Development of a Tool for the Rapid Quantitative Analysis of Multiple Gamma Spectra

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Abstract

Often multiple gamma spectra are acquired for the quantative measurement of process holdup, filter banks, waste containers, D&D objects, or other such items. These spectra can represent data for single items, background data, and multiple assays of the same item or multiple areas representative of a single process area. The spectra are often collected under differing circumstances with regard to attenuating materials, distances, assay times, relative backgrounds, and many other such parameters. Quantative results, and associated errors, are often dependent on multiple calibration constants, assays of varying isotopes, source geometries (point, line, or area), background averaging, Compton effects, and the accurate analysis (i.e. region of interest) of the raw gamma spectra.

A tool has been developed to assist in this endeavor. The calculations have been quality checked so that the tool can readily be used with assurance that the calculations are consistent and correct. This tool allows for multiple spectra (up to 150) to be compared and manipulated. The tool has features for: dynamic average background subtraction; accounting for varying Compton effects; different calibration constants; up to three attenuating materials; any gamma energy; and variance in collection parameters such as distance, angle, assay times, and isotope. Selections of point, line, or area calculations are easily specified.

The tool has a report writer that allows for averaging over multiple assays, graphing of activity (e.g., graphing activity in a sump allows the “hot spots” to be identified), and presentation of results with associated error components or MLDs. The resulting database allows for easy self-documentation and archiving.

INTRODUCTION

The Nuclear Measurements Group at the Savannah Rive Site is often charged with determining quantities of nuclear material for selected waste items or holdup in nuclear material operations areas and equipment. Entry into these areas is often problematic requiring that data be acquired compiled, and analyzed efficiently. Often more than 100 spectra are acquired for each effort. Recently, over 750 spectra were required for a single report. This data can represent the measurement of many individual items, multiple assays of single items, measurements of area sources (e.g. gloveboxes), larger items with varying qualities of nuclear materials spread in some non-uniform, yet systematic way (e.g. sumps), or any combination of these.

With this quantity of data it became necessary to devise a method to compile and reduce large qualities of spectral information into single grams values. The tool described in this document does just that. It was designed to be dynamic to allow for varying detector geometry, shielding material, calculation type, and shifting regions of interest. It also has provision to track measurement control. As the tool has been tested for quality (i.e. the equations verified), it can often shorten the data compilation and analysis effort from 3-4 weeks to several hours.

The tool allows for rapid input of essential data (much if it is electronic), parameter files for constants, contains a report writer for data summarization and to enable further analysis, and when fully populated serves as final assay documentation containing original spectrums, reduced data, assay notes, measurement control, and the calculation of final results.

All examples provided in this report are fictitious. Assay parameters have been modified to prevent the dissemination of any possible sensitive data.

CAPABILITIES

The tool allows up to 5 gamma peaks to be defined for quantitative analysis of each spectrum. Each peak has a low energy and a high energy background associated with it for Compton background subtraction. The characteristic that the Compton background definition is not fixed becomes important when there are nearby interfering peaks near the peaks(s) of interest. The flexibility allows the analyst precise definition of assay peaks for “cluttered” spectra or when peak stripping techniques are applied.

Figure 1 is a representative piece of the tool. The 1st 5 columns consist of row descriptions, MCP data, energy calibration, and other such “overhead” items. The data begins in column 6. Staring at top of each column are the scale factor and the title for each individual spectrum. The scale factor defaults to the maximum data point observed for that dataset but is easily overridden if desired (e.g. to allow multiple spectra to be scaled identically for comparison purposes). The next 15 rows define the five assay peaks. One row each for the definition of low energy background, assay peak, and high background. It should be noted that it is not necessary, and often undesirable, to define both low and high background.

The plot of each individual spectrum, complete with colored ROI (as defined by the color of the cells defines the ROI), follows the peak definition. The definition of up to three ambient room background spectra follows. The columns defined in these cells point to the acquired background spectra. The average of these backgrounds is then subtracted from the assay spectra to yield Compton and ambient room background corrected net peak areas.

Following are the peak areas and errors for each of the 5 peaks in each spectrum. This is followed by the calculation type: point, line, or area. The next five rows are calculated results followed by corresponding calculated MLDs. The tool will bold the more significant between calculated results and MLD.

Scale				145	316	569	598822	2000
Spectrum Title				MCP - pre	1B	2B	1A	2A
ROIs		keV	expected chn					
	lo bkg				45 49	45 49	45 49	45 49
Pu^{235} - 153	peak	153	54		60 62	60 62	60 62	60 62
	hi bkg				0 0	0 0	0 0	0 0
	lo bkg				45 49	45 49	45 49	45 49
U^{235} - 186	peak	186	65		63 73	63 73	63 73	63 73
	hi bkg				0 0	0 0	0 0	0 0
	lo bkg				124 125	124 125	124 125	124 125
Pu^{239} - 414	peak	414	145		125 155	125 155	125 155	125 155
	hi bkg				161 166	161 166	161 166	161 166
	lo bkg				0 0	0 0	0 0	0 0
Np^{237} - 312	peak	312	109		0 0	0 0	0 0	0 0
	hi bkg				0 0	0 0	0 0	0 0
	lo bkg			201 205	252 256	252 256	252 256	252 256
Pu^{238} - 766	peak	766	269	206 250	267 277	267 277	267 277	267 277
	hi bkg			251 255	278 282	278 282	278 282	278 282

Update | Replot | Report

MCP peak: 647 keV

MCP roi 206 250

Data compilation: Select the column in which to start. Enter **F12** to initiate.

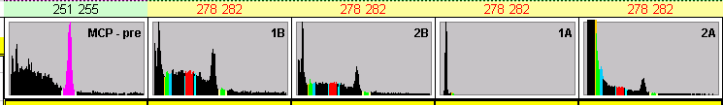
Energy Calibration for MCP @ 647keV

2.850 keV/chn

assumes that 1st spectrum is MCP data & uses the MCP peak for energy calibration

the spectrum color for each roi is keyed on the color of the defining cell

(click on the spectrum to enlarge, click again to miminize)



Calculations	bkg_1							H		J	
	bkg_2 select column										
	bkg_3										

MCP for 647keV

		pre	post	net	σ_{net}	net	σ_{net}	net	σ_{net}	net	σ_{net}	net	σ_{net}
NET COUNTS	Pu^{235} - 153					283	18.78%	200	27.25%	-104671	0.54%	-19740	1.40%
	U^{235} - 186	centroid-chn(keV)	227 (647)	240 (684)		261	17.93%	151	31.34%	-93965	0.50%	-18612	1.25%
	Pu^{239} - 414	net (counts)	2048	22548		203	55.94%	207	52.22%	2000	9.38%	1385	10.87%
	Np^{237} - 312	FHWM (keV)	20.0	28.5									
	Pu^{238} - 766	assumes that 1st and last spectrums are MCP data & uses the MCP roi to define the MCP peak			2048	2.87%	47	68.43%	-21	152.37%	-206	27.30%	-122	38.01%

CALC TYPE: Line ,or Area					area		area		area	
		3865	target rate (c/s)							
		93	target 1σ (c/s)							
RESULTS	Pu^{235} - 153	**MCP limits:** 15	Δ centroid (keV)					-0.007 ± 30.02%		-0.001 ± 30.05%
grams/cm^2	U^{235} - 186	186	Δ rate (c/s)					-0.007 ± 33.32%		-0.001 ± 33.34%
	Pu^{239} - 414	5	Δ FHWM (keV)					**0.000** ± 33.41%		**0.000** ± 34.28%
	Np^{237} - 312	Pre MCP rate failed action limit								
	Pu^{238} - 766	Post MCP rate failed action limit						0.000 ± 44.19%		0.000 ± 55.61%
		MCP peak shift > 15 keV								
MLD	Pu^{235} - 153	MCP rate difference > 186 c/s						**0.000**		**0.000**
grams/cm^2	U^{235} - 186	MCP resolution difference > 5 keV						**0.0001**		**0.0001**
	Pu^{239} - 414	if MLD is **bold**,						0.0000		0.0000
	Np^{237} - 312	then MLD > calculated mass								
	Pu^{238} - 766	if calculated mass is **bold**,						**0.0000**		**0.0000**
		then calculated mass > MLD								

Description	data labels			MCP - pre	1B	2B		
	report code	(to assist in sorting "Report" worksheet)			bkg	bkg	OP3 floor	OP3 floor
Acquisition	angles	sheild	item			45° 60°	45° 45°	45° 45°
Specifics	$distance_{acq}$	(inches)				12.0"	8.0"	8.0"
	attenuating $material_1$	(see table 1 in "Transmission Curves.xls")				cd 0.150"		
	attenuating $material_2$	Z	(thickness in inches)			lexan 0.354"		
	attenuating $material_3$	Z	(thickness in inches)			ss 0.089"		

Spectrum	file name	P:\Users\cRoais\WBL Phase One AlNal\002 CS137 5-3-04 11.52.28 AM.Chn vs AlNal\005 1B 5-4-04 8.24.58 AM.Chn v AlNal\006 2B 5-4-04 8.34.10 AM.Chn vs AlNal\029 1A 5-4-04 9.59.01 AM.Chn AlNal\030 2A 5-4-04 10.04.32 AM.Chn AlNal\031 1AA 5-4-				
Specifics	date	3-May-04	4-May-04	4-May-04	4-May-04	4-May-04
	time	12:08:36 PM	8:34:10 AM	8:36:26 AM	10:04:32 AM	10:15:35 AM
	real time	39.32	101.30	101.34	638.96	239.16
	live time	38.88	100.00	100.00	100.00	100.00
	n channels	512	512	512	512	512
	parsed filename	CS137	1B	2B	1A	2A
Spectral Data						
chn0/0.0keV		0	0	0	0	0
chn1/2.9keV		0	0	0	0	0
chn2/5.7keV		0	0	0	0	0
chn3/8.6keV		0	0	0	0	0
chn4/11.4keV		0	0	0	0	0
chn5/14.3keV		0	0	2	0	0
chn6/17.1keV		16	96	146	0	0
chn7/20.0keV		25	181	216	0	0
chn8/22.8keV		30	220	250	0	0
chn9/25.7keV		40	225	272	0	0
chn10/28.5keV		44	188	267	0	0
chn11/31.4keV		64	189	241	0	0
chn12/34.2keV		78	148	177	0	0
chn13/37.1keV		71	115	176	0	0
chn14/39.9keV		66	105	136	0	0
chn15/42.8keV		55	103	125	15	184
chn16/45.6keV		55	124	133	33839	16823
chn17/48.5keV		45	132	181	121012	43850
chn18/51.3keV		41	146	186	178523	62111
chn19/54.2keV		40	171	245	251401	89737
chn20/57.0keV		31	203	282	345247	135433
chn21/59.9keV		30	264	431	461143	205653
chn22/62.7keV		46	316	569	568271	273451
chn23/65.6keV		41	316	561	598822	284157
chn24/68.4keV		49	280	518	521735	237798
chn25/71.3keV		50	226	400	383382	167037
chn26/74.1keV		59	191	254	233435	88755
chn27/77.0keV		90	163	154	108879	33403
chn28/79.8keV		97	179	178	40846	12045
chn29/82.7keV		101	188	174	18348	7068
chn30/85.5keV		86	146	149	12881	5689
chn31/88.4keV		92	163	148	11439	4864

Figure 1 - Spectra and Calculations Spreadsheet

The data in yellow are assay parameters: item description; report code; assay angle, distance; and shielding information. Item description is any tag the analyst wishes to associate with the data. It is for definition of the specific spectrum. Examples might include position or gloveport number. Report code is simply carried along with the data to the report writer (described in a following section). It is used for grouping the data together. Examples might include a glovebox or room number when the analyst wishes to average many individual results. This is further described in the report writer section.

The balance of the data is spectrum specific: filename, date, time, real time, live time, number of channels in the spectrum. The individual spectrum data, channel-by-channel, follows.

The tool can accept up to 3 unique shields between the item and the detector. This is useful when obtaining data through container walls or when additional shielding is necessary to reduce deadtime in areas of high count rates. The tool adjusts the shielding thickness with regard to the angle the data was collected through the shield. Calculation type: point, line, or area can be specified for each individual spectrum allowing large latitude for data collection. The ROIs are dynamic for each spectrum and can be easily changed at will. This allows for "tuning", especially where interfering peaks are present or small gain shifts occur (often there are large temperature differences during data collection).

Energy calibration is automatic and applies uniformly across all spectra and channel labels. This assists with peak identification and the appropriate setting of ROI information. Data collection specifics: time, distance, angle, shielding, calculation type are unique to each individual spectra for the greatest latitude with data compilation and calculation of results.

Constants are maintained in a separate data file and linked dynamically to the calculation. This allows for calibration constants from many detectors to be used at will by simply modifying the parameter file appropriately.

All the automatic updating, allowances for varying angles, distances, shielding materials, and all the other parameters that are employed in the calculation of final results minimize errors and make it easier to obtain accurate QA'd results in a more timely fashion.

To assist the analyst, individual spectra can be "zoomed" by simply clicking on the spectra (see Figure 2). While zoomed, the analyst can determine peak energy by simply placing the cursor over the desired channel. Spectra are dynamic, that is any change made to the parameters (ROI information and color, energy calibration, scale factor) are immediately incorporated.

A facility exists to automatically download data from most ORTEC™ or Canberra™ MCAs. Two help files are incorporated to assist a novice user through definitions, data acquisition, and set-up. Theory, ROI optimization, and calculations are all detailed in these help files. There are three action buttons: 1) force an update of all calculations; 2) re-plot all spectra; and, 3) report generation.

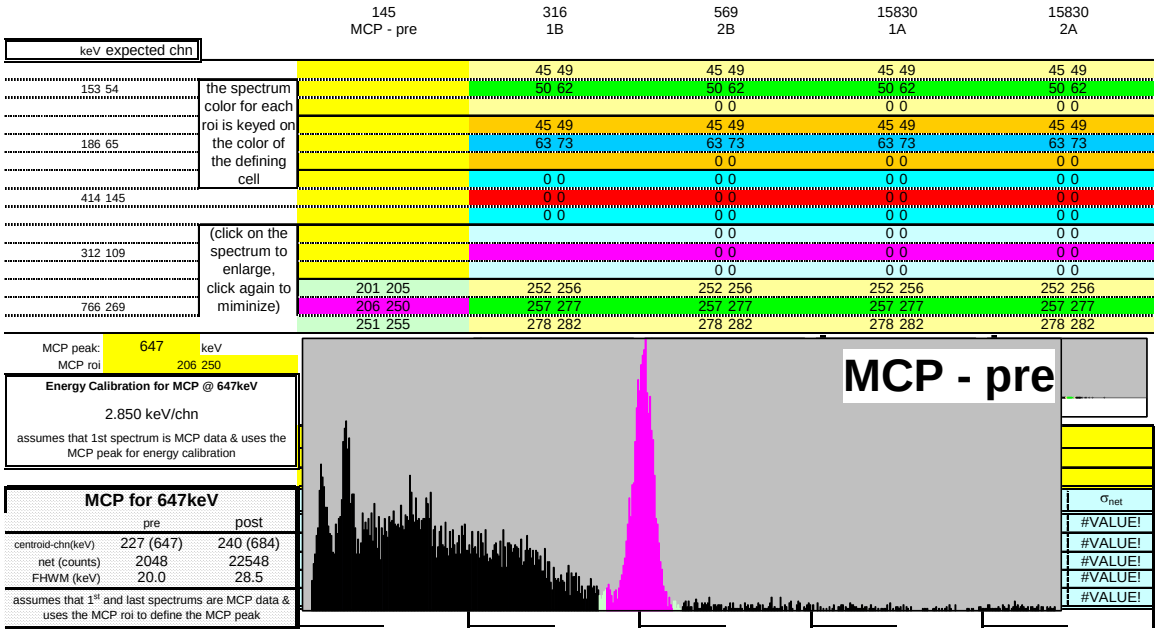


Figure 2 -- Demonstration of the Spectra Zoom

EQUATIONS

Equation 1 gives the generic equation for results. All equations were designed to be self documenting and transportable (i.e. copied from on cell to another). As mentioned, the calculations are parameter file driven. Each individual result contains the appropriate parameter name pointing to the correct constant. The tool incorporates distance appropriately and in the case of an area calculation where distance is inconsequential, the CF_{geom}[1] incorporated. Transmission corrections are discussed below.

Uncertainties are propagated from the raw spectral data, errors in constants, and hooks in the parameter file for introduction of errors associated with enrichment, procedure, uniform planer source, assumptions and systemic errors.

```
net rate - average bkg rate     = (AF27/AF$59 -  bkgrate_avg(COLUMN(),1) )

appropriate K                   * IF(AF$33="point", Kp_Pu238,
                                    IF(AF$33="line", Kl_Pu238,
                                    IF(AF$33="area", Ka_Pu238,NA())))

distance for point/line,        * IF(AF$33="point",(AF50*2.5/COS(RADIANS(AG$49)))^2,
        for area CFgeom             IF(AF$33="line",(AF50*2.54/COS(RADIANS(AG$49))),
                                    IF(AF$33="area",COS(RADIANS(AG$49)),NA())))

transmission corrections        /  (  'Transmission curves.xls'!attn(AF51, AG51*2.54/COS(RADIANS(AF$49)), $C$5)
                                     * 'Transmission curves.xls'!attn(AF52, AG52*2.54/COS(RADIANS(AF$49)), $C$5)
                                     * 'Transmission curves.xls'!attn(AF53, AG53*2.54/COS(RADIANS(AF$49)), $C$5)  )
```

Equation 1 -- Calculation of Results

Corrections for attenuation effects through a shield (labeled as "transmission corrections" in Equation 1) are calculated by Equation 2. Specific values for energy, material, shield thickness, and an option for density, are all calling variables to the subroutine. The subroutine calculates the precise transmission based on these variables and tables[2] imbedded in the subroutine. The subroutine allows for any element or special compound defined in Table 1. The routine also tracks the density for the materials listed in Table 1. In addition, compounds can be further defined by chemical formula (ratioed combinations of elements) and compound density. For example, an analyst could provide H20 and 1.0 to define water.

$$T = e^{-(\mu/\rho)\rho x}$$

Where μ/ρ = mass attenuation coefficient
ρ = density
x = thickness

Equation 2 -- Transmission Correction Factor Calculations

none	air	concrete	HEPA	Pb glass	Lexan	Lucite	PVC
poly	Pyrex	SS	tissue	wood	water	H	Be
B	C	O	Cl	F	Co	Zn	N
Na	K	Ca	Ti	Mg	Al	Si	P
S	Cr	Mn	Fe	Ni	Cu	Ge	Mo
Sn	Cd	I	W	Pb	U	Np-α	Np-β
Np-γ	Pu-γ	Pu-β	201	202	301	302	303
303Se	304	304L	309S	310S	316	316L	317
317L	321	329	330	347	409	410	416
416Se	420	430	440C	442	904L	17-4 PH	17-7 PH
2205	9975						

Table 1 -- List of Elements and Special Compounds Accepted for Transmission Corrections.

Calculation of MLD is by Currie's Method[3]. Equation 3 provides those calculations. Again, all data (K, time, raw assay data) is dynamically provided to the subroutine and the results calculated in real time.

$$L_c = \alpha \times \sqrt{[\,(\text{gross} - \text{net}) + \text{bkg} + \text{abs}(\sigma^2_{\text{gross}} - \sigma^2_{\text{net}}) + \sigma^2_{\text{bkg}}\,]}$$

$$L_d = L_c + \beta\,\sigma_d;\ \text{if one assumes } \alpha = \beta, \text{ then } L_d = \alpha^2 + 2L_c$$

$$\text{MLD} = K \times [\,L_d / \text{LT(sec)}\,] \times CF$$

Where α = probability coefficient (1.645 for 5%)
gross = gross count in peak area
net = Compton corrected peak area
bkg = ambient room background for that peak
σ = uncertainty associated with each term

Equation 3 - Calculation of MLD[3]

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REPORT WRITER

The tool includes a generic report writer which compiles all the calculated data into one spreadsheet. Figure 3 is an example of this capability. The data is compiled with "report code" tags into a more easily manageable table. The analyst can then readily perform further summary calculations. Further summary calculations might include considering several assays together to calculate the average activity over a processing area.

	Acquisition Specifics			Spectrum Specifics							Pu^{238} - 153			U^{235} - 186			Pu^{239} - 414			Np^{237} - 312			Pu^{238} - 766		
report code	Description	angles	distance assay	attenuating material$_1$	attenuating material$_2$	attenuating material$_3$	date	time	live time	CALC TYPE	grams/cm^2		MLD	grams/cm^2		MLD	grams/cm^2		MLD	grams/cm^2		MLD	grams/cm^2		MLD
OP3 floor		45°	8.0"				5/4/04	10:04	100	area	-0.007421	+/-30.02%	**0.000151**	-0.006663	+/-33.32%	**0.000131**	**0.000127**	+/-33.41%	4.27E-05	0			-1.79E-05	+/-44.19%	**1.38E-05**
OP3 floor		45°	8.0"				5/4/04	10:15	100	area	-0.00141	+/-30.05%	**7.23E-05**	-0.001327	+/-33.34%	**6.3E-05**	**8.33E-05**	+/-34.28%	3.43E-05	0			-7.14E-06	+/-55.61%	**1.12E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:02	100	area	**0.000564**	+/-30.61%	0.000108	**0.000682**	+/-33.46%	5.55E-05	**8.84E-05**	+/-36.31%	5.19E-05	0			7.06E-07	+/-99.65%	**1.2E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:05	100	area	**0.000402**	+/-31.03%	9.93E-05	**0.000333**	+/-33.76%	5.1E-05	**6.12E-05**	+/-39.49%	5.29E-05	0			4.81E-06	#########	**0.000014**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:07	100	area	**0.002105**	+/-30.11%	0.000126	**9.15E-05**	+/-37.89%	6.44E-05	**9.11E-05**	+/-42.54%	5.38E-05	0			1.23E-05	+/-50.34%	**1.96E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:09	100	area	**0.000741**	+/-30.55%	9.73E-05	**0.000215**	+/-35.43%	4.87E-05	4.63E-05	+/-44.21%	**4.75E-05**	0			-4.09E-07	+/-45.00%	**1.67E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:13	100	area	**0.00036**	+/-31.03%	9.13E-05	2.38E-05	+/-37.12%	**4.73E-05**	-6.31E-05	#########	**4.62E-05**	0			6.09E-06	+/-78.44%	**1.55E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:15	100	area	**0.000195**	+/-32.46%	0.000105	**0.000286**	+/-33.90%	5.43E-05	2.13E-05	+/-42.37%	**5.45E-05**	0			-1.49E-05	#########	**1.56E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:17	100	area	-0.001075	+/-31.00%	**0.000163**	-0.000892	+/-33.92%	**9.11E-05**	-0.000152	+/-40.30%	**7.56E-05**	0			-1.79E-05	#########	**2.12E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:19	100	area	-0.002632	+/-30.37%	**0.000227**	-0.000369	+/-33.83%	**0.000107**	-0.000167	+/-34.72%	**9.01E-05**	0			6.38E-06	+/-54.64%	**2.51E-05**
item	HEPA - a		12.0"	0" cd			5/5/04	9:22	100	point	**1.167**	+/-30.08%	0.06325	**0.3945**	+/-33.54%	0.05561	**0.2279**	+/-32.98%	0.08993	0			0.0209	+/-70.58%	**0.0286**
item	beaker RD-13	30°	18.0"	0.0715" cd	6" lexan		5/5/04	9:25	100	point	1.681	+/-37.86%	**2.326**	**1.444**	+/-41.09%	1.252	0.4633	#########	**0.9815**	0			0.02083	#########	**0.2143**
item	can	30°	18.0"	0.0715" cd			5/5/04	9:28	100	point	**6.633**	+/-30.09%	0.3564	**1.865**	+/-33.58%	0.2292	**0.7451**	+/-33.69%	0.2394	0			**0.07543**	+/-45.59%	0.07102
item	pestal		10.0"	0" cd	0.5" ss		5/5/04	9:30	100	point	**1.797**	+/-30.24%	0.2023	**1.64**	+/-33.42%	0.1322	**0.2155**	+/-33.78%	0.139	0			0.01065	+/-63.21%	**0.03257**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:38	100	area	**0.001827**	+/-30.19%	0.000176	**0.000588**	+/-33.66%	9.03E-05	**0.000222**	+/-34.43%	8.69E-05	0			8.71E-06	+/-72.11%	**2.74E-05**
item	beaker RD-14	30°	14.0"	0" cd			5/5/04	9:41	100	point	**3.05**	+/-30.08%	0.1136	**2.474**	+/-33.46%	0.09282	**0.3793**	+/-32.09%	0.1779	0			**0.06504**	+/-41.67%	0.05754
OP3 floor		45°	8.0"	0" cd			5/5/04	9:44	100	area	-0.001751	+/-30.62%	**7.46E-05**	-0.000908	+/-34.84%	**6E-05**	-0.000942	+/-48.73%	**9.73E-05**	0			-5.75E-05	#########	**3.57E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:47	100	area	**0.000484**	+/-31.09%	0.000166	**9.24E-05**	+/-34.45%	8.69E-05	3.08E-05	+/-38.88%	**8.36E-05**	0			-6.72E-06	+/-51.12%	**2.74E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:50	100	area	**0.000909**	+/-30.62%	0.000176	**0.001053**	+/-33.46%	9.15E-05	**0.000189**	+/-33.91%	9.42E-05	0			-1.25E-06	+/-55.51%	**2.69E-05**
item	screen		12.0"	0" cd			5/5/04	9:53	100	point	**0.6545**	+/-30.13%	0.04548	-0.04388	+/-39.69%	**0.04002**	0.01599	+/-36.86%	**0.07696**	0			0.01033	+/-46.55%	**0.02689**
item	beaker RD-13		12.0"	0" cd			5/5/04	9:55	100	point	**0.1649**	+/-30.65%	0.04056	**0.1184**	+/-34.08%	0.0354	0.02103	+/-36.06%	**0.07349**	0			-0.000207	+/-44.64%	**0.02865**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	9:57	100	area	-0.00149	+/-37.59%	**0.000139**	6.39E-06	+/-36.27%	**6.18E-05**	-0.000129	+/-57.65%	**6.27E-05**	0			-1.24E-05	+/-59.80%	**2.05E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	10:00	100	area	-0.000745	+/-36.19%	**0.000122**	-0.000257	+/-36.51%	**6.27E-05**	-0.000145	+/-66.89%	**5.97E-05**	0			-0.000039	#########	**2.17E-05**
item	beaker RD-14		12.0"	0" cd			5/5/04	10:02	100	point	**0.167**	+/-30.77%	0.0372	**0.05735**	+/-34.58%	0.03301	**0.08117**	+/-35.54%	0.06563	0			-0.01115	+/-47.96%	**0.02693**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	10:05	100	area	**0.000383**	+/-31.97%	0.000114	**0.000297**	+/-34.01%	5.98E-05	-2.3E-05	+/-53.69%	**6.51E-05**	0			2.49E-06	#########	**1.98E-05**
OP3 floor		45°	8.0"	116269709676" cd			5/5/04	10:07	100	area	**0.000794**	+/-30.76%	0.000163	**0.00085**	+/-33.51%	8.46E-05	8.13E-05	+/-34.10%	**8.81E-05**	0			-6.1E-07	#########	**2.23E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:15	100	area	**0.000281**	+/-31.52%	0.000125	**7.25E-05**	+/-34.42%	6.63E-05	-4.21E-05	+/-46.77%	**7.03E-05**	0			7.22E-06	#########	**2.24E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:17	100	area	**0.000217**	+/-32.32%	0.000113	**9.06E-05**	+/-34.85%	5.92E-05	**6.78E-05**	+/-39.78%	6.28E-05	0			**2.52E-05**	+/-97.14%	2.06E-05
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:20	100	area	2.08E-05	+/-38.98%	**8.49E-05**	1.79E-05	+/-37.41%	**4.45E-05**	-1.35E-05	#########	**4.75E-05**	0			1.14E-05	#########	**1.78E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:26	100	area	**0.000223**	+/-32.66%	9.28E-05	**6.05E-05**	+/-35.49%	4.92E-05	3.34E-05	+/-80.33%	**5.34E-05**	0			-1.06E-06	#########	**1.99E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:28	100	area	6.46E-05	+/-34.69%	**0.000117**	-5.45E-05	+/-35.23%	**6.34E-05**	-8.57E-05	+/-38.37%	**6.2E-05**	0			3.12E-06	#########	**1.88E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:31	100	area	**0.002481**	+/-30.10%	0.000138	-5.38E-05	#########	**7.16E-05**	**0.000142**	+/-34.79%	5.65E-05	0			7.98E-06	#########	**1.94E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:33	100	area	**9.15E-05**	+/-34.69%	8.73E-05	**4.96E-05**	+/-36.48%	4.54E-05	3.53E-05	+/-55.94%	**4.53E-05**	0			1.48E-05	#########	**1.54E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:36	100	area	**0.000216**	+/-32.04%	8.97E-05	3.92E-05	+/-37.31%	**4.66E-05**	**4.73E-05**	+/-45.82%	4.57E-05	0			1.1E-06	#########	**1.44E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:38	100	area	1.56E-05	+/-42.75%	**0.000115**	**0.000123**	+/-35.26%	5.91E-05	**9.21E-05**	+/-34.09%	5.59E-05	0			3.82E-06	#########	**1.34E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:40	100	area	**0.00015**	+/-33.60%	9.5E-05	**9.99E-05**	+/-35.46%	4.92E-05	**5.45E-05**	+/-37.10%	4.84E-05	0			-9.67E-07	+/-86.93%	**1.28E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:45	100	area	7.25E-05	+/-35.78%	**7.5E-05**	2.31E-05	+/-39.15%	**3.89E-05**	5.33E-06	+/-69.23%	**3.88E-05**	0			1.54E-06	#########	**1.19E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:48	100	area	**0.000104**	+/-35.17%	7.12E-05	**3.8E-05**	+/-43.55%	3.63E-05	2.65E-05	+/-42.08%	**3.46E-05**	0			8.52E-06	#########	**1.07E-05**
OP4 floor		45°	8.0"	116269709676" cd			5/5/04	10:55	100	area	**0.000242**	+/-31.75%	7.73E-05	**4.02E-05**	+/-38.38%	4.01E-05	7.97E-06	+/-44.63%	**4.02E-05**	0			2.53E-06	#########	**1.24E-05**
item	RF-24		6.0"	0" cd			5/5/04	10:57	100	point	**0.02726**	+/-31.44%	0.008449	**0.03905**	+/-33.83%	0.007442	**0.05016**	+/-32.68%	0.01536	0			-0.001906	+/-67.38%	**0.004177**
item	RF-24a		6.0"	0" cd			5/5/04	11:00	100	point	**0.01946**	+/-31.63%	0.007722	**0.02543**	+/-34.11%	0.006787	**0.02112**	+/-34.09%	0.01443	0			0.001168	#########	**0.003945**
item	HEPA		18.0"	0" cd			5/5/04	11:02	100	point	**0.5631**	+/-30.38%	0.07476	**0.6623**	+/-33.50%	0.06624	0.1172	+/-35.79%	**0.1285**	0			0.007999	+/-65.33%	**0.04237**
item	RF-23		6.0"	0" cd			5/5/04	11:04	100	point	**0.0341**	+/-31.28%	0.009585	**0.03565**	+/-33.87%	0.008543	**0.04213**	+/-33.12%	0.01723	0			0.001107	+/-68.23%	**0.005265**
item	RF-23a		6.0"	0" cd			5/5/04	11:07	100	point	**0.0438**	+/-30.79%	0.009991	**0.03533**	+/-33.90%	0.008837	**0.04474**	+/-32.66%	0.01714	0			0.003805	+/-60.96%	**0.005142**
item	RF-43		6.0"	0" cd			5/5/04	11:11	100	point	**0.08718**	+/-30.23%	0.008475	0.006056	+/-35.23%	**0.00755**	0.001156	+/-64.46%	**0.01463**	0			-8.55E-05	+/-95.61%	**0.005845**
item	HEPA		18.0"	0" cd			5/5/04	11:14	100	point	**1.137**	+/-30.23%	0.1153	**1.744**	+/-33.38%	0.1026	**0.4609**	+/-32.66%	0.1957	0			-0.02831	+/-60.96%	**0.06525**
item	RT-63		6.0"	0" cd			5/5/04	11:18	100	point	**0.08073**	+/-30.27%	0.008297	-0.003334	+/-38.51%	**0.007438**	-0.002509	#########	**0.01384**	0			0.001501	#########	**0.005663**
item	screen	30°	6.0"	0.0715" cd			5/5/04	11:20	100	point	**0.1981**	+/-30.44%	0.03231	0.002937	+/-35.99%	**0.02114**	**0.04437**	+/-36.14%	0.02398	0			-0.006581	+/-41.44%	**0.009432**

Figure 3 - Report Writer Example

Figure 4 shows an example of such a calculation. The report has been sort by "report code" and the results for Op-3 and Op-4 gloveboxes have been averaged. This average was then multiplied by the total floor glovebox area to achieve the final holdup estimate for the glovebox.

		Pu^{238} - 153			U^{235} - 186			Pu^{239} - 414		
report code	Description	grams/cm²		MLD	grams/cm²		MLD	grams/cm²		MLD
item	HEPA - a	**1.167**	+/-30.08%	0.06325	**0.3945**	+/-33.54%	0.05561	**0.2279**	+/-32.98%	0.08993
item	beaker RD-13	1.681	+/-37.86%	**2.326**	**1.444**	+/-41.09%	1.252	0.4633	#########	**0.9815**
item	can	**6.633**	+/-30.09%	0.3564	**1.865**	+/-33.58%	0.2292	**0.7451**	+/-33.69%	0.2394
item	pestal	**1.797**	+/-30.24%	0.2023	**1.64**	+/-33.42%	0.1322	**0.2155**	+/-33.78%	0.139
item	beaker RD-14	**3.05**	+/-30.08%	0.1136	**2.474**	+/-33.46%	0.09282	**0.3793**	+/-32.09%	0.1779
item	screen	**0.6545**	+/-30.13%	0.04548	-0.04388	+/-39.69%	**0.04002**	0.01599	+/-36.86%	**0.07696**
item	beaker RD-13	**0.1649**	+/-30.65%	0.04056	**0.1184**	+/-34.08%	0.0354	0.02103	+/-36.06%	**0.07349**
item	beaker RD-14	**0.167**	+/-30.77%	0.0372	**0.05735**	+/-34.58%	0.03301	**0.08117**	+/-35.54%	0.06563
item	RF-24	**0.02726**	+/-31.44%	0.008449	**0.03905**	+/-33.83%	0.007442	**0.05016**	+/-32.68%	0.01536
item	RF-24a	**0.01946**	+/-31.63%	0.007722	**0.02543**	+/-34.11%	0.006787	**0.02112**	+/-34.09%	0.01443
item	HEPA	**0.5631**	+/-30.38%	0.07476	**0.6623**	+/-33.50%	0.06624	0.1172	+/-35.79%	**0.1285**
item	RF-23	**0.0341**	+/-31.28%	0.009585	**0.03565**	+/-33.87%	0.008543	**0.04213**	+/-33.12%	0.01723
item	RF-23a	**0.0438**	+/-30.79%	0.009991	**0.03533**	+/-33.90%	0.008837	**0.04474**	+/-32.66%	0.01714
item	RF-43	**0.08718**	+/-30.23%	0.008475	0.006056	+/-35.23%	**0.00755**	0.001156	+/-64.46%	**0.01463**
item	HEPA	**1.137**	+/-30.23%	0.1153	**1.744**	+/-33.38%	0.1026	**0.4609**	+/-32.66%	0.1957
item	RT-63	**0.08073**	+/-30.27%	0.008297	-0.003334	+/-38.51%	**0.007438**	-0.002509	#########	**0.01384**
item	screen	**0.1981**	+/-30.44%	0.03231	0.002937	+/-35.99%	**0.02114**	**0.04437**	+/-36.14%	0.02398
OP3 floor		-0.007421	+/-30.02%	**0.000151**	-0.006663	+/-33.32%	**0.000131**	**0.000127**	+/-33.41%	4.27E-05
OP3 floor		-0.00141	+/-30.05%	**7.23E-05**	-0.001327	+/-33.34%	**6.3E-05**	**8.33E-05**	+/-34.28%	3.43E-05
OP3 floor		**0.000564**	+/-30.61%	0.000108	**0.000682**	+/-33.46%	5.55E-05	**8.84E-05**	+/-36.31%	5.19E-05
OP3 floor		**0.000402**	+/-31.03%	9.93E-05	**0.000333**	+/-33.76%	5.1E-05	**6.12E-05**	+/-39.49%	5.29E-05
OP3 floor		**0.002105**	+/-30.11%	0.000126	**9.15E-05**	+/-37.89%	6.44E-05	**9.11E-05**	+/-42.54%	5.38E-05
OP3 floor		**0.000741**	+/-30.55%	9.73E-05	**0.000215**	+/-35.43%	4.87E-05	4.63E-05	+/-44.21%	**4.75E-05**
OP3 floor		**0.00036**	+/-31.03%	9.13E-05	2.38E-05	+/-37.12%	**4.73E-05**	-6.31E-05	#########	**4.62E-05**
OP3 floor		**0.000195**	+/-32.46%	0.000105	**0.000286**	+/-33.90%	5.43E-05	2.13E-05	+/-42.37%	**5.45E-05**
OP3 floor		-0.001075	+/-31.00%	**0.000163**	-0.000892	+/-33.92%	**9.11E-05**	-0.000152	+/-40.30%	**7.56E-05**
OP3 floor		-0.002632	+/-30.37%	**0.000227**	-0.000369	+/-33.83%	**0.000107**	-0.000167	+/-34.72%	**9.01E-05**
OP3 floor		**0.001827**	+/-30.19%	0.000176	**0.000588**	+/-33.66%	9.03E-05	**0.000222**	+/-34.43%	8.69E-05
OP3 floor		-0.001751	+/-30.62%	**7.46E-05**	-0.000908	+/-34.84%	**6E-05**	-0.000942	+/-48.73%	**9.73E-05**
OP3 floor		**0.000484**	+/-31.09%	0.000166	**9.24E-05**	+/-34.45%	8.69E-05	3.08E-05	+/-38.88%	**8.36E-05**
OP3 floor		**0.000909**	+/-30.62%	0.000176	**0.001053**	+/-33.46%	9.15E-05	**0.000189**	+/-33.91%	9.42E-05
OP3 floor		-0.00149	+/-37.59%	**0.000139**	6.39E-06	+/-36.27%	**6.18E-05**	-0.000129	+/-57.65%	**6.27E-05**
OP3 floor		-0.000745	+/-36.19%	**0.000122**	-0.000257	+/-36.51%	**6.27E-05**	-0.000145	+/-66.89%	**5.97E-05**
OP3 floor		**0.000383**	+/-31.97%	0.000114	**0.000297**	+/-34.01%	5.98E-05	-2.3E-05	+/-53.69%	**6.51E-05**
OP3 floor		**0.000794**	+/-30.76%	0.000163	**0.00085**	+/-33.51%	8.46E-05	8.13E-05	+/-34.10%	**8.81E-05**
OP4 floor		**0.000281**	+/-31.52%	0.000125	**7.25E-05**	+/-34.42%	6.63E-05	-4.21E-05	+/-46.77%	**7.03E-05**
OP4 floor		**0.000217**	+/-32.32%	0.000113	**9.06E-05**	+/-34.85%	5.92E-05	**6.78E-05**	+/-39.78%	6.28E-05
OP4 floor		2.08E-05	+/-38.98%	**8.49E-05**	1.79E-05	+/-37.41%	**4.45E-05**	-1.35E-05	#########	**4.75E-05**
OP4 floor		**0.000223**	+/-32.66%	9.28E-05	**6.05E-05**	+/-35.49%	4.92E-05	3.34E-05	+/-80.33%	**5.34E-05**
OP4 floor		6.46E-05	+/-34.69%	**0.000117**	-5.45E-05	+/-35.23%	**6.34E-05**	-8.57E-05	+/-38.37%	**6.2E-05**
OP4 floor		**0.002481**	+/-30.10%	0.000138	-5.38E-05	#########	**7.16E-05**	**0.000142**	+/-34.79%	5.65E-05
OP4 floor		**9.15E-05**	+/-34.69%	8.73E-05	**4.96E-05**	+/-36.48%	4.54E-05	3.53E-05	+/-55.94%	**4.53E-05**
OP4 floor		**0.000216**	+/-32.04%	8.97E-05	3.92E-05	+/-37.31%	**4.66E-05**	**4.73E-05**	+/-45.82%	4.57E-05
OP4 floor		1.56E-05	+/-42.75%	**0.000115**	**0.000123**	+/-35.26%	5.91E-05	**9.21E-05**	+/-34.09%	5.59E-05
OP4 floor		**0.00015**	+/-33.60%	9.5E-05	**9.99E-05**	+/-35.46%	4.92E-05	**5.45E-05**	+/-37.10%	4.84E-05
OP4 floor		7.25E-05	+/-35.78%	**7.5E-05**	2.31E-05	+/-39.15%	**3.89E-05**	5.33E-06	+/-69.23%	**3.88E-05**
OP4 floor		**0.000104**	+/-35.17%	7.12E-05	**3.8E-05**	+/-43.55%	3.63E-05	2.65E-05	+/-42.08%	**3.46E-05**
OP4 floor		**0.000242**	+/-31.75%	7.73E-05	**4.02E-05**	+/-38.38%	4.01E-05	7.97E-06	+/-44.63%	**4.02E-05**

HEPA - a	0.2279	
beaker RD-13	0.982 (mld)	
can	0.7451	
pestal	0.2155	
beaker RD-14	0.3793	
screen	0.077 (mld)	
beaker RD-13	0.073 (mld)	
beaker RD-14	0.08117	
RF-24	0.05016	
RF-24a	0.02112	
HEPA	0.129 (mld)	
RF-23	0.04213	
RF-23a	0.04474	
RF-43	0.015 (mld)	
HEPA	0.4609	
RT-63	0.014 (mld)	
screen	0.04437	
OP-3		
glovebox area (cm²)	2000	
	g/cm²	grams
conserative activity	6.59E-05	1.32E-01
observed activity	4.79E-05	9.57E-02
OP-4		
glovebox area (cm²)	2200	
	g/cm²	grams
conserative activity	5.09E-05	1.12E-01
observed activity	3.11E-05	6.83E-02

Figure 4 -- Results of Data Grouping for Associated Data

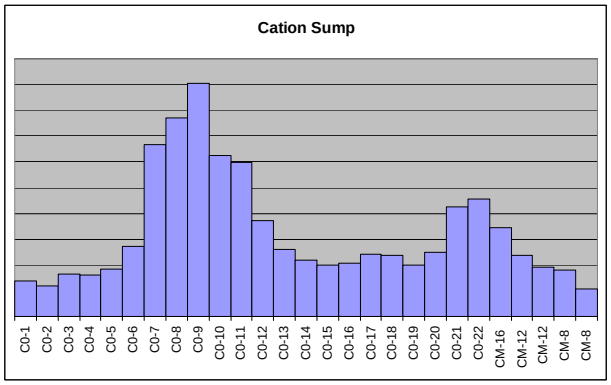

Figure 5 - Example of Report Manipulation for Gathering or Averaging of Associated Data

Another example might be to exam activity across an item. Figure 4 is a plot of a portion of collected data from a similar report. The story this plot reveals is activity build up at certain points along this sump. This comes with no surprise as those areas of increased activity are under processing equipment such as tanks, and columns. The report was used to prioritize cleanup efforts, rather than uniformly cleaning up the entire sump.

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