Brief notes on the company

Friulair Srl is a company founded in 1989 in Friuli Venezia Giulia by Mr. Luigi Vaccaro. The company was born from a core of 5 employees and 150 square meters of production surface, and has grown in 33 years to reach its current size of around 200 employees, more than 14,000 covered square meters and around 200 suppliers (mostly local), more than 1000 customer worldwide.

Friulair also owns a branch in Thailand, engaged in production for the South East Asian market, founded in 2000.

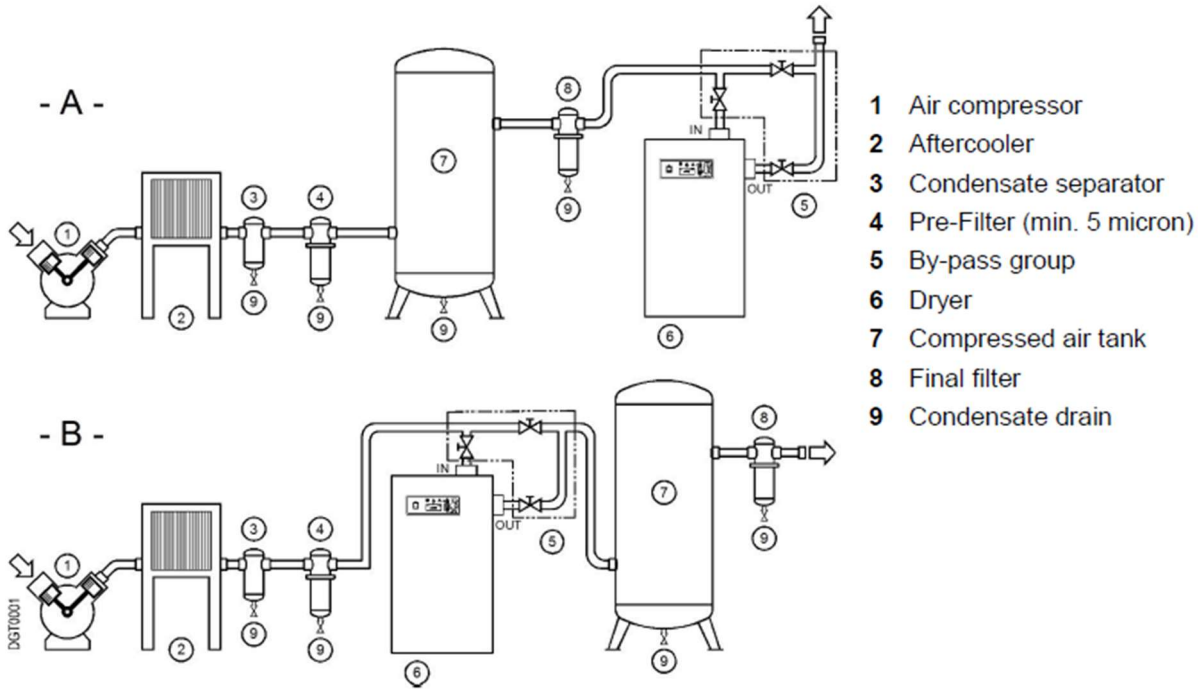
What is Friulair's core business?

Friulair Srl builds refrigeration machines, divided into Dryers, i.e. dryers for compressed air, and Chillers, i.e. systems for cooling process water.

Friulair currently is one of the major players in refrigerated compressed air dryer application divided into different types of dimensions and manufacturing complexity, and its core business at the moment is dryers for compressed air.

What are dryers for?

These dryers are necessary for drying the compressed air generated and intended for use in industrial processes. The dryer is a fundamental element of compressed air systems and of any industrial compressed air system.




Why is it necessary to dry compressed air?

In all systems for the generation and distribution of compressed air, a drying system is necessary for the following reasons:

- Significantly extend the life of the pneumatic equipment connected to the system.

- Reduce maintenance of the parts of the equipment connected to the compressed air system, with effects on reducing impacts on the environment and equipment management costs.
- Processes such as sandblasting and spray painting require very strict specifications regarding the maximum degree of humidity present in the compressed air. Otherwise the quality of the process is significantly affected, generating numerous waste and irreparably damaging the parts and/or products.
- Food-type pneumatic transport processes (flour transport), or where in any case the transported materials (chip transport) cannot be in contact with humidity, in which it is essential that the generation of compressed air has a humidity level below thresholds check.
- Glass blowing or PET bottle blowing processes, where it is essential that the compressed air is free of humidity.
- In the food industry in general where machines with compressed air movements are used and where it is essential that humidity-free air is used.
- Textile and cosmetics industry on production plants.
- In the pharmaceutical industry, in the manufacturing of electronic chips, in the manufacturing and coating processes of optics, and in the medical sector in general.

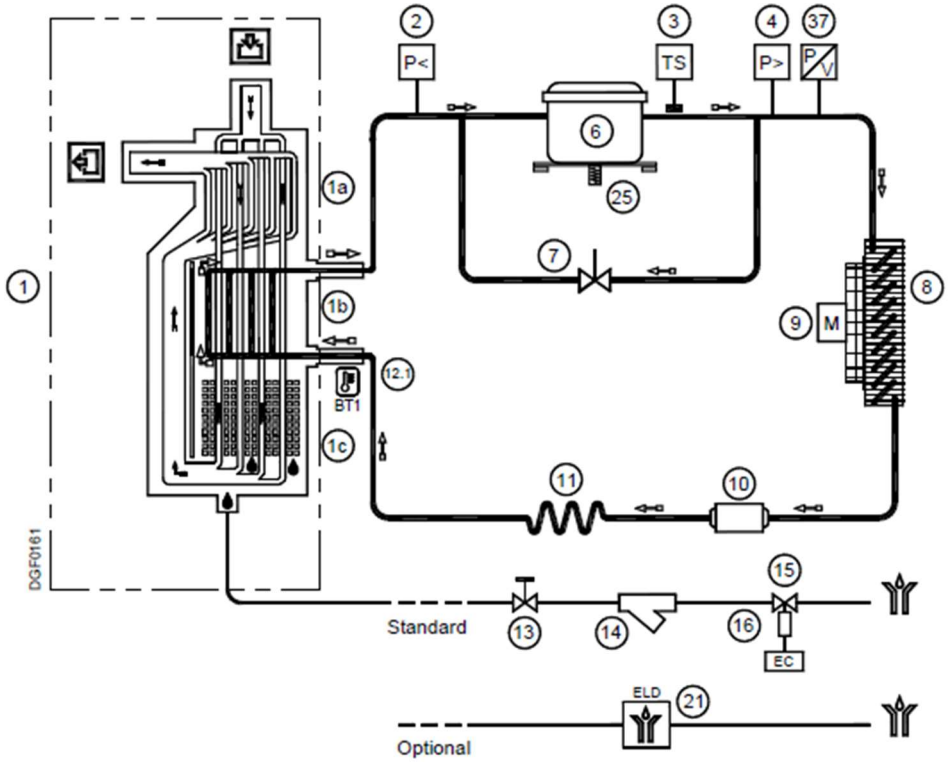
How does a dryer work?

The working principle of the dryers is as follows:

1- The incoming compressed air is cooled.
2- The humidity contained in the air is than condensate.
3- The air and humidity pass through a demister which captures the humidity that is collected.
4- The demister leave dry compressed air.

Cooling is done through a refrigeration circuit that uses HFC or HFC-HFO refrigerant gases which have been included in the list of PFAS substances.

The fundamental part of the machine (dryer) is the evaporator. To optimize the efficiency of the machine, we use a direct expansion evaporator, where the refrigerant gas is separated from the compressed air by a thin layer of aluminum which facilitates heat exchange.




| | | | |
|---|---|---|---|
| **1** | Alu-Dry module | **10** | Filter dryer |
| **1a** | Air-to-air heat exchanger | **11** | Capillary tube |
| **1b** | Air-to-refrigerant heat exchanger | **12** | Temperature probe BT1 – DewPoint |
| **1c** | Condensate separator | **13** | Condensate drain service valve |
| **2** | Refrigerant pressure switch LPS (ACT 80-160 & ACT 55-160 3phase) | **14** | Condensate drain strainer |
| **3** | Safety thermo switch TS (ACT 55-160 & ACT 55-160 3phase) | **15** | Condensate drain solenoid valve |
| **4** | Refrigerant pressure switch HPS (ACT 80-160 & ACT 55-160 3phase) | **16** | Coil for condensate drain solenoid valve |
| **6** | Compressor | **17** | Electronic instrument |
| **7** | Hot gas by-pass valve | **18** | Condenser (Water-Cooled) |
| **8** | Condenser (Air-Cooled) | **19** | Condenser water regulating valve (Water-Cooled) |
| **9** | Condenser fan (Air-Cooled) | **20** | Refrigerant accumulator (Water-Cooled) |
| | Compressed air flow direction | **21** | Electronic drainer |
| | | **25** | Compressor crankcase heater (ACT 55-160 3phase) |
| | | **37** | Pressure Transducer BP2 – Fan control |
| | | | Refrigerant gas flow direction |

<u>Why we choose the use of refrigerant gas HFC & HFC-HFO?</u>

Refrigerant gases today used in compressed air dryer application from Friulair (R134.a / R407C / R513A) have the following technical properties:

- They are not flammable (A1 classified)
- Their operating pressure is relatively low (lower than 30 barg on high pressure side)
- They are not toxic
- Critical point makes these refrigerant suitable also at tropical ambient, with good efficiency

As far as Friulair know, there isn't a refrigerated compressed air dryer manufacturer who use any natural refrigerants like ammonia, hydrocarbons or carbon dioxide.

Basically no alternatives are available in our specific application.

<u>What are the available alternatives without PFAS and what we have to do to use them?</u>

Available alternatives whithout PFAS are following listed:

- Oxygen dioxide
- Ammonia
- Hydrocarbons

But all of them drives to dramatic technology change and do not really preserve the environmental.

Applicability to refrigerated air dryer of oxygen dioxide

Actual heat exchangers and refrigerant circuit components are designed for dramatically lower operating pressure. The redesign of refrigerant circuit components is theoretically possible, but practical limits have to be considered:

- The dryer cannot be used in climate-hot and tropical area
- Dryer efficiency will rise dramatically in climate-hot and tropical area, this means that beside operating cost also environmental impact due to higher power consumption need to be considered
- Service and maintenance of units at so high operating pressure is not easy and could be dangerous
- The dryer cost will be dramatically higher

CO2 at the end cannot be a solution in dryer application.

Applicability to refrigerated air dryer of ammonia

Actual heat exchangers and refrigerant circuit are designed for different refrigerant gas.

The redesign of refrigerant circuit components is theoretically possible, but practical limits have to be considered:

- Copper is a widely used material in refrigeration circuit components (pipes, refrigerant compressor windings, valves…) and is totally not compatible with the use of ammonia, it is needed to replace it with stainless steel
- Actual evaporators are made in aluminum, and are not designed for the use with ammonia. A total re-design and the probable use of stainless steel heat exchangers due to aluminum incompatibility with ammonia has to be considered
- Factory structure need to be reviewed considering the use of toxic refrigerant gases
- Service and maintenance of the units as well as installation area has to be considered as it will be not easy and could be dangerous
- The dryer cost will be dramatically higher

Ammonia at the end cannot be a solution in dryer application.

Applicability to refrigerated air dryer of Hydrocarbons

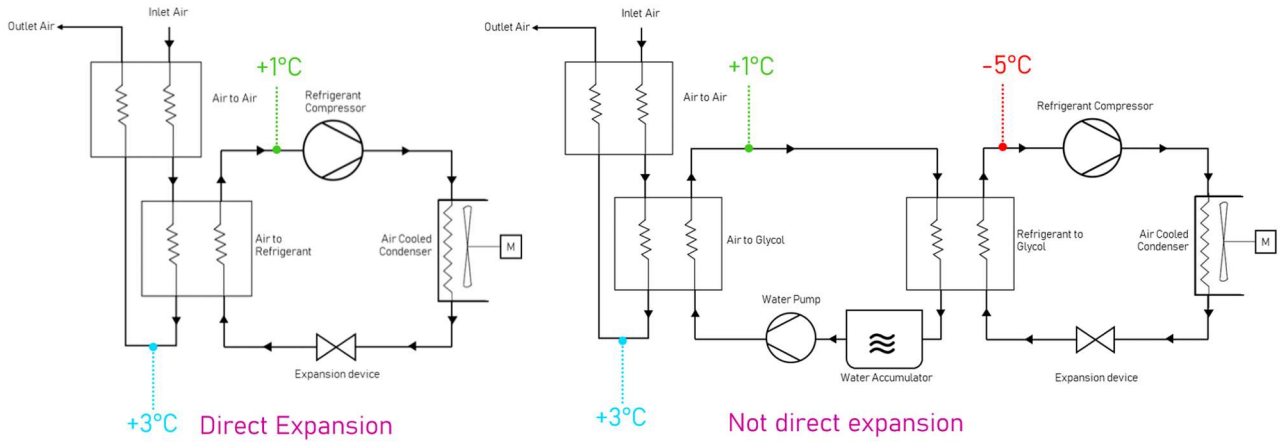
Hydrocarbons has similar or even better thermodynamics properties compared to current refrigerant, but to use them in compressed air dryer application we have to consider that dryer usually are installed in close area, not outdoor. This means that particular attention to explosive mixture in case of leakages to the ambient has to be considered.

Beside this, dryer compressed air heat exchanger today uses direct expansion technology, best technology from efficiency point of view. Direct expansion using flammable refrigerant cannot be an

option because a leakage between compressed air side and refrigerant circuit side drives to create an explosive mixture.

A reasonable solution could be the use of an intermediate heat exchanger.

Comparison between current direct expansion solution and new not direct expansion solution is available in the sketch below:




An efficiency analysis is available in the table below:

| Refrigerant gas | R407C | R290 |
|---|---|---|
| Estimated refrigerant quantity | 3,7 kg | 1,5 kg |
| GWP | 1774 | 3 |
| Tons of equivalent CO2 | 6,56 | 0,0045 |
| Nominal compressed air flow | 25 m³/min | 25 m³/min |
| Evaporating temperature [°C] | 1,0 (evaporator inlet) | -5 |
| Condensing temperature [°C] | 40 (condenser outlet) | 40 |
| Refrigerant compressor power consumption | 1,84 [kW] | 2,24 [kW] |
| Water pump power consumption | 0 [kW] | 0,50 [kW] |
| Total dryer power consumption | 1,84 [kW] | 2,74 [kW] |
| Operating hours in 1 year | 8.000 | 8.000 |
| Refrigerated air dryer lifetime | 10 years | 10 years |
| TOT kWh required during dryer life | 147040 | 217203 |
| | | |
| Conversion factor Power – CO2 according to ISPRA 2022 in Italy | 0,2605 | 0,2605 |
| TOT CO2 released to the ambient during dryer lifetime due to power consumption | 38,3 t | 56,6 t |

CONCLUSION

According to the above exercise, below there is a table that summarize the results

| Refrigerant GAS | R407C | R290 |
|---|---|---|
| Refrigerant tons of CO2 | 6,56 | 0,0045 |
| Power consumption tons of CO2 | 38,3 | 56,6 |

This result drives to say that to achieve same impact to the environment a dryer today manufactured with R407C, has to release its refrigerant charge to the ambient approx. 3 times.

We have to consider that refrigerant circuit are manufactured with all the possible precautions to avoid leakages to the ambient.

To achieve this results Friulair use the best technology for leakage detection, which is “helium leak detector”. This technology is used on 100% of manufactured unit.

It is impossible that a unit verified with this kind of technology will leak 3 times in its lifetime to the ambient. Friulair experience is that leakages can happen much lower than 1 dryer every 1000 manufactured and just once in its lifetime.

In conclusion, in dryer application there are no alternative to HFC or HFC-HFO refrigerant.

More important is that the use of HFC or HFC-HFO refrigerant gas in dryer application is more “eco-friendly” than the use of a natural refrigerant.

There is no reason to force the transition to natural refrigerant.

Friulair S.r.l.

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