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Report

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DQL-AS 033

A Study of Methods for Reducing the Effect of Static Charge when Weighing Filters

David Butterfield and
Paul Quincey

NOT RESTRICTED

October 2006

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A Study of Methods for Reducing the Effect of Static Charge when Weighing Filters

Contents

Executive Summary

This study investigated the effect of static charges on the weighing of filters commonly used for particulate measurement, and the effectiveness of several methods available for reducing these effects, including the active methods of a high voltage bar, an anti-static gun, and a polonium-210 radioactive source.

Most of the experiments were done at low (30%) relative humidity, as a “worst case” for static retention. A limited number of experiments done at 75% relative humidity confirmed that effects were significantly reduced at higher humidities.

Filters made from glass fibre or PTFE-coated glass fibre were found to suffer from negligible effects of static on their weight. Quartz filters were found to need active static reduction to produce stable readings in less than a minute. PTFE filters needed active static reduction and took longer to stabilise than quartz filters.

The anti-static gun was found to be less reproducible and less easy to use than the other two active methods. The high voltage bar and the radioactive source were found to be equally effective for quartz filters, while the radioactive source was somewhat more effective than the high voltage bar for PTFE.

Repeated weighing of the same filter before and after application of charge could produce stable readings that differed from each other by significant amounts, up to 120 µg for quartz and 800 µg for PTFE. This did not appear to be due to the effects of charge on the balance, and the explanation is not entirely clear, but may be due to “uncharged” filters in fact retaining charge at some sites for long periods. This is an argument for neutralising charge by active methods even when stable readings can be obtained without them.

The results emphasise the difficulty of determining the mass of a filter with an accuracy better than around 20 µg, even though balances of much higher resolution can be used.

The work was funded by the Department of Trade and Industry’s Valid Analytical Measurement Programme.

1 Introduction

Airborne particulate matter is generally collected for monitoring purposes on filters, made from material such as quartz, glass fibre and PTFE. The same basic technique is used for ambient air, vehicle emissions, and occupational exposure. When the dampled mass of the particulate matter is measured, for example for PM_{10} or $PM_{2.5}$, measurements of the small mass change involved can be grossly affected by static electric charge on the filter and weighing apparatus.

A typical 47 mm filter mass weighs 100 mg, with the additional particle mass being several hundred micrograms. Errors greater than 20 µg are deemed, for present purposes, to be significant as the collected mass is in the order of a few hundred micrograms. An ambient concentration of 20 $\mu g.m^3$ collected using a low volume sampler would give a collected mass of 480 µg. An error of 20 µg in each weighing would give an error of 5.9%.

The purpose of this study was to make a quantitative assessment of several methods available for reducing the effects of artificially-applied static charge when weighing filters of various materials.

The filters used were:

Filter medium	Manufacturer
Quartz	Pall
Glass fibre	Whatman
PTFE Zefluor	Pall
PTFE-coated glass fibre (Emfab)	Pall
PTFE ring supported	Pall

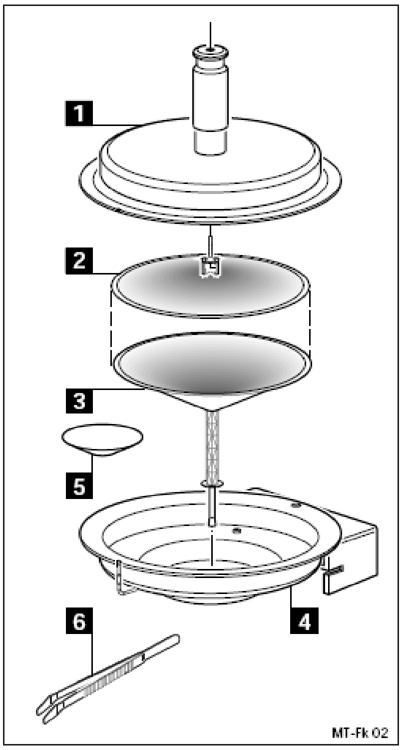
A description of the balance used, and preliminary tests performed on it, are given in Section 2. The static tests and results are described in Section 3.

2 Balance

The balance used for all the weighings was a Mettler Toledo UMT5, with a resolution of 0.1 µg. This was used both with its standard chamber, for weighing filters less than 50 mm in diameter, and a 110 mm Filter Set attachment for weighing larger filters.

The Mettler Toledo 110mm Filter Set is mounted on the top of the balance and is shown diagrammatically in Figure 1. It is metallic in construction and contains a metal shield to neutralise static charging and remove the effects of drafts. To install the filter set, the normal balance pan is removed, along with the top of the existing draft shield and the filter set mounted on the top of the balance.

The balance was contained within a metal glove box with a Perspex window and neoprene gloves. The glove box had active temperature and humidity control, which was switched off when weighing were performed. As the glove box was a closed system the temperature and humidity did not change significantly between weighings. The metal work of the glove box was earthed and the balance was mounted on metal feet on the floor of the glove box. The resistance between the balance pan and the glove box earth was measured and found to be negligible.



Key:

Top housing (1) with mounted filter weighing cover (2)
Filter weighing pan (3)
Bottom housing (4)
Pan (5)
Tweezers (6)

Figure 1 110mm Filter Set

Figure courtesy of Metler Toledo

A similar metallic filter cover could be used within the standard chamber configuration, and this is referred to as the 50 mm Filter Set.

2.1 Balance repeatability

Repeatability was calculated from the standard deviation of ten weighings with no artificially induced static, using the following equation:

$$repeatability = \sqrt{\frac{(x_i - \bar{x})^2}{n-1}} * t_{n-1,0.05}$$

where:

x_i	is the ith measurement;
$\bar{x}$	is the average of the measurements;
n	is the number of measurements
$t_{n\text{-}1,\,0,05}$	is the two-sided Students t-factor at a confidence level of 0.05, with n-1 degrees of freedom

The Zero Corrected Span was calculated by subtracting the average of the zero measurement performed before and after the span measurement from the span measurement.

Previous work (A S Brown et al, 2006) had found that the simple step of placing filters in the balance on aluminium foil was effective at reducing the effects of static, so this practice was also included.

2.1.1 Standard Chamber

The pan, foil and 50mm filter set repeatability measurements were derived from the weighing of the 100mg metallic check weight, while the filter media repeatabilities were derived from the weighing of the filter media only.

Repeatability µg	Pan	Foil	50 mm Filter Set
Zero	5.0	5.9	4.9
Span	5.4	3.4	5.6
Span (Zero Corrected)	3.9	2.8	2.7

Repeatability µg	47 mm Emfab	47 mm Quartz	47 mm Glass Fibre	47 mm PTFE Zeflour	47 mm PTFE ring supported
Zero	7.0	3.6	2.7	1.8	4.6
Span	7.4	6.8	5.6	4.1	2.8
Span (Zero Corrected)	2.3	5.5	6.0	4.6	2.3

The Emfab, quartz, glass fibre and PTFE filters were stored on foil covered metal trays and weighed on a foil sheet.

2.1.2 110mm Filter Set

Repeatability µg	100 mg check weight	47 mm Emfab	47 mm Quartz	47 mm Glass Fibre	47 mm PTFE Zeflour	70 mm Emfab	90 mm Quartz
Zero	12.4	5.8	11.9	5.2	5.7	3.9	22.2
Span	9.6	8.9	17.3	4.6	33.4	6.6	46.7
Span (Zero Corrected)	4.8	5.7	12.1	4.0	36.6	7.3	56.8

The Emfab, quartz, glass fibre and PTFE filters were stored on foil covered metal trays.

2.1.3 Comment

It can be seen that all the repeatabilities within the standard chamber are similar at around 5 µg, well below the 20 µg deemed significant. With the 110 mm Filter Set, on the other hand, some repeatabilities are notably worse, for example with PTFE and larger quartz filters.

The higher repeatability is probably due to the mode of operation of the 110mm Filter Set, as it requires more mechanical interference to load and unload the filter. This interference has the potential to move the position of the balance on the weighing table and possibly change the performance of the balance.

3. Effects of Static

Static charges were applied to filters of different materials using a Milty ZEROSTAT Anti-Static Gun. This device emits a stream of positive and negatively charged ions when the trigger is depressed. To charge a filter, the filter is placed on an insulator and then subjected to a stream of positive and negative charges.

Charged filters were then placed on the balance in different ways and the weight recorded at regular time intervals. The filters were weighed in the following different ways:

1. Straight on the balance pan (no foil);

These initial measurements used four types of filter: Emfab, quartz, glass fibre and PTFE Zefluor. As no significant charge effects were observed for the Emfab or glass fibre filters, the following static reduction techniques were used for the quartz and two types of PTFE filters only:

2. On an aluminium foil disk on the balance pan;
3. Between 50 mm diameter thin metal sheets (the Mettler Toledo 50mm Filter Set).
4. Charge neutralisation from a static elimination bar (see below);
5. Charge neutralisation using the anti-static gun;
6. Charge neutralisation using a polonium-210 radioactive source (see below);
7. Use of the Mettler Toledo 110 mm Filter Set.

The static elimination bar (Fraser Anti-Static Techniques, model 1260) generates a 5 kV potential to ionise the surrounding air and has an effective range of 80 mm. The filter is moved through the ionised volume on both sides before weighing.

To neutralise static charges with the ZEROSTAT ant-static gun the filter was held in free space and subjected to a stream of positive and negative charges.

Polonium-210 produces alpha radiation, which ionises the air in close proximity to the source. The source strength for the polonium was 62.9 MBq in March 2006. The half-life of polonium-210 is 138 days so that the effective lifetime of the device is around 12 months.

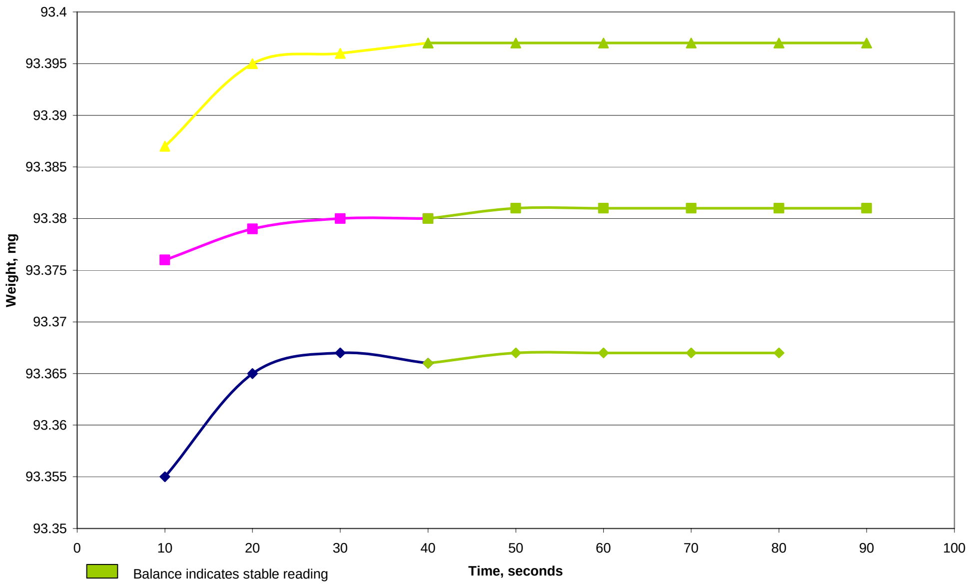
All these tests were carried out at 30% relative humidity, as more static charge is expected to be retained at low humidity. Some further type 1 tests were carried out at 75% relative humidity.

The results from the weighing scenarios are given in the sections below. In all graphs, the green traces denote when the balance considers that its readings are stable and t=0 represents the time when the filter was placed on the balance pan. Unless otherwise indicated each graph shows the multiple weighings of a single filter of the specified media. The lines connecting the points are smoothed curves for indication purposes only.

3.1 Balance Pan without foil

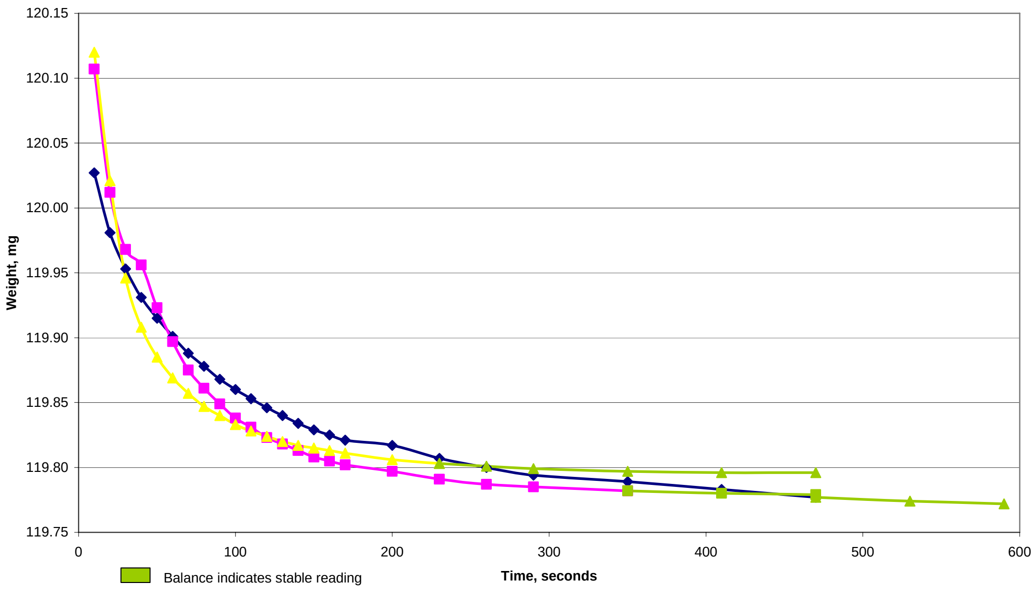
Filter media were charged using the anti-static gun and then placed directly on the balance pan.

3.1a Emfab filter



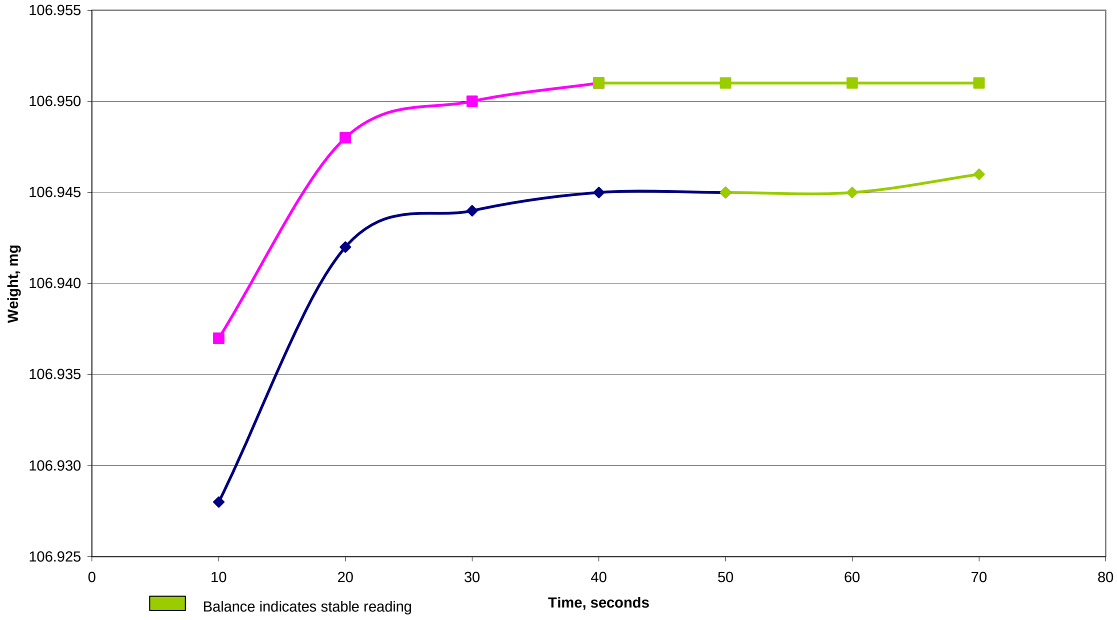
After initial deviations of about 10 µg, stable readings were obtained 40 seconds after placing a filter on the balance. The stable results agreed to within 30 µg.

3.1b Quartz filter



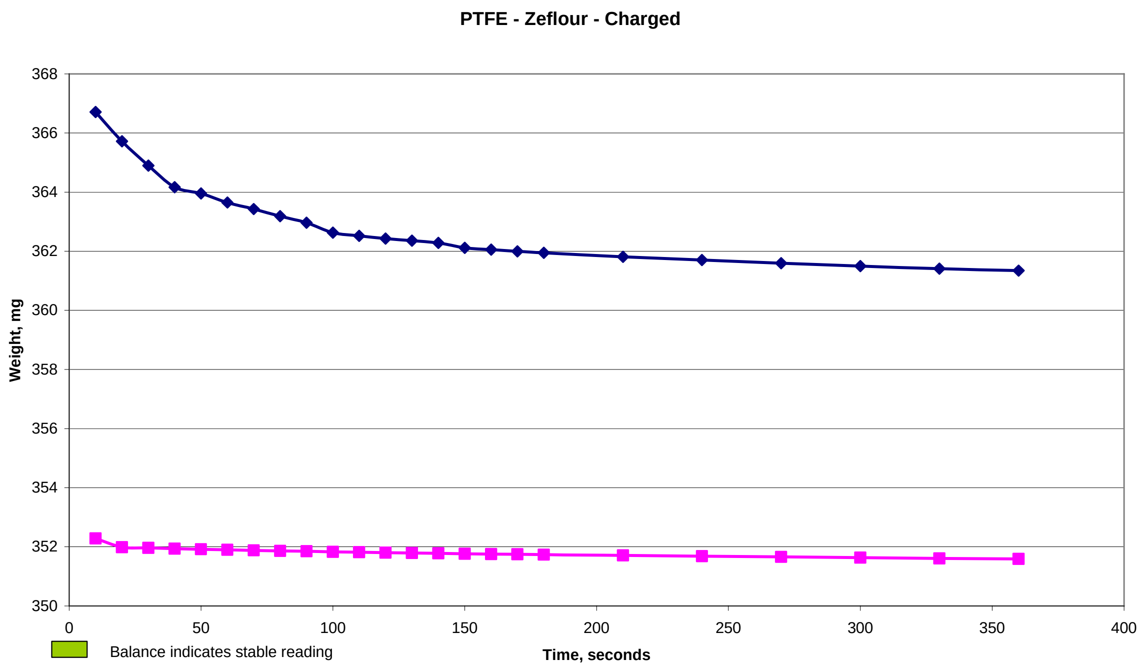
After initial deviations of about 300 µg, stable readings were obtained between 230 and 470 seconds after placing a filter on the balance.

3.1c Glass fibre filter

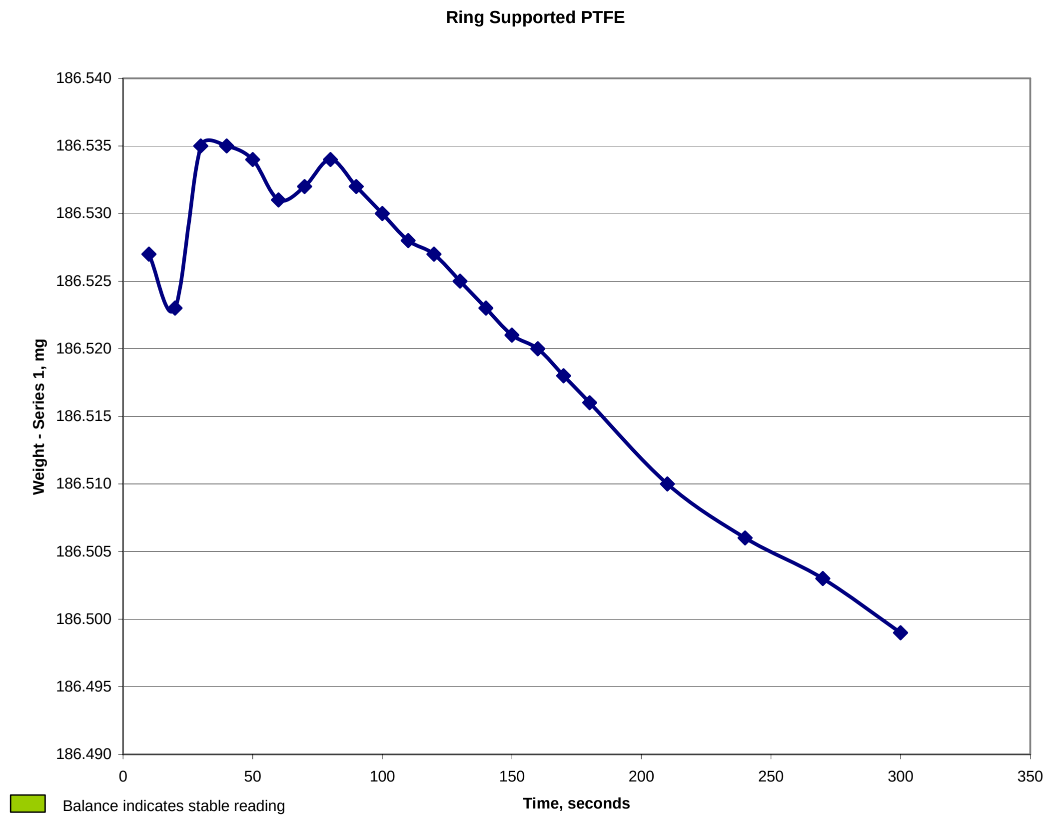


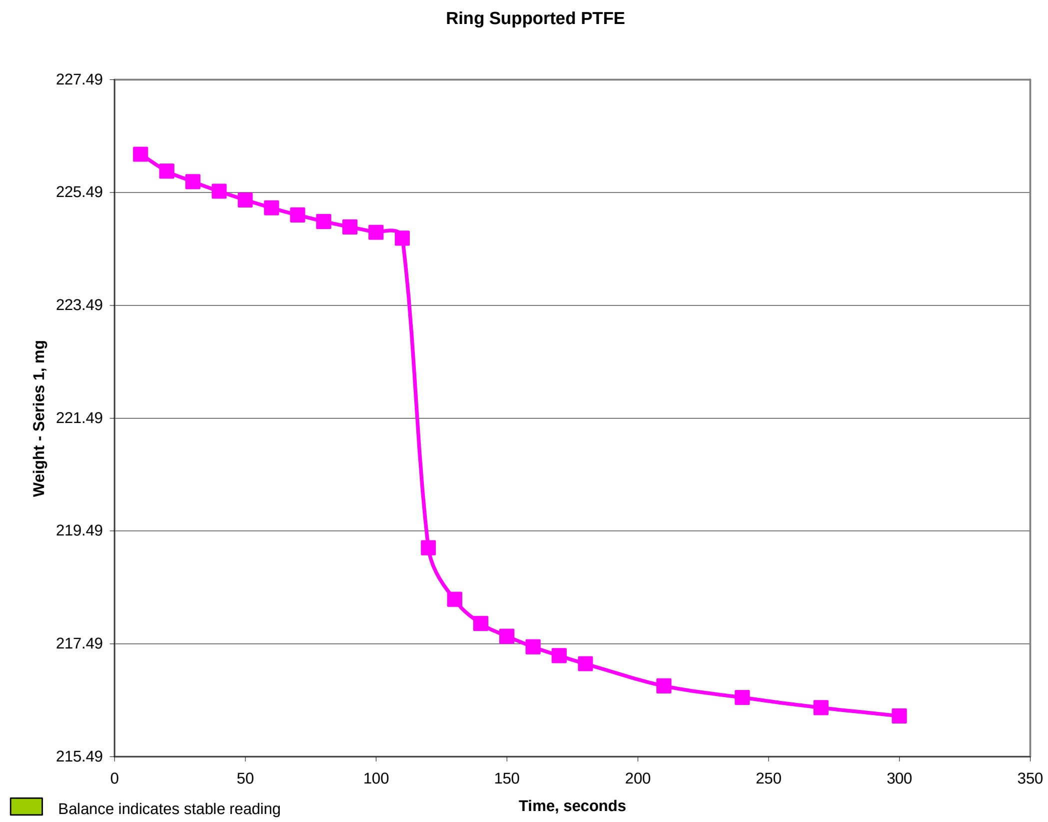
After initial deviations of about 15 µg, stable readings were obtained between 40 and 50 seconds after placing a filter on the balance, agreeing to within 5 µg.

3.1d PTFE filters (Zefluor and ring-supported)



For both attempts with this filter, stable readings were not obtained in the time available.

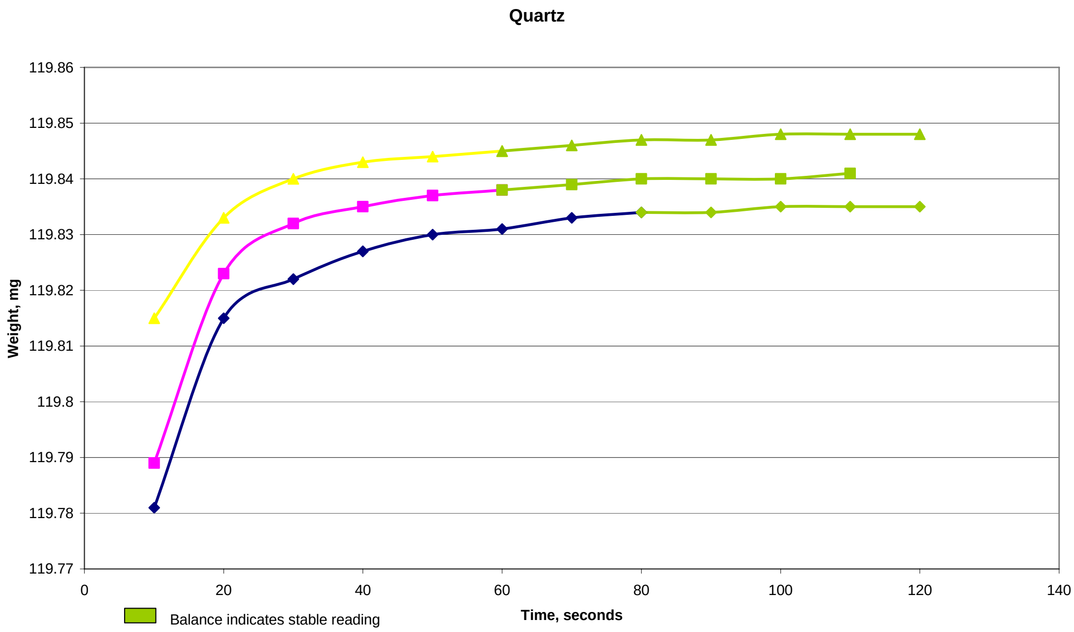




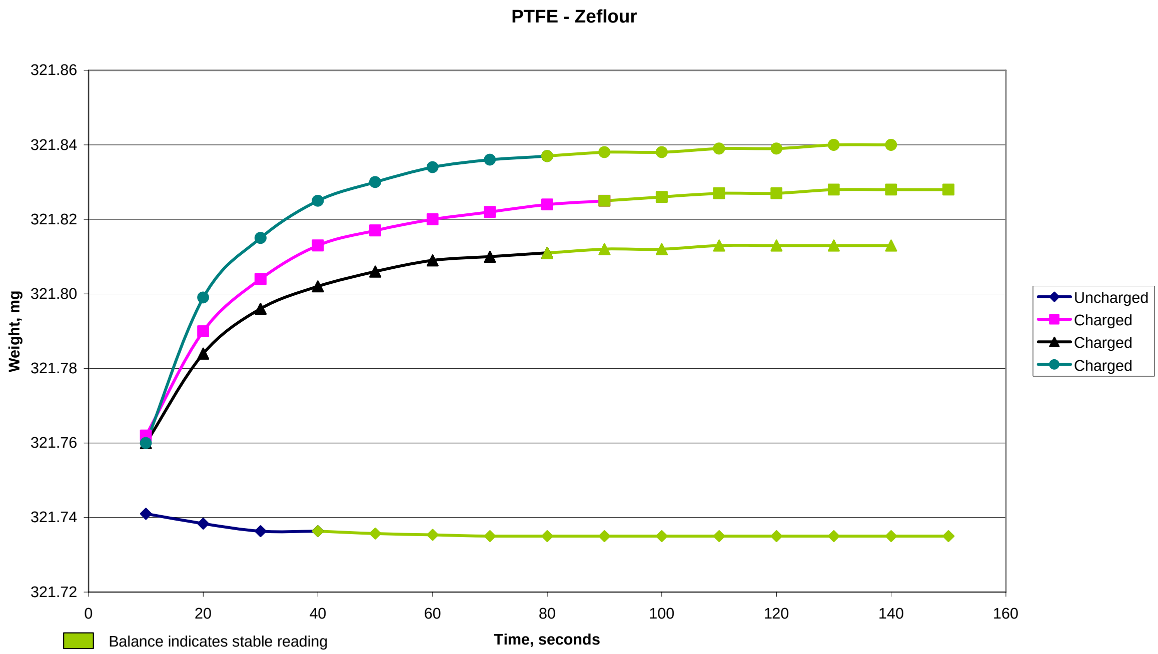
Again, for both attempts, stable readings were not obtained in the time available.

3.2 Balance Pan with foil

Because only the quartz and PTFE filters retained their charge over an appreciable time, tests (2) and (3) were performed on these filters only. Filter media were charged using the anti-static gun and then placed on a piece of aluminium foil on the balance pan.



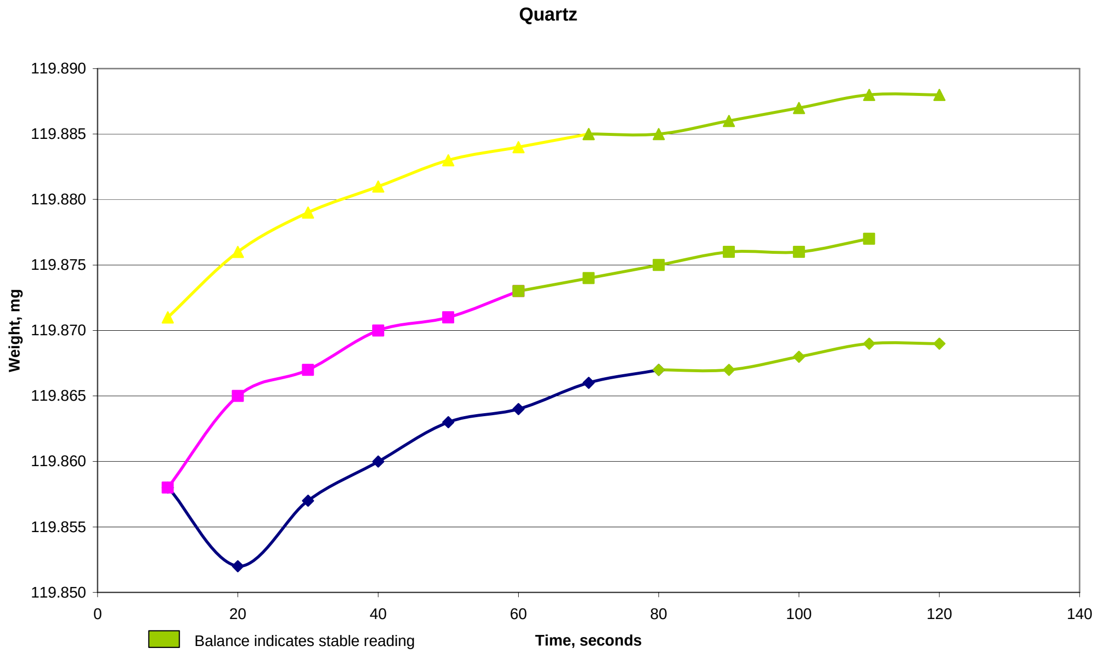
After initial deviations of about 50 µg, stable readings were obtained between 60 and 80 seconds after placing a filter on the balance, agreeing to within about 15 µg.



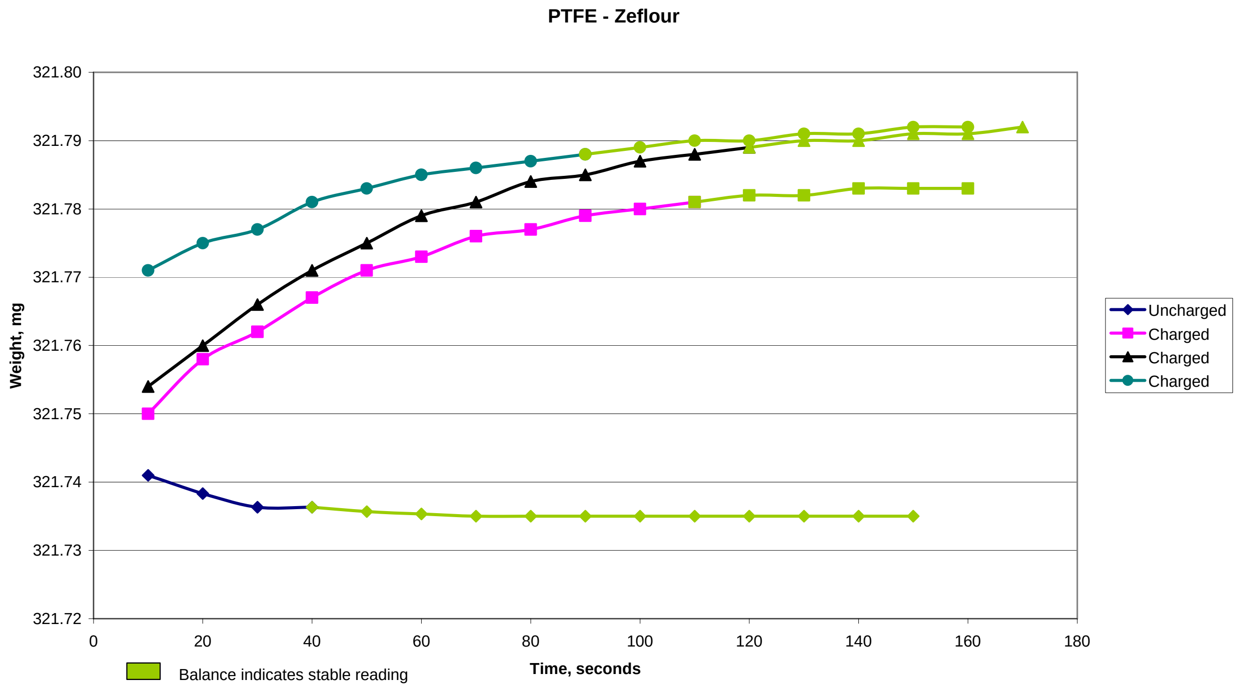
After initial deviations of about 60 µg, stable readings were obtained between 80 and 90 seconds after placing a filter on the balance. These differed by about 30 µg from each other, but by about 100 µg from the "uncharged" value.

3.3 50 mm Filter Set

Filter media were charged using the anti-static gun and then placed between the 50mm Filter Set before being placed on the balance pan.



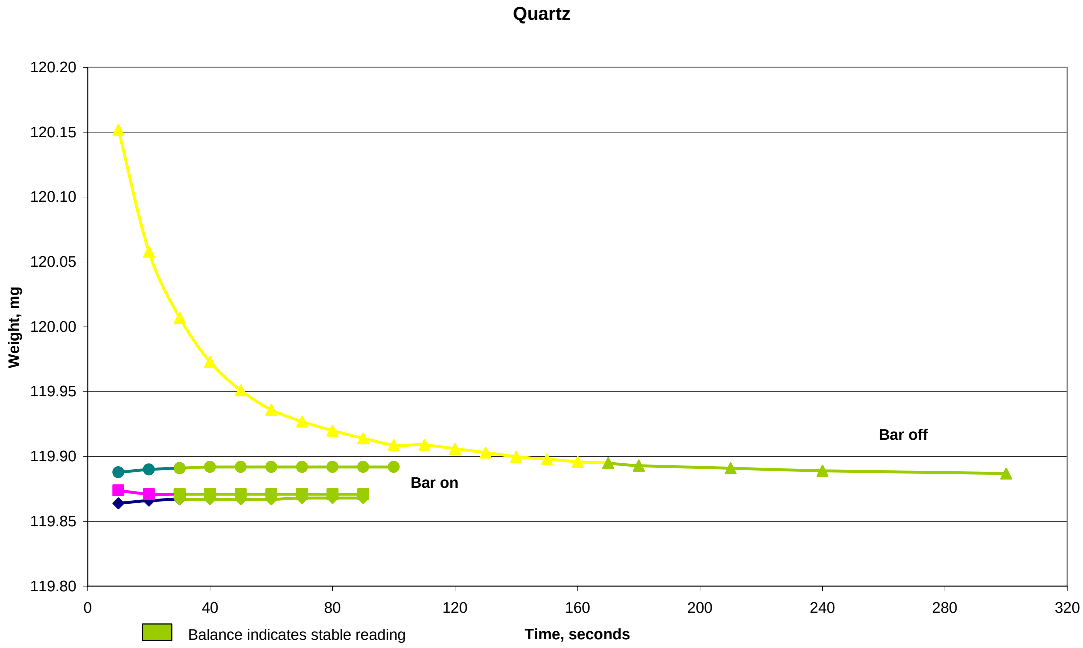
After initial deviations of about 25 µg, stable readings were obtained between 60 and 80 seconds after placing a filter on the balance, agreeing to within about 20 µg.



After initial deviations of about 30 µg, stable readings were obtained between 90 and 120 seconds after placing a filter on the balance. These differed by about 10 µg from each other, and by about 50 µg from the "uncharged" value.

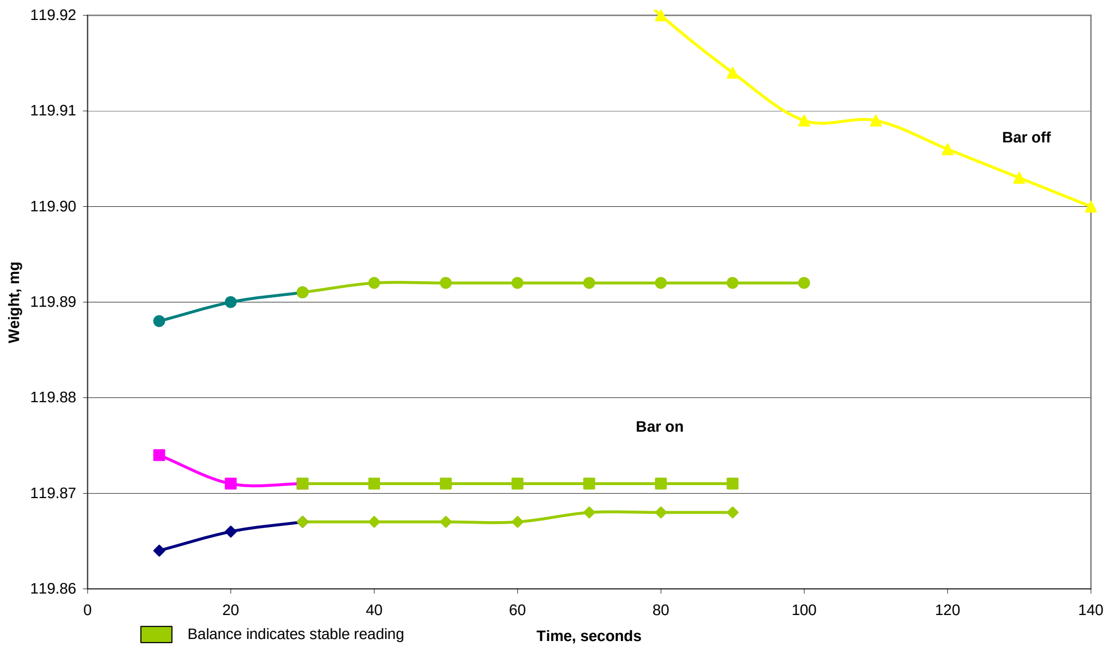
3.4 Static Elimination Bar

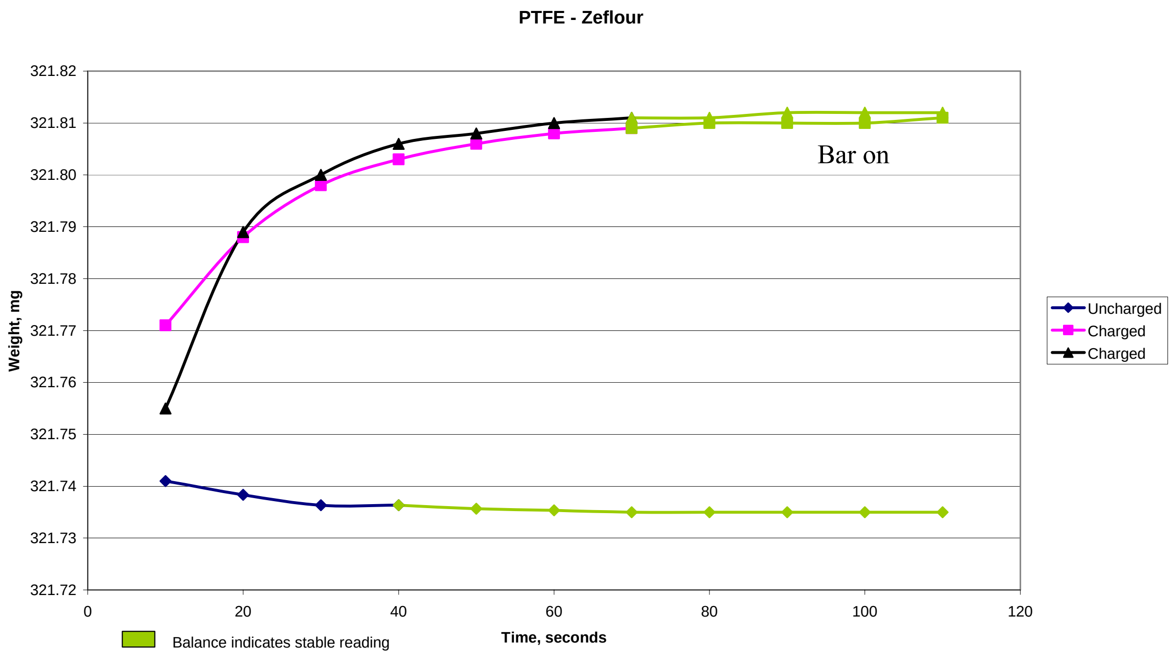
Filter media were charged using the anti-static gun and then passed close to the static elimination bar, before being weighed directly on the balance pan.



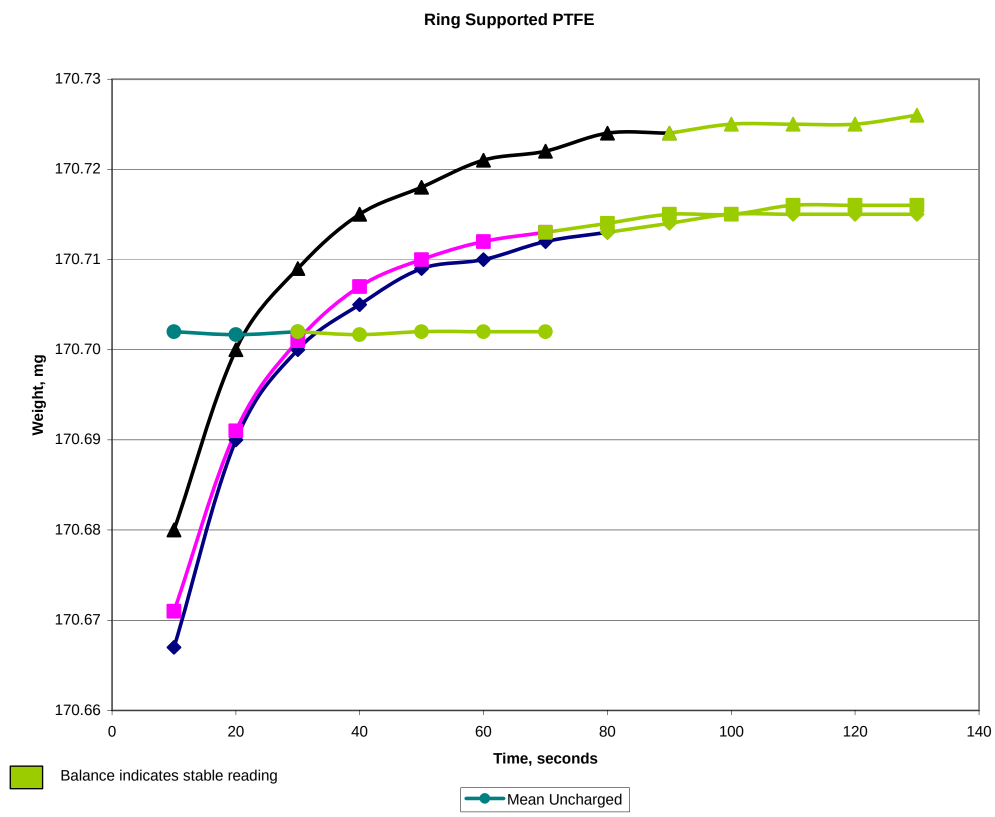
With the static elimination bar turned on, stable readings were obtained within 30 seconds after placing a filter on the balance, after initial deviations of a few µg. With the static elimination bar turned off, similar stable readings were obtained after 170 seconds.

The same results with an expanded weight axis are shown below:





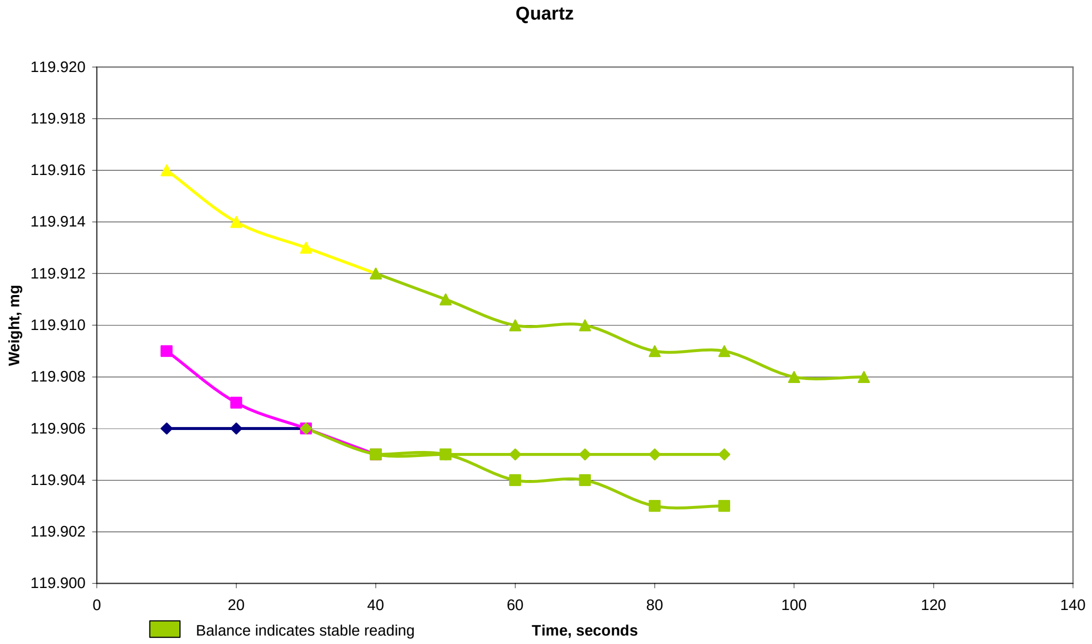
After initial deviations of about 50 µg, stable readings were obtained around 80 seconds after placing a filter on the balance. These agreed very closely, but differed by about 70 µg from the "uncharged" value.



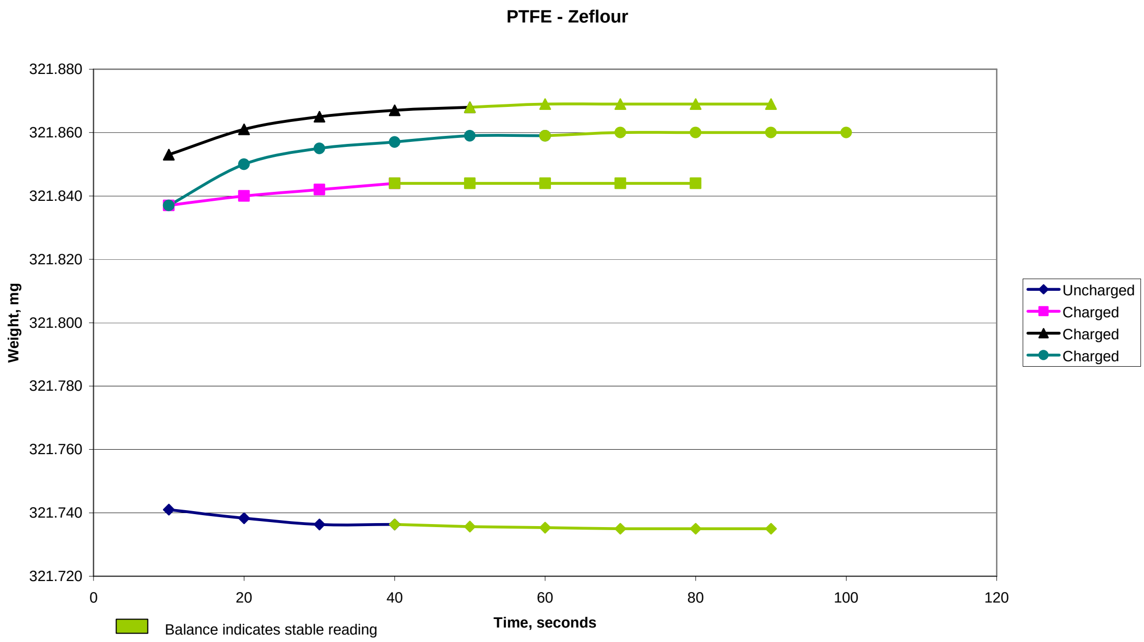
After initial deviations of about 50 µg, stable readings were obtained between 70 and 90 seconds after placing a filter on the balance. All results agreed to within about 20 µg.

3.5 Anti-Static Gun

Filter media were first charged, and then neutralised using the anti-static gun.



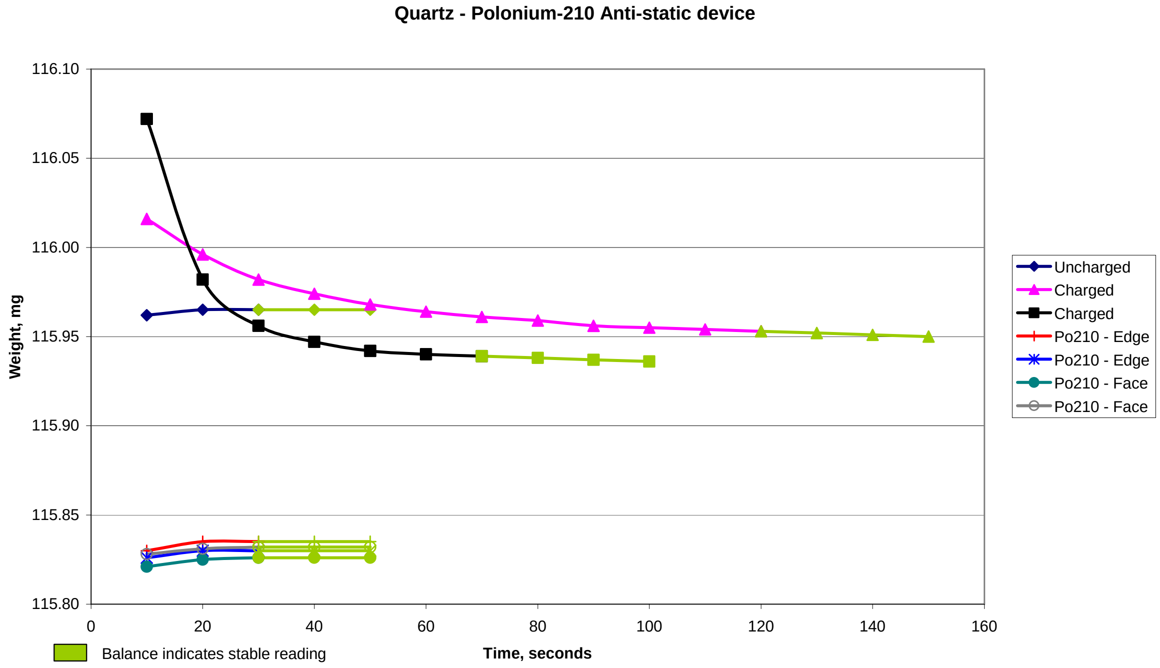
After initial deviations of a few µg, stable readings were obtained between 30 and 40 seconds after placing a filter on the balance, with close agreement.



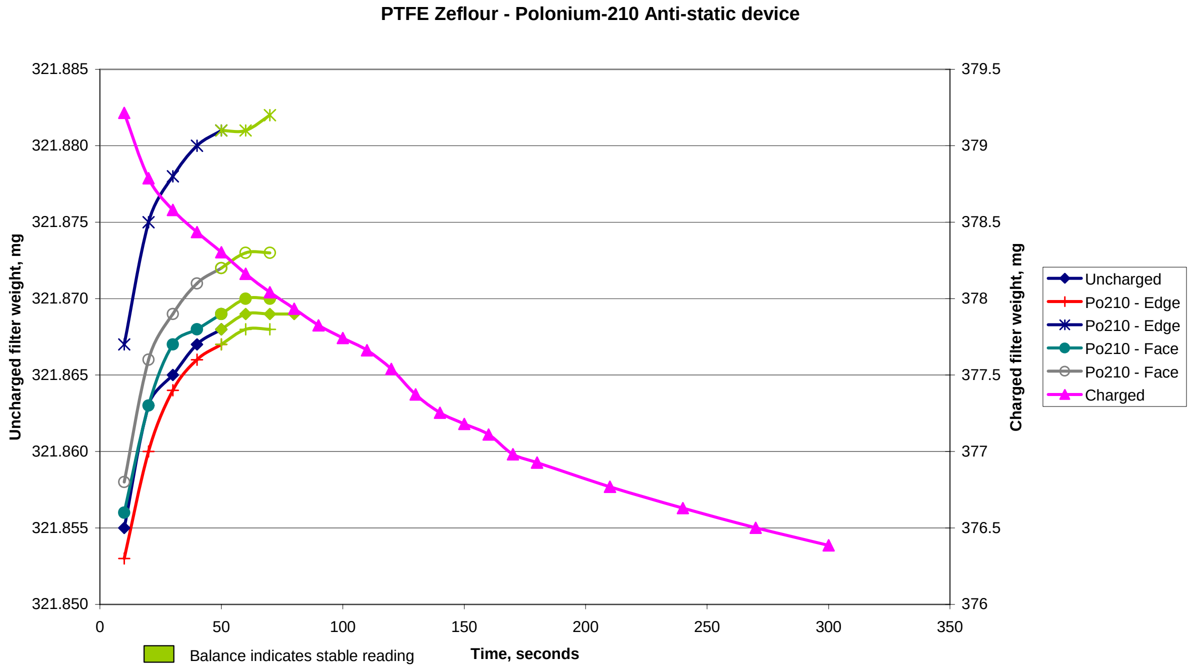
After initial deviations of about 10 µg, stable readings were obtained between 40 and 60 seconds after placing a filter on the balance. These differed by about 30 µg from each other, but by about 100 µg from the "uncharged" value.

3.6 Polonium-210

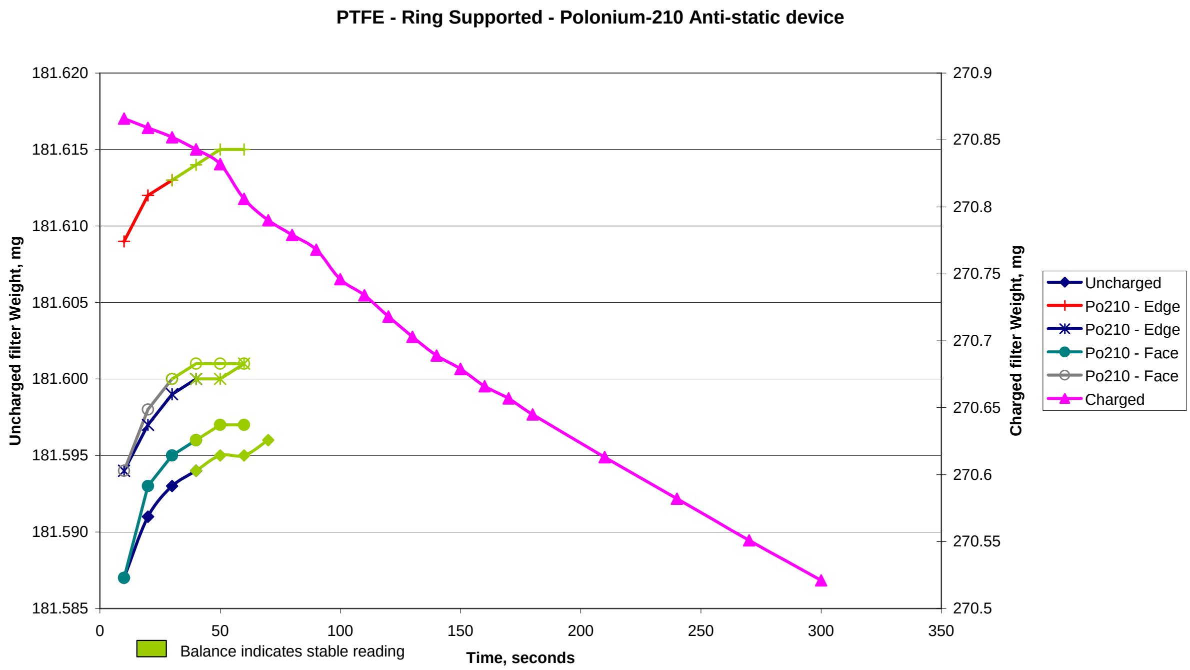
Charged quartz, PTFE Zeflour and Ring Supported PTFE filters were charged with the anti-static gun and then the polonium-210 source was used to try and neutralise the stored static charge. As alpha particles only travel approximately 30 mm in air and the filters were 47 mm in diameter, the charge neutralisation of the filters was performed edge on and face on to the alpha source to see if there was any difference in effectiveness. The effectiveness of the charge neutralisation can be seen from the graphs below:



Stable readings were obtained within 30 seconds after placing a filter on the balance after use of the polonium source compared with between 70 and 120 seconds for a charged filter. The polonium treated filters agreed to within about 10 µg, but these differed by about 120 µg from the "uncharged" value.



Stable readings were obtained 50 seconds after placing a filter on the balance after using the polonium source. Results agreed to within 15 µg. In contrast, charged filters did not give a stable reading over the period studied, but were heading for a value perhaps 30 µg lower.

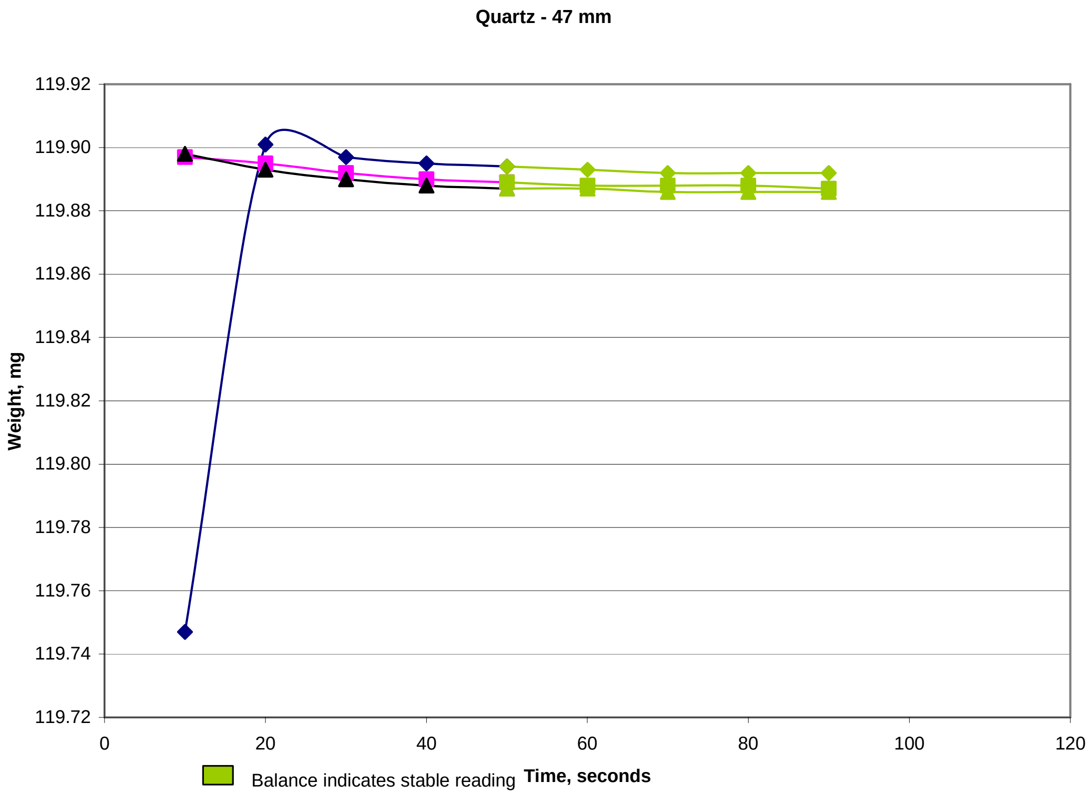


Stable readings were obtained 30 to 40 seconds after placing a filter on the balance after using the polonium source. Results agreed within 20 µg. In contrast, charged filters did not give a stable reading over the period studied.

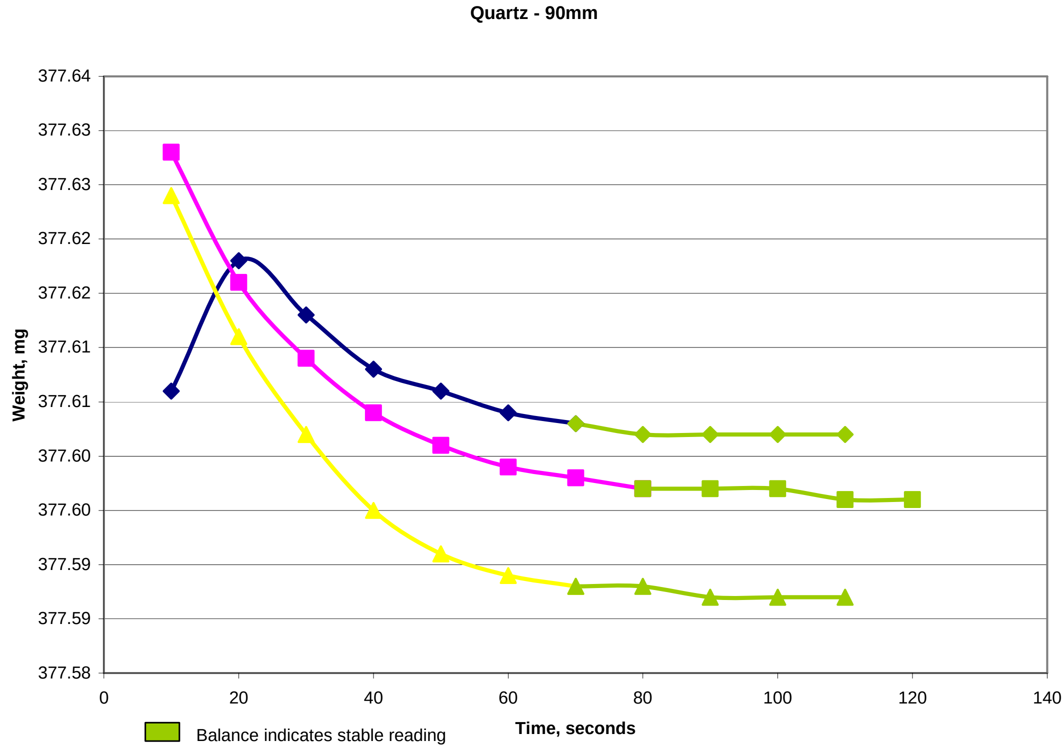
No significant differences were observed between holding the filters edge or face on to the polonium source when neutralising the static charge on the filters.

3.7 110mm Filter Set

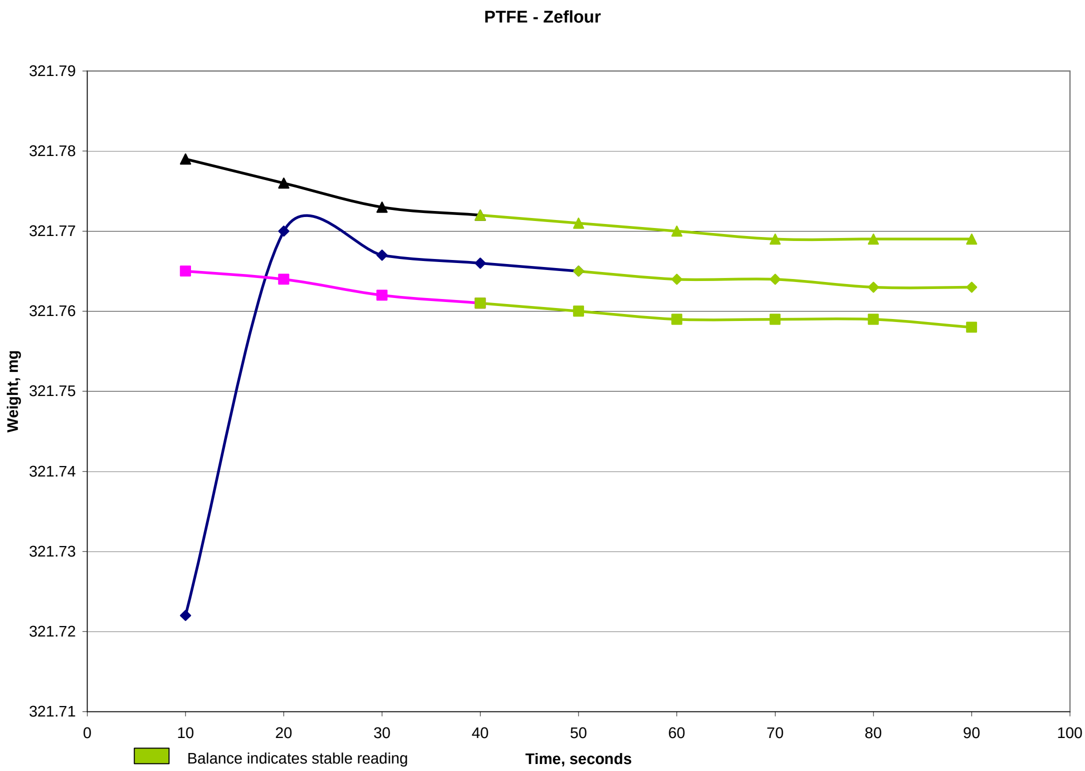
3.7.1 Uncharged Filters



Stable readings were obtained 50 seconds after placing a filter on the balance, with agreement to within about 10 µg.

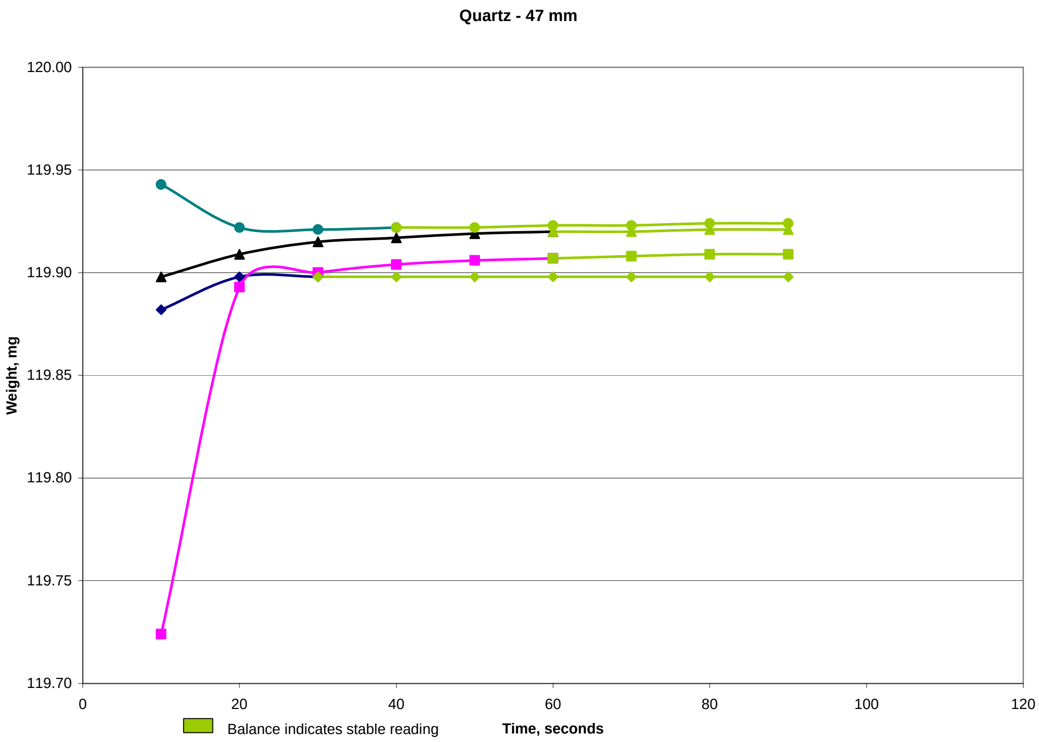


Stable readings were obtained between 70 and 80 seconds after placing a filter on the balance, with agreement within about 20 µg.

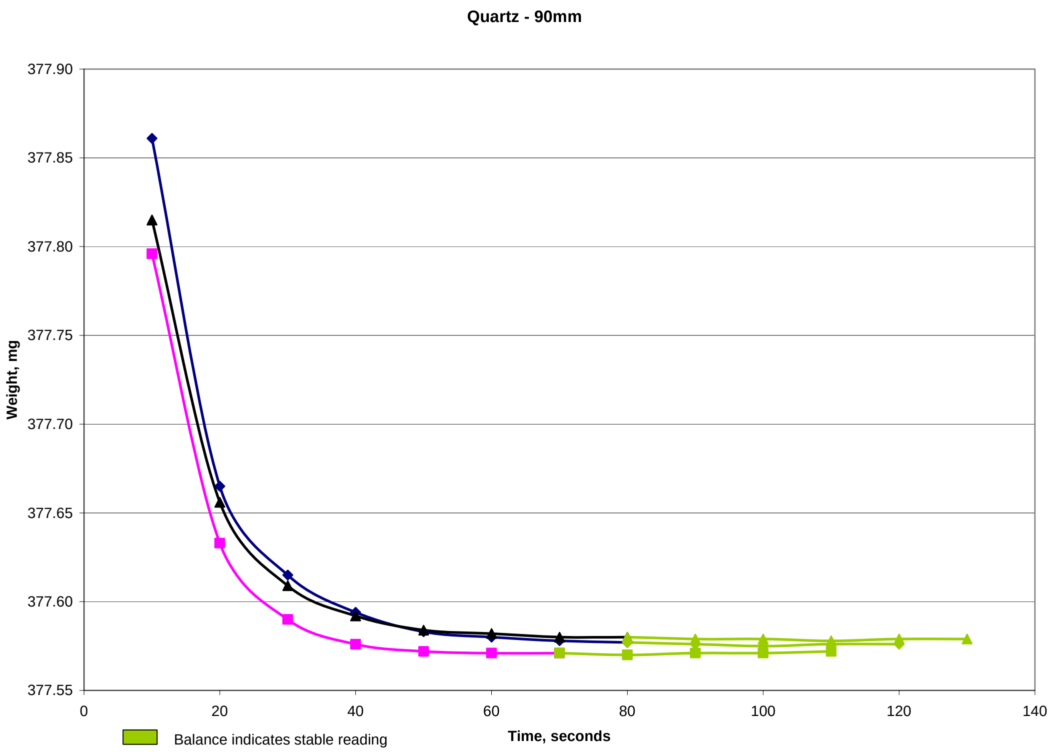


Stable readings were obtained between 40 and 50 seconds after placing a filter on the balance, with agreement to within about 10 µg.

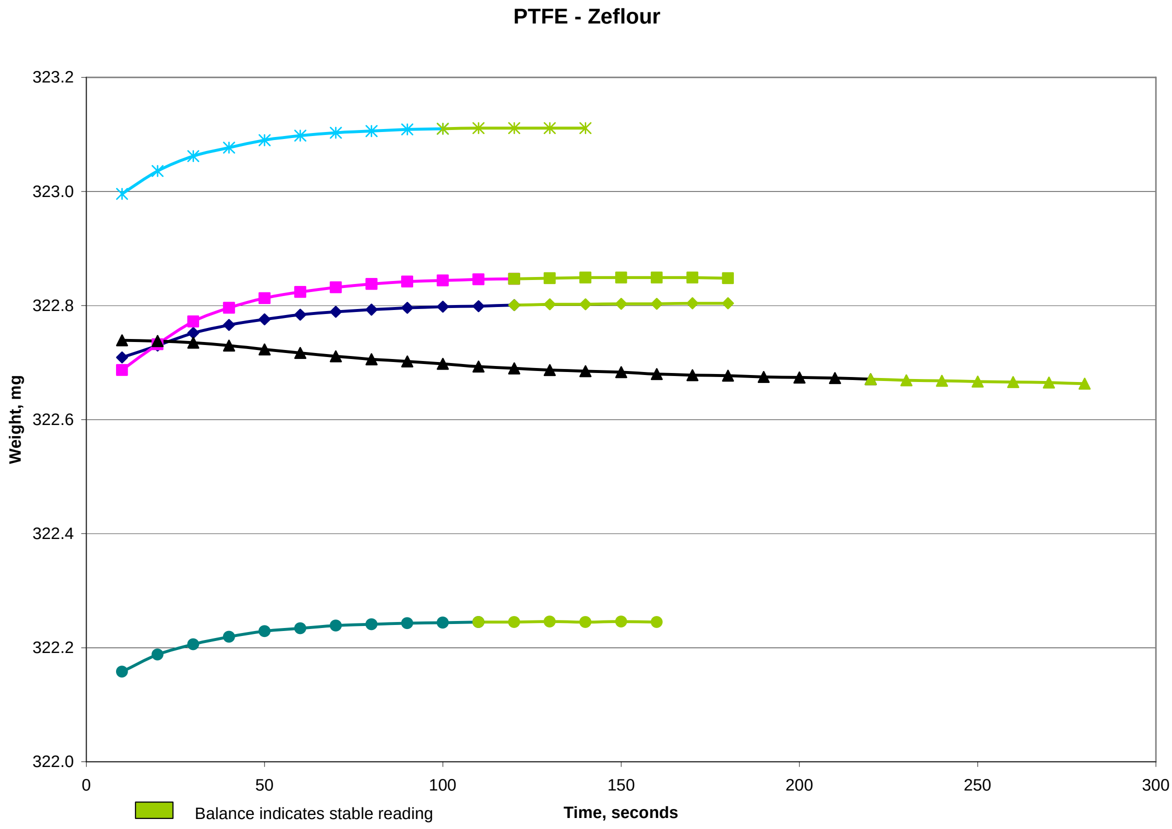
3.7.2 Charged Filters



Stable readings were obtained between 30 and 60 seconds after placing a filter on the balance, with agreement to within about 20 µg.



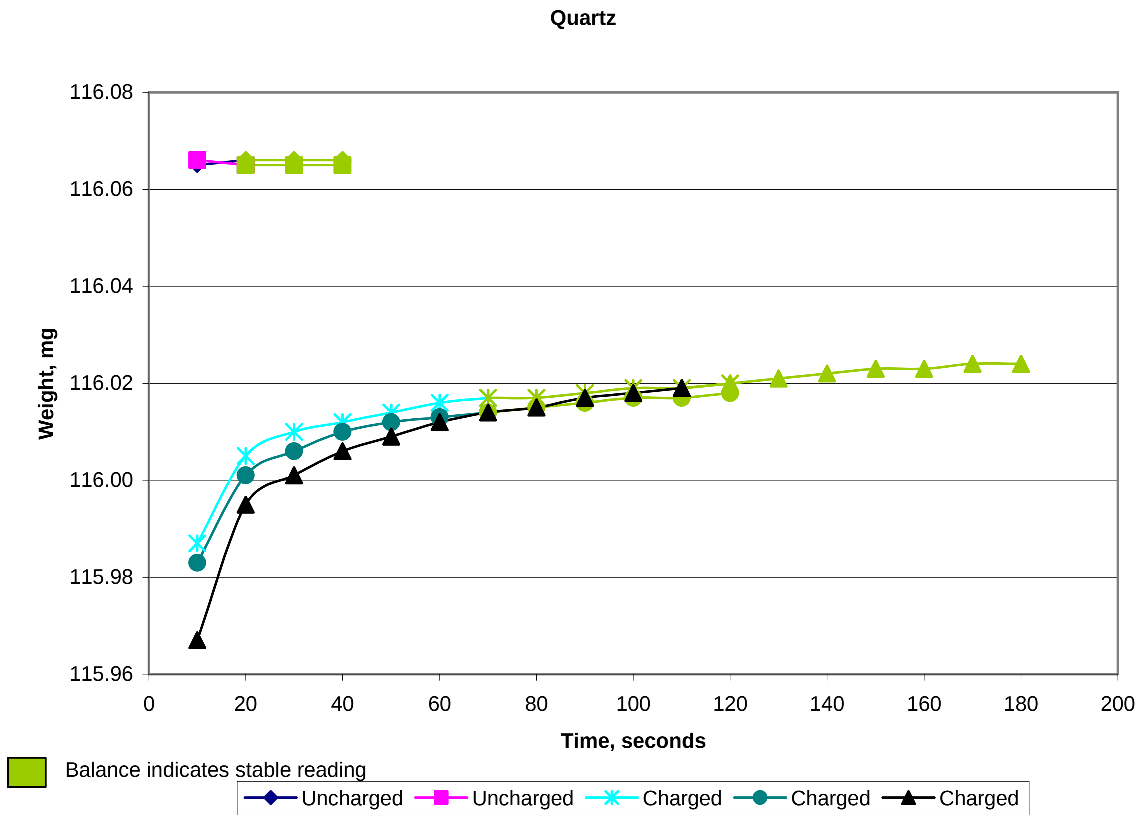
Stable readings were obtained between 70 and 80 seconds after placing a filter on the balance, with agreement to within about 10 µg.



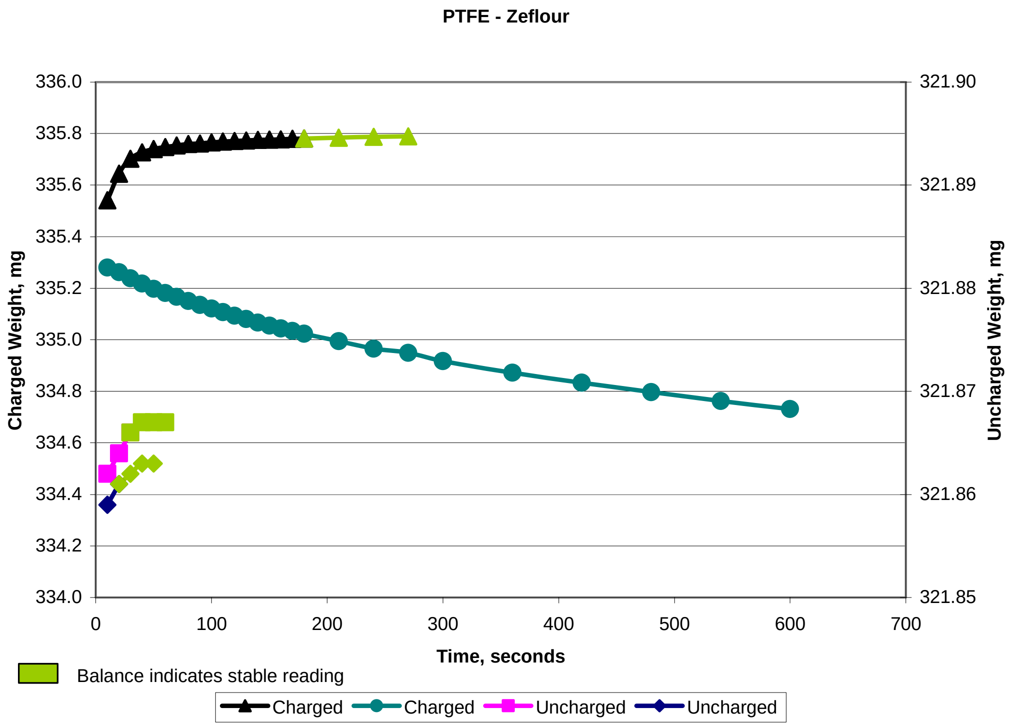
Stable readings were obtained between 100 and 220 seconds after placing a filter on the balance, but they differed by up 800 µg.

3.8 Tests At 75% Relative Humidity

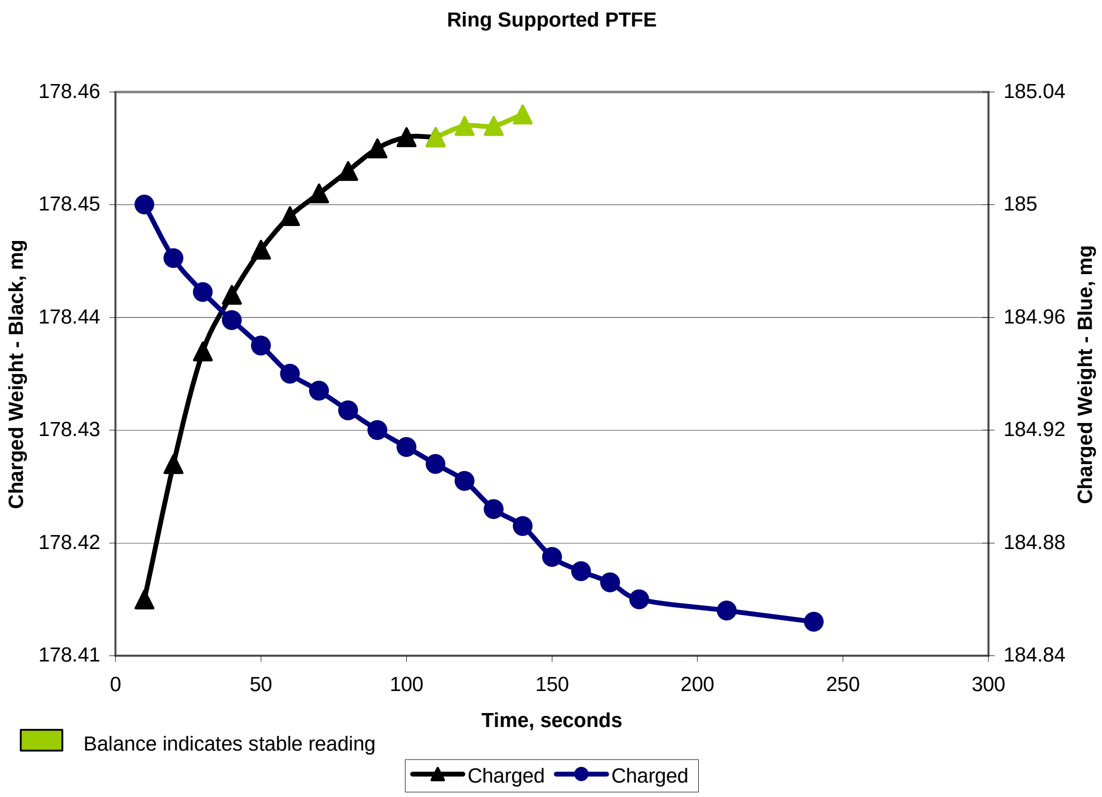
The effects of static charging of filter media were investigated at a relative humidity around 75%. All of the tests were performed on 47mm filters placed directly on the balance pan.



Stable readings were obtained between 70 and 110 seconds after placing a filter on the balance, with close agreement but a difference of around 45 µg from the "uncharged" value.



It should be noted that the charged and uncharged filter exhibited a considerable difference in weight. Stable readings were obtained 180 seconds after placing a charged filter on the balance, but were not obtained after a period of 10 minutes when this was repeated.



It should be noted that the charged filter exhibited a considerable difference in weight. Stable readings were obtained 110 seconds after placing a filter on the balance, but were not obtained after a period of 4 minutes when this was repeated. Uncharged filters were stable 20 seconds after placing the filter on the balance. The uncharged filters are not shown on the graph because their mass was substantially lower than the apparent higher mass of the charged filters. Uncharged filters had an average mass of 170.7 mg, approximately 8 mg less than the charged filters.

3.9 Effects of Charge on the Balance

When stable but differing readings are obtained on the balance for the same filter, it is important to know whether this is due to effects of charge on the balance. Earlier results showed that repeatability was around 5 µg. Before any filters were weighed during these tests, the zero reading was recorded and this never changed by more than 5 µg between weighings. Therefore, differences in mass between charged and uncharged filters that are much larger than 10 µg are not due to zero drift in the balance. The other possibility is that the calibration of the balance can be altered by the presence of net charge. The differences are not due to loss of filter material, because when a charged filter has its charged removed by an anti-charge device the measured mass is similar to the uncharged mass.

Tests were performed on the balance chamber by directly charging it using the anti-static gun, to see if this changed the zero or check weight readings. When the charges were introduced into the balance chamber the readout of the balance temporarily increased or decreased depending on the charge applied and then returned to the uncharged value. The results follow:

<u>Zero Reading (mg)</u>

0.020	Before charging
0.019	After charging
0.021	Before charging
0.021	After charging

<u>100 mg metal check weight</u>

99.804	Before charging
99.806	After charging
99.806	Before charging
99.810	After charging

When the charge has dissipated, the balance returns to the previous reading, therefore the presence of charge within the balance chamber affects the balance reading temporarily but does not significantly change the zero or span calibration of the balance beyond that.

3.10 Summary Of Balance Stabilisation Times

The following tables summarise the time taken (in seconds) for the balance to indicate a stable reading for different filter media.

Charged filters direct on balance pan

Filter media	Emfab 47mm	Quartz 47 mm	Glass Fibre 47mm	PTFE 47mm Zefluor	PTFE 47mm Ring supported
Time (seconds)	40	230 – 470	40 – 50	Never Stable	Never Stable

Emfab and glass fibre filters did not retain enough charge to affect the balance readings and stabilisation times.

Methods for eliminating static charge

	Filter Material		
Method	**Quartz**	**PTFE Zefluor**	**PTFE Ring-supported**
30% RH			
Foil disk on balance pan	60 - 80	80 – 90	Not tested
50 mm filter set	60 - 80	90 - 120	Not tested
Static elimination bar & directly on balance pan	30	80	70 – 90
ZEROSTAT Anti-static Gun & directly on balance pan	30 - 40	40 – 60	Not tested
Polonium-210 source & directly on balance pan	30	50	30 – 40
110 mm filter set Uncharged	50 for 47 mm filter 70 – 80 for 90 mm filter	40 – 50	Not tested
110 mm filter set Charged	30 – 60 for 47 mm filter 70 – 80 for 90 mm filter	110 -220	Not tested
75% RH			
Directly on balance pan	70 - 110	180 – Never Stable	110 – Never Stable

3.11 Effective Range Of Charge Neutralisation Devices

The effective range of the static elimination bar, anti-static gun and the polonium-210 source were tested. The tests were performed using the PTFE ring supported filters. The static elimination bar effectively removed charges up to a distance of 90 mm and had reduced effectiveness up to 120 mm. The polonium-210 effectively removed charges up to a distance of 80 mm and had reduced effectiveness up to 100 mm. The effectiveness of the anti-static gun was very hard to determine, with irreproducible results at distances from 30 mm to 300 mm.

Moving a filter through normal (not ionised) air appeared to have no effect on the static charges applied to the filters.

4 Conclusions

Of the filters studied, Emfab and glass fibre filters did not retain appreciable applied charge for more than 40 seconds even without any precautions. Quartz and PTFE filters, on the other hand, retained applied charge for much longer, so that reported weights could be significantly affected if no precautions are taken. In the case of PTFE filters, the balance never reported a stable reading when weighing directly on the balance pan.

The repeatability of weighings was found not to depend on the filter material. Similar repeatabilities were obtained for Emfab and glass fibre filters to those obtained by PTFE and Quartz filters.

The repeatability of weighings obtained using the 110 mm Filter Set were larger than those obtained by weighing directly on the balance pan, which can only accommodate filters up to 50 mm in diameter. The higher repeatability is probably due to the mode of operation of the 110 mm Filter Set, as it requires more mechanical interference to load and unload the filter. This interference has the potential to move the position of the balance on the weighing table and possibly change the performance of the balance.

Investigations using different methods to eliminate static charges revealed that:

- Placing foil on the balance pan removes charge from filters considerably quicker than just placing the filter on the balance pan, and allows PTFE filters to reach a stable value.
- The 50 mm Filter Set is no better at removing charge than the metal foil.
- The static elimination bar neutralises applied charge very efficiently. Filters only have to be placed in the ionised air for a few seconds for charges to be neutralised. The effective range of the static elimination bar is 90 mm.
- The anti-static gun neutralises charge efficiently, but is not so easy to use and is more time consuming than the static elimination bar. Obtaining repeatable results was difficult.
- The 110 mm Filter Set was found to be better at dissipating static charges than the balance pan, but is no better than putting a piece of metal foil on the balance pan or using an active charge neutralisation device.
- The polonium-210 source neutralises applied charge very efficiently. Filters only have to be placed in the ionised air for a few seconds for charges to be neutralised. The effective range of the static elimination bar is 80 mm.

In some cases the stable weight readings after charging differed significantly from the stable readings obtained from the same filter “uncharged”, by up to 120 µg for quartz and 800 µg for PTFE filters. We believe that the correct value is that obtained after careful neutralisation of the static charges by an active method. The results emphasise the difficulty of determining the mass of a filter with an accuracy of better than around 20 µg, even though balances of much higher resolution can be used.

For quartz filters, weighing at 70% relative humidity was found to be significantly better at dissipating static charges than weighing at 30% relative humidity. A stable weight was obtained in about a quarter of the time at the higher humidity, but there was a 40 µg weight difference between the charged and uncharged filters. For PTFE filters there was a slight improvement in stabilisation time.

5 Reference

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