TESTING SAFETY OF HYDROGEN COMPONENTS

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ABSTRACT

Hydrogen as a new and ecologic energy source is tempting, though it creates the challenge of ensuring the safe use of hydrogen for all future consumers. Making sure that a hydrogen vehicle can be simply and safely used by anyone while performing as expected requires that the car be light with built-in safety features. This is achieved by combining high pressure, composite cylinders with strict test procedures. Composite cylinders of up to 150 L operated to a maximum of 700 bar are required for vehicle applications. Air Liquide has developed test benches to hydraulically cycle such cylinders at 1400 bar and up to 3500 bar for burst tests. These tests are performed under controlled temperature conditions, at ambient and extreme temperatures, in order to simulate cylinder aging. Components in gas service such as valves, hoses and other pressure devices are tested up to 1400 bars with hydrogen to simulate actual usage conditions. Hydrogen is used as a testing gas instead of nitrogen, which is commonly used for such tests, because hydrogen interacts with materials (e.g. hydrogen embrittlement) and because hydrogen has a special thermodynamic behavior (pressure drop, velocity, heat exchange,…).

. The testing facility characteristics, principle safety measures taken and initial findings are presented

Key words : high pressure, hydrogen, component, cylinders, tests, hydrogen energy.

1.0 INTRODUCTION

The target market is the hydrogen energy which requires numerous tests for the components used to handle high hydrogen pressure. For example, the vehicles motorized with fuel cells require high pressure hydrogen cylinders and valves and devices under very high pressure.

Hydrogen is a new and ecological energy source. It flows easily, has a broad flammability range, and ignites with even a small amount energy. To ensure safety, test data must be collected from the point of view of high pressure hydrogen. Air Liquide's " Centre de technologies et d'expertise" has set up a test center dedicated to high pressure hydrogen components and high pressure cylinders.

New equipment has been installed for hydraulic cycling tests (maximum pressure 1400 bars) in a large temperature range, and for burst tests (maximum pressure 3500 bars). A new hydrogen installation has been built in order to perform high pressure component tests (maximum pressure 1400 bars) using hydrogen.

The test center's principle characteristics are described in this paper.

2.0 CYLINDER TESTING FACILITIES

We installed hydraulic pressure test apparatus for measuring high pressure cylinder burst pressure and evaluating ageing by pressure cycle tests under a wide range of temperatures .

Figure 1 presents a general view of our high pressure hydraulic machines, showing the various equipment and its main functions.

Figure 1: General view of hydraulic machines

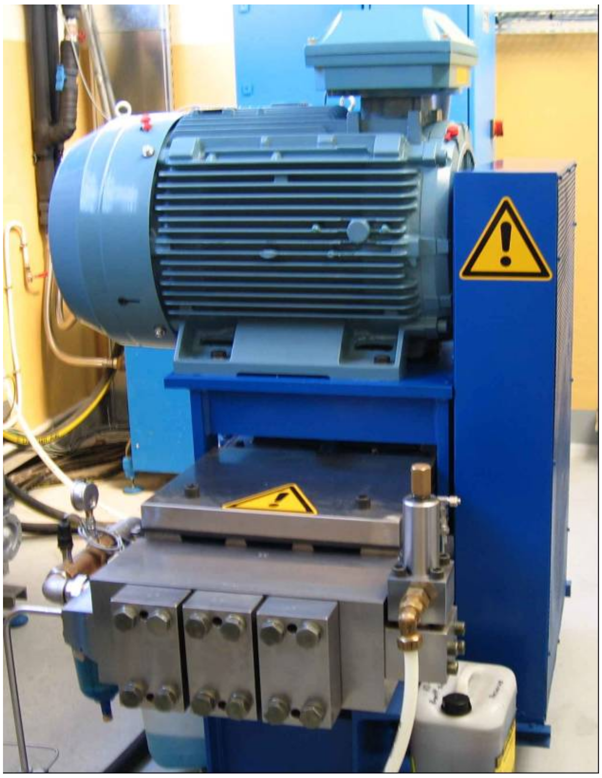


Figure 2: High pressure pump

A specific room is dedicated to machine control, so the operator in a safe location during testing. Main data appears on computers screen during testing.

Figure 3. Machine control room

A new bunker has been built for these high pressure tests. Its design was validated by risk analysis showing the effect of a 150-liter cylinder rupture under a maximum of 3500 bars of pressure.

An additional high pressure pump was installed and is specifically used for proof tests and burst tests.

Since becoming operational in December 2006, these installations have been used to demonstrate the resistance of 700-bar operating pressure composite cylinders. They could be used safely for cylinders

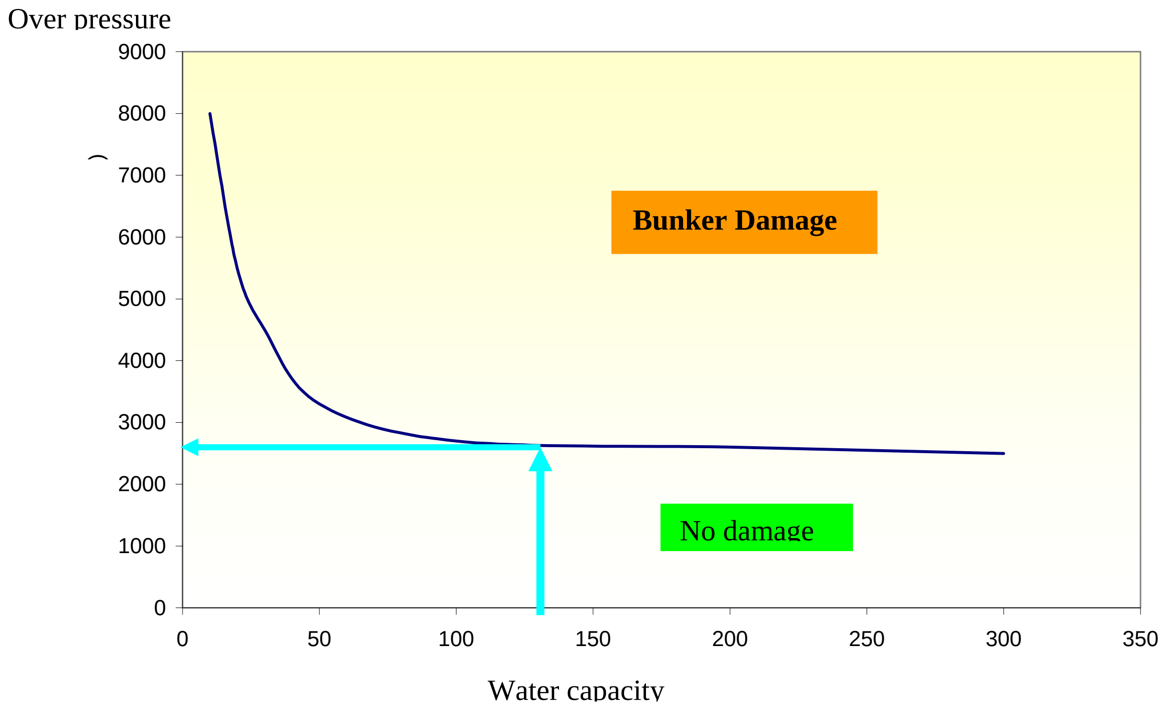


Figure 4 : curve showing the limit of use of our actual bunker

with a maximum capacity of 150 liters and 700 bars operating pressure.

The air generator controlling the temperature during testing is shown on figure 5 in front of our new bunker. For tests at low or high temperature, silicon oil is used in place of water and pressure is controlled via a pressure transfer from water to oil in the “exchanger” (see figure 1). The cylinder is put in an isothermal box, the size of which is adjusted to the cylinder, and the box is placed in the bunker. Temperature range is –60°C to 95°C.

Figure 5. Air generator and bunker

Machines and procedures are now available for testing high pressure cylinders. Some high pressure cyclinders have already been successfully high pressure tested (type II, III and IV cylinders). One example is given in figure 6.

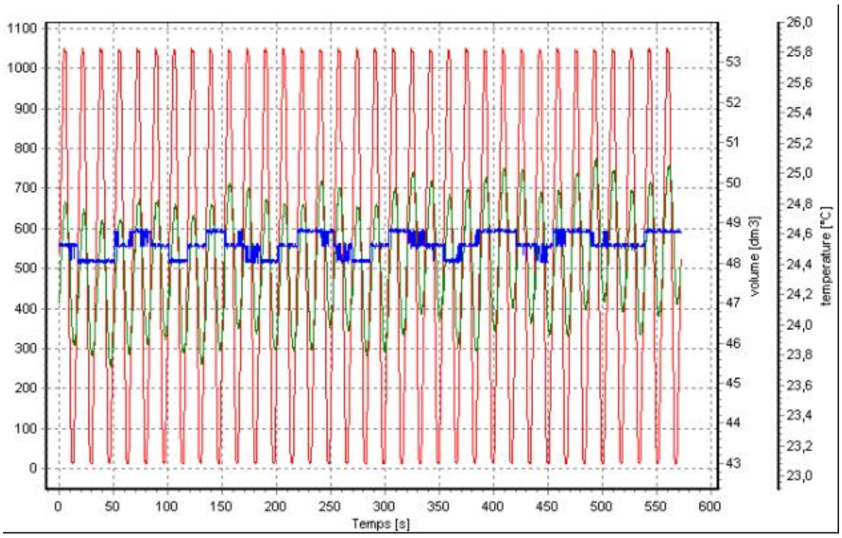


Figure 6. Typical record during high pressure cycling test

3.0 HIGH PRESSURE HYDROGEN TESTS

3.1 The choice of hydrogen as testing gas

Components in gas service such as valves, hoses and other pressure devices are tested up to 1400 bars with hydrogen and at various temperatures to simulate actual usage conditions.

Hydrogen is used as a testing gas instead of nitrogen, which is commonly used for such tests, because hydrogen interacts with materials (e.g. hydrogen embrittlement) and because hydrogen has a special thermodynamic behavior (pressure drop, velocity, heat exchange,…).

The CTE has the capabilities to test these high pressure components using hydrogen with combined cycle pressure and temperature.

3.2 Description of the hydrogen component facility

The next figure 7 shows the current high pressure hydrogen site at AIR LIQUIDE - CTE.

Figure 7 .High pressure hydrogen site at AIR LIQUIDE - CTE

This hydrogen site uses a maximum number of safety devices to work with high pressure components tested under very high hydrogen pressure.

Very high hydrogen pressure is reached using a three-level booster compressor filled with hydrogen from AIR LIQUIDE cylinders at 200 bar.

The next figure 8 shows the 3-level hydrogen boosters with 2 capacities.

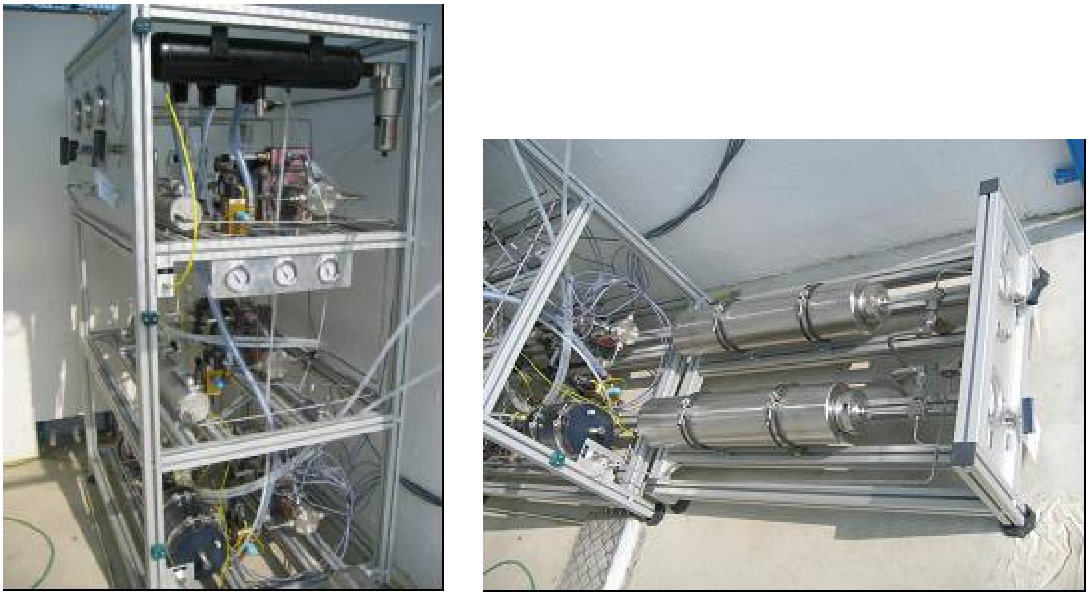


Figure 8. 3-stage hydrogen boosters and capacities

The pressure at the outlet of the 3-level booster can be regulated up to 1400 bar hydrogen in order to give sufficient pressure for the devices being tested.

Figure 9 shows the front panel of the high pressure manifold.

Figure 9 – High pressure manifold

A building contains all monitoring devices in order to work under optimal safety conditions.

The next figure 10 shows the building in front of the high pressure area.

Figure 10. Monitoring building

The devices being tested are placed in a safe area near the compressor area in order to prevent injury to technicians in case of device failure. Figure 11 shows an example of a test bench.

The entire installation is designed to be operational every day of the year, around the clock if necessary. It functions in automatic mode and is able to detect failures in the devices being tested.

3.3 A test bench example

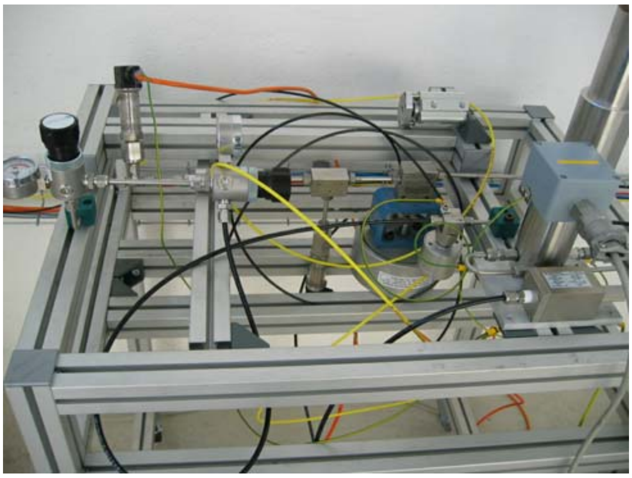


Figure 11. Example of test bench

As an example of our bench test and test procedure, a component could be pressurized one cycle using cold hydrogen (-70°C), and the following cycle using warm hydrogen (100°C), with each cycle lasting a few minutes. These tests conditions are typical of operating conditions for a filling hose, which is submitted to both temperature and pressure variation during cylinder filling.

3.4 Examples of tests carried out

The CTE performs out many tests on hydrogen components, such as :

Endurance tests applying very high pressure hydrogen cycles.

Helium leak tests.

Flow rate measurements.

Pressure drop tests.

Aggeing tests.

Other specific tests relative to customer developments are also performed.

The CTE performs tests according to EN / ISO / NF/EIHP normative regulations or proposals.

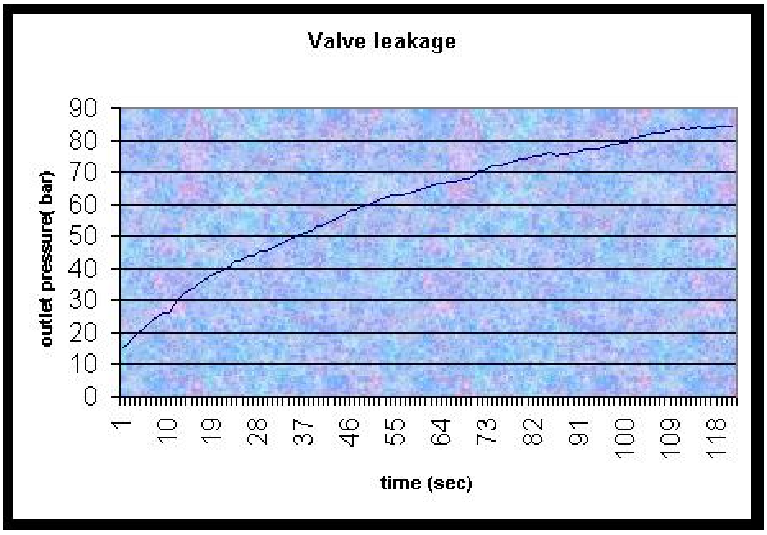
In addition, tests protocols can be designed according to customer specifications if required.

The CTE facilities are opened and available to carry out any tests or to provide any development of component requested by any organizations or companies.

Some tests examples at CTE test using high pressure hydrogen facilities :

Figure 12. Valve leakage applying high pressure upstream

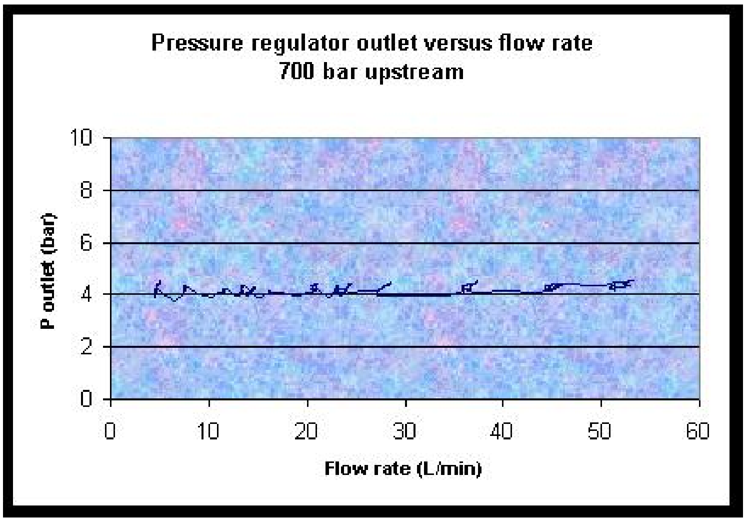
(700- bar hydrogen application device)



A 700- bar hydrogen pressure is applied to a valve. The outlet pressure is recorded and shows an increase due to an internal leakage.

Figure 13. Pressure regulator test

(700- bar hydrogen application device)

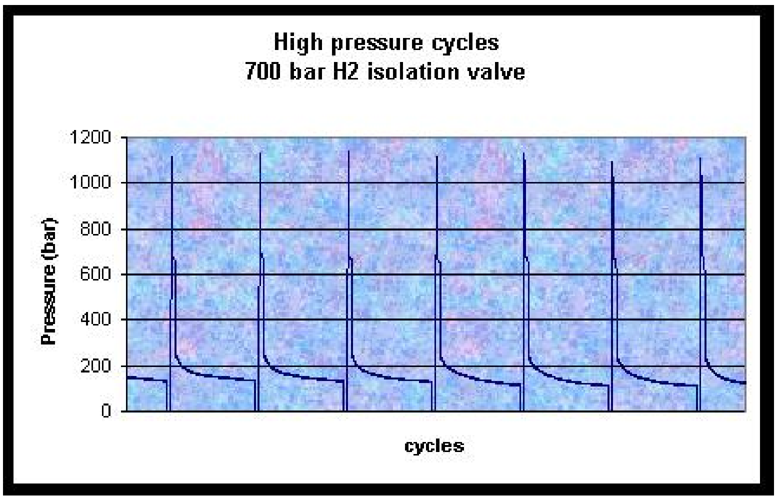


A 700- bar hydrogen pressure is applied to a pressure regulator.

The pressure outlet is quite stable with a flow rate in the range 5 to 45 L/min.

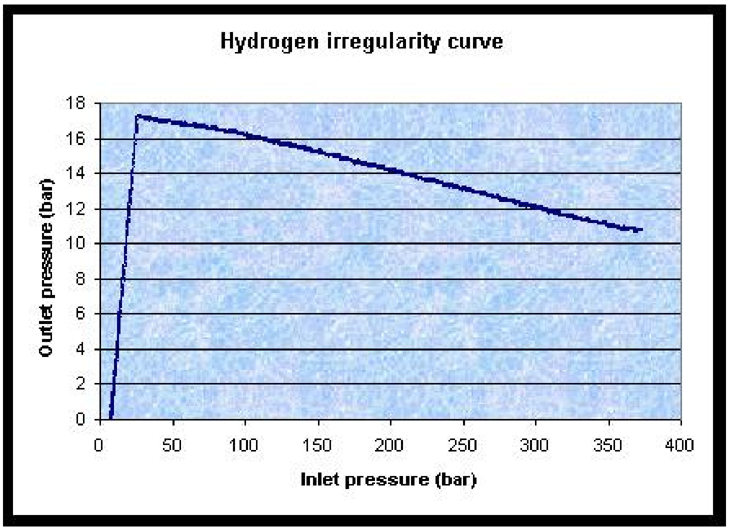
Figure 14 – Valve endurance test

(700- bar hydrogen application device)



This graph shows a typical cycle test on a valve using 700- bar hydrogen bench test.

Figure 15 – Irregularity curve of pressure regulator curve



This example shows an irregularity curve obtained for a 300- bar normal operating pressure device. The outlet pressure varies according tois recorded at the same time the inlet pressure decreases.

5 CONCLUSION

AIR LIQUIDE – CTE is now ready to answer to the customers who wants to test safety of components and cylinders for the hydrogen energy at very high pressure of hydrogen gas up to 1400 bar, and in a large range of temperature.

References

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