HUEMUL: A TRANSPORT CODE FOR GENERAL GEOMETRIES INCLUDING REACTIVITY DEVICES ITS VALIDATION AGAINST MEASUREMENTS

Carlos Rubén Calabrese, Carlos Grant, Ana María Lerner, Carla Notari, Oscar Serra
Comisión Nacional de Energía Atómica (CNEA)
Centro Atómico Constituyentes, Gerencia de Ingeniería
Avenida del Libertador 8250, (1429) Capital Federal,Argentina

1.Introduction

The HUEMUL code (reference 1) was developed in Comisión Nacional de Energía Atómica (CNEA), Argentina. It solves the Two Dimension (2D) Transport Equation using the multigroup collision probability method for general geometries. Arbitrary segments and circunference arc combinations, permit a great flexibility in the geometric treatment. Boundary conditions in the form of an albedo matrix (J+/J-) are included for each face of the model.

Due to these characteristics HUEMUL becomes a useful tool to face a great variety of problems, specially the calculation of parameters associated to control rod and reactivity devices.

2. HUEMUL validation

Several calculations were performed using HUEMUL:

2.1 Comparisons of results between HUEMUL and WIMS (reference 2)

A light water cell with 3% wt enriched UO2 as shown in

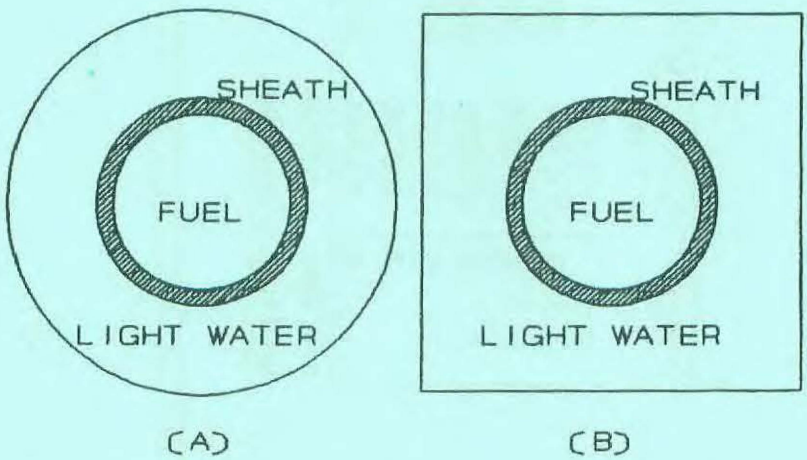

Figure 1. (A) Model Used by WIMS (B) Model used by HUEMUL

TABLE I. WIMS/HUEMUL FLUXES (*) AND K-INF COMPARISONS (3 w% UO2 enr. fresh fuel, see fig.1)

	FUEL FLUX		CLAD FLUX		MODERATOR FLUX		CELL FLUX	
Group	HUEMUL	WIMS	HUEMUL	WIMS	HUEMUL	WIMS	HUEMUL	WIMS
1	1.719	1.709	1.5595	1.5689	1.4441	1.4476	1.5128	1.5134
2	2.168	2.161	2.0063	2.012	1.8706	1.8728	1.9455	1.9457
3	0.902	0.901	0.8962	0.9012	0.8942	0.8952	0.8961	0.8976
4	1.016	1.017	1.024	1.0295	1.0377	1.0385	1.032	1.0333
5	0.3236	0.3237	0.3388	0.3404	0.3511	0.3513	0.3442	0.3447
6	0.2702	0.2708	0.2835	0.2844	0.296	0.2957	0.2895	0.2894
7	0.3998	0.4	0.4037	0.4056	0.4115	0.4109	0.4085	0.4083
8	2.1383	2.1379	2.3484	2.3414	2.65	2.6223	2.5206	2.4975

k-inf WIM =1.3934

k-inf HUE =1.3939

(*) Fluxes are normalized to one fission neutron born in the cell

figure 1 (A) was calculated using the WIMS code. This cell was circularized using the Wigner-Seitz approximation.

Using eight energy group physical properties calculated with WIMS, HUEMUL reproduced the flux distribution in a square arrangement (See figure 1 (B)), supposing reflection along the boundary (J+=J-). Forty equidistant lines and 16 directions (considering simetry) were chosen for the calculation. Normalized fluxes to one neutron born per second uniformly in the cell are shown in Table I. They show a very good agreement in fluxes and multiplication constant k (better than 1.5% in fluxes and 0.5 mk in k, see figure 1 and Table I).
(Detailed calculations may be found in reference 1).

2.2 Comparisons between HUEMUL calculations and copper activity measurements performed in the Canadian D2O facility ZED-2 (Reference 3)

Adjuster rod activity measurements in the Canadian heavy water critical facility ZED-2 were simulated with HUEMUL.
The experiment simulated was an adjuster rod located at the center of the core, parallel to the ZED-2 fuel channels.

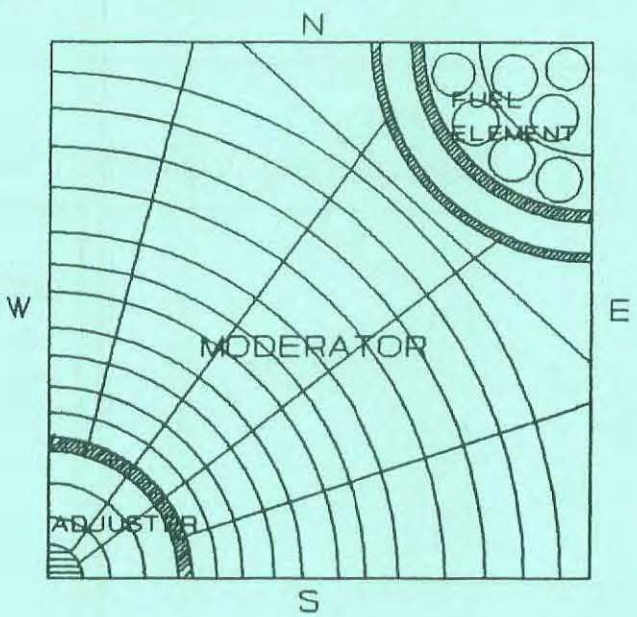

Figure 2. ZED2 model used by HUEMUL

Figure 2 shows the model used by HUEMUL to represent the configuration described above. A very good agreement was obtained (better than 2%, see figures 3 and 4).
(Detailed calculations may be found in reference 1).

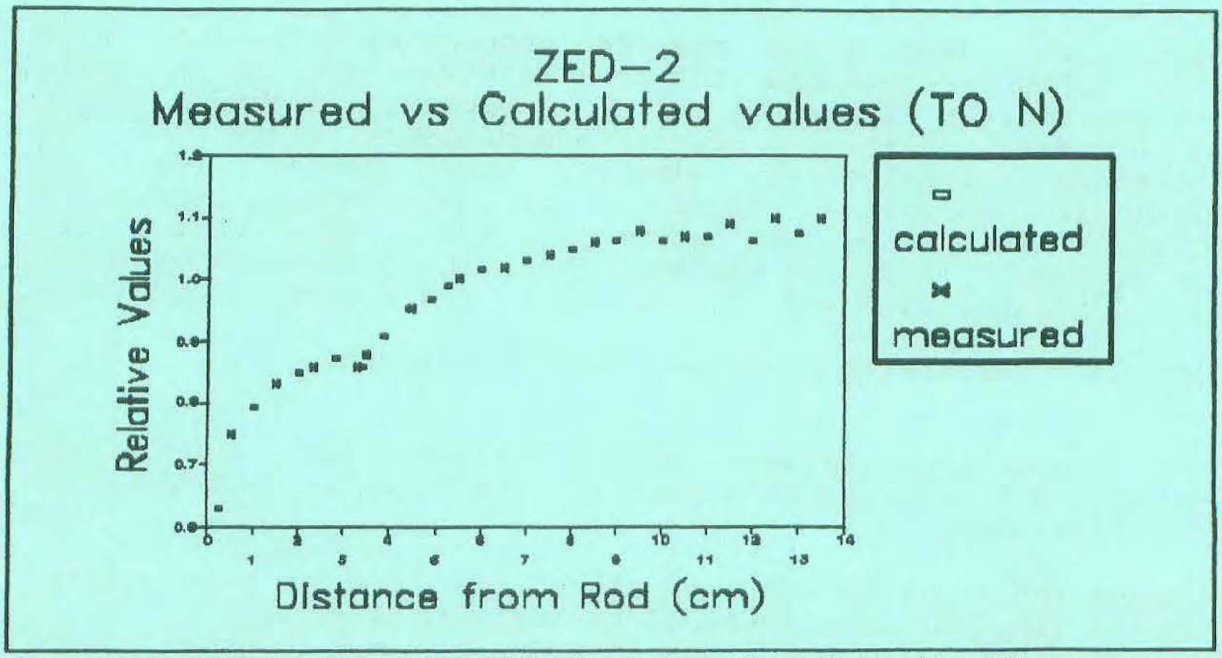

Figure 3. Measured vs HUEMUL calculated values (to N)

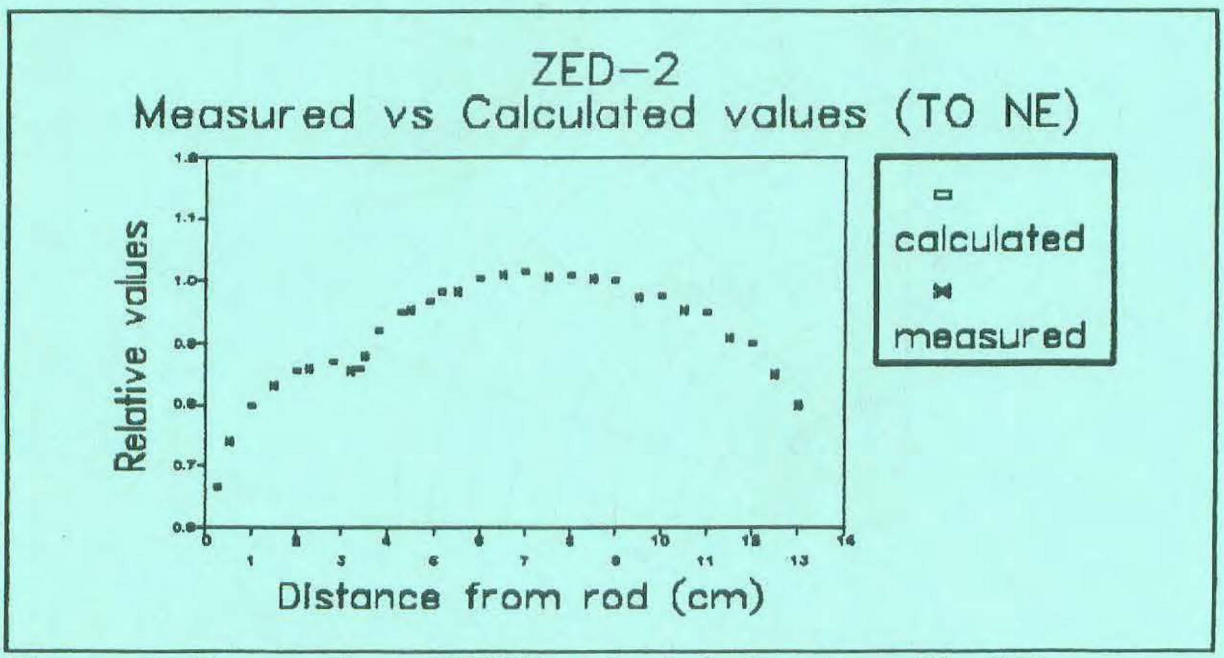

Figure 4. Measured vs HUEMUL calculated values (To NE)

2.3 Comparisons between HUEMUL calculations and manganesum activity measuremets performed in the Argentine H2O facility RA-2 (Reference 4).

Activity measurements in the Argentine light water critical facility RA2 were simulated with HUEMUL. The neutronic flux

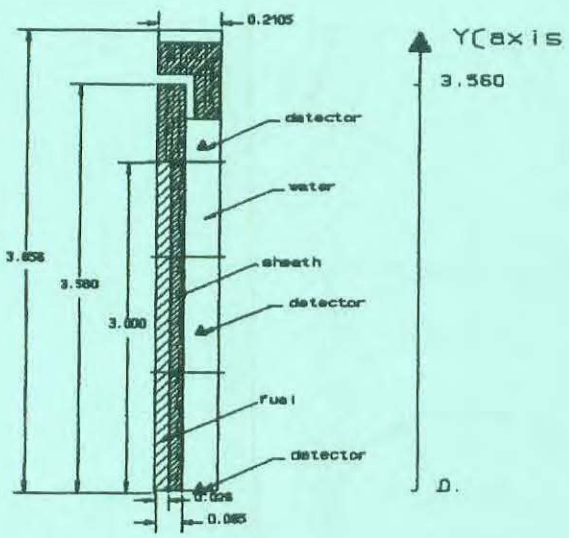

Figure 5. RA2 fuel model used by HUEMUL

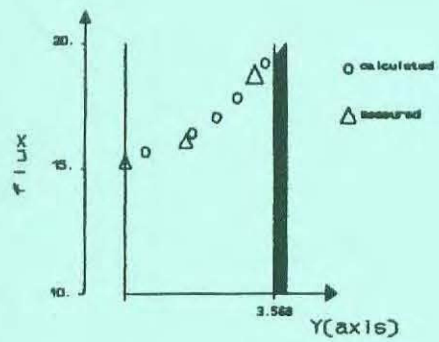

Figure 6. Measured vs HUEMUL calculated val.

was calculated within a 2D MTR cell, considering the leakage across the boundary in such a way that the location of the MTR fuel element is taken into account. A 14 group calculation was performed. The results were compared with experimental values obtained by Mn-Ni activation (See reference 4).

The 2D model is shown in figure 5, and the comparison can be seen in figure 6.

The calculated values agree with the measurements within their experimental errors.

2.4 Rod calculations for the Atucha I power plant (CNA1).

A new methodology to calculate the control rods for the ATUCHA I power reactor was required in order to face problems such as reactivity devices design changes, or slightly enriched uranium calculations. For that reason, and considering that the 2D scheme is appropriate to describe the geometry of the problem, HUEMUL was used.

In order to validate the proposed methodology and code, the first stage was to obtain values of the incremental cross sections for the control rods for Atucha 1 nominal conditions in order to reproduce the experiments mentioning below.

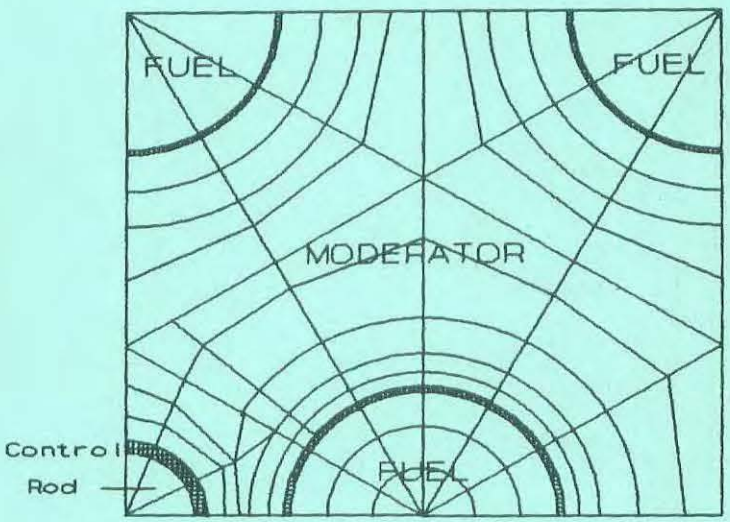

Figure 7 ATUCHA 1 multicell model used by HUEMUL

The model used by HUEMUL can be seen in figure 7. WIMS code was used to calculate the cross sections, and the incremental cross sections representing the control rods were obtained, as usual, as the difference between the perturbed case (rods inserted) and the reference case (without rods).
Comparisons were made between reactor calculations performed with PUMA (finite difeferences, see reference 5) and DELFIN (finite elements, see reference 6) using incremental cross sections calculated by HUEMUL and experimental data obtained at zero power (reference 7). The results show a very good agreement (better than 2%, see figures 8 and 9). PUMA results required a slight adjustement due to the dilution effect.

3.Conclusions

The results obtained show that HUEMUL is a powerful tool to face 2D reactivity device problems. It can be used in experimental and power reactors, specially for Atucha I and II power stations.

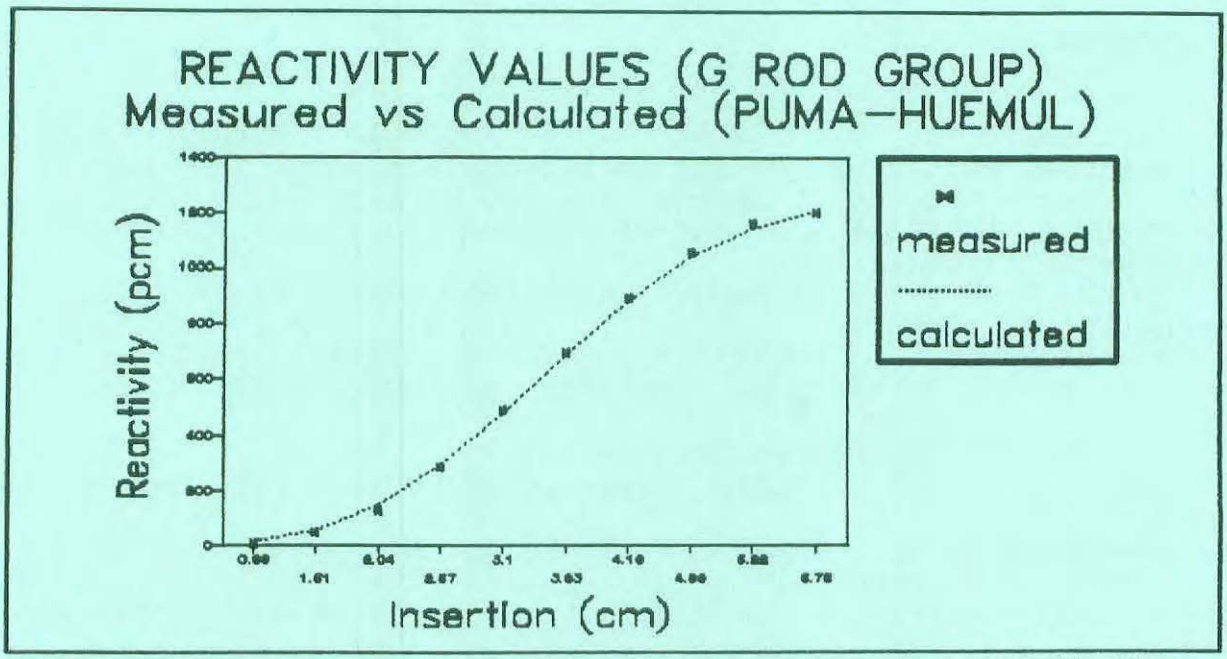

Figure 8. Reactivity values (Measured vs calculated)(PUM/HUE)

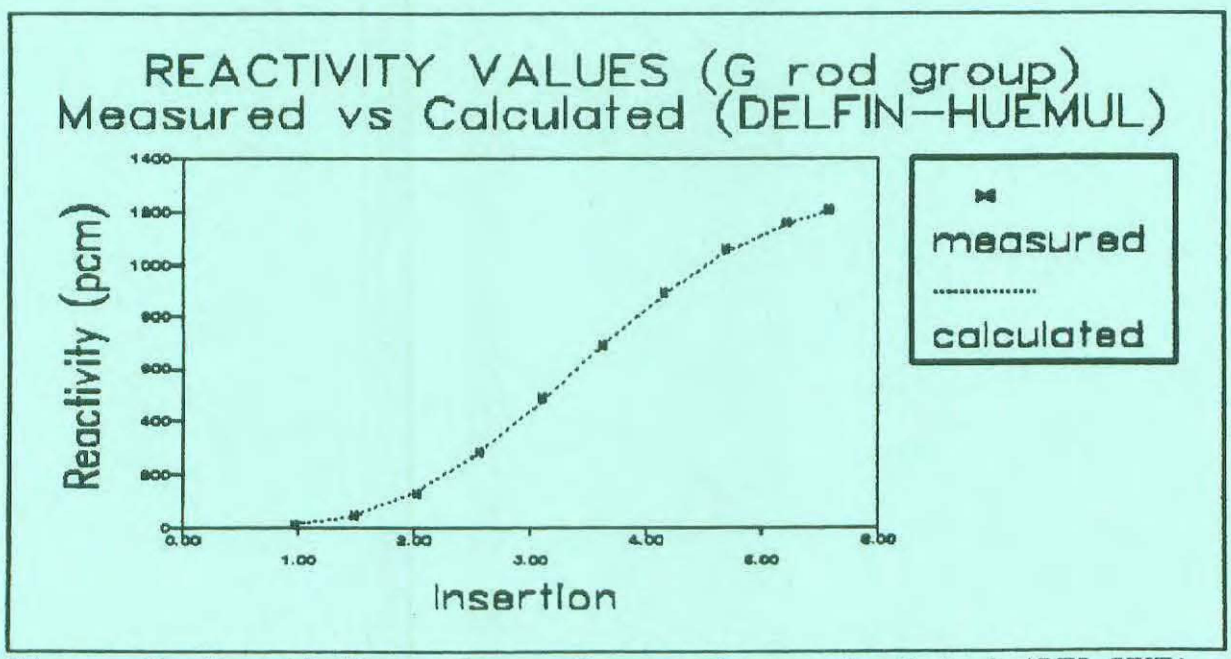

Figure 9. Reactivity values. Measured vs calculated (DEL/HUE)

4.References

1) CALABRESE C. R., GRANT C. R. .(1991) "HUEMUL, a two dimensional multigrup collision probability code for general geometries". Ann. nucl. Energy, Vol 18, No 2 pp 63-73.
2) ASKEW J. FAYERS F. J. and KEMSHELL P. B. J. Br. Nucl. Soc. 5, 564-585 (1966).
3) JONES R. T. (1977) Report AECL-5853, Chalk River Nuclear Laboratories, Ontario.
4) RICABARRA G., RICABARRA M., BANG M. (1984) "Análisis de Mediciones de Buckling en núcleos tipo MTR". CNEA. Proyecto Centro Atómico Perú.
5) GRANT C. (1980) Report CNEA-Re 163.
6) GRANT C. (1991) "DELFIN, Descripción y Uso". CNEA Report IT 1054/91.
7) CALABRESE C. R., GRANT C., LERNER A. M., NOTARI C., SERRA O. (1992) "Incremental cross sections for control rods in CNA1". XX Congreso de la Asociación Argentina de Tecnología Nuclear.