This Standard Reference Material (SRM) consists of radioactive yttrium-90 chloride, non-radioactive yttrium chloride, and hydrochloric acid dissolved in 5 mL of distilled water. The solution is contained in a flame-sealed NIST borosilicate-glass ampoule. The SRM is intended for the calibration of ionization chambers and beta-particle counting instruments.

**Radiological Hazard:** The SRM ampoule contains yttrium-90 with a total activity of approximately 500 MDq. Yttrium-90 decays by beta-particle emission. Some of the beta-particles escape from the SRM ampoule. During the decay process, X-rays and gamma rays with energies from approximately 2 keV to 2.2 MeV are emitted. In addition, the beta particles emitted from yttrium-90 produce bremsstrahlung photons with energies up to 2.3 MeV. Most of these photons escape from the SRM ampoule, and can represent a radiation hazard. Approximate unshielded dose rates at several distances (as of the reference time) are given in note [a]. Appropriate shielding and/or distance should be used to minimize personnel exposure. The SRM should be used only by persons qualified to handle radioactive material.

**Chemical Hazard:** The SRM ampoule contains hydrochloric acid with a concentration of approximately 1 mole per liter of water. The solution is corrosive and represents a health hazard if it comes in contact with eyes or skin. If the ampoule is to be opened to transfer the solution, the recommended procedure is given on page 2. The ampoule should be opened only by persons qualified to handle both radioactive material and strong acid solution.

**Storage and Handling:** The SRM should be stored and used at a temperature between 5 °C and 65 °C. The solution in an unopened ampoule should remain stable and homogeneous until at least December 2001. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material. If the ampoule is transported it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of the radioactivity and because of the strong acid.

**Preparation:** This Standard Reference Material was prepared in the Physics Laboratory, Ionizing Radiation Division, Radioactivity Group, L.R. Karna, Group Leader. The overall technical direction and physical measurements leading to certification were provided by D.B. Golas and O.T. Palabrica, Nuclear Energy Institute Research Associates. The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by I W I. Thomas

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Gaithersburg, Maryland 20899  
March 2001
Recommended Procedure for Opening the SRM Ampoule

1) If the SRM solution is to be diluted, it is recommended that the diluting solution have a composition comparable to that of the SRM solution.

2) Wear eye protection, gloves, and protective clothing and work over a tray with absorbent paper in it. Work in a fume hood. In addition to the radioactive material, the solution contains strong acid and is corrosive.

3) Shake the ampoule to wet all of the inside surface of the ampoule. Return the ampoule to the upright position.

4) Check that all of the liquid has drained out of the neck of the ampoule. If necessary, gently tap the neck to speed the process.

5) Holding the ampoule upright, score the narrowest part of the neck with a scribe or diamond pencil.

6) Lightly wet the scored line. This reduces the crack propagation velocity and makes for a cleaner break.

7) Hold the ampoule upright with a paper towel, a wiper, or a support jig. Position the scored line away from you. Using a paper towel or wiper to avoid contamination, snap off the top of the ampoule by pressing the narrowest part of the neck away from you while pulling the tip of the ampoule towards you.

8) Transfer the solution from the ampoule using a pycnometer or a pipet with dispenser handle. NEVER PIPETTE BY MOUTH.

9) Seal any unused SRM solution in a flame-sealed glass ampoule, if possible, to minimize the evaporation loss.

See also reference [4]*.
**PROPERTIES OF SRM 4427HD-**

### Certified values

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Yttrium-90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference time</td>
<td>1500 EST, 06 December 2000</td>
</tr>
<tr>
<td>Massic activity of the solution</td>
<td>95.06 MBq·g⁻¹</td>
</tr>
<tr>
<td>Relative expanded uncertainty (k=2)</td>
<td>0.98%  [c]  [d]</td>
</tr>
<tr>
<td>Solution mass</td>
<td>(mₚ ± 0.0003) g  [e]</td>
</tr>
<tr>
<td>Solution density</td>
<td>(1.014 ± 0.002) g·mL⁻¹ at 20 °C [e] *</td>
</tr>
</tbody>
</table>

### Uncertified values

**Physical Properties:**

<table>
<thead>
<tr>
<th>Source description</th>
<th>Liquid in flame-sealed NIST borosilicate-glass ampoule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ampoule specifications</td>
<td></td>
</tr>
<tr>
<td>Body outside diameter</td>
<td>(16.5 ± 0.5) mm</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>(0.60 ± 0.04) mm</td>
</tr>
<tr>
<td>Barium content</td>
<td>Less than 2.5%</td>
</tr>
<tr>
<td>Lead-oxide content</td>
<td>Less than 0.02%</td>
</tr>
<tr>
<td>Other heavy elements</td>
<td>Trace quantities</td>
</tr>
</tbody>
</table>

**Chemical Properties:**

<table>
<thead>
<tr>
<th>Solution composition</th>
<th>Chemical Formula</th>
<th>Concentration (mol·L⁻¹)</th>
<th>Mass Fraction (g·g⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂O</td>
<td>54</td>
<td>0.97</td>
<td></td>
</tr>
<tr>
<td>HCl</td>
<td>0.9</td>
<td>0.03</td>
<td></td>
</tr>
<tr>
<td>YCl₃</td>
<td>3 × 10⁻³</td>
<td>6 × 10⁻⁴</td>
<td></td>
</tr>
<tr>
<td>⁹⁰YCl₃</td>
<td>5 × 10⁴</td>
<td>1 × 10⁴</td>
<td></td>
</tr>
</tbody>
</table>

**Radiological Properties:**

<table>
<thead>
<tr>
<th>Beta-particle-emitting impurities</th>
<th>None detected [f]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon-emitting impurities</td>
<td>None detected [f]</td>
</tr>
<tr>
<td>Half lives used</td>
<td>Hydrogen-3: (4500 ± 8) d  [g]  [5,6]</td>
</tr>
<tr>
<td></td>
<td>Yttrium-90: (64.00 ± 0.21) h  [g]  [6]</td>
</tr>
<tr>
<td>Calibration method and measuring instrument(s)</td>
<td>Two 4πβ liquid-scintillation counting systems. The detection efficiencies were calculated using the CIEMAT/NIST method with hydrogen-3 as the detection-efficiency monitor.  [h]</td>
</tr>
</tbody>
</table>
## EVALUATION OF THE UNCERTAINTY OF THE MASSIC ACTIVITY [c,d]*

| Input Quantity $x_i$, the source of uncertainty (and individual uncertainty components where appropriate) | Method Used To Evaluate $u(x_i)$, the standard uncertainty of $x_i$ (A) denotes evaluation by statistical methods (B) denotes evaluation by other methods | Relative Uncertainty Of Input Quantity, $u(x_i)/x_i$, (%) | Relative Sensitivity Factor, $|\partial y/\partial x_i|$, (A) | Relative Uncertainty Of Output Quantity, $u(y)/y$, (%) |
|---|---|---|---|---|
| Dilution of SRM 4427HD to make SRM 4427LD | Estimated (B) | 0.05 | 1.0 | 0.05 |
| Dilution of two ampoules of SRM 4427LD to make two lower-level solutions | Standard deviation of the mean result from the two sets of liquid-scintillation vials (A) | 0.16 | 1.0 | 0.16 |
| Massic liquid-scintillation count rate of each lower-level solution, corrected for background and decay, divided by the computed detection efficiency (Calculated yttrium-90 massic activity) | Standard deviation of the mean (typical) for 9 sets of 4mB liquid-scintillation measurements on a single set of vials (A) | 0.02 | 1.0 | 0.02 |
| Quench-indicating-parameter (QIP) effects | Standard deviation of the mean for 10 repeated measurements on a single sample (A) | 0.58 | 0.00002 | 0.00001 |
| Liquid-scintillation cocktail effects | Estimated (B) | 0.06 | 1.0 | 0.06 |
| Half life of hydrogen-3 | Standard uncertainty of the half life (A) | 0.18 [m] | 0.13 [m] | 0.33 [m] | 0.35 [m] | 0.02 |
| Half life of yttrium-90 | Estimated (B) | 0.91 | 0.35 | 0.32 |
| Yttrium-90 decay time | Estimated (B) | 0.10 | 1.0 | 0.10 |
| Gravimetric measurements | Estimated (B) | 0.10 | 1.0 | 0.10 |
| Live-time [p] | Estimated (B) | 0.10 | 1.0 | 0.10 |
| Neut-particle-emitting impurities | Limit of detection (B) [g] | 100. | 0.00001 | 0.001 |
| Photon-emitting impurities | Limit of detection (B) [a] | 100. | 0.0001 | 0.01 |
| Computed detection efficiency for yttrium 90 | Estimated (B) [h] | 0.27 | 1.0 | 0.27 |

Relative Combined Standard Uncertainty of the Output Quantity, $u_r(y)/y$, (%) 0.49

Coverage Factor, $k$ x 2

Relative Expanded Uncertainty of the Output Quantity, $U_y$, (%) 0.98

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*Notes and references are on pages 5 to 7*
NOTES

[a] The Sievert is the SI unit for dose equivalent. See reference [1]. One μSv is equal to 0.1 mrem. Distance from Ampoule (cm): 1 30 100 Approximate Dose Rate (μSv/h): 330000 1650 65

[b] Massic activity is the preferred name for the quantity activity divided by the total mass of the sample. See reference [1].

[c] The reported value, y, of massic activity (activity per unit mass) at the reference time was not measured directly but was derived from measurements and calculations of other quantities. This can be expressed as \( y = f(x_1, x_2, x_3, \ldots, x_n) \), where \( f \) is a mathematical function derived from the assumed model of the measurement process.

The value, \( x_i \), used for each input quantity \( i \) has a standard uncertainty, \( u(x_i) \), that generates a corresponding uncertainty in \( y \), \( u(y) = \left| \frac{\partial f}{\partial x_i} \right| u(x_i) \), called a component of combined standard uncertainty of \( y \).

The combined standard uncertainty of \( y \), \( u_c(y) \), is the positive square root of the sum of the squares of the components of combined standard uncertainty.

The combined standard uncertainty is multiplied by a coverage factor of \( k = 2 \) to obtain \( U \), the expanded uncertainty of \( y \).

Since it can be assumed that the possible estimated values of the massic activity are approximately normally distributed with approximate standard deviation \( u_c(y) \), the unknown value of the massic activity is believed to lie in the interval \( y \pm U \) with a level of confidence of approximately 95 percent.

For further information on the expression of uncertainties, see references [2] and [3].

[d] The value of each component of combined standard uncertainty, and hence the value of the expanded uncertainty itself, is a best estimate based upon all available information, but is only approximately known. That is to say, the "uncertainty of the uncertainty" is large and not well known. This is true for uncertainties evaluated by statistical methods (e.g., the relative standard deviation of the standard deviation of the mean for the massic response is approximately 50%) and for uncertainties evaluated by other methods (which could easily be over estimated or under estimated by substantial amounts). The unknown value of the expanded uncertainty is believed to lie in the interval \( U/2 \) to \( 2U \) (i.e., within a factor of 2 of the estimated value).

[e] The stated uncertainty is two times the standard uncertainty.

[f] The estimated detection limit for beta-particle-emitting impurities, as of 17 January 2001 (42 days after the reference time), expressed as a massic beta-particle emission rate, is \( 950 \text{ s}^{-1} \cdot \text{g}^{-1} \). The estimated detection limit for strontium-90 is \( 0.11 \text{ Bq} \cdot \text{g}^{-1} \).

The estimated limit of detection for photon-emitting impurities, as of 13 December 2000 (6.5 days after the reference time), expressed as a massic photon emission rate, is: \( 8.0 \times 10^{5} \text{ s}^{-1} \cdot \text{g}^{-1} \) for energies between 35 keV and 1850 keV.

[g] The stated uncertainty is the standard uncertainty.
The relationship between the detection efficiency for yttrium-90 and the detection efficiency for hydrogen-3 was computed using the CIEMAT/NIST method as embodied in the computer program EFFY4. See references [7,8,9].

Relative standard uncertainty of the input quantity \( x \).

The relative change in the output quantity \( y \) divided by the relative change in the input quantity \( x \). If \( |\partial y / \partial x| \cdot (x/y) = 1.0 \), then a 1% change in \( x \) results in a 1% change in \( y \). If \( |\partial y / \partial x| \cdot (x/y) = 0.05 \), then a 1% change in \( x \) results in a 0.05% change in \( y \).

Relative component of combined standard uncertainty of output quantity, rounded to two significant figures or less. The relative component of combined standard uncertainty of \( y \) is given by \( u(y)/y = |\partial y / \partial x| \cdot u(x)/x = |\partial y / \partial x| \cdot (x/y) \cdot u(x)/x \). The numerical values of \( u(x)/x \), \( |\partial y / \partial x| \cdot (x/y) \), and \( u(y)/y \), all dimensionless quantities, are listed in columns 3, 4, and 5, respectively. Thus, the value in column 5 is equal to the value in column 4 multiplied by the value in column 3. The input quantities are independent, or very nearly so. Hence the covariances are zero or negligible.

The relative standard uncertainty of \( \lambda \cdot t \) is determined by the relative standard uncertainty of \( \lambda \) (i.e., the half life). The relative standard uncertainty of \( t \) is negligible.

\( |\partial y / \partial x| \cdot (x/y) = |\lambda \cdot t| \), multiplied by other sensitivity factors where appropriate.

The live time is determined by counting the pulses from a gated crystal-controlled oscillator.

The standard uncertainty for each undetected impurity that might reasonably be expected to be present is estimated to be equal to the estimated limit of detection for that impurity, i.e. \( u(x)/x = 100\% \). \( |\partial y / \partial x| \cdot (x/y) = (\text{response per Bq of impurity} / \text{response per Bq of yttrium-90}) \cdot (\text{Bq of impurity} / (\text{Bq of yttrium-90})) \). Thus \( u(y)/y \) is the relative change in \( y \) if the impurity were present with a massic activity equal to the estimated limit of detection.
REFERENCES


