CONTAINMENT OF CO2 REFRIGERATION INSTALLATIONS

X. CAZAURAN, S. GUYOT, C. HERMON
CETIM, Centre Technique des Industries Mécaniques,
74 route de la Jonelière, 44326 Nantes, France
Fax : +33 (0)251 860 073, e-mail : xavier.cazauran@cetim.fr

ABSTRACT

A project has been carried out on the containment, and more specifically the leak tightness, of installations using CO2.

The objectives are to define a test procedure for the qualification, regarding containment, of components used on installations working with CO2.

The three stages of the project are : a) to define a test procedure in collaboration with a group of refrigeration companies, b) to test the sealing ability of components following the newly built procedure, and c) to detect and measure leaks on installations in service in order to observe the feasibility of the detection method and to measure the real leaks.

This article describes the test procedure for CO2 components, the results of the lab tests and the results and observations of the on-site detections.

1. CONTEXT

Certain refrigeration applications come back with the use of CO2 as a refrigeration fluid. The components have to be specifically adapted to this fluid and particularly prove to be tight enough for security reasons and to avoid loss of energetic performance of the system at these high pressures.

2. AIMS OF THE STUDY

The first aim of this study is to set a procedure for testing the components that are most commonly used in refrigeration installations using CO2. The selection of components, as well as the definition of the testing parameters, are carried out with the collaboration of some of the industry players so as to insure a better representation of real use conditions. Tests include CO2 and helium leak measurements. Helium is chosen as it is a reference gas for leak testing.
The second aim is to perform tests on different components (e.g. valves, hoses, filters) following this new procedure and to determine their leakage rate at their maximum service pressure.
On-site leakage measurements are also performed to collect data in operating conditions.

3. IN-LAB TESTS

3.1. Testing procedure

The procedure is based on work done for the elaboration of the XP E35424-1 and -2 standards.

This present procedure divides components into two categories : universal components used in sub-critical applications and those in trans-critical applications.

The following flow chart (Figure 1) shows the different steps of the procedure.

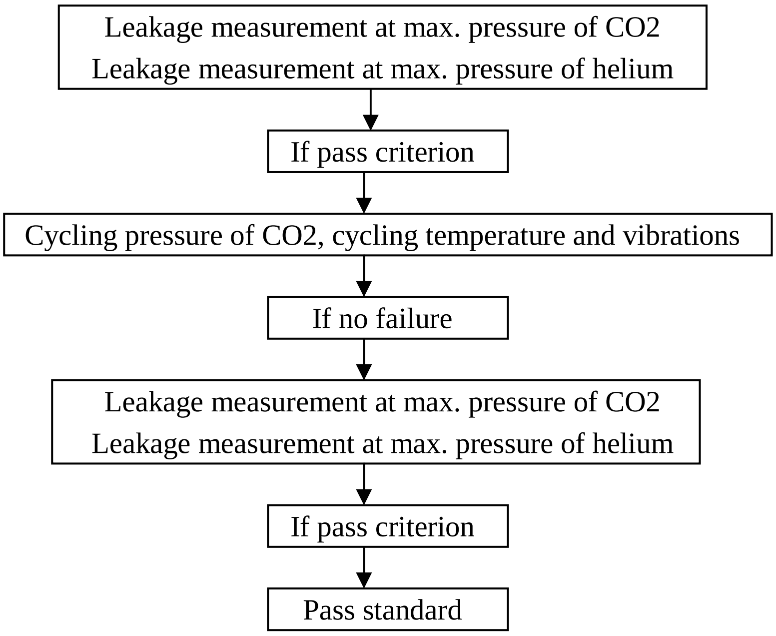

Figure 1 : Procedure steps

3.2. CO2 leakage measurement method

Leakage rate is determined by accumulation of CO2. This method consists of placing a component in a sealed enclosure which is vacuumed and then filled with nitrogen at atmospheric pressure so as to have no residual CO2 from the ambient air. The component is pressurised with CO2 and the increase of the concentration of CO2 over time is measured with an infra-red spectrophotometer. The leak rate is then calculated from this data (minimum 0.1 g/year). The tests are performed at room temperature and at maximum pressure : 65 bar (sub-critical applications) or 120 bar (trans-critical applications).

3.3. Helium leakage measurement method

The tightness is tested according to the global vacuum method to measure the total leak rate of the component. It consists of placing a component in a sealed enclosure which is vacuumed. The component is pressurised with helium and the total leak is measured with a mass spectrometer (range : 10^{-10} to 1 atm.cm^3/s) connected to the enclosure. This method is described in standard EN 1779. The tests are performed at room temperature and at maximum pressure : 65 bar (sub-critical applications) or 120 bar (trans-critical applications).

3.4. Pressure and thermal cycling with vibrations

Components are initially subjected to 24 hours of maximum CO2 pressure so as to leave some permeation time. Pressure cycling with CO2, temperature cycling and vibrations are applied for 225 hours. A tightness inspection, via a multi-gas mass spectrometer in sniffing mode is performed daily allowing the detection of any deterioration in the tightness of the components placed in the climatic chamber.
The pressure and temperature parameters are described in Figures 2 and 3. Vibration parameters are 200 Hz and 10-15 mm/s.

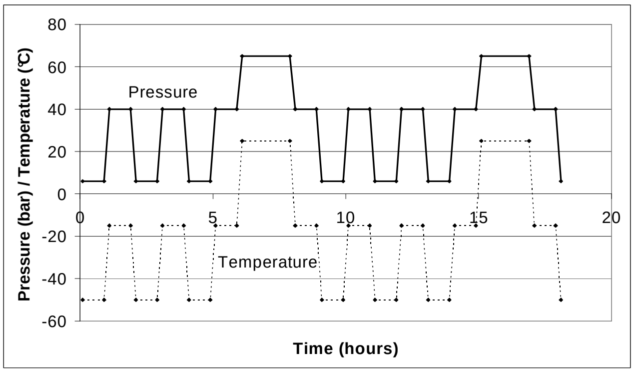

Figure 2 : Cycling for sub-critical applications

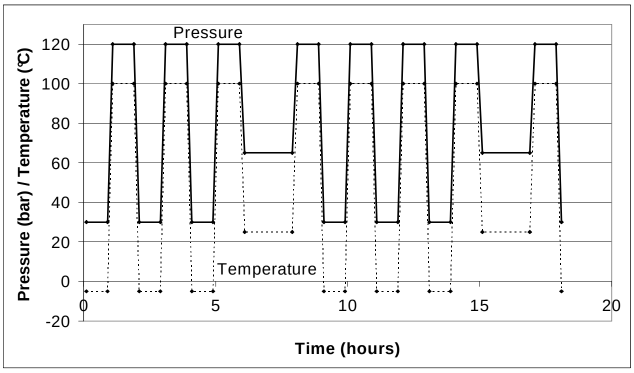

Figure 3 : Cycling for trans-critical applications

3.5. Results of in-lab tests

Below is a summary of the results. The graphs compare the level of leakage for the components before and after accelerated ageing. The leakage values in helium are expressed in atm.cm^3/s and the ones in CO2 are in g/year.

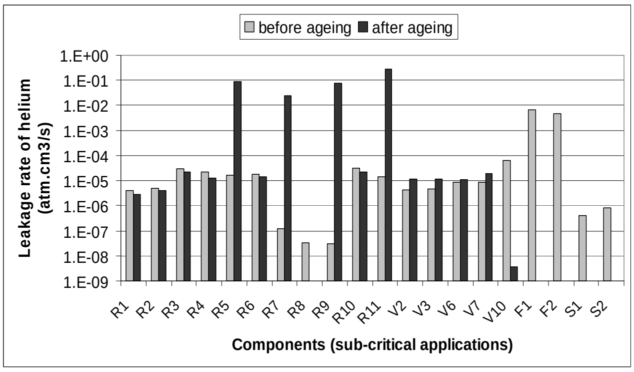

Figure 4 : Helium leakage (sub-critical applications)

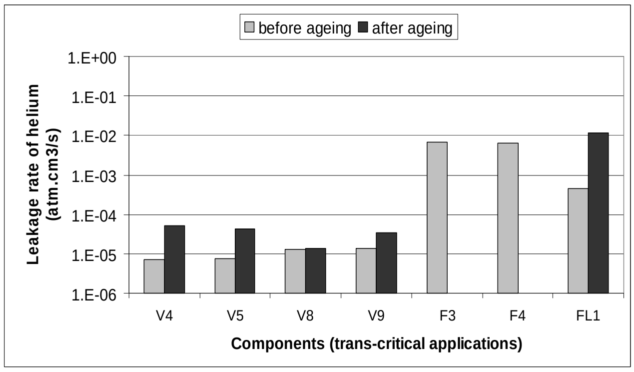

Figure 5 : Helium leakage (trans-critical applications)

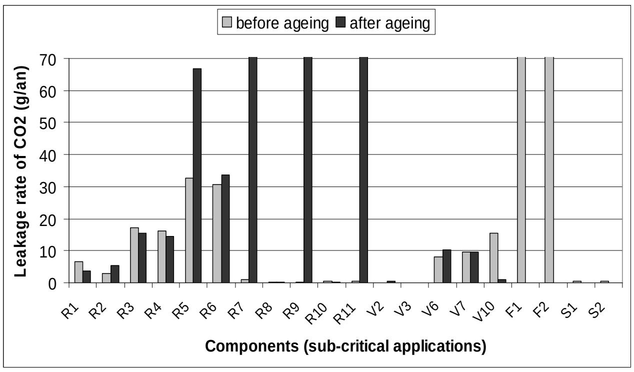

Figure 6 : CO2 leakage (sub-critical applications)

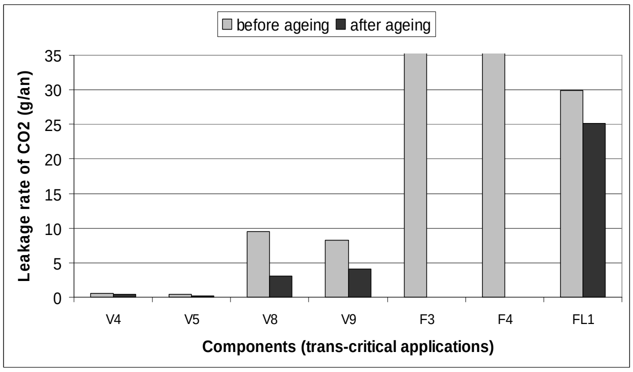

Figure 7 : CO2 leakage (trans-critical applications)

3.6. Conclusion on in-lab tests

This study enables us to observe leakage behaviour of certain components so as to improve their leak tightness in the future.

- Some valves do not show any increase in leakage with either CO2 or helium.
- A few valves show a large increase in leakage (CO2 and helium) after the pressure/thermal cycling.

- The hoses present a very high leakage before the cycling test. They are therefore not subjected to the remaining procedure.
- The fill valves are displaced with pressure during the tests. They are therefore not considered for the remaining tests.
- One valve presents a decrease in leakage for both CO2 and helium. Could the sealing elements react during the cycling test? Could elastomeric materials react with temperature and seal better by adherence?

4. ON-SITE MEASUREMENTS

Leakage detection, with an estimation of its rate, is conducted on industrial and commercial refrigeration sites. This is to validate the detection method with measurement of CO2 in the field.
The installations are of different types : commercial refrigeration (supermarket) with R404A and CO2 in cascade, industrial refrigeration (cold stores, food freezing) with NH3 and CO2 in cascade.
We perform the detection/measurement at the location of components (manual and automatic valves, check valves, sight glasses, filters, etc) and connections (brazed or welded joints, threaded connections, bolted flanges). One measurement corresponds to one emission source (e.g. a welding line, a single connection, a stuffing box, a single flange, etc).

4.1. Leakage detection method

The measurements are performed using a sniffing multi-gas spectrometer set for the application to CO2 detection/measurement mode. The sniffing method is described in standards EN 1779 and EN 13185.
The sniffer is placed as close as possible to the components and gradually moved around the component to locate the leak as precisely as possible.
Most of the installations' components are inspected. This enables us to identify the component types on a site which are leaking the most and to cross-check the results with the ones from all the other sites.

4.2. Results of on-site measurements

Measurements are performed on about 2000 emission sources, one component having frequently several of these sources. The graphs presented below show the level of leakage at sources where the leakage rate was found above 2 or 5 g/year depending on the surrounding conditions.

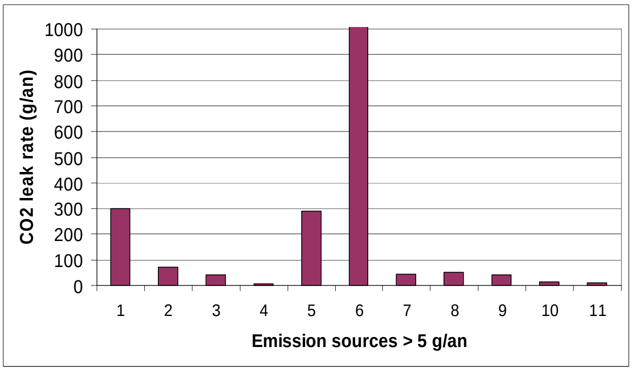

Figure 8 : Cold store

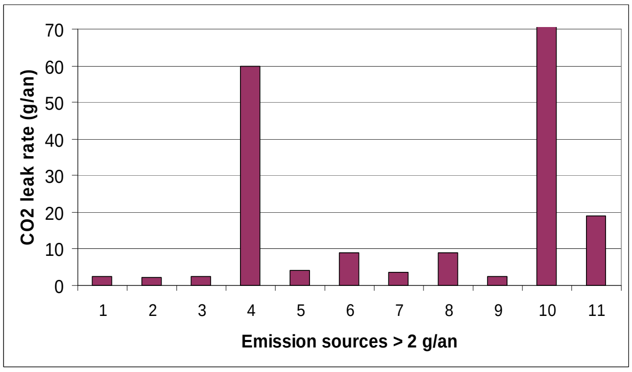

Figure 9 : Installation for training purposes

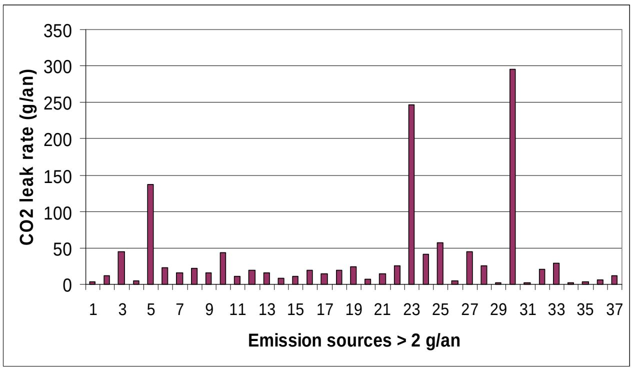

Figure 10 : Supermarket

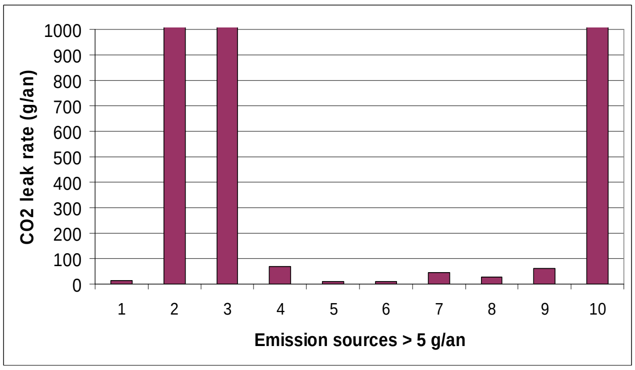

Figure 11 : Food freezing

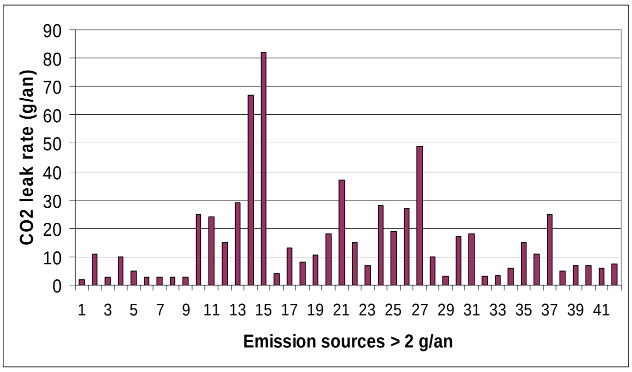

Figure 12 : Cold store

4.3. Conclusion on on-site measurements

The detection method with measurement of CO2 is convincing and leaks of different rates are identified. The advantages of this method is that it can classify the leaks by levels which allows to carry out rapid action and maintenance by priorities on the components.

Most of the installations are fairly new : less than 5 years old.

The most leaking components are :

- Flanges. One of them is not tightened enough. Checking the surfaces of the flanges, putting the right gasket and tightening at the recommended torque is essential.
- Threaded connections. This is often due to either under-tightening or over-tightening the connection. The right torque should be applied in conformity with the instructions from the connection supplier.
- Stuffing boxes.

The number of emission sources falling into different leakage rate ranges are as described in Table 1.

Table 1 : Number of leaking sources for different leakage rate ranges

Leakage rate range (g/an)	**Number of controlled emission sources within the range**	**Around 2000 controlled emission sources**	**% over the total number of controlled emission sources**
2 – 5	23		1.2
5 – 50	70		3.7
50 – 100	8		0.4

100 – 500	5		0.3
> 1000	5		0.3

Certain unit operating conditions prevent leak inspection :

- The presence of ice or insulation casing on some components creates a sort of leaktight envelope. These conditions imply that possible large leaks are not detected at all or not at their real level.
- Access to very few components can be difficult or not possible for a proper detection/measurement.
- The breathing of the operator could increase very slightly the measurement value. We consider that measurements are possible for leakage values above 2 g/year and easy above 5 g/year while still giving attention to an increase of the value if the operator exhales heavily.

5. CONCLUSION

This study provides a specific testing procedure for components used on refrigeration installations working with CO2. An identification of leakage rates of components is performed in-lab and on-site. These results enables our partners to have a good knowledge of the level of leakage of their component and installation, strong of having measured data in hand.

REFERENCES

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