Comparison of alpha-in-air monitors in a challenging environment

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Introduction

- Based on MSc dissertation entitled –

"An Analysis of the Available Methodologies for Radon Compensation"

Submitted to University of Surrey in part fulfilment of a MSc in Radiation and Environmental Protection

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Purpose of dissertation

- To understand the monitoring problems within B462.2
  - B462 is the Harwell solid waste storage facility
  - Waste currently stored in a number of 5m tubes
- To investigate three differing methods of radon compensation
- To investigate potential improvements to the monitoring systems within B462
- If possible identify improvement to existing monitoring rather than replace.

Conclusion

- No clear “winner” for the B462 environment
- All the instruments operate fine in other areas on site
- Just because the radon levels are high, does not automatically equate to a major problem for any of the instruments
- More testing required!!

Background

- Issue since pre 1999 whilst using AB96.
- CMS2000 was purchased to improve the situation and to increase monitoring.
- Slight improvement, but not as good as expected.
- Pete Burgess investigated the cause of the problem in 2003.
- Started to gather more detailed information.
- Realised something unusual occurring.

The “Burgess” report

- **Key points**

1. Building contains large quantity of radium
2. Some buildings on site have high natural radon levels
3. Low ventilation rate (~1 air change / hour)
4. Examination of AB96 archives
5. Alphaguard measurements made:

   Up to 250 Bq m–3, measured over a few days and not in particularly still conditions.

   Peak concentrations will be well in excess of this value.

The “Burgess” report

Conclusions

1. The radon is probably natural.
2. The AB96s are probably as good as they can be.
3. The CMS2000AB is not dramatically better than the AB96, as far as false alarms are concerned.
4. Increasing the alarm level to 5 DACh will give an improvement in the false alarm rate by a factor of about 5
5. Changing the monitors to iCAMs will help, giving a factor of 5 improvement at an alarm setting of 3 DACh
6. If we increase the alarm setting pay special attention to monitor positioning to compensate for the apparent loss of protection.

   Monitors should be positioned as close as possible to the potential release site and in the air flow from that site.

Alarm levels

- Originally set to 3.5 DACh
- Equates to:
  - 0.91 Bq.h/m^3
  - Alarm count-rate of approx 0.53 cps
  - Genuine activity on filter approx 2 Bq
- Uncompensated activity count-rates of up to around 6.5 cps
- Alarm levels increased to 8 DACh – False alarms still occuring

Defining the problem

- Radon results

	Date In	Date Out	Concentration Bq/m3
Area 1 462.2 east wall	07/06/2004	20/09/2004	80
Area 2 462.2 south end	07/06/2004	20/09/2004	60
Area 1 462.2 east wall	20/09/2004	10/01/2005	60
Area 2 462.2 south end	20/09/2004	10/01/2005	80
Area 1 462.2 east wall	10/01/2005	14/04/2005	50
Area 2 462.2 south end	10/01/2005	14/04/2005	70
Area 1 462.2 east wall	14/04/2005	28/07/2005	90
Area 2 462.2 south end	14/04/2005	28/07/2005	70
Area 1 462.2 east wall	28/07/2005	12/10/2005	120
Area 2 462.2 south end	28/07/2005	12/10/2005	150

- Not suitable for real time monitoring due to long averaging time

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Defining the problem

- Kusnetz Sample results

Month		Result (Bq/m^3)
August 2005	Maximum	179
	Average	88
September 2005	Maximum	217
	Average	130
October 2005	Maximum	259
	Average	132
November 2005	Maximum	143
	Average	72
December 2005	Maximum	147
	Average	69

- Again information gained is not usable for real time compensation. Only a short snap shot.

Defining the problem

- Radon results for May to Aug 2006

Location	Radon Concentration (Bq/m^3)
B462.2 Position 1	130
B462.2 Position 2	140
B462.9	100
B462.26	140

- Note B462.26 also has high level of radon concentration.
- Typically (unless certain operations occur) the instruments in this area operate reliably at 3.5 DACh

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Document reviews

- Radon Atlas
  - http://www.hpa.org.uk/radiation/publications/w_series_reports/2002/nrpb_w26.htm
  - For postal area OX11 average = 23 Bq/m3
  - The surrounding area does not appear to have any homes above the action level
- Radon badge operation
  - Environmental Radon Newsletter
    - http://www.hpa.org.uk/radiation/publications/newsletters/environmental_radon/1996/ern7.pdf
  - Simple overview of the operation of the badges

Variation of radon levels

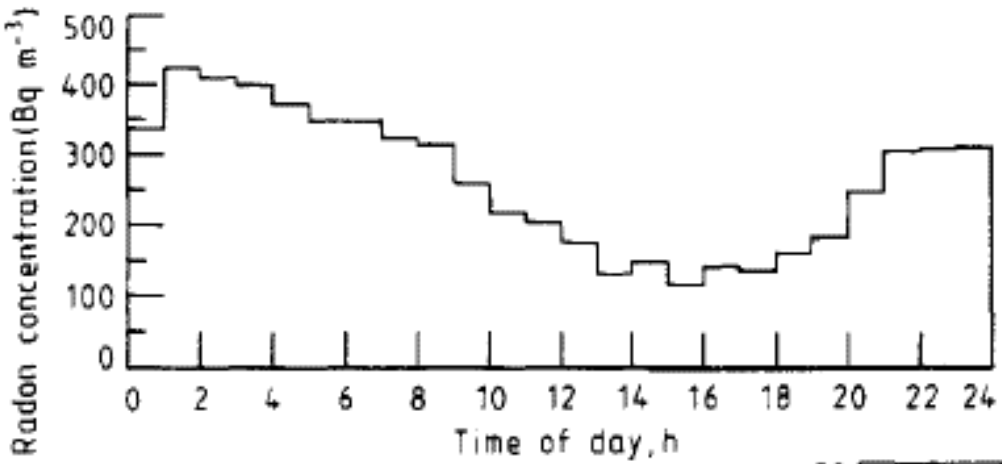
- "Foggy winter day = False particulate alarm"
  - But why??
  - "Variation in Radon-222 concentrations"
    - http://ej.iop.org/links/rXOOuQxCW/cL6h1Hxq2xGGclmkav5vpA/jrv8i2p103.pdf
- Outdoor Variation
  - Source strength
    - Varies with water saturation – even snow and ice
    - Atmospheric pressure

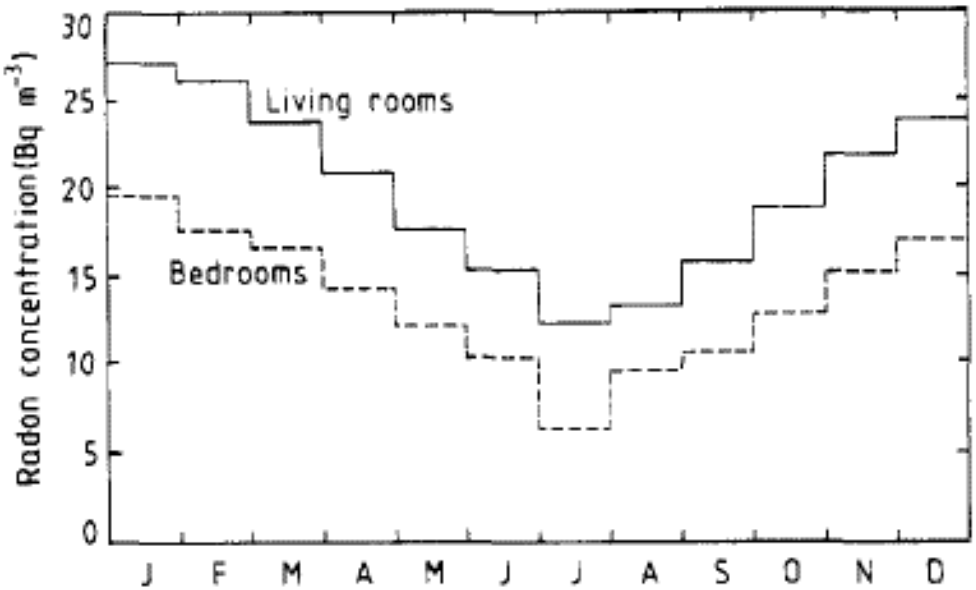
Variation of radon levels

- Mixing
  - Inversion conditions cause little vertical mixing
  - Tend to occur early hours or foggy days.

- Indoor variation
  - Source Strength
    - Lower pressure indoors (especially Nuclear facilities)
    - Wind causes under-pressure
    - Wetness of ground
    - Outdoor levels

Variation of radon levels





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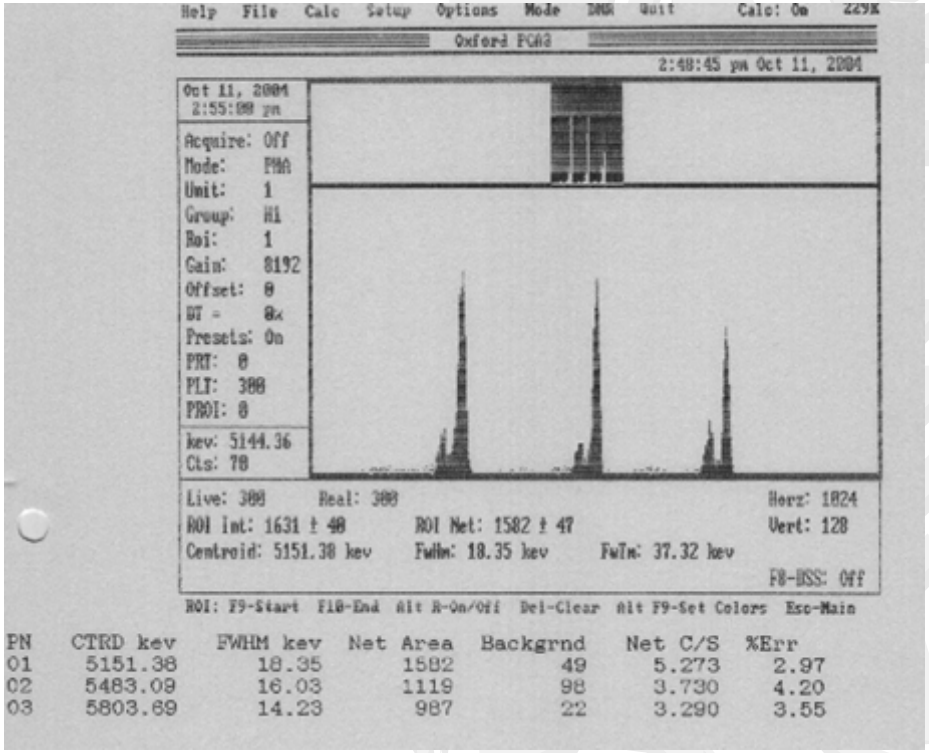
Instruments reviewed

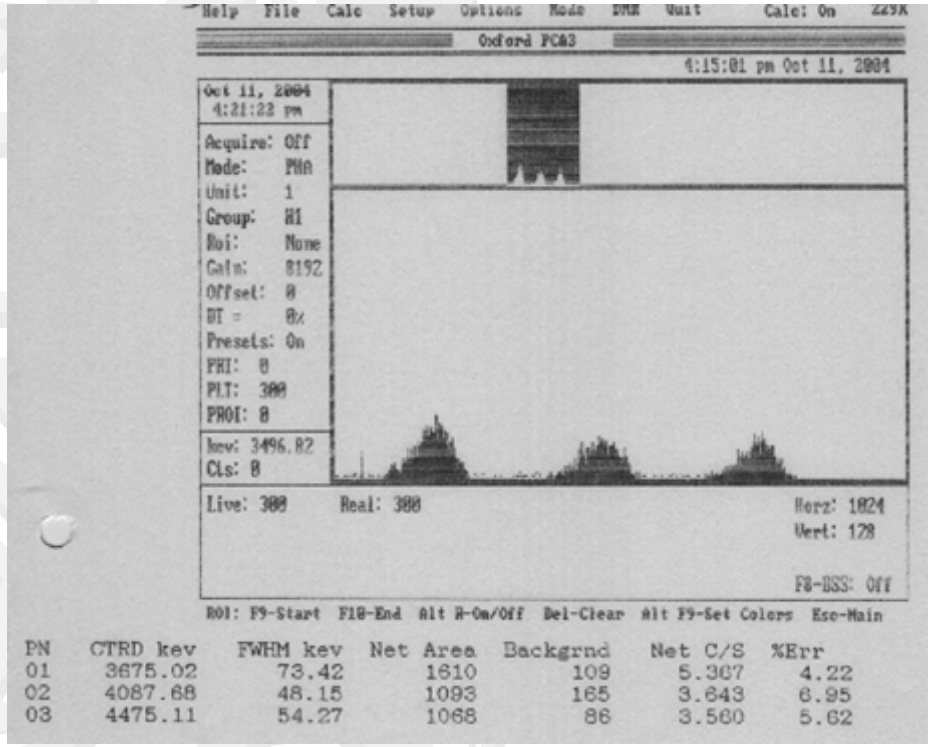
- CMS2000 – Lab Impex Systems
- iCAM – Canberra
- ABPM from MGPi

Alpha spectrum



PN	CTRD kev	FWHM kev	Net Area	Backgrnd	Net C/S	%Err
01	5151.38	18.35	1582	49	5.273	2.97
02	5483.09	16.03	1119	98	3.730	4.20
03	5803.69	14.23	987	22	3.290	3.55

^{239}Pu, ^{241}Am and ^{242}Cm source in a vacuum



PN	CTRD kev	FWHM kev	Net Area	Backgrnd	Net C/S	%Err
01	3675.02	73.42	1610	109	5.367	4.22
02	4087.68	48.15	1093	165	3.643	6.95
03	4475.11	54.27	1068	86	3.560	5.62

^{239}Pu, ^{241}Am and ^{242}Cm source at atmospheric pressure

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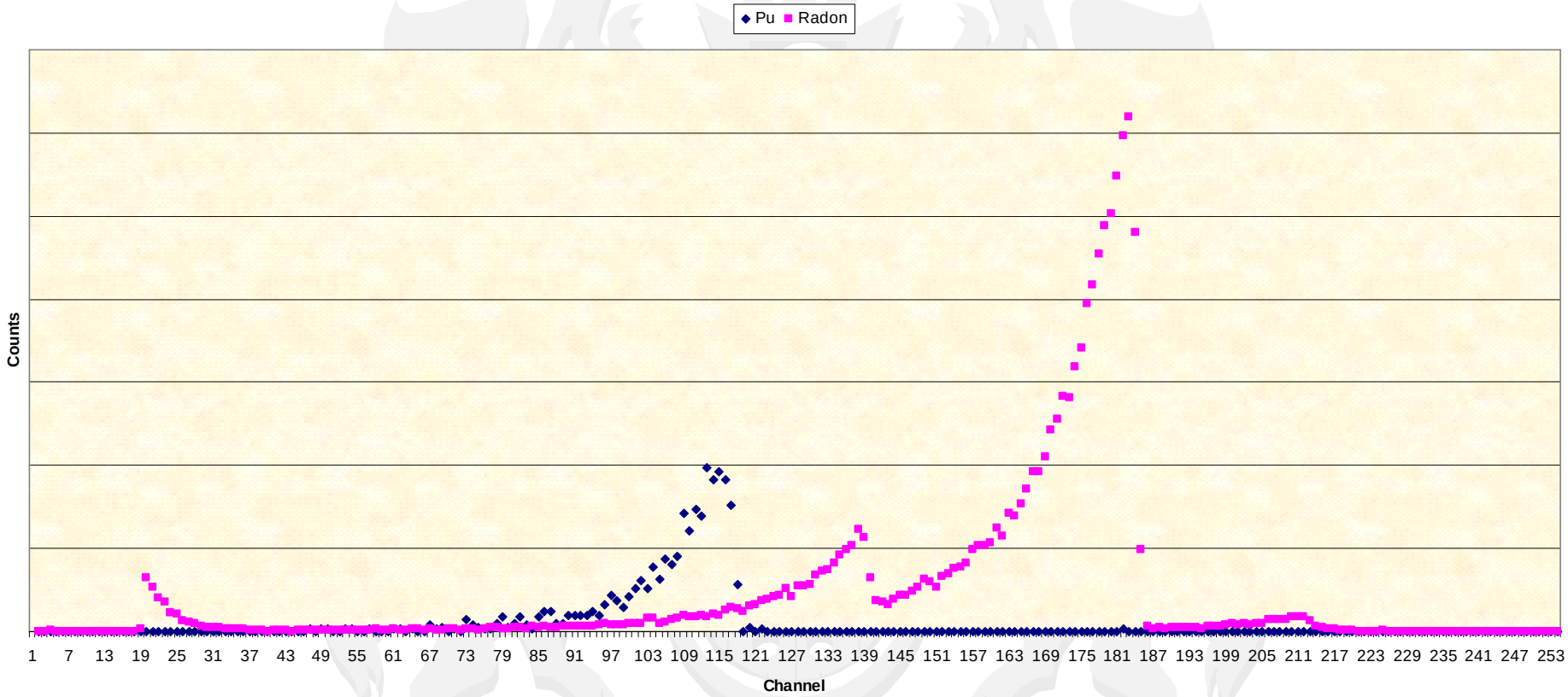
Typical Radon Spectrum



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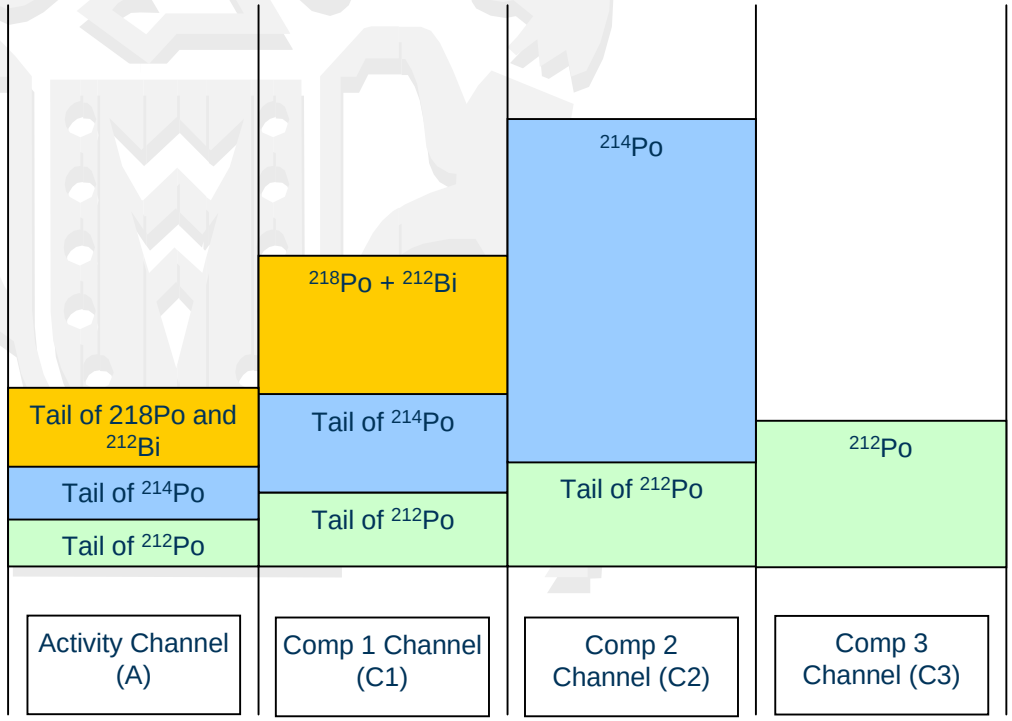
CMS2000

- 4 Channel alpha spectrum analysis
- DAS for compensation adjustment
- Variable averaging time



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iCAM

- Dynamic radon compensation using alpha spec and curve fitting
  - Uses the past hour's spectrum
- Ability to set 3 differing alarms
  - Short term, fast alarm based on cps
  - Medium term, typical alarm based on rolling average
  - Long term, low alarm averaged over LT time
- Radon filter attached after the first 2 weeks

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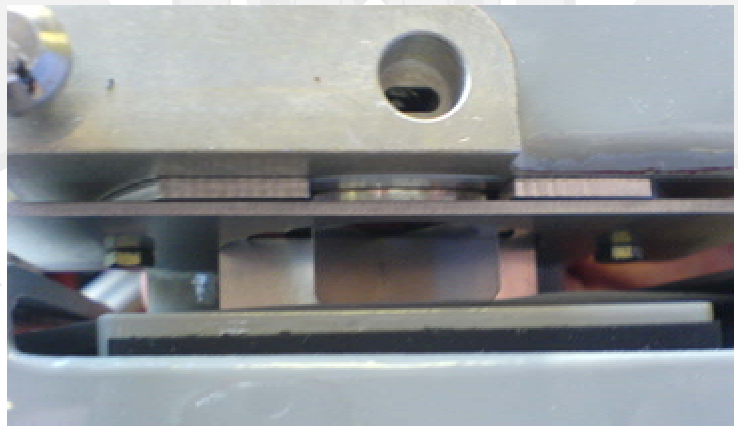
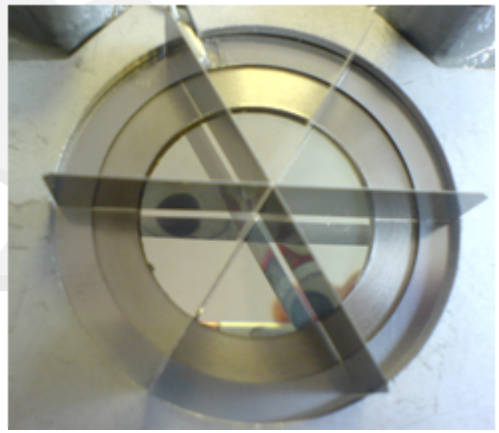
ABPM

- Mechanical radon compensation
  - The attached fins reduce the maximum path length and therefore the energy spread.
  - Reduced instrument efficiency.
- Spectral analysis
- Millipore paper not GFA





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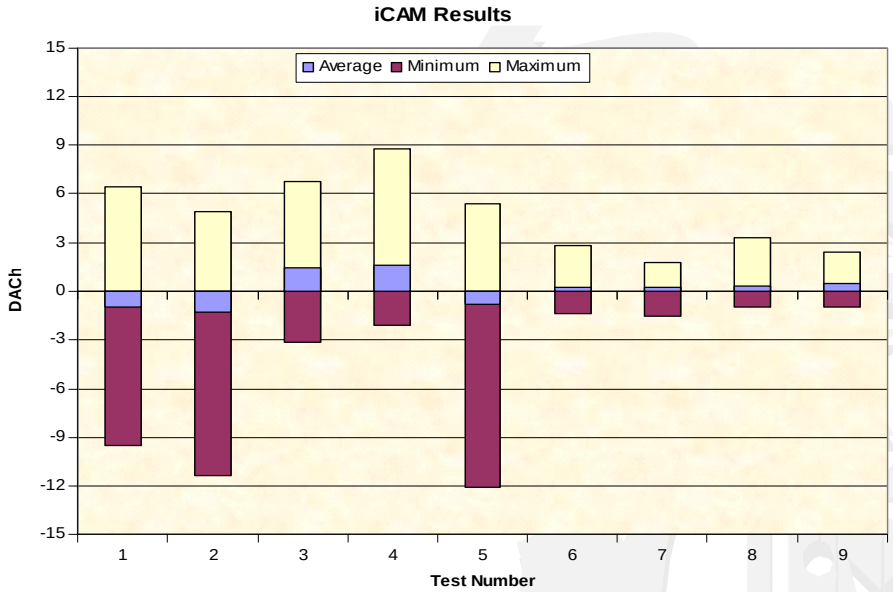
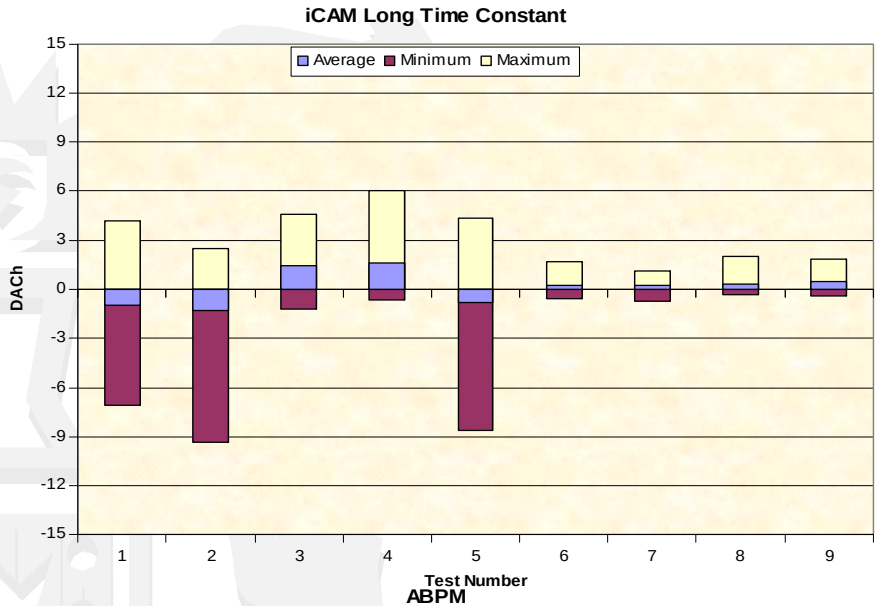
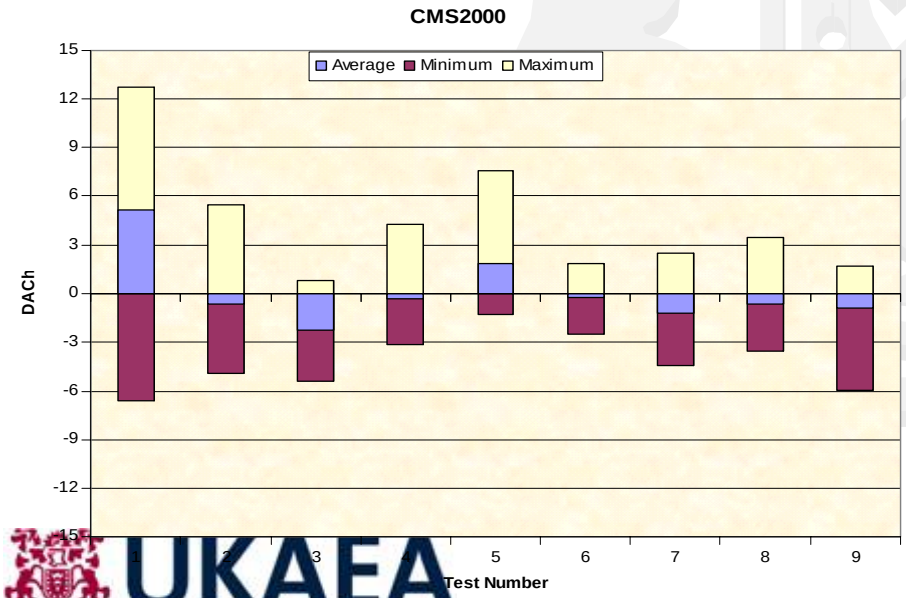
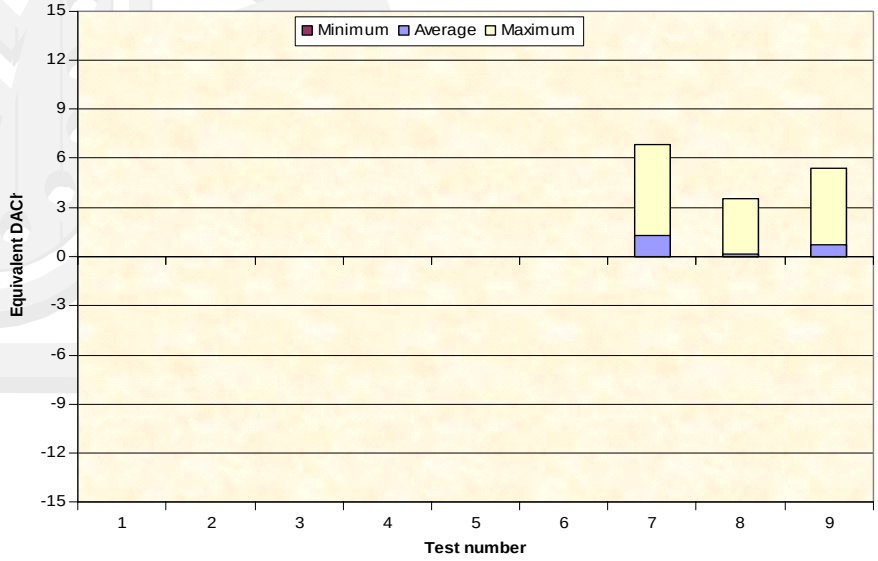
Testing









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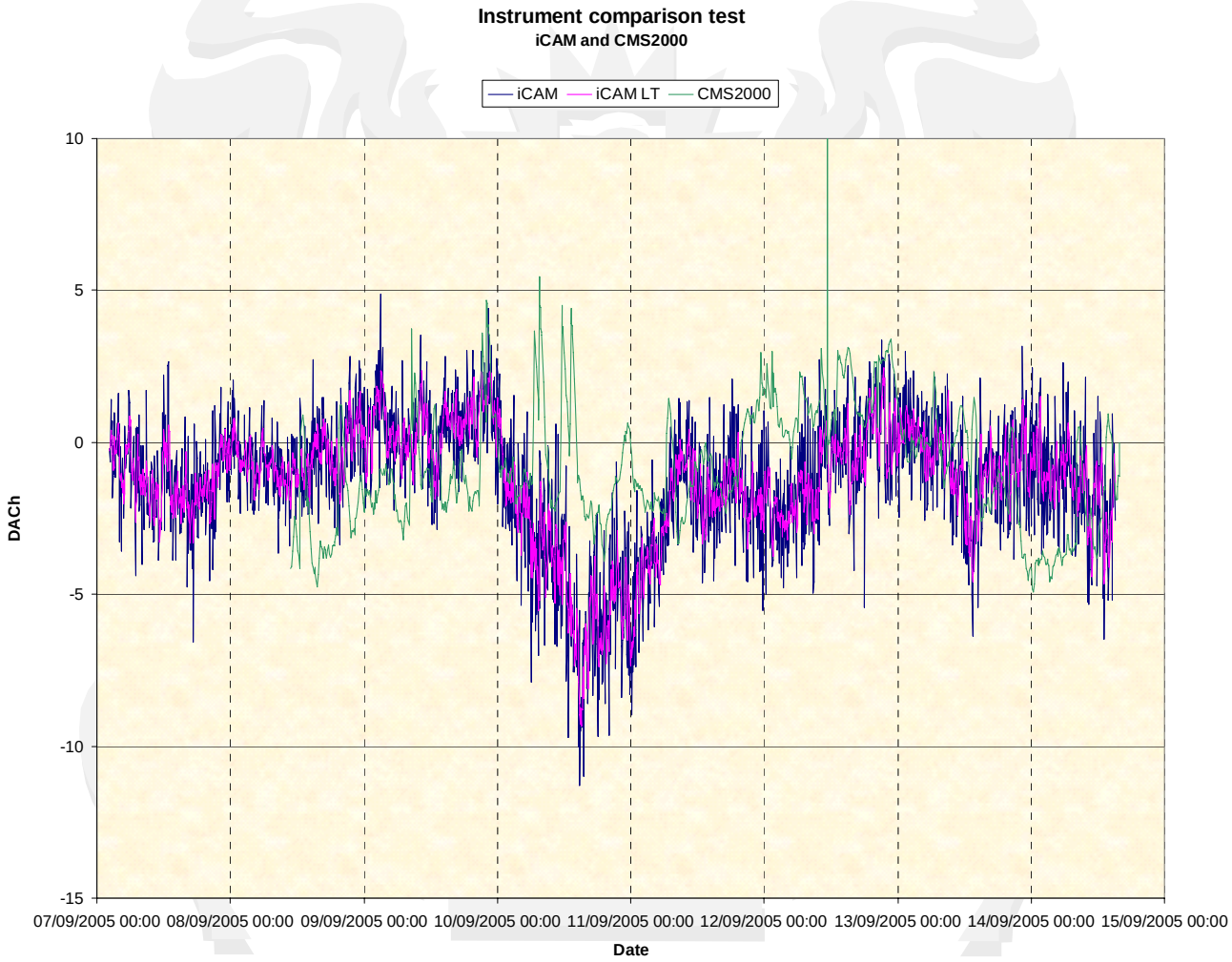
iCAM and CMS (Test 2)



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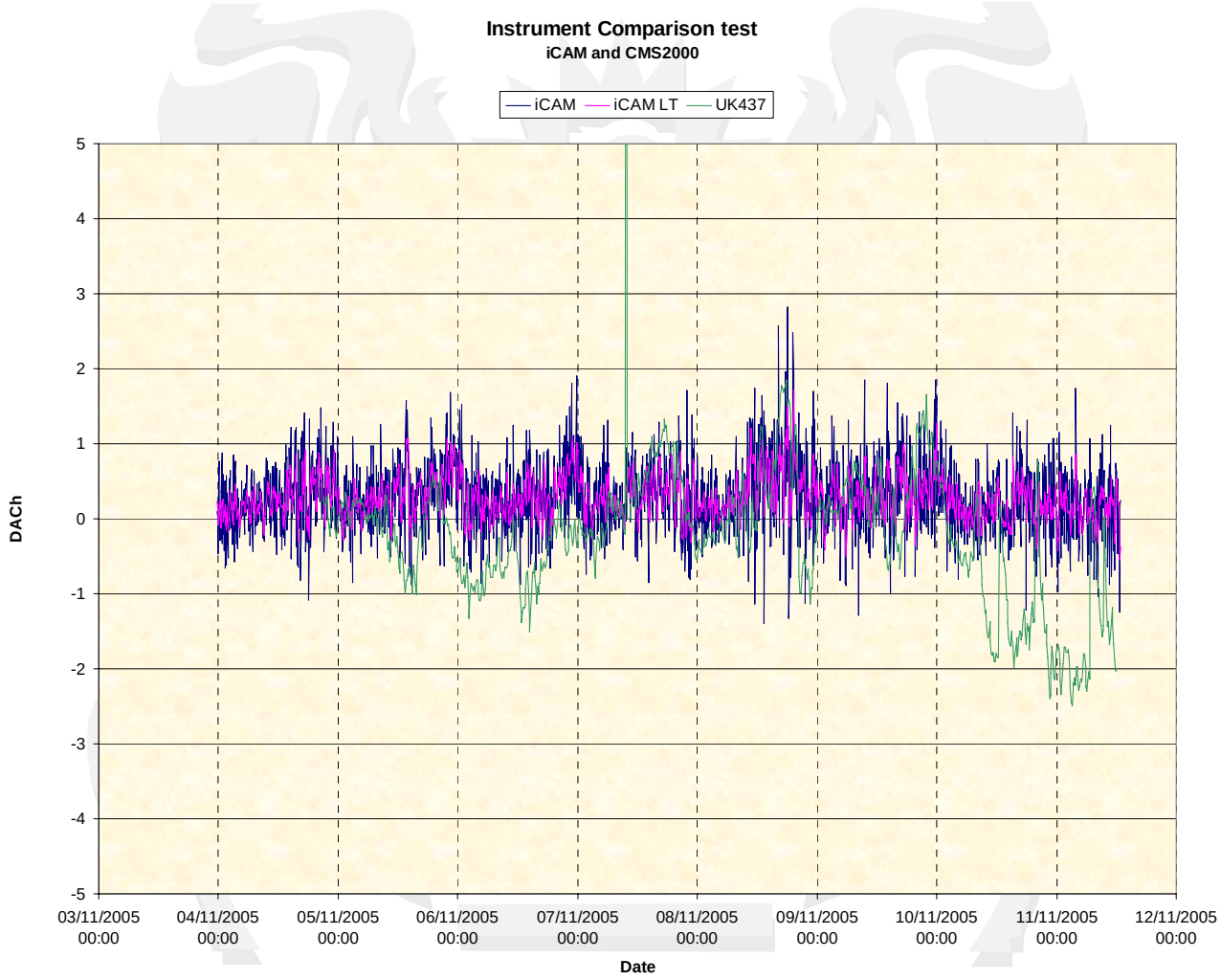
iCAM and CMS (Test 6)



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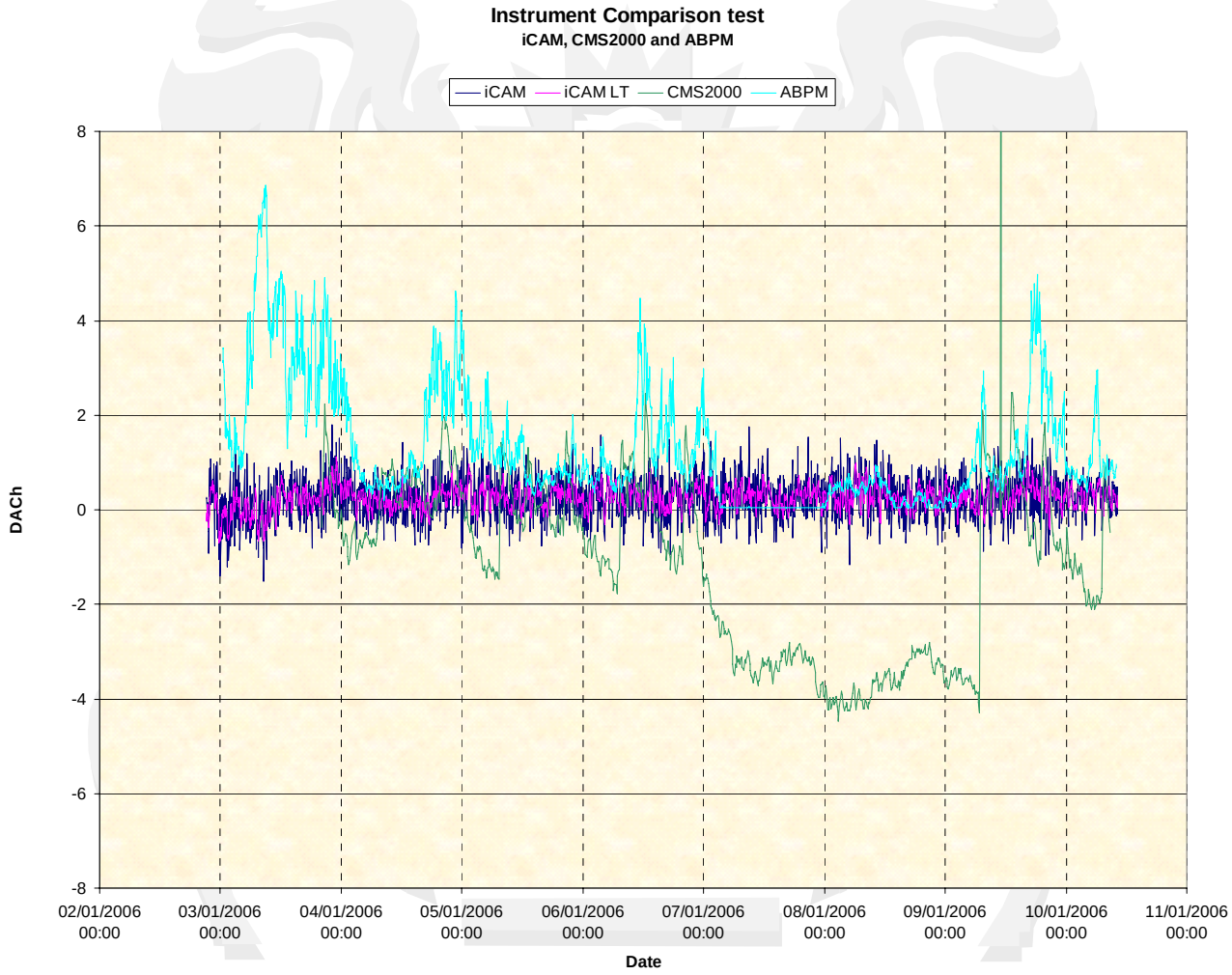
All (test 7)



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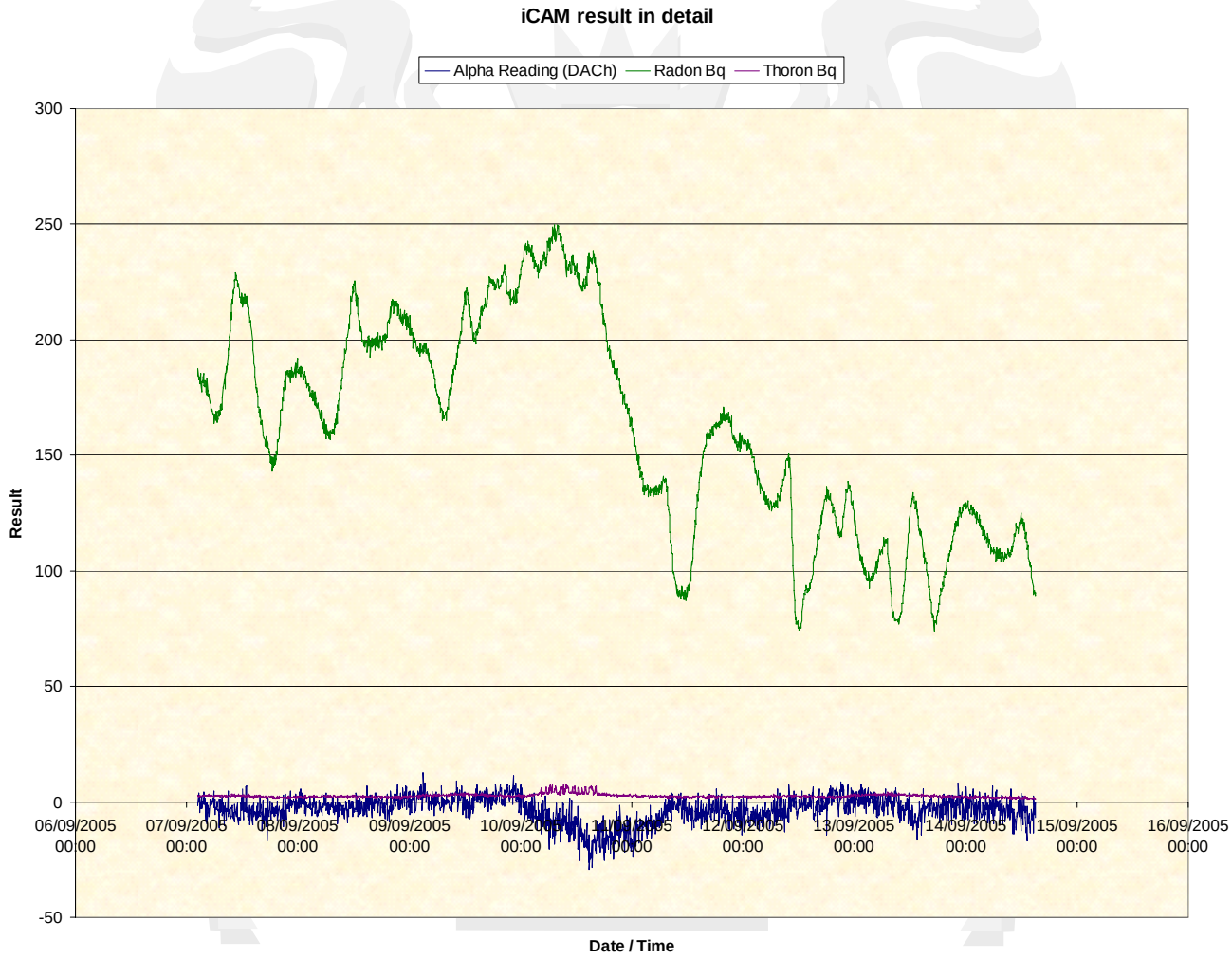
iCAM results in detail



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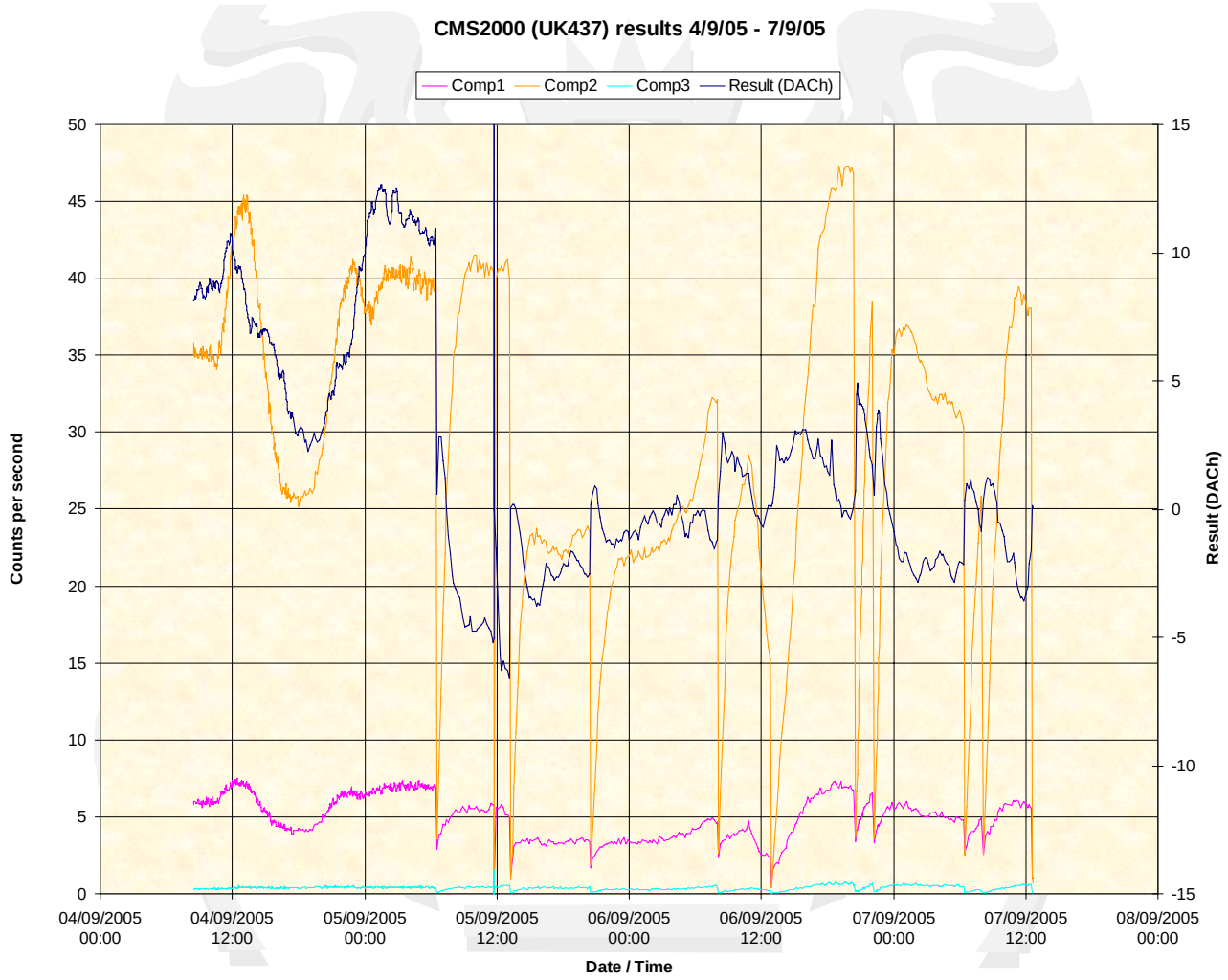
CMS results in detail



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Other issues

- During investigation a number of false alarms due to high flow discovered
  - Found to occur during receipt / dispatch operations
  - A radon problem was immediate diagnoses due to history of radon problems
- Cause identified to be change in air temperature, which effects the mass flow measurement.

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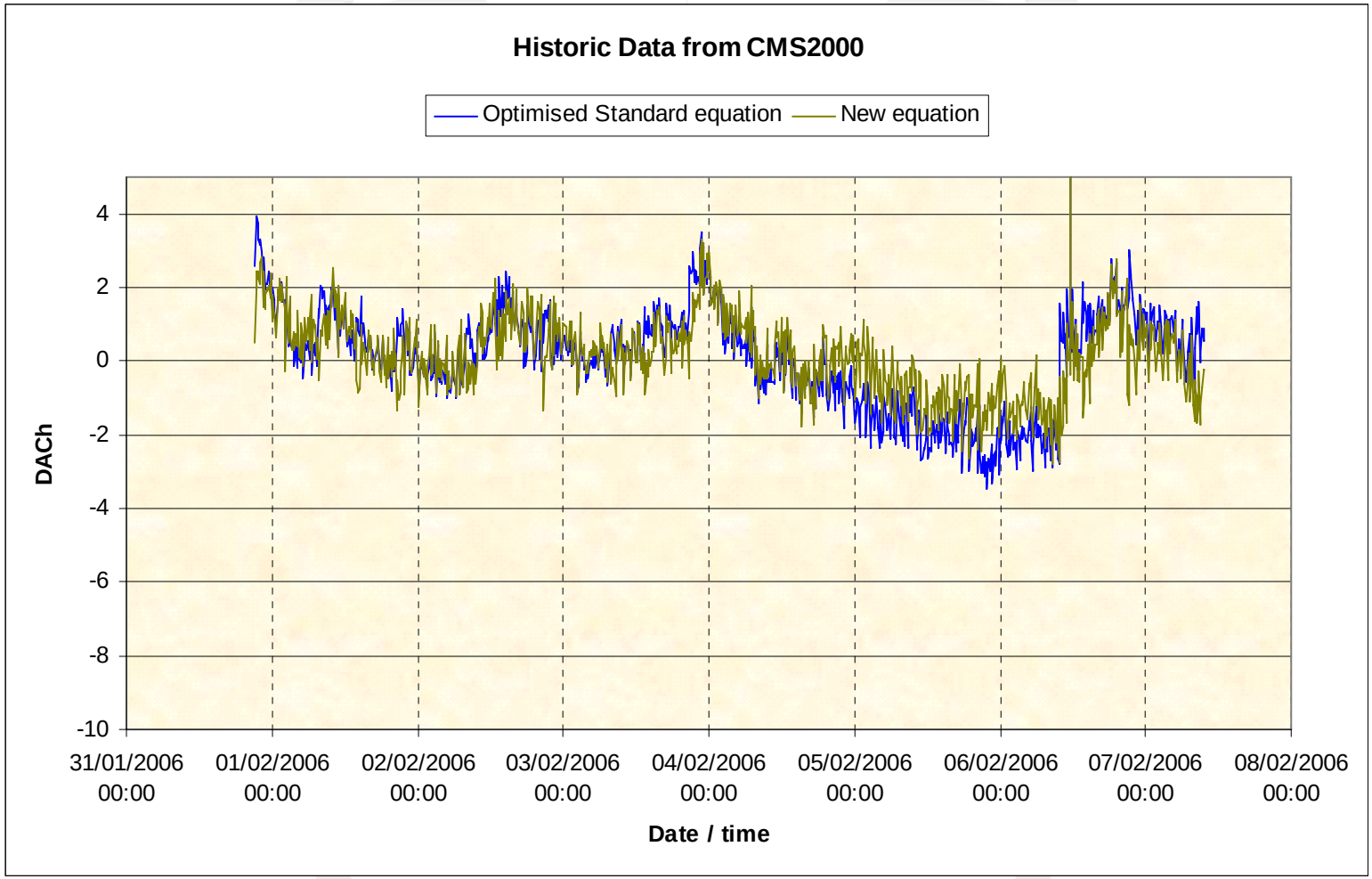
Improvements

- Changes to CMS algorithm
  - Recalculated the CMS algorithm to attempt to copy the iCAM idea
  - Changed from
    - Activity = Raw – K1.C1 – K2.C2 –K3.C3
  - To
    - Activity = Raw – K1.(C1-K2.C2) – K3.C2 – K4.C3

New v Old Algorithm



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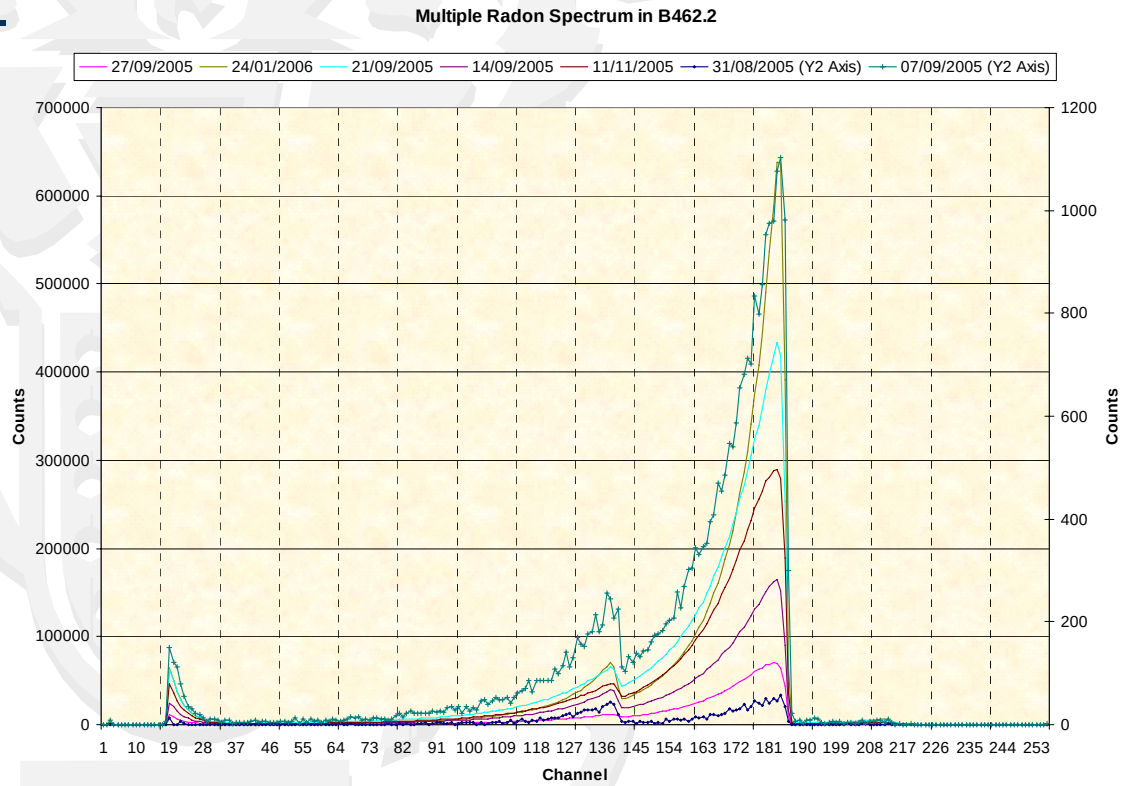
B462 Spectrums

- Confirmed spectral shape is not constant
- Ratio of Po-214 to Po-218 varies
- Fitted curves to spectrum using excel.
- Curves have the form $y=A.e^{Bx}$



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A “weak?” relationship

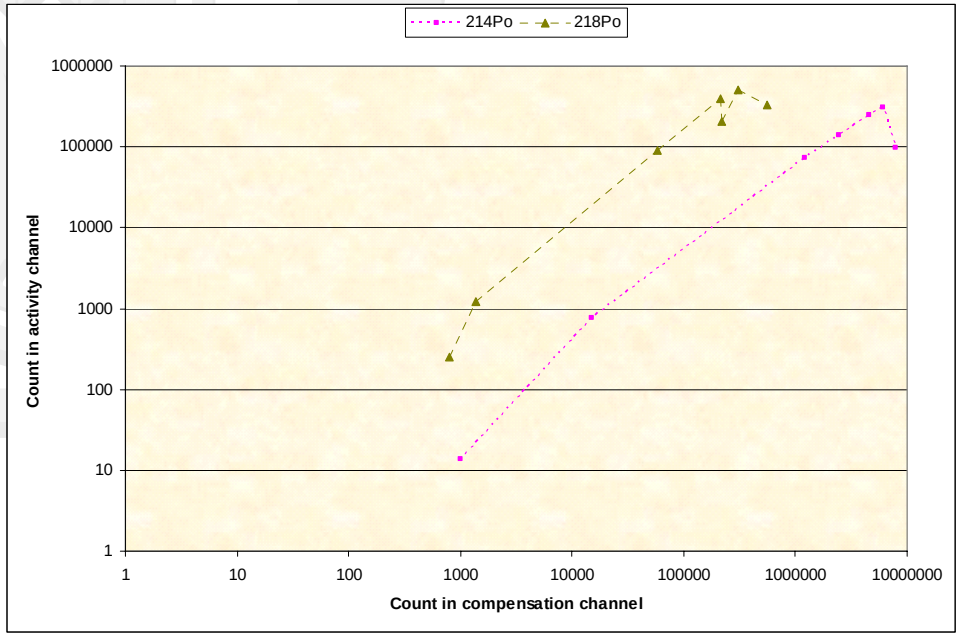
- By integration the total counts between channels c and c+1 (i.e. a compensation window on the CMS2000)

$$= \left[\frac{A}{B} e^{Bx} + K \right]_{x=c}^{x=c+1} = \frac{A}{B} \left(e^{Bc+1} - e^{Bc} \right)$$

- Therefore the ratio of two windows (c:c+1 and d:d+1) on the same curve

$$= \frac{\left(e^{Bc+1} - e^{Bc} \right)}{\left(e^{Bd+1} - e^{Bd} \right)}$$

- A log-log plot of the two of the two windows appears to show a possible linear relationship



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Future work

- Effects of differing filter paper on the CMS2000
- Effects of using a radon screen with the CMS2000
- Effects of reducing the “long time” constant on the iCAM.
- Review information on radon screen against typical particle sizes.

Summary

- Alarm levels increased to reduce false alarms.
- Trialled 3 differing instruments and compensation types.
- Examined the possibility of modifications to existing equipment.
- At present none of the equipment meets the requirements for B462.
- Identified additional trials to be completed.

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