CORRECTION FACTORS TO APPLY TO 
FISSION RATES MEASURED BY MINIATURE 
FISSION CHAMBERS

B. GESLOT, V. LAMIRAND, J. DI SALVO, A. GRUEL, C. DESTOUCHES, P. BLAISE
CEA, DEN, DER/SPEx, Cadarache, France

16TH IGORR, 17-21 NOVEMBER 2014
SAN CARLOS DE BARILOCHE, ARGENTINA
1. CEA Miniature Fission Chambers at EOLE-MINERVE facility

2. Description of the parameter study

3. Results and discussion

4. Conclusion and outlooks
1. CEA MINIATURE FISSION CHAMBERS

CEA designs and manufactures fission chambers for use in experimental reactors

- MTR applications: watertight sub-miniature detectors (Ø3mm, Ø1.5mm) with mineral cable
- ZPR application: non-watertight miniature detectors (Ø4mm, Ø8mm)

Large choice of fissile isotopes

- U-235, U-238
- Pu238, Pu-239, Pu-240
- Np-237,
- Am-241
- Th-232
In reactor physics, lots of measurements involve fission chambers

- Absolute fission rates
- Reactor power
- Absolute neutron flux (fast, thermal)
- Flux distribution
- Spectral indices
- Reactivity worth

→ Absolute measurements require well known calibrated detectors
Introducing MFCs in an experimental reactor is invasive

- Global effect on reactivity
- Local effect on neutron spectrum
- Local effect on flux level
Measured fission rates are biased compared to fission rate without the detector fixture.

→ This can be taken into account using Monte Carlo
  - Full core calculation: by including the detector in the core model
  - Simplified calculation: detector placed in known neutron spectrum

**Full core calculation**
- Account for all effects at once
- Time consuming
- Low accuracy (~1%)

**Two-step calculation**
- Neutron spectrum as an input
- Very fast and accurate (<0.2%)
- Account only for detector effect (no fuel effect)
2. THE PARAMETER STUDY

A parameter study is required to

1. Quantify bias on measured fission rate
2. Validate a method to easily correct measurements

It is based on precise instrumentation modeling

- Detector, connector and transmission cable
- Realistic materials
- Fissile deposit not modeled (thickness ~0.1µm)

Correction factors are calculated

- From two fission rate rate calculation results (with/without detector)
- Depend on the detector, fissile isotope and spectrum

\[
f(x, S, D) = \frac{R_D(x, S)}{R(x, S)} - 1
\]
2. THE PARAMETER STUDY

3 detector geometries
- CF4: Ø4mm, deposit on anode
- CF8R: Ø8mm, deposit on cathode
- CF8Rgr: Ø 8mm, two deposits

7 fissile isotopes
- U-235, Pu-239
- U-238, Np-237, Pu-238, Pu-240, Pu-242

3 neutron spectra
- Boltzmann (thermal)
- Calibration spectrum (fast)
- LWR spectrum (MINERVE)
3. RESULTS: SPECTRUM DEPENDENCE

In thermal neutron spectrum
- Large absorption effect
- Up to a bias of 8%
- Same effect whatever the isotope

<table>
<thead>
<tr>
<th></th>
<th>CF4</th>
<th>CF8R</th>
<th>CF8Rgr</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-235</td>
<td>-3.7%</td>
<td>-6.4%</td>
<td>-8.3%</td>
</tr>
<tr>
<td>Pu-239</td>
<td>-3.6%</td>
<td>-6.6%</td>
<td>-7.8%</td>
</tr>
<tr>
<td>U-238</td>
<td>-3.7%</td>
<td>-6.4%</td>
<td>-8.1%</td>
</tr>
<tr>
<td>Np-237</td>
<td>-3.8%</td>
<td>-6.3%</td>
<td>-8.3%</td>
</tr>
<tr>
<td>Pu-238</td>
<td>-3.9%</td>
<td>-6.4%</td>
<td>-8.5%</td>
</tr>
<tr>
<td>Pu-240</td>
<td>-3.6%</td>
<td>-6.0%</td>
<td>-7.9%</td>
</tr>
<tr>
<td>Pu-242</td>
<td>-3.7%</td>
<td>-6.1%</td>
<td>-8.1%</td>
</tr>
</tbody>
</table>

Convergence ~0.2%
3. RESULTS: ENERGY DEPENDENCE

In thermal neutron spectrum

- Large absorption effect
- Up to a bias of 8%
- Same effect whatever the isotope
3. RESULTS: SPECTRUM DEPENDENCE

In fast neutron spectrum

- Small effect for threshold isotopes
- Depends on the cross section threshold

<table>
<thead>
<tr>
<th></th>
<th>CF4</th>
<th>CF8R</th>
<th>CF8Rgr</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-235</td>
<td>0.0%</td>
<td>0.2%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Pu-239</td>
<td>-0.1%</td>
<td>0.1%</td>
<td>-0.1%</td>
</tr>
<tr>
<td>Pu-238</td>
<td>-0.2%</td>
<td>-0.3%</td>
<td>-0.2%</td>
</tr>
<tr>
<td>U-238</td>
<td>-0.7%</td>
<td>-1.1%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Np-237</td>
<td>-0.3%</td>
<td>-0.4%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Pu-240</td>
<td>-0.3%</td>
<td>-0.4%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Pu-242</td>
<td>-0.3%</td>
<td>-0.3%</td>
<td>-0.4%</td>
</tr>
</tbody>
</table>
3. RESULTS: SPECTRUM DEPENDENCE

In fast neutron spectrum
- Small effect for threshold isotopes
- Depends on the cross section threshold
3. RESULTS: SPECTRUM DEPENDENCE

In mixed neutron spectrum (MINERVE)

- Mixed effect. Comes mainly from thermal absorption
- Small scattering effect on U-238
- Bias up to 6% for U-235

<table>
<thead>
<tr>
<th></th>
<th>CF4</th>
<th>CF8R</th>
<th>CF8Rgr</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-235</td>
<td>-2.5%</td>
<td>-3.9%</td>
<td>-6.1%</td>
</tr>
<tr>
<td>Pu-239</td>
<td>-1.9%</td>
<td>-3.1%</td>
<td>-4.9%</td>
</tr>
<tr>
<td>Pu-238</td>
<td>-1.4%</td>
<td>-2.3%</td>
<td>-3.4%</td>
</tr>
<tr>
<td>U-238</td>
<td>-0.5%</td>
<td>-0.9%</td>
<td>-1.1%</td>
</tr>
<tr>
<td>Np-237</td>
<td>-0.2%</td>
<td>-0.3%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Pu-240</td>
<td>-0.3%</td>
<td>-0.4%</td>
<td>-0.5%</td>
</tr>
<tr>
<td>Pu-242</td>
<td>-0.2%</td>
<td>-0.3%</td>
<td>-0.4%</td>
</tr>
</tbody>
</table>

Convergence ~0.3%
Detector parts are introduced step by step (MINERVE spectrum)

- The chamber itself accounts for all the effect

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Geometry</th>
<th>All</th>
<th>Chamber + Connector</th>
<th>Chamber alone</th>
<th>Connector alone</th>
<th>Cable alone</th>
</tr>
</thead>
<tbody>
<tr>
<td>U235</td>
<td>CF4</td>
<td>-2.6%</td>
<td>-2.6%</td>
<td>-2.5%</td>
<td>-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>CF8R</td>
<td>-4.1%</td>
<td>-4.2%</td>
<td>-4.1%</td>
<td>-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>CF8Rgr</td>
<td>-6.5%</td>
<td>-6.5%</td>
<td>-6.2%</td>
<td>-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>U238</td>
<td>CF4</td>
<td>-0.6%</td>
<td>-0.6%</td>
<td>-0.5%</td>
<td>-0.1%</td>
<td>-0.1%</td>
</tr>
<tr>
<td></td>
<td>CF8R</td>
<td>-0.9%</td>
<td>-0.9%</td>
<td>-0.9%</td>
<td>-0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>CF8Rgr</td>
<td>-1.1%</td>
<td>-1.0%</td>
<td>-0.9%</td>
<td>-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Np237</td>
<td>CF4</td>
<td>-0.3%</td>
<td>-0.2%</td>
<td>-0.1%</td>
<td>-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>CF8R</td>
<td>-0.3%</td>
<td>-0.3%</td>
<td>-0.3%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>CF8Rgr</td>
<td>-0.4%</td>
<td>-0.3%</td>
<td>-0.3%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Convergence ~0.2%

Conclusion for future calculations

- Detector geometry has to be very precise
- Other parts can be removed (connector, cable)
3. RESULTS: METHOD VALIDATION

Comparison with full core calculations

- MINERVE reactor in MAESTRO configuration (4mm geometry)
- Convergence uncertainty ~0.8 %
- Consistent results for all isotopes
Fission chamber measurements are subject to strong biases

- In ZPR, the detector fixture is invasive (local effect and reactivity effect)
- Direct effect is predominant (flux attenuation, neutron scattering)
- Indirect effect is negligible (in our case)

Correction factor can be obtained by simple Monte Carlo simulation

- Factors are dependent on numerous parameters (spectrum, isotope, geometry)
- One full core calculation (independent on the detector) is needed to have the neutron spectrum to feed the simplified geometry

Study will be extended

- to sub-miniature fission chambers (Ø3mm, Ø1.5mm)
- to MTR spectra (JHR applications)
- to fast neutron spectra (ITER, 14 MeV neutron generator)
Thank you for your attention
Principe de détection

Formation du signal en deux temps :

- Convertisseur : dépôt fissile
- Chambre d’ionisation : électrodes, champ et gaz

Fission in fissile deposit

Two fission products \((Q \approx +22e)\)

Ionization of fill gas, charge collection and generation of a current pulse

Signal \(\alpha\) fission rate
Spherical neutron source

- Ti
- Ar (Tally volume)
- void