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AMC PAMPHLET
 NO. 750-20

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Maintenance of Supplies and Equipment

NUCLEAR COUNTING QUALITY ASSURANCE
 (NCQA) PROGRAM

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1. **PURPOSE.** This U.S. Army Materiel Command (AMC) Pamphlet prescribes guidance concerning a quality assurance program for nuclear counting operations.

2. **SCOPE.** a. This AMC Pamphlet is applicable to all AMC facilities that perform nuclear counting. It is intended to provide general guidance for performance of nuclear counting quality assurance. Wet chemistry sample preparation, i.e., bioassay or environmental analysis, is outside the scope of this document. Gamma spectrometry is also considered to be beyond the scope of this document.

b. The general categories of instrumentation covered under these procedures are as follows:

- (1) Gas flow proportional counting system.
- (2) Phoswich counting system.

(3) Liquid scintillation counting system.

c. Sample Categories. The general categories analyzed with the above specified equipment are as follows:

(1) Commodity leak test samples.

(2) Contamination survey/package swipe samples.

3. **RESPONSIBILITIES.** a. U.S. Army Primary Standards Laboratory Directorate (APSLD)--

(1) Establishes and maintains direct traceability to the National Institute of Standards and Technology (NIST) for radiation standards.

(2) Performs calibration/verification of radiation standards at the request of AMC secondary laboratories.

(3) Establishes a nuclear counting audit program that can be used by all AMC secondary laboratories that publish nuclear counting data.

(4) Performs voluntary nuclear counting audits of AMC secondary laboratories. The audit program will consist of two phases. The first phase will include an audit package; the second phase will include a review of quality assurance procedures to ensure that accurate counting data is published.

b. AMC secondary laboratories should--

(1) Comply with applicable requirements of this AMC Pamphlet for quality control procedures.

(2) Prepare user standard operating procedures (SOP). The SOP should include as a minimum: Counting equipment quality assurance (QA) procedures, instrument operating procedures, and sample tracking procedures. Sample collection procedures should be developed by each laboratory performing sample analysis and should be provided to their customers, as needed.

(3) Assure that appropriate calibrated standards or means of correlation to NIST standards are maintained for each analyses performed by the laboratory.

(4) Participate in nuclear counting audit program.

(5) Procure only NIST derived-traceable radioactive standards.

c. Organizations submitting samples for analysis:

(1) Assure that the appropriate sample collection and preparation techniques are maintained and followed for each sample submitted.

(2) Assure that adequate sample identification information is submitted with each sample.

4. **GENERAL.** a. ALARA. All quality control and analysis procedures will be performed in such a manner as to keep external and internal doses to radiation as low as reasonable achievable.

b. Appropriate radiation standards must be maintained for each radionuclide analyzed to include quench standard sets for liquid scintillation counting systems. Standards must have an accuracy of +/- 20 percent and should be calibrated at intervals not to exceed 2 years per TB 43-180. Commercially purchased liquid scintillation standards should not be used past their expiration date (normally 5 years from manufacture) unless verified by the Army Primary Standards Laboratory.

c. Only standards that have NIST or Environmental Protection Agency (EPA) derived traceability should be used to determine counter efficiencies.

d. Standard Operating Procedures should include specific references to be used for the identification of unknown samples, half-lives, and abundances.

e. Verify quality control parameters after equipment repair prior to using the unit to evaluate samples. If any of the parameters fall outside the control limits, reestablish all parameters to ensure proper machine operation.

f. Monthly evaluation of QA documentation should be performed by the laboratory manager or qualified designee.

g. Prepare and maintain instrument logbook for each instrument used for nuclear counting. The logbook entries should include maintenance, date of repair, gas cylinder changes, QA failures, or any changes that may affect the counting data.

h. Mobile laboratories should perform complete recalibration of counting equipment after each move prior to sample analysis. This should include initiation of all quality control parameters as provided in paragraph 5 of this document. Complete recalibration and initiation of a quality control program is warranted due to the shock that the delicate instrumentation must withstand during transportation to the new location.

5. INSTRUMENTATION QUALITY CONTROL PROCEDURES. Provided below are the minimum quality control requirements for nuclear instrumentation categories covered under this AMC Pamphlet.

a. *Gas flow proportional counting system.*

(1) A voltage plateau test should be performed to determine the proper operating voltage. Adherence to the manufacturer's specifications while performing a voltage plateau is important to prevent damage to the counter. This test should be performed upon receipt and after repair.

(2) A quarterly Chi-square test or equivalent should be performed for each radionuclide counted as specified in [appendix C](#). The purpose of this test is to ensure that the counts are consistent with a gaussian distribution. A chi-square should be performed for each radionuclide evaluated with the counter.

(3) A monthly efficiency check should be performed for all radionuclides counted. Isotopic efficiencies should be calculated per the equation in [appendix A](#).

(4) Ultra high purity counting gas should be used to reduce the potential for impurities. Impurities in the counting gas should result in erratic instrument performance. Gas regulators should be provided for accurate and reproducible gas flow settings.

(5) Perform a constancy check prior to sample analysis and incorporate it into the control chart as specified in [appendix D](#). The constancy check should include both background and standard counts. Performing a constancy check before counting samples ensures that these parameters haven't changed during the sample counting. Although not required, performance of a constancy check after completing sample analysis is highly recommended. Performing a postconstancy check ensures that the counter continued to operate properly throughout the counting process thus assuring accurate results.

b. *Phoswich counting system.*

(1) A quarterly Chi-square test should be performed as specified in [appendix C](#). The purpose of this test is to ensure that the counts are consistent with a gaussian distribution. A chi-square should be performed for each radionuclide evaluated with the counter.

(2) Perform a constancy check prior to sample analysis for incorporation into the control chart as specified in [appendix D](#). The constancy check should include both background and standard counts. Although not required, performance of a constancy check

after completing sample analysis is highly recommended. Performing a postconstancy check ensures that the counter continued to operate properly throughout the counting process, thus assuring accurate results.

(3) A monthly efficiency check should be performed for all radionuclides counted. Isotopic efficiencies should be calculated per the equation in [appendix A](#).

c. *Liquid scintillation counting system.*

(1) The liquid scintillation counter must be normalized/autocalibrated for the proper operating voltage on a weekly basis.

(2) A quarterly Chi-square test should be performed as specified in [appendix C](#). The purpose of this test is to ensure that the counts are consistent with a gaussian distribution. A chi-square test should be performed for each radionuclide evaluated with the counter.

(3) Perform a constancy check prior to sample analysis and incorporate it into the control chart as specified in [appendix D](#). The constancy check should include both background and standard counts. Although not required, performance of a constancy check after completing sample analysis is highly recommended. Performing a postconstancy check ensures that the counter continued to operate properly throughout the counting process thus assuring accurate results.

(4) Establish and maintain standard quench spectra for each radionuclide analyzed by the laboratory. Quench curves must be regenerated on an annual basis or after repair or maintenance.

d. *Scintillation Gamma counter.*

(1) A voltage plateau test should be performed to determine the proper operating voltage. This test should be performed upon receipt and after repair.

(2) A quarterly Chi-square test should be performed as specified in [appendix C](#). The purpose of this test is to ensure that the counts are consistent with a gaussian distribution. A chi-square should be performed for each radionuclide evaluated with the counter.

(3) A monthly efficiency check should be performed for all radionuclides counted. Isotopic efficiencies should be calculated per the equation in [appendix A](#).

(4) Perform a constancy check prior to sample analysis for incorporation into the control chart as specified in [appendix D](#). The constancy check should include both background and standard

counts. Although not required, performance of a constancy check after completing sample analysis is highly recommended. Performing a postconstancy check ensures that the counter continued to operate properly throughout the counting process thus assuring accurate results.

e. The table provided in [appendix F](#) provides a summary of control requirements for nuclear counting equipment covered under this AMC Pamphlet.

6. **SAMPLES.** Listed below are the minimum quality control requirements for the radiation sample categories covered under this AMC Pamphlet.

a. Commodity leak test samples.

(1) Establish and maintain procedures for sample leak test analysis. This should include procedures to adequately track the samples through the laboratory.

(2) Determine counting system sensitivity utilizing operational parameter information by performing Limit of Detection (LD) calculation for same radionuclide as commodity being leak tested per procedures specified in [appendix B](#). The LD for leak tests should be less than 0.0001 microcuries and must be stated on the analysis report. Determine the Limit of Decision (LC) per the equation in [appendix B](#). Results less than the LC should be reported as 0.000 microcuries. Since the LD and the LC are highly dependent on the background, the background should be counted frequently and averaged when counting multiple samples.

(3) Efficiencies should be determined using the same radionuclide as those counted. However, efficiencies between different radionuclides of the same energy should have similar efficiencies, i.e., alpha emitters in the 4-5 MeV range. If a radionuclide other than the one being counted is used to determine the efficiency, the radionuclide used to determine the efficiency should be indicated on the analysis report. Underestimating the efficiency is a conservative recommendation to ensure that contamination levels are overestimated instead of underestimated. Questions concerning similar radionuclides can be addressed to the APSL at DSN 746-0472.

(4) Provide sample analysis report; a suggested format is provided in [appendix E](#).

b. Contamination survey/package swipe samples.

(1) Establish and maintain procedures for contamination survey/package swipe sample analysis.

(2) Determine counting system sensitivity utilizing operational parameter information by performing LD calculation for same radionuclide as commodity being leak tested per procedures specified in **appendix B**. The LD for wipe tests should be less than 20 dpm and must be stated on the analysis report. Calculate the limit of decision (LC) per the equation in appendix B. Results below the limit of decision should be reported as 0.0 disintegrations per minute.

(3) Provide sample analysis report; a suggested format is provided in **appendix E**.

7. QUALITY ASSURANCE DOCUMENTATION. a. Prepare leak test analysis reports as suggested in appendix E. Leak tests of sealed sources must be reported in microcuries per federal requirements. Area and package wipes should be reported in disintegrations per minute per federal requirements. The LD should be reported in the same units as the analysis results. Results may be reported in both microcuries and disintegrations per minute simultaneously.

b. Calibration reports/certificates must be maintained for each calibration standard and must include the following information:

- (1) Isotope.
- (2) Source serial number.
- (3) Activity.
- (4) Assay date.
- (5) Counting geometry (2 π vs 4 π).
- (6) Report date.
- (7) Signature of the responsible individual.
- (8) Derivation to NIST standard (if not provided by NIST).

c. The following quality assurance documentation must be maintained to verify counter reliability and function. Quality assurance documentation must be maintained for a minimum of 3 years.

(1) Chi-square test results. This must be performed at least quarterly, for each radionuclide evaluated, to verify that the counter is operating consistently. It is recommended that the last 25 constancy checks be used to determine the chi-square statistic.

(2) Efficiency calculations. This should include the radionuclide, source serial number, and date of determination. These calculations must be done at least once per quarter.

(3) Constancy checks performed on each counter. Constancy checks should be plotted, preferably daily as the counter is used. The graph should be prepared using the chi-square data and be maintained until the next chi-square test is performed. These graphs indicate the consistent working of the counter over time. If the chi-square data is consistent and the centroid has not significantly fluctuated, the control chart can be continued for several quarters; however, the chi-square test must be performed to ensure counting consistency.

8. SUGGESTED CORRECTIVE ACTIONS. a. If the counters fail any of the quality assurance parameters discussed in this pamphlet, the data resulting from any analyses should be considered tainted and not used as official results. This section provides some general suggestions for corrective actions to routine failures. By no means is this list conclusive.

b. Chi square test. If your count data fails the chi-square test, the following items should be checked.

(1) Ensure that the source is counted sufficiently for each repetition to contain 10,000 counts.

(2) Ensure that the voltage is properly set. Incorrect voltage setting will cause small changes in voltage to result in large fluctuations in the number of counts.

c. Constancy check. If the constancy check falls outside three sigma of the mean value, check the following items.

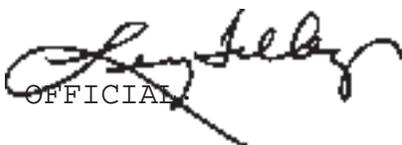
(1) Verify that the operating voltage is still at the appropriate point.

(2) Ensure gas flow is appropriate for gas flow proportional counters.

(3) Verify geometry. Ensure that the source is positioned correctly.

The proponent of this pamphlet is the United States Army Materiel Command. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, HQ AMC, ATTN: AMCSF, 5001 Eisenhower Avenue, Alexandria, VA 22333-001.

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APPENDIX A

COUNTER EFFICIENCY CALCULATION

Efficiency is defined as the probability that a count will be recorded when radiation is incident on a detector. When determining the efficiency, a calibrated source with a known 2π activity producing a minimum of 10,000 counts per minute will be used.

The equation used to calculate % Efficiency of a counting system is as follows:

$$\% \text{ Efficiency} = \frac{\text{Count Rate}}{\text{Disintegration Rate}} \times 100$$

Example: The net count rate of a counting system is 52703 cpm for a 75.1 nCi Am-241 source. Calculate the efficiency of the counting system.

$$\text{Disintegration Rate} = 75.1 \text{ nCi} \times 2.22 \times 10^3 \text{ dpm/nCi}$$

$$= 166,772 \text{ dpm}$$

$$\% \text{ Efficiency} = \frac{52703 \text{ cpm}}{166,722 \text{ dpm}} \times 100$$

$$= 31.6 \%$$

The system efficiency is used to convert recorded counts into activity.

Example: An Am-241 wipe of unknown activity is analyzed with a counting system possessing an AM-241 efficiency of 31.6 percent. Calculate the activity if a count rate of 5212 cpm is observed.

$$\text{Activity} = \frac{\text{Count Rate}}{\% \text{ Efficiency}}$$

$$\text{Activity} = \frac{5212 \text{ cpm}}{0.316}$$

$$= 16,494 \text{ dpm}$$

APPENDIX B

LIMIT OF DETECTION (LD) CALCULATION

The LD is defined as the smallest activity that has a p probability of being detected with only 1-p probability of a false negative. This sensitivity has been defined (EPA 1980) as the level above which there is less than a 5 % probability that radioactivity will be reported when it is really absent (Type I error) or reported absent when it is really present (Type II error). Please note that the formulas below represent the LD when the background and count time are the same.

Provided below is the equation used to calculate LD.

$$LD = \frac{2.71 + 4.65\sqrt{Bkg_{rate} * time}}{time * Efficiency}$$

where:

Bkg_{rate} = Background count rate
 Time = Sample count time
 Eff = Counting system efficiency

Example: A 100 minute background count yields a count rate 0.12 cpm for a counting system with an efficiency of 31.6 percent. Calculate the LD for the counting system in dpm.

$$LD = \frac{2.71 + 4.65\sqrt{0.12 * 100}}{100 * 0.316}$$

$$= 0.59 \text{ dpm}$$

To convert LD in dpm to uCi, divide the LD in dpm by 2.22×10^6 dpm/uCi:

$$\frac{0.59 \text{ dpm}}{2.22 \times 10^6 \text{ dpm/uCi}} = 0.0000003 \text{ uCi.}$$

To convert LD in dpm to Bq, divide the LD in dpm by 60:

$$\frac{0.59 \text{ dpm}}{60.0} = 0.009 \text{ Bq}$$

Limit of Decision Calculation (LC)

The LC is defined as the highest activity that has a p probability of not being detected with only 1-p probability of a false positive. This sensitivity has been defined (EPA 1980) as the level above which there is less than a 5 percent probability that radioactivity will be reported when it is really absent (Type I error) or not be reported when activity is present (Type II error). Please note that the formulas below represent the LC when the background and count time are the same.

The equation used to calculate LC is as follows:

$$LC = \frac{2.32\sqrt{Bkg_{rate} * time}}{time * Efficiency}$$

where:

Bkg_{rate} = Background count rate

Time = Sample count time

Eff = Counting system efficiency

Example: A 10-minute background count yields a count rate 0.12 cpm for a counting system with an efficiency of 31.6 percent. Calculate the LC for the counting system in dpm.

$$LC = \frac{232\sqrt{0.12*100}}{100*0.316}$$

$$= 0.25 \text{ dpm}$$

To convert LC in dpm to uCi, divide the LC in dpm by 2.22 x 10⁶ dpm/uCi:

$$\frac{0.25 \text{ dpm}}{2.22 \times 10^6 \text{ dpm/uCi}} = 0.000001 \text{ uCi.}$$

To convert LC in dpm to Bq, divide the LC in dpm by 60:

$$\frac{0.25 \text{ dpm}}{60.0} = 0.004 \text{ Bq}$$

APPENDIX C

CHI-SQUARE TEST

The operation of the counting system can be checked by determining the "goodness of fit" of data to a Poisson curve. The Chi-square test is a method for checking the operation of a counting system.

The equation used to perform a Chi-square test is as follows:

$$\chi^2 = \frac{\sum (N_i - \bar{N})^2}{\bar{N}}$$

Where:

N_i = Initial count value
 \bar{N} = the average value

A perfect fit to a Poisson distribution would yield a probability of 0.5. Low probabilities (< 0.02) indicate abnormally large statistical fluctuations. High probabilities (> 0.98) indicate abnormally small fluctuations.

Example: Perform a Chi-square test on the following data obtained from a nuclear counting system: 10150 counts, 9998 counts, 9899 counts, 10060 counts, 9954 counts, 10099 counts, 9999 counts, 10005 counts, 10027 counts, and 9979 counts. (Please note that when performing a chi-square test, counts exceeding 10,000 counts should be used.)

Calculate the average count (\bar{x}) as follows:

$$n = 10$$

$$\sum x_i = 100160$$

$$\bar{N} = \frac{1}{n} \sum N_i$$

$$= \frac{1}{10} \cdot 100160$$

$$= 10016 \text{ counts}$$

Calculate the Chi-square value as follows:

i	N_i	$N_i - \bar{N}$	$(N_i - \bar{N})^2$
1	10150	+134	17956
2	9988	-28	784
3	9899	-117	13689
4	10060	+44	1936
5	9954	-62	3844
6	10099	+83	6889
7	9999	-17	289
8	10005	-11	121
9	10027	+11	121
10	9979	-37	1369
	100160	0	46998

$$\chi^2 = \frac{\sum(N_i - \bar{N})^2}{\bar{N}}$$

$$\begin{aligned} \chi^2 &= \frac{46998}{10016} \\ &= 4.692 \end{aligned}$$

Using table C-1 the calculated Chi-square value of 4.692 is determined to be between the probability of 0.050 and 0.950 for 9 degrees of freedom (n-1 or 10-1). The data set is acceptable if the probability of the chi-square statistic is greater than or equal to 0.050 and less than or equal to 0.950 ($P_{\chi^2} \geq 0.050$ and $P_{\chi^2} \leq 0.950$). This represents the acceptable responses at a 95 percent confidence limit.

Table C-1
CHI-SQUARE VALUES

Chi-Square Values Degrees of Freedom (n-1)	There is a probability of						
	0.99	0.95	0.90	0.50	0.10	0.05	0.01
	that the calculated value of Chi-square will be equal to or greater than						
2	0.020	0.103	0.211	1.386	4.605	5.991	9.210
3	0.115	0.352	0.584	2.366	6.251	7.815	11.345
4	0.297	0.711	1.064	3.357	7.779	9.488	13.277
5	0.554	1.145	1.610	4.351	9.236	11.070	15.086
6	0.872	1.635	2.204	5.348	10.645	12.592	16.812
7	1.239	2.167	2.833	6.346	12.017	14.067	18.475
8	1.646	2.733	3.490	7.344	13.362	15.507	20.090
9	2.088	3.325	4.168	8.343	14.684	16.919	21.666
10	2.558	3.940	4.865	9.342	15.987	18.307	23.209
11	3.053	4.575	5.578	10.341	17.275	19.675	24.725
12	2.571	5.226	6.304	11.340	18.549	21.026	26.217
13	4.107	5.892	7.042	12.340	19.812	22.362	27.688
14	4.660	6.571	7.790	13.339	21.064	23.685	29.141
15	5.229	7.261	8.547	14.339	22.307	24.996	30.578
16	5.812	7.962	9.312	15.338	23.542	26.296	32.000
17	6.408	8.672	10.085	16.338	24.769	27.587	33.409
18	7.015	9.390	10.865	17.338	25.989	28.869	34.805
19	7.633	10.117	11.651	18.338	27.204	30.144	36.191
20	8.260	10.851	12.443	19.337	28.412	31.410	37.566
21	8.897	11.591	13.240	20.337	29.615	32.671	38.932
22	9.452	12.338	14.041	21.337	30.813	33.924	40.289
23	10.196	13.091	14.848	22.337	32.007	35.172	41.638
24	10.856	13.848	15.659	23.337	33.196	36.415	42.980
25	11.534	14.611	16.473	24.337	34.382	37.382	44.314
26	12.198	15.379	17.292	25.336	35.563	38.885	45.642
27	12.879	16.151	18.114	26.336	36.741	40.113	46.963
28	13.565	16.928	18.939	27.336	37.916	41.337	48.278
29	14.256	17.708	19.768	28.336	39.087	42.557	49.588

APPENDIX D

CONTROL CHARTS

Once a nuclear counting system is operational and running, it is important to periodically check the system to ensure that it continues to function properly. The Chi-square test is a good method for verifying operation of the system; however, it does not enable the operator to spot trends. The control chart is a graphical representation of past and present performance of the counting system.

To initially generate a control chart, count a source 20-30 times (at approximately 10,000 - 25,000 counts each) and calculate the chi-square statistic. Use the data set if the probability of the chi-square statistic is greater than or equal to 0.10 and less than or equal to 0.90 ($P_{\chi^2} \geq 0.10$ and $P_{\chi^2} \leq 0.90$).

Provided below is an example of control chart preparation. In the example the chart is prepared by obtaining 25 counts of a radiation standard and by calculating the average and ± 2 and 3 sigma of the independent readings. It will be necessary to decay correct each count to the day the chart was prepared to ensure the proper operation of the chart. This example should not be interpreted as the only acceptable method for control chart preparation.

Example: A 25 nCi Cs-137 standard was counted 25 times using identical source/detector geometrical configuration. The following counts were obtained: 22500, 21050, 23100, 22367, 22567, 22199, 22567, 21300, 21963, 23002, 22345, 22752, 22115, 21642, 22603, 21987, 22425, 21775, 23101, 22566, 22242, 22333, 22467, 22345, and 22512.

The average is calculated as follows:

$$\bar{x} = (1/n) \sum x_i$$

$$\bar{x} = 22313 \text{ counts}$$

The standard deviation is calculated as follows:

$$\sigma = \left\{ \frac{\sum (x - x_i)^2}{(n-1)} \right\}^{1/2}$$

$$= 498 \text{ counts}$$

$$2\sigma = 996 \text{ counts}$$

$$3\sigma = 1494$$

$$\text{upper limit } (+3\sigma) = 22313 + 1494 = 23807$$

$$\text{upper warning } (+2\sigma) = 22313 + 996 = 23309$$

$$\text{Centroid} = 22313$$

lower warning (-2σ) = $22313 - 996 = 21317$
 lower limit (-3σ) = $22313 - 1494 = 20819$

The graph is then plotted as the count versus the day of the month. The centroid and the upper and lower limits are indicated on the chart. See the example in figure 1. As long as the daily plot points fall between the upper and lower limit, the counter is operating properly. However, if the plot point falls outside the upper and lower limits, the counter is not operating correctly and corrective action should be performed. Please note, with a 95% confidence limit you can expect one count of every twenty to fall outside the limits. If this happens, recount the standard and background before taking corrective action. If the standard falls within the 2σ limits, continue counting. The 2σ limit is a warning level indicating that a potential problem exists and should be investigated. Do not use counting results if the 3σ limit is exceeded.

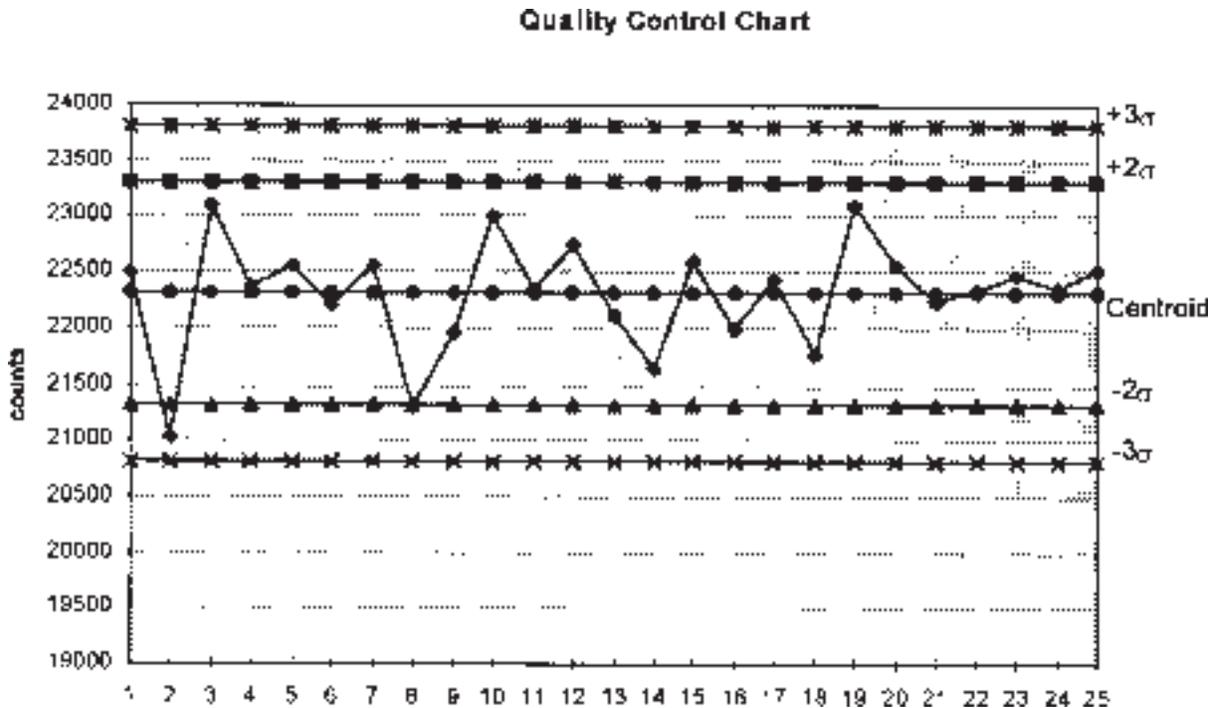


Figure 1

In the above example the 25 counts are plotted as though they were daily constancy checks. Normally, the chart would be prepared as mandated above and then the daily constancy check would be plotted to ensure that the counter is operating correctly that day. A constancy check is performed prior to sample analysis by counting the same standard once and plotting the results at the corresponding timeframe on the control chart. The control chart usually covers a 1-month period.

APPENDIX E

SAMPLE LEAK TEST REPORT

Office Symbol (Marks File Number)

Date

MEMORANDUM FOR RECORD

SUBJECT: Leak Test Analysis Report for Calibrator S/N XXXX

1. The results for subject leak test made on Date are provided below:

<u>Serial Number</u>	<u>Nomenclature</u>	<u>Microcuries (uCi)</u>
Calibrator S/N XXXX	Source Rod	X.XXX
	External Port	X.XXX

Note: The limit of detection is X.XXXXXX uCi.

2. The results for the subject leak test are within routine limits defined by the U.S. Nuclear Regulatory Commission.

Signature Block

APPENDIX F

NUCLEAR COUNTING EQUIPMENT QUALITY CONTROL REQUIREMENTS

Nuclear Counting Equipment Quality Control Requirements			
<i>Counting System</i>	<i>Constancy Check Prior to analysis</i>	<i>Quarterly Chi-Square Test</i>	<i>Voltage Plateau Generation</i>
Gas Flow Proportional Counting System	X	X	X
Liquid Scintillation Counter	X	X	X*
Scintillation Gamma Counter	X	X	X

APPENDIX G

REFERENCES¹

1. Title 10, Code of Federal Regulations, Parts 0-50. Available from the Government Printing Office.
2. National Council for Radiation Protection and Measurement Report No. 58. "Handbook of Radioactivity Measurements," 1 Feb 85. Available from NCRP Publications, 7910 Woodmont Ave, Suite 1016, Bethesda, MD 20814, Phone: (301) 657-2652.
3. NUREG/CR-5849, Manual for Conducting Radiological Surveys in Support of License Termination, June 1992. Available from the US NRC.
4. "Limits for Qualitative Detection and Quantitative Determination," by Lloyd A. Currie, published in Analytical Chemistry, Vol. 40, No. 3, March 1968.
5. Quality Assurance Program Requirements for Nuclear Facilities, ANSI/AMSE NQA-1, 1989 Edition. Available from the American National Standards Institute.
6. "A Method for Computing the Decision Level for Samples Containing Radioactivity in the Presence of Background," by T.B. Borak and T.B. Kirchner, Health Physics Journal, Vol. 69, No. 6, December 1995.
7. Measurement Quality Assurance for Radioassay Laboratories, ANSI-N42.2, 1 June 1993. Available from the American National Standards Institute.
8. Handbook for Analytical Quality Control in Radioanalytic Laboratories, U.S. Environmental Protection Agency, EPA-600/7-77-088, August 1977.
9. Manual for the Certification of Laboratories Analyzing Drinking Water, Criteria and Procedures Quality Assurance, U.S. Environmental Protection Agency, EPA/570/9-90/008, April 1990.
10. Quality Control for Environmental Measurements Using Gamma-Ray Spectroscopy, U.S. Environmental Protection Agency, EPA-600/7-77-144, December 1977.

¹ References have been included for background informational purposes. All references have not been consulted in the preparation of this pamphlet.

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11. Upgrading Environmental Radiation Data, U.S. Environmental Protection Agency, EPA 520/1-80-012, August 1980.

12. Traceability of Radioactive Sources to National Institute of Standards and Technology (NIST) and Associated Instrument Quality Control, American National Standards Institute N42.22, November 1995.

GLOSSARY

a. **ALARA:** (acronym for "as low as is reasonably achievable") means making every reasonable effort to maintain exposures to radiation as far below the dose limits in 10 CFR 20 as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

b. **Chi-square test:** A method for statistically checking the operation of a counting system.

c. **Constancy Check:** A daily, or prior to sample analysis, check of the background and standard performed to ensure proper operation of the counting equipment. The constancy check should be plotted on the control chart to ensure the results fall within acceptable parameters prior to counting unknowns. If the results do not fall within the acceptable parameters, other corrective action should be taken, i.e., checking the voltage setting, checking the efficiency, checking the geometry, etc. The background should be counted for the same time as the samples.

d. **Control Chart:** A graphical representation of past and present performance of a counting system.

e. **Counting System Sensitivity:** The statistically determined quantity of radioactive material that can be measured or detected at a preset confidence level.

f. **Derived Sources:** A radioactive source which has been prepared from a NIST traceable liquid standard, but has not been evaluated for accuracy by a traceable means.

g. **Efficiency:** The probability that a count will be recorded when radiation is incident on a detector. The counting system efficiency is used to convert recorded counts into activity. The equation used to calculate counting system % efficiency is discussed in appendix A.

h. **Energy Resolution:** The energy distribution of incident radiation in a counting system. Energy resolution is defined in terms of the full width of the peak at half maximum altitude (net) [FWHM] divided by the location of the peak centroid E_0 .

i. **Leak Test:** Performed to determine the amount of removable contamination present in a measured unit area. A test performed on a sealed radioactive source to determine if it is leaking. The area tested is not significant in a leak test.

j. **Limit of Decision (LC):** The highest activity that has a p probability of not being detected with a $1-p$ probability of a false positive. The equation used to calculate the LC of a counting system is discussed in appendix B.

k. **Limit of Detection (LD):** A method for determining counting system sensitivity. The LD is defined as the smallest activity that has a p probability of being detected with only $1-p$ probability of a false negative. The equation used to calculate LD of a counting system is discussed in appendix B. The LD is used to determine the counting system sensitivity.

l. **NIST Traceability:** The process of relating the measurement accuracy of radionuclide sources to national physical standards. Traceability is achieved by demonstrating the capability to produce accurate standardized sources by participation in a Measurement Assurance Program (MAP) with linkage to NIST and production of certified materials in accordance with a quality assurance program that meets the guidance provided in ANSI N42.22, Traceability of Radioactive Sources to the National Institute of Standards and Technology and Associated Instrument Quality Control. Traceability of sources requires demonstrated measurement traceability as described in clause 6, N42.22, and applies only to products produced in accordance with N42.22.

m. **Nuclear Counting:** Evaluation of sample media, for official record, to determine if radioactive contamination is present.

n. **Quench Spectra:** Graphic presentations of liquid scintillation counting data indicating the position of the beta peak in relation to the quench. These spectra are used to identify different isotopes by energy and quench level.

o. **Radioactive Standard:** A sample of radioactive material with National Institute of Standards and Technology traceability, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known.

p. **Secondary Laboratories:** All AMC laboratories other than the Primary Standards Laboratory which perform nuclear counting.

q. **Type I Error:** Deciding that radioactivity is present when it is in fact not present.

r. **Type II Error:** Deciding that radioactivity is not present when it is in fact present.

s. **Wipe Test:** Performed to determine the amount of removable contamination present in a measured unit area. Area wipe tests measure the removable contamination within a 100 cm² area. Package wipe tests measure the removable contamination within a 300 cm² area.