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Quality Testing of Gaseous Helium Pressure Vessels by Acoustic Emission

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Abstract

The resistance of pressure equipment is currently tested, before commissioning or at periodic maintenance, by means of normal pressure tests. Defects occurring inside materials during the execution of these tests or not seen by usual non-destructive techniques can remain as undetected potential sources of failure . The acoustic emission (AE) technique can detect and monitor the evolution of such failures. Industrial-size helium cryogenic systems employ cryogens often stored in gaseous form under pressure at ambient temperature. Standard initial and periodic pressure testing imposes operational constraints which other complementary testing methods, such as AE, could significantly alleviate. Recent reception testing of 250 m^3 GHe storage vessels with a design pressure of 2.2 MPa for the LEP and LHC cryogenic systems has implemented AE with the above-mentioned aims.

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The resistance of pressure equipment is currently tested, before commissioning or at periodic maintenance, by means of normal pressure tests. Defects occurring inside materials during the execution of these tests or not seen by usual non-destructive techniques can remain as undetected potential sources of failure . The acoustic emission (AE) technique can detect and monitor the evolution of such failures. Industrial-size helium cryogenic systems employ cryogens often stored in gaseous form under pressure at ambient temperature. Standard initial and periodic pressure testing imposes operational constraints which other complementary testing methods, such as AE, could significantly alleviate. Recent reception testing of 250 m^3 GHe storage vessels with a design pressure of 2.2 MPa for the LEP and LHC cryogenic systems has implemented AE with the above-mentioned aims.

1 INTRODUCTION

Nowadays cryogenics has become an important user of large pressure containers for its process fluids when stored in the gaseous state.

The LHC, the 27 km circular proton-proton collider presently in the initial stages of construction at CERN in Geneva (Switzerland), will use a cryogenic system employing ~ 96000 kg of liquid helium as cooler of the chain of its ~ 2000 supraconducting main magnets and disposing of ~ 50 buffer and storage vessels of 250 m^3 each corresponding to a total capacity of ~ 12.500 m^3 at 2.2 MPa for gaseous helium at ambient temperature.

In the framework of the application of the most advanced techniques also for safety testing, a relatively novel non-destructive (ND) global detection technique, Acoustic Emission (AE), has been associated with the normal mandatory pressure tests in order, firstly, to detect , locate and survey in real time defects which are sometimes hardly recognisable using other ND techniques and, secondly, to keep track of their evolution during the operational life of the vessel. A description and comments concerning the test criteria and procedures for 12 of these ~50 storage vessels, already built, installed and tested, together with the plans for their future operational life, are given in Section 3 of this article.

2 THE ACOUSTIC EMISSION TECHNIQUE

Today’s construction and use of pressure equipment rely on the concurrent application of sciences and techniques on materials, structural design, fabrication, inspection, testing, protection and maintenance. Standards, codes and regulations summarise all useful information for the safe realisation and operation of such equipment. On the basis of the current state of the art in the above mentioned domains these documents are periodically updated according to all new advancements, especially in the field of non-destructive testing.

This is the case for AE, which is useful as a complementary global technique, capable of locating and monitoring in real time the presence and evolution of microcrystalline defects in large vessels or other structures of any size when under stress. The AE technique is based on a naturally occurring phenomenon produced by transient elastic waves travelling within materials when strain energy, produced by microstructural changes inside the material, is suddenly released all around the modified region. If enough energy is released, the sounds produced can be audible.

The present advanced state of development of this technique, mainly due to the fundamental discovery of J. Kaiser, at the beginning of the fifties, known as the Kaiser effect, relies on the non-repeatability of the acoustic phenomenon because of the irreversibility of the behaviour of the defects in the metallic structures not affected by global degradation themselves [3]. Under further loading, structures emit acoustically only after exceeding the highest stress value reached during the previous loading cycles.

Nowadays, the AE technique makes it possible to extend our hearing to detect sounds of higher frequencies and lower intensities; the acoustic signals of all these intercrystalline phenomena being picked up, typically, in the ultrasonic range between 50 kHz and 2 MHz.

Usually, piezoelectric sensors are used to convert the AE stress waves into electric signals that are amplified and further processed. An array of sensors (Fig. 2) can locate the acoustic source by means of the ultrasonic wave arriving at each sensor at different times [4].

During the last 20 years, the AE technique has found more and more applications. Table 1 summarizes the present state of the art in AE standardisaton and application in the field of pressure vessel testing :

Table 1 Standardisation of AE for pressure vessel testing

Country(ies)	Standards	Designation	
USA	Yes	ASTM E1419 and ASME BC 95. Sect.V	1)
Japan	Yes	JSNDI	
Austria and Germany	Yes	VD-TUV 369- 12/93	2)
EC Std.zation Commissions	Under preparation	CEN/TC/138/WG7-Ac. Em./ Press. Vessels	
France	Yes	AFNOR	3)

1) ASTM Standards in application since 1980.
2) The TUVs accept the equivalence between the hydrostatic test and the pneumatic test monitored by Acoustic Emission.
3) In addition to these Standards, a multipartner program named CIAPES (Contrôle et Inspection des Appareils à Pression lors de l'Epreuve et en Service) launched and steered by the CETIM, Senlis (France), in which CERN participates with 9 other different partners from industry and research, is in progress since 1993 with the main aim to develop a real-time surveillance method by Acoustic Emission for ensuring the safety of proof tests on pressure vessels [5].

3 ACOUSTIC EMISSION ON 250 m^3 HELIUM GAS STORAGE VESSELS

Twelve gaseous helium pressure vessels, at present ready for operation on CERN's service and access sites, have each been submitted to two pressure tests : namely, a hydrostatic test, at 1.5 times the design pressure, at the manufacturer's premises in Decin (Czech Republic) and a pneumatic test, at 1.25 times the design pressure, at CERN after transport, handling and installation. The surveillance of these tests by means of AE has been performed within the framework of the above-mentioned CIAPES Program [5,6,7].

The aims of these tests, which led to the implementation of AE as a real-time survey technique complementary to normal mandatory pressure tests on the first batch of twelve pressure vessels, were :

- to acquire the best possible first-hand insight into the quality of the tanks before they leave the workshop
- to collect useful data on the tanks' structure as a support for justifying possible future requests to increase the intervals between periodic inspections
- to apply AE real-time surveillance during the mandatory pneumatic tests on CERN's service sites, in order to detect and locate the appearance of any new defect in the structure and to monitor its evolution, the purpose beeing to decide immediately whether to continue with the pressurisation of the vessel or to stop it and examine the defect by means of other ND techniques.

The common technical conditions for the two types of tests were as specified in the following three tables.

For the pressure vessels (see Figure1 for the dimensions and positioning of the sensors) :

Table 2 Characteristics of pressure vessels

Material and Dimensions	
material	Steel P 355 NL 2
volume	250 m^3
length	28600 mm
diameter	3500 mm
thickness	22 mm

Table 3 Pressure vessels

Pressures	MPa abs
design	2.2
max. working	2.1
hydrostatic test	3.25
pneumatic test	2.65

Table 4 Characteristics of AE signal acquisition system

Item	Type	Characteristics
System	VALLEN AMS3	31 channels equipped
Preamplifiers	VALLEN 20-AP/SN	Gain 34 dB
filters		95 kHz – 1 MHz
Sensors	CETIM	piezoelectric, resonant at 180 kHz

Figure 2 resumes three typical displays of the monitoring during one hydrostatic pressure test, showing some triangular meshes of the localisation array based on 31 sensors.

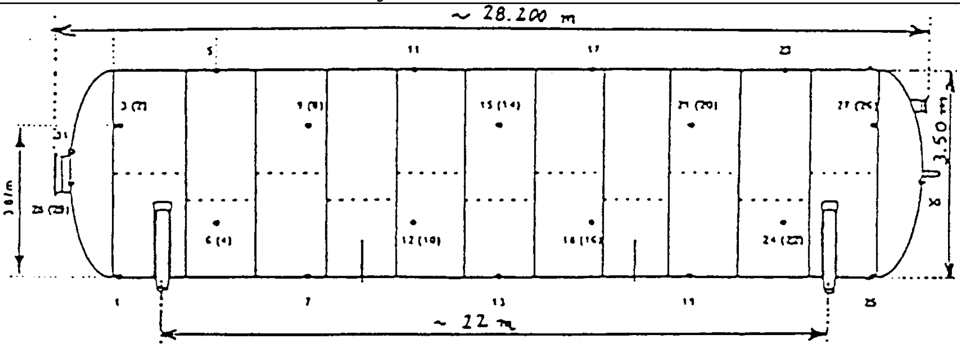

Figure 1

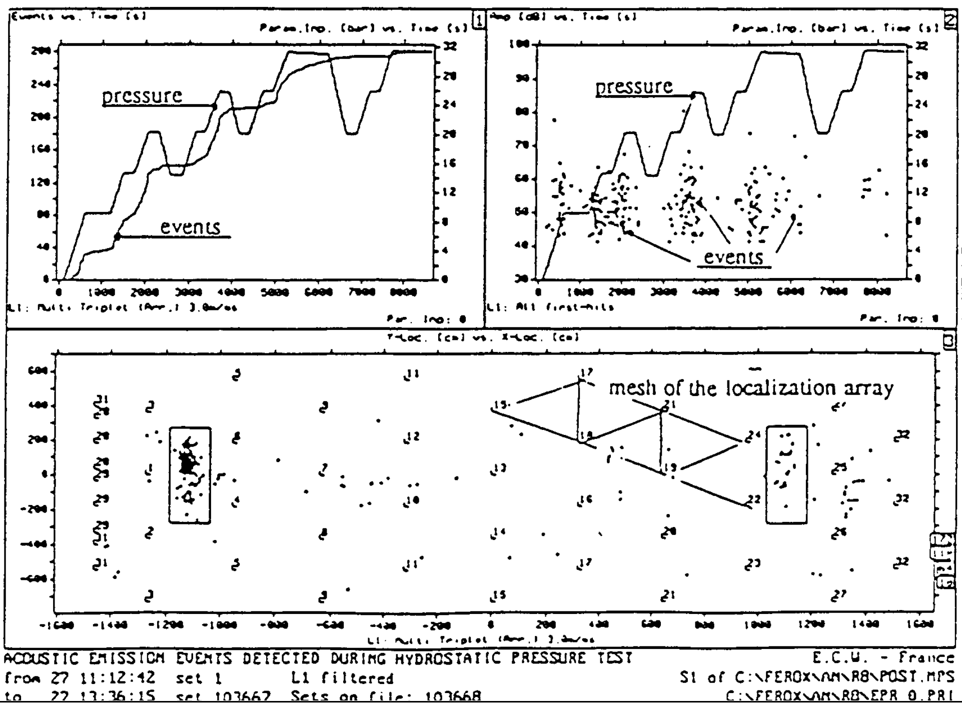

Figure 2

All 24 tests (12 hydrostatic + 12 pneumatic) were monitored in real time by an AE system with the aim of detecting and locating defects as they evolved, thus establishing reference records for future tests. All pressure vessels successfully passed the tests and no acoustic activity indicating evolving defects was detected. For each tank, the acoustic activities during both the hydrostatic and the pneumatic test proved very modest , very similar and occurred in the same regions, namely the two supports (no evidence indicates the presence or absence of water overload during the two tests). The Kaiser effect regularly appeared as expected during all the tests.

4 CONCLUSIONS

For the first time, twelve important pressure vessels are starting their operational life accompanied by precise records on the overall state of their structure which are available, as a reference for all future inspections and tests.

The experience acquired from the execution of the 24 tests assisted by the Acoustic Emission technique provides indications on the simplifications and improvements to be introduced for the same tests on the pressure vessels to be built in the coming years.

Increasing application experience of AE testing and the completion of development programs such as CIAPES are likely to result in EC regulations allowing its use, together with appropriate ND detection methods as a complementary support to the pneumatic tests where hydrostatic tests could be harmful or impractical. This is in agreement with the spirit of what already expressed at Art. 3.2.2 of Annex I of the European Directive 97/23/EC.

The AE records of a pressure vessel should also facilitate the preparation of eventual waiver applications.

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6 REFERENCES

1 Official Journal of the European Communities. L 181, Vol. 40.(9 July 1997), Directive 97/23/C of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

2 Kaiser J., Untersuchungen über das Auftreten von Geraüschen bei Zugversuch. - Archiv für das Eisenhuttenwesen (1953 Germany)

3 Roget J., Essais non destructifs, l’émission acoustique. AFNOR-CETIM Co-editors (1988)

4 Cherfaoui M., Hervé C., Acoustic Emission : New Discoveries in Acoustic Emission Checks on Pressure Vessels during Supervised Tests or Resistance Tests, Proc. 22nd Eur.Conf.on Ac.Em.Testing Aberdeen, (1996) 149-154

5 Cherfaoui M., PROJET C.I.A.P.E.S., Compte-rendu de la réunion No. 2 du 8 juillet 1993 à la Maison de la Mécanique,

6 Cherfaoui M., Hervé C., Procès Verbal du Contrôle par émission acoustique lors de l’épreuve hydraulique du réservoir d’hélium No. 36506 (FEROX)- Progr. CIAPES 2 (1998)

7 Cherfaoui M., Hervé C., Procès Verbal du Contrôle par émission acoustique lors de l’épreuve pneumatique du réservoir d’hélium No. 36506 (FEROX)- Progr. CIAPES 2 (1998)