MDT TUBE LEAK TEST FOR LARGE PRODUCTION

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Abstract

A leak detection system, developed for the QA/QC of the MDT tubes during mass production at LNF, is presented. A prototype of an automated station for three tubes, based on Helium mass spectrometer, has been realized. The preliminary results are reported. The test station for the mass production will have 64 tubes and will perform in an integrated way the gas leak rate and the high voltage test. Only the gas leak test is described here.

1. Introduction

To ensure the mechanical and electrical quality of the tubes during production, the following tests for each single tube are foreseen: gas leak rate, wire tension and current leakage. An amount of ≈30000 tubes have to produced and tested at LNF. As a consequence a computer-controlled system, which minimizes the operator presence, is required. An integrated station for the Quality Assurance and Quality Control of the MDT tubes during mass production at LNF has been designed to test 64 tubes. A prototype of an automated station for three tubes has been realized (fig.1-2). The preliminary results concerning the leak rate test are reported. The Atlas MDT tube assembly specifications [1] require a maximum gas leak rate for the single tube of 1×10^{-8} barl/s, with the tube operated at an absolute pressure of 3 bar. A Helium mass spectrometer to detect the leak has been used.

2. Leak detection system

The general scheme of the leak detection system is shown in fig.3. The system has been designed for the parallel test of 64 tubes, in order to follow the tube daily production at LNF. The leak test will be performed on each single tube, analysing with a mass spectrometer, the He content inside each individual cylindrical tube-case in which the tube is inserted and enclosed by two end-cups.

The main components of the system are:

- Cylindrical tube-cases used to house the tubes to be measured.
- A Helium mass spectrometer to detect the gas leak rate.
- A vacuum pump to empty the system before the measurement (Turbo-molecular pump system).
- A vacuum pump to empty the MDT tube before the gas filling (Dry vacuum pump).
- A valve system to control connection to the pump and to the He spectrometer.

Each tube-case has been realised using a aluminium tube with inner and outer diameters respectively of 36 and 40 mm. The length of the tube-cases was 4 m in order to match the length of the tubes to be tested. In fig.1 a photo of the system is shown and fig.2 describes the gas distribution system. A detailed drawing of the single tube-case and his connection with the valve system is reported in fig.4.

The valve system must have good vacuum characteristics. For cost reasons instead of commercial vacuum valves, specially designed valves have been used. As shown in fig.4, there are two independent valves for each tube-case, one for the connection to the spectrometer and the other to the vacuum pump. The single valve has been realised using a pneumatic valve to control, by means of a neoprene membrane, the opening or closing of the connection. A detailed drawing of the single valve and the valve system realised for the prototype station are shown in fig.5 and fig.6.

The two end-caps, used to close the tube-case, are designed to allow the gas supply and the electrical contact with the ground and the central pin of the tube, so that the high voltage test can also be performed. For this reason a plastic material (Delrin) has been chosen for their realisation. The gas tightness between the tube-case and the end-cap is guaranteed by an o-ring compressed by air at 6 bar. The photos of the tube-case end-cap and a detailed drawing are shown in fig.7-8-9.

The procedure of the measurement is the following. The valves connecting the tube-cases to the vacuum pump are opened and the tube-cases are emptied in order to reach a pressure of 10^{-1}mbar, which is the condition required for starting the operation of the He detector [1].

The tubes are also emptied with the vacuum pump and in order to reduce the time necessary for the successive gas filling, a group of 4 tubes at a time is filled with the gas mixture at 3 bar (abs), directly from the gas bottle. For the final set-up a gas distribution system with high flux flow-meter will be used.

For the leak measurement, a gas mixture of Ar/CO_2 containing 1% He is used. This He percentage is sufficient to detect the leaks.

The measurement is performed connecting each tube-case at a time to the line going to the He spectrometer, while all the other tubes are kept connected in parallel to the line going to the pump. Once the 4 tubes of the first group are measured, the next group of 4 tubes is filled with the gas mixture and the leak is measured.

A PC controls all the operations and records the data using a dedicated software developed in the Labview environment.

The main characteristics of the He spectrometer, are reported in tab.1.

Helium Spectrometer ASM 120H Alcatel	
Measuring range	10^{-9} to 10^{-1} mbar l/s
Response time constant	< 1 second
Pressure threshold for leak measurement	10^{-1} mbar
Vacuum Pump	
Pumping speed	3 l/s

Tab.1

[1] In case such condition are not reached because of a tube with a very large leakage, the tube has to be individuated and excluded.

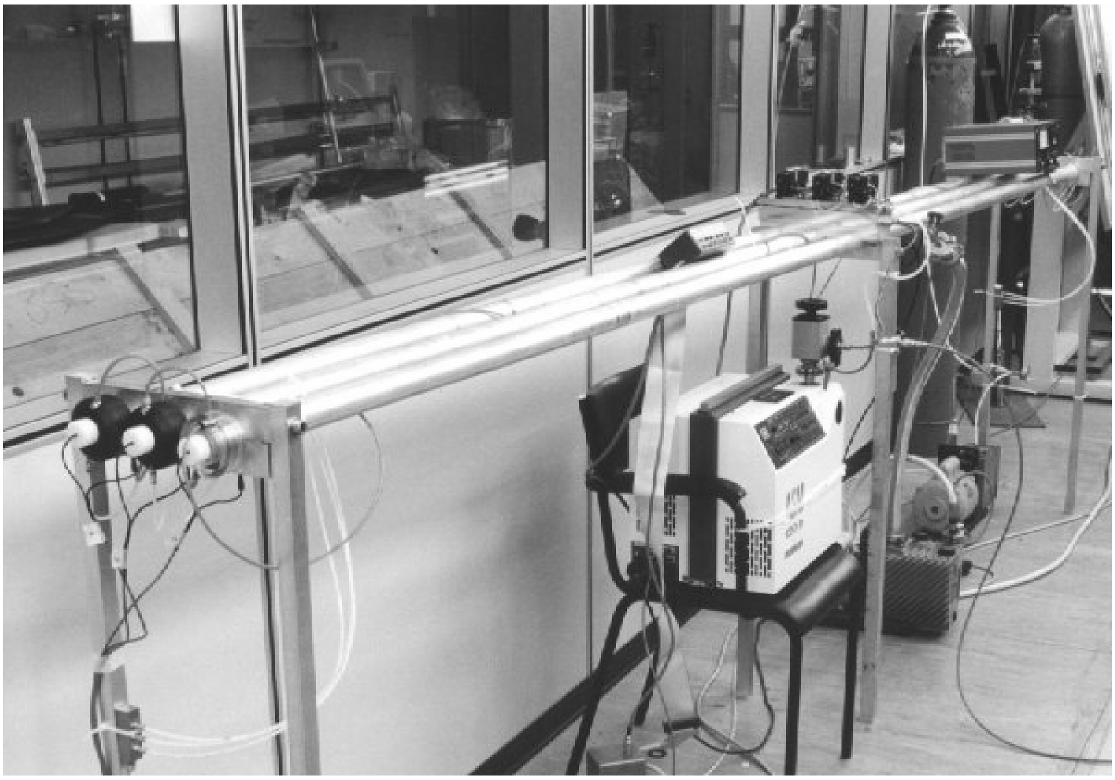

Fig.1 Prototype of the leak detection system for the test of three tubes

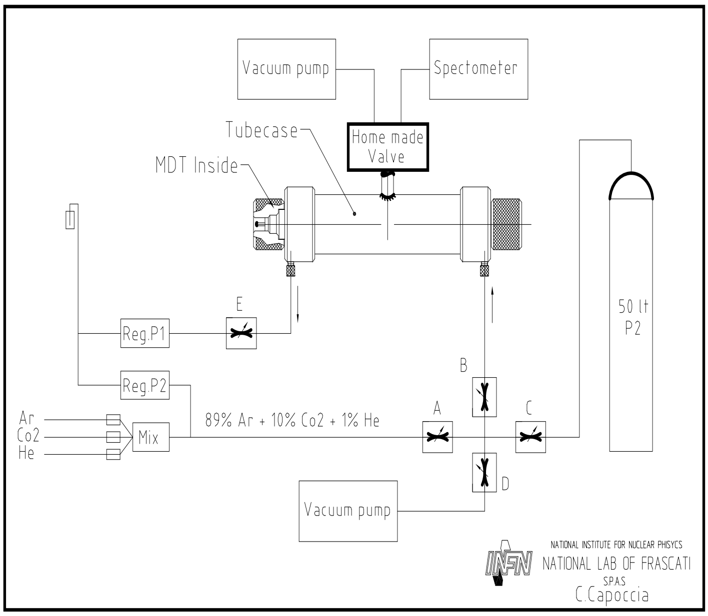

Fig.2 Block diagram of the gas distribution system used for the prototype station

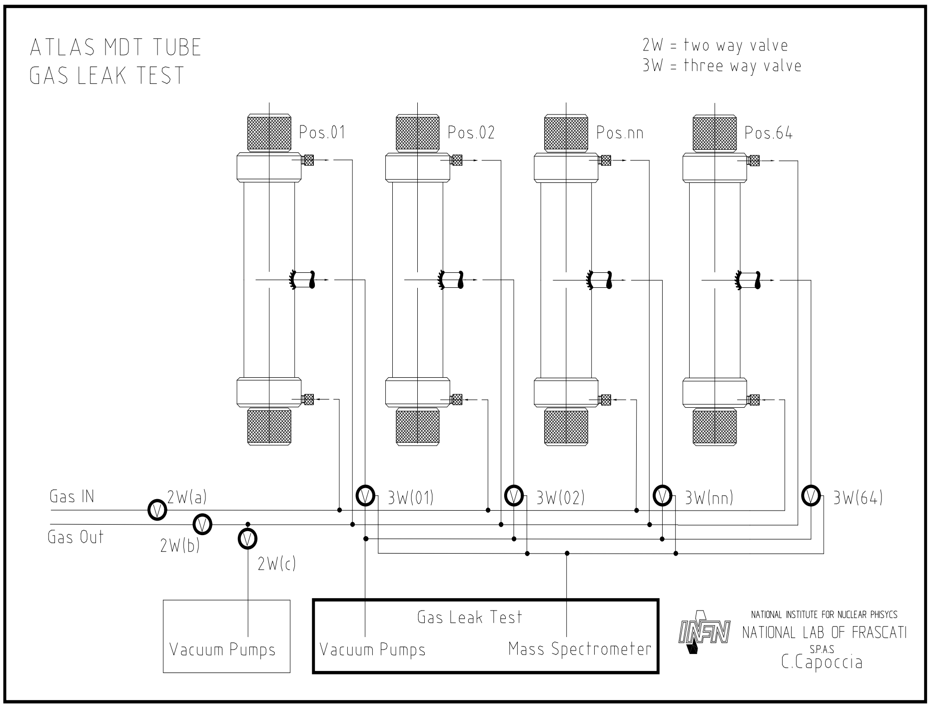

Fig.3 General scheme of the leak detection system

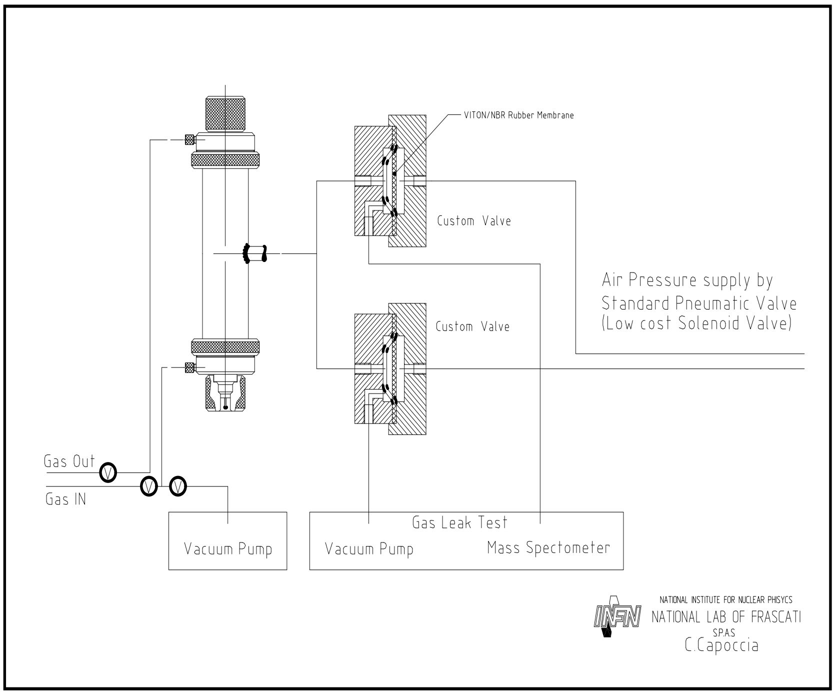

Fig.4 Connection of the tube-case with the home-made valve system

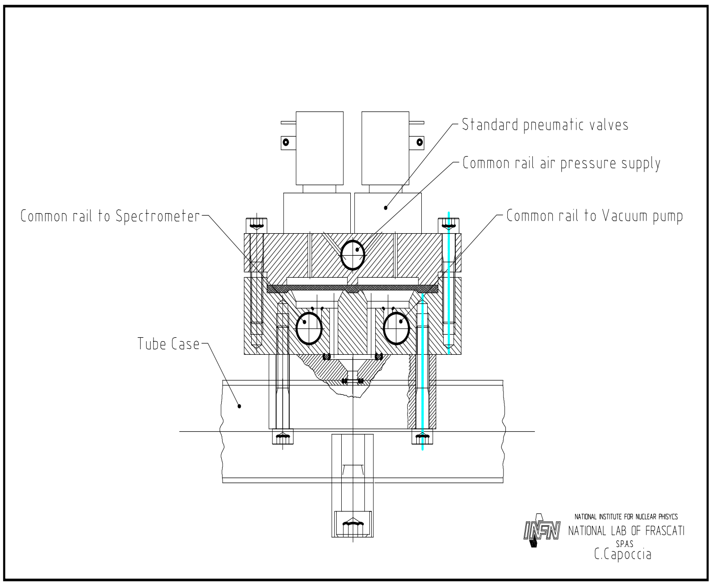

Fig.5 Home-made valve for the connection of the tube-case to the vacuum pump and to the He spectrometer

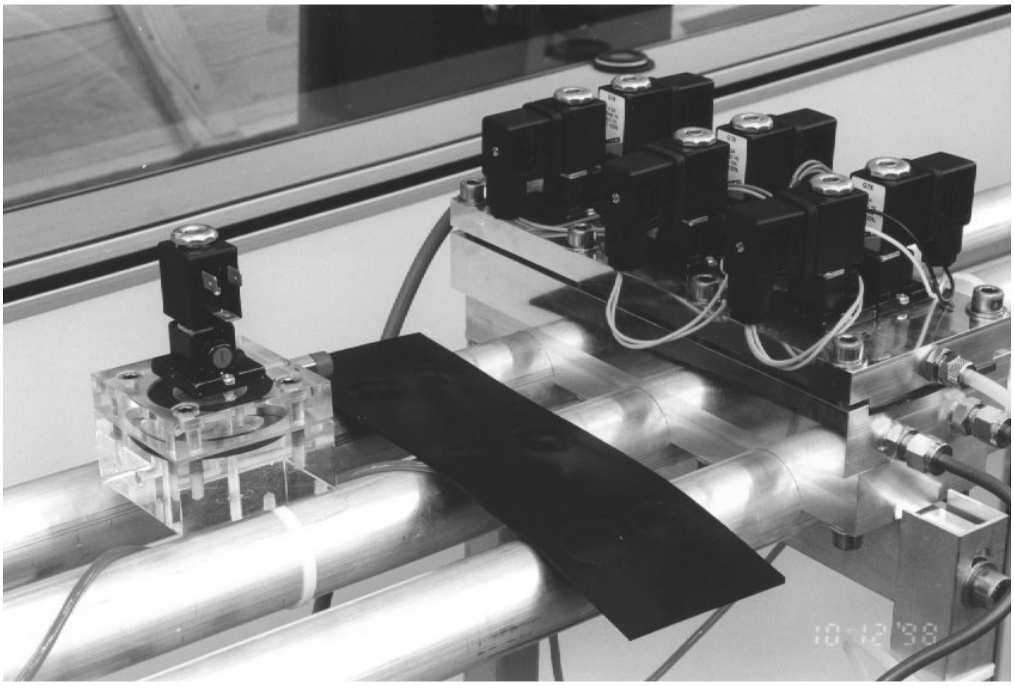

Fig. 6 Valve system.

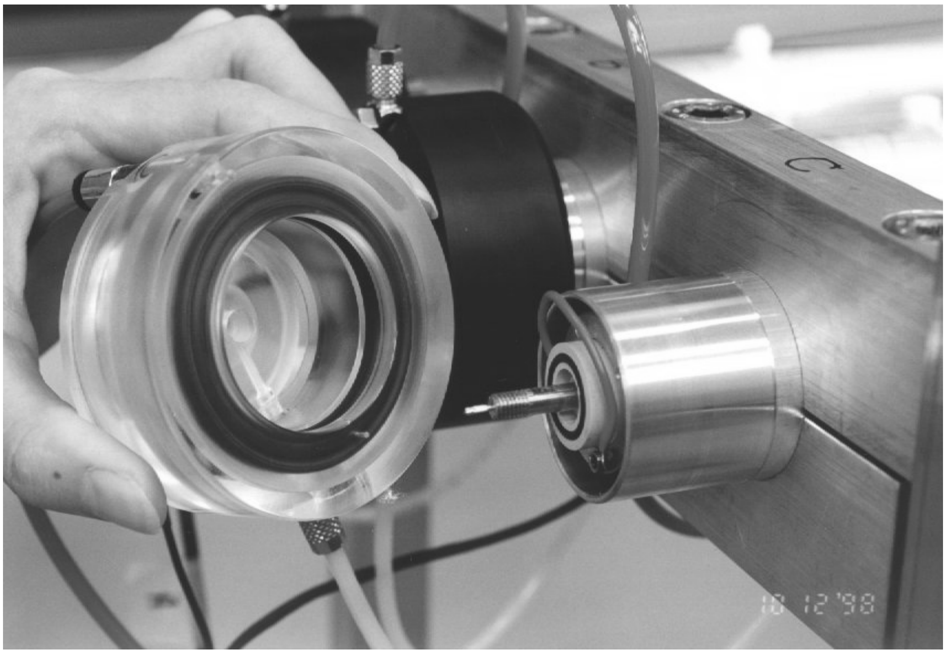

Fig.7

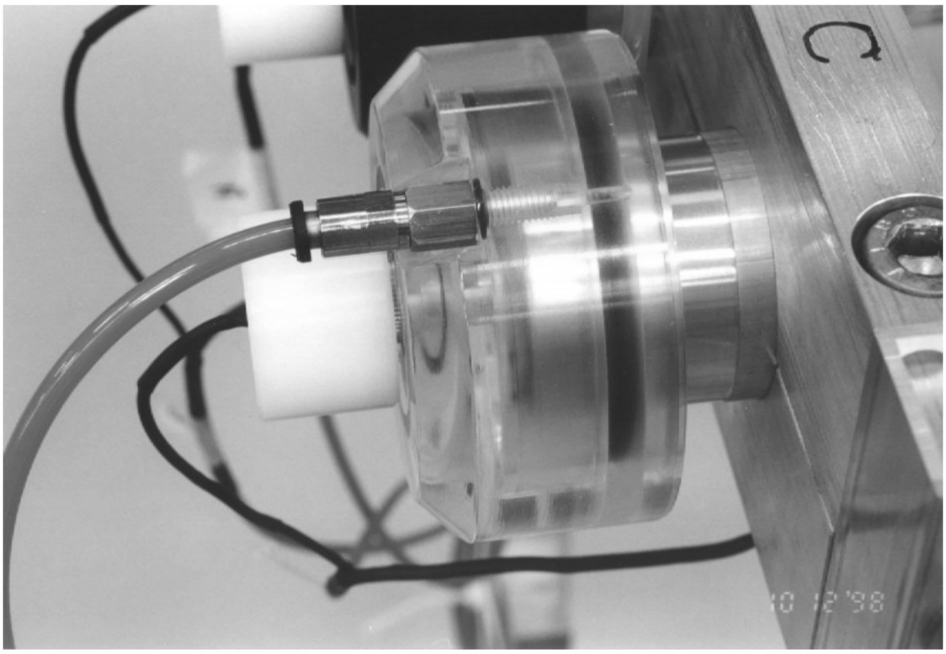

Fig.8

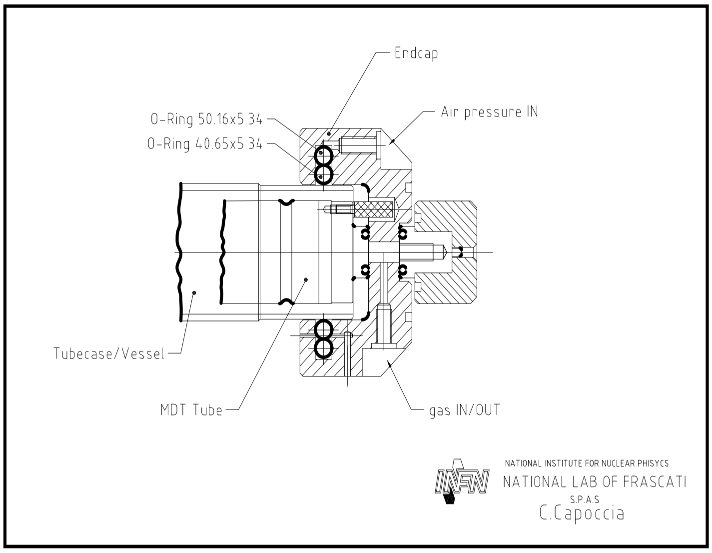

Fig.9 Drawing of the tube-case end-cap

3. Measurements and Results

To measure single tube leak rate, an appropriate procedure has to be studied, in order to allow the test of many tubes in automatic way. To define the measurement procedure a series of preliminary tests have been done, using the leak detection system described in the previous section. The results are described in the following, where the leak value reported in the graphics is the value directly measured by the He spectrometer. In order to compare this value with the maximum leak rate specified in ATLAD Muon Spectrometer TRD [1], a correction factor which takes into account the different mass of He and Ar [3] and the He percentage present in the gas mixture has to be introduced.

To evaluate the "response time" of the system, a calibrated leak has been connected in the measuring setup, at the end of one tube-case, and the time development of the leak has been investigated. As shown in fig.10 the spectrometer immediately detect the presence of He. The peak corresponding to the opening of the leak (leak ON in fig.10) is due to the accumulation of He between the leak and the connection valve. The nominal value of 1.8×10^{-8} mbar l/s, is reached in 5 min after the valve as been opened and remain constant.

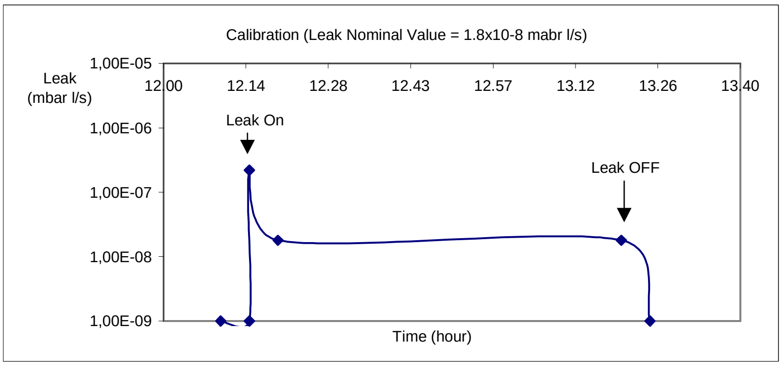

Fig.10 Time development of the leak using the calibrated leak connected at the end of one tube-case

Following the procedure described in the previous section, we have tested three tubes. The time development of each tube has shown an increase of the leak value with time, as shown in fig.11, where the leak of one of the three tubes is reported.

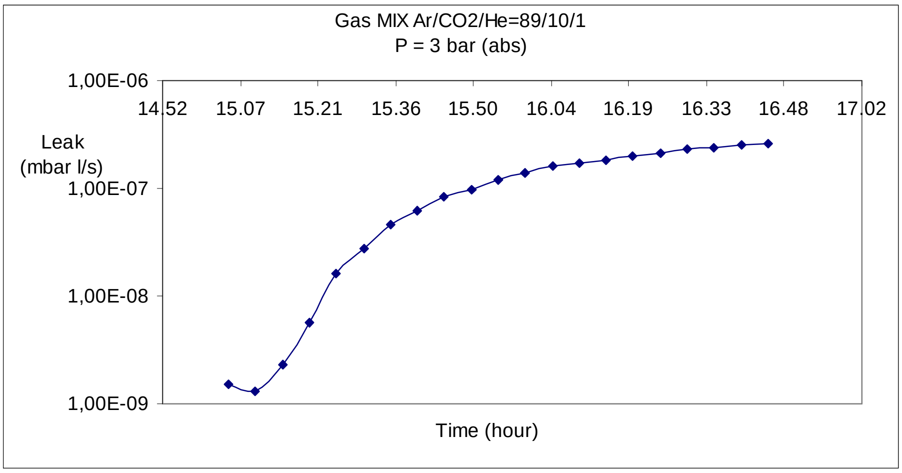

Fig.11 Time development of the leak of one tube

In order to understand the origin of the observed leak rise (fig.11), we have studied a single tube over a long period of time, using also the calibrated leak as reference. In fig.12 and fig.13 the time development of the measure is reported.

First of all we have opened the calibrated leak and verified that his nominal value is reached in 5 minutes (as in the previous measurement reported in fig.10).

Closing the calibrated leak the measured He goes to zero very quickly. At this point we have started the measurement on the tube, filling it with a gas mixture Ar/CO_2 at 3 bar (abs), containing 1% He. The measured leak remains close to zero in the time of a few minutes, which was shown by the previous test with the calibrated leak sufficient to detect the leak.

To verify that the tube leak is less than the leak due to the calibrated source, 3 minutes after the tube gas filling, we have opened again the calibrated leak and we have seen that the spectrometer immediately detect the presence of He. According to the previous measurements the leak nominal value (1.8×10^{-8} mbar l/s) has been reached within five minutes.

At this point we have closed the calibrated leak and again the He measured from the spectrometer goes to zero. Only 15 minutes after the gas filling of the tube, we observe a raising of the leak due, this time, to the tube. The measured leak increases with time reaching a constant value of 4.5×10^{-7} mbar l/s.

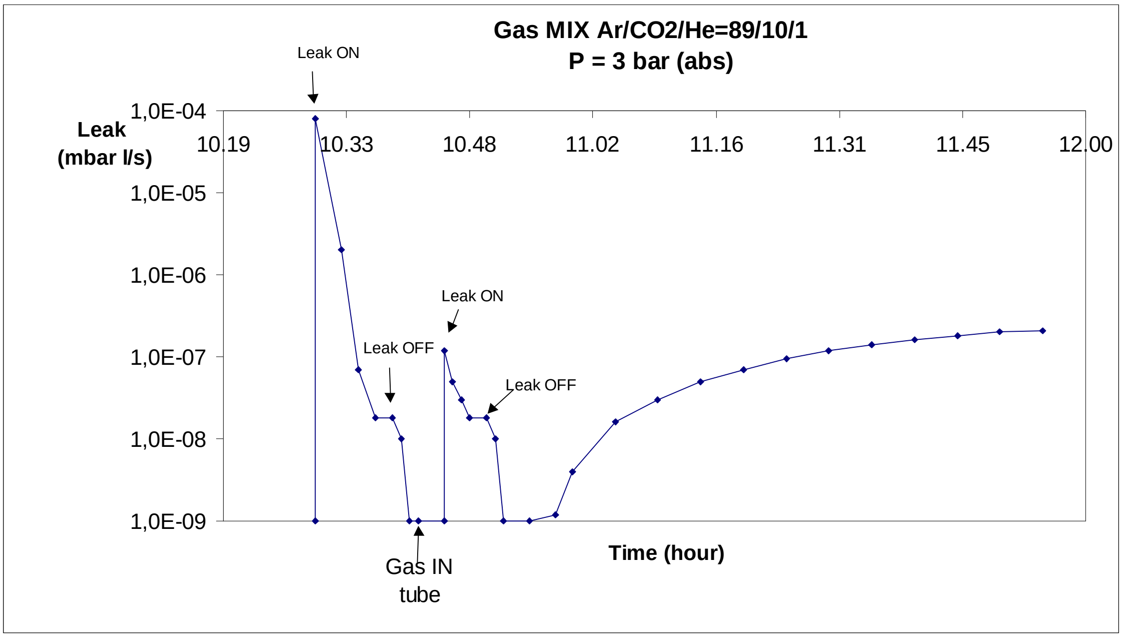

Fig.12 First part of the leak measurement of one tube (the calibrated leak is used as reference)

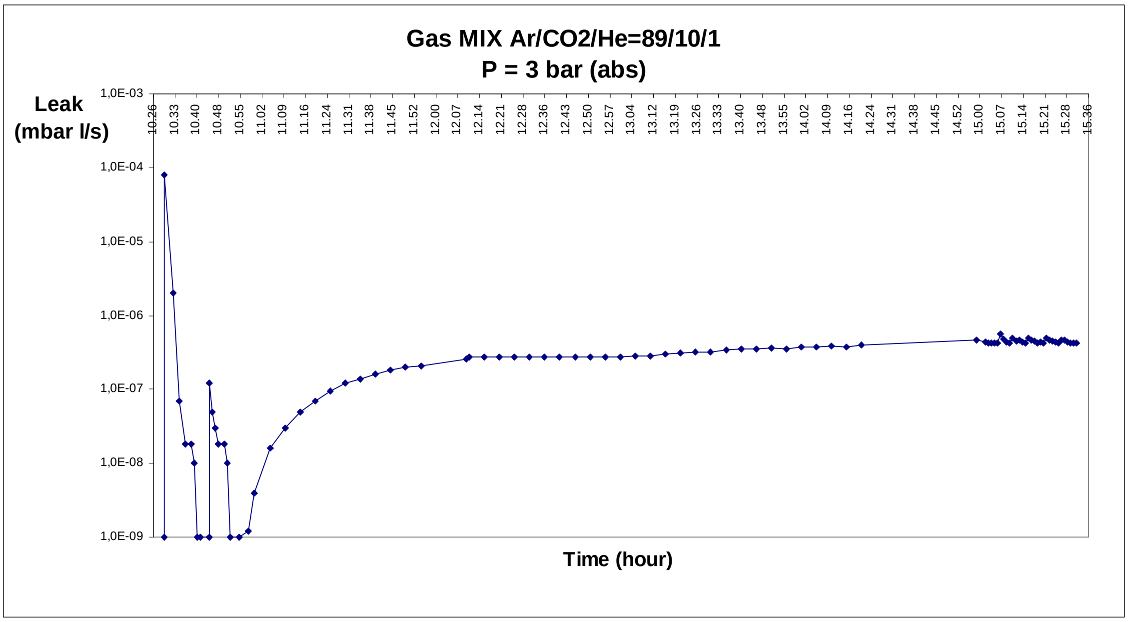

Fig.13 Long time leak measurement of one tube (the calibrated leak is used as reference)

Using a gas mixture with 10% of He we have observed the same time behavior of the leak obtained with 1% of He, but of course the leak value is 10 times grater (fig.14).

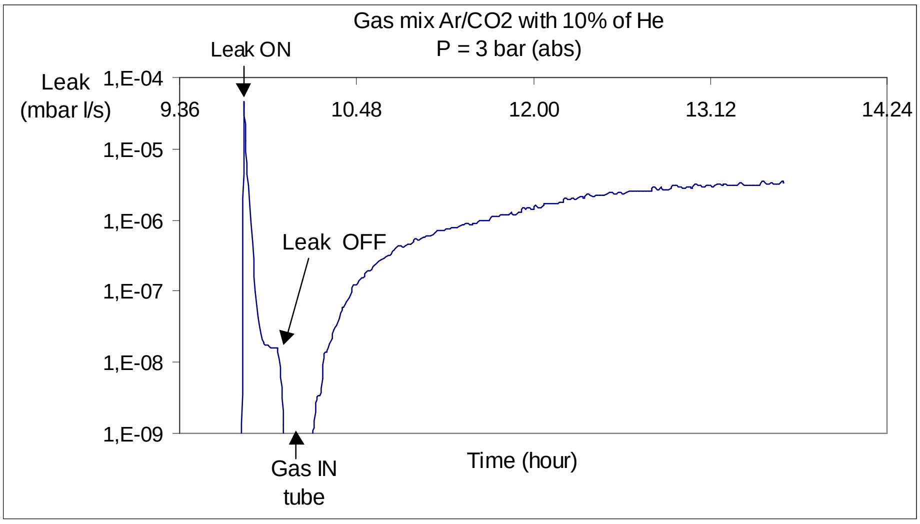

Fig.14 Leak with 10% of He

These series of measurements give us a clear indication that the spectrometer response is very fast (measurement with the calibrated leak) and that the observed long time tube leak is probably due to the He diffusion through the end-plug components (plastic, o-ring).

To study the He diffusion from the plastic material of the tube end-plug we have used the tube tested with 10% of He, masking his end-plugs with aluminum caps. In fig.15 is reported the time development of the leak for the tube with one of the two end-plugs masked and in fig.16 with two end-plugs masked. From comparison with the results reported in fig.14 we can see that the leak of the tube with one end-plug masked (fig.15) is half of the leak measured without any mask (fig.14). Masking also the other end-plug (fig.16) the leak reduces to 1/10 of the total leak (this residual leak is probably due to Al permeability to He).

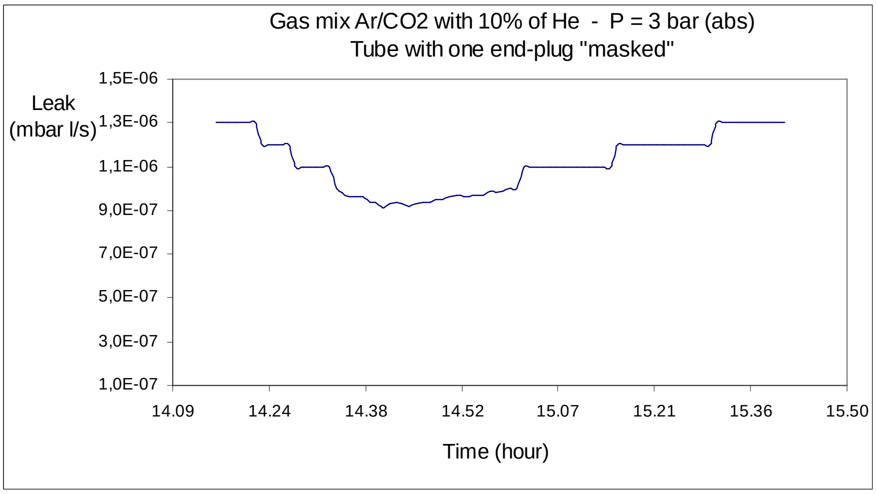

Fig.15 Leak for a tube with one end-plug masked (10% He)

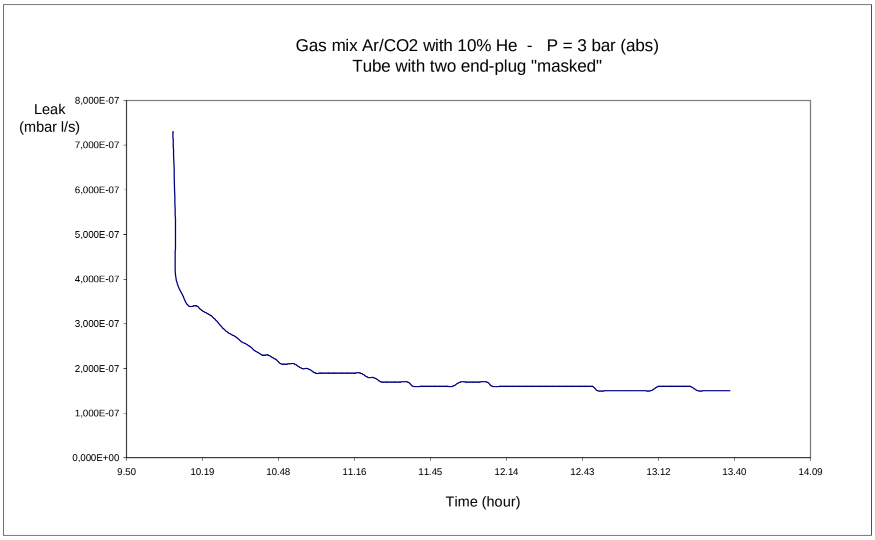

Fig.16 Leak for a tube with two end-plug masked (10% He)

An effect correlated with the He diffusion through the plastic material is the He absorption and his following outgassing observed in tubes after that they have been emptied from the gas mixture.

This is shown in fig.17, where the He signal measured by the spectrometer, after that the tube has been opened and left in air for 24 hours, is reported. During the measurement the tube has been cleaned using the vacuum pump and we can see that the He level goes to zero in a very long time (in 3 hours the He leak drops from 1.1×10^{-8} to 6.9×10^{-9} mbar l/s).

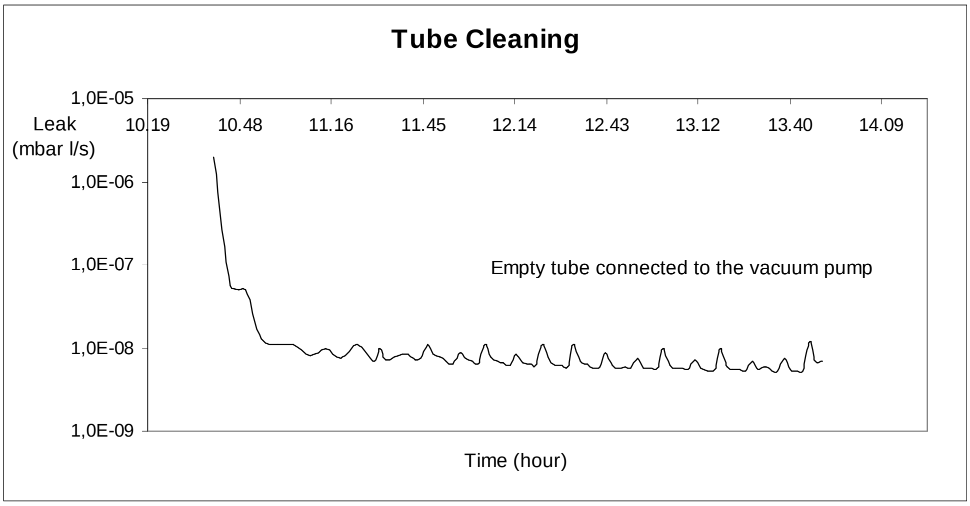

Fig.17 He outgassing from an empty tube

4. Conclusion

A prototype of an automated station to test MDT tubes leak rate during production has been realized. A series of measurements have been performed in order to test the set-up and to define a measurement procedure.

The results obtained indicate that the measurement is very fast and that the effects due to the He diffusion are visible only 15 minutes after the input of the He inside the tube. Furthermore, the procedure is able to individuate tubes with very large leakage before the input of the He inside the tube, avoiding, in this way, to make unusable the system for a long time.

Based on the experience made on this prototype the final set-up of the multi-channels station has been designed.

5. Acknowledgements

We would like to tank G. Bisogni, head of the LNF Workshop, and A. De Paolis, M. Meli and G. Ferretti of the LNF Workshop for their help in the development of the home-made valve system and of the tube-case end-cups.

6. References

[1] ATLAS Collaboration, *ATLAS Muon Spectrometer Technical Design Report*, CERN/LHC/97- 22 ATLAS TDR 10

[2] A.Balla et al., *MDT Wire Tension Measurement using an electrostatic method*, ATLAS MUON Note NO-98-264

[3] V.T.Braic et al., *Leak Detection System for Mass productin of DT Detectors,* ATLAS MUON Note NO-98-225