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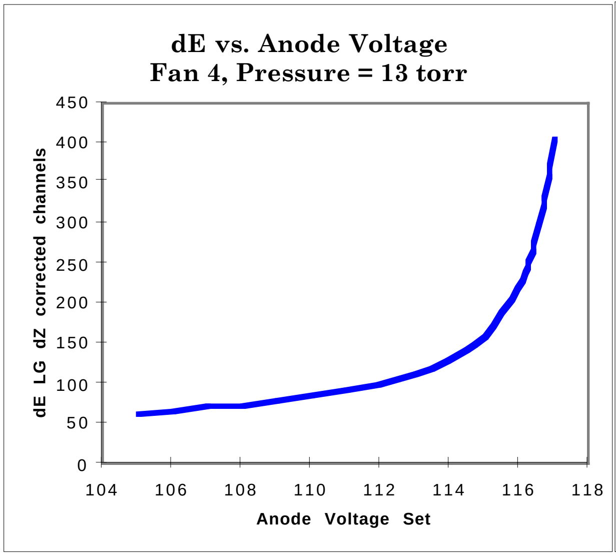
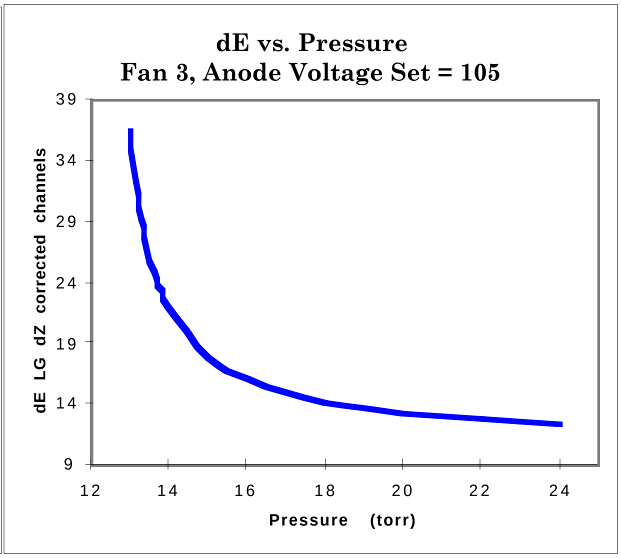
Introduction

The energy lost in the proportional counter (also known as 'dE') varies with instrument conditions. Two of the largest contributing conditions are the pressure of the gas in the proportional counter and the anode voltage. This became significant when regulation of the gas pressure was lost in November '98. Previous data analysis programs and techniques assumed a pressure range of 20-24 torr. The dE variance caused by drastic pressure differences exceeds these bounds. Consequently, new methods are required to compensate and correct for pressure changes.

The first step to understanding the relationship between dE and pressure was to observe the general trends by testing Fan 4. All dE values from Fan 4 are the dE peaks of source alphas, while dE values from Fans 2 and 3 are the dE peaks of calibration alphas. It was seen that as pressure increases, dE decreases according to an altered 1/x function. Physically, this results from a larger density of molecules in the proportional counter which yields a decreased gain in the proportional counter, lowering the output signal.

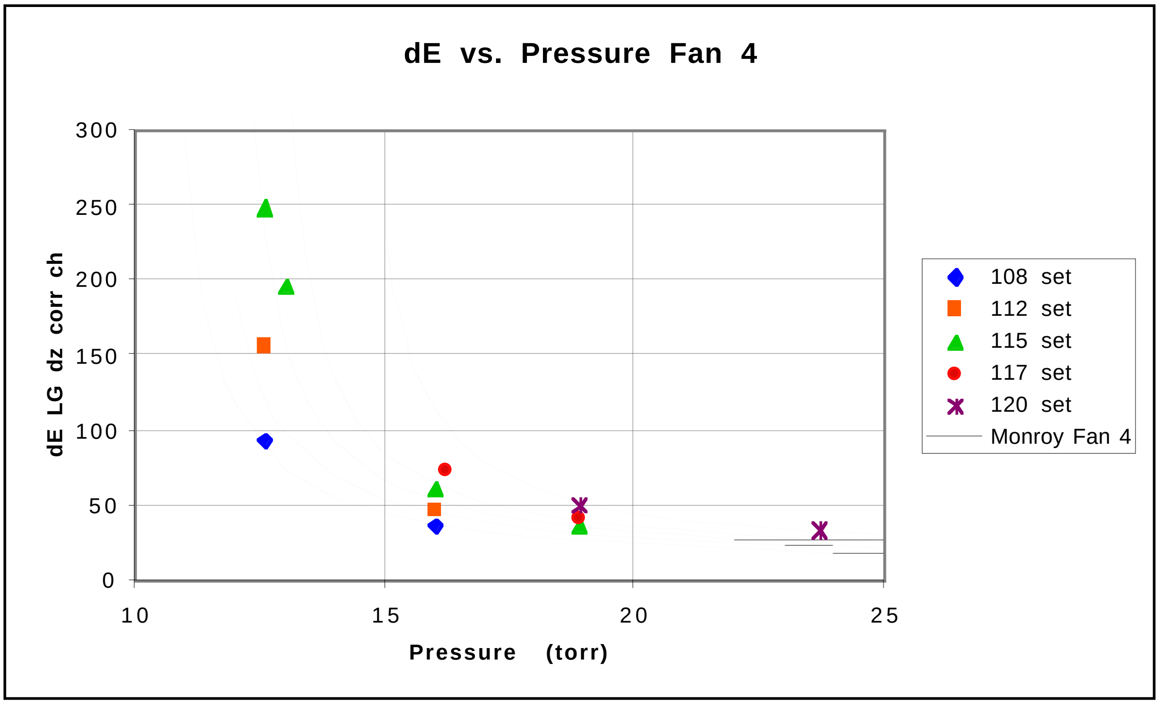




Counteractive to a pressure increase, an anode voltage increase boosts the dE signal. At a constant pressure and rising anode voltage, the dE increases exponentially. This is due to the increased potential field created by the anodes.

One way to view the combined effects of pressure and anode voltage is to observe the dE vs. pressure trail as the anode voltage set is increased. At higher anode voltage sets, the dE vs. pressure trail has the same trend but is translated up and to the right. This translation follows the form of the dE vs. anode voltage trend. It is necessary to have the ability to predict dE values for given pressures and anode voltage sets. Upon closer investigation of experimental trends, an equation of this capacity could be crafted...

Monroy Fan 4
dE=180/(P-B)+D
D=8.6+3.34ln(B-10)
B=1.4*1.16^(2kset-112)+9.6

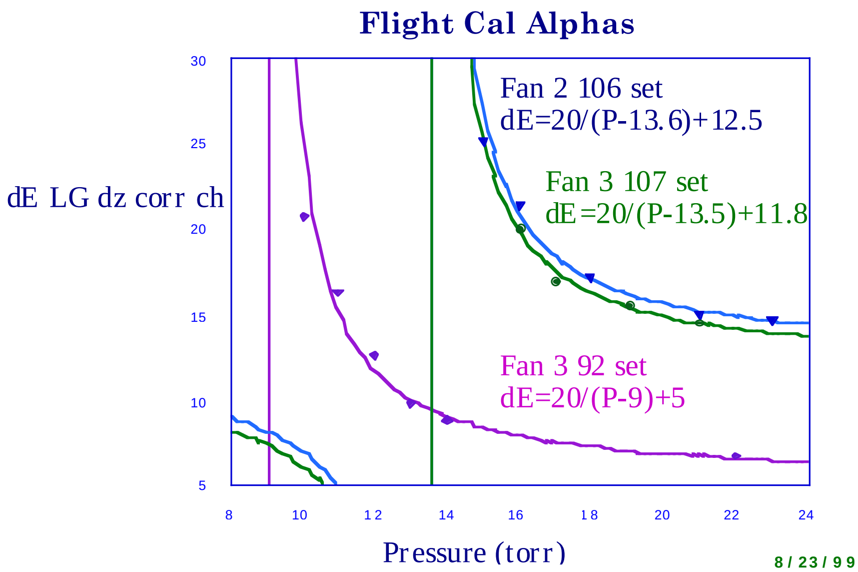


Monroy Fan 4 was created by obtaining dE values for source alphas at various pressures and anode voltages with flowing gas. Files were taken in engineering mode 28h and were run in temp2 without subtracting offsets. Peak dE was obtained by doing a region of interest on the dE low gain(LG) and high gain(HG) plots without smoothing the data first. For LG dE values of less than 50 channels, the file's own HG-LG slope and intercept values were used to convert the HG dE peak to LG. dE vs. pressure trails were plotted for different anode sets. dE (LG dZ corrected channels) as a function of pressure (torr) were found for an anode set at which there were a large number of data points. The function dE=180/(Pressure-B)+D fit all of the different anode set trails by altering B and D to translate the function. The B and D values at which the function best fit the data were recorded for each anode set. Finally, D as a function of B (natural log function) and B as a function of anode set (exponential function) were found.

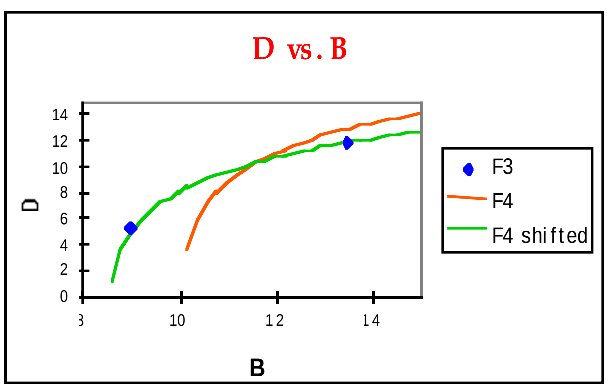
Creation of Monroy Fan 2 and 3

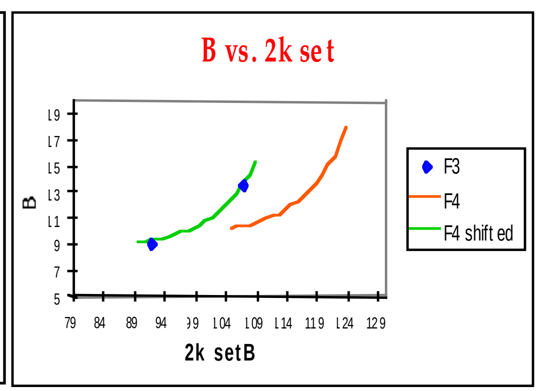
Monroy Fan 2
dE=20/(P-B)+D
D=7+3.34ln(B-8.4)
B=1.4*1.16^(2kset-97.6)+8.7

Monroy Fan 3
dE=20/(P-B)+D
D=6.3+3.34ln(B-8.4)
B=1.4*1.16^(2kset-98.6)+8.6



Monroy Fan 2 and 3 were created by obtaining dE values for calibration alphas and then altering Monroy Fan 4. To get dE peaks, pressure (torr) and set values from housekeeping data of the HDF files were recorded. Bin2D was used to get a listing of events including Rate 0. Calibration alphas were excluded by taking 4-6 E(MeV) and 10-14 mm Y deflection. All dE HG ch were converted into dE LG ch by adding 42, then dividing by 15. All dE LG ch were then dZ corrected by multiplying by COS(ATAN(dZ/22.5)). The dE LG dZ corrected channel peak was found by histogramming. For Fan 3, days 98 318 (107 set, 16-21 torr) and 99 167 (92 set, 10-14 torr) were used. Both trails fit to a dE=20/(Pressure-B)+D function. To make Monroy Fan 3, the same shifting trend of the Fan 4 trails as anode set increases was assumed. The functions D(B) and B(anode set) for Fan 4 were translated to fit the B and D values for the two Fan 3 trails. For Fan 2, day 98 313 (106 set, 15-23 torr) was used. Since this trail was slightly offset from the Fan 3 107 set, Monroy Fan 3 was altered with some minor offsets in B and D to create Monroy Fan 2.





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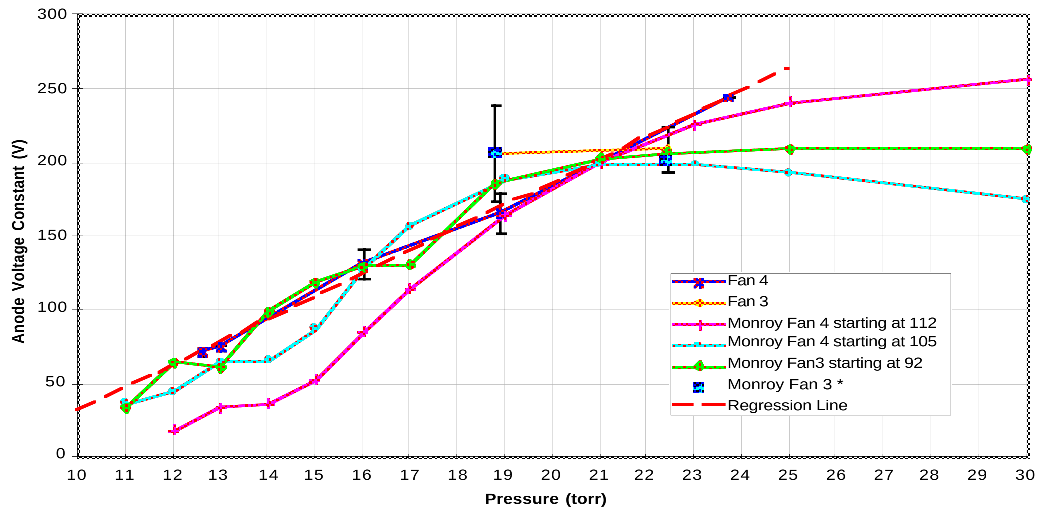
Comparison of Monroy and Previous Methods

It is important to compare Monroy to the methods previously used to deal with pressure and/or anode voltage differences. These previous methods include the 'standard conversion equation' and the 'red-green line polynomial method'. In order to compare these techniques with Monroy, they were improved to account for changing pressures. One factor which required altering was the anode voltage constant.

Anode Voltage Constant vs. Pressure



The anode voltage constant was previously used to convert dE values obtained at one anode set to those obtained at other anode sets. The equation originally used to make this conversion is:

$$dE_{converted}=(dE\ LG)/EXP[(2kset-2kset_{desired})*9.8/AC]$$

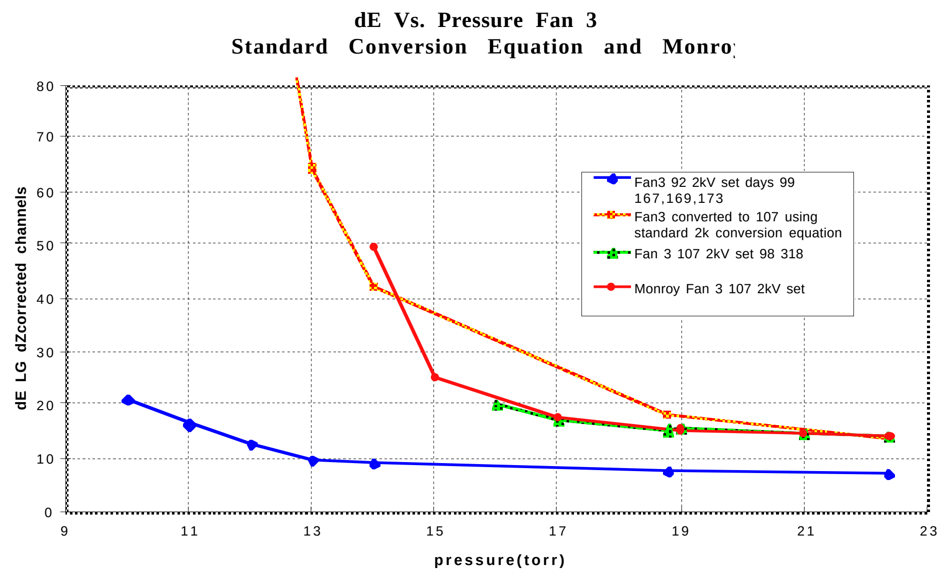
Where AC in this equation stands for the anode voltage constant. This value was originally a constant of 130. To check the validity of this value, tests were conducted on Fan 4 at constant pressures. At each of these pressures the anode voltage was incremented. For each pressure, data could only be obtained once a threshold voltage had been achieved. Since this threshold depends on the pressure, the anode voltage range for each test was limited. The anode voltage constant is calculated by graphing the delta voltage against the natural log of the dE ratio. The delta voltage is the difference between the voltage of the data point and the minimum anode voltage in the constant pressure test. This minimum anode voltage is also referred to as the starting point. All voltages were obtained by using the set-to-voltage conversion for each fan (this conversion is explained in the Anode Voltage Comparison section) . The dE ratio is the dE of the data point divided by the dE at the minimum voltage. All dE values were attained by the same method as described in the Creation of Monroy sections. The slope of ΔV vs. ln((min dE)/dE) is the anode voltage constant for that pressure. By calculating the anode voltage constant at various pressures, trails such as those shown above were attained.

This graph shows that the anode constant varies with pressure. This inherently contradicts the use of the 130 anode voltage constant. Monroy Fan 4 was useful in confirming the difficulties of accurately calculating the anode voltage constant. One major factor that significantly affects anode voltage constant calculations is the starting point. As the graph shows, Monroy Fan 4 starting at an anode voltage set of 112 is obviously different from Monroy Fan 4 starting at an anode voltage set of 105; Fan 3 displays a similar trend. Monroy has the ability to predict the same anode voltage constant values as the experimental data when given the specific voltage increments (Monroy Fan 3 * represents this method). This shows the high sensitivity of the anode voltage constant to the specific conditions of each experiment. Consequently, it would not be feasible to create a generalized equation for the anode voltage constant. The best approximation is a linear fit through the majority of the data points:

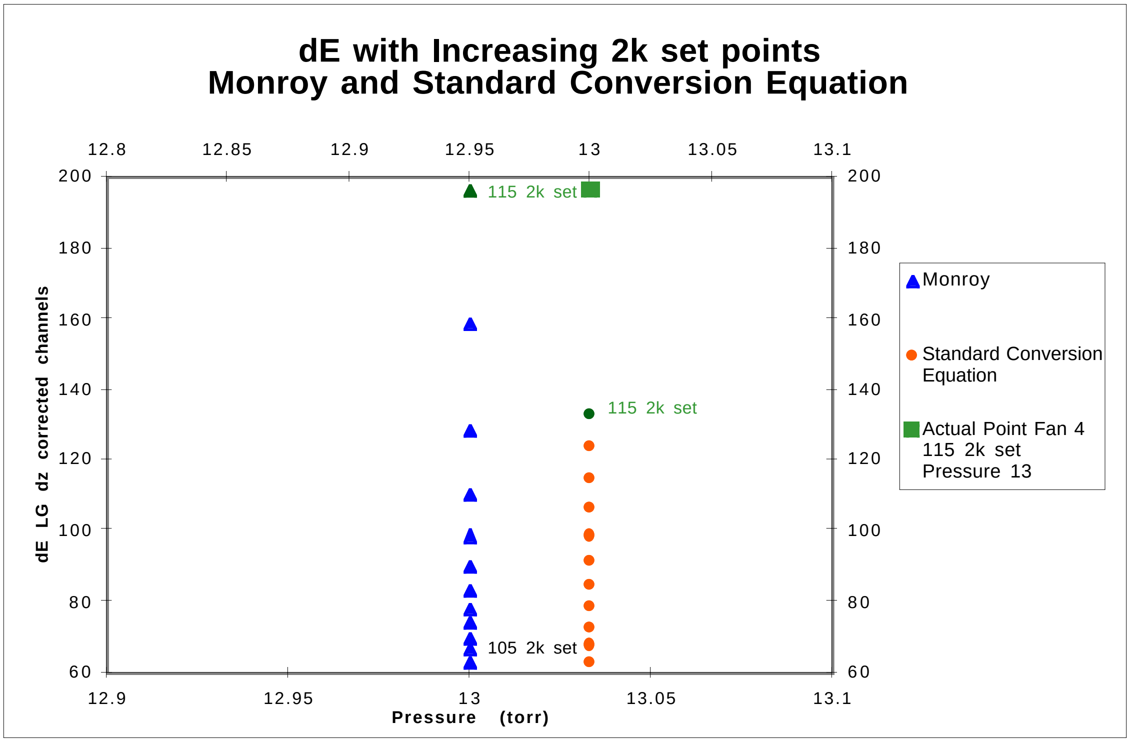
Anode Voltage Constant =15.533*Pressure-123.9

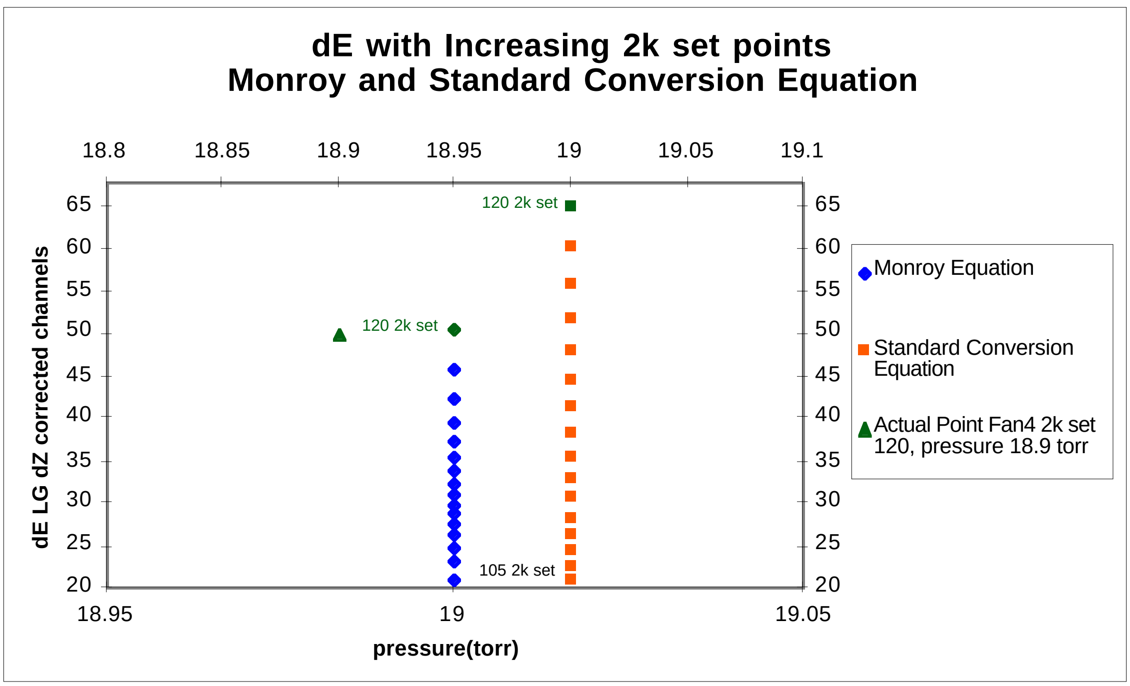
Although this linear fit is the best approximation, it does not accurately represent the properties of the anode voltage constant.

The alteration made to the standard conversion equation was this pressure dependent anode voltage constant. This improved method should now compensate for pressure and anode voltage.



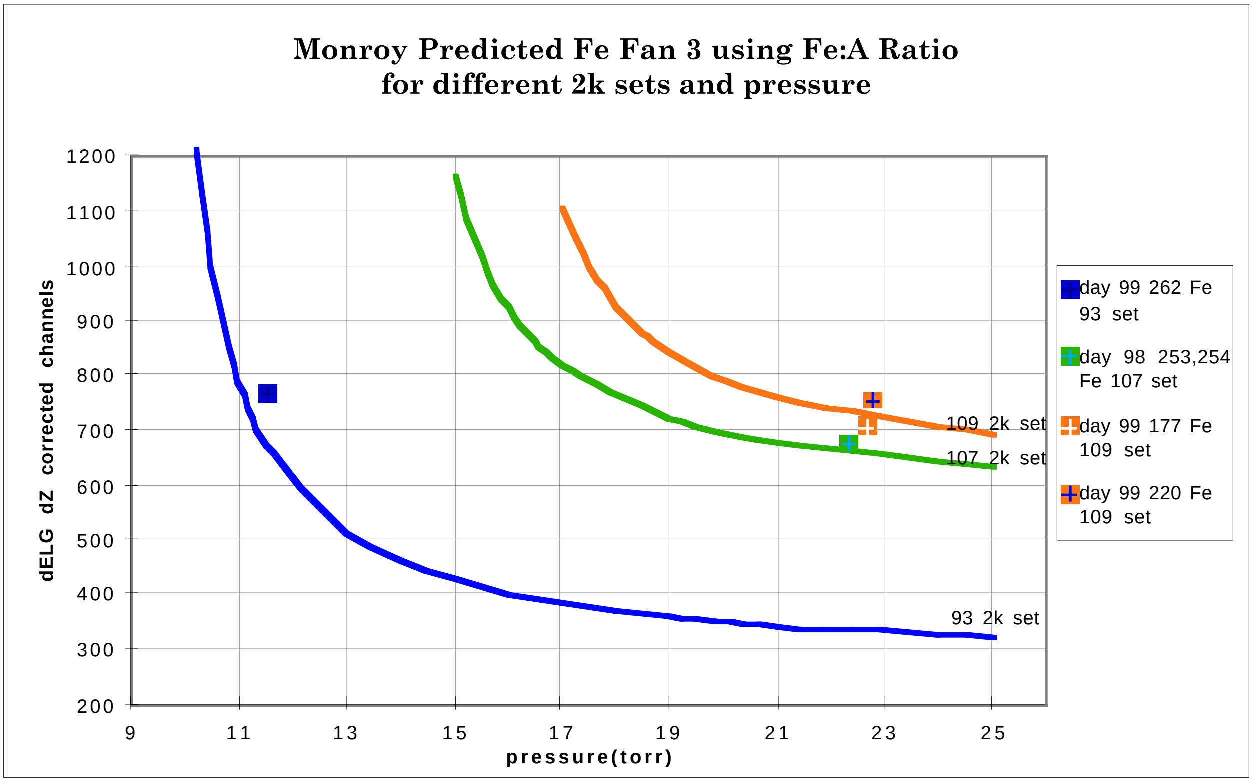
The dE data for days 167, 169, 173 in 1999 and day 318 in 1998 was obtained using the same method as mentioned in the creation of Monroy sections. Monroy for Fan 3 was used at 107 set and at the particular pressure. This graph shows Monroy's ability to predict actual points better than the improved standard conversion equation.





In these graphs, the standard conversion equation was used in contrast to Monroy Fan 4. In this case each equation was at the same pressure and the anode voltage was increased to observe the effect on dE. Both the standard conversion equation and Monroy are at the same pressure, and anode voltage range, but on different axes. Points on the vertical trails represent dE values as the anode voltage is incremented. The green points stand for the same anode voltage set. The single point is an actual experimental point. Clearly, Monroy is much closer to the experimental point than the improved standard conversion equation.

Applying Monroy to All Species



It has been shown that Monroy predicts alpha peaks to a reasonable degree of certainty. Before applying Monroy to all data, it must be determined that other ions follow the same trends as the alphas. If iron, the heaviest ion, and alphas, the lightest ion, exhibit similar behaviors, it is fair to assume that all ions between act accordingly. To test this behavior, a ratio between Monroy alphas and a certain point on the Fe trail was found. At the dE max of the Fe trail there is little dE variance. In order to minimize error, the reference point was selected in this region. Day 98 111 was used as a standard for Fan 2 to create the ratio between the maximum of the Fe trail and the calibration alpha peak. The final ratio for Fan 3 was found by averaging several ratios from different days. The Fan 4 ratio resulted from scaling the Monroy alpha trail to the Berkeley Fe trail.

Fe:Alpha Ratios:

Fan 4	Fan 3	Fan 2
23.5	47.1	40.3

The graph above displays scaled Monroy alpha trails using the appropriate Fe:Alpha ratio. These trails were verified with actual Fe data points. Since Monroy Fe agrees with the actual Fe points, the application of Monroy to all species is substantiated.

Applications of Monroy

Monroy provides a useful tool for any situation where pressure or anode voltage are a concern. The Monroy equations on their own can predict dE for a given pressure and anode voltage. The dE output from the equation is in LG, dZ corrected channels. The input pressure must be in torr and the anode voltage input is the set point.

A common use of Monroy is to compare data from times of different pressure and/or anode voltage and/or fan. This is done by choosing one time as standard and multiplying the dE data from the other time by the ratio :

Monroy at standard time's pressure, set, fan

Monroy at other time's pressure, set, fan

This will scale the data to how it would appear under the instrument conditions of the standard time. Hence, all the data may be compared as though it was taken under the same conditions.

Boundaries of Monroy

Mathematically, Monroy is defined within certain boundaries. These boundaries mimic instrument behavior rather than simply being an iniquity of the equations themselves. One boundary occurs at the vertical asymptote where the 1/x function is undefined. This translates to a minimum pressure limit for each anode voltage set. The pressure must be greater than B, specific to each fan.

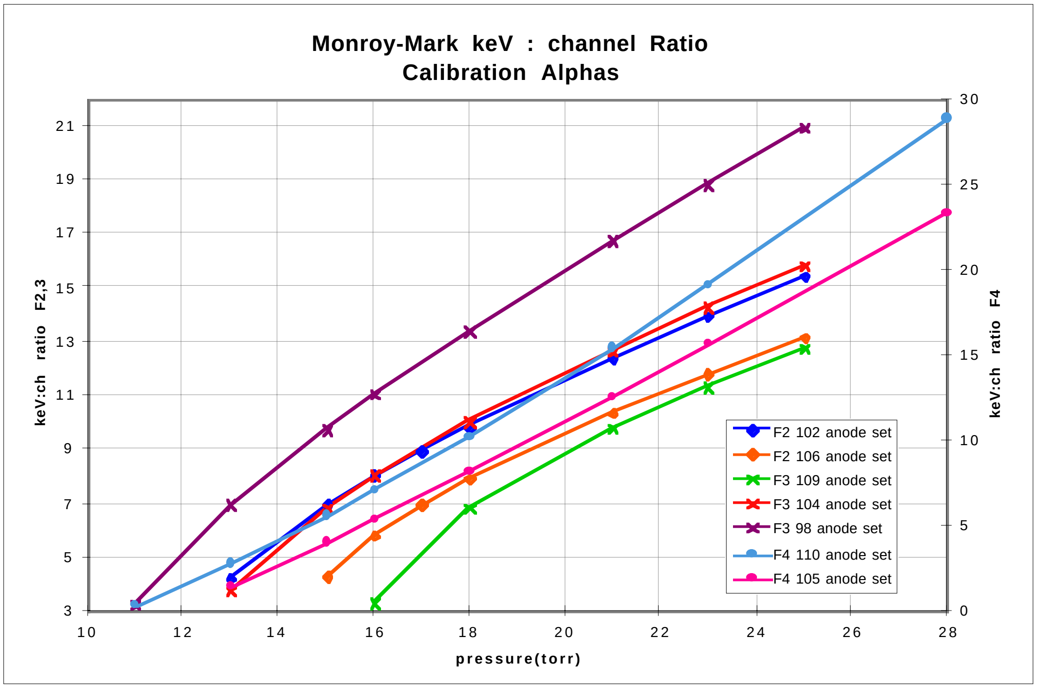
P > 1.4*1.16^(set-112,98.6,97.6) + 9.6,8.6,8.7 Fan4,Fan3,Fan2

If this pressure limit is exceeded, the output dE can be negative, undefined, or out of sync with the general trend. Such data is misleading, false, and should not be used.

With pressures that approach this asymptote, the dE is rapidly increasing. The resulting effect is that a small uncertainty in pressure produces an enormous uncertainty in dE. When analyzing data in this region, caution should be used with small changes in pressure and all uses of this data. Whenever possible, fans should not be operated in steeply sloped dE ranges.

A boundary specific to Fan 4 occurs as a result of its natural log function in the D factor. dE is undefined when B<= 10. This results in an inability to predict Fan 4 data at anode voltage sets lower than 104.

keV:channel Ratios

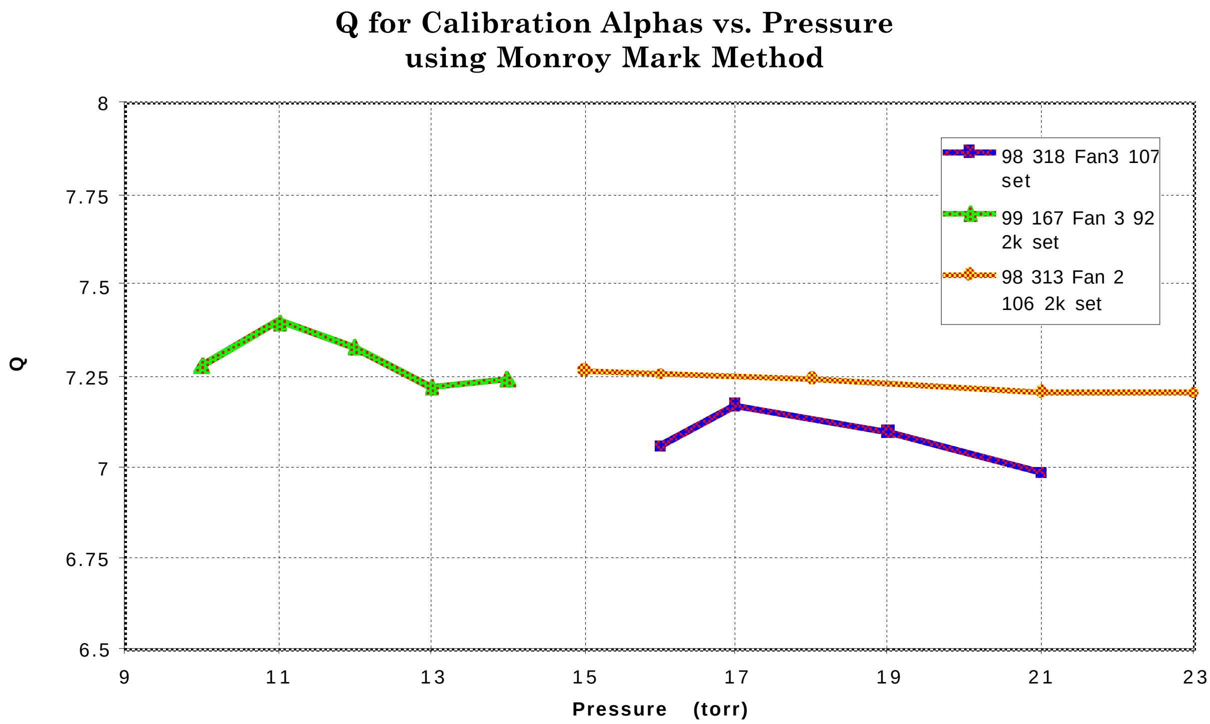


Experimental results show a decrease in the energy lost in the gas as pressure increases. This is contrary, however, to what is actually happening. This decrease is the result of the change in gain and a keV:channel ratio is needed to account for the effect of the gain as pressure increases. These keV:channel ratios were found using the Monroy-Mark Method. This method yields different values for the flight fans than Fan 4, due to the many hardware differences between the fans. The equations for the keV:channel ratio, via the Monroy-Mark Method are as follows:

Fan 4
keV:ch (Monroy F4 19.1 torr 105 set)/(Monroy F4 at set,pressure)*(7300/440)*(Pressure/19.1)
Fan 2,3
keV:ch=(Monroy F3 22.2 torr 107 set)/(Monroy at fan,set,presssure)*(16229/1024)*(Pressure/22.2)

This method was based on the previously used Red-Green line polynomial method. The Monroy-Mark method, unlike the Red-Green line method, can accurately account for differences between fans and anode voltage sets, since each Monroy is made specifically for each fan and its conditions. The constant used is based on experimental data, which can be found in the SEPICA Parameters document. This number is also specific to the fan and relates to the numerator Monroy used in the ratio. The conditions for this standard Monroy value are based on the conditions at which this number was established. Minor adjustments may be necessary, however, for application to all species.

Q Calculations



Q CALCS: underlined areas are affected by pressure and require pressure corrections

dE LG (keV) = dE LG ch * keV:ch Ratio

Window Eloss = 2Windows:Gas Ratio * dE LG (keV)

SSD Dead Layer = .1 * dE LG (keV)

Etot (MeV) = (SSD Dead Layer + Window Eloss + dE LG (keV) + E (keV)) / 1000

Y Deflection mm = (Ypeak mm - 4.5) * (COS(ATAN(dZ/22.5)))^2

Q = (Y Deflection mm * Etot MeV) / (3.36E-4 (mm MeV/(Q V)) * High Voltage V)

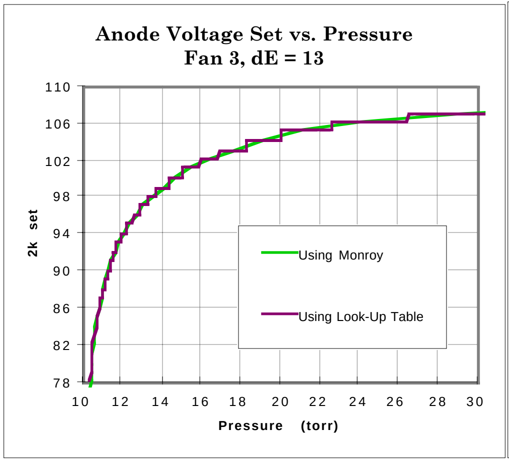
Pressure changes affect Q calculations in two places. The pressure dependence of the keV:ch Ratio has previously been explained. There is also a pressure dependence in the calculation of the energy lost in the windows. The ratio of the energy lost in the two windows to the energy lost in the gas was found using the TRIM program. TRIM predicts energy lost by certain ions after having traveled through various mediums. 10 MeV Fe, 40 MeV Fe, 4.46 MeV He, and 5.38 MeV He were sent through a .5µ polymide window, various thicknesses and pressures of isobutane gas, and a second window. The 2windows:gas ratio was found for each of these conditions and a general fit was formed from all of them.

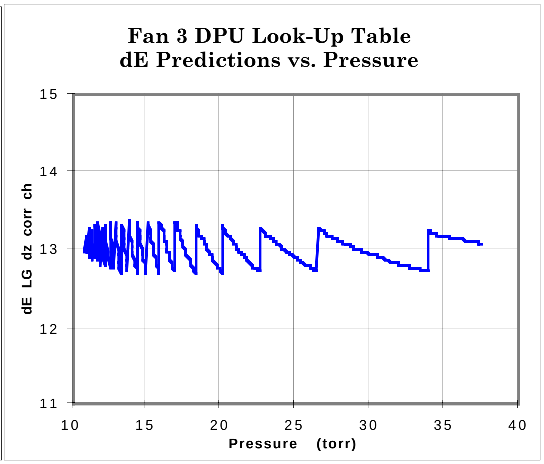
2Windows:Gas Ratio = 15.493*Pressure^(-1.00889)

Without these pressure corrections, the Q values for the same ion vary with pressure, following the same trend seen in dE. The above graph displays days of changing pressure after the pressure corrections have been applied to Q calculations.

DPU Look-Up Tables

It has been demonstrated that pressure and anode voltage have opposing effects on dE. Consequently, when one factor changes, a constant dE may be maintained by deliberately changing the other factor. Intentional shifts in anode voltage can compensate for a roaming pressure such that the dE remains unchanged. Monroy was used for each fan to graph anode voltage set against pressure such that the dE remains constant.





The DPU will read the pressure in the proportional counter and set the anode voltage accordingly. A look-up table for this process was chosen over an equation due to high-accuracy requirements in the low pressure regions and simplicity requirements for the DPU. Look-up tables were created for Fans 2, 3, and 4, each with a different constant dE value. Box boundaries are used in the DPU and analysis programs to categorize data into ion species. The boxes were the determining factor in the choice of constant dE value for Fans 2 and 3. These boxes were crafted around the 98 111 Fan 2 ion trails, when calibration alphas appeared at a dE of 14.4 LG channels. Thus, if the Fan 2 calibration alpha dE peak is maintained at 14.4, all the trails will fit into their respective boxes. Since Fan 3 has a larger Fe:Alpha ratio than Fan 2, the Fan 3 alphas must be a bit lower (13 LG channels) for the heavy ion trails to fit into these boxes. The 50 LG channel dE value was chosen for the Fan 4 source alphas because this is the most common dE which may be obtained throughout a large range of pressures and anode voltages.

DPU Table Look-up F3 dE=13

Pressure Min or Equal to	Pressure Max	2kV set
10.45	10.48	78
10.48	10.51	79
10.51	10.55	80
10.55	10.6	81
10.6	10.65	82
10.65	10.71	83
10.71	10.78	84
10.78	10.85	85
10.85	10.94	86
10.94	11.04	87
11.04	11.15	88
11.15	11.29	89
11.29	11.44	90
11.44	11.6	91
11.6	11.8	92
11.8	12.04	93
12.04	12.3	94
12.3	12.6	95
12.6	12.95	96
12.95	13.37	97
13.37	13.85	98
13.85	14.45	99
14.45	15.15	100
15.15	16	101
16	17	102
17	18.4	103
18.4	20.2	104
20.2	22.7	105
22.7	26.6	106
26.6	34	107
34	40+	108

DPU Table Look-up F2 dE=14.4

Pressure Min or Equal to	Pressure Max	2kV set
10.65	10.7	79
10.7	10.73	80
10.73	10.78	81
10.78	10.83	82
10.83	10.9	83
10.9	11	84
11	11.05	85
11.05	11.15	86
11.15	11.25	87
11.25	11.35	88
11.35	11.47	89
11.47	11.65	90
11.65	11.8	91
11.8	12.05	92
12.05	12.25	93
12.25	12.5	94
12.5	12.8	95
12.8	13.2	96
13.2	13.6	97
13.6	14.1	98
14.1	14.7	99
14.7	15.4	100
15.4	16.25	101
16.25	17.35	102
17.35	18.6	103
18.6	20.3	104
20.3	22.65	105
22.65	25.95	106
25.95	31.85	107
31.85	40+	108

DPU Table Look-up F4 dE=50

Pressure Min or Equal to	Pressure Max	2kV set
13	13.4	105
13.4	14.1	106
14.1	14.8	107
14.8	15.3	108
15.3	15.5	109
15.5	15.6	110
15.6	15.8	111
15.8	15.9	112
15.9	16.3	113
16.3	17	114
17	17.5	115
17.5	17.9	116
17.9	18.2	117
18.2	18.5	118
18.5	18.7	119
18.7	19	120

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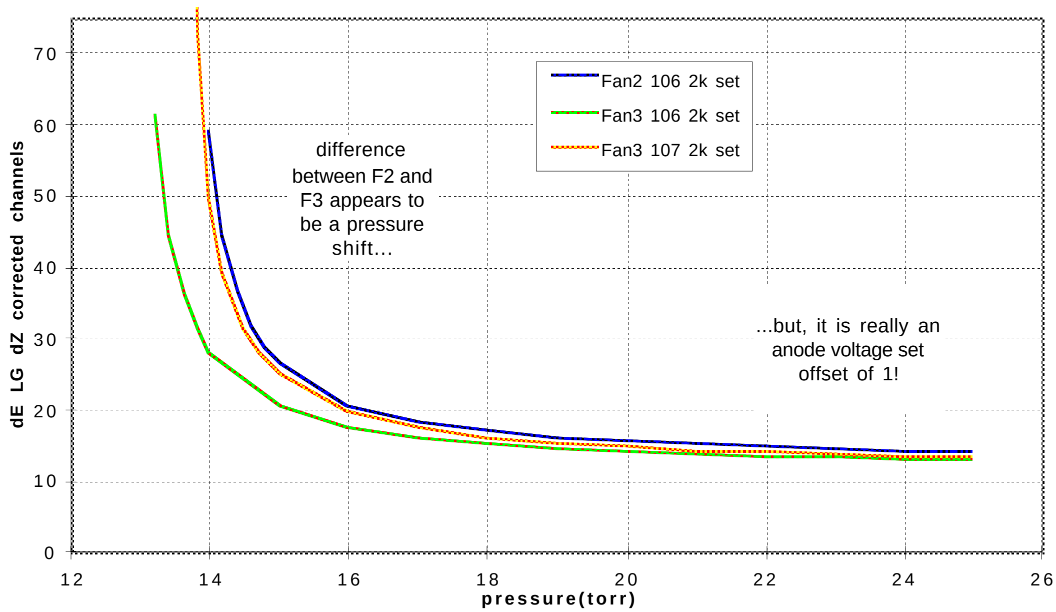
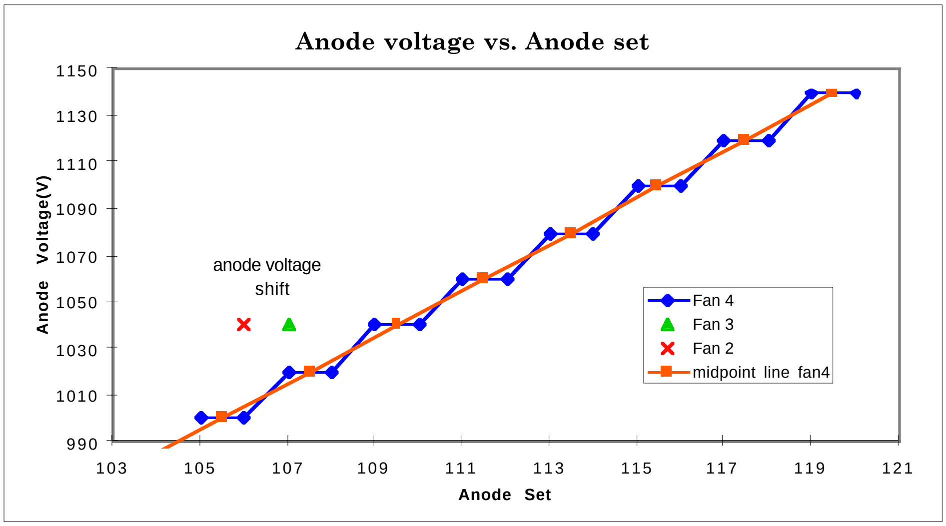
Anode Voltage Comparison for All Fans

Monroy was used to compare the behaviors of the flight and ground fans. These comparisons revealed differences in the anode voltage hardware and in the general dE vs. Pressure trends.

dE vs. Pressure Monroy Comparison Fan 2, 3



Under the same pressure and anode voltage conditions there is a descrepancy between dE values for Fan 2 and Fan 3. Originally, this discrepancy was thought to be due to an offset in the pressure. By shifting Fan 2 to the left in pressure, both fans could be made to have similar dE values. Using Monroy to check this incongruity, it was found that an anode voltage offset of 1 is another possibility. An investigation of housekeeping files confirmed this hypothesis. The offset is explained by a hardware difference between the anode set and the actual voltage for each fan:



Consequently, each fan has a different conversion equation from set point to voltage for the anode:

F2- volts=10(set)-25 F3- volts=10(set)-35 F4- volts=10(set)-55

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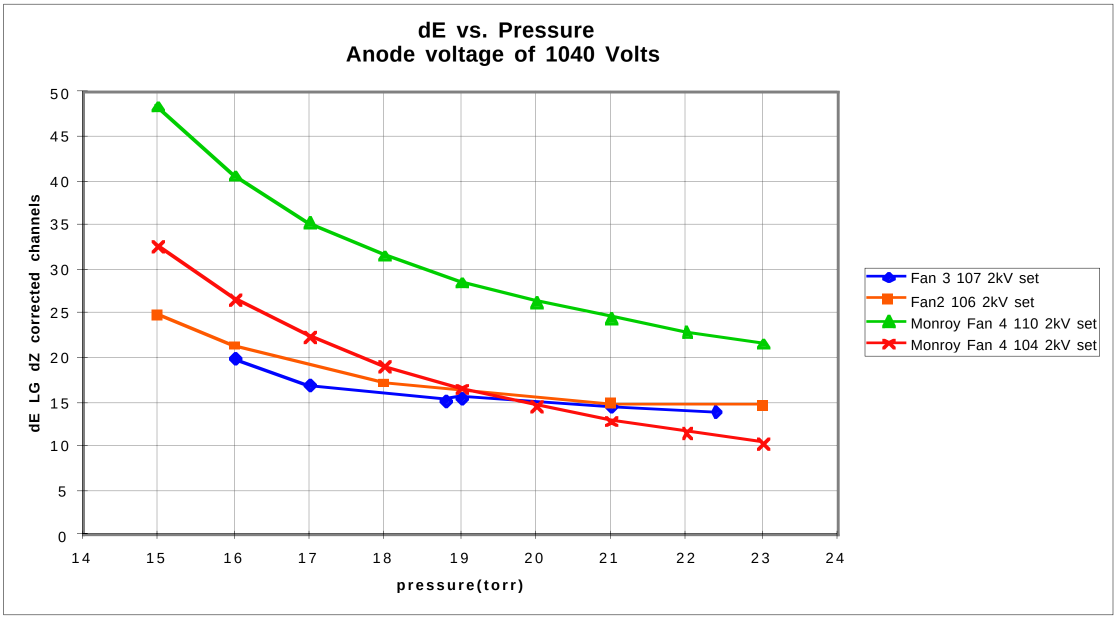
Trend Contrast Between Ground and Flight Fans



This graph illustrates two of the major differences between the flight fans and Fan 4. When the flight fans are operated at the same voltage, but not necessarily the same anode set value, they behave quite similarly. Fan 4, on the other hand, does not follow the same trend. When Fan 4 is set to the same anode voltage as Fans 2 and 3, its dE values are much higher. This corresponds to a difference in operating ranges between the fans. Fan 4 is typically operated within an anode set range of 102-120, while the flight fans are operated within an anode set range of 92-110. Additionally, the dE vs. pressure trend for Fan 4 differs from that of the flight fans. The graph displays Fan 4 dE values at an anode voltage set of 104. Although the dE values for all fans agree at 19.5 torr, away from this pressure the trends diverge. This explains the contrasting Monroy numerator values of 180 for Fan 4 and 20 for Fans 2 and 3. These subtle differences are enough to require particular treatment for each fan.

Notes and References

For additional information or data regarding any of the graphs seen in this document, contact Mark Popecki (mark.popecki@unh.edu).