thermea. Energiesysteme

Product information

Compressed Air Refrigeration Dryer

Series thermeco$_2$ ADR/ADS 3,300 – 61,200

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1 Description of Series thermeco₂ ADR/ADS 3,300–61,200

1.1 General Information

The series thermeco$_2$ ADR/ADS compressed air refrigeration dryers consists of 11 basic types with optimal capacity ranges for adaptation to the respective usage scenario. The compressed air dryers principally work with the environmentally friendly refrigerant CO_2 (R744). The throughput for drying an air volume flow lies between 3,300 to 61,200 m^3/h (relating to 20 °C, 1 bar; operating pressure 7 bar; compressed air intake temperature 35 °C; pressure dew point 3°C according to DIN ISO 7183). The water-cooled design is standard.

If desired, heating capacities from 45 to 840 kW can be decoupled at supply flow temperatures of up to 90 °C at complete utilisation.

The refrigeration machines of the ADR/ADS compressed air refrigeration dryers are engineered with proven components from CO_2 refrigeration technology and are designed especially for the advanced refrigerant CO_2. They are based on the proven "High temperature heat pumps and liquid chillers thermeco$_2$ HHR 45 – HHR 1000" and "thermeco$_2$ HHS 1000" series offered by thermea. Depending on the capacity rating, the machines are equipped with 1 to 6 reciprocating type compressors or a one screw compressor. This provides the precision capacity control. Frequency converters are used for a compressor to provide infinitely variable capacity adjustment. To prevent corrosion damage, the compressed air side, including heat exchangers, is manufactured from stainless steel. An automatic condensate drain and a mist collector are integrated. A Siemens Simatic S7 PLC with convenient touchpanel, handling control and regulation, is integrated in the switching cabinet.

The compressed air refrigeration dryers are marked by a robust design and very compact construction. They contain complete internal piping and are electrically wired with the switching cabinet. Merely the electrical connection, compressed air connection, cooling or hot water connection (for water-cooled refrigeration machine), condensate drain and the connection to the higher level control level need to be established.

1.2 Special benefits

- **Eco-friendly refrigerant CO_2 (R744)**

The use of the natural refrigerant CO_2 ensures great eco-friendliness. CO_2 is taken from the natural metabolic cycles or technical processes, does not contribute further to the greenhouse effect (GWP= 1) and does not contribute to ozone depletion (ODP= 0). The choice of CO_2 as a refrigerant complies with the current developments for the reduction of environmental pollution in the heat pump and refrigeration industry.

Unlike other refrigerants, CO_2 is not threatened by restrictions or even prohibitions. It is a colourless and odourless substance and it is not combustible with air in any concentration and is classified in the safety group A1 (none or only immaterial toxic or caustic effect). Another advantage is its chemical stability at high temperatures and the neutral behaviour to the operating media and materials used in the refrigeration cycle.

The currently widely used fluorinated refrigerants contribute to the increase of the greenhouse effect and thus the acceleration of climate change. For this reason, natural environmentally friendly refrigerants will increasingly gain acceptance in the coming years.

- **Broad scope of applications and heat-cold coupling**

The selection and generous dimensions of all the components and the very fine capacity adaptation to the respective application scenario allow for the nearly unlimited employment of the compressed air dryers. Performance increases can be easily realised by combining several modules with a higher level control. The heat of the refrigeration machine can be transferred both to a cooling tower at 40 °C and a heating grid at 90 °C.

- **High operating reliability**

The thermeco$_2$ compressed air refrigeration dryers are manufactured in compliance with the generally valid and accepted standards of good practice. They conform to the relevant principle standards and directives. The broad application scope combined with the flexible and freely programmable PLC control unit Siemens Simatic S7 ensure very high operational reliability because a customer-specific solution strategy for trouble-free operation can be implemented even in extreme operating conditions.

- **Service-friendly industrial design**

All machine parts are dimensioned in a way that does not require recurring inspections of the pressure tanks according to the German directives over the period of utilisation. The suction side of the CO_2 circuit is designed for a possible pressure increase up to 100 bar thus making any additional cooling of the refrigeration machines during standstill unnecessary.

The modern concept of the compressed air dryers is based on the use of special CO_2semi-hermetic reciprocating type compressors and screw compressors, developed for transcritical CO_2 applications with a pressure up to 130 bar. The nearly maintenance-free semi-hermetic design of the reciprocating type compressors provides a high degree of reliability, service-friendliness and leak integrity of the refrigeration systems.

To prevent any corrosion damage the compressed air side, including heat exchanger, is manufactured from stainless steel. All compressed air-side components are purchased from experienced manufacturers. The transport of the media in the heat exchangers has been chosen to favour simple cleaning and maintenance of the apparatuses.

- **Engineered and manufactured "Made in Germany" - with a certificate**

thermea. Energiesysteme GmbH engineers and manufactures compressed air refrigeration dryers according to principle European directives and standards and is certified according to ISO 9001. thermea possesses extensive know-how of the refrigerant CO_2 gained in the area of high capacity high temperature heat pumps for industrial applications.

All machines are type tested by TÜV SÜD and possess the CE marking.

The quality inspections, compressive strength tests, leak tests and electrical tests by the factory are met. All the machines are subjected to test runs on the test bench to verify their functional reliability.

1.3 Nomenclature

Table 1: Nomenclature, example: thermeco$_2$ ADR 20,000-7-W

thermeco$_2$ ADR	Series designation
AD	**A**ir **D**ryer
R, S	**R**eciprocating compressor, **S**crew-compressor
20,000	Standard dryer capacity according to DIN ISO 7183
7	Operating pressure
W **L**	**W** water-cooled gas cooler **L** air-cooled (upon request)

2 Technical Data

2.1 Overview Table

Table 2 lists the throughput for drying an air volume flow at standard conditions for the series thermeco$_2$ ADR/ADS at transcritical operation. Because of the already mentioned low critical temperatures of the CO_2 (critical point 30.98 °C/73.77 bar) the CO_2 refrigerating machines will run at transcritical operating conditions at the reference conditions according to DIN ISO 7183.

Table 2: Throughputs thermeco$_2$ ADR series

Machine type	ADR …	3,300	4,400	5,500	7,600	11,100	16,600	22,100	30,800	41,000	61,200
Volume flow	m³/h	3,300	4,400	5,500	7,600	11,100	16,600	22,100	30,800	41,000	61,200
Heating capacity)*	kW	45	60	75	105	150	230	305	425	565	840

)* hot water supply flow temperature: 80 °C

thermeco$_2$ ADS series

Machine type		ADS 46,100
Volume flow	m³/h	46,100
Heating capacity)*	kW	715

)* hot water supply flow temperature: 70 °C

Reference conditions according to DIN ISO 7183

Volume flow in m³/h, related to:	20 °C, 1 bar
Operating pressure p_1:	7 bar
Compressed air intake temperature $_1t$:	35 °C
Cooling water temperature $_ct$:	25 °C
Pressure dew point t_{pd}:	3 °C

(Changes reserved, performance values may deviate +/-10 %)

2.2 Application limits

Table 3: Application limits

	Unit of measure	min.	max.
Water temperature gas cooler inlet (cooling medium)	°C	10	50
Water temperature gas cooler outlet	°C	25	90
Compressed air inlet temperature of dryer	°C	30	50
Pressure dew point	°C	3	10
Operating pressure	bar	3	16
Permissible operating pressure (PS_{max}) refrigerating machine	bar	-	130
Permissible operating pressure on compressor suction side	bar	-	100, 130)*
Compressed gas temperature compressor outlet (CO_2)	°C	-	160, 120)*
Compressed gas temperature (gas cooler outlet CO_2)	°C	-	50
Ambient temperature during operation	°C	10	45
Temperature at storage and transport	°C	-20	50

Different value upon request)* for ADS

3 Special features of process management with CO_2 as a refrigerant

The special feature of the transcritical process management consists of the fact that the high pressure side lies above the critical point (KP= 31 °C). The critical point is located at the top of the bell-shaped two-phase area where the steam and liquid phase no longer exhibit any difference in density.

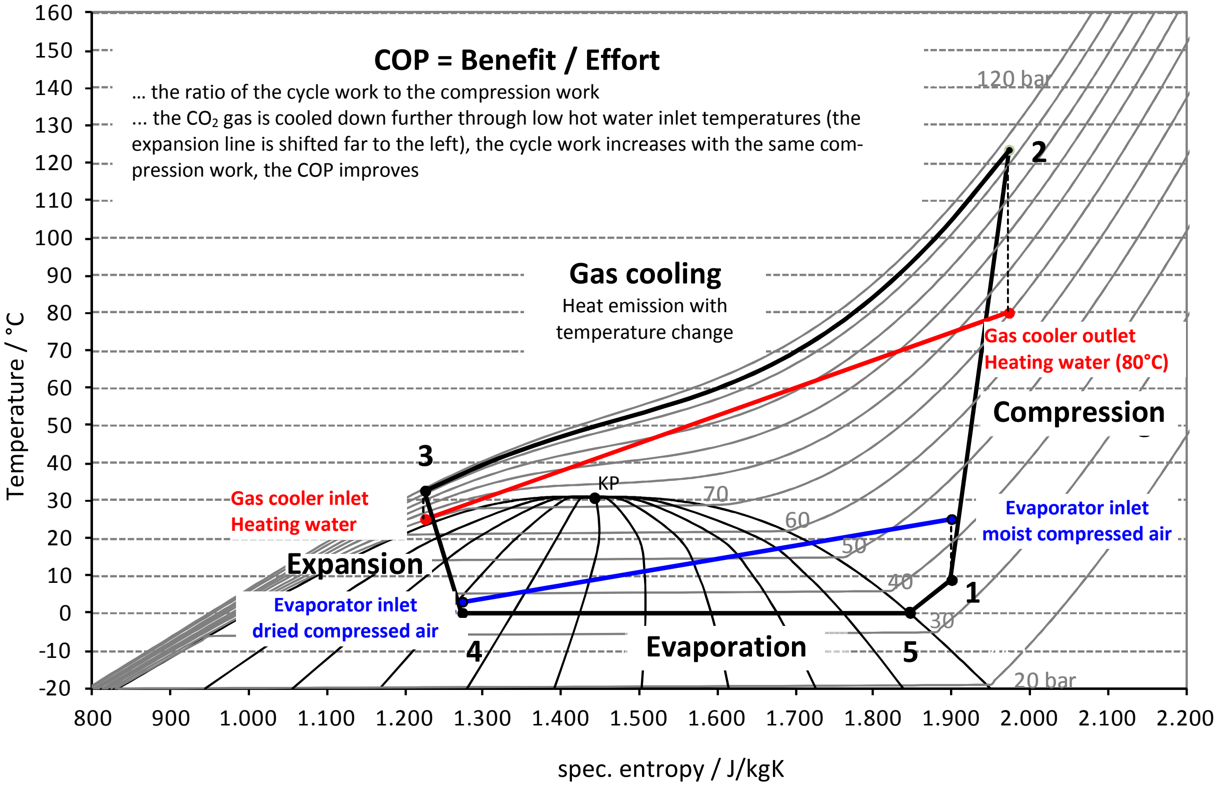

Fig. 1: Process depiction in T-s diagram (example)

Overheated CO_2 is present at point 1, which is sucked in by a compressor and compressed to point 2 by adding technical work. In this example, the pressure increases from approx. 35 bar to approx. 115 bar. The temperature rises from 8 °C to 123 °C. This highly compressed and hot gas is subsequently cooled down in at least one gas cooler at nearly identical pressure to 32 °C at point 3. The cooling medium is water, which is transported in the reverse flow to the gas (red line). In this example, the water is heated from 25 °C to 80 °C. From 3 to 4 the gas is expanded in an expansion valve to evaporating pressure into the two-phase area. The evaporation of the liquid CO_2 and slight overheating (5 to 1) occur from 4 to 5. The heat required for this is withdrawn from the compressed air (cooling and dehumidification).

The CO_2 refrigerating machines of the compressed air refrigeration dryers differ from conventional refrigerating machines through the transcritical process management and a "sliding" temperature change of the CO_2 in the gas cooler. While the refrigerant at subcritical process management is liquefied at a constant temperature, the heat emission in the transcritical range occurs in a sliding manner (see Fig. 2). The thermeco$_2$ refrigeration dryers work both in subcritical and transcritical mode. The changeover and required adaptation of the CO_2 filling take place automatically. The temperature of the medium entering the gas coolers acts as a changeover criterion.

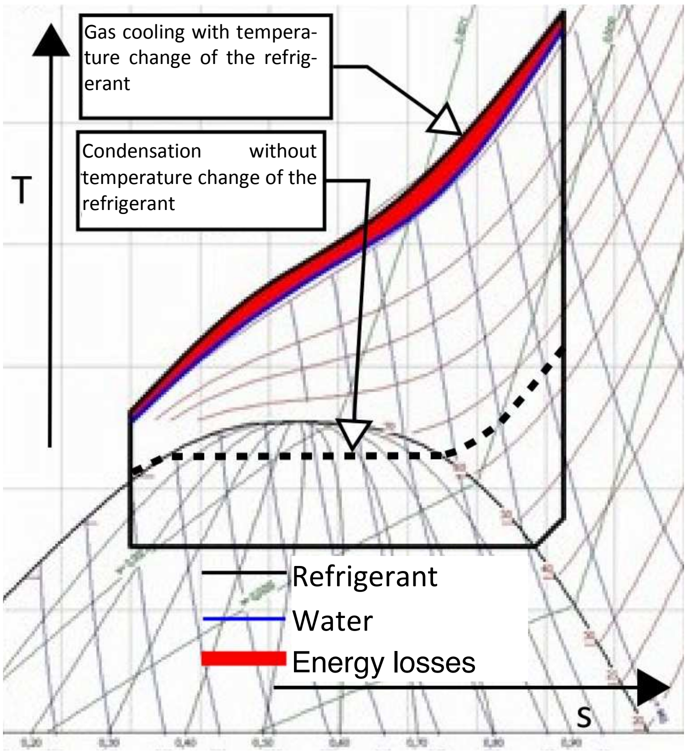

Fig. 2: Comparison of subcritical to supercritical process management

The energy efficiency of refrigeration machines is expressed by the coefficient of performance COP. It is the quotient from the refrigerating capacity $\dot{Q}_H$ (usable) and the related driving power P_{el} (input).

With the supercritical CO_2 process, the COP depends on the medium hot water temperature (with “conventional” refrigerating machines on the hot water outlet temperature). High COPs can be achieved with low average temperatures. When employing CO_2 compressed air dryers, this fact allows for utilising waste heat at a very high temperature level up to 90°C. Although in this isolated case the electrical consumption of the compressor increases, thermal heat is generated very economically in addition to the compressed air generated ("Heat-Cold Coupling"). In addition, the recooling effort for the refrigeration drying can be reduced.

Figure 4 shows a simplified application schema of a thermeco$_2$ ADR by way of example. In this example, the machine generates compressed air at standard conditions according to DIN ISO 7183.

The waste heat generated during this process can "classically" be transferred to the environment with 28/36°C cooling water via a recooling system.

In addition, part of the waste heat can be coupled to a heating system at a high temperature level, e.g. 65/85°C.

The entire thermal heat can be utilised if a thermal heat consumer with low return temperature is available (e.g. service water/hot drinking water heating). Figure 4 shows the service water/hot drinking water volume flow that can be generated for usable temperature from 45°C to 85°C at a heating water return temperature of 25°C.

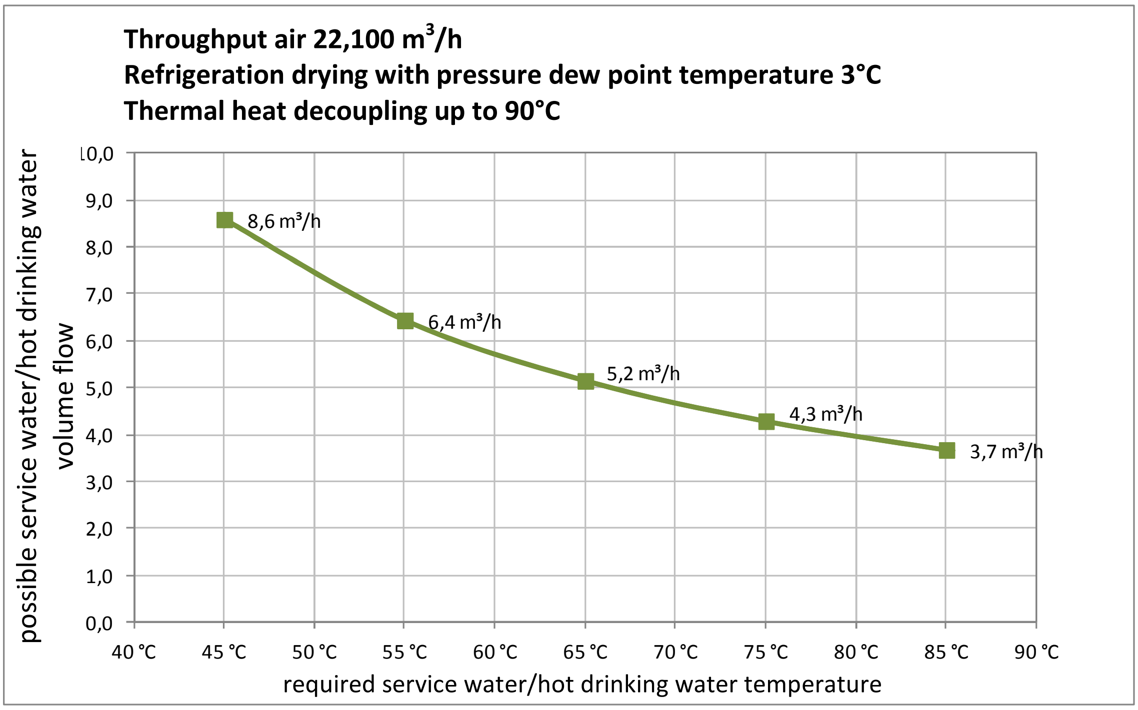

Fig. 3: Service water/hot drinking water volume flow at complete utilisation of the available heating output (example ADR 22.100)

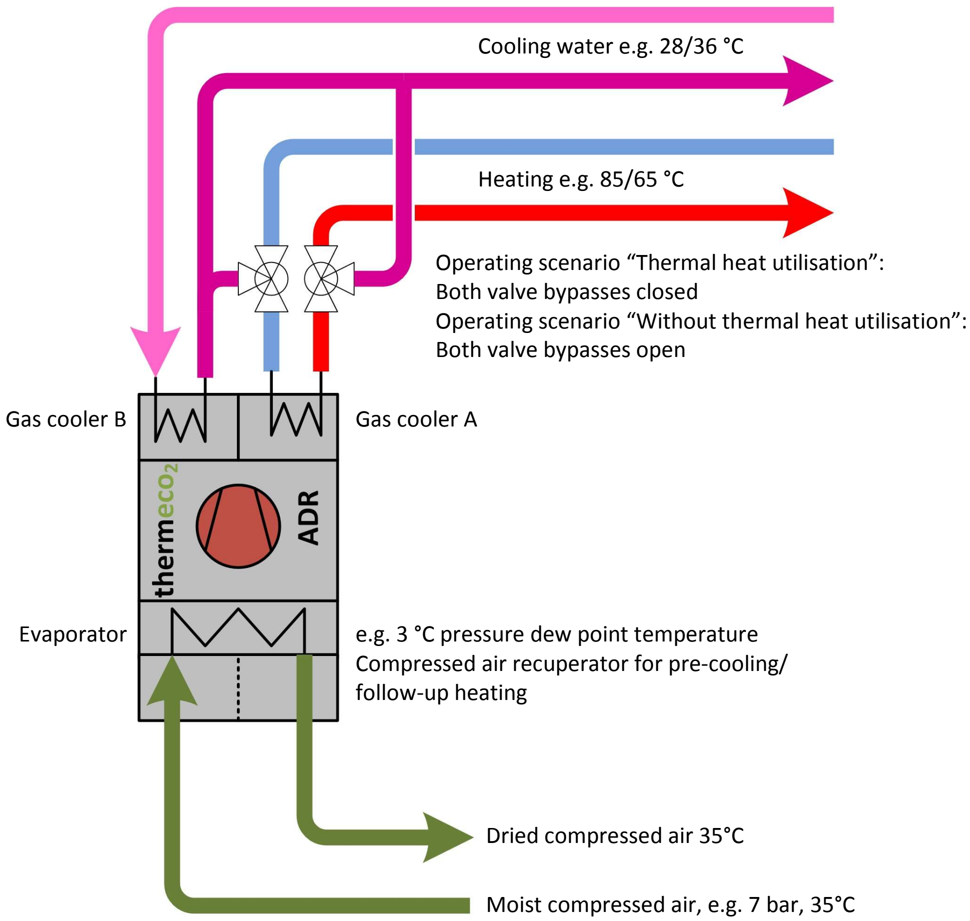

Fig. 4: Waste heat utilisation options on thermeco2 ADR/ADS compressed air refrigerant dryers

4 Function description

4.1 R&I Diagram

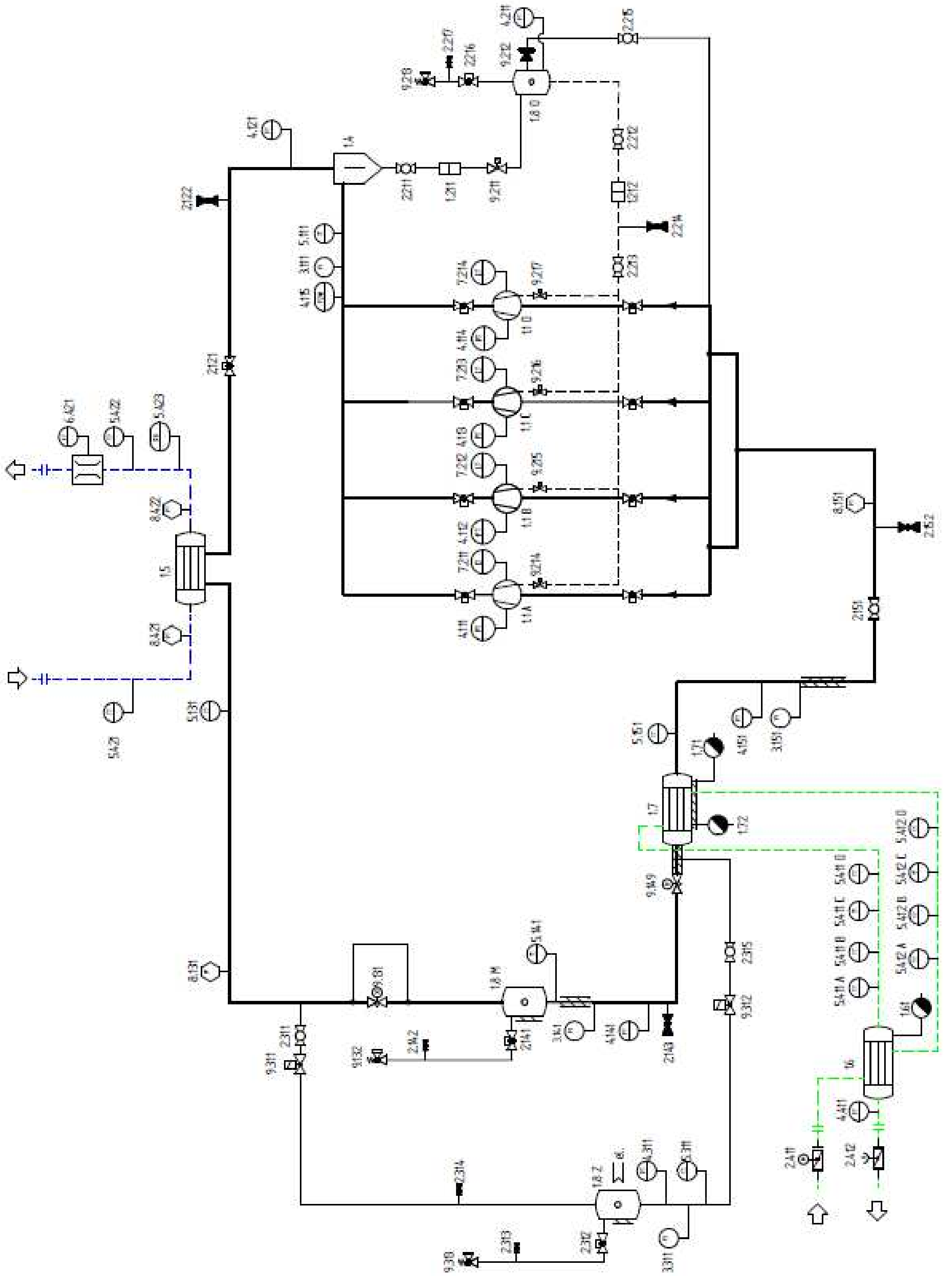

Fig. 5: R&I Schema (Example of ADR with four compressors)

4.2 Functional sequence

The air coming from the air compressors is pre-cooled in a recuperator (1.6) using the cold dry air from the evaporator outlet and is pre-dried in the process. Further cooling and dehumidification to the required pressure dew point takes place in the evaporator (1.7). Next, the cold air - after the separation of water droplets while flowing through the separator - is heated in the recuperator to the outlet temperature of approx. 25 thus preventing condensate formation in the pipes. The water directly separated in the two heat exchangers is each decoupled from the circulation via an automatic condensate separator.
The capacity control with the ADR series takes place by activating and deactivating compressors. Grading up to approx. 16% can thus be reached according to the number of compressors. Nearly infinitely variable output control can be achieved through the rotational speed control of a compressor with frequency converter.
The refrigeration circuit is a single-stage transcritical CO_2 circuit which, under favourable cooling conditions (e.g. in the winter), can run in subcritical operation. The changeover and required adaptation of the CO_2 filling take place automatically. The temperature of the medium entering the gas coolers acts as changeover criterion.
The compressors (1.1 A to 1.1 D) continuously suck the refrigerant from the evaporator (1.7) and compress it to high pressure. The compressors are followed by an oil separator (1.4) which separates delivered refrigerating machine oil from the CO_2 and returns it as needed via an oil management system with oil collectors (1.8 O) to the compressors. The heat is transferred to the cooling water in the heat exchanger (1.5) working as gas cooler or liquefier, depending on the temperature.

With supercritical operation, heat is withdrawn from the compressed gas in the heat exchangers functioning as gas coolers in isobar fashion using sliding temperature heat. The highly compressed refrigerant then flows to the high-pressure valve and is expanded to an intermediate pressure into the intermediate pressure receiver whereby partial liquefaction occurs in the mixing area. The liquid part is separated and collected in the collector.

The heat exchangers work as liquefiers at low cooling water temperatures. The liquid CO_2 is collected in the collector just as with conventional refrigerating machines. If due to rising cooling water temperatures the liquefying temperature approaches the critical value of 31°C, switching to "transcritical operation" occurs.
The CO_2 filling must be adjusted to both modes of operation. This happens fully automatically in that CO_2 is fed to the circuit from a so-called additional collector (1.8 Z) or is returned from the circuit to the additional collector.
The cooled or liquefied CO_2 is injected into the evaporator (1.7) via the expansion valve downstream from the refrigerant collector (1.8 M). Refrigerant overheating, measured via the pressure and temperature of the CO_2 on the evaporator outlet, acts as a controlled variable. Thus, the CO_2 circuit is closed.

Table 4: Main components

Item number	Designation	Remark
Main components		
1.1 A	Compressor 1	semi-hermetic
1.1 B	Compressor 2	
1.1 C	Compressor 3	
1.1 D	Compressor 4	
1.4	Oil separator	
1.5	Gas cooler	Tube and shell heat exchanger
1.6	Air – Air recuperator	Tube and shell heat exchanger
1.7	Evaporator with integrated mist collector	Tube and shell heat exchanger
1.61	automatic condensate drain	
1.71	automatic condensate drain	
1.72	automatic condensate drain	
1.8 M	Refrigerant collector	Horizontal design
1.8 Z	Additional collector	Horizontal design
1.8 O	Oil collector	

5 Construction

5.1 Arrangement of the main components

Figure 4 shows the arrangement of the main components for an ADR machine with 4 compressors and a throughput of 22,100 m^3/h at standard conditions.

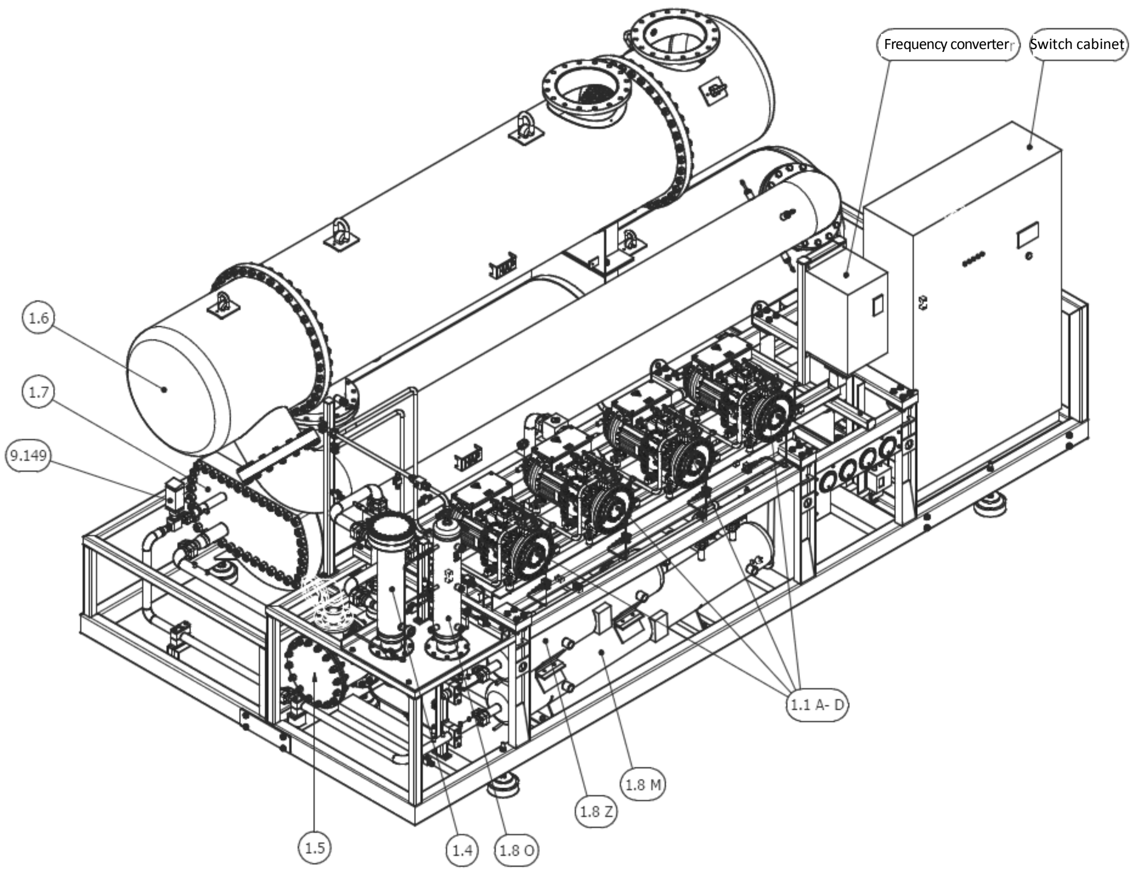

Fig. 6: Main components, (example of ADR with four compressors, legend see table 4)

5.2 Electrical switching system

The electrical switchgear with all the circuit breakers and electronic measuring and control devices is accommodated in a common switch cabinet. It is designed for the protection class IP 54 and built and tested in compliance with applicable European standards and regulations.

The switching cabinet door accommodates:

- Control panel (fully graphic coloured TFT touch display) to display all the status variables and to parameterise the data within the permissible limits.
- EMERGENCY-OFF switch, main switch.
- Key switch to switch between the operating modes "Automatic" and "Service".
- Signal lights for the optical indication of the system states "ready", "fault", "warning" and "operation".

The control valves, safety switches, controllers and sensors as well as electrical devices required for the regulation, control and monitoring of the machine are completely connected and wired to the switch cabinet. Links in a safety chain ensure all the switching operations required for the operational safety.

On the place of installation, the switching cabinet is placed on the floor completely decoupled from any vibration (removed from the frame) to ensure the longest service life of the electronic components.

A detailed electrical circuit diagram is included in the scope of delivery.

5.3 Measurement and control equipment

Control and regulation are performed by programmable logic control Siemens Simatic S7 with the following standard functions:

- Display of all the status variables.
- Monitoring and compliance with permissible operating conditions, over 100 information and error messages for quick diagnosis.
- COP-optimised high-pressure control.
- Stepped performance control, sequential activation/deactivation and run time optimisation at combined compressor operation.
- Fully automatic start and shut-down of the system according to the internal or external release signal.
- Potential-free interface with the signals "ready", "fault", "warning", "operation", and "release".