# Americas novelty:

# $CO_2$ TECHNOLOGY & TRAINING CENTER

Bitzer Brazil inaugurates the first $CO_2$ Technology & Training Center of The Americas in its plant in Sao Paulo.

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## First $CO_2$ Technology & Training Center of The Americas installed in Bitzer's plant in Sao Paulo, Brazil.

Nature demanded and Bitzer complied with a wide program of development and global standardization, utilizing new technologies with natural alternative refrigerants such as Carbon Dioxide - $CO_2$, thus preventing the problems caused by (H) CFC's and HFC's in the Ozone Layer which contributes to Global Warming (the greenhouse effect).

Bitzer also consolidates its presence in Brazil through its new and modern plant, Bitzer Compressores Ltda, which is located at Cotia city in Sao Paulo, and is responsible for attending to the necessities of the Latin American sector. This is the fruit of a company with more than seventy years of service and tradition. Bitzer is a worldwide leader in technology on equipment manufacturing for refrigeration and air conditioning of the highest quality and proven efficiency.

The focus of the $CO_2$ Technology & Training Center of Bitzer Brazil, which is the only one of its kind in the Americas, is to present new technologies and to promote the technical improvement of a simple and objective way of Carbon Dioxide application to be used as a refrigerant in the Industrial and Commercial Refrigeration systems. During the $CO_2$ training courses, safety issues, design features, installation, commissioning, servicing and maintenance procedures will be discussed with practical and theoretical classes. Moreover, energy efficiency comparisons will be carried between the $CO_2$ system and the direct expansion conventional systems using the R404A and R22.

### Equipment features of the $CO_2$ Training & Technology Center

The first stage of the $CO_2$ Training & Technology Center design was completed at the end of 2008. One of the main features is the installation of 03 refrigeration racks with similar cooling capacities that use the most modern semihermetic compressors of the Octagon® series in parallel application, and they are used on medium and low evaporation temperature. According to figure 01, each rack uses a different refrigerant, being the $CO_2$ in the subcritical condition ($CO_2$/R404A), R404A and R22.


Figure 01: Detail of the refrigeration racks from the $CO_2$ Technology & Training Center of Bitzer Brazil.

The $CO_2$ Training & Technology Center also has 03 cold rooms, two being of medium temperature (cooling and walk-in cooler) and one of low temperature (freezing). Installed in each cold room are the evaporators (air coolers) of their respective racks ($CO_2$, R404A and R22). In addition, there are also two low temperature islands, which are linked only to the $CO_2$ rack. In order to conduct energy efficiency comparisons, the equipment operates at just one rack at a time, which means that while one rack is operating the other two will remain turned off.

Figure 02: Detail of the islands and walk-in cooler.

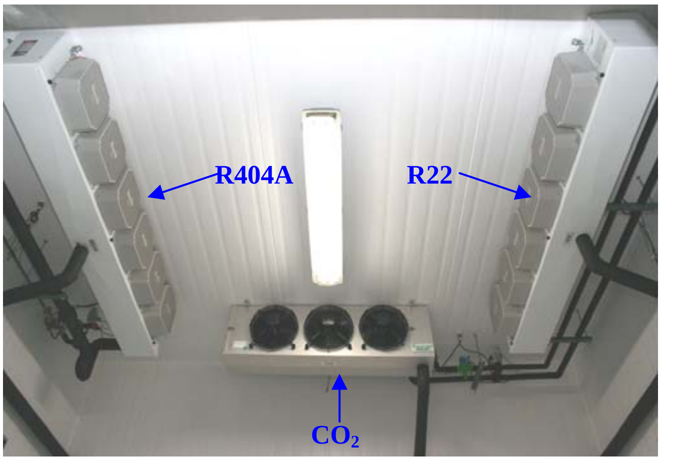


Figure 03: Detail of the air coolers installed in the cold rooms for medium and low temperature.

All the conditions for the operation of the refrigeration equipment are controlled and monitored by the Pco electronic controllers that are fitted in each rack. Moreover, there is a supervision system called PlantVisorPRO, which comes with a high level of precision and reliability and controls the entire refrigeration plant. All electronic controllers were donated by Carel, Italy. This supervision system allows access from all controllers and system variables via the RS 485 Carel; it also has remote access via LAN or the Internet. It comes with an important feature, which sends notification of any alarms activated, by fax or SMS and has graphical descriptions of all system variables.


Figure 04: Detail of the supervision system.

The second stage of the $CO_2$ Training & Technology Center design is predicted to commence at the end of 2009. This will include the installation of two more refrigeration racks, one rack being with $CO_2$ in the transcritical condition and the other one using $CO_2$ and Ammonia (R717) in the subcritical condition. There will also be a water chiller with R1270 that will be used as the center's air conditioner and besides it will keep a constant temperature of the condensing water used in the racks with water-cooled condensers.

## Operation options of each system to conduct the energy efficiency comparisons

### Compressors:

The compressors of each rack also have the operation option with both the Carel frequency inverter and the head capacity control (except for compressor model 4TCS-8.2 which is used in connection with the R22 in low temperature with CIC (controlled injection cooling), and also for the $CO_2$ compressor model 2KC-3.2K which has only one head (2-cilynders), and as a result it is not possible for both compressors to operate by head capacity control). The application range is 30 to 70Hz for compressors with frequency inverters.


Figure 05: Detail of the $CO_2$ compressor.

Figure 06: Carel frequency inverters used in the compressors and condenser fans.

### Condensers:

Each rack has the operating option of both air and water-cooled condensers (mainly the high stage of the subcritical $CO_2$ rack). The air-cooled condenser fans also have the option to operate with frequency inverters and ON/OFF control pressure switches to control the condensing temperature. The water-cooled condenser types are shell-and-tube and they operate with a water-cooling tower.

Figure 07: Detail of both the air and water-cooled condensers.

Figure 08: Detail of the air-cooled condensers and the water-cooling tower.

**Evaporators:** The air-coolers that use the R404A and R22 which are fitted in the cold rooms are direct expansion type (DX); they have the operation option with thermostatic expansion valves (TEV) and Carel electronic valves (EV). The $CO_2$ air-coolers are from Bitzer Australia (Buffalo Trident), the air-cooler for low temperature is DX and uses only the Carel electronic valve option. The other two $CO_2$ air-coolers run with liquid recirculation and only use manual expansion valves to control the refrigerant flow.

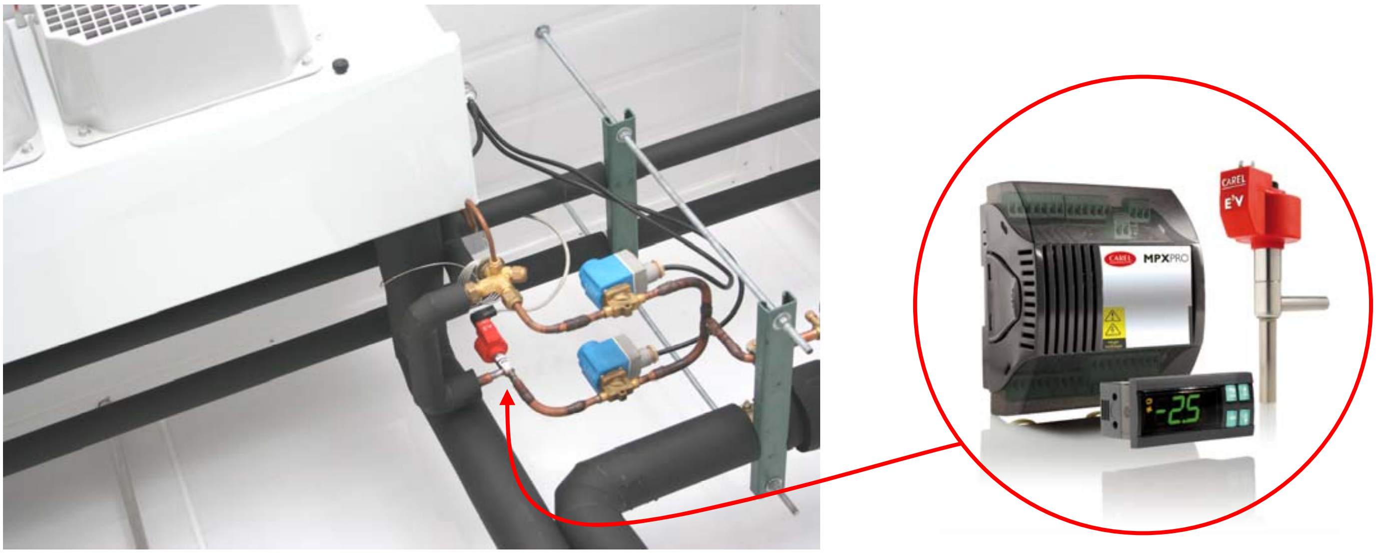


Figure 09: Detail of both options with thermostatic expansion valve and Carel electronic valve fitted in the air-coolers in connection with the R404A and R22. The $CO_2$ air-coolers for low temperature fitted in the freezing room and islands run only with Carel electronic valves.

The Carel electronic valves run with 480 different positions of openings and have an excellent performance in connection with $CO_2$. The "brain" of this valve is an electronic module called MXPRO that receives all the information regarding the temperature and pressure in the evaporator outlet in order to control the opening and closing of the valve according to the superheating. It uses a PID control algorithm that guarantees stabilization of the temperature. As well as controlling the evaporator superheating, the MXPRO controls the defrost routines in real time. It also controls the routine of the evaporator fans along with the liquid line solenoid valve. All the MXPRO's send information such as alarms, the percentage of valve openings, pressure updates and temperature, etc, from the valves to the PlantVisorPRO supervision system, where it is possible visualize, monitor and optimize the operational conditions of all the electronic valves.

MT evaporator defrosting is achieved by off cycle (air) while LT evaporator defrosting is achieved with the electric element, mainly for the LT CO2 evaporators (Islands and LT cold room).

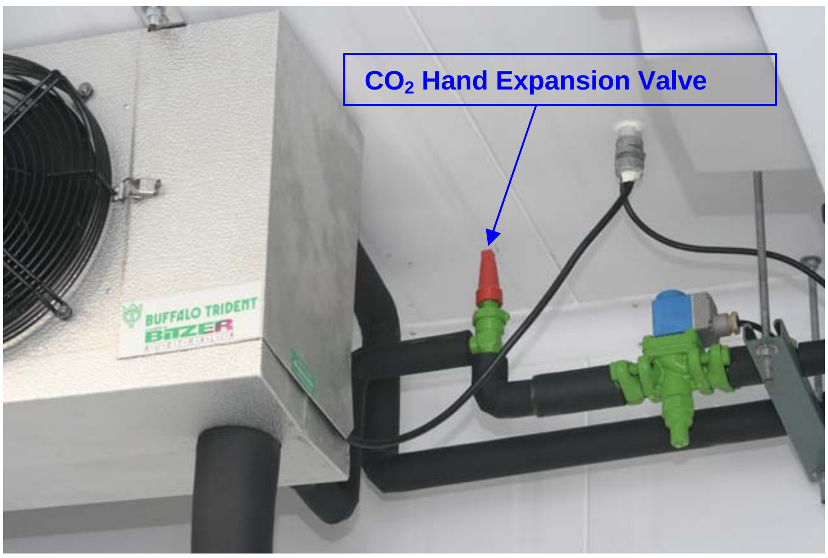


Figure 10: Detail of the $CO_2$ hand expansion valve used in the MT $CO_2$ evaporators that runs with liquid recirculation.

Table 01 lists the major technical data for each refrigeration rack of both the MT and LT systems:

| | **Subcritical $CO_2$ Rack ($CO_2$/R404A)** | **R404A Rack** | **R22 Rack** |
|---|---|---|---|
| **MT design condition** | $T_C$ = -5ºC ($CO_2$ liquid re-circ.)<br>$T_O$ = -10ºC (high stage)<br>$T_C$ = 40ºC (high stage) | $T_O$ = -10ºC<br>$T_C$ = 40ºC | $T_O$ = -10ºC<br>$T_C$ = 40ºC |
| **LT design condition** | $T_O$ = -30ºC ($CO_2$ - DX)<br>$T_C$ = -5ºC ($CO_2$) | $T_O$ = -30ºC<br>$T_C$ = 40ºC | $T_O$ = -30ºC<br>$T_C$ = 40ºC |
| **Compressors** | 01 x 2KC-3.2K ($CO_2$)<br>01 x 4CC-9.2.Y (R404A) | 01 x 4CC-9.2Y (MT)<br>01 x 4TCS-8.2Y (LT) | 01 x 4CC-9.2 (MT)<br>01 x 4TCS-8.2 (LT) |
| **MT cooling capacity** | **21.0 kW** | **21.0 kW** | **19.82 kW** |
| **LT cooling capacity** | **9.81 kW** | **10.66 kW** | **9.9 kW** |
| **Total refrigerante charge** | 32 Kg | 125 Kg | 115 Kg |
| **Total copper piping** | 62 Kg | 196 Kg | 187 Kg |
| **Total oil charge** | 3 liters | 20 liters | 18 liters |
| **Oil type** | BSE60K (Polyolester oil) | BSE32 (Polyolester oil) | B5.2 (semi-synthetic oil) |
| **MT and LT compressor nominal power** | 3 Hp ($CO_2$)<br>9 Hp (R404A)<br>**Total = 12 Hp** | 9 Hp (MT)<br>7.5 Hp (LT)<br>**Total = 16.5 Hp** | 9 Hp (MT)<br>7.5 Hp (LT)<br>**Total = 16.5 Hp** |
| **MT compressor power input** | 8.66 kW (R404A high stage) | 8.66 kW | 7.49 kW |
| **LT compressor power input** | 2.26 kW ($CO_2$ low stage) | 6.72 kW | 6.11 kW |
| **Rack power input** | 10.92 kW (compressors)<br>0.5 kW ($CO_2$ pump)<br>**Total = 11.42 kW** | **Total = 15.38 kW** | **Total = 13.6 kW** |

Table 01: Technical data of multicompressor refrigeration systems.

The cooling capacity of the MT and LT multicompressor refrigeration systems is higher than the required thermal load from cold rooms and Islands, as table 02 shows:

| | **MT cold room** | **Walk-in Cooler** | **LT cold room** | ***Low temperature Islands** |
|---|---|---|---|---|
| **Dimensões** | 3.5m x 4.0m x 3.5 m | 3.5m x 4.0m x 3.5 m | 3.5m x 4.0m x 3.5 m | 5m total length |
| **Thermal load** | **7.5 kW** | **7.5 kW** | **7.5 kW** | **2.5 kW** |
| **Internal temperature** | 0ºC | +2ºC | -25ºC | -25ºC |

Table 02: Overview of refrigeration points.

* The two LT Islands only run with the $CO_2$ refrigeration rack.

## $CO_2$ subcritical system's operation principle

According to figure 11, the MT $CO_2$ evaporators run with liquid recirculation at –5ºC, while the LT $CO_2$ evaporators run with direct expansion at –30ºC of evaporating temperature through the vapor compressor cycle using an Octagon® semi hermetic reciprocating compressor.

To take advantage of the highly efficient of $CO_2$ refrigerant, it is used in the low-pressure stage of a two stage cascade system where the refrigerant is being condensed at approx –5ºC (subcritical condition).

This low stage system is linked to a second refrigeration system (the high stage system), which transfers the heat collected from the refrigerated space by the $CO_2$ system and rejects this heat into the atmosphere through a conventional air or water-cooled condenser.

Due to the high vapour density and very high volumetric efficiency, specially designed Bitzer compressors using $CO_2$ refrigerant can achieve **energy savings far in excess of conventional refrigeration systems using the R404A and R22.**

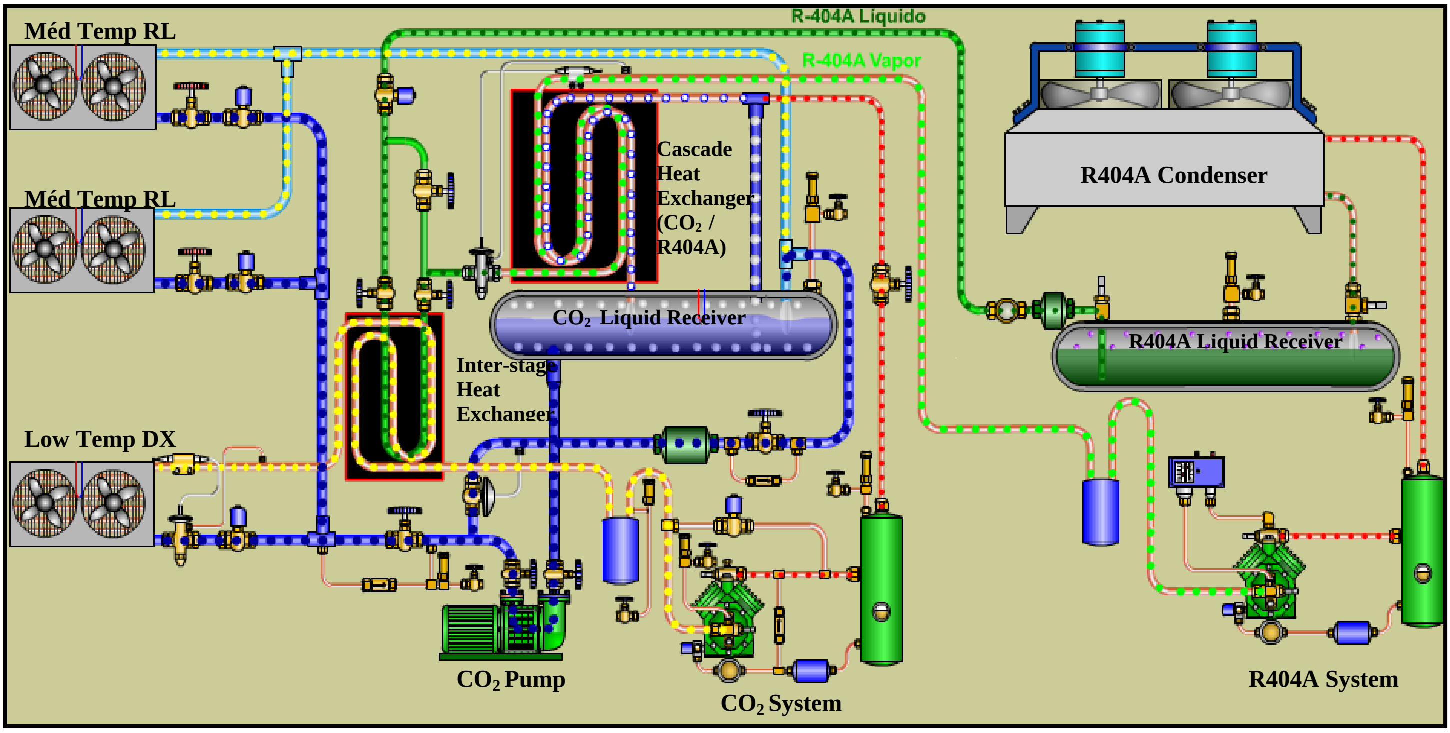


Figure 11: Basic diagram of the cascade system using $CO_2$ / R404A. The LT evaporators run with direct expansion – DX and the MT evaporators run with liquid re-circulation.

The cascade system design can also take advantage of a high degree of liquid sub cooling, which results in substantial reductions in pipe line diameters and a reduced refrigeration charge, compared to conventional refrigerants such as R404A and R22.

As a general guide, pipeline sizes can be reduced to approx 1/5 of the line sizes currently used with R404A and R22 for the same system capacity.

Due to the purchase price of $CO_2$ being considerably less expensive than what is currently used commercially, such as R404A and R22, the total cost of the refrigerant charge can be significantly reduced. (See table 01).

While the medium temperature system through the liquid re-circulation system does not generally provide significant reductions in energy costs, substantial savings can be achieved through a reduced refrigerant charge and a real reduction in the actual cost of the refrigerant.

Additional benefits are apparent with smaller evaporator coils being used and a more rapid room temperature pull down due to increased heat transfer, which is achieved by the flooded coils.

The medium and low temperature refrigerant circuits can be combined into the one integrated piping system, so the equipment size can be surprisingly small.

At the heart of the system is a specifically designed liquid receiver vessel, which feeds liquid $CO_2$ to a liquid pump. This pump supplies the refrigerant to the MT and LT $CO_2$ evaporators.

The $CO_2$ liquid being pumped through the medium temperature evaporators partially boils away, and returns to the receiver vessel as a liquid / gas mixture still at the constant temperature of approx –5°C.

The low temperature evaporators are also fed from this $CO_2$ liquid supply. In this case the refrigerant is fed through an expansion valve, which ensures that only superheated refrigerant vapour is returned to the low stage compressor.

The low side vapour is compressed to a discharge gas pressure / temperature. This high pressure discharge gas is then directed to the same condenser (cascade heat exchanger) as the medium temperature refrigerant return, where they are both condensed to a liquid and returned to the liquid receiver.

## Pressure relief valves

Each conventional system using R404A and R22 has only one pressure relief valve, which is fitted to the liquid receiver. Therefore when those systems stop, the high side pressure is going to fall and the low side pressure will rise until it equalizes to a pressure that is equivalent to the ambient temperature. Consequently, if a valve in any of those systems is closed, the pressure is unlikely to rise dramatically. For safety issues, $CO_2$ cannot be trapped in any confined space in the system, mainly in its liquid phase, if allowed, its pressure and temperature will rise if any heat transfer occurs. For this reason, a pressure relief valve was fitted to each part of the system, which is able to be isolated and thus avoid $CO_2$ trapping. As a result, any pressure reaching beyond the 40 bar high side and the 25 bar low side will be relieved, and the system will continue to run safely.

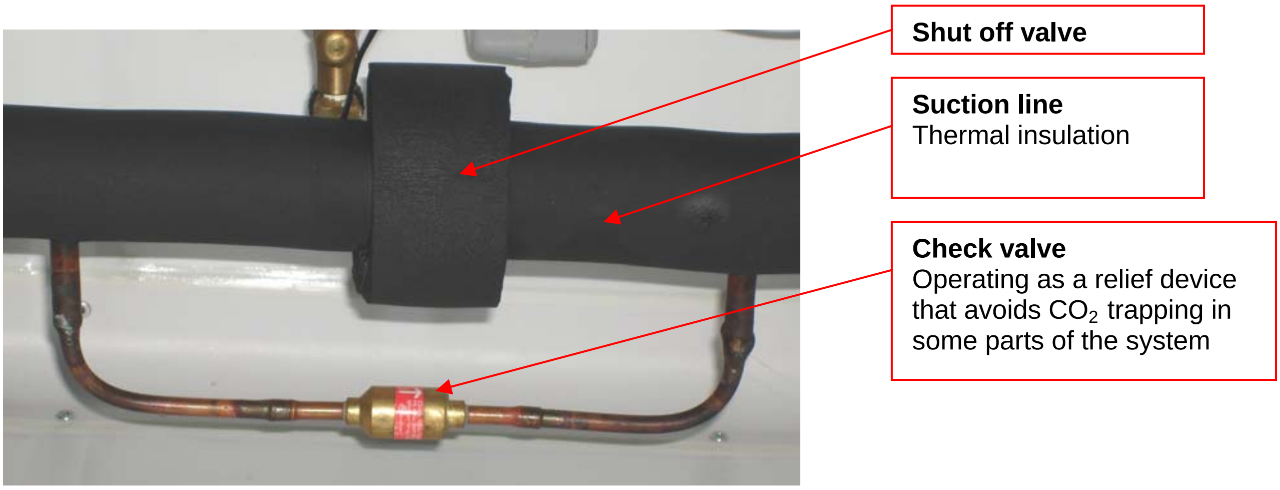


Figure 12: Inline pressure relieving bypass valve fitted across the shut off valve.

The major areas of the $CO_2$ rack are protected by pressure relief valves. These areas include the high and low pressure sides, the liquid receiver and the $CO_2$ pump discharge line (liquid line). For good practice, each relief valve is installed with a ¼"service valve for maintenance purposes. Therefore this will provide access to the system at multiple points, where the refrigerant can be added, removed, vented and transferred, or the pipes can be evacuated. Given that $CO_2$ forms dry ice at temperatures below -56°C or below 5,2 bar, transferring gas from one pipe to another is a very useful tool to prevent ice formation when liquid is present.

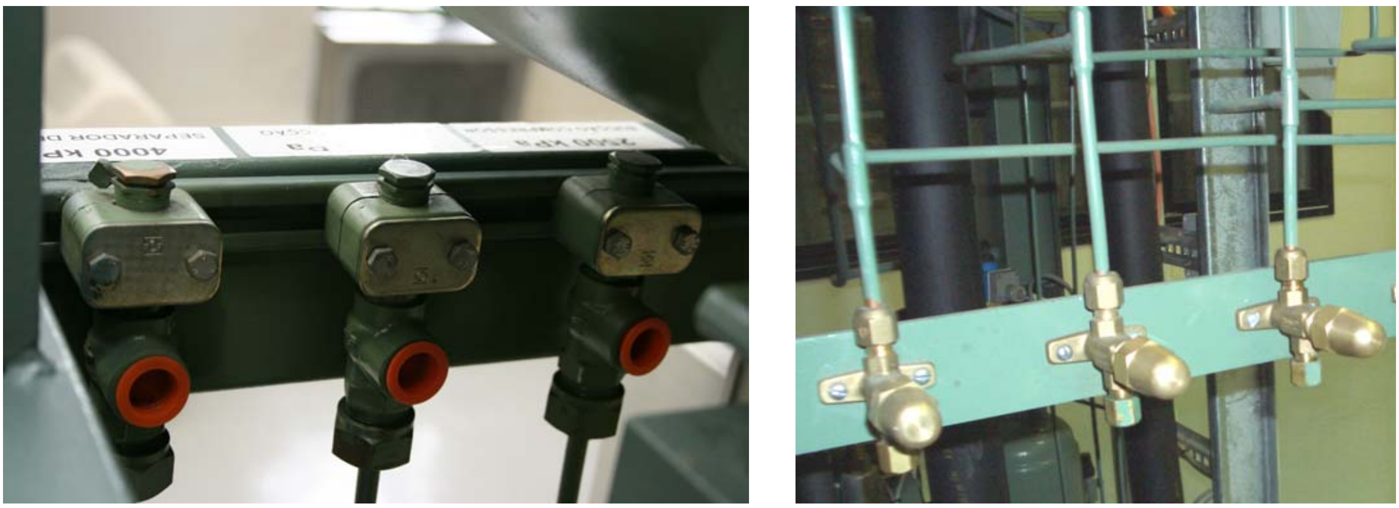

Figure 13: Rack based atmospheric pressure relief valves and service ports.

Relief valves should always be directed away from occupied areas preferably to an area that is outside and away from air conditioning intake ducts. The same procedure should occur when venting $CO_2$ into the atmosphere. It is important to know that when liquid $CO_2$ is vented from a system it will be at -56°C, and as the pressure falls to below 5,2 bar, its temperature will fall to -78°C and solid $CO_2$ (dry ice) will form.

To avoid any kind of obstruction in the safety blow off valves occurred by dry ice formation, it is recommended that a relief line of any description should not be mounted or fitted beyond the safety relief valve. Principally the relief lines should only reach up to the safety relief valves. If the $CO_2$ is released through a relief line fitted beyond the safety relief valve, the line will consequently freeze up and dry ice (solid $CO_2$) will form at the point of expansion, therefore it will still have high pressure $CO_2$ in that line which could potentially cause a problem for the service personnel. Figure 14 shows the safety relief valves installed in the external wall of the $CO_2$ Technology & Training Center, these valves are linked to a liquid receiver and a $CO_2$ pump discharge (liquid line). Both valves are set up to relieve the pressure exceeding the safe working value, which is 40 bar.

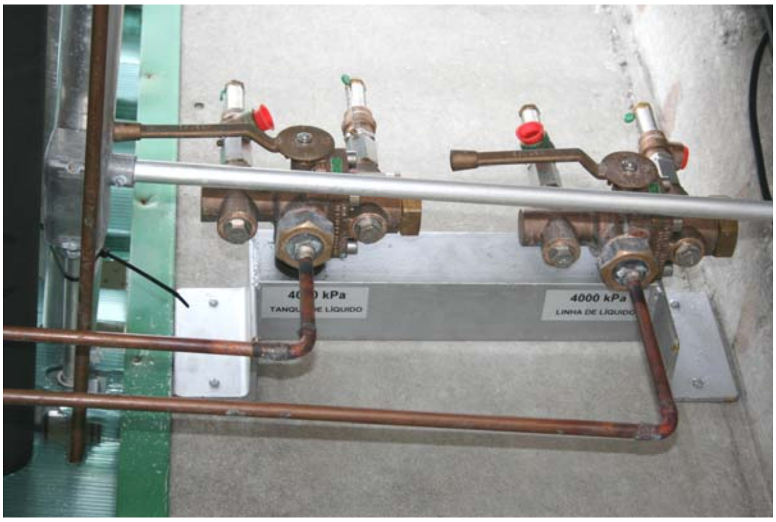


Figura 14: Detail of the pressure relief valves, wall mounted.

## $CO_2$ leak monitoring system

The $CO_2$ sensors (monitors) have been installed in the machine room and cold rooms to detect any $CO_2$ leak in order to activate the exhaustion system as well as the $CO_2$ alarm. The $CO_2$ sensors are infrared and have alarm limits of between 500 - 9,000 ppm.

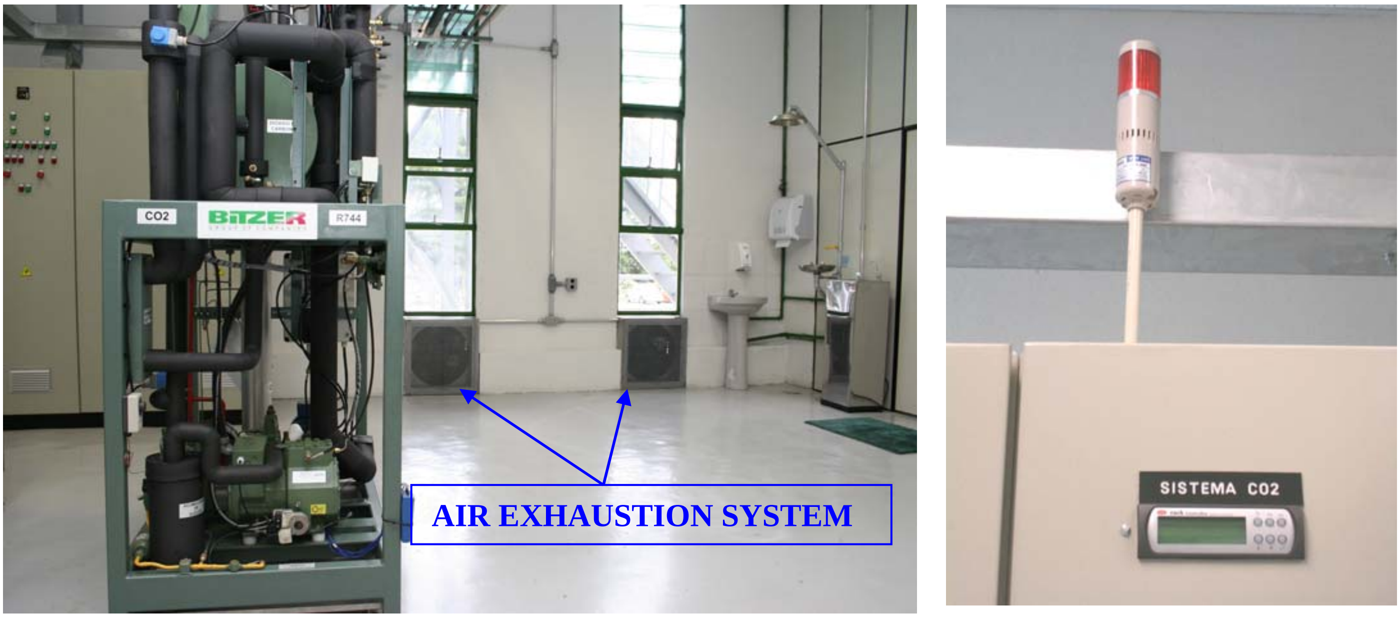


Figure 15: Detail of the air exhaustion system and the alarm system in the case of any $CO_2$ leak.

## $CO_2$ system's emergency unit

To avoid any problems with $CO_2$ pressure rising in the event of a power failure, there is a Bitzer condensing unit model LH64/2FC-2.2Y (standby system) fitted in connection with the $CO_2$ cascade heat exchanger (see figure 16). This condensing unit has the primary function of keeping cooled liquid $CO_2$ in the liquid receiver. This condensing unit, also known as the $CO_2$ emergency unit, is driven with both the concessionary power supply and an independent electric generator that operates automatically in the event of a power failure. However, there are other methods, which could be used to keep cooled $CO_2$ in the liquid receiver. For instance it may simply have a receiver vessel installed in the freezer room to keep its pressure below the relief settings (for a period of time) or by fitting a power generator to the high stage system, etc.

Figure 16: $CO_2$ standby system.

According to figure 17 below, it's possible to see the $CO_2$ standby system's electronic valve. This electronic valve is linked in parallel application to the high-pressure stage's electronic valve in the $CO_2$ cascade heat exchanger.

Carel electronic valve of the high-pressure stage

Carel electronic valve of the $CO_2$ standby system

Figure 17: Detail of the electronic valves used in the $CO_2$ cascade heat exchanger.

## $CO_2$ system's advantages on the systems with R404A and R22:

- Reduction of the electric energy consumption (approx 20 to 35%)
- Low compression ratio & increased useful life of the $CO_2$ compressor
- High $CO_2$ density & high pressure in the low pressure stage
- Reduction of $CO_2$ piping diameter sizes
- Reduction of $CO_2$ refrigerant charge
- Low price of $CO_2$ purchase

- High enthalpy & high degree of liquid sub-cooling & higher cooling capacity
- Low GWP & less carbon taxes ($CO_2$)
- Small volumetric displacement & smaller sized $CO_2$ compressors
- Smaller refrigeration rack & compact installation & smaller compressor numbers
- Smaller and efficient evaporator coils
- Reduced installation & maintenance costs

## Main points that should be considered

It is important and necessary that all technical teams (O&M, installer, end customer, etc.), be previously trained with $CO_2$ technology before starting with the installation, operation and maintenance of the $CO_2$ refrigeration equipments.

The $CO_2$ subcritical system is in some sense very simple and mechanically quite straightforward, but in other areas it can be extremely complicated and requires an extensive understanding of how the system will behave under the changing conditions. Understanding how the system will react in the event of a power failure or a failure in the high stage that removes the cooling from the inter-stage heat exchanger, are the most important issues that need to be addressed.

It is imperative that every possible scenario is run through long before the equipment is even delivered to a site, so that the commissioning team knows exactly how the system will react, and how the staff who are responsible for the system, should in turn react. Only then can the system be installed and operated in a safe and reliable manner, to the satisfaction and safety of all.

Service personnel need an intimate knowledge of the inter-relationships between the high and low stage control systems, as well as each stages individual control systems to be effective at maintaining and servicing of these systems. They must familiarize themselves with all aspects of the plants operation, control and safety issues to ensure that the system will operate in a safe and efficient manner over its working operational life.

## General information about the $CO_2$ training course

Bitzer Brazil's experienced engineers have developed this Carbon Dioxide course. The information about the use of $CO_2$ in refrigeration systems was collected from many sources around the world and put together into a five-module course, including: **$CO_2$ Fundamentals; Systems Safety with $CO_2$ Applications; $CO_2$ Refrigeration Systems; $CO_2$ Refrigeration System Components; Commissioning, Servicing and Maintenance Procedures.**

Bitzer Australia has also contributed to the development of the $CO_2$ course by providing valuable learning material, refrigeration equipment and enough technical information. All this knowledge and shared experiences in the use of $CO_2$ has been brought together to create this ground-breaking course, providing very clear and useful information about the use of $CO_2$ used as a refrigerant.

**Target Audience:** The $CO_2$ training courses are intended for students, technicians, engineers, designers, installers and for those interested for this subject as well.

**Duration:** 5 days with practical and theoretical classes.

**Languages:** The $CO_2$ training courses will be provided in the portuguese, spanish and english versions.

For more information about the $CO_2$ training courses please contact Mrs. Patricia Javara.
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