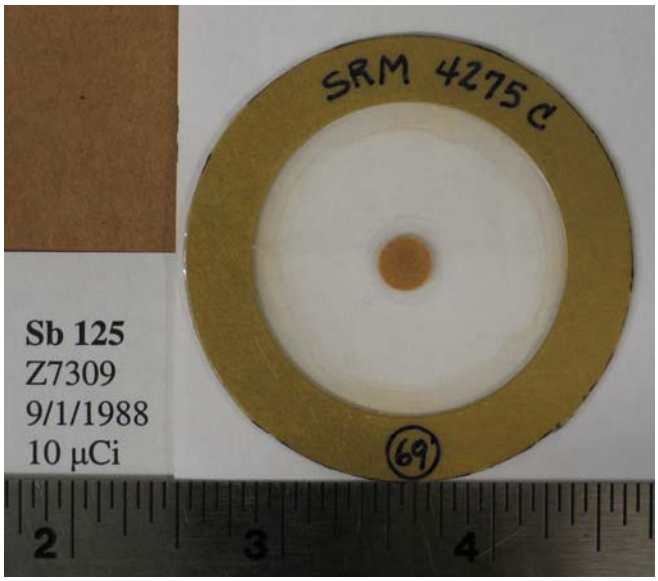
Source Data Sheet:

Sb125

9/1/1988 **10 µCi** **Z7309**

Gamma
Point source on Polyester tape
Supplier: NB



Half-Life: 2.77 years

Comments:

National Institute of Standards & Technology

NSCL-309

Certificate

Standard Reference Material 4275C
Radioactivity Standard

MIXED-RADIONUCLIDE POINT-SOURCE STANDARD
for the
EFFICIENCY CALIBRATION OF GERMANIUM-SPECTROMETER SYSTEMS

Antimony-125-Tellurium-125m
Europium-154
Europium-155

Source identification	SRM 4275C-69
Source description	Point source on polyester tape (1)*
Reference time	1200 EST September 1, 1988

This standard is intended for use in measuring the full-energy-peak efficiencies of spectrometry systems for x and gamma rays from 27 to 1596 keV, provided that the responses to radiations approximately 5 keV apart can be resolved. Emission rates are specified at 18 energies for photon radiations from a mixture of antimony-125-tellurium-125m, europium-154, and europium-155. Uncertainties are estimated and combined at a level corresponding to a standard deviation of the mean, with the intent that the user can propagate this uncertainty along with the other uncertainties in the spectrometer calibration. For a more conservative overall uncertainty corresponding to that given on other NIST radioactivity certificates, multiply the combined uncertainty by three.

Table 1 gives the energies, emission rates, and uncertainties for selected radiations. A footnote indicates how emission rates will change with time. If there are any changes in measured emission rates that would correspond to an emission rate 0.5 percent different from that calculated from Table 1, or in measured half lives that would cause a corresponding difference after five years, notification will be sent to purchasers of the standard.

Table 2 lists the estimates of component uncertainties which have been added in quadrature to give the combined uncertainty in each emission rate.

Notes on the use of this standard are appended. One of the tables in the supplemental notes gives relative emission rates for radiations close in energy to the certified radiations; for spectrometry systems of poorer resolution, it may be necessary to use a combined emission rate for some multiple peaks.

This Standard Reference Material was prepared in the Center for Radiation Research, Ionizing Radiation Division, Radioactivity Group, Dale D. Hoppes, Group Leader.

Gaithersburg, MD 20899
September, 1988

Stanley D. Rasberry, Chief
Office of Standard Reference Materials

*Notes on page 4

THIS IS A PHOTOCOPY OF THE CERTIFICATE
WHICH IS BEING MAILED TO YOU UNDER
SEPARATE COVER.

National Institute of Standards & Technology

Certificate

Standard Reference Material 4275C
Radioactivity Standard

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TABLE 2

Estimates of the Component Uncertainties for
Photon-Emission-Rate Values for SRM 4275C

TYPICAL UNCERTAINTY COMPONENTS (%)

Photon Energy (keV)	Number of Determi-nations	Std. Dev. of the Mean	Effici-ency	Peak Analysis	Pile-up Compen-sation	Geometry	Other*	Combined Uncer-tainty**
27.4	6	0.3	1.0	0.7	0.3	0.1	0.3	1.3
42.8	12	0.05	1.0	0.7	0.1	0.1	0.3	1.3
86.5	12	0.06	0.70	0.5	0.1	0.1	0.3	0.9
105.3	12	0.06	1.2	0.5	0.1	0.1	0.4	1.3
123.1	6	0.08	0.6	0.4	0.1	0.08	0.4	0.8
176.3	6	0.09	0.5	0.2	0.2	0.1	0.4	0.6
247.7	6	0.04	0.5	0.3	0.1	0.08	0.4	0.6
427.9	6	0.23	0.7	0.2	0.2	0.08	0.4	0.8
463.4	7	0.22	0.58	0.2	0.2	0.08	0.4	0.7
591.8	6	0.12	0.45	0.3	0.1	0.08	0.4	0.6
600.6	7	0.20	0.42	0.4	0.2	0.08	0.4	0.7
635.9	6	0.19	0.42	0.2	0.2	0.08	0.4	0.6
723.3	6	0.05	0.54	0.2	0.1	0.08	0.4	0.6
873.2	5	0.12	0.63	0.3	0.1	0.08	0.4	0.7
996.3	5	0.11	0.54	0.75	0.1	0.08	0.4	0.9
1004.7	5	0.06	0.54	0.4	0.1	0.08	0.4	0.7
1274.5	5	0.06	0.45	0.1	0.1	0.08	0.4	0.5
1596.4	6	0.43	0.40	0.1	0.2	0.15	0.4	0.7

* Includes contributions for the half lives for the Te x ray, for the decay schemes for the Gd x ray, and for gravimetric factors in the source preparation.

**Components of the uncertainty have been added in quadrature. This is the uncertainty for a typical detector, and some of the values are slightly greater than those given in the last column in Table 1.

TABLE 1

X-Ray and Gamma-Ray Energies, Emission Rates [2,3], and Uncertainties for Standard Reference Material 4275C-69

Radionuclide	Photon Energy (keV)	Emission Rate ($\times$ s^{-1}) or (γ s^{-1}) 1200 EST September 1, 1988	Total Estimated Uncertainty (%)*
^{125}Sb-^{125m}Te	Kα, 27.4	3.766×10^4	1.3
^{154}Eu-^{155}Eu	Kα, 42.8	2.222×10^4	1.3
^{155}Eu	86.5	8.503×10^3	0.9
^{155}Eu	105.3	5.922×10^3	1.3
^{154}Eu	123.1	3.460×10^4	0.8
^{125}Sb	176.3	4.133×10^3	0.6
^{154}Eu	247.7	5.864×10^3	0.6
^{125}Sb	427.9	1.796×10^4	0.8
^{125}Sb	463.4	6.315×10^3	0.7
^{154}Eu	591.8	4.197×10^3	0.6
^{125}Sb	600.6	1.067×10^4	0.7
^{125}Sb	635.9	6.820×10^3	0.6
^{154}Eu	723.3	1.703×10^4	0.6
^{154}Eu	873.2	1.034×10^4	0.7
^{154}Eu	996.3	8.850×10^3	0.9
^{154}Eu	1004.7	1.534×10^4	0.7
^{154}Eu	1274.5	2.958×10^4	0.5
^{154}Eu	1596.4	1.503×10^3	0.7

* Estimated total uncertainties have the significance of one standard deviation of the mean. Components of these estimates are given in Table 2.

NOTES ON THE USE OF STANDARD REFERENCE MATERIALS 4275-C AND 4276-C

MEASURING EFFICIENCIES OF GERMANIUM SPECTROMETER SYSTEMS

WITH NIST LONG-LIVED MIXED-RADIONUCLIDE STANDARDS

1. Introduction

Careful measurements with many calibrated single-radionuclide sources may give the most accurate efficiency-energy relations for germanium spectrometers, but the use of one source with established photon (gamma-ray or x-ray) emission rates at many energies often suffices and is more convenient. There is a further convenience if the radionuclides involved are long-lived, for experience has shown that system efficiencies should be checked periodically.

Inevitably, there are compromises in the composition of such standards, especially if they are to have a sufficient density of photon energies to define the calibration relation without a strong dependence on an assumed analytic relation. In selecting the components for the present long-lived mixed- radionuclide standard, we considered the balance of emission rates at significant energies, spectral conflicts, source attenuation, simplicity in use, cascade summing, calibration difficulties, and the cost and availability of the radionuclides.

The standard is composed of ^{125}Sb (with ^{125m}Te in equilibrium), ^{154}Eu, and ^{155}Eu. Photon-emission rates for the major radiations have been measured with four germanium spectrometry systems especially calibrated for the purpose, and subsequently checked internationally and with other NIST systems. These emission rates are specified with total uncertainties of from 0.6 to 1.3 percent, estimated to correspond to one standard deviation of the mean. The goal was to provide the users of the standards with a "realistic" uncertainty (as opposed to one which is very conservative) that can be combined with others entering into detector calibrations (such as those from counting statistics, geometry and rate differences, cascade summing, and peak evaluation) to generate an uncertainty for their calibration curves. Note that the combined uncertainty should be multiplied by a factor of approximately three if it is to be compared with the overall uncertainty usually quoted for sources calibrated as to activity.

New information will be supplied to purchasers whenever we have reason to believe that an emission-rate value is different from that stated by 0.5 percent, or when the accuracy has improved significantly. The emission rate at 86.5 keV has been revised relative to that in the A and B issues of these SRMs as a result of further measurements.

These standards supply many useful calibration points between 27 and 1596 keV, with other long-lived NIST standards such as ^{60}Co, ^{133}Ba and ^{152}Eu, available to fill in sparse regions and extend the calibrations to higher energies, if that is required. Standards of ^{22}Na, ^{54}Mn, ^{88}Y, ^{139}Ce, ^{207}Bi, and ^{228}Th (plus progeny) are also sometimes available from NIST or other suppliers with demonstrated traceability of calibrations to NIST.

We will now describe some points that should be considered in using the standards, and in applying gamma-ray spectrometry in general. A bibliography at the end of the report lists a few significant references, some of which describe the techniques used in the gamma-ray emission rate measurements for these standards.

2. Calculation of Emission Rates at Later Times

The half lives of only ^{125}Sb, ^{154}Eu, and ^{155}Eu are involved in the calculation. However, the gadolinium x rays, which supply a useful calibration point for good-resolution detectors, result from both ^{154}Eu and ^{155}Eu decays and hence the calculation involves the sum of two components, as shown on the certificate notes. The current half lives and uncertainties from continuing NIST measurements are: ^{125}Sb - 1008 ± 2 days; ^{154}Eu - 3141 ± 12 days; and ^{155}Eu - 1738 ± 4 days. These values are supported by other recent measurements elsewhere.

We will continue to monitor the emission rates for pure samples of each radionuclide, and report to the purchasers any change that would make a difference of greater than 0.5 percent after 5 years.

3. Spectral Conflicts

A complete list of the more than 200 gamma rays reported for this mixture would discourage any consideration of using such sources as efficiency-calibration standards, but an examination of spectra (similar to those as shown in Figures 1 and 2) indicate that there are about 20 dominant peaks, with few serious energy conflicts for good resolution detectors and few background difficulties (Compton edges or backscatter peaks) that interfere with peak-area analyses to more than one percent. For poorer-resolution detectors, the contributions of weak peaks in the 176-keV region must be considered, and the analysis of the triad at about 600 keV and the doublet at 1 MeV will present a challenge if the peaks are analyzed separately. However, a simple summing of channel contents, after an interpolated or extrapolated background has been subtracted, can give areas accurate to about 2 percent, for energies of 87 keV or greater. For all systems, the challenge of constructing a consistent and smooth calibration curve, within the uncertainties shown on the emission-rate table, may prove informative about techniques and uncertainties. We are investigating better analysis techniques, and would be interested in non-abusive user comments if discrepancies are found.

Above 120 keV, the accuracy of some NIST emission-rate values appear to be limited by peak analysis uncertainties rather than efficiency uncertainties for our detectors. Below 120 keV, the converse is true for gamma rays, with the paucity of reliable efficiency points making interpolations less certain. For the x rays, the deviation of our measured K_α to K_β ratios from literature values indicates that peak-area measurements are less reliable for these radiations at the present time, and this is reflected in the uncertainties quoted.

Table 1 lists the dominant photon energies, and suggests where conflicts may occur. The probability of interfering gamma rays, relative to the probability of the dominant gamma ray, are from NIST measurements, or literature values for some very small contributions. Users can judge if conflicts are significant for their system resolution and their required uncertainties, and make corrections (some of which change with time) if necessary.

4. Pulse-Summing Corrections

When two radiations strike a germanium detector within the shaping time of the amplifier, one or both can fail to be recorded in channels where they would have been otherwise. This time coincidence may occur because of an accidental overlap of pulses resulting from the decay of two separate nuclei, or it may arise from the detection of nearly simultaneous cascade radiations in the decay of the same nucleus.

In the former case of the accidental pile-up of pulses, the rate-dependent losses can be monitored with a constant-rate-pulser peak or almost accounted for with a pile-up rejecter and live-time circuit. The live timer of a slow multi-channel analyzer may provide a partial compensation, but this should not be assumed for total rates, above amplifier noise, of more than a few hundred counts per second.

The effect of summing due to cascade radiations is not rate-dependent but depends on the efficiencies of the detector for the radiations involved, and can result in either the gain or loss of peak counts, depending on the decay scheme of a particular radionuclide.

If a gamma-ray transition competes with two cascade lower-energy gamma rays connecting the same two levels, the peak due to the "crossover" gamma ray may be enhanced by the "summing in" of counts due to correlated gamma-ray pairs which deposit the same energy in the detector. In general the effect is small because the product of peak efficiencies is small compared with the peak efficiency of the crossover gamma ray. (The peak efficiency, ϵ_p, is defined here as the fraction of all emitted gamma rays which are recorded in a full-energy spectral peak.) But, if the crossover gamma-ray probability is much lower than that of those summing, the effect can be significant. This is true for the 1596-keV gamma ray in the decay of ^{154}Eu, and corrections will have to be applied for accurate efficiency determinations even with moderate separations between detector and source.

If "summing in" occurs, the total peak area, compared to what it would have been otherwise, is $1 + [K(a,b,c)\epsilon_p(a)\epsilon_p(b)/\epsilon_p(c)]$, where indices a and b represent the cascade gamma rays and c represents the crossover, and K(a,b,c) is the probability for the a and b gamma rays to be emitted in cascade relative to the probability for the emission of c. If more than one pair of gamma rays can sum to the crossover energy, other terms like that in the square bracket must be added. Therefore, an observed peak must be divided by $1 + \Sigma[K(a_i,b_i,c)\epsilon_p(a_i)\epsilon_p(b_i)/\epsilon_p(c)]$ in order to get the counts due to c alone. Table 2 contains values of K(a,b,c) which have been calculated for the three radionuclides.

Two factors usually make "summing out" of a peak due to the simultaneous detection of a cascade radiation much more significant. It is not required that the summing pulse is one that otherwise would have been stored in a peak; therefore, the total efficiency (ϵ_t = the fraction of radiation emitted at a given energy that generates pulses of any size in the system) must be considered. This efficiency is often much greater than the corresponding ϵ_p, so that it is easy to underestimate the effect if the areas of sum peaks are used as a measure. Secondly, the narrow peaks characteristic of germanium spectrometers suffer losses with any summed pulse, even quite small ones. Summing pulses smaller than those which would correspond to a full-energy peak for correlated radiations can result from Compton or photoelectric interactions in the shielding or can result from partial energy loss or incomplete charge collection in the detector.

It would then appear that the total efficiency would also have to be measured at many energies, but in general it varies slowly with energy above 100 keV, and attenuation in detector housings or added absorbers often reduce it in a calculable way at lower energies. Suggested radionuclides for total-efficiency measurements are ^{125}I, ^{241}Am, ^{109}Cd, ^{139}Ce, ^{137}Cs, ^{54}Mn, ^{60}Co, and ^{88}Y. Radionuclides can be calibrated by the user with sufficient accuracy for total-efficiency measurements from an efficiency-energy relation established with this long-lived standard at a sufficient distance from the detector that summing is small. Note that the effect of correlated summing may be significant, even for total-efficiency measurements, with ^{125}I, ^{60}Co, and ^{88}Y, if the geometry is tight. In any case, the contribution of x rays and other gamma rays must be removed by subtraction of known lower-energy contributions or extrapolation of the spectrum through low-energy-peak regions. A curve of the total efficiency vs energy for a point source at 26 centimeters from a 60-cm^3 wrap-around coaxial germanium detector is shown in Figure 3.

Beta-ray or conversion-electron efficiencies may be appreciable if sufficient absorbers are not present, and can also cause "summing out". In most calculations, including the ones we are going to suggest, it is assumed that electrons, and L and higher-shell x rays, are not detected. K x rays often are important, especially in nuclides decaying by K-electron capture.

The peak area for the rth radiation with summing out by radiation s is related to that which would be measured without the effect by 1 - K(s,r) $\epsilon_t(s)$, where K(s,r) is the probability for the simultaneous emission of the two. If there are other summing possibilities, the total effect is not simply 1 - $\Sigma K(s_j,r)\epsilon_t(s_j)$. If the efficiency is large, additional additive terms such as $\Sigma K(s_j s_k r)\epsilon_t(s_j)\epsilon_t(s_k)$ can be significant (and possibly analogous terms containing the product of three efficiencies must be subtracted, and so forth). We have calculated all pertinent Ks for these three radionuclides (and many other), and will supply the full set on request. However, the first-order terms given in Table 2 will probably be sufficient unless the source is close to the detector and the required accuracy is high.

There are two further complications. In general, angular correlations between pairs of cascade gamma-rays (not x rays) must be taken into account by introducing factors multiplying each K. For the present radionuclides these are sufficiently close to 1 that we do not list them here. This may not be true of other radionuclides that users wish to measure. The second complication is that the discussion so far has been for point sources; if the sources are extended, high accuracy results will require a measurement of ϵ_t and a calculation of the summing effect at different locations, and then an integration over the volume of the source.

This discourse on summing effects does not appear because these standards are especially troublesome in this respect; quite the opposite is true. (Compare them with ^{166m}Ho!) However, the summing loss in the case of the 592 keV transition relative to that of the 601 keV and 636 keV transitions can provide a useful flag that cascade effects are noticeable in high-efficiency situations. If an efficiency function generated with these sources is discordant at 592 keV, beware of larger errors that will be made with many other radionuclides counted under the same conditions if corrections are not applied. If users must count at high efficiencies and yet require accuracies of better than 10 percent (or even 50 percent, in extreme cases), there is another alternative to the admittedly laborious summing corrections. They should ignore the concept of an efficiency-energy relation, and calibrate the detector directly in terms of apparent peak efficiency for selected gamma rays of the radionuclides which will be measured. If standards are not available, the radionuclides can be calibrated in the laboratory by establishing an efficiency-energy relation with this standard at a source-detector distance where summing is a fraction of a percent for all radionuclides (probably 25 centimeters or more). Concentrated solutions of the radionuclides (or mixtures thereof) can be calibrated at this distance, using tabulated P_γs and taking into account container and source absorption and other corrections. These solutions can then be quantitatively diluted (to probably better than 1 percent by simple volume measurements, if the initial volume is greater than a few ml) and counted in the usual geometry.

5. Other Gamma Rays

We have intentionally not given emission rates for weaker gamma rays, although many users might find them convenient. In many cases the values have not been measured well, as evidenced by the considerable discrepancy with literature values. If accurate values become available, purchasers of standards will be informed, although our feeling is that more accurate efficiencies will result from using separate standards with less background.

6. Sample Preparation Considerations

The solution SRMs, 4276-C, are provided in 4 M hydrochloric acid, which has a density of 1.05 g cm^{-3} at 22° C. They also contains 30 μg each of Sb^{+3} and Eu^{+3} per gram of solution. A similar carrier solution should be used for dilutions.

Sources of this mixture are to be evaporated to dryness, care must be taken to avoid loss of ^{125}Sb through volatilization. The present point- source standards (4275-C) were prepared by taking to dryness deposited sources in a hydrogen sulfide gas atmosphere such that the antimony is precipitated as the orange Sb_2S_3.

7. Bibliography

(A) Many useful discussions of techniques, including some used at NIST, appear in three conference reports:

1. Proceedings of ERDA Symposium on X- and Gamma-Ray Sources and Applications, Conf-760539 May 19-21, 1976, Ann Arbor, Michigan. Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. $9.25 (domestic), $11.75 (foreign).

2. Computers in Activation Analysis and Gamma-Ray Spectroscopy. Conf- 780421 Proceeding of the American Nuclear Society Topical Conference at Mayaguez, Puerto Rico, April 30 - May 4, 1978. Also available as above, $15.

3. Fifth Symposium on X- and Gamma-Ray Sources and Applications. June 10- 12, 1981, Ann Arbor, Michigan. Published in Nuclear Instruments and Methods, 193 (1982).

(B) A general discussion of gamma-ray spectrometry, and much information about activity measurements, appears in: A Handbook of Radioactivity Measurements Procedures, NCRP Report No. 58, 2nd edition. National Council on Radiation Protection and Measurements, NCRP Publications, P.O. Box 30175, Washington, D.C. 20014. $11.

(C) Examples of the importance of pulse summing, and reference to other articles on the subject, appear in:

Coincidence summing corrections in Ge(Li) spectrometry at low source-to- detector distances, K. Debertin and U. Schotzig. Nuclear Instruments and Methods 158, 471 (1979).

(D) Gamma- and x-ray spectrometry with semiconductor detectors, by K. Debertin and R.G. Helmer, is scheduled to be issued by North Holland Publishing in 1988.

(E) An extensively revised ANSI standard on germanium spectrometry is now in final draft (December 1988).

TABLE 1

Considerations for Peak Analyses for SRM's 4275-C and 4276-C

Gamma Ray Energy (keV)	Source	Conflict
27.4	^{125}Sb-^{125m}Te K x ray	24.36 keV germanium escape peak from a 35.46 keV γ in ^{125}Sb 26.51 keV γ in ^{155}Eu 0.3% of the 27.4 keV K x-ray emission
42.8	^{154}Eu-^{155}Eu KS x ray	Footnote a)
86.5	^{155}Eu	86.062 keV γ in ^{155}Eu 0.49% of the 86.5 keV γ emission
105.3	^{155}Eu	104.3 keV backscatter peak of the 176.4 keV γ in ^{125}Sb 109.27 keV γ in ^{125m}Te 0.49% of the 105.3 keV γ emission
123.1	^{154}Eu	122.2 keV Compton edge of the 248.04 keV γ in ^{154}Eu
176.3	^{125}Sb	172.6 keV γ in ^{125}Sb, 3.9% 178.8 keV backscatter peak of the 591.7 keV γ in ^{154}Eu 179.35 keV average backscatter peaks of the 600.6 and 606.7 keV γ's in ^{125}Sb
248.0	^{154}Eu	252.5 keV double-escape peak of the 1274.4 keV γ in ^{154}Eu
427.9	^{125}Sb	421.3-426.9 keV Compton edges of the 600.6 and 606.7 keV γ's in ^{125}Sb
463.4	^{125}Sb	Footnote a)
591.8	^{154}Eu	Footnote a)
600.6	^{125}Sb	606.7 keV γ in ^{125}Sb, 27.5% of the 600.6 keV γ emission
635.9	^{125}Sb	Footnote a)
723.3	^{154}Eu	715.8 keV γ in ^{154}Eu 0.89% of the 723.3 keV γ emission [b]
873.2	^{154}Eu	Footnote a)
996.4	^{154}Eu	1004.8 keV γ in ^{154}Eu 168.9% of the 996.4 keV γ emission [b]
1004.8	^{154}Eu	996.4 keV γ in ^{154}Eu 59.2% of the 1004.8 keV γ emission [b]
1274.5	^{154}Eu	Footnote a)
1596.5	^{154}Eu	Footnote a)

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a) No significant conflicts are expected for semiconductor detectors of good resolution.

b) Conflicts may depend on specific detector resolution and counting rates.

TABLE 2

Summing Corrections for 17 Gamma-Rays in SRM's 4275-C and 4276-C

The measured emission rate of a gamma ray having energy E is to be divided by the indicated correction. Terms with coefficients less than 0.01 have been neglected.

E	Correction(a)
86.6	1.0
105.3	1.0
123.1	(1.0-0.072[248.0]-0.055[591.7] -0.019[692.4]-0.120[723.3] -0.049[756.9]-0.130[873.2] -0.201[1004.8]-0.010[1246.2] -0.401[1274.4]-0.021[1596.5])
176.4	(1.0-0.035[204.1]-0.057[321.0])
2[illegible]0	(1.0-0.287[42.8]-0.455[123.1] -0.072[444.4]-0.022[582.0] -0.134[591.7]-0.015[612.2] -0.043[625.2]-0.022[676.6] -0.039[723.3]-0.613[756.9] -0.059[892.7]-0.022[904.1] -0.130[1246.2])
380.5	(1.0+0.157{176.4}{204.1}/{380.5}) *(1.0-0.010[27.4]-0.190[116.9])
427.9	(1.0-0.598[27.4]-0.059[35.5])
463.4	(1.0+0.169{35.5}{427.9}/{463.4})
591.7	(1.0-0.297[42.8]-0.455[123.1] -0.178[248.0]-0.196[756.9] -0.800[1004.8])
600.6	(1.0+0.010{427.9}{172.6}/{600.6}) *(1.0-0.597[27.4]-0.059[35.5])
635.9	(1.0+0.012{427.9}{208.0}/{635.9}) *(1.0-0.597[27.4]-0.059[35.5])
723.3	(1.0-0.154[42.8]-0.243[123.1] -0.013[248.0]-0.014[625.2] -0.518[873.2]-0.465[996.4])
873.2	(1.0+0.024{248.0}{625.2}/{873.2}) *(1.0-0.282[42.8]-0.455[123.1] -0.894[723.3])
996.4	(1.0+0.507{123.1}{873.2}/{996.4}) *(1.0-0.894[723.3])
1004.8	(1.0+0.221{248.0}{756.9}/{1004.8}) *(1.0-0.282[42.8]-0.455[123.1] -0.217[591.7])
1274.4	(1.0+0.014{692.4}{582.0}/{1274.4}) *(1.0-0.281[42.8]-0.455[123.1])
1596.5	(1.0+0.275{692.4}{904.1}/{1596.5} +5.568{873.2}{723.3}/{1596.5} +2.094{1004.8}{591.7}/{1596.5} +0.052{1118.5}{478.3}/{1596.5} *(1.0-0.281[42.8]-0.455[123.1])

(a) {E} is the full energy peak efficiency at E, and [E] is the total efficiency at E.

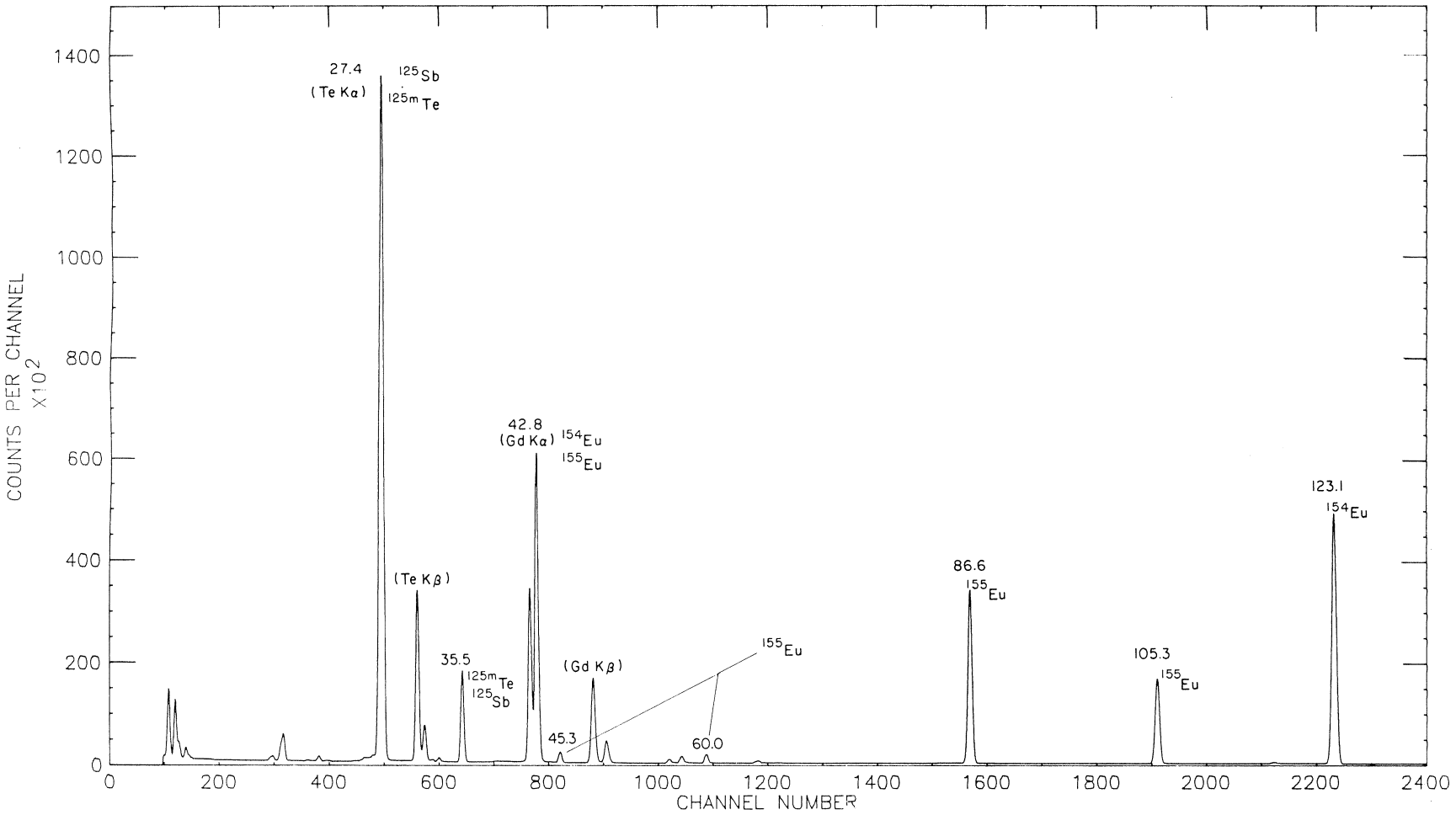

Figure 1. Spectrum of low-energy photons from SRM 4275 taken with a 200-mm^2 area, 5-mm-thick planar germanium detector at a source-to-detector distance of 15 cm.

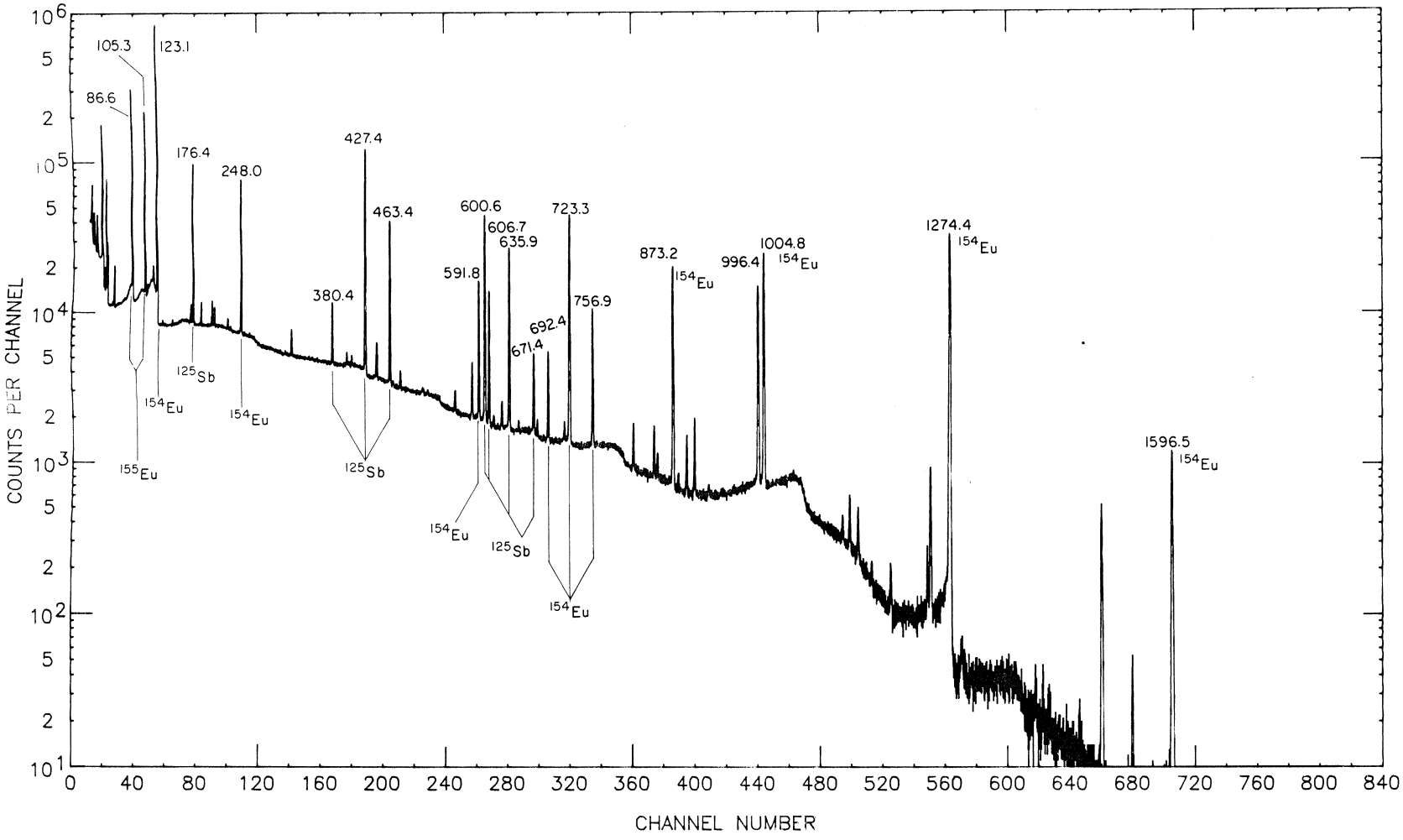

Figure 2. Spectrum of gamma rays from SRM 4275 taken with a 60-cm^3 wrap-around coaxial germanium detector at a source-to-detector distance of 26 cm.

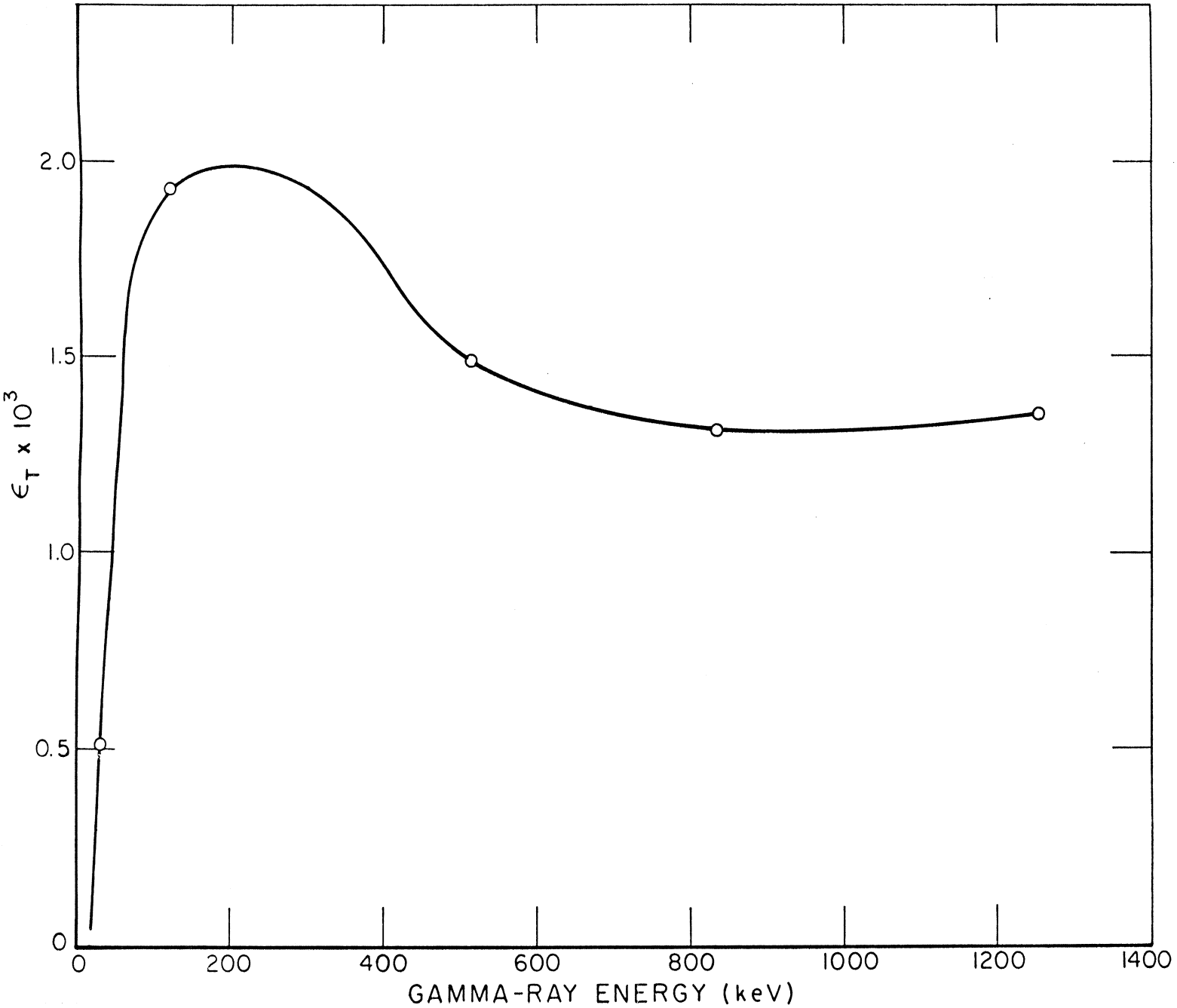

Figure 3. Total efficiency as a function of gamma-ray energy for a point source 15 26 cm from a 60-cm^3 wrap-around coaxial germanium detector.

NATIONAL SUPERCONDUCTING CYCLOTRON LABORATORY
MICHIGAN STATE UNIVERSITY

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Michigan State University
East Lansing, MI 48824-1321 USA

Thursday, January 30, 1992

Ms. Cassandra Beck
National Institute of Standards and Technnology
Rm C-114, Bldg 245
Gaithersburg, MD 20899 301-975-6776

Dear Ms. Beck,

I'm the person who contacted you today about obtaining source strength documentation on some old sources. There are two:

1. SRM-4216 No. 5 June 1, 1973
2. SRM-4215 No. 25 June 1, 1973

Any help would be greatly appreciated! Thank you!

Sincerely,

Reg Ronningen

Reginald M. Ronningen

Staff Physicist

SRM - 4215B (82) 1974) $Cs^{137} + Co^{60}$

Eu 152 14.64 μc

230 - 21 - 8

Th 228 13.81 μc

227 - 32 - 1

72 - 15 - 44

SRM-4216 #15 mixed 6/1 [illegible]

SRM-4215 (25) mixed 6/1/73

Natl Inst. Standards & Technology
Gaithersburg MD 20899
Cassandra Beck

Rm C-114
Bldg 245

FAX 301 926 7416

UNITED STATES DEPARTMENT OF COMMERCE
National Institute of Standards and Technology
Gaithersburg, Maryland 20899

Dear Customer:

The Standard Reference Material(s) (SRM'(s)) for which you have requested a Material Safety Data Sheet (MSDS), 4275C, Mix is excluded from coverage in our regular MSDS system of more than 100 sheets for one or more of the following reasons:

1 ☐ The SRM is an article, as that word is defined in paragraph (c) of section 1910.1200 of title 29 of the Code of Federal Regulations which does not release or otherwise result in exposure to a hazardous chemical, under normal conditions of use.

2 ☐ The SRM has been determined to be non-hazardous by the National Institute of Standards and Technology under paragraph (d) of section 1910.1200 of title 29 of the Code of Federal Regulations. The SRM will not release or otherwise result in exposure to a hazardous chemical under normal conditions of use.

3 ☐ The SRM is a pesticide or hazardous waste labeled according to regulations issued by the Environmental protection Agency.

4 ☐ The SRM is a food, food additive, or drug labeled according to regulations issued by the Food and Drug Administration.

5 ☐ The SRM is a wine labeled according to regulations issued by the Bureau of Alcohol, Tobacco, and Firearms.

6 ☒ The SRM is a radioactive material labeled according to regulations issued by the Nuclear Regulatory Commission. The Shipper's Declaration form included with the shipment states chemical form, physical state, and activity of SRM.

7 ☐ The SRM is a tobacco or tobacco product, wood, or wood product which is exempted by paragraph (b) (5) (ii) and (iii) of section 1910.1200 of title 29 of the Code of Federal Regulations from the provisions of that section.

If we can be of assistance to you in regard to this matter, or any issue related to SRMs, please do not hesitate to write to me.

Sincerely,

Stanley D. Rasberry

Stanley D. Rasberry
Chief
Office of Standard Reference Materials