HELIUM LEAK TEST IN LINE: ENHANCED RELIABILITY FOR HEAT EXCHANGER TUBES

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ABSTRACT

Pneumatic test using air under water or air pressure differential method is a Non Destructive Test specified by current ASTM standards (A1016/A1016M) for welded tubes.

This paper reviews these two leakage testing methods and introduces a new in line helium leak test method developed by Vallourec. The first results obtained by this method demonstrate its advantage to substitute and improve the current pneumatic tests with lower detection level and higher reliability. Besides, this system is closer to the final testing methods used on assembled heat exchangers.

PNEUMATIC TESTING METHODS

The Air Under Water method (AUW)

Pressurized air is introduced into the tube and the tube is placed in a well-lit tank. After a stabilization time, an operator walks along the tube looking for bubbles. If the operator is detecting bubble coming out the tube, there is a leak and the tube is rejected and if no bubble is detected during the inspection, the tube is considered as conform.

The limit of detection mentioned with the method C1 of the EN1779 is 10^{-3} mbar.l/s but in an industrial environment it is commonly considered that the sensitivity of the air under water method is ranging from 10^{-3} mbar.l/s to 10^{-2} mbar.l/s depending on factors like lighting, water, air bubble trapped outside and when the first bubble will appear. The high dependence on operator judgment and possible plugging of the defect by water contamination are significant disadvantages that can cause to lower significantly the sensitivity even more and the repeatability of the AUW test.

The Pressure Differential method (PD)

The PD method is based on the measurement of the pressure drop over a constant period of time. A tube is pressurized with air and after a stabilization time, the pressure drop is measured by differential method, comparing the tested tube pressure to a reference volume pressure over a certain amount of time. If the pressure of the tube drops above a threshold specified, the tube is automatically rejected and if the pressure keeps below the threshold specified, the tube is conform.

On top its good sensitivity, the automatism makes this method independent of human mistake or misjudgment.

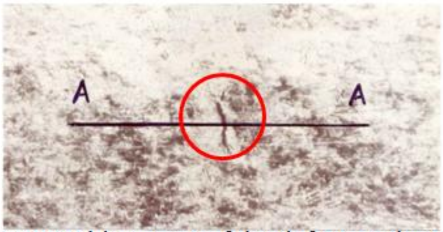
The sensitivity of the test is linked with the testing time and the pressure values. Besides, several factors can disturb the sensitivity and repeatability of the test as mentioned in the EN1779:

- Internal temperature gradient influencing the results
- Variation of the elasticity of the tube due to the variation of mechanical properties
- Mechanical deformation of the equipment itself
- Precision of the transducer
- Thermal fluctuations

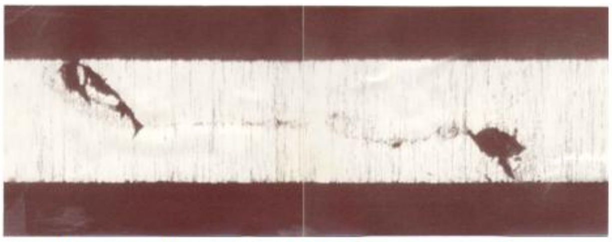
Finally the PD method doesn't allow the leak localization which can be a significant disadvantage for process/quality continuous improvement.

The limit of detection of the current pneumatic tests

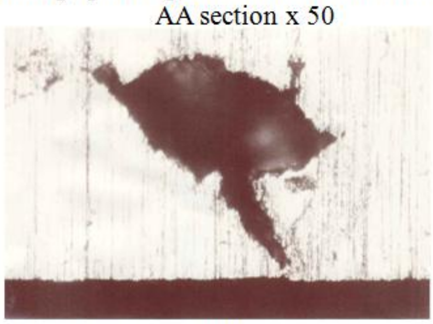
Strip defect or weld defect can be very narrow with a complex geometry as illustrated below. Such “defects” could pass successfully standard Non Destructive Tests on tubes during production but generate some leaks during more stringent tests performed on assembled equipment.



Macrographic aspect of the defect on the tube external surface x 50



Macrographic aspect of the defect according to AA section x 50



Defect detail according to AA section x 200

Strip defect N°1

The development of a new technology for tube leak detection: the helium leak test on tube

Vallourec developed the helium leak test on tube using the sniffing method by accumulation. A tube is set on a bench and the inside is pressurized with a gas tracer.

Why helium is used?

- *Thanks to its low mass and low viscosity, it can rapidly pass through very small and very complex leaks*
- *It is a noble gas so it does not react or combine with metallic surface*
- *The very small amount of helium gas is naturally present in the atmosphere (5ppm) so the background noise is very low and any increment of helium concentration can be detected easily*

The sniffers will be displaced on top of the whole length of the tube and they will detect eventual leak by sniffing concentration of helium in the chamber above the threshold specified.

The detection of the increment of helium concentration is performed thanks to a mass spectrometer. It will detect the presence of helium molecule thanks to their mass and will convert them into an electrical signal.

Assuming that the sniffing probes don't detect any leak of helium, the tube is exhausted and automatically released. In the event of a leak failure, the tube is not released and a~~n~~ visual and noisy alarm is alerting the operator.

Experimentation

To study the reliability of the test, two sets of tests have been carried out:

- The capability and repeatability test
- The comparison test with others pneumatic methods

The minimum threshold is fixed at 1.10^{-5} mbar.l/s which is corresponding to double the helium rate in the air (usual concentration of 5ppm). The setting of the threshold is validated by measurement of helium stability in the surrounding air at the helium test bench place.

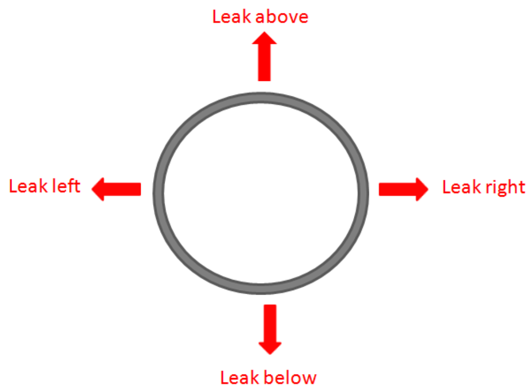
Capability and repeatability tests

Objective

- Evaluation of the capability and the repeatability of an automatic helium test on tubes. Detection on 1m long tubes of 1, 3 and 5 microns diameter laser drilled holes.

Tests of sample tubes in dynamic

- Tests were carried out with two pressures 1 bar and 7 bars on three hole diameters (1 micron, 3 microns, 5 microns)
- For each condition (corresponding to one pressure and one hole diameter), the tube was tested in four position: with the leak above, with the leak below, with the leak on the right side and with the leak on the left side

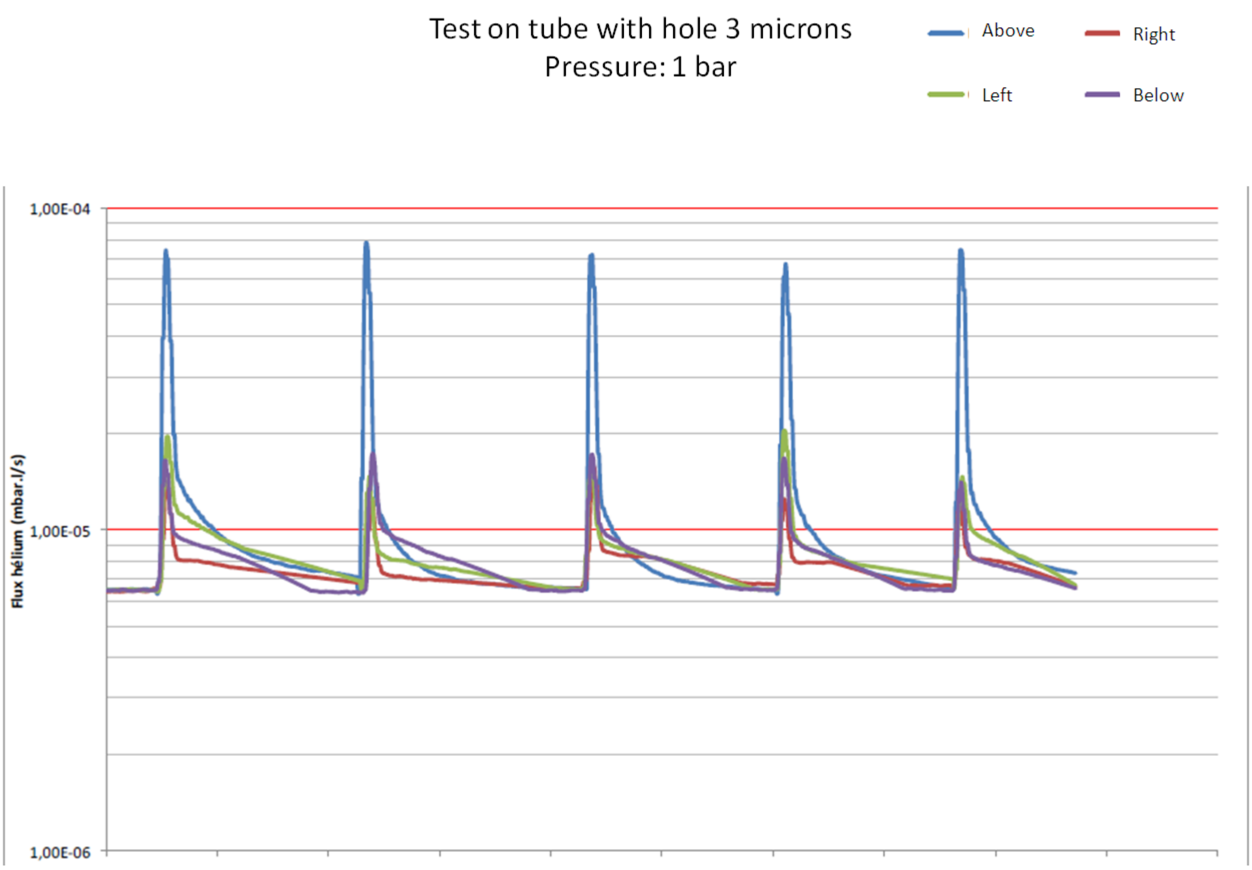


Presentation of results

The results are presented like a graph with the leak rate in ordinate and the passes in abscissa. For example, we can see in the graph below that for a hole of 3 microns and an internal pressure of 1 bar, the leak is detected for all positions with a threshold at 1.10^{-5} mbar.l/s with the maximum signal when the hole is above:

	Above (blue)	Right (red)	Below (purple)	Left (green)
Signal	7.10^{-5}	$1{,}2.10^{-5}$	$1{,}7.10^{-5}$	2.10^{-5}

We can also conclude that the test is repeatable as the leak is detected five times over five passes.



Results

	1 bar				7 bar			
	Top	Right	Below	Left	Top	Right	Below	Left
1µm	2,5x10^{-5}	1,2x10^{-5}	0,95x10^{-5}	0,9x10^{-5}	8x10^{-4}	1x10^{-4}	4x10^{-5}	1x10^{-4}
3µm	7x10^{-5}	1,2x10^{-5}	1,7x10^{-5}	2x10^{-5}	1,5x10^{-3}	1x10^{-4}	2x10^{-4}	3x10^{-4}
5µm	6x10^{-4}	3x10^{-5}	2x10^{-4}	1x10^{-4}	3x10^{-3}	3x10^{-4}	4x10^{-4}	7x10^{-4}

→ **In all conditions, 100% of leaks have been detected**

Comparison between pneumatic tests

Objective

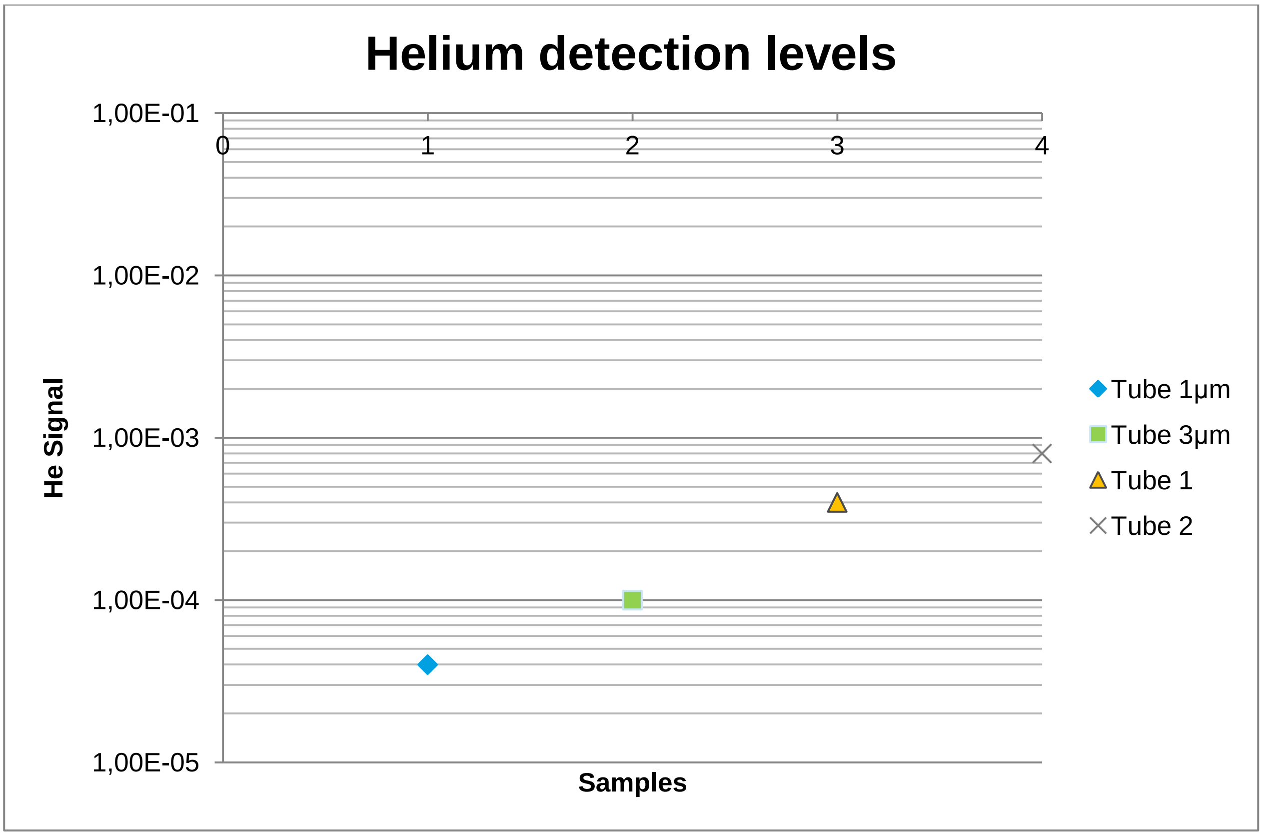
- Comparison between the, air under water method, the air pressure differential method and the helium sniffing method. The thresholds have been fixed according to common industrial practices and standards like ASTM A1016/A1016M and ASTM A1047/A1047M.

- Two sets of titanium tubes grade 2 were tested in order to compare and evaluate the efficiency of the methods with tubes having artificial and industrial defects
  - Set 1: tubes with an outside diameter of 25mm with artificial defects of diameter 1 µm and 3 µm.
  - Set 2: tubes with an outside diameter of 19mm with “industrial” defects (tube 1 and tube 2)

Methods	Time of control	Pressure	Thresholds by current standard
Air Under Water	1 min	7 bars	Detection of bubble with a detection speed of 1m/s, equivalent to 1 bubble per second
Air Pressure Differential	5s	7 bars	Difference of pressure more than 150Pa
Helium Test	Vallourec specific conditions compatible with in-line control	7 bars	Leak rate more than 10^{-5} mbar.l/s

<u>Results</u>

	1 µm	3 µm	Tube 1	Tube 2
AUW	**Below threshold**	**Below threshold**	**Below threshold**	**Below threshold**
PD	**Below threshold**	**Below threshold**	**Below threshold**	**Below threshold**
He	**Detected**	**Detected**	**Detected**	**Detected**



CONCLUSION

With a sensitivity up to 10^{-5} mbar.l/s the helium test proved a very high sensitivity, a hole diameter as small as 1 micron can be detected with a good repeatability. The comparison with the other standard pneumatic testing methods PD and AUW turned clearly to the advantage of the helium test.

Thanks to its higher sensitivity, its repeatability and its automatism, the helium test inline is a perfect candidate to achieve the zero defects during complementary tests requested by our customers for stringent operations.