AE-based requalification of small underground LPG vessels. A 15-year summary of application of ISPESL/INAIL AE procedure

Giuseppe Augugliaro (*), Paolo Lenzuni (**), Canio Mennuti (*)

(*) INAIL, Dipartimento Innovazioni Tecnologiche

(**) INAIL, Unità Operativa Territoriale di Firenze

Dipartimento Innovazioni Tecnologiche e Sicurezza degli Impianti Prodotti e insediamenti Antropici

1

Underground vessels typology

Polyethylene shell

Epoxy resin coating and cathodic protection

GAZZETTA UFFICIALE

According to an italian law of 1974, vessels must be checked every 10 years.

Vessel are dug out for inspection

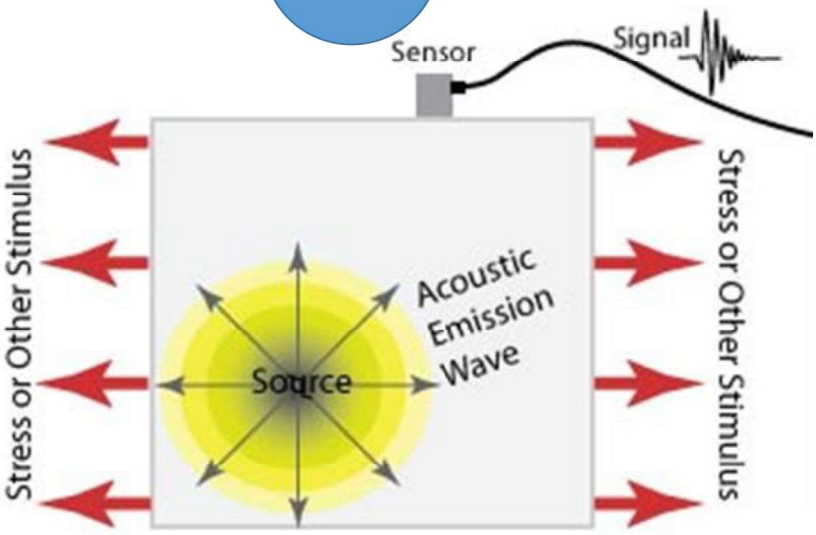
GAZZETTA UFFICIALE

According to an italian law of 1974, vessels must be checked every 10 years.

If found compliant, they can be operated for an additional period of 10 years.

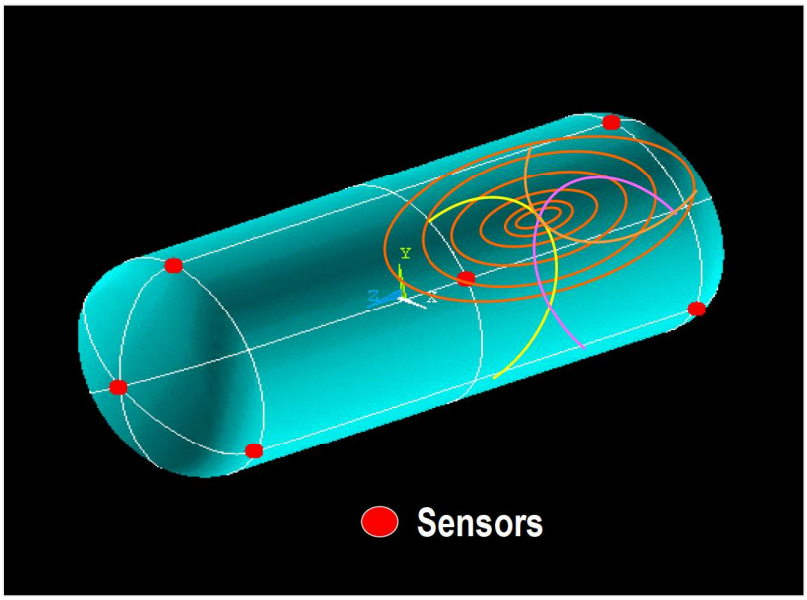
Traditional methods of inspection require that the vessel is unearthed, which means that they are cumbersome, slow and expensive, i.e. very cost-ineffective.

2

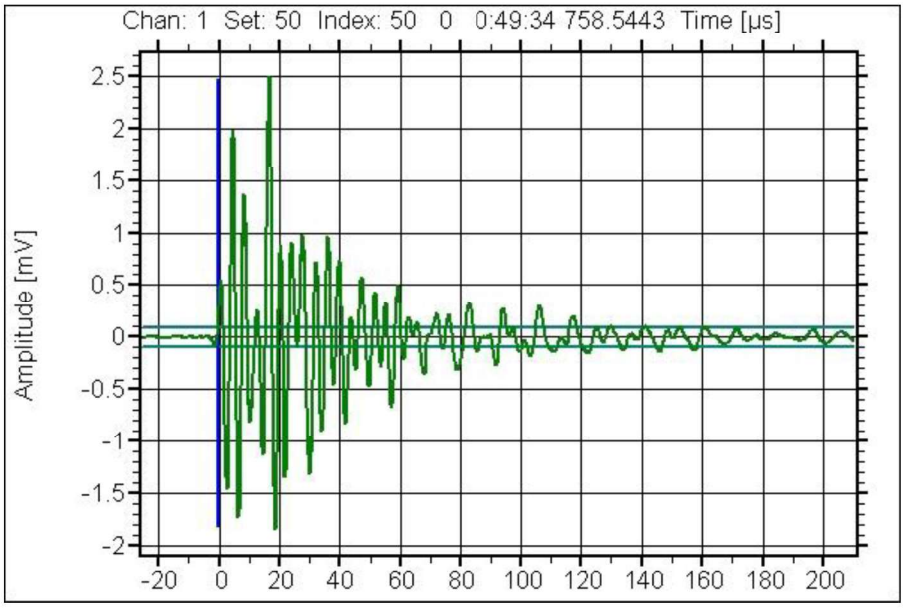


The AE method

Typical AE test arrangement



Typical AE burst

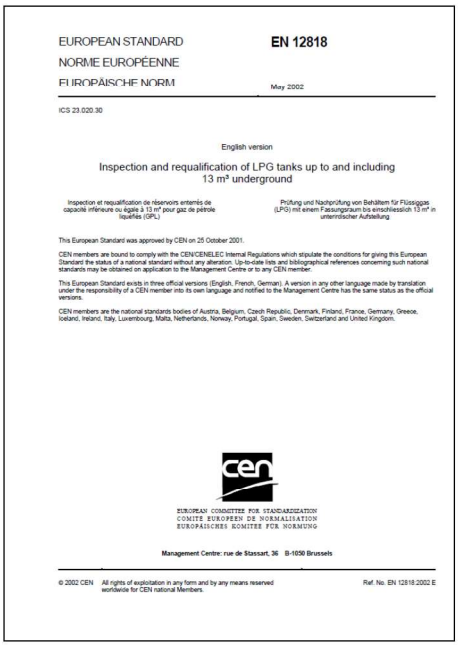


The AE method has many positive characteristics

EN 13554 - Non-destructive testing - Acoustic emission - General principles
5.2 Advantages and features of AE

- It is non only non-destructive, but also **non-invasive**;
- it allows **100 % monitoring**;
- it allows detection of sources, depending of the materials properties, up to a distance of **several meters**;
- it is sensitive to **dynamic (evolving) defects** in the material structure **but not to static defects**;
- it offers a **dynamic real time monitoring** of any discontinuity that grows under the applied stress;
- it can be applied to monitor the structures **during operating conditions**;
- it is capable of accurately **locating** a defect.

EN 12818:2002 / EN 12817:2010



EUROPEAN STANDARD **EN 12818**

NORME EUROPÉENNE

EUROPÄISCHE NORM

May 2002

ICS 23.020.30

English version

Inspection and requalification of LPG tanks up to and including 13 m³ underground

Inspection et requalification de réservoirs enterrés de capacité inférieure ou égale à 13 m³ pour gaz de pétrole liquéfiés (GPL)

Prüfung und Nachprüfung von Behältern für Flüssiggas (LPG) mit einem Fassungsraum bis einschliesslich 13 m³ in unterirdischer Aufstellung

This European Standard was approved by CEN on 25 October 2001.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Management Centre or to any CEN member.

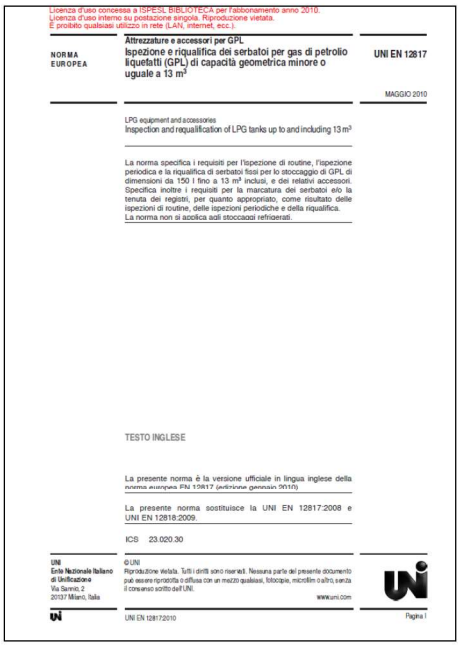
This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

Ref. No. EN 12818:2002 E



NORMA EUROPEA

Attrezzature e accessori per GPL

Ispezione e riqualifica dei serbatoi per gas di petrolio liquefatti (GPL) di capacità geometrica minore o uguale a 13 m³

UNI EN 12817

MAGGIO 2010

LPG equipment and accessories

Inspection and requalification of LPG tanks up to and including 13 m³

La norma specifica i requisiti per l'ispezione di routine, l'ispezione periodica e la riqualifica di serbatoi fissi per lo stoccaggio di GPL di dimensioni da 150 l fino a 13 m³ inclusi, e dei relativi accessori. Specifica inoltre i requisiti per la marcatura dei serbatoi e/o la tenuta dei registri, per quanto appropriato, come risultato delle ispezioni di routine, delle ispezioni periodiche e della riqualifica. La norma non si applica agli stoccaggi refrigerati.

TESTO INGLESE

La presente norma è la versione ufficiale in lingua inglese della norma europea EN 12817 (edizione gennaio 2010).

La presente norma sostituisce la UNI EN 12817:2008 e UNI EN 12818:2009.

ICS 23.020.30

UNI
Ente Nazionale Italiano di Unificazione
Via Sannio, 2
20137 Milano, Italia

EN 12818:2002 / EN 12817:2010

5.3 Requalification

5.3.1 Requalification intervals shall be specified in the written scheme. **Requalification shall conform** to either a) or b).

a) Individual requalification of each tank Individual requalification shall include at least one test from group 1 and one from group 2 of Table 1.

Group 1	Group 2
Internal visual inspection (see annex A) Hydraulic pressure test (see annex B) **Acoustic emission test (see annex C)** Ultrasonic thickness test (see annex D) Other equivalent method	External visual inspection (i.e. excavation) External monitoring by camera etc. (see annex E) Cathodic protection monitoring (see annex F or G) Moisture detection (see annex H)

b) Requalification of a production batch by sampling

Tanks shall be sampled in accordance with annex I. The tanks shall pass an internal inspection (see annex A), and shall be tested as follows before any repair or refurbishment is carried out:

— a hydraulic pressure test (see annex B); and

— an ultrasonic thickness test (see annex D); and

— an X-ray or ultrasonic check on welds, comparable to inspections carried out at the time of manufacture;

— or

— **an acoustic emission test (see annex C).**

3

Research activity was planned (2002 – 2004)

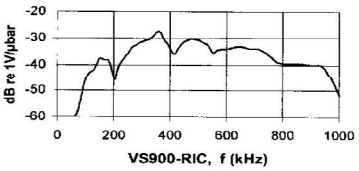
3.1

Frequency range, number and location of sensors were optimized

Sensors

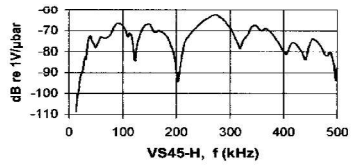
1. VS 900 – Ric 100 - 900 kHz

High sensitivity AE-sensor (wide band) with integrated preamplifier (34 dB) and calibration bypass.



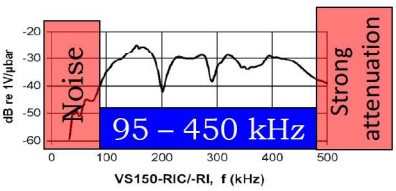
2. VS 45 – H 20 - 450 kHz

Mass – loaded AE-sensor that behaves as a displacement sensor below 45 kHz (leak detection) and as a velocity sensor at 70 kHz and above (crack detection).



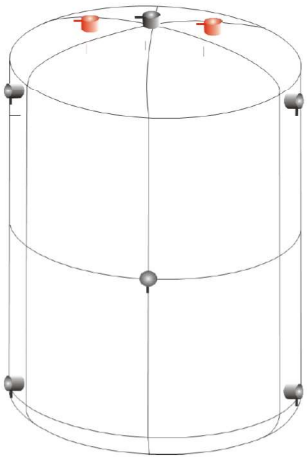
3. VS 150 – RIC 100 - 450 kHz

High sensitivity AE-sensor with integrated preamplifier (34dB) and calibration bypass. Optimized for performing field tests on pressure vessels, piping systems and other structures. Able to drive long cables.

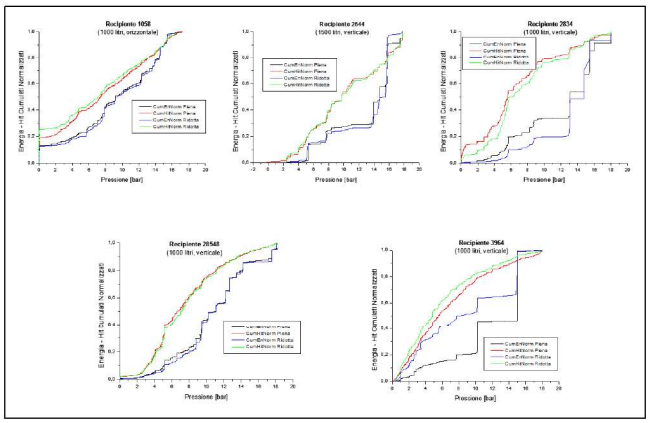


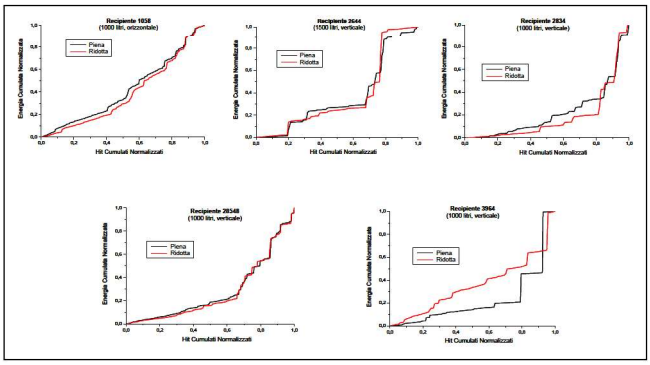
Configurations

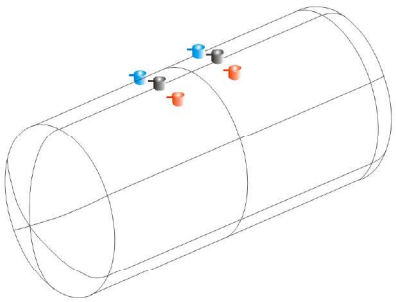
Full (black) and reduced (red) configurations of sensors



- 11 sensors (full)
- 2 sensors (reduced)



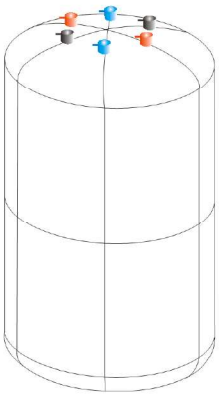




Couple 1
VS 900 - RIC

Couple 2
VS 45 – H, HF

Couple 3
VS 150 – RIC



Couple 1
VS 900 - RIC

Couple 2
VS 45 – H, HF

Couple 3
VS 150 – RIC

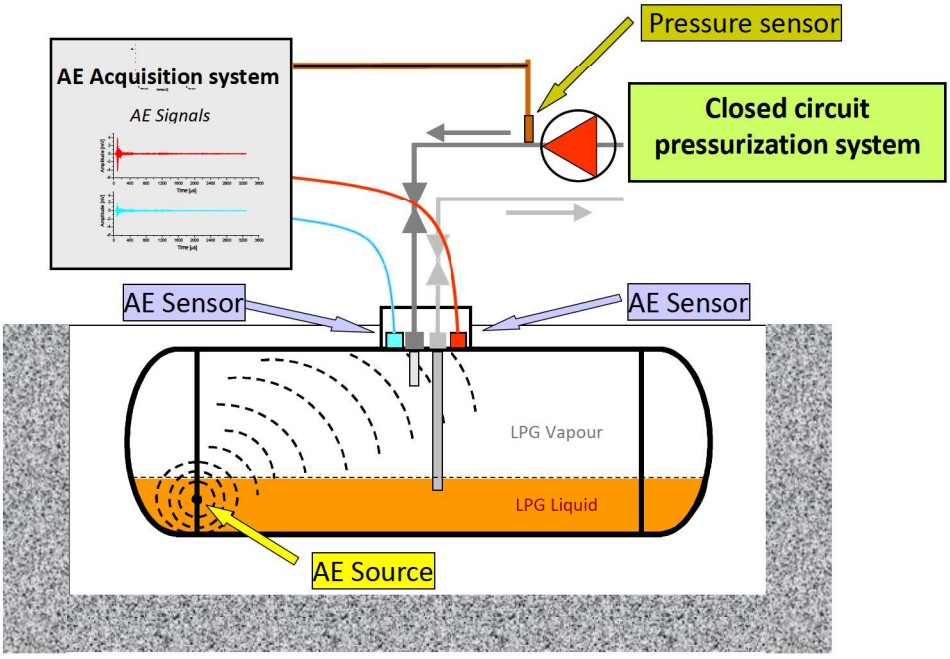
Locations

3.2

Real world tests were performed

Hardware and software aboard a dedicated vehicle

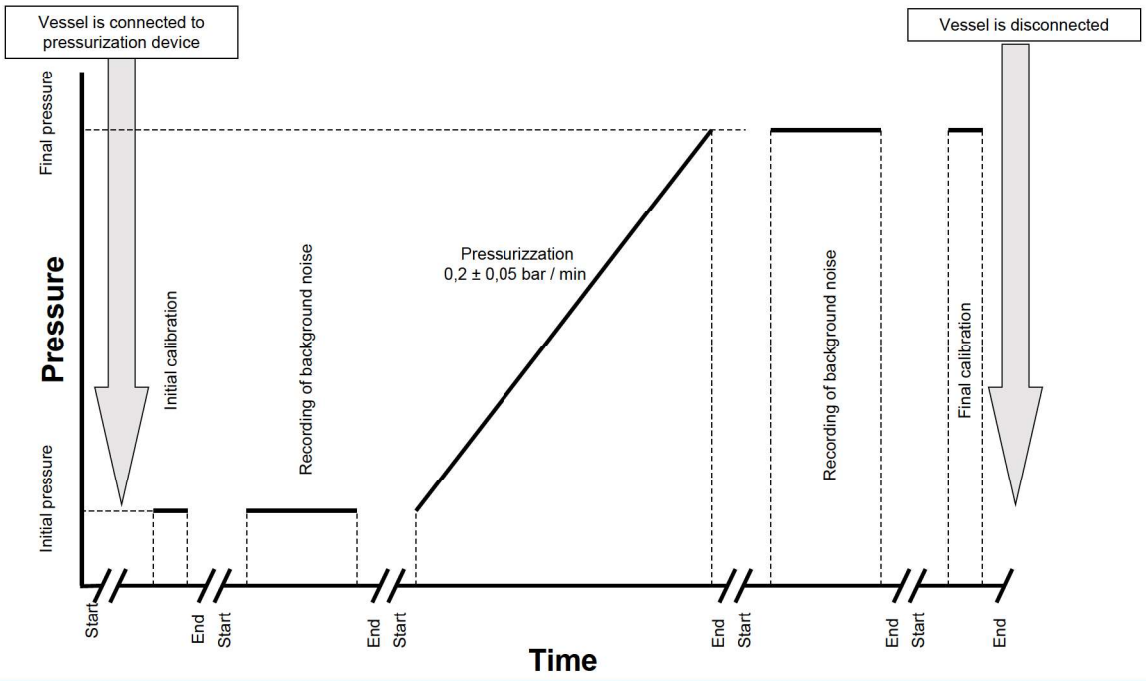
Pressurization system



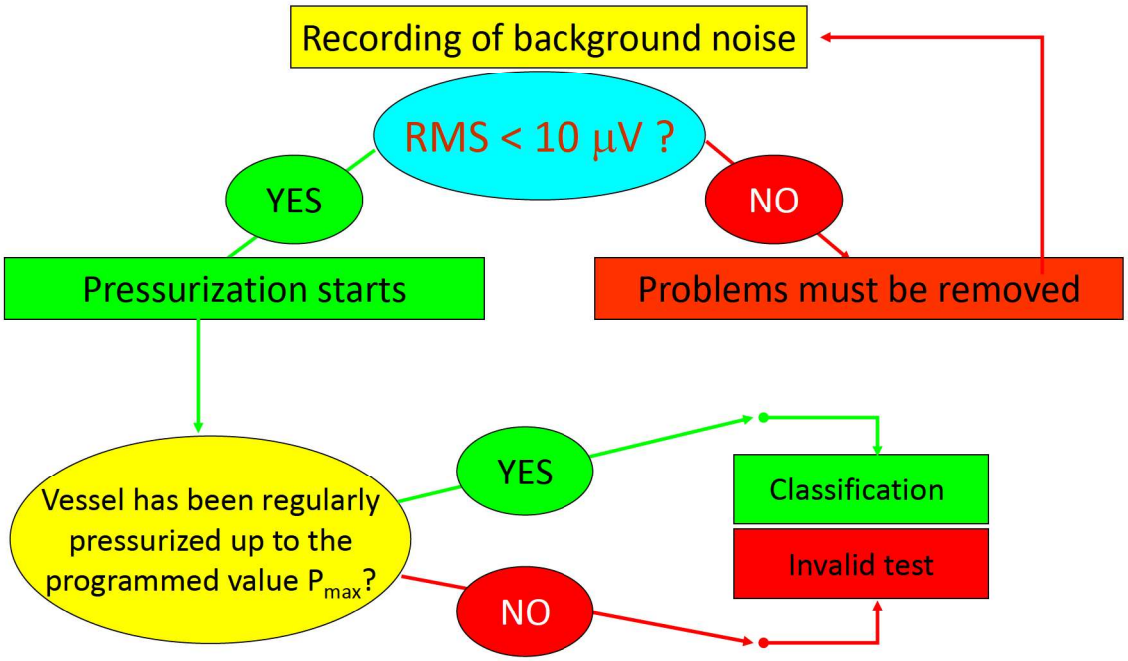
3.3

The operational sequence was laid out

AE test sequence



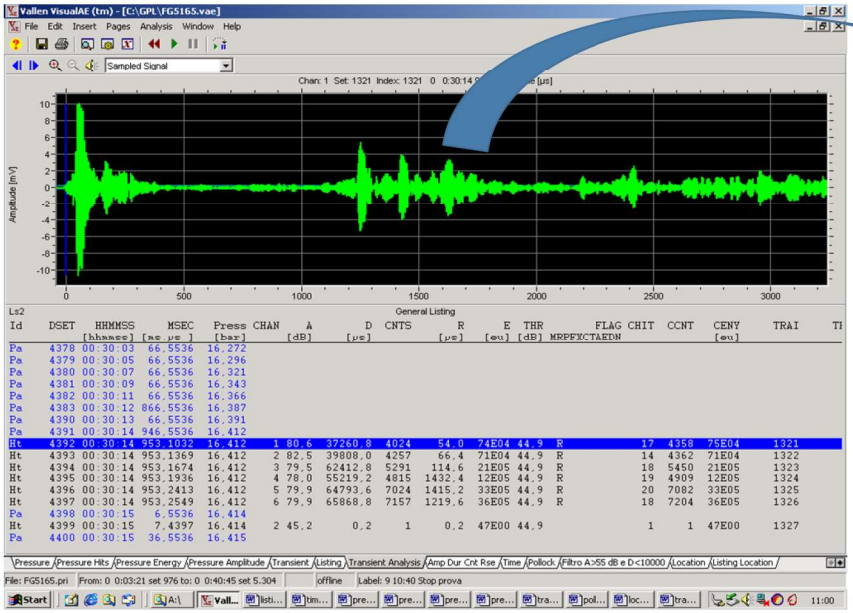
AE test flow chart



4

Data Analysis Model was developed (2004)

Signal acquisition and parameter extraction



$$E = \int_{t_0}^{t_0+D} V^2(t)dt$$

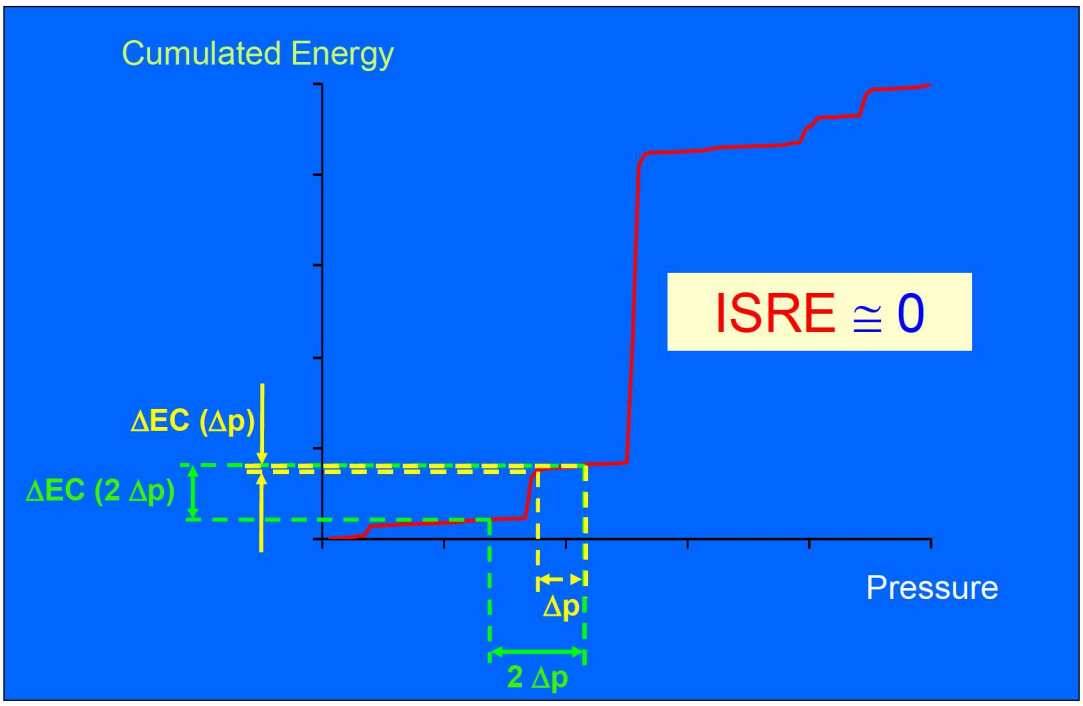
Synthetic evaluation index – 1 (ICSE)

$$ICSE = f(HC, EC, k, |AC - 0.5|)$$

- HC is the cumulative number of AE bursts that can be successfully located;
- EC is the cumulative energy of all HC bursts;
- K is the number of the most energetic events needed
  to account for 50% of the cumulative energy released;
- AC is the "area factor", calculated as the (sign-independent) departure of the
  Normalized Cumulative Hits-Energy (NCHE) area, from the "ideal" value of 0.5.

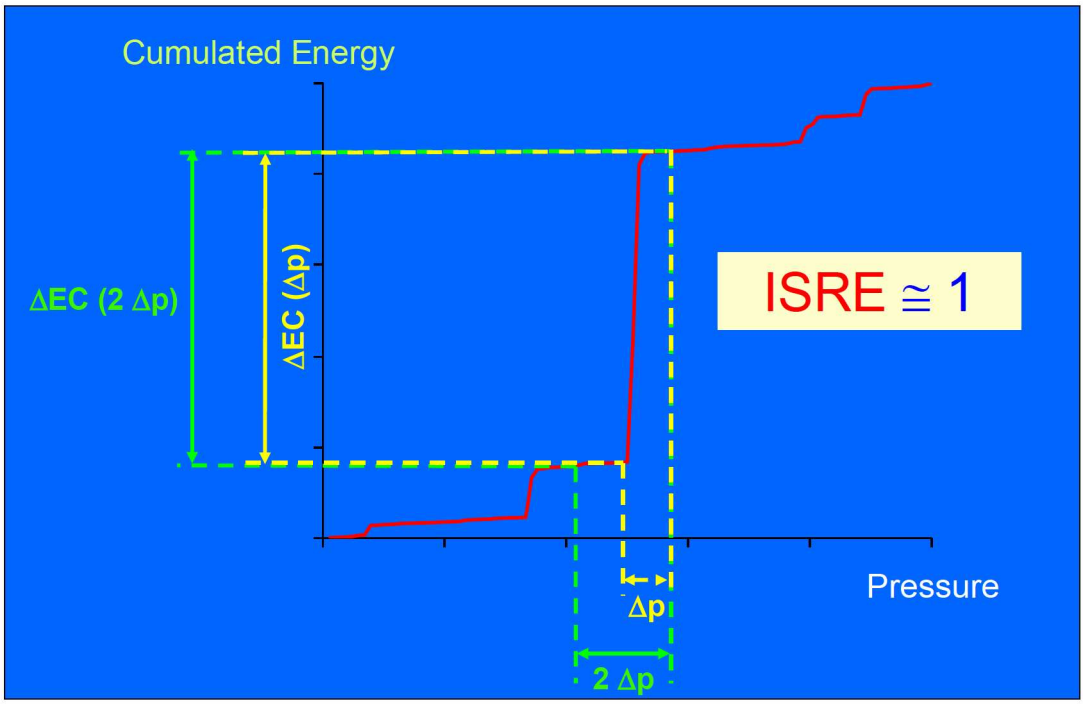
Synthetic evaluation index – 2 (ISRE)

$$ISRE = \frac{\Delta EC(\Delta p)}{\Delta EC(2\Delta p)}$$

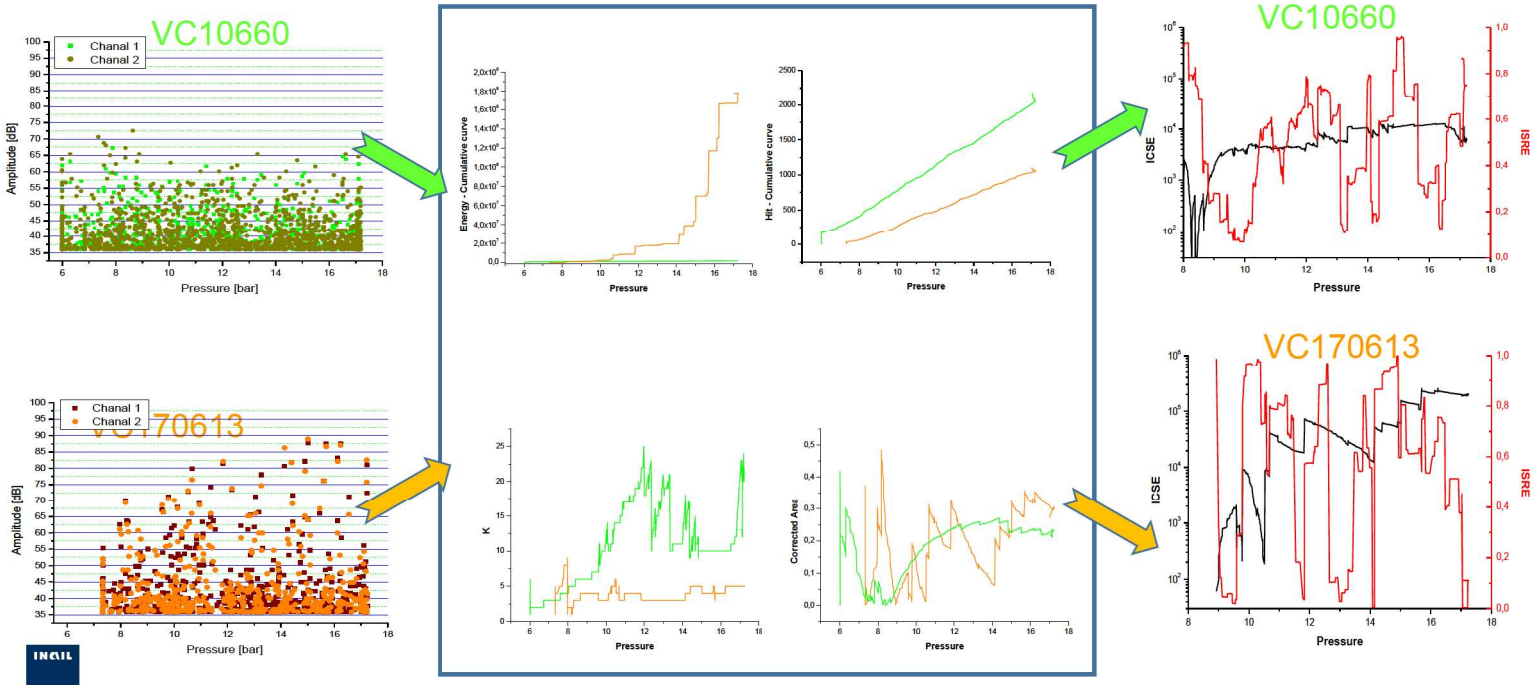


Synthetic evaluation index – 2 (ISRE)

$$ISRE = \frac{\Delta EC(\Delta p)}{\Delta EC(2\Delta p)}$$

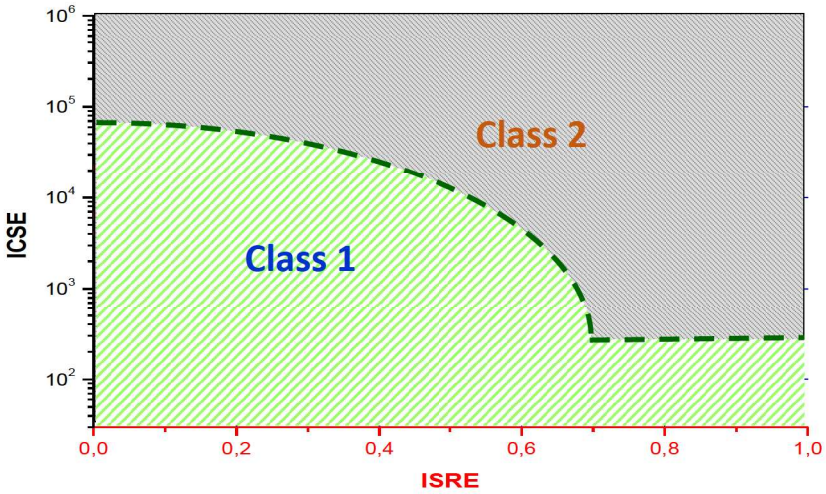


AE test on-line analysis



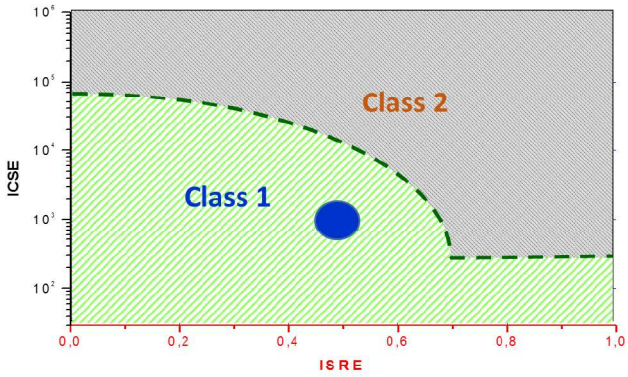
AE test Evaluation Factor γ (Gamma)

ICSE e ISRE are incorporated into a single synthetic index of structural integrity γ
(**Evaluation Factor**)



Class 1

$\gamma_{max} < \gamma_{lim}$?



$\gamma_{lim} = 0.87$

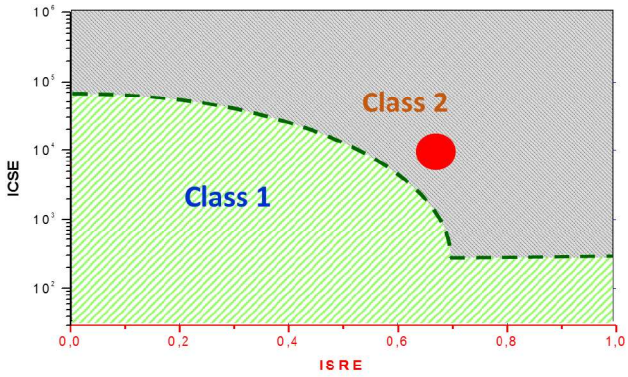
YES → Vessel is compliant

Class 2

$\gamma_{max} < \gamma_{lim}$?

NO → Vessel is NOT compliant

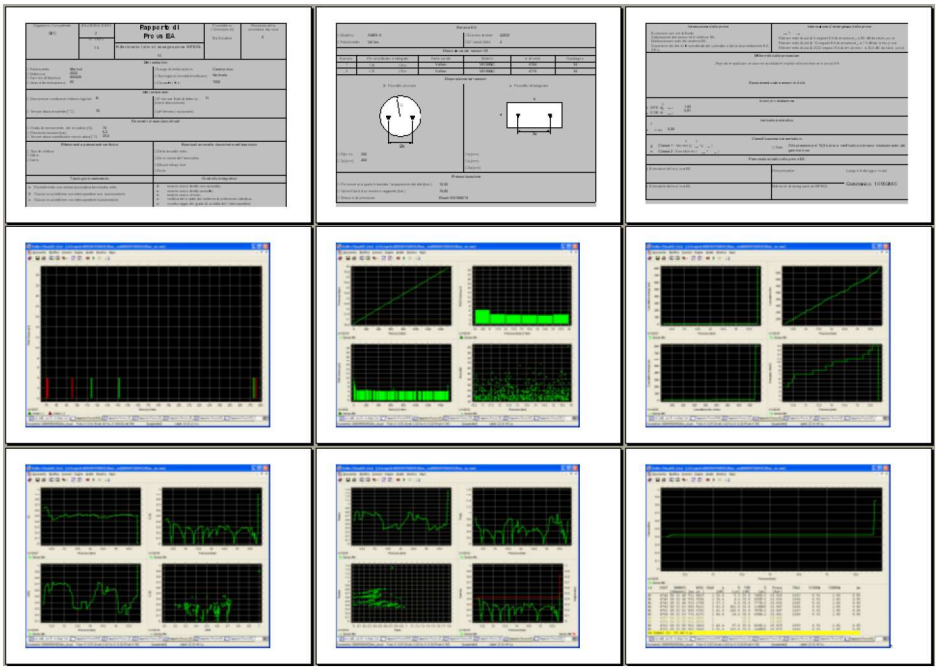
$\gamma_{lim} = 0.87$



Class 2

More than 8 hits with A $\geq$ 85 dB
More than 25 hits with A $\geq$ 75 dB
More than 1000 hits with A $\geq$ 40 dB

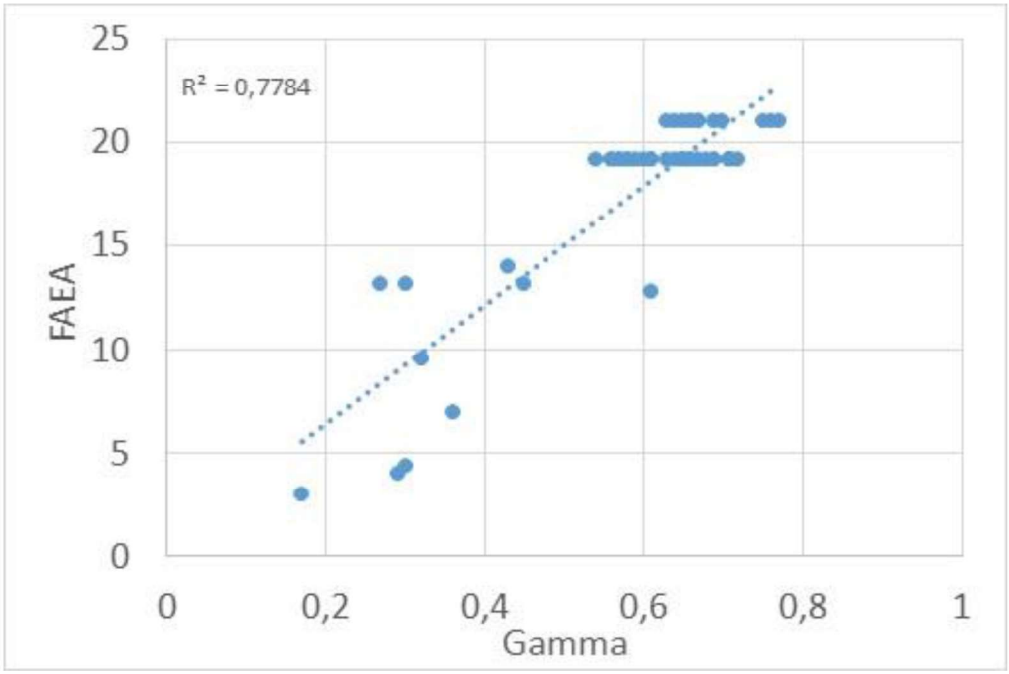
AE procedure test report



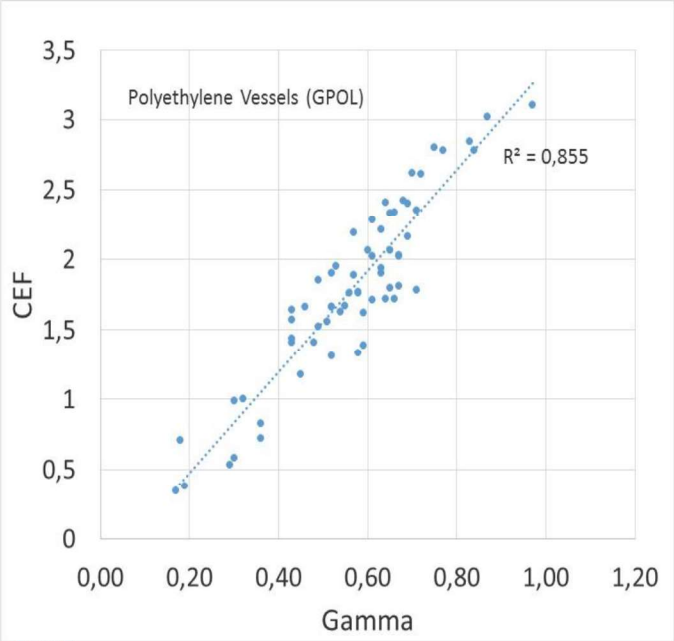
5

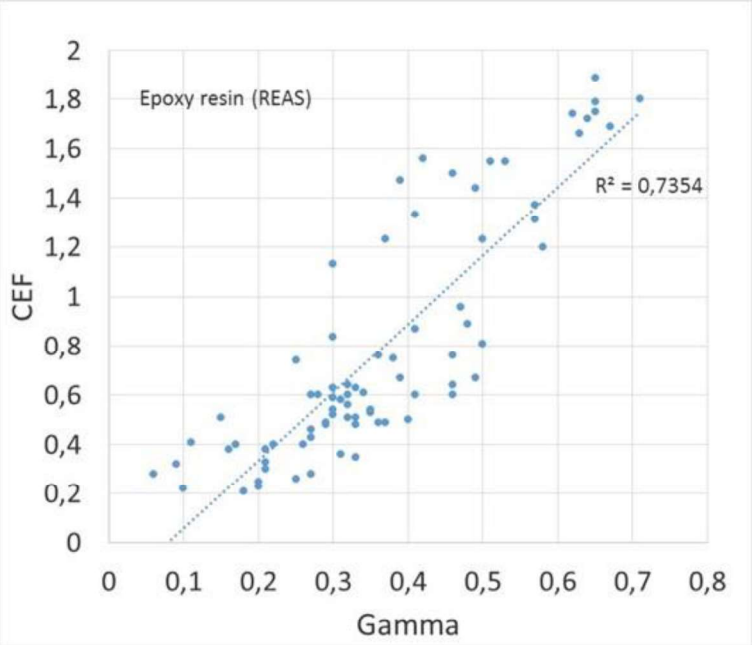
Comparison with other evalutation methods was carried out (2004)

Gamma (Italian method) vs. FAEA (French method)



Gamma (Italian method) vs. CEF (Austrian method)





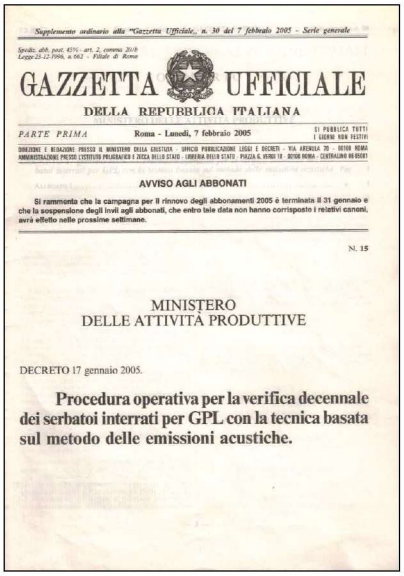
6

Italian Legislation was issued (Sept 2004 – Jan 2005)

Decreto 23 settembre 2004
Ministero delle Attività Produttive. Modifica del decreto del 29 febbraio 1988, recante norme di sicurezza per la progettazione, l'installazione e l'esercizio dei depositi di gas, di petrolio liquefatto con capacità complessiva non superiore a 5 m^3 e adozione dello standard europeo EN 12818 per i serbatoi di gas di petrolio liquefatto di capacità inferiore a 13 m^3.

…..the ten-year checks on LPG vessels with a capacity not exceeding 13 m^3 can be carried out, as an alternative to the methods provided for in art. 4 of the previous inter-ministerial decree of 29 February 1988, using the Acoustic Emission method according to the European standard EN 12818:2002

Decreto 17 gennaio 2005
Procedura operativa per la verifica decennale dei serbatoi interrati per GPL con la tecnica basata sul metodo delle emissioni acustiche.



Supplemento ordinario alla "Gazzetta Ufficiale", n. 30 del 7 febbraio 2005 - Serie generale

Spedizione abb. post. 45% - art. 2, comma 20/b Legge 23-12-1996, n.662 - Filiale di Roma

GAZZETTA UFFICIALE

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AVVISO AGLI ABBONATI

Si rammenta che la campagna per il rinnovo degli abbonamenti 2005 è terminata il 31 gennaio e che la sospensione degli invii agli abbonati, che entro tale data non hanno corrisposto i relativi canoni, avrà effetto nelle prossime settimane.

N. 15

MINISTERO
DELLE ATTIVITÀ PRODUTTIVE

DECRETO 17 gennaio 2005.

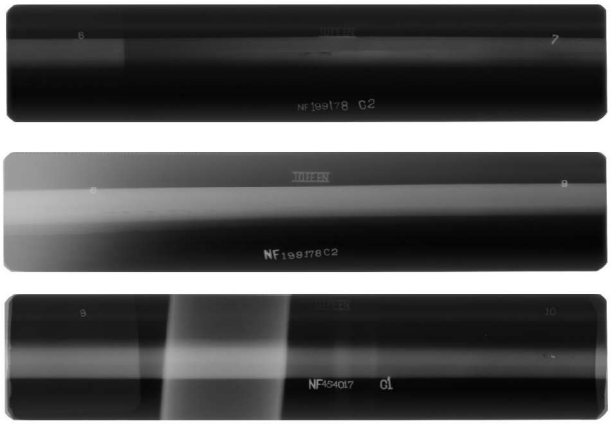
Procedura operativa per la verifica decennale dei serbatoi interrati per GPL con la tecnica basata sul metodo delle emissioni acustiche.

…… structural assessment of underground LPG vessels can be carried out using the ISPESL/INAIL AE procedure only by selected ("competent") bodies which have received an ad-hoc authorization by the competent Italian Authorities. Such "Competent Bodies" must comply with many technical and organizational requirements according to Annex 2 of the above mentioned decree D.M. 17 January 2005. At the same time, only qualified personnel is allowed to operate. The personnel qualification is issued by ISPESL/INAIL after clearing the final exam at the end of an eighty-hour training course, based on the scheme laid out in standard ISO EN 9712.

7

VT

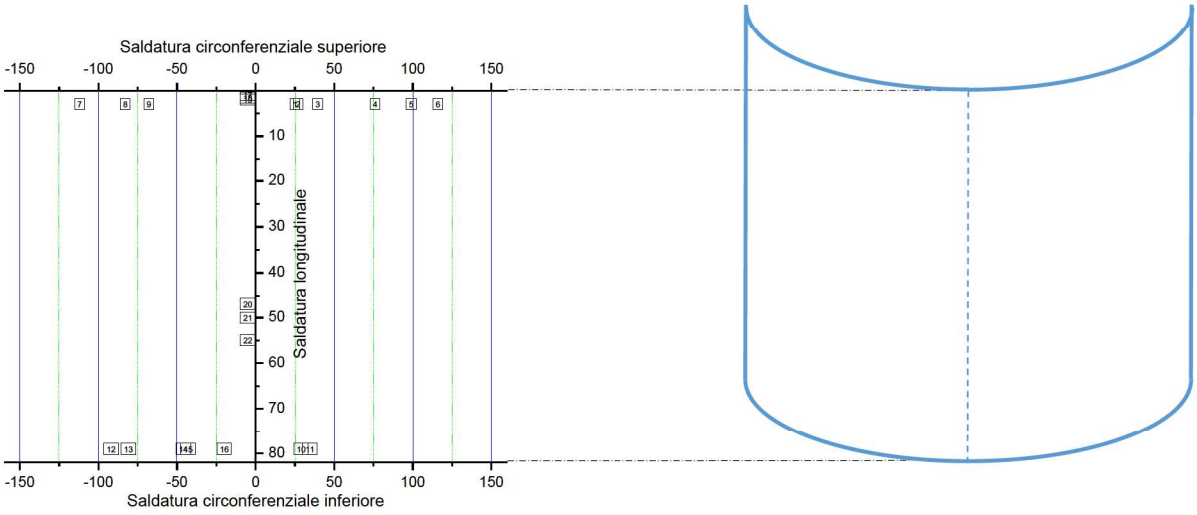
RT



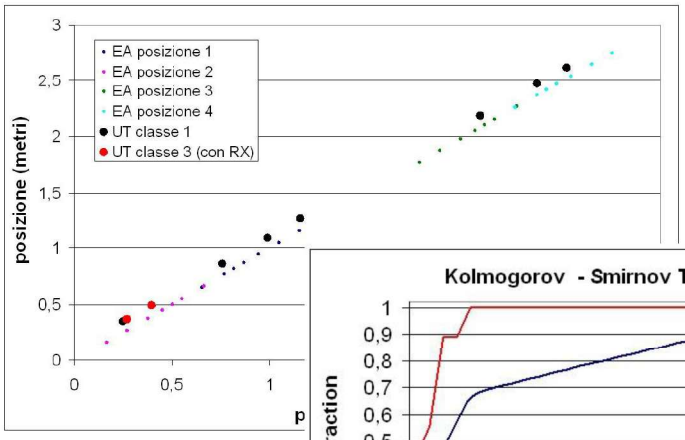
UT

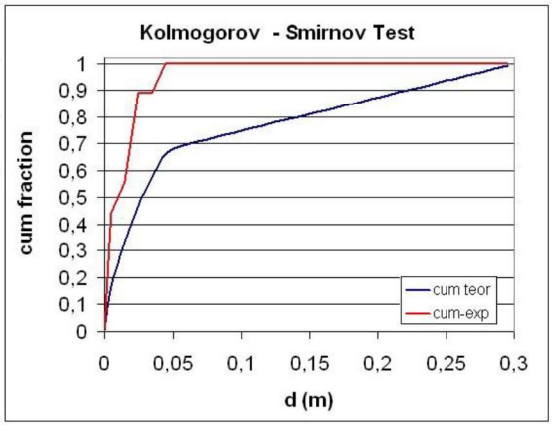
Ex-post verification of results (2006)

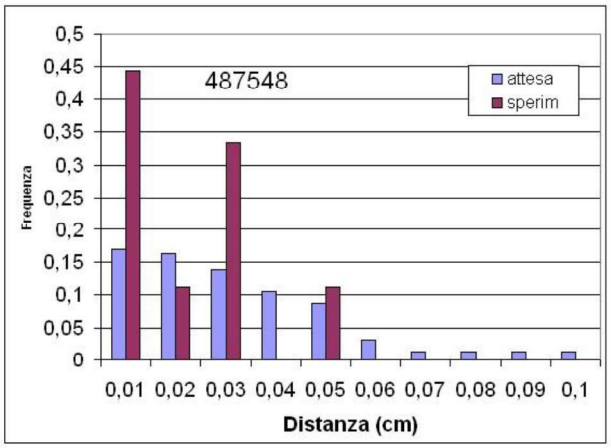
AE source location



Comparative analysis







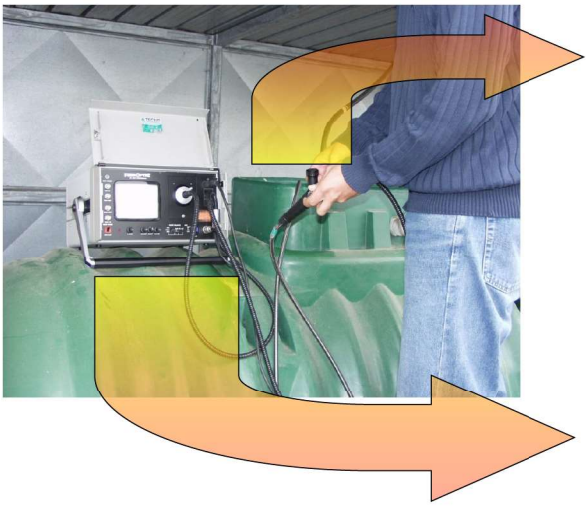
8

Each AE test always comes accompanied by another Non-Destructive Test

according to EN 12818:2002 or EN 12817:2010

Assisted direct Visual Testing by fibre-optic endoscope

polyethylene (GPOL) vessels

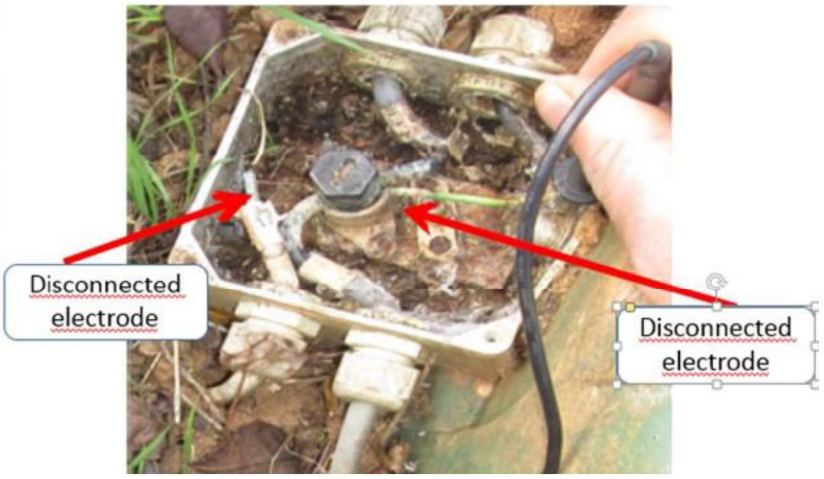


Direct Visual Testing

polyethylene (GPOL) vessels

Cathodic Protection Monitoring

epoxy resin (REAS) vessels



Country	National Law	Subject	Date
Austria	BGBI n. 211/1992 and BGBI. I n. 136/2001	Replacement of the Hydraulic test with an alternative NDT method	24th March 1992
Portugal	Despacho n. 252 30 de Outubro de 2001	LPG vessels with capacity up to 200 m³	30th October 2001
Italy	Decreto del Ministero delle Attività Produttive (GU n. 243, 15.10.2004)	Design, installation and service of LPG vessels with capacity not exceeding 5 m³. Adoption of the EU standard EN 12818 concerning LPG vessels with capacity up to 13 m³	15th October 2004
Austria	BGBLA_2004_II_420	Underground and above-the-ground LPG vessels, along with other pressure equipment	4th November 2004
Italy	Decreto del Ministero delle Attività Produttive (GU n.30, 7.2.2005 + Suppl. Ordinario n. 15)	Periodic 10-year assessment of underground LPG vessels with a technique based and Acoustic Emission	7th February 2005
Spain	Real decreto 918_2006, 28.7 ITC-ICG 03 (adoption of UNE 60250:2008)	LPG vessels with capacity up to 2000 m³	28th July 2006
Portugal	Despacho n 24 260/2007	LPG vessels with capacity up to 200 m³	23th October 2007
France	Décision BSEI n. 09-102 du 29 juin 2009 (application Guide des bonnes pratiques pour le contrôle par émission acoustique de l'AFIAP); Updated by Arrêté du 20.11.2017 (updated AFIAP Guidelines)	Spherical vessels for liquids or gases - Annex III, small LPG vessels (up to 13 m³) both underground and above-the-earth – Annex IV, cylindrical vessels – Annex VI, reactors for chemical substances – Annex VIII – Annex IX	29th July 2009
Turkey	Resmî Gazete n. 28628 25.4.2013 (recepimento EN 12817 e EN 12819)	LPG vessels with capacity up to 13 m³ and exceeding 13m³	25th April 2013
Germany	Betriebssicherheitsverordnung am 1.Juni 2015 (EA Kompendium DGZfP 2018)	Replacement of the Hydraulic test for pressure equipment with an alternative NDT method	1st June 2015

Use of AE-based methods for requalification of underground LPG vessels has spread throughout Europe

GB/T 18182-2012 **Acoustic emission** examination and **evaluation** of metallic **pressure vessels**

超越

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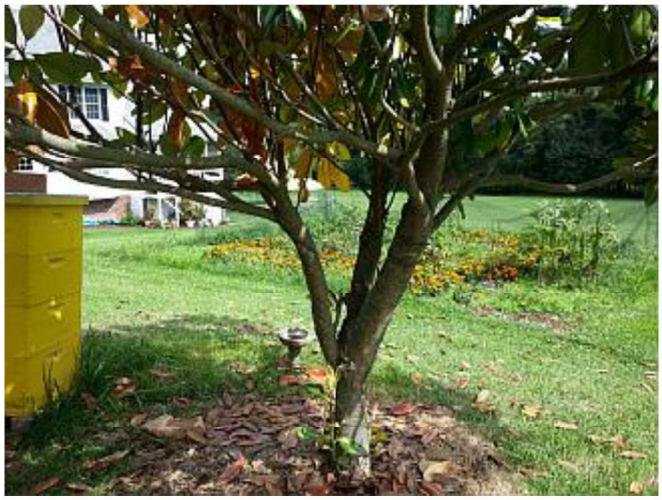


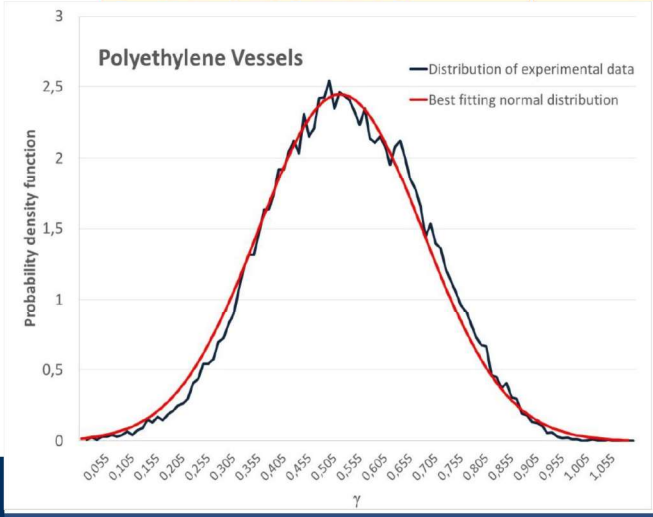
…. and here we are, after 15 years (2018)

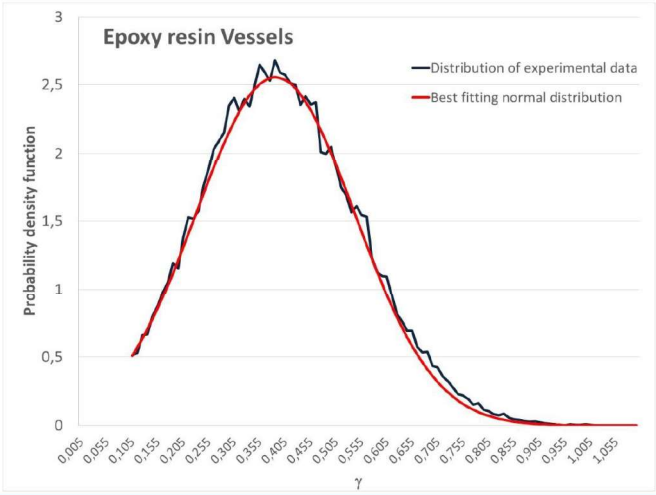
Classification of tested vessels

		Number	Percentage
Tested vessels		215529	100.00
CLASS 1	(acceptable)	209573	97.24
CLASS 2	(rejected)	2403	1.11
CLASS 0	(not evaluable)	3553	1.65

Statistical analysis of Gamma distribution

	GPOL		REAS	
Total number of tested vessels	76395	100 %	138889	100 %
CLASS 1 (acceptable)	73423	96.1 %	135890	97.8 %
CLASS 2 (rejected)	1679	2.2 %	719	0.52 %
CLASS 0 (not evaluable)	1293	1.69 %	2260	1.63 %





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With safety in mind, FIRST

Comitato Italiano Gas
Ente Federato all'UNI
Ente dotato di Personalità Giuridica
Il Direttore Generale

Milano, 20 Febbraio 2019
Ns rif: 36 – EA/ap

Gentile Signor

Ing. Carlo De Petris
Laboratorio Controlli Non Distruttivi
XII Unità Funzionale - Dipartimento Tecnologie di Sicurezza
INAIL - Settore Ricerca, Certificazione e Verifica
Centro Ricerche **INAIL**

Via Fontana Candida, 1

00040 Monte Porzio Catone (RM)

OGGETTO: EVENTI INCIDENTALI PRODOTTI DA SERBATOI PER GPL DI CAPACITÀ SINO A 5 M³

Anno 2013: 1 evento incidentale
L'incidente non è attribuibile al serbatoio stesso, risultato integro ed al momento del fatto non attivo in quanto l'utenza aveva realizzato l'allacciamento al gas naturale di rete; la Perdita di GPL si è verificata dal manometro di livello del serbatoio, e per cause varie ha provocato un'esplosione con incendio, con soli danni materiali.

Anno 2015: 1 evento incidentale
L'incidente non è attribuibile a difetti strutturali del serbatoio, bensì ad una dispersione di GPL avvenuta nella stessa giornata in cui il serbatoio era stato ricaricato.
Si sono registrati solo danni materiali.

Anno 2017: 1 evento incidentale
L'incidente non è attribuibile a difetti strutturali del serbatoio, bensì ad una dispersione di GPL avvenuta a seguito di una errata manovra dell'utente sull'indicatore di riempimento/livello del serbatoio.
Si sono verificati danni materiali e ferimento non grave alla persona che aveva effettuato la manovra. Non si è avuto incendio o scoppio.

1. 2013 - This accident is not linked to the vessel itself, which was found to be intact; LPG leaked out from the manometer and ignited an explosoin with fire, which resulted in material damage only.

2. 2015 - This accident is not due to structural defects of the vessel, but to LPG spilling out of the vessel sometime in the day when it was refilled. This resulted in material damage only.

3. 2017 - This accident is not due to structural defects of the vessel, but to LPG spilling out of the vessel due to an erroneous behavior of the operator filling the vessel itself. The operator was lightly injured. No explosion or fire resulted.

2000 - 2017

Was the procedure for field testing laid out on solid ground, based on a custom-planned experimental research? YES

Was data analysis carefully assembled to give a reliable result, while adopting a conservative approach? YES

Was the entire process validated over and over again both against traditional NDT methods and against AE-based methods developed in other countries? YES

Is it perfect? NO

Thank you for your attention