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EUROPEAN ATOMIC ENERGY COMMUNITY — EURATOM

# THE "PROCELLA" METHOD FOR HEAVY WATER LATTICES

by

R. BONALUMI, F. PALAZZI and G. PIERINI
(CISE)

1968

CIRENE Program

Report prepared by CISE
Centro Informazioni Studi Esperienze, Segrate (Milan) - Italy

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probability allowing for high energy flux peaking and using a simplified absorption cross section which reproduces Hellstrand's resonance integrals; 3) a very special, analytical treatment of thermalization in the fuel element, starting from a Westcott-like flux in the moderator; 4) epithermal cross sections including disadvantage and shielding factors, the latter ones being obtained by a generalized equivalence theorem for resonance capture.

Moreover, standard "transport" methods are used in calculating thermal fine flux (Amouyal-Benoist) and cell diffusion coefficients (Benoist).

The method was tested on a number of experiments: 1) the $K_{eff}$; of about 300 experimentally critical assemblies was calculated, showing that the calculated $K_{eff}$ is generally less than 1 by less than 0.005, 89 % of data being within $\pm$ 0.01 from the average $K_{eff}$; 2) Some detailed lattice parameters were also compared with their experimental values, obtaining an acceptable agreement. A systematic, through slight underestimate in p, increasing with the fuel element size, is due to neglecting spatial interference effects.

The method is embodied in the PROCELLA code, written for the IBM 7040 digital computer: each problem takes no more than 10 sec, thus making this method very attractive for long-term reactivity studies. The code was also carefully conceived so as to give most of the output data useful in design studies (differential coefficients) and in comparisons with experiments.

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**KEYWORDS**

HEAVY WATER MODERATOR
REACTOR CORE
DIFFUSION
FISSION
ABSORPTION
FAST NEUTRONS
EPITHERMAL NEUTRONS
THERMAL NEUTRONS
PROBABILITY THEORY
GROUP THEORY
URANIUM 238
RESONANCE ESCAPE PROBABILITY
NEUTRON FLUX
MATHEMATICS
FUEL ELEMENTS
CROSS SECTIONS
TRANSPORT THEORY
MULTIPLICATION FACTORS
P-CODES
IBM 7040
REACTIVITY
DESIGN
RESONANCE ABSORPTION
CAPTURE
CRITICAL ASSEMBLIES

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## Foreword

This work, originated by earlier research started in 1964, covered the period between March and September 1966: minor changes in the code output were later added for the designer's convenience.

The physical test of the method is kept up-to-date by check with recently published data.

# 1. INTRODUCTION

In the actual design of a power reactor, where extensive calculations are to be carried out, two conflicting requirements in the lattice physics model are to be met:

1) A rather high accuracy in the theoretical prediction of both reactivity and detailed cell parameters (namely those affecting long-term reactivity);

2) A short calculation time and a theoretical formulation simple enough as to allow a physical interpretation of the results.

The first requirement is nearly obvious, and especially it is all the more important to have a calculational method able to deal with hot, irradiated assemblies as well as with room temperature, clean lattices.

For this reason the usual coupling of simple theories with correlated constants (whose usefulness usually covers a very narrow range of lattice situations) was to be discarded. Earlier efforts in that direction confirmed the unreliability of such a procedure.

After the final set up of Benoist's theory on the lattice diffusion coefficients, and a reasonable freezing of monoenergetic first-collision probability methods, major problems to be faced were essentially spectral problems. Such problems involved primarily resonance absorption in $U^{238}$, shielding factors for resonance absorption in other heavy nuclides (including Pu isotopes), a consistent treatment of thermalization in $D_2O$ lattice containing both a hydrogeneous coolant (at various temperatures) and Pu isotopes, a consistent few-group theory able to predict 2-group parameters correctly.

All the above items were investigated carefully, with the aim of obtaining acceptably good predictions of:

1) Reactivity in nominal conditions

2) Reactivity coefficients related to changes in: coolant density and temperature, fuel temperature, moderator density and temperature, moderator poisoning, Xe content in the fuel

3) Long term reactivity evolution.

As for the last point, a separate report will be issued. The present report will describe in some detail: i) the theoretical basis of the integrat ed physics code, named PROCELLA, which was set up at CISE as the final result of the theoretical effort mentioned above; ii) the rather extensive campaign of check calculations which demonstrate that the method is capable of fulfilling both the basic requirements of accuracy and simplicity.

In describing the model, which lends itself even to hand calculations, the overall self-consistency of the several bricks making up the building will be enphasized: for details on the bricks, the reader is referred to the bibliography.

The comparison of theory vs. experiments will concern both integral and detailed measurements: in either case the experimental parameter is calculated, with no effort to derive an "experimental" value of typically theoretical quantities.

For instance, no "experimental" f is evaluated, but theoretical neutron density across the lattice cell is instead compared with the measured one.

## 2. BASIC THEORY

### 2.1. Geometry and definitions

The PROCELLA code has been devised for clustered fuel elements in cylindrical cells; in particular a single fuel rod or tube can be dealt with, whilst annular geometries are to be avoided, owing to the effective resonance and fast fission factor calculation. However such troubles could be removed, if needed, by slightly modifying the code. Further, the cluster can be made up of equal or slightly different size rods or tubes; it has to be pointed out, however, that the $S_{eff}$ and $\varepsilon$ calculations are exact for a cluster of equally sized hexagonal subcells, each containing a fuel rod or tube.

The general geometry of the cell is shown on Fig. 1.

First of all, the cell can be divided into two parts: the clustered part, containing n fuel rods of tubes, and a cylindrically symmetric part, made up of some annuli. Safe the cross-sectional area, the former part may be thought of as replaced by n equally sized hexagonal subcells, each for fuel rod or tube, having a uniform center-to-center spacing t. Each subcell is composed of no more than five subzones, thus denoted:

- subzone 1: inner coolant, radius $a_1$;
- subzone 2: inner cladding, from radius $a_1$ to radius $a_2$,
- subzone 3: fuel material, from radius $a_2$ to radius $a_3$;
- subzone 4: outer cladding, from radius $a_3$ to radius $a_4$;
- subzone 5: outer coolant (inter-rod material), from radius $a_4$ to the subcell boundary.

The whole of the n subzones j constitutes the zone j (j = 1, 2, 3, 4, 5). In order to evaluate the effective resonance surface and the fast fission factor, the zones 1 and 2 and the zones 4 and 5 are collapsed together by a straight volume averaging, so that the cluster part of the cell results made up of three zones:

- zone i (zones 1 and 2 collapsed),
- zone u (zone 3, the fuel material),
- zone e (zones 4 and 5 collapsed).

The remainder of the cell is accounted for by the Dancoff coefficient in the $S_{eff}$ calculation and by the backscattering correction in the $\varepsilon$ calculation.

Such a two-part subdivision of the cell is maintained for evaluating the resonance escape probability, but once $S_{eff}$ has been obtained, the subcells are no more necessary and two simply volume-averaged regions are used for slowing-down calculations.

In order to obtain a spatially averaged description of the neutron spectrum, the annular composition of the cylindrically symmetric part of the cell has to be analysed. Generally, the fuel element will not be completely accounted for by the clustered part; one or more coolant annuli, a pressure tube may be present. Moreover, an empty, annular gap may exist.

The thermalization model requires two material regions: a "fuel" and a "moderator" possibly separated by a "gap" region. If the gap is absent, the natural choice is to take the moderator itself as the "moderator" region and the remainder as the "fuel" region.

The same choice can be used in calculating the cell diffusion coefficients, whilst a cylindrically symmetric description of the whole cell is required for evaluating the thermal flux fine distribution and the f and $\eta$ parameters.

The central fuel rod or tube has obviously a cylindrical symmetry. Instead, the peripheral rods or tubes are to be homogeneized in the proper annuli, the ratio "average flux in the rod/average flux in the annulus" being accounted for by a suitable disadvantage factor.

The cell will then result of

$$N = N_1 + N_2 + N_3 + N_g + N_m$$

cylindrical annuli, such that for increasing values of the radius one finds:

- $N_1$ annuli associated tc the central fuel rod or tube; to each annulus only one of the zones 1 to 4 is associated;
- $N_2$ annuli containing the peripheral (n-1) fuel rods or tubes; each annulus has all the zones 1 to 5;
- $N_3$ annuli completing the "fuel" region (without rods or tubes); the zones 6, 7,... are associated to the 1st, 2nd,... respectively of these $N_3$ annuli;

- an empty annulus, which may be present ($N_g = 1$) or not ($N_g = 0$)
- $N_m$ annuli constituting the "moderator" region; the zones $N_3 + 6$, $N_3 + 7$,... are associated to the 1st, 2nd,... respectively of these $N_m$ annuli.

A material composition is assigned to each zone, by giving the number of nuclides, their order number in the library and their nuclear density for each zone.

## 2.2. The effective resonance surface

The effective resonance integral of U-238 in the fuel element is assumed to have the form $A + I_s$, where A is the mass absorption constant and $I_s$ is the surface contribution due to an unbroadened Breit-Wigner cross section. The effective resonance surface $S_{eff}$ is defined by the relationship

$$I_s = B\sqrt{S_{eff}/M} \qquad (2.2.1)$$

where M is the fuel material mass and B an experimental constant.

In order to calculate $I_s$, it is split into two terms (see Ref. 1)

$$I_s = I_{so} + I_{si} \qquad (2.2.2)$$

Let $S_o$ denote the effective outer surface of the fuel element; for cluster geometry, $S_o$ is the polygonal surface described by those sides of the peripheral subcells which are confining with the moderator. The integral $I_{so}$ is defined as the contribution of the neutrons impacting on $S_o$ which are born in the moderator, while $I_{si}$ takes into account the absorption of the neutrons slowed-down from above into the resonance energies, i.e. into the interval $(q_o E_o, E_o)$, inside the fuel element. $E_o (1-q_o)$ is the effective energy width of the average $U^{238}$ resonance, as defined in Ref. 1.

## 2.3. The neutron thermalization model; thermal and epithermal macroscopic cross sections

### 2.3.1. The thermalization model

The main features of the thermalization model, discussed in detail on Ref. 2, are the following:

- the average spectrum in the moderator is taken, following Westcott, of the form

$$\phi_{mod}(E) = \frac{E}{(k\theta_m)^2} \exp\left(-\frac{E}{k\theta_m}\right) + \alpha \frac{\Delta_4(E/k\theta_m)}{E} \qquad (2.3.1.1)$$

where $\theta_m$ is the neutron temperature of the moderator;

- the average spectrum in the fuel element results from the superposition of a "thermal" and an "epithermal" solution to a two-region balance equation;
- the thermal equation involves a simplified integral operator for the thermalization, use of the adjusted diffusion theory according to Schaefer-Tretiakoff for the moderator, the first collision probability formalism with parabolic scattering source distribution for the fuel element;
- the epithermal equation involves also a simplified integral operator for the slowing-down; a generalized equivalence theorem makes it possible to deal with non-moderating fuel elements only; a flat flux is assumed in both fuel and moderator, but at two different levels.

The average spectrum in the fuel element results of the form

$$\phi_{fuel}(E) = \frac{E \exp(-E/k\theta_m)/(k\theta_m)^2 + W \exp(-E/kT_f)/(kT_f)^2}{1 + \lambda\left[\xi\Sigma_s + \Sigma_a(E)\right]_{fuel}} +$$

$$+ \alpha \frac{\Delta_4(E/k\theta_m)}{E} \quad \chi(E) \qquad (2.3.1.2)$$

where $T_f$ is the physical temperature of the fuel element, $\lambda$ is related to the self-collision of the fuel element and to the moderator incurrent, W accounts for the re-thermalization in the fuel element and is proportional to $\lambda(\xi\ \Sigma_s)_{fuel}$, $\chi(E)$ is a depression factor.

Westcott's absorption and fission g-factors for Pu-239 are calculated by ad-hoc formulae, whilst for the other nuclides they are calculated at a proper neutron temperature, $\theta_f$ for the fuel element and $\theta_m$ for the moderator.

Shielding factors $\chi_R$ are calculated for the resonances of particular nuclides (U-235, Pu-239, Pu-240, Pu-241, for other nuclides, $\chi_R = 1$) in the epithermal region of the spectrum, whilst an average depression factor $\chi_E$ accounts for the epithermal neutron density in the fuel with respect to the one in the moderator.

If

$$\phi = (n_M + n_E)v_o \qquad (2.3.1.3)$$

is the Westcott flux, the thermal and epithermal reaction rates in the fuel element are respectively

$$\text{M.R.R.} = \hat{\sigma}_M\ n_M\ v_o \qquad (2.3.1.4)$$

$$\text{E.R.R.} = \hat{\sigma}_E\ n_E\ v_o \qquad (2.3.1.5)$$

where (b = 1.17626):

$$\hat{\sigma}_M = \sigma_o g(\theta_f) \qquad (2.3.1.6)$$

$$\hat{\sigma}_E = \hat{\sigma}_M + \frac{1}{b}\ \sigma_o s\ (\theta_m)\ \frac{\chi_R}{\chi_E} \qquad (2.3.1.7)$$

The total reaction rate is therefore $\hat{\sigma}\ \phi$, if

$$\hat{\sigma} = \sigma_o \left[ g(\theta_f) + r\ s\ (\theta_m)\ \chi_R/\chi_E \right] \qquad (2.3.1.8)$$

and

$$r = \frac{1}{b}\ \frac{n_E}{n_M+n_E} \qquad (2.3.1.9)$$

Obviously, for the moderator one has to put $\theta_m$ instead of $\theta_f$ into (2.3.1.6) and $\chi_R = \chi_E = 1$ into (2.3.1.7).

### 2.3.2. Thermal and epithermal macroscopic cross sections

In this section some symbols frequently used will be explained and some definitions set up.

Microscopic parameters ($\Delta U_m = \ln(2\cdot 10^6\, eV/\mu k\theta_m)$).

| | |
|---|---|
| $\sigma_{ao}$ | 2200 m/s absorption cross section |
| $\sigma_{sM}$ | thermal scattering cross section |
| $1-\mu_M$ | $u_M$ = average cosine of the thermal scattering angle |
| $\sigma_{sE}$ | epithermal scattering cross section |
| $\sigma_{sV}$ | fast scattering cross section |
| $\xi$ | average lethargy gain per scattering |
| $1-\mu_E$ | $\mu_E$ = average cosine of the epithermal and fast scattering angle |
| $\nu$ | fast neutrons produced per one thermal or epithermal fission |
| $\sigma_{fo}$ | 2200 m/s fission cross section |
| $\alpha$ | $(A-1)^2/(A+1)^2$, where A is the mass number |
| $\sigma_{aM}$ | $\sigma_{ao} g(\theta)\sqrt{\pi T_o/4\theta}$ , average thermal absorption cross section |
| $\sigma_{fM}$ | $\sigma_{fo} g_f(\theta)\sqrt{\pi T_o/4\theta}$, average thermal fission cross section |
| $\sigma_{aE}$ | $\sigma_{ao}\left[b\, g(\theta) + s(\theta_m)\, \chi_R/\chi_E\right] \dfrac{\sqrt{\pi T_o/4\theta_m}}{\Delta U_m}$ , epithermal absorption cross section |
| $\sigma_{fE}$ | $\sigma_{fo}\left[b\, g_f(\theta) + s_f(\theta_m)\chi_R/\chi_E\right] \dfrac{\sqrt{\pi T_o/4\theta_m}}{\Delta U_m}$ , epithermal fission cross section |
| $\sigma_{tr}$ | $\sigma_a + \sigma_s(1-\mu)$, transport cross section |

Composition of the cell(1)

$N_{n,\alpha\beta}$ concentration of the nuclide n in the zone $\beta$ of the annulus $\alpha$

$V_{\alpha\beta}$ volume of the zone $\beta$ in the annulus $\alpha$

$V_{\alpha}$ volume of the annulus $\alpha$

$\Phi_{g,\alpha}$ g-th group flux in the annulus $\alpha$

$\Phi_{g}$ g-th group flux in the cell

$\sigma_{\gamma g,n\alpha}$ microscopic cross section for event $\gamma$ in the group g, relative to the nuclide n in the annulus $\alpha$

$\Sigma_{\gamma g,\alpha\beta}$ macroscopic cross section for event $\gamma$ in the group g, relative to the zone $\beta$ in the annulus $\alpha$

$\Sigma_{\gamma g,\alpha}$ macroscopic cross section for event $\gamma$ in the group g, relative to the annulus $\alpha$

$G_{g,\beta}$ coolant-to-fuel disadvantage factor for group g in the zone $\beta$ (only $G_{M,3} \neq 1$), see Eq. (2.5.35)

$\Sigma_{\gamma g}$ macroscopic cross section for event $\gamma$ in the group g, relative to the lattice cell.

Cross sections for zones and annuli

$$\Sigma_{\gamma g,\alpha\beta} = \sum_{n} N_{n,\alpha\beta}\ \sigma_{\gamma g,n\alpha}$$

$$\Sigma_{\gamma g,\alpha} = \frac{1}{V_{\alpha}} \sum_{\beta} \Sigma_{\gamma g,\alpha\beta} \frac{V_{\alpha\beta}}{G_{g,\beta}}$$

$$\Sigma_{\gamma g} = \sum_{\alpha} \Sigma_{\gamma g,\alpha} V_{\alpha}\ \Phi_{g,\alpha} / \sum_{\alpha} V_{\alpha}\ \Phi_{g,\alpha}$$

$$Q_{\alpha} = \sum_{\beta} \xi\Sigma_{sE,\alpha\beta} V_{\beta}$$

(1) g = M, E, I, S, V (Maxwellian, epithermal (lower + upper), lower epithermal, upper epithermal, fast group; for further details see Sect. 3.1.)

$\beta$ = 1, 2, 3, 4, 5

n = 1,...,30

$\alpha$ = 1,...,20

$$C_{u,\alpha} = \Sigma_{aM,\alpha 3} V_{\alpha 3}/G_{M,3}$$

$$F_{M,\alpha} = \nu \Sigma_{fM,\alpha 3} V_{\alpha 3}/G_{M,3}$$

$$F_{E,\alpha} = \nu \Sigma_{fE,\alpha 3} V_{\alpha 3}$$

Cell cross sections

$$A_g = \sum_\alpha \Sigma_{ag,\alpha} V_\alpha \Phi_{g,\alpha} / \sum_\alpha V_\alpha \Phi_{g,\alpha} \qquad (g = M, E)$$

$$R_g = \sum_\alpha \frac{\xi\Sigma_{sg,\alpha} V_\alpha \Phi_{g,\alpha}}{\Delta u_g} / \sum_\alpha V_\alpha \Phi_{g,\alpha} \qquad (g = I, S, V)$$

$$F_g = \sum_\alpha F_{g,\alpha} \Phi_{g,\alpha} / \sum_\alpha V_\alpha \Phi_{g,\alpha} \qquad (g = E)$$

Four-group constants

$$\Delta u_m = \Delta u_I + \Delta u_S + \Delta u_V$$

$$\Delta u_V = 3, \quad \Delta u_S = \ln(2x10^4), \quad \Delta u_m = \ln(2x10^6/\mu k\theta_m), \quad \Delta u_I = \ln(5/\mu k\theta_m)$$

$$D_I = D_S \quad , \quad \xi\Sigma_{sI} = \xi\Sigma_{sS}$$

$$A_I \Delta u_I + A_S \Delta u_S = A_E \Delta u_m$$

$$F_I \Delta u_I + F_S \Delta u_S = F_E \Delta u_m$$

$$A_S \Delta u_S = \int_{5\text{ eV}}^{0.1\text{ MeV}} \{\sigma_{a5}(E) N_5 + \sigma_{a9}(E) N_9 + \sigma_{a1}(E) N_1\} \frac{dE}{E} \frac{(\phi V)_{fuel}}{(\phi V)_{cell}} + (\tfrac{1}{v} \text{ contribution})$$

$$F_S \Delta u_S = \int_{5\text{ eV}}^{0.1\text{ MeV}} \{\nu_5 \sigma_{f5}(E) N_5 + \nu_9 \sigma_{f9}(E) N_9 + \nu_1 \sigma_{f1}(E) N_1\} \frac{dE}{E} \frac{(\phi V)_{fuel}}{(\phi V)_{cell}}$$

## 2.4. The resonance escape probability

According to Ref. 3, the U-238 resonance escape probability is defined for a two-region cell made up of a fuel of radius a and a moderator of outer radius b, by means of the formula

$$p = \exp(-\ \alpha N_8\ V_u\ I_{eff}/(\xi\Sigma_S V)_{cell}) \qquad (2.4.1)$$

where

$$\alpha = 1 + (\gamma_1 + \gamma_2 \frac{S_{eff}}{M})\ (\sqrt{T_u} - \sqrt{T_o}) \qquad (2.4.2)$$

is the Doppler coefficient at the absolute fuel temperature $T_u$, $\gamma_1$ and $\gamma_2$ being constants.

Two age parameters are defined which account for the moderator region properties(°):

$$\tau_R = \frac{3}{3(\xi\Sigma_s\ \Sigma_{tr})_V} + \frac{\Delta u_R}{3(\xi\Sigma_s\ \Sigma_{tr})_E} \doteq \tau_o + \theta\ \Delta u_R \qquad (2.4.3)$$

$$\tau^* = \frac{3}{3(\xi\Sigma_s\ \Sigma_{tr})_V} + \frac{\Delta u^*}{3(\xi\Sigma_s\ \Sigma_{tr})_E} \doteq \tau_o + \theta\ \Delta u^* \qquad (2.4.4)$$

Let

$$v = \frac{b^2-a^2}{4\ \tau_R}\ ,\quad S_o = \frac{\pi a^2}{4\tau_R}\ ,\quad S = \frac{(\xi\Sigma_s)_{fuel}}{(\xi\Sigma_s)_{mod}}\ ,\quad z = \frac{4a^2}{\pi\tau^*}\ ,\quad z_o = \frac{4a^2}{\pi\tau_o}$$

then it follows that

$$y_m = 0.1073\ \frac{\tau_R}{\theta} \left\{ \frac{f_o(z)}{f(z)} \left[ \frac{\tau^*}{\theta f_o(z)} - (\frac{\tau_o}{\theta} - 3)g(z) \right] - \right.$$

$$\left. - \frac{f_o(z_o)}{f(z_o)} \left[ \frac{\tau_o}{\theta f_o(z_o)} - (\frac{\tau_o}{\theta} - 3)g(z_o) \right] \right\} \qquad (2.4.5)$$

$$y_\infty = y_m + \frac{\beta\sqrt{z_1\ S_{eff}/M + z_2}}{0.7854 + \sqrt{0.046 + S_o}} \qquad (2.4.6)$$

(°) $\tau_o$: fission neutron age down to 0.1 MeV

$\tau_R$: the same down to an equivalent single resonance at $u_R$ = 9.5928

$\tau^*$: the same down to u = 9.17 (smoothed $\sigma_a$ range)

$$t = \frac{v}{0.38} \sqrt{\frac{y_m}{y_\infty}} \qquad (2.4.7)$$

$f_o(z)$, $f(z)$, $g(z)$ being suitable functions (see Ref. 3) and $\beta$, $z_1$, $z_2$ constants. The effective resonance integral of Eq. (2.4.1) can finally be expressed in the form:

$$I_{eff} = A + B\sqrt{S_{eff}/M}\cdot\sqrt{C} + v\, y_\infty \left(1 - \frac{\text{arctg}\ t}{t}\right) \qquad (2.4.8)$$

where C is the Dancoff correction.

For a fuel element in an infinite sea of moderator, Eq. (2.4.1) becomes

$$p_\infty = \exp\{-\alpha\ N_8\ V_u\ y_\infty/(4\pi\tau_R(\xi\Sigma_s)_{mod})\} \qquad (2.4.9)$$

## 2.5. Thermal neutron distribution and related items

### 2.5.1. Some escape and collision probabilities

For a given annular region n let $R_{n-1}$ be the inner radius, $R_n$ the outer radius, $\alpha_n = R_{n-1}/R_n$, $\eta_n = \Sigma_{tr,n}\ R_n$, $S_n = 2\pi\ R_n$ the outer surface, $S_{n-1} = 2\pi\ R_{n-1}$ the inner surface, $V_n = \pi(R_n^2 - R_{n-1}^2)$ the volume.

Define $P_n^{ve}$ and $P_n^{vi}$ as the probability for a neutron uniformly generated in the region n to escape from its outer and inner boundary respectively without colliding; $P_n^{vv} = 1 - P_n^{ve} - P_n^{vi}$ is then the first collision probability in the region n for such a neutron.

Dropping the subscript n, one has the following sequence of formulae (see Ref. 4), where S should not be confused with the outer surface of the annulus:

$$\begin{cases} S = \frac{1}{2}\left(\frac{1}{\alpha}\ \arcsin\alpha + \sqrt{1-\alpha^2}\right) - \frac{\pi\alpha}{4} & \text{if } \alpha \neq 0 \\ S = 1 & \text{if } \alpha = 0 \end{cases} \qquad (2.5.1)$$

$$G_{12} = 1 - \frac{4}{\pi}\ Ki_3\ (\eta S) \qquad (2.5.2)$$

$$\begin{cases} P^{vi} = \dfrac{\alpha\ G_{12}}{2\eta(1-\alpha^2)} & \text{if } \eta \neq 0 \\ P^{vi} = \dfrac{2\ \alpha\ S}{\pi(1-\alpha^2)} & \text{if } \eta = 0 \end{cases} \qquad (2.5.3)$$

$$P_c(x) = \frac{1+(2x-1)(1+2cx)}{1+2x(1+2cx)} \quad , \quad c = \frac{4}{3} - \exp(-0.3\ x) \qquad (2.5.4)$$

$$\begin{cases} P^{vv} = \dfrac{P_c(\eta)-\alpha^2\left\{P_c(\alpha\eta)+G_{12}\left[1-P_c(\alpha\eta)\right](2-G_{12})\right\}}{1-\alpha^2} - P^{vi}\ G_{12}, & \text{if } \eta \neq 0 \text{ and } \alpha \neq 1 \\ P^{vv} = 0 & \text{if } \eta = 0 \text{ or } \alpha = 1 \end{cases} \qquad (2.5.5)$$

$$P^{ve} = 1 - P^{vv} - P^{vi} \qquad (2.5.6)$$

From the above probabilities, further probabilities $G_n^{hk}$ turn out, which refer to the absorption (k = v) or the escape (k = i,e) of one neutron born inside the region (h=v) or entering from boundaries (h = i,e), after any number of collisions in the region n. Such probabilities have the expressions:

$$G_n^{vi} = P_n^{vi}\ (1 - \tau_n\ P_n^{vv})^{-1} \qquad (2.5.7)$$

$$G_n^{ve} = P_n^{ve}\ (1 - \tau_n\ P_n^{vv})^{-1} \qquad (2.5.8)$$

$$G_n^{ii} = (\Sigma_{tr,n} - \Sigma_{a,n})\ P_n^{vi}\ G_n^{vi}\ 4\ V_n/S_{n-1} \qquad (2.5.9)$$

$$G_n^{iv} = \Sigma_{a,n}\ G_n^{vi}\ 4\ V_n/S_{n-1} \qquad (2.5.10)$$

$$G_n^{ev} = \Sigma_{a,n}\ G_n^{ve}\ 4\ V_n/S_n \qquad (2.5.11)$$

$$G_n^{vv} = 1 - G_n^{vi} - G_n^{ve} \qquad (2.5.12)$$

$$G_n^{ei} = (1 - G_n^{ii} - G_n^{iv})\ S_{n-1}/S_n \qquad (2.5.13)$$

where

$$\tau_n = 1 - \left[\Sigma_{a,n}/\Sigma_{tr,n}\right] \qquad (2.5.14)$$

If $R_{n-1} = 0$, instead of Eqs. (2.5.9), (2.5.10) and (2.5.13) one has

$$G_n^{ii} = G_n^{iv} = G_n^{ei} = 0 \qquad (2.5.15)$$

2.5.2. Determination of the flux distribution (BEAM routine)

Let the lattice cell be made up of m annular regions, the outermost one, of subscript m, being the moderator. Moreover, denote by $\Gamma_n^k$ ($k \leq n$) the number of thermal neutrons captured in the first k regions of the cell per neutron incoming from the outer boundary of the n-th region (the innermost region being the first one).

The actual calculation of the $\Gamma_n^k$'s is carried out by means of iterations, whose starting point consists in calculating the slowing-down density with the assumption of a flat flux throughout the cell.

If

$$N_n = \sum_{k=1}^{n} Q_k \quad ,$$

for the moderator region we put (see Ref. 5):

$$\frac{\Gamma_m^m}{\Gamma_m^{m-1}} = A + B \frac{1}{\Gamma_{m-1}^{m-1}} \qquad (2.5.16)$$

where

$$A = \frac{1 + D}{1+(1-Q_m/N_m)\cdot D} \quad , \quad B = \frac{\Sigma_{a,m}\, 4V_m/S_{m-1}}{1+(1-Q_m/N_m)\cdot D}$$

$$D = 3\,\Sigma_{a,m}\,\Sigma_{tr,m}\, C\left(\frac{R_m}{R_{m-1}}\right) R_m^2 + \frac{4V_m}{S_{m-1}}\,\Sigma_{a,m}\left(\frac{3}{4}\lambda_B - 1\right)$$

$$C(x) = \frac{1}{2}\left[\frac{x^2}{x^2-1}\ln x - \frac{3}{4} + \frac{1}{4x^2}\right]$$

$$\lambda_B = 0.7104 + \frac{0.2504}{0.402 + \Sigma_{tr,m} R_{m-1}}$$ (black-body extrapolation distance in units of moderator mean free paths)

and the ratio (2.5.16) fully describes the moderator.

Now, let $\mu_1 = 0$, $\Gamma_o^o = \Gamma_1^o = 0$ and for increasing values of n (n = 1, 2, ..., m-1) apply the recurrence formulae (for the $F_n$'s, see later):

$$q_n = \frac{Q_n}{N_m} F_n \qquad (2.5.17)$$

$$\mu_n = 1 - \Gamma_{n-1}^{n-1} + \frac{N_{n-1}}{N_m} F_{n-1} \qquad (2.5.18)$$

$$T_n = \frac{G_n^{ei} + q_n G_n^{vi}}{1-\mu_n G_n^{ii}} \qquad (2.5.19)$$

$$\Gamma_n^{n-1} = T_n \Gamma_{n-1}^{n-1} \qquad (2.5.20)$$

$$\Gamma_n^{n} = \Gamma_n^{n-1} + G_n^{ev} + q_n G_n^{vv} + \mu_n T_n G_n^{iv} \qquad (2.5.21)$$

When n = m-1, calculate

$$A + B/\Gamma_{m-1}^{m-1}$$

and then $\Gamma_m^m/\Gamma_m^{m-1}$ (see Eq. 2.5.16).

The fraction of thermal neutrons absorbed in the region n is

$$f_n = \frac{\Gamma_m^n}{\Gamma_m^m} \left(1 - \frac{\Gamma_n^{n-1}}{\Gamma_n^n}\right) \qquad (2.5.22)$$

and for the moderator one has

$$f_m = 1 - \frac{\Gamma_m^{m-1}}{\Gamma_m^m} \qquad (2.5.23)$$

Eqs. (2.5.17) to (2.5.23) are used until the $f_m$ values from two consecutive calculations are no longer different (in practice, until)

$$|1 - f_m^{(i-1)}/f_m^{(i)}| < 10^{-3}).$$

Moreover, for decreasing values of n (from m-1 to 1) the $F_n$ values are updated by means of the expressions

$$F_{m-1} = \frac{\Gamma_m^m \, \Gamma_{m-1}^{m-1}}{\Gamma_m^{m-1}} \tag{2.5.24}$$

$$F_n = \frac{F_{n+1}}{T_{n+1}} = \frac{\Gamma_m^m \, \Gamma_n^n}{\Gamma_m^n} \quad (n = m-2,\ m-3, \ldots, 1) \tag{2.5.25}$$

As an initial guess, we take

$$F_n = \sum_{k=1}^{n} \frac{4V_k}{S_n} \Sigma_{a,k} \quad (n = 1,\ 2, \ldots,\ m-1) \tag{2.5.26}$$

2.5.3. Final calculations

The final calculations give for each annular region n the fraction $f_n$ of thermal neutrons absorbed in the region and the mean flux

$$\begin{cases} \Phi_n = \dfrac{N_m \, f_n}{\Sigma_{a,n} \, V_n} & \text{if } \Sigma_{a,n} \neq 0 \\ \Phi_n = \dfrac{2\, N_m}{\pi R_n F_n} \left(P_n^{ve} + \mu_n P_n^{vi}\right) & \text{if } \Sigma_{a,n} = 0 \end{cases} \quad (n = 1,2,\ldots,m) \tag{2.5.27}$$

along with the following parameters:

- the thermal utilization factor of the fuel

$$f = \sum_{i=1}^{m} f_i \frac{C_{u,i}}{\Sigma_{a,i} \, V_i} \tag{2.5.28}$$

- the thermal fission factor

$$\eta = \frac{1}{f} \sum_{i=1}^{m} f_i \frac{F_{M,i}}{\Sigma_{a,i} \, V_i} \tag{2.5.29}$$

- the thermal absorption cross section

$$A_M = \frac{\sum_{i=1}^{m} \Phi_i \, V_i \, \Sigma_{a,i}}{\sum_{i=1}^{m} \Phi_i \, V_i} \tag{2.5.30}$$

- the thermal transport mean free path in the "fuel" region (see Sect. 2.6)

$$\lambda_{u,M} = \frac{\sum_{i=1}^{k'} \Phi_i V_i}{\sum_{i=1}^{k'} \Phi_i V_i \Sigma_{tr,i}} \qquad (2.5.31)$$

- the thermal transport mean free path in the "moderator" region (see Sect. 2.6)

$$\lambda_{m,M} = \frac{\sum_{i=k+1}^{m} \Phi_i V_i}{\sum_{i=k+1}^{m} \Phi_i V_i \Sigma_{tr,i}} \qquad (2.5.32)$$

$k'$ and $(m-k)$ being the number of annuli in the "fuel" and in the "moderator" region respectively ($k=k'+1$ or $k=k'$ according to the presence or absence of a gap).

### 2.5.4. Disadvantage factors

For a region n, the ratio

$$G_s = \frac{\Phi_S}{\Phi_n} = \frac{\text{flux at the surface } r = R_n}{\text{average flux in the volume } \pi R_n^2} \qquad (2.5.33)$$

can be evaluated by means of the formulae given on Sects. 2.5.2. and 2.5.3. Consider a fictitious region of outer radius $R_{n+1} = R_n + \varepsilon_k$ surrounding the region n. One has for such (n+1)-st region

$$\Phi_{n+1} = \frac{N_m}{\Sigma_{a,n+1} V_{n+1}} \frac{\Gamma_{n+1}^{n+1} - \Gamma_{n+1}^{n}}{F_{n+1}} = \frac{N_m}{\Sigma_{a,n+1} V_{n+1}} \frac{G_{n+1}^{ev} + q_{n+1} G_{n+1}^{vv} + r_{n+1} T_{n+1} G_{n+1}^{iv}}{T_{n+1} F_n}$$

When $\varepsilon_R \to o$, $q_{n+1} \to o$,

$$G^{vi}_{n+1} \to P^{vi}_{n+1} \to \tfrac{1}{2}$$

$$G^{ve}_{n+1} \to P^{ve}_{n+1} \to \tfrac{1}{2}$$

$$G^{vv}_{n+1} \to 0 \quad , \quad G^{ii}_{n+1} \to 0$$

$$T_{n+1} \to G^{ei}_{n+1} \to 1$$

and then

$$\Phi_S = \lim_{\varepsilon \to o} \Phi_{n+1} = \frac{N_m}{\Sigma_{a,n+1} V_{n+1}} \; \frac{G^{ev}_{n+1} + \mu_{n+1} G^{iv}_{n+1}}{F_n} =$$

$$= \frac{N_m}{\Sigma_{a,n+1} V_{n+1} F_n} \left[ \frac{2V_{n+1} \Sigma_{a,n+1}}{S_{n+1}} + \mu_{n+1} \frac{2V_{n+1} \Sigma_{a,n+1}}{S_n} \right] =$$

$$= \frac{N_m}{F_n} \; \frac{1+\mu_{n+1}}{\pi R_n}$$

where $\mu_{n+1} = 1 - \Gamma^n_n + \dfrac{N_n}{N_m} F_n .$

An approximate expression for $G_s$ is, in the case of a single solid rod:

$$G_s = 1 + \frac{\lambda - R}{1 - c\rho} \Sigma_{aM} = G_{rod} \tag{2.5.34}$$

where R = rod radius, $\eta = \Sigma_{tr,M} R$, $\lambda = 2R \dfrac{\eta+2}{\eta+3}$ , $c = \Sigma_{sM}/\Sigma_{totM}$,

$$z = \frac{3\eta}{8} \; \frac{\eta + 0.5148}{\eta + 2.70} \quad , \quad \rho = \frac{z}{1+z}$$

The homogenization of peripheral rods in the annular regions is made by using the disadvantage factor

$$G = \frac{\text{average flux in the annulus}}{\text{average flux in the rod}} \qquad (2.5.35)$$

obtained by a run of the BEAM routine for the system single rod-coolant. Generally one has $G \cdot G_{rod}$. In the case of fuel tubes, the code assumes G=1.

2.5.5. Edge flux, extrapolation length, blackness

Some useful parameters will now be given, all of them regarding the thermal flux.

If c is the inner radius of the main moderator, b the cell radius, $x = \frac{b}{c}$, $D_M$ the moderator diffusion coefficient, $j_o$ the net current entering the fuel element, then the edge flux, i.e. the flux at the cell boundary, will be

$$\Phi(b) = \frac{j_o}{D_M}\left(l_{ex} + \frac{cx^2}{x^2-1}\ \ln x - \frac{c}{2}\right) \qquad (2.5.5.1)$$

As the current entering the fuel element is

$$j_o = \frac{1}{2\pi c}\left(Q_m V_m - \Sigma_{a,m} V_m \Phi_m\right) \qquad (2.5.5.2)$$

and the average flux in the moderator is

$$\Phi_m = \frac{j_o}{D_M}\left(l_{ex} + 2\ c\ \frac{x^2\ C\ (x)}{x^2 - 1}\right) \qquad (2.5.5.3)$$

the extrapolation length

$$l_{ex} \equiv \frac{1}{\gamma_M^{(o)}} = \frac{2}{x^2-1}\left[\frac{D_M\ \Phi_m}{c(Q_m - \Sigma_{a,m}\ \Phi_m)} - c\ x^2\ C\ (x)\right] \qquad (2.5.5.4)$$

can be obtained; $\gamma_M^{(o)}$ is the fuel thermal absorption parameter directly used in the heterogeneous approach to lattice calculations.

In addition, one can define:

a) the fuel blackness as

$$\beta = \frac{1}{1 + \frac{3}{4}\left(l_{ex}\ \Sigma_{tr,m} - \lambda_B\right)} \qquad (2.5.5.5)$$

where $\lambda_B$ is the quantity defined on page 14;

b) the weight of the cell in a mixed lattice (+)

$$w = \left[\left(\ln \frac{b}{c} + \frac{l_{ex}}{c}\right)\ (1 - f_m)\right]^{-1} \qquad (2.5.5.6)$$

where $f_m$ is the fraction of thermal neutrons absorbed in the moderator;

c) the cell edge-to-average flux ratio:

$$E = \frac{\phi(b) \sum\limits_{cell} V_k}{\sum\limits_{cell} V_k \Phi_k} \qquad (2.5.5.7)$$

## 2.6. The diffusion coefficients

Regardless of energy group, the diffusion coefficient in the direction k (k = r, z) is calculated for a three-region cell, where:
the "fuel" region has radius a, volume $V_u$, flux $\Phi_u$, transport mean free path $\lambda_u$;
the "gap" region has outer radius c, volume $V_c$, flux $\Phi_c$;
the "moderator" region has outer radius b, volume $V_m$, flux $\Phi_m$, transport mean free path $\lambda_m$.

In addition, let

$$V_t = V_u + V_c + V_m \quad , \qquad \Phi_t V_t = \Phi_u V_u + \Phi_c V_c + \Phi_m V_m$$

(+) Consider a chess-board lattice composed of two types of cells regularly arranged; when the average properties are to be found, the contribution of one cell to $\eta f$ and $L^2$ is proportional to its absorption rate. As the absorption in the fuel element is proportional to $(\ln \frac{b}{c} + \frac{l_{ex}}{c})^{-1}$ and the fuel-to-cell absorption fraction is $1-f_m$, w is proportional to the weight of the considered cell as opposed to the other one. The normalization factor for the results $(w_1(\eta f)_1 + w_2(\eta f)_2)$ and $(w_1 L_1^2 + w_2 L_2^2)$ is obviously $w_1 + w_2$.
This approach to chess-board lattices is described by M. F. Duret (AECL 1235, (1961)).

$$\alpha = a/c \quad , \quad \eta = a/\lambda_u \quad , \quad \gamma = c/\lambda_m$$

$$b_1 = \frac{1+2\ \gamma}{2(1+\gamma)} \quad , \quad \beta = \frac{b_1}{1-b_1(1-V_m/V_t)} \quad , \quad \delta = \frac{\gamma}{1+\gamma-2\beta} \quad .$$

The expression for the diffusion coefficient (see Ref. 6) is

$$\frac{D_k}{\lambda_m/3} = 1 + \frac{\Phi_m V_m}{\Phi_t t} \left\{ \frac{V_c}{V_m} + \frac{V_u}{V_m}(1 - \frac{\lambda_m}{\lambda_u}) + \frac{\Phi_c V_c}{\Phi_m V_m} \frac{c-a}{\lambda_m} Q_k^* + \right.$$

$$+ \frac{V_c}{V_m}\left[\frac{\Phi_c}{\Phi_m}(1 - \frac{\lambda_m}{\lambda_u}) + \frac{\Phi_u}{\Phi_m} - \frac{\lambda_m}{\lambda_u}\right] \frac{a}{\lambda_m} W_k^* +$$

$$\left. + \frac{V_u}{V_m}(1 - \frac{\lambda_m}{\lambda_u})(\frac{\Phi_u}{\Phi_m} - \frac{\lambda_m}{\lambda_u}) \frac{a}{\lambda_m} T_k^* \right\} \qquad (k = r,\ z) \qquad (2.6.1)$$

The explicit expressions of $Q_k^*$, $W_k^*$, $T_k^*$ can be found with the aid of the following table

| | $k = r$ | $k = z$ |
|---|---|---|
| $Q_k^*$ | $F + Q_r' - G\ (1+\alpha)(1-\eta W_r)^2$ | $2\ F + Q_z'$ |
| $W_k^*$ | $W_r - G\ \alpha(1-\ \eta W_r)\ (1-\ \eta T_r)$ | $W_z$ |
| $T_k^*$ | $T_r - G\ \alpha(1-\ \eta T_r)^2$ | $T_z$ |

where

$$\frac{1}{G} = \delta - \alpha\eta\left[1 - \eta\ T_r(\eta)\right] \qquad (2.6.2)$$

$$F = 1 + 0.05\ \alpha - 0.1875\ \ln\ (1-\ \alpha) \qquad (2.6.3)$$

$$Z(\phi) = \sqrt{1 - \alpha^2\ \sin^2\ \phi} - \alpha\ \cos\ \phi \qquad (2.6.4)$$

$$Q'_r = \frac{3\alpha}{\pi(1-\alpha)(1-\alpha^2)} \int_0^{\pi/2} \left[Z(\phi)\right]^2 \; Ki_3(2\eta \cos\phi) \cos\phi \, d\phi \qquad (2.6.5)$$

$$Q'_o = \frac{2\alpha}{\pi(1-\alpha)(1-\alpha^2)} \int_0^{\pi/2} \left[Z(\phi)\right]^2 \; Ki_1(2\eta \cos\phi) \cos\phi \, d\phi \qquad (2.6.6)$$

$$Q'_z = 3\,Q'_o - 2\,Q'_r \qquad (2.6.7)$$

$$W_r = \frac{2\alpha}{\pi\eta(1-\alpha^2)} \int_0^{\pi/2} Z(\phi)\,\{1 - \frac{3}{2}Ki_4(2\eta\cos\phi)\}\cos\phi \, d\phi \qquad (2.6.8)$$

$$W_o = \frac{2\alpha}{\pi\eta(1-\alpha^2)} \int_0^{\pi/2} Z(\phi)\,\{1 - Ki_2\,(2\,\eta\cos\phi)\}\;\cos\phi \, d\phi \qquad (2.6.9)$$

$$W_z = 3\,W_o - 2\,W_r \qquad (2.6.10)$$

$$T_r = \frac{1}{\eta} - \frac{3}{\pi\eta^2} \int_0^{\pi/2} \{Ki_5(0) - Ki_5(2\eta\cos\phi)\}\cos\phi \, d\phi \qquad (2.6.11)$$

$$T_o = \frac{1}{\eta} - \frac{2}{\pi\eta^2} \int_0^{\pi/2} \{Ki_3(0) - Ki_3(2\eta\cos\phi)\}\cos\phi \, d\phi \qquad (2.6.12)$$

$$T_z = 3\,T_o - 2\,T_r \qquad (2.6.13)$$

the $Ki_\ell(x)$ ($\ell$ = 1,2,3,4,5) being Bickley functions.

## 2.7. The fast fission factor

### 2.7.1. General definition and effects taken into account

A fast fission factor definition similar to Carlvik and Pershagen's[8] was used: here $\varepsilon$ is the number of neutrons slowed down below 0.1 MeV per neutron from thermal or epithermal fission throughout the cell.

The overall scheme of $\varepsilon$ calculation (for further details, see Ref. 7) accounts for the following secondary effects, which are to be considered as important in $D_2O$ moderated, cluster fuelled lattices:

a) the heterogeneity of the cluster, as a coolant with non negligible scattering cross section is present;

b) the cell-to-cell interactions, which are important in lattices with a low moderator-to-fuel volume ratio;

c) the back-scattering from the moderator nuclei, with a non-negligible contribution to fast fissions for channel radii above 3 cm;

d) the (n, 2 n) reaction both in moderator and fuel, as equivalent to a fast "fission" with $\nu=2$;

e) the $(\gamma, n)$ reaction in the moderator.

Effects a) and b) are considered by the collision probability calculation; the effect c) has a mixed mode treatment, which follows the Cochran-Reed[9] formalism in the back-scattering probability due to an infinite sea of moderator, such probability being combined with the moderator-to-fuel flat-source collision probability; effects d) and e) are directly accounted for when defining the number of secondary neutrons per collision and in the overall collision density balance.

2.7.2. Space and energy schematization. Some definitions

As described in Sec. 2.1., regardless of the fast fission factor calculation, the fuel region contains three regions:
region 1 (inner coolant): the whole of the n subzones 1 and 2;
region 2 (uranium): the whole of the n subzones 3;
region 3 (external coolant): the whole of the n subzones 4 and 5;
the region 4 is the outer moderator; a 5th region may be present, i.e. an empty region between fuel boundary and moderator inner surface.

As regards the energy groups in fast fission factor calculation, three groups are considered:
group 2: from infinite energy down to 1.49 MeV ($U^{238}$ fission threshold)
group 1: from 1.49 MeV down to 0.1 MeV (fast cut-off)
group 0: from 0.1 MeV down to zero energy.

The following convention will be adopted: upper subscripts refer to the energy groups, lower subscripts refer to the spatial regions.

Let us define the following quantities

$N_i^k$ = collision density of k-group neutrons in region i

$f^k$ = fraction of fission neutrons born in group k

$P_{ij}^k$ = first collision probability in region j for a k-group neutron born uniformly and isotropically in region i

$P_{2j}^k$ = first collision probability in region j for a k-group neutron born in region 2 with a parabolic source distribution

$c_i^{hk}$ = transfer factor from group h to group k after a collision in group h and region i, given by:

$$c_i^{hk} = \frac{\Sigma_i^{hk} + \Sigma_{if}^h \nu_i^h f^k + 2\,\Sigma_{i(n,2n)}^{hk}}{\Sigma_i^h} \tag{2.7.1}$$

where

$\Sigma_i^{hk}$ = macroscopic transfer cross section from group h to group k in region i

$\Sigma_{if}^h$ = macroscopic fission cross section in region i and group h

$\nu_i^h$ = neutrons per fission in region i and group h

$\Sigma_{i(n,2n)}^{hk}$ = macroscopic transfer cross section from group h to group k in region i for (n,2n) reactions

$\Sigma_i^h$ = macroscopic total cross section in region i and group h

$\gamma^k$ = fraction of photoneutrons (per fission neutron) born in group k in the moderator such photoneutrons are supposed to be produced only from thermal fissions.

2.7.3. Definition of the usual fast parameters

Some parameters of interest in lattice calculations are the following ones:

a) Fast fission factor $\varepsilon$ (number of neutrons slowed down below 0.1 MeV per thermal or epithermal fission neutron) given by:

$$\varepsilon = f^{o} + \gamma^{o} + \sum_{\substack{j=1,2,3,4 \\ S=1,2}} N_j \; c_j^{so} \qquad (2.7.2)$$

b) Fast fission ratio $\delta^{28}$ (number of fission events at energy above the $U^{238}$ fission threshold related to the total number of fissions which do not happen in $U^{238}$), given by:

$$\delta^{28} = \frac{N_2^2 \; \Sigma_{2f(8)}^2 / \Sigma_2^2}{\frac{1}{\nu_{th}} + \sum_{s=1,2} N_2^s \frac{\Sigma_{2f(5)}^s}{\Sigma_2^s}} \qquad (2.7.3)$$

where the subscripts (8) and (5) refers to $U^{238}$ and $U^{235}$ and $\nu_{th}$ is the number of neutrons per $U^{235}$ fission

c) Factors giving the fast contribution to the $Pu^{239}$ build up in burn-up calculations:

$$\beta = \sum_{s=1,2} N_2^s \frac{\Sigma_{2,a8}^s}{\Sigma_2^s} \qquad (2.7.4)$$

(absorption rate in $U^{238}$ above 0.1 MeV per thermal or epithermal fission neutron)

$$\gamma = \sum_{s=1,2} N_2^s \frac{\Sigma_{2,c8}^s}{\Sigma_2^s} \qquad (2.7.5)$$

(capture rate in $U^{238}$ above 0.1 MeV per thermal or epithermal fission neutron)

$$R^{*} = \sum_{s=1,2} N_2^s \frac{\Sigma_{2,f8}^s}{\Sigma_2^s} = \beta - \gamma \qquad (2.7.6)$$

(fission rate in $U^{238}$ above 0.1 MeV per thermal or epithermal fission neutron).

The (n,2n) effect has been taken into account in the transfer factor $c_i^{hk}$, as a fission cross section for which $\nu = 2$; the $(\gamma,n)$ effect will be taken into account (for groups 1 and 2) in the overall collision density balance, while the contribution from group 0 appears in the $\varepsilon$ definition.

2.7.4. The collision density equations

The collision rate in region i for k-group neutrons is:

$$N_i^k = 1 \cdot f^k P_{2i}^k + \sum_{\substack{j=1,2,3,4 \\ s=1,2}} N_j^s \, c_j^{sk} \, P_{ji}^k \qquad (2.7.7)$$

(i = 1,2,3,4; k =1,2)

Eq. (2.7.7) can be written in the more suitable form ($\delta_{ji}$ being the usual Kronecker symbol):

$$\sum_{\substack{j=1,2,3,4 \\ s=1,2}} \delta_{sk} \, \delta_{ji} \, N_j^s - \sum_{\substack{j=1,2,3,4 \\ s=1,2}} N_j^s \, c_j^{sk} \, P_{ji}^k = f^k P_{2i}^k + \gamma^k P_{4i}^k \qquad (2.7.8)$$

By using the definitions:

$$l = j + 4\,(s-1) \qquad (2.7.9)$$

$$m = i + 4\,(k-1) \qquad (2.7.10)$$

$$Q_{lm} = c_j^{sk} \; P_{ji}^k \qquad (2.7.11)$$

$$B = f^k P_{2i}^k + \gamma^k P_{4i}^k \qquad (2.7.12)$$

$$A_{lm} = \delta_{lm} - Q_{lm} \qquad (2.7.13)$$

the system of linear equations

$$\sum_{l=1,8} A_{lm} \, n_l = B_m \quad (m = 1,8) \qquad (2.7.14)$$

can be obtained, where the $n_l$'s are the collision densities and in detail:

$$n_1 = N_1^1 \; ; \; n_2 = N_2^1 \; ; \; n_3 = N_3^1 \; ; \; n_4 = N_4^1$$
$$n_5 = N_1^2 \; ; \; n_6 = N_2^2 \; ; \; n_7 = N_3^2 \; ; \; n_8 = N_4^2 \qquad (2.7.15)$$

Solving the linear system (2.7.14) gives the 4-region 2-group collision densities as requested by equations (2.7.2) to (2.7.6).

2.7.5. The fast-cross sections

All the effects of interest in calculating the fast fission factor have been taken into account in the model; therefore only basic constants are to be used; for each nuclide the following microscopic cross sections are to be given:

for group 2:

$\nu^2\,\sigma_f^2$, $\sigma^{22}$ (elastic + inelastic), $\sigma^{21}$ (elastic + inelastic), $\sigma^{20}$ (elastic + inelastic),

$\sigma^{22}_{(n,2n)}$, $\sigma^{21}_{(n,2n)}$, $\sigma^{20}_{(n,2n)}$, $\sigma_c^2$, $\sigma_f^2$, $\sigma_t^2$

for group 1:

$\nu^1\,\sigma_f^1$, $\sigma^{11}$ (elastic + inelastic), $\sigma^{10}$ (elastic + inelastic), $\sigma_c^1$, $\sigma_t^1$

The subscripts c, f, t stand for capture, fission and total respectively.

The (n,2n) reaction is considered to be not negligible only in group 2; the value of $\nu_{th}$ is 2.44.

2.8. Experimental parameters

The PROCELLA code gives also the usual experimental parameters to be compared directly with the measured values.

a) Thermalization index.

The main thermalization index, to be compared with experiments, is the Pu/U activation ratio, both in fuel and moderator. Such a ratio, divided by the analogous ratio for a thermal reference position (a thermal column), gives the measured index.

Following the symbols of Sect. 2.3 , one has:

$$(\dot{Pu/U})_k = \left(\frac{\hat{\sigma}_{f9}}{\hat{\sigma}_{f5}}\right)_k \cdot \left(\frac{\hat{\sigma}^{TH}_{f9}}{\hat{\sigma}^{TH}_{f5}}\right)^{-1} \qquad (2.8.1)$$

where k means either "fuel" or "moderator";

$\hat{\sigma}_{f9}$ and $\hat{\sigma}_{f5}$ are like $\hat{\sigma}$ of Eq. (2.3.1.8), "f" means "fission" and subscripts 9 and 5 stand for $Pu^{239}$ and $U^{235}$;

$\hat{\sigma}^{TH}_{f9}$ and $\hat{\sigma}^{TH}_{f5}$ are the corresponding cross sections in a thermal reference flux, whose caracteristics are summarized by a neutron temperature $T_{TH}$ and a Westcott's index $r_{TH}$.

b) Thermal utilization

The thermal utilization factor calculation gives the thermal flux in each annulus as an output; in such a way the calculated fine flux profile can be compared with experimental activations through the cell.

c) Fast fission parameter

Regardless of the fast fission factor, the only meaningful parameter is $\delta^{28}$, as defined in Sect. 2.7.

d) Resonance escape parameters

In order to check the resonance escape calculation against experimental results 3 parameters are given usually in literature:

d 1) ICR (initial conversion ratio), defined as the total $U^{238}$ capture rate divided by the total $U^{235}$ absorption rate. Such a ratio is calculated from the cell constants and refers to the leakage parameters of the considered reactor:

$$ICR = \frac{\hat{\Sigma}_{a8 1/v}}{\hat{\Sigma}_{a5}} + \left[\frac{1}{C}\,\varepsilon(1-p)(1+\gamma)\,\frac{1}{(1+B^2\,\tau_v)(1+B^2\,\tau_s+\alpha_s+\gamma)} + \Gamma\right]\frac{\nu_5\hat{\sigma}_{f5}}{\hat{\sigma}_{a5}}$$

(2.8.2)

where:

$C$ is the effective multiplication constant;

$B^2$ is the geometrical buckling, calculated with the extrapolated dimensions of the reactor;

$\hat{\Sigma}_{a8 1/v}$ is the macroscopic Westcott cross section for $U^{238}$ 1/v-absorption;

$\hat{\Sigma}_{a5}$ is the macroscopic Westcott cross section for $U^{235}$ absorption;

$\hat{\sigma}_{f5}$ and $\hat{\sigma}_{a5}$ are the Westcott microscopic cross sections, for fission and absorption in $U^{235}$;

$\gamma$, $\tau_v$, $\tau_s$, $\alpha_s$ are defined in Sect. 3.1.

$\Gamma$ is the ratio of the number of fissions above 0.1 MeV to the one below 0.1 MeV.

The 2nd addendum of ICR (which is related to resonance absorption in $U^{238}$) follows directly from the neutron balance equation in the cell (see Sect. 3); the 1st and 3rd addendum are the thermal and fast contributions to ICR, and follow from the thermalization model and the fast fission factor calculation ($\Gamma$ factor).
The above mentioned definition of ICR does not give a true experimental parameter; it has been quoted in this section owing to its analogy with the following parameter.

d 2) RICR (relative initial conversion ratio), defined as the ratio of the $Np^{239}$ production rate to the $U^{235}$ fission rate, divided by the same ratio as calculated in a reference thermal flux:

$$RICR = \left(\frac{\hat{\Sigma}_{a8,1/v}}{\hat{\Sigma}_{f5}} + \frac{1}{C_{ex}} \frac{\varepsilon\ (1-p)(1+\gamma)\ \nu_5}{(1+B^2_{ex}\tau_v)(1+B^2_{ex}\tau_s+\gamma+\alpha_s)} + \Gamma\nu_5\right)\cdot\left(\frac{\hat{\Sigma}^{TH}_{a8}}{\hat{\Sigma}^{TH}_{f5}}\right)^{-1} \qquad (2.8.3)$$

where the new symbols have the following meaning:

$C_{ex}$ is the effective multiplication constant of the experimental facility as seen by the cell under measurement; if no control element is present in that cell, then $C_{ex} = 1$ as can be derived from the neutron balance equations (see Sec. 3);

$B^2_{ex}$ is the geometrical buckling of the experimental facility, in order to account for the effective resonance leakage;

$\hat{\Sigma}_{f5}$ is the Westcott macroscopic cross section for $U^{235}$ fission;

$(\hat{\Sigma}^{TH}_{a8}/\hat{\Sigma}^{TH}_{f5})$ is the ratio of $U^{238}$ capture rate to $U^{235}$ fission rate, in a reference thermal flux and for the same isotopic content of $U^{238}$ and $U^{235}$ as in the fuel.

d 3) $\rho^{28}$, defined as the ratio of epicadmium to subcadmium absorption rate in $U^{238}$:

$$\rho_{28} = \frac{1}{1- rb\sqrt{\frac{\mu k\theta_m}{E_{cd}}}} \left\{ rb\left(\sqrt{\frac{\mu k\theta_m}{E_{cd}}} - \sqrt{\frac{\mu k\theta_m}{5eV}}\right) + \frac{\hat{\Sigma}_{f5}}{\hat{\Sigma}_{a8,1/v}} \left[ \frac{1}{C_{ex}} \quad \frac{\varepsilon(1-p)(1+\gamma)\ \nu_5}{(1+B^2_{ex}\ \tau_v)(1+B^2_{ex}\ \tau_s+\alpha_s+\gamma)} + \Gamma\nu_5 \right] \right\} \quad (2.8.4)$$

where $E_{cd}$ is the effective cadmium cut-off energy and r, b, $\mu$, $\theta_m$ have been defined in Sect. 2.3.1.

Eq. (2.8.4) follows from a group calculation of the $U^{238}$ absorption, in the same approximation of the detailed neutron balance equations (see Sect. 3).

# 3. EQUATIONS FOR THE NEUTRON BALANCE IN THE LATTICE CELL

## 3.1. The four-group diffusion scheme

The neutron spectrum is thought of as fully contained in the energy interval 0 ÷ 2 MeV and is described by means of four energy groups, defined as follows:

- a fast group, subscript V, from 2 MeV down to 0.1 MeV;
- an upper epithermal group, subscript S, from 0.1 MeV to 5 eV;
- a lower epithermal group, subscript I, from 5 eV to $\mu k\theta_m$;
- a Maxwellian, or thermal group, subscript M, below $\mu k\theta_m$.

If

$$D_r \nabla_r^2 + D_z \nabla_z^2 \equiv D \nabla^2 ,$$

and C is the effective multiplication constant, the four-group equations are

$$(-D_V\nabla^2 + R_V)\Phi_V = \frac{1}{C} (\varepsilon\eta f\ A_M\ \Phi_M + \varepsilon\ F_I\ \Phi_I + \varepsilon\ F_S\ \Phi_S) \qquad (3.1.1)$$

$$(-D_S\nabla^2 + (1+\gamma)R_S + A_S)\ \Phi_S = R_V\ \Phi_V \qquad (3.1.2)$$

$$(-D_I\nabla^2 + R_I + A_I)\ \Phi_I = (1+\gamma)p\ R_S\ \Phi_S \qquad (3.1.3)$$

$$(-D_M\nabla^2 + A_M)\ \Phi_M = R_I\ \Phi_I \qquad (3.1.4)$$

where either $\gamma = (1-p)/p$ or $\gamma = o$ according to whether the U-238 resonances are diluted in the group S or concentrated at the energy 5 eV; how ever the former approach has been chosen finally ($1 + \gamma = \frac{1}{p}$)
By making the following changes in notation

$-\nabla^2 = B^2$ , $D_l/R_l = \tau_l$ (l= V,S,I) , $D_M/A_M = L^2$ , $A_l/R_l = \alpha_l$ (l = S,I),

$F_l/R_l = \beta_l$ (l = S, I)

$B^2L^2 \equiv B_r^2\ L_r^2 + B_z^2\ L_z^2$ , $B^2\ \tau_l \equiv B_r^2\ \tau_{r,l} + B_z^2\ \tau_{z,l}$

($\tau_{r,l}$ and $\tau_{z,l}$ refer to radial or axial $D_l$ respectively) one obtains:

$$\frac{\Phi_I}{\Phi_M} = \frac{A_M}{R_I} (1 + B^2 L^2) \tag{3.1.5}$$

$$\frac{\Phi_S}{\Phi_M} = \frac{A_M(1+B^2L^2)(1+\alpha_I+B^2\tau_I)}{p\ R_S(1+\gamma)} \tag{3.1.6}$$

$$\frac{\Phi_V}{\Phi_M} = \frac{A_M(1+B^2L^2)(1+\alpha_I+B^2\tau_I)(1+\gamma+\alpha_S+B^2\tau_S)}{p\ R_V(1+\gamma)} \tag{3.1.7}$$

and then, from Eqs. (3.1.1) to (3.1.4) the effective multiplication constant

$$C = \frac{\frac{\varepsilon\eta f p(1+\gamma)}{1+B^2L^2} + \varepsilon\ p(1+\gamma)\beta_I + \varepsilon\ \beta_S(1+\alpha_I+B^2\tau_I)}{(1+\alpha_I+B^2\ \tau_I)(1+\gamma+\alpha_S+B^2\tau_S)(1+B^2\ \tau_V)} \tag{3.1.8}$$

The infinite multiplication constant follows when $B^2 = 0$ in Eq. (3.1.8):

$$k_\infty = \frac{\varepsilon\eta f p(1+\gamma)+\ \varepsilon p(1+\gamma)\ \beta_I + \varepsilon\ \beta_S(1+\ \alpha_I)}{(1+\ \alpha_I)(1+\gamma\ +\ \alpha_S)} \tag{3.1.9}$$

## 3.2. The two-group diffusion equations

By collapsing the fast and epithermal groups, a two-group scheme can be derived, where

$$\phi_1 = \phi_I + \phi_S + \phi_V = \int_{\mu k\theta_m}^{2\,\mathrm{MeV}} \phi(E)\ dE \tag{3.2.1}$$

$$\phi_2 = \int_0^{\mu k\theta_m} \phi(E)\ dE \tag{3.2.2}$$

and the diffusion equations take on the form

$$(-D_1 \nabla^2 + \Sigma_1)\,\Phi_1 = \frac{1}{k}\,(\Sigma_{11}\,\Phi_1 + \Sigma_{12}\,\Phi_2) \qquad (3.2.3)$$

$$(-D_2 \nabla^2 + \Sigma_2)\,\Phi_2 = \Sigma_{21}\,\Phi_1 \qquad (3.2.4)$$

Simple comparison with Eqs. (3.1.1) to (3.1.4) shows that

$$\Sigma_2 \equiv A_M\,, \quad \Sigma_{12} \equiv \varepsilon\eta\, f A_M\,;$$

If $-\nabla^2 = B^2$, the effective multiplication constant is

$$k = \frac{\Sigma_{11} + \Sigma_{12}\,\Phi_2/\Phi_1}{\Sigma_1 + D_1\,B^2} = \frac{\dfrac{\varepsilon\eta f(\Sigma_{21}/\Sigma_1)}{1+B^2(D_2/\Sigma_2)} + \dfrac{\Sigma_{11}}{\Sigma_1}}{1+B^2(D_1/\Sigma_1)} \qquad (3.2.5)$$

whilst the infinite multiplication constant can be written as

$$k_\infty = \frac{\Sigma_{11} + \Sigma_{12}\,\Sigma_{21}/\Sigma_2}{\Sigma_1} \qquad (3.2.6)$$

The epithermal constants $D_1$, $\Sigma_1$, $\Sigma_{11}$, $\Sigma_{21}$ can be expressed in terms of the known four-group constants if Eq. (3.2.5) is compared with Eq. (3.1.8) where only the terms of order $B^2$ are retained (see Appendix I).
It follows that

$$\frac{D_1}{\Sigma_1} = \frac{\tau_I}{1+\alpha_I} + \frac{\tau_S}{1+\gamma+\alpha_S} + \tau_V - \frac{\beta_S\tau_I}{\beta} \qquad (3.2.7)$$

$$\frac{\Sigma_{11}}{\Sigma_1} = \frac{\varepsilon p(1+\gamma)\beta_I + \varepsilon\beta_S(1+\alpha_I)}{(1+\alpha_I)(1+\gamma+\alpha_S)} \qquad (3.2.8)$$

$$\frac{\Sigma_{21}}{\Sigma_1} = \frac{p(1+\gamma)}{(1+\alpha_I)(1+\gamma+\alpha_S)} \qquad (3.2.9)$$

$$\frac{D_2}{\Sigma_2} = \frac{D_M}{A_M} + \frac{\beta_S\tau_I}{\beta} \qquad (3.2.10)$$

where the constants $\tau$, $\alpha$, $\beta$ are such that

$$D_1/\Sigma_1 = \tau \tag{3.2.11}$$

$$\Sigma_1 = (1+\alpha)R \tag{3.2.12}$$

$$\Sigma_{11} = \varepsilon\beta R \tag{3.2.13}$$

$$\Sigma_{21} = p(1+\gamma)R \tag{3.2.14}$$

$$\alpha = (1+\alpha_I)(1+\gamma+\alpha_S)-1 \tag{3.2.15}$$

$$\beta = p(1+\gamma)\beta_I + \beta_S(1+\alpha_I) \tag{3.2.16}$$

and the "removal" cross section R can be found in such a way that Eq. (3.2.1) be satisfied. From the definitions of $\tau$, $\alpha$, $\beta$, the alternative formal expression follows for $k_\infty$:

$$k_\infty = \frac{\varepsilon\eta f p(1+\gamma)+\varepsilon\beta}{1+\alpha} = H_2 + H_1 \tag{3.2.17}$$

In order to find R, let Eqs. (3.1.5), (3.1.6) and (3.1.7) be summed:

$$\frac{\Phi_1}{\Phi_M} = \frac{\Phi_I}{\Phi_M} + \frac{\Phi_S}{\Phi_M} + \frac{\Phi_V}{\Phi_M} = \left\{\frac{1}{R_I} + \frac{1+\alpha_I+B^2\tau_I}{p(1+\gamma)R_S} + \frac{(1+\alpha_I+B^2\tau_I)(1+\gamma+\alpha_S+B^2\tau_S)}{p(1+\gamma)R_V}\right\} A_M(1+B^2L^2);$$

on the other hand, the neutron conservation requires from Eqs. (3.1.4) and (3.2.4) the identity

$$\Sigma_{21}\,\Phi_1 = R_I\,\Phi_I \quad , \tag{3.2.18}$$

so that, as $R_I\Phi_I = A_M\,\Phi_M(1+B^2L^2)$ and using Eq. (3.2.14), the final expression for R is

$$\frac{1}{R} = \frac{p(1+\gamma)}{R_I} + \frac{1+\alpha_I}{R_S} + \frac{(1+\alpha_I)(1+\gamma+\alpha_S)}{R_V} \tag{3.2.19}$$

once the terms of order $B^2$ have been dropped.

## 3.3. The material buckling

Making $k = 1$, $-\nabla^2 = B^2$ and replacing $\Sigma_j$ by $\Sigma_j + D_{jk} B_k^2$ (where $k = r$ or $k = z$ if the axial or radial material buckling has to be calculated), into Eqs. (3.2.3) and (3.2.4), and eliminating the flux variables, one obtains the equation

$$(B^2)^2 + u B^2 - v = 0 \tag{3.3.1}$$

where, if $L_c^2 = D_2/\Sigma_2$:

$$u = \frac{1}{L_c^2} + \frac{1}{\tau}\left(1 - \frac{\varepsilon\beta}{1+\alpha}\right), \qquad v = \frac{k_\infty - 1}{L_c^2 \tau} \tag{3.3.2}$$

The material buckling is therefore:

$$B_m^2 = \tfrac{1}{2}\left(\sqrt{u^2 + 4v} - u\right) \tag{3.3.3}$$

## 3.4. The migration area

From Eqs. (3.2.5) and (3.2.17) there follows the expression

$$k = \left\{ \frac{\varepsilon\eta f p(1+\gamma)}{1+\alpha} + \frac{\varepsilon\beta}{1+\alpha}(1+B^2L_c^2) \right\} \Big/ \left[(1+B^2L_c^2)(1+B^2\tau)\right] =$$

$$= \left(1+B^2 \cdot \frac{\varepsilon\beta L_c^2/k_\infty}{1+\alpha}\right) \frac{k_\infty}{(1+B^2L_c^2)(1+B^2\tau)} \simeq \frac{k_\infty}{\left(1-B^2L_c^2\,\frac{\varepsilon\beta/k_\infty}{1+\alpha}\right)(1+B^2L_c^2)(1+B^2\tau)}$$

$$\approx \frac{k_\infty}{1+B^2M^2} \tag{3.4.1}$$

where a migration area has been defined by means of the expression

$$M^2 = (1 - \frac{\varepsilon\beta/k_\infty}{1+\alpha}) L_c^2 + \tau \tag{3.4.2}$$

Since $\frac{\varepsilon\beta}{1+\alpha}$ is the epithermal contribution $H_1$ to $k_\infty$ (see Eq. 3.2.17), Eq. (3.4.2) can be rewritten as

$$M^2 = \tau + (1 - \frac{H_1}{k_\infty}) L_c^2 \tag{3.4.3}$$

displaying the physically understandable fact that, were all multiplication to occur in the epithermal range ($k_\infty = H_1$), one should get $M^2 = \tau$.

# 4. COMPARISON OF PROCELLA CALCULATIONS AND EXPERIMENTS

## 4.1. Overall check calculations

We have evaluated $K_{eff}$ for a number of experimentally critical lattices, the experimental material buckling being obtained - in most cases - on critical assemblies. Two general criteria were respected:

a) The data were classified in separate sets according to the basic characteristics of the lattices: metal rods, metal clusters, oxide clusters. Most data are with natural uranium, a few ones with slightly enriched or depleted uranium.

b) For each set, assumed to include N points, the following parameters were evaluated :

$$\bar{K}_{eff} = \frac{\sum_{i=1}^{N} K_i}{N} \qquad \text{(average } K_{eff}\text{)}$$

$$\sigma = \left[ \frac{\sum_{i=1}^{N} (K_i - \bar{K}_{eff})^2}{N - 1} \right]^{1/2} \qquad \text{(standard deviation)}$$

The first value, $\bar{K}_{eff}$, should be 1 for both theory and experiments with no error (in this case each $K_i = 1$ and $\sigma = 0$); the $\sigma$ -value is a good index of the spread-out of data. In case of random K-deviations from unity (e.g. random experimental errors) one would expect to get 68.3% of the calculated points within $\bar{K}_{eff} \pm \sigma$, and 95.4% within $\bar{K}_{eff} \pm 2\sigma$.

The cell characteristics of the lattices considered and the measured bucklings are reported on Tables IV through XLVIII and Figures 2 to 46.

The results are summarized in table IL and may be given the following comments:

a) In every set of cases, the average $\bar{K}_{eff}$ is very close to 1, the standard deviation being of the order 5 to 10 mk, thus well within the limits of accuracy exhibited by far more complicated, multigroup calculations.

b) The dispersion of the calculated data points is very nearly corresponding to a Gaussian distribution, as shown by the table; since no uncertainty is accounted for in the K calculation, the dispersion of data is partially due to the experimental errors.

c) No significant trend of K versus the moderator-to-fuel volume ratio was ever found: this could be visualized by simple inspection of the plots.

d) Some systematic difference between different source experiments was found sometimes as shown in the lower part of the table; in the metal cluster set, calculated $K_{eff}$ for French experiments are systematically above the same $K_{eff}$ calculated for Canadian experiments, with very small standard deviations. In the oxide cluster set instead, a significant difference occurs between French and Canadian experiments on one side, and Swedish data on the other.

The reported values refer to both 4-group and 2-group calculations; as very much the same figures are obtained from 2-group calculations, the explicit value of the 2-group material buckling is equally reliable.

An interesting overall check of the theory is also provided by comparing calculated $K_{\infty}$'s with measured values: Table L summarizes the satisfactory results obtained.

The reliability of the method was also tested as far as some differential reactivity coefficients are concerned. As an example, a set of experiments performed in Sweden (Ref. 28) on isothermal lattices gave $B^2$ vs. the lattice temperature T; the K-values as calculated by our method are slightly decreasing with T (with a 24 cm lattice pitch, K = 1.00617 to 0.99482 when T = 22 to 246 °C), but, what is more important, one can favorably compare the theoretical and experimental values of the average $dB^2/dT$ over the same temperature range:

- experimental values: $B^2$ = 4.90 to 2.56 $m^{-2}$, $(dB^2/dT)$avg = -0.0104 $\frac{m^{-2}}{°C}$
- calculated values : $B^2$ = 5.21 to 2.43 $m^{-2}$, $(dB^2/dT)$avg = -0.0124 $\frac{m^{-2}}{°C}$

4.2. Lattice parameter calculations

Four lattice parameters were selected for a direct comparison between theoretical and experimental values, namely: initial conversion ratio (ICR), $U^{238}$ to $U^{235}$ fission ratio ($\delta_{28}$), Pu/U fission ratio as a spectral index in the fuel, moderator-to-fuel neutron density ratio ($F_m$).

Table LI summarizes the results obtained from comparison between the present model and measurements performed in various laboratories.

The following remarks seem appropriate:

a) A systematic but slight overestimate in ICR seems to imply an underestimate in the resonance escape probability p; this agrees with the fact that our p calculation accounts for the high energy flux peaking near the fuel but it partially neglects the flux depression induced in the fuel at any energy by higher energy absorptions (spatial shadowing).

b) The fast fission phenomena seem to be treated rather well.

c) A very slight underestimate in the Pu/U fission ratio does not invalidate the reliability of our very simple thermalization model: some of the test calculations regard U-Pu fuelled rods.

d) The disadvantage factor $F_m$ shows a very good agreement with experiments except in the case of HB-40 cooled $UO_2$ clusters. In this case the calculated $F_m$ is grossly underestimated (and correspondingly the calculated multiplication constant is overestimated by as much as 0.01): this is caused by the very high HB-40 transport cross section, which invalidates the assumption of a flat flux in each annular region of the fuel element if, as is the case of the results in Table LI, the annular breakdown preserves the integrity of the fuel rod rings. Halving the annuli thickness improves the results appreciably.

Finally, Table LII shows a particular comparison between theory and experiments carried out by CISE. The fuel element was in this case a cluster of seven uranium metal tubes containing expanded polystyrene to simulate a boiling water coolant.

Further comparisons, carried out when issuing this report, are included in Tables LIII through LVII; they regard both buckling and detailed parameter measurements.

## 5. HOW TO USE THE CODE

Before setting the card deck containing data of one or more problems, a "library" card has to be put: if it is a blank card, the cross section library included in PROCELLA will be used (see Table I), if some cross section has to be changed, or some nuclide has to be added, put the number of added nuclides in column 6 of such a card and add the library deck for the new nuclides, according to Sect. 2.3.2 and the sheet 1.

### 5.1.1. Input data for a reference problem

| Name | Format | Meaning |
|---|---|---|
| TITLE (I) | 12 A6 | problem identification |
| ICØ | I6 | designator for the fuel material: put ICØ = 1 for U metal; ICØ = 2 for $UO_2$; ICØ = 3 for UC |
| IMØ | " | designator for the moderator material: put IMØ = 1, $D_2O$ |
| NA1 (+) | " | number of annuli associated to the subcell of the central fuel rod or tube; |
| NA2 (+) | " | number of annuli containing the peripherical fuel rods or tubes |
| NA3 (+) | " | number of annuli completing the "fuel" region |
| NAG | " | number of "gap" annuli (either NAG = 0 or NAG = 1) |
| NAM (+) | " | number of annuli constituting the "moderator" region |
| IRUB (+) | " | order number of the last annulus contained in the clustered part of the cell (for calculating $S_{eff}$, p and $\varepsilon$) |
| ISPA | " | designator for the lattice symmetry (it occurs in the Dancoff coefficient calculation): |

(+) Note that NA1 $\leq$ 4, NA2 $\leq$ 10, NA1+NA2+NA3+NAG+NAM $\leq$ 20,
IRUB $\leq$ NA1+NA2+NA3.

| Name | Format | Meaning |
|---|---|---|
| | | ISPA = 1 for hexagonal; ISPA = 2 for square symmetry |
| IVX | I6 | if IVX = 0 cell-flux constants are calculated<br>if IVX = 1 edge-flux constants are calculated |
| IBUC | " | put IBUC = 0 if the effective multiplication constant has to be calculated using the experimental bucklings BUCSPR, BUCSPZ<br>put IBUC = 1 if the effective multiplication constant has to be calculated using the bucklings obtained from the extrapolated dimensions RAGEX, ALTEX |
| IØPZ | " | put IØPZ = 0 if only the standard problem has to be made; if IØPZ = 1, seven perturbed configurations are calculated also:<br>1) moderator temperature increased of 10 °C,<br>2) fuel temperature increased of 40 °C,<br>3) coolant temperature increased of 20 °C,<br>4) Xe-135 concentration in the uranium increased of $.2x10^{-8}$ a/b.cm,<br>5) Boron concentration in the moderator increased of $.5x10^{-6}$ a/b.cm,<br>6) moderator density reduced by a factor .95,<br>7) coolant density reduced to zero; |
| ISØST | " | put ISØST = 0 if only the standard problem has to be made; put ISØST = 1 if the problem has to be repeated after some changes (in the latter case suitable input data are to be supplied following the standard problem data); |
| RE | E14.8 | density of the fuel (U, $UO_2$, UC) material, expressed in $gm/cm^3$; |
| RAGEX | " | extrapolated radius of the reactor (only if IBUC = 1), expressed in cm; |

| Name | Format | Meaning |
|---|---|---|
| ALTEX | E14.8 | extrapolated height of the reactor (only if IBUC = 1), expressed in cm; |
| TEREFI | " | physical temperature of the zone 1 (inner coolant), expressed in °K; |
| TEMPU | " | physical temperature of the zone 3 (fuel material), expressed in °K; |
| TEREFE | " | physical temperature of the zone 5 (outer coolant, or inter-rod material), expressed in °K; |
| TEMMØD | " | physical temperature of the moderator, expressed in °K; |
| RB(2,I) (+) | " | outer radius, in cm, of the subzone 1 in each fuelled annulus; |
| RB(3,I) (+) | " | outer radius, in cm, of the subzone 2 in each fuelled annulus; |
| RB(4,I) (+) | " | outer radius, in cm, of the subzone 3 in each fuelled annulus; |
| RB(5,I) (+) | " | outer radius, in cm, of the subzone 4 in each fuelled annulus; |
| BAN(I) (+) | " | number of fuel rods or tubes in each fuelled annulus; |
| R(K) (°) | " | outer radius, in cm, of the K-th annulus; |
| NU(J) (x) | I6 | number of nuclides contained in the zone J; |
| IPRETU | " | number of the annulus which is the pressure tube (") |
| ICALAN | " | " " " " " calandria " (") |

(+) NA2+1 groups of numbers, corresponding to the central fuel rod or tube and to the peripherical annuli containing fuel rods or tubes;

(°) NA1+NA2+NA3+NAG+NAM numbers;

(x) 5 + NA3 + NAM numbers;

(") If its neutron temperature has to be the average between the fuel and the moderator ones; otherwise put = 0.

| Name | Format | Meaning |
|---|---|---|
| NTAB(L,J) (') | | order number in the library of the L-th nuclide contained in the zone J (only if NU(J)≠0); |
| CØN(L,J)(') (J≤5) | E14.8 | concentration, in a/b.cm, of the L-th nuclide |
| DEL(L) (J>5) | | contained in the zone J (only if NU(J)≠0); |
| EXECD | " | Cd cut-off for $\rho_{28}$ calculation; |
| TCØL | " | reference value of the neutron temperature used in calculating the ratio Pu-239/U-235 and the relative initial conversion ratio (R.I.C.R.); expressed in °K; |
| RCØL | " | reference value of the spectral index in calculating the ratio Pu-239/U-235 and the R.I.C.R.; |
| B2RAD | " | radial buckling ($cm^{-2}$) of the assembly for the $\rho_{28}$ and R.I.C.R. measurement; |
| B2ASS | " | axial buckling ($cm^{-2}$) of the assembly for the $\rho_{28}$ and R.I.C.R. measurement; |
| BUCSPR | " | experimental radial buckling (in $cm^{-2}$); used only if IBUC = 0; |
| BUCSPZ | " | experimental axial buckling (in $cm^{-2}$); used only if IBUC = 0; |
| IDENS | I6 | if IDENS=1, the cell calculation is repeated for five values of the coolant density; otherwise put IDENS = 0; |
| NUNURE | " | number of nuclides contained in the coolant (≤5); |
| NUREF(I) | " | NUNURE numbers: the order number in the library of the nuclides contained in the coolant; |
| IPUNCH | " | put IPUNCH=1 if cards are to be punched for the MØICANØ-1 code (see CISE Report R-242, to be published); otherwise, put IPUNCH = 0; |
| IZØZØ | " | number of zones containing the coolant material; |
| IREZØ (I) | " | IZØZØ numbers, designating the zones; |

(') L = 1,2,..., NU(J) if NU(J)≠0, following J=1,2,...,5+NA3+NAM.

| Name | Format | Meaning |
|---|---|---|
| IANAN | E14.8 | number of annuli containing the coolant material; |
| IREAN (I) | " | IANAN numbers, designating the annuli; |
| RHØNØM | " | coolant density (in $gm/cm^3$) used in the standard problem; |
| RHØLIQ | " | density (in $gm/cm^3$) of the liquid coolant; the five values used if IDENS = 1 are in the interval (0, RHØLIQ), and are .047, .231, .500, .769, .953 when RHØLIQ = 1. |

5.1.2. Input data for a substitution problem

Substitution problems can be made, having from 1 to a maximum of 12 changed input data. More than one substitution problem can be made.

| Name | Format | Meaning |
|---|---|---|
| TITLE (I) | 12A6 | problem identification |
| ISØST | I6 | as in Sect. 5.1.1. |
| IØPZ | " | as in Sect. 5.1.1. |
| IDENS | " | as in Sect. 5.1.1. |
| IPUNCH | " | as in Sect. 5.1.1. |
| NUSØST | " | number of input data which have to be changed |
| INDICI (I) | " | NUSØST numbers, designating which datum has to be changed (see the Table below) |
| RIDATI (I) | E14.8 | new value of the changed datum INDICI(I) (see the Table below) |

Table for changing input data

| INDICI(I) | RIDATI(I) |
|---|---|
| 1 | RE |
| 2 | RAGEX |
| 3 | ALTEX |
| 4 | TEREFI |
| 5 | TEMPU |
| 6 | TEREFE |
| 7 | TEMMØD |
| 8 | the last of R(K)'s, i.e. the cell radius |
| 9 | B2RAD |
| 10 | B2ASS |
| 11 | BUCSPR |
| 12 | BUCSPZ |

## 5.2. Output data

Page 1 of the output contains the rearrengement of input data, the other outputs are the following ones:

| Name | |
|---|---|
| VU | $V_u$, volume of the fuel material, in $cm^3/cm$ |
| VM | $V_m$, volume of the moderator, in $cm^3/cm$ |
| VM/VU | $V_m/V_u$ |
| TEMP. REG. CØMB. | $T_f$, physical temperature of the fuel element, in $^oK$ (avg.) |
| DEN. CØMB. | density of the fuel material, in $gm/cm^3$ |
| S.EFF | $S_{eff}$, effective resonance surface, in $cm^2$ |
| RAD(S/M) | $\sqrt{S_{eff}/M}$ |
| I.EFF | $I_{eff}$, effective resonance integral, see Eq. (2.4.8) |
| TN CØMB. | $\theta_f$, neutron temperature of the fuel element, in $^oK$ |
| TN MØDE. | $\theta_m$, neutron temperature of the moderator, in $^oK$ |
| ØMEGA | $r/\chi_E$, see Eq. (2.3.1.8) |

| Name | Meaning |
|---|---|
| DELTA U | $\Delta u_m$, lethargy interval from $\mu k\theta_m$ up to 2 MeV |
| CHI EPI | $\chi_E$ , see Eq. (2.3.1.8) |
| CHI TER | $\chi_M$ , moderator-to-fuel depression factor for thermal neutron density |
| CHI R 39 | $\chi_R$ for $Pu^{239}$, see Eq. (2.3.1.8) |
| CHI R 40 | $\chi_R$ for $Pu^{240}$, see Eq. (2.3.1.8) |
| (G+RS) A5 | Westcott microscopic absorption cross section of $U^{235}$, divided by $\sigma_{ao}$, see Eq. (2.3.1.8) |
| (G+RS) F5 | Westcott microscopic fission cross section of $U^{235}$, divided by $\sigma_{fo}$, see Eq. (2.3.1.8) |
| (G+RS) A9 | Westcott microscopic absorption cross section of $Pu^{239}$, divided by $\sigma_{ao}$, see Eq. (2.3.1.8) |
| (G+RS) F9 | Westcott microscopic fission cross section of $Pu^{239}$, divided by $\sigma_{fo}$, see Eq. (2.3.1.8) |
| PI | p, $U^{238}$ resonance escape probability, see Eq. (2.4.1) |
| PIO | the same as PI, when $\alpha = 1$ (i.e. $T_u = T_o$), see Eq. (2.4.2) |
| PI INF | $p_\infty$, see Eq. (2.4.9) |
| DØPPLER 0 | Doppler coefficient at $T_u = T_o$, defined as $\left(\frac{1}{p}\ \frac{dp}{dT_u}\right)_{T_u=T_o}$ |
| DØPPLER 1 | Doppler coefficient at $T_u$, defined as $\left(\frac{1}{p}\ \frac{dp}{dT_u}\right)_{T_u}$ |
| CSI.SCAT.E | $\xi\Sigma_s$ of the cell, for the epithermal group, from $\mu k\theta_m$ up to 0.1 MeV |
| CSI.SCAT.V | $\xi\Sigma_s$ of the cell, for the fast group, from 0.1 up to 2 MeV |
| ASS.E | $\Sigma_a$ of the cell, for the epithermal group ($\mu k\theta_m$, 0.1 MeV), as obtained from the thermalization calculation |
| NU.FISS.E | $\nu\Sigma_f$ of the cell, for the epithermal group ($\mu k\theta_m$, 0.1 MeV), as obtained from the thermalization calculation |
| V(CM3/CM) | volume per unit height of the annuli the cell has been divided into |
| EFFE | fraction of thermal neutrons absorbed in each annulus |
| FLUSSØ | thermal flux in each annulus |

| Name | Meaning |
|---|---|
| DENSITA' | thermal neutron density in each annulus |
| EFFE | f, thermal utilization factor of the fuel |
| ETA | $\eta$, thermal fission factor |
| ASS.M | $A_M$, thermal absorption cross section of the cell |
| F.S.B. | $G_s$, disadvantage factor for thermal flux: surface-to-average in the single rod, Eq. (2.5.33) |
| F.S.C. | disadvantage factor for thermal flux: surface-to-average in the element, Eq. (2.5.33) |
| F.S.R.U. | G, disadvantage factor for thermal flux: coolant-to-fuel average flux Eq. (2.5.35) |
| L.U.M. | $\lambda_{u,M}$, see Eq. (2.5.31) |
| L.M.M. | $\lambda_{m,M}$, see Eq. (2.5.32) |
| L.U.E. | $\lambda_u$ for the epithermal group ($\mu k\theta_m$, 0.1 MeV) |
| L.M.E. | $\lambda_m$ " " " " " |
| L.U.V. | $\lambda_u$ " " fast " (0.1 MeV, 2 MeV) |
| L.M.V. | $\lambda_m$ " " " " " |
| EPSILØN | $\varepsilon$, fast fission factor, see Eq. (2.7.2) |
| DELTA 28 | $\delta_{28}$, see Eq. (2.7.3) |
| BETA | $\beta$, see Eq. (2.7.4) |
| GAMMA | $\gamma$, see Eq. (2.7.5) |
| R* | $R^*$ see Eq. (2.7.6) |
| K INFINITO | $k_\infty$, infinite multiplication constant, see Eq. (3.1.9) or (3.2.6) |
| EPSILØN*PI*ETA*EFFE | $\varepsilon p \eta f$ |
| K EFFETTIVØ A 4 GRUPPI | C, see Eq. (3.1.8) |
| K EFFETTIVØ A 2 GRUPPI | k, see Eq. (3.2.5) |
| DIFF.R | $D_{rM}$, $D_{rI}$, $D_{rS}$, $D_{rV}$ (in cm) |
| DIFF.Z | $D_{zM}$, $D_{zI}$, $D_{zS}$, $D_{zV}$ (in cm) |
| RIMØZ. | -, $R_I$, $R_S$, $R_V$ (in $cm^{-1}$) |
| ASSØR. | $A_M$, $A_I$, $A_S$, - " |
| A.R.U8 | -, -, $\gamma R_S$, - " |
| NU.FIS | $\eta f$ $A_M$, $F_I$, $F_S$, - " |
| EP.NUF | $\varepsilon\eta f A_M$, $\varepsilon F_I$, $\varepsilon F_S$, - " |
| L2 RAD | $L_r^2$, $\tau_{rI}$, $\tau_{rS}$, $\tau_{rV}$ (in $cm^2$) |
| L2 ASS | $L_z^2$, $\tau_{zI}$, $\tau_{zS}$, $\tau_{zV}$ " |

(DIFF.R to L2 ASS: Eqs. (3.1.1) to (3.1.4))

| Name | Meaning | |
|---|---|---|
| M(O-MU.K.T) | thermal group (0, $\mu k\theta_m$) | |
| I(MU.K.T-E ) | lower epithermal group ($\mu k\theta_m$, 5 eV) | |
| S(E -0.1 MEV) | upper " " (5 eV, 0.1 MeV) | |
| V(0.1-2 MEV) | fast group (0.1 MeV, 2 MeV) | |
| DR1 | $D_{r1}$ (in cm) | Eqs.(3.2.3) and (3.2.4) |
| DZ1 | $D_{z1}$ " | |
| S1 | $\Sigma_1$ (in $cm^{-1}$) | |
| S11 | $\Sigma_{11}$ " | |
| S12 | $\Sigma_{12}$ " | |
| DR2 | $D_{r2}$ " | |
| DZ2 | $D_{z2}$ " | |
| S2 | $\Sigma_2$ " | |
| S21 | $\Sigma_{21}$ " | |
| S11 35 | contribution to $\Sigma_{11}$ from $U^{235}$ (in $cm^{-1}$) | |
| S12 35 | contribution to $\Sigma_{12}$ from $U^{235}$ (in $cm^{-1}$) | |
| FLU/FLC | ratio of fuel-to-cell thermal flux | |
| VU/VC | fuel-to-cell volume ratio | |
| SIG XE 1 | epithermal absorption cross section of $Xe^{135}$ (in barns) | |
| SIG XE 2 | average thermal absorption cross section of $Xe^{135}$ (in barns) | |
| AVE VU1 | average velocity of epithermal neutrons (in cm/sec) | |
| AVE VU2 | average velocity of thermal neutrons (in cm/sec) | |
| ELLE EX | $l_{ex}$, extrapolation length, see Eq. (2.5.5.4) | |
| BLACK | $\beta$, blackness, see Eq. (2.5.5.5) | |
| WEIGHT | w, weight of the cell in a mixed lattice, see Eq. (2.5.5.6) | |
| EDGE | E, ratio of edge-to-average thermal flux, see Eq. (2.5.5.7) | |
| B2R GEØ. | geometrical radial buckling (in $cm^{-2}$) | |
| B2Z MAT. | material axial " " | |
| B2Z GEØ | geometrical axial " " | |
| B2R MAT. | material radial " " | |
| AREA MIGRAZ. RADIALE | $M_r^2$, see Eq. (3.4.2) (in $cm^2$) | |
| AREA MIGRAZ. ASSIALE | $M_z^2$, see Eq. (3.4.2) " | |

| Name | Meaning |
|---|---|
| BUCKLING MATERIALE | $B_m^2 = \frac{K_\infty - 1}{M_r^2}$, in $cm^{-2}$. |
| R.C.I.(DEL SIST. CRIT.) | initial conversion ratio, see Eq. (2.8.2) |
| RAPPØRTØ PU/U CØMB. | thermalization index, see Eq. (2.8.1) |
| RAPPØRTØ PU/U MØDE. | thermalization index, see Eq. (2.8.1) |
| RHØ 28 | $\rho_{28}$, see Eq. (2.8.4) |
| R.C.I. RELATIVØ | relative initial convertion ratio, see Eq. (2.8.3) |
| DELTA 28 | $\delta_{28}$, see Eq. (2.7.3) |

If IØPZ = 1:

| Configuration n° | Type of perturbation | Denomination |
|---|---|---|
| 1 | moderator temperature increased of 10 °C | TM+10 |
| 2 | fuel temperature increased of 40 °C | TF+40 |
| 3 | coolant temperature increased of 20 °C | TC+20 |
| 4 | $Xe^{135}$ content increased of $.2 \times 10^{-8}$ a/b.cm | XENØ+.2E-08 |
| 5 | Boron content in the moderator increased of $.5 \times 10^{-6}$ a/b.cm | BØRØ+.5E-06 |
| 6 | moderator density reduced by a factor .95 | RHØ M .95 |
| 7 | coolant density reduced to zero | VUØTØ |

Primed quantities ((EPSILØN)', (PI)' and so on) denote derivatives with respect to the considered perturbation.

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APPENDIX I

Rewrite Eq. (3.1.8) by displaying leakage terms in the form:

$$C = \frac{\dfrac{\varepsilon\eta f p(1+\gamma)}{1+B^2 L^2} + \varepsilon p(1+\gamma)\beta_I + \varepsilon\beta_S(1+\alpha_I)(1+B^2 \dfrac{\tau_I}{1+\alpha_I})}{(1+\alpha_I)(1+\gamma+\alpha_S)(1+B^2 \dfrac{\tau_I}{1+\alpha_I})(1+B^2 \dfrac{\tau_S}{1+\gamma+\alpha_S})(1+B^2 \tau_V)} \qquad \text{(A-1)}$$

With the following positions:

$$1 + \alpha = (1 + \alpha_I)(1 + \gamma + \alpha_S)$$

$$\beta = p(1 + \gamma)\beta_I + (1 + \alpha_I)\beta_S$$

$$\frac{\varepsilon\eta f p(1+\gamma)}{1+\alpha} = H_2$$

$$\frac{\varepsilon\beta}{1+\alpha} = H_1$$

Eq. (A-1) gives, to terms of order $B^2$:

$$C \cong H_2+H_1-B^2 \{H_2(L^2 + \frac{\tau_I}{1+\alpha_I} + \frac{\tau_S}{1+\gamma+\alpha_S} + \tau_V) +$$

$$+ H_1 (\frac{\tau_I}{1+\alpha_I} + \frac{\tau_S}{1+\gamma+\alpha_S} + \tau_V - \frac{\beta_S}{\beta} \tau_I)\} \qquad \text{(A-2)}$$

By proceeding in exactly the same way, Eq. (3.2.5) gives, to the same order:

$$k \cong H_2' + H_1' - B^2 \{ H_2' (\frac{D_2}{\Sigma_2} + \frac{D_1}{\Sigma_1}) + H_1' \frac{D_1}{\Sigma_1} \} \qquad \text{(A-3)}$$

where:

$$H_2' = \varepsilon\eta f \frac{\Sigma_{21}}{\Sigma_1}$$

$$H_1' = \frac{\Sigma_{11}}{\Sigma_1}$$

The conditions $H_2 = H_2'$ and $H_1 = H_1'$ give:

$$\frac{\Sigma_{21}}{\Sigma_1} = \frac{p(1+\gamma)}{1+\alpha} \qquad \text{which is Eq. (3.2.9)}$$

$$\frac{\Sigma_{11}}{\Sigma_1} = \frac{\varepsilon\ \beta}{1+\alpha} \qquad \text{which is Eq. (3.2.8)}$$

By equating the coefficients of $B^2$ in Eqs. (A-2) and (A-3), and applying the identity principle as to $H_2$ and $H_1$, one gets at once Eqs. (3.2.7) and (3.2.10) of the main text.

Eqs. (3.2.7) through (3.2.9) define $D_1$, $\Sigma_{11}$, $\Sigma_{21}$ provided $\Sigma_1$ is known. The position

$$\Sigma_1 = (1+\alpha)R \qquad (3.2.12)$$

leads to the final result expressed by Eq. (3.2.19) as shown in the main text.

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TABLE I

The PROCELLA library

| order number | nuclide | order number | nuclide |
|---|---|---|---|
| 1 | U-235 | 16 | Pu-242 |
| 2 | Pu-239 | 17 | Am-241 |
| 3 | Pu-240 | 18 | Ps-15 (+) |
| 4 | Pu-241 | 19 | Ps-25 (+) |
| 5 | U-238 | 20 | Ps-35 (+) |
| 6 | $H_2O$ | 21 | Ps-45 (+) |
| 7 | $D_2O$ | 22 | Ps-19 (°) |
| 8 | H | 23 | Ps-29 (°) |
| 9 | O | 24 | Ps-39 (°) |
| 10 | Zircaloy-2 | 25 | Ps-49 (°) |
| 11 | U-236 | 26 | Sm-149 |
| 12 | C | 27 | Sm-151 |
| 13 | Al standard | 28 | Gd-157 |
| 14 | B | 29 | Eu-155 |
| 15 | Xe-135 | 30 | Cd-113 |

(+) Pseudofission products from $U^{235}$.

(°) Pseudofission products from $Pu^{239}$.

TABLE II

Constants for the fuel material

| fuel | U | $UO_2$ | UC |
|---|---|---|---|
| ICØ | 1 | 2 | 3 |
| A (barn) | 2.95 | 4.15 | 3.1 |
| B (barn $\sqrt{g}$/cm) | 25.8 | 26.6 | 27.0 |
| $\beta$ (barn $\sqrt{g}$/cm) | 27.62 | 27.62 | 27.62 |
| $z_1$ | 1.0 | 1.07 | 1.0 |
| $z_2$ | 0.0 | 0.066 | 0.0 |
| $\gamma_1$ ($^oK^{-1/2}$) | 0.0051 | 0.0058 | 0.0051 |
| $\gamma_2$ ($g \cdot cm^{-2}\ {}^oK^{-1/2}$) | 0.0050 | 0.0050 | 0.0050 |

TABLE III

Constants for the moderator material

| moderator | $D_2O$ |
|---|---|
| IMØ | 1 |
| $\Delta u_R$ | 6.5928 |
| $\Delta u^*$ | 6.1700 |

TABLE IV

Metal: French: single rods AQ 292 (Saclay)

Reference No. 10 Measurement technique: critical flux mapping

Rod diameter: 2.92 cm Uranium density: 18.94 g/$cm^3$

Cladding: Al, 3.0 cm I.D., 3.2 cm O.D. Lattice pitch (square): 12 to 21 cm.

$D_2O$ Moderator purity: 99.70% Lattice temperature: 20 °C

No. of bucklings: 6 $B_m^2$ and $K_{eff}$ in Fig. 2

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 12 | 20.30 | 8.38 | 8.44 | 1.00121 | 0.99848 |
| 13 | 24.04 | 8.28 | 8.50 | 1.00455 | 1.00172 |
| 15 | 32.40 | 7.81 | 7.99 | 1.00452 | 1.00174 |
| 17 | 41.96 | 7.10 | 7.15 | 1.00157 | 0.99904 |
| 19 | 52.71 | 6.22 | 6.25 | 1.00111 | 0.99896 |
| 21 | 64.66 | 5.35 | 5.40 | 1.00183 | 1.00008 |
| | | | | $\bar{K}_{eff}$ | |
| | | | | (1.00247 | 1.00000) |

TABLE V

Metal: French single rods AQ 356 (Saclay)

Reference No. 10 Measurement technique: critical substitution

Rod diametro: 3.56 cm Uranium density: 18.90 $g/cm^3$

Cladding: Al, 3.68 cm I.D., 3.88 cm O.D. Lattice pitch (square): 13 to 25 cm

$D_2O$ moderator purity: 99.70% Lattice temperature: 20 °C

No. of bucklings: 7 $B_m^2$ and $K_{eff}$ in Fig. 3

| Pitch (cm) | Vm/Vu | $B_m^2$ $(m^{-2})$ exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 13 | 15.79 | 7.99 | 8.056 | 1.00120 | 0.99882 |
| 15 | 21.42 | 8.46 | 8.43 | 0.99934 | 0.99641 |
| 17 | 27.85 | 8.02 | 8.01 | 0.99967 | 0.99677 |
| 19 | 35.08 | 7.23 | 7.28 | 1.00137 | .99879 |
| 21 | 43.12 | 6.44 | 6.47 | 1.00088 | .99863 |
| 23 | 51.96 | 5.68 | 5.67 | .99972 | .99781 |
| 25 | 61.61 | 4.98 | 4.94 | .99822 | .99663 |
| | | | | $\bar{K}_{eff}$ (1.00006 | .99769) |

TABLE VI

Metal: French single rods AQ 44 (Saclay)

Reference No.: 10

Measurement technique: critical flux mapping

Rod diameter: 4.4 cm

Uranium density: 18.90 $g/cm^3$

Cladding: Al, 4.5 cm I.D., 4.7 cm O.D.

Lattice pitch (square): 13 to 30 cm

$D_2O$ moderator purily: 99.70%

Lattice temperature: 20 °C

No. of bucklings: 10

$B_m^2$ and $K_{eff}$ in Fig. 4

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 13 | 9.97 | 6.10 | 5.88 | .99655 | .99531 |
| 15 | 13.66 | 8.09 | 7.86 | .99595 | .99356 |
| 17 | 17.87 | 8.42 | 8.32 | .99799 | .99515 |
| 19 | 22.6 | 8.06 | 8.04 | .99961 | .99676 |
| 21 | 27.86 | 7.38 | 7.44 | 1.00163 | .99901 |
| 23 | 33.65 | 6.70 | 6.72 | 1.00060 | .99825 |
| 25 | 39.96 | 6.01 | 5.98 | .99909 | .99703 |
| 27 | 46.8 | 5.28 | 5.28 | 1.00012 | .99840 |
| 29 | 54.17 | 4.54 | 4.64 | 1.00442 | 1.00302 |
| 30 | 58.05 | 4.32 | 4.34 | 1.00103 | .99972 |
| | | | | $\bar{K}_{eff}$ (.99970 | .99762) |

TABLE VII

Metal: French non natural single rods AQ 292 A/B/C (Saclay)

Reference No. 11 Measurement technique: critical substitution
Enrichment: A: 0.69%; B: 0.83%; C: 0.89%
Uranium density: 18.94 g/cm$^3$ (A and B); 18.75 g/cm$^3$ (C)
Lattice pitch (square): 12 to 19 cm; No. of buckling: 12
$B_m^2$ and $K_{eff}$ in Fig. 5(A), 6(B), 7(C). Other data as in Table IV.

| | Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|---|
| A | 12 | 20.30 | 7.91 | 7.46 | .99124 | .98879 |
| | 13 | 24.04 | 7.84 | 7.59 | .99462 | .99207 |
| | 17 | 41.96 | 6.76 | 6.48 | .99185 | .98955 |
| | 19 | 52.71 | 5.91 | 5.67 | .99187 | .98993 |
| | | | | $\bar{K}_{eff}$ | (.99240 | .99009) |
| B | 12 | 20.30 | 11.12 | 11.31 | 1.00340 | .99875 |
| | 13 | 24.04 | 10.90 | 11.16 | 1.00528 | 1.00055 |
| | 17 | 41.96 | 9.10 | 9.16 | 1.00158 | .99757 |
| | 19 | 52.71 | 8.00 | 7.99 | .99976 | .99635 |
| | | | | $\bar{K}_{eff}$ | (1.00251 | .99831) |
| C | 12 | 20.30 | 11.88 | 12.05 | 1.00305 | .99778 |
| | 13 | 24.04 | 11.56 | 11.84 | 1.00562 | 1.00035 |
| | 17 | 41.96 | 9.62 | 9.65 | 1.00077 | .99632 |
| | 19 | 52.71 | 8.78 | 8.41 | .98858 | .98457 |
| | | | | $\bar{K}_{eff}$ | (.99951 | .99476) |
| | | | | $\bar{K}_{tot}$ | (.99814 | .99439) |

TABLE VIII

Metal: French rods in tubes B 44 T78 and B 44 T106 (Saclay)

Reference No.: 10 and 12 Measurement technique: critical substit.(T78)
" flux mapping(T106)

Lattice pitch: 21 and 23 cm $D_2O$ purity: 99.8% (T 78); 99.7% (T 106)
No. of bucklings: 4 Tube: Al, 7.8 cm I.D., 8.0 cm O.D. (T 78)
10.6 cm I.D., 10.8 cm O.D. (T 106)

Other rod data as in Table VI; no Figures relative to this bucklings.

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 21 | 25.7 | 6.45 | 6.70 | 1.00728 | 1.00464 |
| 23 | 31.48 | 6.01 | 6.35 | 1.01079 | 1.00843 |
| | | | | $\bar{K}_{eff}$ (1.00904 | 1.00654) |
| 21 | 25.7 | 4.85 | 5.34 | 1.01675 | 1.01439 |
| 23 | 31.48 | 4.81 | 5.39 | 1.02078 | 1.01858 |
| | | | | $\bar{K}_{eff}$ (1.01877 | 1.01649) |

TABLE IX

Metal: Scandinavian rods SW 20

Reference No.: 13

Rod diameter: 2.00 cm

Cladding: Al, 2.06 cm I.D., 2.26 cm O.D. Lattice pitch (hexagonal): 8 to 14 cm

$D_2O$ moderator purity: 99.75% Lattice temperature: 20 °C

No. of bucklings: 6 $B_m^2$ and $K_{eff}$ in Fig. 8

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 8 | 16.37 | 6.80 | 6.56 | .99603 | .99437 |
| 9 | 21.05 | 7.74 | 7.75 | 1.00020 | .99789 |
| 10 | 26.29 | 8.34 | 8.13 | .99564 | .99282 |
| 11 | 32.08 | 8.20 | 8.06 | .99676 | .99387 |
| 12 | 38.42 | 7.90 | 7.75 | .99620 | .99336 |
| 14 | 52.75 | 6.83 | 6.83 | .99998 | .99759 |
| | | | $\bar{K}_{eff}$ | (.99747 | .99608) |

Note. The experimental values of $B_m^2$ have been reduced by 0.2 $m^{-2}$ because the experimenters report that their $B_m^2$ values are systematically in excess by such amount over data from Ref. 14.

TABLE X

Metal: Scandinavian rods SW 25

Reference No.: 13 Measurement technique: exponential

Rod diameter: 2.53 cm Uranium density: 18.73 g/cm$^3$

Cladding: Al, 2.61 cm I.D., 2.86 cm O.D. Lattice pitch (hexagonal): 8 to 16 cm

$D_2O$ moderator purity: 99.75% Lattice temperature: 20 °C

No. of bucklings: 7 $B_m^2$ and $K_{eff}$ in Fig. 9

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 8 | 9.75 | 2.86 | 2.13 | .98934 | .98907 |
| 9 | 12.68 | 5.68 | 5.39 | .99539 | .99427 |
| 10 | 15.95 | 7.35 | 7.11 | .99598 | .99400 |
| 11 | 19.57 | 8.10 | 7.94 | .99704 | .99451 |
| 12 | 23.53 | 8.46 | 8.23 | .99530 | .99241 |
| 14 | 32.49 | 8.07 | 7.96 | .99728 | .99436 |
| 16 | 42.82 | 7.33 | 7.21 | .99661 | .99396 |
| | | | | $\bar{K}_{eff}$ (.99528 | .99323) |

Note. Experimental $B_m^2$ reduced by 0.2 $m^{-2}$ (see Note in Table IX).

TABLE XI

Metal: Scandinavian rods SW 305 TER

Reference No.: 15 and 16 Measurement technique: critical

Rod diameter : 3.05 cm Uranium density: 18.76 g/cm$^3$

Cladding: Al, 3.15 cm I.D., 3.45 cm O.D. Lattice pitch (hexagonal): 13 to 21.21 cm

Lattice temperature: 20 °C No. of bucklings: 15

$K_{eff}$ in Fig. 10

| Pitch (cm) | $V_m/V_u$ | $D_2O$ purity % | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 goups | 4 groups |
|---|---|---|---|---|---|---|
| | | | | | $\bar{K}_{eff}$ (1.00186 | .99956) |
| 13 | 21.82 | 99.52 | 8.22 | 8.21 | .99986 | .99717 |
| 14 | 25.49 | 99.52 | 8.12 | 8.11 | .99987 | .99711 |
| 14.85 | 28.77 | 99.72 | 7.98 | 8.04 | 1.00141 | .99858 |
| 15 | 29.21 | 99.52 | 7.81 | 7.87 | 1.00131 | .99864 |
| 15 | 29.28 | 99.73 | 7.95 | 8.00 | 1.00129 | .99846 |
| 16 | 33.55 | 99.65 | 7.54 | 7.61 | 1.00168 | .99902 |
| 17 | 38.10 | 99.58 | 7.07 | 7.13 | 1.00162 | .99919 |
| 17 | 38.02 | 99.72 | 7.19 | 7.27 | 1.00234 | .99979 |
| 18 | 43.02 | 99.75 | 6.83 | 6.87 | 1.00108 | .99866 |
| 18 | 43.02 | 99.54 | 6.57 | 6.63 | 1.00193 | .99973 |
| 19 | 47.77 | 99.59 | 6.19 | 6.26 | 1.00234 | 1.00029 |
| 19 | 47.77 | 99.65 | 6.25 | 6.35 | 1.00314 | 1.00103 |
| 20 | 53.14 | 99.65 | 5.79 | 5.91 | 1.00426 | 1.00236 |
| 21 | 58.80 | 99.72 | 5.51 | 5.59 | 1.00288 | 1.00106 |
| 21.21 | 60.12 | 99.73 | 5.42 | 5.49 | 1.00283 | 1.00106 |

TABLE XII

Metal: American Rods NAA 100 (Nuclear American Aviation)

Reference No.: 14

Rod diameter : 1 in.

Cladding: Al, 1 in. I.D., 1.079 in. O.D.

$D_2O$ moderator purity: 99.76%

No. of bucklings: 7

Measurement technique: exponential

Uranium density: 18.88 g/cm$^3$

Lattice pitch (square): 3.625 in. to 12 in.

Lattice temperature: 20 °C

$B_m^2$ and $K_{eff}$ in Fig. 11

| Pitch (inches) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 3.625 | 15.57 | 7.31 | 7.22 | .99854 | .99665 |
| 4.50 | 24.62 | 8.47 | 8.46 | .99982 | .99692 |
| 4.90 | 29.41 | 8.36 | 8.32 | .99919 | .99620 |
| 6.00 | 44.67 | 7.25 | 7.22 | .99910 | .99648 |
| 7.50 | 70.45 | 5.36 | 5.45 | 1.00338 | 1.00162 |
| 9.00 | 103.41 | 3.92 | 3.94 | 1.00087 | .99973 |
| 12.00 | 182.18 | 2.11 | 2.09 | .99855 | .99808 |
| | | | $\bar{K}_{eff}$ | (.99992 | .99795) |

TABLE XIII

Metal: American Rods NAA 200 (Nuclear American Aviation)

Reference No.: 14 | Measurement technique: exponential
Rod diameter : 2 in. | Uranium density: 18.88 q/cm$^3$
Cladding: Al, 2 in. I.D., 2.079 in. O.D. Lattice pitch (square): 7.25 in. to 12 in.
$D_2O$ moderator purity: 99.76% | Lattice temperature: 20 °C
No. of bucklings: 3 | $B_m^2$ and $K_{eff}$ in Fig. 12

| Pitch (inches) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 7.25 | 15.65 | 8.23 | 8.09 | .99714 | .99446 |
| 9.00 | 24.7 | 7.22 | 7.30 | 1.00221 | .99969 |
| 12.00 | 44.76 | 4.76 | 4.83 | 1.00318 | 1.00167 |
| | | | | $\bar{K}_{eff}$ (1.00084 | .99861) |

TABLE XIV

Metal: Canadian Rods ZEEP

Reference No.: 17

Rod diameter: 3,257 cm

Cladding: Al

Measurement technique: critical

Uranium density: 18,95 g/$cm^3$

Pitch: hexagonal

$D_2O$ moderator purity: 99.77%

No. of bucklings: 8

Lattice temperature: 20 °C

$B_m^2$ and $K_{eff}$ in Fig. 13

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 12.06 | 13.96 | 7.299±0.28 | 7.318 | 1.00031 | .99841 |
| 13.97 | 19.13 | 8.345±0.034 | 8.416 | 1.00138 | .99866 |
| 14.48 | 20.64 | 8.570±0.44 | 8.484 | .99828 | .99534 |
| 17.30 | 29.96 | 7.915±0.35 | 8.035 | 1.00297 | 1.00010 |
| 18.90 | 35.98 | 7.234±0.14 | 7.483 | 1.00690 | 1.00431 |
| 19.68 | 39.10 | 7.069±0.046 | 7.186 | 1.00342 | 1.00087 |
| 20.57 | 42.83 | 6.845±0.062 | 6.840 | .99983 | .99736 |
| 22.00 | 49.16 | 6.192±0.084 | 6.284 | 1.00314 | 1.00097 |
| | | | $\bar{K}_{eff}$ | (1.00203 | .99950) |

TABLE XV

Metal: Canadian Tubes HIPPO

Reference No.: 17 Measurement technique: critical

Tube diameters: 2.273 cm I.D. 2.858 cm O.D. (inner coolant: Air)

Cladding: Al, 2.858 cm I.D., 2.96 cm O.D.

Gap (air): 2.96 cm I.D., 3.651 cm O.D.

Outer Aluminium tube: 3.651 cm I.D., 3.71 cm O.D.

Uranium density: 18.9 g/cm$^3$ Lattice pitch (hexagonal): 18.90 cm to 22 cm

$D_2O$ moderator purity: 99.74% Lattice temperature: 20 °C

No. of bucklings: 3 $B_m^2$ and $K_{eff}$ in Fig. 14

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 18.90 | 27.97 | 5.853±0.15 | 5.761 | .99757 | .99533 |
| 20.57 | 34.02 | 5.728±0.15 | 5.842 | 1.00325 | 1.00111 |
| 22.00 | 39.61 | 5.641±0.15 | 5.725 | 1.00255 | 1.00047 |
| | | | $\bar{K}_{eff}$ | (1.00112 | .99897) |

TABLE XVI

Metal: Savannah River clusters "HURLEY"

Reference No.: 18 Measurement technique: critical

Rods per cluster: 7 Uranium density: 18.9 g/cm$^3$

Rod diameter: 0.998 in. Cladding: Al, 0.998 in I.D., 1.062 in. O.D.

Rod array in the cluster: hexagonal, outer to center spacing: 1.50 in.

Coolant and moderator: $D_2O$ 99.75% Pressure and calandria tube: none

Lattice pitch (hexagonal): 9.33 in. to 21 in. Lattice temperature 22 °C

No. of bucklings: 5 $B_m^2$ and $K_{eff}$ in Fig. 15

| Pitch (inches) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $R_{cella}$ | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|---|
| 9.33 | 11.4 | 6.020±0.054 | 5.98 | 12.443 | .99926 | .99791 |
| 12.12 | 20.87 | 6.115±0.051 | 6.126 | 16.171 | 1.00029 | .99853 |
| 14.00 | 28.63 | 5.160±0.070 | 5.120 | 18.67 | .99867 | .99722 |
| 18.52 | 51.88 | 2.920±0.080 | 2.86 | 24.6978 | .99813 | .99746 |
| 21.00 | 67.38 | 2.095±0.049 | 2.043 | 28.0055 | .99634 | .99592 |
| | | | | $\overline{K}_{eff}$ | (.99854 | .99741) |

TABLE XVII

Metal: French clusters AQ 7 GO/G2/G5 (Saclay)

Reference No.: 10

Measurement technique: critical substitution

Rods per cluster: 7

Uranium density: 18.9 $g/cm^3$

Rod diameter: 1.65 cm

Cladding: Al, 1.7 cm I.D., 1.8 cm O.D.

Rod array in the cluster: hexagonal, outer to center spacing: 1.875 cm (AQ7GO)
2.075 cm (AQ7G2)
2.375 cm (AQ7G5)

Coolant and moderator: $D_2O$ 99.7%

Pressure and calandria tube: none

Lattice pitch (square): 15 to 23 cm. Lattice temperature 20 °C

No. of bucklings: 12

$B_m^2$ and $K_{eff}$ in Fig. 16 (AQ7GO)
17 (AQ7G2)
18 (AQ7G5)

| | Pitch (cm) | $V_m/V_u$ | $B_m^2(m^{-2})$ exp. | $B_m^2(m^{-2})$ calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|---|
| AQ7GO | 15 | 13.5 | 6.48 | 7.016 | 1.00953 | 1.00798 |
| | 17 | 17.78 | 7.43 | 7.808 | 1.00765 | 1.00543 |
| | 19 | 22.59 | 7.39 | 7.737 | 1.00802 | 1.00563 |
| | 21 | 27.93 | 6.99 | 7.264 | 1.00722 | 1.00490 |
| | | | | $\bar{K}_{eff}$ | (1.00811 | 1.00599) |
| AQ7G2 | 15 | 13.27 | 6.35 | 6.712 | 1.00634 | 1.00486 |
| | 19 | 22.35 | 7.31 | 7.678 | 1.00836 | 1.00604 |
| | 21 | 27.7 | 6.97 | 7.261 | 1.00751 | 1.00523 |
| | | | | $\bar{K}_{eff}$ | (1.00740 | 1.00538) |
| AQ7G5 | 15 | 12.88 | 5.76 | 6.346 | 1.01008 | 1.00887 |
| | 17 | 17.16 | 7.02 | 7.487 | 1.00911 | 1.00716 |
| | 19 | 21.96 | 7.22 | 7.629 | 1.00907 | 1.00685 |
| | 21 | 27.31 | 6.93 | 7.284 | 1.00891 | 1.00669 |
| | 23 | 33.19 | 6.48 | 6.717 | 1.00677 | 1.00468 |
| | | | | $\bar{K}_{eff}$ | (1.00879 | 1.00685) |

# TABLE XVIII

Metal: French clusters AQ 19 TP 106 (Saclay)

Reference No. 10 — Measurement technique: critical substitution

Rods per cluster: 19 — Uranium density: 18.8 $g/cm^3$

Rod diameter: 1.0 cm — Cladding: none

Rod array in the cluster: hexagonal, spacing (outer to center) 1.5 cm

Coolant: Air — Moderator: $D_2O$ 99.7%

Shroud : Mg, 10.9 cm I.D., 11.2 cm O.D.; Lattice pitch (square): 19 to 25 cm

No. of bucklings: 4 — Lattice temperature: 20 °C

$B_m^2$ and $K_{eff}$ in Fig. 19

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 17.94 | 4.71 | 5.086 | 1.01115 | 1.00891 |
| 21 | 23.30 | 5.40 | 5.774 | 1.01143 | 1.00881 |
| 23 | 29.2 | 5.63 | 5.938 | 1.00994 | 1.00726 |
| 25 | 35.63 | 5.55 | 5.790 | 1.00828 | 1.00577 |
| | | | | $\bar{K}_{eff}$ | |
| | | | | (1.01020 | 1.00769) |

TABLE XIX

Metal: French clusters AQ 19 TP 78

Shroud: Mg, 7.95 cm I.D., 8.25 cm O.D. No. of bucklings: 2
Lattice pitch (square): 21 to 23 cm Other data as in Table XVIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ $(m^{-2})$ exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 21 | 25.97 | 6.97 | 6.980 | 1.00027 | .99742 |
| 23 | 31.87 | 6.47 | 6.726 | 1.00742 | 1.00489 |
| | | | $\bar{K}_{eff}$ | (1.00385 | 1.00116) |

# TABLE XX

Metal: Canadian clusters CR 131 HWC (Chalk River)

Reference No. 22

Measurement technique: critical

Rods per cluster: 19

Uranium density: 18.93 g/cm$^3$

Rod diameter: 1.31 cm

Cladding: Al, 1.38 cm I.D., 1.59 cm O.D.

Rod array in the cluster: circular, 1.775 cm and 3.425 cm

Coolant: $D_2O$ 99.72%

Moderator: $D_2O$ 99.72%

Shro d tube: Al, 8.58 cm I.D., 8.89 cm O.D.

Lattice pitch (hexagonal): 20 to 40 cm

No. of bucklings: 8

Lattice temperature: 20 °C

$B_m^2$ and $K_{eff}$ in Fig. 20

| Pitch (cm) | $B_m^2$ ($m^{-2}$) exp. | calc. | $V_m/V_u$ | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 20 | 4.473±.064 | 3.784 | 11.10 | .98773 | .98695 |
| 22 | 5.658±.060 | 5.128 | 13.94 | .98962 | .98831 |
| 24 | 6.008±.045 | 5.680 | 17.06 | .99289 | .99132 |
| 26 | 6.016±.055 | 5.766 | 20.44 | .99400 | .99233 |
| 28 | 5.725±.032 | 5.586 | 24.09 | .99631 | .99470 |
| 32 | 4.952±.030 | 4.870 | 32.21 | .99732 | .99596 |
| 36 | 4.149±.022 | 4.039 | 41.4 | .99568 | .99459 |
| 40 | 3.418±.010 | 3.271 | 51.68 | .99301 | .99218 |
| | | | $\bar{K}_{eff}$ | (.99215 | .99204) |

TABLE XXI

Metal: Canadian clusters CR 131 VT (Chalk River)

Coolant: He $B_m^2$ and $K_{eff}$ in Fig. 21

Other data as in Table XX

| Pitch (cm) | $B_m^2$ ($m^{-2}$) exp. | calc. | $V_m/V_u$ | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 20 | 4.587±.087 | 3.964 | 11.10 | .98795 | .98695 |
| 22 | 5.817±.052 | 5.310 | 13.94 | .98945 | .98782 |
| 24 | 6.176±.046 | 5.880 | 17.06 | .99327 | .99137 |
| 26 | 6.186±.041 | 5.983 | 20.44 | .99496 | .99299 |
| 28 | 6.030±.030 | 5.816 | 24.09 | .99417 | .99222 |
| 32 | 5.281±.026 | 5.109 | 32.21 | .99436 | .99271 |
| 36 | 4.442±.030 | 4.272 | 41.4 | .99326 | .99196 |
| 40 | 3.729±.009 | 3.487 | 51.68 | .98855 | .98753 |
| | | | | $\bar{K}_{eff}$ | |
| | | | | (.99200 | .99044) |

TABLE XXII

Metal: CISE Experiments AC-PP-XX (Saclay)

Reference No. 23 Measurement technique: critical substitution

Tubes per cluster: 7 Uranium density: 18.7 g/cm$^3$

Coolant: polystyrene Coolant channel diameter: 1.3 cm

Inner cladding: Al, 1.3 cm I.D., 1.47 cm O.D.

Uranium: 1.5 I.D., 2.26 cm O.D.

Spacing: 2.26 cm center to center Moderator: $D_2O$ 11.10%

No. of bucklings: 8 Lattice temperature: 20 °C

| Denomination | Coolant density (g/cm$^3$) | Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|---|---|
| AC-PP-02 | 0.552 | 17 | 14.87 | 4.85±.04 | 4.238 | .98789 | .98676 |
| " | " | 19 | 19.43 | 5.49±.08 | 5.310 | .99608 | .99459 |
| " | " | 20 | 21.9 | 5.62±.04 | 5.545 | .99827 | .99668 |
| " | " | 21 | 24.5 | 5.61±.09 | 5.642 | 1.00077 | .99915 |
| " | " | 24 | 33.04 | 5.27±.08 | 5.420 | 1.00428 | 1.00275 |
| | | | | | ($\bar{K}_{eff}$= | .99746 | .99599) |
| AC-PP-00 | 0.0 | 20 | 21.9 | 6.18±.04 | 6.223 | 1.00104 | .99884 |
| AC-PP-01 | 0.317 | 20 | 21.9 | 5.76±.04 | 5.776 | 1.00039 | .99862 |
| AC-PP-03 | 0.953 | 20 | 21.9 | 5.32±.04 | 5.316 | .99990 | .99858 |

The lattice configurations named AC-PP-02 are reported, regardless $B_m^2$ and $K_{eff}$, in Fig. 22.

TABLE XXIII

Oxide: French rods OX AQ 46 (Saclay)

Reference No. 10 Measurement technique: critical substitution
Rod diameter: 4.6 cm Fuel density: 9.7 $g/cm^3$
Cladding: Al, 4.7 cm I.D., 49 cm O.D. Lattice pitch (square): 15 to 21 cm
$D_2O$ moderator purity: 99.70% Lattice temperature: 20 °C
No. of bucklings: 4 $B_m^2$ and $K_{eff}$ in Fig. 23

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 15 | 12.4 | 6.76 | 7.22 | 1.01026 | 1.00818 |
| 17 | 16.26 | 6.69 | 6.983 | 1.007524 | 1.00534 |
| 19 | 20.59 | 6.14 | 6.438 | 1.00882 | 1.00683 |
| 21 | 25.4 | 5.58 | 5.768 | 1.00635 | 1.00458 |
| | | | $K_{eff}$ | 1.00824 | 1.00623 |

TABLE XXIV

Oxide: Scandinavian rods OX SW 13.5

Reference No.: 15 Measurement technique: critical

Rod diameter: 1.35 cm Fuel density: 10.42 g/cm$^3$

Cladding: Al, 1.37 cm I.D., 1.57 cm O.D. Lattice pitch (square): 4.5 to 6.4 cm

$D_2O$ moderator purity: 99.69% Lattice temperature: 20 °C

No. of bucklings: 3 $B_m^2$ and $K_{eff}$ in Fig. 24

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 4.5 | 12.95 | 4.44 | 4.192 | .99521 | .99439 |
| 5.4 | 18.82 | 5.62(+) | 5.587 | .99926 | .99784 |
| 6.4 | 27.26 | 5.81 | 5.719 | .99757 | .99592 |
| | | | $\bar{K}_{eff}$ | .99735 | .99605 |

(+) The value $B_m^2$ = 5.65 has been reduced from 99.55% to 99.69% $D_2O$ purity using the correction values reported in Ref. 15.

TABLE XXV

Oxide: Canadian 7-rod clusters Z2 7 HWC (Chalk River)

Reference No.: 19.20 Measurement technique: critical

Rod diameter: 2.4 cm Fuel density: 10.2 g/cm$^3$

Cladding: Al, 2.438 cm I.D., 2.54 cm O.D. Rod spacing (center to center): 2.667 cm

Shroud: Al, 8.256 cm I.D., 8.434 cm O.D. Coolant: $D_2O$ 99.73%

Lattice pitch (hexagonal): 18 to 36 cm Moderator: $D_2O$ 99.73% (temper.: 20°C)

No. of bucklings: 7 $B_m^2$ and $K_{eff}$ in Fig. 25

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 18 | 7.10 | 4.56 | 4.426 | .99748 | .99661 |
| 19 | 8.11 | 5.25 | 5.166 | .99833 | .99715 |
| 22 | 11.47 | 5.97 | 6.049 | 1.00185 | 1.00019 |
| 24 | 13.99 | 5.84 | 6.008 | 1.00436 | 1.00268 |
| 24.6 | 14.79 | 5.82 | 5.942 | 1.00326 | 1.00157 |
| 28 | 19.68 | 5.17 | 5.322 | 1.00488 | 1.00339 |
| 36 | 33.68 | 3.45 | 3.545 | 1.00458 | 1.00373 |
| | | | $\bar{K}_{eff}$ | 1.00211 | 1.00076 |

TABLE XXVI

Oxide: Canadian 7-Rod clusters Z2 7 VT (Chalk River)

Coolant: Air Lattice pitch (hexagonal): 19 to 36 cm

No. of bucklings: 5 $B_m^2$ and $K_{eff}$ in Fig. 26

Other data as in Table XXV

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 8.11 | 4.87 | 4.861 | .99979 | .99854 |
| 22 | 11.47 | 5.69 | 5.921 | 1.00568 | 1.00393 |
| 24.6 | 14.79 | 5.72 | 5.918 | 1.00549 | 1.00365 |
| 28 | 19.68 | 5.28 | 5.354 | 1.00242 | 1.00074 |
| 36 | 33.68 | 3.62 | 3.648 | 1.00134 | 1.00038 |
| | | | $\bar{K}_{eff}$ | 1.00294 | 1.00145 |

TABLE XXVII

Oxide: Canadian 7-Rod clusters Z2 7 HB40 (Chalk River)

Coolant: HB-40 ($C_{18}$ $H_{22}$ density: 1 gm/cm$^3$) Lattice pitch (hexagonal): 19 to 28 cm

No. of bucklings: 5 $B_m^2$ and $K_{eff}$ in Fig. 27

Other data as in Table XXV

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 19 | 8.12 | 3.24 | 3.978 | 1.01277 | 1.01243 |
| 20 | 9.17 | 3.44 | 4.181 | 1.01377 | 1.01338 |
| 22 | 11.47 | 3.48 | 4.289 | 1.01721 | 1.01676 |
| 24 | 13.99 | 3.26 | 4.14 | 1.02159 | 1.02115 |
| 28 | 19.68 | 2.68 | 3.508 | 1.02626 | 1.02591 |
| | | | $\bar{K}_{eff}$ | 1.01832 | 1.01793 |

TABLE XXVIII

Oxide: Canadian 19-Rod clusters Z2 19 HWC (Chalk River)

Reference No.: 19,20 Measurement technique: critical
Rod diameter: 1.42 cm Fuel density: 10.45 $g/cm^3$
Cladding: 2, 1.43 cm I.D., 1.52 cm O.D. Rod array in the cluster: circular; 1.65 cm, 3.19 cm radii

Pressure tube: Al, 8.26 cm I.D., 8.79 cm O.D.
Calandria tube: Al, 10.16 cm I.D., 10.44 cm O.D.
Air gap between pressure and calandria Coolant: $D_2O$ 99.63%
Lattice pitch (hexagonal): 18 to 36 cm Moderator: $D_2O$ 99.63% (temp. 20 °C)
No. of bucklings: 12 $B_m^2$ and $K_{eff}$ in Fig. 28

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 18 | 6.48 | 1.407 | 1.341 | .99853 | .99840 |
| 19 | 7.55 | 2.407 | 2.365 | .99906 | .99871 |
| 20 | 8.67 | 2.995 | 3.107 | 1.00264 | 1.00210 |
| 21 | 9.85 | 3.479 | 3.627 | 1.00359 | 1.00287 |
| 22 | 11.09 | 3.804 | 3.973 | 1.00427 | 1.00342 |
| 24 | 13.73 | 4.045 | 4.293 | 1.00684 | 1.00586 |
| 26 | 16.61 | 4.078 | 4.291 | 1.00641 | 1.00539 |
| 28 | 19.72 | 3.952 | 4.103 | 1.00498 | 1.00399 |
| 30 | 23.06 | 3.690 | 3.816 | 1.00459 | 1.00370 |
| 32 | 26.63 | 3.380 | 3.486 | 1.00422 | 1.00344 |
| 34 | 30.43 | 3.052 | 3.142 | 1.00393 | 1.00327 |
| 36 | 34.46 | 2.754 | 2.804 | 1.00241 | 1.00184 |
| | | | $\bar{K}_{eff}$ | 1.00346 | 1.00275 |

TABLE XXIX

Oxide: Canadian 19-Rod clusters Z2 19 VT (Chalk River)

Coolant: Air Lattice pitch (hexagonal): 18 to 36 cm

No. of bucklings: 11 $B_m^2$ and $K_{eff}$ in Fig. 29

Other data as in Table XXVIII

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 18 | 6.48 | 0.72 | 1.367 | 1.01643 | 1.01639 |
| 20 | 8.67 | 2.77 | 3.156 | 1.00992 | 1.00934 |
| 21 | 9.85 | 3.35 | 3.694 | 1.00904 | 1.00823 |
| 22 | 11.09 | 3.72 | 4.061 | 1.00921 | 1.00823 |
| 24 | 13.73 | 4.12 | 4.418 | 1.00861 | 1.00745 |
| 26 | 16.61 | 4.17 | 4.424 | 1.00792 | 1.00673 |
| 28 | 19.72 | 4.07 | 4.259 | 1.00640 | 1.00525 |
| 30 | 23.06 | 3.86 | 3.986 | 1.00466 | 1.00361 |
| 32 | 26.63 | 3.58 | 3.662 | 1.00329 | 1.00236 |
| 34 | 30.43 | 3.28 | 3.319 | 1.00171 | 1.00089 |
| 36 | 34.46 | 2.97 | 2.978 | 1.00040 | .99971 |
| | | | $\bar{K}_{eff}$ | 1.00705 | 1.00620 |

TABLE XXX

Oxide: Canadian 19-Rod clusters Z2 19 HB40 (Chalk River)

Coolant: HB 40 ($C_{18}H_{22}$, density: 1 gm/cm$^3$) Lattice pitch (hexagonal): 18 to 28 cm

No. of bucklings: 4 $B_m^2$ and $K_{eff}$ in Fig. 30

Other data as in Table XXVIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 18 | 6.48 | -0.37 | 0.431 | 1.01470 | 1.01470 |
| 21 | 9.85 | 1.21 | 1.800 | 1.01271 | 1.01264 |
| 24 | 14.57 | 1.57 | 2.225 | 1.01743 | 1.01731 |
| 28 | 19.72 | 1.53 | 2.064 | 1.01724 | 1.01711 |
| | | | $\bar{K}_{eff}$ | 1.01552 | 1.01544 |

TABLE XXXI

Oxide: Canadian 19-Rod clusters Z2 19 HWC BIS (Chalk River)

Reference No. 19
No. of bucklings: 5
$B_m^2$ and $K_{eff}$ in Fig. 31

Pressure tube: Zr. 2, 8.28 cm I.D., 9.14 cm O.D.
Lattice pitch (hexagonal): 30 to 34 cm
Other data as in Table XXVIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 18 | 6.48 | 1.19 | .943 | .99467 | .99459 |
| 21 | 9.85 | 3.30 | 3.349 | 1.00117 | 1.00055 |
| 24 | 13.73 | 3.89 | 4.063 | 1.00474 | 1.00387 |
| 28 | 19.72 | 3.80 | 3.909 | 1.00359 | 1.00270 |
| 36 | 34.46 | 2.64 | 2.664 | 1.00114 | 1.00062 |
| | | | $\bar{K}_{eff}$ | 1.00106 | 1.00047 |

TABLE XXXII

Oxide: Canadian 19-Rod clusters NPD-1

Reference No. 17 | Measurement technique: critical

Rod diameter: 1.323 cm | Fuel density: 9.53 $g/cm^3$

Cladding: Al, 1.385 cm I.D., 1.589 cm O.D.

Rod spacing(hexagonal, center to center): 1.791 cm

Pressure and calandria tube: none

Coolant and moderator: $D_2O$ 99.60%

Lattice pitch (hexagonal): 19.05 to 30.48 cm | No. of bucklings: 5

$B_m^2$ and $K_{eff}$ in Fig. 32 | Lattice temperature: 20 °C

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19.05 | 9.73 | 4.21 | 4.499 | 1.00620 | 1.00537 |
| 21.59 | 13.15 | 5.04 | 5.147 | 1.00260 | 1.00135 |
| 24.13 | 17.00 | 5.00 | 5.089 | 1.00248 | 1.00117 |
| 26.67 | 21.28 | 4.45 | 4.709 | 1.00826 | 1.00714 |
| 30.48 | 28.5 | 3.74 | 3.934 | 1.00755 | 1.00668 |
| | | | $\bar{K}_{eff}$ | 1.00542 | 1.00434 |

TABLE XXXIII

Oxide: French 7-Rod clusters OX - AQ - 7 - 162

Reference No.: 10 Measurement technique: critical substitution

Rod diameter: 1.62 cm Fuel density: 9.85 g/cm$^3$

Cladding: Al, 1.7 cm I.D., 1.9 cm O.D. Rod spacing (center to center): 2.1 cm

Shroud tube: none Coolant and moderator: $D_2O$ 99.70%

Lattice temperature: 20 °C Lattice pitch (square): 17 to 23 cm

No. of bucklings: 4 $B_m^2$ and $K_{eff}$ in Fig. 23

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 17 | 18.00 | 6.02 | 5.952 | .99822 | .99641 |
| 19 | 23.00 | 5.57 | 5.584 | 1.00043 | .99877 |
| 21 | 28.54 | 5.07 | 5.052 | .99939 | .99791 |
| 23 | 34.64 | 4.45 | 4.478 | 1.00109 | .99987 |
| | | | $\bar{K}_{eff}$ | .99978 | .99824 |

TABLE XXXIV

Oxide: French 19-rod clusters OX - AQ - 19 - 162

Rod array in the cluster: hexagonal, spacing 2.1 cm

Lattice pitch (square): 21 to 25 cm

No. of bucklings: 3 $B_m^2$ and $K_{eff}$ in Fig. 34

Other data as in Table XXXIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 21 | 9.13 | 5.15 | 4.753 | .99149 | .99027 |
| 23 | 11.38 | 5.44 | 5.217 | .99471 | .99328 |
| 25 | 13.83 | 5.33 | 5.241 | .99768 | .99623 |
| | | | $\bar{K}_{eff}$ | .99496 | .99326 |

TABLE XXXV

Oxide: French 19-rod clusters OX - AQ - 19 - 162 VT

Rod array in the cluster: hexagonal, spacing 2.2 cm

Lattice pitch (square): 25 to 32 cm

Shroud tube: Al, 11.6 cm I.D., 11.8 cm O.D. Coolant: $N_2$

No. of bucklings: 4 $B_m^2$ and $K_{eff}$ in Fig. 35

Other data as in Table XXXIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 25 | 13.17 | 4.37 | 4.495 | 1.00372 | 1.00234 |
| 27 | 15.82 | 4.39 | 4.503 | 1.00362 | 1.00224 |
| 29 | 18.68 | 4.28 | 4.329 | 1.00171 | 1.00039 |
| 32 | 23.35 | 3.84 | 3.899 | 1.00232 | 1.00122 |
| | | | $\bar{K}_{eff}$ | 1.00284 | 1.00155 |

TABLE XXXVI

Oxide: French 7-rod clusters OX - AQ - 7 - 220

Reference No.: 10 Measurement technique: critical substitution

Rod diameter: 2.2 cm Fuel density: 10.19 g/cm$^3$

Cladding: Al, 2.3 cm I.D., 2.5 cm O.D. Rod spacing (center to center): 3.2 cm

Shroud tube: none Coolant and moderator: $D_2O$ 99.70%

Lattice temperature: 20 °C Lattice pitch (square): 19 to 24 cm

No. of bucklings: 3 $B_m^2$ and $K_{eff}$ in Fig. 36

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 11.23 | 5.51 | 5.977 | 1.01036 | 1.00895 |
| 21 | 14.24 | 5.64 | 6.117 | 1.01184 | 1.01029 |
| 24 | 19.31 | 5.28 | 5.693 | 1.01220 | 1.01071 |
| | | | $\bar{K}_{eff}$ | 1.01147 | 1.00998 |

TABLE XXXVII

Oxide: French 7-Rod clusters OX - AQ - 7 - 220 - VT

Shroud tube: Al, 10.6 cm I.D., 10.8 cm O.D. Coolant: $N_2$
Lattice pitch (square): 19 to 25 cm No. of bucklings: 4
$B_m^2$ and $K_{eff}$ in Fig. 37
Other data as in Table XXXVI

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 19 | 10.12 | 3.22 | 3.577 | 1.01049 | 1.00954 |
| 21 | 13.13 | 3.97 | 4.297 | 1.01003 | 1.00871 |
| 23 | 16.44 | 4.38 | 4.541 | 1.00527 | 1.00374 |
| 25 | 20.05 | 4.33 | 4.486 | 1.00550 | 1.00404 |
| | | | $\bar{K}_{eff}$ | 1.00782 | 1.00651 |

TABLE XXXVIII

Oxide: French 19-Rod clusters OX - AQ - 19 - 132 - A

Reference No. 10 Measurement technique: critical substitution

Rod diameter: 1.32 cm Fuel density: 9.52 g/cm$^3$

Cladding: Al, 1.4 cm I.D., 1.6 cm O.D.

Rod array in the cluster: hexagonal, spacing 2.8 cm

Shroud tube: none Coolant and moderator: $D_2O$ 99.70%

Lattice temperature: 20 °C Lattice pitch (square): 19 to 28 cm

No. of bucklings: 3 $B_m^2$ and $K_{eff}$ in Fig. 38

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 11.55 | 5.08 | 5.007 | .99833 | .99707 |
| 21 | 14.62 | 5.21 | 5.247 | 1.00045 | .99957 |
| 23 | 18.00 | 5.04 | 5.110 | 1.00202 | 1.00066 |
| | | | $\bar{K}_{eff}$ | 1.00043 | .99910 |

TABLE XXXIX

Oxide: French 19 - Rod clusters OX - AQ - 19 - 132 - B

Rod array in the cluster: hexagonal, spacing (center to center): 2.0 cm
Lattice pitch (square): 19 and 23 cm No. of bucklings: 2
Other data as in Table XXXVIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 11.10 | 4.89 | 4.795 | .99785 | .99670 |
| 23 | 17.56 | 5.02 | 5.075 | 1.00155 | 1.00021 |
| | | | $\bar{K}_{eff}$ | .99970 | .99846 |

TABLE XL

Oxide: French 19-Rod clusters OX - AQ - MG - 19 - 120 - A

Reference No.: 10 Measurement technique: critical substitution

Rod diameter: 1.2 cm Fuel density: 10.15 g/cm$^3$

Cladding: Mg, 1.3 cm I.D., 1.5 cm O.D.

Rod array in the cluster: hex., spacing 1.6 cm

Shroud tube: Mg, 10.6 cm I.D., 10.9 cm O.D. Coolant: $N_2$

Moderator: $D_2O$, 99.70% Lattice temperature: 20 °C

Lattice pitch (square): 19 to 25 cm No. of bucklings: 4

$B_m^2$ and $K_{eff}$ in Fig. 39

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 12.46 | 3.75 | 4.517 | 1.02487 | 1.02341 |
| 21 | 16.18 | 4.20 | 4.963 | 1.02594 | 1.02429 |
| 23 | 20.28 | 4.43 | 4.993 | 1.02037 | 1.01864 |
| 25 | 24.74 | 4.32 | 4.787 | 1.01828 | 1.01667 |
| | | | $\bar{K}_{eff}$ | 1.02237 | 1.02075 |

TABLE XLI

Oxide: French 19-Rod clusters OX - AQ - MG - 19 - 120 - B

Shroud tube: Mg, 7.95 cm I.D., 8.25 cm O.D. No of bucklings: 2
Other data as in Table XL

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 19 | 14.31 | 5.34 | 5.947 | 1.01616 | 1.01442 |
| 25 | 26.6 | 4.87 | 5.165 | 1.01067 | 1.00911 |
| | | | $\bar{K}_{eff}$ | 1.01342 | 1.01177 |

TABLE XLII

Oxide: French 19-rod clusters OX - AQ - MG - 19 - 120 C

Rod array in the cluster: hexagonal, spacing (center to center): 2.0 cm
No. of bucklings: 4 $B_m^2$ and $K_{eff}$ in Fig. 40

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 19 | 12.46 | 3.68 | 4.366 | 1.02176 | 1.02040 |
| 21 | 16.18 | 4.14 | 4.887 | 1.02485 | 1.02327 |
| 23 | 20.28 | 4.43 | 4.969 | 1.01904 | 1.01735 |
| 25 | 24.74 | 4.34 | 4.798 | 1.01748 | 1.01589 |
| | | | $\bar{K}_{eff}$ | 1.02078 | 1.01923 |

TABLE XLIII

Oxide: Scandinavian 7-Rod clusters OX - SW - 7 - 156

Reference No.: 21 Measurement technique: exponential

Rod diameter: 1.56 cm Fuel density: 9.42 g/cm$^3$

Cladding: Al, 1.56 cm I.D., 1.72 cm O.D. Rod spacing: 2.375 cm

Shroud tube: Al, 7.2 cm I.D., 7.4 cm O.D.

Coolant and moderator: $D_2O$, 99.65%

Lattice temperature: 20 °C Lattice pitch (hexag.): 12 to 30 cm

No. of bucklings: 10 $B_m^2$ and $K_{eff}$ in Fig. 41

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 12 | 6.11 | 2.36 | 1.521 | .98458 | .98434 |
| 14 | 9.47 | 4.47 | 4.093 | .99222 | .99132 |
| 16 | 13.36 | 5.19 | 5.019 | .99600 | .99472 |
| 18 | 17.76 | 5.25 | 5.145 | .99719 | .99580 |
| 20 | 22.68 | 4.96 | 4.891 | .99791 | .99659 |
| 22 | 28.11 | 4.43 | 4.473 | 1.00147 | 1.00034 |
| 24 | 34.07 | 4.00 | 3.997 | .99990 | .99892 |
| 26 | 40.54 | 3.54 | 3.521 | .99916 | .99833 |
| 28 | 47.53 | 3.01 | 3.069 | 1.00296 | 1.00232 |
| 30 | 55.04 | 2.58 | 2.654 | 1.00416 | 1.00365 |
| | | | $\bar{K}_{eff}$ | .99756 | .99663 |

TABLE XLIV

Oxide: Scandinavian 19-Rod clusters OX - SW - 19 - 156

Rod array in the cluster: hexagonal, center to center spacing: 1.85 cm
Shroud tube: Al, 9.64 cm I.D., 10. cm O.D.

Lattice pitch (exagonal): 20 to 28 cm

No. of bucklings: 5 $B_m^2$ and $K_{eff}$ in Fig. 42

Other data as in Table XLIII

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 20 | 7.38 | 3.95 | 3.509 | .99107 | .99035 |
| 22 | 10.17 | 4.60 | 4.462 | .99692 | .99591 |
| 24 | 12.37 | 4.88 | 4.807 | .99820 | .99702 |
| 26 | 14.75 | 4.90 | 4.797 | .99720 | .99595 |
| 28 | 17.33 | 4.64 | 4.586 | .99839 | .99721 |
| | | | $\bar{K}_{eff}$ | .99636 | .99529 |

TABLE XLV

Oxide: Scandinavian 7-Rod clusters OX - SW - 7 - 122 - A

Reference No. 21
Measurement technique: Exponential
Rod diameter: 1.22 cm
Fuel density: 9.27 g/cm$^3$
Cladding: Al, 1.24 cm I.D., 1.38 cm O.D. Rod spacing: 1.5 cm
Shroud tube: none
Coolant and moderator: $D_2O$ 99.57%
Lattice temperature: 20 °C
Lattice pitch (hex.): 12 to 18 cm
No. of bucklings: 4
$B_m^2$ and $K_{eff}$ in Fig. 43

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 12 | 13.40 | 5.73 | 5.718 | .99973 | .99825 |
| 14 | 18.9 | 5.96 | 5.886 | .99809 | .99636 |
| 16 | 25.25 | 5.62 | 5.421 | .99399 | .99235 |
| 18 | 32.45 | 4.95 | 4.793 | .99447 | .99308 |
| | | | $\bar{K}_{eff}$ | .99657 | .99501 |

TABLE XLVI

Oxide: Scandinavian 7-Rod clusters OX - SW - 7 - 122 - B

Rod spacing: 2.0 cm

No. of bucklings: 4

$B_m^2$ and $K_{eff}$ in Fig. 44

Other data as in Table XLV

| Pitch (cm) | $V_m/V_u$ | $B_m^2$ ($m^{-2}$) exp. | $B_m^2$ ($m^{-2}$) calc. | $K_{eff}$ 2 groups | $K_{eff}$ 4 groups |
|---|---|---|---|---|---|
| 12 | 12.46 | 5.28 | 5.386 | 1.00230 | 1.00104 |
| 14 | 17.97 | 5.80 | 5.757 | .99892 | .99731 |
| 16 | 24.31 | 5.55 | 5.432 | .99653 | .99495 |
| 18 | 31.51 | 4.95 | 4.855 | .99675 | .99538 |
| | | | $\bar{K}_{eff}$ | .99862 | .99717 |

TABLE XLVII

Oxide: Scandinavian 19-Rod clusters OX - SW - 19 - 122

Reference No.: 21
Measurement technique: exponential
Rod diameter: 1.22 cm
Fuel density: 9.27 $g/cm^3$
Cladding: Al, 1.24 cm I.D., 1.38 cm O.D.
Rod away in the cluster: hexag., spacing 1.485 cm

Shroud tube: Al, 7.5 cm I.D., 7.7 cm O.D.
Coolant: $D_2O$
Moderator: $D_2O$, 99.63%
Lattice temperature: 20 °C
Lattice pitch (hexagonal): 18 to 30 cm
No. of bucklings: 7
$B_m^2$ and $K_{eff}$ in Fig. 45

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 18 | 10.54 | 4.94 | 4.818 | .99733 | .99618 |
| 20 | 13.50 | 5.31 | 5.227 | .99797 | .99658 |
| 22 | 16.78 | 5.26 | 5.177 | .99772 | .99629 |
| 24 | 20.36 | 5.01 | 4.889 | .99630 | .99493 |
| 26 | 24.26 | 4.65 | 4.491 | .99455 | .99330 |
| 28 | 28.25 | 4.09 | 4.052 | .99853 | .99750 |
| 30 | 33.00 | 3.66 | 3.611 | .99791 | .99703 |
| | | | $\bar{K}_{eff}$ | .99719 | .99597 |

TABLE XLVIII

Oxide: Scandinavian 19-Rod clusters OX - SW - 19 - 122 - VT

Coolant: Air $B_m^2$ and $K_{eff}$ in Fig. 46

Other data as in Table XLVII

| Pitch (cm) | Vm/Vu | $B_m^2$ ($m^{-2}$) exp. | calc. | $K_{eff}$ 2 groups | 4 groups |
|---|---|---|---|---|---|
| 18 | 10.54 | 5.35 | 4.632 | .98296 | .98132 |
| 20 | 13.50 | 5.54 | 5.123 | .98913 | .99737 |
| 22 | 16.78 | 5.61 | 5.136 | .98643 | .98460 |
| 24 | 20.36 | 5.40 | 4.894 | .98403 | .98229 |
| 26 | 24.26 | 4.97 | 4.527 | .98450 | .98296 |
| 28 | 28.47 | 4.46 | 4.109 | .98634 | .98504 |
| 30 | 33.00 | 4.10 | 3.680 | .98200 | .98085 |
| | | | $\bar{K}_{eff}$ | .98506 | .98349 |

TABLE IL

Overall test calculations based on buckling measurements

For each set of N points: $\bar{K}_{eff} = \frac{\sum_{i=1}^{N} K_i}{N}$ ; $\sigma = \left[ \frac{\sum_{i=1}^{N} (K_i - \bar{K}_{eff})^2}{N-1} \right]^{1/2}$

| Part | Type of lattice | | No. of lattices | $\bar{K}_{eff}$ (4-group) | $\sigma$ | Percentage of lattices within $\bar{K}_{eff} \pm \sigma$ | Percentage of lattices within $\bar{K}_{eff} \pm 2\sigma$ | $\bar{K}_{eff}$ (2-groups) |
|---|---|---|---|---|---|---|---|---|
| Overall survey | U metal | Rods and tubes | 88 | 0.99902 | 0.00461 | 64.8 | 90.9 | 1.00153±0.00429 |
| | | Clusters | 76 | 0.99852 | 0.00702 | 61.7 | 100. | 1.00029±0.00738 |
| | $UO_2$ | Single rods + 7 rod clusters | 53 | 1.00189 | 0.00752 | 77. | 94. | 1.00316±0.00743 |
| | | 19 or more rod clusters | 78 | 1.00282 | 0.01010 | 72. | 92. | 1.00376±0.01005 |
| Selected data | Metal clusters | French data only | 18 | 1.00597 | 0.00258 | 78. | 94. | 1.00817±0.00243 |
| | | Canadian data only | 16 | 0.99124 | 0.00289 | 62. | 100. | 0.99208±0.00312 |
| | 19-rod $UO_2$ clusters | French + Canadian data | 44 | 1.00248 | 0.00438 | 79.6 | 93. | 1.00340±0.00447 |
| | | Swedish (exponentials) | 19 | 0.99119 | 0.00639 | 73.7 | 100. | 0.99250±0.00626 |

TABLE L

Measured vs. calculated $K_\infty$ values

| Lattices (1) | No. of cases N | $\frac{\text{Sum of exper. } K_\infty}{\text{Sum of calc. } K_\infty} = \alpha$ | σ (2) |
|---|---|---|---|
| Hanford 19-rod $UO_2$ lattices | 6 | 1.00972 | 0.00977 |
| PLATR 37-rod $UO_2$ lattices | 24 | 1.00676 | 0.00389 |

(1) Experimental data from UNC-5012

(2) For each set of measurements: $\sigma = \left[ \frac{\sum_{i=1}^{N} \left\{ K_{\infty,i}(\exp) - \alpha K_{\infty,i}(\text{calc}) \right\}^2}{N - 1} \right]^{1/2}$

TABLE LI

Comparison of theory and experiments:
detailed lattice parameters

| Parameter | No. of cases | % Error ($\frac{\text{theory-exp.}}{\text{exp.}}$) | Source of exp. data |
|---|---|---|---|
| Initial conversion ratio, ICR | 47 | + 2.4 ± 2.0 | AECL - 2025; AECL - 2636; AEEW - R.336 (1), (2) |
| $U^{238}$ to $U^{235}$ fission ratio, $\delta_{28}$ | 35 | - 0.3 ± 2.0 | AECL - 2025; AECL - 2636 (2) |
| Pu/U fission ratio in the fuel element | 20 | - 1.5 ± 0.5 | CEAR - 2482; AEEW - R.336 |
| Moderator-to-fuel neutron density ratio, $F_m$ | | | |
| Air and $D_2O$ cooling | 15 | + 1.0 ± 2.0 | AECL - 2025 |
| HB-40 ($C_{18}$ $H_{22}$) cooling | 7 | -10.0 ± 3.0 | |

Notes: 1. Zero error assumed in the experimental data.

2. The reported oscillations in the errors cover the whole span of data.

References (1) F. Accinni et al.:"Evaluation of lattice parameters for a heavy water moderated, natural uranium fuelled power reactor" presented at the Int. Conf. on Physics Problems in Thermal Reactor Design. London, June 27-29, 1967.

(2) J.Bergeron:"Mesures de facteur de conversion des réseau à uranium naturel" - thèse présentée à la Faculté des Sciences de l'Université de Paris (1965).

TABLE LII

Theory vs. CISE experiments

| Square lattice pitch, cm | Coolant density,(1) g/cm$^3$ | $B_m^2$ ($m^{-2}$) Exp. | $B_m^2$ ($m^{-2}$) 2-group calc. | $10^2$ $\delta^{28}$ Exp. | $10^2$ $\delta^{28}$ Calc. | ICR(2) Exp. | ICR(2) Calc. | Pu/U(3) Exp. | Pu/U(3) Calc. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 0. --- | 6.18 ± 0.04 | 6.22 | 6.95 ± 0.35 | 6.91 | 0.825 | 0.822 | 1.198 | 1.19 |
| 20 | 0.382 | 5.62 ± 0.04 | 5.54 | 6.53 ± 0.33 | 6.62 | 0.844 | 0.843 | 1.245 | 1.23 |
| 20 | 0.660 | 5.32 ± 0.04 | 5.32 | 6.39 ± 0.32 | 6.46 | 0.841 | 0.843 | - | - |
| 19 | 0.382 | 5.49 ± 0.07 | 5.31 | - | - | - | - | - | - |
| 21 | " | 5.61 ± 0.09 | 5.64 | - | - | - | - | - | - |
| 24 | " | 5.27 ± 0.07 | 5.42 | - | - | - | - | - | - |

(1) "Equivalent" density of a water coolant with the same hydrogen content as the polystyrene used.

(2) Experimental uncertainty ± 0.004.

(3) Experimental uncertainty ± 2%, including reference spectrum uncertainties.

Reference: F. Accinni et al.: "Evaluation of lattice parameters for a heavy water moderated, natural uranium fuelled power reactor" - presented at the Int. Conf. on Physics Problems in Thermal Reactor Design. London, June 27-29, 1967.

## TABLE LIII

Bucklings of $UO_2$ clusters - 9.33 in lattice pitch; results of substitution measurements; moderator at 22.8°C and 99.58 mol % $D_2O$

| No. of rods in cluster | Rod spacing center-to-center (inches) | Coolant | Housing tube OD(in) | thick.(in) | Avg. $B_m^2 (m^{-2})$ from DP-873 | $B_m^2 (m^{-2})$ PROCELLA calc. | $k_{eff}$ (4-groups) PROCELLA calc. | $\delta(\Delta k_{eff}^{VT})$ (pcm) |
|---|---|---|---|---|---|---|---|---|
| 19 | 0.607 | Organic | 3.080 | 0.030 | 3.53 | 4.06 | 1.0135 | - 1310 |
| 19 | 0.607 | $H_2O$ | 3.080 | 0.030 | 2.07 | 2.89 | 1.0209 | - 2050 |
| 19 | 0.607 | Air | 3.080 | 0.030 | 5.45 | 5.52 | 1.0004 | = |
| 19 | 0.598 | Organic | 2.679 | 0.030 | 4.57 | 4.81 | 1.0056 | - 840 |
| 19 | 0.598 | Air | 2.679 | 0.030 | 5.60 | 5.56 | 0.9972 | = |
| 37 | 0.607 | Organic | 4.350 | 0.050 | 2.52 | 2.86 | 1.0061 | - 900 |
| 37 | 0.607 | $H_2O$ | 4.350 | 0.050 | 0.70 | 1.63 | 1.0157 | - 1860 |
| 37 | 0.607 | Air | 4.350 | 0.050 | 4.35 | 4.27 | 0.9971 | = |
| 37 | 0.607 | Organic | 4.746 | 0.050 | 0.31 | 1.43 | 1.0202 | = |
| 37 | 0.650 | Organic | 4.746 | 0.050 | 1.11 | 1.46 | 1.0060 | - 750 |
| 37 | 0.650 | Organic | 4.970 | 0.162 | - 0.80 | - 0.17 | 1.0113 | = |
| 37 | 0.650 | $D_2O$ | 4.746 | 0.050 | 4.00 | 3.63 | 0.9917 | + 680 |
| 37 | 0.650 | Air | 4.746 | 0.050 | 3.65 | 3.63 | 0.9985 | = |

Note: $\Delta k_{eff}^{VT}$ is the change in $k_{eff}$ for voiding the coolant channel, $\delta(\Delta k_{eff}^{VT})$ represents the error affecting such a quantity when the experimental $B_m^2$ is assumed exact.

Reference: F.D. Bentan: "Measurements of bucklings and void effects in $D_2O$-moderated, organic or $H_2O$-cooled lattices of $UO_2$ rod cluster; DP-873 (1964).

TABLE LIV

Comparison of calculated and measured results for Hanford 19-Rod $UO_2$ lattices

Description of the lattice:

Fuel: natural $UO_2$, density 10.1 gm/cm$^3$
Fuel rod radius: 0.6401 cm
Al cladding: IR = 0.6413 cm, OR = 0.7175 cm
Center-to-center rod spacing: 1.646 cm (hexagonal except in outer shell)
Tubes sourrounding cluster:
Al inner tube: IR = 4.1275 cm, OR = 4.450 cm
Al outer tube: IR = 4.762 cm, OR = 5.080 cm
$D_2O$ purity: 99.7%

| Hexagonal lattice pitch, inches | Coolant | $k_\infty$ | | $\Delta k_\infty$ for voiding the coolant channel | |
|---|---|---|---|---|---|
| | | Measured | PROCELLA | Measured | PROCELLA |
| 7.0 | $D_2O$ | 1.005 | 0.9991 | + 0.006 | + 0.004 |
| 7.0 | None | 1.011 | 1.003 | | |
| 8.0 | $D_2O$ | 1.052 | 1.045 | + 0.009 | + 0.009 |
| 8.0 | None | 1.061 | 1.054 | | |
| 9.0 | $D_2O$ | 1.088 | 1.072 | + 0.022 | + 0.011 |
| 9.0 | None | 1.110 | 1.083 | | |

Reference: R. Sullivan, H. Soodak: "Extended comparison of calculated and measured reactivities for $D_2O$-moderated lattices; UNC-5012 (1962).

TABLE LV

Comparison of calculated and measured results for PLATR 37-Rod $UO_2$ lattices

Description of the lattice: Hexagonal lattice pitch: 11.1 in; Fuel: natural $UO_2$, density 10.3 $gm/cm^3$;
Fuel rod radius: 0.25 in.; Al cladding: IR = 0.255 in, OR = 0.275 in;
Pressure tube: IR=2.325 in.; OR=2.487 in. Calandria tube: IR = 2.8775 in; OR = 2.9375 in.

| Experiment No. | Center-center rod spacing (inches) | % coolant voids | Pressure and Calandria | $k_\infty$ | | $\Delta k_\infty$ | | Effect of |
|---|---|---|---|---|---|---|---|---|
| | | | | Measured | PROCELLA | Measured | PROCELLA | |
| 1 | 0.648 | 0 | | 1.043 | 1.037 | | | |
| 2 | " | 32 | | 1.050 | 1.044 | 0.007 | 0.007 | voiding coolant (2-1) |
| 3 | " | 100 | | 1.074 | 1.059 | 0.031 | 0.022 | voiding coolant (3-1) |
| 4 | " | 0 | None | 1.103 | 1.093 | 0.060 | 0.056 | tubes (4-1) |
| 5 | " | 0 | | 1.077 | 1.075 | | | |
| 6 | " | 30 | | 1.081 | 1.080 | 0.004 | 0.005 | voiding coolant (6-5) |
| 7 | " | 100 | | 1.100 | 1.093 | 0.023 | 0.018 | voiding coolant (7-5) |
| 8 | " | 100 | | 1.098 | 1.086 | 0.022 | 0.011 | voiding coolant (8-5) |
| 9 | " | 0 | | 1.068 | 1.064 | | | |
| 10 | " | 0 | | 1.093 | 1.088 | -0.051 | -0.047 | tubes (10-11) |
| 11 | " | 0 | None | 1.144 | 1.135 | 0.067 | 0.060 | tubes (11-5) |
| 12 | " | 0 | None | 1.134 | 1.131 | | | |
| 13 | " | 0 | None | 1.130 | 1.129 | | | |
| 14 | " | 28 | None | 1.147 | 1.136 | 0.003 | 0.001 | voiding coolant(14-11) |
| 15 | 0.580 | 0 | None | 1.152 | 1.144 | 0.008 | 0.009 | rod spacing (15-11) |
| 16 | 0.580 | 22 | None | 1.152 | 1.143 | 0.000 | -0.001 | voiding coolant(16-15) |
| 17 | 0.720 | 0 | None | 1.137 | 1.125 | -0.007 | -0.010 | rod spacing (17-11) |
| 18 | 0.720 | 33 | None | 1.144 | 1.130 | 0.007 | 0.005 | voiding coolant(18-17) |

Reference: R. Sullivan, H. Soodak: " Extended comparison of calculated and measured reactivities for $D_2O$-moderated lattices" - UNC-5012 (1962).

TABLE LVI

Measurements on Ågesta 19-Rod clusters in the pressurized exponential assembly TZ.

Description of the lattice:

Fuel natural $UO_2$, density 10.5 gm/cm$^3$; Coolant and moderator: $D_2O$ 99,44%

Fuel rod radius: 0.85 cm

Zircaloy-2 cladding: IR = 0.86 cm, OR = 0.93 cm

Zircaloy-2 shroud tube: IR = 5.65 cm, OR = 5.74 cm

Center-to-center rod spacing: 2.21 cm; hexagonal lattice pitch

| Temp. (°C) | 24 cm lattice pitch $k_{eff}$ | 27 cm lattice pitch $k_{eff}$ |
|---|---|---|
| 21 | - | 1.0130 |
| 22 | 1.0062 | - |
| 50 | - | 1.0116 |
| 61 | - | 1.0121 |
| 68 | - | 1.0115 |
| 75 | 1.0037 | - |
| 90 | 1.0029 | 1.0116 |
| 125 | - | 1.0097 |
| 150 | 1.0008 | - |
| 152 | - | 1.0085 |
| 180 | - | 1.0058 |
| 190 | 0.9971 | - |
| 207 | 0.9972 | - |
| 210 | - | 1.0041 |
| 239 | - | 1.0014 |
| 246 | 0.9948 | - |
| 248 | - | 1.0016 |

Reference: R. Persson, A.J.W. Andersson, C.E. Wikdahl: "Buckling measurements up to 250 °C on lattices of Ågesta clusters and on $D_2O$ alone in the pressurized exponential assembly TZ" - AE-254 (1966).

TABLE LVII

Comparison of calculated and measured results for some 37-rod $UO_2$ SGHW lattices

Description of the lattice:

Fuel: 0.91% enriched $UO_2$

Fuel rod cladding: OD = 0.578 in, cladding thickness = 0.036 in

| | | | | |
|---|---|---|---|---|
| Pressure tube | ID = 5.250 in, | OD = 5.500 in | for SG2 | lattices |
| | ID = 4.520 in, | OD = 4.776 in | " SG3, SG4, SG5 | " |
| Calandria tube | ID = 6.240 in, | OD = 6.625 in | " SG2, SG3 | " |
| | ID = 5.520 in, | OD = 5.900 in | " SG4, SG5 | " |
| Coolant-to-fuel volume ratio | = 1.7 | | " SG2 | " |
| | = 0.9 | | " SG3, SG4, SG5 | " |
| Moderator-to-fuel volume ratio | = 6.3 | | " SG2, SG3, SG5 | " |
| | = 7.3 | | " SG4 | " |

Triangular lattice pitch: 9.5 in

Reference: C.G. Campbell, I. Johnstone, D.C. Leslie, D.A. Newmarch: "Reactor physics studies for SGHWR's. A comparison of experimental results with theoretical predictions". AEEW-R 336 (1964).

TABLE LVII (cont'd)

| Core | Coolant | F.S.(P.T./$UO_2$) | | | | F.S. (C.T./$UO_2$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Exp. | METHUSELAH | THULE | PROCELLA | Exp. | METHUSELAH | THULE | PROCELLA |
| SG3 | Air | 1.301±0.014 | 1.207 | 1.316 | 1.411 | 1.415±0.015 | 1.271 | 1.438 | 1.523 |
| | Mixture | 1.564±0.017 | 1.485 | 1.500 | 1.566 | 1.672±0.019 | 1.547 | 1.593 | 1.650 |
| | Beads | 1.652±0.035 | 1.549 | 1.528 | - | 1.761±0.024 | 1.608 | 1.613 | - |
| | Water | 1.689±0.019 | 1.639 | 1.581 | 1.639 | 1.779±0.020 | 1.689 | 1.649 | 1.700 |
| | Water (90°C) | | | | | | | | |
| SG4 | Air | 1.315±0.014 | 1.218 | 1.313 | 1.432 | 1.413±0.016 | 1.260 | 1.401 | 1.517 |
| | Mixture | 1.585±0.017 | 1.534 | 1.503 | 1.598 | 1.674±0.019 | 1.580 | 1.569 | 1.663 |
| | Water | 1.729±0.019 | 1.684 | 1.598 | 1.687 | 1.796±0.020 | 1.717 | 1.648 | 1.736 |

TABLE LVII (cont'd)

| Core | Coolant | F.S. ($D_2O/UO_2$) | | | | Pu/U | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Exp. | METHUSELAH | THULE | PROCELLA | Exp. | METHUSELAH | THULE | PROCELLA |
| SG3 | Air | 1.675±0.021 | 1.496 | 1.745 | 1.796 | 1.35±0.02 | 1.180 | 1.301 | 1.358 |
| | Mixture | 1.885±0.024 | 1.764 | 1.834 | 1.861 | 1.27±0.01 | 1.240 | 1.234 | 1.240 |
| | Beads | 1.937±0.029 | 1.814 | 1.836 | - | 1.26±0.01 | 1.214 | 1.216 | 1.211 |
| | Water | 1.914±0.024 | 1.870 | 1.843 | 1.863 | 1.21±0.01 | 1.170 | 1.184 | 1.164 |
| | Water (90°C) | | | | | 1.29±0.01 | 1.225 | 1.241 | 1.223 |
| SG4 | Air | 1.729±0.023 | 1.582 | 1.828 | 1.886 | | | | |
| | Mixture | 1.911±0.025 | 1.920 | 1.916 | 1.958 | 1.28±0.02 | 1.234 | 1.220 | 1.217 |
| | Water | 2.045±0.027 | 1.977 | 1.934 | 1.969 | - | 1.170 | 1.177 | 1.153 |
| SG5 | Mixture | | | | | 1.25±0.02 | 1.243 | 1.221 | 1.239 |
| | Water | | | | | 1.19±0.01 | 1.175 | 1.193 | 1.164 |

TABLE LVII (cont'd)

| Core | Coolant | R.C.R. | | | | $\delta_{28}$ | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Exp. | METHUSELAH | THULE | PROCELLA | Exp. | METHUSELAH | THULE | PROCELLA |
| SG2 | Air | 2.004±0.020 | 1.899 | 1.987 | 1.995 | 0.0598±0.0014 | 0.0679 | 0.0603 | 0.0671 |
| SG3 | Air | 1.984±0.009 | 1.889 | 1.960 | 1.992 | 0.0658±0.0014 | 0.0730 | 0.0652 | 0.0671 |
| | Mixture | 1.881±0.010 | 1.838 | 1.901 | 1.896 | 0.0532±0.0011 | 0.0624 | 0.0506 | 0.0561 |
| | Beads | 1.811±0.010 | 1.768 | 1.843 | 1.834 | 0.0584±0.0013 | 0.0648 | 0.0537 | 0.0593 |
| | Water | 1.698±0.011 | 1.667 | 1.738 | 1.733 | 0.0517±0.0011 | 0.0592 | 0.0489 | 0.0549 |
| | Water (90°C) | 1.709±0.016 | 1.694 | 1.754 | 1.764 | 0.0499±0.0021 | 0.0592 | 0.0491 | 0.0553 |
| SG4 | Air | | | | | | | | |
| | Mixture | 1.771±0.010 | 1.785 | 1.814 | 1.812 | 0.0521±0.0011 | 0.0603 | 0.0494 | 0.0548 |
| | Water | 1.648±0.015 | 1.638 | 1.688 | 1.687 | 0.0510±0.0011 | 0.0583 | 0.0474 | 0.0537 |
| SG5 | Air | | | | | | | | |
| | Mixture | 1.875±0.013 | 1.866 | 1.897 | 1.888 | 0.0506±0.0011 | 0.0623 | 0.0508 | 0.0560 |
| | Water | 1.701±0.013 | 1.693 | 1.740 | 1.727 | 0.0512±0.0011 | 0.0604 | 0.0482 | 0.0549 |

TABLE LVII (cont'd)

| Core | Coolant | $k_\infty$ | | | $k_{eff}$ ($B^2_{exp.}$) | | |
|---|---|---|---|---|---|---|---|
| | | METHUSELAH | THULE | PROCELLA | METHUSELAH | THULE | PROCELLA |
| SG2 | Air | 1.0747 | 1.0450 | 1.0527 | 1.0213 | 1.0135 | 1.0187 |
| | Water | 0.9865 | - | 0.9332 | 1.0017 | - | 0.9739 |
| SG3 | Air | 1.0751 | 1.0519 | 1.0564 | 1.0153 | 1.0191 | 1.0161 |
| | Mixture | 1.0451 | 1.0217 | 1.0415 | 0.9951 | 1.0003 | 1.0182 |
| | Beads | 1.0391 | 1.0214 | 1.0348 | - | - | - |
| | Water | 1.0257 | 1.0066 | 1.0172 | 0.9892 | 1.0009 | 1.0136 |
| | Water (90°C) | | | | | | |

Note: SG4 and SG5 lattices not calculated because thickness of interstitial tubes was unknown.

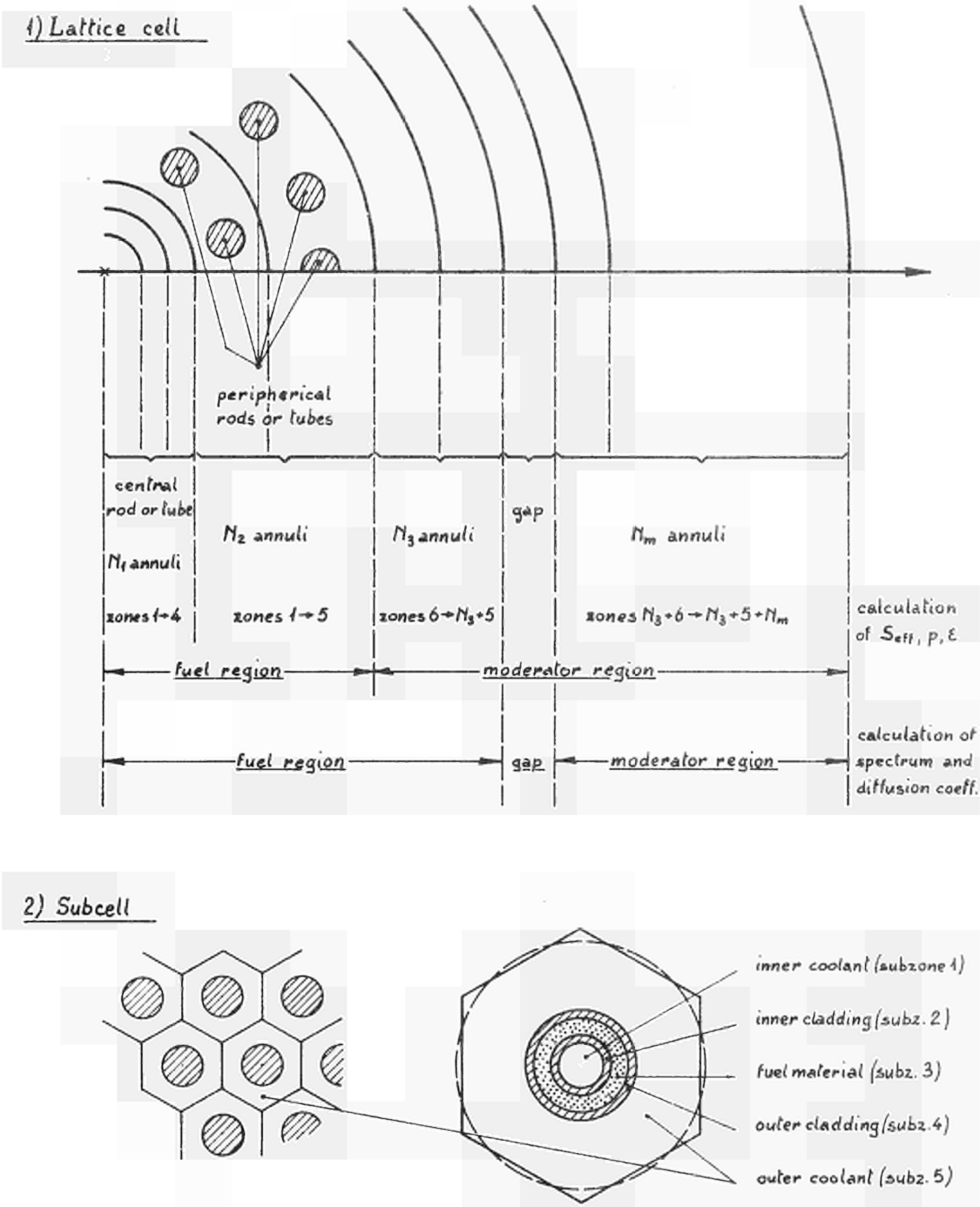



Fig. 1 - Configuration of the lattice cell considered by the PROCELLA code.

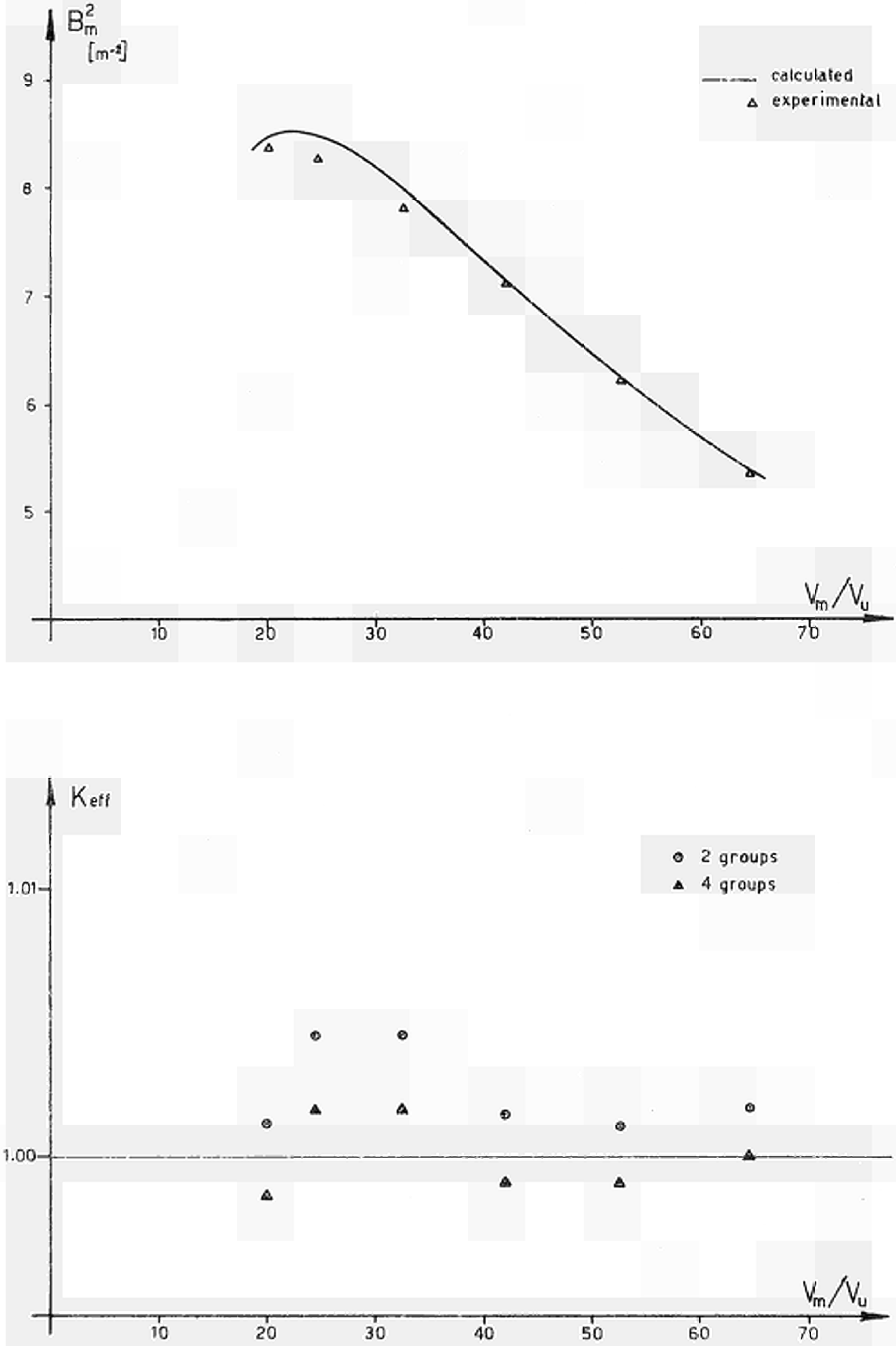
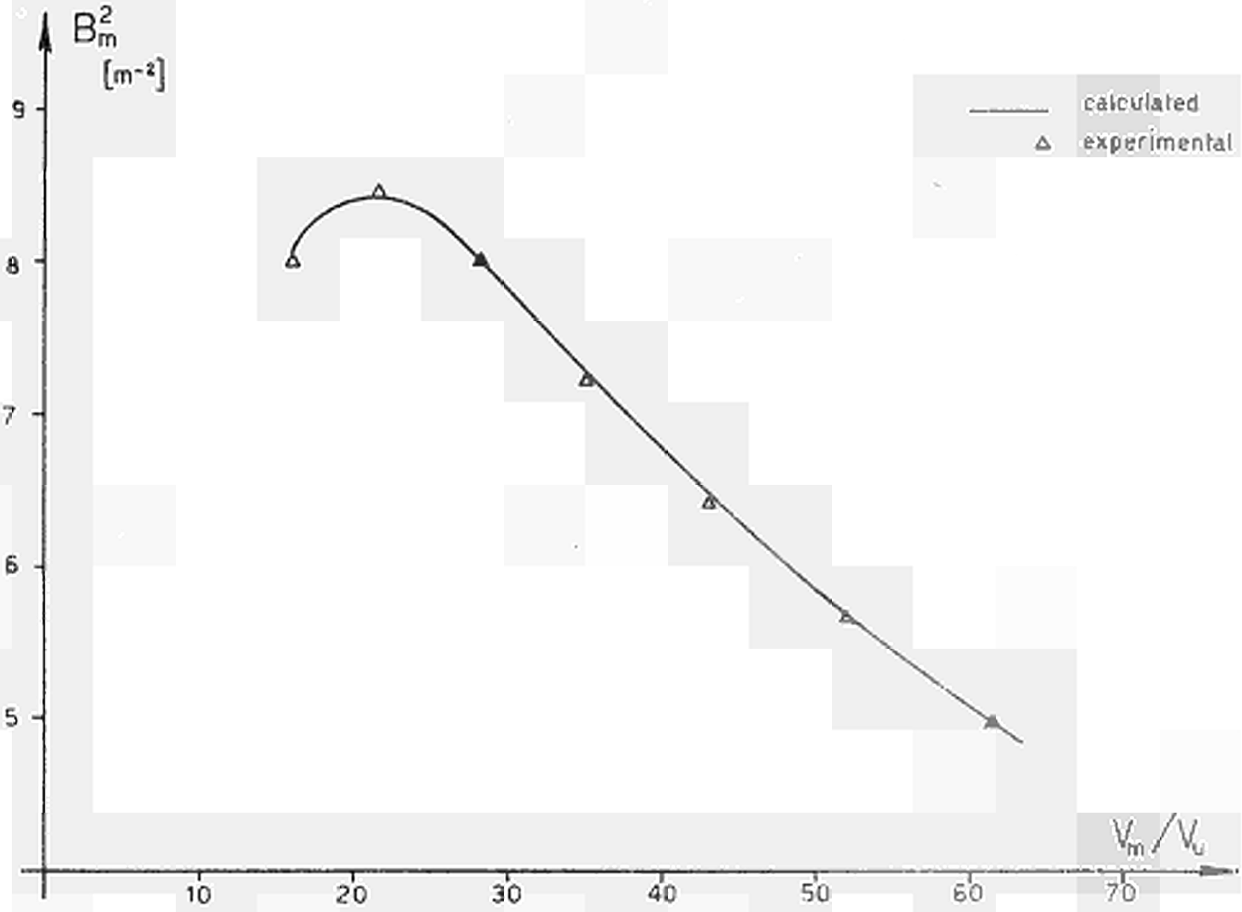



Fig. 2 - French metal single rod AQ-292 (Table IV).



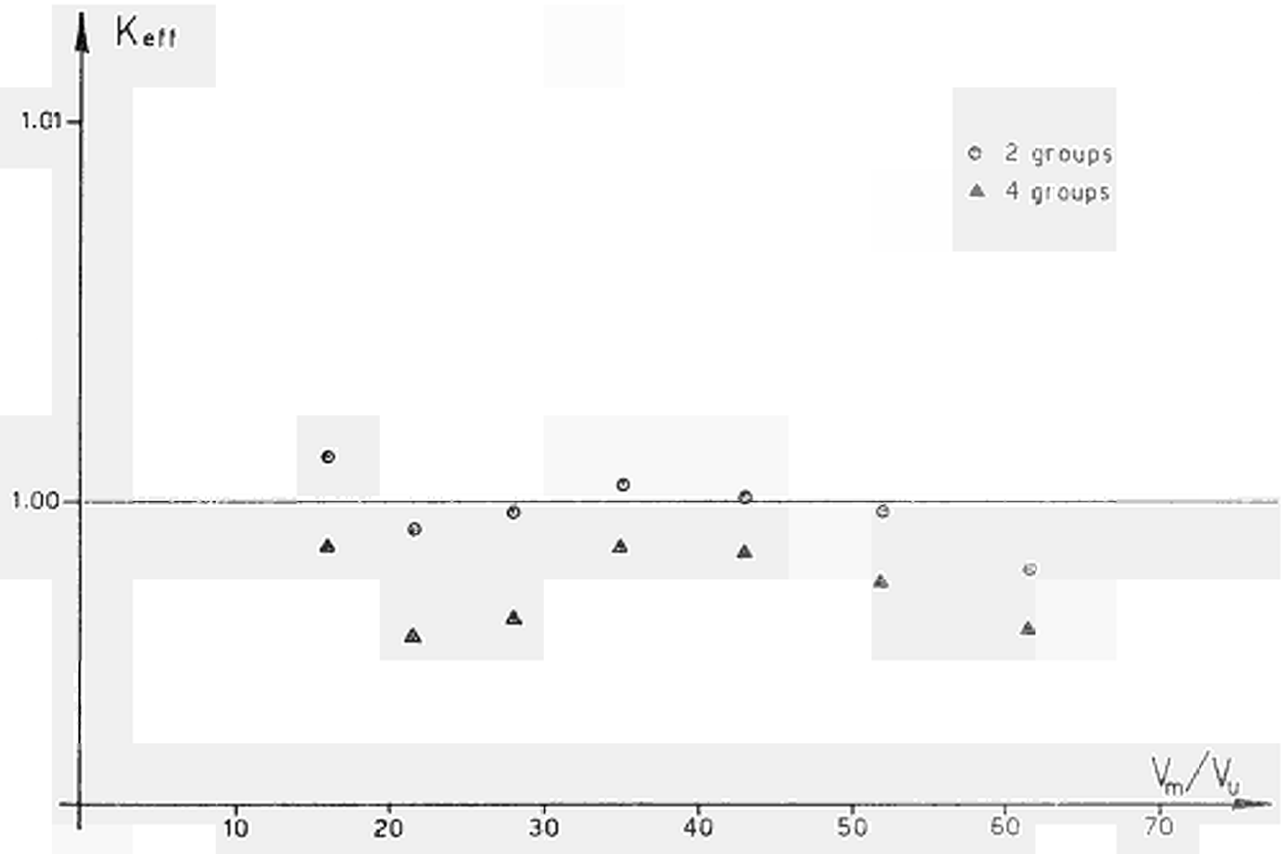




Fig. 3 - French metal single rod AQ-256 (Table V).

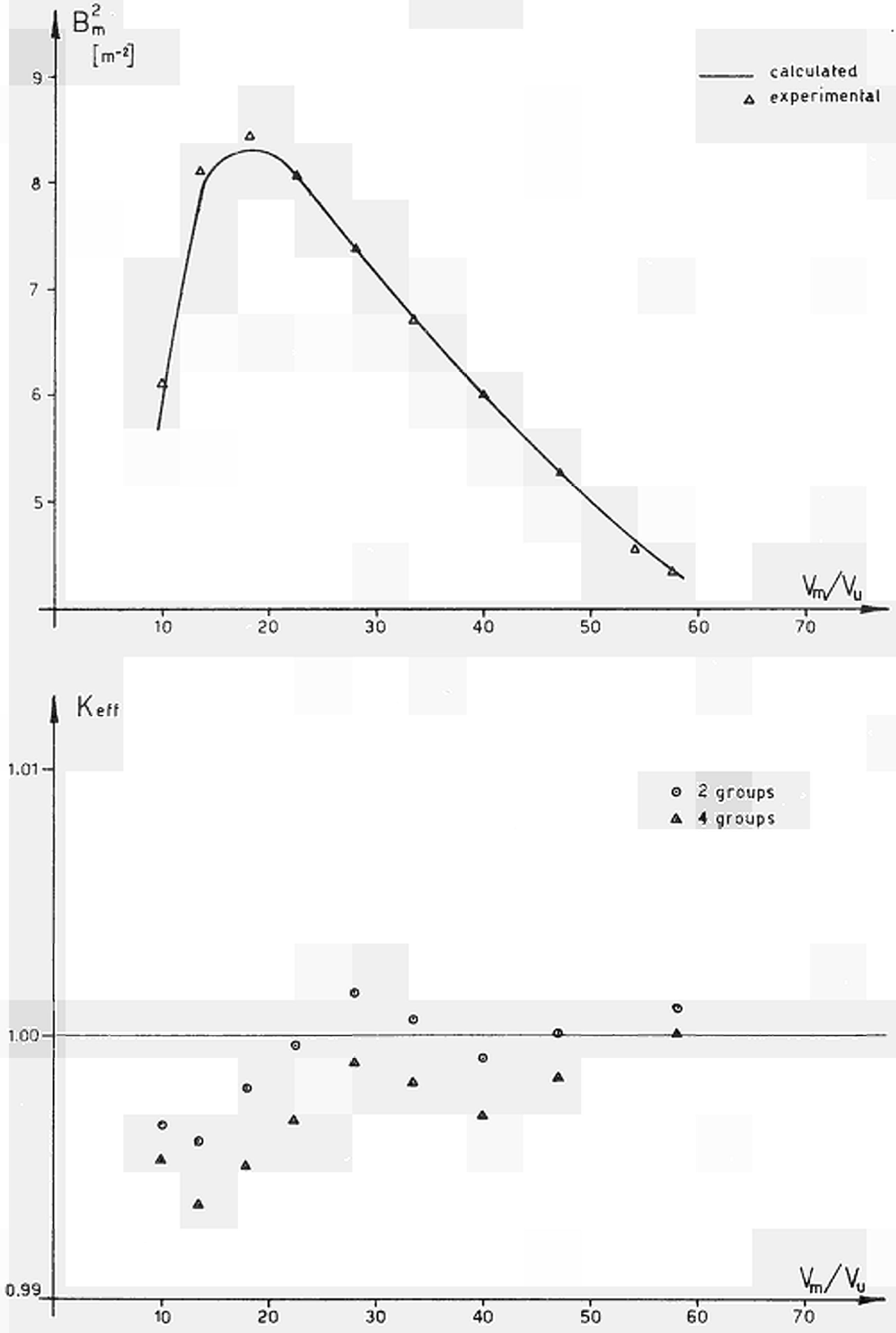



Fig. 4 - French metal single rod AQ-44 (Table VI).

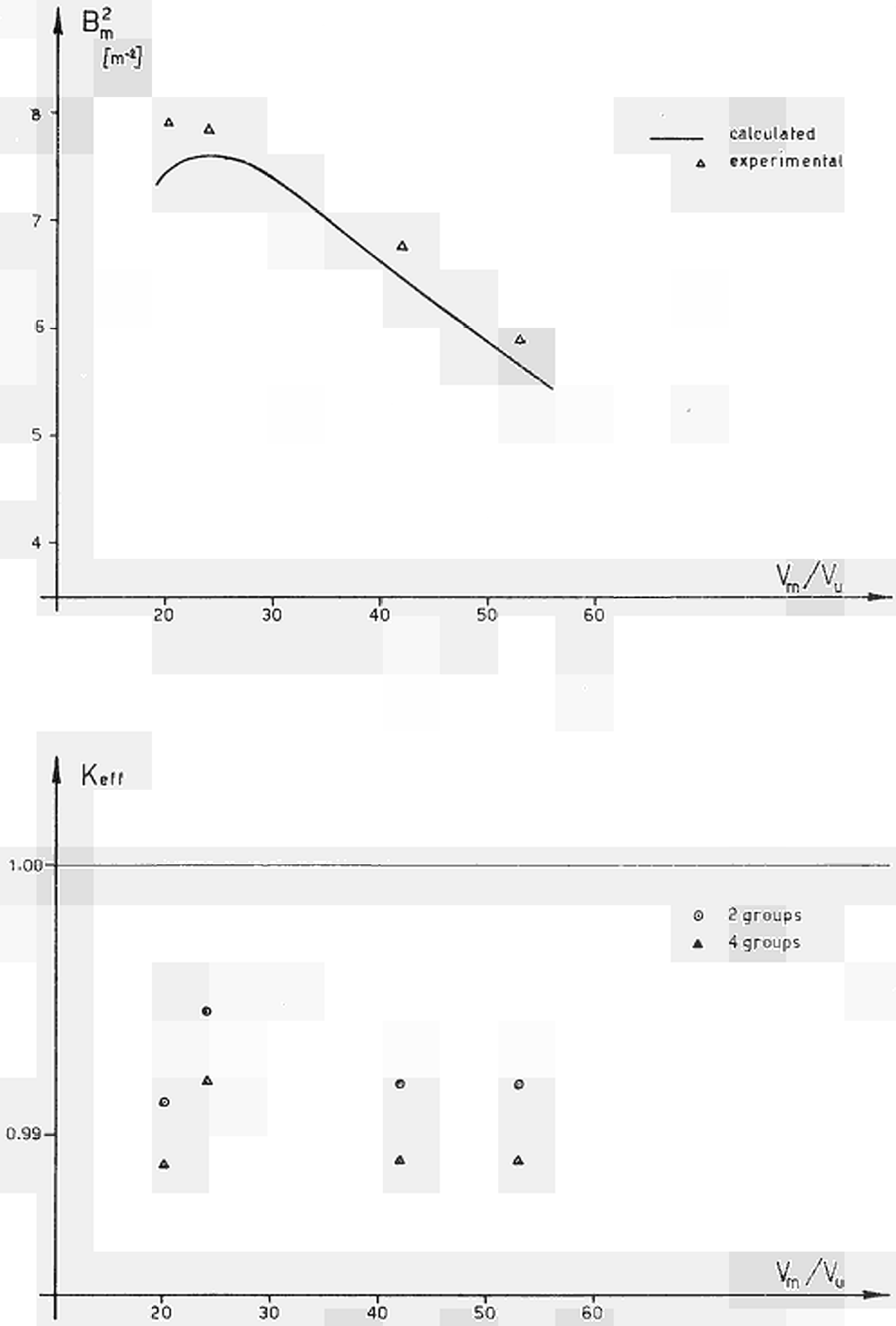



Fig. 5 - French non-natural U metal single rod AQ-292-A (Table VII).

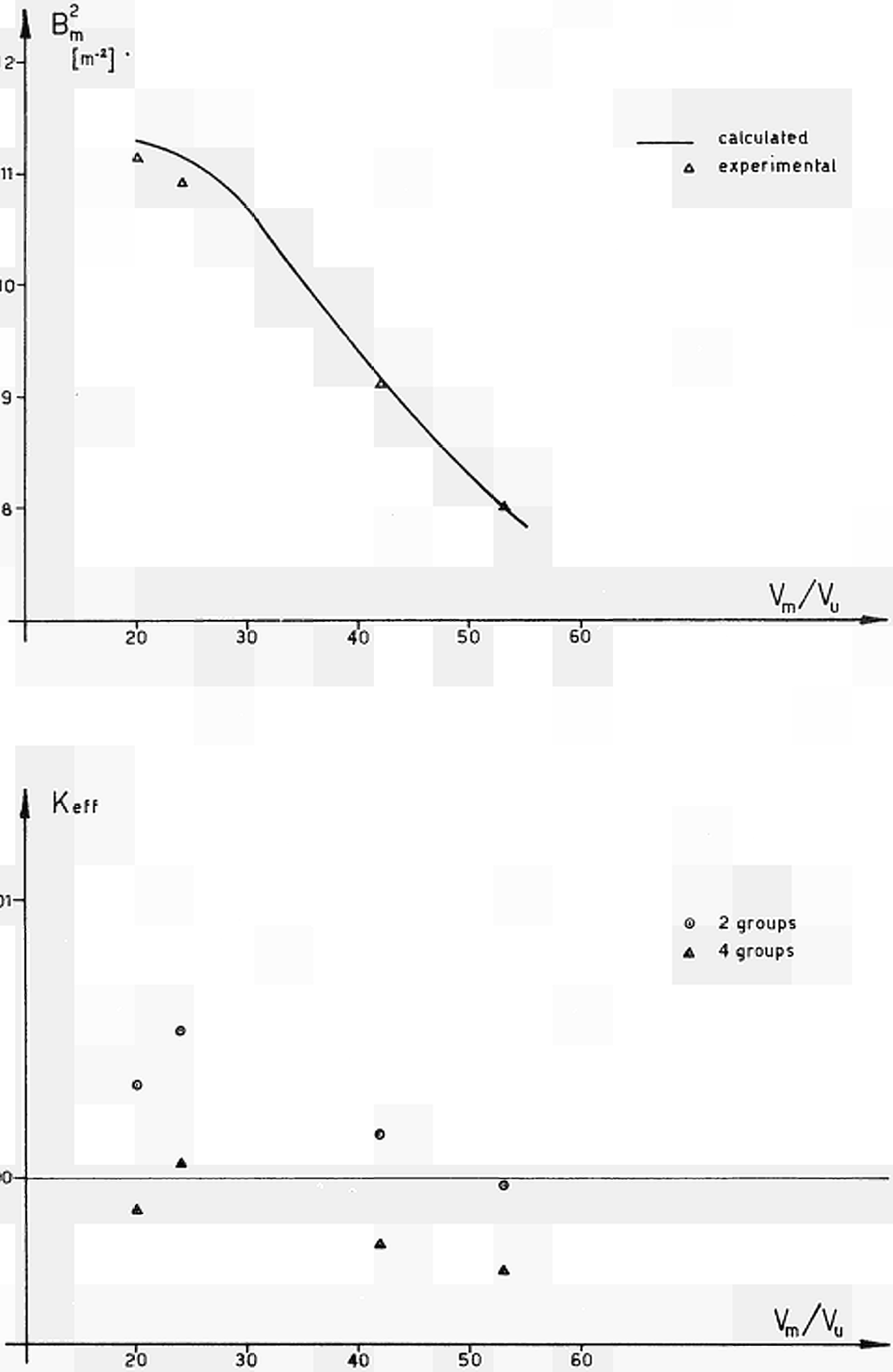



Fig. 6 - French non-natural U metal single rod AQ-292-B (Table VII).

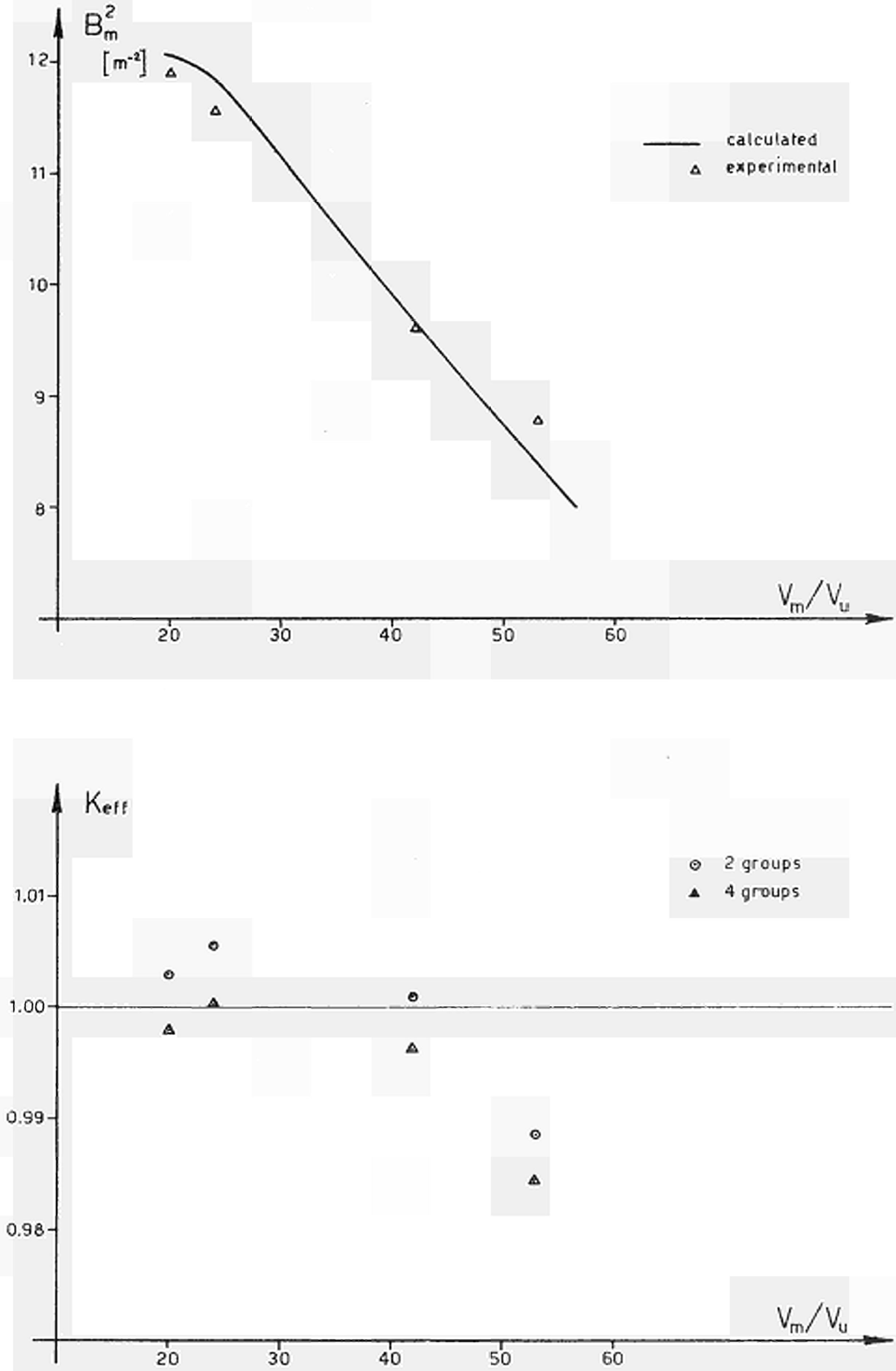
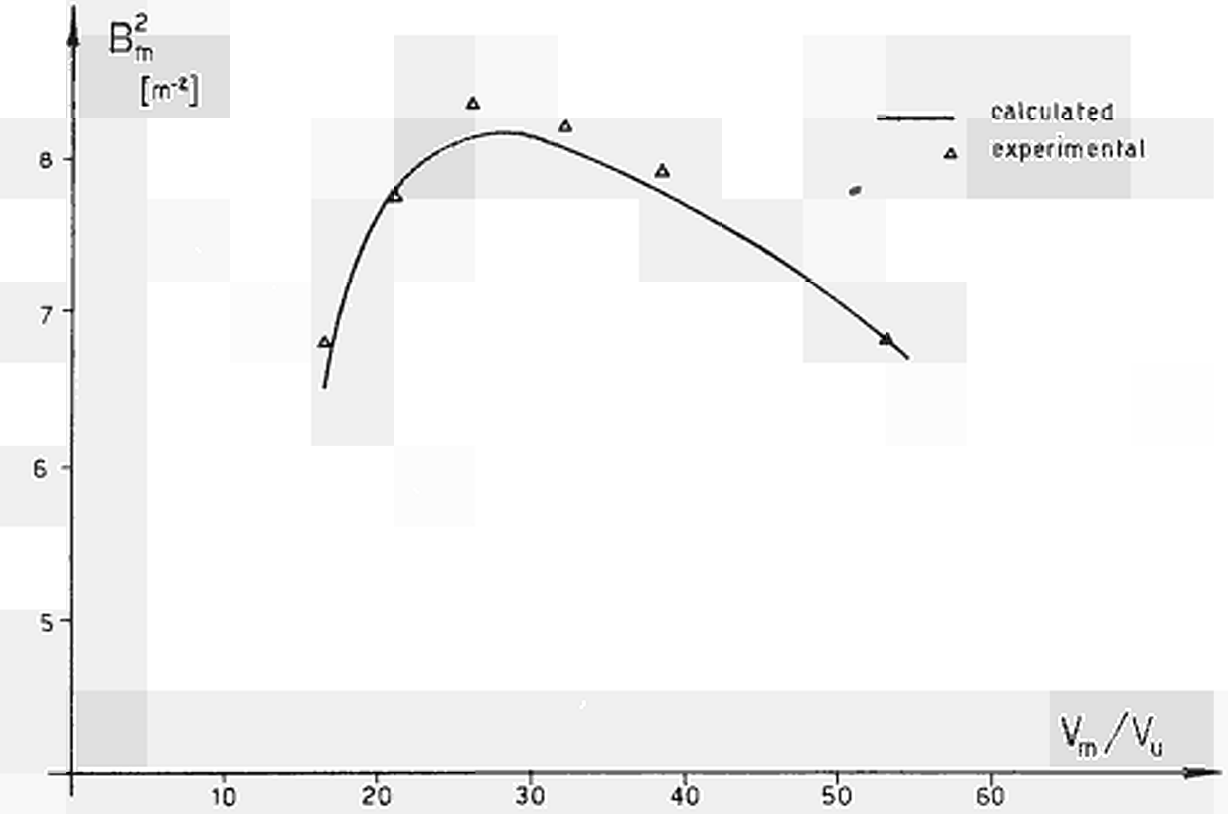



Fig. 7 - French non-natural U metal single rod AQ-292-C (Table VII).



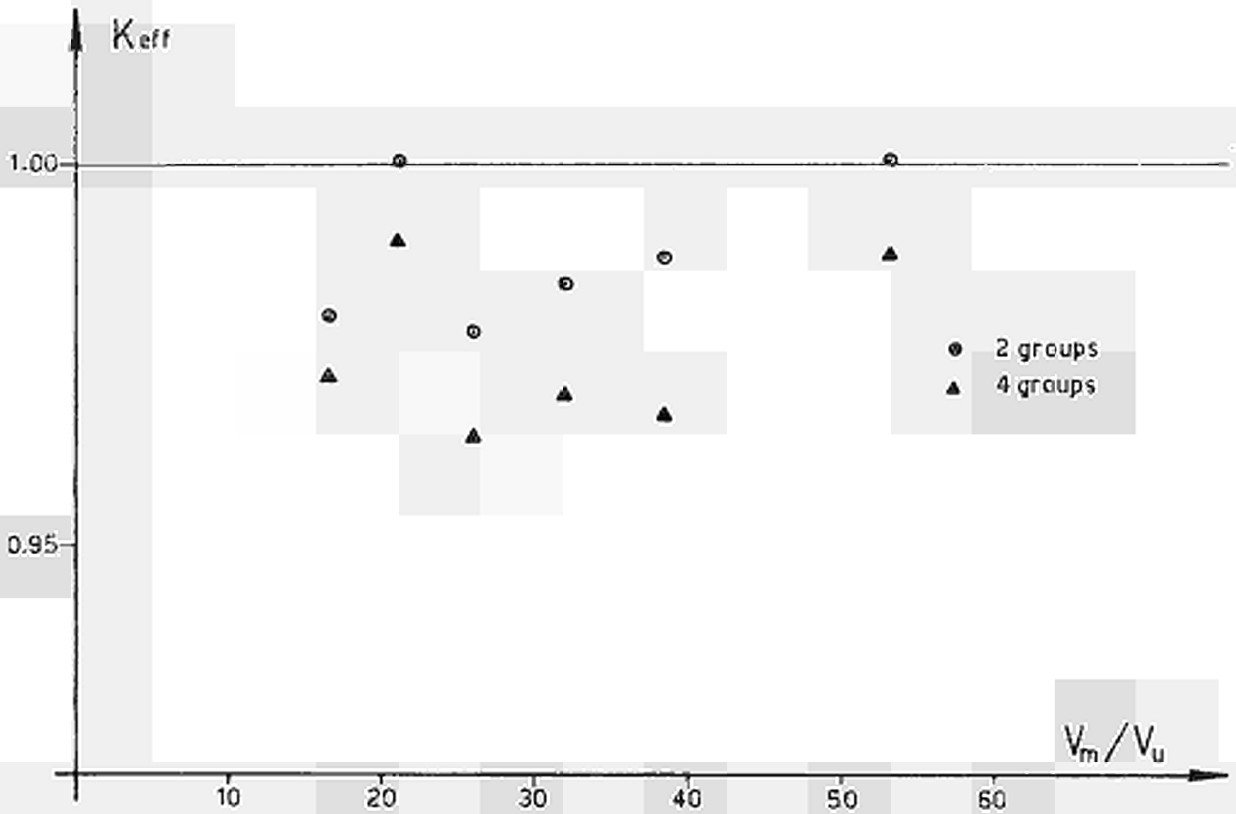
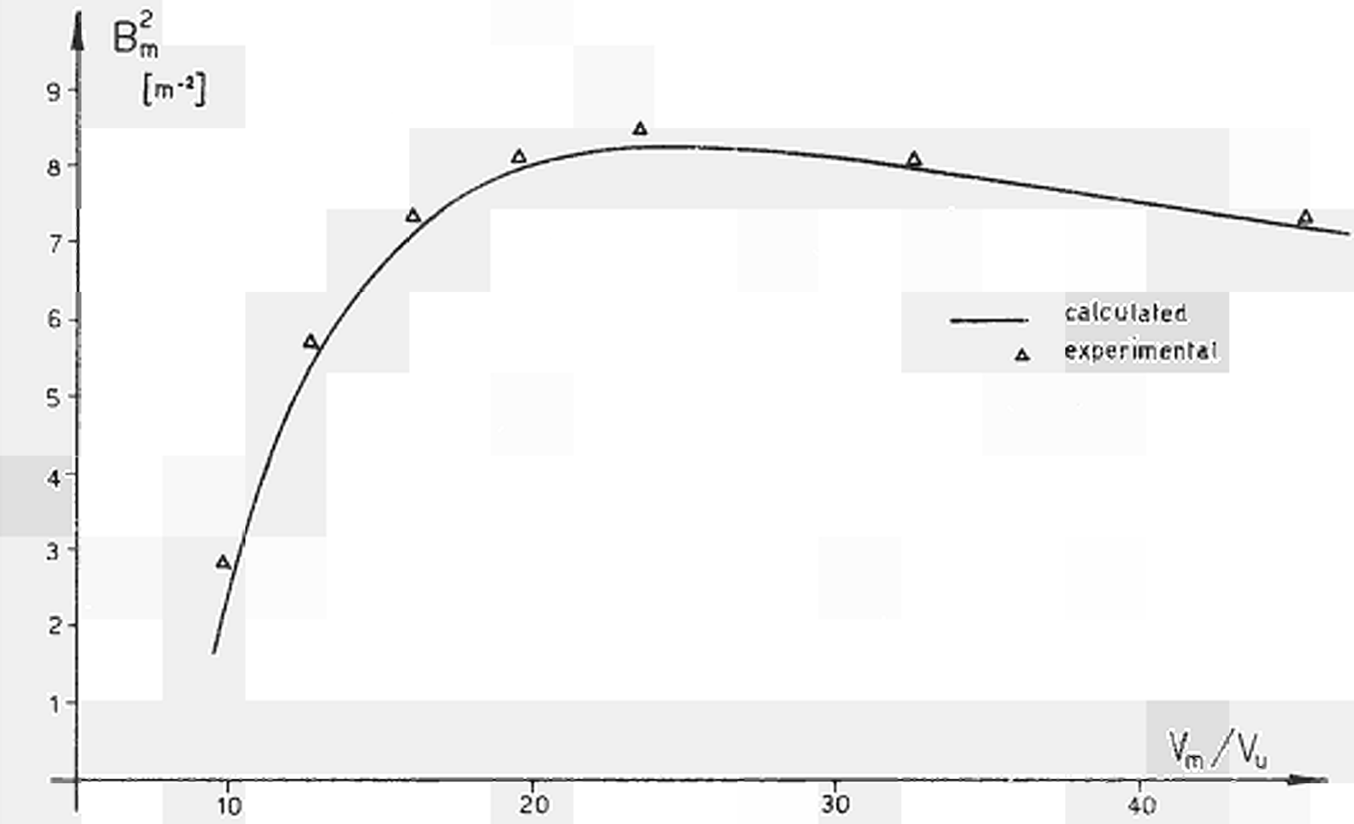




Fig. 8 - Swedish metal single rod SW-20 (Table IX).



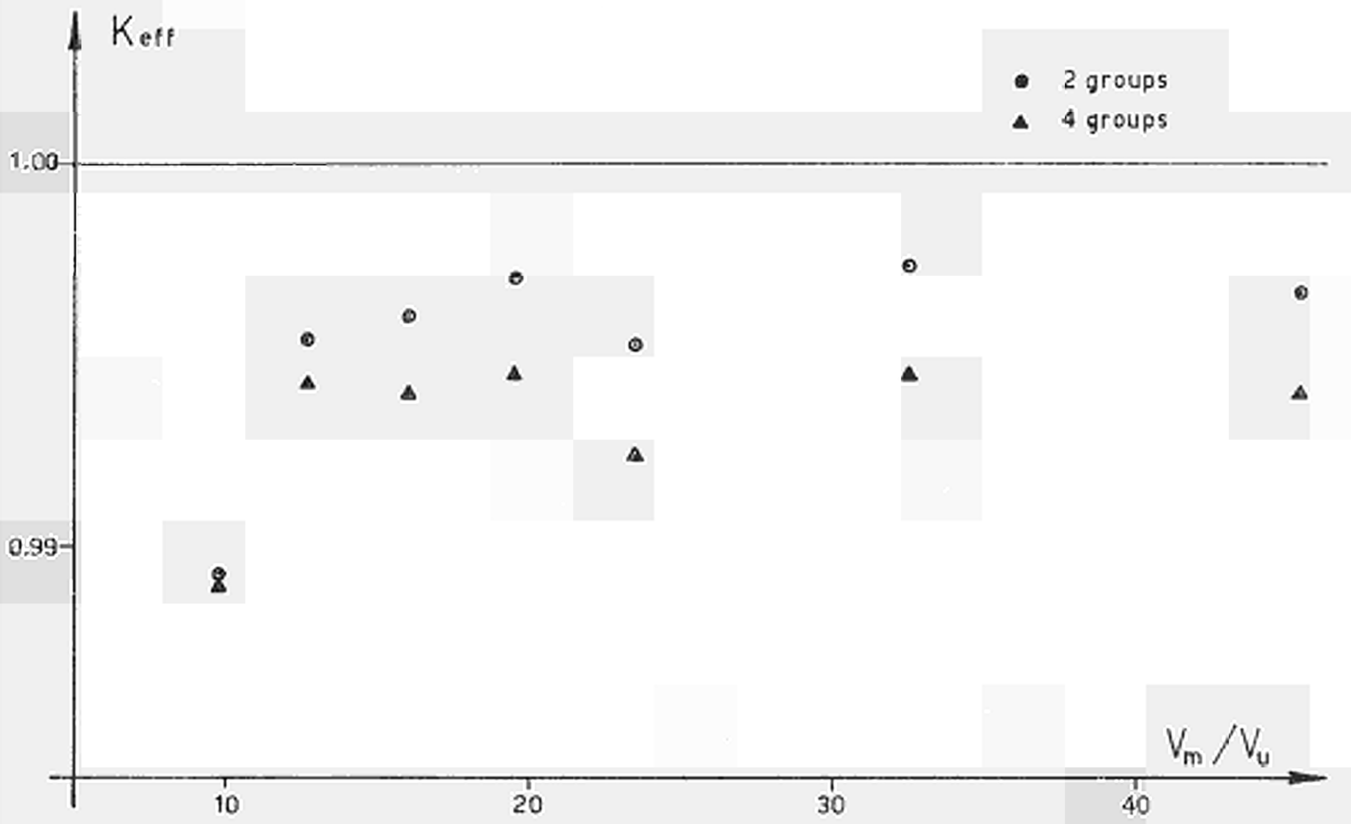




Fig. 9 - Swedish metal single rod SW-25 (Table X).

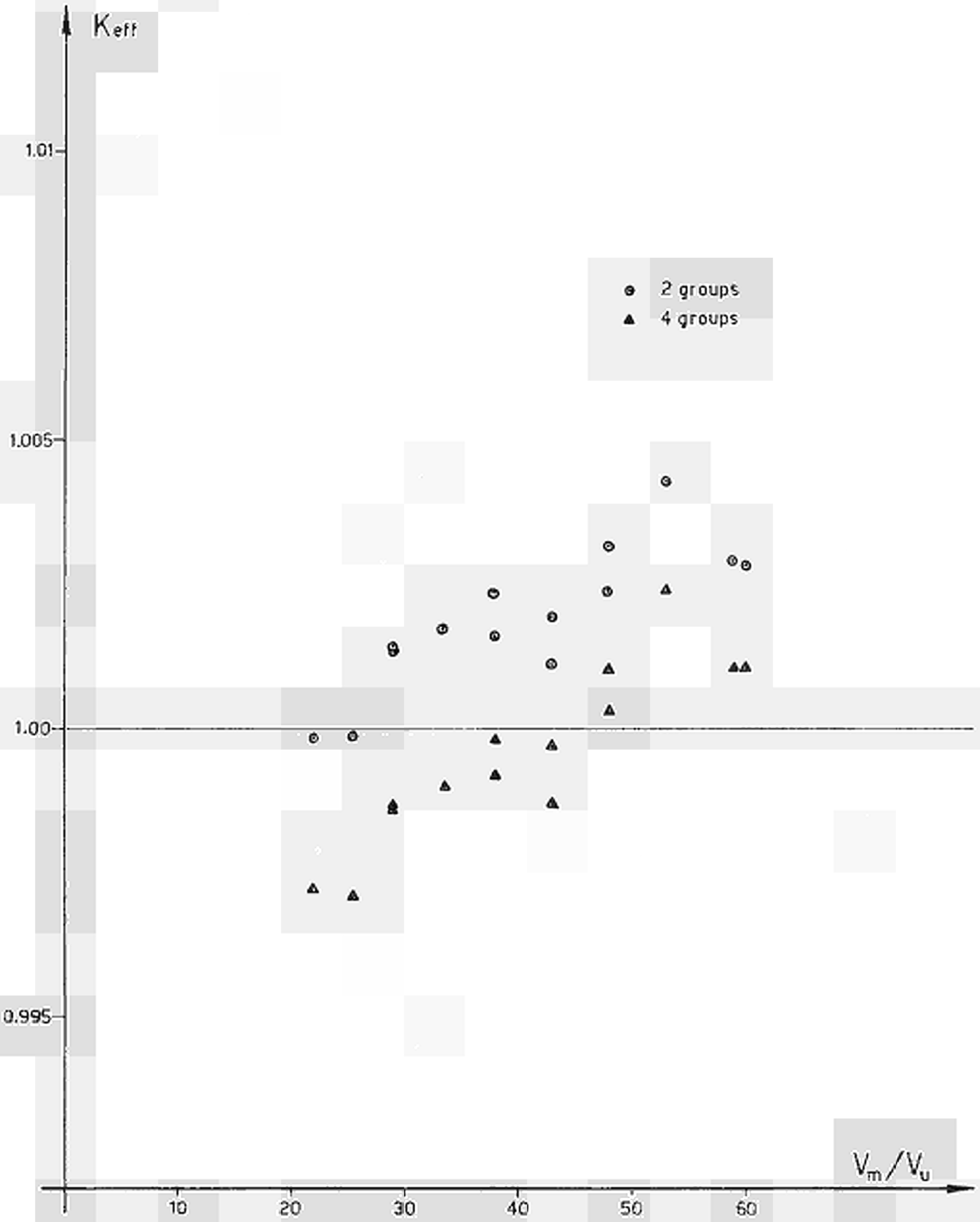



Fig. 10 - Swedish metal single rod SW-305-TER (Table XI).

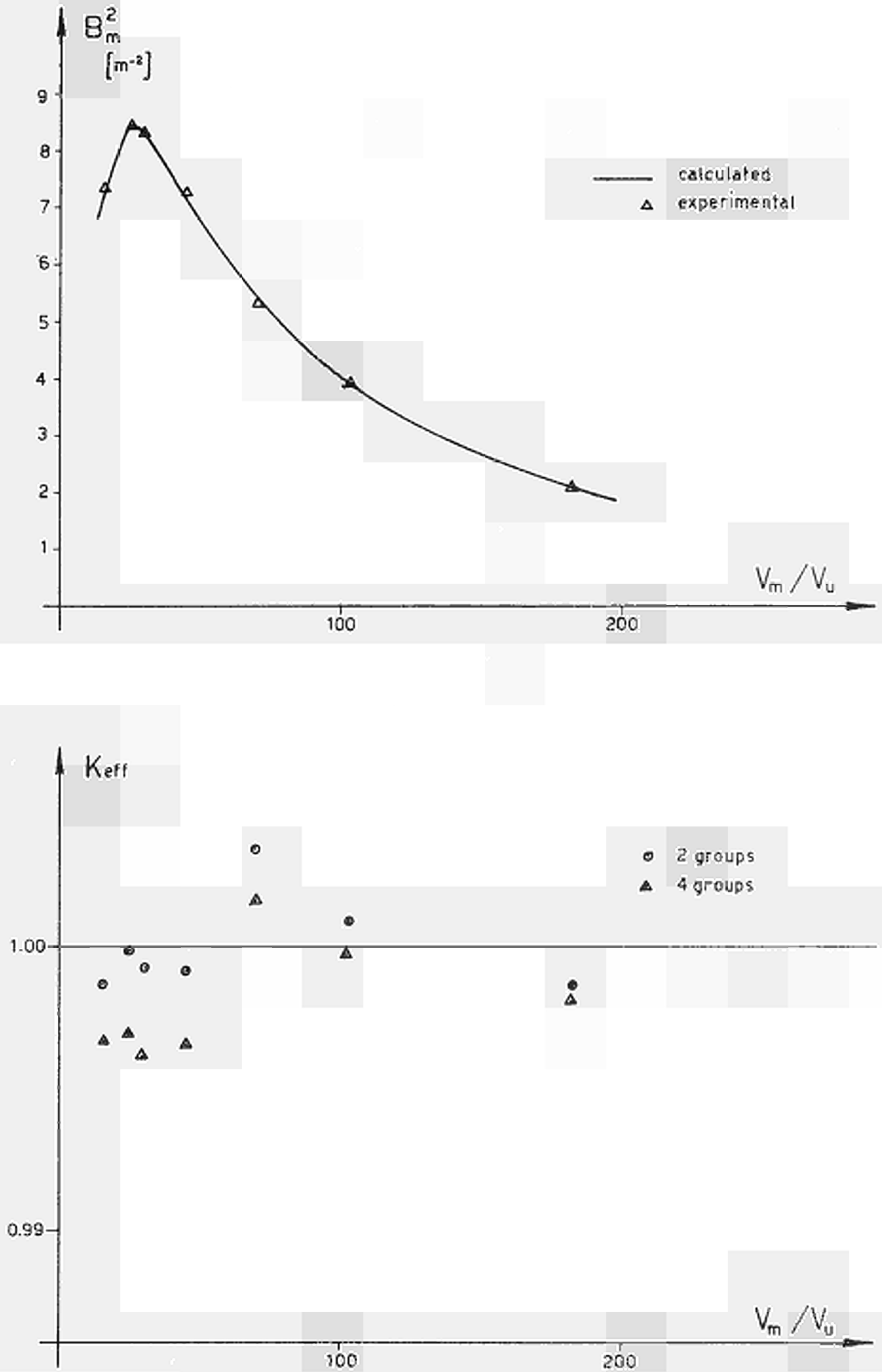
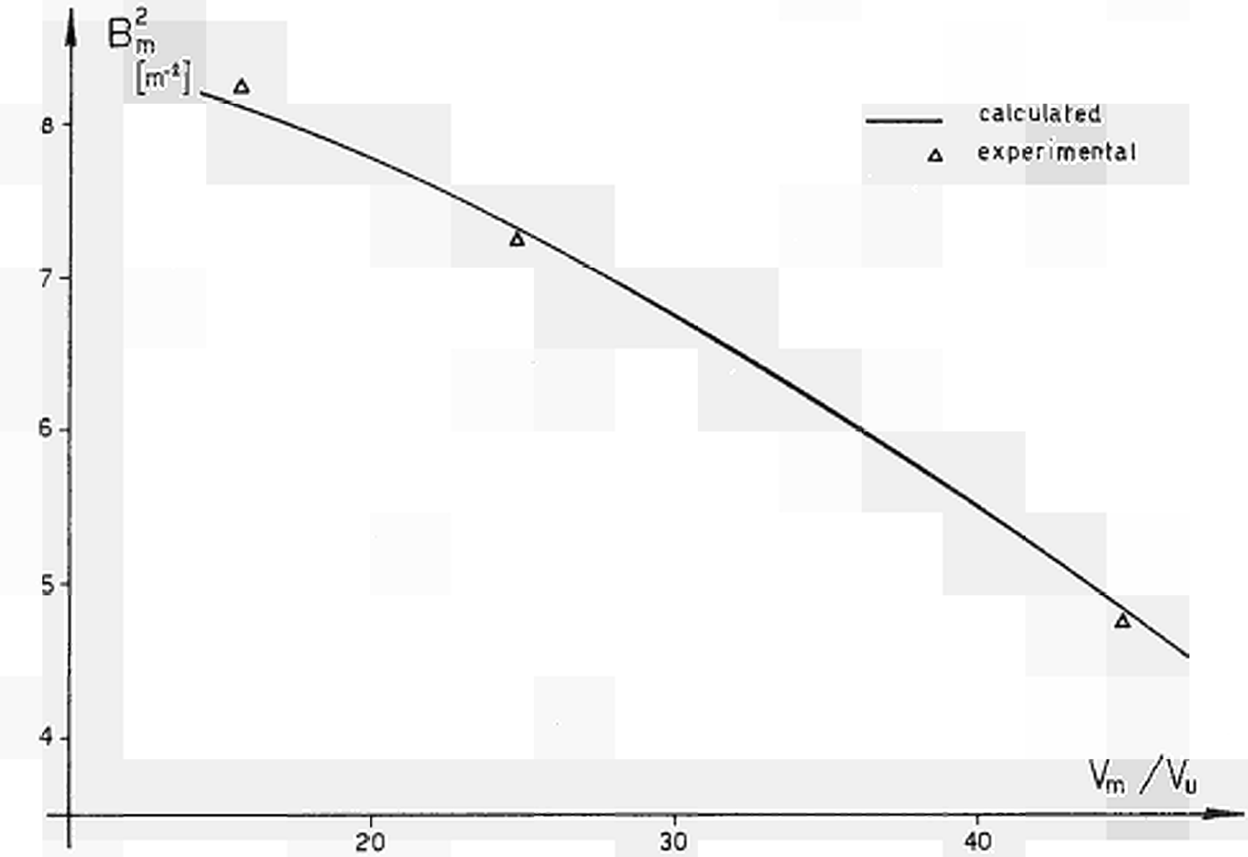



Fig. 11 - American metal single rod NAA-100 (Table XII).



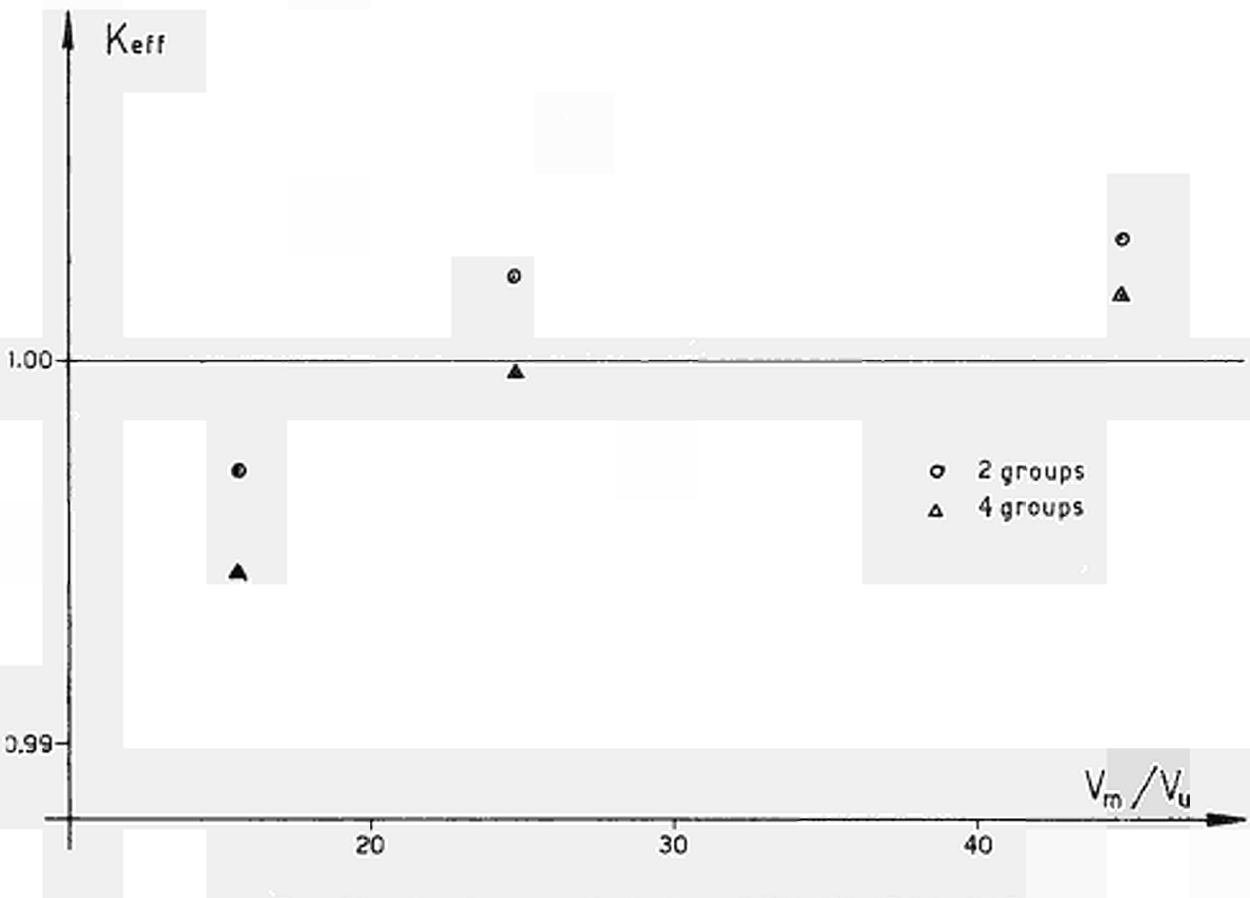




Fig. 12 - American metal single rod NAA-200 (Table XIII).

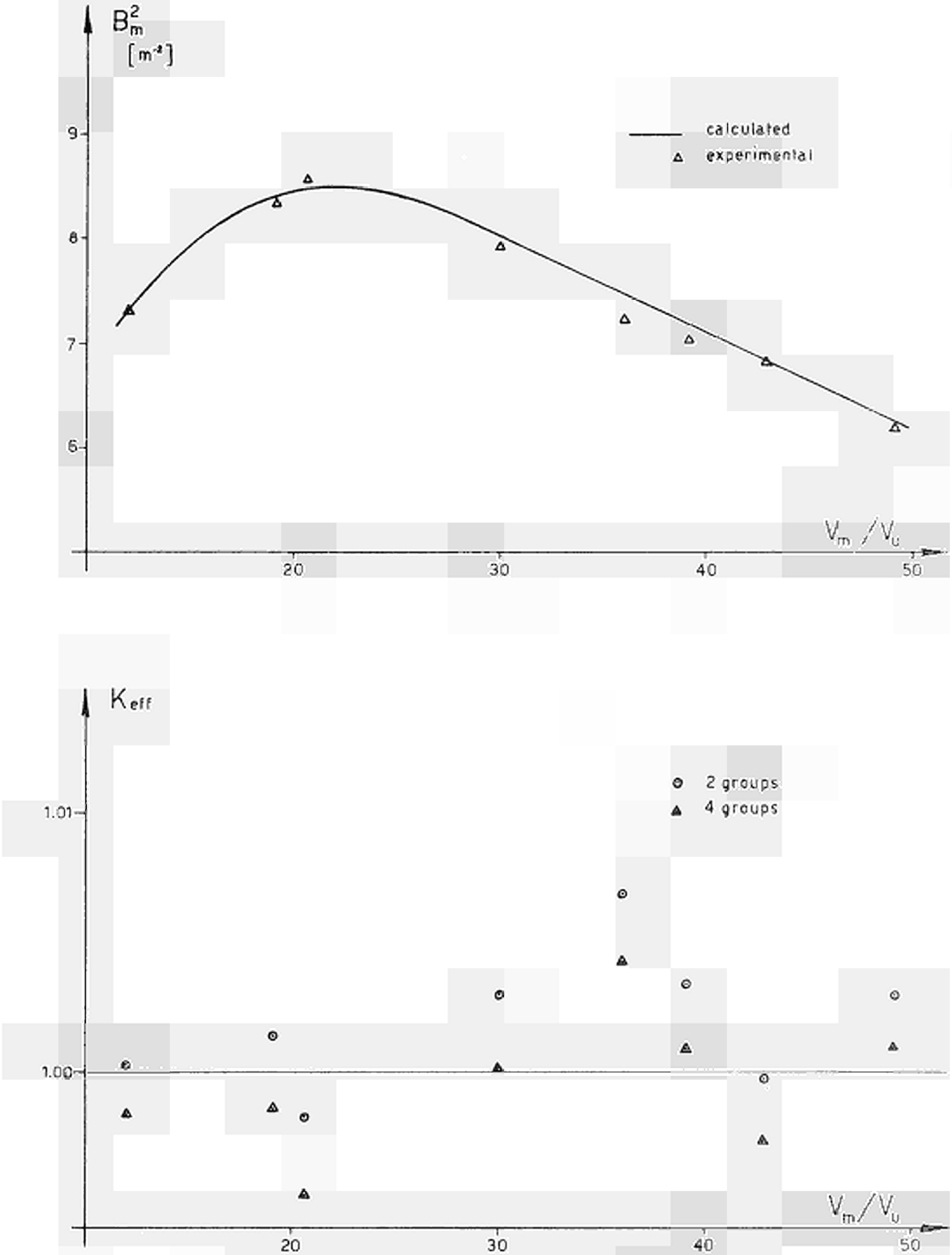



Fig. 13 - Canadian metal single rod ZEEP (Table XIV).

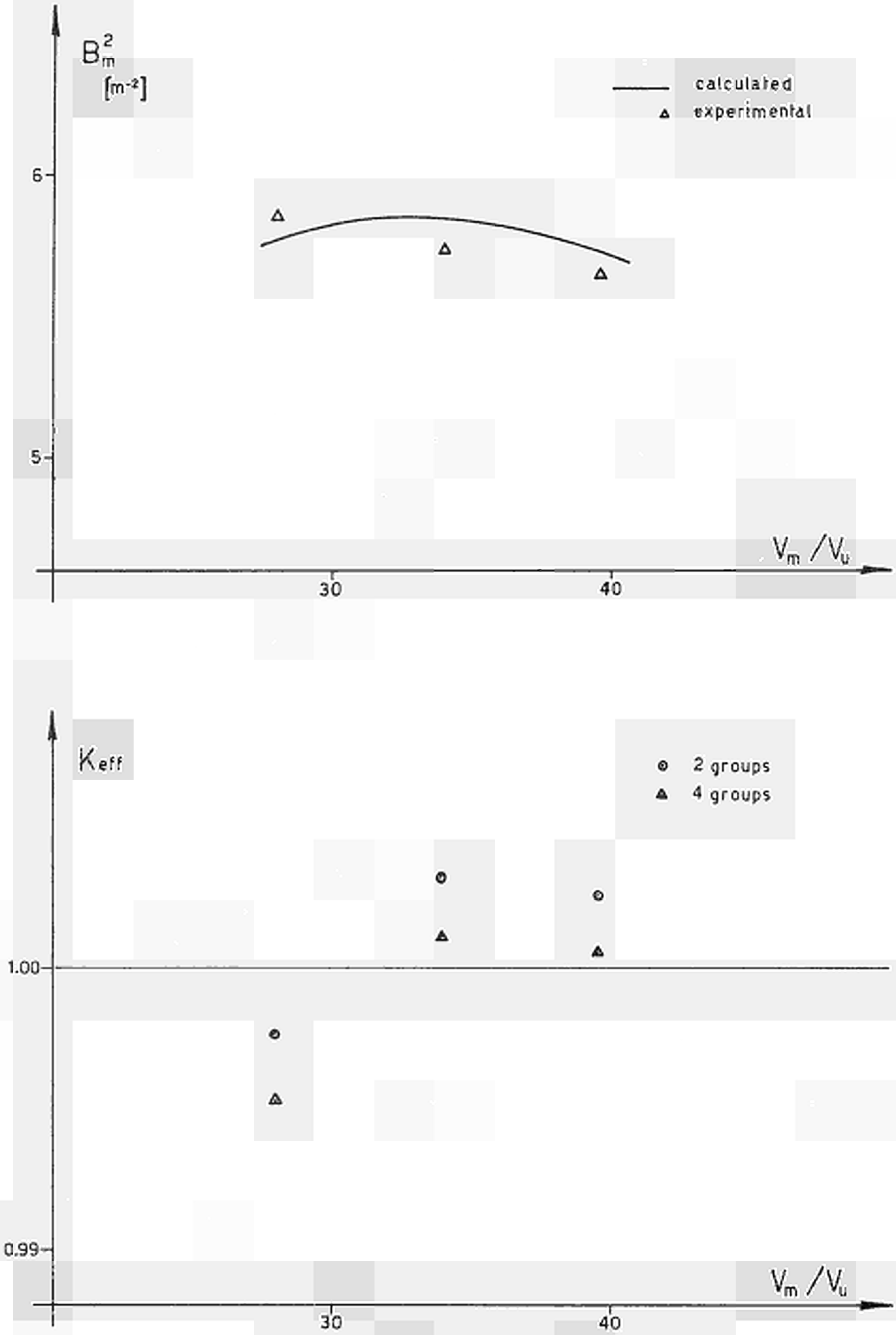



Fig. 14 - Canadian metal tube HIPPO (Table XV).

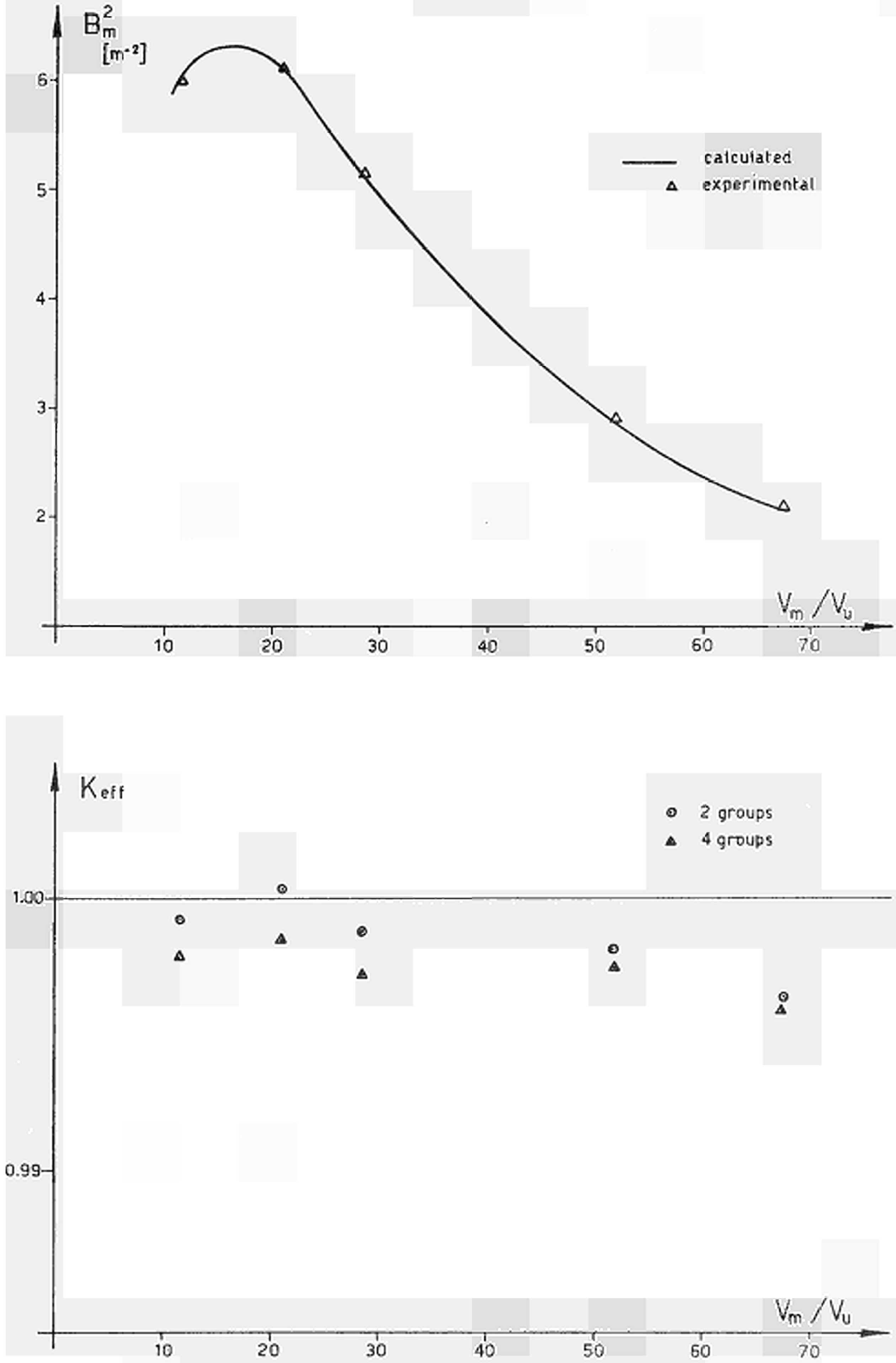
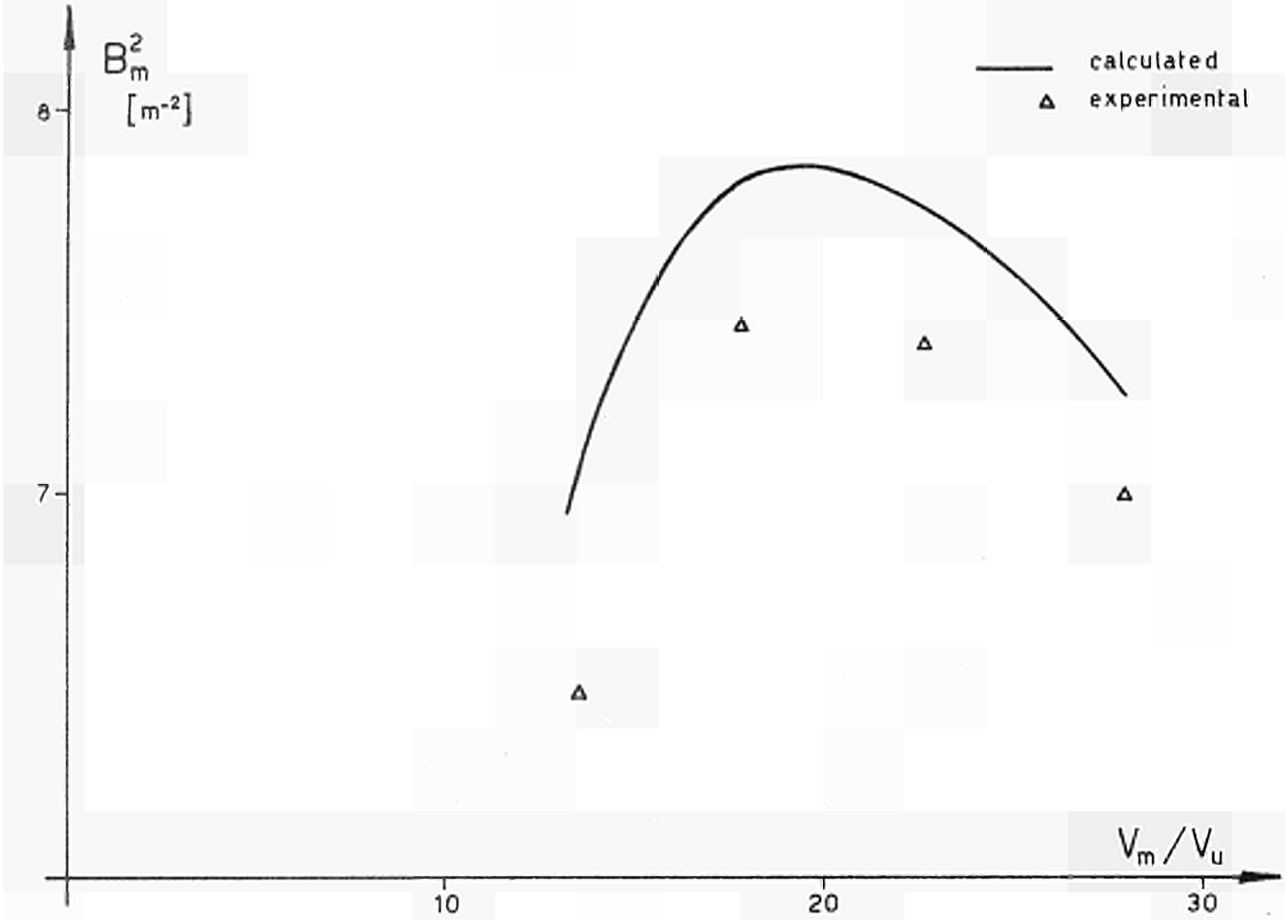



Fig 15 - American metal cluster HURLEY-7 (Table XVI).



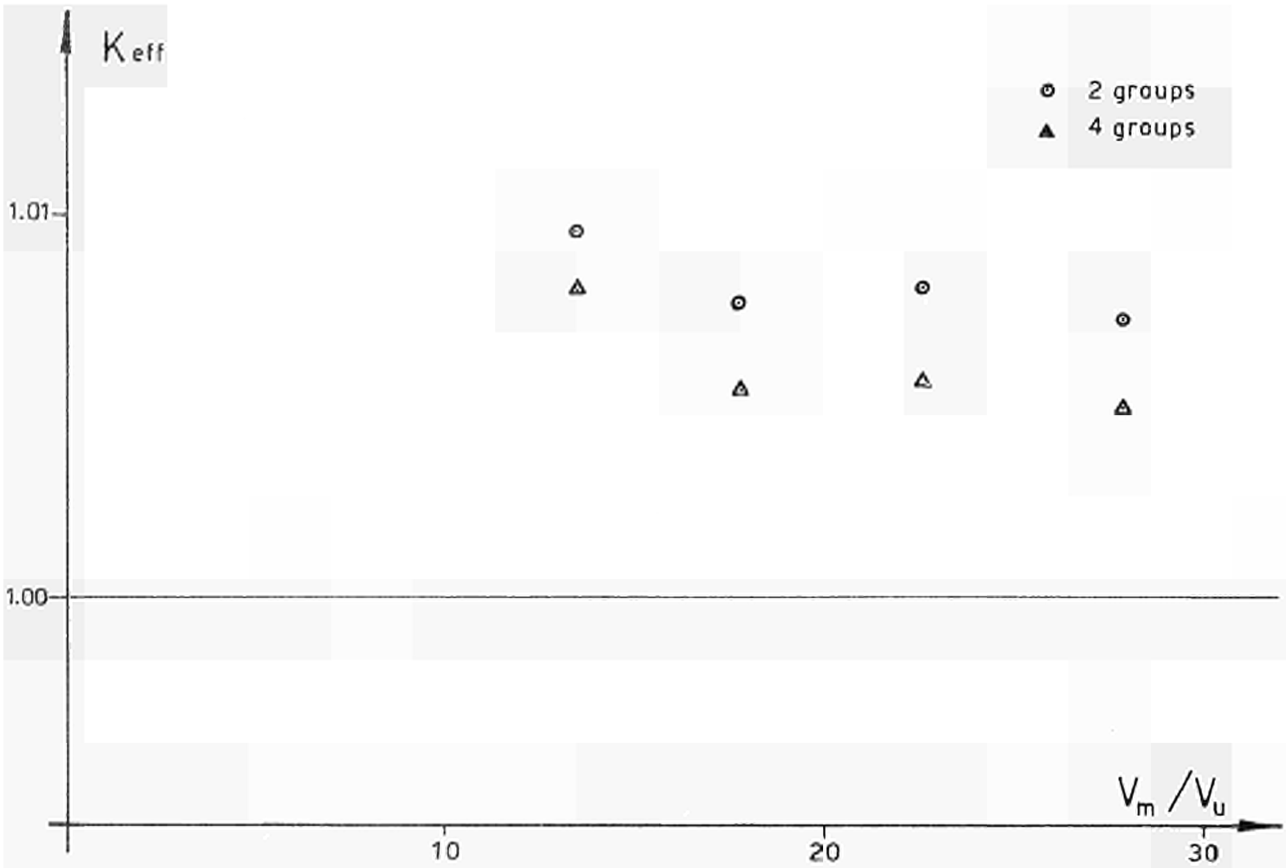




Fig 16 - French metal cluster AQ-7-GO (Table XVII).

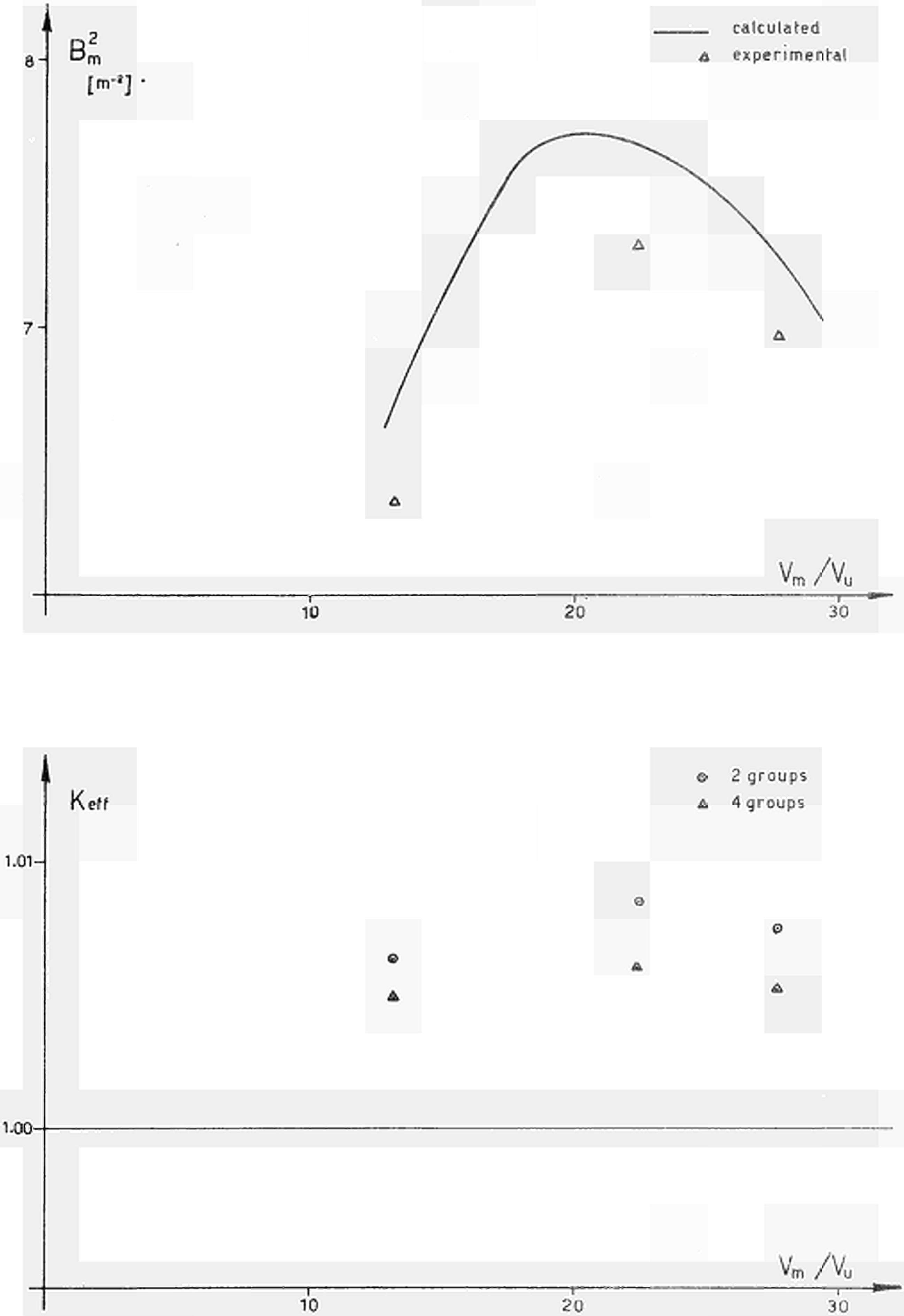
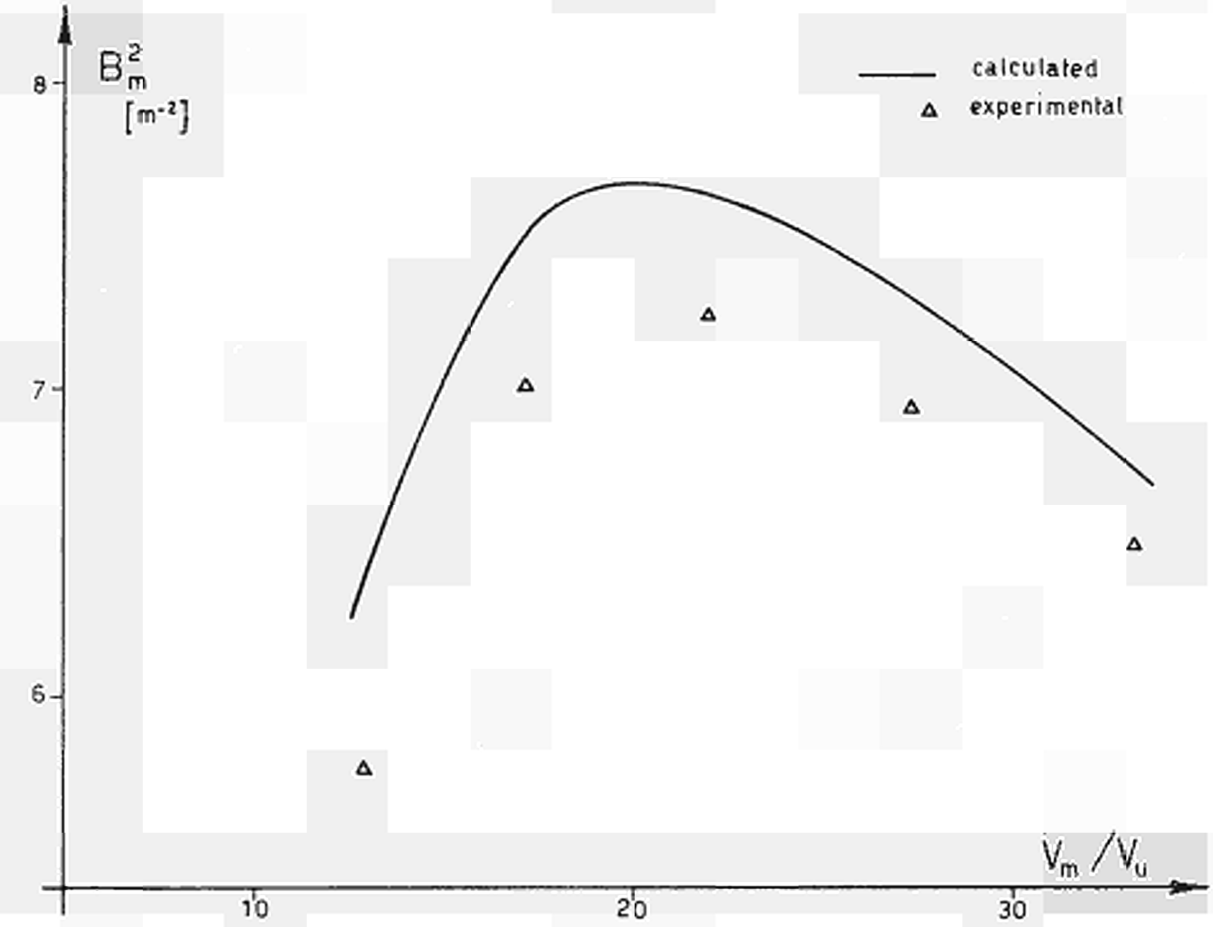



Fig. 17 - French metal cluster AQ-7-G2 (Table XVIII).



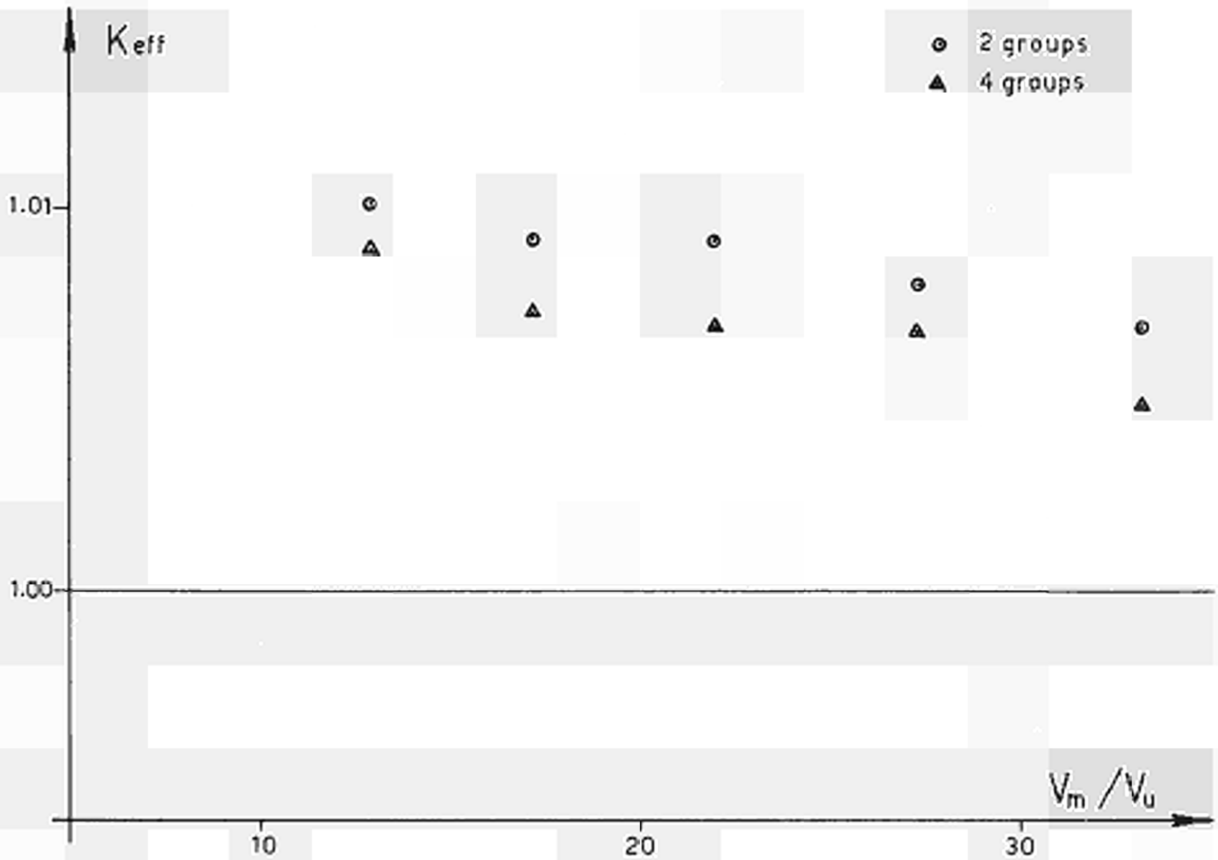




Fig. 18 - French metal cluster AQ-7-G5 (Table XVII).

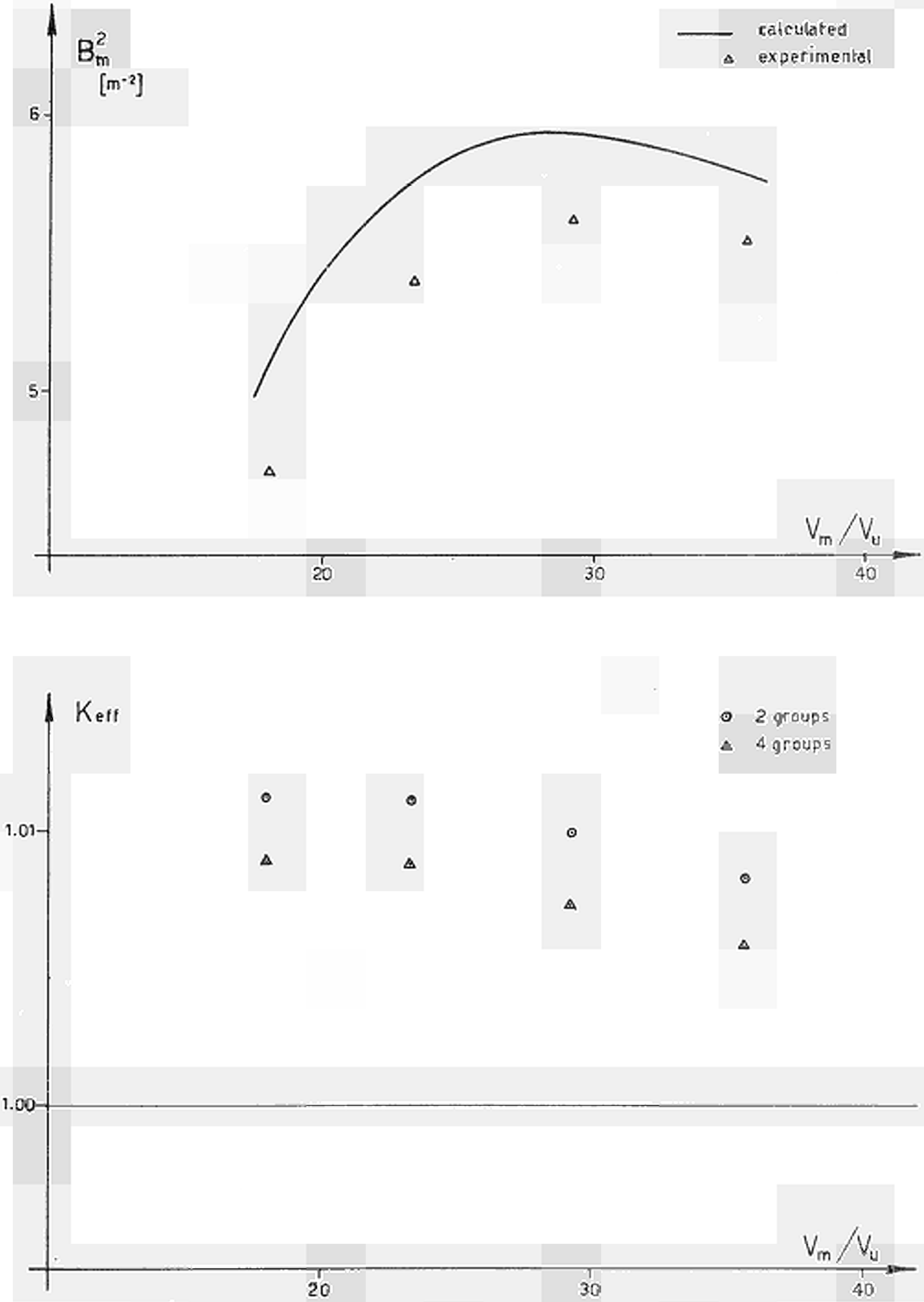



Fig. 19 - French metal cluster AQ-19-TP-106 (Table XVIII).

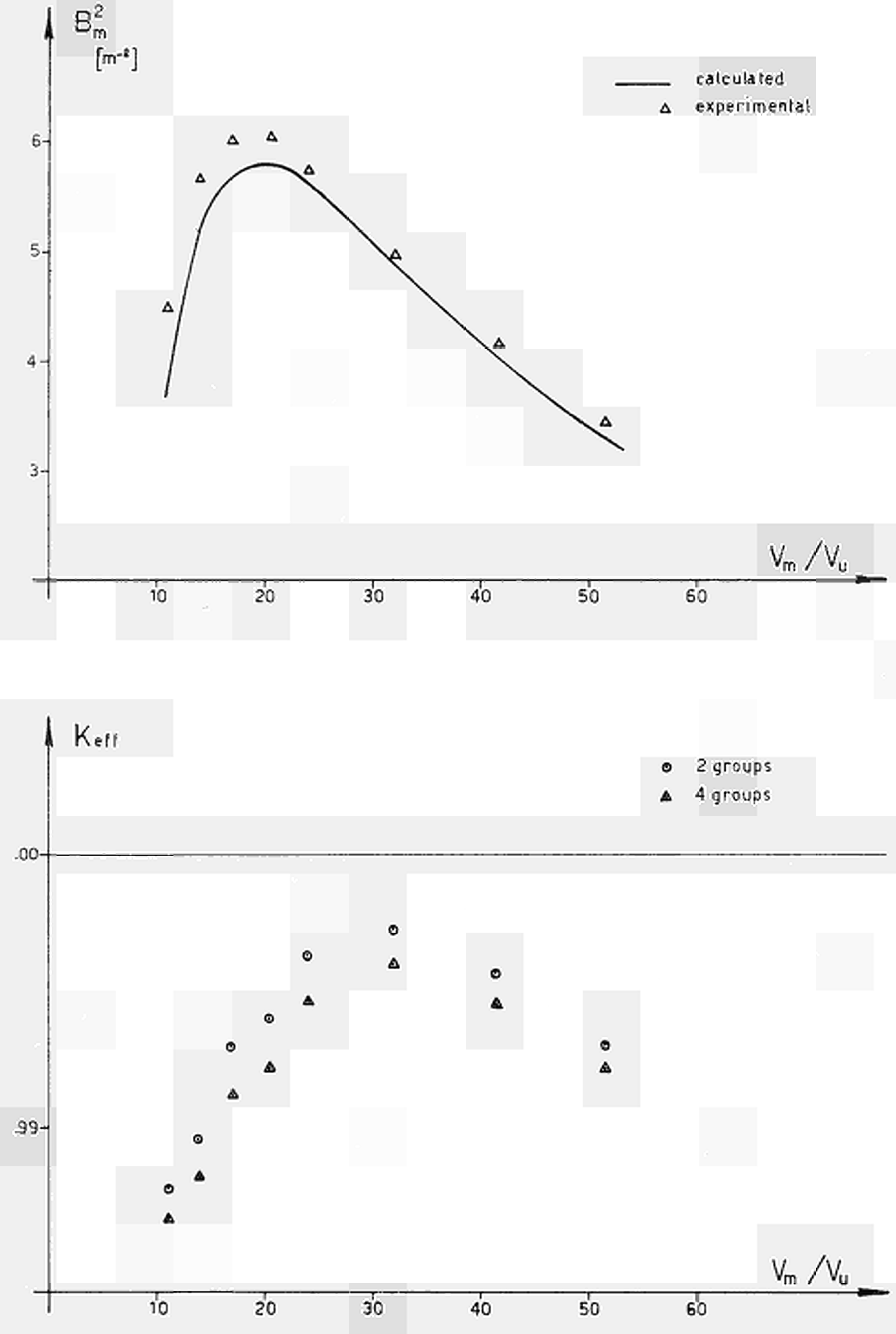
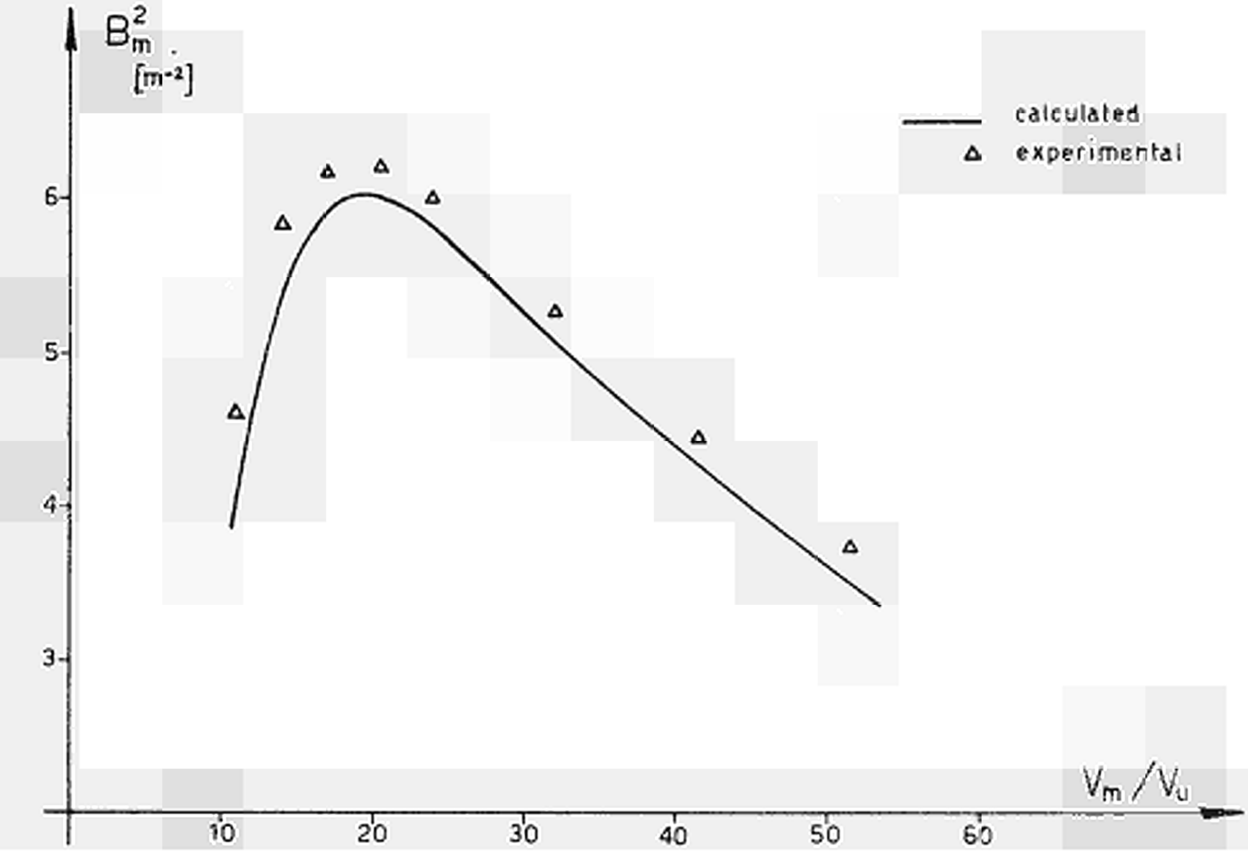



Fig. 20 - Canadian metal cluster CR-131-HWC (Table XX).



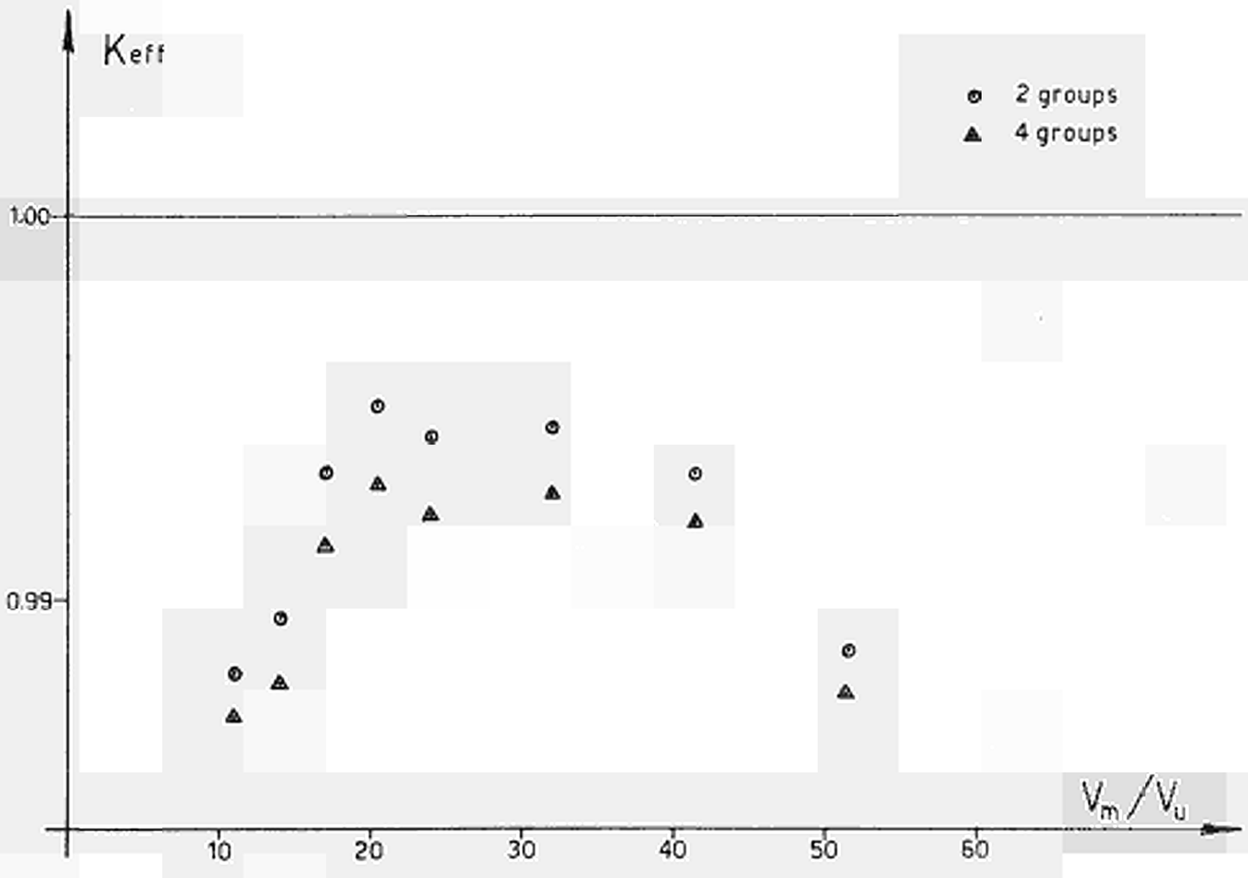
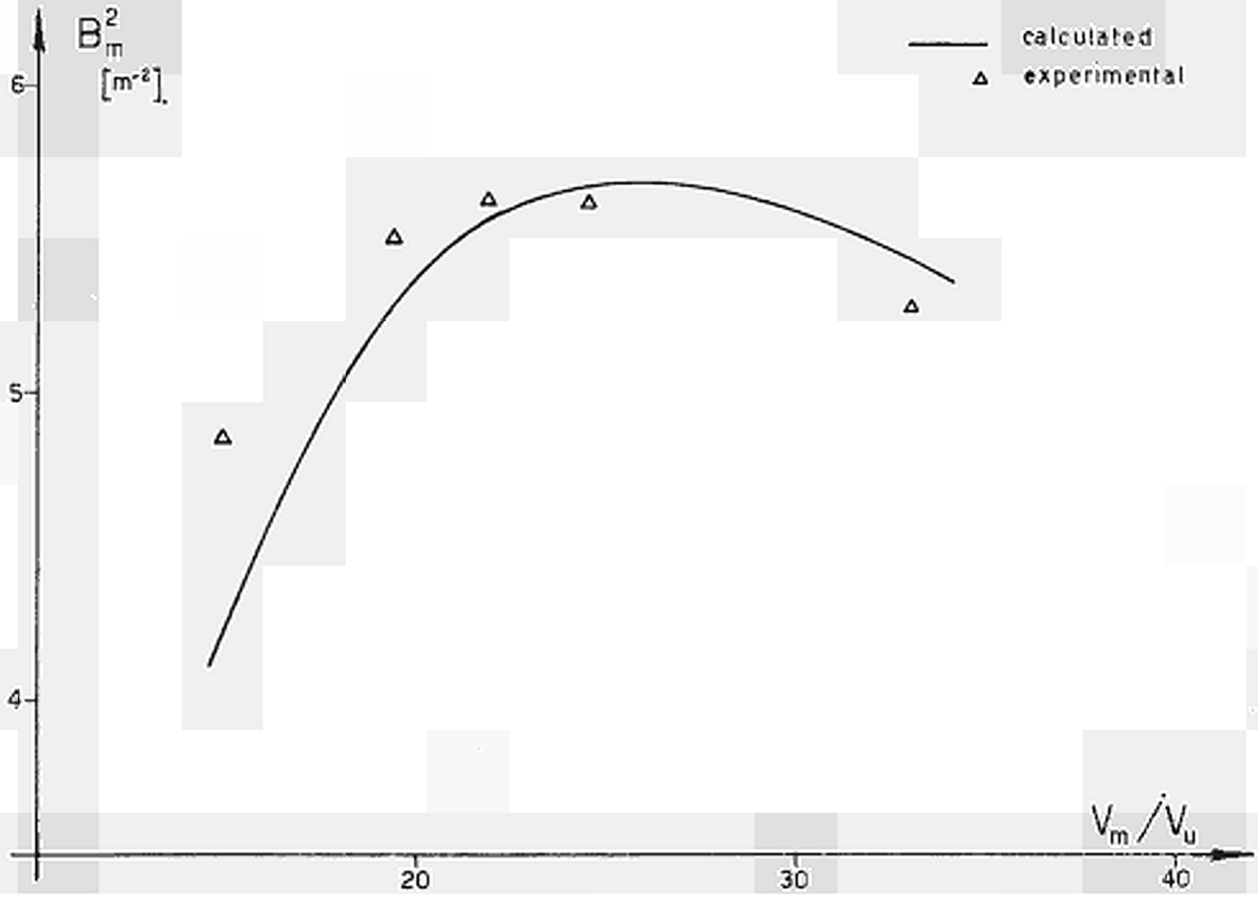




Fig. 21 - Canadian metal cluster CR-131-VT (Table XXI).



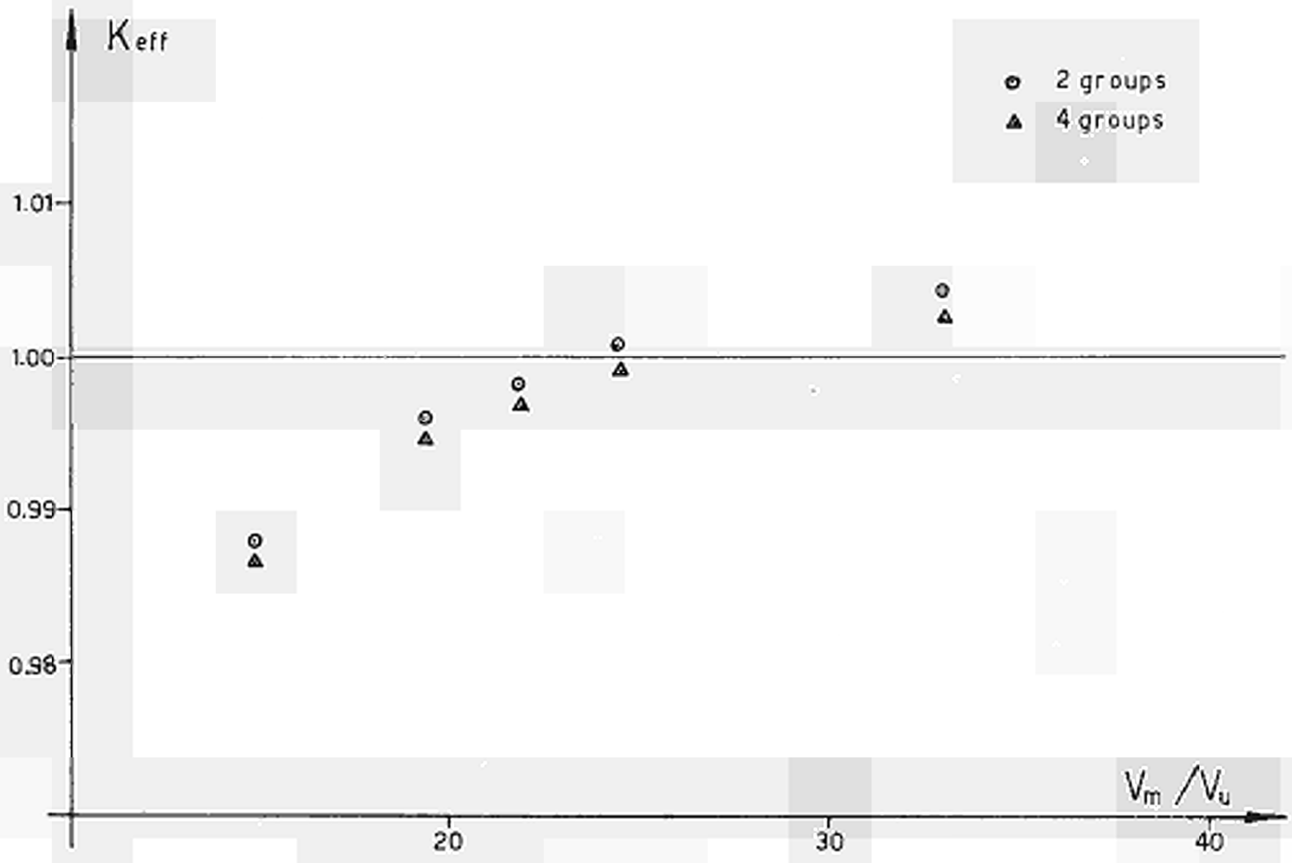
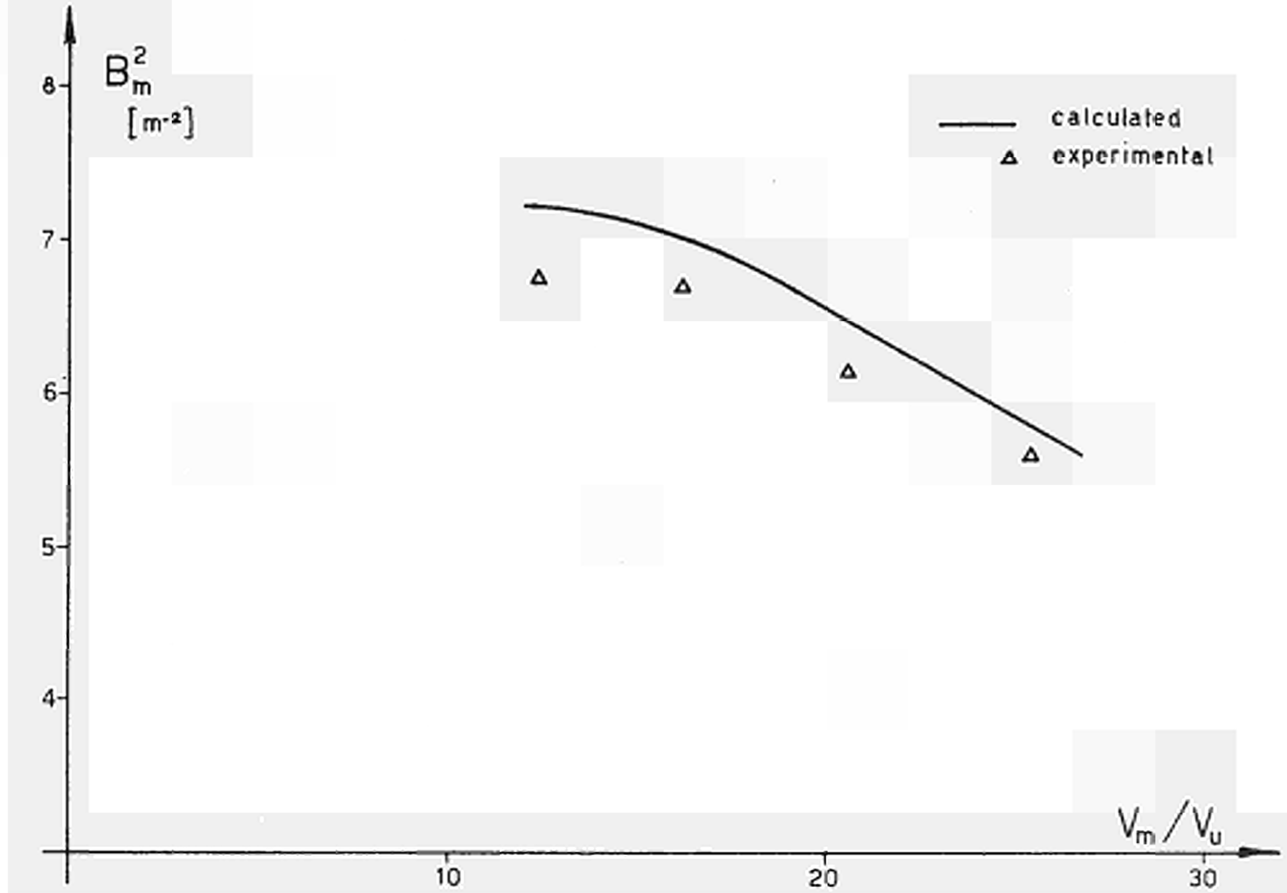




Fig. 22 - CISE metal cluster AC-PP-02 (Table XXII).



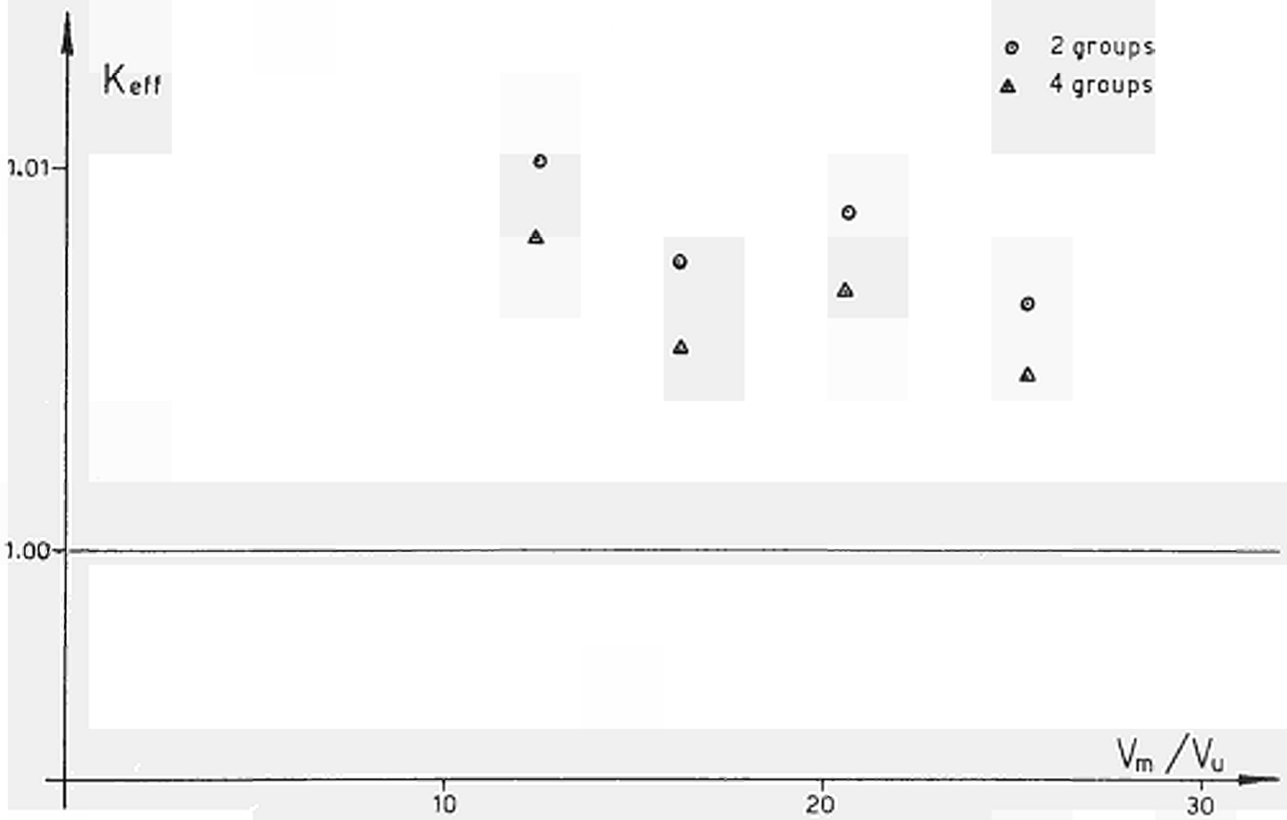




Fig 23 - French oxide single rod OX-AQ-46 (Table XXIII).

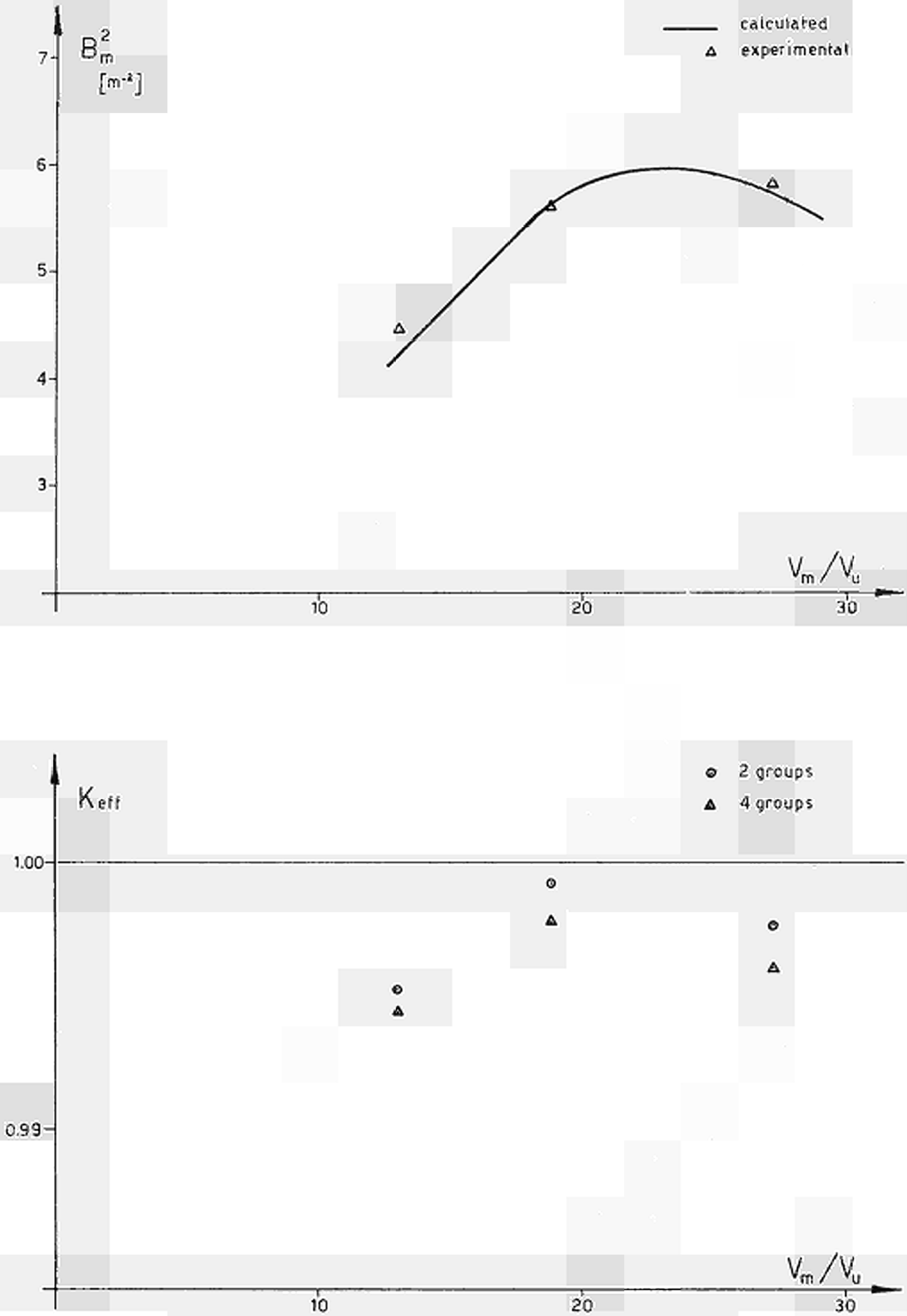



Fig. 24 - Swedish oxide single rod OX-SW-13.5 (Table XXIV).

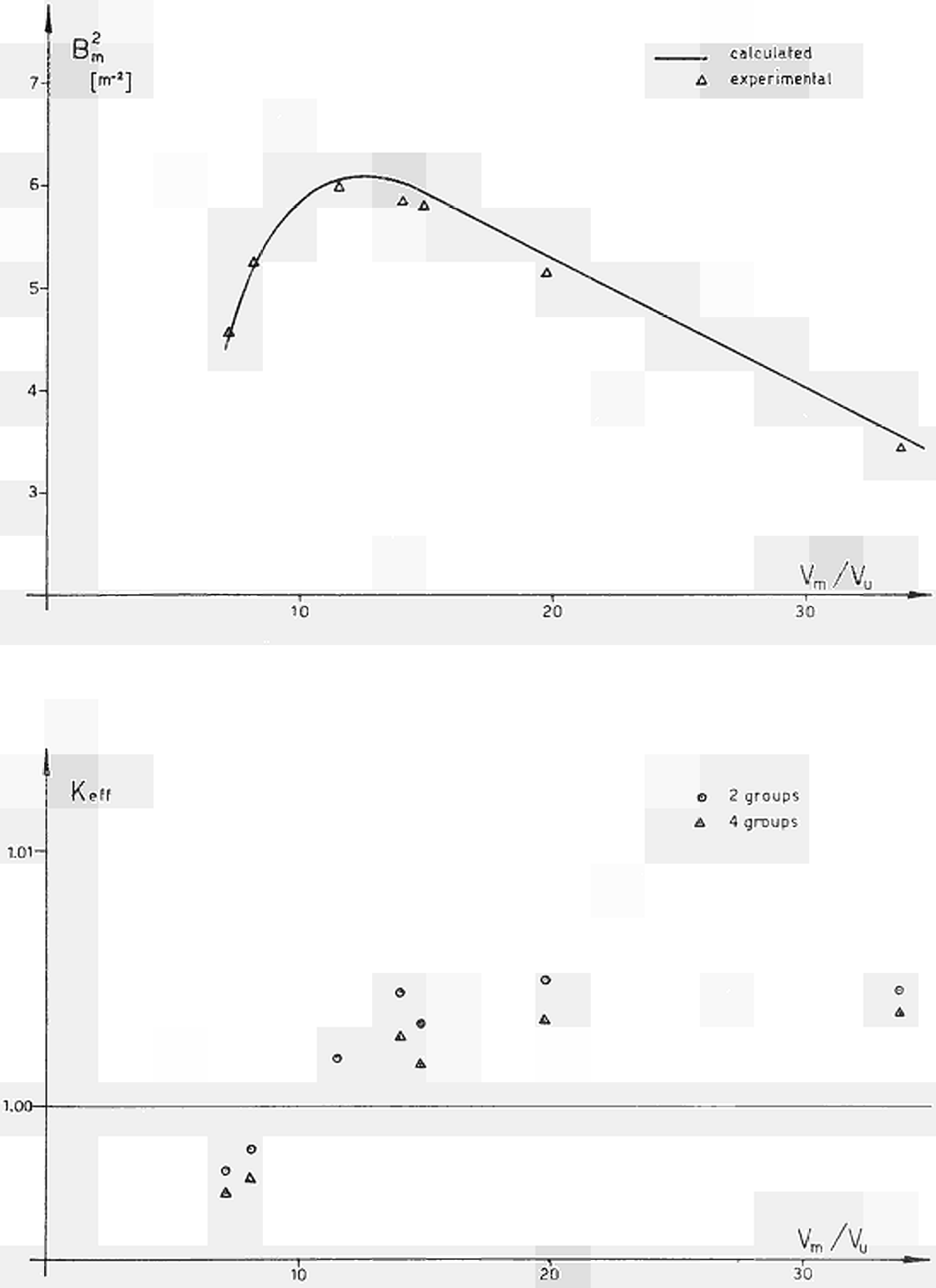



Fig. 25 - Canadian oxide 7-rod cluster Z2-7-HWC (Table XXV).

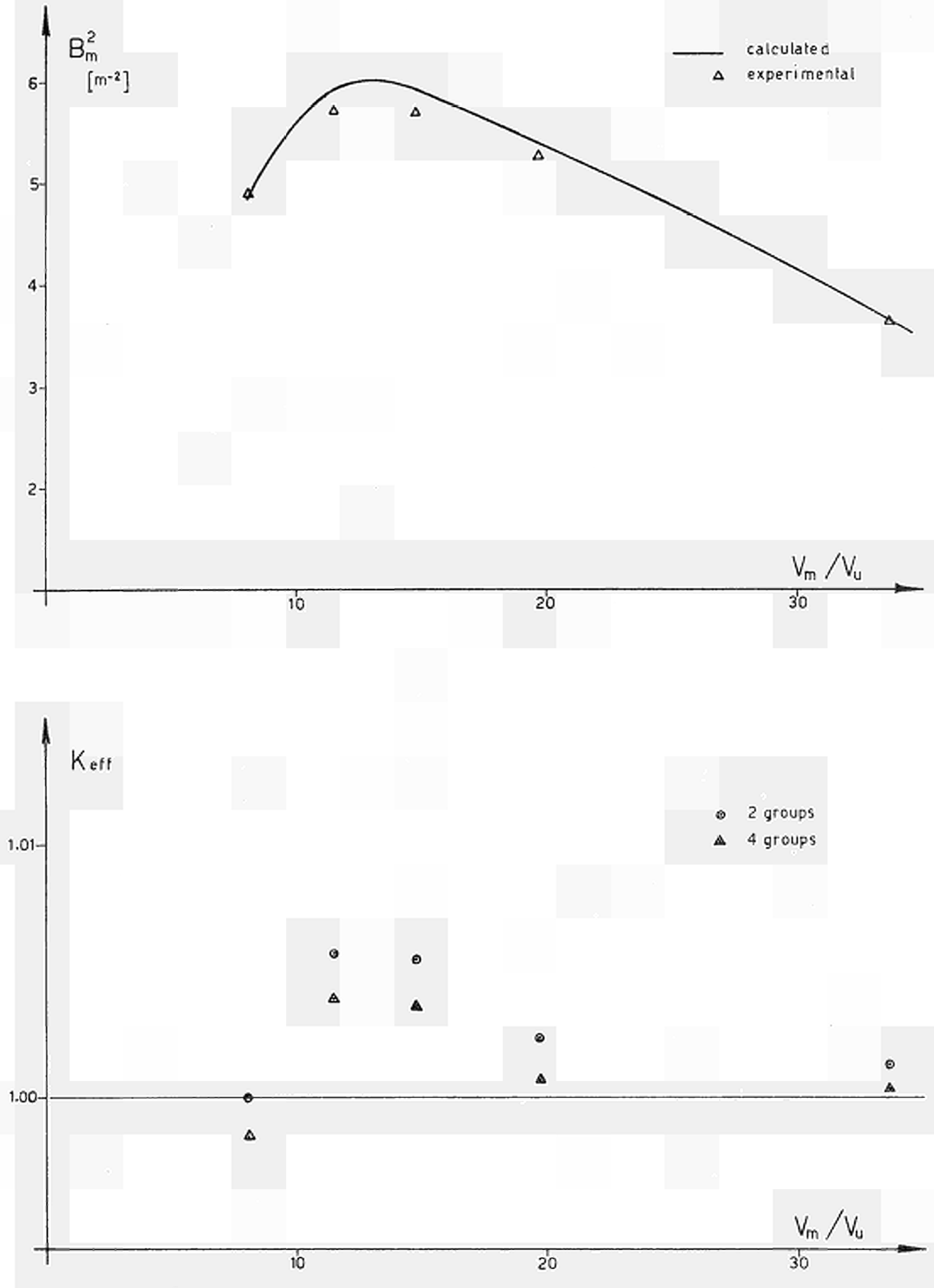
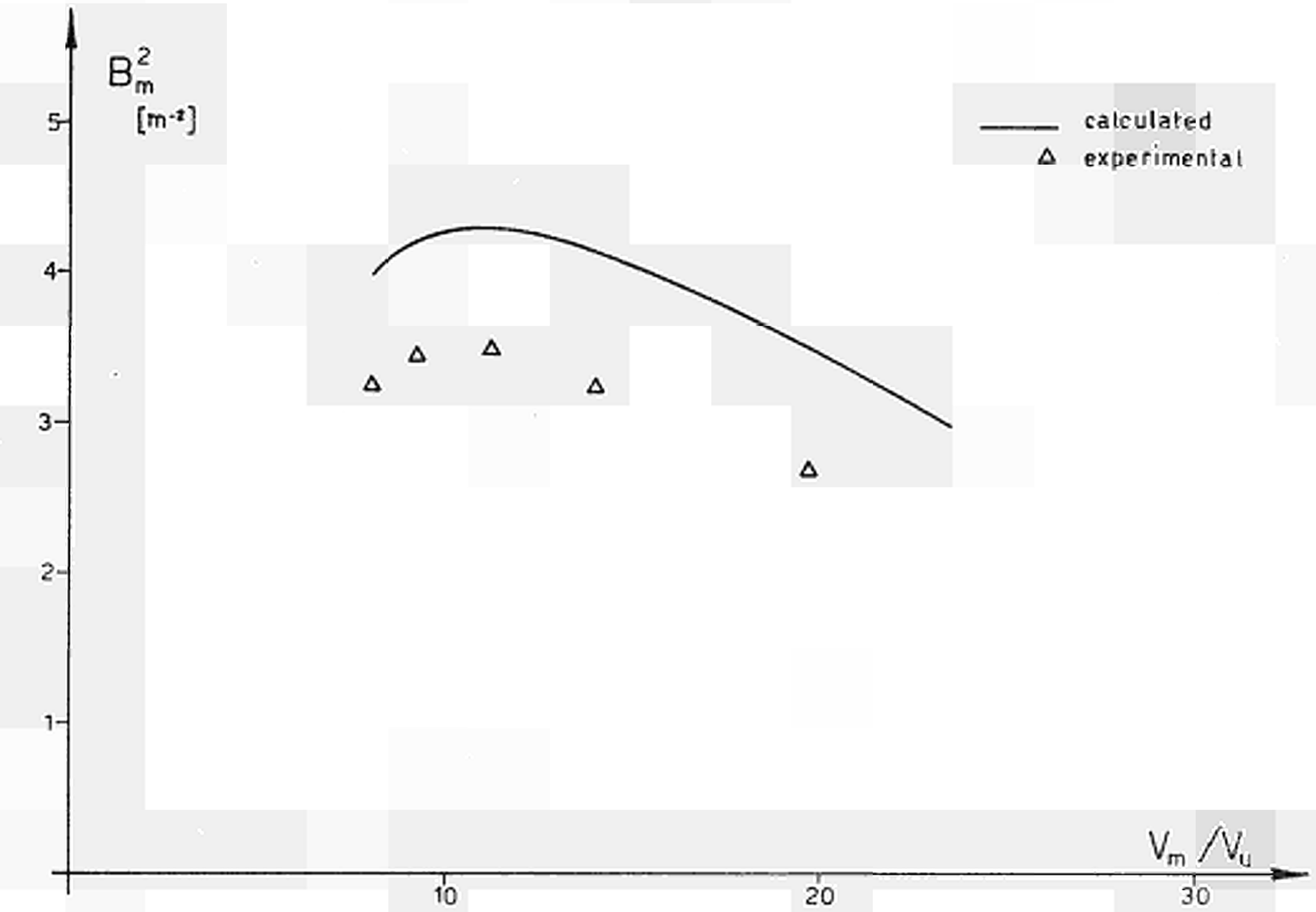



Fig. 26 - Canadian oxide 7-rod cluster Z2-7-VT (Table XXVI).



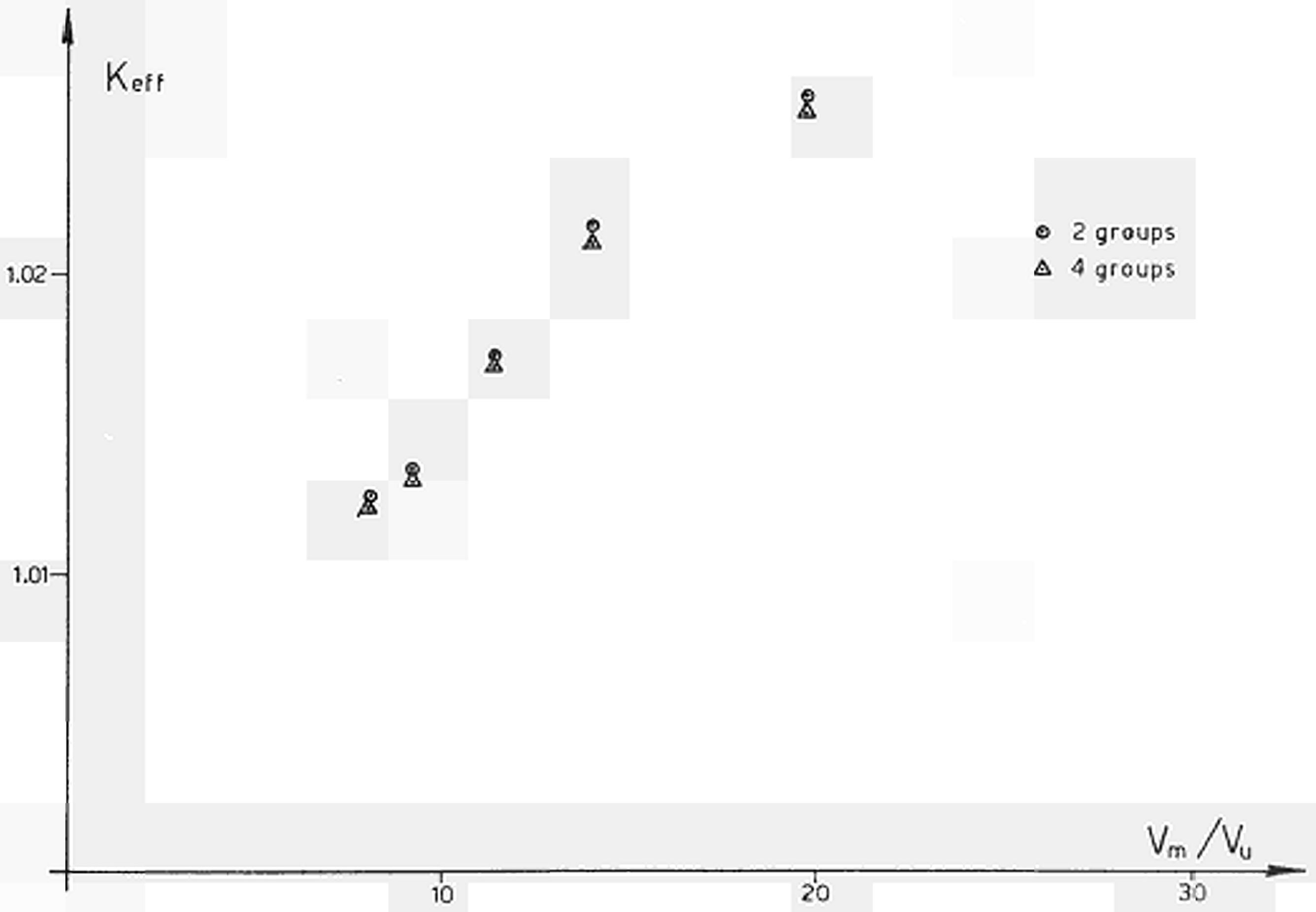




Fig. 27 - Canadian oxide 7-rod cluster Z2-7-HB40 (Table XXVII).

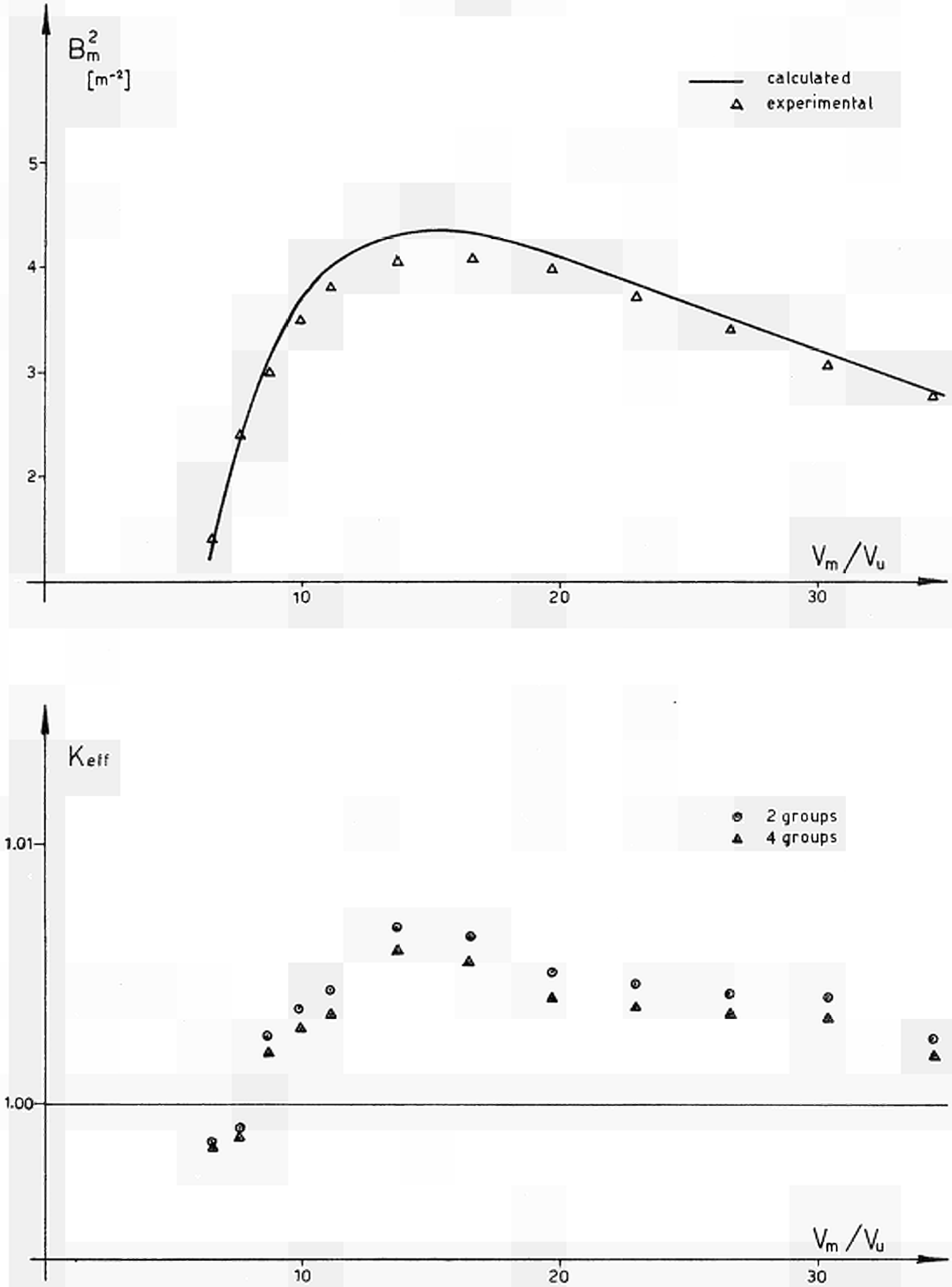



Fig. 28 - Canadian oxide 19-rod cluster Z2-19-HWC (Table XXVIII).

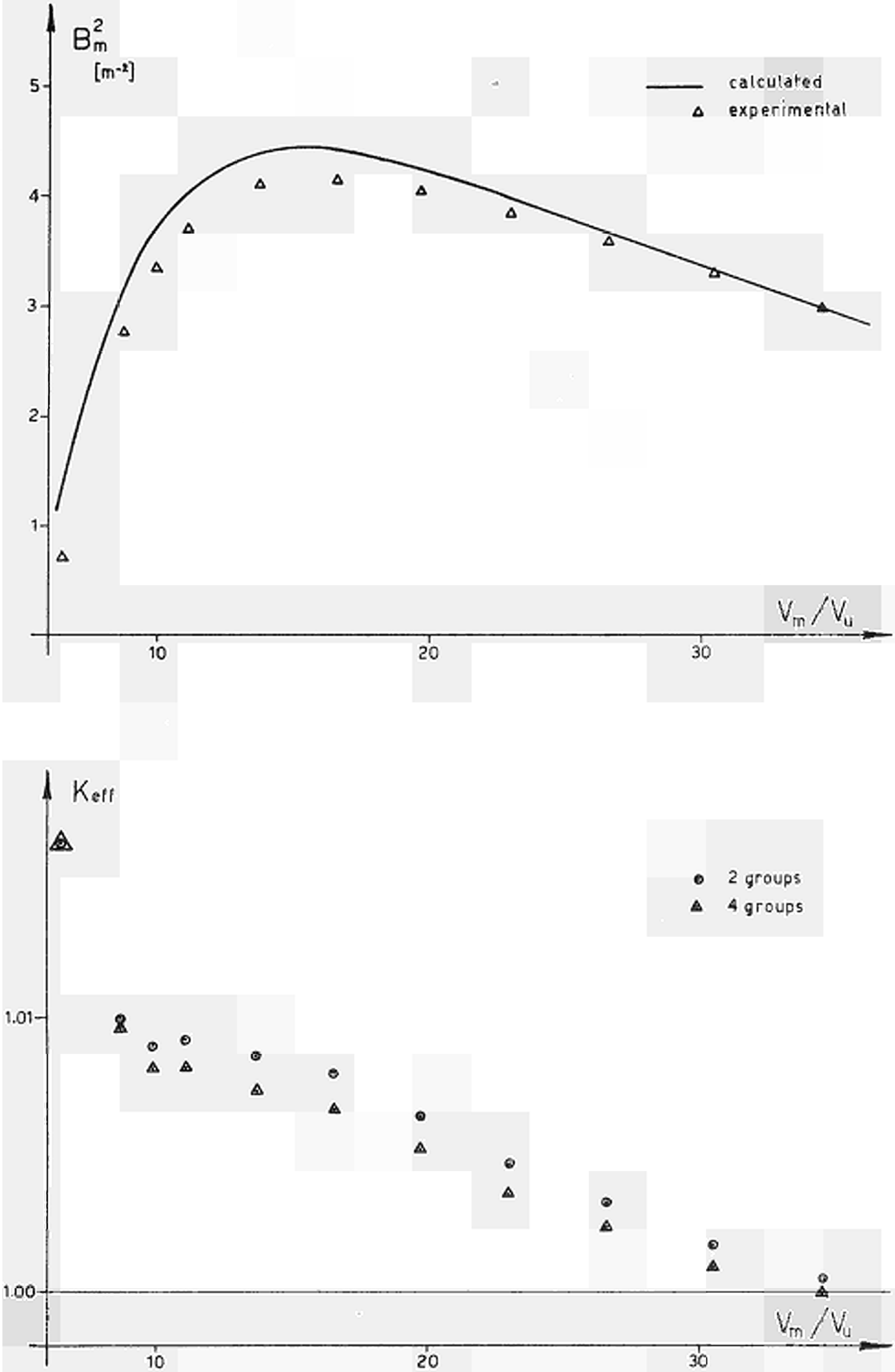



Fig 29 - Canadian oxide 19-rod cluster Z2-19-VT (Table XXIX).

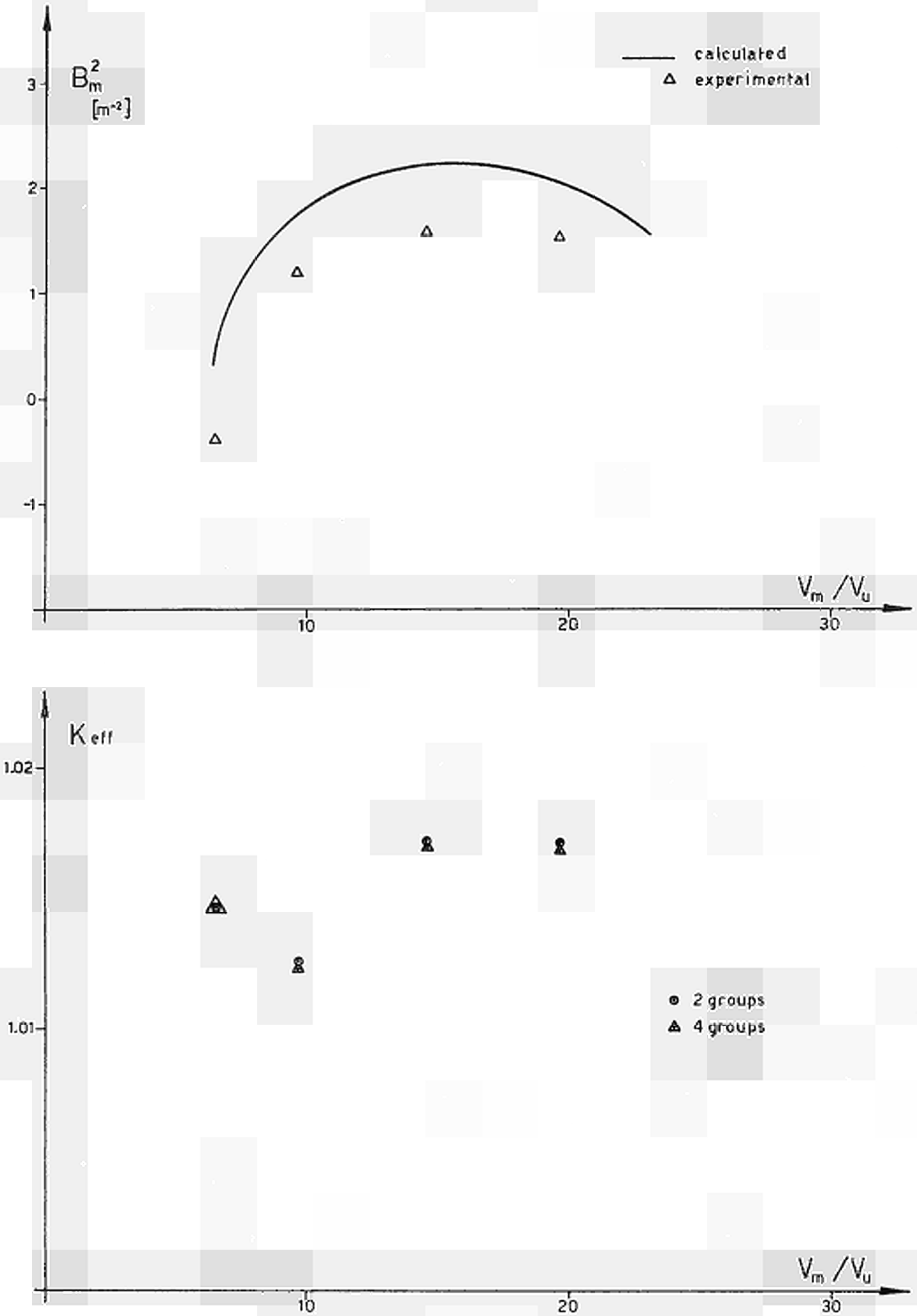
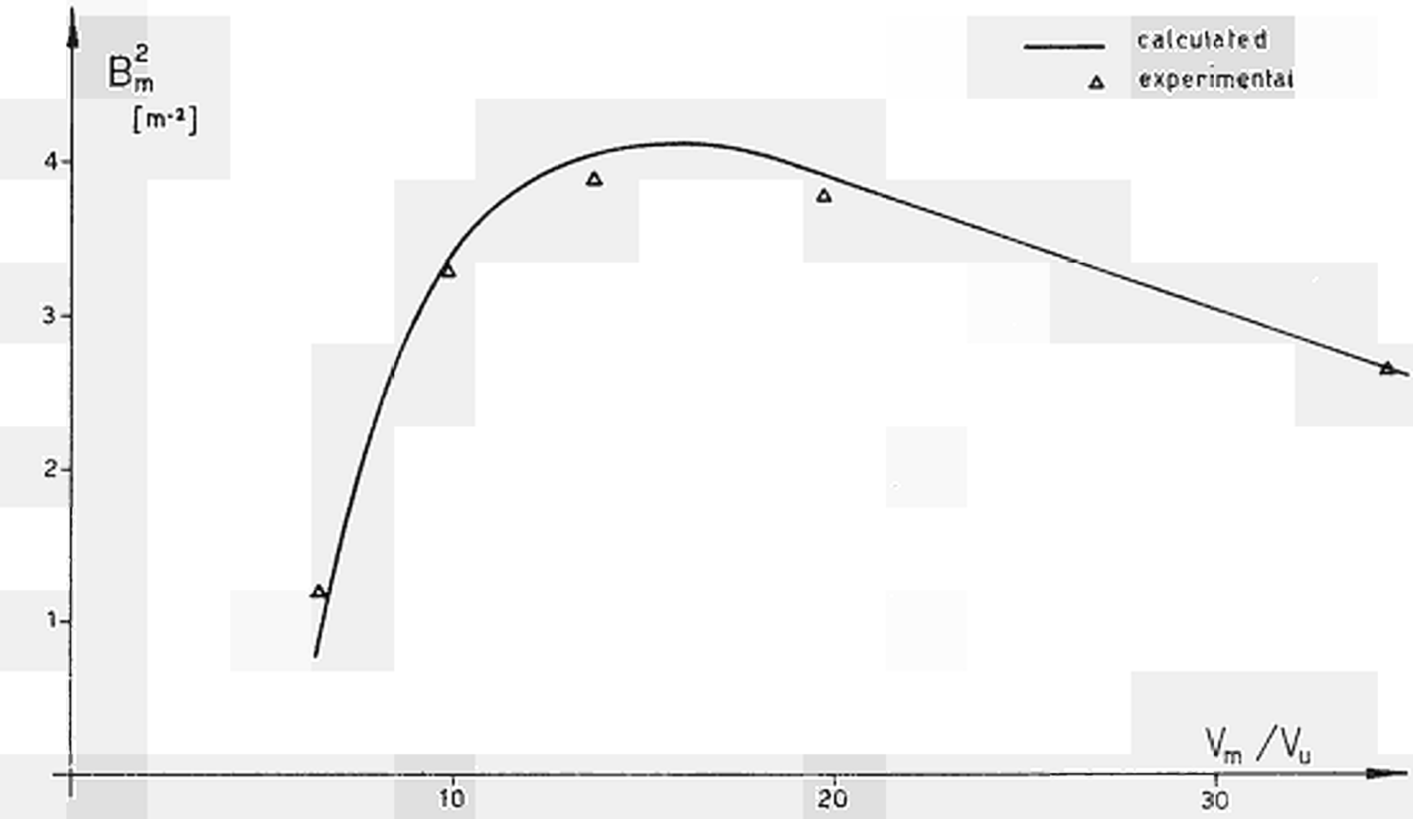



Fig. 30 - Canadian oxide 19-rod cluster Z2-19-HB40 (Table XXX).



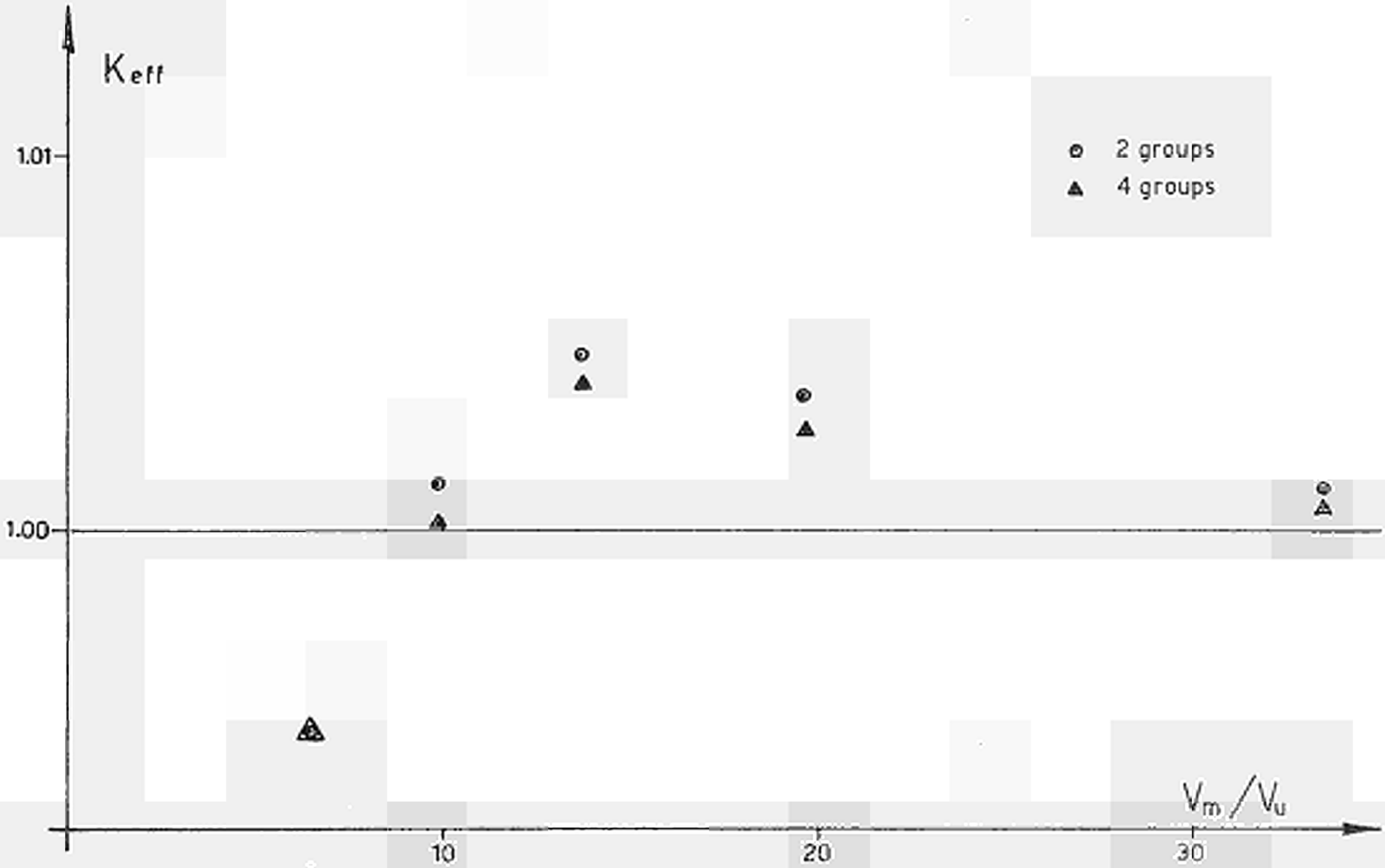




Fig. 31 - Canadian oxide 19-rod cluster Z2-19-HWC-BIS (Table XXXI).

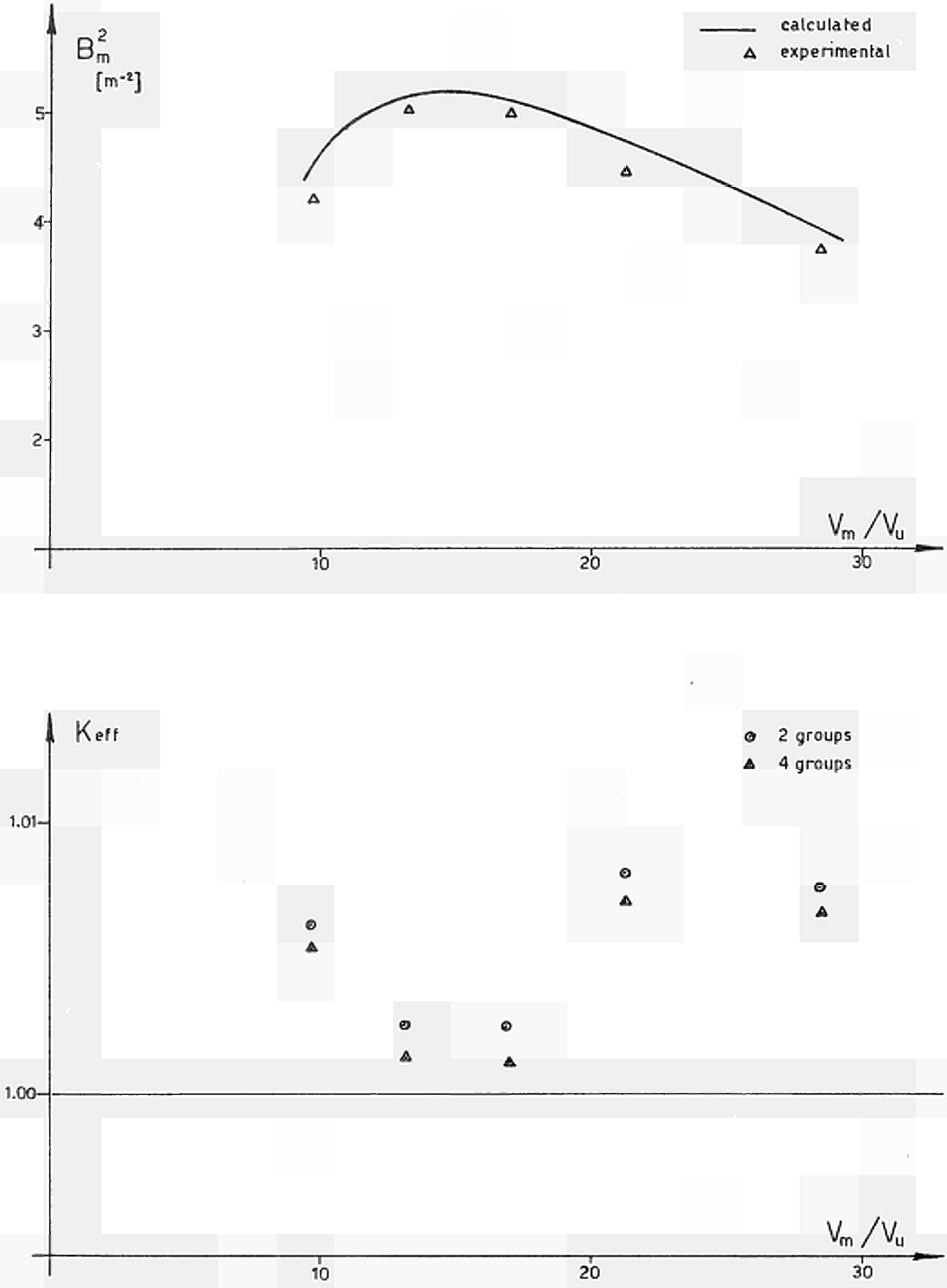



Fig. 32 - Canadian oxide 19-rod cluster NPD-1 (Table XXXII).

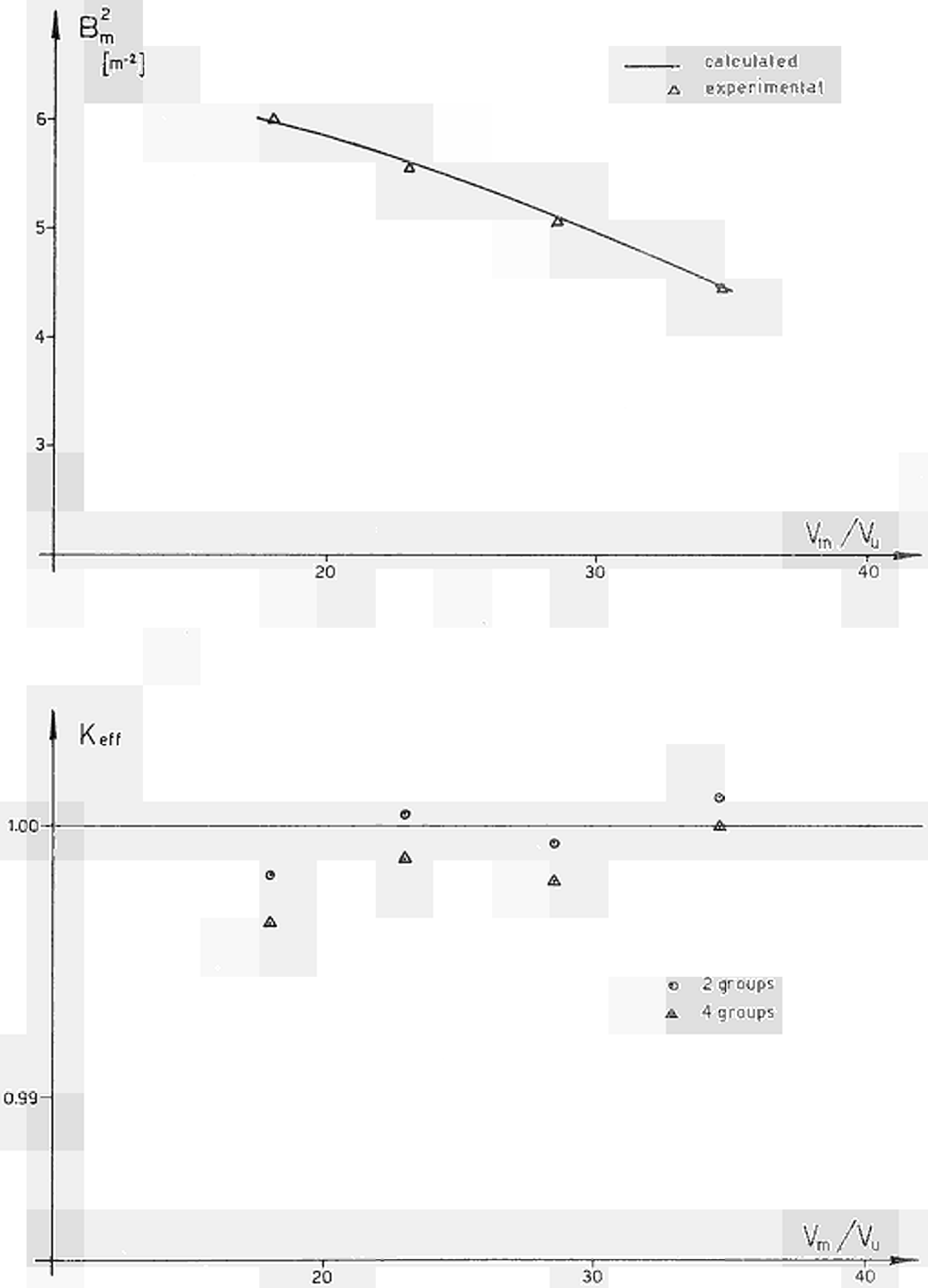



Fig. 33 - French oxide 7-rod cluster OX-AQ-7-162 (Table XXXIII).

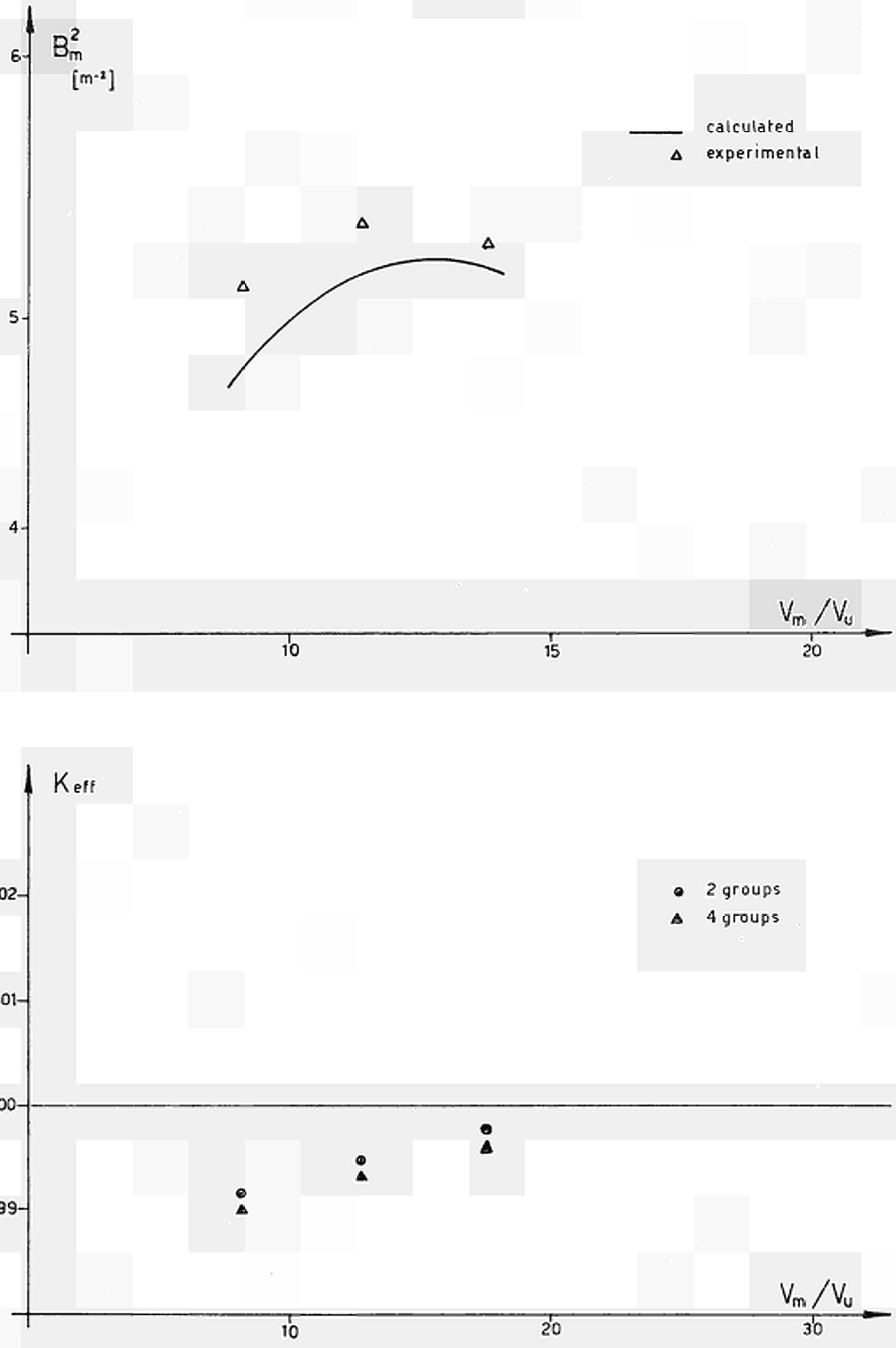



Fig. 34 - French oxide 19-rod cluster OX-AQ-19-162 (Table XXXIV).

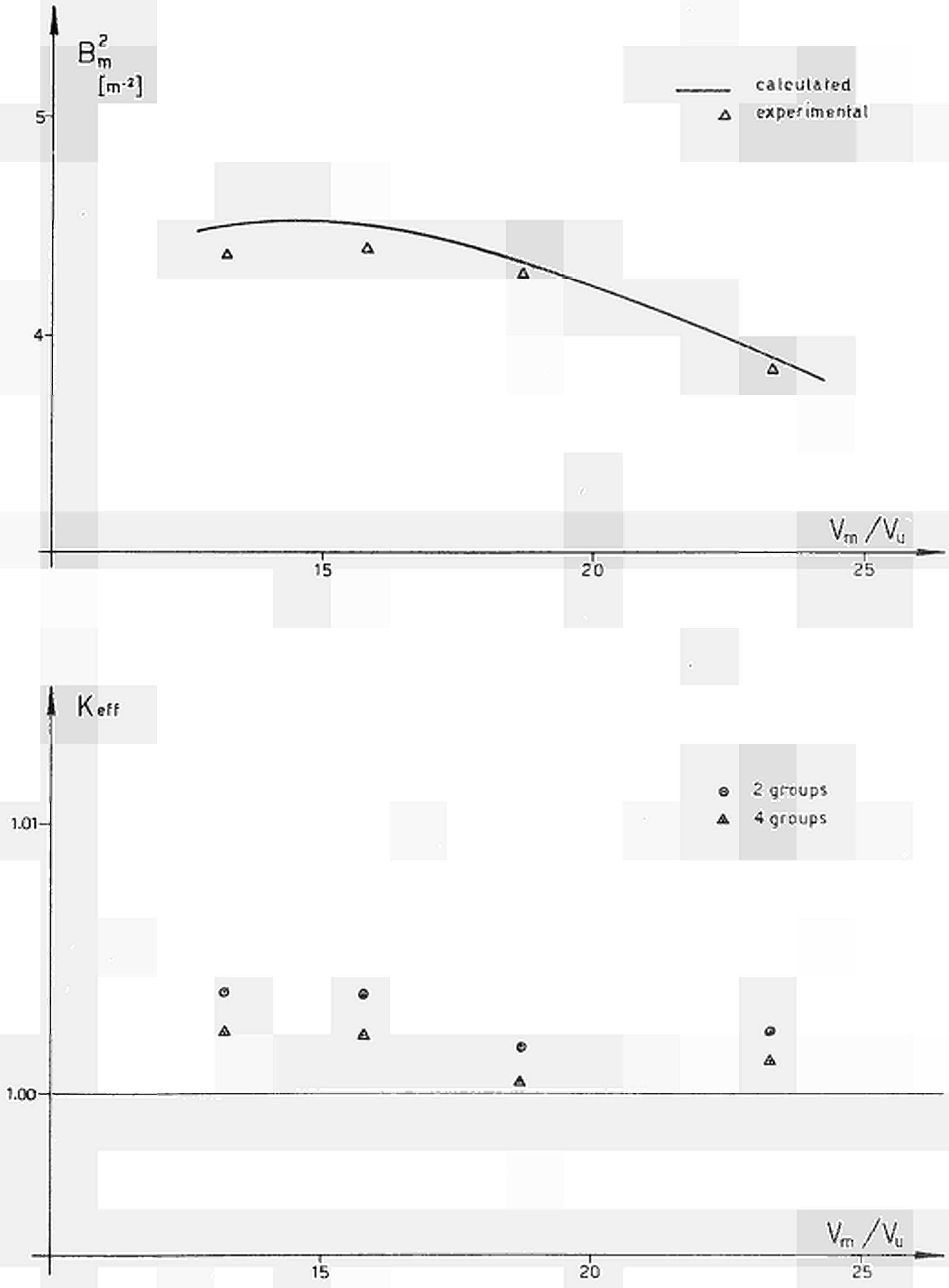



Fig. 35 - French oxide 19-rod cluster OX-AQ-19-162-VT (Table XXXV).

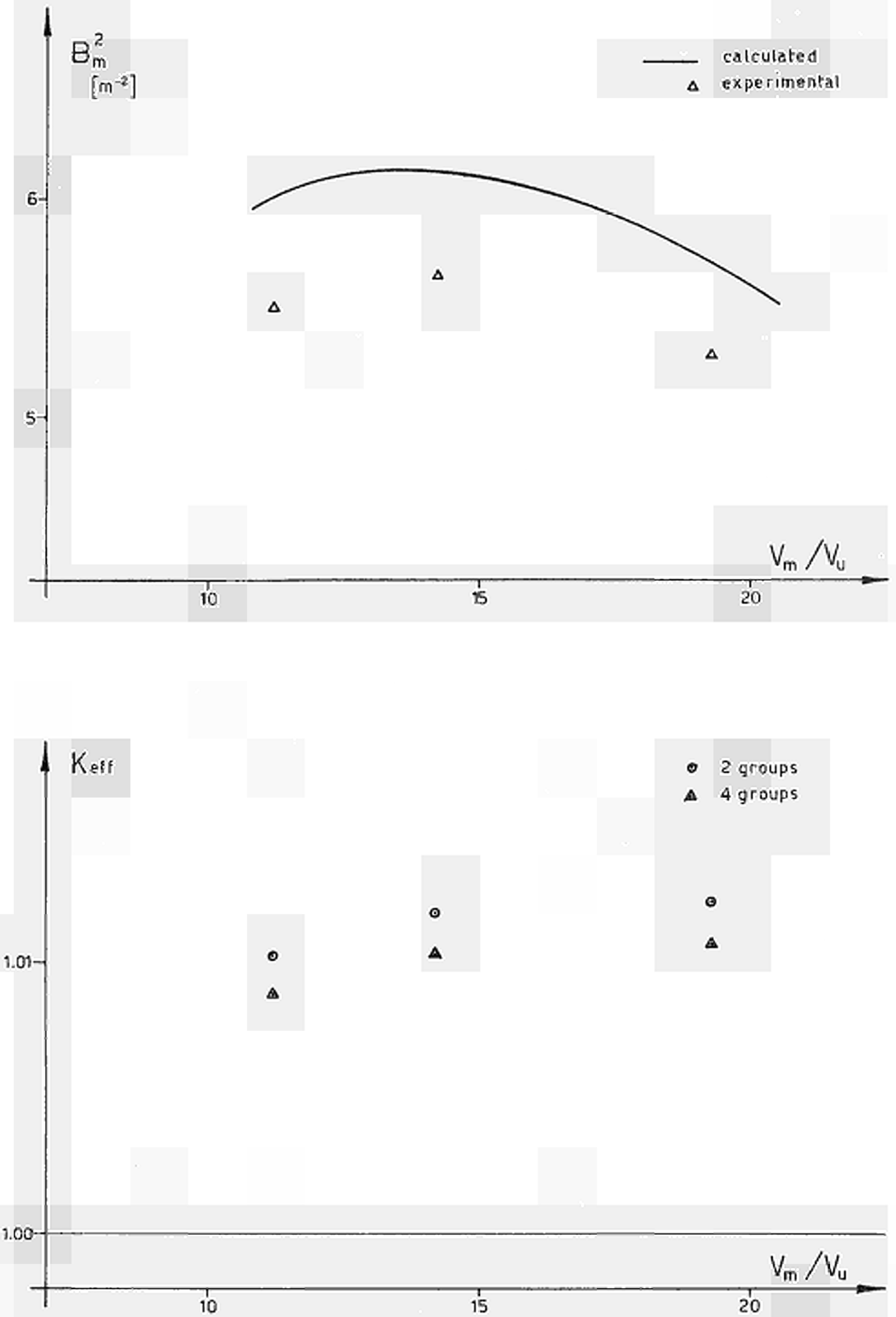



Fig. 36 - French oxide 7-rod cluster OX-AQ-7-220: (Table XXXVI).

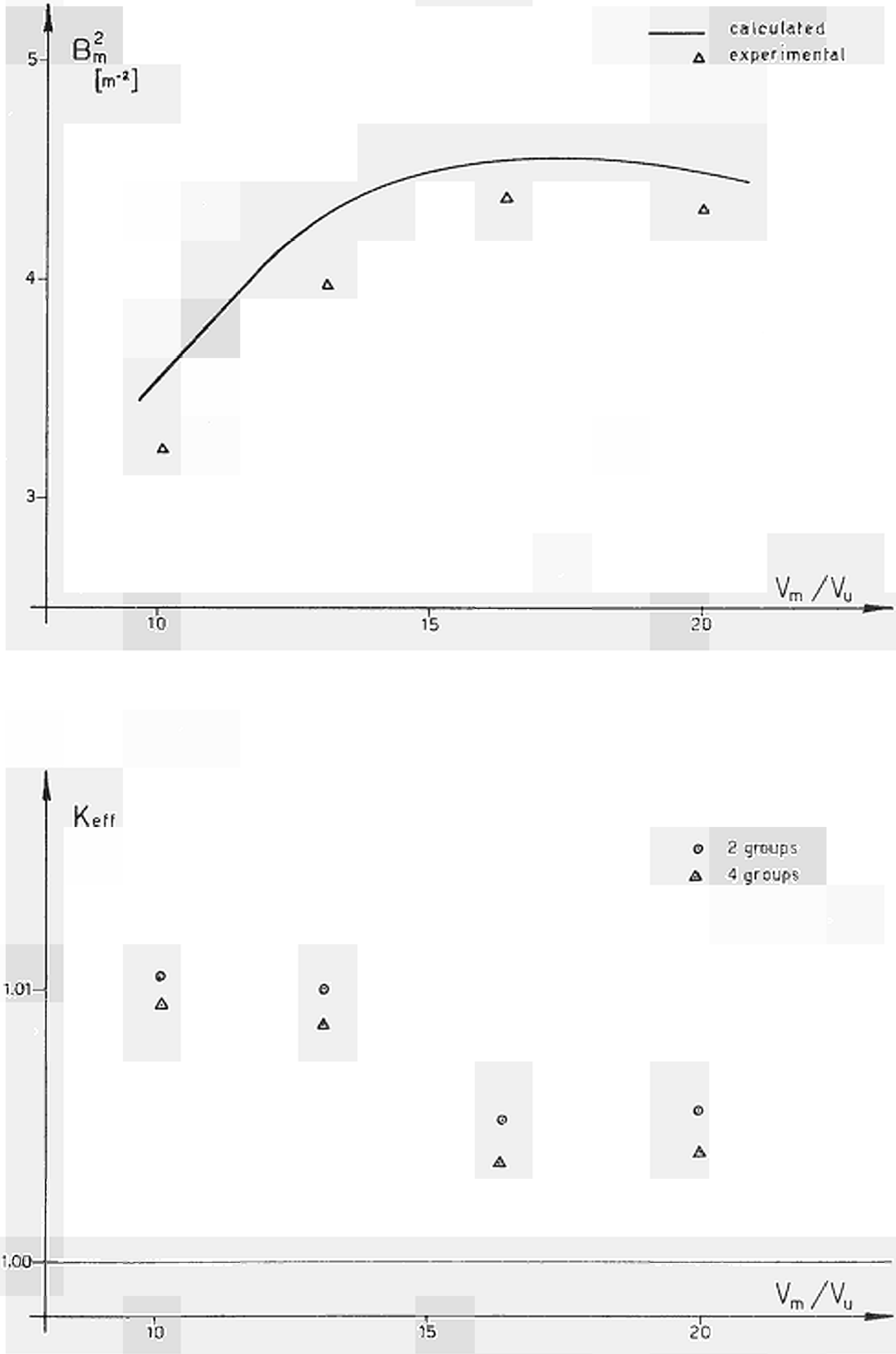
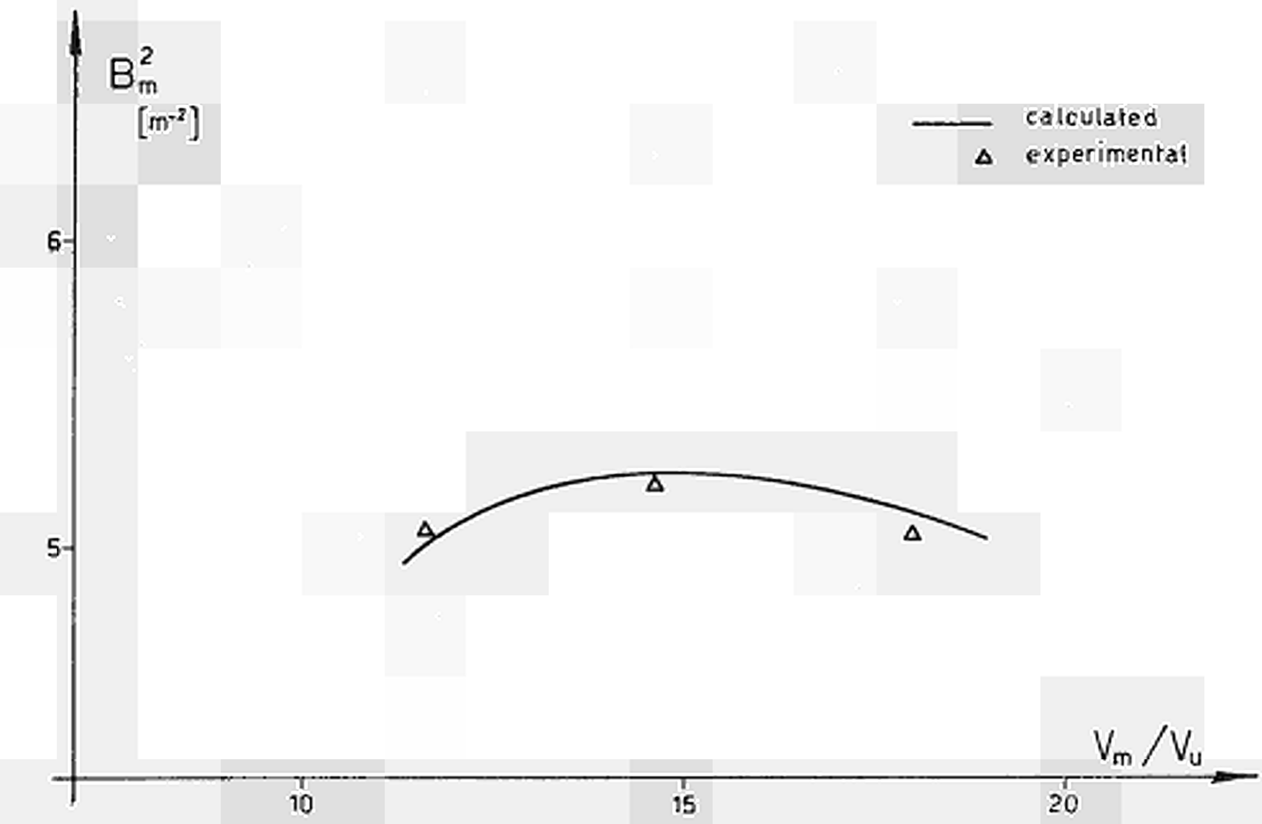



Fig. 37 - French oxide 7-rod cluster OX-AQ-7-220-VT (Table XXXVIII).



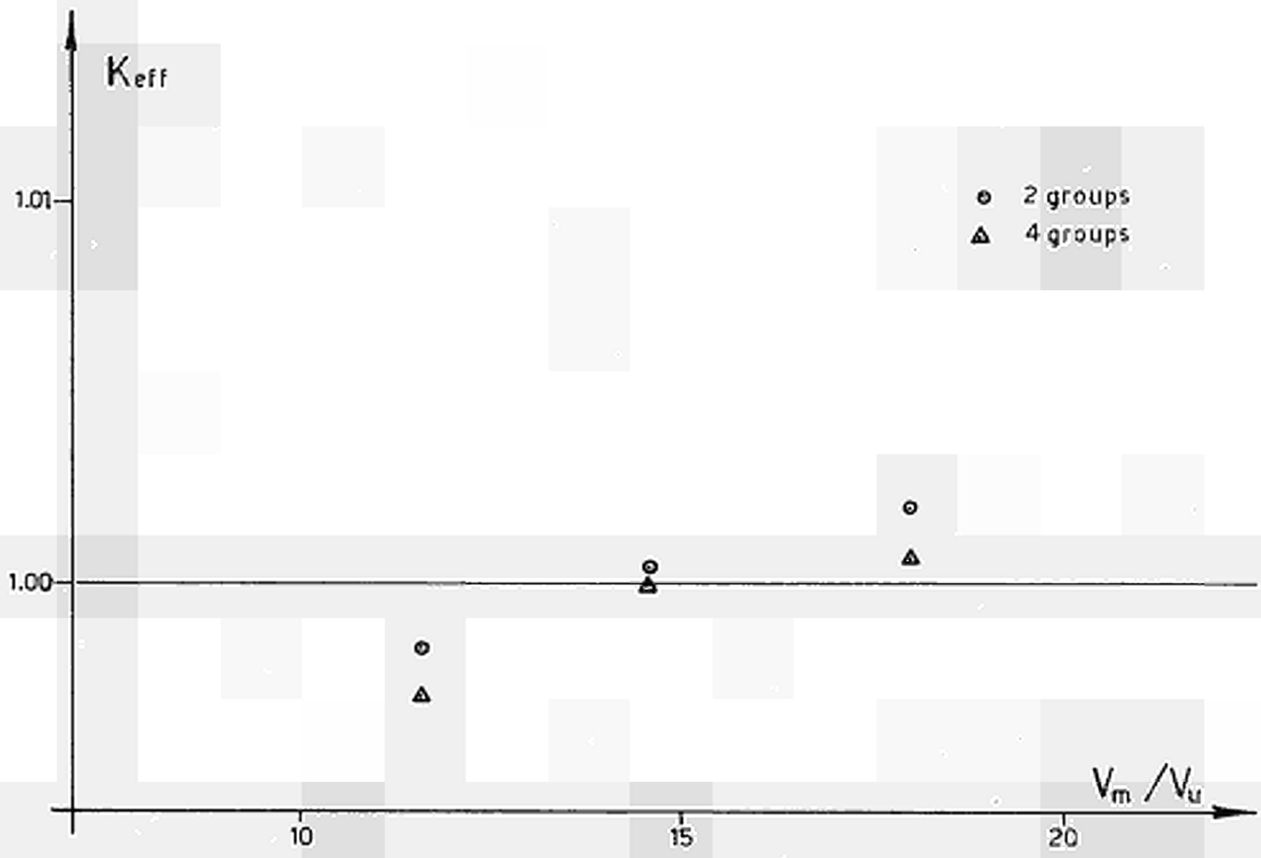




Fig. 38 - French oxide 19-rod cluster OX-AQ-19-132-A (Table XXXVIII).

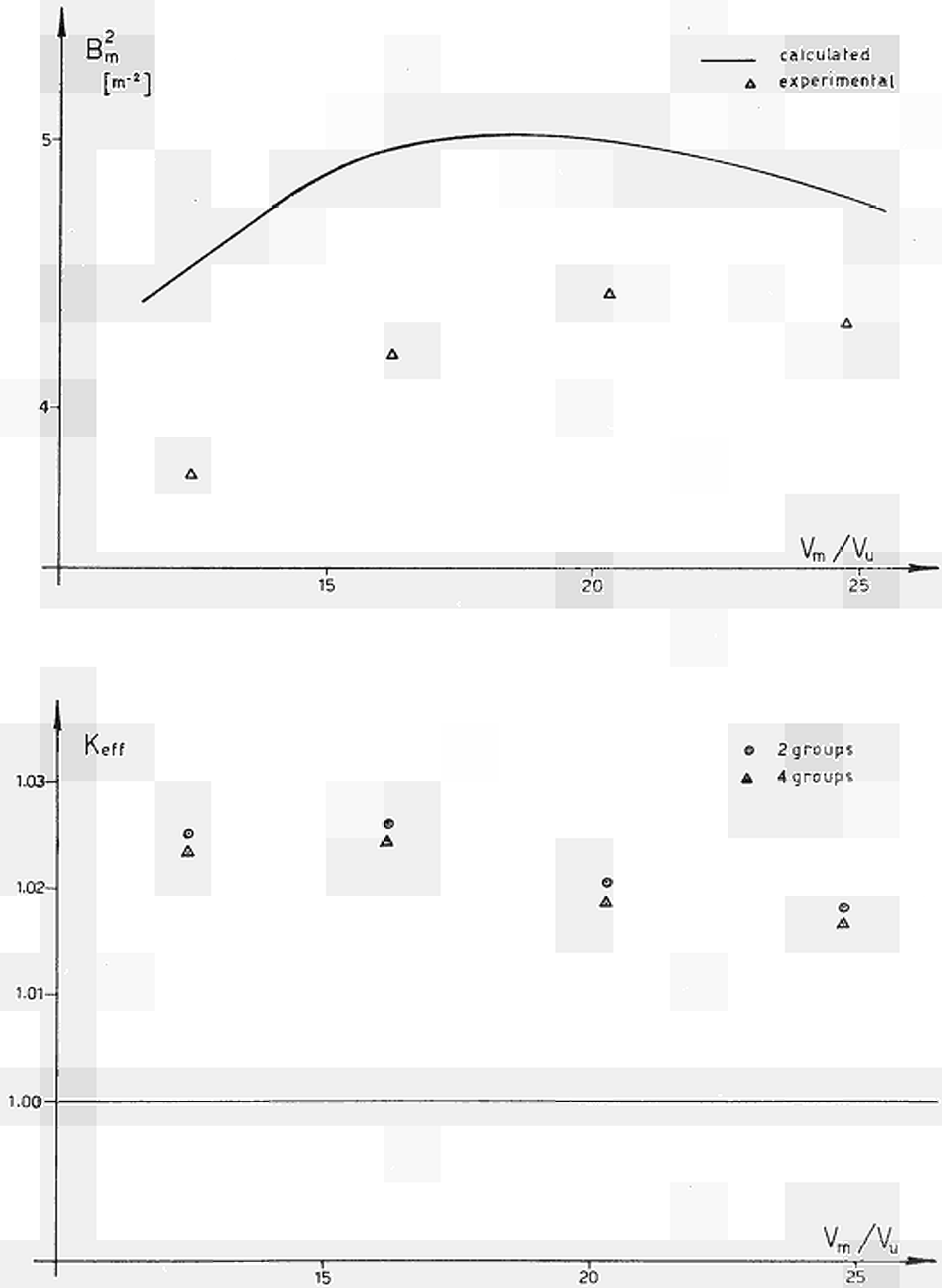



Fig. 39 - French oxide 19-rod cluster OX-AQ-MG-19-120-A (Table XL).

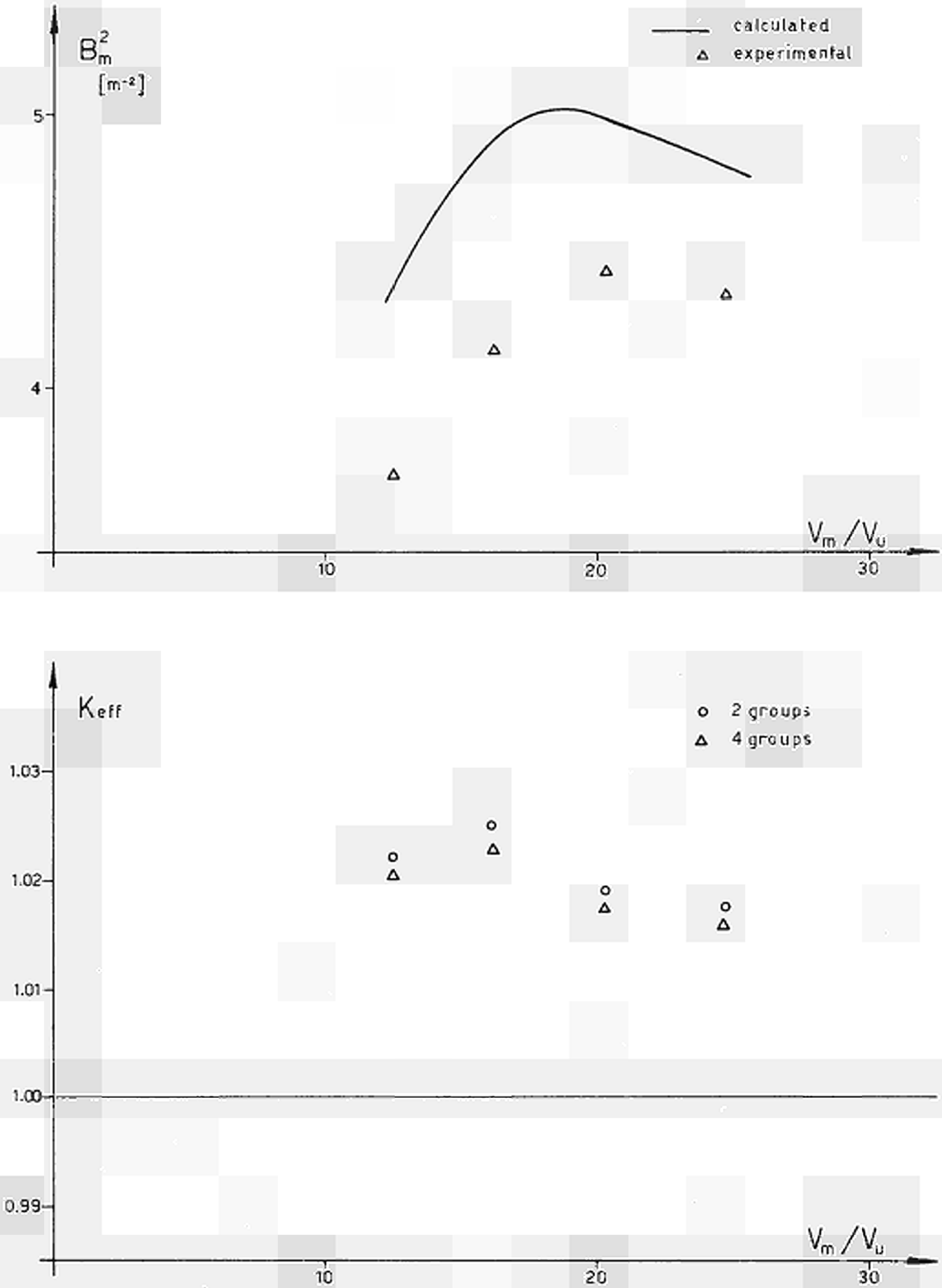
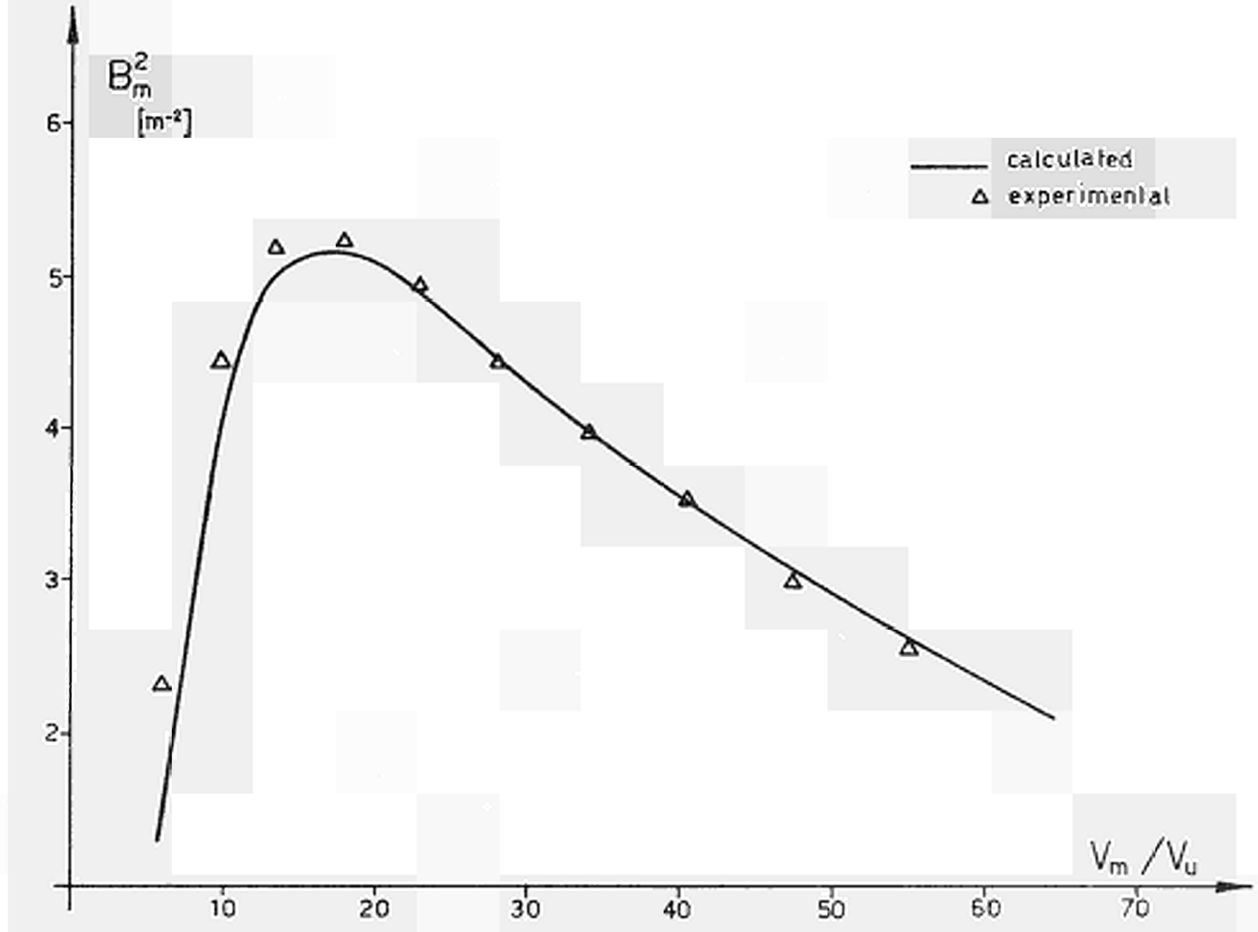



Fig. 40 - French oxide 19-rod OX-AQ-MG-19-120-C (Table XLII).



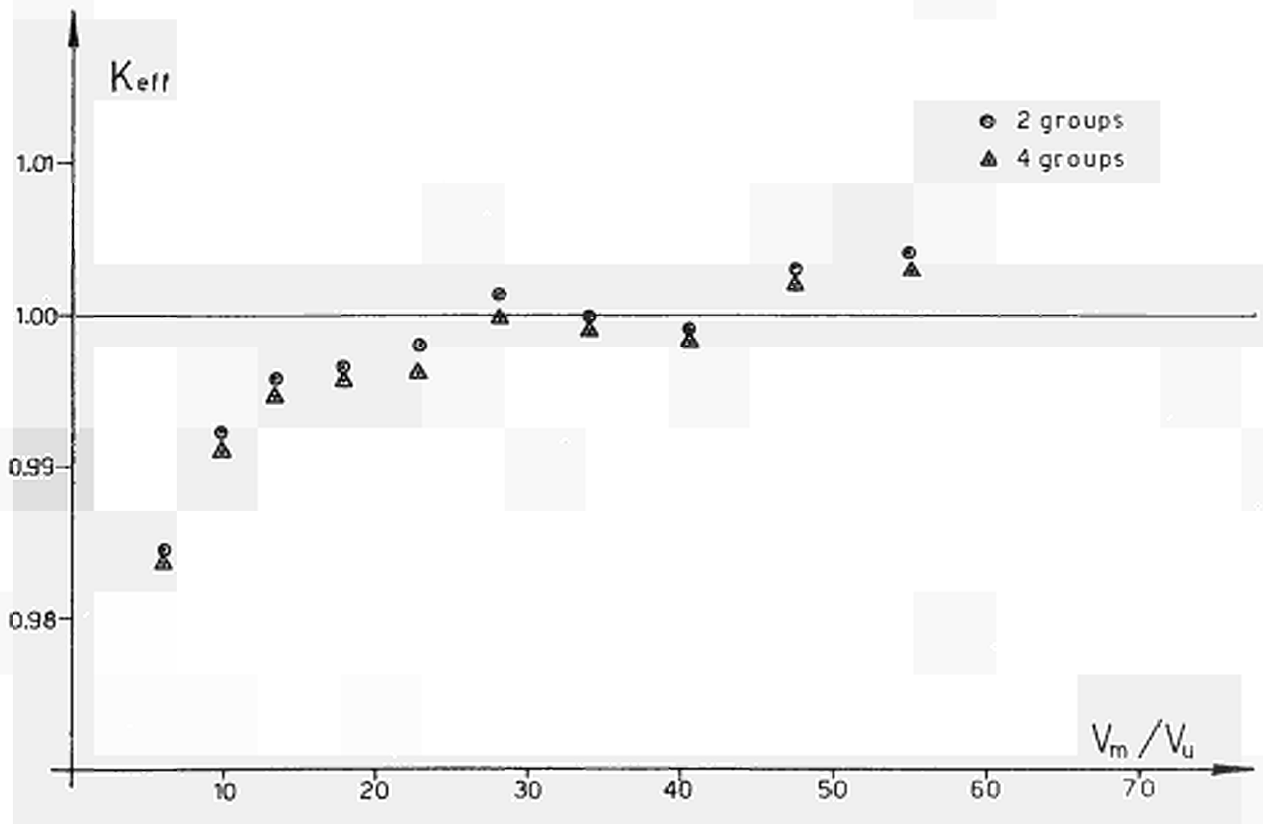




Fig. 41 - Swedish oxide 7-rod cluster OX-SW-7-156 (Table XLIII).

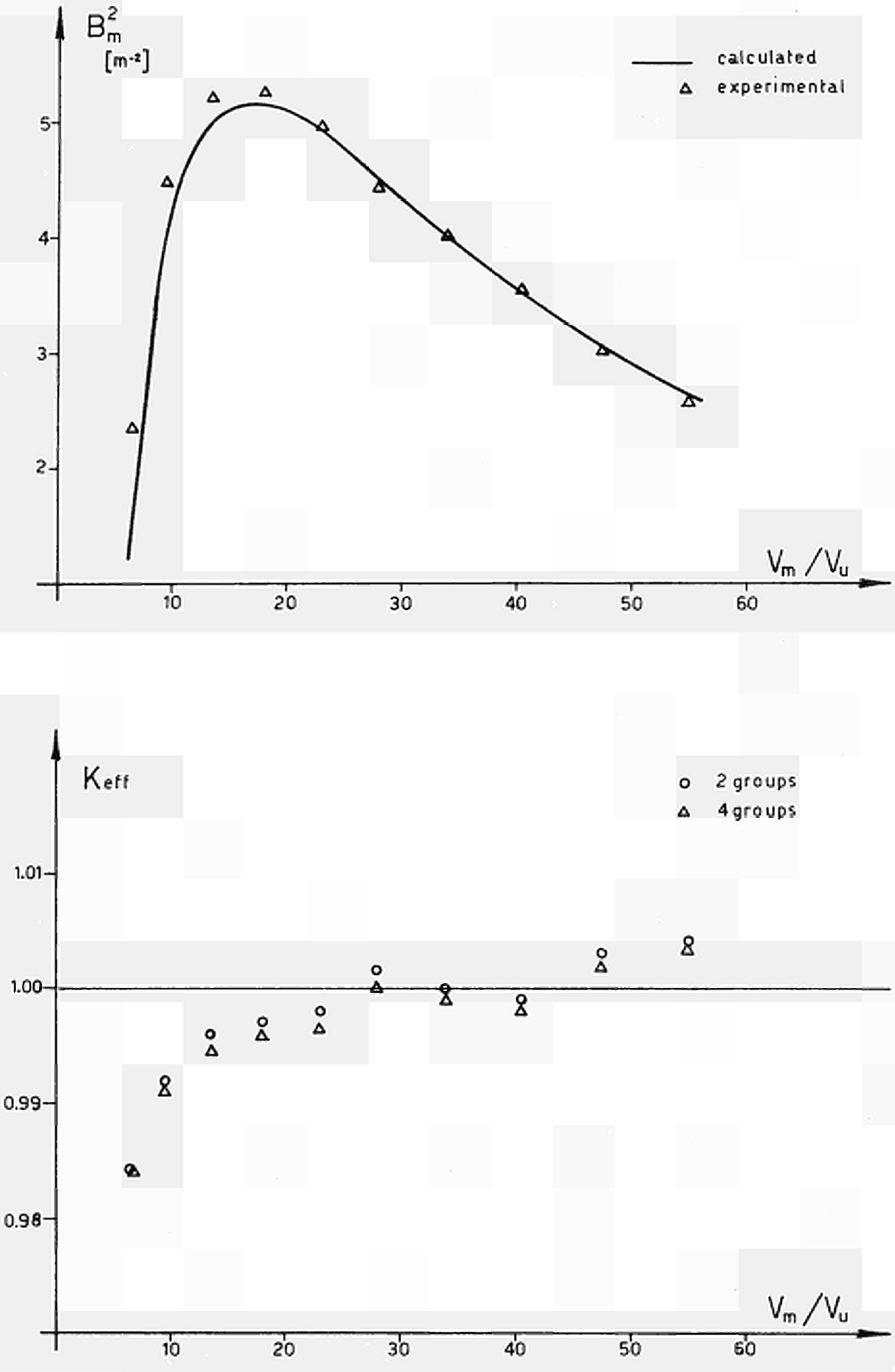
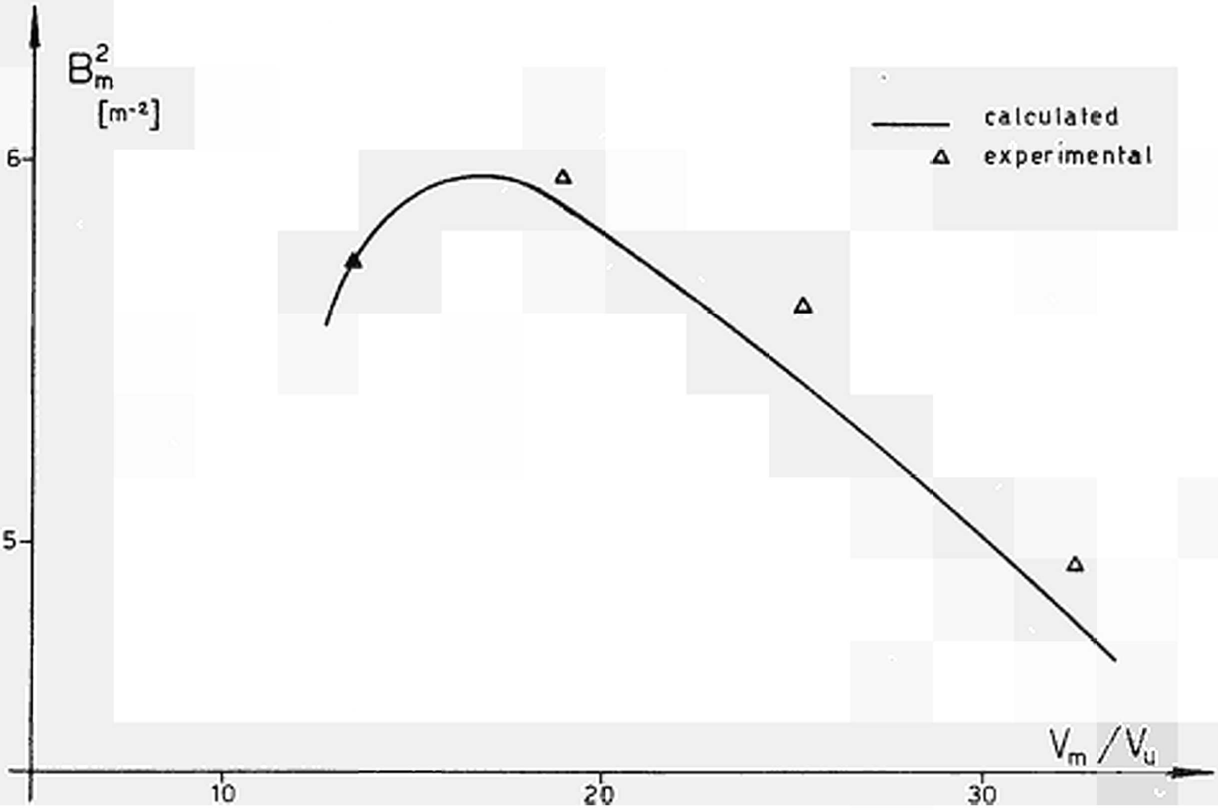



Fig. 42 - Swedish oxide 7-rod cluster OX-SW-19-156 (Table XLIV).



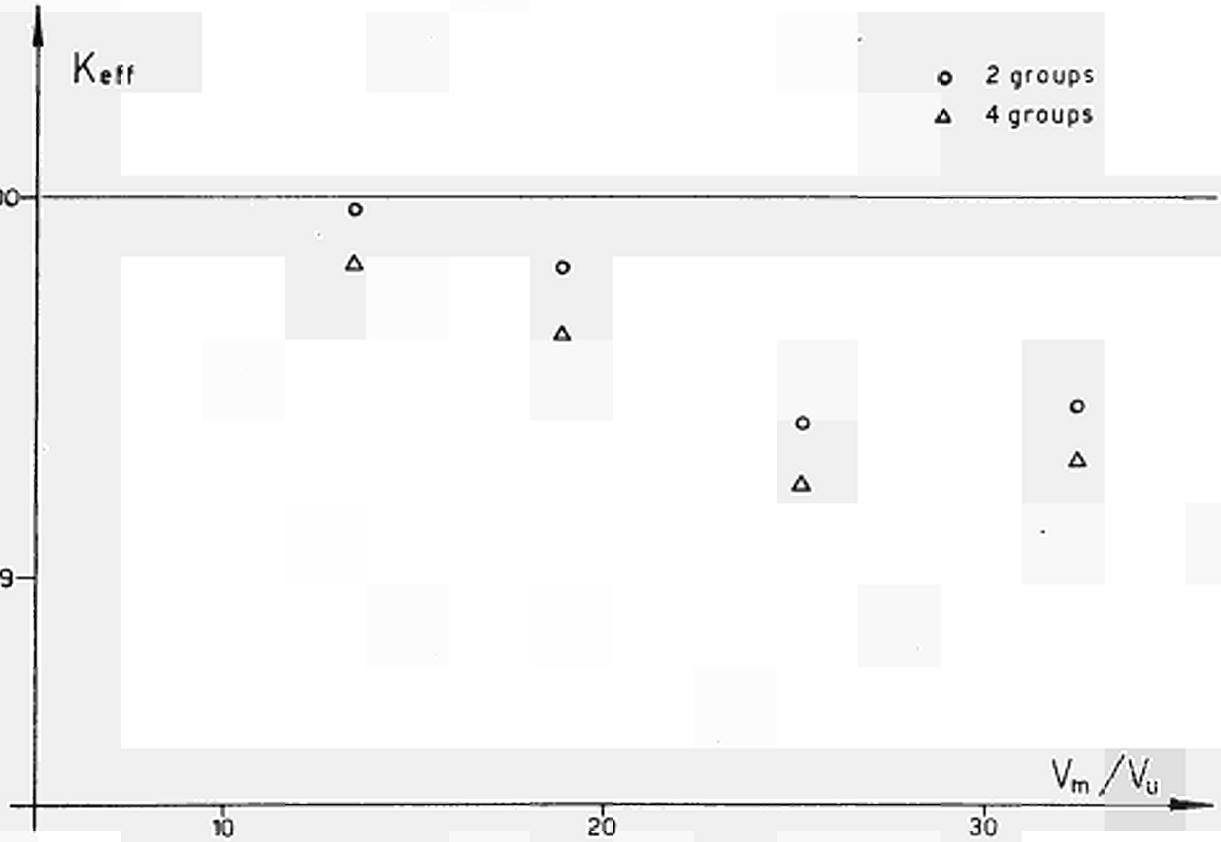
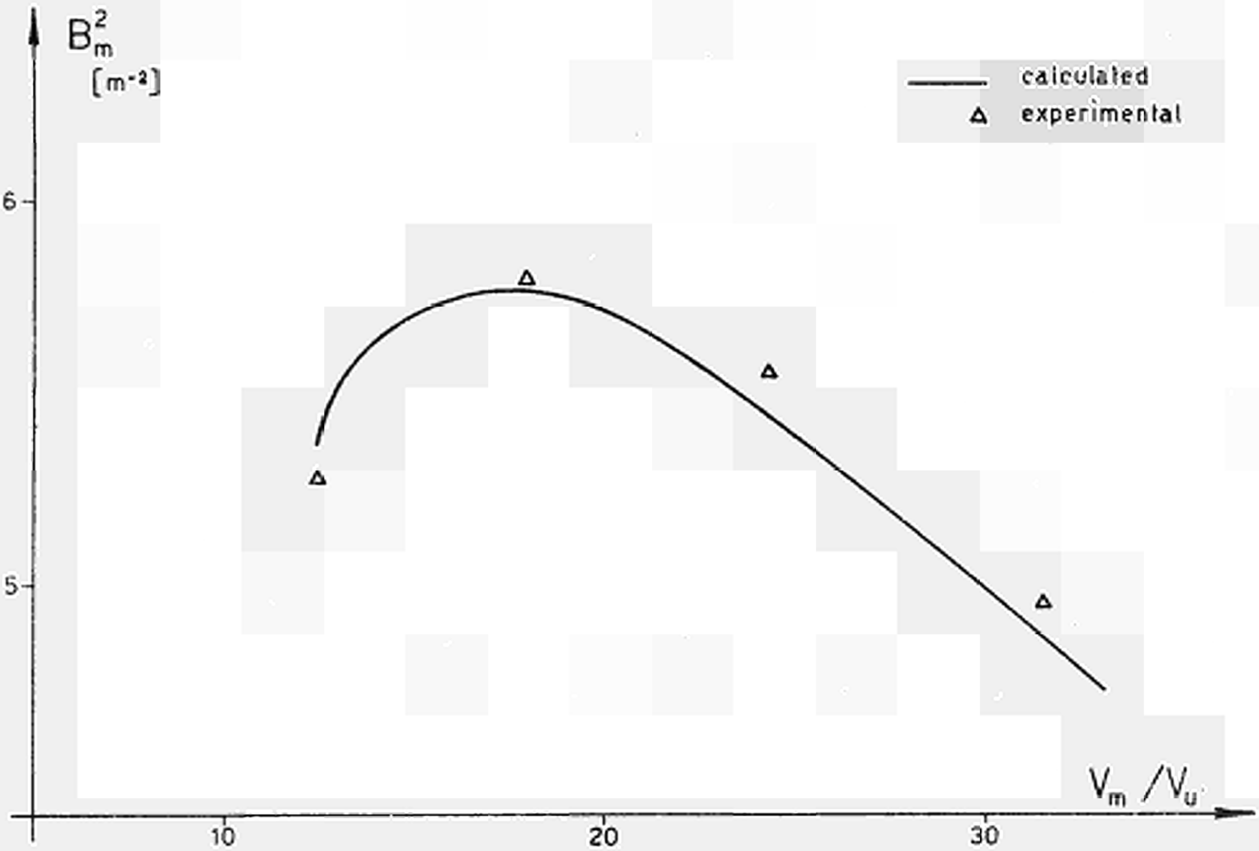




Fig. 43 - Swedish oxide 7-rod cluster OX-SW-7-122-A (Table XLV).



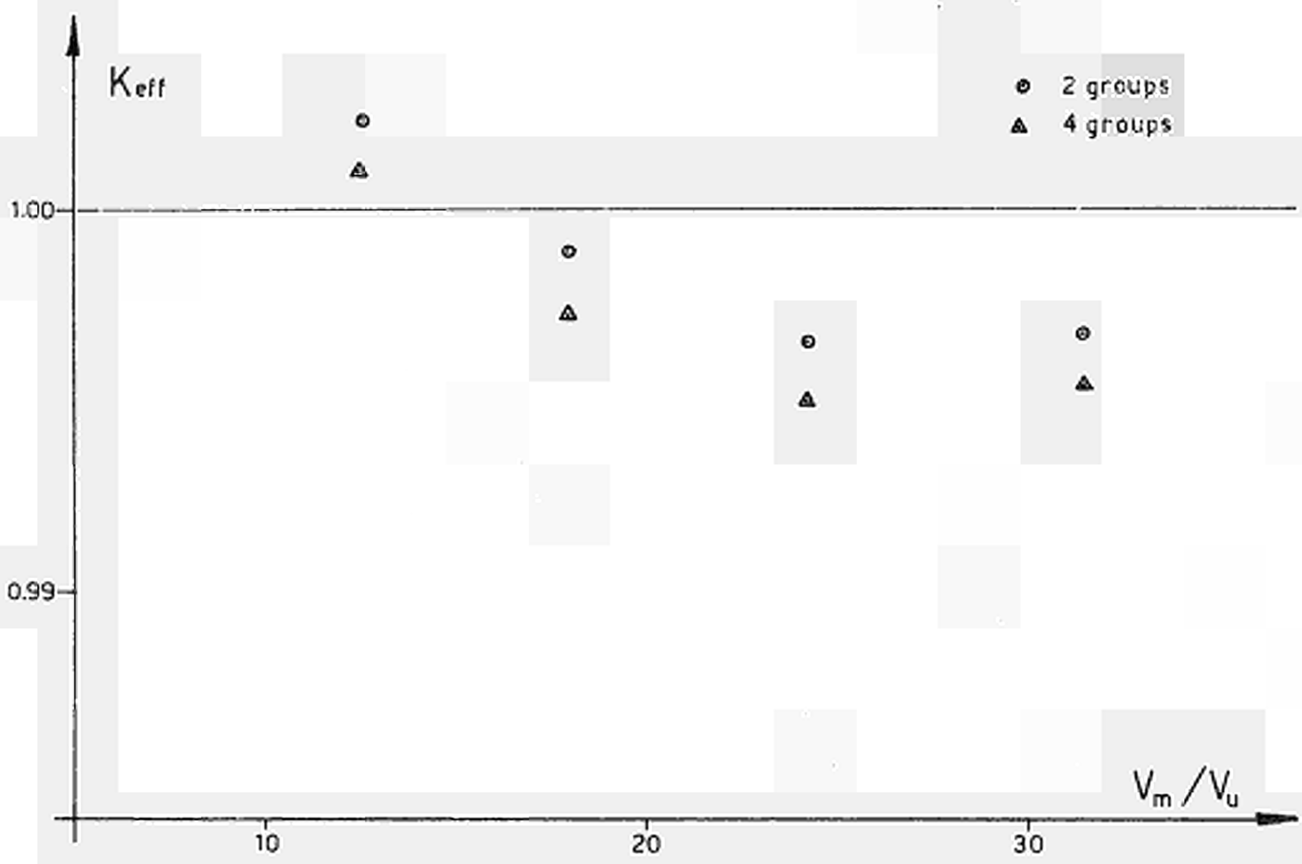
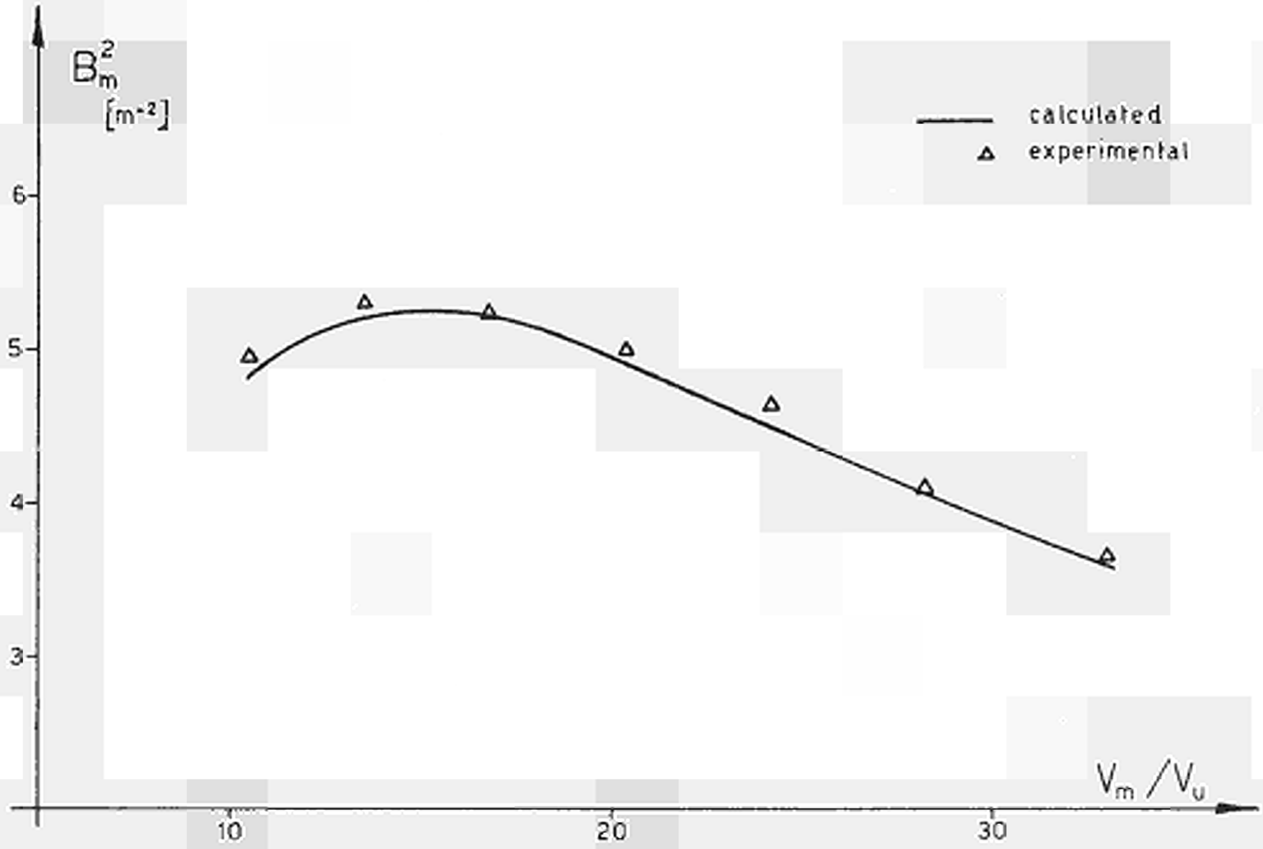




Fig. 44 - Swedish oxide 7-rod cluster OX-SW-7-121-B (Table XLVI).



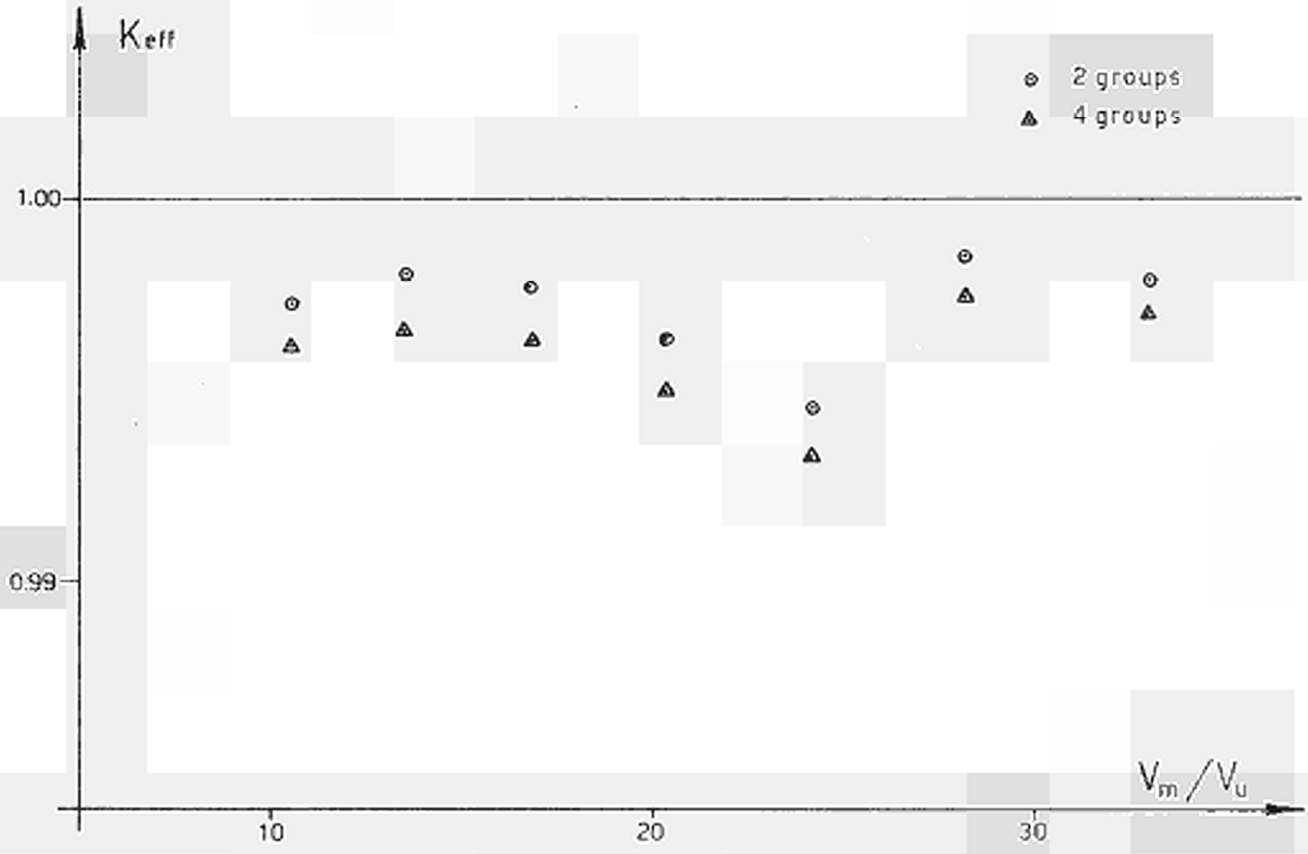
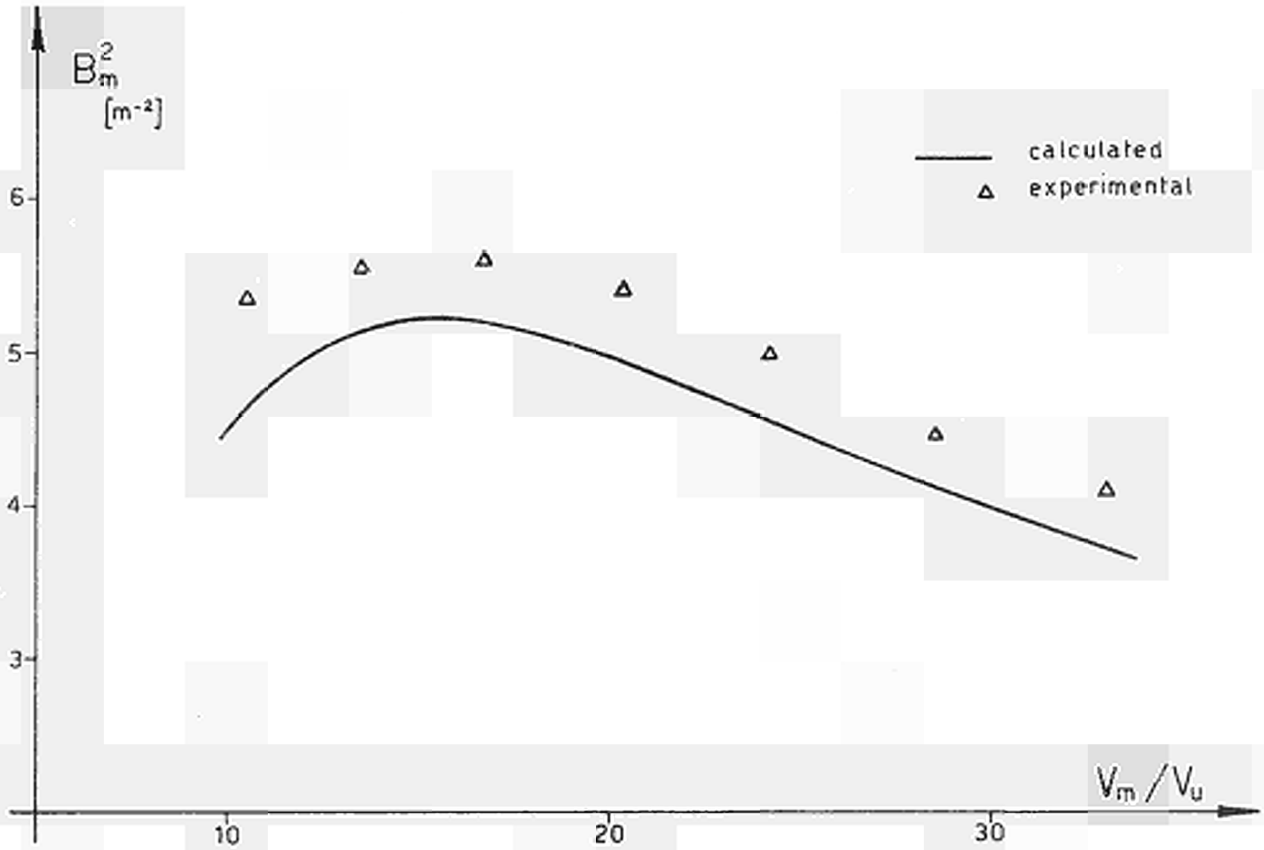




Fig. 45 - Swedish oxide 19-rod cluster OX-SW-19-122 (Table XLVII).



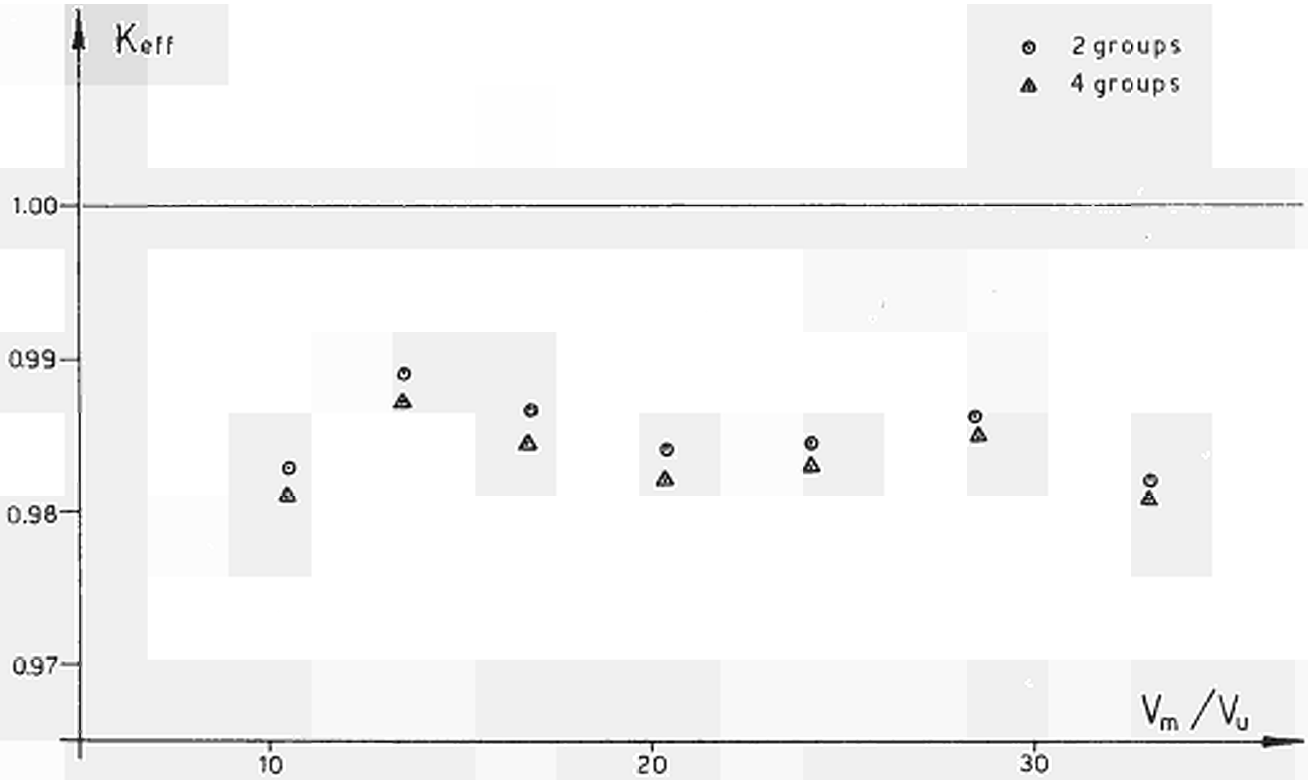




Fig. 46 - Swedish oxide 19-rod cluster OX-SW-19-122-VT (Table XLVIII).

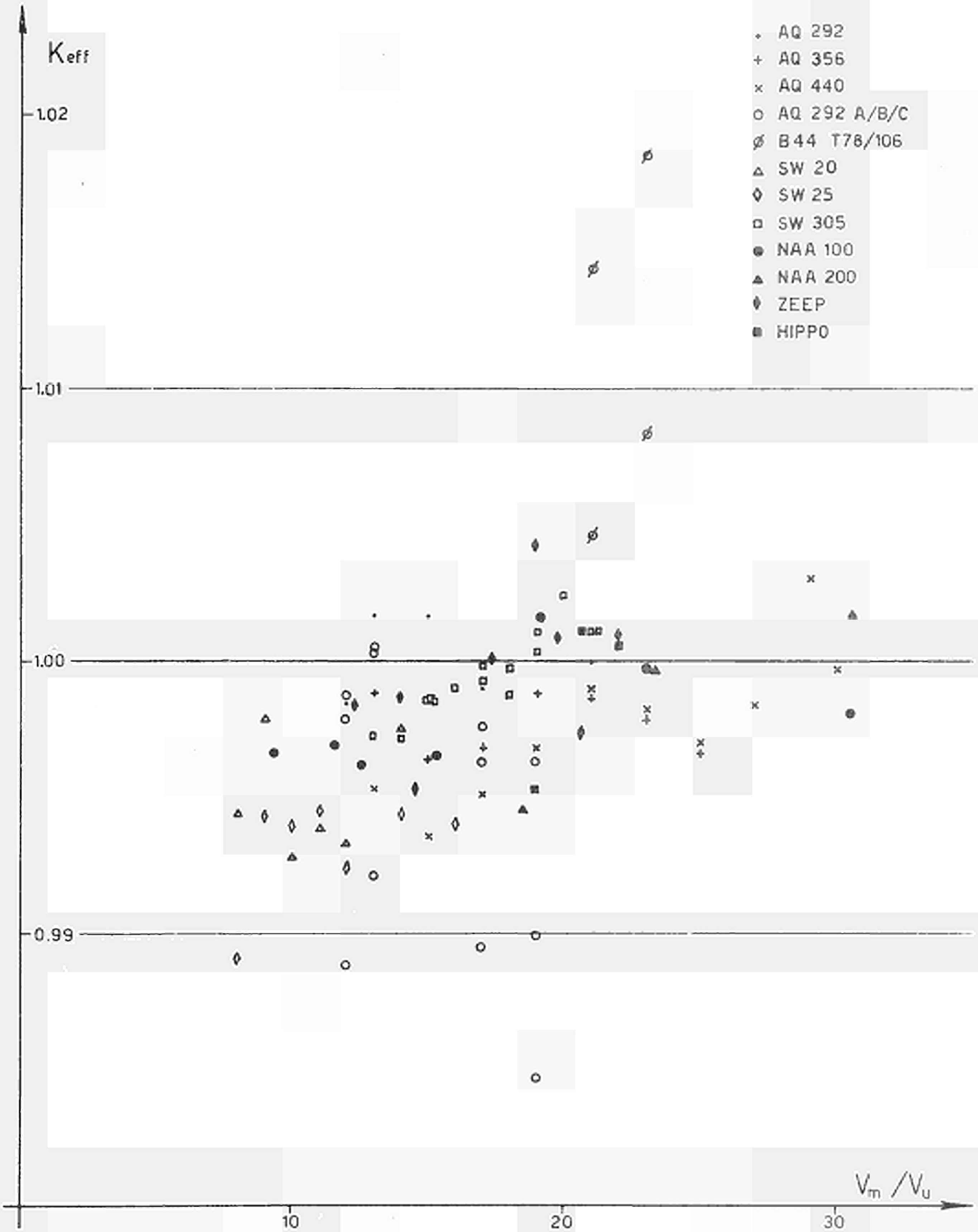



Fig. 47 - PROCELLA check vs. experiments: summary of $k_{eff}(B_m^2)$ for U metal rods.

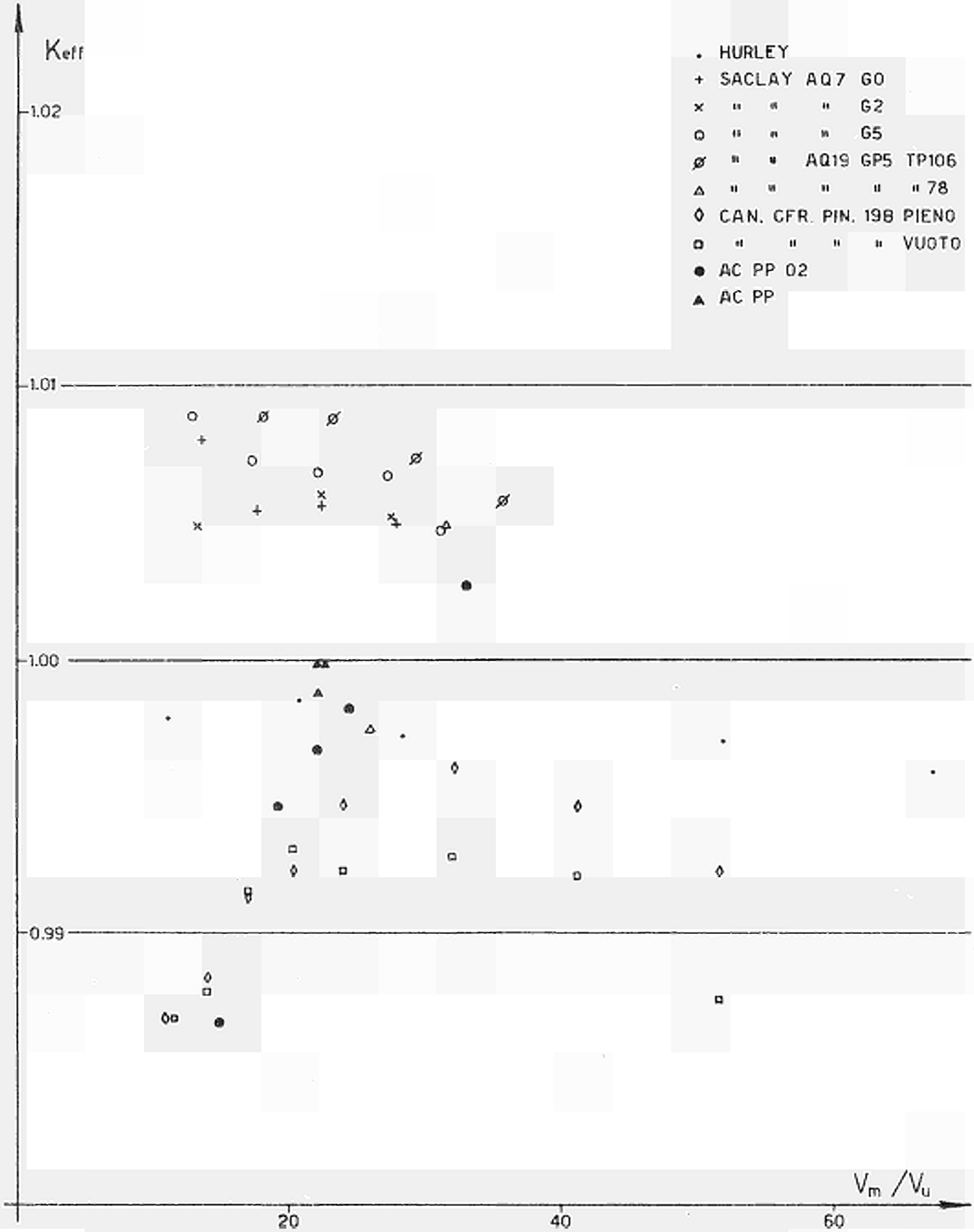



Fig. 48 - PROCELLA check vs. experiments: summary of $k_{eff}(B_m^2)$ for U metal clusters.

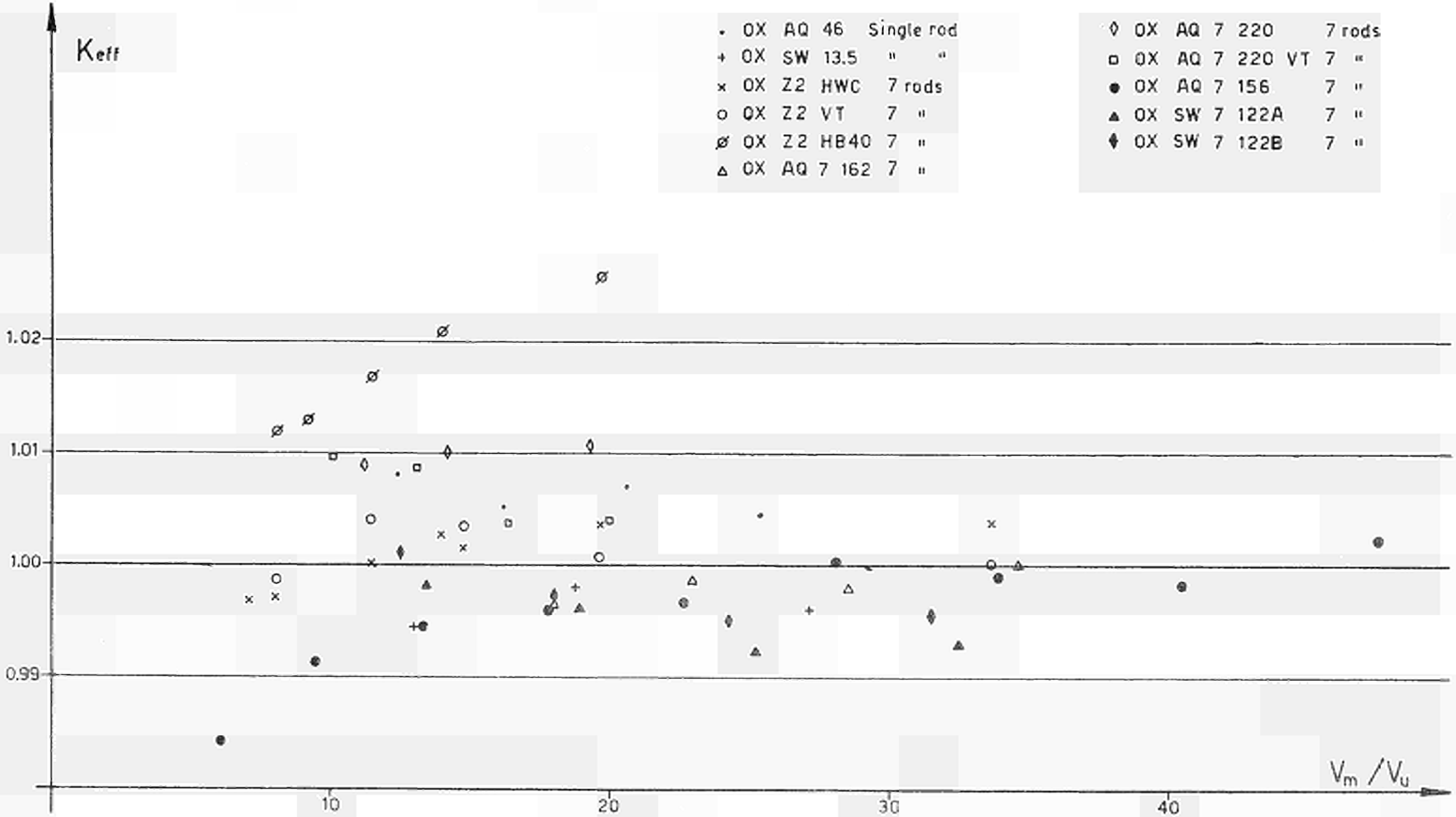



Fig. 49 - PROCELLA check vs. experiments: summary of $k_{eff}(B_m^2)$ for $UO_2$ single rods and 7-rod clusters.

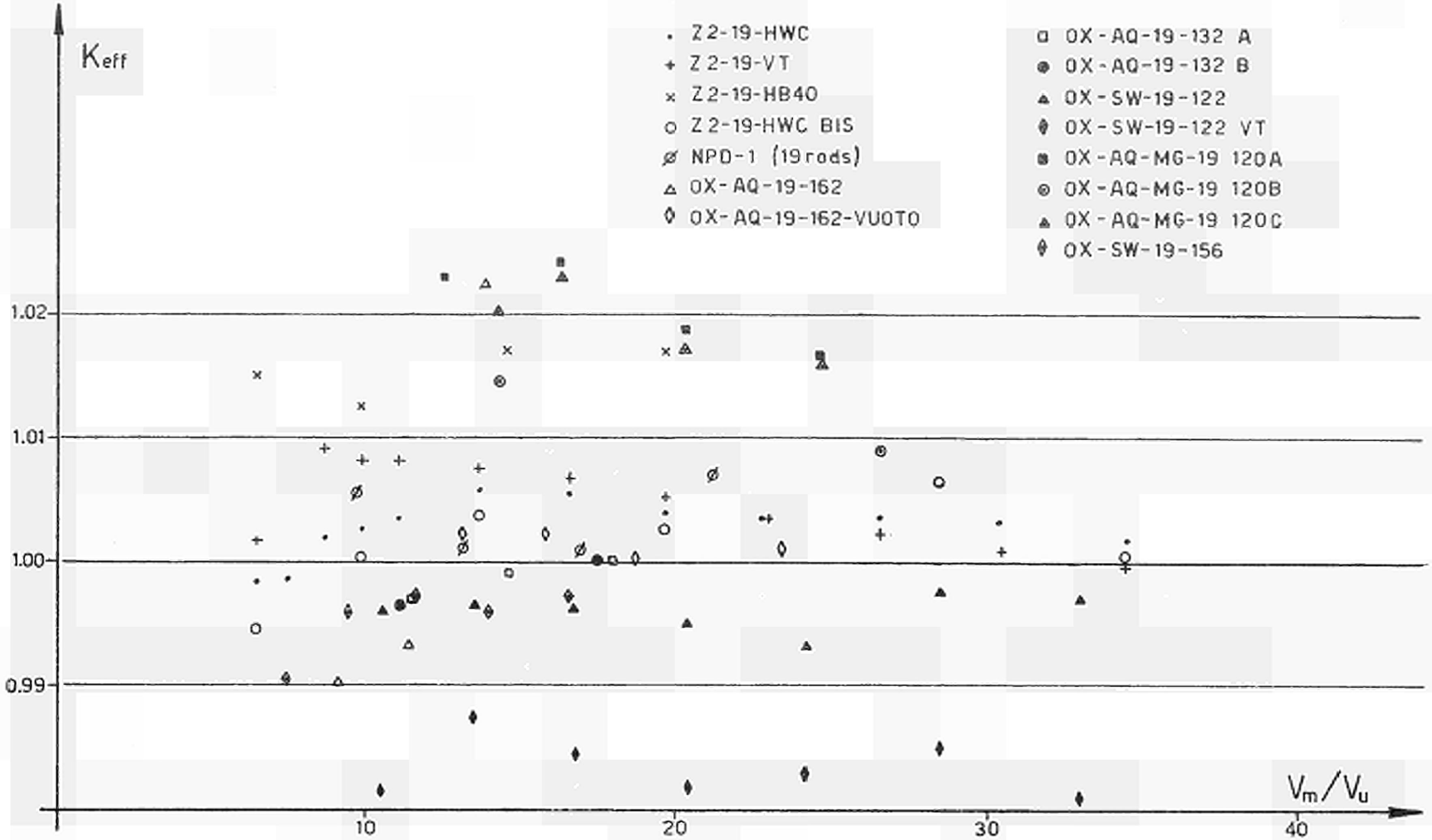



Fig. 50 - PROCELLA check vs. experiments: summary of $k_{eff}(B_m^2)$ for $UO_2$ 19-rod clusters.

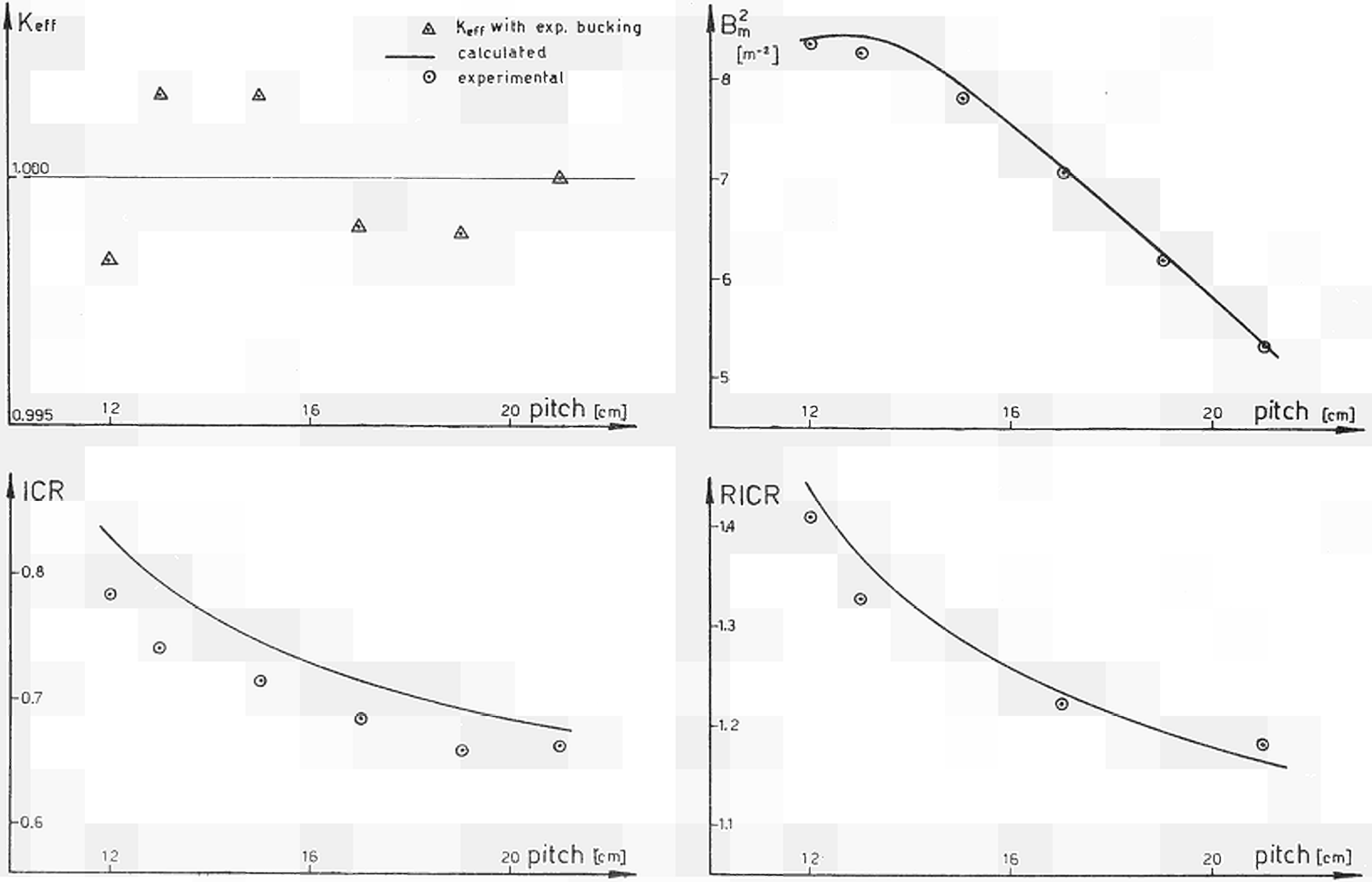



Fig. 51 - PROCELLA check vs. experiments; $k_{eff}(B_m^2)$, $B_m^2$, ICR, RICR for Saclay AQ-292 metal rods (Ref. 24)

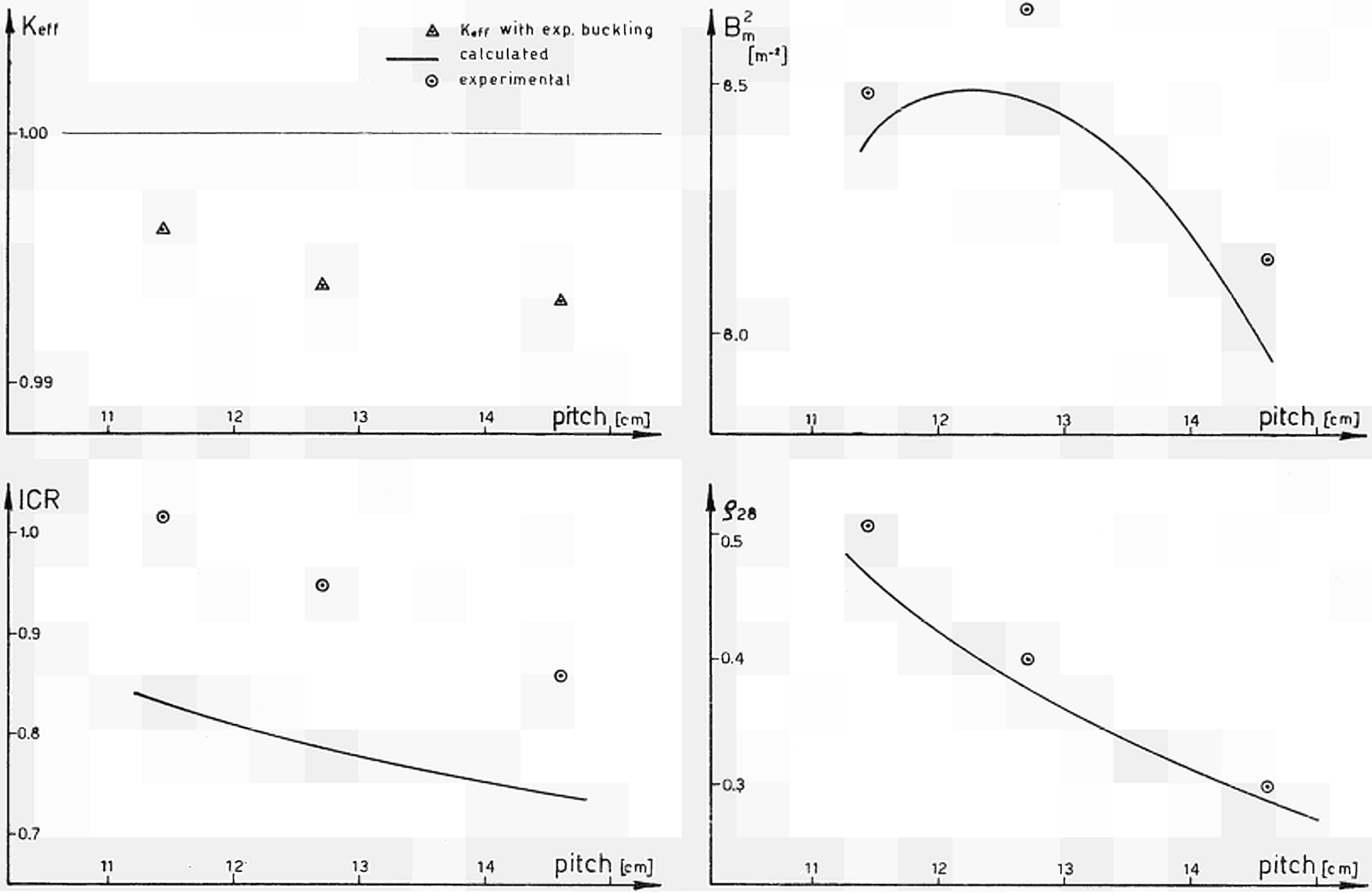



Fig. 52 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, ICR, $\rho_{28}$ for MIT natural U metal rods (Ref. 25).

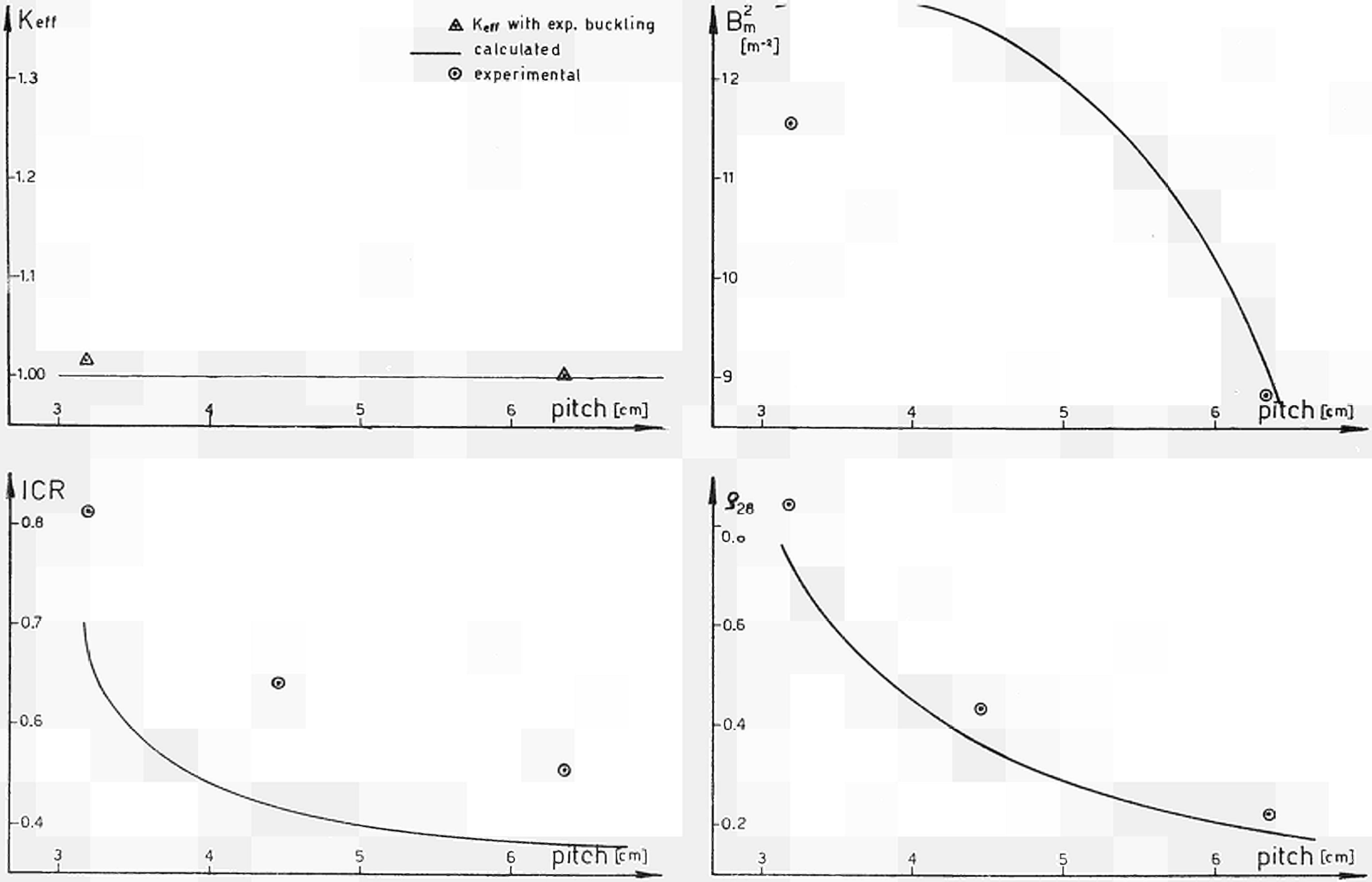



Fig. 53 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, ICR, $\rho_{28}$ for MIT 1.03% enriched U metal rods (Ref. 25).

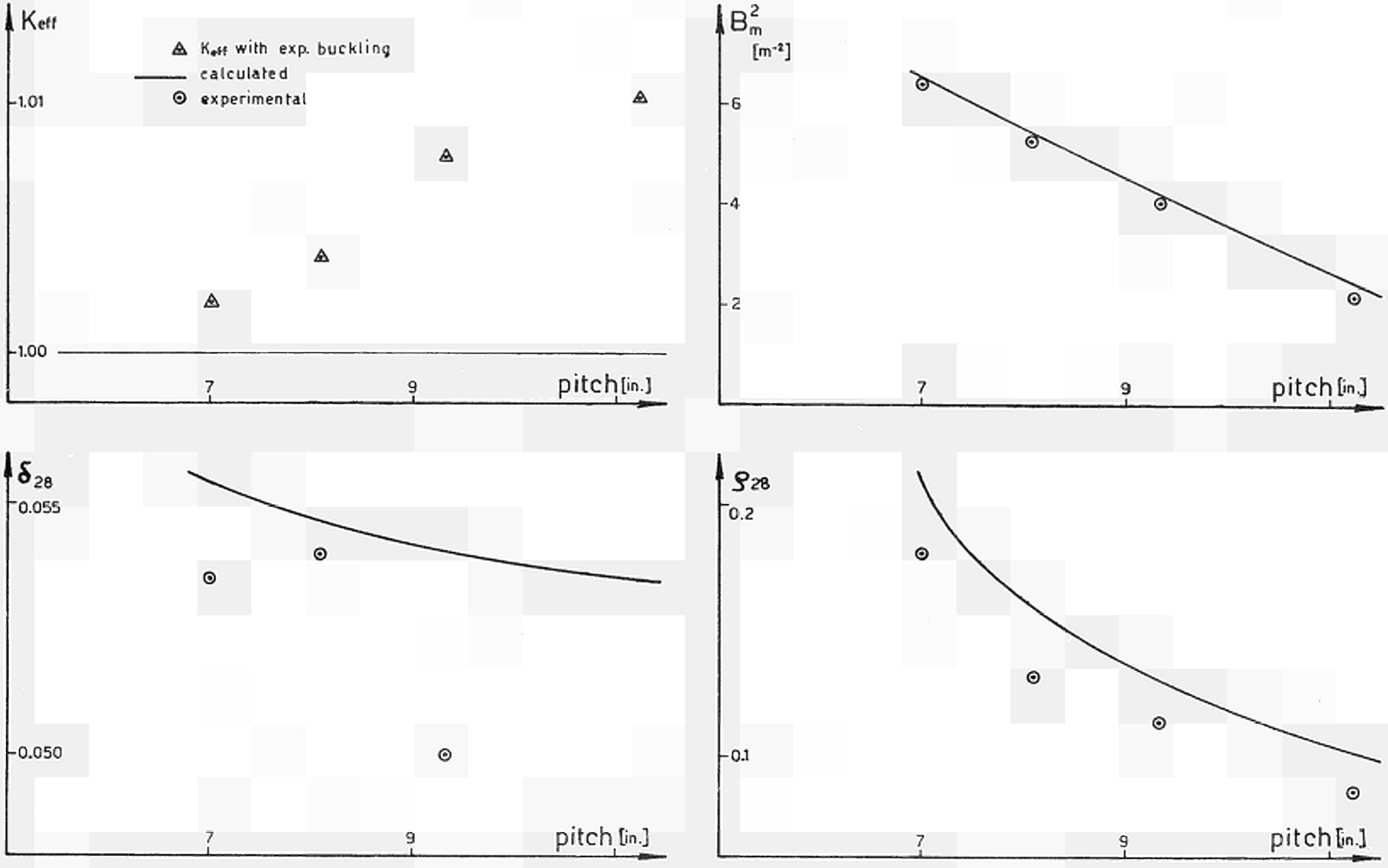



Fig. 54 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, $\rho_{28}$ for Savannah River natural U metal rods (Ref. 26).

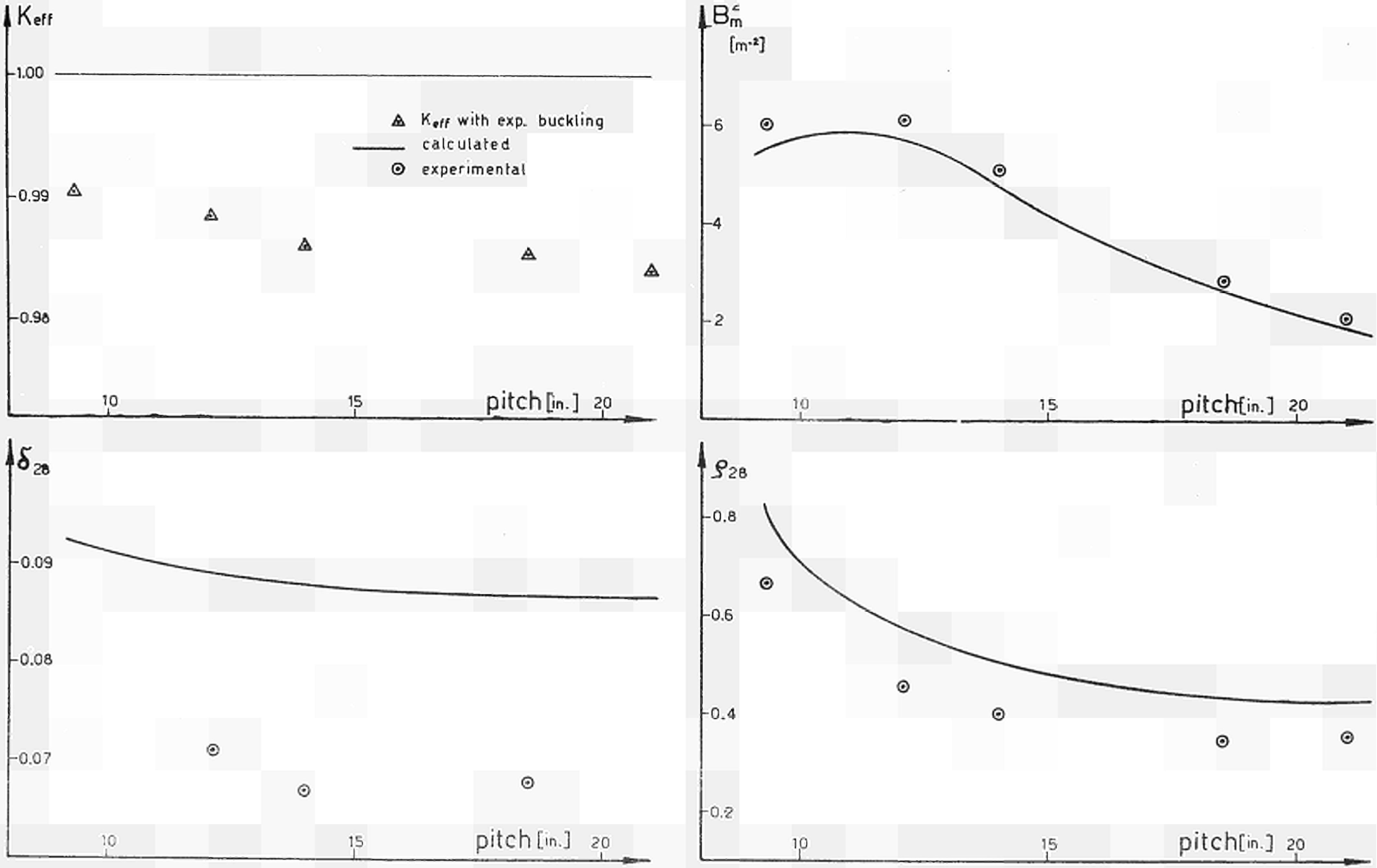



Fig. 55 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, $\rho_{28}$ for Savannah River U metal 7-rod clusters (Ref. 26).

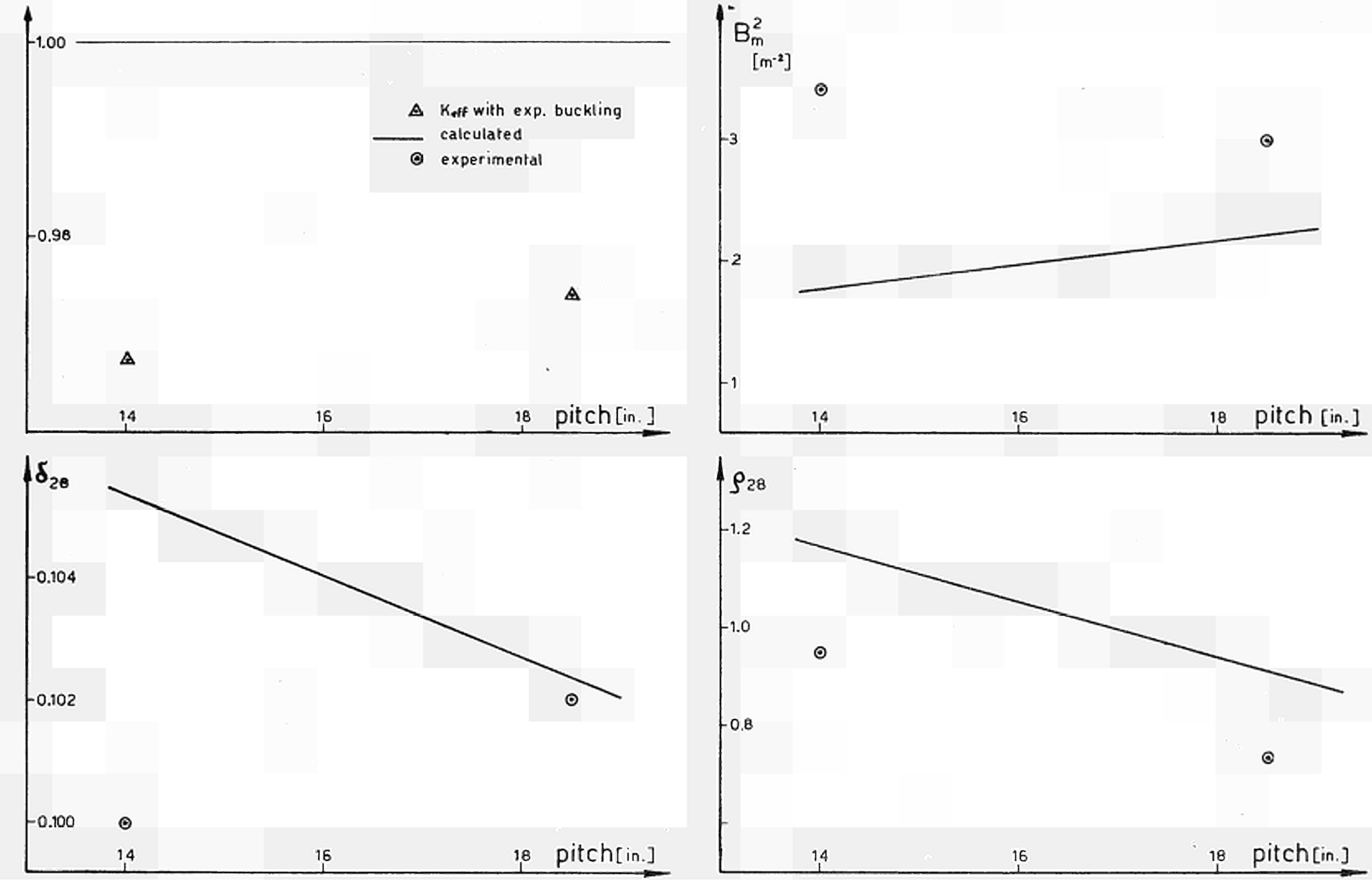





Fig. 56 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, $\rho_{28}$ for Savannah River U metal 19-rod clusters (Ref. 26).

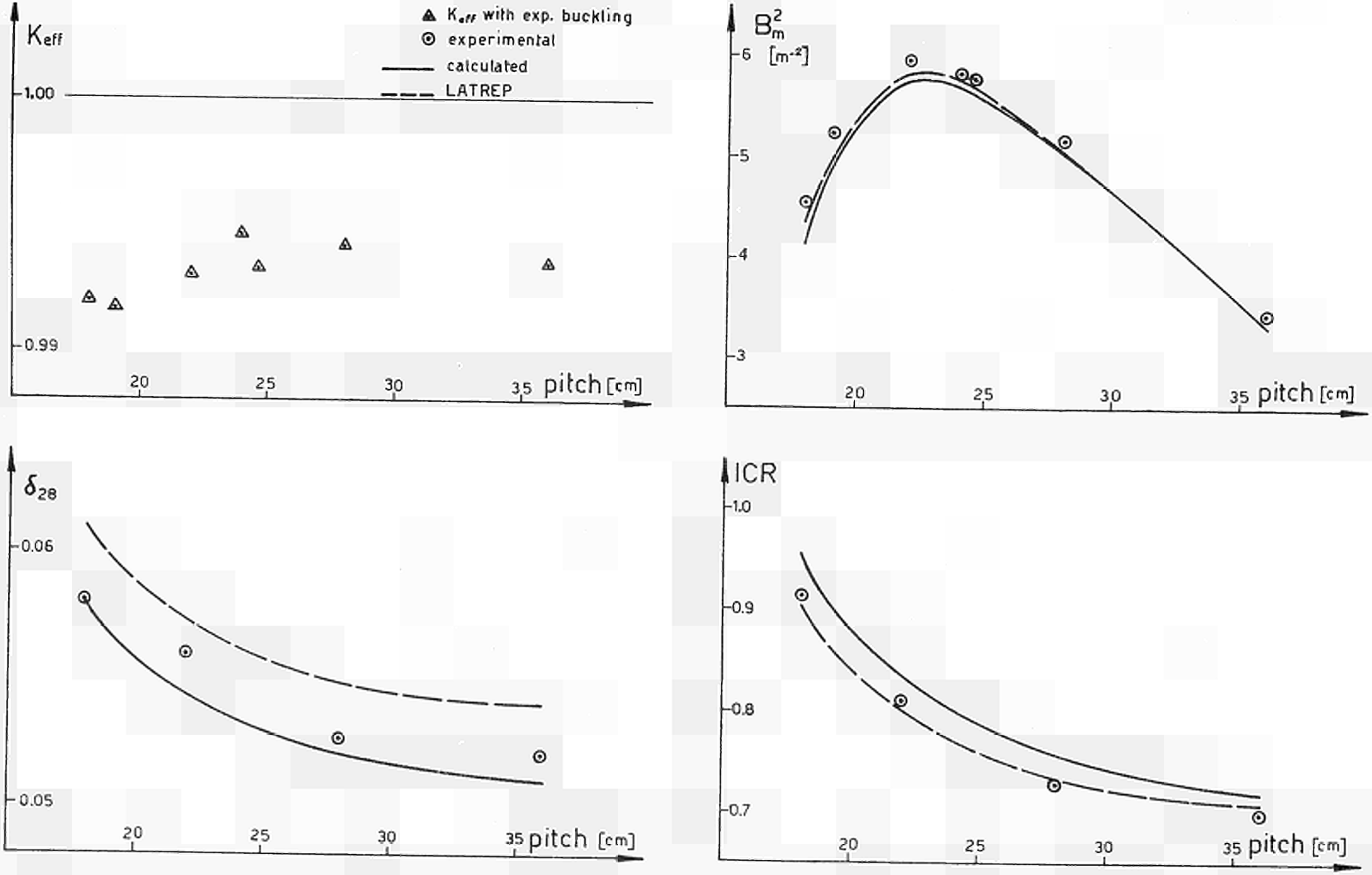



Fig. 57 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 7-rod clusters; coolant: $D_2O$ (Ref. 19).

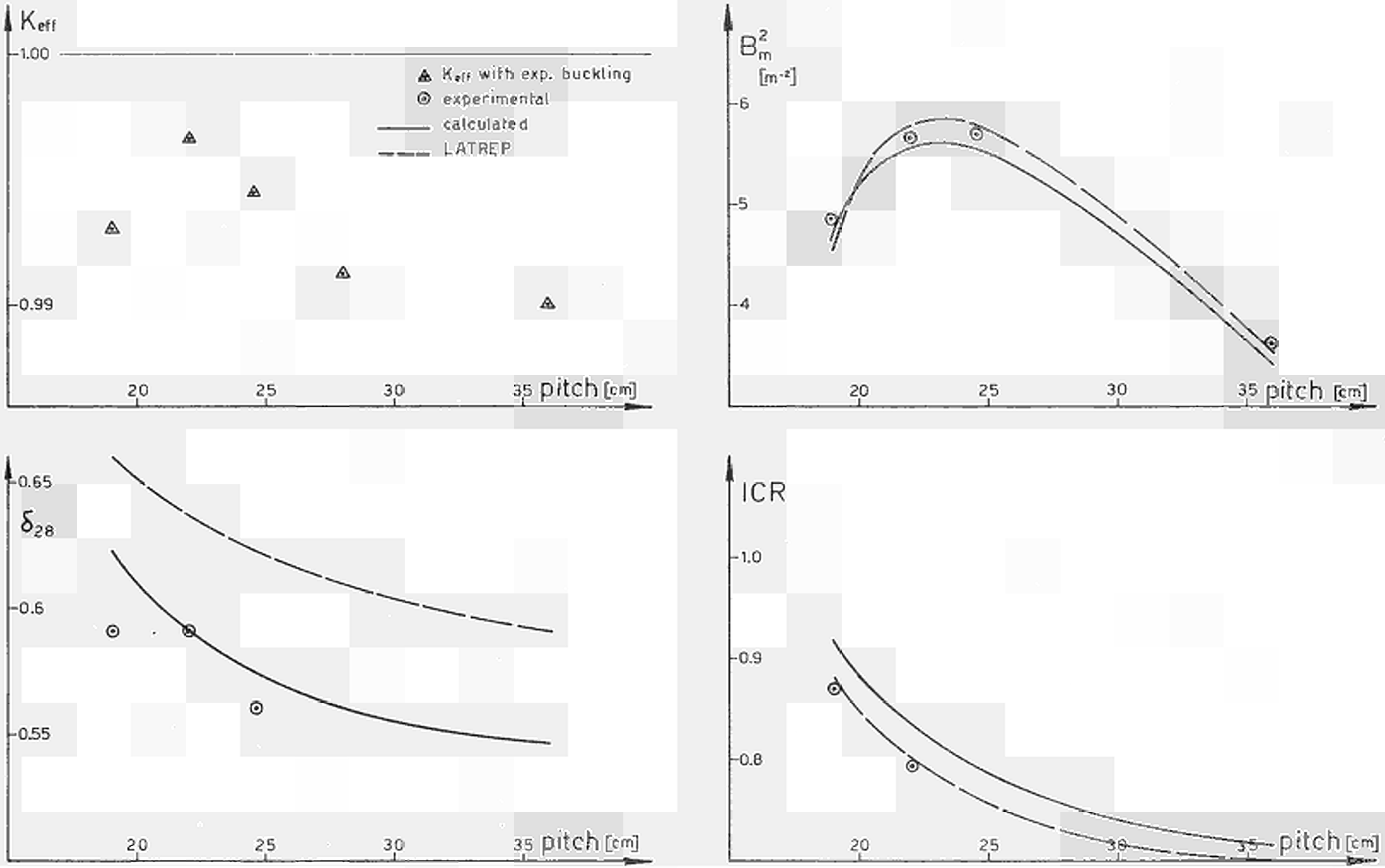



Fig. 58 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 7-rod clusters; coolant: air (Ref. 19).

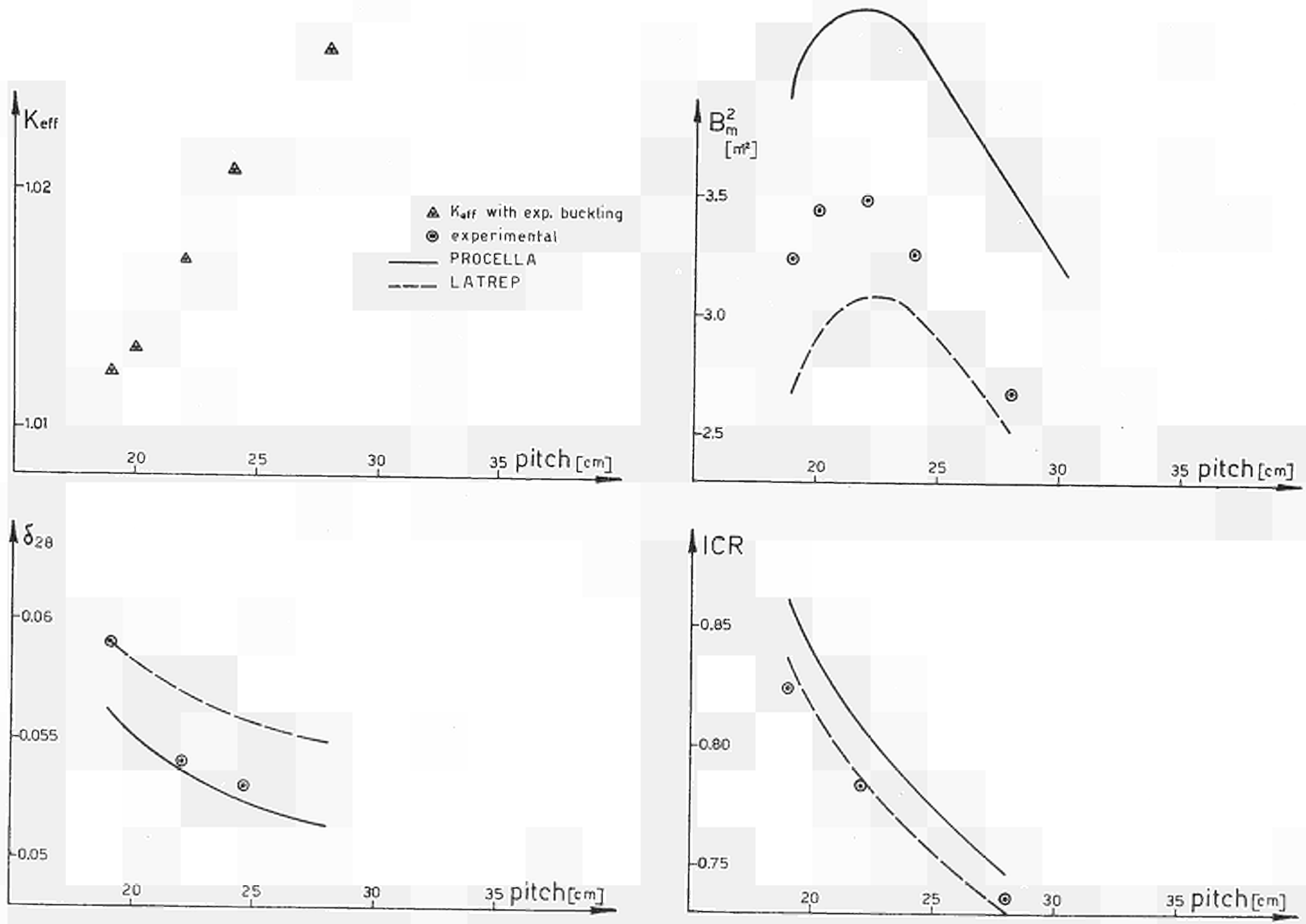



Fig. 59 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 7-rod clusters; coolant: HB40 (Ref. 19).

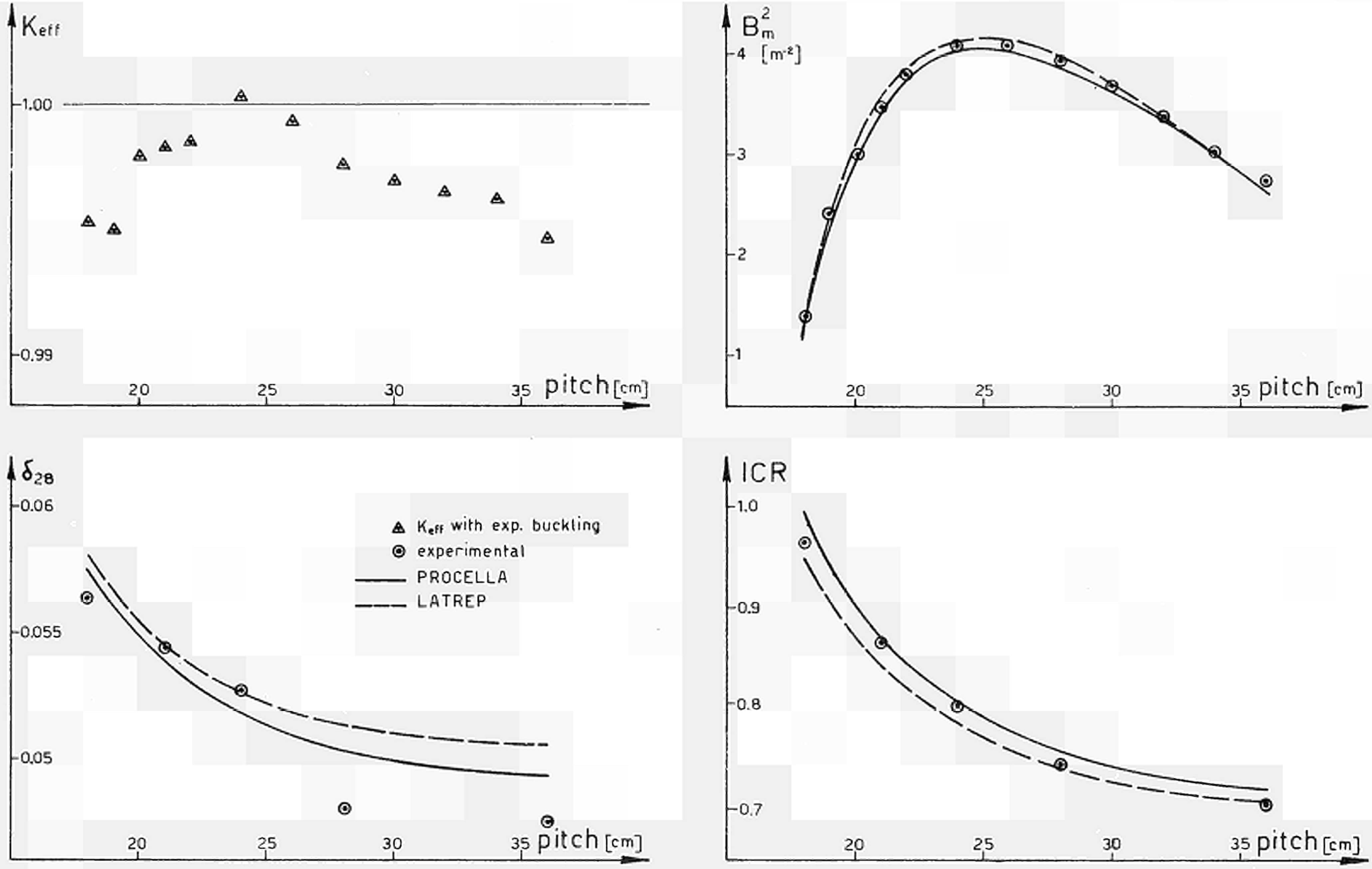



Fig. 60 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 19-rod clusters; coolant: $D_2O$ (Ref. 19)

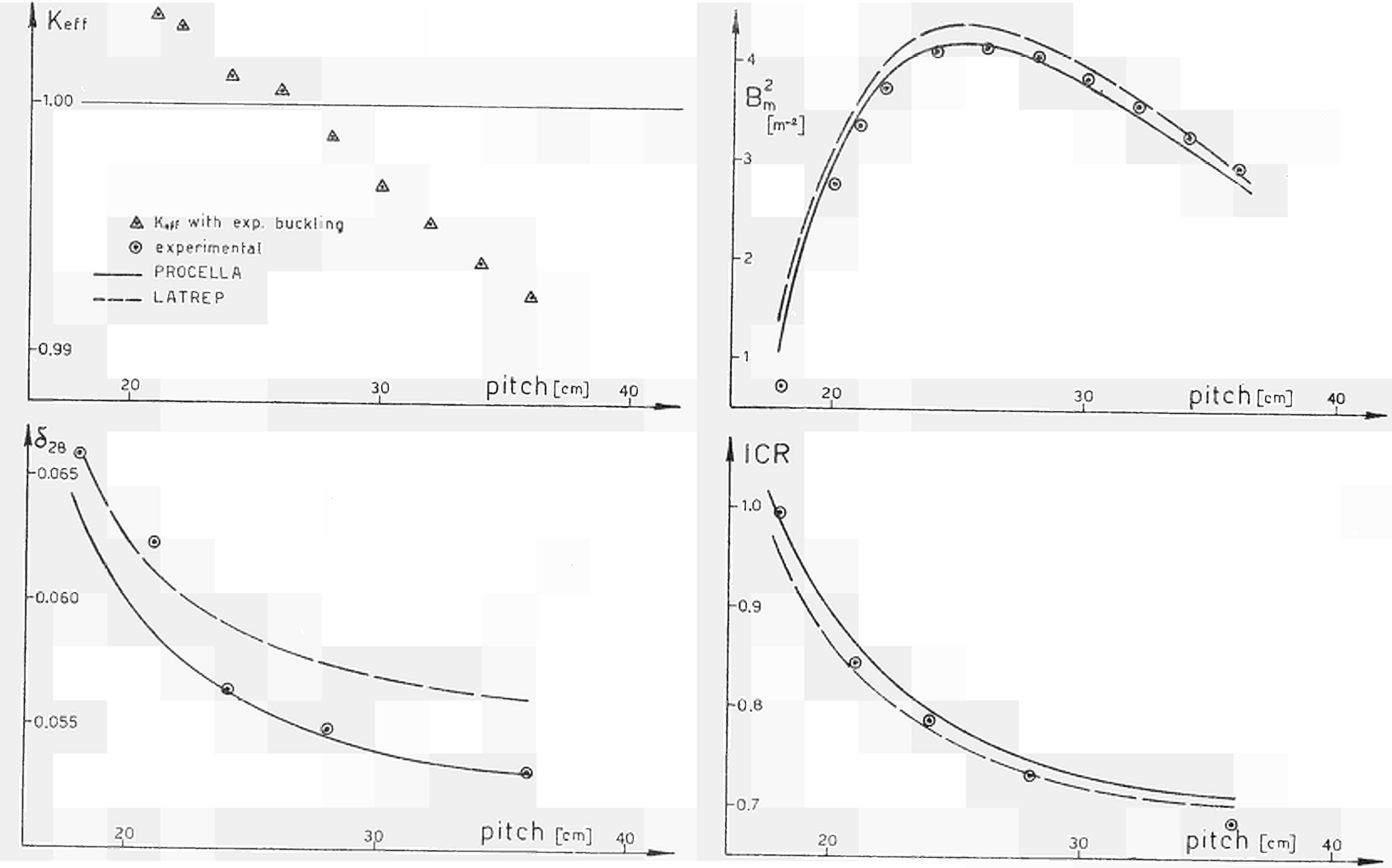



Fig. 61 - PROCELLA check vs. experiments: $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 19-rod clusters; coolant: air (Ref. 19).

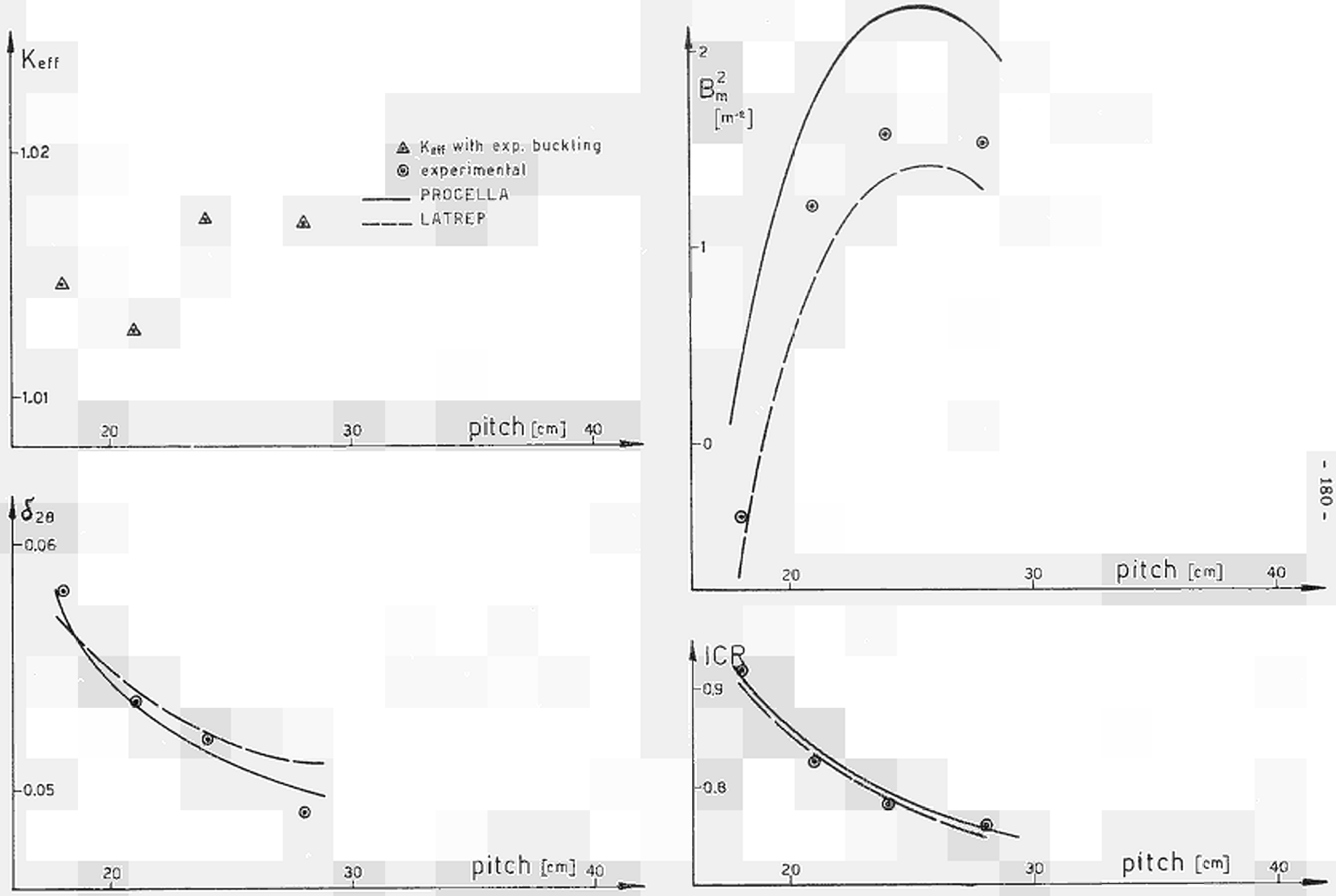



Fig. 62 - PROCELLA check vs. experiments; $k_{eff}(B_m^2)$, $B_m^2$, $\delta_{28}$, ICR for Chalk River oxide 19-rod clusters; coolant: HB40 (Ref. 19).

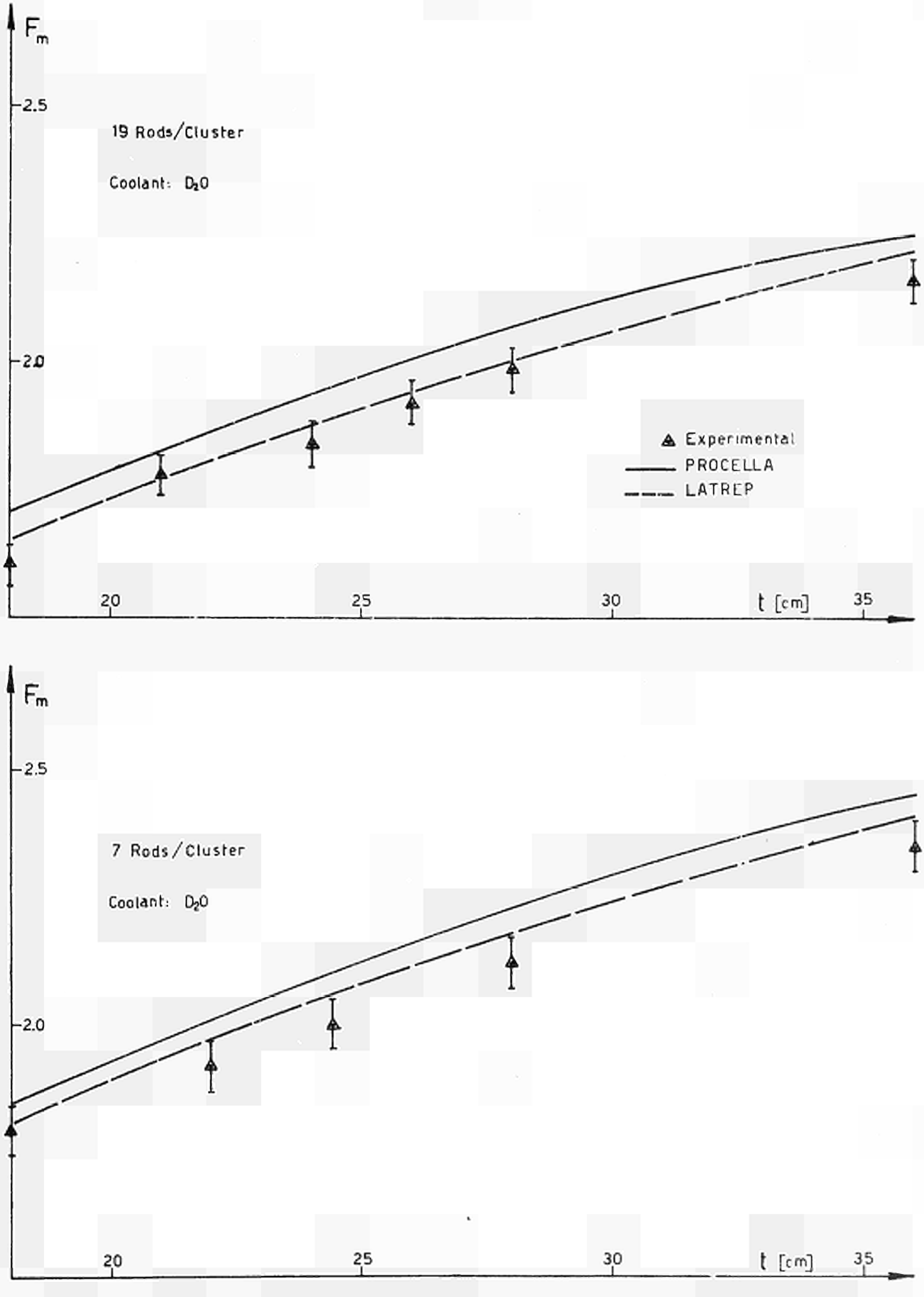
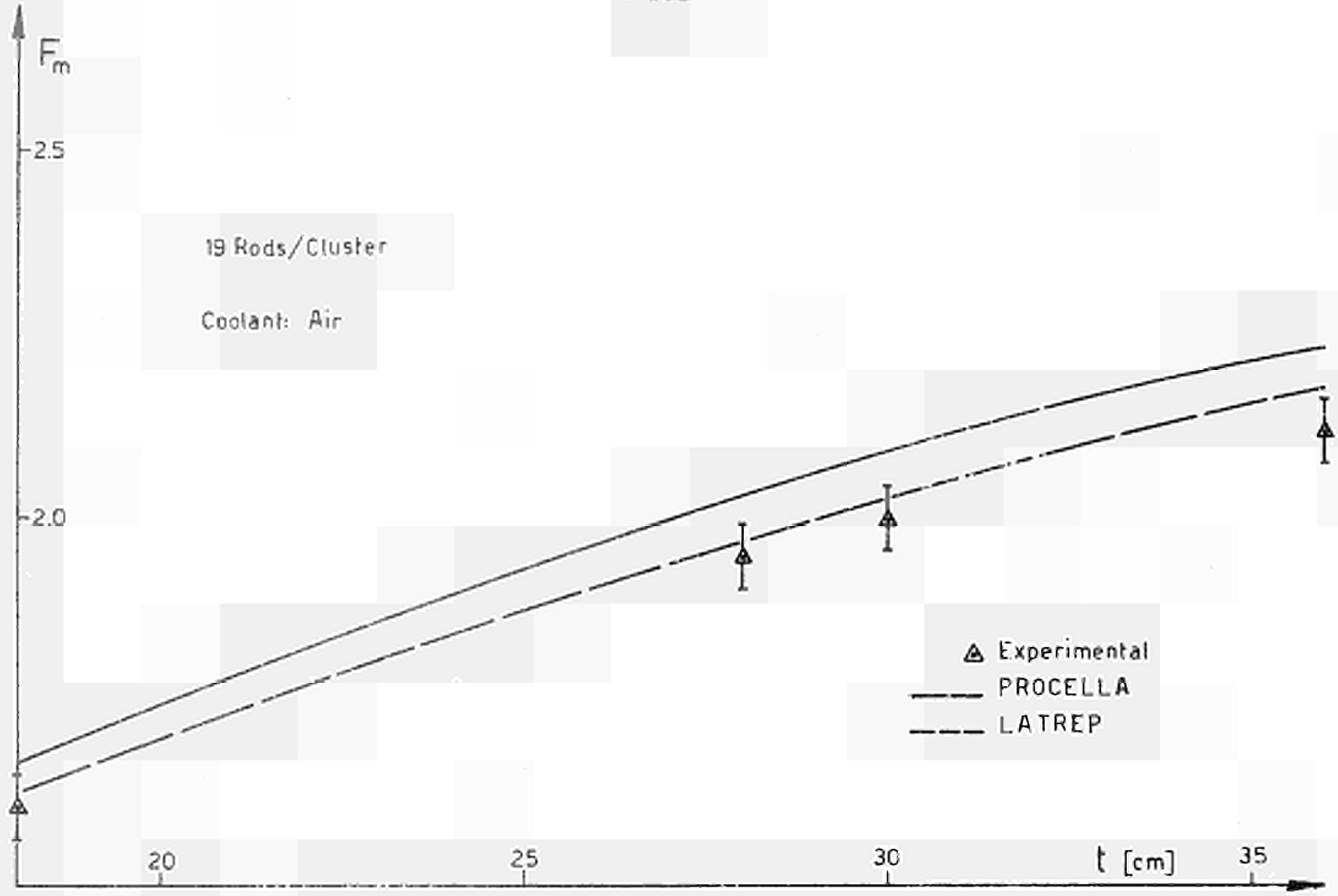



Fig. 63 - PROCELLA check vs. experiments; fuel-to-moderator neutron density ratio for oxide 7-rod and 19-rod clusters; coolant: $D_2O$ (Ref. 19).



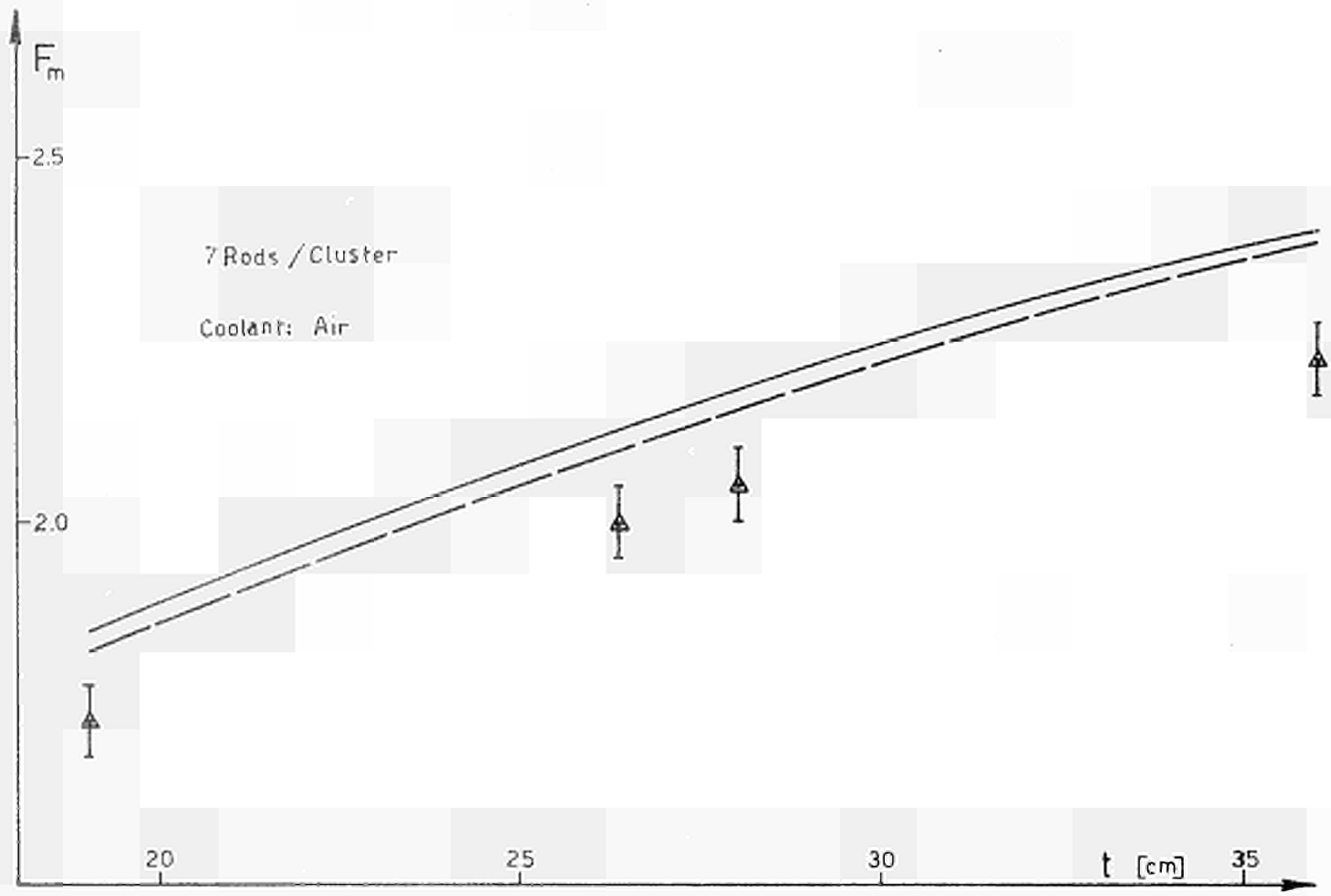
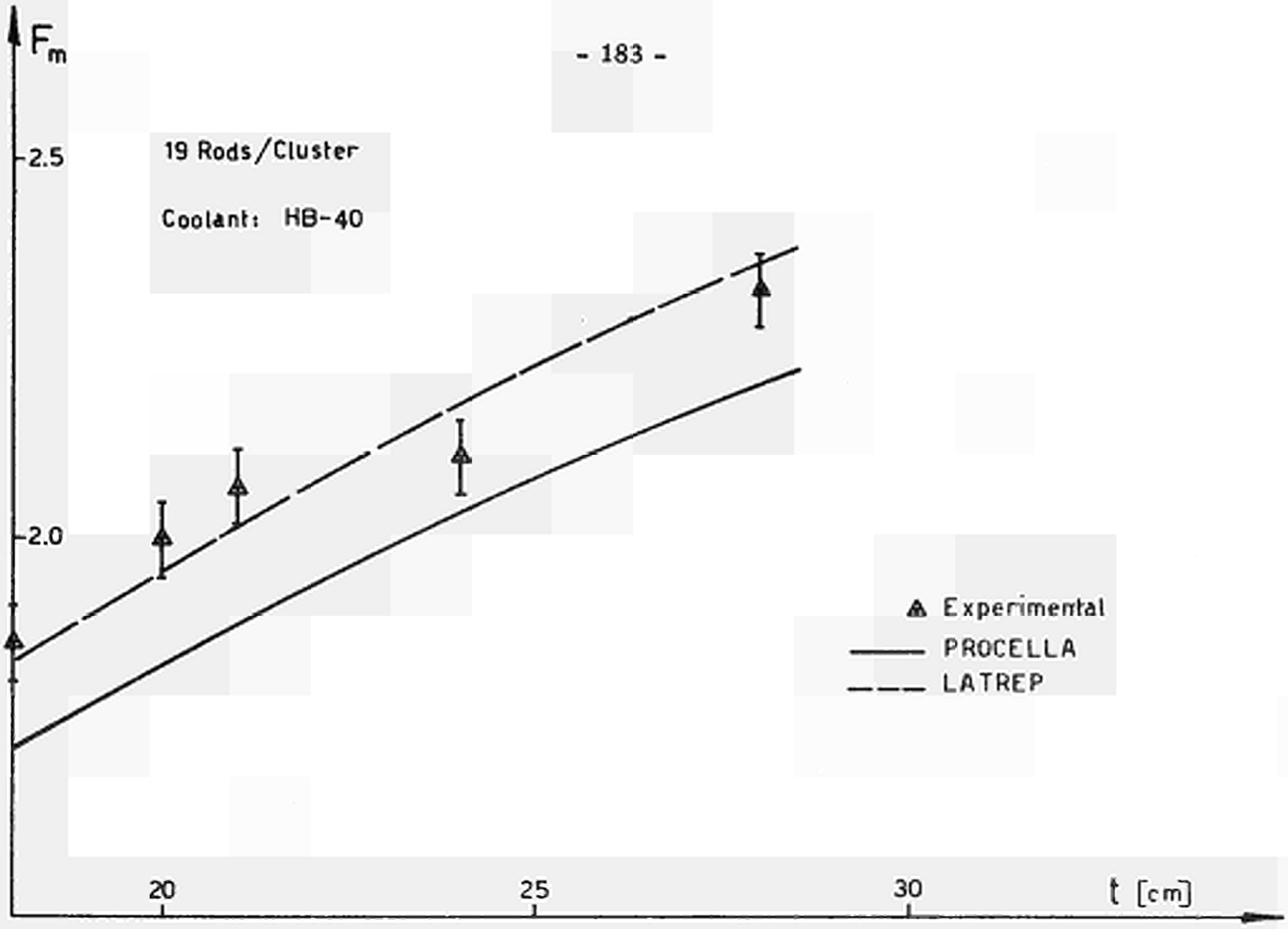




Fig. 64 - PROCELLA check vs. experiments; fuel-to-moderator neutron density ratio for oxide 7-rod and 19-rod clusters; coolant: air (Ref. 19).



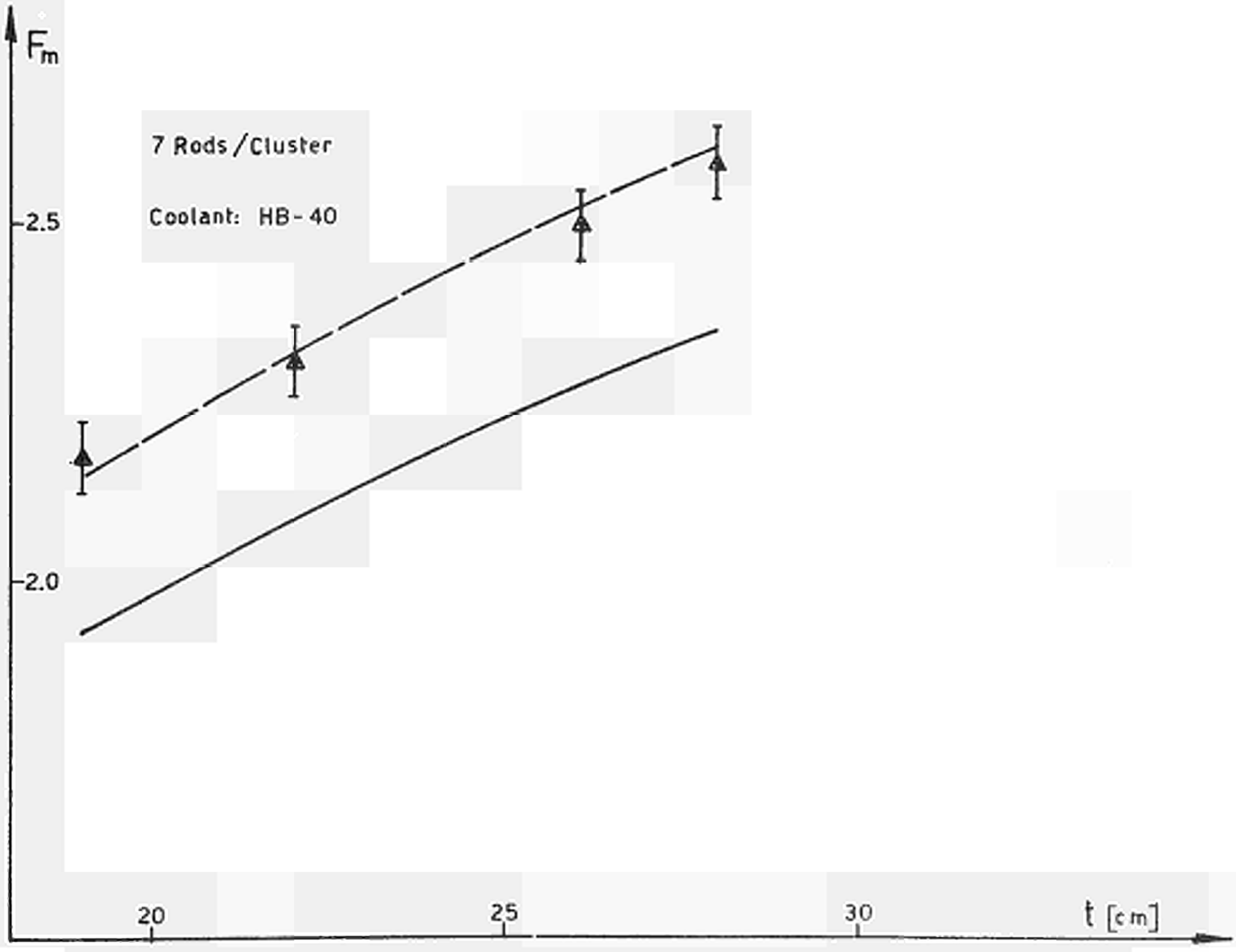




Fig. 65 - PROCELLA check vs. experiments: fuel-to-moderator neutron density ratio for oxide 7-rod and 19-rod clusters; coolant: HB40 (Ref. 19).

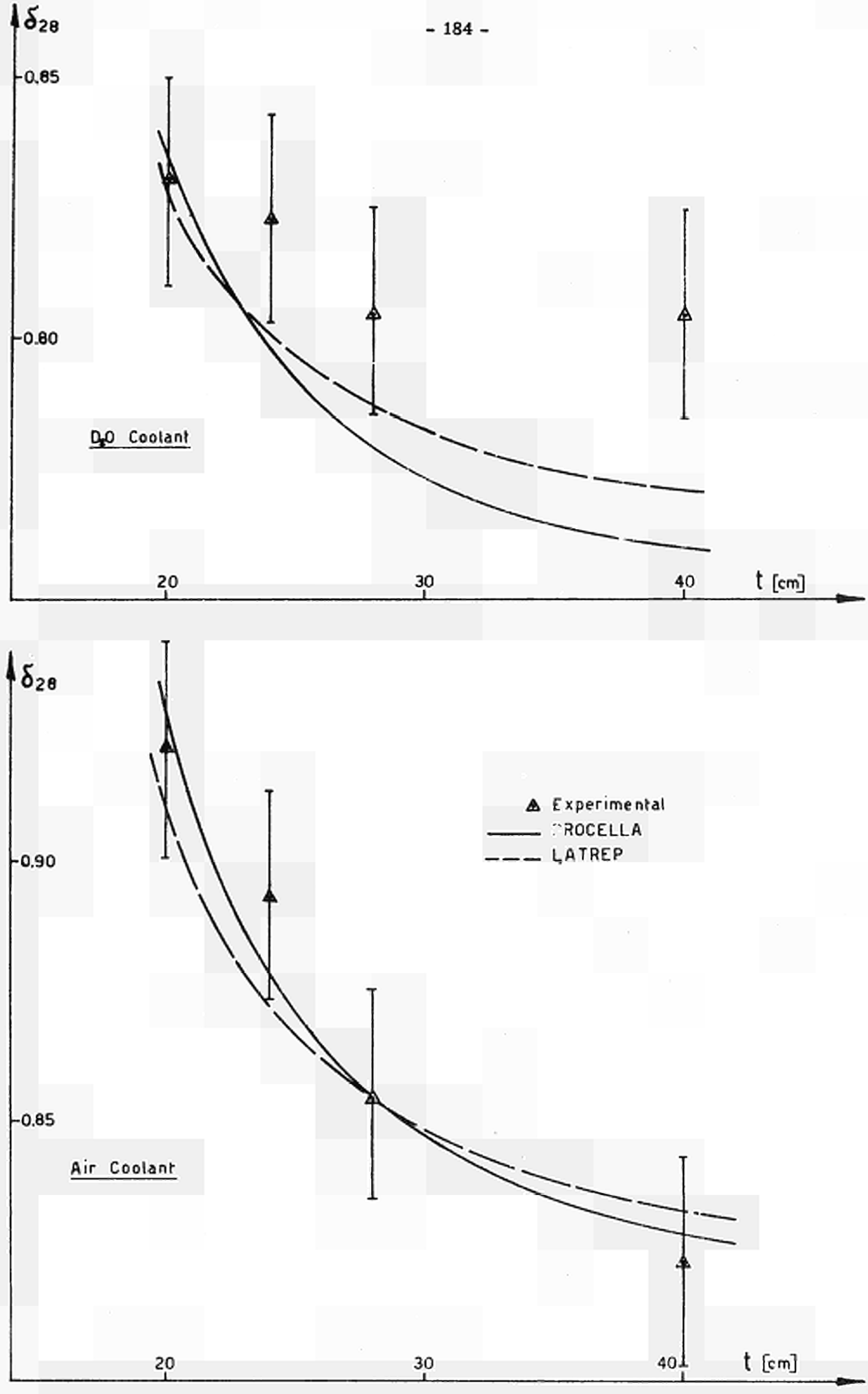
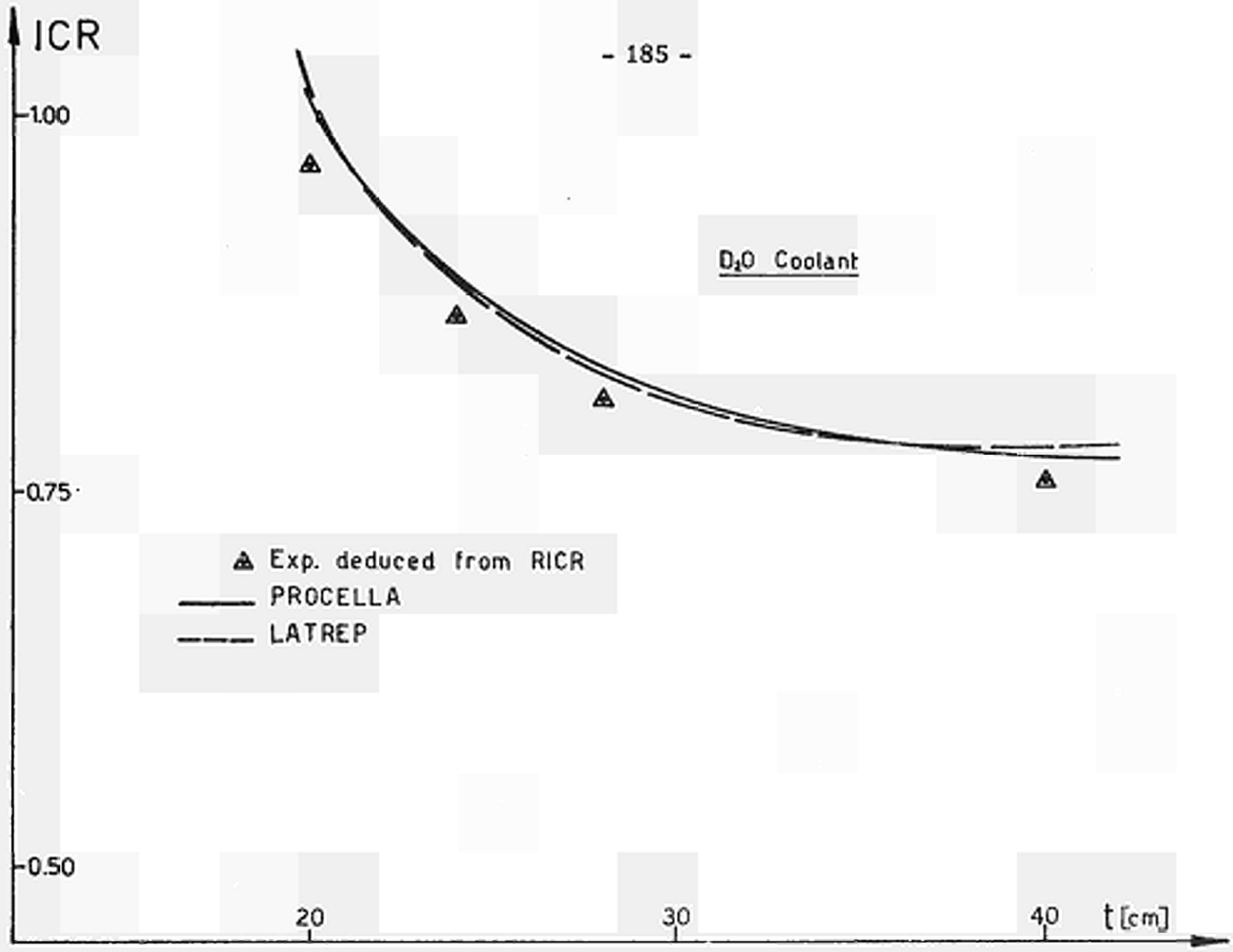



Fig. 66 - PROCELLA check vs. experiments; $\delta_{28}$ for Chalk River natural U metal 19-rod clusters (Ref. 22).



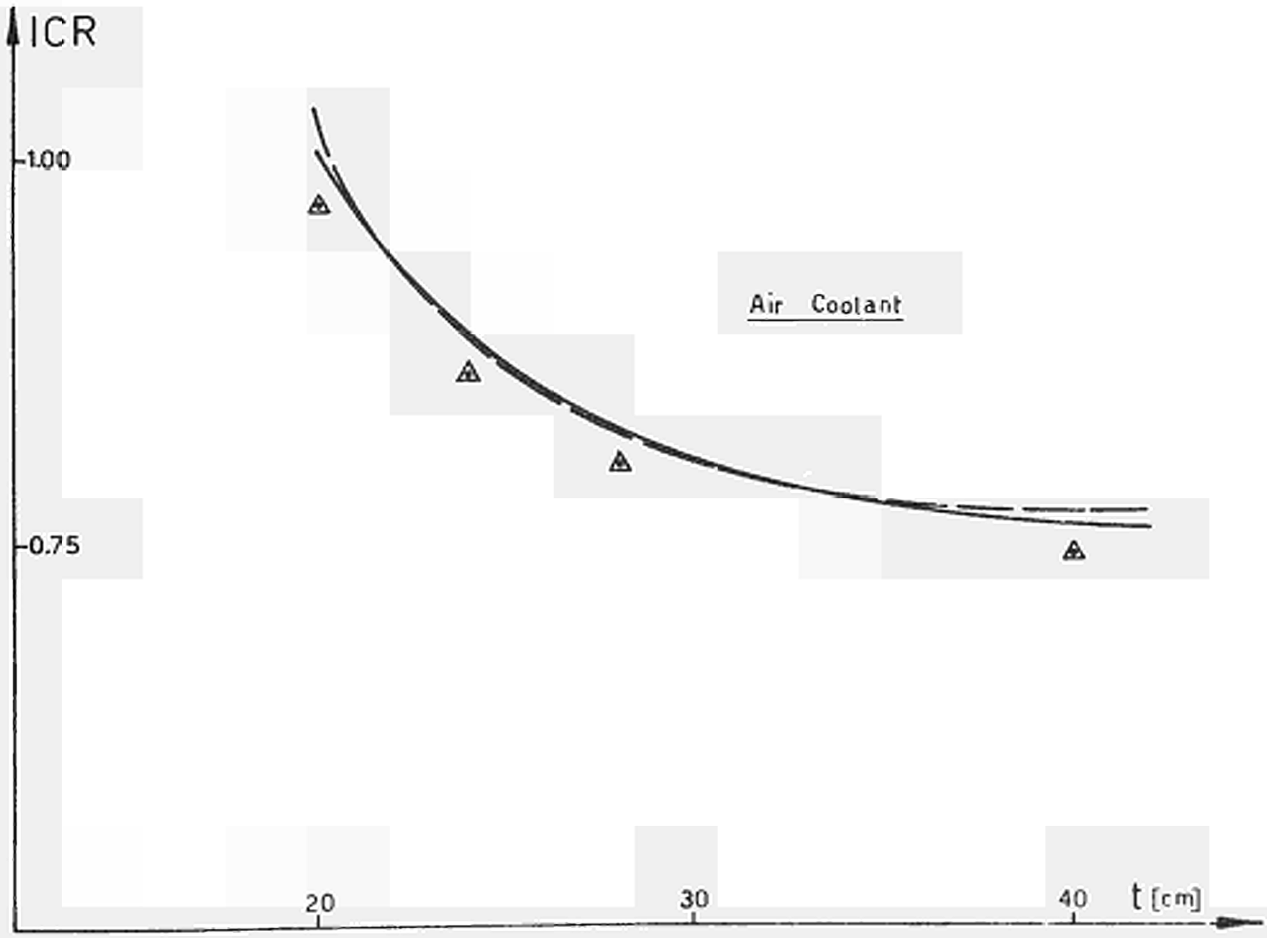
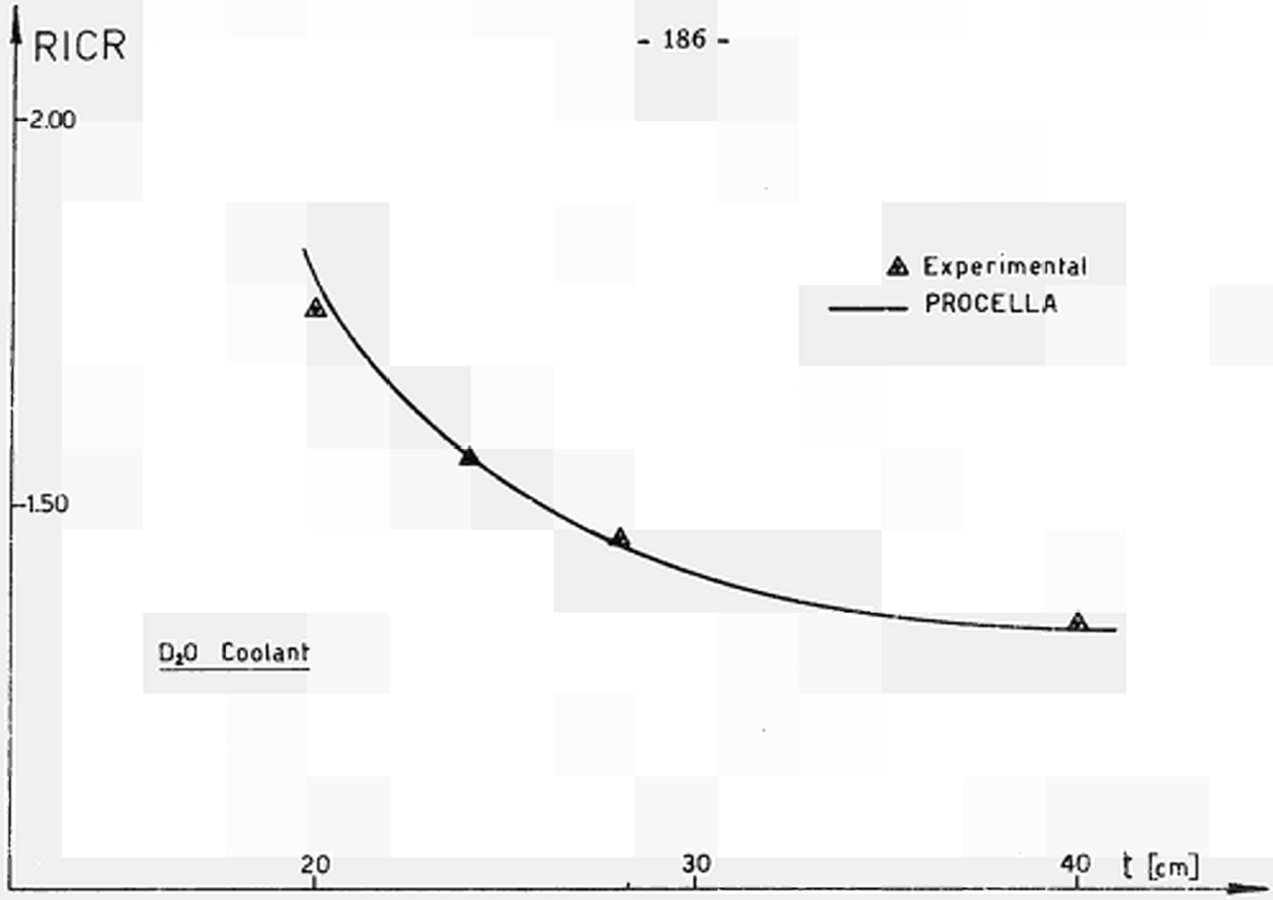




Fig. 67 - PROCELLA check vs. experiments: ICR for Chalk River natural U metal 19-rod clusters (Ref. 22).



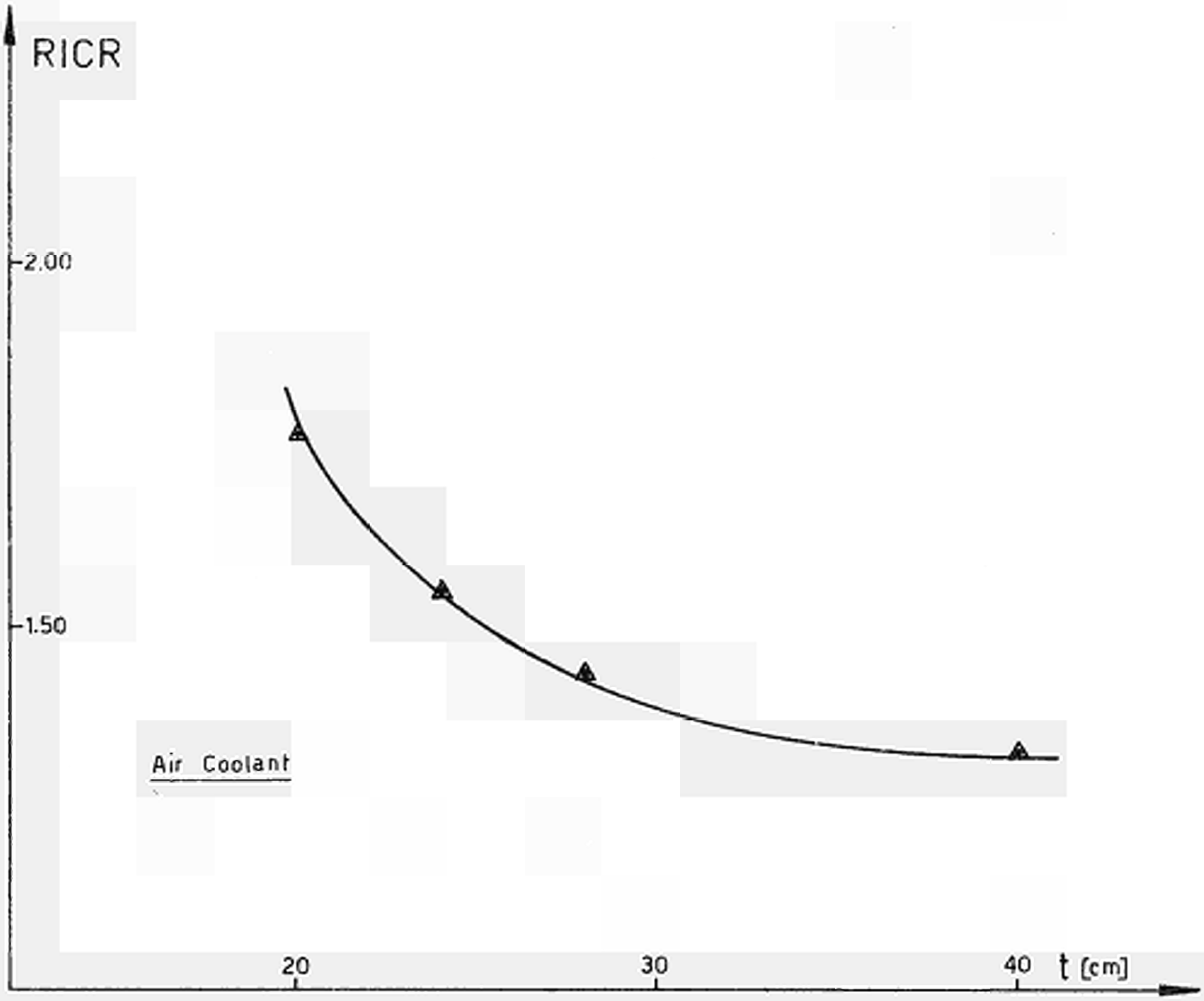




Fig. 68 - PROCELLA check vs. experiments: RICR for Chalk River natural U metal 19-rod clusters (Ref. 22).

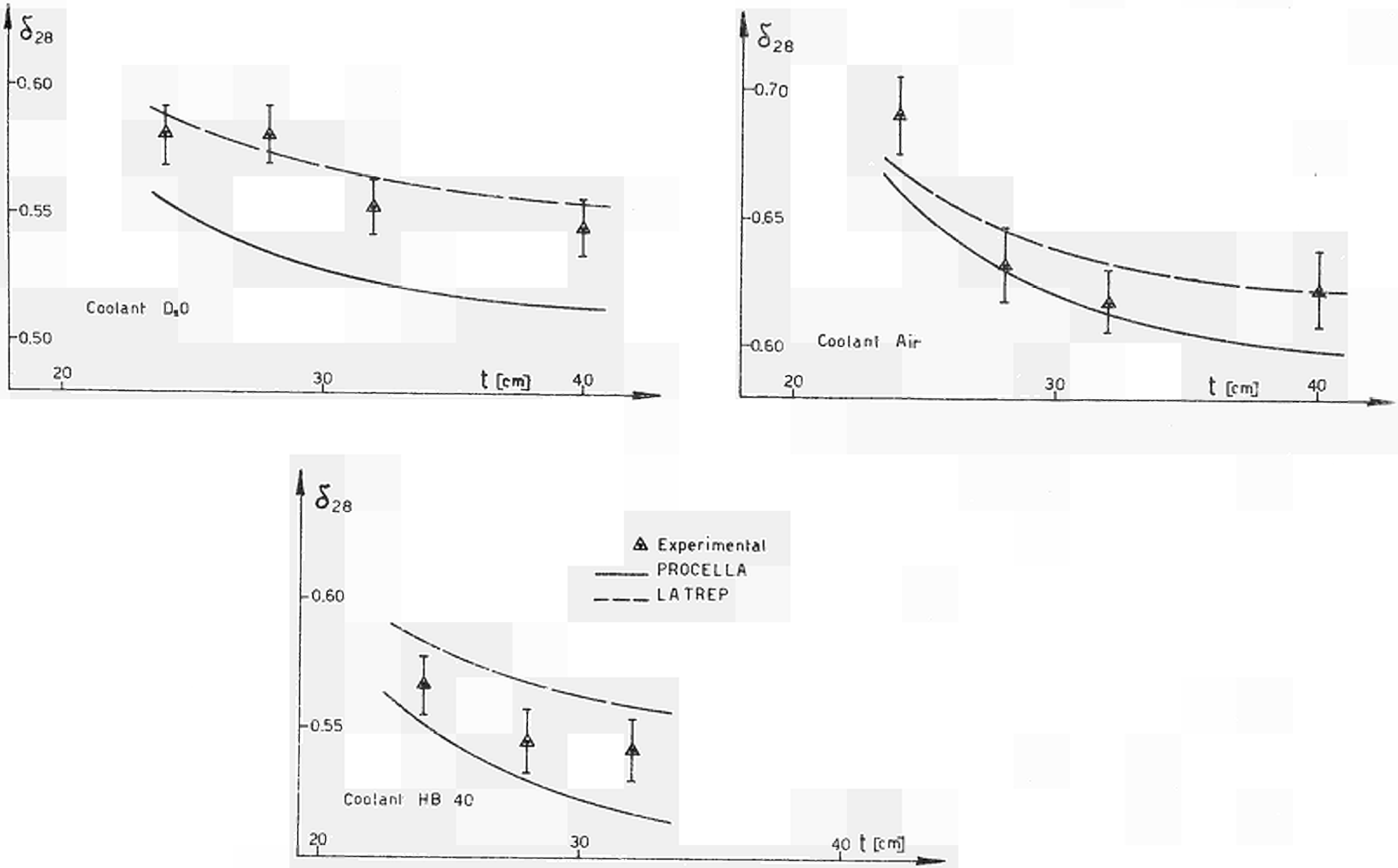



Fig. 69 - PROCELLA check vs. experiments: $\delta_{28}$ for Chalk River oxide 28-rod clusters (Ref. 27).

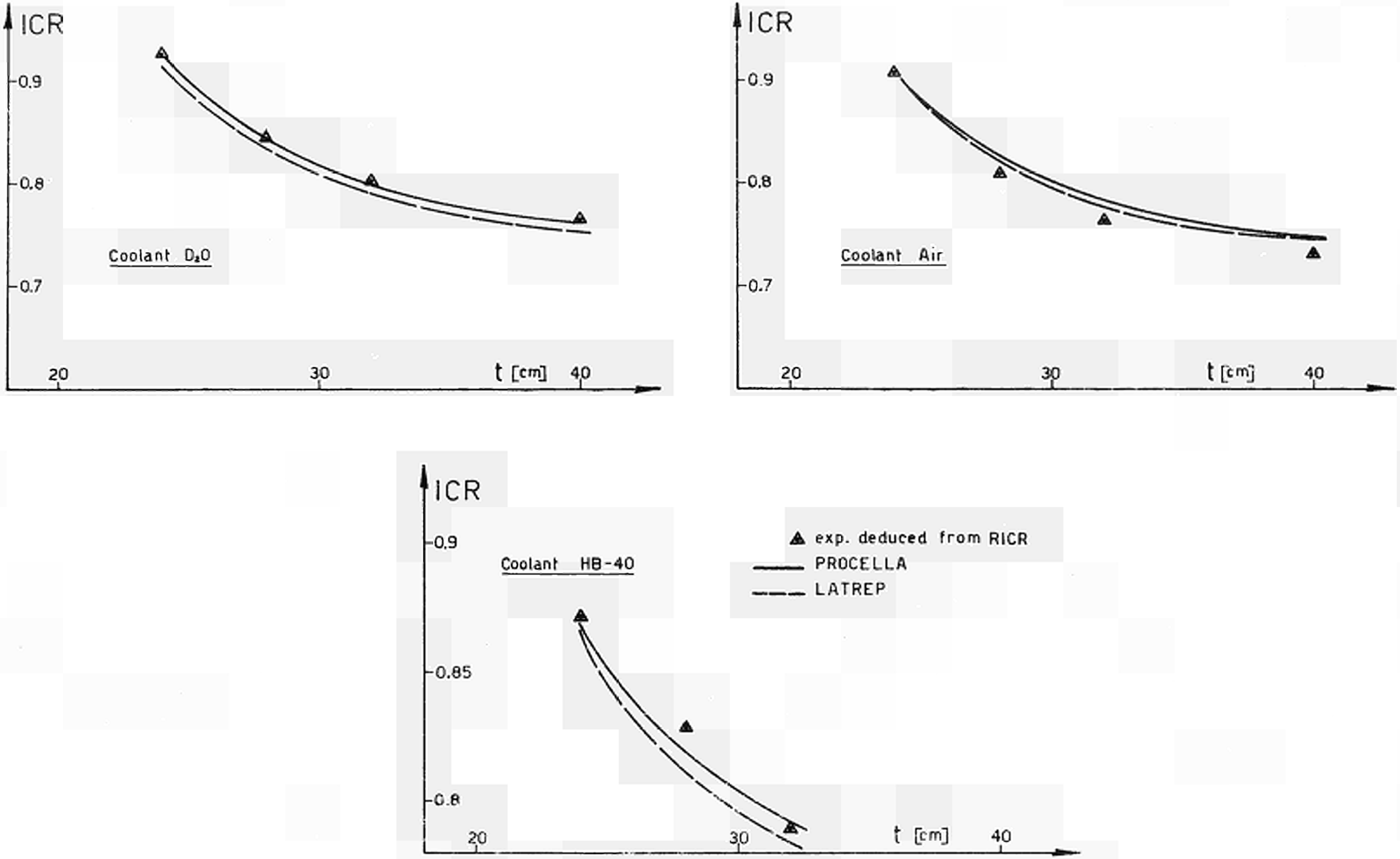



Fig. 70 - PROCELLA check vs. experiments: ICR for Chalk River oxide 28-rod clusters (Ref. 27).

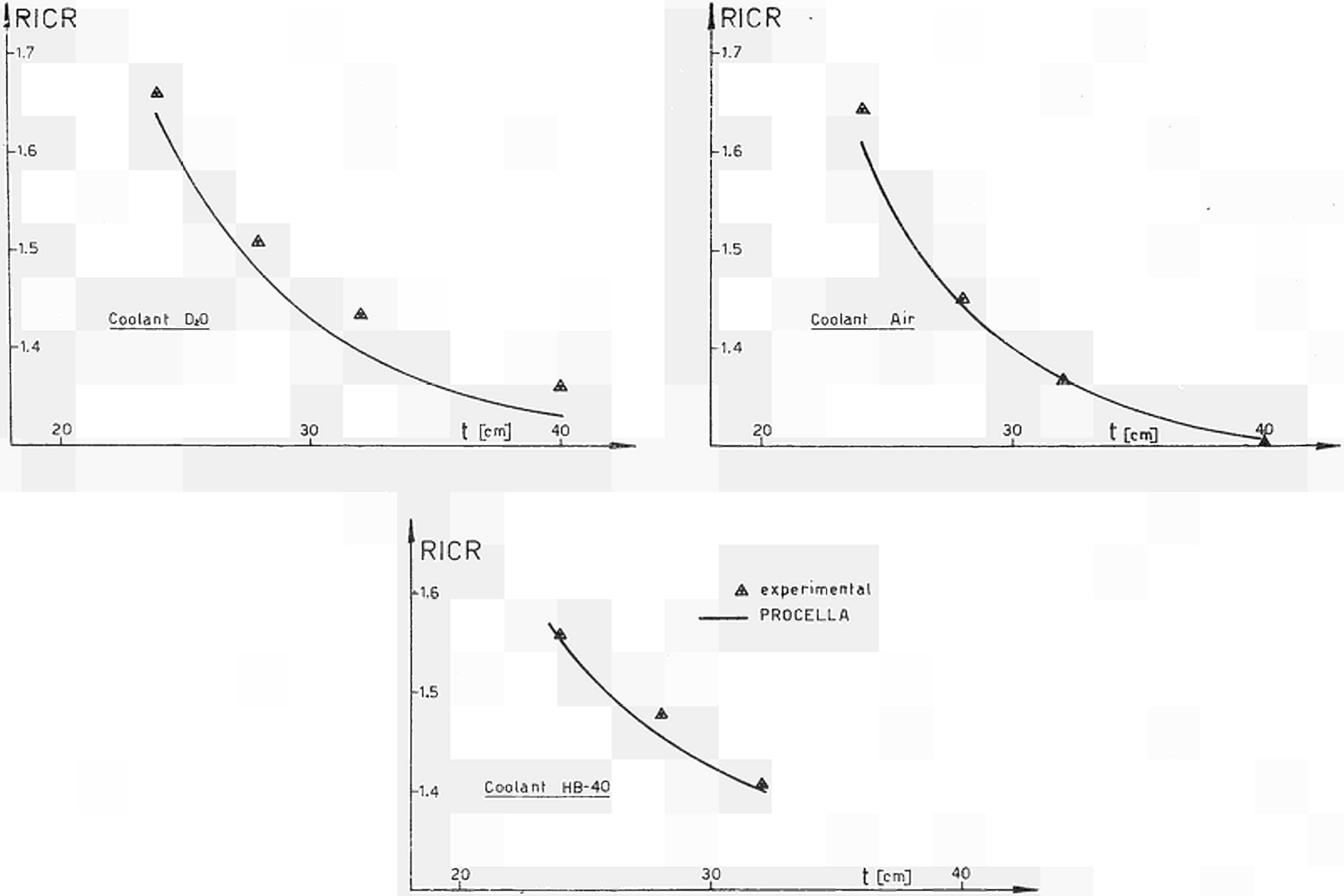



Fig. 71 - PROCELLA check vs. experiments: RICR for Chalk River oxide 28-rod clusters (Ref. 27).

# P R O C E L L A

Sample problem

**CISE**

# DATA (Zones de 10 colonnes)

PROBLEM: INPUT ØF PRØCELLA | DATE | PAGE 1 | Ø7 LIBRARY DECK

| Row | Col. 1–20 | Col. 21–40 | Col. 41–60 | Col. 61–80 | Col. 81–100 | Notes |
|---|---|---|---|---|---|---|
| 1 | NUNUTA | | | | | |
| 2 | | TARGA(I) | | | | |
| 3 | IX(I) NTE(I) | | | | | |
| 4 | SEZIØ(1,L,I) | SEZIØ(2,L,I) | SEZIØ(3,L,I) | SEZIØ(4,L,I) | SEZIØ(5,L,I) | L=1,NTE(I) |
| 5 | SEZIØ(6,L,I) | SEZIØ(7,L,I) | SEZIØ(8,L,I) | SEZIØ(9,L,I) | SEZIØ(10,L,I) | |
| 6 | SEZIØF(1,L,IFISS) | SEZIØF(2,L,IFISS) | SEZIØF(3,L,IFISS) | SEZIØF(4,L,IFISS) | SEZIØF(5,L,IFISS) | L=1,2 [only if IX(I) ≠ 2] |
| 7 | SEZIØF(6,L,IFISS) | SEZIØF(7,L,IFISS) | SEZIØF(8,L,IFISS) | SEZIØF(9,L,IFISS) | SEZIØF(10,L,IFISS) | |
| 8 | SEZ(1,I) | SEZ(2,I) | SEZ(3,I) | SEZ(4,I) | SEZ(5,I) | |
| 9 | SEZ(6,I) | SEZ(7,I) | SEZ(8,I) | SEZ(9,I) | SEZ(10,I) | |
| 10 | SEZ(11,I) | SEZ(12,I) | SEZ(13,I) | SEZ(14,I) | | |

Rows 2–10: NUNUTA blocks

**CISE**

# DATA (Zones de 10 colonnes)

PROBLEM: INPUT ØF PRØCELLA | DATE | PAGE 2 | Reference problem

| Card | Entries |
|---|---|
| 1 | ← TITLE → |
| 2 | ICØ · IMØ · NA1 · NA2 · NA3 · NAG · NAM · IRUB · ISPA · IVX · IBUC · IØPZ · ISØST |
| 3 | RE · RAGEX · ALTEX |
| 4 | TEREFI · TEMPU · TEREFE · TEMMØD |
| 5 | RB(1, L) · RB(2, L) · RB(3, L) · RB(4, L) · BAN(L) · (NA2+1) blocks |
| 6 | R(1) · R(2) · ... · R(NA1+NA2+NA3+NAG+NAM) |
| 7 | NU(1) · NU(2) · NU(3) · ....... · NU(5+NA3+NAM) · IPRETU · ICALAN |
| 8 | NTAB(1,I) · NTAB(2,I) · .... · NTAB(NU(I)) · [only for NU(I) ≠ 0] } for I = 1,5 (not more than 5 blocks) |
| 9 | CØN(1,I) · CØN(2,I) · ... · [ » » » ] |
| 10 | NTAB(1,K) · NTAB(2,K) · ... · NTAB(NU(K)) · [only for NU(K) ≠ 0] } for K = 6,5+NA3+NAM (no more than NA3+NAM blocks) |
| 11 | DE1(1,K) · DE1(2,K) · ... · [ » » » ] |
| 12 | EXECD · TCØL · RCØL · B2RAD · B2ASS |
| 13 | BUCSPR · BUCSPZ |
| 14 | IDENS · NUNURE · NUREF(1) · NUREF(2) · ..... · IPUNCH |
| 15 | IZØZØ · IREZØ(1) · IREZØ(2) · ... |
| 16 | IANAN · IREAN(1) · IREAN(2) · ... |
| 17 | RHØNØM · RHØLIQ |
| 18 | |
| 19 | |
| 20 | |
| 21 | |
| 22 | |
| 23 | |
| 24 | |
| 25 | |

**CISE**

# DATA (Zones de 10 colonnes)

PROBLEM: INPUT ØF PRØCELLA | DATE | PAGE 3 | P1 Substitution problem

```
<------------- T I T L E ------------->
 ISØST   IØPZ  IDENSIPUNCHNUSØST
INDICI(1) INDICI(2) ....                 (NUSØST numbers)
    RIDATI(1)    |    RIDATI(2)    | ...  (NUSØST numbers)
```

**CISE**

# DATA (Zones de 10 colonnes)

PROBLEM CHECK-PROBLEM-PROCELLA | DATE | PAGE 1 OF

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            CHECK PRØBLEM
     2     1     2     2     2     1     2     4     2     0     1     1     1
 9.91          203.7         344.9
 273.          873.14        536.14        323.14
 .0            .0            .945          1.            1.
 .0            .0            .945          1.            6.
 .0            .0            .945          1.            12.
 .945          1.            3.154         5.154         5.304
 5.573         5.875         5.975         15.7973
     0     0    28     1     2     2     1     1     2     0     0
     1     2     3     4     5     8     9    10    11    12    13    14    15
    16    17    18    19    20    21    22    23    24    25    26    27    28
    29    30
 .159166  E-03 .552169  E-04 .1       E-04 .1       E-04 .0219473
 .001          .0442129      .0013586      .000016       .001
 .01           .1       E-05 .1       E-08 .1       E-05 .1       E-05
 .1       E-05 .1       E-05 .1       E-05 .1       E-05 .1       E-05
 .1       E-05 .1       E-05 .1       E-05 .1       E-05 .1       E-05
 .1       E-05 .1       E-05 .1       E-05
    10
 .04072
     6    10
 .0093775      .000314
     6    10
 .0093775      .000314
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**CISE**

# DATA (Zones de 10 colonnes)

PROBLEM CHECK – PROBLEM – PROCELLA | DATE | PAGE 2 OF

| Line | Field 1 | Field 2 | Field 3 | Field 4 | Field 5 |
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| 1 | 10 | | | | |
| 2 | .043186 | | | | |
| 3 | 10 | | | | |
| 4 | .043186 | | | | |
| 5 | 6 | 7 | | | |
| 6 | .82389 E-04 | .032734 | | | |
| 7 | .5 | 293.14 | .002 | .0 | .0 |
| 8 | .0 | .0 | | | |
| 9 | 1 | 1 | 6 | | |
| 10 | 5 | 1 | | | |
| 11 | 5 | 1 | | | |
| 12 | .2943 | .79 | | | |

```
                     CHECK  PROBLEM

ICO= 2  IMO= 1  NA1= 2  NA2= 2  NA3= 2  NAG= 1  NAM= 2  IRUB= 4  ISPA= 2  IVX=-0  IBUC = 1  IOPZ= 1     ISOST= 1
DATI  GEOMETRICI  (CM)

REGIONE      ANELLO      RAGGIO I        RAGGIO E  N.BARRE        A              B              R              C

COMBUSTIBILE
                   1   0.              0.945000E 00    1    -0.          -0.          0.945000E 00   0.100000E 01
                   2   0.945000E 00    0.100000E 01
                   3   0.100000E 01    0.315400E 01    6    -0.          -0.          0.945000E 00   0.100000E 01
                   4   0.315400E 01    0.515400E 01   12    -0.          -0.          0.945000E 00   0.100000E 01
                   5   0.515400E 01    0.530400E 01
                   6   0.530400E 01    0.557300E 01
VUOTO
                   7   0.557300E 01    0.587500E 01
MODERATORE
                   8   0.587500E 01    0.597500E 01
                   9   0.597500E 01    0.157973E 02

TEMP.RI.= 0.27300000E 03    TEMP.U. = 0.87314000E 03    TEMP.RE.= 0.53614000E 03    TEMP.M. = 0.32314000E 03

COMPOSIZIONE DELLE ZONE (A/B CM)

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 U 235= 0.1591660E-03     U 238= 0.2194730E-01       O  = 0.4421290E-01    ZOY2 = 0.1358600E-02     PU 239= 0.5521620E-04
PU 240= 0.1000000E-04    PU 241= 0.1000000E-04       H  = 0.1000000E-02     U 236= 0.1600000E-04    PECHIN= 0.1000000E-02
 AL ST= 0.1000000E-01       B  = 0.1000000E-05   XE 135= 0.1000000E-08    PU 242= 0.1000000E-05     PS 15= 0.1000000E-05
 PS 25= 0.1000000E-05     PS 35= 0.1000000E-05    PS 45= 0.1000000E-05     PS 19= 0.1000000E-05     PS 29= 0.1000000E-05
 PS 39= 0.1000000E-05     PS 49= 0.1000000E-05   AM 241= 0.1000000E-05    SM 149= 0.1000000E-05    SM 151= 0.1000000E-05
GD 157= 0.1000000E-08    EU 155= 0.1000000E-08   CD 113= 0.1000000E-08
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 ZOY2 = 0.4072000E-01
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  H2O = 0.9377500E-02     ZOY2 = 0.3140000E-03
------------------
  H2O = 0.9377500E-02     ZOY2 = 0.3140000E-03
------------------
 ZOY2 = 0.4318600E-01
------------------
 ZOY2 = 0.4318600E-01
------------------
  H2O = 0.8238900E-04      D2O = 0.3287340E-01

R   EXTR.= 0.20370000E 03    H  EXTR.= 0.34490000E 03    B2R EXP.=-0.                 B2Z EXP.=-0.
E    CD  = 0.50000000E 00    TN  TH  = 0.29314000E 03    RW  TH  = 0.20000000E-02     TAU     =-0.
RHO NOM.= 0.29480000E 00     RHO LIQ.= 0.79000000E 00
B2 INS. MISURA  RADIALE=   -0.
B2 INS. MISURA  ASSIALE=   -0.
```

VU= 53.31 VM= 671.84 VM/VU = 12.60 TEMP. REG. COMB. = 602.42

| DEN. COMB. | S. EFF | RAD(S/M) | I. EFF |
|---|---|---|---|
| 0.99100000E 01 | 0.45098038E 02 | 0.29218537E 00 | 0.11922131E 02 |

| | | | |
|---|---|---|---|
| TN COMB.= 0.46767430E 03 | TN MODE.= 0.33578227E 03 | OMEGA = 0.12628388E 00 | DELTA U = 0.16748275E 02 |
| CHI EPI = 0.70895922E 00 | CHI TER = 0.25663940E 00 | CHI R 39= 0.47848539E 00 | CHI R 40= 0.33529732E 00 |
| (G+RS)A5= 0.95075334E 00 | (G+RS)F5= 0.94017556E 00 | (G+RS)A9= 0.14913547E 01 | (G+RS)F9= 0.13756553E 01 |

| PI | PI O | PI INF | DOPPLERO | DOPPLER1 |
|---|---|---|---|---|
| 0.87620781E 00 | 0.88455633E 00 | 0.91949623E 00 | -0.22290021E-04 | -0.12925054E-04 |

| CSI.SCAT. E | CSI.SCAT. V | ASS. E | NU.FISS. E |
|---|---|---|---|
| 0.16494426E 00 | 0.12384943E 00 | 0.13491935E-02 | 0.16097882E-02 |

| V (CM3/CM) | EFFE | FLUSSO | DENSITA' |
|---|---|---|---|
| 0.28055273E 01 | 0.30533158E-01 | 0.56711166E 01 | 0.17408267E 00 |
| 0.33607268E 00 | 0.99031141E-04 | 0.63675449E 01 | 0.19190245E 00 |
| 0.28110145E 02 | 0.22566750E 00 | 0.77978517E 01 | 0.22850027E 00 |
| 0.52200825E 02 | 0.71578032E 00 | 0.12395314E 02 | 0.34613735E 00 |
| 0.49282289E 01 | 0.29013882E-02 | 0.17744079E 02 | 0.48299831E 00 |
| 0.91920485E 01 | 0.86123097E-02 | 0.19089984E 02 | 0.51743649E 00 |
| 0.10861441E 02 | 0. | 0.19904442E 02 | 0.58631141E 00 |
| 0.37227958E 01 | 0.43274366E-02 | 0.20068590E 02 | 0.64688610E 00 |
| 0.67184391E 03 | 0.12062497E-01 | 0.31762127E 02 | 0.10000000E 01 |

| EFFE | ETA | ASS. M | F.S.B. | F.S.C. | F.S.R.U. |
|---|---|---|---|---|---|
| 0.96058010E 00 | 0.10816225E 01 | 0.58481228E-02 | 0.11118404E 01 | 0.15687175E 01 | 0.11319145E 01 |
| L.U.M | L.M.M | L.U.E | L.M.E | L.U.V | L.M.V |
| 0.19518445E 01 | 0.25722413E 01 | 0.28580280E 01 | 0.37324951E 01 | 0.42453289E 01 | 0.47429244E 01 |

| EPSILON | DELTA 28 | BETA | GAMMA | R* |
|---|---|---|---|---|
| 0.10371392E 01 | 0.62692147E-01 | 0.36314482E-01 | 0.12191339E-01 | 0.24123143E-01 |

```
K      INFINITO            =    0.96543211E 00
EPSILON*PI*ETA*EFFE        =    0.94417709E 00
K EFFETTIVO A 4 GRUPPI     =    0.91354474E 00
K EFFETTIVO A 2 GRUPPI     =    0.91376659E 00
```

COSTANTI A 4 GRUPPI

| | M (0-MU.K.T) | I (MU.K.T-E*) | S (E*-0.1MEV) | V (0.1-2 MEV) |
|---|---|---|---|---|
| DIFF.R | 0.85291633E 00 | 0.12218516E 01 | 0.12218516E 01 | 0.15823304E 01 |
| DIFF.Z | 0.85496607E 00 | 0.12244567E 01 | 0.12244567E 01 | 0.15846043E 01 |
| RIMOZ. | 0. | 0.42900742E-01 | 0.16655170E-01 | 0.41283142E-01 |
| ASSOR. | 0.58481228E-02 | 0.45631997E-02 | 0.51013622E-03 | 0. |
| A.R.U8 | 0. | 0. | 0.23530718E-02 | 0. |
| NU.FIS | 0.60761123E-02 | 0.52061859E-02 | 0.70121704E-03 | 0. |
| EP.NUF | 0.63017739E-02 | 0.53995392E-02 | 0.72725965E-03 | 0. |
| L2 RAD | 0.14584446E 03 | 0.28480896E 02 | 0.73361702E 02 | 0.38328730E 02 |
| L2 ASS | 0.14619496E 03 | 0.28541621E 02 | 0.73518118E 02 | 0.38383811E 02 |

COSTANTI A 2 GRUPPI

| DR 1 | DZ 1 | S 1 | S 11 | S 12 |
|---|---|---|---|---|
| 0.12793016E 01 | 0.12817441E 01 | 0.10702658E-01 | 0.14377223E-02 | 0.63017739E-02 |
| DR 2 | DZ 2 | S 2 | S 21 | |
| 0.89467372E 00 | 0.89681250E 00 | 0.58481228E-02 | 0.82546371E-02 | |

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S11 35   = 0.53128818E-03     S12 35    = 0.33927990E-02     FLU/FLC = 0.32321462E 00     VU/VC     = 0.67991008E-01
SIG XE 1= 0.17793072E 05      SIG XE 2= 0.25662758E 07       AVE VU 1= 0.37801624E 07     AVE VU 2= 0.26754443E 06
ELLE EX  = 0.56023036E 01     BLACK     = 0.49234750E 00     WEIGTH   = 0.52332031E 00    EDGE      = 0.12004941E 01

B2R GEO.= 0.13937210E-03      B2Z MAT.=-0.27735950E-03       B2Z GEO.= 0.82968909E-04      B2R MAT.=-0.22173550E-03

AREA MIGRAZ. RADIALE   =    0.25122920E 03
AREA MIGRAZ. ASSIALE   =    0.25177225E 03

BUCKLING    MATERIALE  =   -0.13858726E-03

R.C.I.(DEL SIST. CRIT.)=    0.89135341E 00
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PARAMETRI SPERIMENTALI

```
RAPPORTO PU/U COMB.    =    0.13553903E 01
RAPPORTO PU/U MODE.    =    0.11099716E 01
RHO 28   =                  0.58900649E 00
R.C.I.RELATIVO         =    0.12685720E 01
```

PROCELLA * PAG.4 CONFIGURAZIONI VARIATE

| | TM + 10 | TF + 40 | TC + 20 | XENO + .2E-08 | BORO + .5E-06 | RHO M *.95 | VUOTO |
|---|---|---|---|---|---|---|---|
| EPSILON | 0.10370932E 01 | 0.10370816E 01 | 0.10370830E 01 | 0.10370505E 01 | 0.10370884E 01 | 0.10371136E 01 | 0.10381928E 01 |
| PI | 0.87620799E 00 | 0.87575997E 00 | 0.87620778E 00 | 0.87620787E 00 | 0.87620638E 00 | 0.87411886E 00 | 0.88124223E 00 |
| ETA | 0.10811591E 01 | 0.10818412E 01 | 0.10820773E 01 | 0.10602837E 01 | 0.10816225E 01 | 0.10815950E 01 | 0.10809780E 01 |
| EFFE | 0.96094219E 00 | 0.96060934E 00 | 0.96063939E 00 | 0.96098873E 00 | 0.91494995E 00 | 0.96141550E 00 | 0.97254992E 00 |
| K-INF | 0.96583857E 00 | 0.96507205E 00 | 0.96582039E 00 | 0.94909102E 00 | 0.92450705E 00 | 0.96489308E 00 | 0.98491717E 00 |
| K-EFF | 0.91378729E 00 | 0.91320831E 00 | 0.91390750E 00 | 0.89827164E 00 | 0.87620788E 00 | 0.91009403E 00 | 0.92984914E 00 |
| DR 1 | 0.12790966E 01 | 0.12794838E 01 | 0.12793911E 01 | 0.12788425E 01 | 0.12792875E 01 | 0.13386732E 01 | 0.12926860E 01 |
| DZ 1 | 0.12815368E 01 | 0.12819267E 01 | 0.12818340E 01 | 0.12812836E 01 | 0.12817296E 01 | 0.13414375E 01 | 0.12949644E 01 |
| DR 2 | 0.89944516E 00 | 0.89467826E 00 | 0.89468289E 00 | 0.89512304E 00 | 0.89621734E 00 | 0.94080240E 00 | 0.92675301E 00 |
| DZ 2 | 0.90162255E 00 | 0.89680973E 00 | 0.89680690E 00 | 0.89728752E 00 | 0.89835037E 00 | 0.94378580E 00 | 0.92507207E 00 |
| S 1 | 0.10717027E-01 | 0.10706687E-01 | 0.10702582E-01 | 0.10698172E-01 | 0.10707175E-01 | 0.10239380E-01 | 0.10128170E-01 |
| S 11 | 0.14290714E-02 | 0.14383078E-02 | 0.14394469E-02 | 0.14300497E-02 | 0.14365485E-02 | 0.14312408E-02 | 0.14250328E-02 |
| S 12 | 0.62995446E-02 | 0.63021369E-02 | 0.63029584E-02 | 0.62169548E-02 | 0.63213011E-02 | 0.64167148E-02 | 0.64557121E-02 |
| S 2 | 0.58466151E-02 | 0.58474240E-02 | 0.58467195E-02 | 0.58835225E-02 | 0.61591060E-02 | 0.59499132E-02 | 0.59147637E-02 |
| S 21 | 0.82803770E-02 | 0.82526654E-02 | 0.82532931E-02 | 0.82556240E-02 | 0.82451793E-02 | 0.78340449E-02 | 0.78339075E-02 |
| BUCKLING | -0.13655249E-03 | -0.14005234E-03 | -0.13700548E-03 | -0.20560762E-03 | -0.31455562E-03 | -0.13297721E-03 | -0.57762573E-04 |
| MIGR. R | 0.25195259E 03 | 0.25120904E 03 | 0.25125425E 03 | 0.25025121E 03 | 0.24387347E 03 | 0.26595216E 03 | 0.26193431E 03 |
| MIGR. Z | 0.25250128E 03 | 0.25175098E 03 | 0.25179519E 03 | 0.25079546E 03 | 0.24439761E 03 | 0.26665091E 03 | 0.26191567E 03 |
| TN. COMB. | 0.47728109E 03 | 0.46930866E 03 | 0.47098989E 03 | 0.46782549E 03 | 0.46768494E 03 | 0.46758101E 03 | 0.44613259E 03 |
| TN. MODE. | 0.34617002E 03 | 0.33578189E 03 | 0.33578042E 03 | 0.33583067E 03 | 0.33577866E 03 | 0.33664687E 03 | 0.33763192E 03 |
| OMEGA | 0.12465108E 00 | 0.12642611E 00 | 0.12656262E 00 | 0.12849640E 00 | 0.12628492E 00 | 0.13221427E 00 | 0.13410181E 00 |
| DELTA U | 0.16717837E 02 | 0.16748279E 02 | 0.16748286E 02 | 0.16748135E 02 | 0.16748286E 02 | 0.16745754E 02 | 0.16742551E 02 |
| CHI EPI. | 0.71132354E 00 | 0.70876820E 00 | 0.70856954E 00 | 0.70519385E 00 | 0.70895751E 00 | 0.70921915E 00 | 0.71982829E 00 |
| CHI TER. | 0.25992979E 00 | 0.25633592E 00 | 0.25602235E 00 | 0.25313083E 00 | 0.25656095E 00 | 0.26189366E 00 | 0.27747497E 00 |
| CHI R 39 | 0.47829876E 00 | 0.47841299E 00 | 0.47833805E 00 | 0.47537937E 00 | 0.47848512E 00 | 0.47849220E 00 | 0.44814238E 00 |
| CHI R 40 | 0.33526135E 00 | 0.33652196E 00 | 0.33528357E 00 | 0.33447063E 00 | 0.33529727E 00 | 0.33528639E 00 | 0.27686937E 00 |
| SIG XE 1 | 0.11581240E 05 | 0.17766892E 05 | 0.17738452E 05 | 0.16712428E 05 | 0.17795328E 05 | 0.17249496E 05 | 0.18732518E 05 |
| SIG XE 2 | 0.25419214E 07 | 0.25621217E 07 | 0.25578524E 07 | 0.25658898E 07 | 0.25662486E 07 | 0.25665078E 07 | 0.26213755E 07 |
| FLU/FLC | 0.32551488E 00 | 0.32339320E 00 | 0.32357287E 00 | 0.31896667E 00 | 0.32423253E 00 | 0.32912782E 00 | 0.32702067E 00 |
| SIG 11 35 | 0.52693547E-03 | 0.53090438E-03 | 0.53069376E-03 | 0.52866855E-03 | 0.53099223E-03 | 0.52946082E-03 | 0.54625732E-03 |
| SIG 12 35 | 0.33772734E-02 | 0.33877185E-02 | 0.33826809E-02 | 0.33473070E-02 | 0.34032734E-02 | 0.34551928E-02 | 0.35303155E-02 |
| AVE VU 1 | 0.38312130E 07 | 0.37801611E 07 | 0.37801543E 07 | 0.37804032E 07 | 0.37801446E 07 | 0.37844563E 07 | 0.37892640E 07 |
| AVE VU 2 | 0.27160316E 06 | 0.26756515E 06 | 0.26758594E 06 | 0.26754584E 06 | 0.26754903E 06 | 0.26790948E 06 | 0.26796977E 06 |
| ELLE EX | 0.56483331E 01 | 0.56031582E 01 | 0.56040157E 01 | 0.55544163E 01 | 0.56150872E 01 | 0.59296705E 01 | 0.48107473E 01 |
| BLACK | 0.49146444E 00 | 0.49228687E 00 | 0.49222579E 00 | 0.49576425E 00 | 0.49111614E 00 | 0.49102478E 00 | 0.55590761E 00 |
| WEIGHT | 0.52109256E 00 | 0.52328213E 00 | 0.52324384E 00 | 0.52546904E 00 | 0.54881930E 00 | 0.50829554E 00 | 0.56205205E 00 |
| EDGE | 0.11995265E 01 | 0.12004579E 01 | 0.12004215E 01 | 0.12017307E 01 | 0.12001389E 01 | 0.11951191E 01 | 0.12125002E 01 |

| | P.C.M./K | P.C.M./K | P.C.M./K | PCM/A.B.CM*E-08 | PCM/A.B.CM*E-06 | P.C.M./P.C. | DELTA VT (PCM) |
|---|---|---|---|---|---|---|---|
| (EPSILON)' | 0.13 | 0.00 | 0.01 | -14.81 | 1.64 | 0.67 | 111.26 |
| (PI)' | 0.00 | -1.12 | -0.00 | 0.03 | -0.29 | -41.78 | 503.44 |
| (ETA)' | -4.63 | 0.55 | 2.27 | -10669.43 | -0.01 | -0.55 | -64.45 |
| (EFFE)' | 3.62 | 0.07 | 0.30 | 204.32 | -9126.03 | 16.71 | 1196.98 |
| (K-INF)' | 4.61 | -0.76 | 2.22 | -8143.09 | -8174.03 | -9.68 | 1954.00 |
| (K-EFF)' | 2.95 | -0.71 | 2.07 | -7610.57 | -7456.98 | -67.97 | 1635.64 |

| | CM-1/K | CM-1/K | CM-1/K | CM-1/A.B.CM | CM-1/A.B.CM | CM-1/P.C. | DELTA VT (CM-1) |
|---|---|---|---|---|---|---|---|
| (1/DR1)' | 0.12529641E-04 | -0.27826056E-05 | -0.27332455E-05 | 0.14031678E 06 | 0.17315150E 02 | -0.69336399E-02 | -0.80934316E-02 |
| (1/DZ1)' | 0.12623519E-04 | -0.27781352E-05 | -0.27343630E-05 | 0.14022365E 06 | 0.17732382E 02 | -0.69435998E-02 | -0.79649240E-02 |
| (1/DR2)' | -0.59293955E-03 | -0.14193356E-06 | -0.57294964E-06 | -0.28052926E 06 | -0.38502812E 04 | -0.10960692E-01 | -0.38689777E-01 |
| (1/DZ2)' | -0.59487074E-03 | 0.86054205E-07 | 0.34868717E-06 | -0.29514730E 06 | -0.38177073E 04 | -0.11099565E-01 | -0.34063414E-01 |
| (S 1)' | 0.14369725E-05 | 0.10074000E-06 | -0.37718564E-08 | -0.22429740E 04 | 0.90342946E 01 | -0.92655419E-04 | -0.57448726E-03 |
| (S 11)' | -0.85691280E-06 | 0.16681224E-07 | 0.90318644E-07 | -0.37953869E 04 | -0.21839515E 01 | -0.12799515E-05 | -0.12607721E-04 |
| (S 12)' | -0.18709106E-06 | 0.18032733E-07 | 0.77142612E-07 | -0.42230356E 05 | 0.39771200E 02 | 0.23059849E-04 | 0.15429658E-03 |
| (S 2)' | -0.15077530E-06 | -0.17469574E-07 | -0.70166423E-07 | 0.17699815E 05 | 0.62196620E 03 | 0.20358071E-04 | 0.66640787E-04 |
| (S 21)' | 0.25739893E-05 | -0.49293157E-07 | -0.67200743E-07 | 0.49348455E 03 | -0.18915627E 02 | -0.84118428E-04 | -0.42072963E-03 |

PROCELLA * PAG.5 PROFILO DI DENSITA'

| | .047*RHO L | .231*RHO L | .500*RHO L | .769*RHO L | .953*RHO L |
|---|---|---|---|---|---|
| EPSILON | 0.10380461E 01 | 0.10374928E 01 | 0.10367248E 01 | 0.10360028E 01 | 0.10355319E 01 |
| PI | 0.88009185E 00 | 0.87720507E 00 | 0.87590194E 00 | 0.87637381E 00 | 0.87723046E 00 |
| ETA | 0.10810317E 01 | 0.10812845E 01 | 0.10819417E 01 | 0.10825774E 01 | 0.10829577E 01 |
| EFFE | 0.97096669E 00 | 0.96473874E 00 | 0.95663931E 00 | 0.94846852E 00 | 0.94302393E 00 |
| K-INF | 0.98173232E 00 | 0.97126446E 00 | 0.96066350E 00 | 0.95218663E 00 | 0.94714614E 00 |
| K-EFF | 0.92714607E 00 | 0.91832030E 00 | 0.90963864E 00 | 0.90279546E 00 | 0.89876731E 00 |
| DR 1 | 0.12910605E 01 | 0.12844542E 01 | 0.12747859E 01 | 0.12656058E 01 | 0.12597153E 01 |
| DZ 1 | 0.12933131E 01 | 0.12867465E 01 | 0.12774256E 01 | 0.12687990E 01 | 0.12633536E 01 |
| DR 2 | 0.92156478E 00 | 0.90477761E 00 | 0.88717791E 00 | 0.87460600E 00 | 0.86787619E 00 |
| DZ 2 | 0.92035134E 00 | 0.90550151E 00 | 0.89045055E 00 | 0.87989699E 00 | 0.87428691E 00 |
| S 1 | 0.10205812E-01 | 0.10493421E-01 | 0.10882049E-01 | 0.11247663E-01 | 0.11488876E-01 |
| S 11 | 0.14275769E-02 | 0.14343642E-02 | 0.14395283E-02 | 0.14412445E-02 | 0.14411548E-02 |
| S 12 | 0.64301953E-02 | 0.63449042E-02 | 0.62680807E-02 | 0.62197423E-02 | 0.62001286E-02 |
| S 2 | 0.59015321E-02 | 0.58626005E-02 | 0.58414277E-02 | 0.58469532E-02 | 0.58627725E-02 |
| S 21 | 0.78854170E-02 | 0.80918249E-02 | 0.84008664E-02 | 0.87131009E-02 | 0.89268211E-02 |
| BUCKLING | -0.70415843E-04 | -0.11335552E-03 | -0.15984778E-03 | -0.19957372E-03 | -0.22446627E-03 |
| MIGR. R | 0.26040987E 03 | 0.25501626E 03 | 0.24810900E 03 | 0.24197522E 03 | 0.23807304E 03 |
| MIGR. Z | 0.26045426E 03 | 0.25534081E 03 | 0.24883468E 03 | 0.24304226E 03 | 0.23933837E 03 |
| TN. COMB. | 0.45004500E 03 | 0.46139170E 03 | 0.47213426E 03 | 0.47921702E 03 | 0.48276379E 03 |
| TN. MODE. | 0.33737913E 03 | 0.33644654E 03 | 0.33522886E 03 | 0.33416147E 03 | 0.33350757E 03 |
| OMEGA | 0.13315790E 00 | 0.12927887E 00 | 0.12367031E 00 | 0.11835964E 00 | 0.11494236E 00 |
| DELTA U | 0.16743327E 02 | 0.16746210E 02 | 0.16750000E 02 | 0.16753332E 02 | 0.16755372E 02 |
| CHI EPI. | 0.71819301E 00 | 0.71264805E 00 | 0.70600820E 00 | 0.70054553E 00 | 0.69729926E 00 |
| CHI TER. | 0.27448503E 00 | 0.26397883E 00 | 0.25052426E 00 | 0.23857225E 00 | 0.23106462E 00 |
| CHI R 39 | 0.45310045E 00 | 0.46902967E 00 | 0.48538963E 00 | 0.49667302E 00 | 0.50248808E 00 |
| CHI R 40 | 0.28635980E 00 | 0.31693371E 00 | 0.34898362E 00 | 0.37241725E 00 | 0.38538713E 00 |
| SIG XE 1 | 0.18614515E 05 | 0.18148430E 05 | 0.17492629E 05 | 0.16908987E 05 | 0.16547333E 05 |
| SIG XE 2 | 0.26113200E 07 | 0.25822775E 07 | 0.25549507E 07 | 0.25370244E 07 | 0.25280749E 07 |
| FLU/FLC | 0.32650063E 00 | 0.32445057E 00 | 0.32225140E 00 | 0.32091134E 00 | 0.32046833E 00 |
| SIG 11 35 | 0.54389982E-03 | 0.53617585E-03 | 0.52742118E-03 | 0.52049014E-03 | 0.51644936E-03 |
| SIG 12 35 | 0.35066077E-02 | 0.34334096E-02 | 0.33630272E-02 | 0.33183393E-02 | 0.32983245E-02 |
| AVE VU 1 | 0.37880209E 07 | 0.37834331E 07 | 0.37774350E 07 | 0.37721666E 07 | 0.37689329E 07 |
| AVE VU 2 | 0.26792559E 06 | 0.26771769E 06 | 0.26738931E 06 | 0.26707181E 06 | 0.26686853E 06 |
| ELLE EX | 0.49153054E 01 | 0.53106592E 01 | 0.58514550E 01 | 0.63505676E 01 | 0.66709287E 01 |
| BLACK | 0.54659378E 00 | 0.51401231E 00 | 0.47522661E 00 | 0.44425839E 00 | 0.42641153E 00 |
| WEIGHT | 0.55661572E 00 | 0.53696258E 00 | 0.51219182E 00 | 0.49123717E 00 | 0.47864904E 00 |
| EDGE | 0.12107784E 01 | 0.12046701E 01 | 0.11971498E 01 | 0.11909200E 01 | 0.11872122E 01 |

POLINOMI DA DENSITA'

| | | | | | |
|---|---|---|---|---|---|
| SIGMA 11 | 0.14252635E-02 | 0.66084945E-04 | -0.10153145E-03 | 0.75366028E-04 | -0.26375557E-04 |
| SIGMA 1 * | 0.87031460E-02 | 0.20479789E-02 | -0.60511302E-03 | 0.47121273E-03 | -0.17275379E-03 |
| SIGMA 21 | 0.78337181E-02 | 0.13886361E-02 | 0.17924129E-03 | -0.17863416E-03 | 0.69002264E-04 |
| SIGMA 12 | 0.64587338E-02 | -0.81531209E-03 | 0.12688112E-02 | -0.13310599E-02 | 0.63514561E-03 |
| SIGMA 2 | 0.59159126E-02 | -0.41638427E-03 | 0.78811636E-03 | -0.64367402E-03 | 0.27483189E-03 |
| 1/DR1 | 0.77357030E 00 | 0.26390564E-01 | 0.67813990E-02 | -0.11792034E-01 | 0.49107580E-02 |
| 1/DR2 | 0.10790754E 01 | 0.16846548E 00 | -0.15518419E 00 | 0.10803691E 00 | -0.36780727E-01 |
| 1/DZ1 | 0.77220982E 00 | 0.26829420E-01 | 0.31637508E-02 | -0.93909273E-02 | 0.41947906E-02 |
| 1/DZ2 | 0.10810718E 01 | 0.15345682E 00 | -0.16282019E 00 | 0.12811090E 00 | -0.47310478E-01 |

# P R O C E L L A

FORTRAN statements

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£IBFTC PRO2
C
C
C      PROCELLA 2
C
       DIMENSION TOTDEN(20)
       DIMENSION                REFCO(2,5),REFDE(5,5),ST1(6,7),ST2(9,7),
      1VST3(7),VST4(7)
       DIMENSION BRUOPZ(9,8),BRU1(2),BRU2(2),BRU3(2),BRU4(2),BRU5(18)
       DIMENSION BRU10(2),BRU11(2),BRU12(2),BRU13(2)
       DIMENSION BRU6(2),BRU7(2),BRU8(2),BRU9(2)
       DIMENSION NUREF(5),IREZO(2),IREAN(5),VDENS(5),RCONS(20),VCONS(20)
       DIMENSION   IBAN(10),DAB(2),RB(6,10),NU(20),BAN(10),NTAB(30,20)
       DIMENSION   CON(30,5),DE1(30),DE(30,20),CONC(30,5),V(5,10)
       DIMENSION DATI(12),BIDATI(12),RIDATI(12),INDICI(12)
       DIMENSION             CONC3(4,30),TARSTA(30)
       DIMENSION TITLE(12),PIER(56),PIERI(12),PIERIN(18)
       DIMENSION BONA (9)
       DIMENSION PIER1(8),PIER2(6),PIER3(4),PIER4( 3),PIER5(4),PIER6(2),
      1PIER8(2),PIER9(6)
       DIMENSION PIER10(2),PIER11(2),PIER12(2),PIER13(2),PIER14(2),
      1PIER15(2),PIER16(2),PIER17(2),PIER18(2),PIER19(2),PIER20(2),
      2PIER21(2)
       DIMENSION PIER22(4),PIER23(4),PIER24(4),PIER25(4),PIER26(4),
      1          PIER27(4),PIER28(4),PIER29(4),PIER30(4)
      2,         PIER35(4),PIER36(4),PIER37(4),PIER38(4)
      3,         PIER47(4),PIER48(4)
       DIMENSION PIER31(2),PIER32(2),PIER33(2),PIER34(2),PIER39(2),
      1          PIER40(2),PIER41(2),PIER42(2),PIER43(2),PIER44(2),
      2          PIER45(2),PIER46(2)
       DIMENSION PIER49(2),PIER50(2),PIER51(2),PIER52(2)
       DIMENSION PIER53(8),BONALU(18),PIER55(12)
       COMMON/NEM1/IX(30),NTE(30),ASTRO(10,30),SEZIO(10,2,30),SEZIOF(10,
      12,5),CROMI(15,30,2),TARGA(30),SEZ(14,30)
       COMMON/NEM2/DEN(30,2),TE(3),VV(2),SIGMA(16,2),CZ,ZZ,BLACK
       COMMON/NEM3/NUCLEI,DUM,VU,SEF,DUI,TAU,CHIE,CHIT,OME,TEN(2),CHI(4)
      1,DG
       COMMON/SIR3/RC(3)
       COMMON/SIR4/FCL
       COMMON/SIR5/R(21),        STT(20),SA(20),C(20),Q(20),FIM(20)
       COMMON/SIR6/AUEI,AUES,AMEI,AMES,IRUB,EFU,ETAPR,SACM,DRM,DREI,DRES,
      1DZM,DZEI,DZES,AMDUBE,AMDMBE,IRC,FLU(20),EFF(20),VO(20)
       COMMON/PAL/SEZMA(4,14),SEZMAT(4,2),VEPSI(9),FOV,GAMO,FV(2),GAM(2)
       COMMON/PAL1/ANVTH,        AN,RCAN,FSB,      BETDAN,BI,PASSO
      1,RAGGB,RAGGR,RAGGT
       COMMON/PAL2/EPSI,DELT28,BETA,GAMMA,RASTER,DENOM,GAMA5,GAMF5
       COMMON/PAL3/OPZIO(28,8),RHO(5),POLINO(5,9),IPOLIN(9)
       COMMON/BON/SEM(15,20),SEMZ(15,5)
       COMMON/ACC/ACE(30,3),VET(17),PE(20),NUCLE
     1 FORMAT (13I6)
     2 FORMAT (5E14.8)
     3 FORMAT (12A6)
   336 FORMAT (5X,21A6)
   103 FORMAT(20X,12A6)
   811 FORMAT (A6,A6,7E17.8)
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      812 FORMAT (A6,A6,7F17.2)
      602 FORMAT (5X,4A6,E18.8)
      702 FORMAT (5X,A6,12X,4E18.8)
      760 FORMAT(2X,2A6,E15.8,2X,2A6,E15.8,2X,2A6,E15.8,2X,2A6,E15.8)
      102 FORMAT (5X ,5E20.8)
       43 FORMAT(5X,6E18.8)
       53 FORMAT(6X,I3,6X,I3, 2X,4E18.8)
       63 FORMAT(17X,I6,2E15.6,I5,2X,4E15.6)
      809 FORMAT (1H1)
      716 FORMAT (/)
      715 FORMAT (//)
       55 FORMAT (1H1,5X,15HPROCELLA * PAG.,I2,//)
       50 FORMAT(//5X,4HICO=,I2,2X,4HIMO=,I2,2X,4HNA1=,I2,2X,4HNA2=,I2,2X,4H
         1NA3=,I2,2X,4HNAG=,I2,2X,4HNAM=,I2,2X,5HIRUB=,I2,2X,5HISPA=,I2,2X,4
         2HIVX=,I2,2X,6HIBUC =,I2,2X,5HIOPZ=,I2,5X,6HISOST=,I2/)
       71 FORMAT(13X,10HDEN. COMB.,12X,6HS. EFF,13X,8HRAD(S/M),13X,6HI. EFF)
       72 FORMAT(17X,2HPI,17X,4HPI 0,15X,6HPI INF,13X,8HDOPPLER0,
         112X,8HDOPPLER1)
       73 FORMAT(12X,12HCSI.SCAT. E ,8X,12HCSI.SCAT. V ,11X,6HASS. E,12X,10H
         1NU.FISS. E)
       74 FORMAT (14X,5HL.U.M,13X,5HL.M.M,12X,6HL.U.E ,12X,6HL.M.E ,12X,
         16HL.U.V ,12X,6HL.M.V )
       75 FORMAT(14X,4HEFFE,14X,3HETA,14X,6HASS. M,12X,6HF.S.B.,12X,6HF.S.C.
         1,12X,8HF.S.R.U.)
       77 FORMAT(14X,7HEPSILON,13X,8HDELTA 28,14X,4HBETA,16X,5HGAMMA,16X,2HR
         1*)
      620 FORMAT ( //5X,19HCOSTANTI A 4 GRUPPI//28X,12HM (O-MU.K.T),5X,13HI
         1(MU.K.T-E*),5X,13HS (E*-0.1MEV),5X,13HV (0.1-2 MEV)/ )
      622 FORMAT(14X,4HDR 2,14X,4HDZ 2,14X,4HS  2,14X,4HS 21)
      623 FORMAT( //5X,19HCOSTANTI A 2 GRUPPI//14X,4HDR 1,14X,4HDZ 1,14X,4HS
         1  1,14X,4HS 11,14X,4HS 12)
      406 FORMAT (//5X,22HPARAMETRI SPERIMENTALI//)
      338 FORMAT(//11X,10HV (CM3/CM),11X,4HEFFE,13X,6HFLUSSO,11X,8HDENSITA')
      810 FORMAT (15X,7HTM + 10,10X,7HTF + 40,10X,7HTC + 20,10X,13HXENO + .2
         1E-08,4X,13HBORO + .5E-06,4X,10HRHO M *.95,7X,5HVUOTO//)
      849 FORMAT ( /15X,8HP.C.M./K,9X,8HP.C.M./K,9X,8HP.C.M./K,9X,
         115HPCM/A.B.CM*E-08,2X,15HPCM/A.B.CM*E-06,2X,11HP.C.M./P.C.,6X,
         214HDELTA VT (PCM)/ )
      850 FORMAT ( /15X,6HCM-1/K,11X,6HCM-1/K,11X,6HCM-1/K,11X,
         111HCM-1/A.B.CM,6X,11HCM-1/A.B.CM,6X,9HCM-1/P.C.,8X,
         215HDELTA VT (CM-1)/ )
      766 FORMAT (//15X,3HVU=,F9.2,10X,3HVM=,F9.2,10X,7HVM/VU =,F9.2,
         110X,18HTEMP. REG. COMB. =,F9.2)
      864 FORMAT (15X,10H.047*RHO L,7X,10H.231*RHO L,7X,10H.500*RHO L,
         17X,10H.769*RHO L,7X,10H.953*RHO L//)
      868 FORMAT (//5X,22HPOLINOMI  DA  DENSITA'/)
      876 FORMAT (5X,46HPROCELLA * PAG. 6      PUNCH PER CODICE MOICANO//)
      893 FORMAT (5X,7HREGIONE,5X,6HANELLO,5X,8HRAGGIO I,7X,8HRAGGIO E,2X,
         17HN.BARRE,8X,1HA,14X,1HB,14X,1HR,14X,1HC//)
      894 FORMAT (5(5X,A6,1H=,E14.7))
      895 FORMAT (/5X,6HISOST=,I3,5X,5HIOPZ=,I3,5X,6HIDENS=,I3,5X,7HIPUNCH=,
         1I3,5X,7HNUSOST=,I3/)
      897 FORMAT (5X,15HDATI SOSTITUITI)
          DATA BONALU/6H SIGMA,6H 11   ,6H SIGMA,6H 1 *  ,6H SIGMA,6H 21   ,
         1               6H SIGMA,6H 12   ,6H SIGMA,6H 2    ,6H 1/DR1,6H      ,
```

```
         2          6H 1/DR2,6H      ,6H 1/DZ1,6H      ,6H 1/DZ2,6H       /
112       DATA PIER/6H EPSIL,6HON    ,6H PI   ,6H      ,6H ETA  ,6H      ,
         16H EFFE ,6H      ,6H K-INF,6H      ,6H K-EFF,6H      ,6H DR 1 ,
         26H      ,6H DZ 1 ,6H      ,6H DR 2 ,6H      ,6H DZ 2 ,6H      ,
         36H S  1 ,6H      ,6H S 11 ,6H      ,6H S 12 ,6H      ,6H S  2 ,
         46H      ,6H S 21 ,6H      ,                6H BUCKL,6HING   ,
         56H MIGR.,6H R    ,6H MIGR.,6H Z    ,6H TN. C,6HOMB.  ,6H TN. M,
         66HODE.  ,6H OMEGA,6H      ,6H DELTA,6H U    ,6H CHI E,6HPI.   ,
         76H CHI T,6HER.   ,6H CHI R,6H 39   ,6H CHI R,6H 40   ,6H SIG X,
         86HE 1   ,6H SIG X,6HE 2   /
113       DATA PIERI/6H (EPSI,6HLON)' ,6H (PI)',6H      ,6H (ETA),6H'     ,
         16H (EFFE,6H)'    ,6H (K-IN,6HF)'   ,6H (K-EF,6HF)'   /
114       DATA PIERIN/6H (1/DR,6H1)'   ,6H (1/DZ,6H1)'   ,6H (1/DR,6H2)'   ,
         16H (1/DZ,6H2)'   ,6H (S 1),6H'     ,6H (S 11,6H)'    ,6H (S 12,
         26H)'    ,6H (S 2),6H'     ,6H (S 21,6H)'    /
115       DATA BRU5/6H FLU/F,6HLC    ,6H SIG 1,6H1  35 ,6H SIG 1,6H2  35 ,
         16H AVE V,6HU  1  ,6H AVE V,6HU  2  ,6H ELLE ,6HEX    ,6H BLACK,
         26H      ,6H WEIGH,6HT     ,6H EDGE ,6H      /
116       DATA BONA/6HDIFF.R,6HDIFF.Z,6HRIMOZ.,6HASSOR.,6HA.R.U8,6HNU.FIS,
         16HEP.NUF,6HL2 RAD,6HL2 ASS/
117       DATA PIER1/6HPROCEL,6HLA * P,6HAG.4  ,6H   CONF,6HIGURAZ,6HIONI  ,
         16H VARIA,6HTE    /
120       DATA PIER2/6HPROCEL,6HLA * P,6HAG.1 E,6H 2  (S,6HOSTITU,6HTIVO) /
121       DATA PIER3/ 6HDATI  ,6HGEOMET,6HRICI  ,6H(CM)  /
122       DATA PIER4/6H------,6H------,6H------/
123       DATA PIER5/6H   RHO,6H NOM.=,6H   RHO,6H LIQ.=/
124       DATA PIER6/6HCOMBUS,6HTIBILE/
125       DATA PIER7/6HVUOTO /
126       DATA PIER8/6HMODERA,6HTORE  /
127       DATA PIER9/6HCOMPOS,6HIZIONE,6H DELLE,6H ZONE ,6H(A/B C,6HM)    /
130       DATA PIER10/6H   TN ,6HCOMB.=/
131       DATA PIER11/6H   TN ,6HMODE.=/
132       DATA PIER12/6H   OME,6HGA   =/
133       DATA PIER13/6H   DEL,6HTA U =/
134       DATA PIER14/6H   CHI,6H EPI =/
135       DATA PIER15/6H   CHI,6H TER =/
136       DATA PIER16/6H   CHI,6H R 39=/
137       DATA PIER17/6H   CHI,6H R 40=/
140       DATA PIER18/6H   (G+,6HRS)A5=/
141       DATA PIER19/6H   (G+,6HRS)F5=/
142       DATA PIER20/6H   (G+,6HRS)A9=/
143       DATA PIER21/6H   (G+,6HRS)F9=/
144       DATA PIER22/6HK     ,6HINFINI,6HTO    ,6H     =/
145       DATA PIER23/6HEPSILO,6HN*PI*E,6HTA*EFF,6HE    =/
146       DATA PIER24/6HK EFFE,6HTTIVO ,6HA 4 GR,6HUPPI =/
147       DATA PIER25/6HK EFFE,6HTTIVO ,6HA 2 GR,6HUPPI =/
150       DATA PIER26/6HRAPPOR,6HTO PU/,6HU COMB,6H.    =/
151       DATA PIER27/6HRAPPOR,6HTO PU/,6HU MODE,6H.    =/
152       DATA PIER28/6HRHO 28,6H  =   ,6H      ,6H     /
153       DATA PIER29/6HR.C.I.,6HRELATI,6HVO    ,6H     =/
154       DATA PIER30/6HDELTA ,6H28  = ,6H      ,6H     /
155       DATA PIER31/6H   B2R,6H GEO.=/
156       DATA PIER32/6H   B2Z,6H MAT.=/
157       DATA PIER33/6H   B2Z,6H GEO.=/
160       DATA PIER34/6H   B2R,6H MAT.=/
```

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      DATA PIER35/6HAREA M,6HIGRAZ.,6H RADIA,6HLE    =/
      DATA PIER36/6HAREA M,6HIGRAZ.,6H ASSIA,6HLE    =/
      DATA PIER37/6HBUCKLI,6HNG    ,6HMATERI,6HALE   =/
      DATA PIER38/6HR.C.I.,6H(DEL S,6HIST. C,6HRIT.)=/
      DATA PIER39/6H   R  ,6HEXTR.=/
      DATA PIER40/6H   H  ,6HEXTR.=/
      DATA PIER41/6H   B2R,6H EXP.=/
      DATA PIER42/6H   B2Z,6H EXP.=/
      DATA PIER43/6H   E  ,6H CD  =/
      DATA PIER44/6H   TN ,6H TH  =/
      DATA PIER45/6H   RW ,6H TH  =/
      DATA PIER46/6H   TAU,6H     =/
      DATA PIER47/6HB2 INS,6H. MISU,6HRA  RA,6HDIALE=/
      DATA PIER48/6HB2 INS,6H. MISU,6HRA  AS,6HSIALE=/
      DATA PIER49/6H   TEM,6HP.RI.=/
      DATA PIER50/6H   TEM,6HP.U. =/
      DATA PIER51/6H   TEM,6HP.RE.=/
      DATA PIER52/6H   TEM,6HP.M. =/
      DATA BRU1/6H   S11,6H 35  =/
      DATA BRU2/6H   S12,6H 35  =/
      DATA BRU3/6H   FLU,6H/FLC =/
      DATA BRU4/6H   VU/,6HVC   =/
      DATA BRU6/6H   SIG,6H XE 1=/
      DATA BRU7/6H   SIG,6H XE 2=/
      DATA BRU8/6H   AVE,6H VU 1=/
      DATA BRU9/6H   AVE,6H VU 2=/
      DATA BRU10/6H   ELL,6HE EX =/
      DATA BRU11/6H   BLA,6HCK   =/
      DATA BRU12/6H   WEI,6HGTH  =/
      DATA BRU13/6H   EDG,6HE    =/
      DATA PIER53/6HPROCEL,6HLA * P,6HAG.5  ,6HPROFIL,6HO  DI,6H   DEN,
     16HSITA' ,6H    /
      DATA PIER55/6HRHO F ,6HR  EX.,6HH  EX.,6HT.R.I.,6HT.UR. ,6HT.R.E.,
     16HT.MO. ,6HRCELLA,6HBIMRAD,6HBIMASS,6HB2REXP,6HB2ZEXP/
      DATA VST3/.1E+05,.25E+04,.5E+04,.5E+06,.2E+06,.2E+05,.1E+06/
      DATA VST4/.1,.025,.05,.5E+09,.2E+07,.2,1./
      DATA DAB/2.125,5.67/
      DATA FOV/.015365/
      DATA FV/.4113,.57333/
      DATA GAMO/.0/
      DATA GAM/.0,.0/
      DATA VDENS/.04691,.230766,.5,.769235,.953090/
      DATA IPOLIN/12,11,15,13,14,7,9,8,10/
      DATA EAST/5./
      DATA IFILTR/1/
      PCHP(X)=1.-1./(1.+2.*X-2.*X/(2.*X+1./(1.3333333-EXP(-.3*X))))
      NUCLEI=30
      NUCLE=NUCLEI
      READ(5,1)NUNUTA
      IF (NUNUTA.EQ.0) GO TO 6
      NUNUTA=NUNUTA+15
      IFISS=4
      DO 4 I=16,NUNUTA
      READ(5,3) TARGA(I)
      READ(5,1) IX(I),NTE(I)
```

```
      IYT=NTE(I)
      READ (5,2) (ASTRO(J,I),J=1,10)
                     READ(5,2) ((SEZIO(J,L,I ),J=1,10),L=1,IYT)
      IF(IX(I).EQ.2)READ(5,2) ((SEZIOF(J,L,IFISS),J=1,10),L=1,2)
      IF(IX(I).EQ.2) IFISS=IFISS+1
    4 READ (5,2) (SEZ(M,I),M=1,14)
    6 DO 440 K=1,20
      NU(K)=0
      PE(K)=0.
      VO(K)=0.
      R(K)=0.
      FLU(K)=0.
      EFF(K)=0.
      STT(K)=0.
      SA(K)=0.
      C(K)=0.
      Q(K)=0.
      FIM(K)=0.
      DO 440 L=1,30
      DE1(L)=0.
  440 NTAB(L,K)=0
      IPRINT=0
      IPAGE=0
      R(21)=0.
      DO 765 I=1,6
      DO 765 J=1,10
      BAN(J)=0.
      IBAN(J)=0
  765 RB(I,J)=0.
      IOPZ=0
      IXENO=0
      IVUOTO=0
      DO 8 L=1,NUCLEI
      DO 9 K=1,20
    9 DE(L,K)=0.
      DO 8 I=1,5
    8 CONC(L,I)=0.
      DO 441 I=1,5
      DO 441 J=1,10
  441 V(I,J)=0.
      DO 786 I=1,5
      DO 786 J=1,30
  786 CON(J,I)=0.
      DO 801 I=1,5
      DO 801 J=1,2
  801 REFCO(J,I)=0.
      DO 834 I=1,5
      DO 834 J=1,5
  834 REFDE(I,J)=0.
      DO 442 M=1,15
      DO 443 N=1,5
  443 SEMZ(M,N)=0.
       DO 442 L=1,20
  442 SEM(M,L)=0.
      READ (5,3) (TITLE(N),N=1,12)
```

```
      READ             (5,1)ICO,IMO,NA1,NA2,NA3,NAG,NAM,IRUB,ISPA,
     1IVX,IBUC, IOPZ,ISOST
      IPAGE=1
      WRITE (6,55) IPAGE
      WRITE(6,103)(TITLE(L),L=1,12)
      WRITE(6,50)ICO,IMO,NA1,NA2,NA3,NAG,NAM,IRUB,ISPA,IVX,IBUC,
     1IOPZ,ISOST
      WRITE (6,336) PIER3
      WRITE (6,716)
      READ (5,2)RE,RAGEX,ALTEX,DUI,TAU
      READ (5,2) TEREFI,TEMPU,TEREFE,TEMMOD
      IRC=NA1+NA2+NA3+NAM+NAG
      K1=NA1+NA2
      KO=NA1+1
      READ (5,2) (RB(I,1),I=2,5),BAN(1)
      IF (NA2.EQ.0) GO TO 698
      DO 130 L=KO,K1
  130 READ             (5,2)(RB(I,L),I=2,5),BAN(L)
  698 R(1)=0.
      J=IRC+1
      READ             (5,2)(R(I),I=2,J)
      NZ=5+NA3+NAM
      DO 750 I=1,10
  750 IBAN(I)=BAN(I)
      WRITE (6,893)
      WRITE (6,336) PIER6
      J2=NA1+NA2+NA3
      DO 64 K=1,J2
      IF (IBAN(K).EQ.0) WRITE (6,63) K,R(K),R(K+1)
      IF (IBAN(K).NE.0) WRITE (6,63) K,R(K),R(K+1),IBAN(K),(RB(I,K),I=2,
     15)
   64 CONTINUE
      IF (NAG.EQ.0) GO TO 66
      WRITE (6,336) PIER7
      J2=J2+1
      WRITE(6,63)J2,R(J2),R(J2+1)
   66 WRITE (6,336) PIER8
      J2=J2+1
      DO 67 K=J2,IRC
   67 WRITE(6,63)K,R(K),R(K+1)
      WRITE (6,716)
      WRITE (6,760) PIER49,TEREFI,PIER50,TEMPU,PIER51,TEREFE,PIER52,
     1TEMMOD
      READ(5,1) (NU(K),K=1,NZ),IPRETU,ICALAN
      WRITE (6,716)
      WRITE (6,336) PIER9
      WRITE (6,716)
      WRITE(6,1)(NU(K),K=1,NZ),IPRETU,ICALAN
      DO 132 I=1,5
      J=NU(I)
      IF (J.EQ.0) GO TO 132
      READ             (5,1)(NTAB(N,I),N=1,J)
      READ             (5,2)(CON(N,I),N=1,J)
      DO 905 N=1,J
      M=NTAB(N,I)
```

```
  905 TARSTA(N)=TARGA(M)
      WRITE (6,336) PIER4
      WRITE (6,894) ((TARSTA(N),CON(N,I)),N=1,J)
  132 CONTINUE
      J1=NA1+NA2+1
      J2=NA1+NA2+NA3
      IN=1
      KA=6
      IF (NA3.EQ.0) GO TO 410
  146 DO 147 L=J1,J2
      K=KA+L-J1
      J=NU(K)
      IF (J.EQ.0) GO TO 147
      READ (5,1) (NTAB(N,K),N=1,J)
      READ             (5,2)(DE1(NN),NN=1,J)
       DO 703 N=1,J
      M=NTAB(N,K)
      TARSTA(N)=TARGA(M)
  703 DE(M,L)=DE1(N)
      WRITE (6,336) PIER4
      WRITE (6,894) ((TARSTA(NN),DE1(NN)),NN=1,J)
  147 CONTINUE
      GO TO(410,144),IN
  410 J1=J2+NAG+1
      J2=J1+NAM-1
      KA=6+NA3
      IN=2
      GO TO 146
  144 CONTINUE
      READ (5,2) EXECD,TCOL,RCOL,B2RAD,B2ASS
      READ(5,2)  BUCSPR,BUCSPZ
      WRITE (6,715)
      WRITE (6,760) PIER39,RAGEX,PIER40,ALTEX,PIER41,BUCSPR,PIER42,BUCSI
     1Z
      WRITE (6,760) PIER43,EXECD,PIER44,TCOL,PIER45,RCOL,PIER46,TAU
      READ (5,1) IDENS,NUNURE,(NUREF(I),I=1,NUNURE),IPUNCH
      READ (5,1) IZOZO,(IREZO(K),K=1,IZOZO)
      READ (5,1) IANAN,(IREAN(K),K=1,IANAN)
      READ (5,2)  RHONOM,RHOLIQ,DG
      WRITE (6,760) PIER5(1),PIER5(2),RHONOM,PIER5(3),PIER5(4),RHOLIQ
      WRITE (6,602) PIER47,B2RAD
      WRITE (6,602) PIER48,B2ASS
C
      JRAG=IRC+1
      DATI ( 1)=RE
      DATI ( 2)=RAGEX
      DATI ( 3)=ALTEX
      DATI ( 4)=TEREFI
      DATI ( 5)=TEMPU
      DATI ( 6)=TEREFE
      DATI ( 7)=TEMMOD
      DATI ( 8)=R(JRAG)
      DATI ( 9)=B2RAD
      DATI (10)=B2ASS
      DATI (11)=BUCSPR
```

```
      DATI (12)=BUCSPZ
      DO 561 I=1,12
  561 BIDATI(I)=DATI(I)
C
  411 CONTINUE
      RE=BIDATI(1)
      RAGEX=BIDATI(2)
      ALTEX=BIDATI(3)
      TEREFI=BIDATI(4)
      TEMPU =BIDATI(5)
      TEREFE=BIDATI(6)
      TEMMOD=BIDATI(7)
      R(JRAG)=BIDATI(8)
      B2RAC=BIDATI(9)
      B2ASS=BIDATI(10)
      BUCSPR=BIDATI(11)
      BUCSPZ=BIDATI(12)
      I1=NA1+NA2+NA3+1
      I2=I1+NAG
      I3=IRC+1
      RC(1)=R(I1)
      RC(2)=R(I2)
      RC(3)=R(I3)
      I=2
      LL=1
  134 IF((RB(I,1)-RB(I-1,1)).EQ.0.) GO TO 137
      K=I-1
      J=NU(K)
      IF (J.EQ.0) GO TO 136
      DO 136 N=1,J
      M=NTAB(N,K)
      DE(M,LL)=CON(N,K)
      IF (K.NE.3) GO TO 136
      IXENO=LL
  136 CONTINUE
      LL=LL+1
  137 I=I+1
      IF (I.LE.5) GO TO 134
  138 CONTINUE
      L2=NA1+NA2
      DO 140 L=1,L2
      DO 139 K=1,4
  139 V(K,L)=3.1416*(RB(K+1,L)**2-RB(K,L)**2) *BAN(L)
      VO(L)=3.1416*(R(L+1)**2-R(L)**2)
  140 V(5,L)=VO(L)-V(1,L)-V(2,L)-V(3,L)-V(4,L)
      J1=NA1+NA2+1
      DO 141 I=J1,IRC
  141 VO(I)=3.1416*(R(I+1)**2-R(I)**2)
      DO 142 I=1,5
      J=NU(I)
      IF (J.EQ.0) GO TO 142
      DO 725 N=1,J
      M=NTAB(N,I)
      CONC(M,I)=CON(N,I)
  725 CONTINUE
```

```
  142 CONTINUE
C
C
C
C
C     RIENTRO OPZIONI
C
  787 CONTINUE
C
C
      DO 7 L=1,NUCLEI
      DO 7 IR=1,2
    7 DEN(L,IR)=0.
      DO 445 L=1,17
  445 VET(L)=0.
      DO 726 N=1,30
      ACE(N,1)=0.
      ACE(N,2)=0.
  726 ACE(N,3)=0.
      CA=0.
      CI=0.
      CS=0.
      CE=0.
      CC=0.
      K1=NA1+NA2
      DO 240 L=1,K1
      CA=CA+BAN(L)*(RB(4,L)**2-RB(3,L)**2)
      CI=CI+BAN(L)*RB(3,L)
      CE=CE+BAN(L)*RB(4,L)
      CC=CC+BAN(L)*RB(2,L)**2
  240 CS=CS+BAN(L)*RB(5,L)**2
      AN=(CE*CE-CI*CI)/CA
      VET(1)=SQRT (CC/AN)
      VET(2)=CI/AN
      VET(3)=CE/AN
      VET(4)=SQRT (CS/AN)
      T=.9282*SQRT (AN-.25)+3.4641*AN-1.12635
      VRUB=3.1416*R(IRUB+1)**2
      RUB=SQRT (VRUB/3.1416)
      VET(5)=2.*SQRT (VRUB/T)
      RAGGA=VET(1)
      RAGGB=VET(2)
      RAGGR=VET(3)
      RAGGC=VET(4)
      RAGGT=VET(5)
      VET(6)=AN
      VET(7)=CONC(5,3)
      VET(8)=RE
      GO TO (40,42,41), ICO
   40 VET( 9)=2.95
      VET(10)=25.8
      GO TO 753
   42 VET( 9)=4.15
      VET(10)=26.6
      GO TO 753
```

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   41 VET(9)=3.1
      VET(10)=27.
  753 VET(11)=DAB(ISPA)
      GO TO (401,402),ISPA
  401 DAT=1.9047*R(IRC+1)-2.*R(IRC)
      GO TO 403
  402 DAT=1.7724*R(IRC+1)-2.*R(IRC)
  403 VET(12)=DAT
      VET(13)=VO(IRC)
      VET(14)=6.2832*R(IRC)
      DASIG=0.
      J=NU(NZ)
      DO 253 K=1,J
      M=NTAB(K,NZ)
  253 DASIG=DASIG+DE(M,IRC)*ASTRO(4,M)
      VET(15)=DASIG
C
C
C     OMOGENIZZ. EPSILON  E SURF
C
C
C
C     COSTRUZ. MATRICI SEZMA,SEZMAT
C
       DO 658 J=1,2
       DO 658I=1,4
  658 SEZMAT(I,J)=0.
       DO 657 J=1,NUCLEI
       DO 657I=1,4
  657 CONC3(I,J)=0.
      DO 656 J=1,14
       DO 656I=1,4
  656 SEZMA(I,J)=0.
      DO 659 I=1,9
  659 VEPSI(I)=0.
C
      VOL2=3.1415927*(RAGGB**2-RAGGA**2)
      VOL1=3.1415927*RAGGA**2
      VOL4=3.1415927*(RAGGC**2-RAGGR**2)
      VOLSC=.8660254*RAGGT**2-3.1415927*RAGGC**2
      DO 342 I=1,NUCLEI
      CONC3(1,I)=(CONC(I,1)*VOL1+CONC(I,2)*VOL2)/(VOL1+VOL2)
  342 CONC3(2,I)=CONC(I,3)
      IF (AN.GT.1.0001) GO TO 343
      IF ((RAGGC-RAGGR).GT.0.00001) GO TO 345
      DO 346 I=1,NUCLEI
      CONC3(4,I)=DE(I,IRC)
  346 CONC3(3,I)=0.
      RCAN=RAGGR
      RAGGT=2.*RAGGR
      GO TO 348
  345 DO 347 I=1,NUCLEI
      CONC3(4,I)=DE(I,IRC)
  347 CONC3(3,I)=CONC(I,4)
      RCAN=RAGGC
      RAGGT=1.904626*RAGGC
```

```
  348 GO TO 349
  343 CONTINUE
      DO 300 I=1,NUCLEI
  300 CONC3(3,I)=(CONC(I,4)*VOL4+CONC(I,5)*VOLSC)/(VOL4+VOLSC)
  349 DO 301 L=1,3
      DO 301 M=1,14
      SEZMA(L,M)=0.
      DO 301 K=1,NUCLEI
  301 SEZMA(L,M)=CONC3(L,K)*SEZ(M,K)+SEZMA(L,M)
      DO 303 L=1,3
      SEZMAT(L,2)=0.
      DO 303 M=2,9
  303 SEZMAT(L,2)=SEZMAT(L,2)+SEZMA(L,M)
      DO 305 L=1,3
      SEZMAT(L,1)=0.
      DO 305 M=11,14
  305 SEZMAT(L,1)=SEZMAT(L,1)+SEZMA(L,M)
C
C     COSTRUZ. RIGA 4 DELLE MATRICI SEZMA E SEZMAT
C
      IF (AN.LT.1.0001) GO TO 317
      SIG321=SEZMAT(3,2)+SEZMAT(3,1)
      IF(SIG321.GT.0.) GO TO 308
      RCAN=RC(2)
      VMODE=3.1415927*(R (IRC+1)**2-R (IRC)**2)
      VCAL=3.1415927*(R (IRC)**2-RC(2)**2)
      DO 309 I=1,NUCLEI
  309 CONC3(4,I)=(DE(I,IRC-1)*VCAL+DE(I,IRC)*VMODE)/(VCAL+VMODE)
      GO TO 317
  308 RCAN=RUB
      KRC=NA1+NA2+1
      DO 311 I=1,NUCLEI
      VTOT=0.
      CONTOT=0.
      DO 311 KK=KRC,IRC
      VTOT=VTOT+VO(KK)
      CONTOT=CONTOT+DE(I,KK)*VO(KK)
  311 CONC3(4,I)=CONTOT/VTOT
  317 DO 319 M=1,14
      SEZMA(4,M)=0.
      DO 319 K=1,NUCLEI
  319 SEZMA(4,M)=SEZMA(4,M)+CONC3(4,K)*SEZ(M,K)
      SEZMAT(4,2)=0.
      SEZMAT(4,1)=0.
      DO 321 M=2,9
  321 SEZMAT(4,2)=SEZMAT(4,2)+SEZMA(4,M)
      DO 322 M=11,14
  322 SEZMAT(4,1)=SEZMAT(4,1)+SEZMA(4,M)
C
C     COSTRUZ) VETTORE VEPSI
C
      VEPSI(1)=SEZ(9,5)*CONC3(2,5)
      VEPSI(2)=SEZ(9,1)*CONC3(2,1)
      VEPSI(3)=SEZ(14,1)*CONC3(2,1)
      VEPSI(4)=(SEZ(8,5)+SEZ(9,5))*CONC3(2,5)
```

```
      VEPSI(5)=(SEZ(13,5)+SEZ(14,5))*CONC3(2,5)
      VEPSI(6)=SEZ(8,5)*CONC3(2,5)
      VEPSI(7)=SEZ(13,5)*CONC3(2,5)
      VEPSI(8)=(SEZ(8,1)+SEZ(9,1))*CONC3(2,1)
      VEPSI(9)=(SEZ(13,1)+SEZ(14,1))*CONC3(2,1)
      DO 254 I=1,NUCLEI
      ACE(I,1)=CONC3(1,I)*ASTRO(4,I)
      ACE(I,2)=CONC3(3,I)*ASTRO(4,I)
      ACE(I,3)=ASTRO(10,I)
      VET(16)=VET(16)+ACE(I,1)
  254 VET(17)=VET(17)+ACE(I,2)
C
C
      CALL SURF
C
C
      EFFIC=VET(3)
      RADSUM=VET(1)
      AAIEF=VET(2)
      KK1=NA1+1
      KK2=NA1+NA2
      KK3=KK2+1
      KK4=NA1+NA2+NA3
      SEF=VET(3)
      B=0.
      DO 258 L=1,KK2
  258 B=B+V(3,L)
      VU=B
      VOLUR=VU
      PE(3)=VU
      A=0.
      B=0.
      DO 256 N=1,NUCLEI
      A=A+(VOL1*CONC(N,1)*ASTRO(6,N)*ASTRO(4,N)+
     1      VOL2*CONC(N,2)*ASTRO(6,N)*ASTRO(4,N))*TEREFI*AN
     2       +VU*CONC(N,3)*ASTRO(6,N)*ASTRO(4,N)*TEMPU
     3+(VOL4    *CONC(N,4)*ASTRO(6,N)*ASTRO(4,N)+
     4VOLSC     *CONC(N,5)*ASTRO(6,N)*ASTRO(4,N))*TEREFE*AN
  256 B=B+(VOL1*CONC(N,1)*ASTRO(6,N)*ASTRO(4,N)+
     1      VOL2*CONC(N,2)*ASTRO(6,N)*ASTRO(4,N))*AN
     2       +VU*CONC(N,3)*ASTRO(6,N)*ASTRO(4,N)
     3+(VOL4    *CONC(N,4)*ASTRO(6,N)*ASTRO(4,N)+
     4VOLSC     *CONC(N,5)*ASTRO(6,N)*ASTRO(4,N))*AN
      IF(NA3.EQ.0)  GO TO 255
      DO 650 I=KK3,KK4
      DO 650 K=1,NUCLEI
      A=A+VO(I)*DE(K,I)*ASTRO(6,K)*ASTRO(4,K)*TEREFE
  650 B=B+VO(I)*DE(K,I)*ASTRO(6,K)*ASTRO(4,K)
  255 TE(1)=A/B
      TE(2)=TEMMOD
      TE(3)=TEMPU
      DO 263 M=1,NUCLEI
      A=0.
      DO 260 L1=1,NA1
  260 A=A+DE(M,L1)*VO(L1)
```

```
      DO 261 L2=KK1,KK2
      DO 261 N=1,5
  261 A=A+CONC(M,N)*V(N,L2)
      IF(NA3.EQ.0) GO TO 413
      DO 262 L3=KK3,KK4
  262 A=A+DE(M,L3)*VO(L3)
  413 CONTINUE
  263 DEN(M,1)=A/(3.1416*RC(1)**2)+DEN(M,1)
      DO 265 M=1,NUCLEI
      A=0.
      DO 264 L=I2,IRC
  264 A=A+DE(M,L)*VO(L)
  265 DEN(M,2)=A/(3.1416*(RC(3)**2-RC(2)**2))+DEN(M,2)
C
C
      CALL NEMO
      CHA5=CROMI(11,1,1)/ASTRO(1,1)
      CHF5=CROMI(12,1,1)/ASTRO(9,1)
      CHA9=CROMI(11,2,1)/ASTRO(1,2)
      CHF9=CROMI(12,2,1)/ASTRO(9,2)
      F9F5F=CHF9/CHF5
      F9F5M=CROMI(12,2,2)*ASTRO(9,1)/(CROMI(12,1,2)*ASTRO(9,2))
C
C
      AUA=(CROMI(2,6,2)+CROMI(1,6,2)/VV(2))*DE (6,IRC)
      AUB=(CROMI(2,7,2)+CROMI(1,7,2)/VV(2))*DE (7,IRC)
      AMDAM=               -AUA*.1434/1.1434-AUB*.0226/1.0226
      PE(1)=RUB
      PE(2)=RC(3)
      PE(4)=TE(3)
      A=SIGMA(5,1)*(RC(1)**2-RUB**2)+SIGMA(5,2)*(RC(3)**2-RC(2)**2)
      PE(7)=A/(RC(3)**2-RUB**2)
      PE(5)=SIGMA(5,1)/PE(7)
      PE(6)=(A+SIGMA(5,1)*RUB**2)*3.1416
      PE(8)=CONC(5,3)
      PE(9)=VET(1)
      PE(10)=VET(2)
      PE(11)=2.05
      PE(12)=.44
      PE(13)=27.62
      PE(17)=.005
      GO TO (56,57,56),ICO
   56 PE(14)=1.
      PE(15)=.0
      PE(16)=.0051
      GO TO 754
   57 PE(14)=1.07
      PE(15)=.066
      PE(16)=.0058
  754 B=(SIGMA(3,1)+SIGMA(14,1))*(RC(1)**2-RUB**2)+(SIGMA(3,2)+SIGMA(14
     12))*(RC(3)**2-RC(2)**2)
      B=B/(RC(3)**2-RUB**2)
      A=3.*B*PE(7)
      PE(18)=5.0183/A
      PE(19)=6.5928/A
```

```
      A=SIGMA(6,1)*(RC(1)**2-RUB**2)+SIGMA(6,2)*(RC(3)**2-RC(2)**2)
      B=SIGMA(4,1)*(RC(1)**2-RUB**2)+SIGMA(4,2)*(RC(3)**2-RC(2)**2)
      PE(19)=PE(19)+(RC(3)**2-RUB**2)**2/(A*B)
      ESSE=PE(5)
C
C
      CALL ESCA
C
C
      PEPE=PE(1)
      PEPEO=PE(2)
      PINF=PE(3)
      DOPP=PE(4)
      DOPPO=PE(5)
      SIGSC=0.
      SIGAM=0.
      SIGSS=0.
      DO 453 K=1,NUCLEI
      SIGSC=SIGSC+CONC(K,3)*CROMI(2,K,1)
      SIGSS=SIGSS+CONC(K,3)*CROMI(13,K,1)
  453 SIGAM=SIGAM+CONC(K,3)*CROMI(1,K,1)/VV(1)
      SIGTR=SIGAM+SIGSC
       BET=RAGGR*SIGTR
      BAMD=(PCHP(BET)/(1.-PCHP(BET)))/SIGTR
      BZET=(3.*BET**2+1.5444*BET)/(8.*BET+21.6)
      BERS=BZET/(1.+BZET)
      FSUP=1.+SIGAM*(BAMD-RAGGR)/(1.-BERS*SIGSC/SIGTR)
      IF (RAGGA.GT..1E-06) GO TO 450
      IF (RAGGB.GT..1E-06) GO TO 450
      IF (AN.GT.1.) GO TO 901
      FSB=FSUP
      FSBB=1.
      GO TO 454
  901 IF (RAGGC.GT.RAGGR) GO TO 902
      FSB=FSUP
      FSBB=FSUP
      GO TO 454
  902 SPACVE=.5*(R(NA1+2)+R(NA1+1))
      DO 913 I=1,20
      VCONS(I)=VO(I)
  913 RCONS(I)=R(I)
      RB(6,NA1+1)=.525037*SPACVE
      DO 914 I=2,4
  914 R(I)=RB(I+2,NA1+1)
      R(5)=RC(3)
      IIRC=IRC
      IRC=4
      DO 908 I=1,4
  908 VO(I)=3.1416*(R(I+1)**2-R(I)**2)
      DO 916 IZ=1,4
      SA(IZ)=0.
      STT(IZ)=0.
      FIM(IZ)=0.
      C  (IZ)=0.
  916 Q  (IZ)=0.
```

```
      DO 907 IZ=1,4
      DO 907 IN=1,NUCLEI
      IF (IZ.LE.3) SA (IZ)=SA (IZ)+CROMI(1,IN,1)*CONC(IN,IZ+2)/VV(1)
      IF (IZ.LE.3) STT(IZ)=SA (IZ)+CROMI(2,IN,1)*CONC(IN,IZ+2)
      IF (IZ.LE.3) FIM(IZ)=FIM(IZ)+CROMI(14,IN,1)*CONC(IN,IZ+2)*VO(IZ)/
     1VV(1)
      IF (IZ.LE.3) C  (IZ)=C  (IZ)+CROMI(1 ,IN,1)*CONC(IN,IZ+2)*VO(IZ)/
     1VV(1)
      IF (IZ.LE.3) Q  (IZ)=Q  (IZ)+CROMI(5 ,IN,1)*CONC(IN,IZ+2)*VO(IZ)
      IF (IZ.EQ.4) SA (IZ)=SA (IZ)+CROMI( 1,IN,2)*DE(IN,IIRC)/VV(2)
      IF (IZ.EQ.4) STT(IZ)=SA (IZ)+CROMI( 2,IN,2)*DE(IN,IIRC)
      IF (IZ.EQ.4) FIM(IZ)=FIM(IZ)+CROMI(14,IN,2)*DE(IN,IIRC)*VO(IZ)/
     1VV(2)
      IF (IZ.EQ.4) C  (IZ)=C  (IZ)+CROMI( 1,IN,2)*DE(IN,IIRC)*VO(IZ)/
     1VV(2)
      IF (IZ.EQ.4) Q  (IZ)=Q  (IZ)+CROMI( 5,IN,2)*DE(IN,IIRC)*VO(IZ)
  907 CONTINUE
      CALL BEAM
      FSB=FLU(2)/FLU(1)
      FSBB=FLU(3)/FLU(1)
      IRC=IIRC
      DO 909 I=1,20
      VO(I)=VCONS(I)
  909 R (I)=RCONS(I)
      GO TO 454
  450 FSB=1.
      FSBB=1.
  454 CONTINUE
      DO 51 K=1,20
      SA(K)=0.
      STT(K)=0.
       C(K)=0.
   51 FIM(K)=0.
      DO 154 IR=1,NA1
      DO 152 L=1,15
      A=0.
      DO 151 IN=1,NUCLEI
  151 A=A+DE(IN,IR)*CROMI(L,IN,1)
  152 SEM(L,IR)=A
      IF(SEM(9,IR).EQ.0.) GO TO 885
      C(IR)=SEM(1,IR)*VO(IR)/VV(1)
      FIM(IR)=SEM(14,IR)*VO(IR)/VV(1)
  885 SA(IR)=SEM(1,IR)/VV(1)
      STT(IR)=SEM(2,IR)+SA(IR)
  154 CONTINUE
      IF(NA2.EQ.0) GO TO 421
      DO 161 IR=KK1,KK2
      DO 158 IZ=1,5
      DO 156 L=1,15
      A=0.
      DO 155 IN=1,NUCLEI
  155 A=A+CONC(IN,IZ)*CROMI(L,IN,1)
  156 SEMZ(L,IZ)=A*V(IZ,IR)
      IF (IZ.GT.3) GO TO 883
      SEMZ(1,IZ)=SEMZ(1,IZ)/FSBB
```

```
      SEMZ(2,IZ)=SEMZ(2,IZ)/FSBB
      SEMZ(9,IZ)=SEMZ(9,IZ)/FSBB
       SEMZ(14,IZ)=SEMZ(14,IZ)/FSBB
  883 IF(SEMZ(9,IZ).EQ.0.) GO TO 886
      C(IR)=C(IR)+SEMZ(1,IZ)/VV(1)
      FIM(IR)=FIM(IR)+SEMZ(14,IZ)/VV(1)
  886 SA(IR)=SA(IR)+SEMZ(1,IZ)/(VV(1)*VO(IR))
      STT(IR)=STT(IR)+SEMZ(1,IZ)/(VV(1)*VO(IR))+SEMZ(2,IZ)/VO(IR)
  158 CONTINUE
      DO 884 IZ=1,3
      SEMZ( 1,IZ)=SEMZ( 1,IZ)*FSBB
      SEMZ( 2,IZ)=SEMZ( 2,IZ)*FSBB
      SEMZ( 9,IZ)=SEMZ( 9,IZ)*FSBB
  884 SEMZ(14,IZ)=SEMZ(14,IZ)*FSBB
      DO 160 L=1,15
      A=0.
      DO 159 IZ=1,5
  159 A=A+SEMZ(L,IZ)
  160 SEM(L,IR)=A/VO(IR)
  161 CONTINUE
  421 CONTINUE
      K1=NA1+NA2+1
      K2=NA1+NA2+NA3
      K3=K2+NAG+1
      IF(NA3.EQ.0) GO TO 415
      DO 887 IR=K1,K2
      DO 163 L=1,15
      A=0.
      DO 162 IN=1,NUCLEI
  162 A=A+DE(IN,IR)*CROMI(L,IN,1)
  163 SEM(L,IR)=A
      SA(IR)=SEM(1,IR)/VV(1)
      IF(IR.EQ.IPRETU) SA(IR)=SEM(1,IR)*2./(VV(1)+VV(2))
  887 STT(IR)=SEM(2,IR)+SA(IR)
  415 DO 165 IR=K3,IRC
      DO 165 L=1,15
      A=0.
      DO 164 IN=1,NUCLEI
  164 A=A+DE(IN,IR)*CROMI(L,IN,2)
  165 SEM(L,IR)=A
      ASSOR=0.
      FISSI=0.
      AUEI=0.
      AMEI=0.
      AUES=0.
      AMES=0.
      DO 166 I=1,K2
      FIE   =(1.17626*SEM(14,I)+SEM(15,I))*CHIE/(DUM*VV(2))
      SAE   =(1.17626*SEM(1,I)+SEM(8,I))*CHIE/(DUM*VV(2))
      ASSOR=ASSOR+SAE*VO(I)
      FISSI=FISSI+FIE*VO(I)
      Q(I)=SEM(5,I)*VO(I)
      AUES=AUES+SEM(4,I)*VO(I)/3.1416
  166 AUEI=AUEI+(SAE+SEM(3,I))*VO(I)/3.1416
       CASSOR=ASSOR
```

```
      AFISSI=FISSI
      DO 167 L=K3,IRC
      SA(L)=SEM(1,L)/VV(2)
      IF(L.EQ.ICALAN) SA(L)=SEM(1,L)*2./(VV(1)+VV(2))
      STT(L)=SEM(2,L)+SA(L)
      SAE   =(1.17626*SEM(1,L)+SEM(8,L))/(DUM*VV(2))
      ASSOR=ASSOR+SAE*VO(L)
      Q(L)=SEM(5,L)*VO(L)
      AMES=AMES+SEM(4,L)*VO(L)/3.1416
  167 AMEI=AMEI+(SAE+SEM(3,L))*VO(L)/3.1416
      STT(IRC)=STT(IRC)+AMDAM
      VOCHIE=CHIE*(RC(1)/RC(3))**2
      CSSEI=SIGMA(5,1)*VOCHIE+SIGMA(5,2)*(1.-(RC(2)/RC(3))**2)
      CSSES=SIGMA(6,1)*(RC(1)/RC(3))**2+SIGMA(6,2)*(1.-(RC(2)/RC(3))**2)
      ASSOR=ASSOR/(3.1416*RC(3)**2)
      FISSI=FISSI/(3.1416*RC(3)**2)
      AUEI=RC(1)**2/AUEI
      AUES=RC(1)**2/AUES
      AMEI=(RC(3)**2-RC(2)**2)/AMEI
      AMES=(RC(3)**2-RC(2)**2)/AMES
C
C
      CALL BEAM
C
C
C     CALCOLO DENSITA' NEUTRONICHE
      OMEPRI=OME*(1.+(BUCSPR*DRM+BUCSPZ*DZM)/SACM)
      ESUTM=1.17626*OMEPRI*CHIT/(1.-1.17626*OMEPRI*CHIE)
      EPDENM=ESUTM*FLU(IRC)/VV(2)
      DO 903 L=1,K2
  903 TOTDEN(L)=FLU(L)/VV(1)+CHIE*EPDENM
      IF(IPRETU.EQ.K2) TOTDEN(K2)=FLU(K2)*2./(VV(1)+VV(2))+(1.+CHIE)*.5*
     1EPDENM
      K2G = K2 + 1
      IF ( NAG. EQ. 1 ) TOTDEN ( K2G ) = FLU ( K2G ) * 2./ (  VV(1) + VV
     1(2)) + ( 1. + CHIE ) * .5 * EPDENM
      DO 904 L=K3,IRC
  904 TOTDEN(L)=FLU(L)/VV(2)+EPDENM
      IF(ICALAN.EQ.K3) TOTDEN(K3)=FLU(L)*2./(VV(1)+VV(2))+EPDENM*.5*
     1(1.+CHIE)
C
C     CALCOLO PARAMETRI TIPO ETEROGENEO
C
      KAGA=NA1+NA2+NA3+NAG+1
      EFFMOD=0.
      STMO=0.
      SAMO=0.
      FLUMMO=0.
      RIK=0.
      QMODE=0.
      DO 1001 I=KAGA,IRC
      STMO=STMO+STT(I)*VO(I)
      SAMO=SAMO+SA(I)*VO(I)
      EFFMOD=EFFMOD+EFF(I)
      QMODE=QMODE+Q(I)
```

```
              RIK=RIK+VO(I)
         1001 FLUMMO=FLUMMO+FLU(I)*VO(I)
              FLUMMO=FLUMMO/RIK
              STMO=STMO/RIK
              SAMO=SAMO/RIK
              QMODE=QMODE/RIK
              AAJO=QMODE -SAMO*FLUMMO
              AJO=AAJO*RIK     /(6.2831854*RC(2))
              CCZ=0.5*CZ
              DDM=AMDMBE/3.
              ELLEX=2.*((DDM*FLUMMO   )/(RC(2)*AAJO)-RC(2)*ZZ*ZZ*CCZ)/(ZZ*ZZ-1.)
              FIDIBI=AJO*(ELLEX+RC(2)*ZZ*ZZ*ALOG(ZZ) /(ZZ*ZZ-1.)-0.5*RC(2))/DDM
              VIRNA=1./(1.+0.75*(ELLEX*STMO         -BLACK))
              WEIGHT=(1.-EFFMOD    )*(ALOG(RC(3)/RC(2))+ELLEX/RC(2))
               WEIGHT=1./WEIGHT
              RIK=0.
              FICELL=0.
              DO 1000 I=1,IRC
              RIK=RIK+VO(I)
         1000 FICELL=FICELL+FLU(I)*VO(I)
              FICELL=FICELL/RIK
              EDGE=FIDIBI/FICELL
       C
       C       CALCOLO PARAM. INPUT PER FIFA
       C
       C      COSTRUZ.  ANUTH
       C
              ANVTH=ASTRO(8,1)
              BI=R(IRC+1)
              GO TO(325,326),ISPA
          325 BETDAN=2.125
              PASSO=BI*1.904624
              GO TO 327
          326 BETDAN=5.67
              PASSO=BI*1.7724539
          327 CONTINUE
              IF (AN.GT.1.0001) GO TO 341
              FCL=1.
          341 TEST=0.
              DO 329 I=1,3
              DO 329 J=1,2
          329 TEST=TEST+SEZMAT(I,J)
              IF(TEST.LT..1E-10) GO TO 331
              CALL FIFA
              GO TO 335
          331 EPSI=1.
              DELT28=0.
              BETA=0.
              GAMMA=0.
              RASTER=0.
          335 CONTINUE
       C
       C
       C
       C
```

```
C
C
C     CONDENSAZ. A 4 GRUPPI
C
      VOLUM=(RC(1)/RC(3))**2
      ASSOP=DEN(1,1)*(CROMI(1,1,1)*1.17626+CROMI(8,1,1))+DEN(2,1)*(CROMI
     1(1,2,1)*1.17626+CROMI(8,2,1))+DEN(4,1)*(CROMI(1,4,1)*1.17626+CROMI
     2(8,4,1))
      ASSOP=ASSOR*DUM-VOLUM*ASSOP/VV(2)
      DUMS=11.512925-ALOG(EAST)
      DUMI=DUM-3.-DUMS
      ARI5=(370.*141.)/(149.+EAST**2)
      ARI9=(478.5*324.)/(482.+EAST**2)
      ARI1=(781.*324.)/(482.+EAST**2)
      FRI5=(269.*3.27)/(3.07+SQRT(EAST))       *ASTRO(8,1)
      FRI9=(319.*5.15)/(6.96+SQRT(EAST))    *ASTRO(8,2)
      FRI1=(567.5*5.15)/(6.96+SQRT(EAST))       *ASTRO(8,4)
      RISOS=(ARI5*DEN(1,1)+ARI9*DEN(2,1)+ARI1*DEN(4,1))/DUMS
      ASSOS=ASSOP*VV(2)*(SQRT(.02531/EAST)-.000503)/(.58813*DUMS)+VOLUM
     1*RISOS
      ASSOI=(ASSOR*DUM-ASSOS*DUMS)/DUMI
      FISSES=(FRI5*DEN(1,1)+FRI9*DEN(2,1)+FRI1*DEN(4,1))*VOLUM/DUMS
      FISSEI=(FISSI*DUM-FISSES*DUMS)/DUMI
      REMOV=CSSES/3.
      REMOS=CSSEI/DUMS
      REMOI=CSSEI/DUMI
      REMOM=0.
      IF(IFILTR.GT.0) GO TO 712
      GAMM=0.
      GO TO 713
  712 GAMM=1./PEPE -1.
  713 CONTINUE
      REMO8=GAMM*REMOS
      TAUVR=DRES/REMOV
      TAUVZ=DZES/REMOV
      TAUSR=DREI/REMOS
      TAUSZ=DZEI/REMOS
      TAUIR=DREI/REMOI
      TAUIZ=DZEI/REMOI
      RL2=DRM/SACM
      ZL2=DZM/SACM
      ALFAS=ASSOS/REMOS
      ALFAI=ASSOI/REMOI
      BETAS=FISSES/REMOS
      BETAI=FISSEI/REMOI
      ICAPP=1
      ICEFF=1
      B2R=0.
      B2Z=0.
  603 FLUI=(1.+B2R*RL2+B2Z*ZL2)*SACM/REMOI
      FLUS=FLUI*(1.+ALFAI+B2R*TAUIR+B2Z*TAUIZ)*REMOI/(REMOS*
     1PEPE *(1.+GAMM))
      FLUV=FLUS*(1.+GAMM+ALFAS+B2R*TAUSR+B2Z*TAUSZ)*REMOS/REMOV
      COSTK=(ETAPR*EFU*SACM+FISSEI*FLUI+FISSES*FLUS)*EPSI/(REMOV
     1*FLUV*(1.+TAUVR*B2R+TAUVZ*B2Z))
```

```
      GO TO (626,627),ICAPP
  626 GO TO (600,652),ICEFF
  600 CMINF=COSTK
      ICEFF=2
      COCUFA=EPSI*ETAPR*EFU*PEPE
      DITAU=BETAS/(BETAI*PEPE*(1.+GAMM)+BETAS*(1.+ALFAI))
      SF1=ETAPR*EFU*SACM
      SF2=EPSI*FISSEI
      SF3=EPSI*FISSES
      SO2=EPSI*SF1
      RIMOZ=(PEPE *(1.+GAMM))/REMOI+(1.+ALFAI)/REMOS+(1.+GAMM+ALFAS)*(1.
     1+ALFAI)/REMOV
      RIMOZ=1./RIMOZ
      COAL=(1.+ALFAI)*(1.+GAMM+ALFAS)-1.
      TAUEPR=TAUSR/(1.+GAMM+ALFAS)+TAUIR/(1.+ALFAI)+TAUVR-DITAU*TAUIR
      TAUEPZ=TAUSZ/(1.+GAMM+ALFAS)+TAUIZ/(1.+ALFAI)+TAUVZ-DITAU*TAUIZ
      COBE=PE(1)*(1.+GAMM)*BETAI*(1.+ALFAI)*BETAS
      DR1=TAUEPR*(1.+COAL)*RIMOZ
      DZ1=TAUEPZ*(1.+COAL)*RIMOZ
      S1=(1.+COAL)*RIMOZ
      S11=EPSI*COBE*RIMOZ
      S21=PEPE *(1.+GAMM)*RIMOZ
      RL22=DRM/SACM+DITAU*TAUIR
      ZL22=DZM/SACM+DITAU*TAUIZ
      DR2=RL22*SACM
      DZ2=ZL22*SACM
      ETA=1.+(S11/RIMOZ)/(COCUFA*(1.+GAMM))
      AMIGRR=RL22/ETA+DR1/S1
      AMIGR =ZL22/ETA+DZ1/S1
      IF (IBUC .EQ.1) GO TO 717
      B2R=BUCSPR
      B2Z=BUCSPZ
      GO TO 718
  717 B2R=(2.4048/RAGEX)**2
      B2Z=(3.1416/ALTEX)**2
  718 CONTINUE
      CMEF2=(S11+SO2*S21/(SACM+DR2*B2R+DZ2*B2Z))/(S1+DR1*B2R+DZ1*B2Z)
      GO TO 603
  652 COCRIT=COSTK
      IBUCK=1
      BUZ=(3.1416/ALTEX)**2
      COB1=(S1-S11+DZ1*BUZ)/DR1
      COB2=(SACM+DZ2*BUZ)/DR2
      COB=COB1+COB2
      COC=SO2*S21/(DR1*DR2)  -COB1*COB2
      COU1=(S1-S11)/DR1
      COU2=SACM/DR2
      COU=COU1+COU2
      COV=SO2*S21/(DR1*DR2)-COU1*COU2
      GO TO 610
  611 BUR=(2.4048/RAGEX)**2
      COB1=(S1-S11+DR1*BUR)/DZ1
      COB2=(SACM +DR2*BUR)/DZ2
      COB=COB1+COB2
      COC=SO2*S21/(DZ1*DZ2)-COB1*COB2
```

```
      COU1=(S1-S11)/DZ1
      COU2=SACM/DZ2
      COU=COU1+COU2
      COV=S02*S21/(DZ1*DZ2)-COU1*COU2
      IBUCK=2
      BUMATT=BUMAT
  610 BUMAT=.5*(SQRT(COB*COB+4.*COC)-COB)
      GO TO(611,612),IBUCK
  612 CONTINUE
      ICAPP=2
      B2R=B2RAD
      B2Z=B2ASS
      GO TO 603
  627 CONTINUE
      BUMATE=BUMATT+BUZ*AMIGR/AMIGRR
      IF (IVX.GT.0) SACM=SACM/EDGE
      IF (IVX.GT.0) DR1=DR1/EDGE
      IF (IVX.GT.0) DR2=DR2/EDGE
      IF (IVX.GT.0) S02=S02/EDGE
C
C     CALCOLO FIU/FIC  E SIGMA 11 E 12 DEL SOLO U 235
C
      VOLCEL=3.1416*RC(3)**2
      RVURCE=VOLUR/VOLCEL
      I=1
      IF(RAGGA.GT.0.00001) I=I+1
      IF((RAGGB-RAGGA).GT.0.00001) I=I+1
      FINOM=FLU(I)*VO(I)
      IF(AN.EQ.1.) GO TO 870
      KBRU1=NA1+1
      KBRU2=NA1+NA2
      DO 871 I=KBRU1,KBRU2
  871 FINOM=FINOM+FLU(I)*V(3,I)/FSBB
  870 FIDEN=0.
      DO 872 I=1,IRC
  872 FIDEN=FIDEN+FLU(I)*VO(I)
      RFURCE=FINOM/(FIDEN*RVURCE)
C
C      CALCOLO VELOCITA'  MEDIE A 2 GRUPPI
      VUMEFU=.22E 06*VV(1)
      VUMEMO=.22E 06*VV(2)
      FLMEFU=0.
      DEMEFU=0.
      DO 920 I=1,K2
      FLMEFU=FLMEFU+FLU(I)*VO(I)
  920 DEMEFU=DEMEFU+FLU(I)*VO(I)/VUMEFU
      IBRUSA=K2+1
      FLMEMO=0.
      DEMEMO=0.
      DO 921 I=IBRUSA,IRC
      FLMEMO=FLMEMO+FLU(I)*VO(I)
  921 DEMEMO=DEMEMO+FLU(I)*VO(I)/VUMEMO
      AVEVU2=(FLMEFU+FLMEMO)/(DEMEFU+DEMEMO)
      AVEVU1=.22E 06*DUM*VV(2)/1.17626
C
```

```
      A=(1.17626*CROMI(14,1,1)+CROMI(15,1,1))*DEN(1,1)
      A=A*CHIE*VOLUM/VV(2)
      FISS5=FRI5*DEN(1,1)*VOLUM/DUMS
      FISI5=(A-FISS5*DUMS)/DUMI
      S1135=   (FISI5/REMOI+(FISS5/REMOS)*(1.+ALFAI))*EPSI*RIMOZ
      S1235=EPSI*ASTRO(8,1)*CONC(1,3)*RVURCE*RFURCE*CROMI(9,1,1)/VV(1)
C
      SIGXE1=(1.17626*CROMI(1,15,1)+CROMI(8,15,1))/(VV(2)*DUM)
      SIGXE2=CROMI(1,15,1)/VV(1)
C      CALCOLO PARAMETRI PER PUNCH MOICANO
C
      IF (IDENS.GT.1) GO TO 875
      IF (IOPZ .GT.1) GO TO 875
      SXE1=SIGXE1
      SXE2=SIGXE2
      YIELD=.064/RVURCE
      PSIMO=RFURCE
  875 CONTINUE
C
C         CALCOLO ICR (CRITICO)
C
      TERM1=CROMI(1,5,1)*CONC(5,3)/(CROMI(11,1,1)*CONC(1,3))
      TERM3=GAMMA*ASTRO(8,1)*CROMI(12,1,1)/CROMI(11,1,1)
      TERM2=TERM3/GAMMA
      TERM2=TERM2*EPSI*(1.-PEPE )*(1.+GAMM)/COCRIT
      TERM2=TERM2/(1.+TAUVR*BUR+TAUVZ*BUMAT)
      TERM2=TERM2/(1.+GAMM+ALFAS+TAUSR*BUR+TAUSZ*BUMAT)
      RCI=TERM1+TERM2+TERM3
C
C          CALCOLO RCIR E RHO 28
C
C     CALCOLO G8,GF5,SF5,S8 PER RRCI
C
      X=.001*TCOL-.27314
      G8=0.
      DO 400 I=1,10
      K=I-1
  400 G8=G8+SEZIO(I,1,5)*X**K
      SF9=0.
      SF5=0.
      DO 422 I=1,10
      SF9=SF9+SEZIOF(I,2,2)*X**(I-1)
  422 SF5=SF5+SEZIOF(I,2,1)*X**(I-1)
      GF9=0.
      GF5=0.
      DO 423 I=1,10
      GF9=GF9+SEZIOF(I,1,2)*X**(I-1)
  423 GF5=GF5+SEZIOF(I,1,1)*X**(I-1)
      S8=.0658555*SQRT(TCOL)*(103.6765-.4743181*G8)
C
      PURAEX=(GF9+RCOL*SF9)/(GF5+RCOL*SF5)
      F9F5F=F9F5F/PURAEX
      F9F5M=F9F5M/PURAEX
C
      TH=ASTRO(1,5)*(G8+RCOL*S8)      *CONC(5,3)/CONC(1,3)
```

```
      TH=TH/(ASTRO(9,1)*(GF5+RCOL*SF5))
      TERM3=GAMMA*ASTRO(8,1)
      TERM2=EPSI*(1.-PEPE  )*(1.+GAMM)*ASTRO(8,1)/COSTK
      FUVEL=1.+B2RAD*TAUVR+B2ASS*TAUVZ
      FUSUP=1.+GAMM+ALFAS+B2RAD*TAUSR+B2ASS*TAUSZ
      TERM2=TERM2/(FUVEL*FUSUP)
      TERM1=TERM1*CROMI(11,1,1)/CROMI(12,1,1)
      RCIR=(TERM1+TERM2+TERM3)/TH
C
C
      RECD=SQRT(3.681*TEN(2)*.02531/(293.58*EXECD))
      REAST=RECD*SQRT(EXECD/EAST)
      OMEGA=1.17626*OME
      RHO28=((TERM2+TERM3)/TERM1+OMEGA*(RECD-REAST))/(1.-OMEGA*RECD)
C
C         STAMPE  FINALI
C
      RATIO=VO(IRC)/VOLUR
      IF(IDENS.GT.1) GO TO 854
      IF (IOPZ.GT.1) GO TO 840
      IF (IPRINT.EQ.1) GO TO 719
      IPAGE=2
      WRITE (6,55) IPAGE
  719 WRITE (6,766) VOLUR,VO(IRC),RATIO,TE(1)
      WRITE (6,715)
      WRITE(6,71)
      WRITE (6,102) RE,EFFIC,RADSUM,AAIEF
      WRITE (6,715)
      WRITE (6,760)  PIER10,TEN(1),PIER11,TEN(2),PIER12,OME,PIER13,DUM
      WRITE (6,760)  PIER14,CHIE,PIER15,CHIT,PIER16,CHI(2),PIER17,CHI(3
      WRITE (6,760)  PIER18,CHA5,PIER19,CHF5,PIER20,CHA9,PIER21,CHF9
      WRITE (6,715)
      WRITE(6,72)
      WRITE (6,102) PEPE,PEPEO,PINF,DOPP,DOPPO
      WRITE (6,715)
      WRITE(6,73)
      WRITE(6,102)CSSEI,CSSES,ASSOR,FISSI
      WRITE(6,715)
      WRITE(6,715)
      WRITE (6,338)
      DO 784 K=1,IRC
      TOTDEN(K)=TOTDEN(K)/TOTDEN(IRC)
  784 WRITE (6,43) VO(K),EFF(K),FLU(K),TOTDEN(K)
      WRITE (6,715)
      WRITE(6,75)
      WRITE(6,43 )EFU,ETAPR,SACM ,FSB,FCL,FSBB
      WRITE(6,74)
      WRITE (6,43) AMDUBE,AMDMBE,AUEI,AMEI,AUES,AMES
      WRITE (6,715)
      WRITE(6,77)
      WRITE (6,102) EPSI,DELT28,BETA,GAMMA,RASTER
      IPAGE=3
      WRITE (6,55) IPAGE
      WRITE (6,602) PIER22,CMINF
      WRITE (6,602) PIER23.COCUFA
```

```
      WRITE (6,602) PIER24,COCRIT
      WRITE (6,602) PIER25,CMEF2
      WRITE(6,620)
      WRITE (6,702) BONA(1),DRM,DREI,DREI,DRES
      WRITE (6,702) BONA(2),  DZM,DZEI,DZEI,DZES
      WRITE (6,702) BONA(3),  REMOM,REMOI,REMOS,REMOV
      WRITE (6,702) BONA(4),  SACM,ASSOI,ASSOS,REMOM
      WRITE (6,702) BONA(5),  REMOM,REMOM,REMO8,REMOM
      WRITE (6,702) BONA(6),  SF1,FISSEI,FISSES,REMOM
      WRITE (6,702) BONA(7),  SO2,SF2,SF3,REMOM
      WRITE (6,702) BONA(8),  RL2,TAUIR,TAUSR,TAUVR
      WRITE (6,702) BONA(9),  ZL2,TAUIZ,TAUSZ,TAUVZ
      WRITE(6,623)
      WRITE(6,43)DR1,DZ1,S1,S11,SO2
      WRITE(6,622)
      WRITE(6,43)DR2,DZ2,SACM,S21
      WRITE (6,715)
      WRITE (6,760) BRU1,S1135,BRU2,S1235,BRU3,RFURCE,BRU4,RVURCE
      WRITE (6,760) BRU6,SIGXE1,BRU7,SIGXE2,BRU8,AVEVU1,BRU9,AVEVU2
      WRITE (6,760) BRU10,ELLEX,BRU11,VIRNA,BRU12,WEIGHT,BRU13,EDGE
      WRITE (6,715)
      WRITE (6,760) PIER31,BUR,PIER32,BUMAT,PIER33,BUZ,PIER34,BUMATT
      WRITE (6,716)
      WRITE (6,602) PIER35,AMIGRR
      WRITE (6,602) PIER36,AMIGR
      WRITE (6,716)
      WRITE (6,602) PIER37,BUMATE
      WRITE (6,716)
      WRITE (6,602) PIER38,RCI
      WRITE (6,406)
      WRITE (6,602) PIER26,F9F5F
      WRITE (6,602) PIER27,F9F5M
      WRITE (6,602) PIER28,RHO28
      WRITE (6,602) PIER29,RCIR
      WRITE (6,602) PIER30,DELT28
  840 CONTINUE
C
C
C     O P Z I O N I
C
C
      IF (IOPZ.EQ.0) GO TO 854
      OPZIO( 1,IOPZ)=EPSI
      OPZIO( 2,IOPZ)=PEPE
      OPZIO( 3,IOPZ)=ETAPR
      OPZIO( 4,IOPZ)=EFU
      OPZIO( 5,IOPZ)=CMINF
      OPZIO( 6,IOPZ)=COCRIT
      OPZIO( 7,IOPZ)=DR1
      OPZIO( 8,IOPZ)=DZ1
      OPZIO( 9,IOPZ)=DR2
      OPZIO(10,IOPZ)=DZ2
      OPZIO(11,IOPZ)=S1
      OPZIO(12,IOPZ)=S11
      OPZIO(13,IOPZ)=SO2
```

```
      OPZIO(14,IOPZ)=SACM
      OPZIO(15,IOPZ)=S21
      OPZIO(16,IOPZ)=BUMATE
      OPZIO(17,IOPZ)=AMIGRR
      OPZIO(18,IOPZ)=AMIGR
      OPZIO(19,IOPZ)=TEN(1)
      OPZIO(20,IOPZ)=TEN(2)
      OPZIO(21,IOPZ)=OME
      OPZIO(22,IOPZ)=DUM
      OPZIO(23,IOPZ)=CHIE
      OPZIO(24,IOPZ)=CHIT
      OPZIO(25,IOPZ)=CHI(2)
      OPZIO(26,IOPZ)=CHI(3)
      OPZIO(27,IOPZ)=SIGXE1
      OPZIO(28,IOPZ)=SIGXE2
      BRUOPZ(1,IOPZ)=RFURCE
      BRUOPZ(2,IOPZ)=S1135
      BRUOPZ(3,IOPZ)=S1235
      BRUOPZ(4,IOPZ)=AVEVU1
      BRUOPZ(5,IOPZ)=AVEVU2
      BRUOPZ(6,IOPZ)=ELLEX
      BRUOPZ(7,IOPZ)=VIRNA
      BRUOPZ(8,IOPZ)=WEIGHT
      BRUOPZ(9,IOPZ)=EDGE
      IF (IOPZ.EQ.8) GO TO 838
      GO TO (791,792,793,794,795,796,797),IOPZ
  791 TEMMOD=TEMMOD+10.
      IOPZ=2
      GO TO 787
  792 TEMMOD=TEMMOD-10.
      TEMPU=TEMPU+40.
      IOPZ=3
      GO TO 787
  793 TEMPU=TEMPU-40.
      TEREFI=TEREFI+20.
      TEREFE=TEREFE+20.
      IOPZ=4
      GO TO 787
  794 TEREFI=TEREFI-20.
      TEREFE=TEREFE-20.
      CONBOR=CONC(15,3)
      CONC(15,3)=.2E-08+CONBOR
      IF (IXENO.EQ.0) GO TO 832
      DE(15,IXENO)=DE(15,IXENO)+.2E-08
  832 IOPZ=5
      GO TO 787
  795 CONC(15,3)=CONBOR
      IF (IXENO.EQ.0) GO TO 833
      DE(15,IXENO)=DE(15,IXENO)-.2E-08
  833 DEBOR=DE(14,IRC)
      DE(14,IRC)=.5E-06+DEBOR
      IOPZ=6
      GO TO 787
  796 DE(14,IRC)=DEBOR
      DO 798 I=1,NUCLEI
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```
  798 DE(I,IRC)=.95*DE(I,IRC)
      IOPZ=7
      GO TO 787
  797 DO 799 I=1,NUCLEI
  799 DE(I,IRC)=DE(I,IRC)/.95
      DO 800 I=1,NUNURE
      J=NUREF(I)
      DO 802 K=1,IZOZO
      L=IREZO(K)
      REFCO(K,I)=CONC(J,L)
  802 CONC(J,L)=0.
      DO 837 K=1,IANAN
      L=IREAN(K)
      REFDE(K,I)=DE(J,L)
  837 DE(J,L)=0.
  800 CONTINUE
  803 IOPZ=8
      GO TO 787
C
C     RIPRISTINO ULTIMA OPZIONE E STAMPE
C
  838 DO 806 I=1,NUNURE
      J=NUREF(I)
      DO 807 K=1,IZOZO
      L=IREZO(K)
  807 CONC(J,L)=REFCO(K,I)
      DO 839 K=1,IANAN
      L=IREAN(K)
  839 DE(J,L)=REFDE(K,I)
  806 CONTINUE
      DO 841 I=1,6
      DO 841 J=1,7
      K=J+1
  841 ST1(I,J)=(OPZIO(I,K)-OPZIO(I,1))*VST3(J)
      DO 842 I=5,9
      L=I+6
      DO 842 J=1,7
      K=J+1
  842 ST2(I,J)=(OPZIO(L,K)-OPZIO(L,1))*VST4(J)
      DO 768 I=1,4
      L=I+6
      DO 768 J=1,7
      K=J+1
  768 ST2(I,J)=(1./OPZIO(L,K)-1./OPZIO(L,1))*VST4(J)
      WRITE (6,809)
      WRITE (6,336) PIER1
      WRITE (6,715)
      WRITE (6,810)
      DO 813 J=1,28
  813 WRITE (6,811) PIER(2*J-1),PIER(2*J),(OPZIO(J,I),I=2,8)
      DO 873 J=1,9
  873 WRITE (6,811) BRU5(2*J-1),BRU5(2*J),(BRUOPZ(J,I),I=2,8)
      WRITE (6,849)
      DO 814 J=1,6
  814 WRITE (6,812) PIERI(2*J-1),PIERI(2*J),(ST1(J,I),I=1,7)
```

```
      WRITE (6,850)
      DO 815 J=1,9
  815 WRITE (6,811) PIERIN(2*J-1),PIERIN(2*J),(ST2(J,I),I=1,7)
C
C
C        VARIE  DENSITA'
C
C
  854 IF (IDENS.EQ.0) GO TO 788
      IF (IDENS.GT.1) GO TO 858
      DO 851 I=1,NUNURE
      J=NUREF(I)
      DO 852 K=1,IZOZO
      L=IREZO(K)
  852 REFCO(K,I)=CONC(J,L)*RHOLIQ/RHONOM
      DO 853 K=1,IANAN
      L=IREAN(K)
  853 REFDE(K,I)=DE(J,L)*RHOLIQ/RHONOM
  851 CONTINUE
  859 DO 855 I=1,NUNURE
      J=NUREF(I)
      DO 856 K=1,IZOZO
      L=IREZO(K)
  856 CONC(J,L)=REFCO(K,I)*VDENS(IDENS)
      DO 857 K=1,IANAN
      L=IREAN(K)
  857 DE(J,L)=REFDE(K,I)*VDENS(IDENS)
  855 CONTINUE
      IDENS=IDENS+1
      GO TO 787
  858 OPZIO( 1,IDENS-1)=EPSI
      OPZIO( 2,IDENS-1)=PEPE
      OPZIO( 3,IDENS-1)=ETAPR
      OPZIO( 4,IDENS-1)=EFU
      OPZIO( 5,IDENS-1)=CMINF
      OPZIO( 6,IDENS-1)=COCRIT
      OPZIO( 7,IDENS-1)=DR1
      OPZIO( 8,IDENS-1)=DZ1
      OPZIO( 9,IDENS-1)=DR2
      OPZIO(10,IDENS-1)=DZ2
      OPZIO(11,IDENS-1)=S1
      OPZIO(12,IDENS-1)=S11
      OPZIO(13,IDENS-1)=S02
      OPZIO(14,IDENS-1)=SACM
      OPZIO(15,IDENS-1)=S21
      OPZIO(16,IDENS-1)=BUMATE
      OPZIO(17,IDENS-1)=AMIGRR
      OPZIO(18,IDENS-1)=AMIGR
      OPZIO(19,IDENS-1)=TEN(1)
      OPZIO(20,IDENS-1)=TEN(2)
      OPZIO(21,IDENS-1)=OME
      OPZIO(22,IDENS-1)=DUM
      OPZIO(23,IDENS-1)=CHIE
      OPZIO(24,IDENS-1)=CHIT
      OPZIO(25,IDENS-1)=CHI(2)
```

```
      OPZIO(26,IDENS-1)=CHI(3)
      OPZIO(27,IDENS-1)=SIGXE1
      OPZIO(28,IDENS-1)=SIGXE2
      BRUOPZ(1,IDENS-1)=RFURCE
      BRUOPZ(2,IDENS-1)=S1135
      BRUOPZ(3,IDENS-1)=S1235
      BRUOPZ(4,IDENS-1)=AVEVU1
      BRUOPZ(5,IDENS-1)=AVEVU2
      BRUOPZ(6,IDENS-1)=ELLEX
      BRUOPZ(7,IDENS-1)=VIRNA
      BRUOPZ(8,IDENS-1)=WEIGHT
      BRUOPZ(9,IDENS-1)=EDGE
      IF (IDENS.GE.6) GO TO 860
      GO TO 859
C
C          RIPRISTINO DENSITA' E STAMPE
C
  860 DO 861 I=1,NUNURE
      J=NUREF(I)
      DO 862 K=1,IZOZO
      L=IREZO(K)
  862 CONC(J,L)=REFCO(K,I)*RHONOM/RHOLIQ
      DO 863 K=1,IANAN
      L=IREAN(K)
  863 DE(J,L)=REFDE(K,I)*RHONOM/RHOLIQ
  861 CONTINUE
      WRITE (6,809)
      WRITE (6,336) PIER53
      WRITE (6,715)
      WRITE (6,864)
      DO 865 J=1,28
  865 WRITE (6,811) PIER(2*J-1),PIER(2*J),(OPZIO(J,I),I=1,5)
      DO 874 J=1,9
  874 WRITE (6,811) BRU5(2*J-1),BRU5(2*J),(BRUOPZ(J,I),I=1,5)
      DO 866 J=1,5
      OPZIO(11,J)=OPZIO(11,J)-OPZIO(12,J)
      DO 866 I=7,10
  866 OPZIO(I,J)=1./OPZIO(I,J)
      DO 867 I=1,5
  867 RHO(I)=RHOLIQ*VDENS(I)
      CALL PODE
      WRITE (6,868)
      DO 869 I=1,9
  869 WRITE (6,811) BONALU(2*I-1),BONALU(2*I),(POLINO(J,I),J=1,5)
C
C     PUNCH PER CODICE MOICANO
C
      IF (IPUNCH.NE.1) GO TO 788
      WRITE (6,809)
      WRITE (6,876)
      WRITE (6,103)    (TITLE(L),L=1,12)
      WRITE (7,3  )    (TITLE(L),L=1,12)
      WRITE (6,715)
      WRITE (6,102)   (POLINO(1,I),I=2,5)
      WRITE (7,2  )   (POLINO(1,I),I=2,5)
```

```
      A=ST2(5,5)-ST2(6,5)
      WRITE (6,102)  A,ST2(9,5),ST2(7,5),ST2(8,5)
      WRITE (7,2  )  A,ST2(9,5),ST2(7,5),ST2(8,5)
      A=ST2(5,4)-ST2(6,4)
      WRITE (6,102)  A,ST2(9,4),ST2(7,4),ST2(8,4)
      WRITE (7,2  )  A,ST2(9,4),ST2(7,4),ST2(8,4)
      DO 878 I=6,9
       K=I-5
  878 ST1(K     ,1)=1./POLINO(1,I)
      WRITE (6,102)   (ST1(I,1),I=1,4)
      WRITE (7,2  )   (ST1(I,1),I=1,4)
      WRITE (6,102) ST2(1,5),ST2(3,5),ST2(2,5),ST2(4,5)
      WRITE (6,102) ST2(1,4),ST2(3,4),ST2(2,4),ST2(4,4)
      WRITE (7,2  ) ST2(1,5),ST2(3,5),ST2(2,5),ST2(4,5)
      WRITE (7,2  ) ST2(1,4),ST2(3,4),ST2(2,4),ST2(4,4)
      WRITE (6,715)
      WRITE (6,102)  POLINO(1,1),REMOM,SXE1,SXE2
      WRITE (7,2  )  POLINO(1,1),REMOM,SXE1,SXE2
      WRITE (6,102)  ST2(6,5),ST2(6,4)
      WRITE (7,2  )  ST2(6,5),ST2(6,4)
      WRITE (6,102)  YIELD,ASTRO(8,1),ASTRO(8,1),PSIMO
      WRITE (7,2  )  YIELD,ASTRO(8,1),ASTRO(8,1),PSIMO
      WRITE (6,715)
      DO 880 J=1,9
      WRITE (6,102) REMOM,(POLINO(I,J),I=2,5)
  880 WRITE (7,2  ) REMOM,(POLINO(I,J),I=2,5)
C
C
C     PROBLEMI SOSTITUTIVI
C
  788 IF(ISOST-1)6,560,555
  560 READ(5,3)(TITLE(N),N=1,12)
      READ(5,1) ISOST,IOPZ,IDENS,IPUNCH,NUSOST
      IPRINT=1
      WRITE (6,809)
      WRITE (6,336) PIER2
      WRITE (6,716)
      WRITE (6,103)    (TITLE(L),L=1,12)
      WRITE (6,895) ISOST,IOPZ,IDENS,IPUNCH,NUSOST
      READ(5,1) (INDICI(I),I=1,NUSOST)
      READ(5,2) (RIDATI(I),I=1,NUSOST)
      DO 906 I=1,NUSOST
      M=INDICI(I)
  906 TARSTA(I)=PIER55(M)
      WRITE (6,897)
      WRITE (6,894) ((TARSTA(I),RIDATI(I)),I=1,NUSOST)
      DO 881 I=1,12
  881 BIDATI(I)=DATI(I)
      DO 882 K=1,NUSOST
      IJK=INDICI(K)
  882 BIDATI(IJK)=RIDATI(K)
      GO TO 411
  555 STOP
      END
```

```
$IBFTC SURF
      SUBROUTINE SURF
      COMMON/ACC/ACE(30,3),A,B,R,C,T,AN,EN8,RE,AG,BG,CABE,CAT,CAV,CAS,
     1CASIG,S0,S2,PE(20),NUCLE
C
C
      GAM=B/R
      ROS=0.
      CCS=0.
      R2S=0.
      C2S=0.
      REQ=.525037*T
      W2=1.-(R/REQ)**2
C
C
      GW=.275664*(T/R)**2-1.
      ETO=2.*S0*B
      ET1=2.*S2*R
      ET=ETO
      INC=1
  203 IF(ET-4.)150,150,151
  150 CCH=ET*(ET+4.)/(6.+5.*ET+ET**2)
      GO TO(205,207,209),INC
  151 CCH=1.-(1.-.75/ET**2)/ET
      GO TO (205,207,209),INC
  205 PCO=CCH
      ET=ET1
      INC=2
      GO TO 203
  207 PL11=CCH
      CS=S2*T*.5
      ET=S2*T*(1.+.04775/(1.+S2*T*.2619375))
      INC=3
      GO TO 203
  209 PL=CCH
      D1=2.*R
      ALFA=D1/T
      IF(ALFA-.999)213,215,215
  215 P=.06667
      GO TO 223
  213 X=ALFA**2
      T1=.5*ALFA/SQRT(1.-.75*X)
      D1=.866025*ALFA
      D1=D1/SQRT(1.-D1*D1)
      D1=ATAN(D1)
      D2=ALOG((ALFA+T1)/(ALFA-T1))
      D3=ALOG((1.+T1)/(1.-T1))
      P=(.57735*D1+ALFA*D2-.5*(1.+X)*D3-.82247*X)*.95493/ALFA
  223 X=CS*P
      D1=(7.2+X)*X+5.42
      D2=D1+.4*X
      D3=SQRT(.63662*X+1.62114)
      EF1=D1/(D2*D3*EXP(X))
      D1=1.-GAM**2
      G12=1.-1.27324*EF1
```

```
      S=1.+(.1704*D1-1.)*GAM
      P10=.63662*ET0*S*(1.-PC0)*GAM/D1
      CAP1=1.27324*R*S
      Y=ET1*GW
      SG=.9069*ALFA
      P02=(1.-PC0)*G12
      D1=GAM**2
      IF(S2)405,407,405
  405 P20=S0*D1*P02/(S2*GW)
      GO TO 409
  407     P20=.63662*S0*T*D1*(1.-PC0)*P/GW
  409 EFFE=PL/W2-(PL11+G12*(2.-G12)*(1.-PL11))/GW
      P22=EFFE-P20*G12
      GHIR=Y*(1.-P22-P20)
      PIAZ=GHIR+GAM*ET0*(1.-P00-P02)
      ZAM=2.*R*(1.-D1)*(1.-P10)*(1.-G12)
      IF(PIAZ)411,413,411
  411 FF22=GHIR/PIAZ
      GO TO 415
  413 FF22=0.
  415 G=SG*PIAZ
      IND=1
  509 D1=1.-G
      IF(G-.95238)152,152,153
  152 ET=(SQRT(36.*D1+G*G)-6.+5.*G)*.5/D1
      ACCA=ET*(ET+4.)/(6.+5.*ET+ET**2)
      GO TO 157
  153 ET=.866025/SQRT(D1)
      ACCA=1.-(1.-.75/ET**2)/ET
  157 D1=ET*SQRT(AN)
      IF(D1-4.)158,158,159
  158 CAPPA=D1*(D1+4.)/(6.+5.*D1+D1**2)
      GO TO 160
  159 CAPPA=1.-(1.-.75/D1**2)/D1
  160 RO=(CAPPA-ACCA)/(1.-ACCA)
      GO TO (505,507),IND
  505 IF(PIAZ)511,513,511
  511 ULMBD=ZAM*RO/PIAZ
      GO TO 515
  513 ULMBD=ZAM*SG*(SQRT(AN)-1.)*.66667
  515 ROO=RO
      TETA=Y*(1.+EFFE)/(1.-G12)-G12
      G=SG*(1.-G12)*(1.+TETA)
      IND=2
      GO TO 509
  507 ROI=RO
      TAU=(T-2.*R)*S2
      TAU1=TAU+Y/(7.+2.125*Y)
      GM=1.-EXP(-TAU*Y)/(1.+(1.-TAU1)*Y)
      CM=(GM-G12)/(1.-G12)
      D1=1.-G12
      ELLE0=2.*R*(1.-GAM**2)/(D1*(1.-ROI))
      WI=(CAP1+D1*ULMBD)/(ELLE0*(1.-P10)*D1*(1.-ROO))
      WI=SQRT(WI)
      WE=(1.-ROO)*(G12+ROI*(CM-G12))
```

```
      IF(WE-.C001)25C,250,251
  250 EPWE=2.*ALFA*GW/P
      WE=1./(1.-ROO)+ROO*EPWE/((1.-RCO)*ETO*(1.-POO))
      WE=WE/(1.+ROI*EPWE/(1.-ROI))
      GO TO 252
  251 WE=(1.-ROI)*(G12+D1*RCC*FF22)/WE
  252 CONTINUE
      WE=SQRT(WE)
C
C
      CH=(1.-ROO)*D1*(1.-P10)
      SN=6.283185*AN*R*(1.-RCI)*D1
      E=12.56637*R*R*(1.-GAM**2)*CH*AN/SN
      Q=1.-.343*SQRT(3.1415926*EN8*E)
      QS=-ALOG(Q)
      DO 4 I=1,NUCLE
      D1=ACE(I,3)
      IF(D1) 717,715,717
  717 CS=1.+D1*ALOG(D1)/(1.-D1)
      GO TO 721
  715 CS=1.
  721 IF(Q-D1)723,725,725
  723 RR    =CS/QS
      GO TO 720
  725 RR    =(1.-Q-D1*QS)/((1.-D1)*QS)
  720 CONTINUE
      ROS=ROS+RR*ACE(I,1)
    4 R2S=R2S+RR*ACE(I,2)
      ROS=ROS/SO
      COS=1.-ROS
      R2S=R2S/S2
      C2S=1.-R2S
      D4=12.56637*R*R/SN
C
C
      GME=1.-SN/DAS
      T1=4.*DAV/DAS
      T2=T1*DASIG
      T3=DAT/T1
      T4=T3+T2/(7.+DABE*T2)
      GE=(1.+(1.-T4)*T2)*EXP(T2*T3)
      GE=1.-1./GE
      GE=GE/(1.-(1.-GE)*GME)
      GE=GE/(1.+.1*(1.-GE))
C
C
      DELTA=SO*(1.-POO)*ROS*WI/(1.-COS*PCO)
      D5=GAM**2
      D1=D4*D5*DELTA*AN
      IF(S2)905,907,905
  907 PJ=0.
      PU=.63662*P*(1.-ROI)/(ALFA*GW)+RCI
      GO TO 909
  905 F2=1.-CM/TETA
      D3=G12/Y
```

```
      D2=EFFE-D3*G12
      PJ=D2+(1.-D2-D3)*ROI*F2
      PU=(G12+(1.-G12)*ROI*CM)/Y
  909 R2S=R2S+C2S*(1.-PJ-PU)
      DELTA=S2*PU*R2S*WE/(1.-C2S*PJ)
      D2=D4*GW*AN*DELTA
      DELTA=(1.+D1+D2)*SQRT(CH*SN*GE)
      D1=3.1415926*RE*AN*(1.-D5)
      D1=DELTA/(R*SQRT(D1))
      D2=AG+BG*D1
      A=D1
      B=D2
      R=DELTA**2
      RETURN
      END
```

```
£IBFTC NEMO
      SUBROUTINE NEMO
      COMMON/ACC/FI(3,4),CRON(4),FT(4),TN(2),TI(2),PIN(3),PT(3),V(2)
      COMMON/NEM1/IX(30),NTE(30),ASTRO(10,30),SEZIO(10,2,30),SEZIOF(10,
     12,5),CROMI(15,30,2),TARGA(30),SEZ(14,30)
      COMMON/NEM2/DEN(30,2),TE(3),VV(2),SIGMA(16,2),CZ,Z  ,BLACK
      COMMON/NEM3/NUCLEI,DUM,VU,SEF,DUI,TAU,CHIE,CHIT,OME,TEN(2),CHI(4)
     1,DG
      COMMON/SIR3/RC(3)
      COMMON/PUPO/IFUN
      COMMON/COREA/A,B,T,      E0,ERIS,GAM2
      DATA E0/.02531/
      DATA ERIS/.297/
      DATA GAM2/.0495/
      DO 7  I=1,15
      DO 7  L=1,NUCLEI
      DO 7  IR=1,2
      CROMI(I,L,IR)=0.
    7 CONTINUE
      GGP1=0.
      GGP2=0.
      IPV=1
      Z=RC(3)/RC(2)
      CZ=Z*Z*ALOG(Z)/(Z*Z-1.)-.75+.25/(Z*Z)
      DC=2.*RC(1)
      DM=2.*RC(2)*(Z*Z-1.)
      RV=RC(1)**2/(RC(3)**2-RC(2)**2)
      A=1.+4044.8*DC*DEN(2,1)
      A=.5236*SQRT(A)
      QU=EXP(-A)
      TEN(1)=TE(2)
      TEN(2)=TE(2)
      OME=0.
      DO 99  N=1,4
   99 CHI(N)=1.
      CHIE=1.
      CHIT=1.
C
C
   10 CONTINUE
      FT(1)=1./(1.+.3333*DUI*TAU*DG*DG*CROMI(11,1,1))
      FT(2)=1.+.3333*DUI*DG*DG*EXP(-.4*TAU*CROMI(11,2,1))
      FT9=FT(2)
      FT(3)=1.-FT9*DUI*(1.+DG*DG)/(1.+0.3333*DG*DG)**2
      FT(4)=FT(3)
      V(1)=TEN(1)/293.58
      V(2)=TEN(2)/293.58
      VV(1)=1.12838*SQRT(V(1))
      VV(2)=1.12838*SQRT(V(2))
      IR=1
   12 IFISS=0
      DO 11  ITP=1,NUCLEI
      IF(IPV-1)90,90,91
   90 IF(QU-ASTRO(10,ITP))92,92,93
   92 CS1=ASTRO(6,ITP)
```

```
      CROMI(7,ITP,1)=CS1*ASTRO(4,ITP)
      GO TO 91
   93 CS1=1.-QU+ASTRO(10,ITP)*ALOG(QU)
      CS1=CS1/(1.-ASTRO(10,ITP))
      CROMI(7,ITP,1)=CS1*ASTRO(4,ITP)
   91 CONTINUE
      IF(ASTRO(2,ITP))13,14,14
   14 SSM=ASTRO(2,ITP)
      UNM=ASTRO(3,ITP)
      GO TO 15
   13 DO 16 J=1,3
      FLJ=J
   16 PT(J)=FLJ+ASTRO(2,ITP)
      PIN(1)=0.5*PT(2)*PT(3)
      PIN(2)=(-1.)*PT(1)*PT(3)
      PIN(3)=0.5*PT(1)*PT(2)
      SSM=(45.7*PIN(1)+95.5*PIN(2)+14.29*PIN(3))*V(IR)**(-2.971*PIN(1)-0
     1.2849*PIN(2)-0.1232*PIN(3))
      UNM=(0.7812*PIN(1)+0.7895*PIN(2)+0.85704*PIN(3))*V(IR)**(-0.1827*P
     1IN(1)-0.1679*PIN(2)-0.0626*PIN(3))
   15 IF(IX(ITP))18,17,18
   17 GG=SEZIO(1,1,ITP)
      IF(SEZIO(2,1,ITP))20,19,20
   19 SS=0.
      GO TO 21
   20 SS=(VV(2)/ASTRO(1,ITP))*(SEZIO(2,1,ITP)+2.*ASTRO(1,ITP)*(SQRT(1./(
     13.681*V(2)))-SQRT(.0253/SEZIO(3,1,ITP))))-1.17626*GG
      GO TO 21
   18 TN(1)=.001*TEN(1)-.27314
      TN(2)=.001*TEN(2)-.27314
      GG=0.
      DO 22 IL=1,10
      IM=IL-1
   22 GG=GG+SEZIO(IL,1,ITP)*TN(IR)**IM
      SS=0.
      DO 23 IL=1,10
      IM=IL-1
   23 SS=SS+SEZIO(IL,2,ITP)*TN(2)**IM
      IF(IX(ITP)-1)21,21,28
   28 GFG=0.
      SFS=0.
      IFISS=IFISS+1
      DO 24 IL=1,10
      IM=IL-1
      GFG=GFG+SEZIOF(IL,1,IFISS)*TN(IR)**IM
   24 SFS=SFS+SEZIOF(IL,2,IFISS)*TN(2)**IM
      IF(ITP-2)50,51,50
   51 IF(IPV-1)50,50,52
   52 GO TO (3,50),IR
    3 GG=GGP1
      GFG=GGP2
   50 CONTINUE
      CROMI(9,ITP,IR)=GFG*ASTRO(9,ITP)
      CROMI(10,ITP,IR)=SFS*ASTRO(9,ITP)
   21 CONTINUE
```

```
      CROMI(1,ITP,IR)=GG*ASTRO(1,ITP)
      CROMI(2,ITP,IR)=SSM*UNM
      CROMI(13,ITP,IR)=SSM
      CROMI(3,ITP,IR)=ASTRO(4,ITP)*ASTRO(7,ITP)
      CROMI(4,ITP,IR)=ASTRO(5,ITP)*ASTRO(7,ITP)
      CROMI(5,ITP,IR)=ASTRO(6,ITP)*ASTRO(4,ITP)
      CROMI(6,ITP,IR)=ASTRO(6,ITP)*ASTRO(5,ITP)
      CROMI(8,ITP,IR)=ASTRO(1,ITP)*SS
      CROMI(11,ITP,IR)=CROMI(1,ITP,IR)+OME*CROMI(8,ITP,IR)
   11 CONTINUE
      IF(IR-1)32,32,33
   32 IR=2
      DO 102 II=1,NUCLEI
      CROMI(8,II,1)=CROMI(8,II,1)/CHIE
  102 CROMI(10,II,1)=CROMI(10,II,1)/CHIE
      DO 30 M=1,4
      CROMI(1,M,1)=CROMI(1,M,1)*FT(M)
      CROMI(9,M,1)=CROMI(9,M,1)*FT(M)
      CROMI(14,M,1)=ASTRO(8,M)*CROMI(9,M,1)
      CROMI(8,M,1)=CROMI(8,M,1)*CHI(M)
      CROMI(10,M,1)=CROMI(10,M,1)*CHI(M)
      CROMI(15,M,1)=ASTRO(8,M)*CROMI(10,M,1)
      CROMI(11,M,1)=CROMI(1,M,1)+OME*CROMI(8,M,1)*CHIE
   30 CROMI(12,M,1)=CROMI(9,M,1)+OME*CROMI(10,M,1)*CHIE
      GO TO 12
   33 CONTINUE
      CROMI(12,1,2)=CROMI(9,1,2)+CROMI(10,1,2)*OME*CHIT
      CROMI(12,2,2)=CROMI(9,2,2)+CROMI(10,2,2)*OME*CHIT
C
C
      DUM=ALOG(.63046E+10/TEN(2))
      DO 37 IR=1,2
      DO 37 J=1,11
   37 SIGMA(J,IR)=0.
      DO 38 IR=1,2
      DO 38 J=1,11
      DO 38 L=1,NUCLEI
   38 SIGMA(J,IR)=SIGMA(J,IR)+DEN(L,IR)*CROMI(J,L,IR)
      SIGMA(12,1)=SIGMA(1,1)-DEN(2,1)*CROMI(1,2,1)
      SIGMA(16,1)=SIGMA(12,1)-DEN(1,1)*CROMI(1,1,1)-DEN(3,1)*CROMI(1,3
     1)-DEN(4,1)*CROMI(1,4,1)
      DO 39 IR=1,2
      SIGMA(13,IR)=SIGMA(2,IR)+SIGMA(1,IR)/VV(IR)
   39 SIGMA(14,IR)=(SIGMA(8,IR)+1.17626*SIGMA(1,IR))/DUM
      SIGMA(7,1)=SIGMA(7,1)/ALOG(1./QU)
      SIGMA(15,1)=0.
      DO 40 M=1,4
      CRON(M)=CROMI(10,M,1)+1.17626*CROMI(9,M,1)
   40 SIGMA(15,1)=SIGMA(15,1)+DEN(M,1)*CRON(M)*CHIE/(DUM*VV(2))
      SIGMA(14,1)=SIGMA(14,1)*CHIE/VV(2)
      SIGMA(14,2)=SIGMA(14,2)/VV(2)
      OME=VV(2)*(SIGMA(5,1)+SIGMA(5,2)/RV)
      OME=SIGMA(11,1)/OME
      BLACK=0.7104+0.2504/(0.402+RC(2)*SIGMA(13,2))
      ETA=RC(1)*SIGMA(13,1)
```

```
      AMDA2=DC*(ETA+2.)/(ETA+3.)
      ACAST=.375*ETA*(ETA+.5148)/(ETA+2.7)
      ACAST=ACAST/(1.+ACAST)
      COC=SIGMA(2,1)/SIGMA(13,1)
      COCS=SIGMA(5,1)-11.75*DEN(6,1)-1.216*DEN(7,1)
      COCS=COCS/SIGMA(13,1)
      COC=COC*ACAST
      ACAST=1.-COC*(1.-COCS)
      COG=(AMDA2-RC(1))/ACAST
      THETA=COG*COC*COCS/(1.-COC)
      AMDA0=(AMDA2-RC(1)*(1.-COCS)*COC)/ACAST
      DELTA=1.5*RC(3)*RC(3)*CZ*SIGMA(13,2)-DM*(1.-0.75*BLACK)
      AMDA=AMDA0+DELTA*RV
      ESSE=AMDA*(SIGMA(5,1)-11.75*DEN(6,1)-1.216*DEN(7,1) -4.0214*DEN(8
     11))
      AMDA1=AMDA/(1.+ESSE)
      BB=(1.+SIGMA(5,1)*RV/SIGMA(5,2))*VV(1)
      BB=AMDA*SIGMA(1,1)/BB
      BTH=1./(1.+BB)
      TEN(2)=(1.+1.2*OME*CHIT)*TE(2)
      TI(2)=TEN(2)/293.58
      TI(1)=TE(1)/293.58
      COST1=.445149
      COST2=16.60133
      B=AMDA1*DEN(2,1)*ASTRO(1,2)*COST2
      A=AMDA1*SIGMA(12,1)+B*COST1/COST2
      SPL1=A/AMDA1
      SPL2=B/AMDA1
C
C
      DO 501 N = 1, 2
      T = 0.02531 * TI (N)
      DO 502 K = 1, 2
      LL =K + 1
      IFUN = K
  502 FI(LL,N)=AINTG(0.,18.)
 501  FI ( 1,N ) = 1. - A* FI ( 2, N ) - B * FI ( 3 ,N )
      FI(3,3)=FI(2,1)*SPL1+FI(3,1)*SPL2
      FI(3,4)=FI(2,2)*SPL1+FI(3,2)*SPL2
C
C
      W=ESSE*(1.-FI(1,1))+1.+FI(3,3)*THETA
      W=(ESSE*FI(1,2)-FI(3,4)*THETA     )/W
      UU=(FI(1,2)+W*FI(1,1))/(FI(2,2)+W*FI(2,1))
      TEN(1)=3.1416*.25*293.58*UU*UU
      COST3=.553374
      COST4=13.0388
      GGP1=COST1+COST2*(FI(3,2)+W*FI(3,1))/(FI(2,2)+W*FI(2,1))
      GGP2=COST3+COST4*(FI(3,2)+W*FI(3,1))/(FI(2,2)+W*FI(2,1))
      VV(1)=1.12838*SQRT (TEN(1)/293.58)
      VV(2)=1.12838*SQRT (TEN(2)/293.58)
      WWU=1.
      BE=.58813*AMDA2*SIGMA(1,1)*WWU/VV(2)
      CHIE=ALOG(1.+BE)/BE
      CHIT=(FI(2,2)+W*FI(2,1))*VV(2)/(1.+ESSE)
```

```
C
C
      S40=105.*DEN(1,1)+50.*DEN(2,1)+SIGMA(16,1)*0.155
      CH40=1./(1.+AMDA2*S40*WWU)
      RO=DEN(3,1)*1.0493E+06*RC(2)**2/SEF
      X=0.0267*TE(3)/42.24
      IF(X-.025)69,69,71
   69 PSI=1.-2.*X+12.*X*X
      GO TO 70
   71 XX=1./SQRT(4.*X)
      IF(XX-1.E-05)72,72,73
   72 ER=1.-1.12838*XX
      GO TO 74
   73 ER=1./(1.+XX*(.1411282+XX*(.0886403+XX*(.0274335+XX*(-.00039446+X)
     1*.00328975)))))**8
   74 PSI=ER*EXP(.25/X)/(1.12838*SQRT(X))
   70 ZITA=PSI*(1.+0.5*RO*CH40*PSI)/(1.+0.4*RO*CH40*PSI**2)
      EP=1.5708*RO*ZITA*CH40
      CHI(3)=CH40/SQRT(EP+1.)
C
C
      S49=226.*DEN(1,1)+3230.*DEN(2,1)+160.*DEN(3,1)+SIGMA(16,1)*.314
      AEQ=AMDA2/(1.+.7854*DC*SIGMA(7,1))
      CHI(2)=1./(1.+AEQ*S49*WWU)
      S49M=SIGMA(1,1)/3.155
      CHI(2)=CHI(2)*(1.+AEQ*S49M)/(1.+AMDA2*S49M)
      CHI(1)=CHI(2)
      CHI(4)=CHI(2)
      IF(IPV-2   )100,100,101
  100 CONTINUE
      IPV=IPV+1
      GO TO 10
  101 CONTINUE
      RETURN
      END
```

```
$IBFTC AINTG
      FUNCTION AINTG ( EI,ES )
      DIMENSION X(24), COE(24)
      DATA X/0.99877101,0.99353017,0.98412458,0.97059159,0.95298770,
     10.93138669,0.90587913,0.87657202,0.84358826,0.80706620,0.76715903,
     20.72403413,0.67787238,0.62886740,0.57722473,0.52316097,0.46690290,
     30.40868649,0.34875589,0.28736249,0.22476379,0.16122236,0.09700470,
     40.03238017/,COE/3.1533460E-3,7.3275539E-3, .011477235, .015579316,
     5 .019616160, .023570761, .027426510, .031167228, .034777223,
     6 .038241351, .041545083, .044674561, .047616658, .050359036,
     7 .052890189, .055199504, .057277292, .059114840, .060704439,
     8 .062039423, .063114192, .063924239, .064466164, .064737697/
      BB1=(EI+ES)*.5
      AA1=(ES-EI)*.5
      AINTG=0.
      DO 1 I=1,24
    1 AINTG=AINTG+COE(I)*(FUN(AA1*X(I)+BB1)+FUN(BB1-AA1*X(I)))
      AINTG=AINTG*AA1
      RETURN
      END
```

```
£IBFTC ESCA
      SUBROUTINE ESCA
      COMMON/ACC/ACE(30,3),VET(17),PE(20),NUCLE
      AP=PE(1)
      BP=PE(2)
      S=PE(5)
      TAOR=PE(19)
      IND=1
      THETA=PE(18)/5.018304
      TAUO=PE(19)-6.592816*THETA
      TAO=TAUO+6.17*THETA
      Z=1.2732395*AP*AP/TAO
      ZO=Z*TAO/TAUO
      SO=.78539816*AP*AP/TAOR
    1 DLAMO=SQRT (.07466+Z)
      DLAM1=DLAMO+1.
      DLAMM=DLAMO-.27324
      DLAPP=DLAMO+.27324
      DLO=DLAPP**3.4645/(DLAM1**2.3357*DLAMM**1.1288)
      DLO=ALOG(DLO)
      FO=.785398/(1./DLAM1-Z*(DLO+1.08068/DLAM1))
      GZ=DLAM1**2.1614/(DLAPP**1.376*DLAMM**.7854)
      GZ=1.2732395*ALOG(GZ)
      DLAMO=.785398*Z
      T=SQRT (.464703+.07958*DLAMO)
      TP=(T+.681691)**28.647
      TM=(T-.681691)**6.087
      DLO=(T+.7826)**28.734*(T-.464313)**6.
      DLO=ALOG(TP*TM/DLO)
      F1=DLO+3.170617/(T+.681691)+1.152137/(T-.681691)
      F1=19.73905/(DLAMO*F1)
      F3=(FO*(1.-S)+2.*S*F1)/(1.+S)
      GO TO (2,4),IND
    2 FOFO=FO
      GZGZ=GZ
      F3F3=F3
      Z=ZO
      IND=2
      GO TO 1
    4 CONTINUE
      CLAND=TAUO/THETA-3.
      YINFM1=(TAO /(THETA*FOFO)-CLAND*GZGZ)*FOFO/F3F3
      YINFM2=(TAUO /(THETA*FO)-CLAND*GZ)*FO/F3
      YINFM =(YINFM1-YINFM2)*TAOR*  .1073  /THETA
      RSM1=PE(14)*PE(9)**2+PE(15)
      RSM1=SQRT (RSM1)
      YINFI=YINFM+PE(13)*RSM1/(.78539816+SQRT (.046057504+SO))
      VI=(BP*BP-AP*AP)*.25/TAOR
      T=2.63160*VI*SQRT (YINFM/YINFI)
      VN=PE(3)*PE(8)
      DL1=YINFI*VN/(12.56637*TAOR*PE(7))
      PINF=EXP (-DL1)
      DLO=(PE(10)+VI*YINFI*(1.-ATAN (T)/T))*VN/PE(6)
      ETA=PE(16)+PE(17)*PE(9)**2
      CHI=-.5*ETA*DLO
```

```
      DEP=SQRT (PE(4))
      DO=CHI/17.1342
      D1=CHI/DEP
      PPO=EXP (-DLO)
      ALFA=1.+ETA*(DEP-17.1342)
      PP=EXP (-ALFA*DLO)
      PE(1)=PP
      PE(2)=PPO
      PE(3)=PINF
      PE(4)=DO
      PE(5)=D1
      RETURN
      END
```

```
£IBFTC BEAM
      SUBROUTINE BEAM
      DIMENSION  E(20)
      COMMON/BON/G12(20),GVI(20),GVE(20),GIV(20),GEV(20),GII(20),GVV(20)
     1,GEI(20),P11(20),PVI(20),PVE(20),PVV(20),GAM(20),GAMP(20),EF(20),
     2ENBV(20),CSV(20),FIO(20)
      COMMON/SIR3/RC(3)
      COMMON/SIR4/FCL
      COMMON/SIR5/R(21),        STT(20),SA(20),C(20),Q(20),FIM(20)
      COMMON/SIR6/AUEI,AUES,AMEI,AMES,IRUB,EFU,ETAPR,SACM,DRM,DREI,DRES,
     1DZM,DZEI,DZES,AMDUBE,AMDMBE,IRC,FLU(20),EFF(20),VO(20)
      COMMON/COREA1/ET,AL
      COMMON/PUPO/IFUN
      IRC=IRC
      DO 20  IR=1,IRC
      IAL=1
      ALFA=R(IR)/R(IR+1)
      ETA=STT(IR)*R(IR+1)
      IF(ALFA-1.)10,11,10
   11 PVI(IR)=.5
      PVE(IR)=.5
      GO TO 20
   10 IF(ALFA)12,13,12
   12 ES=(ARSIN (ALFA)/ALFA+SQRT (1.-ALFA**2))*.5-.7854*ALFA
      IF(ETA)14,15,14
   14 X=ETA*ES
      D1=(7.2+X)*X+5.42
      D2=D1+.4*X
      D3=SQRT (.63662*X+1.62114)
      EE=D1/(D2*D3*EXP (X))
      G12(IR)=1.-1.27324*EE
      PVI(IR)=ALFA*G12(IR)/(2.*ETA*(1.-ALFA**2))
      Y=2.*ALFA*ETA
   18 P=1.33333-EXP (-.15*Y)
      P=1.+Y-P*Y/(1.+P*Y)
      P=1.-1./P
      GO TO(16,17),IAL
   16 P11(IR)=P
   19 Y=2.*ETA
      IAL=2
      GO TO 18
   17 PVV(IR)=(P-(P11(IR)+G12(IR)*(1.-P11(IR))*(2.-G12(IR)))*ALFA**2)/(1
     1.-ALFA**2)-PVI(IR)*G12(IR)
      PVE(IR)=1.-PVV(IR)-PVI(IR)
      GO TO 20
   15 PVI(IR)=2.*ALFA*ES/(3.1416*(1.-ALFA**2))
      PVE(IR)=1.-PVI(IR)
      G12(IR)=0.
      GO TO 20
   13 PVI(IR)=0.
      P11(IR)=0.
      G12(IR)=0.
      GO TO 19
   20 CONTINUE
      ENB=0.
```

```
      CS=0.
      IRS=IRC-1
      DO 30 K=1,IRS
      IF(STT(K))32,31,32
   31 ZAU=0.
      GO TO 36
   32 ZAU=1.-SA(K)/STT(K)
   36 GVI(K)=PVI(K)/(1.-ZAU*PVV(K))
      GVE(K)=PVE(K)/(1.-ZAU*PVV(K))
      IF(R(K))34,33,34
   33 GII(K)=0.
      GIV(K)=0.
      GEI(K)=0.
      GO TO 35
   34 GII(K)=GVI(K)*PVI(K)*ZAU*STT(K)*2.*(R(K+1)**2-R(K)**2)/R(K)
      GIV(K)=GVI(K)*SA (K)*2.*(R(K+1)**2-R(K)**2)/R(K)
      GEI(K)=(1.-GII(K)-GIV(K))*R(K)/R(K+1)
   35 GEV(K)=GVE(K)*SA (K)*2.*(R(K+1)**2-R(K)**2)/R(K+1)
      GVV(K)=1.-GVE(K)-GVI(K)
      ENB=ENB+Q(K)
      CS=CS+SA(K)*VO(K)
      ENBV(K)=ENB
      CSV(K)=CS
   30 CONTINUE
C
C
      BLACK=.7104+.2504/(.402+R(IRC)*STT(IRC))
      CAP2M=3.*SA(IRC)*STT(IRC)
      Z=R(IRC+1)/R(IRC)
      CZ=(Z*Z*ALOG(Z)/(Z*Z-1.)-.75+.25/Z**2)*.5
      ENM=ENB+Q(IRC)
      CM=CS+SA(IRC)*VO(IRC)
      YY=(3.*BLACK-4.)*SA(IRC)*(R(IRC+1)**2-R(IRC)**2)/R(IRC)
      YY=.5*YY
      W=Q(IRC)/ENM
      D2=CZ*CAP2M*R(IRC+1)**2
      B1=1.+(1.-W)*(YY+D2)
      D1=2.*SA(IRC)*(R(IRC+1)**2-R(IRC)**2)/R(IRC)
      FP=0.
      CZ=0.
      IR=0
      MEG=1
   41 IR=IR+1
      IF(IR-IRS)42,42,43
   43 MEG=2
      GO TO 54
   42 IF(IR-1)44,45,44
   44 CZ=1.-GAMAS+EFAS*ENAS/ENM
   45 GO TO(46,47),MEG
   46 EF(IR)=CM/(1.5708*R(IR+1))
   47 CONTINUE
   48 CONTINUE
      QQ=EF(IR)*Q(IR)/ENM
      T1=1./(1.-CZ*GII(IR))
      CAP1=GEI(IR)+QQ*GVI(IR)
```

```
      E(IR)=PVE(IR)+CZ*PVI(IR)
      FIO(IR)=CAP1*T1
   50 IF(IR-1)52,51,52
   51 GAMP(IR)=0.
      GO TO 53
   52 GAMP(IR)=CAP1*T1*GAMAS
   53 D3=CAP1*T1*CZ*GIV(IR)
      GAM(IR)=GAMP(IR)+D3+GEV(IR)+QQ*GVV(IR)
      GAMAS=GAM(IR)
      ENAS=ENBV(IR)
      EFAS=EF(IR)
      GO TO 41
   54 D4=(1.+YY+D2+D1/GAMAS)/B1
      FMOD=1.-1./D4
      IF(ABS (1.-FP/FMOD)-.001)70,70,55
   55 FP=FMOD
      IR=IR-1
      EF(IR)=GAM(IR)*D4
   61 IR=IR-1
      IF(IR)56,63,56
   56 EF(IR)=EF(IR+1)/FIO(IR+1)
      GO TO 61
   63 IR=1
      CZ=0.
      GO TO 48
   70 CONTINUE
      K=1
      IAL=1
      SACM=0.
      APR=0.
      FPR=0.
      TPR=0.
      FID=0.
      EFU=0.
      ETAPR=0.
      AA=RC(1)
      CC=RC(2)
      BB=RC(3)
   80 CONTINUE
      IF(STT(K)) 72,73,72
   72 IF(K-IRC) 74,75,75
   74 EFFE=(GAM(K)-GAMP(K))/EF(K)
      GO TO 76
   75 EFFE=FMOD
      IAL=2
   76 FLU(K)=EFFE*ENM/(SA(K)*VO(K))
      GO TO 77
   73 EFFE=0.
      FLU(K)=ENM*E(K)/(1.5708*R(K+1)*EF(K))
   77 CONTINUE
      EFF(K)=EFFE
      APR=APR+VO(K)*FLU(K)*SA(K)
      FPR=FPR+VO(K)*FLU(K)
      IF(R(K+1)-AA) 87,87,95
   87 IET=1
```

```
      83 CONTINUE
         TPR=TPR+FLU(K)*VO(K)*STT(K)
      88 FID=FID+VO(K)*FLU(K)
         IF(SA(K)) 89,90,89
      89 EFU=EFU+EFFE*C(K)/(SA(K)*VO(K))
         ETAPR=ETAPR+EFFE*FIM(K)/(SA(K)*VO(K))
      90 CONTINUE
         K=K+1
         GO TO (80,91),IAL
      91 IAL=1
         AMDM=TPR
         FLM=FID
         VF=3.1416*AA**2
         VG=3.1416*CC**2-VF
         VM=3.1416*(BB**2-CC**2)
         VT=3.1416*BB**2
         EFSU=EF(IRUB)
         FLUSU=(2.-GAM(IRUB)+ENBV(IRUB)*EFSU/ENM)*ENM/(3.1416*R(IRUB+1)*EFS
        1U)
         FLUAV=0.
         VOCLU=0.
         DO 192 J=1,IRUB
         VOCLU=VOCLU+VO(J)
     192 FLUAV=FLUAV+FLU(J)*VO(J)
         FCL=FLUSU*VOCLU/FLUAV
         IF(VG) 92,93,92
      92 FIV=FIV/VG
         GO TO 94
      93 FIV=0.
      94 AMDU=FIU/AMDU
         FIU=FIU/VF
         AMDM=FLM/AMDM
         FLM=FLM/VM
         SACM=APR/FPR
         IF(EFU)58,99,58
      58 ETAPR=ETAPR/EFU
         GO TO 99
      95 GO TO (81,82,82),IET
      81 AMDU=TPR
         TPR=0.
         FIU=FID
         FID=0.
         IF(AA-CC) 96,97,97
      96 IET=3
         GO TO 88
      97 IET=3
      82 IF(R(K+1)-CC) 96,96,98
      98 GO TO (83,83,84),IET
      84 FIV=FID
         FID=0.
         IET=2
         GO TO 83
      99 CONTINUE
         AMDUBE=AMDU
         AMDMBE=AMDM
```

```
      IOM=1
      IPS=1
      W=0.
      QP=0.
      QS=0.
      AL=AA/CC
  150 CONTINUE
      ET=AA/AMDU
      GA=CC/AMDM
      IF(AL-.9999)151,151,152
  151 QS=1.+.05*AL-.1875*ALOG(1.-AL)
      DEP=3.1415927*(1.-AL*AL)
      DEP1=DEP*(1.-AL)
      QP1=3.*AL/DEP1
      QO=2.*AL/DEP1
      W1=2.*AL/(DEP*ET)
      WO=W1
      IFUN=3
      QP1=AINTG(0.,1.5707963)*QP1
      QP=QP1
      IFUN=5
      W1=W1*AINTG(0.,1.5707963)
      W=W1
      WW=W
  152 IFUN=7
      T=1./ET*(1.-3./(3.1415927*ET)*AINTG(0.,1.5707963))
      IFUN=8
      TO=1./ET*(1.-0.63661977/ET*AINTG(0.,1.5707963))
      C3=3.*TO-2.*T
      IF (AL-.9999)153,153,154
  153 C4=.66667*T+.33333*C3
      C4=1.-ET*C4
      W=.75*AL*C4
  154 D2A=QP+QS
  155 CONTINUE
      D1=1.-ET*W
      D2=1.-ET* T
      D3=AL*ET*D2
      DEL=.5+.5*GA/(1.+GA)
      DELA=1.-DEL*(VF+VG)/VT
      DEL=GA+1.-2.*DEL /DELA
      DEL=GA/DEL-D3
      D3=(1.+AL)*D1**2/DEL
      D1=AL*D1*D2/DEL
      D2=AL*D2**2/DEL
      D2A=D2A-D3
      T=T-D2
      WW=W
      W=W-D1
  156 CONTINUE
      D1=1.-AMDM/AMDU
      W=(D1*(FIV+FLM)+FIU-FLM)*W*AA
      W=W+FIV*D2A*(CC-AA)
      W=W*VG
      T=D1*T*AA*VF*(FIU-FLM*AMDM/AMDU)
```

```
      W=W+T+AMDM*FLM*(D1*VF+VG)
      FT=FIU*VF+FIV*VG+FLM*VM
      W=(W/FT+AMDM)/3.
      GO TO (157,158),IPS
  157 GO TO (159,160),IOM
  159 DRM=W
  161 IPS=2
      T=C3
      IFUN=4
      QO=QO*AINTG(0.,1.5707963)
      QP=3.*QO-2.*QP1
      IFUN=6
      WO=WO*AINTG(0.,1.5707963)
      W=3.*WO-2.*W1
      D2A=QP+2.*QS
      GO TO 156
  160 GO TO (162,163),ICS
  162 DREI=W
      GO TO 161
  163 DRES=W
      GO TO 161
  158 GO TO (164,165),IOM
  164 DZM=W
      IOM=2
      ICS=1
      AMDU=AUEI
      AMDM=AMEI
  166 IPS=1
      FIU=1.
      FIV=1.
      FLM=1.
      GO TO 150
  165 GO TO (167,168),ICS
  167 DZEI=W
      AMDU=AUES
      AMDM=AMES
      ICS=2
      GO TO 166
  168 DZES=W
      RETURN
      END
```

```
£IBFTC PODE
C
C
C       SUBROUTINE PODE (= POLINOMI DA DENSITA')
C
C
      SUBROUTINE PODE
      COMMON/PAL3/OPZIJ(28,8),RHO(5),POLINO(5,9),IPOLIN(9)
      COMMON/ACC/ A(5,5),B(5)
      DO 3 K=1,9
      DO 2 I=1,5
      A(I,1)=1.
      DO 2 J=2,5
    2 A(I,J)=RHO(I)**(J-1)
      M=IPOLIN(K)
      DO 4 I=1,5
    4 B(I)=  OPZIJ(M,I)
      CALL INVL (A,B,5,1)
      DO 5 I=1,5
    5 POLINO(I,K)=A(I,1)
    3 CONTINUE
      RETURN
      END
```

```
£IBFTC FUN
      FUNCTION FUN(X)
      COMMON/PUPO/IFUN
      COMMON/COREA/A,B,T,      EO,ERIS,GAM2
      COMMON/COREA1/ET,AL
      COMMON/COREA2/APICC,AQU,GAMGAM
      BKI1(X)=((X*X+1.932839*X+.182922)/(X*X+2.236914*X+.182922
     1))/SQRT(2.*X/3.141593+.405285)
      BKOAM(X)=(-.57722-ALOG(.5*X))*(1.+.25*X**2+.015625*X**4+.00043403*
     1X**6)*EXP(X)+(.25*X**2+.0023438*X**4+.0007957*X**6)*EXP(X)
      BKOBM(X)=(SQRT(3.141593/2.)*(1.-1./(8.*X)+9./(128.*X**2))*X**2.5/(
     1X**2.5+.0352802))/SQRT(X)
      IF (IFUN.GT.2) GO TO 1
      DEP=SQRT(EO/T)
      XR=ERIS/T
      BETA=(T/GAM2)**2
      A1=A*DEP
      B1=B*DEP
      SQ=SQRT( X)
      AM1=SQ*EXP(- X)
      GP=1.+BETA*( X-XR)**2
      F2=B1/GP+A1+SQ
      F2=SQ*AM1/F2
      IF(IFUN.EQ. 1)  FUN =F2*DEP
      IF(IFUN.EQ. 2)  FUN =F2*DEP/GP
      GO TO 3
    1 IF (IFUN.GT.8) GO TO 2
      COFI=COS(X)
      Z=SQRT(1.-AL*AL*SIN(X)**2)-AL*COFI
      Z2=Z*Z
      DX=2.*ET*COFI
      D2X=DX*DX
      EXF=EXP(-DX)
      GIG=DX*0.63661977
      AKI3=EXF/SQRT(GIG+1.6211)*(D2X+7.2*DX+5.42)/(D2X+7.6*DX+5.42)
      AKI1=EXF/SQRT(GIG+0.4053)*(D2X+1.933*DX+0.183)/(D2X+2.237*DX+.183)
      AKI2=EXF/SQRT(GIG+1.)*(D2X+5.202*DX+1.869)/(D2X+5.606*DX+1.769)
      AKI4=.66666667*AKI2+DX*.33333333*(AKI1-AKI3)
      AKI5=.75*AKI3+DX*.25*(AKI2-AKI4)
      IF (IFUN.EQ.3)  FUN=COFI*Z2*AKI3
      IF (IFUN.EQ.4)  FUN=COFI*Z2*AKI1
      IF (IFUN.EQ.5)  FUN=(1.-1.5*AKI4)*Z*COFI
      IF (IFUN.EQ.6)  FUN=(1.-AKI2)*Z*COFI
      IF (IFUN.EQ.7)  FUN=COFI*(.589049-AKI5)
      IF (IFUN.EQ.8)  FUN=COFI*(.785398-AKI3)
      GO TO 3
    2 IF (APICC.LE.1.) GAMGAM=BKOAM(APICC)*EXP(-APICC)
      IF (APICC.GT.1.) GAMGAM=BKOBM(APICC)*EXP(-APICC)
      IF (IFUN.EQ.9) FUNFUN=BKI1(AQU*(X-APICC))*EXP(-(AQU*(X-APICC)))
      IF (X.LE.1.) FUN=FUNFUN*BKOAM(X)*EXP(-X)
      IF (X.GT.1.) FUN=FUNFUN*BKOBM(X)*EXP(-X)
    3 RETURN
      END
```

```
£IBFTC FIFA
C
C
C
C
C      SOTTOPROGRAMMA FIFA (=FISSION FACTOR)
C
       SUBROUTINE FIFA
       DIMENSION ASIG(4)
       COMMON/SIR4/FCL
       COMMON/PAL/SEZMA(4,14),SEZMAT(4,2),VEPSI(9),FOV,GAMO,FV(2),GAM(2)
       COMMON/PAL1/ANVTH,        AN,RCAN,FSB,     BETDAN,BI,PASSO
      1,RAGGB,RAGGR,RAGGT
       COMMON/PAL2/EPSI,DELT28,BETA,GAMMA,RASTER,DENOM,GAMA5,GAMF5
       COMMON/BON/C(4,2,2),CO(4,2),P(4,4,2),P2C(4,2),AP(8),PP(3,3),GO(3),
      1PIGRE(3),EICC(3),V(3),PPC(3),A(8,8),B(8)
       COMMON/PUPO/IFUN
       COMMON/COREA2/APICC,AQU,GAMGAM
C
C      COSTRUZ. MATR. C(J,S,K) E CO(J,S)
C
       DO 202 J=1,4
  202  ASIG(J)=SEZMAT(J,1)+SEZMAT(J,2)
       DO 1 J=1,4
       IF(ASIG(J))200,201,200
  201  C(J,2,2)=0.
       C(J,1,1)=0.
       C(J,2,1)=0.
       C(J,1,2)=0.
       CO(J,1)=0.
       CO(J,2)=0.
       GO TO 1
  200  C(J,2,2)=(SEZMA(J,2)+SEZMA(J,1)*FV(2)+2.*SEZMA(J,5))/SEZMAT(J,2)
       C(J,1,1)=(SEZMA(J,11)+SEZMA(J,10)*FV(1))/SEZMAT(J,1)
       C(J,2,1)=(SEZMA(J,3)+SEZMA(J,1)*FV(1)+2.*SEZMA(J,6))/SEZMAT(J,2)
       C(J,1,2)=SEZMA(J,10)*FV(2)/SEZMAT(J,1)
       CO(J,1)=(SEZMA(J,12)+SEZMA(J,10)*FOV)/SEZMAT(J,1)
       CO(J,2)=(SEZMA(J,4)+SEZMA(J,1)*FOV+2.*SEZMA(J,7))/SEZMAT(J,2)
    1  CONTINUE
       R1=RAGGB
       R2=RAGGR
       T=RAGGT
       RC=RCAN
C
C      DEFINIZ. FUNZIONI USATE
C
       BICK2(X)=((X*X+5.201634*X+1.7690977)/(X*X+5.605543*X+1.7690977))*E
      1XP(-X)/SQRT(0.63662*X+1.)
       BICK3(X)=((X*X+7.2*X+5.42)/(X*X+7.6*X+5.42))*EXP(-X)/SQRT(0.63662*
      1X+1.6211389)
       SBON(X)=0.5*(ARSIN(X)/X+SQRT(1.-X*X))-.7853981*X
       PCHP(X)=1.-1./(1.+2.*X-2.*X/(2.*X+1./(1.3333333-EXP(-.3*X))))
       PBON(X)=(.9549296/X)*(.5773502*ARSIN(.8660254*X)+X*ALOG((SQRT(4.-3
      1.*X*X)+1.)/(SQRT(4.-3.*X*X)-1.))-.5*(1.+X*X)*ALOG((SQRT(4.-3.*X*X)
      2+X)/(SQRT(4.-3.*X*X)-X))-.822467*X*X)
```

```
C
C       CALCOLO PROBABILITA DI SOTTOCELLA
C
        IFUN=9
        AKAP=SQRT(3.*SEZMAT(4,2)*(SEZMA(4,3)+SEZMA(4,4)))
        AQU=SEZMAT(4,2)/AKAP
        APICC=RC*AKAP
        ELLEP=(.7104+.25/(.402+RC*SEZMAT(4,2)))/AQU
        SINF=AINTG(APICC,25.)
        IF(APICC-1.)212,212,213
    212 ALFA=GAMGAM
        BETA=1./APICC+ALOG(.5*APICC)*(.5*APICC+APICC**3/16.+APICC**5/384.)
        BETA=BETA+.07722*APICC/2.-.6728*APICC**3/16.-1.08945*APICC**5/384.
        GO TO 214
    213 ALFA=GAMGAM
        BETA=EXP(-APICC)*(1.+3./(8.*APICC)-15./(128.*APICC**2))*APICC**2.5
        BETA=BETA/((APICC**2.5-.0364896)*SQRT(APICC/1.5708))
    214 ALFA=1./(ELLEP*BETA+ALFA)
        ALFA=ALFA*.25*(3.*AQU**2-1.)*(ELLEP+.66667/AQU)
        SINF=ALFA*SINF
        DO 1000 K=1,2
C
C
        ETA1=SEZMAT(1,K)*R1
        ETA2=SEZMAT(2,K)*R2
        ALFA2=R1/R2
        S2=SBON(ALFA2)
        ETAES2=ETA2*S2
        PRR=PCHP(ETA1)
        GRV=1.-1.2732395*BICK3(ETAES2)
        PRV=(1.-PRR)*GRV
C
        ALFA3=2.*R1/T
        R3=.5*T
        IF(ALFA3-.00001)146,146,147
    146 PBB=1.049095
        GO TO 152
    147 IF(ALFA3-.9999     )150,151,151
    151 PBB=.06667
        GO TO 152
    150 PBB=PBON(ALFA3)
    152 QQ=R3*PBB-R2*S2
        X3=ETAES2+SEZMAT(3,K)*QQ
        GAMRD=1.-BICK3(X3)/BICK3(ETAES2)
        PRD=(1.-PRR)*(1.-GRV)*GAMRD
C
        R2QAL=ALFA2**2/(1.-ALFA2**2)
        IF(SEZMAT(2,K))3,5,3
      3 PVR=PRV*(SEZMAT(1,K)/SEZMAT(2,K))*R2QAL
        GO TO 7
      5 PVR=1.2732395*SEZMAT(1,K)*R2*S2*(1.-PRR)*R2QAL
      7 CONTINUE
C
        ETA21=SEZMAT(2,K)*R1
        PTIL=PCHP(ETA2)
```

```
      PRRTIL=PCHP(ETA21)
      FPV=(PTIL-ALFA2**2*(PRRTIL+GRV*(1.-PRRTIL)*(2.-GRV)))/(1.-ALFA2**2
     1)
      PVV=FPV-PVR*GRV
C
      PVRTIL=R2QAL*(1.-PRRTIL)*GRV
      ALFA3P=2.*R2/T
      IF(ALFA3P-.00001)148,148,149
  148 PBB=1.049095
      GO TO 155
  149 IF(ALFA3P-.9999    )153,154,154
  154 PBB=.06667
      GO TO 155
  153 PBB=PBON(ALFA3P)
  155 W=.5*T*PBB
      YY=SEZMAT(3,K)*W
      GVD=1.-1.2732395*BICK3(YY)
      AMDA=PVRTIL-PVR+R2QAL*(1.-PRRTIL)
      PVD=(1.-PTIL)*GVD/(1.-ALFA2**2)+AMDA*(1.-GRV)*GAMRD
C
      V1=3.1415927*R1**2
      V3=.8660254*T*T-3.1415927*R2**2
      IF(SEZMAT(3,K))9,11,9
   11 PDR=(V1/V3)*(1.-PRR)*(1.-GRV)*SEZMAT(1,K)*QQ*BICK2(ETAES2)/BICK3(E
     1TAES2)
      GO TO 13
    9 PDR=((SEZMAT(1,K)*V1)/(SEZMAT(3,K)*V3))*PRD
   13 CONTINUE
C
      V2=3.1415927*(R2*R2-R1*R1)
      IF(SEZMAT(3,K))15,17,15
   15 PDV=((SEZMAT(2,K)*V2)/(SEZMAT(3,K)*V3))*PVD
      GO TO 19
   17 PDV=(V2/V3)*SEZMAT(2,K)*(1.2732395*W*(1.-PTIL)/(1.-ALFA2**2)+AMDA*
     1(1.-GRV)*QQ*BICK2(ETAES2)/BICK3(ETAES2))
   19 CONTINUE
C
      IF(SEZMAT(3,K))21,23,21
   23 PDD=0.
      GO TO 25
   21 WP1=3.6275987*(R2/T)**2
      ETA3=.5*SEZMAT(3,K)*T*(1.+.04775/(1.+.2619375*SEZMAT(3,K)*T))
      HTIL=PCHP(ETA3)
      ETA32=SEZMAT(3,K)*R2
      HDDTIL=PCHP(ETA32)
      FPD=(HTIL-WP1*(HDDTIL+GVD*(1.-HDDTIL)*(2.-GVD)))/(1.-WP1)
      PDD=FPD-(PDV+PDR)*GVD
   25 CONTINUE
C
      S3=3.4641016*T
      GSR=(4.*SEZMAT(1,K)*V1/S3)*(1.-PRR-PRV-PRD)
      GSV=(4.*SEZMAT(2,K)*V2/S3)*(1.-PVR-PVV-PVD)
      GSD=(4.*SEZMAT(3,K)*V3/S3)*(1.-PDR-PDV-PDD)
      GST=GSR+GSV+GSD
C
```

```
C       RISOLUZ. EQUAZ. Y(1-PC(Y))=GST E CALCOLO RHO
C
        IF(GST-.953)27,27,29
     27 RAD=SQRT ((6.-5.*GST)**2+24.*GST*(1.-GST))
        YO=(RAD-6.+5.*GST)/(2.*(1.-GST))
        GO TO 31
     29 YO=SQRT(3./(4.*(1.-GST)))
     31 ETAEQ=.5*YO
        ETAPR=ETAEQ*SQRT(AN)
        RHO=(PCHP(ETAPR)-PCHP(ETAEQ))/(1.-PCHP(ETAEQ))
C
C       CALCOLO PROBABILITA DI CLUSTER
C
        ER=(1.-PRR-PRV-PRD)*RHO
        EV=(1.-PVR-PVV-PVD)*RHO
        ED=(1.-PDR-PDV-PDD)*RHO
        U1=GSR/GST
        U2=GSV/GST
        U3=GSD/GST
        PP(1,1)=PRR+ER*U1
        PP(1,2)=PRV+ER*U2
        PP(1,3)=PRD+ER*U3
        PP(2,1)=PVR+EV*U1
        PP(2,2)=PVV+EV*U2
        PP(2,3)=PVD+EV*U3
        PP(3,1)=PDR+ED*U1
        PP(3,2)=PDV+ED*U2
        PP(3,3)=PDD+ED*U3
C
C       CALCOLO CELL TO CELL INTERACTIONS
C
        DMOD=2.*(BI*BI-RC*RC)/RC
        YM=SEZMAT(4,K)*DMOD
        TAVM=(PASSO-2.*RC)/DMOD
        BETAD=BETDAN
        Y=YM
        TAU=TAVM
        DENGD=1.+(1.-TAU-Y/(7.+BETAD*Y))*Y
        GM=1.-EXP(-TAU*Y)/DENGD
        DO 39 I=1,3
     39 EICC(I)=1.-PP(I,1)-PP(I,2)-PP(I,3)
        V(1)=V1
        V(2)=V2
        V(3)=V3
        SC4N=0.63662*AN/RC
        DO 41 I=1,3
     41 GO(I)=SC4N*V(I)*SEZMAT(I,K)*EICC(I)
        GFO=GO(1)+GO(2)+GO(3)
        GDEN=1.-(1.-GM)*(1.-GFO)
        DO 43 I=1,3
     43 PIGRE(I)=(1.-GM)*GO(I)/GDEN
        PIGREM=GM/GDEN
C
C       COSTRUZ. MATRICE P(J,I,K)
C
```

```
      DO 45 I=1,3
      DO 45 J=1,3
   45 P(J,I,K)=PP(J,I)+EICC(J)*PIGRE(I)
      DO 47 I=1,3
   47 P(I,4,K)=EICC(I)*PIGREM
      VMOD=3.1415927*(BI*BI-RC*RC)
      GO TO (215,216),K
  215 P4FBF=0.
      GO TO 217
  216 P4FBF=(1./C(4,2,2)-1.)/(1./SINF-1.)
  217 CONTINUE
      DO 49 I=1,3
   49 P(4,I,K)=P(I,4,K)*AN*(SEZMAT(I,K)*V(I))/(SEZMAT(4,K)*VMOD)
     1+P4FBF*GO(I)
      P(4,4,K)=1.-P(4,1,K)-P(4,2,K)-P(4,3,K)
C
C     COSTRUZ. MATRICE P2C(I,K)DISTR. PARABOL.
C
      IF(FSB-1.0001)170,170,171
  170 PVVC=PVV
      PVRC=PVR
      PVDC=PVD
      EVC=EV
      GO TO 172
  171 AMDA1=.375*(ETA2+.5148)/(ETA2+2.7)
      RSEGN=AMDA1*ETA2/(1.+AMDA1*ETA2)
      PVRC=PVR
      PVVC=PVV-(FSB-1.)*(1.-PVV)*RSEGN
      PVDC=(1.-PVVC)*GVD
      EVC=(1.-PVVC)*(1.-GVD)*RHO
  172 PF2=PP(2,1)+PP(2,2)+PP(2,3)
C
C     RISOLUZ. EQUAZ. PF2=PC(XEQ)
C
      IF(PF2-.8)55,55,57
   55 RAD=SQRT((4.-5.*PF2)**2+24.*PF2*(1.-PF2))
      YPEQ=(RAD-4.+5.*PF2)/(2.*(1.-PF2))
      GO TO 59
   57 YPEQ=1./(1.-PF2)
   59 XEQ=YPEQ*0.5
C
C     PROBABIL. PARABOL. DI CLUSTER
C
      AMDA2=.375*(XEQ+.5148)/(XEQ+2.7)
      RFSEGN=AMDA2*XEQ/(1.+AMDA2*XEQ)
      PF2C=PF2-(FCL-1.)*(1.-PF2)*RFSEGN
      CHI=PF2C/PF2
      PPC(1)=(PVRC+EVC*U1)*CHI
      PPC(2)=(PVVC+EVC*U2)*CHI
      PPC(3)=(PVDC+EVC*U3)*CHI
C
C     INTERAZ. CELLA/CELLA
C
      E2C=1.-PPC(1)-PPC(2)-PPC(3)
      DO 61 I=1,3
```

```
   61 P2C(I,K)=PPC(I)+E2C*PIGRE(I)
      P2C(4,K)=E2C*PIGREM
 1000 CONTINUE
C
C     COSTRUZ. MATRICE COEFF.
C
      DO 69 K=1,2
      DO 69 I=1,4
      M=I+4*(K-1)
      B(M)=  FV(K)*P2C(I,K)+GAM(K)*P(4,I,K)
      DO 69 IS=1,2
      DO 69 J=1,4
      L=J+4*(IS-1)
      IF(L-M)63,65,63
   63 A(M,L)=-1.*C(J,IS,K)*P(J,I,K)
      GO TO 69
   65 A(M,L)=1.-C(J,IS,K)*P(J,I,K)
   69 CONTINUE
C
C     RISOLUZ. SISTEMA E VETTORE RISULT.
C
      CALL INVL (A,B,8,1)
      DO 71 IK=1,8
   71 AP(IK)=A(IK,1)
C
C     CALCOLO EPSILON DELTA 28 GAMMA BETA
      EPSIN=0.
      DO 73 K=1,2
      DO 73 I=1,4
      M=I+4*(K-1)
   73 EPSIN=EPSIN+AP(M)*CO(I,K)
      EPSI=FOV+GAMO+EPSIN
      DELT28=(AP(6)*VEPSI(1)/SEZMAT(2,2))/(1./ANVTH+AP(6)*VEPSI(2)/SEZMA
     1T(2,2)+AP(2)*VEPSI(3)/SEZMAT(2,1))
      DENOM=1.+AP(6)*SEZMA(2,1)/SEZMAT(2,2)+AP(2 )*SEZMA(2,10)/SEZMAT(2,
     11)
      BETA=(AP(6)*VEPSI(4)/SEZMAT(2,2)+AP(2)*VEPSI(5)/SEZMAT(2,1))/DENOM
      GAMMA=(AP(6)*VEPSI(6)/SEZMAT(2,2)+AP(2)*VEPSI(7)/SEZMAT(2,1))/DENO
     1M
      GAMA5=(AP(6)*VEPSI(8)/SEZMAT(2,2)+AP(2)*VEPSI(9)/SEZMAT(2,1))/DENO
     1M
      GAMF5=(AP(6)*VEPSI(2)/SEZMAT(2,2)+AP(2)*VEPSI(3)/SEZMAT(2,1))/DENO
     1M
      RASTER=BETA-GAMMA
      RETURN
      END
```

```
£IBFTC BLDT
       BLOCK DATA
       COMMON/NEM1/IX(30),NTE(30),ASTRO(10,30),SEZIO(10,2,30),SEZIOF(10,
      12,5),CROMI(15,30,2),TARGA(30),SEZ(14,30)
       DATA   TARGA  (  1)/6H U 235/
       DATA      IX  (  1)/   2/
       DATA     NTE  (  1)/   2/
       DATA ASTRO    (  1,  1)/ 0.67990000E 03/
       DATA ASTRO    (  2,  1)/ 0.15200000E 02/
       DATA ASTRO    (  3,  1)/ 0.99720000E 00/
       DATA ASTRO    (  4,  1)/ 0.12000000E 02/
       DATA ASTRO    (  5,  1)/ 0.67000000E 01/
       DATA ASTRO    (  6,  1)/ 0.84999999E-02/
       DATA ASTRO    (  7,  1)/ 0.99720000E 00/
       DATA ASTRO    (  8,  1)/ 0.24400000E 01/
       DATA ASTRO    (  9,  1)/ 0.57950000E 03/
       DATA ASTRO    (10,  1)/ 0.98312300E 00/
       DATA SEZIO    (  1,  1,  1)/ 0.98295704E 00/
       DATA SEZIO    (  2,  1,  1)/-0.25643905E 00/
       DATA SEZIO    (  3,  1,  1)/ 0.38775725E 00/
       DATA SEZIO    (  4,  1,  1)/-0.14401915E 00/
       DATA SEZIO    (  5,  1,  1)/-0.23481466E 00/
       DATA SEZIO    (  6,  1,  1)/ 0.24283898E 00/
       DATA SEZIO    (  7,  1,  1)/-0.66456560E-01/
       DATA SEZIO    (  8,  1,  1)/-0.            /
       DATA SEZIO    (  9,  1,  1)/-0.            /
       DATA SEZIO    (10,  1,  1)/-0.            /
       DATA SEZIO    (  1,  2,  1)/ 0.37336754E-01/
       DATA SEZIO    (  2,  2,  1)/ 0.63240385E 00/
       DATA SEZIO    (  3,  2,  1)/-0.67980764E 00/
       DATA SEZIO    (  4,  2,  1)/-0.18948251E 01/
       DATA SEZIO    (  5,  2,  1)/ 0.40089487E 01/
       DATA SEZIO    (  6,  2,  1)/-0.46002181E 00/
       DATA SEZIO    (  7,  2,  1)/-0.17723823E 01/
       DATA SEZIO    (  8,  2,  1)/-0.            /
       DATA SEZIO    (  9,  2,  1)/-0.            /
       DATA SEZIO    (10,  2,  1)/-0.            /
       DATA SEZIOF   (  1,  1,  1)/ 0.98096714E 00/
       DATA SEZIOF   (  2,  1,  1)/-0.26029186E 00/
       DATA SEZIOF   (  3,  1,  1)/ 0.32309143E 00/
       DATA SEZIOF   (  4,  1,  1)/-0.33009670E-01/
       DATA SEZIOF   (  5,  1,  1)/-0.31636412E 00/
       DATA SEZIOF   (  6,  1,  1)/ 0.27165781E 00/
       DATA SEZIOF   (  7,  1,  1)/-0.70406703E-01/
       DATA SEZIOF   (  8,  1,  1)/-0.            /
       DATA SEZIOF   (  9,  1,  1)/-0.            /
       DATA SEZIOF   (10,  1,  1)/-0.            /
       DATA SEZIOF   (  1,  2,  1)/-0.59807780E-01/
       DATA SEZIOF   (  2,  2,  1)/ 0.49270779E 00/
       DATA SEZIOF   (  3,  2,  1)/-0.56207500E 00/
       DATA SEZIOF   (  4,  2,  1)/-0.65231610E 00/
       DATA SEZIOF   (  5,  2,  1)/-0.16775110E 01/
       DATA SEZIOF   (  6,  2,  1)/ 0.92599191E 01/
       DATA SEZIOF   (  7,  2,  1)/-0.61555490E 01/
       DATA SEZIOF   (  8,  2,  1)/-0.70957180E 01/
```

```
      DATA SEZIOF ( 9, 2, 1)/ 0.70266919E 01/
      DATA SEZIOF (10, 2, 1)/-0.            /
      DATA SEZ    ( 1, 1)/ 0.37866000E 01/
      DATA SEZ    ( 2, 1)/ 0.15390900E 01/
      DATA SEZ    ( 3, 1)/ 0.15337700E 01/
      DATA SEZ    ( 4, 1)/ 0.78300000E-02/
      DATA SEZ    ( 5, 1)/ 0.            /
      DATA SEZ    ( 6, 1)/ 0.            /
      DATA SEZ    ( 7, 1)/ 0.            /
      DATA SEZ    ( 8, 1)/ 0.56909999E-01/
      DATA SEZ    ( 9, 1)/ 0.13109000E 01/
      DATA SEZ    (10, 1)/ 0.34357000E 01/
      DATA SEZ    (11, 1)/ 0.55767300E 01/
      DATA SEZ    (12, 1)/ 0.33394000E 00/
      DATA SEZ    (13, 1)/ 0.11394000E 00/
      DATA SEZ    (14, 1)/ 0.13133900E 01/
      DATA   TARGA ( 2)/6HPU 239/
      DATA      IX ( 2)/   2/
      DATA     NTE ( 2)/   2/
      DATA ASTRO  ( 1, 2)/ 0.10311000E 04/
      DATA ASTRO  ( 2, 2)/ 0.12100000E 02/
      DATA ASTRO  ( 3, 2)/ 0.99720000E 00/
      DATA ASTRO  ( 4, 2)/ 0.96000000E 01/
      DATA ASTRO  ( 5, 2)/ 0.63200000E 01/
      DATA ASTRO  ( 6, 2)/ 0.83000000E-02/
      DATA ASTRO  ( 7, 2)/ 0.99720000E 00/
      DATA ASTRO  ( 8, 2)/ 0.28710000E 01/
      DATA ASTRO  ( 9, 2)/ 0.74770000E 03/
      DATA ASTRO  (10, 2)/ 0.98340260E 00/
      DATA SEZIO  ( 1, 1, 2)/ 0.10553482E 01/
      DATA SEZIO  ( 2, 1, 2)/ 0.81791738E 00/
      DATA SEZIO  ( 3, 1, 2)/ 0.12196434E 01/
      DATA SEZIO  ( 4, 1, 2)/ 0.15442179E 02/
      DATA SEZIO  ( 5, 1, 2)/-0.41046917E 02/
      DATA SEZIO  ( 6, 1, 2)/ 0.46774941E 02/
      DATA SEZIO  ( 7, 1, 2)/-0.28973220E 02/
      DATA SEZIO  ( 8, 1, 2)/ 0.95698293E 01/
      DATA SEZIO  ( 9, 1, 2)/-0.13243948E 01/
      DATA SEZIO  (10, 1, 2)/-0.            /
      DATA SEZIO  ( 1, 2, 2)/ 0.28663415E 01/
      DATA SEZIO  ( 2, 2, 2)/ 0.52057689E 01/
      DATA SEZIO  ( 3, 2, 2)/-0.27494554E 02/
      DATA SEZIO  ( 4, 2, 2)/ 0.30234210E 02/
      DATA SEZIO  ( 5, 2, 2)/-0.14108127E 03/
      DATA SEZIO  ( 6, 2, 2)/ 0.95752600E 02/
      DATA SEZIO  ( 7, 2, 2)/ 0.81249420E 03/
      DATA SEZIO  ( 8, 2, 2)/-0.16294605E 04/
      DATA SEZIO  ( 9, 2, 2)/ 0.89209078E 03/
      DATA SEZIO  (10, 2, 2)/-0.            /
      DATA SEZIOF ( 1, 1, 2)/ 0.10364946E 01/
      DATA SEZIOF ( 2, 1, 2)/ 0.58732232E 00/
      DATA SEZIOF ( 3, 1, 2)/ 0.10087133E 01/
      DATA SEZIOF ( 4, 1, 2)/ 0.12693947E 02/
      DATA SEZIOF ( 5, 1, 2)/-0.33738968E 02/
      DATA SEZIOF ( 6, 1, 2)/ 0.38520790E 02/
```

```
      DATA SEZIOF ( 7, 1, 2)/-0.23933484E 02/
      DATA SEZIOF ( 8, 1, 2)/ 0.79368450E 01/
      DATA SEZIOF ( 9, 1, 2)/-0.11037983E 01/
      DATA SEZIOF (10, 1, 2)/-0.             /
      DATA SEZIOF ( 1, 2, 2)/ 0.22519073E 01/
      DATA SEZIOF ( 2, 2, 2)/ 0.42789198E 01/
      DATA SEZIOF ( 3, 2, 2)/-0.22230395E 02/
      DATA SEZIOF ( 4, 2, 2)/ 0.23690340E 02/
      DATA SEZIOF ( 5, 2, 2)/-0.11081660E 03/
      DATA SEZIOF ( 6, 2, 2)/ 0.68638700E 02/
      DATA SEZIOF ( 7, 2, 2)/ 0.67224470E 03/
      DATA SEZIOF ( 8, 2, 2)/-0.13322271E 04/
      DATA SEZIOF ( 9, 2, 2)/ 0.72713153E 03/
      DATA SEZIOF (10, 2, 2)/-0.             /
      DATA SEZ    ( 1, 2)/ 0.62520000E 01/
      DATA SEZ    ( 2, 2)/ 0.36580000E 01/
      DATA SEZ    ( 3, 2)/ 0.10450000E 01/
      DATA SEZ    ( 4, 2)/ 0.45000000E-01/
      DATA SEZ    ( 5, 2)/-0.             /
      DATA SEZ    ( 6, 2)/-0.             /
      DATA SEZ    ( 7, 2)/-0.             /
      DATA SEZ    ( 8, 2)/ 0.81000000E-01/
      DATA SEZ    ( 9, 2)/ 0.19410000E 01/
      DATA SEZ    (10, 2)/ 0.52110000E 01/
      DATA SEZ    (11, 2)/ 0.60380000E 01/
      DATA SEZ    (12, 2)/ 0.31000000E-01/
      DATA SEZ    (13, 2)/ 0.15200000E 00/
      DATA SEZ    (14, 2)/ 0.17480000E 01/
      DATA   TARGA ( 3)/6HPU 240/
      DATA      IX ( 3)/  1/
      DATA     NTE ( 3)/  2/
      DATA ASTRO  ( 1, 3)/ 0.30000000E 03/
      DATA ASTRO  ( 2, 3)/ 0.13000000E 02/
      DATA ASTRO  ( 3, 3)/ 0.99720000E 00/
      DATA ASTRO  ( 4, 3)/ 0.11300000E 02/
      DATA ASTRO  ( 5, 3)/ 0.48000000E 01/
      DATA ASTRO  ( 6, 3)/ 0.83000000E-02/
      DATA ASTRO  ( 7, 3)/ 0.99720000E 00/
      DATA ASTRO  ( 8, 3)/-0.             /
      DATA ASTRO  ( 9, 3)/-0.             /
      DATA ASTRO  (10, 3)/ 0.98347120E 00/
      DATA SEZIO  ( 1, 1, 3)/ 0.10202082E 01/
      DATA SEZIO  ( 2, 1, 3)/ 0.35239270E 00/
      DATA SEZIO  ( 3, 1, 3)/-0.60950050E 00/
      DATA SEZIO  ( 4, 1, 3)/ 0.29800680E 01/
      DATA SEZIO  ( 5, 1, 3)/-0.59416634E 01/
      DATA SEZIO  ( 6, 1, 3)/ 0.56237042E 01/
      DATA SEZIO  ( 7, 1, 3)/-0.15225777E 01/
      DATA SEZIO  ( 8, 1, 3)/-0.             /
      DATA SEZIO  ( 9, 1, 3)/-0.             /
      DATA SEZIO  (10, 1, 3)/-0.             /
      DATA SEZIO  ( 1, 2, 3)/ 0.32480985E 02/
      DATA SEZIO  ( 2, 2, 3)/ 0.65080531E 02/
      DATA SEZIO  ( 3, 2, 3)/-0.10518495E 03/
      DATA SEZIO  ( 4, 2, 3)/ 0.50962277E 03/
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      DATA SEZIO  ( 5, 2, 3)/-0.13947088E 04/
      DATA SEZIO  ( 6, 2, 3)/ 0.28190418E 04/
      DATA SEZIO  ( 7, 2, 3)/-0.34117145E 04/
      DATA SEZIO  ( 8, 2, 3)/ 0.16683786E 04/
      DATA SEZIO  ( 9, 2, 3)/-0.            /
      DATA SEZIO  (10, 2, 3)/-0.            /
      DATA SEZ    ( 1, 3)/-0.           /
      DATA SEZ    ( 2, 3)/-0.           /
      DATA SEZ    ( 3, 3)/-0.           /
      DATA SEZ    ( 4, 3)/-0.           /
      DATA SEZ    ( 5, 3)/-0.           /
      DATA SEZ    ( 6, 3)/-0.           /
      DATA SEZ    ( 7, 3)/-0.           /
      DATA SEZ    ( 8, 3)/-0.           /
      DATA SEZ    ( 9, 3)/-0.           /
      DATA SEZ    (10, 3)/-0.           /
      DATA SEZ    (11, 3)/-0.           /
      DATA SEZ    (12, 3)/-0.           /
      DATA SEZ    (13, 3)/-0.           /
      DATA SEZ    (14, 3)/-0.           /
      DATA   TARGA ( 4)/6HPU 241/
      DATA      IX ( 4)/  2/
      DATA     NTE ( 4)/  2/
      DATA ASTRO  ( 1, 4)/ 0.13975000E 04/
      DATA ASTRO  ( 2, 4)/ 0.12100000E 02/
      DATA ASTRO  ( 3, 4)/ 0.99730000E 00/
      DATA ASTRO  ( 4, 4)/ 0.97000001E 01/
      DATA ASTRO  ( 5, 4)/ 0.42000000E 01/
      DATA ASTRO  ( 6, 4)/ 0.83000000E-02/
      DATA ASTRO  ( 7, 4)/ 0.99730000E 00/
      DATA ASTRO  ( 8, 4)/ 0.29690000E 01/
      DATA ASTRO  ( 9, 4)/ 0.10153000E 04/
      DATA ASTRO  (10, 4)/ 0.98353930E 00/
      DATA SEZIO  ( 1, 1, 4)/ 0.10336279E 01/
      DATA SEZIO  ( 2, 1, 4)/ 0.48083587E 00/
      DATA SEZIO  ( 3, 1, 4)/ 0.10190645E 01/
      DATA SEZIO  ( 4, 1, 4)/ 0.40369574E 01/
      DATA SEZIO  ( 5, 1, 4)/-0.16274236E 02/
      DATA SEZIO  ( 6, 1, 4)/ 0.23264510E 02/
      DATA SEZIO  ( 7, 1, 4)/-0.17441372E 02/
      DATA SEZIO  ( 8, 1, 4)/ 0.68781976E 01/
      DATA SEZIO  ( 9, 1, 4)/-0.11282760E 01/
      DATA SEZIO  (10, 1, 4)/-0.            /
      DATA SEZIO  ( 1, 2, 4)/ 0.10377796E 01/
      DATA SEZIO  ( 2, 2, 4)/ 0.95337210E 00/
      DATA SEZIO  ( 3, 2, 4)/-0.13197060E 02/
      DATA SEZIO  ( 4, 2, 4)/ 0.29798152E 02/
      DATA SEZIO  ( 5, 2, 4)/-0.19480844E 03/
      DATA SEZIO  ( 6, 2, 4)/ 0.74373152E 03/
      DATA SEZIO  ( 7, 2, 4)/-0.13089940E 04/
      DATA SEZIO  ( 8, 2, 4)/ 0.10957206E 04/
      DATA SEZIO  ( 9, 2, 4)/-0.35715017E 03/
      DATA SEZIO  (10, 2, 4)/-0.            /
      DATA SEZIOF ( 1, 1, 3)/ 0.10336279E 01/
      DATA SEZIOF ( 2, 1, 3)/ 0.48083587E 00/
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      DATA SEZIOF ( 3, 1, 3)/ 0.10190645E 01/
      DATA SEZIOF ( 4, 1, 3)/ 0.40369574E 01/
      DATA SEZIOF ( 5, 1, 3)/-0.16274236E 02/
      DATA SEZIOF ( 6, 1, 3)/ 0.23264510E 02/
      DATA SEZIOF ( 7, 1, 3)/-0.17441372E 02/
      DATA SEZIOF ( 8, 1, 3)/ 0.68781976E 01/
      DATA SEZIOF ( 9, 1, 3)/-0.11282760E 01/
      DATA SEZIOF (10, 1, 3)/-0.             /
      DATA SEZIOF ( 1, 2, 3)/ 0.10377796E 01/
      DATA SEZIOF ( 2, 2, 3)/ 0.95337210E 00/
      DATA SEZIOF ( 3, 2, 3)/-0.13197060E 02/
      DATA SEZIOF ( 4, 2, 3)/ 0.29798152E 02/
      DATA SEZIOF ( 5, 2, 3)/-0.19480844E 03/
      DATA SEZIOF ( 6, 2, 3)/ 0.74373152E 03/
      DATA SEZIOF ( 7, 2, 3)/-0.13089940E 04/
      DATA SEZIOF ( 8, 2, 3)/ 0.10957206E 04/
      DATA SEZIOF ( 9, 2, 3)/-0.35715017E 03/
      DATA SEZIOF (10, 2, 3)/-0.             /
      DATA SEZ    ( 1, 4)/-0.             /
      DATA SEZ    ( 2, 4)/-0.             /
      DATA SEZ    ( 3, 4)/-0.             /
      DATA SEZ    ( 4, 4)/-0.             /
      DATA SEZ    ( 5, 4)/-0.             /
      DATA SEZ    ( 6, 4)/-0.             /
      DATA SEZ    ( 7, 4)/-0.             /
      DATA SEZ    ( 8, 4)/-0.             /
      DATA SEZ    ( 9, 4)/-0.             /
      DATA SEZ    (10, 4)/-0.             /
      DATA SEZ    (11, 4)/-0.             /
      DATA SEZ    (12, 4)/-0.             /
      DATA SEZ    (13, 4)/-0.             /
      DATA SEZ    (14, 4)/-0.             /
      DATA   TARGA ( 5)/6H U 238/
      DATA      IX ( 5)/  1/
      DATA     NTE ( 5)/  2/
      DATA ASTRO  ( 1, 5)/ 0.27100000E 01/
      DATA ASTRO  ( 2, 5)/ 0.84000000E 01/
      DATA ASTRO  ( 3, 5)/ 0.99720000E 00/
      DATA ASTRO  ( 4, 5)/ 0.12000000E 02/
      DATA ASTRO  ( 5, 5)/ 0.90000000E 01/
      DATA ASTRO  ( 6, 5)/ 0.84000000E-02/
      DATA ASTRO  ( 7, 5)/ 0.99720000E 00/
      DATA ASTRO  ( 8, 5)/-0.             /
      DATA ASTRO  ( 9, 5)/-0.             /
      DATA ASTRO  (10, 5)/ 0.98333340E 00/
      DATA SEZIO  ( 1, 1, 5)/ 0.10014191E 01/
      DATA SEZIO  ( 2, 1, 5)/ 0.16864079E-01/
      DATA SEZIO  ( 3, 1, 5)/ 0.18382706E-02/
      DATA SEZIO  ( 4, 1, 5)/-0.34606259E-03/
      DATA SEZIO  ( 5, 1, 5)/-0.             /
      DATA SEZIO  ( 6, 1, 5)/-0.             /
      DATA SEZIO  ( 7, 1, 5)/-0.             /
      DATA SEZIO  ( 8, 1, 5)/-0.             /
      DATA SEZIO  ( 9, 1, 5)/-0.             /
      DATA SEZIO  (10, 1, 5)/-0.             /
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      DATA SEZIO  ( 1, 2, 5)/ 0.                /
      DATA SEZIO  ( 2, 2, 5)/ 0.                /
      DATA SEZIO  ( 3, 2, 5)/ 0.                /
      DATA SEZIO  ( 4, 2, 5)/ 0.                /
      DATA SEZIO  ( 5, 2, 5)/ 0.                /
      DATA SEZIO  ( 6, 2, 5)/ 0.                /
      DATA SEZIO  ( 7, 2, 5)/ 0.                /
      DATA SEZIO  ( 8, 2, 5)/ 0.                /
      DATA SEZIO  ( 9, 2, 5)/ 0.                /
      DATA SEZIO  (10, 2, 5)/ 0.                /
      DATA SEZ    ( 1, 5)/ 0.15202000E 01/
      DATA SEZ    ( 2, 5)/ 0.19054000E 01/
      DATA SEZ    ( 3, 5)/ 0.21980000E 01/
      DATA SEZ    ( 4, 5)/ 0.11670000E 00/
      DATA SEZ    ( 5, 5)/ 0.92650000E-02/
      DATA SEZ    ( 6, 5)/ 0.18499000E-01/
      DATA SEZ    ( 7, 5)/ 0.45100000E-03/
      DATA SEZ    ( 8, 5)/ 0.38220000E-01/
      DATA SEZ    ( 9, 5)/ 0.52630000E 00/
      DATA SEZ    (10, 5)/ 0.10984000E-01/
      DATA SEZ    (11, 5)/ 0.64499000E 01/
      DATA SEZ    (12, 5)/ 0.21467000E 00/
      DATA SEZ    (13, 5)/ 0.16549000E 00/
      DATA SEZ    (14, 5)/ 0.41990000E-02/
      DATA   TARGA ( 6)/6H   H2O /
      DATA      IX ( 6)/  0/
      DATA     NTE ( 6)/  1/
      DATA ASTRO  ( 1, 6)/ 0.66400000E 00/
      DATA ASTRO  ( 2, 6)/-0.20000000E 01/
      DATA ASTRO  ( 3, 6)/ 0.78950000E 00/
      DATA ASTRO  ( 4, 6)/ 0.43910000E 02/
      DATA ASTRO  ( 5, 6)/ 0.10510000E 02/
      DATA ASTRO  ( 6, 6)/ 0.92380000E 00/
      DATA ASTRO  ( 7, 6)/ 0.39220000E 00/
      DATA ASTRO  ( 8, 6)/-0.             /
      DATA ASTRO  ( 9, 6)/-0.             /
      DATA ASTRO  (10, 6)/ 0.18819100E-01/
      DATA SEZIO  ( 1, 1, 6)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1, 6)/ 0.                /
      DATA SEZIO  ( 3, 1, 6)/ 0.10000000E 30/
      DATA SEZIO  ( 4, 1, 6)/-0.                /
      DATA SEZIO  ( 5, 1, 6)/-0.                /
      DATA SEZIO  ( 6, 1, 6)/-0.                /
      DATA SEZIO  ( 7, 1, 6)/-0.                /
      DATA SEZIO  ( 8, 1, 6)/-0.                /
      DATA SEZIO  ( 9, 1, 6)/-0.                /
      DATA SEZIO  (10, 1, 6)/-0.                /
      DATA SEZIO  ( 1, 2, 6)/ 0.                /
      DATA SEZIO  ( 2, 2, 6)/ 0.                /
      DATA SEZIO  ( 3, 2, 6)/ 0.                /
      DATA SEZIO  ( 4, 2, 6)/ 0.                /
      DATA SEZIO  ( 5, 2, 6)/ 0.                /
      DATA SEZIO  ( 6, 2, 6)/ 0.                /
      DATA SEZIO  ( 7, 2, 6)/ 0.                /
      DATA SEZIO  ( 8, 2, 6)/ 0.                /
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      DATA SEZIO  ( 9, 2, 6)/ 0.              /
      DATA SEZIO  (10, 2, 6)/ 0.              /
      DATA SEZ    ( 1, 6)/ 0.              /
      DATA SEZ    ( 2, 6)/ 0.15157300E 01/
      DATA SEZ    ( 3, 6)/ 0.29475700E 01/
      DATA SEZ    ( 4, 6)/ 0.24428000E 00/
      DATA SEZ    ( 5, 6)/ 0.              /
      DATA SEZ    ( 6, 6)/ 0.              /
      DATA SEZ    ( 7, 6)/ 0.              /
      DATA SEZ    ( 8, 6)/ 0.22600000E-01/
      DATA SEZ    ( 9, 6)/ 0.              /
      DATA SEZ    (10, 6)/ 0.              /
      DATA SEZ    (11, 6)/ 0.38878000E 01/
      DATA SEZ    (12, 6)/ 0.72868000E 01/
      DATA SEZ    (13, 6)/ 0.              /
      DATA SEZ    (14, 6)/ 0.              /
      DATA  TARGA (  7)/6H   D20 /
      DATA     IX (  7)/   0/
      DATA    NTE (  7)/   1/
      DATA ASTRO  ( 1, 7)/ 0.11000000E-02/
      DATA ASTRO  ( 2, 7)/-0.30000000E 01/
      DATA ASTRO  ( 3, 7)/ 0.85480000E 00/
      DATA ASTRO  ( 4, 7)/ 0.10500000E 02/
      DATA ASTRO  ( 5, 7)/ 0.82860000E 01/
      DATA ASTRO  ( 6, 7)/ 0.50700000E 00/
      DATA ASTRO  ( 7, 7)/ 0.77220000E 00/
      DATA ASTRO  ( 8, 7)/-0.              /
      DATA ASTRO  ( 9, 7)/-0.              /
      DATA ASTRO  (10, 7)/ 0.27809000E 00/
      DATA SEZIO  ( 1, 1, 7)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1, 7)/ 0.              /
      DATA SEZIO  ( 3, 1, 7)/ 0.10000000E 30/
      DATA SEZIO  ( 4, 1, 7)/-0.              /
      DATA SEZIO  ( 5, 1, 7)/-0.              /
      DATA SEZIO  ( 6, 1, 7)/-0.              /
      DATA SEZIO  ( 7, 1, 7)/-0.              /
      DATA SEZIO  ( 8, 1, 7)/-0.              /
      DATA SEZIO  ( 9, 1, 7)/-0.              /
      DATA SEZIO  (10, 1, 7)/-0.              /
      DATA SEZIO  ( 1, 2, 7)/ 0.              /
      DATA SEZIO  ( 2, 2, 7)/ 0.              /
      DATA SEZIO  ( 3, 2, 7)/ 0.              /
      DATA SEZIO  ( 4, 2, 7)/ 0.              /
      DATA SEZIO  ( 5, 2, 7)/ 0.              /
      DATA SEZIO  ( 6, 2, 7)/ 0.              /
      DATA SEZIO  ( 7, 2, 7)/ 0.              /
      DATA SEZIO  ( 8, 2, 7)/ 0.              /
      DATA SEZIO  ( 9, 2, 7)/ 0.              /
      DATA SEZIO  (10, 2, 7)/ 0.              /
      DATA SEZ    ( 1, 7)/ 0.              /
      DATA SEZ    ( 2, 7)/ 0.17224900E 01/
      DATA SEZ    ( 3, 7)/ 0.27043700E 01/
      DATA SEZ    ( 4, 7)/ 0.              /
      DATA SEZ    ( 5, 7)/ 0.89500000E-02/
      DATA SEZ    ( 6, 7)/ 0.10598000E-01/
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      DATA SEZ      ( 7, 7)/ 0.15800000E-03/
      DATA SEZ      ( 8, 7)/ 0.22630000E-01/
      DATA SEZ      ( 9, 7)/ 0.              /
      DATA SEZ      (10, 7)/ 0.              /
      DATA SEZ      (11, 7)/ 0.64812000E 01/
      DATA SEZ      (12, 7)/ 0.24538000E 01/
      DATA SEZ      (13, 7)/ 0.20000000E-03/
      DATA SEZ      (14, 7)/ 0.              /
      DATA  TARGA   ( 8)/6H    H  /
      DATA     IX   ( 8)/   0/
      DATA    NTE   ( 8)/   1/
      DATA ASTRO    ( 1, 8)/ 0.33200000E 00/
      DATA ASTRO    ( 2, 8)/-0.10000000E 01/
      DATA ASTRO    ( 3, 8)/ 0.78120000E 00/
      DATA ASTRO    ( 4, 8)/ 0.20055000E 02/
      DATA ASTRO    ( 5, 8)/ 0.28000000E 01/
      DATA ASTRO    ( 6, 8)/ 0.10000000E 01/
      DATA ASTRO    ( 7, 8)/ 0.33860000E 00/
      DATA ASTRO    ( 8, 8)/-0.              /
      DATA ASTRO    ( 9, 8)/-0.              /
      DATA ASTRO    (10, 8)/ 0.              /
      DATA SEZIO    ( 1, 1, 8)/ 0.10000000E 01/
      DATA SEZIO    ( 2, 1, 8)/ 0.              /
      DATA SEZIO    ( 3, 1, 8)/ 0.10000000E 30/
      DATA SEZIO    ( 4, 1, 8)/-0.              /
      DATA SEZIO    ( 5, 1, 8)/-0.              /
      DATA SEZIO    ( 6, 1, 8)/-0.              /
      DATA SEZIO    ( 7, 1, 8)/-0.              /
      DATA SEZIO    ( 8, 1, 8)/-0.              /
      DATA SEZIO    ( 9, 1, 8)/-0.              /
      DATA SEZIO    (10, 1, 8)/-0.              /
      DATA SEZIO    ( 1, 2, 8)/ 0.              /
      DATA SEZIO    ( 2, 2, 8)/ 0.              /
      DATA SEZIO    ( 3, 2, 8)/ 0.              /
      DATA SEZIO    ( 4, 2, 8)/ 0.              /
      DATA SEZIO    ( 5, 2, 8)/ 0.              /
      DATA SEZIO    ( 6, 2, 8)/ 0.              /
      DATA SEZIO    ( 7, 2, 8)/ 0.              /
      DATA SEZIO    ( 8, 2, 8)/ 0.              /
      DATA SEZIO    ( 9, 2, 8)/ 0.              /
      DATA SEZIO    (10, 2, 8)/ 0.              /
      DATA SEZ      ( 1, 8)/ 0.              /
      DATA SEZ      ( 2, 8)/ 0.11116000E 00/
      DATA SEZ      ( 3, 8)/ 0.13634000E 01/
      DATA SEZ      ( 4, 8)/ 0.12214000E 00/
      DATA SEZ      ( 5, 8)/ 0.              /
      DATA SEZ      ( 6, 8)/ 0.              /
      DATA SEZ      ( 7, 8)/ 0.              /
      DATA SEZ      ( 8, 8)/ 0.              /
      DATA SEZ      ( 9, 8)/ 0.              /
      DATA SEZ      (10, 8)/ 0.              /
      DATA SEZ      (11, 8)/ 0.94109000E-01/
      DATA SEZ      (12, 8)/ 0.35402000E 01/
      DATA SEZ      (13, 8)/ 0.              /
      DATA SEZ      (14, 8)/ 0.              /
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      DATA   TARGA (  9)/6H     0 /
      DATA      IX (  9)/  0/
      DATA     NTE (  9)/  1/
      DATA ASTRO   (  1,  9)/ 0.18000000E-03/
      DATA ASTRO   (  2,  9)/ 0.42000000E 01/
      DATA ASTRO   (  3,  9)/ 0.95830000E 00/
      DATA ASTRO   (  4,  9)/ 0.38000000E 01/
      DATA ASTRO   (  5,  9)/ 0.23920000E 01/
      DATA ASTRO   (  6,  9)/ 0.12000000E 00/
      DATA ASTRO   (  7,  9)/ 0.95830000E 00/
      DATA ASTRO   (  8,  9)/-0.             /
      DATA ASTRO   (  9,  9)/-0.             /
      DATA ASTRO   (10,  9)/ 0.77854660E 00/
      DATA SEZIO   (  1,  1,  9)/ 0.10000000E 01/
      DATA SEZIO   (  2,  1,  9)/ 0.             /
      DATA SEZIO   (  3,  1,  9)/ 0.10000000E 30/
      DATA SEZIO   (  4,  1,  9)/-0.             /
      DATA SEZIO   (  5,  1,  9)/-0.             /
      DATA SEZIO   (  6,  1,  9)/-0.             /
      DATA SEZIO   (  7,  1,  9)/-0.             /
      DATA SEZIO   (  8,  1,  9)/-0.             /
      DATA SEZIO   (  9,  1,  9)/-0.             /
      DATA SEZIO   (10,  1,  9)/-0.             /
      DATA SEZIO   (  1,  2,  9)/ 0.             /
      DATA SEZIO   (  2,  2,  9)/ 0.             /
      DATA SEZIO   (  3,  2,  9)/ 0.             /
      DATA SEZIO   (  4,  2,  9)/ 0.             /
      DATA SEZIO   (  5,  2,  9)/ 0.             /
      DATA SEZIO   (  6,  2,  9)/ 0.             /
      DATA SEZIO   (  7,  2,  9)/ 0.             /
      DATA SEZIO   (  8,  2,  9)/ 0.             /
      DATA SEZIO   (  9,  2,  9)/ 0.             /
      DATA SEZIO   (10,  2,  9)/ 0.             /
      DATA SEZ     (  1,  9)/ 0.             /
      DATA SEZ     (  2,  9)/ 0.12934100E 01/
      DATA SEZ     (  3,  9)/ 0.22077000E 00/
      DATA SEZ     (  4,  9)/ 0.             /
      DATA SEZ     (  5,  9)/ 0.             /
      DATA SEZ     (  6,  9)/-0.             /
      DATA SEZ     (  7,  9)/-0.             /
      DATA SEZ     (  8,  9)/ 0.22620000E-01/
      DATA SEZ     (  9,  9)/-0.             /
      DATA SEZ     (10,  9)/-0.             /
      DATA SEZ     (11,  9)/ 0.36996000E 01/
      DATA SEZ     (12,  9)/ 0.20640000E 00/
      DATA SEZ     (13,  9)/-0.             /
      DATA SEZ     (14,  9)/-0.             /
      DATA   TARGA (10)/6H ZOY2 /
      DATA      IX (10)/  0/
      DATA     NTE (10)/  1/
      DATA ASTRO   (  1,10)/ 0.21560000E 00/
      DATA ASTRO   (  2,10)/ 0.60100000E 01/
      DATA ASTRO   (  3,10)/ 0.99270000E 00/
      DATA ASTRO   (  4,10)/ 0.60000000E 01/
      DATA ASTRO   (  5,10)/ 0.56000000E 01/
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      DATA ASTRO  ( 6,10)/ 0.21800000E-01/
      DATA ASTRO  ( 7,10)/ 0.99270000E 00/
      DATA ASTRO  ( 8,10)/-0.            /
      DATA ASTRO  ( 9,10)/-0.            /
      DATA ASTRO  (10,10)/ 0.95706700E 00/
      DATA SEZIO  ( 1, 1,10)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,10)/ 0.70000000E 00/
      DATA SEZIO  ( 3, 1,10)/ 0.49000000E 00/
      DATA SEZIO  ( 4, 1,10)/-0.            /
      DATA SEZIO  ( 5, 1,10)/-0.            /
      DATA SEZIO  ( 6, 1,10)/-0.            /
      DATA SEZIO  ( 7, 1,10)/-0.            /
      DATA SEZIO  ( 8, 1,10)/-0.            /
      DATA SEZIO  ( 9, 1,10)/-0.            /
      DATA SEZIO  (10, 1,10)/-0.            /
      DATA SEZIO  ( 1, 2,10)/ 0.            /
      DATA SEZIO  ( 2, 2,10)/ 0.            /
      DATA SEZIO  ( 3, 2,10)/ 0.            /
      DATA SEZIO  ( 4, 2,10)/ 0.            /
      DATA SEZIO  ( 5, 2,10)/ 0.            /
      DATA SEZIO  ( 6, 2,10)/ 0.            /
      DATA SEZIO  ( 7, 2,10)/ 0.            /
      DATA SEZIO  ( 8, 2,10)/ 0.            /
      DATA SEZIO  ( 9, 2,10)/ 0.            /
      DATA SEZIO  (10, 2,10)/ 0.            /
      DATA SEZ    ( 1,10)/-0.            /
      DATA SEZ    ( 2,10)/ 0.24638001E 01/
      DATA SEZ    ( 3,10)/ 0.68260000E 00/
      DATA SEZ    ( 4,10)/ 0.52800000E-02/
      DATA SEZ    ( 5,10)/-0.            /
      DATA SEZ    ( 6,10)/-0.            /
      DATA SEZ    ( 7,10)/-0.            /
      DATA SEZ    ( 8,10)/-0.            /
      DATA SEZ    ( 9,10)/-0.            /
      DATA SEZ    (10,10)/-0.            /
      DATA SEZ    (11,10)/ 0.66214000E 01/
      DATA SEZ    (12,10)/ 0.17440000E 00/
      DATA SEZ    (13,10)/-0.            /
      DATA SEZ    (14,10)/-0.            /
      DATA   TARGA (11)/6H U 236/
      DATA      IX (11)/  0/
      DATA     NTE (11)/  1/
      DATA ASTRO  ( 1,11)/ 0.55000000E 01/
      DATA ASTRO  ( 2,11)/ 0.10000000E 02/
      DATA ASTRO  ( 3,11)/ 0.99720000E 00/
      DATA ASTRO  ( 4,11)/ 0.12000000E 02/
      DATA ASTRO  ( 5,11)/ 0.90000000E 01/
      DATA ASTRO  ( 6,11)/ 0.84999999E-02/
      DATA ASTRO  ( 7,11)/ 0.99720000E 00/
      DATA ASTRO  ( 8,11)/-0.            /
      DATA ASTRO  ( 9,11)/-0.            /
      DATA ASTRO  (10,11)/ 0.98319340E 00/
      DATA SEZIO  ( 1, 1,11)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,11)/ 0.25900000E 03/
      DATA SEZIO  ( 3, 1,11)/ 0.40000000E 00/
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      DATA SEZIO  ( 4, 1,11)/-0.              /
      DATA SEZIO  ( 5, 1,11)/-0.              /
      DATA SEZIO  ( 6, 1,11)/-0.              /
      DATA SEZIO  ( 7, 1,11)/-0.              /
      DATA SEZIO  ( 8, 1,11)/-0.              /
      DATA SEZIO  ( 9, 1,11)/-0.              /
      DATA SEZIO  (10, 1,11)/-0.              /
      DATA SEZIO  ( 1, 2,11)/ 0.              /
      DATA SEZIO  ( 2, 2,11)/ 0.              /
      DATA SEZIO  ( 3, 2,11)/ 0.              /
      DATA SEZIO  ( 4, 2,11)/ 0.              /
      DATA SEZIO  ( 5, 2,11)/ 0.              /
      DATA SEZIO  ( 6, 2,11)/ 0.              /
      DATA SEZIO  ( 7, 2,11)/ 0.              /
      DATA SEZIO  ( 8, 2,11)/ 0.              /
      DATA SEZIO  ( 9, 2,11)/ 0.              /
      DATA SEZIO  (10, 2,11)/ 0.              /
      DATA SEZ    ( 1,11)/-0.              /
      DATA SEZ    ( 2,11)/-0.              /
      DATA SEZ    ( 3,11)/-0.              /
      DATA SEZ    ( 4,11)/-0.              /
      DATA SEZ    ( 5,11)/-0.              /
      DATA SEZ    ( 6,11)/-0.              /
      DATA SEZ    ( 7,11)/-0.              /
      DATA SEZ    ( 8,11)/-0.              /
      DATA SEZ    ( 9,11)/-0.              /
      DATA SEZ    (10,11)/-0.              /
      DATA SEZ    (11,11)/-0.              /
      DATA SEZ    (12,11)/-0.              /
      DATA SEZ    (13,11)/-0.              /
      DATA SEZ    (14,11)/-0.              /
      DATA  TARGA (12)/6HPECHIN/
      DATA     IX (12)/   0/
      DATA    NTE (12)/   1/
      DATA ASTRO  ( 1,12)/ 0.37000000E-02/
      DATA ASTRO  ( 2,12)/ 0.52400000E 01/
      DATA ASTRO  ( 3,12)/ 0.94440000E 00/
      DATA ASTRO  ( 4,12)/ 0.47000000E 01/
      DATA ASTRO  ( 5,12)/ 0.28160000E 01/
      DATA ASTRO  ( 6,12)/ 0.15800000E 00/
      DATA ASTRO  ( 7,12)/ 0.94440000E 00/
      DATA ASTRO  ( 8,12)/ 0.              /
      DATA ASTRO  ( 9,12)/ 0.              /
      DATA ASTRO  (10,12)/ 0.71619640E 00/
      DATA SEZIO  ( 1, 1,12)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,12)/ 0.              /
      DATA SEZIO  ( 3, 1,12)/ 0.10000000E 30/
      DATA SEZIO  ( 4, 1,12)/-0.              /
      DATA SEZIO  ( 5, 1,12)/-0.              /
      DATA SEZIO  ( 6, 1,12)/-0.              /
      DATA SEZIO  ( 7, 1,12)/-0.              /
      DATA SEZIO  ( 8, 1,12)/-0.              /
      DATA SEZIO  ( 9, 1,12)/-0.              /
      DATA SEZIO  (10, 1,12)/-0.              /
      DATA SEZIO  ( 1, 2,12)/ 0.              /
```

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      DATA SEZIO  ( 2, 2,12)/ 0.             /
      DATA SEZIO  ( 3, 2,12)/ 0.             /
      DATA SEZIO  ( 4, 2,12)/ 0.             /
      DATA SEZIO  ( 5, 2,12)/ 0.             /
      DATA SEZIO  ( 6, 2,12)/ 0.             /
      DATA SEZIO  ( 7, 2,12)/ 0.             /
      DATA SEZIO  ( 8, 2,12)/ 0.             /
      DATA SEZIO  ( 9, 2,12)/ 0.             /
      DATA SEZIO  (10, 2,12)/ 0.             /
      DATA SEZ    ( 1,12)/ 0.             /
      DATA SEZ    ( 2,12)/ 0.13454400E 01/
      DATA SEZ    ( 3,12)/ 0.24361000E 00/
      DATA SEZ    ( 4,12)/-0.             /
      DATA SEZ    ( 5,12)/-0.             /
      DATA SEZ    ( 6,12)/ 0.             /
      DATA SEZ    ( 7,12)/ 0.             /
      DATA SEZ    ( 8,12)/ 0.             /
      DATA SEZ    ( 9,12)/ 0.             /
      DATA SEZ    (10,12)/ 0.             /
      DATA SEZ    (11,12)/ 0.29022000E 01/
      DATA SEZ    (12,12)/ 0.30697000E 00/
      DATA SEZ    (13,12)/-0.             /
      DATA SEZ    (14,12)/-0.             /
      DATA  TARGA (13)/6H AL ST/
      DATA     IX (13)/  0/
      DATA    NTE (13)/  1/
      DATA ASTRO  ( 1,13)/ 0.23000000E 00/
      DATA ASTRO  ( 2,13)/ 0.13200000E 01/
      DATA ASTRO  ( 3,13)/ 0.97540000E 00/
      DATA ASTRO  ( 4,13)/ 0.14000000E 01/
      DATA ASTRO  ( 5,13)/ 0.30500000E 01/
      DATA ASTRO  ( 6,13)/ 0.72300000E-01/
      DATA ASTRO  ( 7,13)/ 0.97540000E 00/
      DATA ASTRO  ( 8,13)/-0.             /
      DATA ASTRO  ( 9,13)/-0.             /
      DATA ASTRO  (10,13)/ 0.86214990E 00/
      DATA SEZIO  ( 1, 1,13)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,13)/ 0.18000000E 00/
      DATA SEZIO  ( 3, 1,13)/ 0.40000000E 00/
      DATA SEZIO  ( 4, 1,13)/-0.             /
      DATA SEZIO  ( 5, 1,13)/-0.             /
      DATA SEZIO  ( 6, 1,13)/-0.             /
      DATA SEZIO  ( 7, 1,13)/-0.             /
      DATA SEZIO  ( 8, 1,13)/-0.             /
      DATA SEZIO  ( 9, 1,13)/-0.             /
      DATA SEZIO  (10, 1,13)/-0.             /
      DATA SEZIO  ( 1, 2,13)/ 0.             /
      DATA SEZIO  ( 2, 2,13)/ 0.             /
      DATA SEZIO  ( 3, 2,13)/ 0.             /
      DATA SEZIO  ( 4, 2,13)/ 0.             /
      DATA SEZIO  ( 5, 2,13)/ 0.             /
      DATA SEZIO  ( 6, 2,13)/ 0.             /
      DATA SEZIO  ( 7, 2,13)/ 0.             /
      DATA SEZIO  ( 8, 2,13)/ 0.             /
      DATA SEZIO  ( 9, 2,13)/ 0.             /
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      DATA SEZIO  (10, 2,13)/ 0.
      DATA SEZ    ( 1,13)/-0.            /
      DATA SEZ    ( 2,13)/ 0.15658000E 01/
      DATA SEZ    ( 3,13)/ 0.35539000E 00/
      DATA SEZ    ( 4,13)/-0.            /
      DATA SEZ    ( 5,13)/-0.            /
      DATA SEZ    ( 6,13)/-0.            /
      DATA SEZ    ( 7,13)/-0.            /
      DATA SEZ    ( 8,13)/ 0.67000000E-02/
      DATA SEZ    ( 9,13)/-0.            /
      DATA SEZ    (10,13)/-0.            /
      DATA SEZ    (11,13)/ 0.34269000E 01/
      DATA SEZ    (12,13)/ 0.15296000E 00/
      DATA SEZ    (13,13)/ 0.23000000E-02/
      DATA SEZ    (14,13)/-0.            /
      DATA  TARGA (14)/6H   B  /
      DATA     IX (14)/  0/
      DATA    NTE (14)/  1/
      DATA ASTRO  ( 1,14)/ 0.75500000E 03/
      DATA ASTRO  ( 2,14)/ 0.40000000E 01/
      DATA ASTRO  ( 3,14)/ 0.93940000E 00/
      DATA ASTRO  ( 4,14)/ 0.36900000E 01/
      DATA ASTRO  ( 5,14)/ 0.28800000E 01/
      DATA ASTRO  ( 6,14)/ 0.17100000E 00/
      DATA ASTRO  ( 7,14)/ 0.93940000E 00/
      DATA ASTRO  ( 8,14)/-0.            /
      DATA ASTRO  ( 9,14)/-0.            /
      DATA ASTRO  (10,14)/ 0.69022060E 00/
      DATA SEZIO  ( 1, 1,14)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,14)/ 0.28000000E 03/
      DATA SEZIO  ( 3, 1,14)/ 0.49000000E 00/
      DATA SEZIO  ( 4, 1,14)/-0.            /
      DATA SEZIO  ( 5, 1,14)/-0.            /
      DATA SEZIO  ( 6, 1,14)/-0.            /
      DATA SEZIO  ( 7, 1,14)/-0.            /
      DATA SEZIO  ( 8, 1,14)/-0.            /
      DATA SEZIO  ( 9, 1,14)/-0.            /
      DATA SEZIO  (10, 1,14)/-0.            /
      DATA SEZIO  ( 1, 2,14)/ 0.            /
      DATA SEZIO  ( 2, 2,14)/ 0.            /
      DATA SEZIO  ( 3, 2,14)/ 0.            /
      DATA SEZIO  ( 4, 2,14)/ 0.            /
      DATA SEZIO  ( 5, 2,14)/ 0.            /
      DATA SEZIO  ( 6, 2,14)/ 0.            /
      DATA SEZIO  ( 7, 2,14)/ 0.            /
      DATA SEZIO  ( 8, 2,14)/ 0.            /
      DATA SEZIO  ( 9, 2,14)/ 0.            /
      DATA SEZIO  (10, 2,14)/ 0.            /
      DATA SEZ    ( 1,14)/-0.            /
      DATA SEZ    ( 2,14)/-0.            /
      DATA SEZ    ( 3,14)/-0.            /
      DATA SEZ    ( 4,14)/-0.            /
      DATA SEZ    ( 5,14)/-0.            /
      DATA SEZ    ( 6,14)/-0.            /
      DATA SEZ    ( 7,14)/-0.            /
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      DATA SEZ      ( 8,14)/-0.              /
      DATA SEZ      ( 9,14)/-0.              /
      DATA SEZ      (10,14)/-0.              /
      DATA SEZ      (11,14)/-0.              /
      DATA SEZ      (12,14)/-0.              /
      DATA SEZ      (13,14)/-0.              /
      DATA SEZ      (14,14)/-0.              /
      DATA  TARGA   (15)/6HXE 135/
      DATA     IX   (15)/   1/
      DATA    NTE   (15)/   2/
      DATA ASTRO    ( 1,15)/ 0.27200000E 07/
      DATA ASTRO    ( 2,15)/ 0.43000000E 01/
      DATA ASTRO    ( 3,15)/ 0.99510000E 00/
      DATA ASTRO    ( 4,15)/ 0.40000000E 01/
      DATA ASTRO    ( 5,15)/ 0.40000000E 01/
      DATA ASTRO    ( 6,15)/ 0.14700000E-01/
      DATA ASTRO    ( 7,15)/ 0.99510000E 00/
      DATA ASTRO    ( 8,15)/-0.              /
      DATA ASTRO    ( 9,15)/-0.              /
      DATA ASTRO    (10,15)/ 0.97080440E 00/
      DATA SEZIO    ( 1, 1,15)/ 0.12287596E 01/
      DATA SEZIO    ( 2, 1,15)/ 0.12411058E 01/
      DATA SEZIO    ( 3, 1,15)/-0.44027269E 01/
      DATA SEZIO    ( 4, 1,15)/ 0.68046441E 01/
      DATA SEZIO    ( 5, 1,15)/-0.81250162E 01/
      DATA SEZIO    ( 6, 1,15)/ 0.65212884E 01/
      DATA SEZIO    ( 7, 1,15)/-0.23221932E 01/
      DATA SEZIO    ( 8, 1,15)/-0.              /
      DATA SEZIO    ( 9, 1,15)/-0.              /
      DATA SEZIO    (10, 1,15)/-0.              /
      DATA SEZIO    ( 1, 2,15)/-0.76577332E 00/
      DATA SEZIO    ( 2, 2,15)/-0.46870211E 01/
      DATA SEZIO    ( 3, 2,15)/ 0.84313472E 01/
      DATA SEZIO    ( 4, 2,15)/ 0.11679808E 02/
      DATA SEZIO    ( 5, 2,15)/-0.92289962E 02/
      DATA SEZIO    ( 6, 2,15)/ 0.22248705E 03/
      DATA SEZIO    ( 7, 2,15)/-0.28488849E 03/
      DATA SEZIO    ( 8, 2,15)/ 0.19279294E 03/
      DATA SEZIO    ( 9, 2,15)/-0.54153100E 02/
      DATA SEZIO    (10, 2,15)/-0.              /
      DATA SEZ      ( 1,15)/-0.              /
      DATA SEZ      ( 2,15)/-0.              /
      DATA SEZ      ( 3,15)/-0.              /
      DATA SEZ      ( 4,15)/-0.              /
      DATA SEZ      ( 5,15)/-0.              /
      DATA SEZ      ( 6,15)/-0.              /
      DATA SEZ      ( 7,15)/-0.              /
      DATA SEZ      ( 8,15)/-0.              /
      DATA SEZ      ( 9,15)/-0.              /
      DATA SEZ      (10,15)/-0.              /
      DATA SEZ      (11,15)/-0.              /
      DATA SEZ      (12,15)/-0.              /
      DATA SEZ      (13,15)/-0.              /
      DATA SEZ      (14,15)/-0.              /
      DATA  TARGA   (16)/6HPU 242/
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```
      DATA     IX   (16)/   1/
      DATA     NTE  (16)/   2/
      DATA ASTRO   ( 1,16)/ 0.30090000E 02/
      DATA ASTRO   ( 2,16)/ 0.13000000E 02/
      DATA ASTRO   ( 3,16)/ 0.99730000E 00/
      DATA ASTRO   ( 4,16)/ 0.11300000E 02/
      DATA ASTRO   ( 5,16)/ 0.48000000E 01/
      DATA ASTRO   ( 6,16)/ 0.82000000E-02/
      DATA ASTRO   ( 7,16)/ 0.99730000E 00/
      DATA ASTRO   ( 8,16)/-0.              /
      DATA ASTRO   ( 9,16)/-0.              /
      DATA ASTRO   (10,16)/ 0.98360670E 00/
      DATA SEZIO   ( 1,  1,16)/ 0.10048917E 01/
      DATA SEZIO   ( 2,  1,16)/ 0.67687810E-01/
      DATA SEZIO   ( 3,  1,16)/-0.14598010E-02/
      DATA SEZIO   ( 4,  1,16)/ 0.10885102E-01/
      DATA SEZIO   ( 5,  1,16)/-0.              /
      DATA SEZIO   ( 6,  1,16)/-0.              /
      DATA SEZIO   ( 7,  1,16)/-0.              /
      DATA SEZIO   ( 8,  1,16)/-0.              /
      DATA SEZIO   ( 9,  1,16)/-0.              /
      DATA SEZIO   (10,  1,16)/-0.              /
      DATA SEZIO   ( 1,  2,16)/ 0.36282434E 02/
      DATA SEZIO   ( 2,  2,16)/ 0.65939632E 02/
      DATA SEZIO   ( 3,  2,16)/-0.57355898E 02/
      DATA SEZIO   ( 4,  2,16)/ 0.82423251E 02/
      DATA SEZIO   ( 5,  2,16)/-0.10175007E 03/
      DATA SEZIO   ( 6,  2,16)/ 0.79197544E 02/
      DATA SEZIO   ( 7,  2,16)/-0.27156685E 02/
      DATA SEZIO   ( 8,  2,16)/-0.              /
      DATA SEZIO   ( 9,  2,16)/-0.              /
      DATA SEZIO   (10,  2,16)/-0.              /
      DATA SEZ     ( 1,16)/-0.              /
      DATA SEZ     ( 2,16)/-0.              /
      DATA SEZ     ( 3,16)/-0.              /
      DATA SEZ     ( 4,16)/-0.              /
      DATA SEZ     ( 5,16)/-0.              /
      DATA SEZ     ( 6,16)/-0.              /
      DATA SEZ     ( 7,16)/-0.              /
      DATA SEZ     ( 8,16)/-0.              /
      DATA SEZ     ( 9,16)/-0.              /
      DATA SEZ     (10,16)/-0.              /
      DATA SEZ     (11,16)/-0.              /
      DATA SEZ     (12,16)/-0.              /
      DATA SEZ     (13,16)/-0.              /
      DATA SEZ     (14,16)/-0.              /
      DATA   TARGA (17)/6HAM 241/
      DATA     IX   (17)/   1/
      DATA     NTE  (17)/   2/
      DATA ASTRO   ( 1,17)/ 0.58369000E 03/
      DATA ASTRO   ( 2,17)/ 0.15000000E 02/
      DATA ASTRO   ( 3,17)/ 0.99730000E 00/
      DATA ASTRO   ( 4,17)/ 0.12000000E 02/
      DATA ASTRO   ( 5,17)/ 0.70000000E 01/
      DATA ASTRO   ( 6,17)/ 0.83000000E-02/
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      DATA ASTRO  ( 7,17)/ 0.99730000E 00/
      DATA ASTRO  ( 8,17)/ 0.30000000E 01/
      DATA ASTRO  ( 9,17)/ 0.35980000E 01/
      DATA ASTRO  (10,17)/ 0.98353930E 00/
      DATA SEZIO  ( 1, 1,17)/ 0.10088454E 01/
      DATA SEZIO  ( 2, 1,17)/ 0.45658457E 00/
      DATA SEZIO  ( 3, 1,17)/-0.28041564E 01/
      DATA SEZIO  ( 4, 1,17)/ 0.26939836E 02/
      DATA SEZIO  ( 5, 1,17)/-0.58563020E 02/
      DATA SEZIO  ( 6, 1,17)/ 0.63478318E 02/
      DATA SEZIO  ( 7, 1,17)/-0.35287779E 02/
      DATA SEZIO  ( 8, 1,17)/ 0.82178292E 01/
      DATA SEZIO  ( 9, 1,17)/-0.20739348E 00/
      DATA SEZIO  (10, 1,17)/-0.            /
      DATA SEZIO  ( 1, 2,17)/ 0.50566223E 01/
      DATA SEZIO  ( 2, 2,17)/ 0.11063912E 02/
      DATA SEZIO  ( 3, 2,17)/-0.75390960E 01/
      DATA SEZIO  ( 4, 2,17)/-0.60979790E 02/
      DATA SEZIO  ( 5, 2,17)/ 0.47024200E 03/
      DATA SEZIO  ( 6, 2,17)/-0.25905500E 04/
      DATA SEZIO  ( 7, 2,17)/ 0.65855005E 04/
      DATA SEZIO  ( 8, 2,17)/-0.75539225E 04/
      DATA SEZIO  ( 9, 2,17)/ 0.32437987E 04/
      DATA SEZIO  (10, 2,17)/-0.            /
      DATA SEZ    ( 1,17)/-0.            /
      DATA SEZ    ( 2,17)/-0.            /
      DATA SEZ    ( 3,17)/-0.            /
      DATA SEZ    ( 4,17)/-0.            /
      DATA SEZ    ( 5,17)/-0.            /
      DATA SEZ    ( 6,17)/-0.            /
      DATA SEZ    ( 7,17)/-0.            /
      DATA SEZ    ( 8,17)/-0.            /
      DATA SEZ    ( 9,17)/-0.            /
      DATA SEZ    (10,17)/-0.            /
      DATA SEZ    (11,17)/-0.            /
      DATA SEZ    (12,17)/-0.            /
      DATA SEZ    (13,17)/-0.            /
      DATA SEZ    (14,17)/-0.            /
      DATA   TARGA (18)/6H PS 15/
      DATA      IX (18)/  0/
      DATA     NTE (18)/  1/
      DATA ASTRO  ( 1,18)/ 0.21681000E 03/
      DATA ASTRO  ( 2,18)/ 0.10000000E 01/
      DATA ASTRO  ( 3,18)/ 0.10000000E 01/
      DATA ASTRO  ( 4,18)/ 0.10000000E 01/
      DATA ASTRO  ( 5,18)/ 0.10000000E 01/
      DATA ASTRO  ( 6,18)/ 0.            /
      DATA ASTRO  ( 7,18)/ 0.10000000E 01/
      DATA ASTRO  ( 8,18)/-0.            /
      DATA ASTRO  ( 9,18)/-0.            /
      DATA ASTRO  (10,18)/ 0.10000000E 01/
      DATA SEZIO  ( 1, 1,18)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,18)/ 0.17817000E 03/
      DATA SEZIO  ( 3, 1,18)/ 0.41400000E 00/
      DATA SEZIO  ( 4, 1,18)/-0.            /
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      DATA SEZIO  ( 5,  1,18)/-0.                  /
      DATA SEZIO  ( 6,  1,18)/-0.                  /
      DATA SEZIO  ( 7,  1,18)/-0.                  /
      DATA SEZIO  ( 8,  1,18)/-0.                  /
      DATA SEZIO  ( 9,  1,18)/-0.                  /
      DATA SEZIO  (10,  1,18)/-0.                  /
      DATA SEZIO  ( 1,  2,18)/ 0.                  /
      DATA SEZIO  ( 2,  2,18)/ 0.                  /
      DATA SEZIO  ( 3,  2,18)/ 0.                  /
      DATA SEZIO  ( 4,  2,18)/ 0.                  /
      DATA SEZIO  ( 5,  2,18)/ 0.                  /
      DATA SEZIO  ( 6,  2,18)/ 0.                  /
      DATA SEZIO  ( 7,  2,18)/ 0.                  /
      DATA SEZIO  ( 8,  2,18)/ 0.                  /
      DATA SEZIO  ( 9,  2,18)/ 0.                  /
      DATA SEZIO  (10,  2,18)/ 0.                  /
      DATA SEZ    ( 1,18)/-0.                 /
      DATA SEZ    ( 2,18)/-0.                 /
      DATA SEZ    ( 3,18)/-0.                 /
      DATA SEZ    ( 4,18)/-0.                 /
      DATA SEZ    ( 5,18)/-0.                 /
      DATA SEZ    ( 6,18)/-0.                 /
      DATA SEZ    ( 7,18)/-0.                 /
      DATA SEZ    ( 8,18)/-0.                 /
      DATA SEZ    ( 9,18)/-0.                 /
      DATA SEZ    (10,18)/-0.                 /
      DATA SEZ    (11,18)/-0.                 /
      DATA SEZ    (12,18)/-0.                 /
      DATA SEZ    (13,18)/-0.                 /
      DATA SEZ    (14,18)/-0.                 /
      DATA   TARGA (19)/6H PS 25/
      DATA      IX (19)/  0/
      DATA     NTE (19)/  1/
      DATA ASTRO  ( 1,19)/ 0.31520000E 02/
      DATA ASTRO  ( 2,19)/ 0.10000000E 01/
      DATA ASTRO  ( 3,19)/ 0.10000000E 01/
      DATA ASTRO  ( 4,19)/ 0.10000000E 01/
      DATA ASTRO  ( 5,19)/ 0.10000000E 01/
      DATA ASTRO  ( 6,19)/-0.             /
      DATA ASTRO  ( 7,19)/ 0.10000000E 01/
      DATA ASTRO  ( 8,19)/-0.             /
      DATA ASTRO  ( 9,19)/-0.             /
      DATA ASTRO  (10,19)/ 0.10000000E 01/
      DATA SEZIO  ( 1,  1,19)/ 0.10000000E 01/
      DATA SEZIO  ( 2,  1,19)/ 0.29868000E 03/
      DATA SEZIO  ( 3,  1,19)/ 0.41400000E 00/
      DATA SEZIO  ( 4,  1,19)/-0.             /
      DATA SEZIO  ( 5,  1,19)/-0.             /
      DATA SEZIO  ( 6,  1,19)/-0.             /
      DATA SEZIO  ( 7,  1,19)/-0.             /
      DATA SEZIO  ( 8,  1,19)/-0.             /
      DATA SEZIO  ( 9,  1,19)/-0.             /
      DATA SEZIO  (10,  1,19)/-0.             /
      DATA SEZIO  ( 1,  2,19)/ 0.             /
      DATA SEZIO  ( 2,  2,19)/ 0.             /
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      DATA SEZIO  ( 3,  2,19)/ 0.                        /
      DATA SEZIO  ( 4,  2,19)/ 0.                        /
      DATA SEZIO  ( 5,  2,19)/ 0.                        /
      DATA SEZIO  ( 6,  2,19)/ 0.                        /
      DATA SEZIO  ( 7,  2,19)/ 0.                        /
      DATA SEZIO  ( 8,  2,19)/ 0.                        /
      DATA SEZIO  ( 9,  2,19)/ 0.                        /
      DATA SEZIO  (10,  2,19)/ 0.                        /
      DATA SEZ    ( 1,19)/-0.                       /
      DATA SEZ    ( 2,19)/-0.                       /
      DATA SEZ    ( 3,19)/-0.                       /
      DATA SEZ    ( 4,19)/-0.                       /
      DATA SEZ    ( 5,19)/-0.                       /
      DATA SEZ    ( 6,19)/-0.                       /
      DATA SEZ    ( 7,19)/-0.                       /
      DATA SEZ    ( 8,19)/-0.                       /
      DATA SEZ    ( 9,19)/-0.                       /
      DATA SEZ    (10,19)/-0.                       /
      DATA SEZ    (11,19)/-0.                       /
      DATA SEZ    (12,19)/-0.                       /
      DATA SEZ    (13,19)/-0.                       /
      DATA SEZ    (14,19)/-0.                       /
      DATA  TARGA (20)/6H PS 35/
      DATA     IX (20)/   0/
      DATA    NTE (20)/   1/
      DATA ASTRO  ( 1,20)/ 0.14094000E 03/
      DATA ASTRO  ( 2,20)/ 0.10000000E 01/
      DATA ASTRO  ( 3,20)/ 0.10000000E 01/
      DATA ASTRO  ( 4,20)/ 0.10000000E 01/
      DATA ASTRO  ( 5,20)/ 0.10000000E 01/
      DATA ASTRO  ( 6,20)/-0.                 /
      DATA ASTRO  ( 7,20)/ 0.10000000E 01/
      DATA ASTRO  ( 8,20)/-0.                 /
      DATA ASTRO  ( 9,20)/-0.                 /
      DATA ASTRO  (10,20)/ 0.10000000E 01/
      DATA SEZIO  ( 1,  1,20)/ 0.10000000E 01/
      DATA SEZIO  ( 2,  1,20)/ 0.97516000E 03/
      DATA SEZIO  ( 3,  1,20)/ 0.41400000E 00/
      DATA SEZIO  ( 4,  1,20)/-0.                 /
      DATA SEZIO  ( 5,  1,20)/-0.                 /
      DATA SEZIO  ( 6,  1,20)/-0.                 /
      DATA SEZIO  ( 7,  1,20)/-0.                 /
      DATA SEZIO  ( 8,  1,20)/-0.                 /
      DATA SEZIO  ( 9,  1,20)/-0.                 /
      DATA SEZIO  (10,  1,20)/-0.                 /
      DATA SEZIO  ( 1,  2,20)/ 0.                 /
      DATA SEZIO  ( 2,  2,20)/ 0.                 /
      DATA SEZIO  ( 3,  2,20)/ 0.                 /
      DATA SEZIO  ( 4,  2,20)/ 0.                 /
      DATA SEZIO  ( 5,  2,20)/ 0.                 /
      DATA SEZIO  ( 6,  2,20)/ 0.                 /
      DATA SEZIO  ( 7,  2,20)/ 0.                 /
      DATA SEZIO  ( 8,  2,20)/ 0.                 /
      DATA SEZIO  ( 9,  2,20)/ 0.                 /
      DATA SEZIO  (10,  2,20)/ 0.                 /
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      DATA SEZ    ( 1,20)/-0.              /
      DATA SEZ    ( 2,20)/-0.              /
      DATA SEZ    ( 3,20)/-0.              /
      DATA SEZ    ( 4,20)/-0.              /
      DATA SEZ    ( 5,20)/-0.              /
      DATA SEZ    ( 6,20)/-0.              /
      DATA SEZ    ( 7,20)/-0.              /
      DATA SEZ    ( 8,20)/-0.              /
      DATA SEZ    ( 9,20)/-0.              /
      DATA SEZ    (10,20)/-0.              /
      DATA SEZ    (11,20)/-0.              /
      DATA SEZ    (12,20)/-0.              /
      DATA SEZ    (13,20)/-0.              /
      DATA SEZ    (14,20)/-0.              /
      DATA  TARGA (21)/6H PS 45/
      DATA     IX (21)/  0/
      DATA    NTE (21)/  1/
      DATA ASTRO  ( 1,21)/ 0.26665000E 03/
      DATA ASTRO  ( 2,21)/ 0.10000000E 01/
      DATA ASTRO  ( 3,21)/ 0.10000000E 01/
      DATA ASTRO  ( 4,21)/ 0.10000000E 01/
      DATA ASTRO  ( 5,21)/ 0.10000000E 01/
      DATA ASTRO  ( 6,21)/-0.              /
      DATA ASTRO  ( 7,21)/ 0.10000000E 01/
      DATA ASTRO  ( 8,21)/-0.              /
      DATA ASTRO  ( 9,21)/-0.              /
      DATA ASTRO  (10,21)/ 0.10000000E 01/
      DATA SEZIO  ( 1, 1,21)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,21)/ 0.25815100E 04/
      DATA SEZIO  ( 3, 1,21)/ 0.41400000E 00/
      DATA SEZIO  ( 4, 1,21)/-0.              /
      DATA SEZIO  ( 5, 1,21)/-0.              /
      DATA SEZIO  ( 6, 1,21)/-0.              /
      DATA SEZIO  ( 7, 1,21)/-0.              /
      DATA SEZIO  ( 8, 1,21)/-0.              /
      DATA SEZIO  ( 9, 1,21)/-0.              /
      DATA SEZIO  (10, 1,21)/-0.              /
      DATA SEZIO  ( 1, 2,21)/ 0.              /
      DATA SEZIO  ( 2, 2,21)/ 0.              /
      CATA SEZIO  ( 3, 2,21)/ 0.              /
      DATA SEZIO  ( 4, 2,21)/ 0.              /
      DATA SEZIO  ( 5, 2,21)/ 0.              /
      DATA SEZIO  ( 6, 2,21)/ 0.              /
      DATA SEZIO  ( 7, 2,21)/ 0.              /
      DATA SEZIO  ( 8, 2,21)/ 0.              /
      DATA SEZIO  ( 9, 2,21)/ 0.              /
      DATA SEZIO  (10, 2,21)/ 0.              /
      DATA SEZ    ( 1,21)/-0.              /
      DATA SEZ    ( 2,21)/-0.              /
      DATA SEZ    ( 3,21)/-0.              /
      DATA SEZ    ( 4,21)/-0.              /
      DATA SEZ    ( 5,21)/-0.              /
      DATA SEZ    ( 6,21)/-0.              /
      DATA SEZ    ( 7,21)/-0.              /
      DATA SEZ    ( 8,21)/-0.              /
```

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      DATA SEZ     ( 9,21)/-0.              /
      DATA SEZ     (10,21)/-0.              /
      DATA SEZ     (11,21)/-0.              /
      DATA SEZ     (12,21)/-0.              /
      DATA SEZ     (13,21)/-0.              /
      DATA SEZ     (14,21)/-0.              /
      DATA  TARGA  (22)/6H PS 19/
      DATA     IX  (22)/  0/
      DATA    NTE  (22)/  1/
      DATA ASTRO   ( 1,22)/ 0.20470000E 03/
      DATA ASTRO   ( 2,22)/ 0.10000000E 01/
      DATA ASTRO   ( 3,22)/ 0.10000000E 01/
      DATA ASTRO   ( 4,22)/ 0.10000000E 01/
      DATA ASTRO   ( 5,22)/ 0.10000000E 01/
      DATA ASTRO   ( 6,22)/-0.              /
      DATA ASTRO   ( 7,22)/ 0.10000000E 01/
      DATA ASTRO   ( 8,22)/-0.              /
      DATA ASTRO   ( 9,22)/-0.              /
      DATA ASTRO   (10,22)/ 0.10000000E 01/
      DATA SEZIO   ( 1, 1,22)/ 0.10000000E 01/
      DATA SEZIO   ( 2, 1,22)/ 0.19204000E 03/
      DATA SEZIO   ( 3, 1,22)/ 0.41400000E 00/
      DATA SEZIO   ( 4, 1,22)/-0.              /
      DATA SEZIO   ( 5, 1,22)/-0.              /
      DATA SEZIO   ( 6, 1,22)/-0.              /
      DATA SEZIO   ( 7, 1,22)/-0.              /
      DATA SEZIO   ( 8, 1,22)/-0.              /
      DATA SEZIO   ( 9, 1,22)/-0.              /
      DATA SEZIO   (10, 1,22)/-0.              /
      DATA SEZIO   ( 1, 2,22)/ 0.              /
      DATA SEZIO   ( 2, 2,22)/ 0.              /
      DATA SEZIO   ( 3, 2,22)/ 0.              /
      DATA SEZIO   ( 4, 2,22)/ 0.              /
      DATA SEZIO   ( 5, 2,22)/ 0.              /
      DATA SEZIO   ( 6, 2,22)/ 0.              /
      DATA SEZIO   ( 7, 2,22)/ 0.              /
      DATA SEZIO   ( 8, 2,22)/ 0.              /
      DATA SEZIO   ( 9, 2,22)/ 0.              /
      DATA SEZIO   (10, 2,22)/ 0.              /
      DATA SEZ     ( 1,22)/-0.              /
      DATA SEZ     ( 2,22)/-0.              /
      DATA SEZ     ( 3,22)/-0.              /
      DATA SEZ     ( 4,22)/-0.              /
      DATA SEZ     ( 5,22)/-0.              /
      DATA SEZ     ( 6,22)/-0.              /
      DATA SEZ     ( 7,22)/-0.              /
      DATA SEZ     ( 8,22)/-0.              /
      DATA SEZ     ( 9,22)/-0.              /
      DATA SEZ     (10,22)/-0.              /
      DATA SEZ     (11,22)/-0.              /
      DATA SEZ     (12,22)/-0.              /
      DATA SEZ     (13,22)/-0.              /
      DATA SEZ     (14,22)/-0.              /
      DATA  TARGA  (23)/6H PS 29/
      DATA     IX  (23)/  0/
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      DATA     NTE  (23)/   1/
      DATA ASTRO   ( 1,23)/ 0.31520000E 02/
      DATA ASTRO   ( 2,23)/ 0.10000000E 01/
      DATA ASTRO   ( 3,23)/ 0.10000000E 01/
      DATA ASTRO   ( 4,23)/ 0.10000000E 01/
      DATA ASTRO   ( 5,23)/ 0.10000000E 01/
      DATA ASTRO   ( 6,23)/-0.              /
      DATA ASTRO   ( 7,23)/ 0.10000000E 01/
      DATA ASTRO   ( 8,23)/-0.              /
      DATA ASTRO   ( 9,23)/-0.              /
      DATA ASTRO   (10,23)/ 0.10000000E 01/
      DATA SEZIO   ( 1, 1,23)/ 0.10000000E 01/
      DATA SEZIO   ( 2, 1,23)/ 0.29299000E 03/
      DATA SEZIO   ( 3, 1,23)/ 0.41400000E 00/
      DATA SEZIO   ( 4, 1,23)/-0.              /
      DATA SEZIO   ( 5, 1,23)/-0.              /
      DATA SEZIO   ( 6, 1,23)/-0.              /
      DATA SEZIO   ( 7, 1,23)/-0.              /
      DATA SEZIO   ( 8, 1,23)/-0.              /
      DATA SEZIO   ( 9, 1,23)/-0.              /
      DATA SEZIO   (10, 1,23)/-0.              /
      DATA SEZIO   ( 1, 2,23)/ 0.              /
      DATA SEZIO   ( 2, 2,23)/ 0.              /
      DATA SEZIO   ( 3, 2,23)/ 0.              /
      DATA SEZIO   ( 4, 2,23)/ 0.              /
      DATA SEZIO   ( 5. 2,23)/ 0.              /
      DATA SEZIO   ( 6, 2,23)/ 0.              /
      DATA SEZIO   ( 7, 2,23)/ 0.              /
      DATA SEZIO   ( 8, 2,23)/ 0.              /
      DATA SEZIO   ( 9, 2,23)/ 0.              /
      DATA SEZIO   (10, 2,23)/ 0.              /
      DATA SEZ     ( 1,23)/-0.              /
      DATA SEZ     ( 2,23)/-0.              /
      DATA SEZ     ( 3,23)/-0.              /
      DATA SEZ     ( 4,23)/-0.              /
      DATA SEZ     ( 5,23)/-0.              /
      DATA SEZ     ( 6,23)/-0.              /
      DATA SEZ     ( 7,23)/-0.              /
      DATA SEZ     ( 8,23)/-0.              /
      DATA SEZ     ( 9,23)/-0.              /
      DATA SEZ     (10,23)/-0.              /
      DATA SEZ     (11,23)/-0.              /
      DATA SEZ     (12,23)/-0.              /
      DATA SEZ     (13,23)/-0.              /
      DATA SEZ     (14,23)/-0.              /
      DATA   TARGA (24)/6H PS 39/
      DATA      IX (24)/   0/
      DATA     NTE (24)/   1/
      DATA ASTRO   ( 1,24)/ 0.16965000E 03/
      DATA ASTRO   ( 2,24)/ 0.10000000E 01/
      DATA ASTRO   ( 3,24)/ 0.10000000E 01/
      DATA ASTRO   ( 4,24)/ 0.10000000E 01/
      DATA ASTRO   ( 5,24)/ 0.10000000E 01/
      DATA ASTRO   ( 6,24)/-0.              /
      DATA ASTRO   ( 7,24)/ 0.10000000E 01/
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      DATA ASTRO  ( 8,24)/-0.               /
      DATA ASTRO  ( 9,24)/-0.               /
      DATA ASTRO  (10,24)/ 0.10000000E 01/
      DATA SEZIO  ( 1, 1,24)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,24)/ 0.10022500E 04/
      DATA SEZIO  ( 3, 1,24)/ 0.41400000E 00/
      DATA SEZIO  ( 4, 1,24)/-0.               /
      DATA SEZIO  ( 5, 1,24)/-0.               /
      DATA SEZIO  ( 6, 1,24)/-0.               /
      DATA SEZIO  ( 7, 1,24)/-0.               /
      DATA SEZIO  ( 8, 1,24)/-0.               /
      DATA SEZIO  ( 9, 1,24)/-0.               /
      DATA SEZIO  (10, 1,24)/-0.               /
      DATA SEZIO  ( 1, 2,24)/ 0.               /
      DATA SEZIO  ( 2, 2,24)/ 0.               /
      DATA SEZIO  ( 3, 2,24)/ 0.               /
      DATA SEZIO  ( 4, 2,24)/ 0.               /
      DATA SEZIO  ( 5, 2,24)/ 0.               /
      DATA SEZIO  ( 6, 2,24)/ 0.               /
      DATA SEZIO  ( 7, 2,24)/ 0.               /
      DATA SEZIO  ( 8, 2,24)/ 0.               /
      DATA SEZIO  ( 9, 2,24)/ 0.               /
      DATA SEZIO  (10, 2,24)/ 0.               /
      DATA SEZ    ( 1,24)/-0.               /
      DATA SEZ    ( 2,24)/-0.               /
      DATA SEZ    ( 3,24)/-0.               /
      DATA SEZ    ( 4,24)/-0.               /
      DATA SEZ    ( 5,24)/-0.               /
      DATA SEZ    ( 6,24)/-0.               /
      DATA SEZ    ( 7,24)/-0.               /
      DATA SEZ    ( 8,24)/-0.               /
      DATA SEZ    ( 9,24)/-0.               /
      DATA SEZ    (10,24)/-0.               /
      DATA SEZ    (11,24)/-0.               /
      DATA SEZ    (12,24)/-0.               /
      DATA SEZ    (13,24)/-0.               /
      DATA SEZ    (14,24)/-0.               /
      DATA   TARGA (25)/6H PS 49/
      DATA      IX (25)/   0/
      DATA     NTE (25)/   1/
      DATA ASTRO  ( 1,25)/ 0.20556000E 03/
      DATA ASTRO  ( 2,25)/ 0.10000000E 01/
      DATA ASTRO  ( 3,25)/ 0.10000000E 01/
      DATA ASTRO  ( 4,25)/ 0.10000000E 01/
      DATA ASTRO  ( 5,25)/ 0.10000000E 01/
      DATA ASTRO  ( 6,25)/-0.               /
      DATA ASTRO  ( 7,25)/ 0.10000000E 01/
      DATA ASTRO  ( 8,25)/-0.               /
      DATA ASTRO  ( 9,25)/-0.               /
      DATA ASTRO  (10,25)/ 0.10000000E 01/
      DATA SEZIO  ( 1, 1,25)/ 0.10000000E 01/
      DATA SEZIO  ( 2, 1,25)/ 0.25009800E 04/
      DATA SEZIO  ( 3, 1,25)/ 0.41400000E 00/
      DATA SEZIO  ( 4, 1,25)/-0.               /
      DATA SEZIO  ( 5, 1,25)/-0.               /
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      DATA SEZIO  ( 6,  1,25)/-0.                /
      DATA SEZIO  ( 7,  1,25)/-0.                /
      DATA SEZIO  ( 8,  1,25)/-0.                /
      DATA SEZIO  ( 9,  1,25)/-0.                /
      DATA SEZIO  (10,  1,25)/-0.                /
      DATA SEZIO  ( 1,  2,25)/ 0.                /
      DATA SEZIO  ( 2,  2,25)/ 0.                /
      DATA SEZIO  ( 3,  2,25)/ 0.                /
      DATA SEZIO  ( 4,  2,25)/ 0.                /
      DATA SEZIO  ( 5,  2,25)/ 0.                /
      DATA SEZIO  ( 6,  2,25)/ 0.                /
      DATA SEZIO  ( 7,  2,25)/ 0.                /
      DATA SEZIO  ( 8,  2,25)/ 0.                /
      DATA SEZIO  ( 9,  2,25)/ 0.                /
      DATA SEZIO  (10,  2,25)/ 0.                /
      DATA SEZ    ( 1,25)/-0.                /
      DATA SEZ    ( 2,25)/-0.                /
      DATA SEZ    ( 3,25)/-0.                /
      DATA SEZ    ( 4,25)/-0.                /
      DATA SEZ    ( 5,25)/-0.                /
      DATA SEZ    ( 6,25)/-0.                /
      DATA SEZ    ( 7,25)/-0.                /
      DATA SEZ    ( 8,25)/-0.                /
      DATA SEZ    ( 9,25)/-0.                /
      DATA SEZ    (10,25)/-0.                /
      DATA SEZ    (11,25)/-0.                /
      DATA SEZ    (12,25)/-0.                /
      DATA SEZ    (13,25)/-0.                /
      DATA SEZ    (14,25)/-0.                /
      DATA   TARGA (26)/6HSM 149/
      DATA      IX (26)/   1/
      DATA     NTE (26)/   2/
      DATA ASTRO  ( 1,26)/ 0.41380000E 05/
      DATA ASTRO  ( 2,26)/ 0.50000000E 01/
      DATA ASTRO  ( 3,26)/ 0.99560000E 00/
      DATA ASTRO  ( 4,26)/ 0.80000000E 01/
      DATA ASTRO  ( 5,26)/ 0.70000000E 01/
      DATA ASTRO  ( 6,26)/ 0.13300000E-01/
      DATA ASTRO  ( 7,26)/ 0.99560000E 00/
      DATA ASTRO  ( 8,26)/-0.                /
      DATA ASTRO  ( 9,26)/-0.                /
      DATA ASTRO  (10,26)/ 0.97351090E 00/
      DATA SEZIO  ( 1,  1,26)/ 0.15329951E 01/
      DATA SEZIO  ( 2,  1,26)/ 0.43613889E 01/
      DATA SEZIO  ( 3,  1,26)/-0.80901591E 01/
      DATA SEZIO  ( 4,  1,26)/-0.35317150E 01/
      DATA SEZIO  ( 5,  1,26)/ 0.32023057E 02/
      DATA SEZIO  ( 6,  1,26)/-0.52980269E 02/
      DATA SEZIO  ( 7,  1,26)/ 0.44013089E 02/
      DATA SEZIO  ( 8,  1,26)/-0.18906109E 02/
      DATA SEZIO  ( 9,  1,26)/ 0.33345561E 01/
      DATA SEZIO  (10,  1,26)/-0.                /
      DATA SEZIO  ( 1,  2,26)/-0.93210618E 00/
      DATA SEZIO  ( 2,  2,26)/-0.12512128E 02/
      DATA SEZIO  ( 3,  2,26)/ 0.43799777E 02/
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      DATA SEZIO  ( 4, 2,26)/-0.74314120E 02/
      DATA SEZIO  ( 5, 2,26)/-0.11974240E 02/
      DATA SEZIO  ( 6, 2,26)/ 0.39538249E 03/
      DATA SEZIO  ( 7, 2,26)/-0.91666310E 03/
      DATA SEZIO  ( 8, 2,26)/ 0.94140428E 03/
      DATA SEZIO  ( 9, 2,26)/-0.37764314E 03/
      DATA SEZIO  (10, 2,26)/-0.                /
      DATA SEZ    ( 1,26)/-0.                /
      DATA SEZ    ( 2,26)/-0.                /
      DATA SEZ    ( 3,26)/-0.                /
      DATA SEZ    ( 4,26)/-0.                /
      DATA SEZ    ( 5,26)/-0.                /
      DATA SEZ    ( 6,26)/-0.                /
      DATA SEZ    ( 7,26)/-0.                /
      DATA SEZ    ( 8,26)/-0.                /
      DATA SEZ    ( 9,26)/-0.                /
      DATA SEZ    (10,26)/-0.                /
      DATA SEZ    (11,26)/-0.                /
      DATA SEZ    (12,26)/-0.                /
      DATA SEZ    (13,26)/-0.                /
      DATA SEZ    (14,26)/-0.                /
      DATA  TARGA (27)/6HSM 151/
      DATA     IX (27)/  1/
      DATA    NTE (27)/  2/
      DATA ASTRO  ( 1,27)/ 0.15400000E 05/
      DATA ASTRO  ( 2,27)/ 0.10000000E 01/
      DATA ASTRO  ( 3,27)/ 0.99560000E 00/
      DATA ASTRO  ( 4,27)/ 0.80000000E 01/
      DATA ASTRO  ( 5,27)/ 0.70000000E 01/
      DATA ASTRO  ( 6,27)/ 0.13300000E-01/
      DATA ASTRO  ( 7,27)/ 0.10000000E 01/
      DATA ASTRO  ( 8,27)/-0.             /
      DATA ASTRO  ( 9,27)/-0.             /
      DATA ASTRO  (10,27)/ 0.97385730E 00/
      DATA SEZIO  ( 1, 1,27)/ 0.92759670E 00/
      DATA SEZIO  ( 2, 1,27)/-0.10658819E 01/
      DATA SEZIO  ( 3, 1,27)/ 0.12880297E 01/
      DATA SEZIO  ( 4, 1,27)/-0.11283102E 01/
      DATA SEZIO  ( 5, 1,27)/ 0.40377169E 00/
      DATA SEZIO  ( 6, 1,27)/ 0.12671061E 00/
      DATA SEZIO  ( 7, 1,27)/-0.                /
      DATA SEZIO  ( 8, 1,27)/-0.                /
      DATA SEZIO  ( 9, 1,27)/-0.                /
      DATA SEZIO  (10, 1,27)/-0.                /
      DATA SEZIO  ( 1, 2,27)/-0.32815716E 00/
      DATA SEZIO  ( 2, 2,27)/-0.26164700E 00/
      DATA SEZIO  ( 3, 2,27)/ 0.73091184E 01/
      DATA SEZIO  ( 4, 2,27)/-0.84154049E 02/
      DATA SEZIO  ( 5, 2,27)/ 0.58126843E 03/
      DATA SEZIO  ( 6, 2,27)/-0.24185814E 04/
      DATA SEZIO  ( 7, 2,27)/ 0.61220067E 04/
      DATA SEZIO  ( 8, 2,27)/-0.92125660E 04/
      DATA SEZIO  ( 9, 2,27)/ 0.75659445E 04/
      DATA SEZIO  (10, 2,27)/-0.26085909E 04/
      DATA SEZ    ( 1,27)/-0.                /
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      DATA SEZ    ( 2,27)/-0.              /
      DATA SEZ    ( 3,27)/-0.              /
      DATA SEZ    ( 4,27)/-0.              /
      DATA SEZ    ( 5,27)/-0.              /
      DATA SEZ    ( 6,27)/-0.              /
      DATA SEZ    ( 7,27)/-0.              /
      DATA SEZ    ( 8,27)/-0.              /
      DATA SEZ    ( 9,27)/-0.              /
      DATA SEZ    (10,27)/-0.              /
      DATA SEZ    (11,27)/-0.              /
      DATA SEZ    (12,27)/-0.              /
      DATA SEZ    (13,27)/-0.              /
      DATA SEZ    (14,27)/-0.              /
      DATA   TARGA (28)/6HGD 157/
      DATA      IX (28)/  1/
      DATA     NTE (28)/  2/
      DATA ASTRO  ( 1,28)/ 0.24000000E 06/
      DATA ASTRO  ( 2,28)/ 0.10000000E 01/
      DATA ASTRO  ( 3,28)/ 0.99580000E 00/
      DATA ASTRO  ( 4,28)/ 0.20000000E 02/
      DATA ASTRO  ( 5,28)/ 0.70000000E 01/
      DATA ASTRO  ( 6,28)/ 0.12700000E-01/
      DATA ASTRO  ( 7,28)/ 0.99580000E 00/
      DATA ASTRO  ( 8,28)/-0.              /
      DATA ASTRO  ( 9,28)/-0.              /
      DATA ASTRO  (10,28)/ 0.97484360E 00/
      DATA SEZIO  ( 1, 1,28)/ 0.84991436E 00/
      DATA SEZIO  ( 2, 1,28)/-0.53358635E 00/
      DATA SEZIO  ( 3, 1,28)/-0.37097170E 01/
      DATA SEZIO  ( 4, 1,28)/ 0.38825612E 02/
      DATA SEZIO  ( 5, 1,28)/-0.24052283E 03/
      DATA SEZIO  ( 6, 1,28)/ 0.88117788E 03/
      DATA SEZIO  ( 7, 1,28)/-0.18386220E 04/
      DATA SEZIO  ( 8, 1,28)/ 0.20194511E 04/
      DATA SEZIO  ( 9, 1,28)/-0.90543132E 03/
      DATA SEZIO  (10, 1,28)/-0.              /
      DATA SEZIO  ( 1, 2,28)/-0.46179706E 00/
      DATA SEZIO  ( 2, 2,28)/-0.56268730E 00/
      DATA SEZIO  ( 3, 2,28)/ 0.35813209E 01/
      DATA SEZIO  ( 4, 2,28)/-0.23737260E 02/
      DATA SEZIO  ( 5, 2,28)/ 0.14344935E 03/
      DATA SEZIO  ( 6, 2,28)/-0.54540721E 03/
      DATA SEZIO  ( 7, 2,28)/ 0.11887980E 04/
      DATA SEZIO  ( 8, 2,28)/-0.13613422E 04/
      DATA SEZIO  ( 9, 2,28)/ 0.63389894E 03/
      DATA SEZIO  (10, 2,28)/-0.              /
      DATA SEZ    ( 1,28)/-0.              /
      DATA SEZ    ( 2,28)/-0.              /
      DATA SEZ    ( 3,28)/-0.              /
      DATA SEZ    ( 4,28)/-0.              /
      DATA SEZ    ( 5,28)/-0.              /
      DATA SEZ    ( 6,28)/-0.              /
      DATA SEZ    ( 7,28)/-0.              /
      DATA SEZ    ( 8,28)/-0.              /
      DATA SEZ    ( 9,28)/-0.              /
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      DATA SEZ     (10,28)/-0.             /
      DATA SEZ     (11,28)/-0.             /
      DATA SEZ     (12,28)/-0.             /
      DATA SEZ     (13,28)/-0.             /
      DATA SEZ     (14,28)/-0.             /
      DATA   TARGA (29)/6HEU 155/
      DATA      IX (29)/  0/
      DATA     NTE (29)/  1/
      DATA ASTRO   ( 1,29)/ 0.14000000E 05/
      DATA ASTRO   ( 2,29)/ 0.10000000E 01/
      DATA ASTRO   ( 3,29)/ 0.99560000E 00/
      DATA ASTRO   ( 4,29)/ 0.80000000E 01/
      DATA ASTRO   ( 5,29)/ 0.80000000E 01/
      DATA ASTRO   ( 6,29)/ 0.13100000E-01/
      DATA ASTRO   ( 7,29)/ 0.10000000E 01/
      DATA ASTRO   ( 8,29)/-0.             /
      DATA ASTRO   ( 9,29)/-0.             /
      DATA ASTRO   (10,29)/ 0.97452310E 00/
      DATA SEZIO   ( 1, 1,29)/ 0.10000000E 01/
      DATA SEZIO   ( 2, 1,29)/ 0.             /
      DATA SEZIO   ( 3, 1,29)/ 0.10000000E 30/
      DATA SEZIO   ( 4, 1,29)/-0.             /
      DATA SEZIO   ( 5, 1,29)/-0.             /
      DATA SEZIO   ( 6, 1,29)/-0.             /
      DATA SEZIO   ( 7, 1,29)/-0.             /
      DATA SEZIO   ( 8, 1,29)/-0.             /
      DATA SEZIO   ( 9, 1,29)/-0.             /
      DATA SEZIO   (10, 1,29)/-0.             /
      DATA SEZIO   ( 1, 2,29)/ 0.             /
      DATA SEZIO   ( 2, 2,29)/ 0.             /
      DATA SEZIO   ( 3, 2,29)/ 0.             /
      DATA SEZIO   ( 4, 2,29)/ 0.             /
      DATA SEZIO   ( 5, 2,29)/ 0.             /
      DATA SEZIO   ( 6, 2,29)/ 0.             /
      DATA SEZIO   ( 7, 2,29)/ 0.             /
      DATA SEZIO   ( 8, 2,29)/ 0.             /
      DATA SEZIO   ( 9, 2,29)/ 0.             /
      DATA SEZIO   (10, 2,29)/ 0.             /
      DATA SEZ     ( 1,29)/-0.             /
      DATA SEZ     ( 2,29)/-0.             /
      DATA SEZ     ( 3,29)/-0.             /
      DATA SEZ     ( 4,29)/-0.             /
      DATA SEZ     ( 5,29)/-0.             /
      DATA SEZ     ( 6,29)/-0.             /
      DATA SEZ     ( 7,29)/-0.             /
      DATA SEZ     ( 8,29)/-0.             /
      DATA SEZ     ( 9,29)/-0.             /
      DATA SEZ     (10,29)/-0.             /
      DATA SEZ     (11,29)/-0.             /
      DATA SEZ     (12,29)/-0.             /
      DATA SEZ     (13,29)/-0.             /
      DATA SEZ     (14,29)/-0.             /
      DATA   TARGA (30)/6HCD 113/
      DATA      IX (30)/  1/
      DATA     NTE (30)/  2/
```

```
      DATA ASTRO  ( 1,30)/ 0.19800000E 05/
      DATA ASTRO  ( 2,30)/ 0.10000000E 01/
      DATA ASTRO  ( 3,30)/ 0.99400000E 00/
      DATA ASTRO  ( 4,30)/ 0.78800000E 01/
      DATA ASTRO  ( 5,30)/ 0.66500000E 01/
      DATA ASTRO  ( 6,30)/ 0.17800000E-01/
      DATA ASTRO  ( 7,30)/ 0.99400000E 00/
      DATA ASTRO  ( 8,30)/-0.            /
      DATA ASTRO  ( 9,30)/-0.            /
      DATA ASTRO  (10,30)/ 0.96521990E 00/
      DATA SEZIO  ( 1, 1,30)/ 0.12643259E 01/
      DATA SEZIO  ( 2, 1,30)/ 0.35743064E 01/
      DATA SEZIO  ( 3, 1,30)/-0.91351420E 01/
      DATA SEZIO  ( 4, 1,30)/ 0.22863093E 03/
      DATA SEZIO  ( 5, 1,30)/-0.22201068E 04/
      DATA SEZIO  ( 6, 1,30)/ 0.11701323E 05/
      DATA SEZIO  ( 7, 1,30)/-0.36411414E 05/
      DATA SEZIO  ( 8, 1,30)/ 0.66019739E 05/
      DATA SEZIO  ( 9, 1,30)/-0.64123067E 05/
      DATA SEZIO  (10, 1,30)/ 0.25700691E 05/
      DATA SEZIO  ( 1, 2,30)/-0.65784290E 00/
      DATA SEZIO  ( 2, 2,30)/-0.30081416E 01/
      DATA SEZIO  ( 3, 2,30)/-0.31432517E 01/
      DATA SEZIO  ( 4, 2,30)/-0.14984932E 02/
      DATA SEZIO  ( 5, 2,30)/ 0.10379760E 03/
      DATA SEZIO  ( 6, 2,30)/-0.19807726E 03/
      DATA SEZIO  ( 7, 2,30)/ 0.12722813E 03/
      DATA SEZIO  ( 8, 2,30)/-0.            /
      DATA SEZIO  ( 9, 2,30)/-0.            /
      DATA SEZIO  (10, 2,30)/-0.            /
      DATA SEZ    ( 1,30)/-0.            /
      DATA SEZ    ( 2,30)/-0.            /
      DATA SEZ    ( 3,30)/-0.            /
      DATA SEZ    ( 4,30)/-0.            /
      DATA SEZ    ( 5,30)/-0.            /
      DATA SEZ    ( 6,30)/-0.            /
      DATA SEZ    ( 7,30)/-0.            /
      DATA SEZ    ( 8,30)/-0.            /
      DATA SEZ    ( 9,30)/-0.            /
      DATA SEZ    (10,30)/-0.            /
      DATA SEZ    (11,30)/-0.            /
      DATA SEZ    (12,30)/-0.            /
      DATA SEZ    (13,30)/-0.            /
      DATA SEZ    (14,30)/-0.            /
      END
```

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Alfred Nobel

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