

Subgroup SG10 on "Inelastic Scattering Cross-Sections of Fission Product Nuclides"

Subgroup members:

- M. Kawai (coordinator) (Toshiba)
- H. Gruppelaar (monitor) (ECN)
- A. Hogenbirk (ECN)
- A.B. Smith (ANL)
- B. Schenter (HEDL)
- R.Q. Wright (ORNL)
- P.G. Young (LANL)
- Y. Nakajima (JAERI)
- T. Nakagawa (JAERI)
- S. Chiba (JAERI)
- T. Watanabe (Kawasaki Heavy Industry)
- A. Zukeran (Hitachi)

Objective:

To write a status report on inelastic scattering cross-sections including a graphical intercomparison between available experimental data and recent evaluations for fission product nuclei (e.g. Ru, Pd isotopes and for Nd and Sm isotopes) which show anomalous behavior, as Dr. Gruppelaar reported in his integral tests on the reactivity worth measured at STEK.

To obtain a recommendation on methods and model parameters for evaluation of the inelastic scattering cross sections of fission product nuclei.

Scope of the activities of the subgroup:

(1) Priority and goal:

- Priority 1 ---- Zr, Mo, Pd and Nd,
- Priority 2 ---- others. (Ru, Cd, Ba, Ce, Sm and so on).

The job for the nuclides listed as Priority 1 is expected to be finished before the NEANSC Specialists' Meeting on Fission Product Nuclear Data on May 25 - 27, 1992 at Tokai, and that for Priority 2 within one year.

(2) Status review of the inelastic scattering cross-sections

- Graphical intercomparison between available experimental data and the evaluated data on total, nonelastic and inelastic scattering cross sections as well as level excitation functions (Nakagawa, Kawai and collaborators in JNDC FPND Working Group)
- Review of the evaluated data in JEF-2, ENDF/B-VI and JENDL-3 (Gruppelaar, Schenter, Wright and Kawai)
- Review of available measurements (Smith).

(3) Examination of the nuclear models and their parameters

- Status review on the models and parameters used in the recent evaluation for JEF-2, ENDF/B-VI and JENDL-3 (Gruppelaar, Hogenbirk, Schenter, Young, Nakajima and Chiba)

The above members must make a review of their own evaluation and exchange it

between each other. This group will hopefully make a recommendation of the nuclear model parameters at the NEANSC Specialists' Meeting.

(4) Integral test by analyzing sample worth measured in the STEK reactor

- Integral test of JENDL-3 for the STEK experiments (Watanabe, Zukeran and collaborators in JNDC FPND Working Group). Sensitivity study will clarify the importance of inelastic scattering cross sections to the scattering components of sample reactivity. Reevaluation of the neutron and adjoint spectra with neutronics calculation will be made in order to solve problems which probably come from ambiguities of the spectra of the adjusted 27-group spectrum reported in the ECN-35 report as well as uncertainties of the inelastic scattering cross sections.

- Review the results of the integral tests made for JENDL-3, JEF and ENDF/B-VI (Gruppelaar, Hogenbirk, Wright, Watanabe and Zukeran).

Present status of activities:

(1) Status review of the evaluated data:

- Graphical intercomparison between available experimental data and the evaluated data of JENDL-3, JEF-2 and ENDF/B-VI.

The graphs of the evaluated data of total and inelastic scattering cross sections for the nuclides with the first priority were prepared by Nakagawa and distributed to Gruppelaar, Schenter, Young, Wright and Japanese members in January 1992 (as shown in Figs. 1-4 for example of Pd-106).

The graphs of level excitation functions were prepared by Nakagawa, Nakajima, Chiba and Sugi (JAERI) and sent to the members in the middle of February (See Fig. 5 for Mo-96).

- Review of the evaluated data:

Review work of the evaluated data is in progress. First, evaluation method is checked through the comment files (MF=1). Intercomparison of thermal values, resonance integrals and 30-keV Maxwellian average cross sections is made by Nakagawa and Kawai for capture cross section.

Brief comparison of the evaluated level excitation functions with the experimental data was made by Nakajima, Chiba and Kawai for the nuclides of the first priority, although selection of the experimental data was needed for the serious comparison. The results obtained so far are summarized in Table 1.

Wright clarified the evaluation of ENDF/B-VI and its revision schedule.

(2) Review of the measurements.

Review of the experimental data of the inelastic scattering cross section is important to determine the nuclear model parameters. It is left to Smith. As a result, recommendation of select data will be made and sent to Gruppelaar, Schenter, Young, Nakajima. He sent Kawai the letter telling that elastic angular distributions of neutrons for many nuclides in ENDF/B-VI are isotropic.

(3) Examination of the nuclear models and their parameters

- Status review on the models and parameters used in the recent evaluations is being made by Gruppelaar and Hogenbirk for JEF-2, Schenter, Wright and Young for ENDF/B-VI, Nakajima and Chiba for JENDL-3.

- Direct inelastic scattering cross sections for even mass isotopes of Zr, Mo and Nd were estimated by Nakajima, Chiba and collaborators of JNDC FPND WG with the distorted wave Born approximation, using nuclear model parameters employed to the JENDL-3 evaluation.

(See an example of Mo-96 in Fig. 5). Hogenbirk also investigates the cross sections of Pd isotopes.

- Some recommendation is expected for the nuclear models and their parameters in the NEANSC Specialists' Meeting.

4) Integral test by analyzing sample worth measured in the STEK reactor

- The integral test for the STEK experiments is made by Japanese members for JENDL-3. At the first stage, sample worth was calculated by using spectra which were reported in the report ECN-35. The results were compared with the experimental data at STEK and those at EBR-II and CFRMF for capture reaction. Systematic discrepancy was observed between the STEK measurements and the calculations with JENDL-3 for weak absorber nuclei. It could be attributed to the underestimation of the scattering components of worth; the origins of the underestimation are likely to be ambiguities in the neutron and adjoint spectra, and uncertainties of inelastic scattering cross sections.

- At the second stage, reevaluation of the neutron and adjoint spectra with neutronics calculation is made according to the STEK data, which are not completely sufficient to make a rigorous model and the detailed analyses. The typical results were sent to ECN and ORNL.

Table 1

~~Attachment~~ Intercomparison of Evaluated Inelastic Scattering
Excitation Curves with the Experimental Data.

- Zr-90: JENDL-3 underestimates the first two levels and agrees well with the experimental data for the other levels. Addition of direct inelastic contribution is expected to reduce the discrepancy. JEF-2 is close to JENDL-3. ENDF/B-VI overestimates the cross sections for the fourth level.
- Zr-92: Underestimation is observed for most levels in the JENDL-3 and JEF-2 evaluation. ENDF/B-VI gives better results.
- Zr-94: JENDL-3 gives slightly low but generally good results. JEF-2 is close to JENDL-3. ENDF/B-VI is too large.
- Zr-96: There is no experimental data. Large discrepancy is observed between JENDL-3 and ENDF/B-VI. For the third level of JENDL-3, unreasonable dip is observed at 2.3 MeV.
- Mo-92: JEF-2 gives good agreement for the second level, but it gives the same excitation curves as NT-52 and 53. JENDL-3 slightly underestimates the cross sections and improvement is expected by adding direct inelastic scattering contribution.
- Mo-94: The experimental data are given only for the first level. Three evaluation files give underestimation for this level. ENDF/B-VI and JEF data make a triangle shape because of few energy points. Higher excitation levels ($-Q > 2$ MeV) of JENDL-3 differs much from those of ENDF/B-VI and JEF-2.
- Mo-96: JENDL-3 agrees well with the experimental data, except for the first and second levels, whose excitation cross sections are slightly underestimated and expected to be improved by adding direct inelastic scattering components. JEF-2 and ENDF/B-VI show a triangle shape and disagree with the experimental data. In these two files, level missing is observed.
- Mo-98: ENDF/B-VI gives no data. JENDL-3 underestimate the cross sections for the first three levels. These underestimation may be recovered by adding direct inelastic scattering contributions. JEF-2 is better than JENDL-3 for these levels.
- Mo-100: JENDL-3 underestimate the cross sections for the first three levels. These underestimation is expected to be recovered by adding direct inelastic scattering contributions. JEF-2 is close to JENDL-3 but has an level which can not be

Table 1 (cont'd)

assigned to a certain observed level.

Pd: The experimental data are reported for natural paradium from ANL. They contains the contribution of odd mass nuclides.

The three evaluated files generally underestimate the cross section in the threshold region, which might be attributable to small reaction cross sections. JENDL-3 includes contributions from the direct process.

Nd-142: Experimental data are given only for the first level. JENDL-3 gives good results. JEF-2 and ENDF/B-VI underestimate the cross sections.

Nd-144: JENDL-3 agree well with the experimental data for the first level. Underestimation is observed in ENDF/B-VI and JEF-2 in the higher energy but is expected to be overcome by adding the direct inelastic scattering contribution.

Nd-146: JENDL-3 is good for the first level, but slightly underestimates the excitation for the second to sixth levels. ENDF/B-VI gives the first two level excitations. The curves show a triangle shape and pass along the experimental data. JEF-2 is lower than the experimental data.

Nd-148: JENDL-3 is good. JEF-2 gives a strange shaped curve. Underestimation of ENDF/B-VI probably arises from lack of the contribution of direct inelastic scattering.

Nd-150: JENDL-3 and ENDF/B-IV underestimate the peak of the first level excitation. For the second level, the data of Haouat at 7 MeV might suggest very large contribution of direct inelastic scattering. JEF-2 shows the same behavior as ENDF/B-VI. For the third and fifth level, good agreement is observed in the three data files.

N.B. JENDL-3 for Nd isotopes contains the contribution of direct inelastic scattering.

That is all.

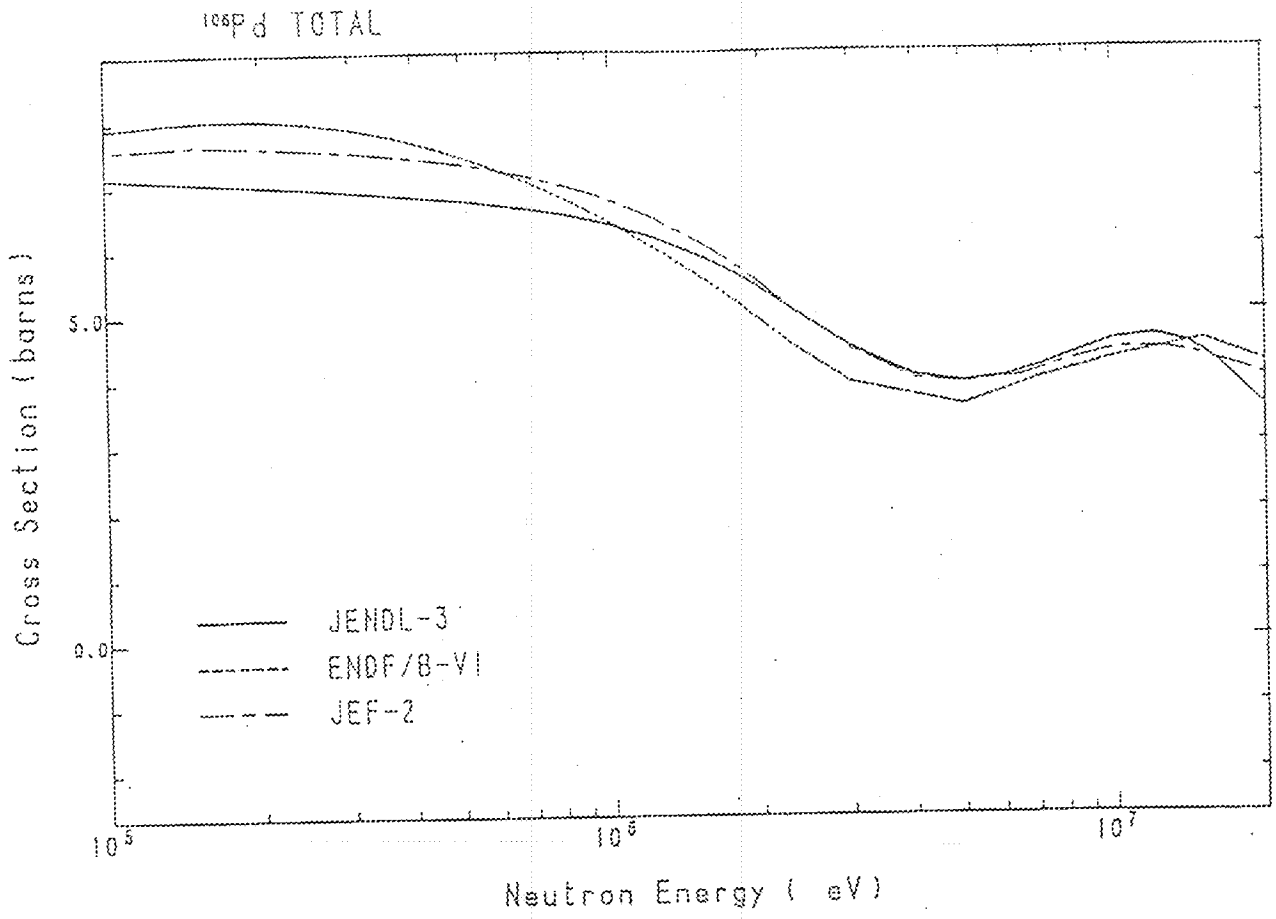


Fig. 1

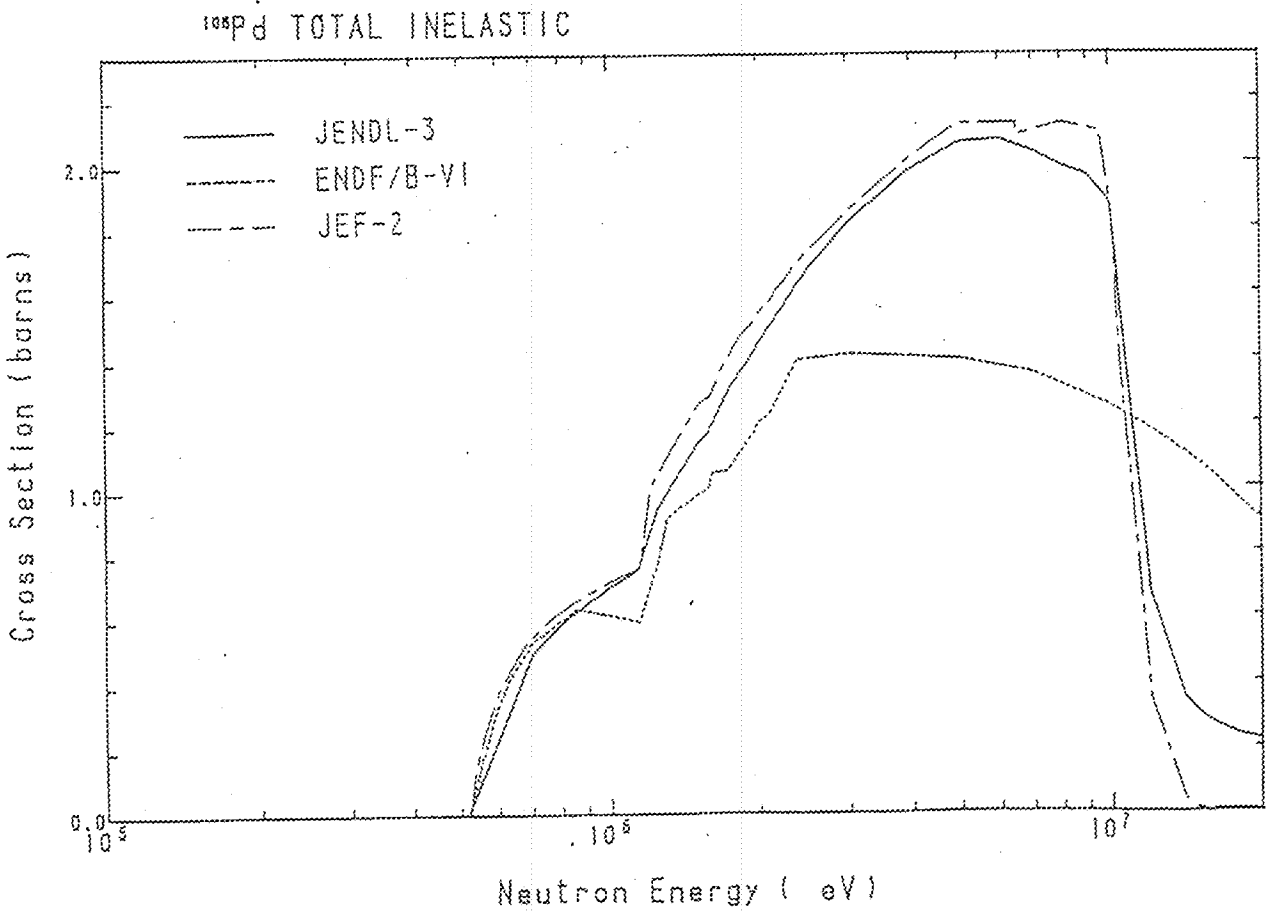


Fig. 2

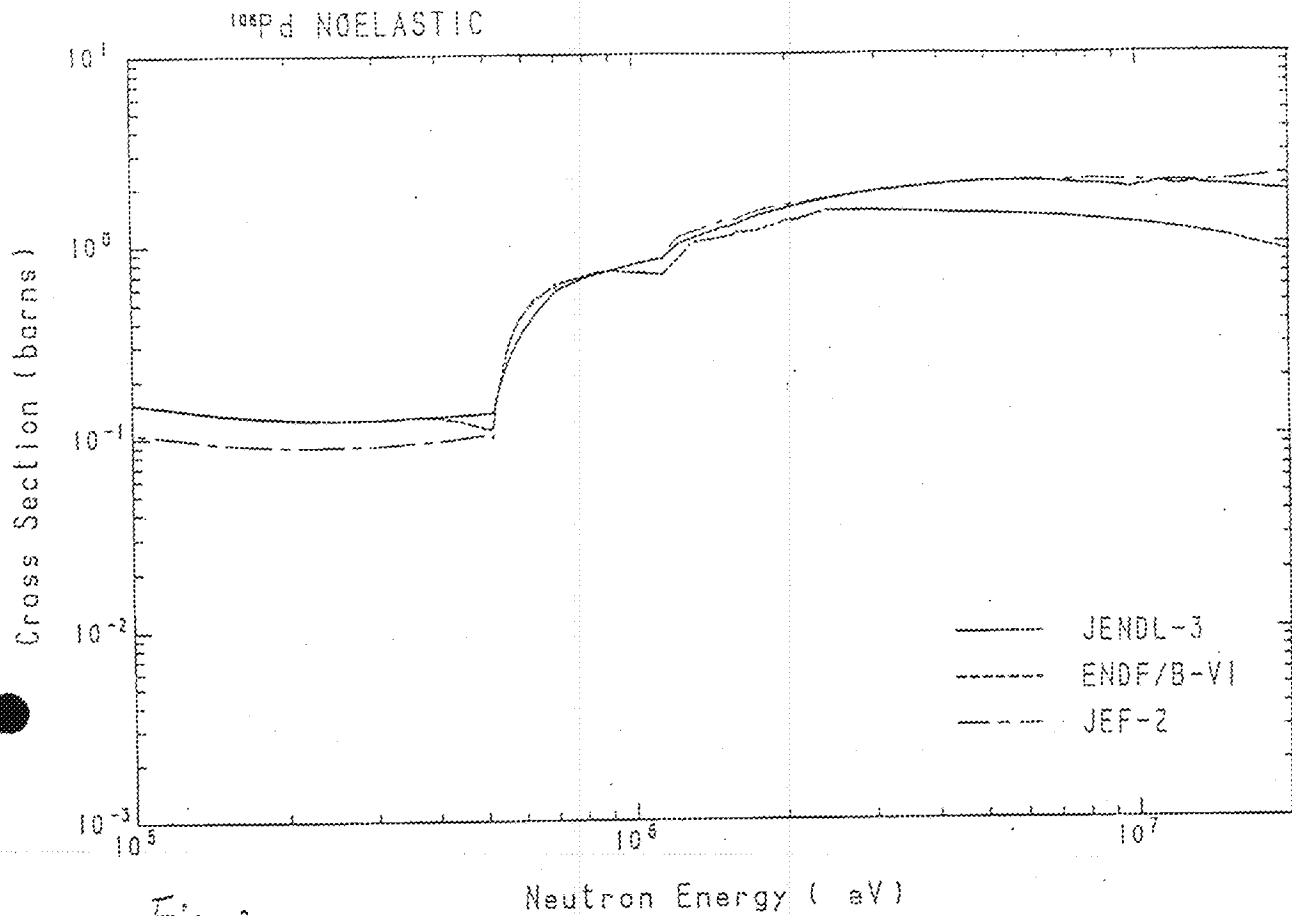


Fig. 3

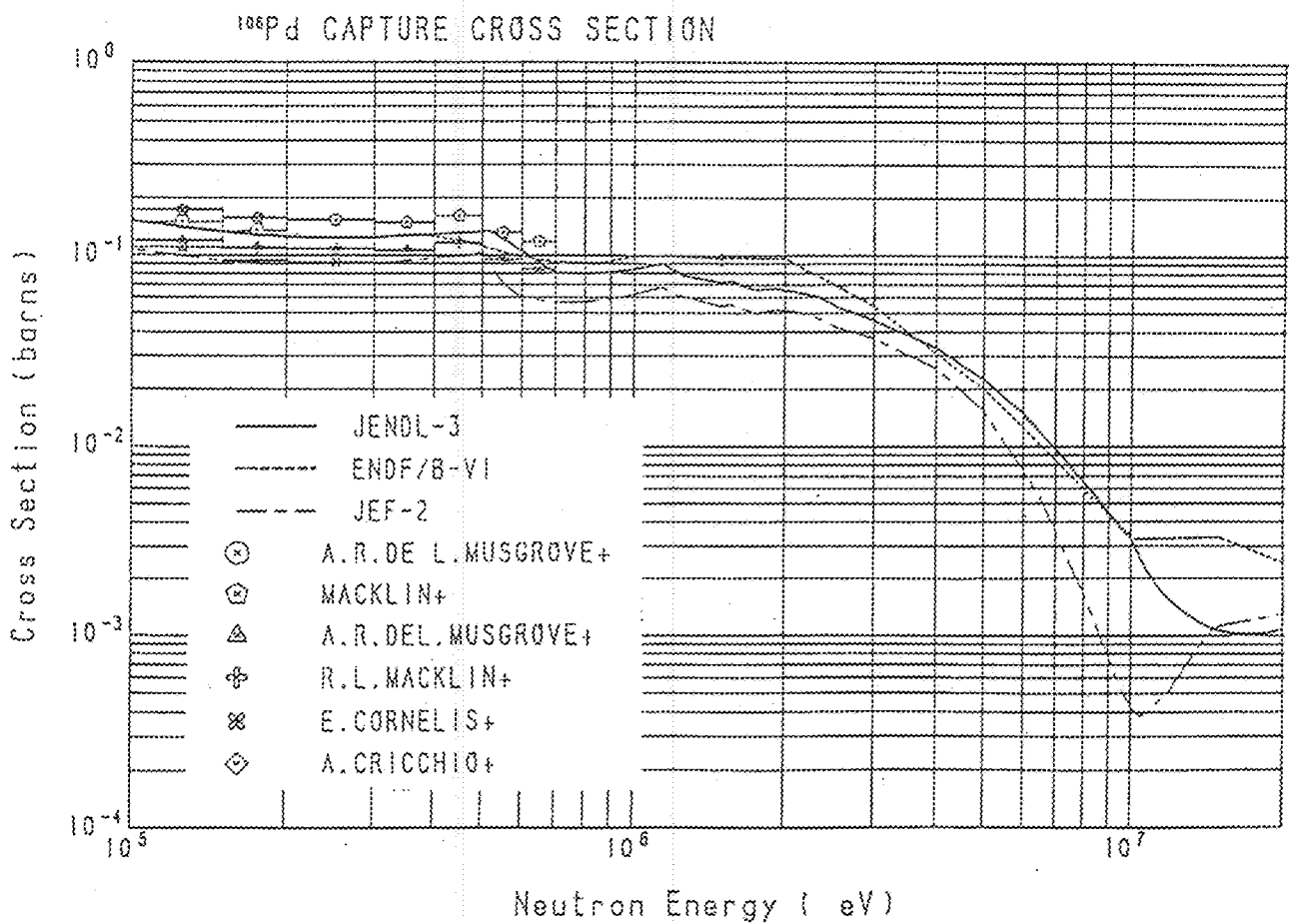
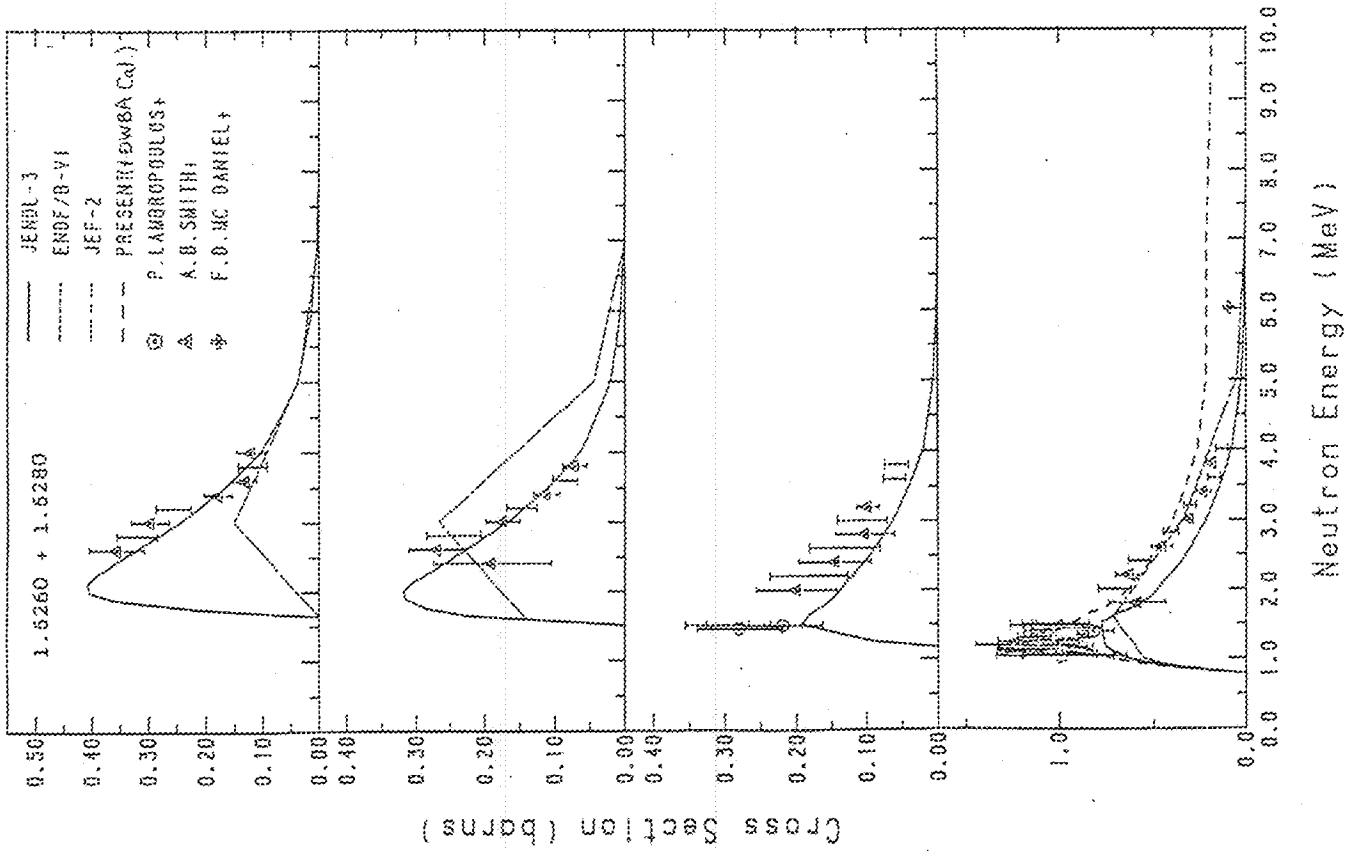


Fig. 4

⁹⁸Mo INELASTIC SCATTERING



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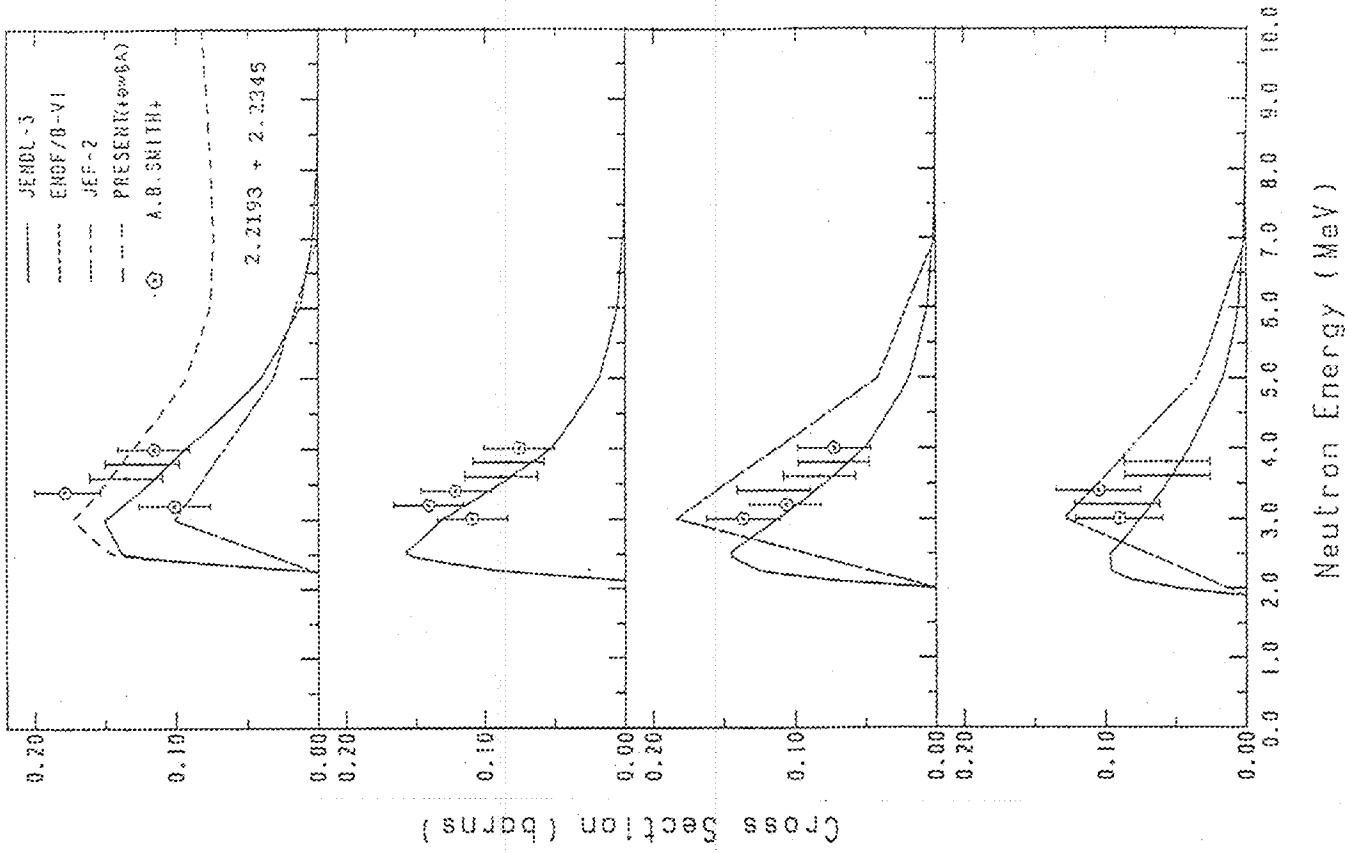


Fig 7