RAL-TR-2007-011

THE AGEING PERFORMANCE OF GAS MICROSTRIP DETECTORS UNDER INTENSE X-RAY ILLUMINATION

D.M.Duxbury, A.S.Marsh, E.J.Spill and R.Stephenson

Rutherford Appleton Laboratory, Chilton, Didcot, Oxon, OX11 0QX, U.K.

16th January 2008

Abstract

The results of a programme of work undertaken to test the operation of gas microstrip detectors under intense X-ray irradiation are presented. The compatibility of various engineering materials and electronic components with long detector lifetimes while under intense irradiation is examined. The purpose is to guarantee successful long-term MSGC operation in projects such as HOTWAXS (High Overall Throughput Wide Angle X-ray Scattering) and HOTSAXS (High Overall Throughput Small Angle X-ray Scattering).

1. Introduction and background

Microstrip Gas Chambers (MSGC's) have long been identified as possible candidates for high intensity particle tracking, imaging and counting applications. They were introduced in the late eighties [1] and are generally composed of an interleaving pattern of anodes (typically 2-10μm wide) and cathodes (typically 50-500μm wide) on a suitable substrate. They were immediately seen as a potential replacement for multiwire proportional counters for the following reasons. Firstly, detectors have successfully been made with an anode pitch of 100μm [2]. Secondly, the positional accuracy of the electrodes is very precise and easily achieved. Finally the electrodes can be produced with a small anode cathode gap, leading to smaller ion transit times. These three properties have allowed MSGCs to demonstrate a spatial resolution of 30μm in high energy particle tracking [3], excellent energy resolution [4] and a count rate capability of 1×10^6 counts per second per mm^2 [5]. The repeatability of these properties is guaranteed in large part by the lithographic method of production.

2. Ageing of gas detectors

The deterioration of gas detectors as a result of the avalanche process, commonly referred to as ageing, has been well documented in the literature [6-10] and at dedicated workshops [11,12]. Because of the extreme detector event fluxes made possible by their use, MSGC detectors are prone to ageing and several large work programs have previously been undertaken, for High Energy Physics applications, both at RAL [13] and more extensively at CERN [5,14,15]. This ageing generally manifests itself as a loss of gain within the detector, which deteriorates over time and/or with further irradiation. This is generally found to be due to the creation of polymer deposits within the gas mixture attached to the electrodes or substrate which subsequently modify the amplifying electric field resulting in a loss of gain (although some cases of a positive ageing coefficient have been reported [16]). These deposits are formed from the breakdown of the quench gas during the avalanche process and great care is needed to control the amount of further contamination which may catalyse polymerisation of the fragments into harmful deposits.

The aim of this study was to demonstrate that the detector designs for the very high rate HOTWAXS and HOTSAXS projects have a useful operating lifetime under large fluxes of X-ray irradiation, an essential requirement for their proposed use at synchrotron radiation sources. By carefully introducing materials into our test detectors and monitoring the detector behaviour, a list of acceptable and non-acceptable materials was obtained, which enabled us to engineer longer lasting detectors, ultimately reducing downtime on experiments at synchrotron sources where these type of detectors will be routinely used.

Given the extreme sensitivity of high rate gas counters to pollution at the ppm level every new design of high rate gas detector must be thoroughly checked out for the ageing properties of the design. Funding was obtained from the Diamond synchrotron project for the HOTSAXS detector project, the basis of which is an MSGC. The first phase of this project was to prove that this type of detector could

survive the very high intensities foreseen in these applications. Testing was performed in the lab with an X-ray generator and a small MSGC, housed in a dedicated detector vessel. The disappointing results of these initial tests, reported in section 4.1 below, led to the Centre for Instrumentation funding further investigation into the ageing properties of these detector systems.

3. Testing regime

Two parameters are used in the tests reported here to determine how the detectors 'age' with time. The first is the avalanche gain – generally normalised to the initial value at the start of the exposure. This is measured from the peak of the X-ray pulse height distribution. The second parameter is the width of the pulse height distribution which exhibits the effect of fluctuations in the avalanche gain caused by deterioration of the electrode surfaces. This is measured as the FWHM or the standard deviation (sigma) of the X-ray peak pulse height distribution.

The total amount of chemical degradation in the quencher gases is assumed to be proportional to the total signal charge delivered by a detector. Since we have linear detecting electrodes the charge density is estimated per unit length of anode.

The measurements reported in [13] showed that the gain change of the detector was less than 10% for an accumulated charge of 40mC/cm, with a 3% increase in the FWHM (figures 1 and 2). These measurements were made with a system that was not ultra clean. The measurements made at CERN showed that with extra care these devices could be operated up to 160mC/cm with no degradation in the gain or increase in σ. Both these results were made with the detectors operating in an argon, dimethylether (DME) gas mixture. In extensive tests of various candidate quench gases at CERN, DME was found to give the best detector operation and ageing results providing the gas system was scrupulously clean. Thus an argon DME gas mixture was chosen as the standard mixture in the ratio of 83% noble gas and 17% quencher.

3.1 The test detectors

All of the tests reported here use MSGC plates manufactured from S8900 semiconducting Schott glass [17] which have been lithographically processed at IMT [18]. The electrode pattern has been metallised with chrome at a thickness of 0.27μm The particular MSGC plate design used for these tests was developed for the Soft X-ray detector (SOXAFS) [19], which consists of eight separate sections of 12 anodes on a pitch of 300μm (with corresponding interleaved cathodes of 100μm width), each 10μm wide with an active length of 32mm. The eight sections operate as independent detectors, albeit with the same operating characteristics (and the same biasing supplies). The plates themselves are supported on standard printed circuit boards (PCB) where electrical connections are made to the plate via ultrasonic bonding. A further PCB is connected to the supporting board, which provides the high voltage biasing and the signals from the detector. These are housed in a gas tight vessel and the detector signals are fed via a vacuum connector to an electronics housing mounted on the back of a standard 150mm conflat flange, exactly the same as in [19] (see figure 3). An X-ray transparent beryllium window (50μm thick) was used, which also functioned as the drift electrode (10mm from the plate surface). The detector is

operated with the drift plane at ground potential and the plate biased positively (+1000V on the anodes and typically +1440V on the cathodes). The biasing components inside the active gas volume were potted in Stycast 1266 [20] and the circuit board material was glass reinforced plastic.

3.2 The readout electronics

The SOXAFS test vessel was designed to be instrumented with a fast 16 channel charge preamplifier and shaper card of the type described in [19,21]. The amplified signal (shaping time of 25ns) is then fed to an NE 4684 NIM-based discriminator and then to a Tektronix DC503 scaler unit which provides a diagnostic for high rate operation. This signal was also fed to a Tektronix TDS 3054 digital oscilloscope enabling a direct measurement of the pulse height from the preamp to be made.

Measurements are also made at low rate where the fast signal is stretched in time (by a simple RC circuit) before being amplified by a standard Ortec 575 post-amplifier. From here the signal is then fed to a Pulse Height Analyser (PHA) to give the corresponding X-ray pulse height spectrum. The system is calibrated by using a test pulser which injects a known amount of charge into the preamplifier. This is then used to determine the avalanche gain corresponding to the observed X-ray peak position in the pulse height spectrum. Tests are conducted by irradiating a $1mm^2$ spot, with 8keV X-rays from a crystallography X-ray set at a count rate controlled by the use of attenuating sheets of aluminium.

3.3 Gas system

The gas delivery system used was composed entirely of 6mm stainless steel tubing (a mixture of both rigid and flexible) which was cleaned and dried, however the initial tests raised serious doubts that this was adequately performed. Stainless steel regulators (with Kel-F seat material) were used on the gas cylinders (the flammable DME line having a non-return valve present). The gas was then fed to two Brookes mass flow controllers before being mixed in a stainless steel manifold and then piped to the detector vessel at a rate of 100cc/min. The grade of the gas used was 99.99% pure. No oil-based bubblers were used in the exhaust line; the gas was vented to atmosphere through a 30m long stainless steel tube of 6mm diameter.

3.4 The test procedure

The tests described here were performed using a Philips PW1830 X-ray generator. The fine focus tube had a copper target and the layout of the set was such that two ports could be opened simultaneously. The detector under test was mounted on an X-Y stage, the position of which combined with a purpose built collimator, defined the beam footprint on the detector surface of area $1mm^2$.

Before an ageing test is begun, a low rate gain scan along the length of the particular section of the detector under study is first performed. This then highlights any non-uniformity's along the section and is used as a reference during and after an ageing test is completed. With the plates having eight independent sections, a neighbouring section to the one under study can be used as a control. This permits the

normalisation of gain changes caused by variation in ambient conditions (atmospheric pressure and temperature). At the beginning of a new test, a low rate measurement is made at the position where the ageing will be performed (referred to as the ageing spot). The detector is then moved to the control section and a further low rate measurement is made thus enabling the ageing spot to be normalised to the control spot. The pulse height is also measured on the oscilloscope at this low rate which is then used to obtain a correction factor for the charge per unit length at high rates, where the avalanche gain drops slightly.

Once the baseline, low rate measurements were made, operation at high rate was begun. This was generally between 400 to 700kHz/mm^2 and was continuous, 24 hours a day over the duration of the test, except during the periods when the low rate measurement was performed. These were performed twice a day throughout the duration of the ageing test to permit monitoring of the detector stability over time, and were accompanied by a control measurement for normalisation. Throughout the high rate irradiation the rate and pulse height were routinely recorded along with the ambient conditions and the elapsed time.

As referred to in section 3 above, the ageing of the detector is characterised in terms of the accumulated charge per unit length of anode. This is determined using the measurement of the rate, the elapsed time of the test and the gain of the detector. Several other factors are also needed which are as follows. At rates above about 250kHz/mm^2 the gain of the detector begins to fall. Therefore, from the measurement of the pulse height at low rate and the measurement of the pulse height at high rate, a correction factor is obtained (usually between 0.7 and 0.8) which is applied to the charge calculation. A geometric correction must also be applied. The pitch of the anodes on these plates is 300μm and the beam footprint of approximately 1mm^2. Therefore a further correction of 3.33 is needed to obtain the charge per cm of anode length. The accumulated charge is the obtained as follows:

$$Q = \Sigma\, g \times n_{ei} \times R \times \Delta t \times k \times e \times 1000 \times 3.33 \text{ mC/cm}$$

Where Q is the charge per cm, g is detector gain (typically 1000), n_{ei} is the number of ion pairs created in the gas by one X-ray conversion (~300 for an 8keV X-ray), R is the counting rate per square mm (ranging from 400 to 700kHz/mm^2), Δt is the exposure time, k is the correction factor for the gain loss at high rate and e is the electronic charge. The summation is over successive sessions of the test period.

4. Initial results and implications

Six ageing tests were initially performed, five with an Ar:DME mixture and one with an Ar:CO_2 mixture, none of which produced satisfactory results. Figure 4 shows a typical pulse height spectrum obtained from the detector at the beginning of ageing test 4. The fit to the X-ray peak is a log normal of the form described in [22]. The gain is estimated from the peak position in the distribution and the standard deviation from its width as given by the fit. Figure 5 shows the pulse height distribution after 3.3mC/cm of charge has been acquired. The gain has dropped by 30% and the sigma has increased by 62% since the test began. At this point we began to suspect that our ‘clean’ system was not as clean as we believed, and various changes to the system

were subsequently made. In the paper by Capeans et al [23] are various lists of compatible materials for use with DME, and it was during the process of the removal of non-compatible materials that we found the cause of the problem. This turned out to be a check valve in the DME line with an o-ring which was lubricated with a silicone based lubricant. As reported in [23] silicone pollutants of ppm quantities seriously affect the lifetime characteristics of MSGC based devices operating with DME gas mixtures. Unfortunately, even though we specified that these materials should not be included in our gas delivery system, we have fallen foul of the same problem encountered by other groups [23], namely that specifying a lubricant free system from a manufacturer does not ensure that you receive such a system.

A separate detector and gas delivery system was then assembled to test one of these detectors in an argon CO_2 mixture (in a 75:25 ratio). This system was not all stainless steel, as it was not known if this was necessary when using CO_2. The results obtained with this system are still inadequate and are shown in figures 6 and 7 along with those from the contaminated DME system. The figures show how the relative gain and sigma vary as a function of accumulated charge for these 6 tests.

The above results were disturbing, given the fact that we believed that we had a DME-safe gas delivery system. What was even more disturbing was the fact that we specified what materials could and could not use within our system to the manufacturer yet still had non-compatible components within the system. The results of these tests had serious implications on various large projects within the Instrumentation department. The continued investigation into the cause of this loss of performance was therefore prosecuted under the auspices of the Centre for Instrumentation.

5. Further results

A program of work was now put in hand to completely replace the existing gas system with an ultra clean system. This included the purchase of specially cleaned stainless steel gas pipes; ultra clean regulators and non-lubricated mass flow controllers. Unless otherwise stated, the epoxy of choice was Stycast 1266, the conductive epoxy used was Traduct 2902 [24] and all the O-rings are Kalrez [25] as given in the list of compatible materials in [23]. Whilst waiting for these components to be delivered, it was decided that we would purchase some ‘semi-clean’ stainless steel gas pipes and attempt to clean up the remainder of the contaminated system. The gas pipes and mass flow controllers were cleaned with liquid DME. Previous experience has shown that companies will specify products as lubricant free and/or DME safe, when this is not the case. If we were to have any problems with lubricants dissolving in gaseous DME, flushing with liquid DME would hopefully remove any DME soluble contaminants.

The system was re-assembled after cleaning and after some preliminary measurements were made, an ageing test was begun. Initially the test was carried out at a rate of 25kHz until 3mC/cm of charge was accumulated. The rate was then increased by a factor of five and the test continued. No significant gain loss was observed up to an accumulated charge of 45mC/cm. The illumination rate was then increased by a further factor of five and the test continued to an accumulated charge

of 83mC/cm where the test was ended. See figures 8 and 9 for the variation of normalised gain and normalised sigma throughout the duration of this ageing test. These results compare favourably with the results obtained previously [13].

The results of the test described above now gave us the confidence to introduce a filter into the gas line, which was placed on the gas inlet of the detector. The stainless steel Swagelock filter [26] was first flushed with liquid DME before its insertion into the gas system and the test was conducted at the high illumination rate (~600kHz in the $1mm^2$ beam spot). Figure 10 and 11 shows the normalised gain and sigma for this test (DME 10). After an acquired charge of 500mC/cm the gain has fallen by 6% from its starting value. The sigma of the low rate pulse height distribution dropped by 10% after 2mC/cm but then remained constant throughout the rest of the test. A scan of the detector section was performed at the beginning of the test and then at weekly intervals throughout the test. The gain variation along the section is shown in figure 12 and the variation of sigma is shown in figure 13. This ageing test (DME 10) was performed at a horizontal position of 252mm and figures 12 and 13 have been normalised to the horizontal position 261mm. The figures show a significant gain decrease and sigma increase one mm either side of the ageing spot. This is consistent with the formation of a 'ring' of deposits formed during the avalanche being deposited in the surrounding area. This is also observed upon inspection under a microscope, see figure 14. The ring of deposits delineating the beam spot is clearly visible (figure 14a) and deposits are seen on the edges of both electrodes in the centre of the beam spot (figure 14b).

The ring structures visible in figures 12 and 13 and in the micrographs of figure 14 arise because of the distortion of the drift field by the drifting of the positive ions generated by the intense beam.

6. Material testing

In order to test the various engineering materials planned for our larger detector projects such as HOTWAXS [27], a method of introducing such materials into the gas stream was proposed. This consisted of an empty gas filter housing which was placed upstream of the gas filter placed on the detector gas inlet. A second identical system was assembled in order to test larger system changes, which could have otherwise compromised our clean system. However, both of these systems use the same cylinders of gas with individual feeds to it. The X-ray machine which was used for these tests had two output ports which could be independently used, enabling two ageing tests to be run in parallel.

In order to minimise the length of the ageing tests it was decided to limit the material tests to 100mC/cm (where possible), as it was felt that this would give a good indication of the detectors ageing performance compared to our baseline test DME 10. Table 1 lists the tests performed. An initial rise in gain of 5-10% is seen in most of the tests and the material is deemed acceptable if the normalised gain and sigma are within 10% of the initial value. Unless otherwise stated, the materials are first cleaned in liquid DME to remove any dissolvable contaminants. Clearly if the material itself is physically changed during this process then an ageing test is unnecessary.

Item	Accumulated charge mC/cm	Relative gain	Relative sigma	Pass or Fail?
Second system	45.8	1.03	1.03	Pass
DME cylinder change	94.8	1.07	1.02	Pass
Small swagelock valve	53.5	1.06	0.98	Pass
VCR fittings	53.5	1.06	0.98	Pass
LCP conductive coated window	99.8	0.99	1.08	Pass
Stycast 2850	30.7	0.87	9.58	Fail
Perlast O-rings	86	1.14	1.2	Fail
JAE 70 pin connector	88.6	1.06	1.01	Pass
HOTWAXS PCB material	88.5	1.06	1.03	Pass
Surface mount biasing components	81.2	1.04	1.00	Pass
LCP flexi rigid	90	1.02	1.00	Pass
Torrseal (diluted with ethanol)	90.3	1.01	1.03	Pass
Large HOTWAXS valve	90.3	1.01	1.03	Pass
Drift plane biasing components	92.5	0.99	1.05	Pass
MKS flow meters	89.9	1.03	1.11	Pass
SC11 fittings (1) – not flushed with liquid DME	43.3	0.99	1.03	Pass
SC11 fittings (2) – not flushed with liquid DME	115.4	1.09	1.29	Pass
SC11 fittings (3) – not flushed with liquid DME	46.8	1.07	0.99	Pass
Gold MSGC electrodes	59.5	1.11	1.14	Fail
Nylon pipe	112.6	0.76	2.76	Fail
SC11 filter	92.4	1.02	1.17	Pass
Daresbury HOTWAXS system (detector and gas rig)	76.7	1.05	0.99	Pass
Gas cut out valve	92.4	1.02	1.17	Pass
HOTSAXS gas rig	98.2	1.18	0.97	Pass
HOTSAXS system (detector and gas rig)	94.9	1.05	1.02	Pass
Kapton flexi rigid	101.2	1.00	1.03	Pass
I22 HOTWAXS system (detector and gas rig)	257	0.95	1.10	Pass

Table 1: List of materials and systems tested as part of this program

Some of the tests listed warrant further discussion. The Stycast 2850 test listed in the table was one of 8 tests performed with this epoxy, and all of these ended suddenly not gradually. This was seen as a material which could be used for potting a flexi rigid PCB into a feeedtrough flange. An alternative solution was to use torrseal, but this epoxy is very viscous. Diluting it with ethanol increased the fluidity sufficiently to enable it to flow into the flange correctly. The Perlast o-rings were investigated as they are perfluoroelastomer o-rings similar to kalrez, but much cheaper. These would only be used in an application where a Kalrez o-ring could not be retro fitted. The MKS flow meters were tested as their controllers have a warning system indicating when the flow meter is out of control (which can be used to switch

off the High Voltage system supplying the detector) as running out of quencher whilst under illumination is usually fatal for the detector. The test with the nylon pipe was the only test which seemed to contaminate the detector other than at the ageing spot. This is seen in the SC11 filter test, where the sigma has increased by 17%, but in subsequent tests where the filter was in use on the system gas rigs, this is not the case. The rise in sigma seen in the second SC11 fittings test, was not fully understood, as in subsequent tests (and again in the system tests where these fittings and pipework have been used) such a large rise was not seen.

For the detector system tests listed, the 'system' consists of the detector, the gas pipes that will be used on station and the individual gas control rig and mixing manifold. The difference between the Daresbury HOTWAXS and the Diamond I22 HOTWAXS are that the Daresbury system had Brookes mass flow controllers and SC11 snap fittings for the gas pipes. The I22 system had MKS flow meters and VCR connections for the gas supply. For these tests, the system is inserted into the gas stream the exhaust of which is fed to the detector used for the ageing tests. These tests turned out to be a very sensitive way of detecting a leak in the vessels, as the relative gain and the X-ray interaction rate in the ageing detector dropped by 20% or more within the first few mC/cm of accumulated charge.

Once the engineering material tests had been completed, a series of control tests were undertaken with the DME quench gas replaced with the same percentage (17%) of isobutane (99.5% pure), carbon dioxide (99.999% pure) and methane (99.95% pure) respectively, the results of which are shown in figures 15 and 16. Previous measurements had shown that the ageing of MSGCs with isobutane had shown them to age very rapidly, figure 1. However, this was not found to be the case in this study. In fact for an acquired charge of 95mC/cm the gain only rose by ~9% and the sigma of the low rate pulse height distribution remained constant. A similar situation arose for the case of carbon dioxide. For the test result shown in figures 6 and 7, after 3mC/cm of accumulated charge the gain had dropped by 10% and the sigma had increased by 15%. But now both the gain and the sigma did not change after 95mC/cm of accumulated charge. For both these cases no great care was taken in the choice of regulator for the gas, however the gas delivery system etc. was clean and free from leaks. The results for methane showed a rapid increase in gain and sigma for a relatively small amount of accumulated charge. Again, no great care was taken with the choice of regulator, but it is expected that this would give much better results if more care were taken with the choice of materials used. Table 2 lists all the tests undertaken along with the gas mixture and gives an indication of the system cleanliness.

7. Conclusions

The ageing performance of our test detector is now better than that previously measured at RAL, and approaching the lifetimes demonstrated at CERN. Since the ageing program began, we have conducted over 100 ageing tests. The focus of these tests has been to test materials that we are likely to want (or need) to use in some of our large detector projects. The initial tests were based around the X-ray detectors, for which our gas mixture of choice is argon and dimethylether (DME). All the materials

Test No.	Gas Mixture	System cleanliness	Notes
DME 1 – 5	Ar:DME 83:17	Dirty	Initial tests
CO_2 (1)	Ar: CO_2 75:15	Dirty	Initial tests
DME 6	Ar:DME 83:17	Semi-clean	Major pollutants removed, system cleaned
DME 7-9	Ar:DME 83:17	Semi-clean	High rate tests
DME 10	Ar:DME 83:17	Semi-clean	High rate test, in line filter in place
DME 11-14	Ar:DME 83:17	Semi-clean	High rate tests
DME 15	Ar:DME 83:17	Semi-clean	Small swagelock valve
DME 16	Ar:DME 83:17	Semi-clean	Second system
DME 17,19,20,21, 25,26,27,28	Ar:DME 83:17	Semi-clean	Stycast 2850 tests
DME 18	Ar:DME 83:17	Semi-clean	LCP coated window
DME 22 - 24	Ar:DME 83:17	Semi-clean	Perlast o-rings
DME 29	Ar:DME 83:17	Semi-clean	JAE 70 pin connector
DME 30-32,34-37,39,40,42,43	Ar:DME 83:17	Semi-clean	Developed leak in HT feedthrough
DME 33	Ar:DME 83:17	Semi-clean	HOTWAXS PCB material
DME 38	Ar:DME 83:17	Semi-clean	Surface mount biasing components
DME 41	Ar:DME 83:17	Semi-clean	LCP flexi rigid
DME 44,48,50,51	Ar:DME 83:17	Semi-clean	System testing
DME 45 - 47	Ar:DME 83:17	Semi-clean	Torrseal (diluted with ethanol)
DME 49	Ar:DME 83:17	Semi-clean	Drift plane biasing components
DME 52,54,55,56, 59,60,61	Ar:DME 83:17	Semi-clean	Daresbury HOTWAXS gas rig testing
DME 53	Ar:DME 83:17	Semi-clean	MKS flow meters
DME 57,58,62 – 65,70	Ar:DME 83:17	Ultra-clean	SC11 fittings
DME 66,69	Ar:DME 83:17	Semi-clean	Gold MSGC electrodes
DME 68	Ar:DME 83:17	Ultra-clean	Nylon pipe
DME 71	Ar:DME 83:17	Semi-clean	Daresbury HOTWAXS system
DME 72	Ar:DME 83:17	Ultra-clean	Gas cut out valve
IB 73	Ar:Isobutane 83:17	Semi-clean	Control test
DME 74	Ar:DME 83:17	Ultra-clean	HOTSAXS gas rig
CO_2 (2) 75	Ar: CO_2 83:17	Semi-clean	Control test
DME 76,77	Ar:DME 83:17	Ultra-clean	HOTSAXS system (detector and gas rig)
CH_4 78-80	Ar:CH_4 83:17	Semi-clean	Control tests
DME 94,95	Ar:DME 83:17	Ultra-clean	Kapton flexi rigid
DME 102–111, 115,123,125	Ar:DME 83:17	Ultra-clean	I22 HOTWAXS system (detector and gas rig)

Table 2: Summary of ageing tests performed

used in the construction of HOTWAXS and HOTSAXS have now been tested and where materials failed, alternatives have been tested and verified as acceptable.

A series of control tests with the standard gas mixtures (argon:isobutane, argon:carbon dioxide, argon:methane (83:17)) were then performed and some very encouraging results were obtained. These results appear to be due to the cleanliness of the system used for testing, compared with previous results with both isobutane and carbon dioxide which showed a very rapid drop in gain with accumulated charge. It is postulated that better results with isobutane and methane could be achieved by methodically changing the materials exposed to the gas, as has been done here for DME. The results of figures 15 and 16 encourage one to believe with gas and detector systems of the level of cleanliness currently available there is no advantage in any particular gas mixture and good lifetimes can be obtained with standard quencher combinations.

This program is now investigating materials for compatibility with helium and tetrafluoromethane (CF_4) gas mixtures. These are our gases of choice for our neutron detectors (FastGas, OSMOND). Initially we are using a flowing gas mixture, but will move towards a sealed system in view of the fact that the neutron detectors run with a sealed pressurised gas mixture. Material outgassing then becomes a significant factor.

8. Acknowledgements

The authors would like to acknowledge the continuing interest and support from J.E.Bateman for this project, for his helpful comments and fruitful discussions. This work was supported by the Centre for Instrumentation, STFC.

References

1. A. Oed, Nucl. Instr. & Meth. A261(1988) 351
2. S.F. Biagi, J.N. Jackson, T.J. Jones and S. Taylor, Nucl. Instr. & Meth. A32**3** (1992) 258
3. F. Angelini, R. Bellazzini, R. Brez, M.M Massai, G. Spandre, M.R. Torquati, R. Bouclier, J. Gaudaen and F. Sauli, IEEE trans. Nucl. Sci. NS-37 (2) (1990) 112
4. H. Hartjes and F. Udo, Proc. ECFA Study Week on Instr. Tech. For High-Luminosity Hadron Colliders, CERN 89-10 p.455
5. R. Bouclier, M. Capeans, C. Garabatos, G. Manzin, G. Million, L. Ropelewski, F. Sauli, L.I. Shektman, T. Temmel, G. Della Mea, G. Maggioni and V. Rigato, Nucl. Instr. & Meth. A367 (1995) 168
6. F. Sauli, Principles of Operation of Multiwire Proportional and Drift Chambers, CERN 77-09 (1977)
7. J. Va'vra, Nucl. Instr. & Meth. A252 (1986) 547
8. M. Jibaly, P. Chrusch, G. Hilgenberg, S. Majewski, R. Wojcik, R. Weintraub and F. Sauli, Nucl. Instr. & Meth. A273 (1988) 161
9. A.V. Zarubin, Nucl. Instr. & Meth. A283 (1989) 409
10. J.A. Kadyk, Nucl. Instr. & Meth. A300 (1991) 436

11. Proceedings of the International Workshop on Aging Phenomena in Gaseous Detectors, DESY. Nucl. Instr. & Meth. A515 (1991) 1 - 385
12. http://www.desy.de/agingworkshop/
13. J.E.Bateman, J.F.Connolly, Yu N.Pestov, L.I.Shekhtman, R.Mutikainen and I.Suni, RAL-TR-1994-114
14. R. Bouclier, C. Garabatos, G. Manzin, G. Million, F. Sauli, T. Temmel and L. Shekhtman, Nucl. Instr. & Meth. A348 (1994) 109-11
15. R. Bouclier, M. Capeáns, C. Garbatos, G. Manzin, G. Million, L. Ropelewski, F. Sauli, L. Shekhtman, K. Silander and T. Ropelewski-Temmel, Nucl. Instr. & Meth. A381 (1996) 289-319
16. J.E. Bateman and J.F. Connolly, RAL-TR-1992-085
17. Schott Glass, Duryea, Pennsylvania, USA
18. IMT, Greifensee, Switzerland
19. A.D.Smith, J.E.Bateman, G.E.Derbyshire, D.M.Duxbury, J.Lipp, E.J.Spill and R.Stephenson, Nucl. Instr. and Meth. A467-468 (2001) 1136
20. Emerson & Cuming, 46 Manning Road, Billerica, MA 01821 USA
21. J.E.Bateman, J.F.Connolly, R.Stephenson, M.Edwards and J.C.Thompson, Nucl. Instr. and Meth. A348 (1994) 372
22. J.E.Bateman, Nucl. Instr. and Meth. A488 (2002) 610
23. M. Capeans, Nucl. Instr. and Meth. A515 (2003) 73
24. Tra-Con Inc. 45 Wiggins Ave. Bedford, MA 01730 USA
25. Dupont Elastomers, Bellevue Park Corp. Center Suite 300, Wilmington, Delaware 19809 USA
26. Swagelok, 29500 Solon Road, Solon, OH 44139 USA
27. J.E.Bateman, G.E.Derbyshire, G.Diakun, D.M.Duxbury, J.P.A.Fairclough, I.Harvey, W.I.Helsby, J.D.Lipp, A.S.Marsh, J.Salisbury, G.Sankar, E.J.Spill, R.Stephenson and N.J.Terrill, Nucl. Instr. and Meth. A580 (2007) 1526

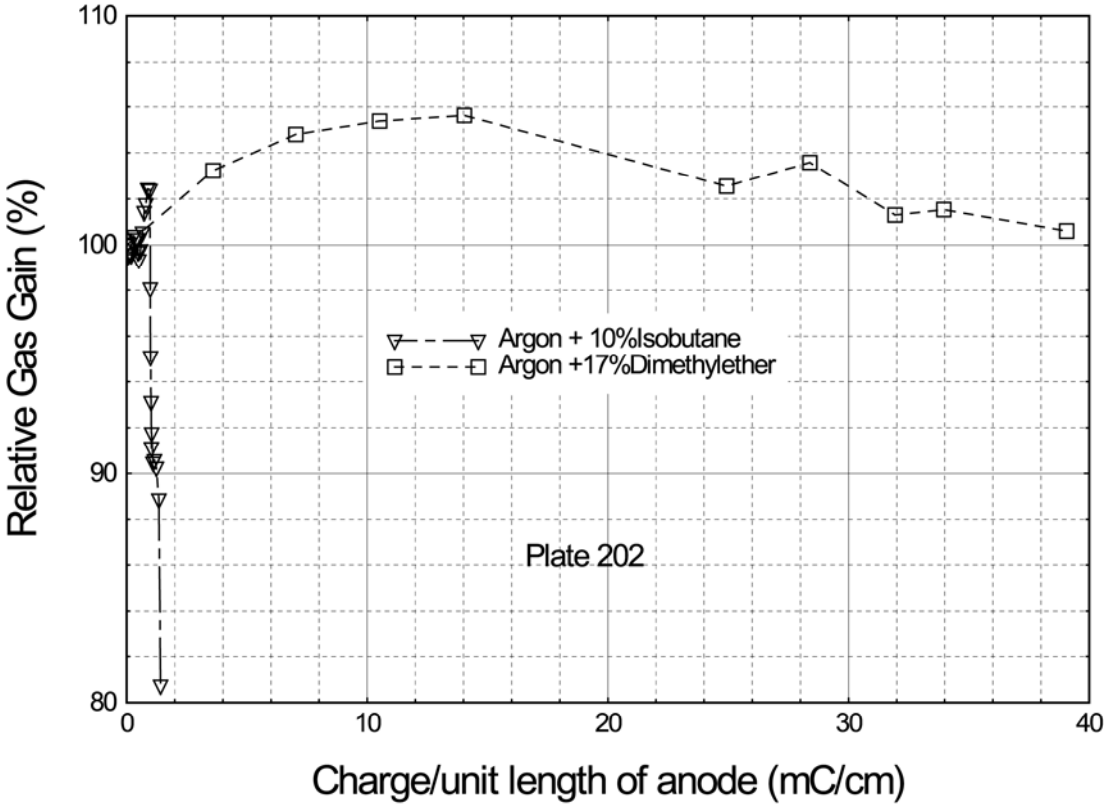


Figure 1: Ageing curve obtained with non clean system, showing gain change as a function of accumulated charge, taken from [13].

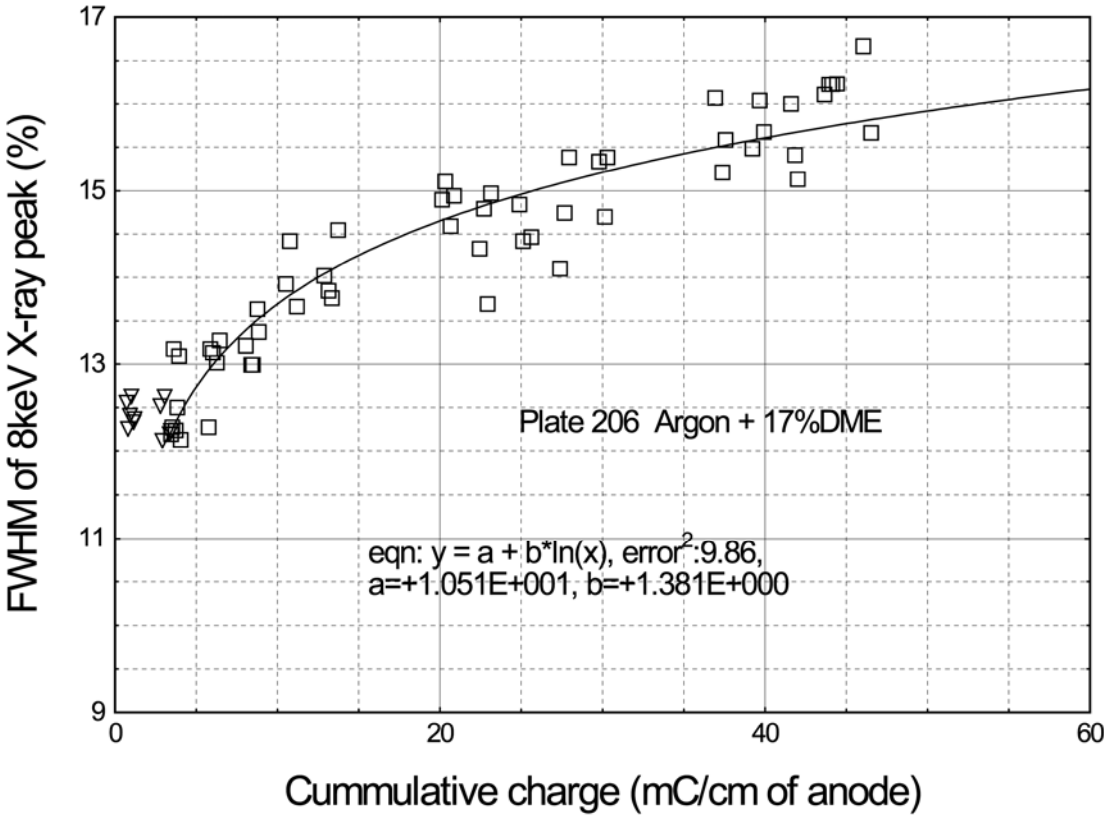


Figure 2: Increase of FWHM of Cu peak as a function of accumulated charge, taken from [13]

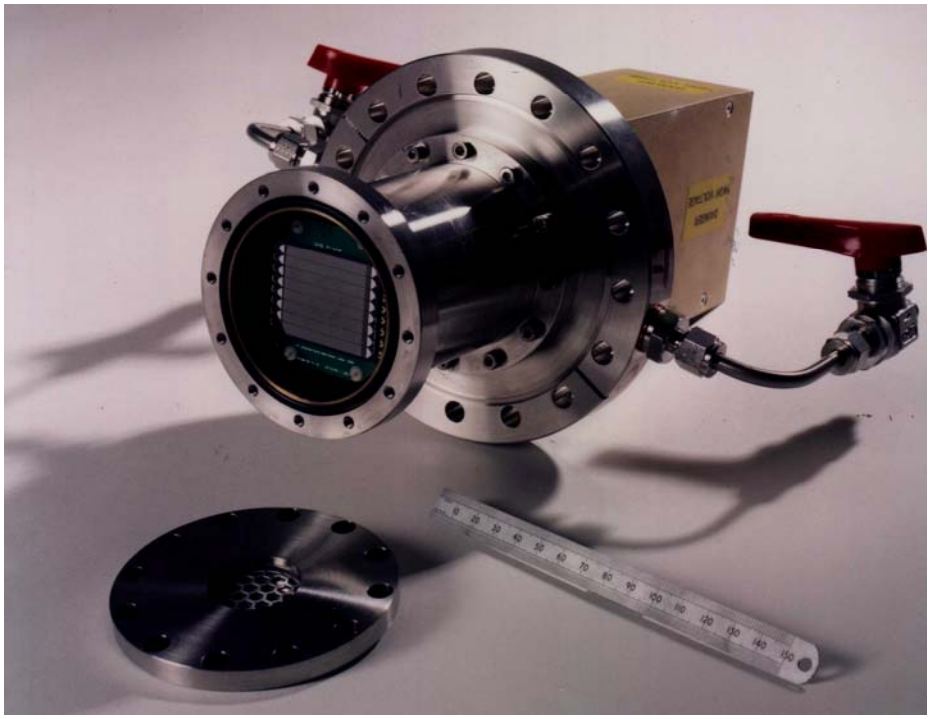


Figure3: The SOXAFS test vessel, identical to that used in the tests reported here

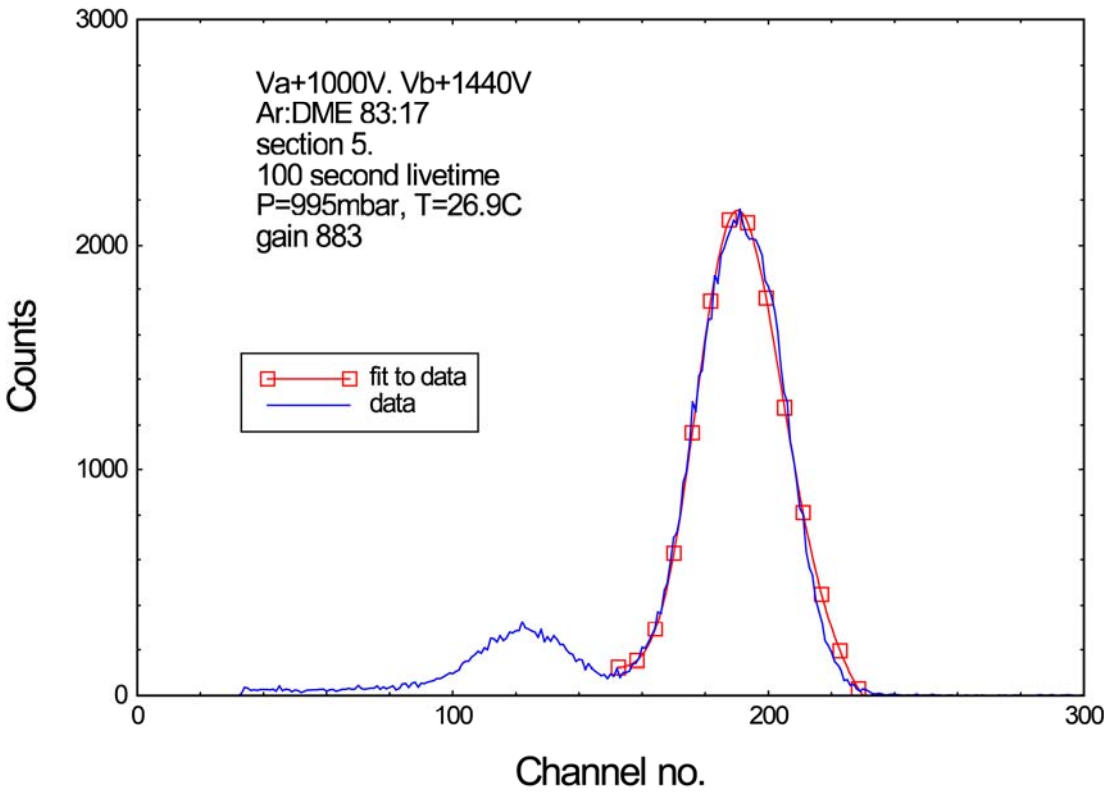


Figure 4: Low rate spectrum obtained at the beginning of test 4

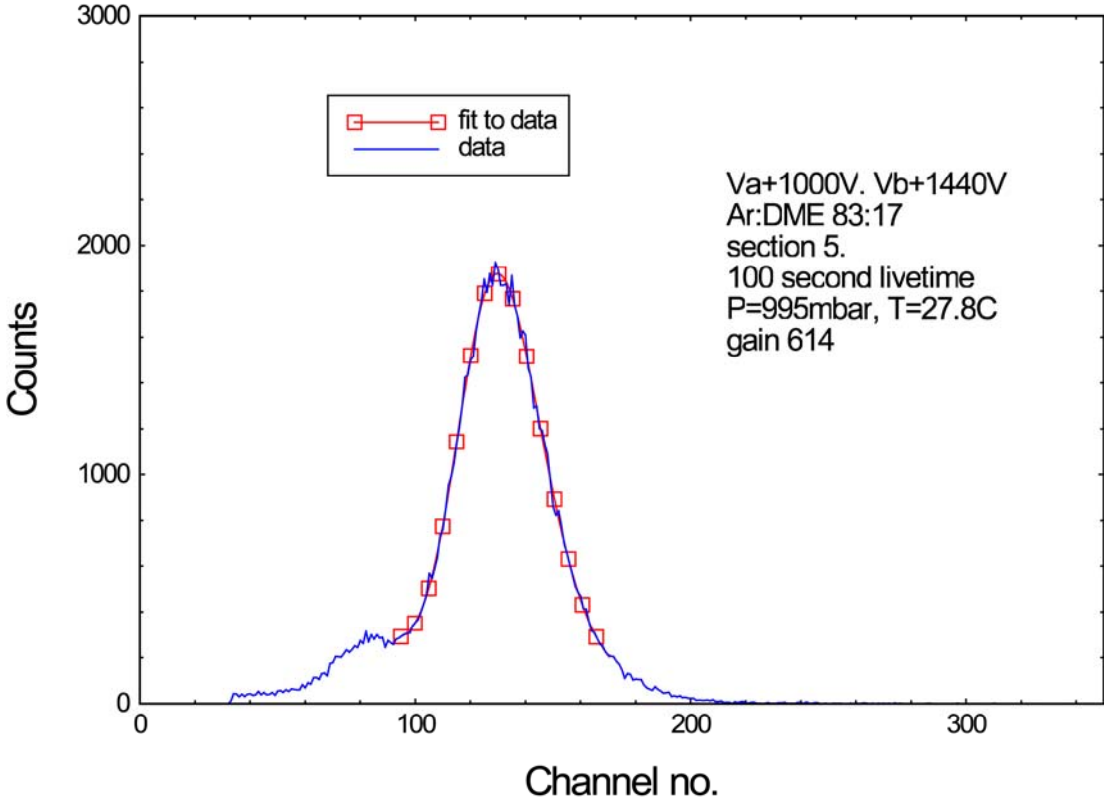


Fig 5: Low rate spectrum obtained after 3.3mC/cm of charge acquired (DME test 4)

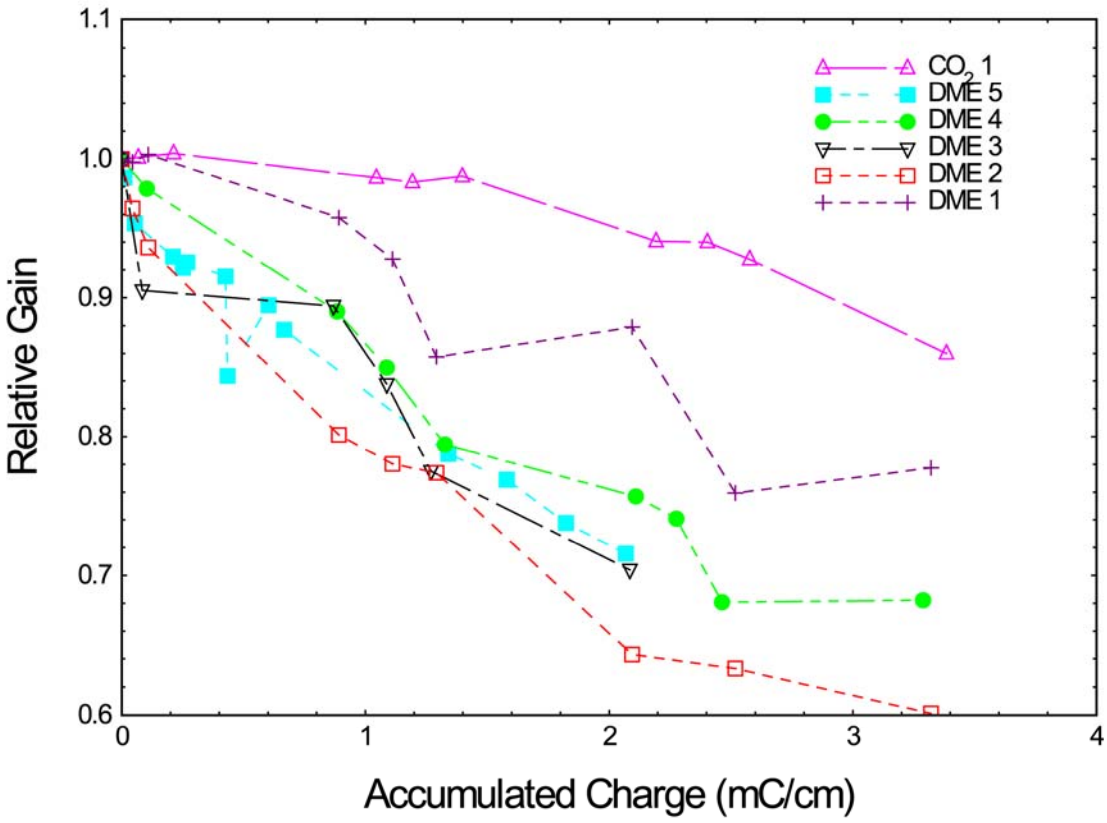


Figure 6: Relative gain of the first 6 ageing tests as a function of accumulated charge

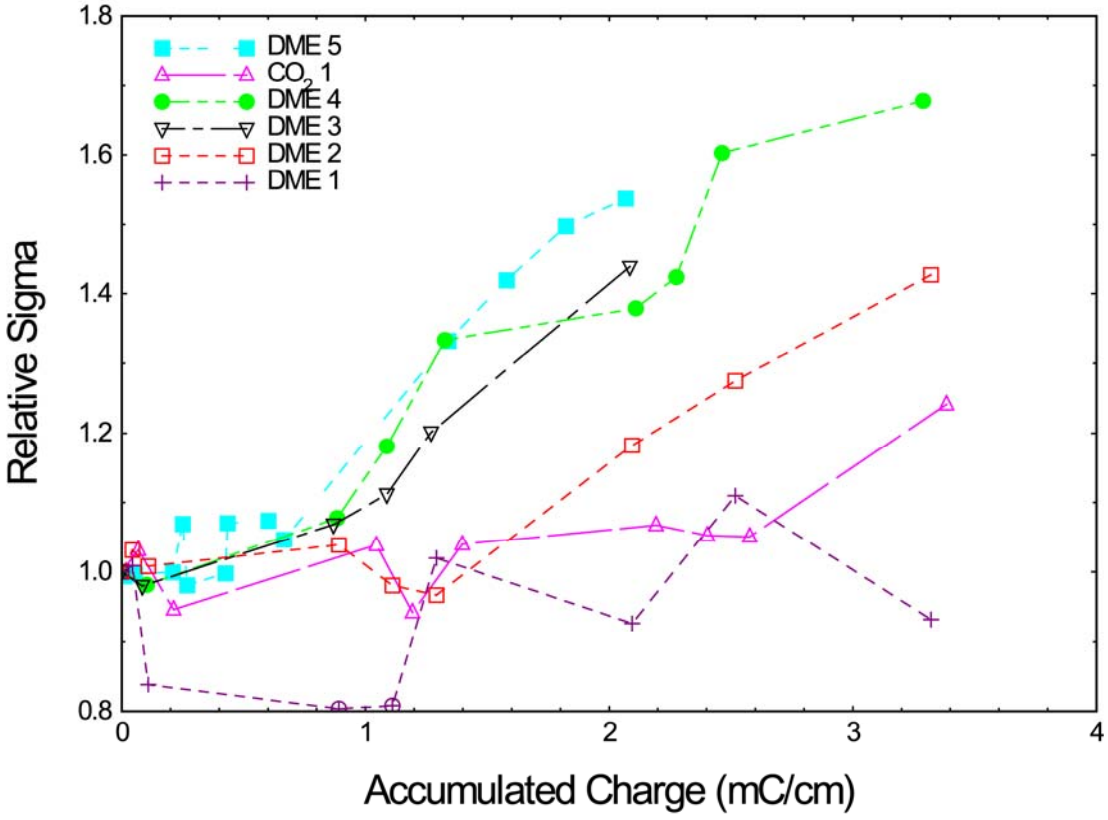


Figure 7: Relative increase in sigma for the first 6 ageing tests
as a function of accumulated charge

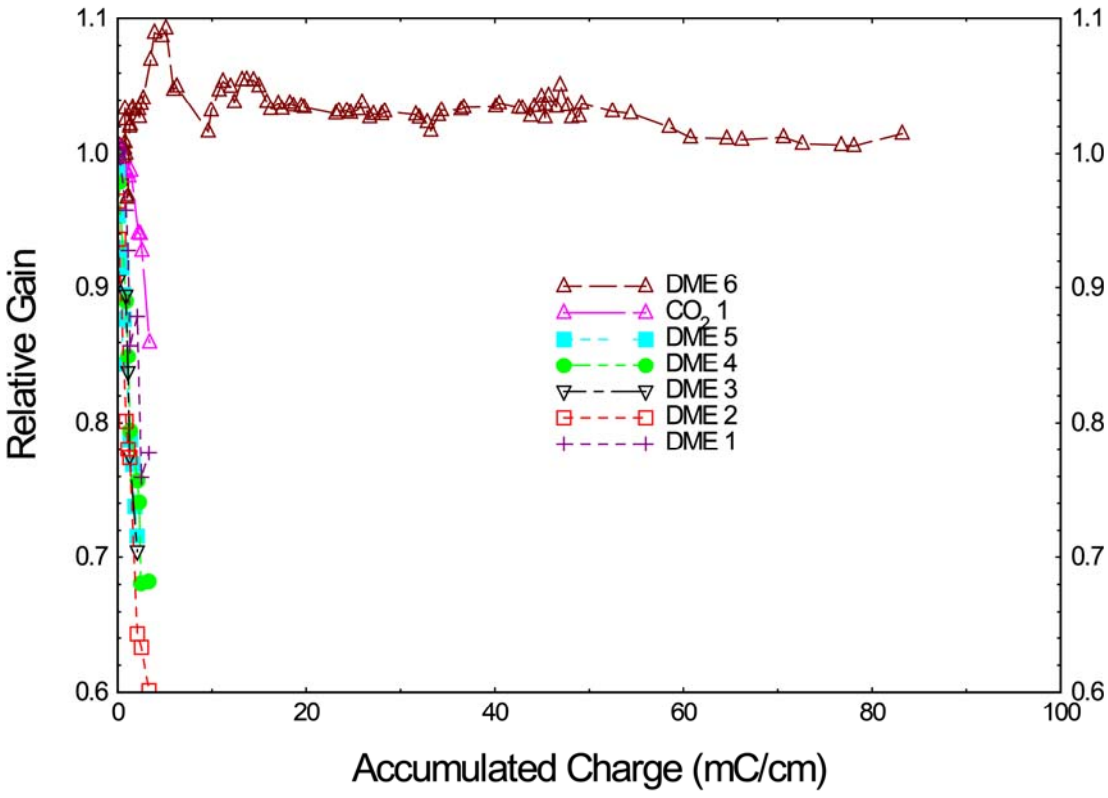


Figure 8: Comparison of ‘semi-clean’ system to ‘dirty’ system: normalised gain

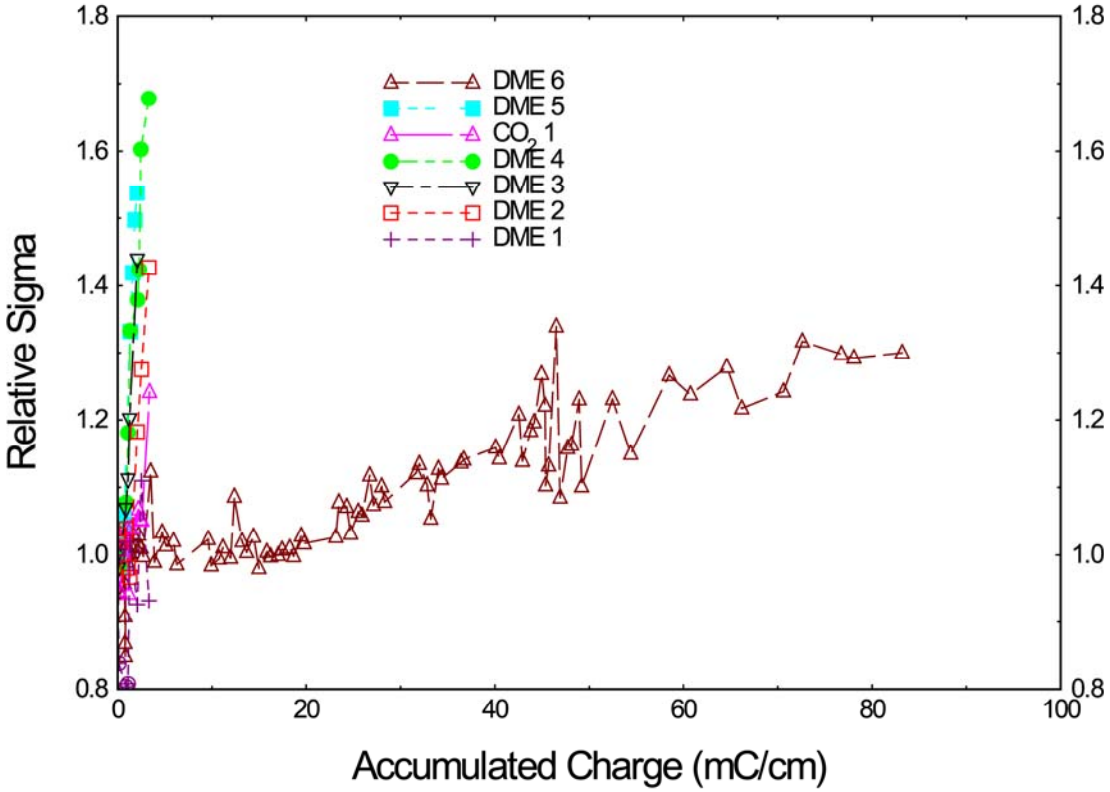


Figure 9: Comparison of 'semi-clean' system to 'dirty' system: normalised sigma

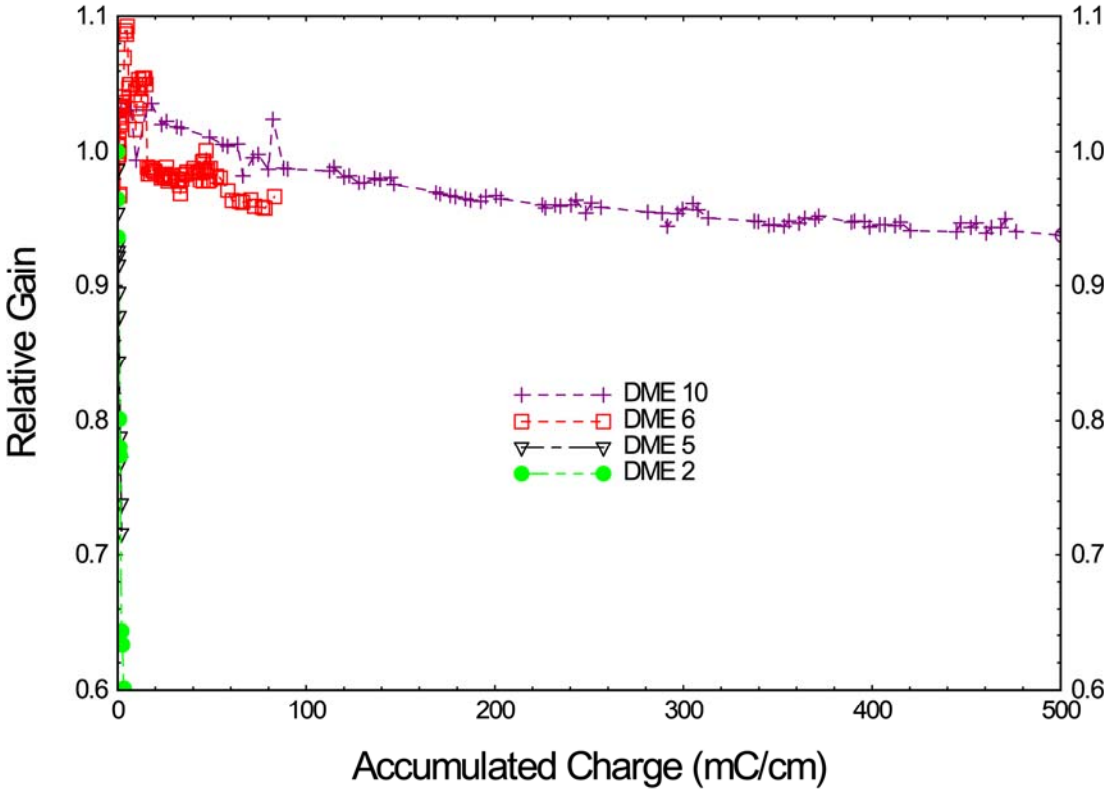


Figure 10: Normalised gain for DME test number 10

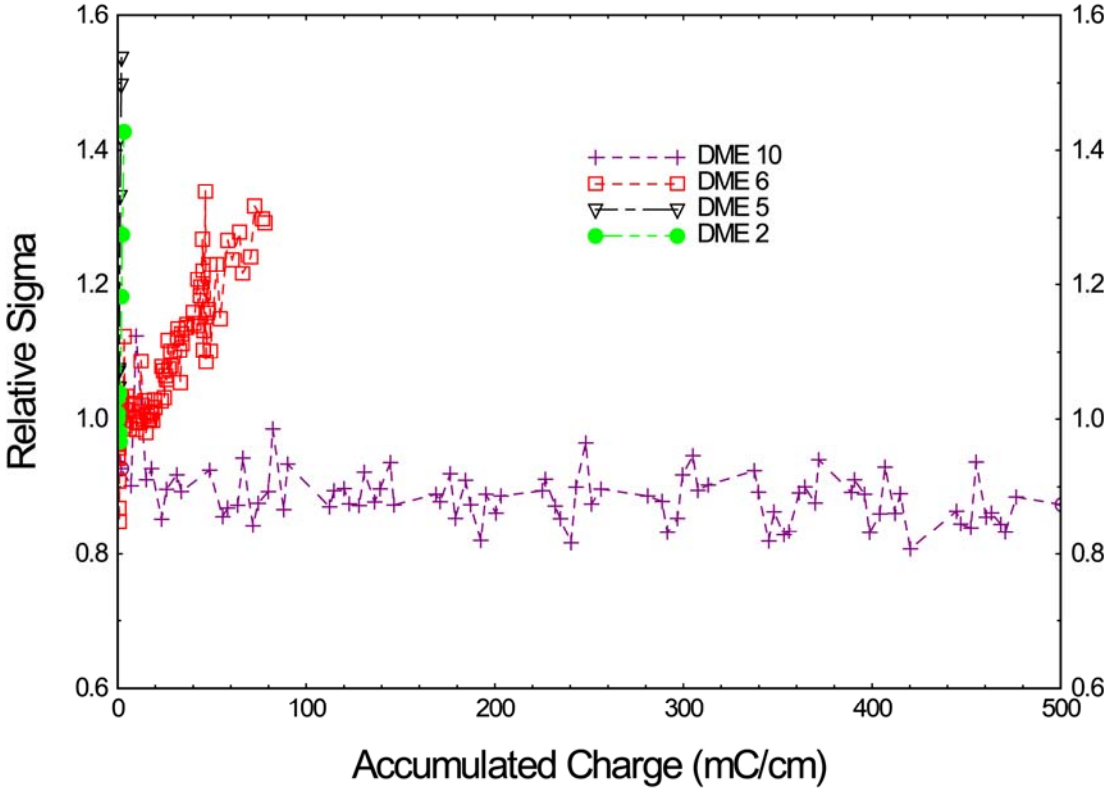


Figure 11: Normalised sigma for DME test number 10

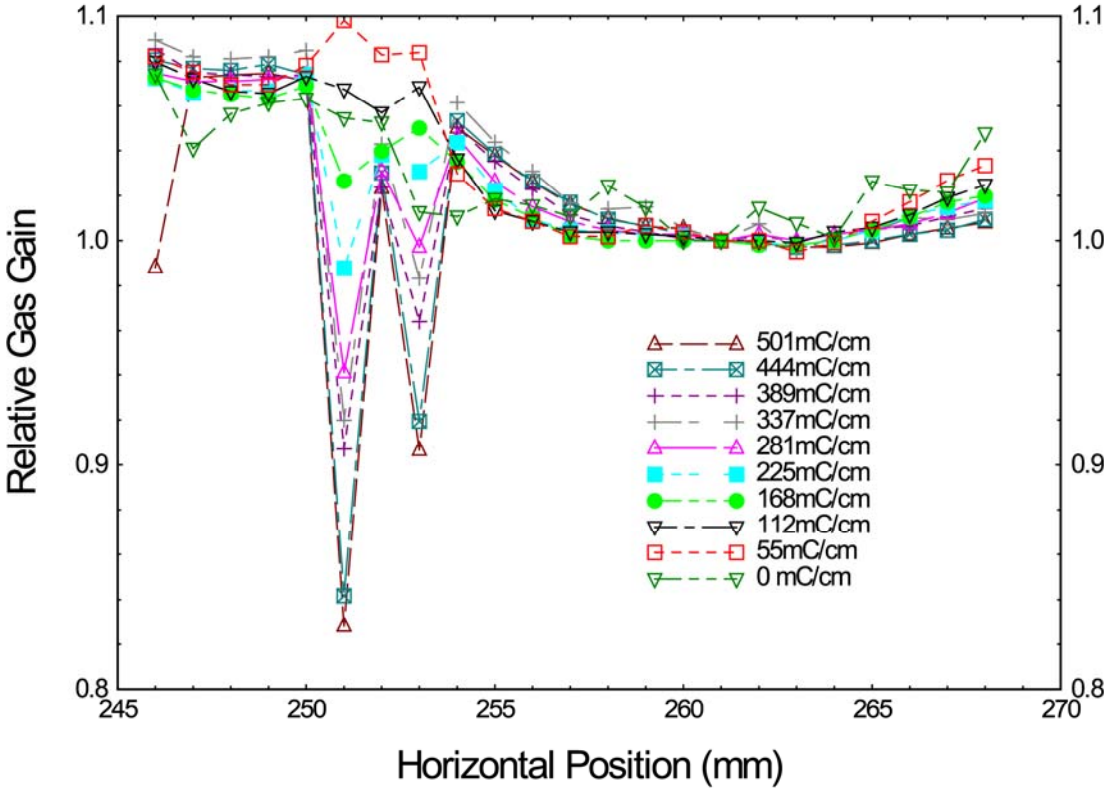


Figure 12: Gain variation along the detector section for DME test number 10 (normalised to horizontal position 261)

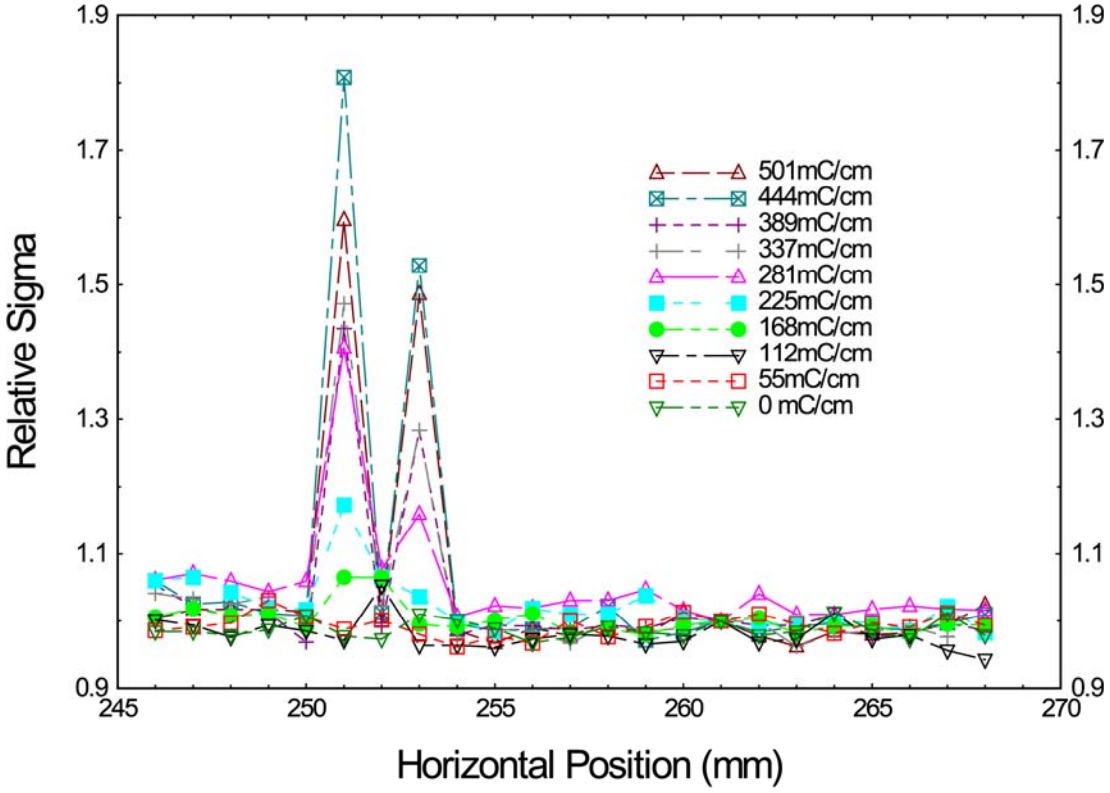
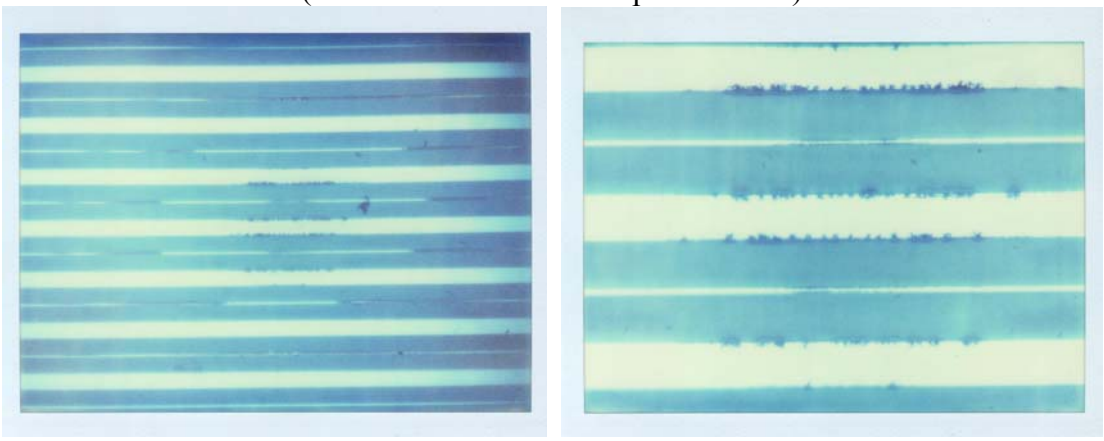


Figure 13: Sigma variation along the detector section for DME test number 10 (normalised to horizontal position 261)



a b

Figure 14: Micrographs of ageing spot for DME test number 10

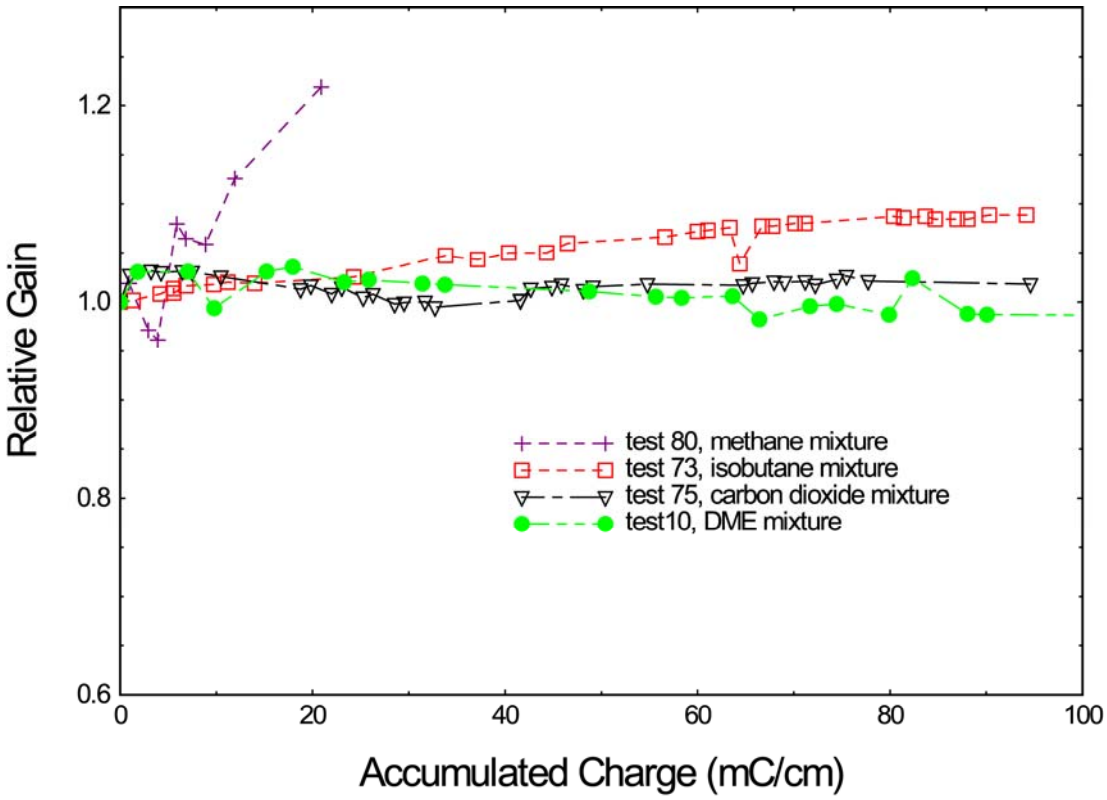


Figure 15: Variation of normalised gain for the control ageing tests in various gas mixtures

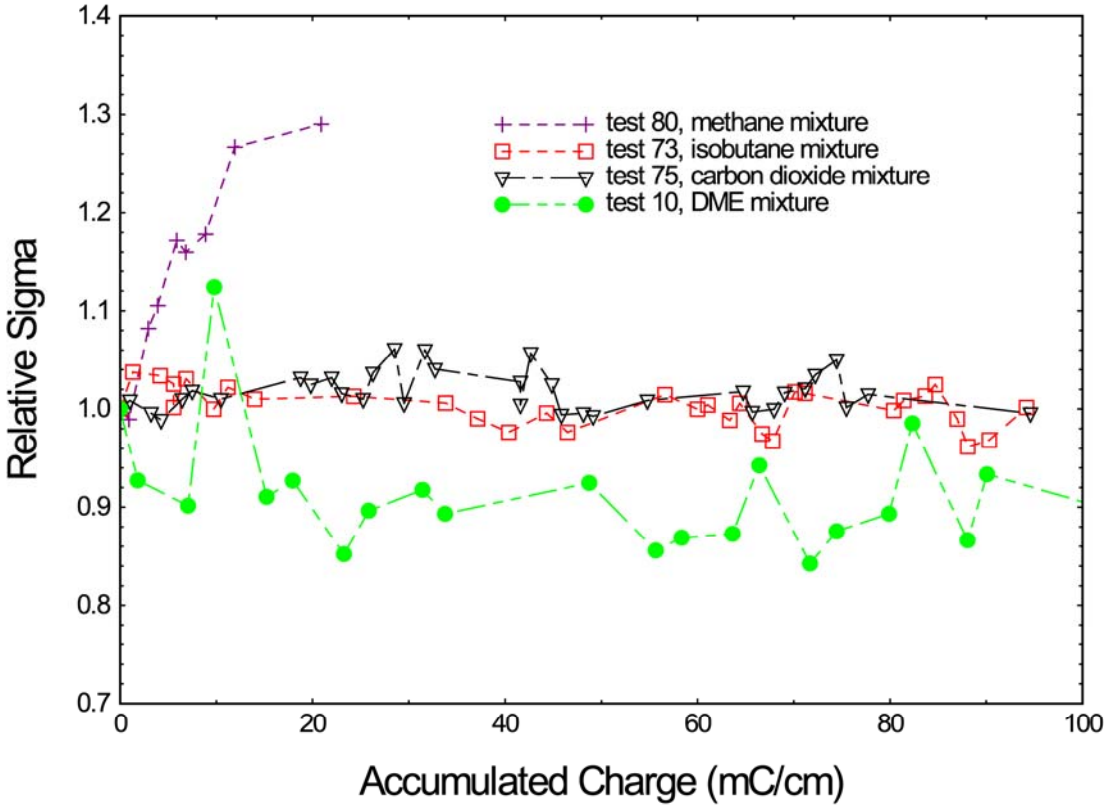


Figure 16: Variation of normalised sigma for the control ageing tests in various gas mixtures