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Nuclear Reactor of the Technical University Budapest

Netherlands Energy Research Foundation ECN

INFORMATION SHEET FOR THE REAL84 EXERCISE

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SUMMARY

This document gives information on the interlaboratory exercise REAL84. This exercise has as aim the improvement of the assessment of accuracies in radiation damage predictions by using good quality input data and proper calculation methods.
In the exercise integral damage parameters (such as displacements per atom, or produced gas atoms) and spectrum characteristics are calculated for neutron spectra which are adjusted to fit experimental reaction rates obtained with activation spectrometry.
The main difference with the preceding exercise REAL80 is that now improved information can be applied in the input data sets of the exercise. The improvement concerns mainly the availability of uncertainty information for the neutron spectrum and cross-section data.
All interested parties are encouraged to participate in the exercise and to request from the IAEA the magnetic tape R84, which contains all input information.
In order to meet the time schedule (see appendix 3) fast action is required.

1. BACKGROUND

The REAL84 exercise is a follow-up of the REAL80 exercise, the results of which have been published in a final report [1] and in a summarizing publication [2].
The aim of the REAL80 intercomparison ,organized by the International Atomic Energy Agency (IAEA) was to determine the state of art (in 1981) of the capabilities of laboratories to adjust neutron spectrum information on the basis of a series of experimental activation rates, and subsequently to predict the number of displacements in steel together with its uncertainty. The solutions submitted by 13 laboratories (33 solutions for the ORR spectrum and 35 solutions for the YAYOI spectrum) were analyzed by a joint team of evaluators from the Technical University in Budapest and from the Netherlands Energy Research Foundation ECN in Petten.
The results of the REAL80 exercise have shown that discrepancies in the prediction of radiation damage parameters and unrealistic values in the uncertainties of these data originate partly from using incomplete and/or unrealistic input data in the calculations, and partly from incorrect (or not optimal) processing of the available data by spectrum adjustment and activity calculation codes.
During the IAEA Consultants' Meeting in Vienna (13-15 June 1983) [3] and in Hamburg (26 September 1984) [4] the benefits and the requirements for a follow-up of the REAL80 exercise have been discussed. At the Hamburg meeting is was recommended that a new exercise, called REAL84, should be organized by the IAEA, and the joint team of evaluators was asked to make the necessary preparations for the IAEA and to continue as a team for the analysis of the results.

2. PROJECT NAME AND ORGANIZATION

The exercise will have the code name REAL84 (Reaction Rates Estimates Evaluated by Adjustment Analysis in Leading Laboratories, year 1984). The exercise is organized by the Nuclear Data Section (D.E. Cullen and V. Piksaikin) of the International Atomic Energy Agency (IAEA) in Vienna. The analysis of the responses to the exercise will be performed by a joint team of evaluators from the Training Nuclear Reactor of

Technical University in Budapest (É.M. Zsolnay and E.J. Szondi) and the Netherlands Energy Research Foundation ECN (W.L. Zijp and H.J. Nolthenius).

3. AIMS OF REAL84

The main aim is improving the assessment of accuracies in radiation damage predictions by various laboratories by using good quality input data and proper calculation methods. The emphasis should be on radiation damage to reactor pressure vessels and related nuclear technology. Therefore the neutron energy range of interest is primarily below 20 MeV. The long term aims of REAL84 will be to strive towards establishment of standardized procedures and recommended data for use in spectrum adjustments and damage parameter calculations.
The short term aims will be improvements in the available data, particularly in spectra and cross-section covariance information.
In addition, the REAL84 exercise will allow the participants to assess and validate the accuracy of the methods and codes they are presently using.
The joint effort of the participants will contribute in solving some basic mathematical and physical problems recently encountered in neutron spectrum adjustments for selected neutron spectra.

4. MEANS AND METHODS

The REAL84 exercise has the form of an international comparison of damage production parameters, calculated for adjusted spectra obtained with adjustment codes which explicitly consider covariance matrices.
The seven spectrum data sets available in REAL84 comprise various representative spectra (see section 13).
Participants don't have to adjust all seven spectrum data sets but for a good success of the exercise the treatment of several spectrum data sets by each participants is highly appreciated.

5. REQUESTED ACTION BY PARTICIPANTS

The participation is open to all laboratories, which are able to per-

form adjustment with procedures which can take into account available uncertainty information in the form of covariance matrices.
It is essential that the participants should contribute to the exercise not only by giving characteristic parameters of interest etc., but also by reporting the physical information applied to obtain improved results for the given input data. (Improved calculation method, conversion method, reaction set, cross section data, covariance data for activity, cross section and spectrum etc.)

The specific actions which the participants should perform are the following:

- select the spectrum data sets of their own interest for their data treatment;
- make a critical judgement of the input data;
- perform a good neutron spectrum adjustment by means of their laboratory procedure, taking into account the input covariance matrices;
- perform calculations on displacements for steel (and their uncertainties);
- specify where relevant, the procedure for conversion of data from one group structure to another;
- perform, where relevant, calculations on gas production rates per atom (and its uncertainty) for steel;
- give answer to the specific questions mentioned in a questionnaire on procedures followed, decisions taken and values obtained (see section 11);
- submit the questionnaire with solution information before the deadline (see appendix 3);
- submit if possible a magnetic tape with numerical data on output spectra and corresponding output spectrum covariance matrices.

6. INPUT DATA SETS

The magnetic tape, which will be distributed by the IAEA will contain two types of files:

- Files with problem dependent data, describing seven spectrum data sets.

  Each spectrum data set in these files contains:

a. input spectrum information and a relative spectrum covariance matrix in a multigroup form.

b. experimentally determined reaction rates and where possible a complete reaction rate covariance matrix.

For the seven spectrum data sets there will be utility programs to read these files.

- The other type of files contain problem independent data.

  These data comprise:

  c. a dosimetry cross section library with cross section covariances which the participants may use.
     This library is the IRDF-85 (International Reactor Dosimetry File), which has the ENDF/B-V format. For a number of reactions the contents of the IRDF are the same as those of the ENDF/B-V dosimetry file.

  d. several utility programs which may be used in the conversion from library to group values (for cross sections and cross section covariances).

  The tape will be accompanied by a report with some extra data and information.

  In order to obtain the above mentioned data please contact D.E. Cullen of the IAEA (see chapter 10 for the address) starting your wishes for magnetic tape parameters. For your convenience we have included for this purpose a blank form request which you may use.

7. JUDGEMENTS BY PARTICIPANTS

The exercise is not merely a comparison of the outcome of straightforward calculations with computer codes. It implies scientific judgement by the participants on questions like:

- Which group structure should I use in my calculations?
- Is there consistency in the input data for the spectrum data sets of interest to me?
  If not, what can I do to make these data sets consistent?
- Can improvement be expected, if I use my special laboratory data set or procedure in combination with the REAL84 data?

- Is there reason to delete one or more reaction rates in the analysis?
- Is the input spectrum covariance matrix acceptable from physical and mathematical point of view for the spectrum set of interest? If not, what can I do to improve it?
- What do I miss in the input data set?
- What is needed in order to improve the quality of the output information (e.g. weight of certain reactions, better quality cross sections etc.)?
- Which value in the input data set should I like to improve in order to arrive at a better accuracy of the output information?

The participants are requested to make statements on additions, changes, deletions in the input data set, and give short and clear reasons for their decision. With respect to the output data the participants are requested to make statements on the acceptability of the outcome of the calculations.

8. RULES FOR PARTICIPATION

The participants have some possibilities to make changes in the input data of the sets. They have however to stick to some rules.
The participants are requested:

- to take into account the reaction rate variances, or covariances if available;
- to use where relevant the covariance matrices of the input sets.

The participants are however free:

- to select the spectrum data sets of their interest;
- to use any group structure they consider to be suitable;
- to apply a cross section file other than the IRDF-85 for some or all cross sections (it is however recommended to use only cross section libraries which are documented in open literature);
- to delete one or more reaction rate values (if inconsistent);
- to prepare additional solutions for the chosen spectrum data sets for other adjustment conditions (e.g. for other normalization procedures or for other adjustioned codes);

- to prepare additonal solutions for the chosen spectrum data sets for modified input data sets (e.g. referring to other cross section libraries or to deletions of one or more reactions).

However: any change should be documented clearly in the questionnaire.

9. DIFFERENCES IN SOLUTIONS

It is expected that the solutions submitted by the participants will show differences due to one or more effects. At present we think of the following possible effects:

- differences in the procedures for processing of data in the ENDF/B-V format into group values;
- differences in procedures for processing of uncertainty data from the ENDF/B-V format into group values;
- definitions of the detailed shape of the weighting function for calculating new group cross section values;
- participants changes in input values;
- deletion(s) or addition(s) of input values (e.g. cross correlations between different cross section sets etc.);
- differences in group structures;
- different mathematical models (e.g. based on linear or logarithmic normal distributions of uncertainties);
- different numerical procedures in the algorithm (e.g. numerical precision, word length, rounding, number of iterations, interpolation and extrapolation procedures, occurrence of numerical instabilities in the calculations etc.);
- difference in procedures for propagation of variance and covariances in the adjustment (exact or linearized formula);
- differences in procedures for calculating integral parameters and their standard deviations (may be different interpretations of the use of damage cross sections could arise)

10. CORRESPONDENCE

A mailing list of interested persons and prospective participants is given in appendix 1.

At this stage of the exercise all correspondence with respect to participation should be send to:

D.E. Cullen
IAEA
P.O. Box 100
A-1400 VIENNA
Austria

Information on physical and technical topics should be addressed directly to:

W.L. Zijp
ECN
P.O. Box 1
1755 ZG PETTEN
The Netherlands

11. QUESTIONNAIRE

It is not the intention of this exercise that all numerical information of the calculation results which the participants obtain will be analyzed in detail by the joint team. For this reason a questionnaire is made (see appendix 2) which gives a good overview of the obtained results. The questionnaires with results from participants have to be returned before 31st August 1985.
The returned questionnaires will be reviewed by the team. In case that points are observed which have to be clarified, the participants will be informed at the end of 1985 or early 1986.
For that reason the participants are asked not to discard output information and working papers of the adjustments before the publication of the final report.

12. SUBMISSION OF OUTPUT DATA

The questionnaire with selected numerical data should be send directly to W.L. Zijp (see address under point 10). Magnetic tapes with numerical data on output spectrum and corresponding output spectrum covariance matrices should however be send directly to D.E. Cullen (see address under point (10)).

13. INPUT DATA SETS

In appendix 4 information is given on the input data sets which can be used in REAL84.
For most of these spectra a complete combination of reaction rates and calculated input spectrum with the covariances is available (see appendix 4 for details). The data will be made available in the original group structure etc.
The reaction rates can be considered to have negligible neutron self-shielding effects; furthermore corrections for any gamma radiation effects have already been incorporated.
No checks on the quality of the data were performed during the preparations for the exercise.
Remark: Only those reaction rates which have uncertainty data in the cross section file were inserted in the input.
The input data sets are composed from data gathered by the joint team. An important part of these data is not published in open literature. For this reason the input data sets should not be considered as benchmark data, but only as good quality input information for REAL84.

14. REFERENCES

[1] Zijp, W.L., Zsolnay, É.M., Nolthenius, H.J., Szondi, E.J., Verhaag, G.H.C.M., Cullen, D.E., Ertek, C.;
Final Report on the REAL80 exercise;
Report INDC (NED)-7; BME-TR-RES-6/82; ECN-128;
(Netherlands Energy Research Foundation, Petten, 1983.)

[2] Zijp, W.L., Zsolnay, É.M., Nolthenius, H.J., Szondi, E.J., Verhaag, G.H.C.M.;
Intercomparison of predicted displacement rates based on neutron spectrum adjustments (REAL80 exercise);
Nuclear Technology 67 (1984) 282-301.

[3] Minutes of the IAEA consultants meeting on the REAL80 exercise (distributed February 1984).

[4] Minutes of the IAEA consultants meetings on the REAL80 exercise; Report INDC (NDS) 165.

APPENDIX 1 Mailing list (February 1985)

A. Albermann	(CEA, Saclay, France)
M. Austin	(RRA, Derby, UK)
H. Bondars	(LVU, Riga, USSR)
D. Ciftcioglu	(TU, Istanbul, Turkey)
D.E. Cullen	(IAEA, Vienna, Austria)
R. Dierckx	(JRC, Ispra, Italy)
C. Ertek	(IAEA, Vienna, Austria)
P. Genthon	(CEN, Cadaraches, France)
I. Conçalves	(LNETI, Sacavém, Portugal)
L.R. Greenwood	(ANL, Argonne IL, USA)
F. Hegedüs	(EIR, Würenlingen, Switzerland)
I. Kondo	(JAERI, Ibaraki-Ken, Japan)
E.P. Lippincott	(HEDL, Richland WA, USA)
R. Lloret	(CEN, Grenoble, France)
R.E. Maerker	(ORNL, Oak Ridge, USA)
W. Mannhart	(PTB, Braunschweig, Fed. Rep. Germany)
G.C. Martin Jr.	(GEVNC, Pleasanton CA, USA)
A.K. McCracken	(UKAEA, AEE, Dorchester, UK)
W.N. McElroy	(HEDL, Richland WA, USA)
D.W. Muir	(LANL, Los Alamos NM, USA)
M. Najzer	(IJS, Ljubljana, Yugoslavia)
M. Nakazawa	(University of Tokyo, Tokyo, Japan)
D. Nikodemova	(RIPM, Bratislava, Czechoslovakia)
H.J. Nolthenius	(ECN, Petten, The Netherlands)
B. Osmera	(NRI, Rez, CSSR)
O. Ozer	(EPRI, Palo Alto CF, USA)
F.G. Perey	(ORNL, Oak Ridge TN, USA)
M. Petilli	(ENEA, Casaccia, Italy)
V. Piksaikin	(IAEA, Vienna, Austria)
J.T. Routti	(HUT, Espoo, Finland)
J.M. Ryskamp	(EG&G, Idaho Falls, USA)
J. Sandberg	(HUT, Espoo, Finland)
V. Sangiust	(CESNEF, Milano, Italy)
F.A. Schmittroth	(Westinghouse, Richland WA, USA)
A. Sekiguchi	(University of Tokyo, Tokyo, Japan)

F.W. Stallmann	(ORNL, Oak Ridge TN, USA)
E.J. Szondi	(BME, Budapest, Hungary)
K. Takeuchi	(SRI, Tokai-Mura, Japan)
A.F. Thomas	(RRA, Derby, UK)
J. Végh	(KFKI, Budapest, Hungary)
J.J. Wagschal	(H.U., Jerusalem, Israel)
É.M. Zsolnay	(BME, Budapest, Hungary)
W.L. Zijp	(ECN, Petten, The Netherlands)

LIST OF SYMBOLS USED - QUESTIONNAIRE

A_c	calculated reaction rate at saturation, derived from input or output spectrum
$s_\sigma\ (A_c)$	standard deviation in calculated reaction rate at saturation, due to uncertainties in cross sections only
$s_\phi\ (A_c)$	standard deviation in calculated reaction rate at saturation, due to uncertainties in spectrum only
$s^*\ (A_c)$	any other standard deviation in calculated reaction rate at saturation, as specified by the participant
ϕ (E>0.1 MeV)	fluence rate of neutrons with energies greater than 1 MeV
ϕ (>1 MeV)	fluence rate of neutrons with energies greater than 1 MeV
ϕ_{int}	fluence rate of intermediate neutrons, i.e. with energies between 0.563 eV and 1.05 MeV
ϕ_{Ni}	equivalent nickel fluence rate, i.e. the nickel reaction rate at saturation divided by the cross section of nickel, averaged over a fission neutron spectrum of ^{235}U
ϕ_{tot}	total neutron fluence rate, i.e. the fluence rate of neutrons with energies lower than 20 MeV
ϕ_{th}	thermal neutron fluence rate, i.e. the fluence rate of neutrons with energies lower than 0.563 eV
ϕ_{Co}	equivalent cobalt fluence rate, i.e. the cobalt reaction rate at saturation divided by the 2200 m/s cross section
R_{dpa}(Fe)	displacement rate in pure iron
R_{dpa} (St)	displacement rate in "steel" (with a composition as specified below)
R_{He} (St)	number of helium atoms produced per second in "steel" as specified below
R_H (St)	number of hydrogen atoms produced per second in "steel" as specified below
N_{He} (St)	number of helium atoms produced in "steel" in a continuous irradiation during one year
St	"steel" with the following composition:

element	atom percentage
Fe	71
Cr	18
Ni	11

QUESTIONNAIRE ON REAL84 SOLUTIONS

The participants are requested to fill in as many of the questions as possible.

GENERAL QUESTIONS

Name of participant:
Name of laboratory :
Detailed address :

1. Name of adjustment code:

2. Literature reference for adjustment code:

3. What is the advantage of your code from a physics point of view:

4. Which source of cross section data did you use in the adjustment?
   - O the International Reactor Dosimetry File IRDF-85
   - O the 640 group Cross Section file CS640
   - O other source (please specify):

5. For the calculation of coarse group cross section data and the corresponding cross section covariance matrices one needs a weighting spectrum. Which method was applied to derive the required shape of the weighting spectrum from the coarse group spectrum data?
   - O log-log interpolation of ϕ_E point values for the energy points calculated from the group energy boundaries E_L and E_U with the formula

$$\bar{E} = (E_U - E_L) / (\ell n\, E_U - \ell n\, E_L)$$

O spline method with conservation of group neutron fluences

O other method (please specify):

6. Which calculation method was applied for the determination of cross section covariances?

   O the program UNC33 present on the R84 tape

   O other method (please specify):

7. Which method was applied for the conversion of point or fine group data to coarse group data?

   O the program GROUPIE present on the R84 tape

   O the program FITOCO present on the R84 tape

   O other method (please specify):

8. Which method was applied in the treatment of covariance matrices for the conversion from one group structure to another?
   Please specify, or give the relevant literature reference:

9. If you calculated a fitting parameter, how is this defined?
   Please specify, or give the relevant literature reference:

10. In which way is your normalization factor defined?
    With the notation of the final report on REAL80, [1].

    O $f_1 = \Sigma\alpha_i^c . \alpha_i^m / \Sigma(\alpha_i^c)^2$

    O $f_2 = (\Sigma\alpha_i^m / \alpha_i^c) / n$

    O $f_3 = [\Sigma(\alpha_i^c / \alpha_i^m)] / [\Sigma(\alpha_i^c / \alpha_i^m)^2]$

o $f_4 = \Sigma\alpha_i^m / \Sigma\alpha_i^c$

o f_0, based on least squares fit see [1]

QUESTIONS FOR SPECTRUM ...

11. Number of groups used in adjustment:

12. Number of reactions used in adjustment:

13. Value of fitting parameter (if available):

14. Value of your normalization factor of input spectrum:

15.

no	reaction name	data for input spectrum				data for output spectrum		
		A_c	$s_\sigma(A_c)$	$s_\phi(A_c)$	$s^*(A_c)$	A_c	$s_\phi(A_c)$	$s^*(A_c)$
1								
2								
3								
.								
.								
.								
.								
.								
.								
.								
.								
.								
.								
23								

Specification (if relevant) of quantity $s^*(A_c)$, listed by participant

16.

Spectrum characteristics		
quantity	value	standard deviation*
ϕ (>0,1 MeV)		
ϕ (>1,0 MeV)		
ϕ_{int}		
ϕ_{Ni}		
ϕ_{tot}		
ϕ_{th}		
ϕ_{Co}		

17.

Integral damage characteristics		
quantity	value	standard deviation*
R_{dpa}(Fe)		
R_{dpa}(St)		
R_{He}(St)		
R_{H}(St)		
N_{He}(St) for 1 year		

* Are correlation matrices for these quantities at the left side and for quantities at the right side available? If so, please transmit them.

18. Did you observe inconsistencies or clearly incorrect values in the input data set?
    Please describe:

19. In the case of inconsistent or incorrect input values, what was your remedy?
    Please describe:

20. Which changes or additions in the input data are required to obtain improved characterization of the damage characteristics?

21. And what gain do you expect and did you experience from changes (or additions)?

22. Have you comments on the group structure of the input spectrum of this data set?
    Please describe:

23. Which uncertainty values in the input data set will (in your opinion) determine mainly the uncertainty in the integral damage characteristics?
    Can you specify the type of the uncertainty s(a), s(σ), or s(ϕ)?
    And, if relevant, the energy range?
    Could you elaborate on this question?

APPENDIX 3 Time schedule for REAL84

1984 September		Start of preparations.
1985 February		Distribution of information sheet.
1985 March		Distribution of magnetic tapes by the IAEA.
1985 March 1985 August	till}	Participating laboratories prepare their adjustment results and report.
1985 August		Start of evaluation of the results of the participants.
1985 Fall 1986 Spring	till}	Communication with participants.
1986 August		Draft report REAL84 available.
1987 April		Presentation of conclusions of the REAL84 exercise at the 6th ASTM-Euratom symposium on Reactor Dosimetry in San Antonio (Texas, USA)

APPENDIX 4 Input data sets

Spectrum data sets are available for the following neutron fields.

Input code	Description
ANO	Pressure-vessel cavity of the Arkansas Power and Light Reactor (Arkansas Nuclear One-1). A sketch of the position of interest in respect to the core is shown in figure 1.
PS1	Oak Ridge Research Reactor Poolside Facility in the metallurgical irradiation experiment. Position simulated surveillance capsule. A sketch is shown in figure 2.
PS2	Oak Ridge Research Reactor Poolside Facility in the metallurgical irradiation experiment. 1/4 T position in the simulated pressure vessel capsule. (See also figure 2.)
RTN	Fusion simulation spectrum measured at the RTNS-II, a 14 MeV neutron source at Lawrence Livermore Laboratory. The spectrum is a pretty fail simulation of a fusion first wall spectrum.
TAN	Accelerator spectrum Be(d,n) with deuteron energies of 16 MeV.
U35	Fission spectrum of ^{235}U.
CFR	Neutron spectrum in the centre of coupled fast reactivity measurement facility (CFRMF). A sketch is shown in figure 3.

Technical details for the input information and references*

Input data	Measured reaction rates	Covariances measured reaction rates	Calculated input spectrum	Covariances calculated input spectrum
ANO	6 reaction rates; no subcadmium responses [1]	available [2]	55 groups [3]	16 groups [3]
PS1	10 reaction rates [4]	only variances [4]	37 groups calculated [4]	37 groups calculated [4]
PS2	6 reaction rates [4]	only variances [4]	37 groups calculated [4]	37 groups calculated [4]
RTN	12 reaction rates [5]	available [5]	60 groups [5]	good estimates 60 groups [5]
TAN	18 reaction rates [5]	available [5]	39 groups [5]	good estimates 39 groups [5]
U35	23 reaction rates [6]	only variances [6]	24 groups [7]	24 groups [7]
CFR	23 reaction rates [6]	only variances [6]	26 groups [8]	26 groups [8]

* The references of this appendix are listed on the next page

REFERENCES for appendix 4

[1] Private communication from R.E. Maerker (1985-01-18).

[2] Wagschal, J.J., Maerker, R.E., Broadhead, B.L., Williams, M.L.; Unfolded ANO-1 fluences using the Lepricon methodology; Paper presented at the 5th ASTM-Euratom symposium for reactor dosimetry in Geesthacht (1984 September 24-28).

[3] Maerker, R.E.; Calculated spectra for ANO-1 and their covariances; Communication given at the 5th ASTM-Euratom Symposium on Reactor Dosimetry in Geesthacht (1984 September 24-28).

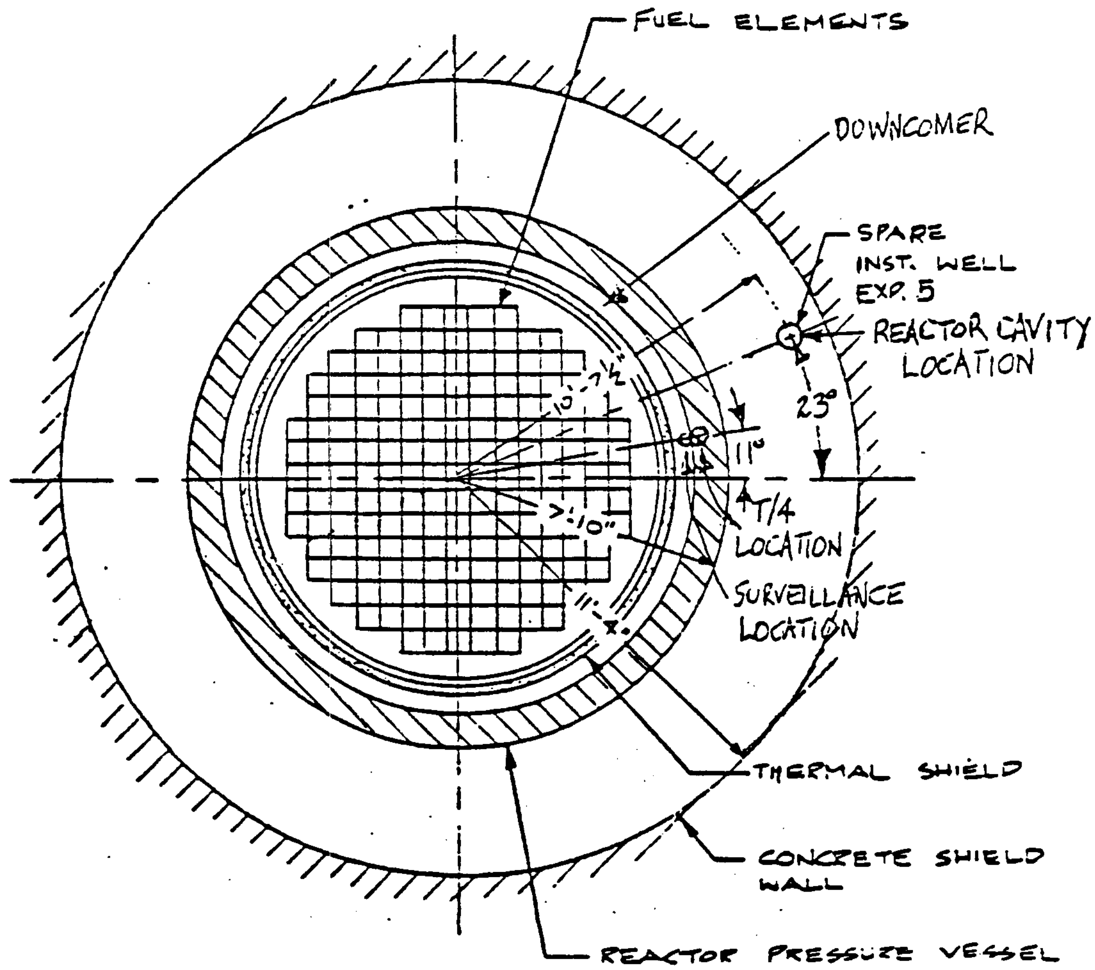
[4] Private communication from F.W. Stallman (1984-09-24...28).

[5] Private communication from L.R. Greenwood (1984-08-31).

[6] Zijp, W.L. et al.; Comparison of measured and evaluated spectrum averaged cross section data; Proc. 4th ASTM-Euratom Symposium on Reactor Dosimetry, Gaithersburg, March 22-26, 1982; Report NUREG/CD-0029 Vol 2; CONF-820321/V2 p. 725; (National Bureau of Standards, Gaithersburg, Maryland, 1982).

[7] Maerker, R.E., Wagschal, J.J., Broadhead, B.L.; Development and demonstration of an advanced methodology for LWR dosimetry applications; Report EPRI NP-2188 (Electric Power Research Institute, Palo Alto, December 1981).

[8] Ryskamp, J.M., Anderl, R.A., Broadhead, B.L., Ford III, W.E., Lucius, J.L., Marable, J.H., Wagschal, J.J.; Sensitivity and Uncertainty Analysis of the Coupled Fast Reactivity Measurements Facility central flux spectrum; Nuclear Technology 57 (1982) 20-35.



ANO UNIT #1 PLAN VIEW WITH LOCATION OF NEUTRON SPECTRUM EXPERIMENT 5 SHOWN.

N

<u>Figure 1</u> Position sketch for ANO input

ORNL DWG 84-12041

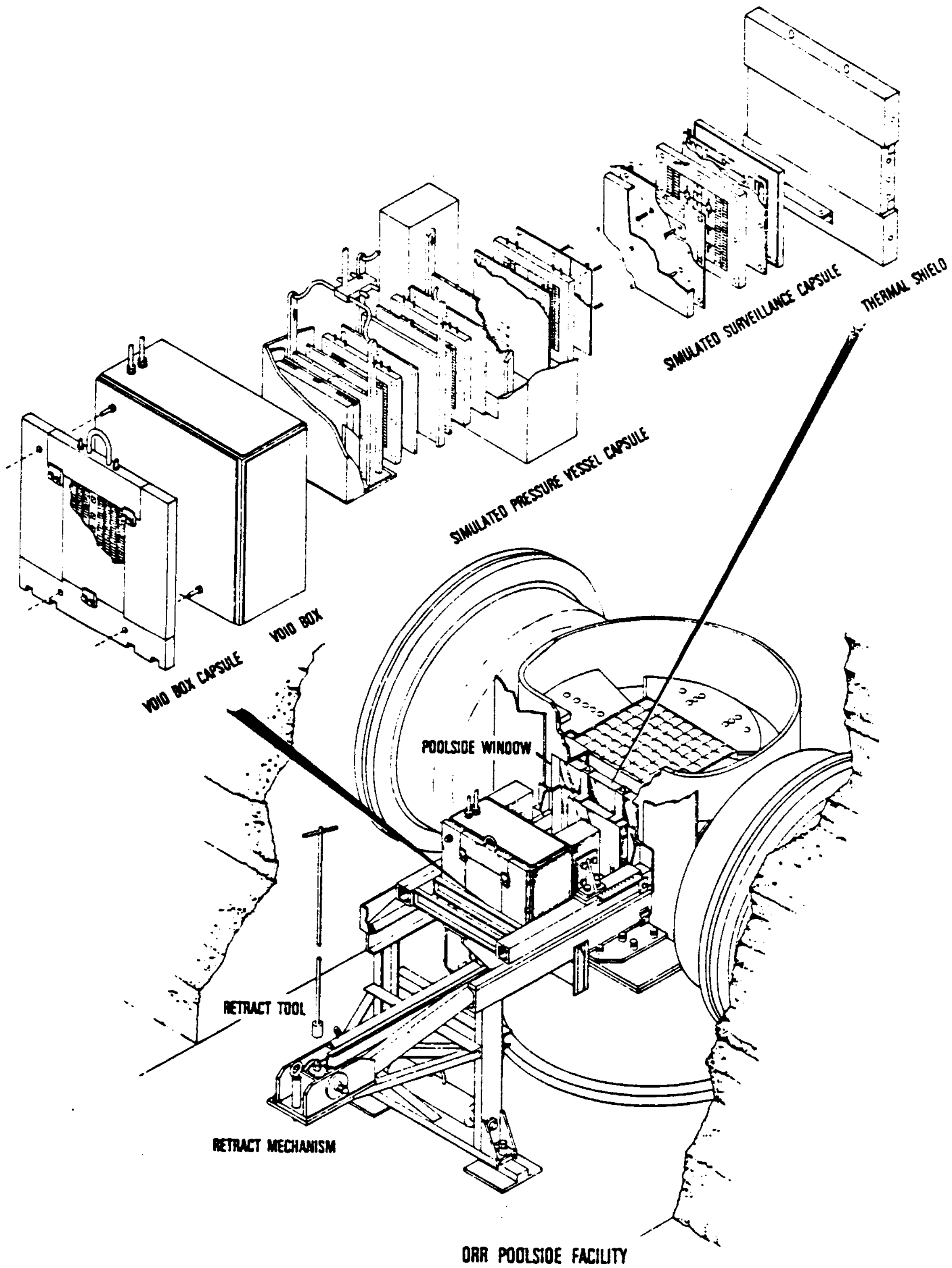


Fig. 2 View of the PSF facility.

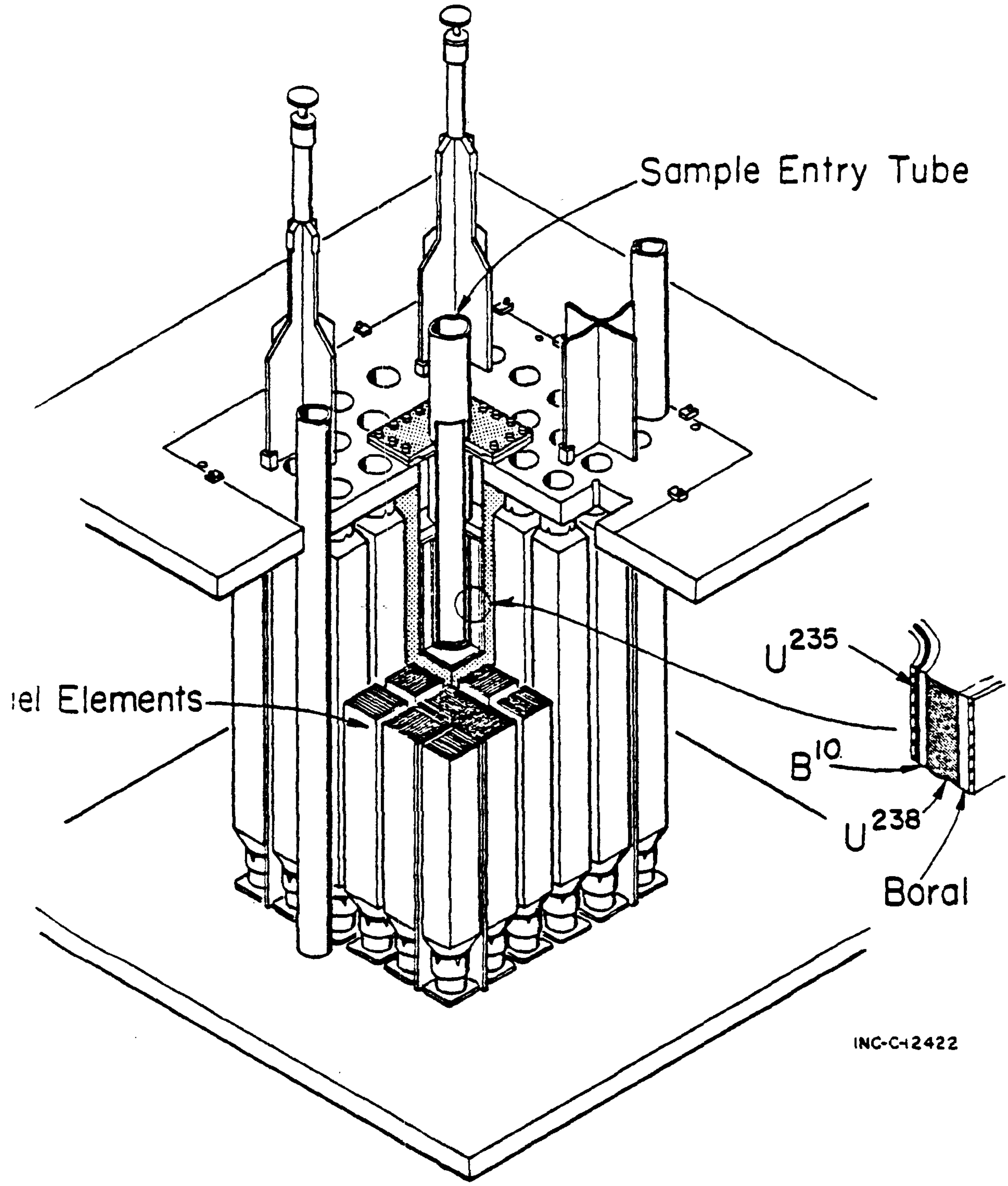


Figure 3 Cutaway pictorial diagram showing general assembly of the CFRMF.