ENERGYSOLUTIONS

CS-FO-PR-004

QA/QC of Portable Radiological Survey Instruments

Revision 1

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☐ New

☐ Title Change

☒ Revision

☐ Re-Write

☐ Cancellation

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1.0 SCOPE

1.1 Purpose

The purpose of this procedure is to specify the general test requirements for handheld and portable radiological survey instruments to ensure continued proper operation. Any project specific requirements in addition to those specified in this procedure should be included in the site-specific Work Plans or other project specific documentation.

1.2 Applicability

This procedure applies to the following types of instruments for Commercial Services (CS) field projects:

- Radiation Survey Instruments (dose rate-meters),
- Contamination Survey Instruments (friskers), and
- Portable and Stationary Scalar Counters.

Instrumentation not specifically covered by this procedure, include laboratory analytical and specialized equipment such as:

- Gamma Spectroscopy Equipment,
- Alpha or Beta Spectroscopy Equipment,
- Liquid Scintillation Counters,
- Automated Counters, and
- Portal Monitors.

Although this procedure does not directly apply to the listed laboratory and specialized equipment, many of the concepts and test requirements as specified in this procedure can be applicable to these devices.

2.0 REFERENCES

2.1 ANSI N323A-1997, *American National Standard Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments*, April 1997.

2.2 CS-AD-PR-002, *Commercial Services Project Records*.

2.3 CS-FO-PR-001, *Performance of Radiological Surveys*

2.4 CD-FO-PR-002, *Calibration and Maintenance of Radiological Survey Instruments*.

2.5 DOE G 441.1-7, *Portable Monitoring Instrument Calibration Guide for Use with Title 10, Code of Federal Regulations, Part 835, Occupational Radiation Protection,* June 17, 1999.

2.6 ISO Standard 7503-1, *Evaluation of Surface Contamination - Part 1 Beta Emitters (Maximum Beta Energy Greater than 0.15 MeV) and Alpha Emitters*.

2.7 NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM), Revision 1, August 2000.

2.8 ES-AD-PR-009, *Control of Measuring and Test Equipment*.

3.0 GENERAL

3.1 Definitions

3.1.1. *Calibration* – Setting the response or reading of an instrument relative to a series of conventionally true values traceable to the National Institute of Standards and Technology (NIST).

3.1.2. *Check Source* – A radioactive source, not necessarily traceable to NIST, which is used to confirm the continuing satisfactory operation of an instrument.

3.1.3. *General Maintenance* – Activities allowable on instruments without requiring recalibration. These include light cleaning, battery and cable change outs, Mylar window replacements and repair, and other similar activities that do not impact the instruments' response.

3.1.4. *Radiological Survey Instrument* – A complete system designed to quantify one or more characteristics of ionizing radiation or radioactive material.

3.1.5. *Range* – All values lying between an upper and lower bound or an indicated limit.

3.1.6. *Response* – The instruments reading produced as a result of some influence quantity.

3.1.7. *Response Check* – The verification of an instruments response to a check source to determine whether the instrument is functioning within an acceptable range.

3.2 Responsibilities

Note: Depending upon personnel qualifications and the size of the project, project personnel may be assigned multiple roles and/or responsibilities.

3.2.1. Project Manager (PM)

The Project Manager is responsible for ensuring that the proper procedures and programs are implemented on the project site as required by customer agreements and contracts. The PM is responsible for ensuring that these programs and procedures are properly incorporated into project specific plans and procedures. The PM is responsible for ensuring that Commercial Services and/or client programs and procedures are available for use by field personnel.

3.2.2. CS Radiation Safety Officer (RSO)

The CS RSO maintains and oversees the implementation of the CS Radiation Protection Program (RPP). The CS RSO shall ensure that radiation safety, radioactive materials management, and radiological operations procedures and programs are kept up to date such that they comply with current regulations and incorporate current and relevant industry practices and regulatory guidance.

3.2.3. Radiation Protection Supervisor (RPS)

The RPS is responsible for implementing the CS RPP and the project specific radiological requirements at the field project location. The RPS manages and oversees the technicians performing radiation protection surveys and site monitoring and reports directly to both the PM and the CS RSO.

3.2.4. Project Health Physicist (PHP)

The PHP is responsible for assisting the CS RSO in providing health physics support to the PM and RPS. This includes technical support to ensure procedural and regulatory compliance and to ensure that the project specific Data Quality Objective are met.

3.3 Precautions and Limitations

3.3.1. This procedure is for the exclusive use of Energy*Solutions* Commercial Services field projects.

3.3.2. This procedure does not include discussions on electronic calibrations.

3.3.3. It should be noted that field instruments are often used in hostile environments different from those where the calibration and initial baseline response check was performed. As such, a baseline evaluation should be re-performed in the field as determined by the PHP or designee. Hostile environments are defined as those where extreme moisture, humidity, temperature or other similar condition exists which could potentially affect the operation or accuracy of the device.

3.3.4. For portable scalar counters such as smear counters, the tray height may have moved during shipment through normal vibration unless locked in place using a type of glue, adhesive or fingernail polish. As a result, the baseline evaluation as provided by the calibration facility should be evaluated and re-performed in the field as necessary.

3.3.5. Establish reproducible counting geometries for the baseline response evaluation and subsequent daily source checks.

3.3.6. Select a source to which the instrument will respond. This source does not have to be NIST traceable; however, if using the source to determine the instruments field efficiency, a NIST traceable source must be used.

3.3.7. When performing multiple source readings for Chi-Square testing, perform repetitive counting without handling the source.

3.3.8. When generating the data set for developing the systems control charts, **do not** repetitively count the source without handling. The source must be handled to remove and reposition the source between counts to introduce the inherent variability as a result of day to day source checks. If the source is repetitively counted without source handling, the counting statistics may be too restrictive and not representative of normal daily use. Obtain at least half of the measurements the first day while collecting the remaining measurements over a series of days to introduce any potential daily variances.

3.3.9. The Chi-Square test data may be used to establish preliminary control charts until a proper data set may be established; however, caution should be exercised as the sample set statistics from the Chi-Square test may be too restrictive until the proper day to day variance is established in the data set from normal source handling and counting.

3.3.10. Daily response tests and control charts are not required for instruments used for high radiation areas for qualitative or semi-quantitative measurements, as check sources of sufficient strength may not be available. Project specific procedures may provide specific requirements for these situations. A site acquired source of radioactivity may be used as a reference to check instrument response since source traceability is not required for response tests.

3.4 Records

3.4.1. The following records shall be maintained by the RPS or designee as applicable:

- Instrument calibration certificates,
- Maintenance histories of the instruments during the project,
- Post-calibration range determinations or baseline field readings,
- Identification of the source(s) used, and
- Daily instrument response test results and control charts to document instrument performance.

3.4.2. Copies of all the instrument records shall be maintained at the field project location in accordance with Reference 2.2.

4.0 REQUIREMENTS AND GUIDANCE

Radiation and contamination survey instruments shall have a baseline response evaluation performed to establish a test range in order to verify that the instrument continues to respond properly when in use. Results of the baseline evaluation should be kept with the instrument Calibration Certificate.

Depending upon the type of instrument, the baseline response evaluation will either consist of a Chi-Square Test for scalar counters and/or an initial response test for both dose rate and rate-meters and may either be performed at the calibration facility or at the project site (the preferred method). If using the control charts and baseline evaluations as performed at the calibration facility, caution should be taken in the event that the instrument setup may have changed during shipment through normal transportation and handling or due to differences in conditions between the calibration and operational locations (i.e., tray height and/or differences in operating temperatures and pressures).

4.1 Baseline Field Response (Rate-meters and Ion Chambers)

4.1.1. Establish a reproducible counting geometry as needed in order to perform the baseline evaluation and subsequent daily response tests.

4.1.2. Record the instrument and source information on the Baseline Response Evaluation Form, Attachment 5.1.

4.1.3. Obtain a baseline background reading at the response test location and record the reading on the Baseline Response Evaluation Form.

4.1.4. Using the selected source and the specific instrument, obtain the baseline instrument response or reading and record the reading on the Baseline Response Evaluation Form.

4.1.5. Calculate and record the **net** source reading.

4.1.6. Calculate and record the upper and lower control limits for the control chart. The upper and lower control limits shall be set at +/- 20% of the **net** source reading.

4.1.7. Complete the Baseline Response Evaluation Form and maintain the form with the project instrument records.

4.2 Background Evaluation (Scalar Counters)

4.2.1. Perform a minimum of ten (10) one (1) minute background counts (twenty (20) are preferred) to establish a background control chart in order to track the potential contamination of the instrument.

4.2.1.1. The number of measurements obtained will depend upon the detection sensitivity requirements for the instrument for subsequent field readings as applicable.

4.2.1.2. The individual background measurements may be summed to account for a longer background count time in order to obtain lower instrument detection sensitivities.

4.2.1.3. Record the individual measurement results on the Background Evaluation Form, Attachment 5.2.

4.2.1.4. In order to introduce any variability from background, perform background measurement staggered throughout the day.

Note: For portable scalar counters, the background evaluation is performed only for determining the presence of detector contamination or other problems with the detector. For detection sensitivity, background readings will be taken in the field within the area of the measurement location(s).

4.3 Chi-Square Test (Scalar Counters)

For scalar counters such as the Ludlum Model 2929, Eberline Model BC-4 or SAC-4, and gas flow proportional detectors used for direct field measurements (e.g., Ludlum Model 43-68) perform the following as directed by the PHP or designee.

4.3.1. If the Chi-Square tests and control charts were provided as part of the calibration paperwork, the PHP or designee may evaluate the acceptability of the paperwork in accordance with Step 4.4.1; otherwise, perform the Chi-Square test on-site as follows:

4.3.2. Establish a reproducible counting geometry as needed in order to perform the baseline evaluation and subsequent daily response tests.

4.3.3. Record the instrument and check source information on the Background and Chi-Square Test Forms, Attachments 5.2 and 5.3, as applicable.

4.3.4. If using the check source to determine the instruments field efficiency rather than using the efficiency as reported by the calibration facility, a NIST traceable source must be used.

4.3.5. Perform a minimum of ten (10) one (1) minute check source counts (twenty (20) are preferred) for Chi-Square testing. Record the **gross** readings in counts per minute (cpm) on the Chi-Square Test Evaluation From, Attachment 5.3.

4.3.6. Using the individual baseline check source readings, perform a Chi-Square test using, Attachment 5.3.

4.3.6.1. Calculate the mean of the gross source counts.

4.3.6.2. Calculate the difference between each gross source count and the mean.

4.3.6.3. Calculate the square of the differences for each source count.

4.3.6.4. Calculate the Chi-Square test value by summing the square of the differences and dividing by the mean.

$$\chi^2 = \frac{\sum (x - Mean)^2}{Mean}$$

4.3.6.5. Determine the acceptable confidence interval or decision errors for the statistical counting. Typical decision errors are 5 and 95 percent.

4.3.6.6. Determine the number of degrees of freedom (i.e., n-1 measurements).

4.3.6.7. Select the appropriate Chi-Square critical values for the Chi-Square test from Attachment 5.4.

4.3.6.8. If the Chi-Square test value as determined in Step 4.3.6.4 falls between the Chi-Square critical values, the instrument passes the Chi-Square test.

4.3.6.9. If the Chi-Square test value does not fall between the critical values, the instrument fails.

4.3.6.10. If the Chi-Square test fails, consult the PHP or designee. Additional measurements may be required (i.e., not enough measurements), there may not be enough variability within the measurement data set or the instrument is not operating properly and needs to be taken out of service.

4.3.7. Using the average background reading from the Background Evaluation, Attachment 5.2, determine and record the Instrument efficiency (ε_i) based upon the source surface emission rate (i.e., 2π geometry) in accordance with Reference 2.3.

4.3.7.1. Calculate the net source counts for each individual measurement using the average background reading.

4.3.7.2. Calculate the mean of the net source counts.

4.3.7.3. Divide the mean by the surface emission rate of the check source and record the Instrument efficiency.

4.3.8. Complete the Background and Chi-Square Test Forms and maintain the forms with the project instrument records.

4.4 Control Charts

4.4.1. Control charts may be provided by the calibration facility for use based upon baseline readings and a Chi-Square test performed at the calibration facility.

4.4.1.1. The PHP or designee shall evaluate the use of these forms.

4.4.1.2. If used, perform three baseline source checks prior to initial instrument use to ensure the control charts as provided are adequate.

4.4.1.3. If any of the three measurements fall outside the upper or lower control limit, contact the PHP and determine if a new Chi-Square test should be performed on-site and the control charts re-generated in accordance with Section 4.3 or if the instrument needs to be recalibrated.

4.4.2. If using field response data to generate the control charts as preferred, use the first 20 separate source counts.

4.4.2.1. Do not repetitively count the source without handling the source between counts.

4.4.2.2. Reposition the source between source counts to capture any inherent variability introduces source handling and positioning.

Figure 4-1

Rate-meter Control Chart (Example)

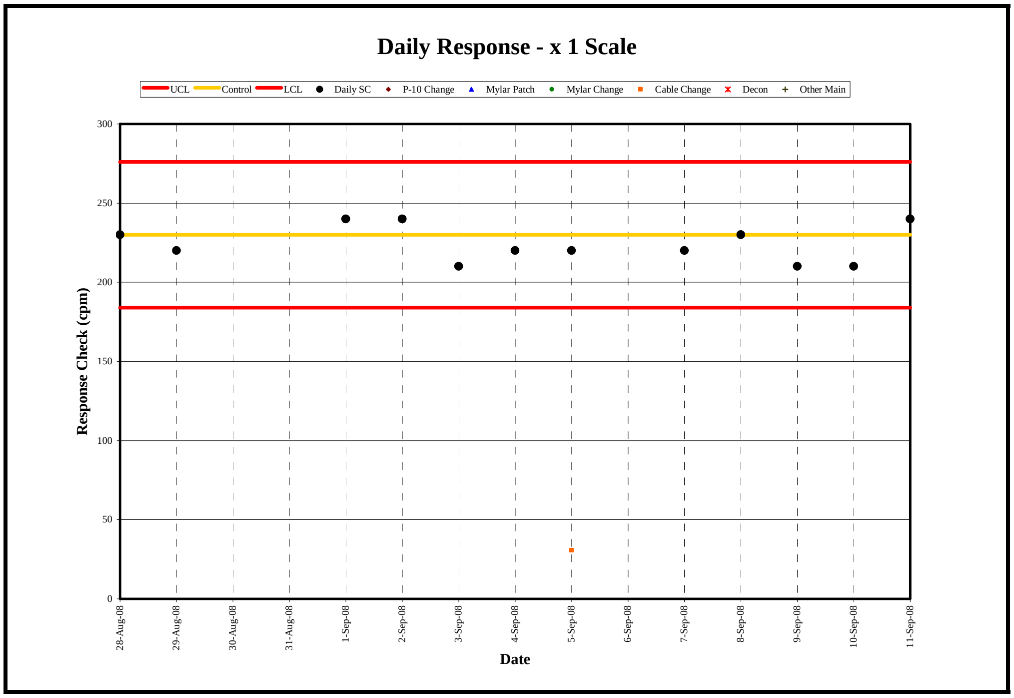
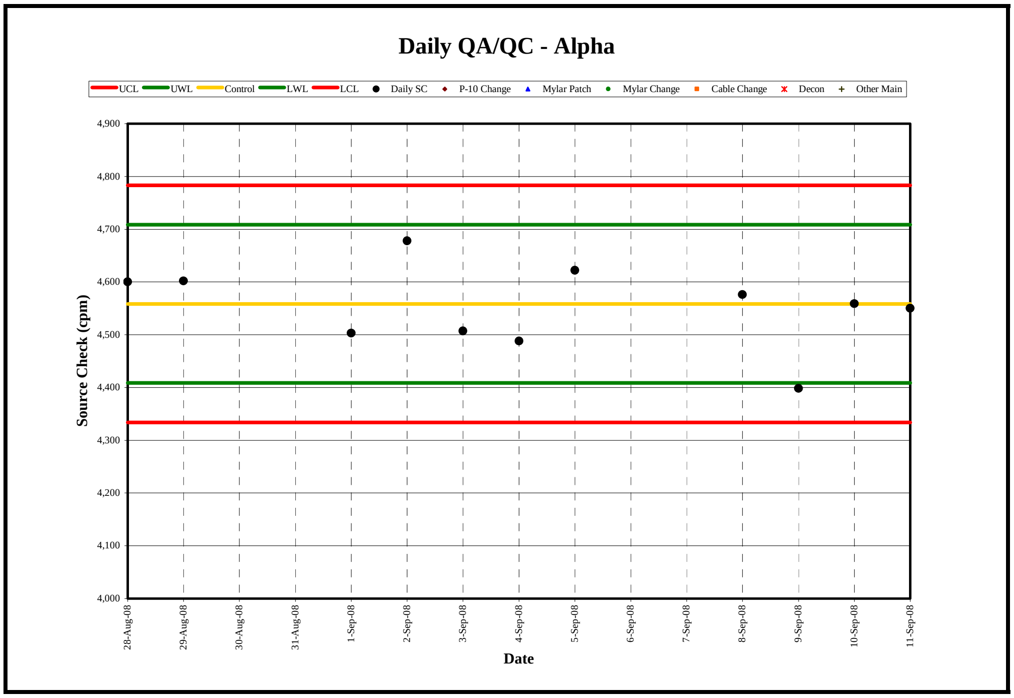


Figure 4-2

Scalar Counter Control Chart (Example)



4.4.2.3. In order to introduce any variability from day to day source checks, the source counts may be performed over a period of days by taking a minimum of ten (10) measurements the first day and then an additional ten (10) measurements over the next two days as determined by the PHP or designee.

4.4.3. For the daily response of rate and dose rate instruments, the upper and lower control limits of the control chart will be established at +/- 20% of the **net** baseline response reading in accordance with the guidance as provided in Reference 2.1. Figure 4-1 provides an example of rate-meter control chart.

4.4.4. For scalar counters, both upper and lower warning and control limits shall be established based upon the standard deviation of the **net** source count data set as determined using the first 20 source counts in accordance with Step 4.4.2. As a result, the control parameters will not be completely set until the first 20 counts are performed. Figure 4-2 provides an example of a scalar counter control chart.

4.4.4.1. The upper and lower warning limits shall be set as +/- 2 times the standard deviation around the mean.

4.4.4.2. The upper and lower control limits will be set at +/- 3 times the standard deviation around the mean.

4.4.5. Establish control charts to track the instrument background on a daily basis in order to identify any potential detector contamination.

4.4.5.1. The background control charts shall be established using the same methodology as described above depending upon the type instrument (scalar counter vs. rate/dose rate-meter).

4.4.5.2. The Upper and Lower background control limits for scalar counters will be set at +/- 3 time the standard deviation.

4.4.5.3. The Upper and Lower background control limits for rate and dose rate metes will be set at +/- 50% of the baseline background measurement.

4.4.5.4. For alpha meters, the lower control limit for the alpha background will typically be set at zero.

4.5 Daily Response / Source Check

4.5.1. The same source and geometry as used for the baseline response evaluation and control chart generation shall be used to verify the instrument response each day the instrument is used. The response shall be tracked on a control chart and be performed using the same reproducible geometry.

4.5.2. Record and plot the background reading on the applicable daily response or daily source check form, Attachments 5.5 or 5.6.

4.5.3. For rate and dose rate instruments, allow the instrument to stabilize over approximately 10 to 20 seconds and record the average observed gross instrument response on the applicable daily response check form, Attachment 5.5, and calculate the net reading.

4.5.4. For scalar counters, record the gross source check reading on the daily source check form, Attachment 5.6, and calculate the net reading.

4.5.5. Plot the net instrument readings on the applicable control chart(s).

4.5.6. If the instrument falls outside the upper or lower warning limits but within the upper or lower control limit for scalar counters, continue use of the instrument; however, take note and notify the RPS.

4.5.7. If the instrument response for either the scalar or rate/dose rate instruments falls outside the upper and lower control limit of the response range:

4.5.7.1. Perform two additional measurements.

4.5.7.2. If one of the two additional measurements fall outside the control limits, the instrument shall be removed from service for evaluation and/or repair. This is likely an indication of an instrument failure.

4.5.7.3. If both measurements fall within the control limits, continue use of the instrument; however, take note and monitor the instrument.

4.5.8. If the instrument is removed from service for repair and re-calibration, follow the guidance as provided in Reference 2.4.

4.5.9. Evaluate the control chart for any trends to determine if the instrument may be developing problems and not be operating properly.

4.5.9.1. The daily instrument response should fluctuate around the mean or control value randomly.

4.5.9.2. Evaluate the prior seven days of data and determine if the daily instrument response is either trending upward or downward. Seven consecutive measurements that are trending in a specific direction are an indication that the instrument may not be operating properly.

4.5.9.3. Determine whether the instrument is continually responding high or low in relation to the mean or control value. Seven consecutive measurements either above or below the mean or control value are an indication that the instrument may not be operating properly.

4.5.9.4. If any trends are identified, notify the PHP or designee so the instrument can be evaluated.

5.0 ATTACHMENTS AND FORMS

5.1 Baseline Field Response (*Rate-meters / Dose meters*)

5.2 Background Evaluation (*Scalar Counters*)

5.3 Chi-Square Test Form (*Scalar Counters*)

5.4 Chi-Square Critical Test Values (*Scalar Counters*)

5.5 Daily Response Check (*Rate-meters / Dose meters*)

5.6 Daily Source Check (*Scalar Counters*)

(Attachment 5.1)
Equivalent

Baseline Field Response

Instrument Model: ______________ Detector Model: ______________

Serial number: ______________ Serial Number: ______________

Calib. Due Date: ______________ Calib. Due Date: ______________

Scale	Background Counts (cpm)	Source Reading Counts (cpm)	Source Reading Net Count Rate (cpm)	(Net) Response Test Range LCL (cpm)	(Net) Response Test Range UCL (cpm)	Geometry
x 0.1						
						Source Isotope / SN /
x 1						
						Source Isotope / SN /
x 10						
						Source Isotope / SN /
x 100						
						Source Isotope / SN /
x 1,000						
						Source Isotope / SN /

Performed by: ______________________________ Date: __________

Reviewed by: ______________________________ Date: __________

(Attachment 5.2) Equivalent

Background Evaluation

Instrument Model: ____________________
Serial number: ____________________
Calib. Due Date: ____________________

Detector Model ____________________
Serial Number ____________________
Calib. Due Date ____________________
Emissions Detected: ____________________

Bkg Count Time (min): ____________________

Count	Alpha Background		Beta Background	
	Counts (gross counts)	Count Rate (cpm)	Counts (gross counts)	Count Rate (cpm)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

Mean: ____________________
Std Deviation: ____________________
LCL α ____________________
UCL α ____________________

Mean: ____________________
Std Deviation: ____________________
LCL β ____________________
UCL β ____________________

$$LCL = Mean - (3 * Std\ Dev) \qquad UCL = Mean + (3 * Std\ Dev)$$

Note: If the LCL is less than 0, then assign the LCL as 0.

Performed by: ______________________________ Date: __________

Reviewed by: ______________________________ Date: __________

(Attachment 5.3)

Chi-Square (χ^2) Test – Alpha / Beta Equivalent

Instrument Model: ____________
Serial number: ____________
Calib. Due Date: ____________

Mean Bkg Rate (cpm): ____________
Source CT (min): ____________

Tail Test Error (a): ____________
Tail Test Error (1-a): ____________

Detector Model: ____________
Serial Number: ____________
Calib. Due Date: ____________

Source Isotope: ____________
Serial Number: ____________
2π Emiss. (α or β/m): ____________

Instrument Eff. (ε_i): ____________

Count	Gross Counts "x" (cpm)	"x"-Mean (cpm)	("x"-Mean)²	Net Count Rate (cpm)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
Mean:				

Σ: ____________
Deg. Freedom (n): ____________

χ^2: ____________

$$\chi^2 = \frac{\sum (x - Mean)^2}{Mean}$$

Lower Control Limit: ____________
Upper Control Limit: ____________

χ^2 Test Results: ____________

Performed by: ______________________ Date: ____________

Reviewed by: ______________________ Date: ____________

(Attachment 5.4)

Chi-Square (χ^2) Critical Test Values

Degrees of Freedom (n-1)	Upper Critical Value					Lower Critical Value				
	$\chi^2_{0.995}$	$\chi^2_{0.990}$	$\chi^2_{0.975}$	$\chi^2_{0.950}$	$\chi^2_{0.900}$	$\chi^2_{0.100}$	$\chi^2_{0.050}$	$\chi^2_{0.025}$	$\chi^2_{0.010}$	$\chi^2_{0.005}$
1	0.000039	0.000157	0.000982	0.003932	0.015791	2.70554	3.84146	5.02389	6.63490	7.87944
2	0.010025	0.020101	0.050636	0.102587	0.210720	4.60517	5.99147	7.37776	9.21034	10.5996
3	0.071721	0.114832	0.215795	0.351846	0.584375	6.25139	7.81473	9.34840	11.3449	12.8381
4	0.206990	0.297110	0.484419	0.710721	1.06362	7.77944	9.48773	11.1433	13.2767	14.8602
5	0.411740	0.554300	0.831211	1.14548	1.61031	9.23635	11.0705	12.8325	15.0863	16.7496
6	0.675727	0.872085	1.23735	1.63539	2.20413	10.6446	12.5916	14.4494	16.8119	18.5476
7	0.989265	1.23904	1.68987	2.16735	2.83311	12.0170	14.0671	16.0128	18.4753	20.2777
8	1.34442	1.64648	2.17973	2.73264	3.48954	13.3616	15.5073	17.5346	20.0902	21.9550
9 (n=10)	1.73493	2.08791	2.70039	**3.32511**	4.16816	14.6837	**16.9190**	19.0228	21.6660	23.5893
10	2.15585	2.55821	3.24697	3.94030	4.86518	15.9871	18.3070	20.4831	23.2093	25.1882
11	2.60321	3.05347	3.81575	4.57481	5.57779	17.2750	19.6751	21.9200	24.7250	26.7569
12	3.07382	3.57056	4.40379	5.22603	6.30380	18.5494	21.0261	23.3367	16.2170	28.2995
13	3.56503	4.10691	5.00874	5.89186	7.04150	19.8119	22.3621	24.7356	27.6883	29.8194
14	4.07468	4.66043	5.62872	6.57063	7.78953	21.0642	23.6848	26.1190	29.1413	31.3193
15	4.60094	5.22935	6.26214	7.26094	8.54675	22.3072	24.9958	27.4884	30.5779	32.8013
16	5.14224	5.81221	6.90766	7.96164	9.31223	23.5418	26.2962	28.8454	31.9999	34.2672
17	5.69724	6.40776	7.56418	8.67176	10.0852	24.7690	27.5871	30.1910	33.4087	35.7185
18	6.26481	7.01491	8.23075	9.39046	10.8649	25.9894	28.8693	31.5264	34.8053	37.1564
19 (n=20)	6.84398	7.63273	8.90655	**10.1170**	11.6509	27.2036	**30.1435**	32.8523	36.1908	38.5822
20	7.43386	8.26040	9.59083	10.8508	12.4426	28.4120	31.4104	34.1696	37.5662	39.9968

(Attachment 5.5) Equivalent

Daily Response Check

Instrument Model: ________________ Detector Model: ________________

Serial Number: ________________ Serial Number: ________________

Cal. Due Date: ________________ Cal. Due Date: ________________

Instrument Scale ________________

Source Isotope: ________________ Source Number: ________________

Date	Background	Response Check		Performance	
	Reading (cpm)	Reading (cpm)	Net Count Rate (cpm)	Status (Pass / Fail)	Initials

Reviewed by: ________________________________ Date: __________

(Attachment 5.6) Equivalent

Daily QA/QC Systems Check – Alpha / Beta

Instrument Model: ________________ Detector Model: ________________ Source Isotope: ________________

Serial Number: ________________ Serial Number: ________________ Source Number: ________________

Cal. Due Date: ________________ Cal. Due Date: ________________ Instrument Eff. (ε_i): ________________

Count Times (min) Background: ________________ Source Check: ________________

Date	Background		Source Check			Performance	
	Gross Reading (counts)	Count Rate (cpm)	Gross Reading (counts)	Count Rate (cpm)	Net Count Rate (cpm)	Status (Pass / Fail / Warn)	Initials

Reviewed by: ________________________________ Date: __________