Pre-Calibrated detectors and impact on CTBT stations

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Vienna, October 07 2015
Agenda

What is ISOCS/LABSOCS
- What it is and how it works
- Characterizations of the detectors
- Calibration validations & Verification
- QA/QC, Unbroken chain, Chain of Custody

How using in CTBTO station applications
- Geometries
- Efficiency
- Field use
- Saving time & money
- Worst case scenario’s
Generalized Efficiency Computation Method (ISOCS/LabSOCS)

- ISOCS/LabSOCS method is designed to quickly and accurately compute efficiencies for a wide range of geometries commonly found in in-situ and laboratory applications.

- Relies on a factory characterization of the vacuum efficiency response of the detector.

\[ \varepsilon = \sum_{i} N_i \varepsilon_i^{vac} \sum_{j} W_{ij} e \]

U.S. Patent 6,228,664 B1
How it works…

The different FACTORY steps…

- **Detector characterization**
  - Response around the detector

- **Validation**
  - Using sources to fully validate the response for real world sources

- **QA source measurement**
  - Ensuring unchanged response over time
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Detector Characterization Process

- Performed on every *SOCS detector
- NIST-traceable multi-energy sources
- Counted at 7 locations
- MCNP model of detector created and validated by sources
- Validated MCNP model used to extend the efficiency to other spatial locations
  - 0 mm to 500 m distance
  - all directions (4π)
  - 10 keV - 7000 keV
- Controlled process with rigorous quality checking
- Detector Characterization file used by *SOCS software to create sample efficiency
How it works…

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ISOXVRFY - Optional Verification

- Using the characterized detector and 7 laboratory geometries 2 liter Marinelli beaker water-equivalent epoxy
  - 350 cc beaker water-equivalent epoxy (0cm, 10cm from detector)
  - Filter paper / planchet (0cm, 10cm) (~ 3M and Spalax CTBT geometry)
  - 20cc vial water-equivalent epoxy (0cm, 10cm)
- Sources are NIST traceable standards, and have multiple gamma energies, 60 keV - 1836 keV, including X-rays down to ~10keV range
- Each counted and analyzed as “unknown” using the LabSOCS efficiency
- Calibration certificates for the traceable standards used for the verification
How it works…

The different FACTORY steps…

▶ Detector characterization
  ▶ Response around the detector

▶ Validation
  ▶ Using sources to fully validate the response for real world sources

▶ QA source measurement
  ▶ Ensuring unchanged response over time
ISOCS Check Source
Model ISOXSRCE

- Check source with positioning fixture
- Eu-155 and Na-22 (or any other)
- Gamma energies: 43, 60, 86, 105, 511, 1275keV
  - Ratio 86 to 105 for SEGe type detectors
- 2-3 years half life
- ~ 1 uCi (~37kBq) [exempt quantity]
- Measurements are taken during the characterization
- Source is shipped with detector

- Measurements are repeated on site to confirm no changes – UNBROKEN CHAIN
How it works…

The **CTBTO specific** steps...

- **Create the geometry** (typically 5-30 minutes each)
  - Once per each geometry, already available for 3M manual and SPALAX
  - Applicable to all detector systems and station setups

- **Create the efficiency curve** (once per each detector setup – <10 minutes)
  - Per detector (TUNING energy lines according to detector and station type)
  - Per geometry (TUNING DETECTOR SYSTEM SETUP for the station – based on source position, presence of sample holder, etc)

- **Start the QA/QC program**
  - 1 per detector (already implemented at IMS stations)
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3M Filter geometry in LABSOCS

![Image of 3M Filter geometry in LABSOCS]

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
<th>d.1</th>
<th>d.2</th>
<th>Material</th>
<th>Density</th>
<th>Volume, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Side Walls</td>
<td>0.5</td>
<td>50</td>
<td>PVC</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Bottom Wall</td>
<td>0.5</td>
<td></td>
<td>PVC</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sample</td>
<td>6</td>
<td></td>
<td>3m5270</td>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Absorber 1</td>
<td>0</td>
<td></td>
<td>none</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Absorber 2</td>
<td>0</td>
<td></td>
<td>none</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Source-Detector</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3M (5379) CTBTO Filter in LABSOCS

Table 2. Elemental composition of organic filter materials (weight-%). C, H and N were analysed with a C-H-N-analyser and the other elements with INAA.

<table>
<thead>
<tr>
<th>Element</th>
<th>3M5379 filter</th>
<th>3M5379 scrim</th>
<th>Petrianov</th>
<th>LYDAL scrim</th>
<th>Relative analytical uncertainty, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>85</td>
<td>85</td>
<td>36</td>
<td>63</td>
<td>10</td>
</tr>
<tr>
<td>H</td>
<td>14.3</td>
<td>14.1</td>
<td>5.4</td>
<td>5.7</td>
<td>10</td>
</tr>
<tr>
<td>N</td>
<td>0.3</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>Cl</td>
<td>0.012</td>
<td>0.006</td>
<td>27.5</td>
<td>0.019</td>
<td>Petrianov 10, others 20</td>
</tr>
<tr>
<td>Na</td>
<td>0.0045</td>
<td>0.0013</td>
<td>0.0083</td>
<td>0.14</td>
<td>15</td>
</tr>
<tr>
<td>Al</td>
<td>0.008</td>
<td>0.0035</td>
<td>&lt;0.01</td>
<td>0.007</td>
<td>20</td>
</tr>
<tr>
<td>Ti</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.01</td>
<td>0.12</td>
<td>20</td>
</tr>
<tr>
<td>Ca</td>
<td>0.046</td>
<td>&lt;0.006</td>
<td>&lt;0.08</td>
<td>&lt;0.03</td>
<td>30</td>
</tr>
<tr>
<td>K</td>
<td>0.033</td>
<td>0.021</td>
<td>0.013</td>
<td>0.035</td>
<td>25</td>
</tr>
<tr>
<td>V</td>
<td>&lt;0.00001</td>
<td>&lt;0.00003</td>
<td>&lt;0.001</td>
<td>&lt;0.00002</td>
<td>15</td>
</tr>
<tr>
<td>Mg</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.1</td>
<td>&lt;0.02</td>
<td>-</td>
</tr>
<tr>
<td>Cu</td>
<td>&lt;0.001</td>
<td>&lt;0.0003</td>
<td>&lt;0.01</td>
<td>&lt;0.002</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>99.8</td>
<td>99.4</td>
<td>71.9</td>
<td>69.0</td>
<td></td>
</tr>
</tbody>
</table>
How it works…

The CTBTO specific steps…

- Create the geometry
- Create the efficiency curve
- Start the QA/QC program
SPALAX efficiency on BEGE5030

Example: b15181 prototype (VIX00)

Typical calibration range: 20 – 900 keV
How it works...

The CTBTO specific steps...

➤ Create the geometry

➤ Create the efficiency curve

➤ Start the QA/QC program
  ➤ Current CTBT source is perfect
Using your current QA/QC source is perfect

3M manual QC

RASA QC movable point source
Example “real world” QC Program
Looking for trends...

Canberra, Genie-2000 QA/QC package
Example “real world” PTS QC Program
Looking for trends...
Conclusion: what does/could this all mean to CTBTO?
Conclusion: “Unbroken Chain”, faster, easier and cheaper

Detector Factory Characterization

ISOXVRFY Optional Verification Measurements (laboratory geometries only)

At the supplier

using the Check Source ISOCS Source Measurements on Site (after detector install and regularly)

1 time at arrival at the station

to prove no change since characterization

Customer QA Program

to prove ongoing detector stability

As done today already

with NIST traceable sources, deriving justifiable systematic uncertainties

verification with common lab geometries
Approach for CTBTO?
The power of LABSOCS

► What IF analysis
  ► Inhomogeneous distributions?
  ► Varying density and/or thickness (e.g., filter clogging, dust loading)
  ► With LABSOCS: Perfectly possible to determine the boundaries resulting in better determination of station specific uncertainties

► Ability to correct, remotely, for certain changes in detector response
  ► Or other parameters influencing the measurements
  ► Response curve can be remotely corrected and send back to the station

► We “Canberra” do characterize also N”O”N Canberra detectors!
  ► 😊
Thank you for your appreciated attention

Questions?
Backup slides
Why is LabSOCS faster than source calibrations?

- Source calibrations require the following things to be done:
  - plan, budget, identify supplier, etc.
  - Order and wait…
  - perform the leak tests and enter into radioactive material inventory
  - prepare the individual sources from the master sources
  - count them
  - turn the counts into calibration file
  - validate that the calibration is good
  - prepare calibration documentation
  - NOW …. analyze your unknown sample

- Very long elapsed time
- Mathematical calibrations available in seconds
- Easier / faster to respond to
  - new situations
  - new samples
  - new customers
Why is LabSOCS cheaper than source calibrations?

- **Labor costs money**
  - Salary, direct overhead, indirect overhead, ...
  - All of the items on the previous slide take man-hours to do
  - Isn’t there something better to do with all those man-hours?

- **Sources cost money**
  - Purchase, shipment, inventory
  - disposal

- **Calibration facilities cost money**
  - generally special labs for hotter sources than environmental labs
  - special equipment sometimes required
  - sometimes there is accidental contamination that must be fixed

- **Sources decay, and replacements must be purchased every ~year**
  - Mathematical method also costs money, but:
  - can be used to make MANY MANY different calibrations
  - costs nothing to keep in inventory [no leak tests]
  - won't cause any contamination
  - won't decay
Why is LabSOCS better than source calibrations?

- **Radioactive liquids not desirable for long term storage [leak]**
  - non-water surrogates often used [gel, epoxy, plastic, …]
  - surrogates are not the same as the sample [different Z, different density]
  - unless identical to sample, inaccurate calibrations

- **Uniform sources are difficult to produce**
  - precipitation and fall to bottom
  - plate-out onto walls
  - volatilization and outgassing
  - unless uniform, inaccurate calibrations

- **Non-water matrices much more complicated to prepare as homogeneous, and to prove that they are homogeneous**
  - soil, gas (NPP’s), metal, concrete, vegetation, charcoal, resin
  - unless homogeneous, inaccurate calibrations
  - unless exact density and Z, then inaccurate calibrations

- **Many nuclides have coincidence summing problems**
  - Co-60, Y-88, Eu-152, Cs-134 …
  - any source using these will introduce errors

- **Long lived calibration-quality sources not easily available**
  - 200-500 keV, 50-100 keV, >1500 keV
  - interpolation and extrapolation may cause inaccurate calibration
Over 100 Technical Reports (1)


Over 100 Technical Reports (2)


Over 100 Technical Reports (3)


Over 100 Technical Reports (4)

Over 100 Technical Reports (5)


Over 100 Technical Reports (6)


