SEMI-AUTOMATIC TESTING OF GAS CYLINDERS

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Abstract

Requalification tests on gas cylinders are carried out either by hydrostatic or by pneumatic pressurization. The reason for choosing pneumatic pressurization is usually based on considerations regarding residual humidity. The standard hydrostatic test introduces risk of inside corrosion and risk of storage product contamination to the service of the gas cylinder. Using a dry gaseous product for pressurization reduces those risks. It has a positive impact on availability of the equipment due to a procedure focused on testing without the necessity to subsequent steps in order to re-gain service conditions (cleaning, drying). After passing the test, the cylinder may be filled immediately with the storage product. If the pressurization has been performed with the storage product itself, then only a depressurization down to the service pressure is necessary. In such a case the gas cylinder is tested and filled in one step. Messer Austria has commissioned a semi-automatic test rig for acoustic emission (AE) testing of gas cylinders using pneumatic pressurization to TÜV Austria. After setting into service in 2001, thousands of gas cylinders have been tested successfully to date. This contribution gives an overview on the past service and the experience gained. Follow-up inspections have been performed on several rejected cylinders in order to show the correlation between AE indications recorded and the actual condition of the tested specimens.

Introduction

In 1998, Messer Austria decided to build a semi-automatic testing facility (manual sensor mounting, automatic testing) for the requalification of gas cylinders (200 bar, 50 litres) at their Herzogenburg site. As an alternative to the conventional procedure, pressurization with gaseous products (nitrogen and argon, later oxygen too) had been selected, mainly because of the following advantages:

1. No water inside the cylinder means no risk of residual humidity (prevention of inside corrosion as well as contamination of storage product) and
2. Short down-time (no further activities necessary after the test).

Filling and testing operations had to be integrated within the new facility (see Fig. 1). Acoustic emission testing (AT) was chosen to monitor pressurization. The requirement on the instrumentation was that automatic on-line evaluation had to be employed. The concept comprised one system to identify the cylinders to be tested (Messer Austria gas cylinder database) with the help of barcode labels mounted at the neck of the gas cylinder. Another system was used to control the pressurization to test pressure at a constant rate and the third system, the AMSY4 system of Vallen Systeme GmbH, was used to prevent unsafe situations during pressurization. The communication between the three systems inside the control room (see Fig. 2) was established via LAN network. It was defined that the concluding step after the test had to be the update of the gas cylinder database.

One important feature of this database among others is that it holds the status of each gas cylinder regarding requalification test. It is implemented that before the start of the filling process it has to be checked, if the gas cylinder has already reached the allowable service duration (maximum 10 years). After reading the barcode the cylinder can be identified within the database and the respective data is analyzed. If it turns out that the gas cylinder is due for testing, then filling is denied. The gas cylinder has to pass the requalification test before service can be continued.
When the storage product is available for pressurization, then the gas cylinder just has to be depressurized after the passed test down to the service pressure and is immediately ready for service.

As for every new application based on AE, pre-tests on several different specimens with and without defects had to be performed [1, 2]. The worst-case scenario for detection with AE has been identified to be a low-cycle fatigue crack evolving under service conditions. The measured peak amplitudes may be expected in the range of up to 70 to 80 dB\textsubscript{AE} (Vallen VS150-RIC sensors, 20 kHz high-pass filter, 300 kHz low-pass filter). In case the fatigue crack has already evolved to more than 50% of the wall thickness, then the number of events to be detected before burst might be rather low. It is quite unlikely that this scenario exists on a gas cylinder in real life. Nevertheless, it has been selected as reference since testing takes place in working environment and minimum risk for health or even life of employees has to be ensured. A much more realistic scenario will be to have gas cylinders with inside corrosion due to improper drying procedure after hydrostatic testing. These corrosion defects are characterized by a higher number of events to be detected with peak amplitudes usually in the lower range.

**Setting up the Testing Facility into Service**

After completion of the facility together with all necessary installation in autumn 2001 the testing facility was put into trial service. The bunker structure at one end of the facility is divided into two sections with two test rigs inside each section. At one test rig, twelve gas cylinders can be tested simultaneously. While pressurizing gas cylinders in one section (flow scheme see Fig.

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**Fig. 1:** Filling and testing shop at Herzogenburg site of Messer Austria (front side on the left, backside on the right), entry into bunker structure at the end of the shop (left photo).

**Fig. 2:** Control room next to shop (left) with measuring system (right left), control unit (right middle) and Messer Austria gas cylinder database client (right right).
3), it is possible to prepare safely the next test (manual sensor mounting) inside the other section. The gas flow to the test objects is controlled by a regulating valve to achieve a constant pressurization rate. After proper mounting of the sensors the pressurization starts with performing several safety checks (infrared check to ensure that personnel has left bunker structure section, and door-closed check). It was the first aim to find proper parameters to be entered into the software of the control unit for the regulating valve. Several trial runs have been performed to find proper settings. In parallel to this the interface provided by Vallen Systeme to run on the AMSY4 for communication of the measuring system with the control unit was tested. The usual Vallen-Acquisition32 software is used to provide the functionality for acquiring the AE data. In addition, the control unit sends to AMSY4 the testing parameters with the stop criteria to be compared with the measured data and the derived results, especially the location results. As long as the stop criteria are not met, the pressurization is continued. Otherwise the Vallen interface program sends an alarm to the control unit to stop the pressurization. This command leads to immediate depressurization of the gas cylinders. These core functions have been checked in every detail.

![Scheme of the pressurization with nitrogen or argon](image)

Fig. 3: Scheme of the pressurization with nitrogen or argon, S1: storage tank (liquefied nitrogen or argon), P: pump, V: vaporizer, S2: storage tank, RV: regulating valve, FP: gas cylinders.

Step by step all other functions have been verified so that testing of gas cylinders could be started. The sequence of activities to be performed prior to pressurization includes mounting of sensors at predefined positions and of course verification of each single measuring chain. Right after the start of pressurization it is checked with the help of the background noise (RMS-value), if all gas cylinder valves are open.

Two sensors are mounted on each gas cylinder to enable linear location. The result of linear location is used as the third main criterion to assess automatically on-line the condition of the test objects. The first one is the activity criterion followed by the intensity criterion, both without taking into account if a location result has been found or not. These three criteria are permanently checked to enable safe pressurization at a rate of approximately 5 bar/min. Having a service pressure of 200 bar, the gas cylinders are pressurized to the test pressure of 280 bar. This has proven to be at least equivalent to the hydrostatic testing using the low-cycle fatigue crack as the reference defect. Since this represents the worst-case scenario, AT will detect defects with a much better sensitivity compared to hydrostatic testing. The trial service was switched to normal service in 2003 with already several thousands of gas cylinders tested. Training of personnel for AT was done on the job so that after a few weeks, only Messer Austria personnel operated the testing facility. Messer Austria has contracted TÜV Austria for the supervision of testing operation. TÜV Austria is consulted by Messer Austria to evaluate measured data and decide on follow-up activities in case of rejected cylinders.
Service Experience of Testing Facility

To date, approximately 40000 gas cylinders have been tested using test rigs shown in Fig. 4. During trial service the stop criteria had to be adjusted according to the experience gained on-site. Testing operations are performed inside the bunker structure while gas cylinders are transported by fork lifts and filled inside the same work shop. These and other operational interferences were taken into account by adjusting the stop criteria. With signal peak amplitude correction the attenuation could be taken into account, which helped keep the stop criteria as stringent as possible.

![Test rigs inside bunker structure](image)

Compared to the pre-tests performed under laboratory conditions the main differences observed on-site were:

- High background noise,
- Indications due to the gas cylinder neck ring,
- Leakage of pipes and hoses inside bunker structure.

There were many activities like opening and closing of the work shop doors, fork-lift traffic and the like, which led to an increase of the background noise. Analysis of the frequency content revealed that 300-kHz low-pass filters had to be used instead of 850 kHz. With this configuration, the background noise has been within acceptable limits.

Some gas-cylinder neck rings caused indications near in the upper part of the cylinder. Further investigation with additional sensors and other location algorithms could provide proof that there is an influence from this area. Since the ring is held in place on the gas cylinder due to mechanical deformation after it has been put on the neck, there is some probability that there is a response to load in terms of slight movements at this connection.

Leakage of pipes and hoses connected to the gas cylinders raise the background noise significantly, which leads to stop of pressurization by exceeding the maximum allowable hit-rate or the maximum allowable background noise level. Especially the connection to the gas cylinder valve is critical since it is loosened and connected frequently. Pipes and connections used for pressurization with oxygen are made from copper due to safety considerations.

A sensitivity check is performed annually on all sensors (using Vallen sensor-tester software plus necessary hardware) to ensure rather constant system properties over the years. Checking of the measurement-chain sensitivity is a key feature of the applied procedure. After mounting of sensors and closing the doors of the bunker structure to the work shop, the first step of the measuring system is to perform a sensitivity check (Vallen auto-calibration). If this step has been completed successfully, then the gas flow into the cylinders is enabled and the pressurization...
starts at a rather high rate. In this phase the background noise level is measured (RMS-value). If the RMS on any gas cylinder stays low then the gas flow is stopped and the test is aborted in order to check the gas cylinder valve. This prevents performing a test without pressurizing one or more gas cylinders to be tested. After reaching approx. 150 bar, the pressurization rate is adjusted to approximately 5 bar/min and the automatic on-line monitoring starts. The first phase is up to 200 bar, where a pressure hold period is performed. At this stage, the sensitivity check is repeated and if passed then the next load phase is initiated up to 240 bar, where again pressure hold plus sensitivity check are performed. If this is done successfully, then the concluding load phase up to 280 bar is initiated. At the test pressure the final sensitivity check is done and after that the depressurization starts. In case one or more stop criteria have been met, depressurization is initiated immediately at any moment of the test. Figure 5 shows some examples of rejected gas cylinders. These gas cylinders and all others with similar findings were scrapped.

Fig. 5: Photos of inside corrosion with videoscope and the corresponding location results (number of located events within intervals of 14.4-cm length along the axis of gas cylinder with reference to the bottom) of gas cylinders 304407 (left), 304405 (middle) and 304204 (right).

Statistics on the performed test runs revealed that approximately 1% of the tested gas cylinder population shows indications, which exceed one or more stop criteria. These gas cylinders are removed from the test rig and replaced by others, not tested before. The test run is repeated with more stringent stop criteria to take into account the previous loading (Kaiser effect).

Analysis of test data and visual inside inspection (lowering videoscope with a light bulb into the gas cylinder) was performed on all rejected cylinders. Until now, no findings were made at this stage of follow-up, which have led to immediate rejection (to scrap yard). The next stage is to perform another test run after at least six month with manual monitoring of the pressurization by an experienced test engineer. On approximately 20% of these re-tested cylinders, further follow-up (videoscope, see Fig. 5) has been done in order to clarify the indications. The vast majority of them have been caused by inside corrosion.
Conclusions

With the use of AE technology, the semi-automatic testing facility for requalification of gas cylinders (200 bar, 50 liters) of Messer Austria at their Herzogenburg site enables safe pneumatic testing. Risks of inside corrosion or contamination of storage product due to remaining humidity are minimized. Operating costs are minimized as well. In service since 2001, testing of approximately 40000 gas cylinders has shown the successful application of this new testing concept with AE. Due to the flexibility of the system (software solutions), it may be adapted to other gas cylinder types as required.

References