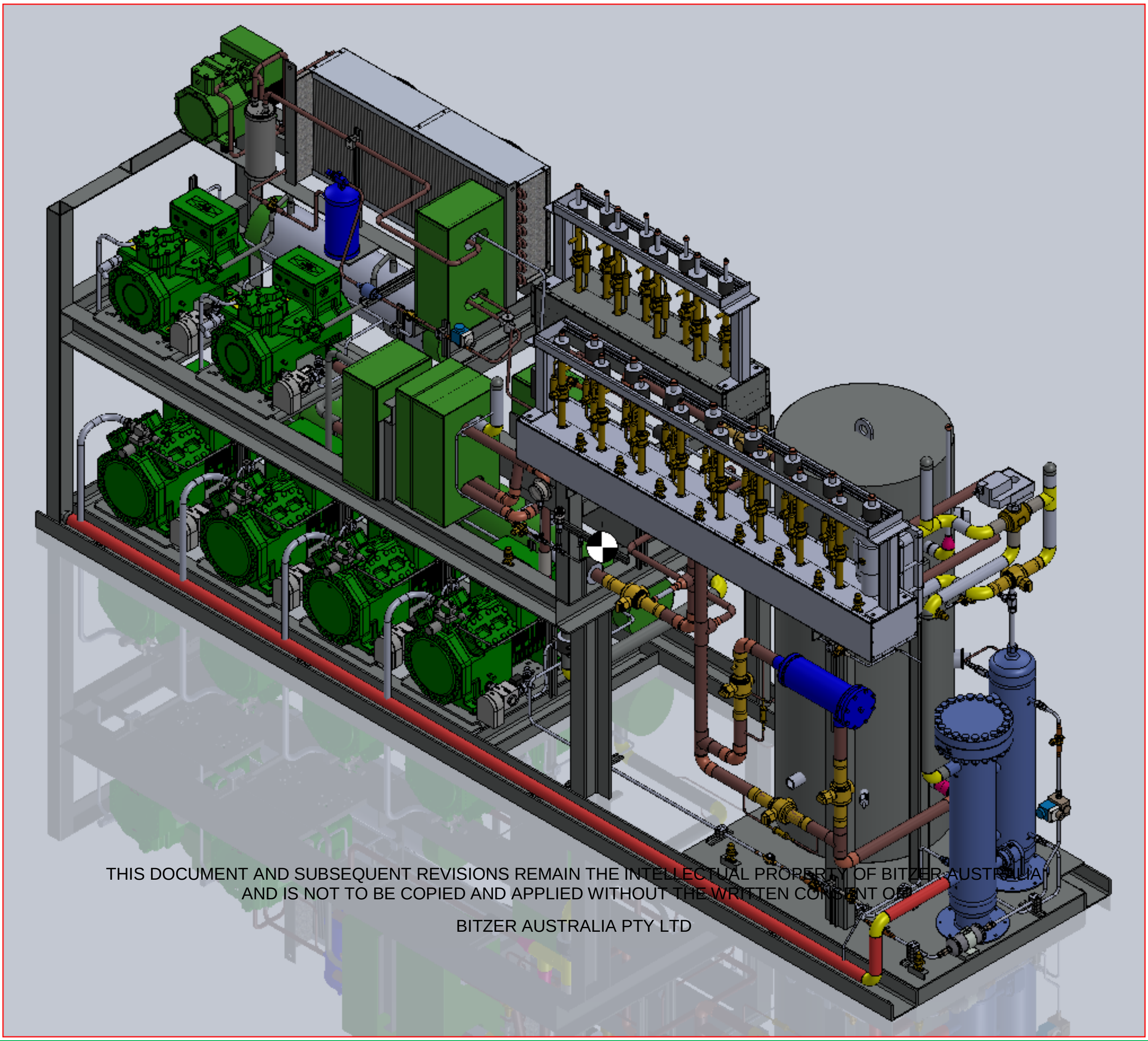
OPERATING INSTRUCTION

FOR

BITZER CO_2 BOOSTER RACK



1 REVISION RECORD

Rev	Date	Revised By	Approved By	ECN	Description
1A	XX/03/2017	AX	IS	TBA	First Release BAO-107-1 AUS

Important Note

The information provided in this document is subject to change without notice.

BITZER Australia is committed to the company policy of Continuous Improvement.

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2 KEY INFORMATION

Information!

Important information:

The key information are project specific design parameters, and subject to change without notice.

High Side Relief Valve	120 bar, 1 off
	2 off if a discharge isolation valve is fitted
Heat Reclaim Relief Valve (if fitted)	120 bar, 1 off
Oil Reservoir Relief Valve	60 bar, 1 off
MT Receiver Relief Valve	60 bar, 2 off
MT Suction Line Relief Valve	60 bar, 1 off
LT Suction Line Relief Valve	60 bar, 1 off
MT T/C Discharge Condition	90 bar(a), 120°C
MT T/C Gas Cooler Outlet	90 bar(a), 32°C
MT S/C Discharge Condition	68.9 bar(a), 28°C SCT, 92°C
MT S/C Gas Cooler Outlet	68.9 bar(a), 28°C SCT, 2K S/C
MT Suction Condition	25.0 bar(a), -12°C SST, 20K S/H
LT Discharge Condition	25.0 bar(a), 50°C
LT Suction Condition	13.3 bar(a), -32°C SST, 20K S/H
MT Receiver Flash Gas Bypass System	40 bar(a), 5.3°C
MT Receiver Parallel Compression System	
• Parallel Compression Mode	40 bar(a), 5.3°C
• Flash Gas Bypass Mode	38 bar(a), 3.3°C
Emergency Comp Discharge Condition	45°C SCT
Emergency Comp Suction Condition	-7°C SST, 0K S/C, 10K S/H

Danger!

Considering the mounting location of the pressure relief valves to avoid the CO2 intake by the air conditioning fresh air louver.

3 INTRODUCTION

This document is a general operating instruction for a BITZER CO2 Trans-critical Booster Rack, a product designed and manufactured by BITZER Australia.

THANK YOU!

For purchasing a BITZER Australia product.

This operating instruction is suitable for a BITZER CO2 trans-critical booster rack fitted with,

- the standard Flash Gas Bypass (FGB) type of configuration; or,
- the optional Parallel Compression type of configuration.

It outlines the minimum requirements and/or guidance in the areas of safety, installation, commissioning, operation and maintenance, etc. in order to have a long term safe and successful operation with a BITZER CO2 trans-critical booster rack.

This operating instruction is not intended to be a training material.

Working on any CO2 trans-critical system requires a specific knowledge of both the complex refrigeration system and the characteristics of CO2.

This special skill can be obtained by the means of industry training courses and/or on-job training with qualified personnel.

This document should be read in conjunction with project associated design documents, such as project specific P&ID, wiring schematics and rack controller user manual, etc.

4 SAFELY APPLYING CO2 AS A REFRIGERANT

4.1 SAFETY REFERENCES

Safety references are instructions intended to prevent hazards. Safety instructions must be strictly observed!

Information!	General or product specific information.
Attention!	Instructions on preventing a possible damage to equipment.
Caution!	Instructions on preventing a possible minor hazard to persons.
Warning!	Instructions on preventing a possible severe hazard to persons.
Danger!	Instructions on preventing an immediate risk of severe hazard to persons.

4.2 CO2 AS A REFRIGERANT

4.2.1 General Perception of CO2

CO2 is a colourless, odourless, non-flammable and naturally occurring gas at the ambient temperature and pressure.

It exists in the atmosphere at a concentration around 350ppm, or 0.035% composition of the air we normally breathe.

Information!	At atmospheric pressure, solid CO2, so called dry ice does exist. Its surface temperature is around -78.4°C. It will directly sublime into vapour when the temperature rises, no liquid formed.

Warning!	Dry ice can cause cold burn. Wear appropriate PPE before attempting to charge any system with refrigerant CO2.

4.2.2 From National and Local Regulations Point of View

In according to the Australian Standards AS/NZS 5149.1:2016 and AS/NZS ISO 817:2016,

- It is a group A1 type refrigerant, nontoxic, non-flammable;
- The refrigerant designation is R744, an inorganic compound substance;
- The chemical name is carbon dioxide. The chemical formula is CO2;
- It has no environmental impact on Ozone depletion. The ODP is zero;
- The global warm potential (GWP) is 1. Other refrigerants are measured as per CO2 equivalent;
- The Molar mass is 44 kg/kmol comparing to that for air is 28.8 kg/kmol. Thus it is heavier than air;
- Its practical limit is 0.1kg/m3.

Information!

The practical limit for group A1 refrigerants, at up to 2000m sea level, is less than half the concentration which can lead to suffocation due to oxygen displacement or which has narcotic or cardiac sensitization effects after a short time whichever is the most critical.

It determines the maximum refrigerant charge limit for an occupied space which may consequently require a health hazard prevention plan / procedure such as mechanical ventilation, CO2 visual and / or audible alarm, evacuation process, etc.

Warning!

CO2 is heavier than air, and may accumulate in an isolated or non-ventilated space if there is a refrigerant leak and/or activated pressure relief into such spaces.

CO2 detectors, audible and visible alarms are mandatory in such situations to alert, warn and inform all personnel in and near the hazard area.

The Safe Work Australia specifies its exposure standard value of 5,000ppm at an 8-hour time-weighted average, and the short term exposure limit is 30,000ppm for CO2.

Information!

The 8-hour time-weighted average (TWA) exposure standards are the average airborne concentration of a particular substance that is permitted over an 8-hour working day, and a 5-day working week. It is the most common types of exposure standards.

The short term exposure limit (STEL) standards are the time-weighted average airborne concertation of a particular substance that is permitted over a 15-minute period.

Refer Table 4.1 for the physiological effect of CO2 to human.

PPM	Effects on Health
350	Normal value in the atmosphere
1,000	Recommended not to be exceed for human comfort
5,000	Exposure limit, 8-hour time-weighted average
20,000	50% increase in breathing rate;

	Can affect the respiration function & cause excitation followed by depression of the central nervous system
30,000	100% increasing breathing rate; Short term exposure limit, 15-minute time-weighted average
50,000	Immediately dangerous to life or health (IDLH) Escape within 30 minutes without any irreversible health effects
100,000	Lowest lethal concentration; Few minutes exposure produces unconsciousness
200,000	Death accidents have been reported
300,000	Quickly results in an unconsciousness and convulsions

Table 4.1 – Physiological Effect of CO2

4.2.3 Simple Thermodynamics

CO2 has a low critical temperature 31.1°C and a high triple point temperature -56°C comparing to other popular refrigerants. Refer the Figure 4.1.

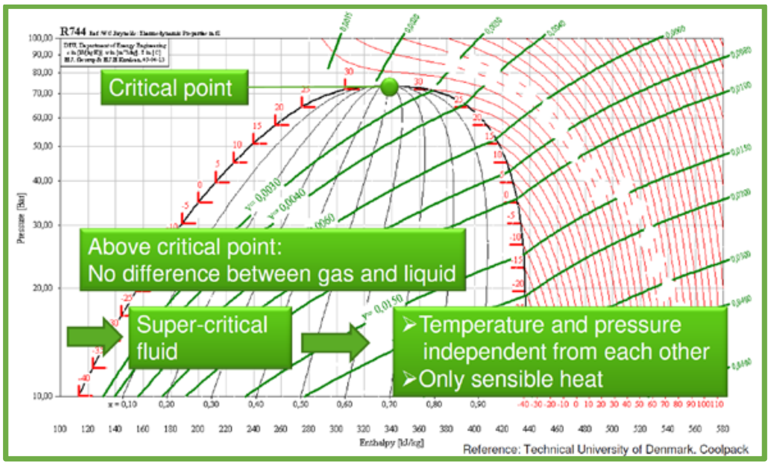


Figure 4.1 – CO2 Critical Point

Information!

Above its critical point, 31.1°C and 73.8 bar(a), CO2 has no distinguishable difference between its gas and liquid phases.

It's a high density vapour called supercritical fluid with no relationship between the temperature and the pressure.

Depending on the design selection of a heat rejection equipment and/or the high side discharge pressure, ambient temperature, the heat rejection of a CO2 refrigeration system can only be done in the supercritical state.

The CO2 compressor(s) compress the MT return vapour from the subcritical state, across the critical point, into the supercritical state forming the so called trans-critical process. Refer the Figure 4.2.

During the trans-critical heat rejection process, unlike the normal refrigeration condensers no liquid is generated, only the sensible heat transfer is occurred in the outdoor gas coolers.

Information!

The usually called condensers in the subcritical state become the gas coolers in the supercritical state.

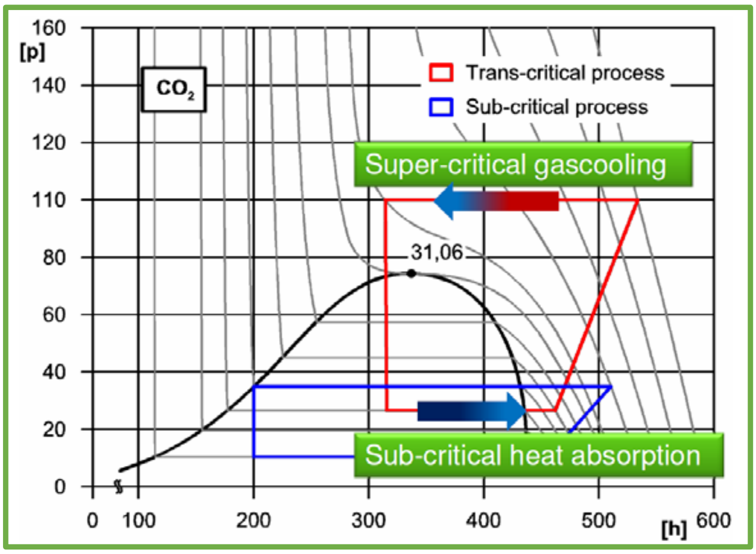


Figure 4.2 – Simple Refrigeration Process Cycles

CO2 has high vapour pressure.

The isovolumetric process in the Figure 4.3 shows that an isolated vessel containing the two-phase liquid and vapour CO2 with a specific volume of 0.003 m3/kg will endure a 45 bar pressure rise.

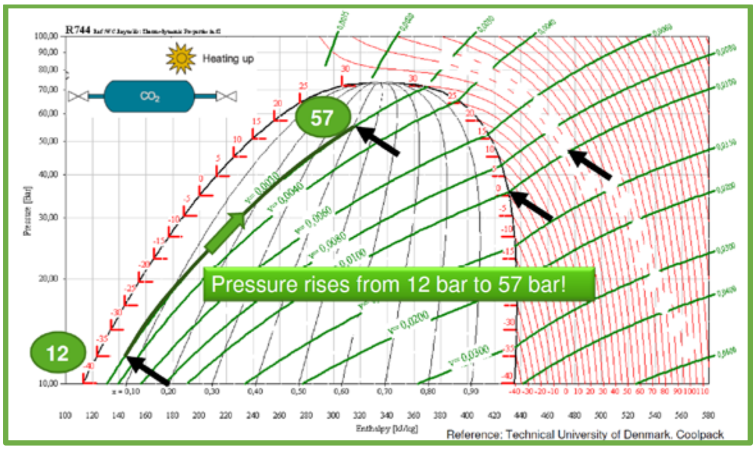


Figure 4.3 – CO2 Pressure Rise

It was 12 bar(a) at -35°C but it quickly becomes 57 bar(a) when the vessel reaches 20°C.

Attention!

The vessel and/or any section of pipe could be isolated with the liquid CO2 should be protected by the pressure relief valve or the device to release the pressure such as bypass check valve.

Information!	The Australian Standards AS/NZS5149.2:2016 outlines the safety requirements on refrigeration system design.

At its triple point, -56°C and 5.2 bar(a), CO2 coexists in vapour, liquid and solid states.

Information!	On the P-h diagram, the triple point is actually a line rather than a point. Refer the Figure 4.4.

Three downward arrows in the Figure 4.4 point out the potential 58%, 3% or 0% liquid CO2 would be generated if the pressure is reduced from the respective states of 45 bar(a) saturate liquid, 45 bar(a) saturate vapour or 28 bar(a) saturate vapour to the final triple point state.

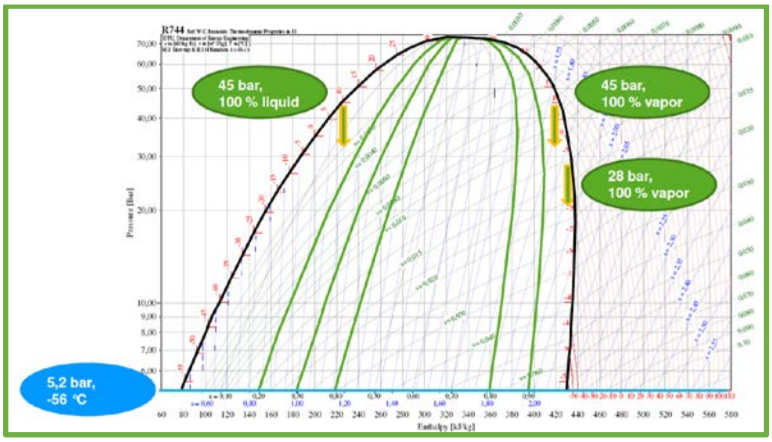


Figure 4.4 – CO2 Triple Point

This implies that 58%, 3% or 0% CO2 solids, also known as dry ice, would be generated if there is a pressure relief valve activated at above states respectively.

Therefore it is suggested that if possible the pressure relief valve should be applied to the CO2 vapour rather than the liquid because of the large potential of piping blockage by the CO2 solids.

Attention!	Do not connect the pipe at the outlet of the last pressure relief valve due to the potential blockage by the dry ice formation.

Handle CO2 with care, only the experienced personnel should carry out the CO2 handling type of work.

Warning!	Always wear the appropriate PPE such as safety glasses, safety gloves, safety boots and long sleeve shirt to prevent the body harm from the hot burn, cold burn and/or possible high pressure event. Individual risk assessment is recommended to determine the actual PPE required for certain operations.

5 SYSTEM CONFIGURATIONS & COMPONENTS

The BITZER CO2 trans-critical booster rack is comprised of,

- A high side system with a 120 bar design pressure;
- A medium temperature receiver system with a 60 bar design pressure; and,
- A low side system with a 60 or 30 bar project specific design pressure.

Consult system specific documents for details of each individual system.

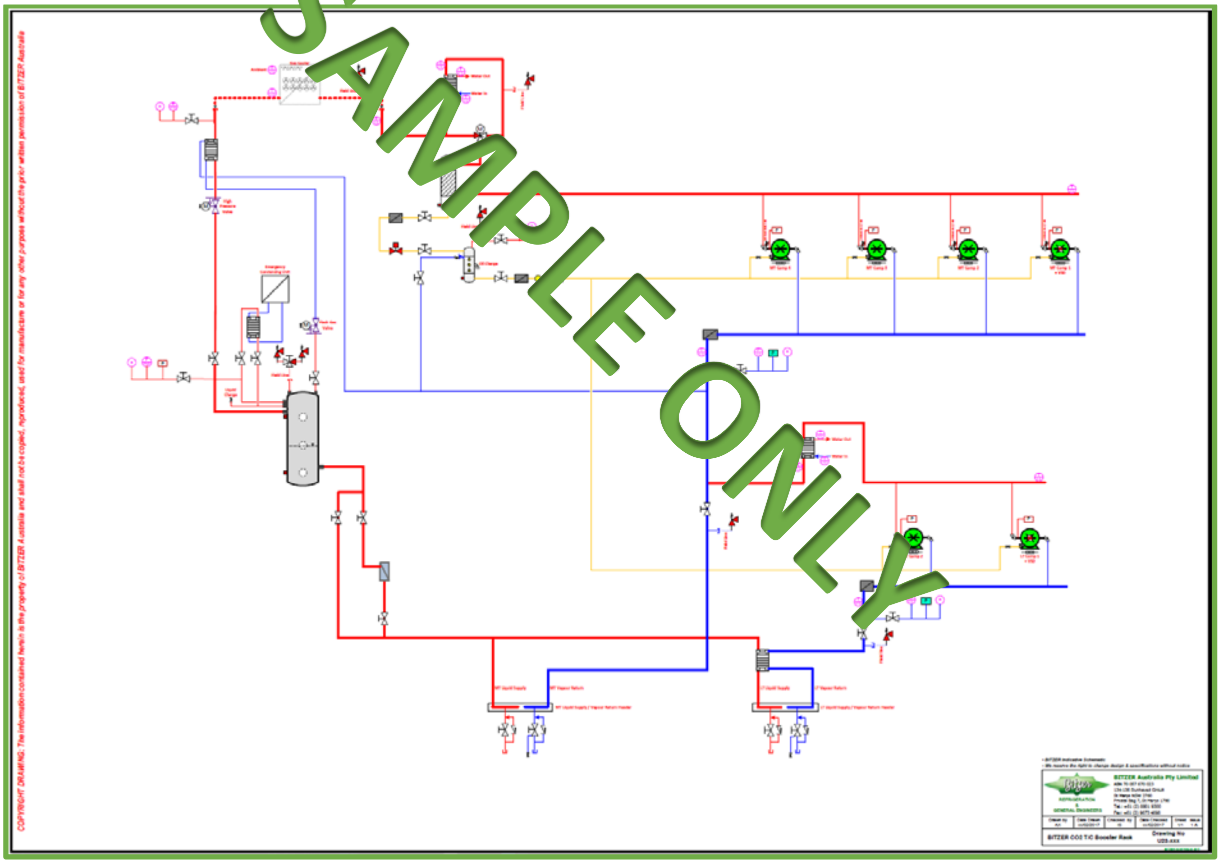


Figure 5.1 – Generic P&ID of a BITZER CO2 Trans-critical Booster Rack

5.1 Medium Temp, Low Temp and Optional Parallel Compressors

The MT and parallel compressors are so called trans-critical compressors because they are the ones will crossover the CO2 critical point and operate in the supercritical area.

The LT compressors are generally the subcritical compressors.

The BITZER CO2 trans-critical booster rack is usually equipped with,

- Common discharge for MT/Parallel compressors, and suction headers,
- Common suction LP cut-out safety switches, pressure gauges, isolation valves and access valves,
- Minimum of one frequency inverter to the lead compressor in each suction line.

Each compressor has following peripherals fitted,

- Discharge and suction isolation valves,
- HP cut-out safety switch,
- Compressor crankcase oil level control, and oil line isolation valve,
- Compressor crankcase heater,
- Compressor motor protection SE-B1.
- An OEM fitted 148-bar discharge pressure relief valve for each trans-critical compressor.

If a rackmount switchboard is included in the sales contract, the compatible temperature sensors and pressure transducers will be fitted on the rack and wired to the switchboard.

Alternatively consult with BITZER Sales for the scope of supply for the arrangement of fitting the suitable temperature sensors and pressure transducers for the rack control system.

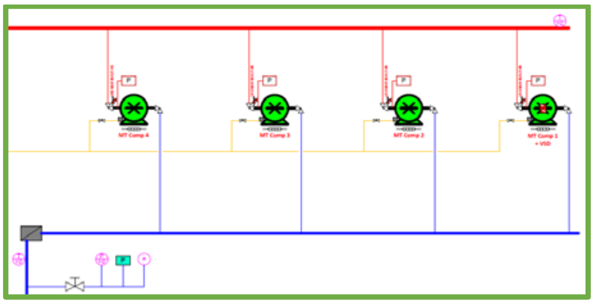


Figure 5.2 – MT Compressors

Attention!	Whenever a compressor stops, its crankcase heater should be energized to keep the refrigerant out of the oil sump.

5.2 Oil Separator & Oil Reservoir

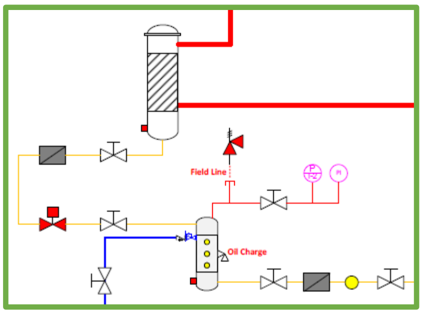


Figure 5.3 – Oil Separator and Oil Reservoir

The oil separator and oil reservoir have following peripherals fitted, refer the figure 5.3.

- Replaceable coalescent oil filter,
- Oil level switches for oil separator and reservoir,
- Oil line filter driers, sight glass, isolation valves and access valves,
- Oil reservoir fill solenoid valve,
- 4.5 bar pressure differential check valve, linked to the highest SST suction line,
- Pressure relief valve,
- Pressure transducer (check scope of supply with BITZER Sales).

The oil separator level switch commands the oil line solenoid valve via the MT rack controller.

When the oil separator level switch detects the oil level, it outputs a digital signal to inform the MT rack controller which in turn pulsing the oil line solenoid valve pressing the oil into the oil reservoir.

After the oil level drops below the sensor level, the oil separator level switch de-energizes the signal to the MT rack controller resulting in the shut off of the oil line solenoid valve hence stopping the oil flow.

Information!	The MT rack controller capable of trans-critical operation should have a built-in control logic for the oil line solenoid valve.

Similarly, the oil reservoir level switch signals an alarm to the MT rack controller if the oil level in the oil reservoir drops below the sensor level.

The pressure differential check valve keeps the oil reservoir pressure low but high enough to deliver the oil to all the compressors.

The reference level is the highest SST suction pressure.

The pressure transducer monitors the pressure level of the oil reservoir.

Attention!	The MT rack controller should energize and pulse the oil line solenoid valve to pressurize the oil reservoir should its pressure drop to a pre-determined level hindering the oil delivery.

Many system controllers have inbuilt functionality for oil fill control and these are recommended.

However as a guide, the following operation is suggested.

- If the oil separator level switch is open, do not fill except if the pressure differential between the highest SST and the oil reservoir is less than 2 bar. In this instance, pulse the oil line solenoid valve for 1 second every 30 seconds.
- If the oil separator level switch is closed, pulse the oil line solenoid valve for 1 second every 10 seconds.
- If the oil reservoir level switch is open, pulse the oil line solenoid valve for 1 second every 10 seconds.

5.3 MT Heat Reclaim Plate Heat Exchanger (Optional)

The heat reclaim PHE generally has following peripherals fitted,

- 3-way ball valve with an on/off type actuator,
- Pressure relief valve,
- Water inlet and outlet temperature sensors (check scope of supply with BITZER sales),
- Refrigerant inlet temperature sensor (check scope of supply with BITZER sales),
- Isolation ball valve and access valve.

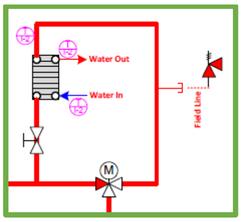


Figure 5.4 – Heat Reclaim Plate Heat Exchanger

When the heat reclaim is required, the MT rack controller energizes the actuator changing the opening position of the 3-way ball valve.

The refrigerant goes through the heat reclaim PHE passing the heat to the process water.

The water outlet temperature sensor informs the MT rack controller about the heat reclaim result which determines whether the MT compressor discharge pressure level should be raised or lowered.

Caution!	The heat reclaim plate heat exchanger is Water Mark approved. However the water in this process is not suitable for potable water application.

The heat reclaim plate heat exchanger should be bypassed if the heat reclaim is not required.

If more heat is required, the MT rack controller should manage system operation to maximise heat reclaim.

5.4 GAS COOLER

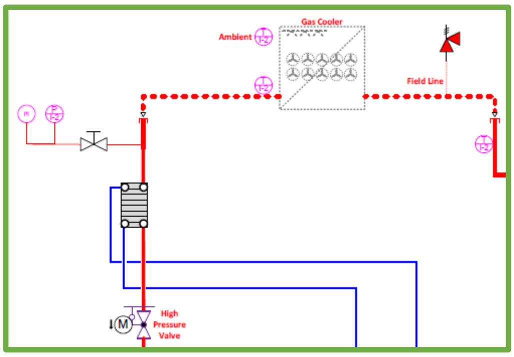


Figure 5.5 – Gas Cooler and Superheater PHE

The gas cooler has following peripherals fitted ex-factory, or supplied loose and to be fitted on site by others,

- Gas cooler outlet temperature sensor (supplied loose), should be installed within 1.5m of the gas cooler outlet for reliable operation of the system.
- Gas cooler outlet pressure transducer (check scope of supply with BITZER sales), pressure gauge, isolation valve and access valve,
- Ambient temperature sensor (not supplied), an additional ambient probe (not supplied) and a gas cooler air on probe (not supplied) are required for control if the water spray system is fitted.
- Pressure relief valve (supplied loose).

Information!	The gas cooler is manufactured by others.

The gas cooler pressure is monitored by the pressure transducer, and controlled by the MT rack controller or the high pressure valve driver which regulating the opening and closing of the high pressure valve.

The gas cooler performance is monitored by its outlet temperature sensor, and controlled by the MT rack controller which regulating the speed of the gas cooler EC fans.

Information!	The high pressure valve driver regulates the high pressure valve and the flash gas valve. The high pressure valve driver cannot regulate the gas cooler EC fans.

The ambient temperature sensor is used to determine the timing when to activate the water spray if the gas cooler is fitted with an adiabatic water spraying system.

Also, the MT rack controller regulates the condensing floating head based on the reading of the ambient temperature sensor when the ambient temperature favours the subcritical mode operation.

Information!	In the trans-critical mode, it's called the gas cooler. In the subcritical mode, it's called the condenser.

5.5 Superheater Plate Heat Exchanger (If Fitted)

The superheater PHE ensures the flash gas from the MT receiver become superheated vapour before entering the MT compressors. Refer the Figure 5.5.

On the other side of the superheater PHE, the refrigerant will be subcooled slightly before entering the high pressure valve, reducing the flash gas formation in the receiver.

Attention!	If droplets of liquid refrigerant entrained in the suction gas flow enter the compressor, there is chance of serious damage to the compressor.

5.6 High Pressure Valve

The high pressure valve is the device separates the high side system and the medium temperature receiver system. Refer the Figure 5.5.

Upstream the high pressure valve, it is the 120 bar rated high side system.

Downstream the high pressure valve, it is the 60 bar rated MT receiver system.

The high pressure valve, a motorised valve constantly regulates the refrigerant flow, either the trans-critical gas or the subcritical liquid, coming out of the gas cooler / condenser.

The MT rack controller or the high pressure valve driver controls the valve opening percentage to maintain the optimum gas cooler pressure during the trans-critical mode, or the constant sub-cooling during the subcritical mode.

This valve must be closed by the means of backup power supply if its driver or the MT rack controller has lost the power supply.

! Attention!	UPS or capacitor device is mandatory for shutting off the HP valve.

This is to prevent the medium temperature receiver system from damage or unnecessary pressure relief due to the pressure surge from the high pressure side.

5.7 Flash Gas Valve (RPRV Valve)

The purpose of the flash gas valve is to maintain the MT receiver pressure during the system operation. Refer the Figure 5.6.

The refrigerant vapour from the MT receiver passes through the FG valve and expands the pressure down to the highest SST pressure level.

Mixing with the MT suction vapour and/or the LT discharge vapour, the confluence enters the MT compressors.

! Attention!	The flash gas expansion process creates a small amount of liquid that has potential to damage the compressors. If droplets of liquid refrigerant entrained in the suction gas flow enter the compressor, there is chance of serious damage to the compressor.

The MT rack controller or the high pressure valve driver varies the valve opening percentage based on the signal from the receiver pressure transducer.

This valve must be closed by the means of backup power supply if its driver or the MT rack controller has lost the power supply.

This is to prevent the pressure equalisation and/or refrigerant migration from the receiver to the MT suction or LT discharge side resulting in refrigerant condensation.

! Attention!	UPS or capacitor device is mandatory for shutting off the FG valve.

5.8 Medium Temperature Receiver

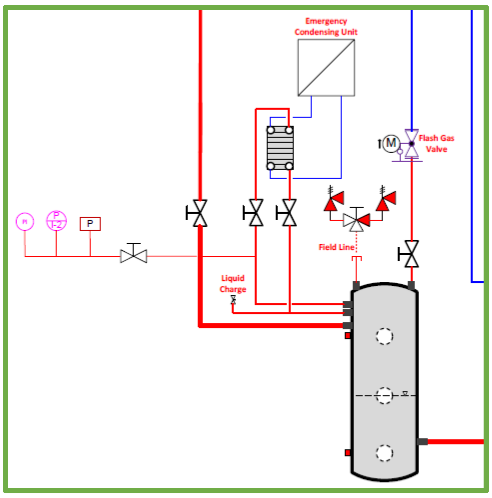


Figure 5.6 – Medium Temperature Receiver

The medium temperature receiver has following peripherals fitted,

- Liquid charging valve,
- Isolation valves,
- High and low liquid level switches,
- MT receiver pressure transducer (check scope of supply with BITZER Sales), pressure gauge, isolation valves and access valves,
- Dual pressure relief valves,
- Optional emergency plate heat exchanger and the start/stop switch for the R134a emergency condensing unit.

The liquid level switch signals the MT rack controller to alarm the high or low liquid level.

The pressure transducer monitors the receiver pressure and sends its analogue signal to the MT rack controller.

The receiver pressure is maintained by the high pressure valve and the flash gas valve through the commands of the MT rack controller or the high pressure valve driver.

The receiver pressure could also be maintained by the parallel compressor(s) if the system is in the parallel compression mode.

5.9 R134a Emergency System for Medium Temperature Receiver (Optional)

Other refrigerants available on request.

The emergency system is to keep the MT receiver under the maximum safe working pressure at stand still conditions without losing the refrigerant charge unnecessarily.

The emergency system is generally fitted with following equipment and peripherals,

- R134a compressor with discharge and suction valves,
- Compressor crankcase heater,
- Compressor motor protection SE-B1,
- Dual pressure safety (HP) / control (LP) switch,
- Air-cooled condenser,
- Liquid receiver,

- Liquid line filter drier, sight glass, solenoid valve,
- TX valve, and replaceable orifice,
- Emergency plate heat exchanger,
- Isolation valves,
- Emergency system start/stop pressure switch.

The emergency system is on/off controlled by the emergency system start/stop pressure switch fitted on the MT receiver.

! Attention!	The emergency system needs to be operational even when normal power supply is interrupted. A backup power supply such as a diesel generator or an UPS capable of a few hours, is required.

! Attention!	Whenever a compressor stops, its crankcase heater should be energized to keep the refrigerant out of the oil sump.

5.10 MT & LT Liquid Supply / Vapour Return Piping

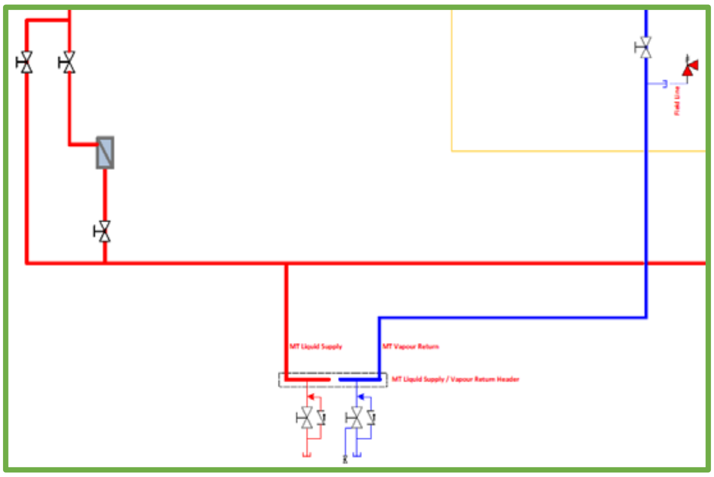


Figure 5.7 – Medium Temperature Liquid Supply / Vapour Return Piping

The MT & LT liquid supply and vapour return piping comprises of,

- Main liquid line filter drier and optional associated bypass valves and access valve,
- Optional insulated headers with multiple pairs of liquid supply / vapour return isolation ball valves,
- Suction line main isolation ball valves,
- Suction side pressure relief valves.

The liquid / vapour header enables the Bitzer CO2 Booster Rack to support multiple individual MT & LT load branches for simultaneous operation and/or services.

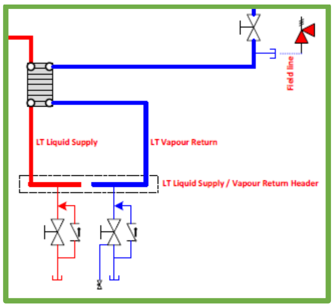


Figure 5.10 – Low Temperature Liquid Supply / Vapour Return Piping

5.11 WATER-COOLED / AIR-COOLED LT DE-SUPERHEATER (OPTIONAL)

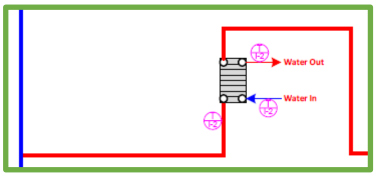


Figure 5.9 – LT De-Superheater PHE

The LT de-superheater releases the heat from the LT compressor discharge gas to the process water circuits if using a water-cooled method, or to the surrounding atmosphere if it's an air-cooled one.

Information!	The heating capacity in a commercial application is usually limited due to the insignificant LT load capacity and the operating conditions of the LT compressors.

The LT de-superheater reduces the MT compressor suction superheat hence improving the overall system efficiency.

Caution!	The de-superheater plate heat exchanger is Water Mark approved. However the water in this process is not suitable for potable water application.

The temperature sensors monitor the inlet and outlet temperatures on both refrigerant and water sides.

Attention!	The outlet temperature of the refrigerant should not be lower than the dew point temperature of the LT discharge pressure. The de-superheating process should be stopped if the MT suction return temperature is below a per-determined set point.

6 SYSTEM PREPARATION

Upon receiving the BITZER CO2 booster rack, the inspection should be conducted immediately to confirm no obvious damage occurred during the transport.

Information!	Please contact your local BITZER Sales immediately should any obvious damage to the rack occur during the transport.

It is the purchaser's responsibility that the installation of the BITZER CO2 booster rack should be carried out professionally before the system can be prepared for commissioning and operation.

Attention!	The installation should be carried out by the qualified / licensed suitably experienced personnel accredited by the national and local regulations. The installation should be in compliance with the requirements by the national and local regulations.

The system preparation involves the pressure testing, pressure switch setting, oil filling, system vacuuming, control logic testing and CO2 charging etc.

Information!	The BITZER CO2 booster rack is charged with 10 bar (1000 kPa) dry Nitrogen gas ex-factory to prevent the moisture ingress during the transport. Carefully release the pressure charge before cutting the pipe.

Warning!	Always wear the appropriate PPE such as safety glasses, safety gloves, safety boots and long sleeve shirt to prevent the body harm from the hot burn, cold burn and/or possible high pressure event.

6.1 PRESSURE TESTING & SETTING UP PRESSURE SWITCHES

The BITZER CO2 booster rack has been leak tested ex-factory at specified design pressures of 120 bar for the high side and project specific at 60 or 30 bar for the low side.

After the successful installation of the complete system such as the booster rack, the gas cooler, the evaporators and the field piping, etc., the system should be charged with dry Nitrogen or Trace-A-Gas (95% Nitrogen and 5% Hydrogen) for leak testing.

The high side, from the discharge valves of MT and optional parallel compressors, including the gas cooler, the high pressure valve, up to the immediate isolation ball valve should be charged to 120 bar.

The low side, i.e. the rest of the system, should be charged to 60 or 30 bar in accordance with the project specific design.

Danger!	Ensure only authorized personnel conduct the pressure test. Ensure the pressure test area is isolated from the public access. Inform the people nearby about the pressure test in progress.

Concurrent to the pressure testing process, the pressure switches can be set up in according to the references listed in the section 8 “System Device Settings”.

Attention!	Apply the good refrigeration practices in accordance with the guidance from the ANZ refrigerant handling code of practice 2007.

6.2 System Vacuuming & Refrigerant Oil Charging

After the successful pressure testing, the system can be vacuumed with multiple vacuum pumps, and large diameter vacuum pipes in order to reduce vacuum time.

Energize the crankcase heaters to assist with removal of moisture.

At the same time the refrigerant oil, BSE85K for CO2 trans-critical application purpose, can be added into all MT, parallel and LT compressor crankcases, the oil separator and the oil reservoir.

Attention!	Do not mix the BSE85K with any other refrigerant oil. Otherwise operational issues may follow.

If the moisture cannot be removed by vacuuming, break the vacuum with dry Nitrogen a few times to flush out the moisture.

Minimum of 50 microns vacuum must be achieved, triple evacuation is recommended.

Attention!	Apply the good refrigeration practices in accordance with the guidance from the ANZ refrigerant handling code of practice 2007.

6.3 Control Logic Testing

Attention!	The electrical work should be carried out by the qualified / licensed personnel accredited by the national and local regulations. The electrical work should be in compliance with the requirements by the national and local regulations.

Control logic testing involves,

- Continuity checking the wiring connections between the switchboard and the field equipment;
- Confirming the analogue and digital signals received correctly by the controllers;
- Confirming the analogue and digital outputs activated correctly by the controllers;
- Ensuring the relays functioned correctly with NO/NC setups;

- Ensuring the parameters correctly set up for all the controllers in according to the project specific design requirements.

6.4 CO2 CHARGING

Warning!	Always wear the appropriate PPE such as safety glasses, safety gloves, safety boots and long sleeve shirt to prevent the body harm from the hot burn, cold burn and/or possible high pressure event.

Attention!	Use only the refrigerant grade CO2 with 99.99% high purity and less than 10ppm moisture.

As soon as the system vacuuming is complete, break the vacuum immediately with the CO2 vapour and raise the system pressure to 10 bar pressure to prevent the moisture ingress.

Keep in mind that CO2 can be in solid state at the triple point condition, 5.2 bar(a) and -56°C.

Information!	At the atmospheric condition, it is -78.4°C. It presents as the dry ice and sublimes into vapour directly.

Continue to charge the CO2 vapour into the system until the pressure is stabilized at 10 bar throughout the entire system.

Attention!	Never break the system vacuum with the liquid CO2. The instantaneous liquid evaporation at the condition below the triple point could see the formation of CO2 solids and extremely low temperature which could cause thermal shock and brittleness to the steel material.

Energize the crankcase heaters to avoid CO2 vapour dissolved in the refrigerant oil.

Charging liquid would be a lot quicker than charging the system with vapour.

Once the system pressure reaches 10 bar, the CO2 liquid can be charged directly into the MT receiver for commissioning and operation.

Information!	Always use the scale when charging the refrigerant. Always update the record of how much charge is in the system.

Shut the CO2 cylinders and the charging valve on the rack.

Leave the charging hose and CO2 cylinders connected for further charging during the commissioning period.

Danger!	Release the remaining CO2 liquid / vapour inside the charging hose. Only authorized and trained personnel capable of CO2 handling should carry out the charging procedures.

Switch on the R134a emergency system, if fitted, to condense the CO2 vapour should the pressure inside the MT receiver rise to the set point.

7 SYSTEM COMMISSIONING, OPERATION & DECOMMISSIONING

After the successful completion of pressure testing, pressure switch setting, oil filling, system vacuuming, control logic testing and CO2 charging procedures, the system can be connected to the three phase power supply and put into real operation.

Danger!	Only trained, authorized and experienced personnel who understands the operating principle of the BITZER CO2 booster system should carry out the commissioning procedures. Contact BITZER Engineering should you require assistance.

7.1 System Start Sequence

In principle, the BITZER CO2 booster rack should be started with the medium temperature (MT) system.

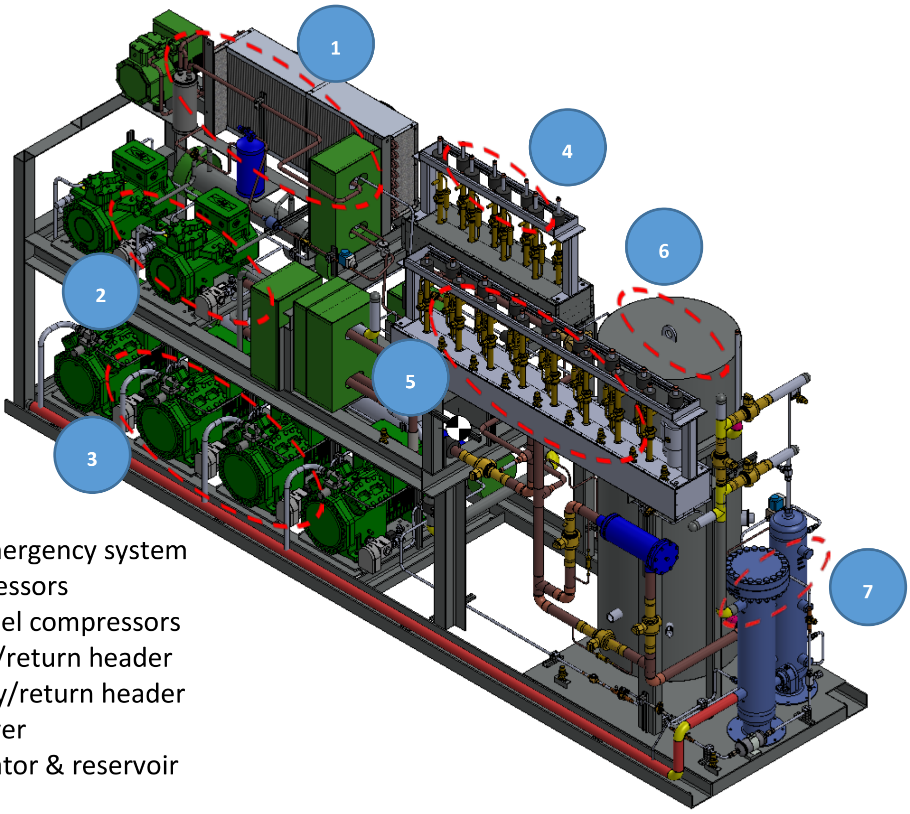
After switching on a MT cool room controller, monitoring the system operation.

Only switching on the next MT cool room controller when the system stabilizes.

One evaporating load at a time, gradually switching on all MT system loads.

The low temperature (LT) system shall wait until the stable operation is achieved with the MT evaporators and compressors.

Then similarly one by one gradually switching on the LT freezer room controllers.



1. R134a emergency system
2. LT compressors
3. MT/Parallel compressors
4. LT supply/return header
5. MT supply/return header
6. MT receiver
7. Oil separator & reservoir

Figure 7.1 – BITZER CO2 Booster Rack General Only

7.2 Medium Temperature System Commissioning & Operation

Ensure that all circuit breakers, power and control switches are OFF before starting the MT system.

Refer to project specific wiring schematics for details, turn on following devices in sequence:

7.2.1 R134a Emergency System

- Main power switch,
- Power supply to emergency condenser fans,
- Power supply to emergency compressor contactor,
- Power supply to emergency system control circuit,
- Control switch to activate emergency system in auto control.

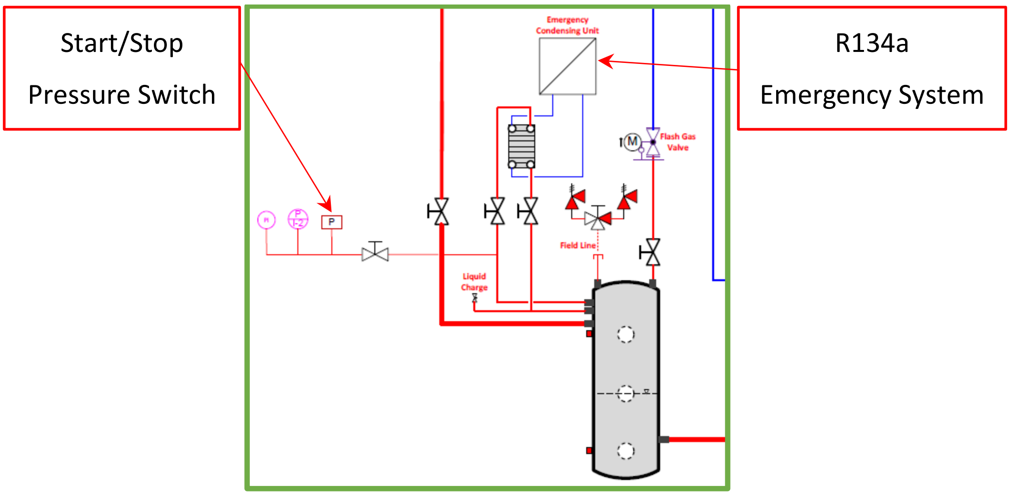


Figure 7.2 – R134a Emergency System

The R134a emergency system now is in automatic control.

The MT receiver is rated at 60 bar, about 21°C equivalent.

The emergency system start / stop pressure switch, monitors the MT receiver pressure.

It shall energize the R134a liquid line solenoid valve when the MT receiver pressure reaches a pre-determined level, say 54 bar, about 18°C equivalent.

The emergency compressor will then start when its HP/LP switch cuts in at 125 kPa, equivalent to -7°C SST saturate suction temperature.

When the emergency system pulls/cools the MT receiver pressure down to 45 bar, about 11°C equivalent, the start/stop pressure switch shall de-energize the R134a liquid line solenoid valve.

The R134a emergency system will then be pumped down until its HP/LP switch cuts out the compressor at 45 kPa, equivalent to -18°C SST saturate suction temperature.

The R134a emergency system is now in operation.

7.2.2 Medium Temperature System and Control

- Power supply to gas cooler EC fans,
- Power supply to the MT external VSD and all MT compressors,
- Power supply to main control circuit.
- Power supply to the HP valve driver, driving both high pressure and flash gas valves,

- Power supply to both MT and LT rack controllers,

The ventilation fan fitted on the switchboard panel should be running.

Both MT and LT rack controllers are now activated.

They can read analogue and digital inputs and correspond with analogue and digital outputs to the devices connected to their output terminals.

The LT devices however have not been switched on at this moment, cannot be driven by the output signals from the LT rack controller.

7.2.2.1 Gas Cooler EC Fans and Water Spray System (Optional)

The MT rack controller and the HP valve driver read the analogue signals from the gas cooler pressure transducer and the gas cooler outlet temperature sensor.

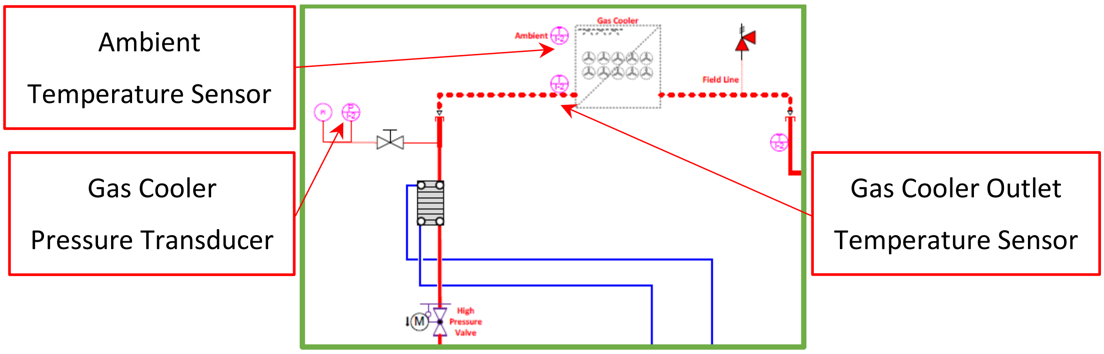


Figure 7.3 – Gas Cooler and Pressure Transducer / Temperature Sensors

Information!

The high pressure valve driver regulates the high pressure valve and the flash gas valve.

The high pressure valve driver cannot regulate the gas cooler EC fans.

The communication between the MT rack controller and the HP valve driver shall be established to ensure the coordinated control between the gas cooler pressure, gas cooler outlet temperature and the MT receiver pressure.

The MT rack controller outputs 0-10V analogue signal to control the speed of all EC fans simultaneously.

The ambient temperature sensor is used by the MT rack controller to regulate the floating condensing temperature should the ambient condition and the system demand allow.

If a water spray system is fitted on the gas cooler, the MT rack controller shall also require the analogue signal from the ambient temperature sensor to initiate the adiabatic cooling.

When the ambient dry bulb temperature reaches the design set point, the MT rack controller should energize the water supply solenoid valve(s) to spray water mist against the air on stream before being drawn onto the front face of the gas cooler.

The evaporative cooling effect would result in lower air on temperature to the gas cooler.

Information!

The effectiveness of this evaporating cooling process is mainly determined by the differential of the ambient dry bulb and wet bulb temperatures.

The water spray system can be advanced further to improve the water consumption and use the natural resource in an effective way.

Implementing a few more conditions into the MT rack controller to restrict the water initiation and/or termination conditions, such as reaching the pre-set gas cooler outlet temperature and/or the EC fan speed, etc.

Warning!

Be aware of that warm and stagnant water can provide ideal conditions for the growth of organism.

De-energize the water drain solenoid valve(s) to empty the water spray system to avoid any potential health hazard if the water spray is not required for a continuous period of, say 12 hours.

The gas cooler EC fans and the water spray system (if fitted) are now in operation.

7.2.2.2 System Operating Modes

Depending on the selection of the gas cooler and the instantaneous system load, the refrigeration system could be operating in the trans-critical mode when the ambient dry bulb temperature is above 23°C.

The gas cooler outlet temperature could be 2 to 3K higher than the ambient dry bulb temperature if the water spray is not required.

When the ambient dry bulb temperature reaches the design set point, say 30°C, the water spray system will be activated resulting in the gas cooler outlet temperature about 3K higher than the ambient wet bulb temperature.

The state of CO2 at the gas cooler outlet is dense vapour.

On the other hand, the refrigeration system would be in the subcritical mode which the CO2 refrigerant condenses in the gas cooler.

The state of CO2 changes from vapour to liquid in this heat rejection operating mode.

The so called gas cooler thus changes its terminology back to the condenser just like it for any other refrigerants.

The MT rack controller recognises the system operating modes based on the signals from the gas cooler pressure transducer and the gas cooler outlet temperature sensor.

In the trans-critical mode, the MT rack controller optimises the gas cooler pressure via regulating the high pressure valve, and controlling the gas cooler outlet temperature by ramping the EC fan speed.

In the subcritical mode, the MT rack controller controls the condenser sub-cooling just like for any other refrigerants by ramping the EC fan speed.

As a normal energy saving practice, the MT rack controller can also float the condensing pressure should the ambient dry bulb temperature and the system demand allow.

7.2.2.3 Medium Temperature Evaporators & Compressors

Accurate control of the evaporators especially superheat is vital to stable operation of trans-critical booster system.

- Activate MT compressors in auto control mode,
- Power supply to the 1st cool room evaporator controller, the evaporator fans, and the electronic expansion valve (EEV),

The EEV is controlled by the evaporator controller and regulated by the superheat, say minimum 8K, which is measured at the outlet of the evaporator via its temperature sensor and the pressure transducer.

The EEV, either the stepper motor type or the pulse width modulation type, is capable of maintaining a tight superheat control of an evaporator.

When the evaporator controller energizes the EEV, the liquid refrigerant enters into the evaporator absorbing the heat from the passing air stream propelled by the fans, and evaporates becoming the superheated refrigerant vapour.

The pressure of the refrigerant vapour in the compressor suction line builds up to a level, say 24 bar about -12°C equivalent, at which the MT compressor LP safety switch was set and closes.

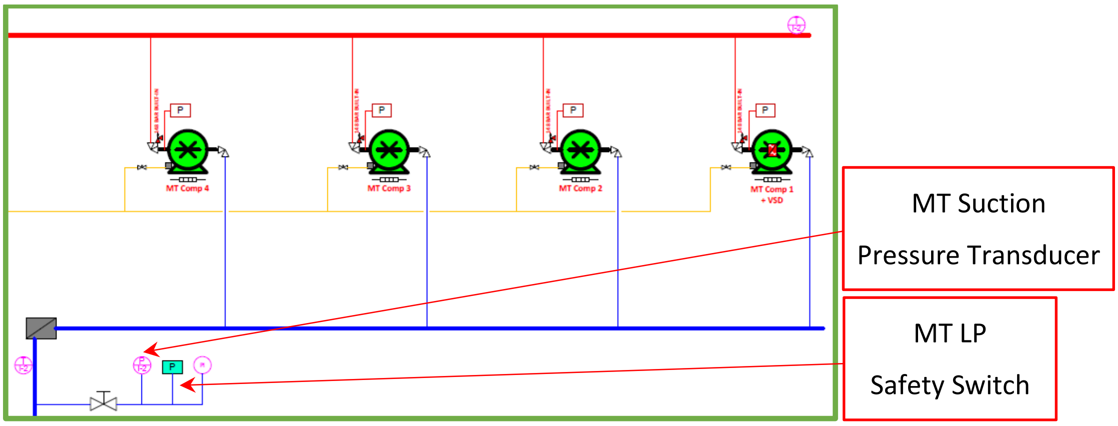


Figure 7.4 – MT Suction Pressure Transducer and LP Safety Switch

The MT VSD and the compressors now should be fully enabled and under the control of the MT rack controller via the MT suction pressure transducer.

When the MT suction pressure rises continuously reaching the set point, say 29 bar or -6°C equivalent, the MT rack controller starts to output 0-10V analogue signal to the MT VSD, which drives the lead MT compressor.

If the lead compressor could not handle the load of the 1^{st} cool room, the MT rack controller may energize the 2^{nd} MT compressor, and 3^{rd}, and so on until the MT suction pressure is maintained within the regulation zone, say set point ± 1K.

Vice versa, the MT rack controller will de-energize the running compressors one by one and/or ramp down the speed of the lead compressor when the MT load demand is decrease.

The MT compressors will then raise the vapour pressure from suction to discharge level and send it to the remote gas cooler for rejecting the heat to the atmosphere.

7.2.2.4 High Pressure Valve

The refrigerant at the outlet of the gas cooler could be dense vapour if the refrigerant state is in the supercritical area, or liquid if in the liquid area.

The high pressure (HP) valve, refer the Figure 7.3, throttles the refrigerant from the discharge pressure down to a pre-determined MT receiver pressure, say 40 bar(a) or 5.3°C equivalent, which is at a state of mixture of the liquid and vapour.

The refrigerant then drains into the MT receiver. Refer the Figure 7.2.

Depending on the ambient condition, the MT rack controller and/or the HP valve driver will calculate the operating mode and pressure for the HP valve based on the temperature and pressure values at the outlet of the gas cooler.

In trans-critical mode, the regulation is to achieve an optimum gas cooler pressure in terms of the best efficiency for the MT compressors.

In subcritical mode, the regulation is to control the liquid sub-cooling of the condenser.

7.2.2.5 Flash Gas Valve

As mentioned previously that the HP valve generates a mixture of liquid and vapour refrigerants when dropping the discharge pressure to the MT receiver pressure.

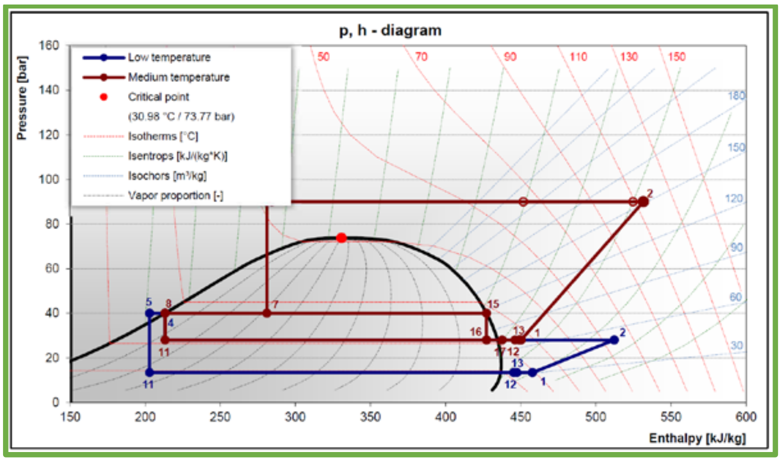


Figure 7.5 – The P-h Diagram of a Typical CO2 Booster System

The vapour portion of this mixture, or the flash gas, could be 30% or more indicated as point 7 in the Figure 7.5.

The accumulation of this amount of flash gas could soon see the MT receiver pressure rise to the receiver design pressure and/or the setting of its pressure relief valve, say 60 bar.

The flash gas needs to be removed constantly from the MT receiver in order to satisfy the continuous operation.

The purpose of the flash gas (FG) valve, which is controlled by the MT rack controller and/or the HP valve driver, is to ensure the MT receiver pressure not to be in the proximity of its design limit.

The FG valve maintains the MT receiver pressure at a stable operating condition, say 40 bar(a) or 5.3°C equivalent in any operating mode whether in high ambient and/or high evaporating load conditions, which have a high potential to reach the vessel design limit.

The FG valve throttles the flash gas from the MT receiver pressure down to the highest SST suction pressure indicated as point 15 to 16 in the Figure 7.5.

At this point 16, the FG is a two phase mixture of the liquid and vapour refrigerants, has 2 – 3% liquid content depending on the suction pressure level.

The higher the MT suction pressure, the lower the liquid content generated by the process of FG throttling.

Conversely, the lower the MT suction pressure the higher the liquid content.

The two phase FG enters the superheater plate heat exchanger (PHE, where fitted), has the liquid content burnt out and superheated by the liquid refrigerant on the other side of the PHE, before entering the MT compressors. Refer the Figure 7.3.

The pressure differential between the MT receiver and the MT suction drives the FG flow.

7.2.2.6 General Medium Temperature System Operation

The refrigerant out of the gas cooler passes through the HP valve, enters into the MT receiver.

The pressure of the MT receiver is taken care of by the MT rack controller and/or the HP valve driver via the HP valve and FG valve.

The FG valve releases the receiver from the FG pressure build-up as described earlier.

If the MT receiver pressure is below the minimum operating set point, say 35 bar(a) or about 0°C equivalent, the HP valve will open up and add pressure from the gas cooler to the MT receiver.

The liquid refrigerant stored in the bottom half of the MT receiver fills the liquid line to the 1st cool room evaporator(s) when its isolation ball valve opens.

The corresponding suction line isolation ball valve for the 1st cool room evaporators should be opened as well. Refer the Figure 5.7 for the indication of the MT liquid supply and vapour return header.

Both the liquid and suction lines should have about 10 bar vapour pressure pre-charged during the system preparation stage.

! Attention!	Never break the system vacuum with the liquid CO2. The instantaneous liquid evaporation at the condition below the triple point could see the formation of CO2 solids and extremely low temperature which could cause thermal shock and brittleness to the steel material.

When the 1st cool room evaporator controller energizes its EEV, the liquid enters the evaporator absorbing the heat from the passing air stream propelled by the fans, and evaporates becoming superheated refrigerant vapour.

The refrigerant vapour then returns to the MT compressor(s) and restarts the refrigeration cycle described as above.

Observe the operation of the MT system, closely monitor the discharge and suction pressures and temperatures of the compressors, MT receiver pressure, oil reservoir pressure, and cool room temperature etc.

When the MT system becomes stable with this 1st cool room load in terms of above observation, the 2nd cool room controller can be energized and its liquid and vapour isolation ball valves can be opened.

When the MT system stabilizes again, add the 3rd MT load into the MT system operation.

One by one until all MT load is in operation.

This completes the MT system start-up operation.

7.3 Parallel Compression System Commissioning & Operation (Optional)

When the MT system becomes stable, the parallel compression system can be switched on provided that the discharge pressure is above the minimum threshold value.

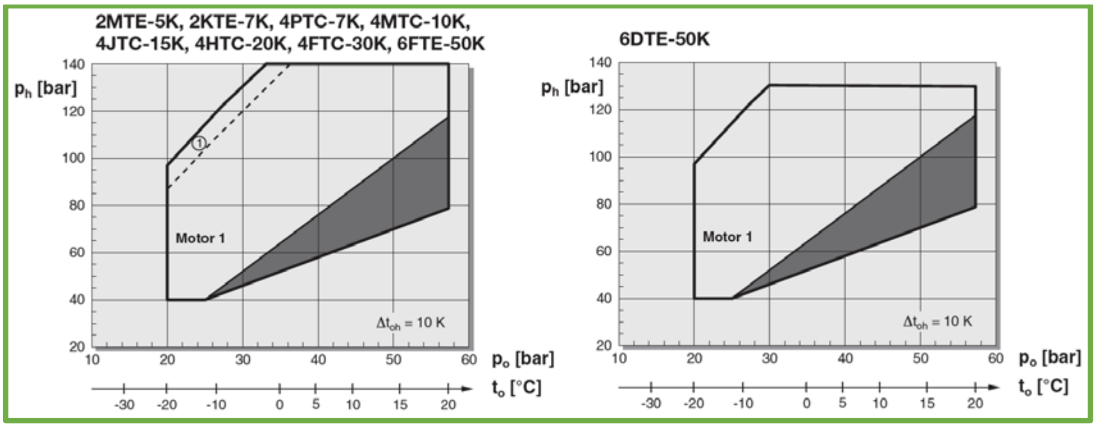


Figure 7.6 – Parallel Compressor Operating Envelope

This value is determined by the compressor operating envelope which in turn is related with the MT load demand and the ambient dry bulb condition.

Now refer to your MT rack controller operating manual to understand that the set point of a MT receiver of a parallel compression system is usually 2 bar higher, or whatever a pressure differential value you think is appropriate, than a flash gas bypass system.

Hence the vapour pressure in the parallel compressor suction line is actually the MT receiver pressure, about 38 bar or +3.3°C equivalent with the FG operation, before the lead parallel compressor cuts in.

The LP safety switch of the parallel compressors is set at 31 bar or -3°C equivalent, should be in a closed position at the moment.

- Power supply to the parallel compressor external VSD and all parallel compressors,
- Activate the parallel compressors in auto control mode.

The parallel compressor VSD and the compressors now should be fully enabled and under the control of the MT rack controller via the parallel suction pressure transducer.

When the FG valve reaches to the pre-set port opening percentage, say 30%, the MT rack controller starts to output 0-10V analogue signal to the parallel VSD, which drives the lead parallel compressor.

The MT rack controller will then raise the MT receiver set point 2 bar to switch off the FG valve.

If the lead compressor could not handle the FG load of the MT receiver, the MT rack controller may energize the 2nd parallel compressor, and 3rd, and so on until the MT receiver pressure is maintained within the regulation zone, say set point ± 1 bar.

Vice versa, the MT rack controller will de-energize the running compressors one by one and/or ramp down the speed of the lead compressor when the receiver FG load is decrease.

If all parallel compressors are cycled down, the MT rack controller will revert the parallel compression system back to the flash gas bypass system, and drop the MT receiver set point 2 bar to re-enable the FG valve operation.

The parallel compression system now is in automatic control.

7.4 Low Temperature System Commissioning & Operation

When the MT system becomes stable, the LT system load can be gradually switched on.

- Power supply to the LT external VSD and all LT compressors,
- Activate LT compressors in auto control mode,
- Power supply to the 1st freezer room evaporator controller, its evaporator fans, and the EEV,

Both the liquid and suction lines should have about 10 bar vapour pressure pre-charged during the system preparation stage.

! Attention!	Never break the system vacuum with the liquid CO2. The instantaneous liquid evaporation at the condition below the triple point could see the formation of CO2 solids and extremely low temperature which could cause thermal shock and brittleness to the steel material.

The liquid refrigerant stored in the bottom half of the MT receiver fills the 1st freezer room evaporator liquid line when its isolation ball valve opens.

The corresponding suction line isolation ball valve of the 1st freezer room evaporators should be opened as well. Refer the Figure 5.10 for the indication of the LT liquid supply and vapour return header.

When the 1st freezer room controller energizes its EEV, the liquid enters the evaporator absorbing the heat from the passing air stream propelled by the fans, and evaporates becoming the superheated refrigerant vapour.

The EEV is controlled by the freezer room evaporator controller and regulated by the superheat, say minimum 8K, which is measured at the outlet of the evaporator via its temperature sensor and the pressure transducer.

The EEV, either the stepper motor type or the pulse width modulation type, is capable of maintaining a tight superheat control of an evaporator.

The pressure of the refrigerant vapour then builds up to a level, say 11 bar about -35°C equivalent, at which the LT compressor LP safety switch was set and closes.

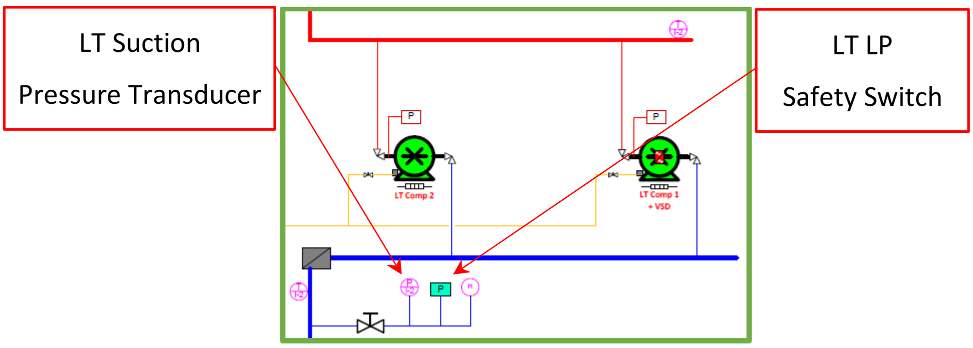


Figure 7.6 – LT Suction Pressure Transducer and LP Safety Switch

The LT VSD and compressors now should be enabled and under the control of the LT rack controller via the LT suction pressure transducer.

When the LT suction pressure reaches the set point, say 12 bar about -32°C equivalent, the LT rack controller outputs 0-10V analogue signal to the LT VSD, which drives the lead LT compressor.

Depend on the load of the 1st freezer room, the lead compressor alone might be able to handle it otherwise the LT rack controller may energize the 2nd LT compressor in order to maintain the LT suction pressure within the regulation zone, say set point ± 1K.

Vice versa, the LT rack controller will de-energize the 2nd compressor and/or ramp down the speed of the lead compressor when the LT load is decrease.

The LT refrigerant vapour returns to the LT compressor(s) via a LT liquid-vapour sub-cooler which superheating the return vapour while sub-cooling the liquid for the LT evaporators. Refer the Figure 5.10.

The LT compressors raise the LT refrigerant vapour from suction to discharge pressure which is the same as the MT suction pressure.

If fitted, the LT discharge vapour goes through a LT de-superheater (optional), either a PHE or an air-cooled fan coil before entering the MT suction line and merging with the MT suction vapour.

Observe the operation of both LT and MT systems, closely monitor the discharge and suction pressures and temperatures of the all compressors, MT receiver pressure and its liquid level, oil reservoir pressure and its oil level, and freezer room and cool room temperatures etc.

If required, charge more liquid refrigerant directly into the MT receiver or vapour refrigerant through the suction line.

When the entire booster system becomes stable with this 1st freezer room load in terms of above observation, the 2nd freezer room controller can be energized and its liquid and vapour isolation ball valves can be opened.

One by one until all LT load is in operation.

This completes the LT and actually the entire booster system start-up operation.

7.5 Oil Management System

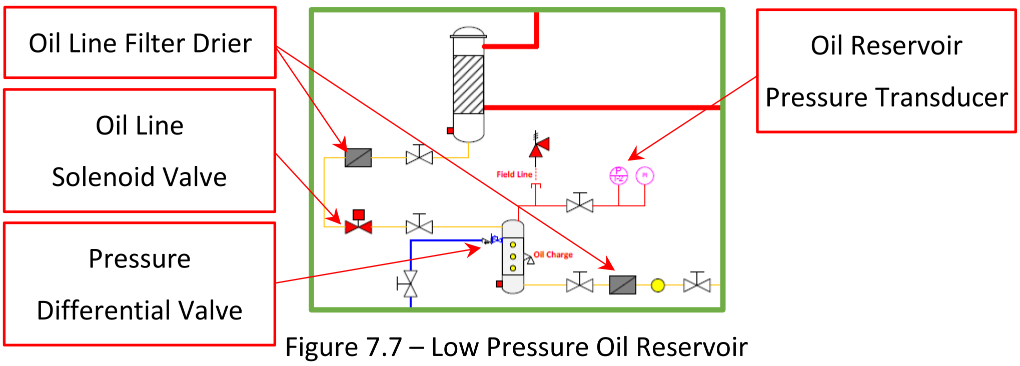


Figure 7.7 – Low Pressure Oil Reservoir

The BITZER CO2 booster system adopts the low pressure oil reservoir principle for its oil management system.

It has the benefit of lower oil temperature and pressure for the compressors.

The result would be a better system efficiency due to less superheat imposed on the refrigerant vapour, as well as less oil foaming effect in the crankcase because of less refrigerant being dissolved in the oil.

7.5.1 Oil Level Regulator for the Compressor

All trans-critical and subcritical CO2 compressors are equipped with an electronic oil level regulator fitted on the crankcase.

The electronic oil level regulator has a built-in level sensor, either an infra-red type or a Hall Effect float type, and an integrated solenoid valve controlling the oil feed to the crankcase.

It constantly monitors the oil sump level and injects oil if the level is below its set level, and/or raises an alarm when the level is below the limit.

7.5.2 Oil Separator and Oil Reservoir

The BITZER CO2 booster system uses a coalescent type of oil separator with an accessible filter element.

The oil reservoir downstream stores the excess refrigerant oil transferred from the oil separator.

The oil line solenoid valve is mounted in between the oil separator and the oil reservoir, controlling the oil flow. Refer the Figure 7.7.

The oil level switches fitted on both oil separator and oil reservoir constantly monitor the oil level in respective vessels.

They send a digital signal to the MT rack controller when the oil level reaches to or drops below their respective levels.

The MT rack controller pulses the oil line solenoid valve to transfer the excess oil from the oil separator to the oil reservoir.

A pressure transducer is also fitted on the top of the oil reservoir, in the vapour space.

It is to ensure that the oil reservoir has a sufficient pressure differential to supply the refrigerant oil to all trans-critical and subcritical CO2 compressors.

If the oil reservoir pressure drops below the highest SST suction pressure, the MT rack controller shall pulse the oil line solenoid valve using the oil separator pressure to build up the oil reservoir pressure to a pre-set level.

The initiation and termination of this oil-on-demand technique can be simply set up in the MT rack controller.

7.6 Heat Reclaim System (Optional)

The BITZER CO2 booster system can have an optional heat reclaim system built into the MT and/or LT discharge lines depending on the project specific design requirement.

Many system controllers have inbuilt functionality for heat recovery and to maximise heat recovery, careful commissioning of water and refrigeration system are required.

However, the following is a guide to basic commissioning of this system.

7.6.1 MT Heat Reclaim System

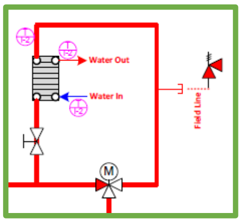


Figure 7.8 – MT Heat Reclaim

When the MT rack controller receives a signal for the hot water demand, it energizes the water pump and the heat reclaim 3-way motor driven valve. Refer the Figure 7.8.

In a normal refrigeration mode, the MT heat reclaim system is bypassed by the 3-way valve.

When it is activated by the MT rack controller, it starts to rotate its spindle and takes about 150 seconds to complete the 90° rotation.

Vice versa when it is de-activated by the MT rack controller.

In the heat reclaim mode, the MT discharge vapour goes through the MT heat reclaim plate heat exchanger passing the heat to the medium, usually water or glycol, on the other side of the PHE.

Caution!

The heat reclaim PHE is Water Mark approved.

However the water in this process is not suitable for potable water application.

The MT rack controller monitors all the temperatures such as, water inlet and outlet temperatures, and refrigerant inlet and outlet temperatures.

The MT discharge pressure is raised in steps if the water outlet temperature is not high enough to satisfy the heat reclaim requirement.

The step increment can be set in the MT rack controller such as 75, 80, 85 and up to 90 bar(a).

The MT rack controller can only control the MT discharge pressure and the heat reclaim 3-way valve.

The continuous regulation of the water outlet temperature should be done by the water flow regulation via the water loop bypass control or a variable speed water pump.

Information!

The heat reclaim capacity is determined by the availability of instantaneous cooling load.

More available cooling load, more heat reclaim capability.

7.6.2 LT Heat Reclaim System

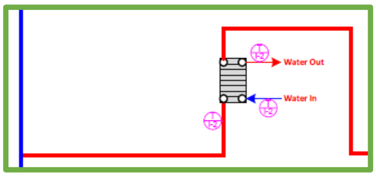


Figure 7.9 – LT Heat Reclaim

The LT heat reclaim or water-cooled de-superheating system is project specific, determined by the LT load conditions such as LT load mass flow rate and LT discharge temperature.

⚠ Caution!	The de-superheating PHE is Water Mark approved. However the water in this process is not suitable for potable water application.

For a commercial application, the LT load is usually small, and the LT discharge temperature is not sufficiently high. Refer the Figure 7.9.

An industrial application would usually be beneficial to have a LT heat reclaim system due to a large heat capacity coming from the LT booster compressors.

The LT discharge vapour always goes through the LT heat reclaim PHE passing the heat to the medium, usually water or glycol, on the other side of the PHE.

The LT rack controller monitors all the temperatures such as, water inlet and outlet temperatures, and refrigerant inlet and outlet temperatures.

The LT de-superheating system should be controlled by the refrigerant outlet temperature to avoid any potential LT discharge vapour condensation.

When the LT rack controller receives such signal, it de-energizes the water pump or the fans of the fan coil.

7.7 SYSTEM MAINTENANCE

The BITZER CO2 booster rack adopts the same service and maintenance program as per any other BITZER rack products.

In general, as a minimum requirement, the following guidance is recommended.

After the completion of the commissioning,

- Conduct an oil sampling test, change the oil if necessary,
- Change the oil separator coalescent filter element, and the oil line filter driers,
- Check the liquid line and oil line moisture indicators / sight glasses,
- Change the liquid line filter drier cores, and the suction line filters,
- Check the oil levels for all compressors and the oil reservoir,
- Check the liquid level in the liquid receiver,
- Check the temperature and pressure at all monitoring locations,
- Check all mechanical joints for potential refrigerant and oil leaks,
- Check the tightness of all bolts, nuts and screws on the rack and in the switchboard,
- Check the power supply and current draw for all motors,
- Log above activities.

Then, annually, in addition to above,

- Conduct general inspection as per usual maintenance program,
- Check the operation of the safety devices such as pressure switches, bleed solenoid valves, and recalibrate the pressure relief valves,
- Check the operation of all motor driven valves, and respective UPS,
- Check the compressor run hours and adjust if necessary,
- Clean gas cooler fins, and check its water spray system if fitted.

7.8 DE-COMMISSIONING THE SYSTEM

⚠ Warning!	Always wear the appropriate PPE when conducting the de-commissioning work. It should be carried out by the qualified / licensed personnel. Apply the good refrigeration practices in accordance with the guidance from the ANZ refrigerant handling code of practice 2007. R134a refrigerant in the emergency back-up system (if fitted) must be reclaimed before cutting open the pipes. The refrigerant and refrigerant oil in both CO2 booster system and the emergency back-up system (if fitted) must be recovered and returned to the collection agents for disposal.

8 SYSTEM DEVICE SETTINGS

Emergency System Start/Stop Pressure Switch		
	HP Control Cut-In	53.7 bar, 18°C equivalent
	HP Control Cut-Out	45 bar, 10.8°C equivalent
R134a Emergency Compressor HP/LP Control		
	LP Control Cut-In	125 kPa, -7°C equivalent
	LP Control Cut-Out	45 kPa, -18°C equivalent
	HP Control Cut-Out	14.3 bar, 56°C equivalent
	HP Control Cut-In	10.3 bar, 44°C equivalent
MT Compressor LP Safety Pressure Switch		
	LP Safety Cut-In	24 bar, -12°C equivalent
	LP Safety Cut-Out	19 bar, -19.5°C equivalent
Parallel Compressor LP Safety Pressure Switch		
	LP Safety Cut-In	38 bar, +3°C equivalent
	LP Safety Cut-Out	31 bar, -3°C equivalent
MT & Parallel Compressor HP Safety Pressure Switch		
	HP Safety Cut-Out	108 bar
	HP Safety Cut-In	92.1 bar
LT Compressor LP Safety Pressure Switch		
	LP Safety Cut-In	11 bar, -35°C SST
	LP Safety Cut-Out	9.6 bar, -38.6°C SST
LT Compressor HP Safety Pressure Switch		
	HP Safety Cut-Out	54 bar (ME Compressor)
	HP Safety Cut-In	45.2 bar (ME Compressor)
	HP Safety Cut-Out	48 bar (SL Compressor)
	HP Safety Cut-In	40 bar (SL Compressor)

9 REFERENCES

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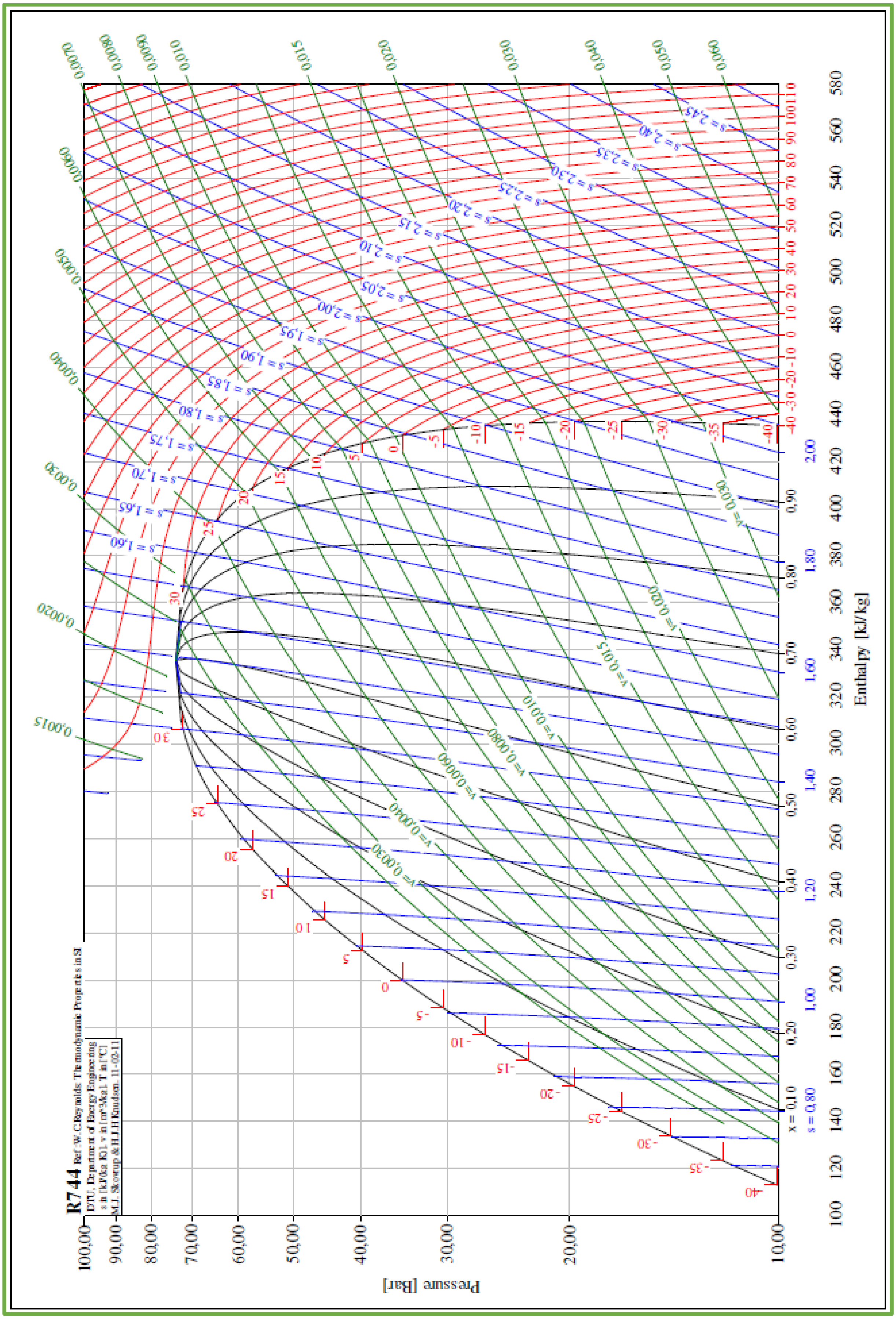
10 P-T TABLE / CHART

CO2 Saturated Conditions

Temperature (°C)	Temperature (°F)	Pressure (abs.) (bar)	Pressure (abs.) (psi)
31	87.8	73.74	1070
30	86.0	72.05	1045
29	84.2	70.42	1022
28	82.4	68.82	998
27	80.6	67.27	976
26	78.8	65.74	954
25	77.0	64.25	932
24	75.2	62.79	911
23	73.4	61.36	890
22	71.6	59.95	870
21	69.8	58.57	850
20	68.0	57.22	830
19	66.2	55.89	811
18	64.4	54.58	792
17	62.6	53.30	773
16	60.8	52.05	755
15	59.0	50.81	737
14	57.2	49.60	720
13	55.4	48.41	702
12	53.6	47.24	685
11	51.8	46.10	669
10	50.0	44.57	647
9	48.2	43.87	637
8	46.4	42.78	621
7	44.6	41.70	605
6	42.8	40.67	590
5	41.0	39.65	575
4	39.2	38.64	561
3	37.4	37.66	547
2	35.6	36.69	533
1	33.8	35.74	519
0	32.0	34.81	505
-1	30.2	33.90	492
-2	28.4	33.00	479
-3	26.6	32.12	466
-4	24.8	31.26	454
-5	23.0	30.42	442
-6	21.2	29.59	430
-7	19.4	28.78	418
-8	17.6	27.99	406
-9	15.8	27.21	395
-10	14.0	26.45	384
-11	12.2	25.71	373
-12	10.4	24.98	363

Temperature (°C)	Temperature (°F)	Pressure (abs.) (bar)	Pressure (abs.) (psi)
-13	8.6	24.26	352
-14	6.8	23.56	342
-15	5.0	22.88	332
-16	3.2	22.21	323
-17	1.4	21.55	313
-18	-0.4	20.91	304
-19	-2.2	20.28	295
-20	-4.0	19.67	286
-21	-5.8	19.07	277
-22	-7.6	18.49	269
-23	-9.4	17.91	260
-24	-11.2	17.35	252
-25	-13.0	16.81	244
-26	-14.8	16.27	236
-27	-16.6	15.75	229
-28	-18.4	15.25	222
-29	-20.2	14.75	214
-30	-22.0	14.26	207
-31	-23.8	13.79	200
-32	-25.6	13.33	194
-33	-27.4	12.88	187
-34	-29.2	12.44	181
-35	-31.0	12.02	175
-36	-32.8	11.60	169
-37	-34.6	11.19	163
-38	-36.4	10.80	157
-39	-38.2	10.42	152
-40	-40.0	10.04	146
-41	-41.8	9.68	141
-42	-43.6	9.32	136
-43	-45.4	8.98	131
-44	-47.2	8.64	126
-45	-49.0	8.32	121
-46	-50.8	8.00	116
-47	-52.6	7.70	112
-48	-54.4	7.40	108
-49	-56.2	7.11	104
-50	-58.0	6.83	100
-51	-59.8	6.55	95
-52	-61.6	6.29	92
-53	-63.4	6.03	88
-54	-65.2	5.78	84
-55	-67.0	5.54	81
-56	-68.8	5.31	77


R744 Ref: W.C.Reynolds: Thermodynamic Properties in SI
DTU, Department of Energy Engineering
s in [kJ/(kg K)], v in [m^3/kg], T in [ºC]
M.J. Skovrup & H.J.H Knudsen. 11-02-11
Pressure [Bar]
Enthalpy [kJ/kg]
x = 0,10
s = 0,80