• **CASMO-3:** State-of-the-art: 1980’s
  Homogeneous Trans. Prob., 40 group ENDF/B III Library, External Gd depletion (MICBURN code)

• **CASMO-4/4E:** State-of-the-art: 1990’s, 2000’s
  Heterogeneous MoC, 70 group ENDF/B IV Library, Internal Gd depletion
  Widely used, solid production code

• **CASMO5:** State-of-the-art: 2010’s
  Heterogeneous MoC, 586 group ENDF/B-VII.0 library,
  Many advanced models for new lattice designs,
  Quadratic Gd depletion, resonance upscatter, etc.
What is going on in CASMO?

2010
CASMO-5
CASMO-5M

2011
CASMO5

One code for single assembly, multi-assembly (MxN), rack calculations (FSS/FSC) and higher-order Pn-scattering
CASMO5 has full downstream CMS compatibility.
CASMO5 Benchmarking/Validation

Always ongoing…..

• Validation against criticals:
  – B&W 1810
  – B&W 1484
  – Kritz-3 (PWR)/Kritz-4 (BWR)
  – Dimple
  – And now TCA (Tank Critical Assembly)
TCA : Tank Critical Assembly - JAERI
TCA Iron Reflector Experiment

• Basic Idea: examine the reactivity effect of using an iron reflector of various thicknesses: (0 cm → 15 cm)

• Square lattice of 15x15 fuel rods (2.6 wt%) (pitch=2.293 cm)

• Model using CASMO5 generalized rack geometry (FSS/FSC input) -- can model these criticals without geometrical approximation
Convert Delta Critical Height to Reactivity

\[ \Delta \rho = -K \pi^2 \left\{ \left( \frac{1}{H_0 + \lambda} \right)^2 - \left( \frac{1}{H_1 + \lambda} \right)^2 \right\} \]

where
- \( \Delta \rho \): Reactivity change (\$)
- \( H_0 \): Critical water level of water-reflected core (cm)
- \( H_1 \): Critical water level of iron-reflected core (cm)
- \( \lambda \): Extrapolation distance (cm)
- \( K \): Proportional constant (\$·cm²)
There are always questions about the quality of iron XS data and it is even more important with regards to heavy steel block reflectors, e.g. EPR, APR
TCA Refl. Critical: 1 Plate (0.56 cm)
TCA Refl. Critical: 27 Plates (15.12 cm)
CASMO5 TCA Model

~ 250,000 flat source regions
~47 million tracks
~7 gigabytes RAM
95 energy groups
5 CPU hours
# TCA Results Solid Plates

<table>
<thead>
<tr>
<th>Reflector Thickness (mm) (# plates)</th>
<th>Critical water Level (mm)</th>
<th>CASMO5 (Calc. at Critical Height)</th>
<th>CASMO5 (Calc. at Fixed Height H₀)</th>
<th>%Δk/k CASMO5</th>
<th>%Δk/k Measured*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>914.5</td>
<td>0.99969</td>
<td>0.99969</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>5.6 (1)</td>
<td>1286.3</td>
<td>0.99895</td>
<td>0.98596</td>
<td>-1.319</td>
<td>-1.310</td>
</tr>
<tr>
<td>28.0 (5)</td>
<td>1300.6</td>
<td>0.99872</td>
<td>0.98528</td>
<td>-1.366</td>
<td>-1.341</td>
</tr>
<tr>
<td>33.6 (6)</td>
<td>1234.0</td>
<td>0.99892</td>
<td>0.98695</td>
<td>-1.214</td>
<td>-1.189</td>
</tr>
<tr>
<td>61.6 (11)</td>
<td>1024.1</td>
<td>0.99995</td>
<td>0.99459</td>
<td>-0.539</td>
<td>-0.522</td>
</tr>
<tr>
<td>89.6 (16)</td>
<td>925.6</td>
<td>1.00044</td>
<td>0.99981</td>
<td>-0.063</td>
<td>-0.061</td>
</tr>
<tr>
<td>117.6 (21)</td>
<td>878.7</td>
<td>1.00089</td>
<td>1.00310</td>
<td>0.220</td>
<td>0.209</td>
</tr>
<tr>
<td>151.2 (27)</td>
<td>851.7</td>
<td>1.00140</td>
<td>1.00547</td>
<td>0.404</td>
<td>0.383</td>
</tr>
<tr>
<td>Ave.</td>
<td></td>
<td>0.99987</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S.D.</td>
<td></td>
<td>0.00099</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

TCA Reflector: No water between steel plates

![Graph showing reactivity effect vs. iron reflector thickness](image-url)
Discussion

• Minimum reactivity effect is a thickness between 1.0 and 2.0 cm (typical of a PWR baffle)

• Reactivity increases up to about 15 cm where it saturates

• **CASMO5** matches the experiment quite well!
TCA 10% Water Volume 25 plates
## TCA Results with 10% Water Volume Between Plates

<table>
<thead>
<tr>
<th>Reflector Thickness (mm) (# plates)</th>
<th>Critical water Level (mm)</th>
<th>CASMO5 (Calc. at Critical Height)</th>
<th>CASMO5 (Calc. at Fixed Height:H₀)</th>
<th>%Δk/k CASMO5</th>
<th>%Δk/k Measured*</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 (0)</td>
<td>914.5</td>
<td>0.99969</td>
<td>0.99969</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>37.3 (6)</td>
<td>1286.3</td>
<td>0.99793</td>
<td>0.98671</td>
<td>-1.139</td>
<td>-1.118</td>
</tr>
<tr>
<td>67.9 (11)</td>
<td>1300.6</td>
<td>0.99885</td>
<td>0.99332</td>
<td>-0.557</td>
<td>-0.542</td>
</tr>
<tr>
<td>99.6 (16)</td>
<td>1234.0</td>
<td>0.99856</td>
<td>0.99675</td>
<td>-0.183</td>
<td>-0.176</td>
</tr>
<tr>
<td>130.7 (21)</td>
<td>1024.1</td>
<td>0.99863</td>
<td>0.99850</td>
<td>-0.013</td>
<td>-0.013</td>
</tr>
<tr>
<td>156.5 (25)</td>
<td>925.6</td>
<td>0.99772</td>
<td>0.99891</td>
<td>0.119</td>
<td>0.115</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Ave.</th>
<th>0.99856</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S.D.</td>
<td>0.00070</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum experimental error estimated to be 0.04% dk/k

Water volume 10% between steel plates
Observations:

• The reactivity effect of 10% water is smaller than without water

• Under the same thickness of reflector region thermal neutron absorption increases because of the softer spectrum

• Iron has been displaced so there is less reflector effect
Baffle and reflector effects are well modeled in CASMO5
Conclusions:

• ENDF/B-VII Fe data appears to be good

• **CASMO5** models heavy steel reflectors quite well!

• Ready for next generation reactors