 ^{0}C saturation)
- 14 ^{0}C sub-cooling – Evaporator area wasted

Effect of higher than required pump pressure at inlet of evaporators



Adjusting Pump By pass PRV valve –Important

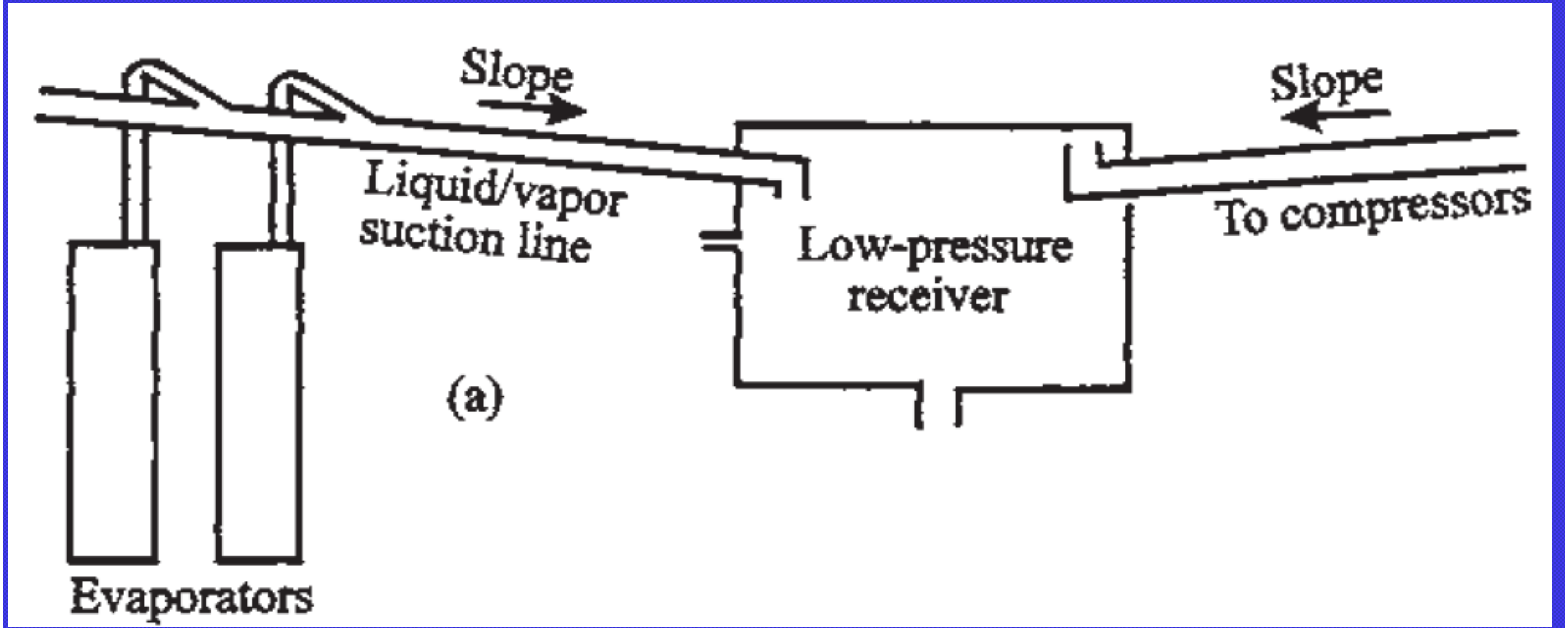
1. Normally the pump capcity is selected which is in excess of requirement especially on part load operation, such as say out of 4 coolers only two are operating and others are closed
2. The excess liquid is then bypassed from pump outlet back to L.P. vessel through PRV
3. Setting of PRV is important-
    1. When the plant is new , open all the valves , start the pump and record pump inlet and out let pressures
    2. This is maximum pressure drop of the system
    3. Adjust PRV to open at 1 kg/cm2 pressure , more than the total system pressure drop
    4. This will ensure that when some air coolers are not operating, the higher pressure developed by pump due to reduced pressure drop, is by passed back to L.P. vessel

Ammonia Pump Protection

1. Q max-This orifice installed in the line ensures that pump motor does not get overloaded, due to higher flow which can happen when there is less pressure drop in the entire system, due to some freezers/coolers are not in operation

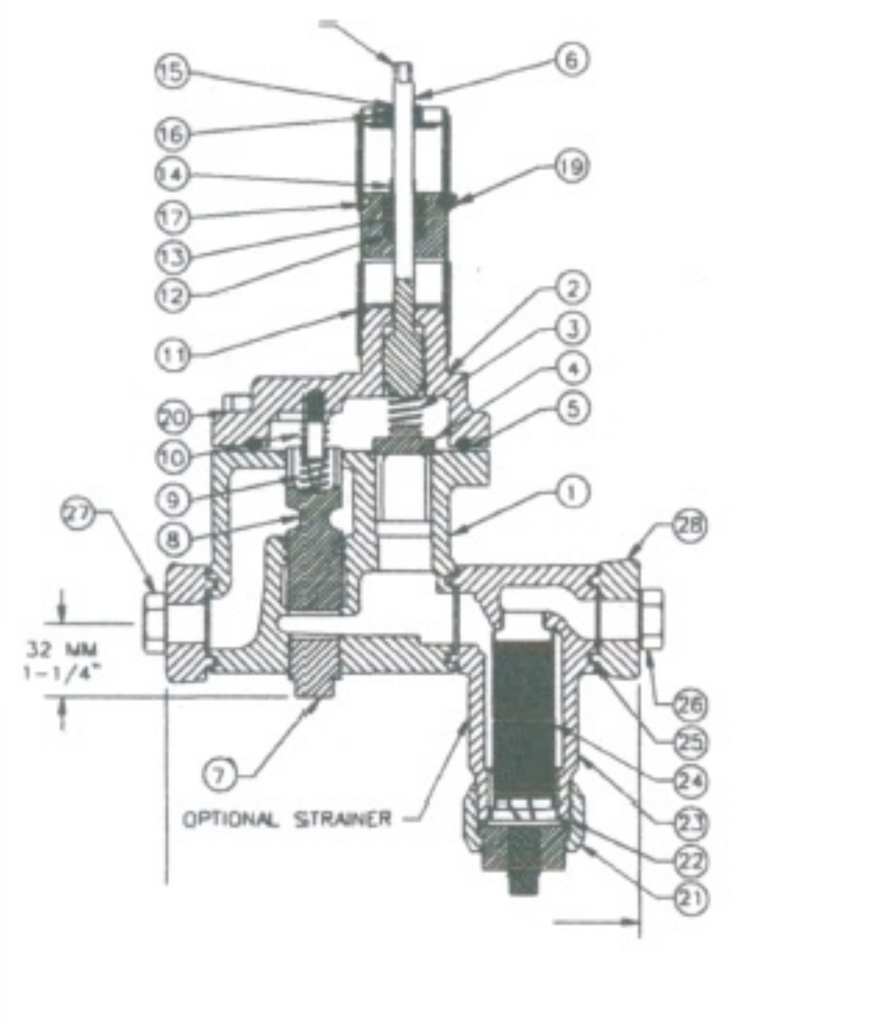
2. Q Min-This orifice installed in the pipe line ensures that the pump motor does not get overheated and the minimum flow is maintained to ensure pump motor winding e cooling

L.P. Vessel Piping Arrangement



Automatic Liquid Flow Regulating Valve(FRV) V/S Hand Expansion valve

Flow Regulating Valve



Hand operated expansion valve

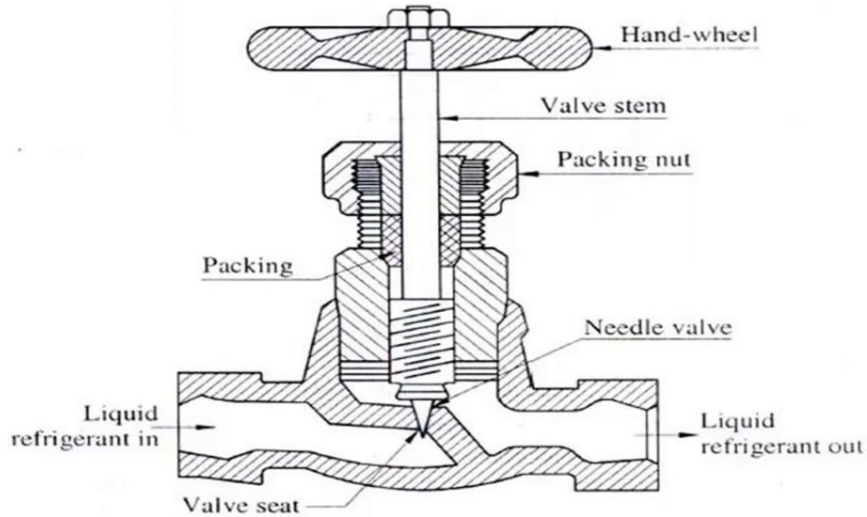


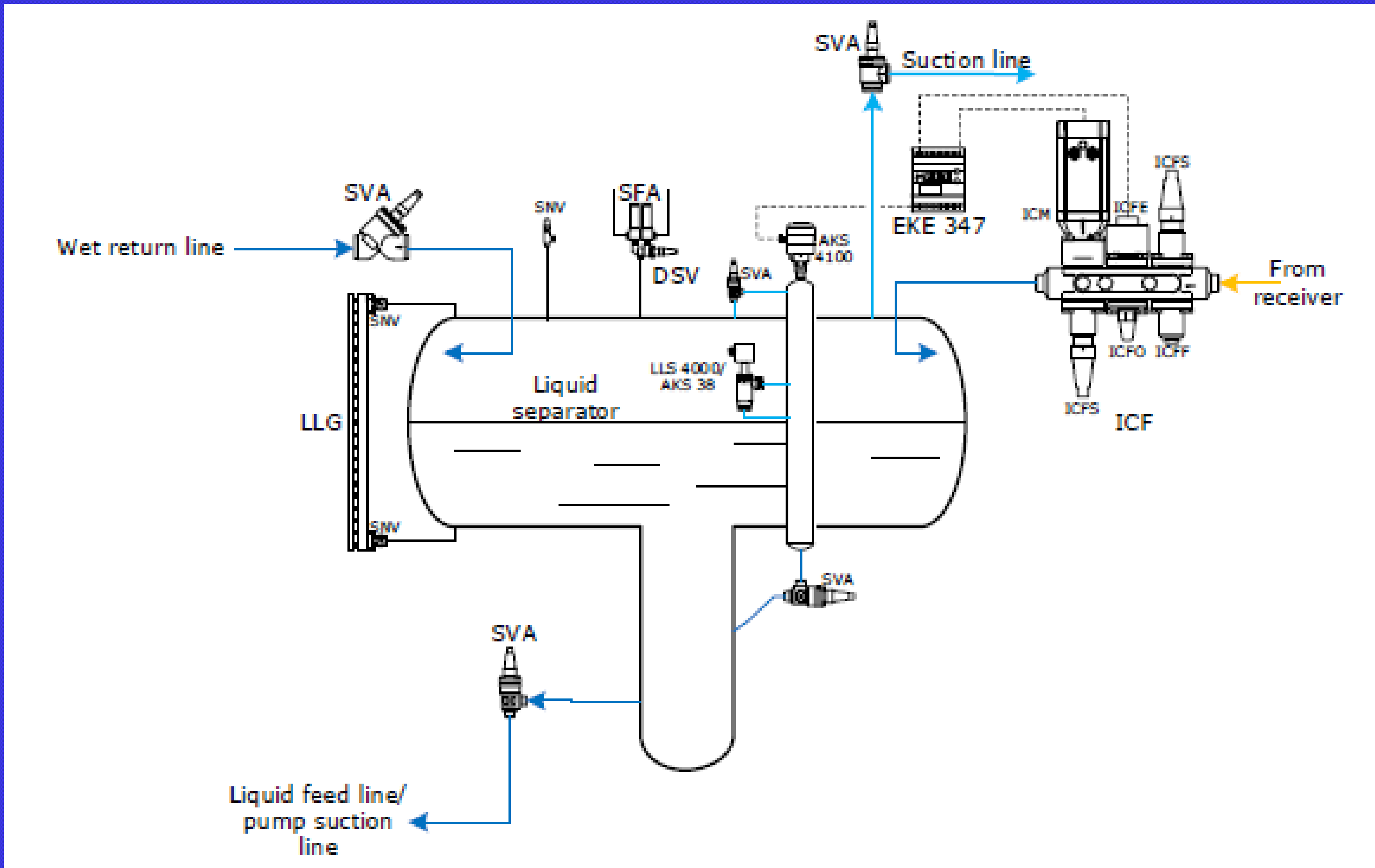
Fig. Hand operated expansion valve

Flow Regulating Valve for Pump circulation systems

The precision built, Automatic flow regulator is used for Ammonia pump circulation overfeed systems.

The flow regulator once set, by the adjusting stem which is marked for flow ratio, for particular flow ratio say 4:1, maintains constant flow rate of liquid to the evaporator despite fluctuations in the liquid inlet or evaporator pressures due to load fluctuations.

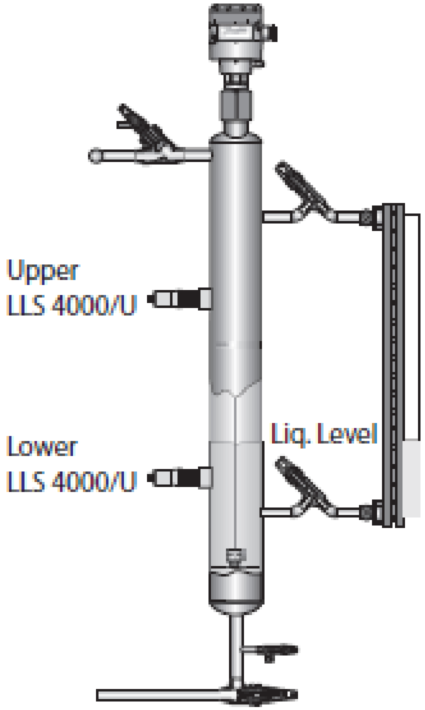
It also serves as non return valve to prevent back flow into the liquid line from the evaporator during pressure reversals which is required during hot gas defrost cycle.



SVA
Suction line
EKE 347
ICM
ICFE
ICFS
SVA
Wet return line
SNV
SFA
DSV
SVA
AKS 4100
From receiver
SNV
LLG
Liquid separator
LLS 4000/ AKS 38
ICFO
ICFF
ICFS
ICF
SNV
SVA
SVA
Liquid feed line/ pump suction line

LLS Electronic Level control Switch

The LLS can be used wherever liquid levels of ammonia and certain H(C)FC refrigerants must be controlled.

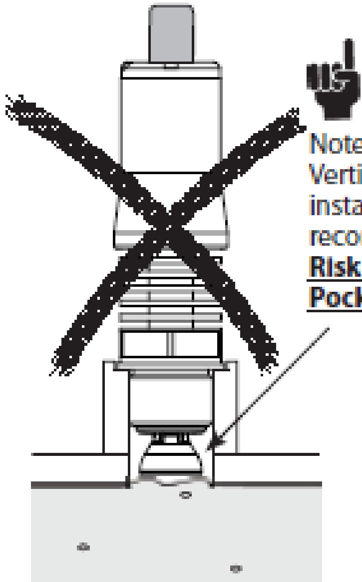


Note:
Horizontal installation recommended.

The LLS comes in two versions:

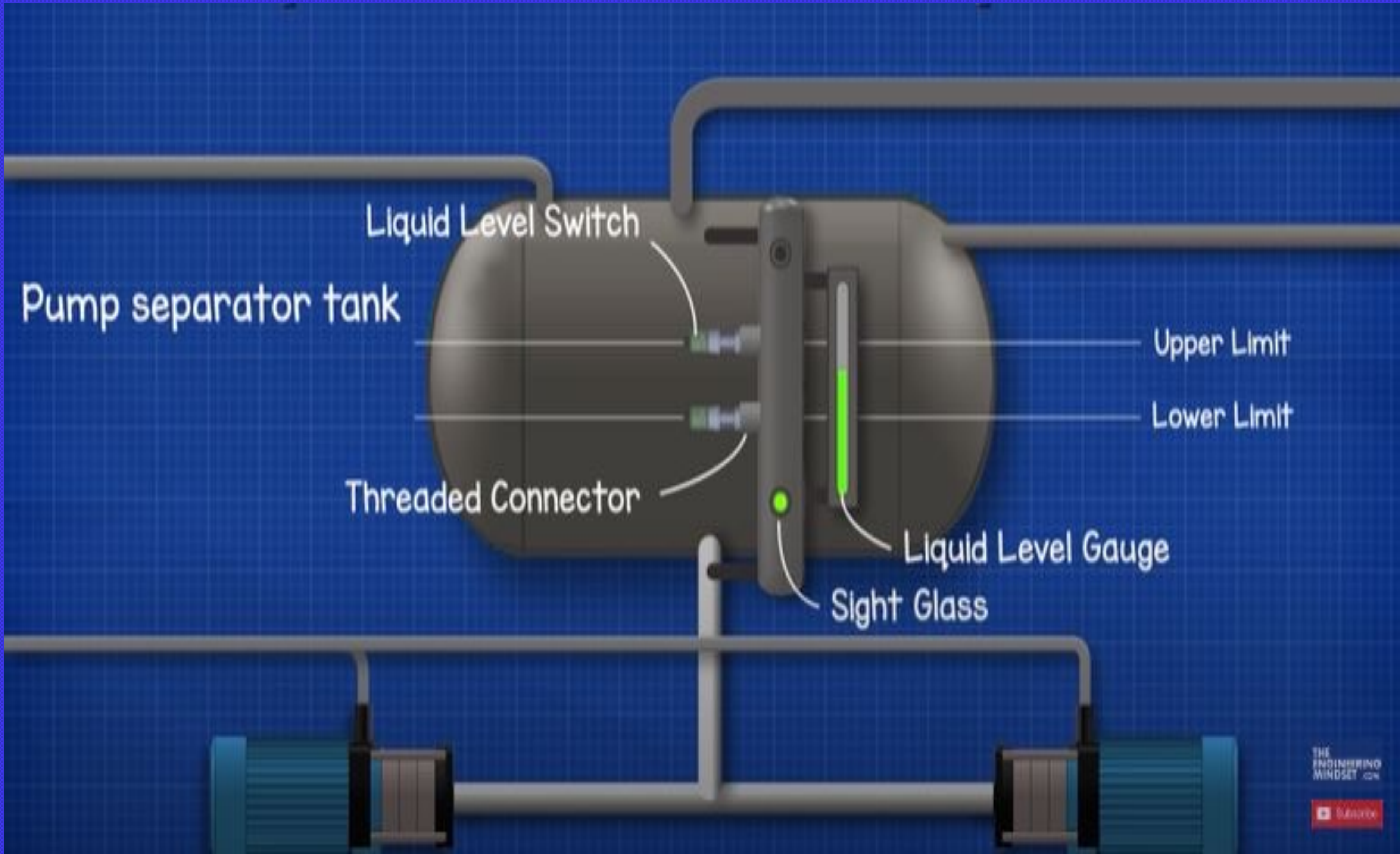
- A standard version, which is applicable for most refrigeration or processing plants, and is fully configurable regarding type of liquid and relay setting.

- A SIL2 version applicable for SIL compliant process plants. This version is non-configurable regarding relay setting (see section: Configurable parameters) and is intended specific as the **upper** level switch.



Note:
Vertical or inclined installation not recommended:
Risk of Gas Pockets

- Compact single weld connection Installation – Simple, Fast, Cost effective, involving less pipes and fittings. No moving parts
- Commissioning and troubleshooting via advanced Bluetooth device
- Safe and reliable design, best suited for high / low safety switch.
- Auto diagnostics / trouble shooting using Bluetooth device help do calibration, testing etc., without pump down.


Liquid Level Switch
Pump separator tank
Upper Limit
Lower Limit
Threaded Connector
Liquid Level Gauge
Sight Glass

Suggested Line Sizing Velocities

a) Suction line (NH3)	15.0-17.5m/sec
b) Discharge line (NH3)	17.5-20.00m/sec
c) Liquid line (NH3) condenser to receiver	0.5 - 0.6 m/sec
d) Liquid line (NH3) receiver to system	1.0 to 1.5 m/sec
e) Wet return line (NH3)	8 to 10 m/sec
f) Suction line (H20)	1.0 to 1.2 m/sec
g) discharge line (H20)	2.0-2.5 m/sec

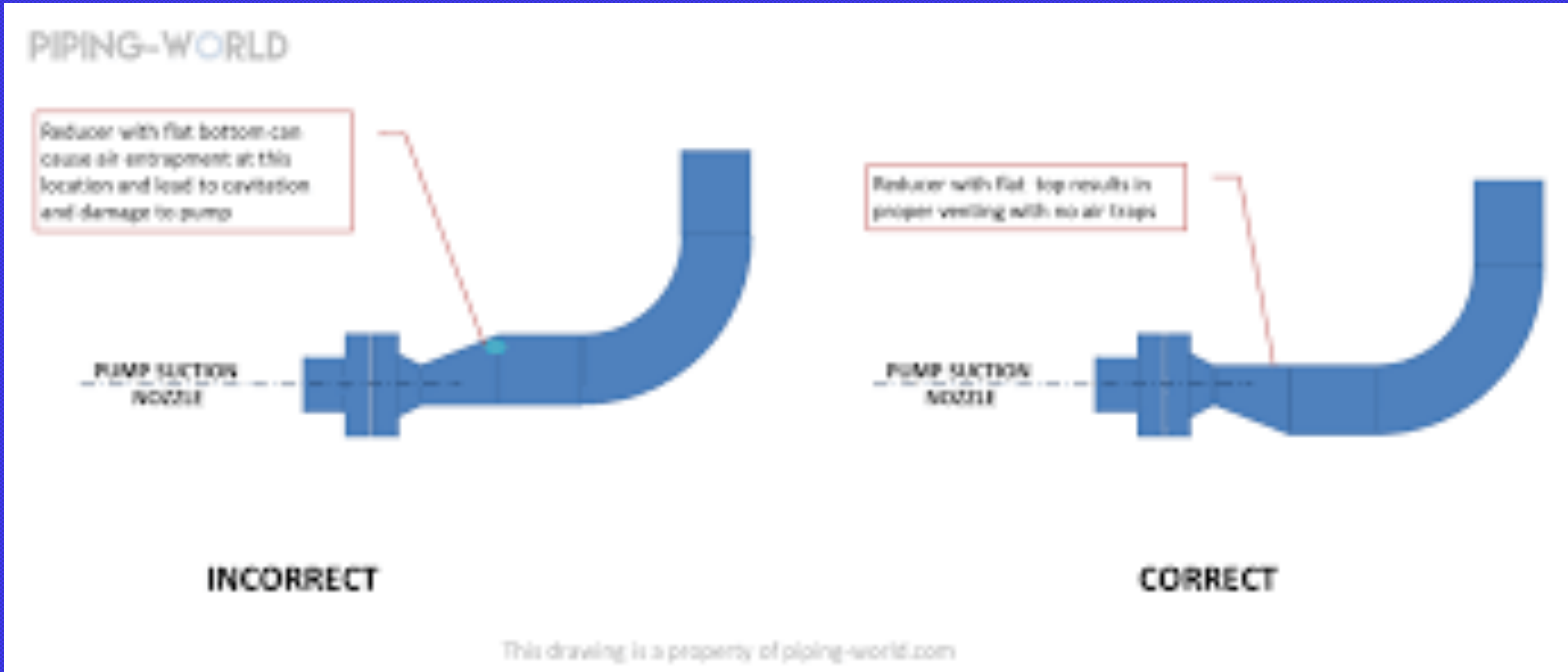
Piping valves

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

Recommended Sizes For Down Leg to Pump

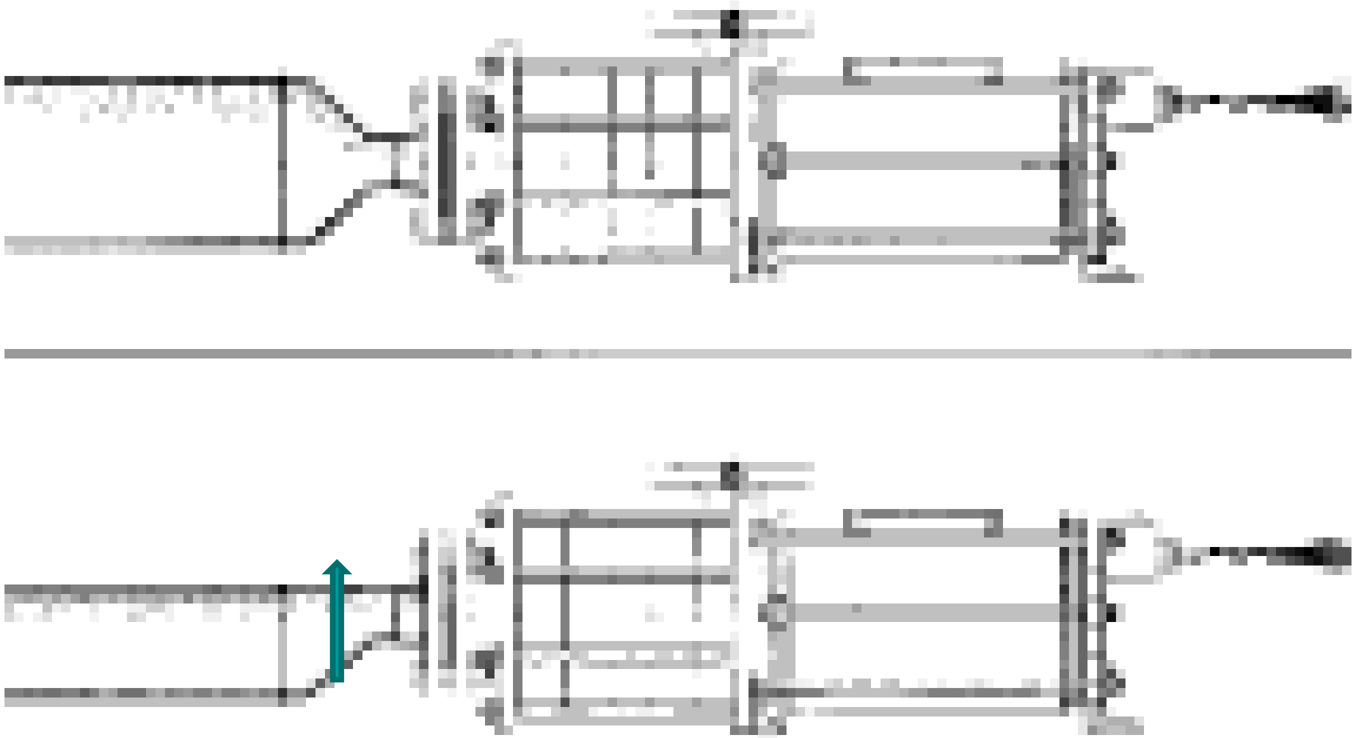
Approx. Pump Flow Rate	$5m^3/hr$	$12m^3/hr$	$15m^3/hr$	$35m^3/hr$	$70m^3/hr$
Pump Suction Size-mm	32	50	50	80	100
Down Leg Size-mm	80	100	125	150	250

Reducer Installation



Reducer At Ammonia Pump Inlet

wrong



correct

ANGLE VALVE

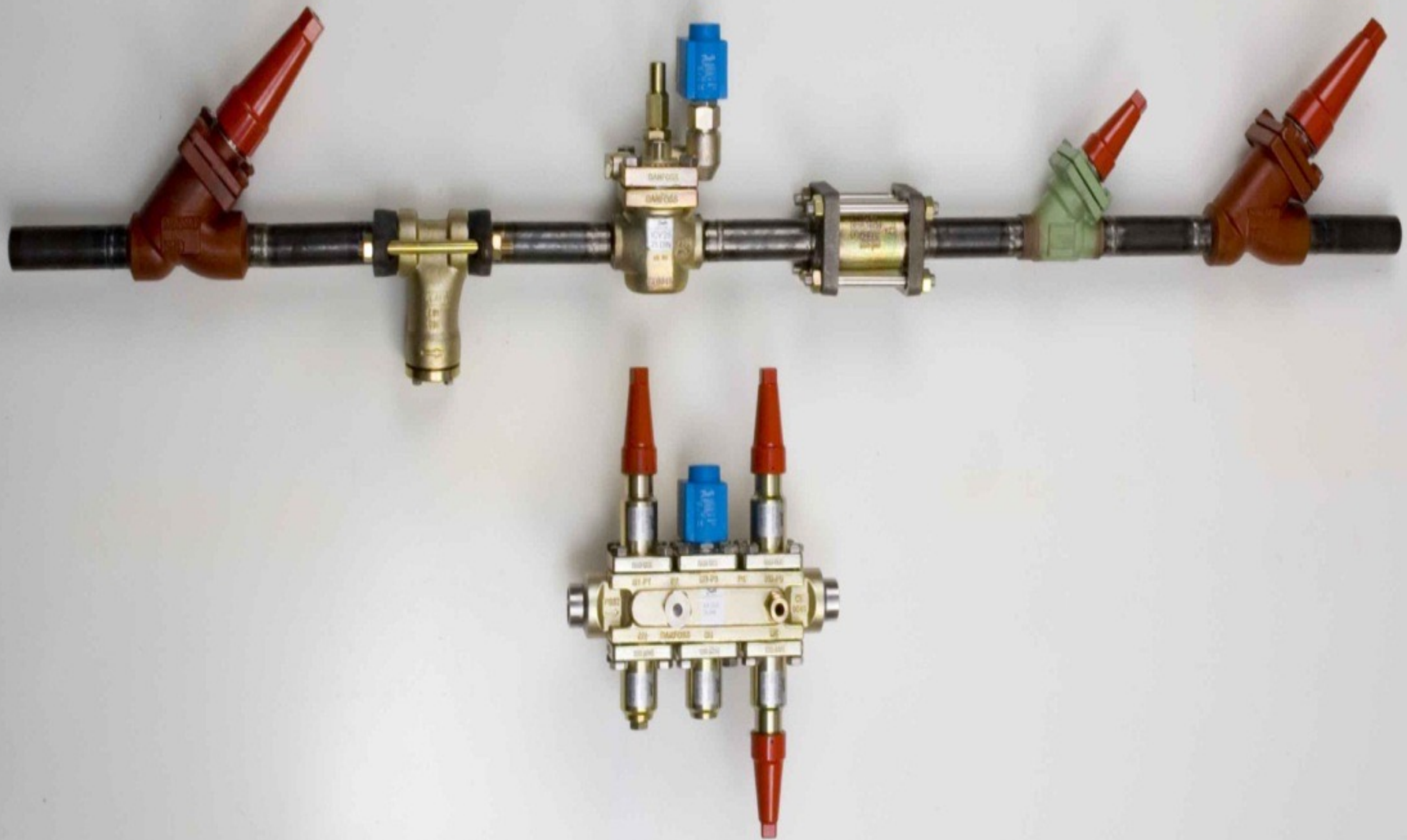
=

GLOBE VALVE

+

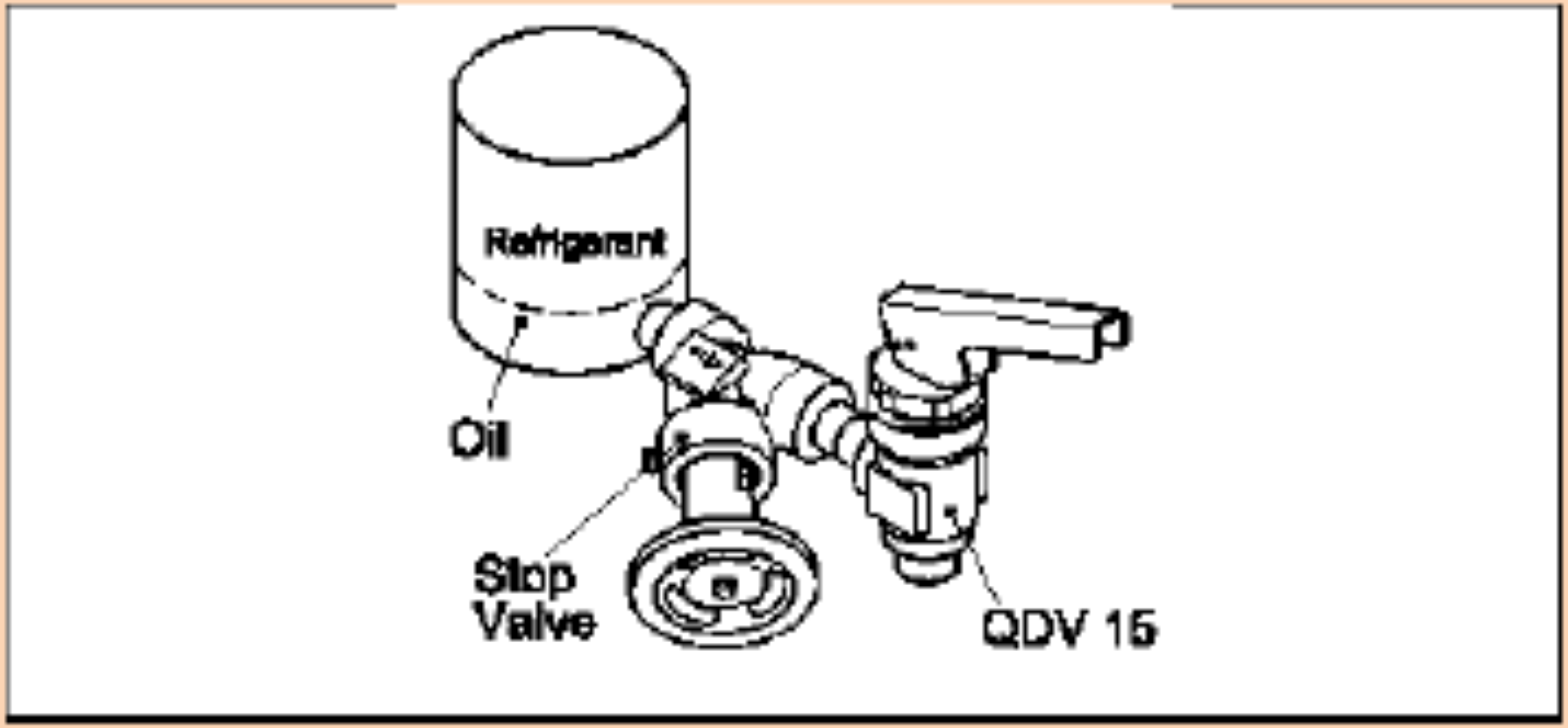
BEND

To build and install valve station takes hours



Same job using ICF takes just minutes

QUICK CLOSING OIL DRAIN VALVE



Important Considerations often overlooked

1. Cavitations to be avoided as it affects pump capacity & cause considerable damage to pump seals, impellers, motors, and casing and does not build pressure
2. Reverse rotation of pump to be avoided-Can be checked from pump discharge pressure & noise
3. NPSH should be considered from bottom of LP vessel to center line of pump
4. Pump head should be sufficient to overcome the required height lift, pressure drop in liquid lines,& valves, throttling devices & evaporators
5. Pump inlet filter may be removed after some time when system becomes clean
6. If there are more pumps, then each pump should be connected to the LP vessel independently to avoid interaction with other pumps

Important Considerations often overlooked

7. Horizontal surge drum preferred over vertical to provide sufficient surface for settlement of oil & enable stable suction head conditions
8. Use of vortex breaker essential in down leg to avoid cavitations
9. Down leg should protrude 30 to 40 mm in the LP vessel to avoid oil and dirt in the pump suction
10. In pump inlet horizontal pipe lines should be avoided
11. Full bore valves are recommended in the pump inlet line
12. The down leg should be designed for velocity less than 0.3m/s
13. Pump venting line should be provided from top of pump to minimize possibility of vapor collecting in pumps

Important Considerations often overlooked

14. Pump discharge pipe should be designed for velocity not exceeding 1.5m/s

15. Stop check valve in pump discharge essential when two or more pumps are connected to common discharge manifold to avoid reverse running of pumps not in use

16. At all times pump suction valve containing sub-cooled liquid should be kept open. Discharge valve can be closed

17. Pumps should be mounted on flexible mounts to avoid stresses on flanges due to expansion/contraction of pipes subjected to temperature fluctuations from ambient to minus 40 deg C

18. Pump operation should be rotated between working and standby pumps

Important Considerations often overlooked

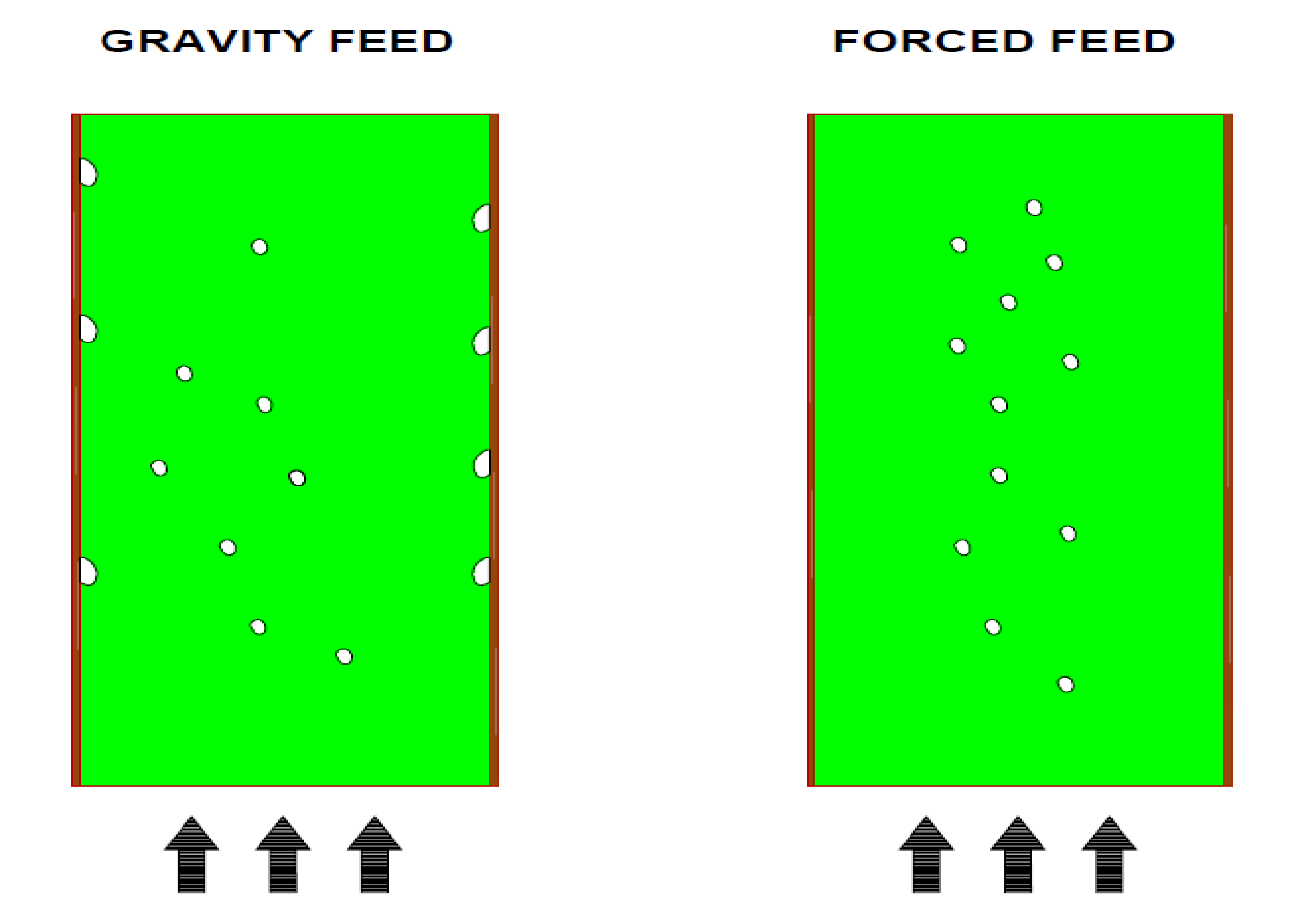
19. If more than one evaporators on working on common liquid header use two solenoid valves for each cooler inlet. Small solenoid to open first to equalize pressure. After time delay of 4 to5 minutes main solenoid to open to avoid liquid hammer and vibrations

20. Use FRV in evaporator inlet preferred instead hand expansion valve

Advantages with Overfeed

1. Higher circulation: Improved heat transfer by completely wetting internal tube surface
2. Compressors are protected from liquid slugs caused by fluctuating loads
3. Efficient freezer operation: Freezer operation de-coupled from main refrigeration system
4. Refrigerant feed independent of fluctuating condensing conditions due to ambient conditions variation

Gravity Flow V/S Pumped Flow



Advantages with Overfeed

Better Compressor operation

5. Minimum superheat: Means Less discharge temperature-L.P. vessel is in the machine room

6. Oil recovery simple in L.P. vessel/oil drain pot

7. With simple controls, evaporators can be defrosted with hot gas with no disturbance to the system

8. Flash gas is removed in the LP vessel before the liquid enters the evaporators. This gas is directly drawn by compressor. It does not contribute additional pressure drop in liquid line

Advantages with Overfeed

9. Trouble shooting easier since L.P. vessel and evaporators are having independent circuits.

10. As long as L.P. vessel is having sufficient liquid and at required temperature, it means compressor side there is no system fault

11. One can then concentrate on L.P. circuit and evaporators if there is any malfunction

12. All major equipment is in the plant room including controls and L.P. vessel ,Pumps which is under operator's surveillance and has limited access to outsiders.

Advantages with Overfeed

13. Ideal suction gas conditions entering compressor with minimum superheat

14. Compressor life is extended

15. Less maintenance-fewer breakdowns

16. Oil circulation rate at evaporators is reduced because of low compressor discharge superheat

17. Liquid feed to evaporators more reliable since liquid is sub-cooled(pressurized) hence no flashing in the liquid feed line

18. Automatic operation convenient

Advantages with Overfeed

19. Oil does not accumulate in evaporators. Oil draining is convenient in the plant room from L.P. vessel

20.There is uniform liquid distribution in all evaporators.

21 Each evaporator does not require independent accumulator, and level controller

22. More suitable for low temperature applications since flash gas is removed in LP vessel & only low temperature liquid goes to the evaporators

Possible Disadvantages

1. Total refrigerant charge in system is higher
2. Due to higher flow rates of liquid to evaporator liquid line and wet return line sizes are of larger diameter
3. Insulation cost is more due to larger pipes
4. liquid supply lines also need to be insulated as they are conveying low temperature liquid
5. Installed cost is higher
6. Pumps consume extra energy but is usually compensated due to higher efficiency

Possible Disadvantages

7. Pumping units require maintenance

8. Mechanical pumps subjected to cavitation if proper precautions not taken in providing sufficient net positive suction pressure

9. Problems of liquid hammer during defrosting need to be taken care by proper piping design and defrosting sequences

10. Automatic defrost independent to each cooler essential to avoid liquid accumulation

11. Liquid traps to be avoided-safety valve may be essential in liquid line

.

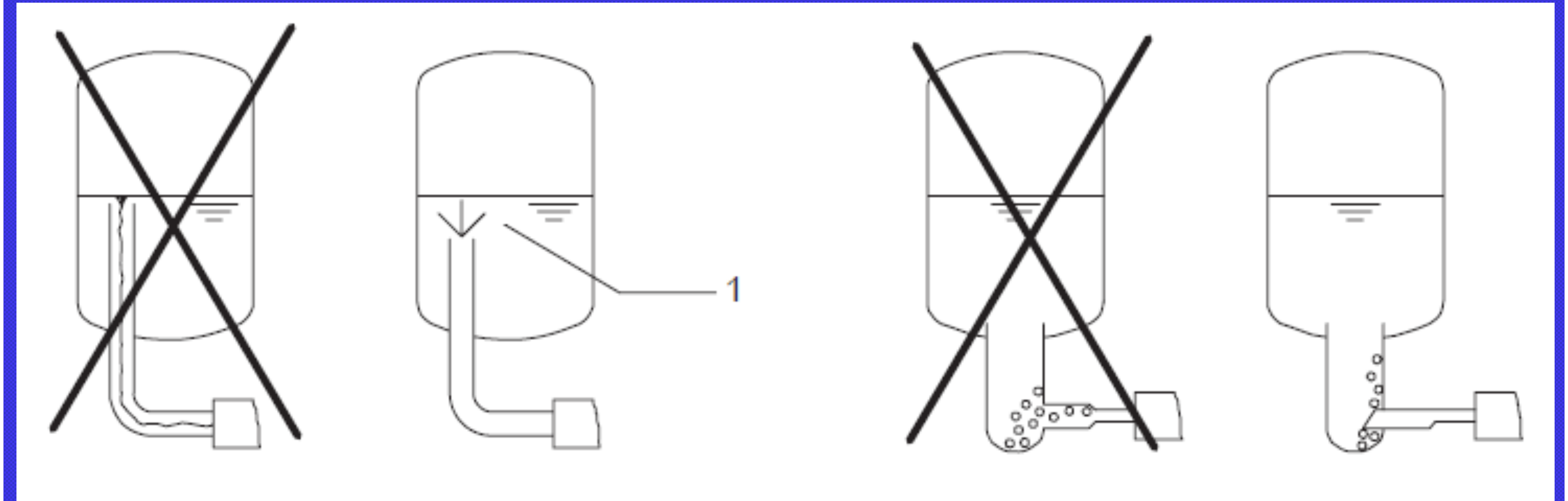
Cavitation-Problem No.1

Many forced circulation Ammonia pump system designers face this problem some day or the other in one of their plants

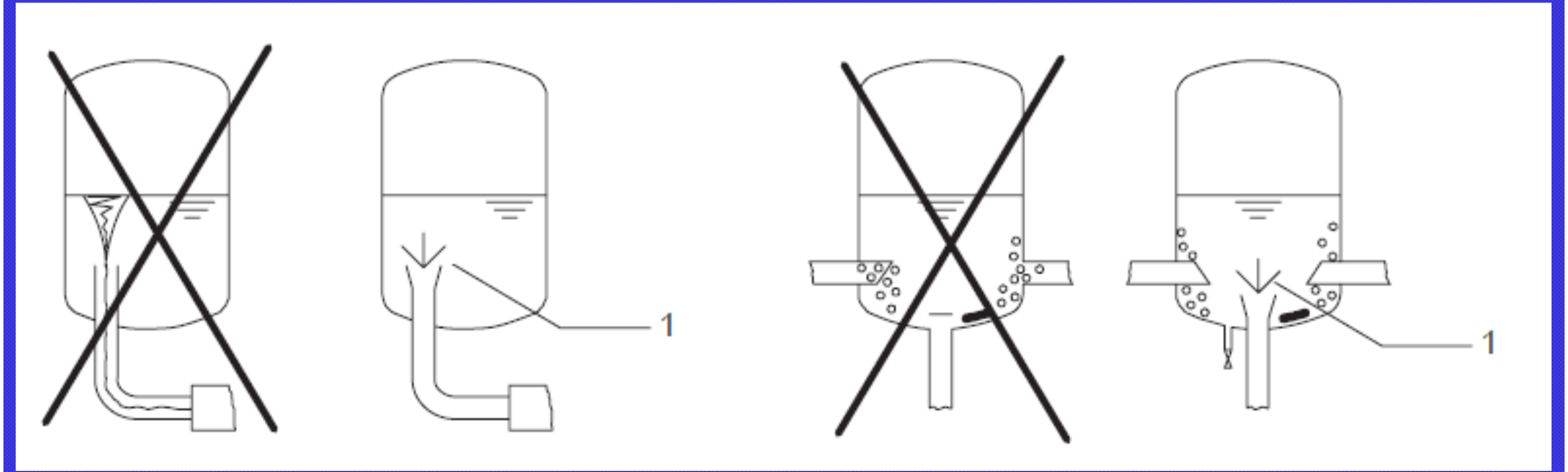
The reasons could be many

1. Undersized liquid leg
2. Connections to pump not proper
3. Incorrect connection of reducers
4. No vortex breaker
5. And many more

Avoid Cavitation



Avoid Cavitation



Avoid Cavitation

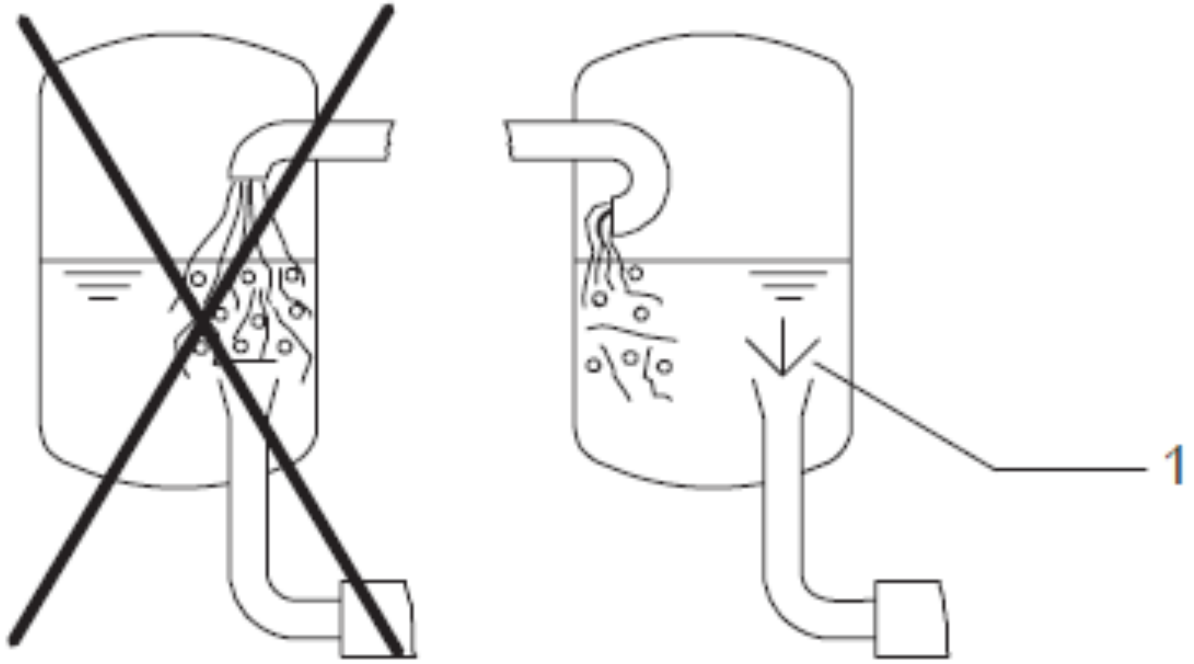


Fig. 9 Vessel inlet/vessel outlet arrangement

1 Vortex breaker

AVOID CAVITATION

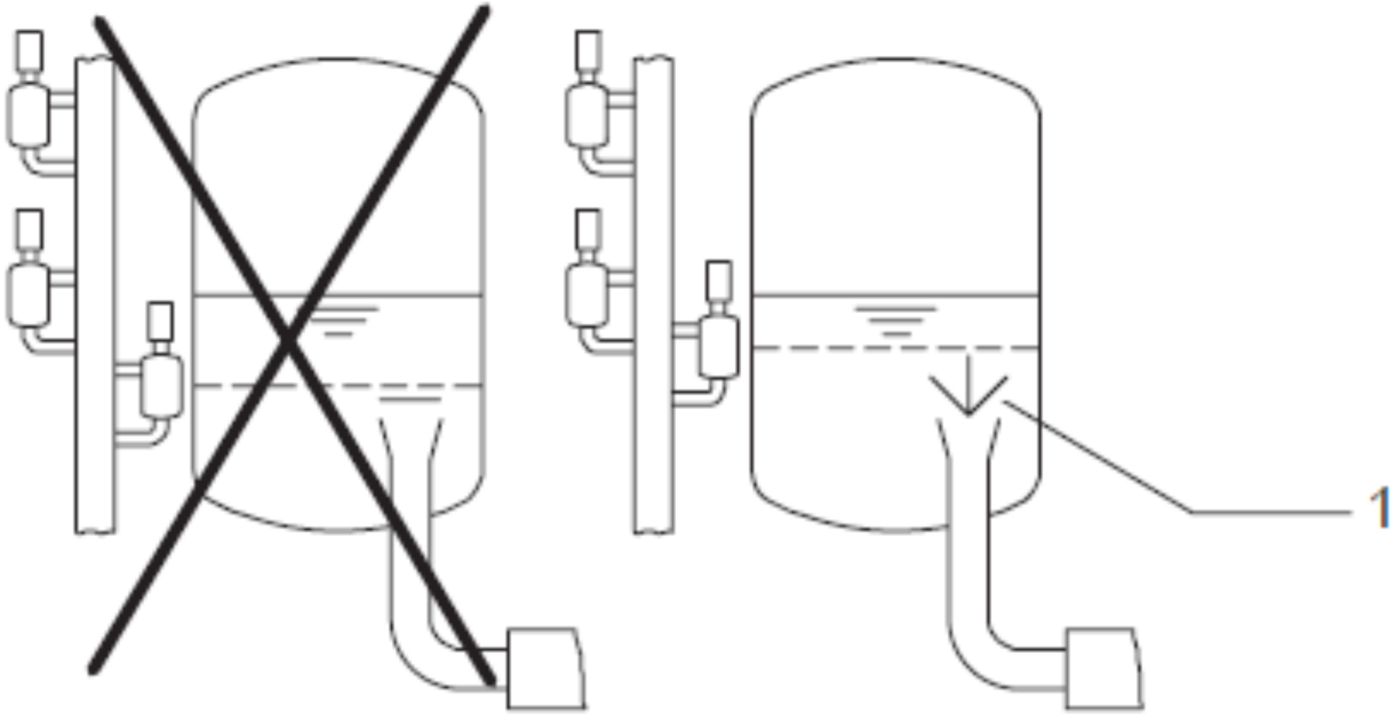


Fig. 10 Level monitor arrangement

1 Vortex breaker

Avoid Cavitation

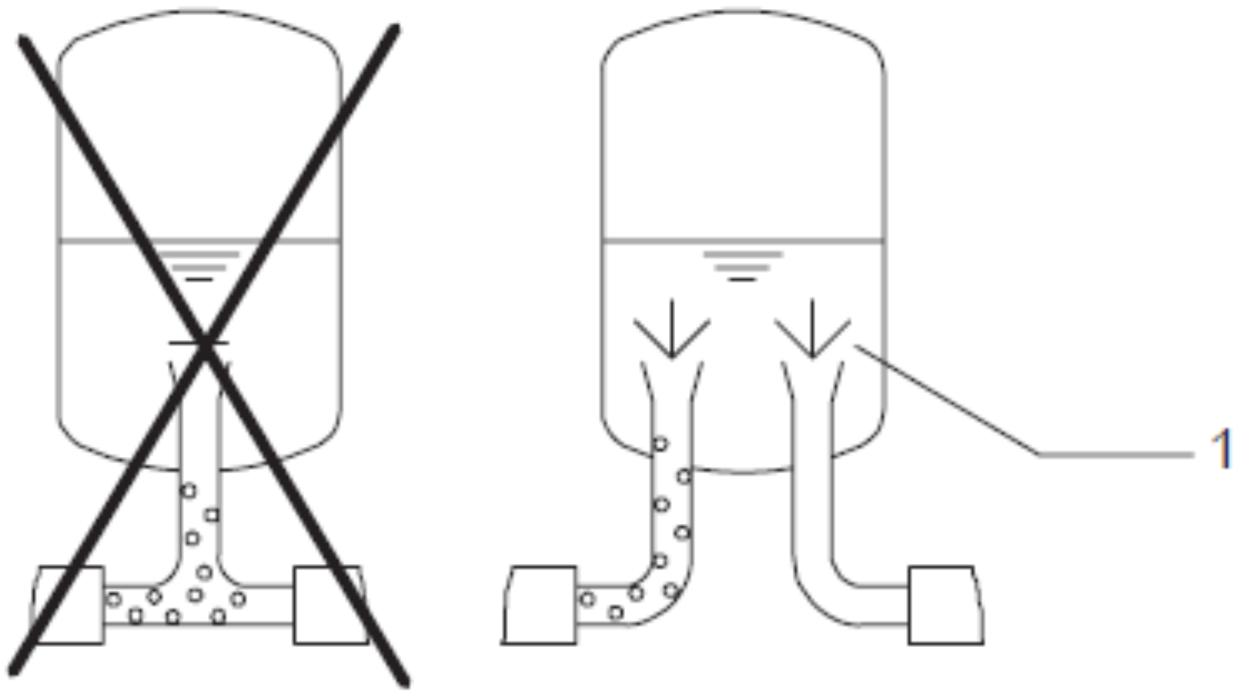


Fig. 11 Parallel operation arrangement

1 Vortex breaker

Problem No -2

Hydraulic shock or water hammer

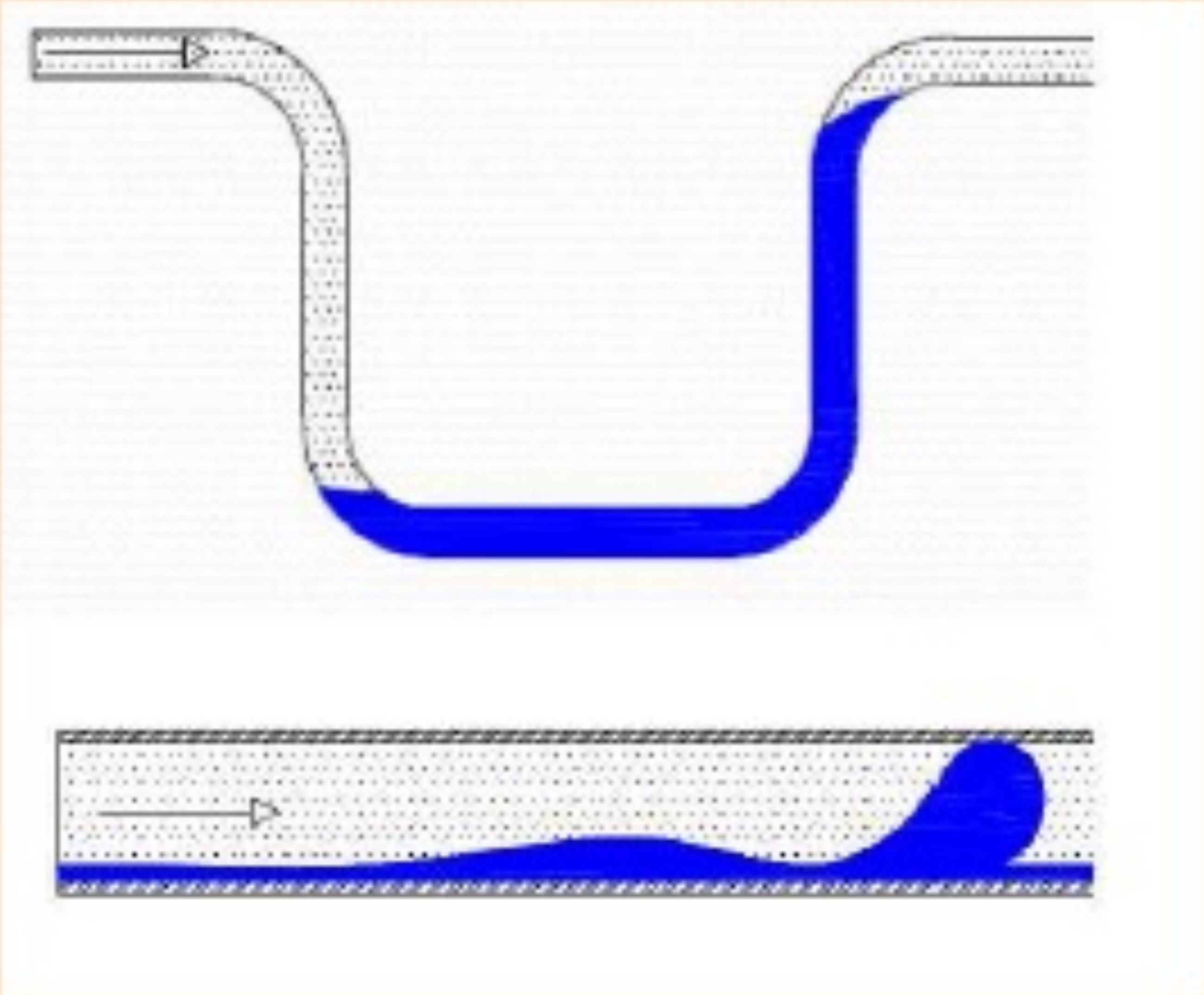
Liquid hammer or hydraulic shock

1. Hydraulic shock is a sudden localized spike in pressure that can occur in piping or equipment when there is rapid change in the velocity of a flowing liquid. Often referred to as “water hammer”, hydraulic shock is well understood phenomenon that has occurred in water and steam systems found in both domestic and industrial settings.

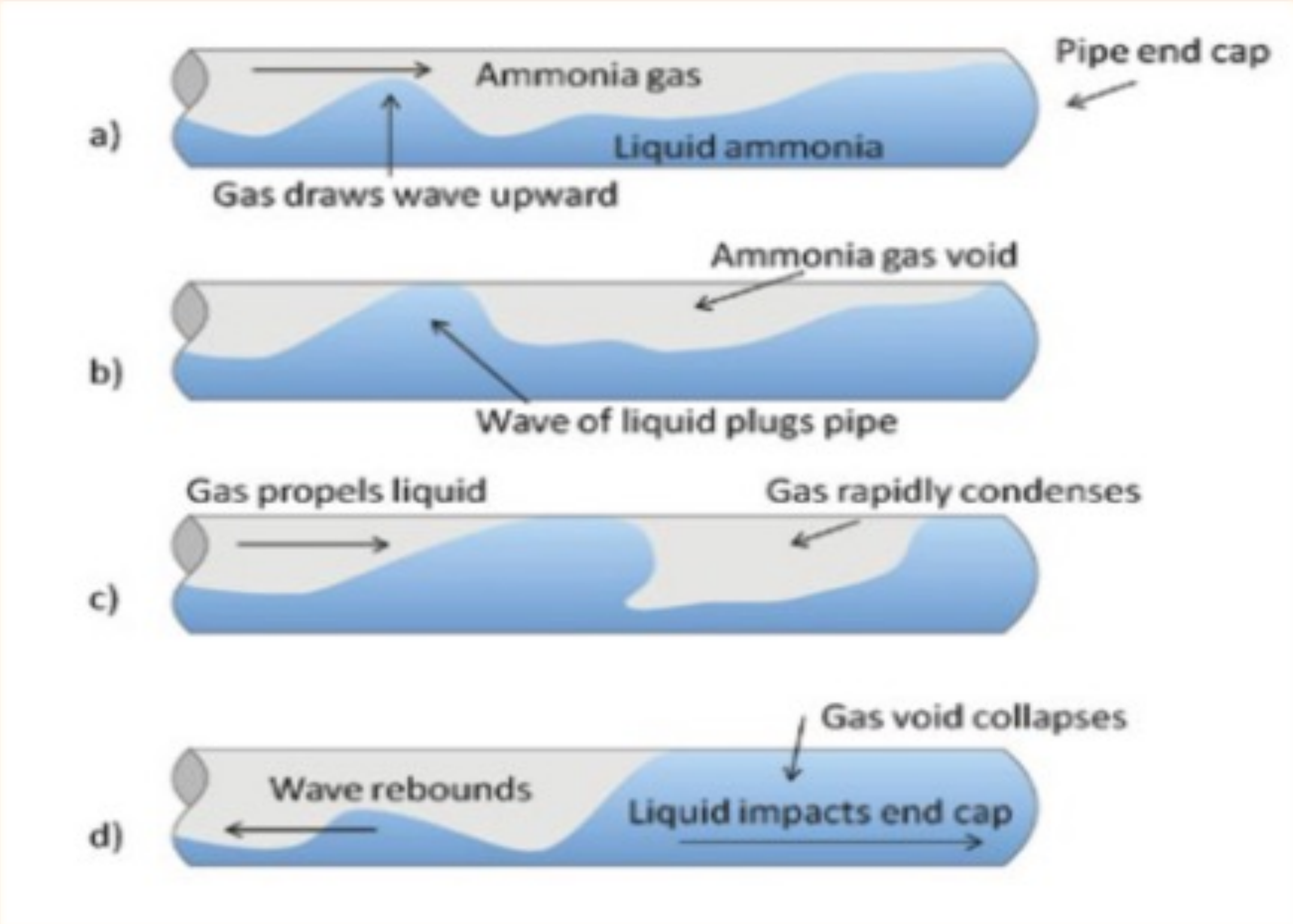
2. In ammonia refrigeration, hydraulic shock events can generate extremely high pressures with the potential of failure of piping, valves, and other equipment. The highest pressure often occur when vapour or liquid ammonia are present in a single line and are disturbed by a sudden change in volume.”

3. Moderate hydraulic shocks lead to vibrations and a knocking sound emanating from piping or valves.

Liquid Hammer-Liquid Trap



HYDRAULIC SHOCK



A Pipe ruptured due to liquid Stroke

A Pipe ruptured due to liquid hammer

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.

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

CONCLUSIONS

References:

1. ASHRAE Refrigeration volume
2. IOR(Institute of Refrigeration)-UK
3. ASHRAE Journal Articles
4. IIAR(International Institute of Ammonia refrigeration) – USA
5. Hermetic Pumpen-Germany
6. W.F. Stoecker-Industrial Refrigeration handbook
7. Field experience of designing/building refrigeration plants

Any Questions????

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