Summaries of Workshop Meetings

F. H. Ruddy (Westinghouse Science & Technology Center) ASTM Workshops Co-chairman

H. J. Nolthenius (ECN–Petten) Euratom Workshops Co-chairman

Nine workshop meetings were held at the symposium in order to foster informal exchanges of information on a variety of subjects identified as being of major concern based on a polling of the meeting registrants prior to the meeting. Three workshops, each lasting two hours, were run in parallel on three days. The results of the survey were also used to schedule the workshops with minimum potential conflicts for those participants interested in a variety of topics, so that as many workshops of interest as possible could be attended.

Each workshop was organized by two co-chairpersons, one representing the ASTM dosimetry community and one representing the European dosimetry community. The two co-chairs jointly organized each workshop by defining the workshop scope, identifying potential presenters using the individual survey questionnaires and abstracts of papers to be presented at the symposium. The workshops were scheduled so that the presented papers on related topics generally preceded the workshop to allow the workshop discussions to build on the results of the papers.

After the workshops, the co-chairs for each workshop prepared the summaries that follow. Each workshop summary was then subjected to peer review, including one of the attendees at the workshop who was selected as a result of his expertise on the subject of the workshop.

WORKSHOP ON QUALITY ASSURANCE IN REACTOR DOSIMETRY

JW Rogers (INEL) and D. Beretz (CEA–Grenoble)

The workshop was attended by more than 25 persons. At the beginning of the workshop, each attendee made a short statement on his particular interests in the workshop subject. The only formal presentation was given by Dr. Bruno Baers on how problems related to liquid scintillation counting were solved in his laboratory.

The workshop focus quickly changed to a discussion of the generic aspects of quality assurance (QA). There was a wide diversity of opinion on the meaning or intent of QA. Quasi-philosophical discussion centered on the definitions of QA, quality control (QC), procedures, validation, documentation, scientific discipline, and so forth. Excellent participation by the attendees was experienced. *1S

The status of QA is confusing because of the different concepts people and organizations have. A distinction between QA and good scientific discipline is that QA is the required documentation associated with a process in order that an acceptable product is produced, whereas scientific discipline is the description of what was done and how it was done in enough detail to allow it to be repeated or reinterpreted. Consequently, quality without assurance or assurance without quality may exist for a product.

QA is dictated by the customer and must be adapted to our activities in reactor dosimetry. Much discussion centered on how to ensure that calculations were producing the correct

Copyright© 1994 by ASTM International www.astm.org

results in an application other than a benchmark or reference facility. QA is not QC but must include QC as well as procedures and qualified review for validation. QA is time-consuming and, consequently, expensive to the customer.

Many countries, companies, and laboratories have QA requirements and procedures, and others apparently do not. QA standards (such as ISO 9000) exist for some purposes, but other standards are needed in the field of reactor dosimetry.

The following agenda topics were covered in the workshop discussions:

- people who perform dosimetry tasks
- purpose and requirements of the dosimetry
- design and location of the dosimetry
- characterization of dosimetry materials
- recovery of dosimetry materials
- dosimetry product measurements, including both radioactive and stable products
- nuclear and decay data
- preparation of dosimetry materials (pre- and post-irradiation)
- measurement data analyses
- reporting of dosimetry data and analyses
- disposal and storage of used dosimetry materials
- calculation and measurement comparisons
- documentation and presentation of dosimetry QA data

An additional topic discussed was the transfer of knowledge from the older reactor dosimetry people to the younger ones, so that the loss of information or experience is avoided.

Recommendations

It is recommended that another workshop on QA be held at the next symposium so that unanswered questions can be addressed and conclusions can be reached. It would be advantageous to have professional QA people in attendance at the next QA workshop, and perhaps a technical session on QA should be held with presentations on specific aspects of QA.

It is also recommended that ASTM implement the development of QA standards, both general and reactor-dosimetry specific.

It is recommended that ASTM include in its standards on terminology, definitions of the terms frequently associated with QA, including:

- quality assurance
- quality control
- data validation
- process validation
- scientific discipline
- documentation
- quality assessment

At the end of the workshop, each attendee provided written comments which, along with the notes taken by the co-chairmen, are the basis for this summary report.

WORKSHOP ON GAMMA-RAY DOSIMETRY

S. Q. King (B&W Nuclear Technologies) and H. Ait Abderrahim (SCK/CEN)

The workshop was attended by 22 participants. Eight investigators made presentations on their recent experiences with various types of gamma-ray dosimetry. During the discussion periods that followed each presentation, the group discussed the investigator's findings and made several constructive suggestions based on their experiences.

In addition to the natural interest in gamma-ray dosimetry in general, there were two areas that were of particular interest to most participants of this workshop: gamma-ray dosimetry in mixed fields (neutron/gamma) and low-dose gamma-ray dosimetry.

Gamma-Ray Dosimetry in High-Level Mixed Fields

D. M. Gilliam (NIST) and A. Alberman (CEA) made presentations relating to their experiences with the use of high-level gamma fluence monitors.

Dr. Gilliam reported recent experiences with the use of the NIST-designed LiF gamma dosimeter. While comparisons to calculations have been surprisingly good [*1*], the investigators are nevertheless skeptical of such close agreement because of the persistence of two problems: thermal annealing during irradiation and the accuracy of the calculated neutron response (which is used to deduce gamma response from total response).

Dr. Alberman reported his experiences with high doses obtained by OSIRIS spent fuel at the irradiator at CEA-Saclay. Operation features continuous monitoring, final check of integrated dose, and temperature control (10 to 300°C). Difficulties have been found in correlating ionization chamber signals integrated over the length of the irradiation with integral post-irradiation measurements. This disagreement may be the result of fission product spectrum evolution with time. J. Ponsard of Mol suggested that intermediate measurements might be helpful.

Ian Thomson (Thomson & Nielsen Electronics, Ltd.) presented a discussion of his experiences with the use of MOS dosimeters to measure high-level gamma doses. These dosimeters are quite promising for a number of applications, since they can be used in both passive and direct-reading modes. The gamma dose response is linear in the range 10 to 200 Gy where they have found applications in radiotherapy and blood-product irradiation dosimetry. Beyond 200 Gy, the dose is nonlinear, but reproducible and usable to at least 50 kGy. Applications in the higher dose ranges have included gamma dose mapping in reactor containment areas. Testing in mixed fields has shown that the thermal neutron response is negligible.

M. Tichy (Institute of Radiation Dosimetry, Czech Academy of Sciences) discussed his work with NE213 scintillation detectors [*2*]. Proper accounting for neutron-induced prompt gammas in the scintillator material was discussed. The use of a "pure" neutron source at PTB was identified as a possible tool for use in resolving the problem.

Low-Dose Gamma-Ray Dosimetry

M. Oliver (APG) presented a discussion of his very successful work using TLDs as low dose rate gamma fluence detectors. Some of the difficulties that were discussed were problems with read-out procedures, interpretation of data, and fading of low-temperature peaks.

H. Ait Abderrahim (SCK/CEN–Mol) also discussed the use of TLDs for low-fluence applications [*3,4*]. The effects of fast and thermal neutrons were determined to be non-negligible, and cavity corrections were deemed necessary.

I. Remec (ORNL) discussed his work in the determination and characterization of the neutron and gamma fields at HFIR. Photofission reactions can be very important, as illustrated by the fact that at some locations, the photoreactions were estimated to be as high as 95%.

The workshop was concluded with a presentation by H. Farrar IV (Consultant and Chairman of ASTM E10.01) on the dosimetry used in the radiation processing industry.

References

[1] King, S. Q. and Gilliam, D. M., ''Characterization of the Gamma Field in the B&W Owners Group Cavity Dosimetry Benchmark Experiment,'' this publication, pp. 447–455.
[2] Guldbakke, S., et al., ''Response Matrices of NE213 Scintillation Detectors for Neutrons,'' this publication, pp. 280–289.
[3] Ait Abderrahim, H., et al., ''Assessment of the Fast Neutron Sensitivity of Thermoluminescent Gamma Dosimeters,'' *Proceedings of the Seventh ASTM-Euratom Symposium on Reactor Dosimetry,* G. Tsotridis, R. Dierckx, and P. D'hondt, Eds.
[4] Ait Abderrahim, H., et al., ''Intercomparison of Gamma-Ray Dose Rate Measurement Techniques and Calculation Results for Several Benchmark Radiation Fields,'' *Proceedings of the Seventh ASTM-Euratom Symposium on Reactor Dosimetry,* G. Tsotridis, R. Dierckx, and P. D'hondt, Eds.

WORKSHOP ON IMPACT OF CHANGES IN NEUTRON TRANSPORT CROSS SECTIONS

C. Garat (Framatome) and E. Polke (Siemans AG)

This workshop was attended by 30 participants who discussed comparisons between neutron transport cross-sections. Four oral presentations were made:

- R. Maerker (ORNL) compared ENDF/B-V and ENDF/B-VI calculational results with measurements performed in the HB Robinson power reactor and in the Czechoslovakian iron sphere experiment.
- C. Garat (Framatome/BWNS) compared the Davis Besse cavity dosimetry benchmark calculations using ENDF/B-II, ENDF/B-IV, and ENDF/B-VI.
- D. Ingersoll (ORNL) compared ENDF/B-V and ENDF/B-VI B_4C and Fe cross-sections in the framework of the LMR program.
- R. Simons (Westinghouse) reported Fast Flux Test Facility calculations using MCNP with ENDF/B-V.

Comparisons of ENDF/B-IV and V with ENDF/B-VI

R. Maerker described calculations done by LSU on the HB Robinson 2 power reactor that gave the following results:

- The ENDF/B-IV (or V) SAILOR calculation and the ENDF/B-IV ELXSIR calculation agreed to better than 10% for all dosimeter reactions in both the cavity and downcomer locations.
- Dosimeter responses calculated with SAILOR using ENDF/B-VI can be greater than the responses calculated with ELXSIR ENDF/B-IV by as much as 20% (47%) in the downcomer (cavity) region.
- Dosimeter response calculated with SAILOR ENDF/B-VI can be greater than the original SAILOR calculations by as much as 35% in the cavity.

Dr. Maerker's conclusion was that SAILOR ENDF/B-VI gives very good C/E values in the downcomer and the cavity (except for Np dosimeters).

Maerker reported the results of an iron sphere experiment carried out by the Czechoslovakians, where a detector was placed 1 m away from the 25-cm diameter sphere containing a ^{252}Cf point source. The ENDF/B-VI C/E values varied from 1 or 2 to 0.68 as calculated by NRI for fluxes greater than 0.1 MeV to fluxes greater than 4 MeV. Similar calculations by Skoda produced C/E values that varied from 1.11 to 0.77. The reader should note here that the C/Es in this case represent values computed as a function of an integral response cutoff energy, unlike all the other C/Es mentioned in this Workshop Summary, which are from dosimeter activities.

Comparisons of ENDF/B-II, ENDF/B-IV, and ENDF/B-VI

C. Garat reported on results from the Babcock & Wilcox Owners Group cavity dosimetry benchmark experiment that was analyzed using all three transport cross-section sets [1], leading to the following results:

- The ENDF/B-II (with the CASK energy structure) calculation gives a surprisingly good C/E agreement in both downcomer and cavity dosimetry locations; the average C/E (excluding the Cu dosimeters) for fast neutron dosimeters equals 0.98 in the cavity and 1.05 in the in-vessel capsules.
- The ENDF/B-IV (BUGLE) calculation gives good C/E agreement in the capsule locations and poor C/E agreement in the cavity locations. The average C/E for fast neutron dosimeters (excluding Cu) equals 0.79 in the cavity and 1.02 in the capsules.
- The ENDF/B-VI (with the BUGLE energy structure) calculation gives good C/E agreement in the cavity locations.

Comparisons of ENDF/B-V and ENDF/B-VI B4C and Fe Cross-Sections

D. Ingersoll reported on the work done in the fast reactor program (ORNL) that showed a C/E improvement from 0.61 to 0.90 when the ENDF/B-V Fe and ^{11}B cross-sections were replaced by the corresponding ENDF/B-VI cross-sections.

Fast Flux Test Facility MCNP Calculations Using ENDF/B-V

R. Simons reported on Monte Carlo neutron transport calculations using a three-dimensional geometry model of the Fast Flux Test Facility core, reflector, and radial shield that was used to calculate damage rates for in-vessel structural components. The calculated damage rates after penetration through 0.7 m of solid stainless steel (70% iron) blocks disagreed with dosimetry base damage rates by up to 300%. The observed discrepancy is possibly because of bias in the ENDF/B-V iron inelastic scattering cross-sections, as is observed in calculations for light water reactor pressure vessels.

Discussion

On the Fe sphere experimental results (presented by Maerker), E. P. Lippincott (Westinghouse) and F. B. K. Kam (Martin-Marietta) insisted that one should first check on the quality of the measurements and consistency with other experiments before drawing any conclusions in regard to cross-section inadequacies. However, it was noted that the qualitative trends observed in this experiment (which are actually opposite to the trends observed in HB Robinson) were also reported in Ref. 2. Thus, it was not clear to everyone that the measurements were the problem, and no real consensus formed with regard to this issue.

On the ENDF/B-II versus ENDF/B-IV versus ENDF/B-VI comparisons presented by Garat, several workshop participants were very troubled by the surprisingly good C/E agreement obtained using ENDF/B-II. J. Helm (Columbia University) voiced concern about the use of the ^{235}U spectrum to collapse the activation cross-sections, because a bias in the weighted one-group cross-sections of about a factor of 1.5 could be introduced [*3*]. Since older evaluations of the iron cross-section are believed to overestimate the high-energy cross-section [*2*], the bias caused by the overestimation would tend to compensate for the bias caused by over-estimating the dosimeter cross-section. Helm believes that this was a plausible explanation of why the ENDF/B-II-based results appeared to be so good.

As a general comment, E. P. Lippincott suggested that the Fe transport cross-sections could be collapsed using different energy structure in different regions, since collapsing seems to be a cause of errors.

Lippincott also pointed out that Westinghouse's cavity measurements are in better agreement with calculations when no thermal shield is present.

Finally, R. de Wouters (Tractebel) briefly reported on good results with ENDF/B-III coupled with Monte Carlo calculations. However, D. Maerker answered that ENDF/B-III was known to have some anomalies.

Conclusions

Based on the presentations at this workshop, it can be concluded that ENDF/B-VI iron transport cross-sections increase the neutron transport through the pressure vessel; this, in turn, leads to improved cavity dosimetry C/E results. However, older cross-section sets can also lead to very good results (ENDF/B-II or ENDF/B-III, for example); however, it was suggested that these good results might be fortuitous and remain unexplained.

Acknowledgment

The co-chairs of this workshop are grateful to Lisa Petrusha (B&W Nuclear Service Company) for providing organizational input to this workshop prior to the symposium.

References

[1] Petrusha, L. and Garat, C., "Evaluation of the Results of the B&W Owners Group Cavity Dosimetry Benchmark Experiment," this publication, pp. 358–367.
[2] Williams, M. L., Aboughantous, C., Asgari, M., White, J. E., Wright, R. Q., and Kam, F. B. K., "Transport Calculations of Neutron Transmission Through Steel Using ENDF/B-V, Revised ENDF/B-V, and ENDF/B-VI Iron Evaluations," NUREG/CR-5648, U.S. Nuclear Regulatory Commission (NRC), 1991.
[3] Helm, J. L., *Reactor Vessel Irradiation Damage: Absorbed Dose Estimation,* Second Edition, ESEERCO Research Report EP89-21, 18 Oct. 1993.

WORKSHOP ON EXPOSURE UNITS AND DAMAGE CROSS-SECTIONS

M. P. Manahan (MPN Associates) and N. P. Kocherov (IAEA)

A total of 24 participants attended the workshop. The workshop opened with an appeal from J. Helm (Columbia University) to discontinue the use of the term dpa and to replace it with an energy-based parameter, such as the absorbed dose to the lattice. Most participants agreed that the energy deposited to the lattice is a physically meaningful concept. One of the participants stated that the electronics damage community has always refrained from thinking in terms of displacements and instead prefers displacement Kerma. Mention was also made of the fact that dose to the lattice needs to be defined in a meaningful way for nonhomogeneous materials, such as ceramics. The group agreed with this point and noticed that for steels, the single element approximation is quite good, provided that the masses are comparable. Interest was expressed in performing experiments on a wider variety of materials.

Next, it was agreed that within the narrow context of U.S. LWRs, it is very difficult to demonstrate experimentally the clear superiority of one exposure unit over another. Many participants stated that in the broader context of different reactor designs, dose to the lattice or dpa units are much more useful for correlating mechanical behavior trends, and are therefore preferred.

A lively discussion concerned the strengths and weaknesses of dpa, dose to the lattice, and fast neutron fluence. It is not clear at present how these exposure units relate to specific damage mechanisms in various materials and in different neutron energy spectra. All the participants agreed that none of the currently conceived exposure units will be the ''last word'' for damage correlation work. Therefore, it is essential that spectrum calculations, irradiation histories, dosimetry data, and calculational procedures be fully documented and described. The same recommendation holds for mechanical property determinations.

The group also recommends that ASTM continue standards work on spectra calculations, but that it must be at a detailed level to achieve the desired purpose.

WORKSHOP ON BENCHMARKS

J. Grundl (NIST) and J. J. Wagschal (The Hebrew University of Jerusalem)

The Benchmark Workshop, attended by 35 participants, was limited by external constraints to one hour and twenty minutes. J. Wagschal, in his opening remarks, noted the different perceptions on the idea of a ''benchmark'' and would not, therefore, want to limit the workshop by any particular definition. J. Grundl, the co-chairman, was introduced as one with experience in benchmarks going back to the time of GODIVA at LANL. Dr. Grundl briefly summarized the classification of benchmark neutron fields discussed at an earlier ASTM-Euratom Symposium. Standard neutron fields were recalled as permanent neutron fields characterized by intrinsic simplicity and state-of-the-art specification of the neutron field quantities. Isolated fission neutron sources are an example. A reference neutron field also presumes long-term availability but is less well-characterized, generally because of significant neutron transport effects. The new materials dosimetry reference facility (MDRF) reported at this symposium is an example of a reference neutron field. The third class of benchmarks is the controlled environment designed to address a specific need and characterized to the extent required. The PCA pressure vessel mockup, in this context, was a controlled environment that is no longer available for measurement.

The major presentation at the workshop was given by R. Maerker (ORNL) who demonstrated the leverage benchmarks provided in setting up the comprehensive LEPRICON spectrum adjustment code for PWR calculations. In particular, he stressed that for each output parameter, there are both experimental and calculational uncertainties, and that for most benchmarks, calculational uncertainties are higher than experimental uncertainties. The importance of the PCA and PSF systems in revealing the problem of the Fe inelastic cross section was emphasized. A point was made regarding how the built-in benchmarks in LEPRICON substantially reduced uncertainties in the analysis of fluence and radiation damage in the HB Robinson power reactor.

F. Kam (Martin-Marietta) followed with an outline of the sequence of experimental benchmarks developed in the LWR-PV surveillance program. PCA/PSF, NESDIP, VENUS, and HBR-2 were involved in the bulk of the program, and more recently, in order to help resolve the Fe inelastic scattering problem, the leakage spectra from iron spheres driven by a Cf fission neutron source have become important. The latter, ironically, had to be discovered at the Nuclear Research Institute in the Czech Republic. R. Dierckx (JRC-Ispra) next described his experimental techniques for obtaining the fission source strength of a Cf source, and M. Tichy (IRD-Prague) demonstrated how different experimental techniques can result in differences of up to 80% in fluence rate determinations.

D. Ingersoll (ORNL) outlined efforts to generate a convenient computer data base for shielding benchmarks that are no longer available. General interest in archiving benchmark experiments, before experienced people retire and the experimental facilities themselves disappear, is shared by CSEWG and NEARP. Itsuro Kimura described damage measurements in four benchmark fields in Japan. On the basis of his experience with the "concrete benchmark" at SCK/CEN, Hamid Ait Abderrahim (SCK/CEN) stressed the need for a very complete description of a controlled environment, and the need to establish its relevance to the real problem involved. C. Eisenhauer (NIST) then described neutron spectrum measurements with the ROSPEC differential spectrometer and a comparison with calculation and with integral fission reaction rates in NIST benchmark fields. The analysis was aimed at the elusive problem of the iron inelastic cross-section. R. Venkataraman (University of Michigan) described proposed applications of the MDRF to establish photofission corrections for fission dosimeters and also to investigate the iron inelastic scattering problem by means of fission reaction rates in iron cylinders of varying thickness.

It is clear that the number of benchmarks and their significance for neutron dosimetry have increased in recent years, and more time should be allocated for discussion of these matters.

WORKSHOP ON LIGHT WATER REACTOR SURVEILLANCE DOSIMETRY

S. L. Anderson (Westinghouse) and R. dE Wouters (Tractebel)

The Workshop on Light Water Reactor (LWR) Surveillance Dosimetry was attended by 15 participants. Discussions during the Workshop started with formal presentations by Roger de Wouters of Tractebel and Frank Walters of B&W Nuclear Service Company.

The talk by de Wouters described, in some detail, the use of Monte Carlo methods to predict LWR surveillance capsule and reactor vessel exposure. This talk was an in-depth expansion of a paper presented in an oral session at this conference [*1*]. The results of the work showed good agreement between the analytical approach and available methods. In addition to the description of the analysis and subsequent comparison to measurements, there were fairly extensive discussions regarding the uncertainty evaluations that were performed in conjunction with the calculations. In general, those present at the workshop were in agreement with the approach used in both the analysis itself and the uncertainty evaluations. However, it was noted by de Wouters that, as yet, the uncertainty analysis has not been accepted by the Belgian regulatory body. It was concluded by those present that regulatory acceptance of the uncertainty associated with LWR pressure vessel exposure predictions seems to be a global problem that is in need of resolution in the near future.

Frank Walters presented recent neutron dosimetry results obtained from the Davis Besse Unit 1 Reactor for the Babcock & Wilcox Owners Group Cavity Dosimetry Benchmark Experiment [2]. In particular, the results of beryllium helium accumulation fluence monitors (HAFMs) showed excellent consistency (standard deviations of about 1.8%) and agreement with calculations (adjusted E/C approximately 0.96), and, as a result, showed significant potential as neutron monitors in ex-vessel locations. The beryllium, in fact, had the lowest 1σ variation of any of the dosimetry used in the irradiation, with iron being the next best at 2.7%. Presentations of the B&WOG results were followed by a short discussion on the use of HAFMs, and beryllium in particular, for LWR surveillance and cavity dosimetry.

References

[*1*] de Wouters, R. M., Laurent, D. J., and D'hondt, P. J., "Analysis of PWR Pressure Vessel Surveillance Dosimetry with MCBEND," this publication, pp. 123–131.

[2] Petrusha, L. and Garat, C., "Evaluation of the Results of the B&W Owners Group Cavity Dosimetry Benchmark Experiment," this publication, pp. 358–367.

WORKSHOP ON ADJUSTMENT METHODS, CROSS-SECTION FILES, AND UNCERTAINTIES

R. E. Maerker (ORNL) and M. Matzke (PTB)

The workshop was attended by 33 participants. The following topics were discussed.

Correlations and Uncertainties in Adjustment Procedures

R. E. Maerker (ORNL) presented several observations based on his experience with the LEPRICON adjustment code. First, he emphasized the crucial importance of the cross-correlation matrix between the PV group fluxes and dosimetry activities, stating that the larger these correlations, the more effective is the dosimetry in providing information on the PV fluxes. Second, he presented a table that illustrated another required property of any adjustment procedure. That is, that comparisons between two sets of PV adjusted fluxes, each starting with a different cross-section library in the calculation of the prior fluxes should be in virtual agreement both for the values of the adjusted fluxes, as well as their uncertainties. This agreement verifies that the magnitudes of the adjustments is still within the range of linearity of the sensitivities. Lastly, Dr. Maerker demonstrated with his HB Robinson power reactor calculations the adequacy of a simplified one-dimensional transport scaling procedure to quantify the effects of cross-section changes on three-dimensional LWR transport calculations.

Simultaneous Adjustment of Neutron and Gamma-Ray Spectra

I. Remec (ORNL) reported on his determination of the neutron spectrum in his HFIR calculations. He pointed out that at distances of the order of 100 cm from the core he observed discrepancies up to a factor of 20 between calculated and measured reaction rates for some dosimeters such as Be, Np, and U. These alarming discrepancies could be explained by photofission and photoneutron reactions that dominate the measured reaction rates due to the presence of an intense gamma-ray flux at these larger distances. To remove the discrepancies, Dr. Remec introduced correction factors to take into account the photonuclear reactions. In a second step, he performed a simultaneous adjustment of the neutron and photon fluxes, using the LSLM2 code of Fred Stallmann, based on the reaction rates of 69 measured activities of gamma-ray and neutron reactions. This simultaneous adjustment resulted in good agreement between measured and adjusted reaction rates. Dr. Remec concluded that in HFIR, at the larger penetration distances, the gamma-ray induced displacement in iron might well be higher than the corresponding neutron-induced displacement component.

IRDF-File and NMF-File

H. Nolthenius (ECN-Petten) gave a comparison of results from adjustments using the codes of the NMF-90 package and the IRDF-90 library. The NMF package was previously introduced at the Seventh ASTM-Euratom symposium in Strasbourg, and contains computer codes, cross-sections, and measured reaction rates in six benchmark fields defined in the REAL84 and 88 exercises [*1,2*]. Dr. Nolthenius displayed fluence and uncertainty results that he obtained from three adjustment codes of the package (STAYS'L, MIEKE, and LSL). The results indicate that there are no serious errors in the IRDF-90 [*3*] dosimetry cross-section file or in the adjustment codes, although several small errors in the file should be repaired. It was also recommended that contributions from experts be directed towards updating the covariance matrices in the NMF data.

Bonner Spheres

A. V. Alevra (PTB-Germany) reported on his determination [*4*] of response matrices for Bonner Spheres in the range of 0 to 20 in. (0 to 50 cm) in diameter. He also reported the comparison of MCNP [*5*] calculations with measured monoenergetic neutron beam data. Although comparison with thermal incident beams indicates very good agreement, there remains a discrepancy of about 10% between measurement and calculation at most of the nonthermal energies used for calculation. If, by scaling, this discrepancy is removed, a discrepancy in the thermal region appears. In the ensuing discussion, it was suggested that there be an investigation into whether or not the effects of chemical binding of the carbon and hydrogen molecules in the polyethylene thermal neutron cross-section data were included in the MCNP calculation.

General Discussion

Additional discussions on several other topics then took place. M. Tichy (IRD-Prague) reported on response matrices for NE213 detectors and emphasized that good response matrices for both gamma-ray induced as well as neutron-induced scintillations are now available. He pointed out that the light output curve, as a function of energy, is non-linear for the higher electron energies. J. Williams (University of Arizona) and J. Helm (Columbia University) discussed the interpretation of small Chi-squared values, and Dr. Williams mentioned that, in his opinion, there is an inconsistency in the use of the normalization option in adjustment codes that do not simultaneously change the covariance input. He also suggested that Chi-squared is not a sufficient indicator for testing the consistency of input covariance data when the number of measurements to be adjusted is large.

Acknowledgment

The co-chairs of this workshop gratefully acknowledge the efforts of F. Stallmann (Oak Ridge National Laboratory) for serving as ASTM co-chair until immediately prior to the workshop and for providing much of the planning and organization for the workshop.

References

[*1*] Zsolnay, E. M., Nolthenius, H. J., Greenwood, L. R., and Szondi, E. J., "Reference Data Fields for Neutron Spectrum Adjustment and Related Damage Calculations," *Reactor Dosimetry: Methods, Applications, and Standardization, ASTM STP 1001,* Harry Farrar IV and E. P. Lippincott, Eds., American Society for Testing and Materials, Philadelphia, 1989, p. 299.

[*2*] Nolthenius, H. J., "Progress Report on the REAL88 Exercise," Report ECN-89-140, Petten, Sept. 1989.

[*3*] "International Reactor Dosimetry File (IRDF-90)," assembled by N. P. Kocherov and P. K. McLaughlin, International Atomic Energy Agency, Nuclear Data Section, IAEA-NDS-141, Revision 2, Oct. 1993.

[*4*] Alevra, A. V., "Accurate Neutron Fluence Measurements Using Bonner Spheres," this publication, pp. 290–299.

[*5*] "MCNP—A General Monte Carlo Code for Neutron and Photon Transport, Version 3A," J. Briesmeister, Ed., Los Alamos National Laboratory Report LA-7396-M, Los Alamos, Sept. 1986.

WORKSHOP ON RADIATION DAMAGE CORRELATIONS

A. L. Lowe, Jr. (B&W Nuclear Service Co.) and A. Alberman (CEA–Saclay)

This workshop was attended by 16 people. The workshop opened with a statement that it would deal with experimental work and data and not address the role of exposure units, since exposure units were the subject of another workshop.

Dr. A. Alberman (CEA-Saclay) suggested that any future radiation damage support programs address two parallel considerations to ensure obtaining reliable and well-characterized data that will produce acceptable correlations. Briefly, the correlations are outlined as follows:

1. *Physics-Dosimetry*—Experimental irradiations of reference materials such as model alloy and damage monitors to characterize neutron field effects.
2. *Metallurgy*—Studies of well-characterized material in carefully controlled environments to evaluate the interaction processes.

Currently, experiments are in progress at Saclay to identify if displacements per atom (dpa) is a better parameter for characterizing radiation damage in pressure vessel materials than the currently used fluence parameter, E>1MeV [*1*].

Dr. R. McElroy (AEA-Harwell) stated that damage correlations require careful evaluation of both experimental data and physical processes. He presented trend curve evaluations that indicate the role of identifiable physical processes. Of primary consideration is the condition of the matrix copper as related to neutron radiation damage of steels [*2*].

New research techniques such as FIM, TEM, and SANS, along with the use of model alloys (Fe, Cu) contribute to this advanced understanding of the role of copper in irradiation damage of reactor vessel materials.

Physical properties other than Charpy impact energy may provide better correlations of irradiation damage as was demonstrated by an evaluation of yield strength versus irradiation damage behavior.

The role of irradiation temperature on irradiation damage was reviewed with a stated need that the data bases contain a better-defined irradiation temperature base [*3*].

Dr. W. McElroy (CTS-Richland) discussed the potential impact of dose rate as reviewed at the workshop in Atlantic City. This effect may be material condition dependent and exposure time related [*4–8*].

Mr. T. Lewis (Nuclear Electric–Berkeley) expressed support for use of dpa in developing correlation PV. Experience showed that for correlation of Magnox Reactor steels, the use of dpa was far superior to fluence (E>1MeV). This result was attributed to the very different spectra from various surveillance positions. A question: If dpa works for Magnox reactors, why won't it work for correlations in light water reactors?

The role of gamma field on irradiation damage was discussed [*9*]. In specific neutron fields such as HFIR [*10*] or D_2O reflectors [*11*], the role of gamma field should be considered along with thermal neutron displacements [*12*] in modeling of irradiation damage.

Recommendations based on the just mentioned discussions are:

1. There is a need for better materials characterization using advanced metallurgical techniques (that is, FIM, TEM, SANS, and so forth) for all materials used in irradiation studies.
2. There is a need for further experimental programs to evaluate the following parameters:

(a) sensitivity of materials to the neutron energy spectrum;
(b) environmental control, especially the role of temperature; and
(c) material condition.

3. There is a need for complete documentation of material condition and irradiation environment including measured data and analysis.

Finally, concern was expressed as to whether or not it would be possible to obtain answers to the many problems identified because of the high cost of performing test reactor irradiation studies and the reluctance of utilities and regulators to fund such programs.

References

[1] Alberman, A., Beretz, D., Bourdet, L., and Carcreff, H., "Neutron Spectrum Effect on PV Steels Embrittlement: Dosimetry and Qualification of Irradiation Locations in OSIRIS and SILOE Reactors," this publication, pp. 472–479.

[2] McElroy, R. J. and Lowe Jr., A. L., "Irradiation Embrittlement Modeling of Linde 80 Weld Metal," *Proceedings,* 17th Symposium on Effects of Radiation on Materials, Sun Valley Idaho, June 1994, to be published.

[3] Nanstad, R. K. and Berggren, R. G., "Irradiation Effects on Charpy Impact and Tensile Properties of Low Upper-Shelf Welds," HSSI Series 2 and 3, NUREG/CR-5696, U.S. Nuclear Regulatory Commission (NRC), Washington, D.C., Aug. 1991.

[4] ASTM Workshop on Neutron Dose Rate and Spectral Effects on Material Irradiation Degradation, ASTM Committee E-10 Summer Meeting, Atlantic City, NJ, 26 June 1991.

[5] Hawthorne, J. R. and Menke, B. H., "Notch Ductility and Tensile Strength Determination of Reference Steels in PSF," *Proceedings of the 5th ASTM-Euratom Symposium on Reactor Dosimetry,* EUR 9869, Vol. 1, CEC, Geesthacht, FRG, Sept. 1984, 1985, p. 69.

[6] McElroy, W. N., Gold, R., Simons, R. L., and Roberts, J. H., "Trend Curve Data Development and Testing," *Influence of Radiation on Material Properties: 13th International Symposium, ASTM STP 956,* F. A. Garner, C. H. Henager, Jr., and N. Igata, Eds., American Society for Testing and Materials, Philadelphia, 1987, p. 505.

[7] Simons, R. L., Ibid., p. 535.

[8] Gold, R. and McElroy, W. N., "Radiation Embrittlement in LWR Pressure Vessels," Nuclear Engineering and Design 104, 155, 1987.

[9] Gold, R., Roberts, J. H., and Doran, D. G., "Determination of Gamma Ray Displacement Rates," LWR-PV-SDIP Progress Report, Oct. 1984 to Sept. 1985, NUREG/CR-4307, Vol. 1, HEDL-TME 85-14, Nuclear Regulatory Commission (NRC), Washington, D.C., Nov. 1985, p. HEDL-22.

[10] Pace III, J. V., Slater, C. O., and Smith, M. S., "Three-Dimensional Discrete Ordinates Radiation Transport Calculations of Neutron Fluence for Beginning-of-Cycle at Several Pressure Vessel Surveillance Positions in the High Flux Isotope Reactor," this publication, pp. 140–146.

[11] Baumann, N. P., "Gamma-Ray Induced Displacements in D_2O Reactors," *Proceedings,* 7th ASTM-Euratom Symposium on Reactor Dosimetry, Strasbourg, France, 27–31 August 1990, p. 689.

[12] Alberman, A., et al., "Influence des Neutrons Thermiques sur la Fragilisation de l'Acier de Peau d'Etancheite des Reacteurs a Haute Temperature," *Proceedings of the 4th ASTM-Euratom Symposium on Reactor Dosimetry,* Gaithersburg, MD, March 1982, NUREG/CP-0029, Nuclear Regulatory Commission, Washington, D.C., Vol. 2, July 1982, p. 839 and *Nuclear Technology 66,* 1984, p. 639.

WORKSHOP ON DOSIMETRY FOR IRRADIATION FACILITIES AT TEST AND RESEARCH REACTORS

W. P. Voorbraak (ECN–Petten) and C. Heimbach (Aberdeen Proving Ground)

The subject of this workshop covered a wide variation of neutron sources, starting from the conventional ^{252}Cf source, used for calibration purposes, via reactors of different sizes with and without shielding, to high-energy neutron sources. Consequently, this variety leads to a diversity of characterization methods depending on specific characteristics such as neutron flux and neutron energy spectrum. Specialists were invited to give presentations on their experiences in the particular fields that were discussed. Due to insufficient time, high-energy neutron sources received less attention than is necessary to cover these types of sources.

C. Eisenhauer (NIST) gave a survey of the different corrections, due to neutron scattering, for the calibration of neutron instruments with the ^{252}Cf source at NIST. In addition, A. Alevra (PTB, Germany) mentioned the same type of work at PTB. Discussed was whether the measured uncertainties of the calibration procedure contribute significantly to the restricted accuracy of the neutron counter.

M. Flanders (White Sands) gave a survey of the neutron spectra at different locations around the White Sands Missile Range Reactor. The calculated spectra were adjusted with the results from activation foils. The influence of housing of the reactor, especially the borated floor, was mentioned. The different spectra were analyzed with regard to their impact on the damage produced in silicon. The calculations were focused only on neutrons.

Dr. Alevra gave a survey of the results of a benchmark investigation with different types of neutron monitors in Europe, including Bonner Spheres [*1*]. The various techniques are used to characterize the neutron spectra in the environment of reactors, fuel storage arrays, hospital radiotherapy facilities, and so forth. M. Stanka (U.S. Army Pulse Radiation Facility) gave a survey of his experience with measurements at the APRF. He described the application of the rotating spectrometer (ROSPEC) [*2*]. Restrictions in use and the used method for analysis were discussed. W. Voorbraak (ECN–Petten) gave an analysis of the restrictions that are present if neutron metrology has to be performed under conditions that are not attractive for neutron metrology such as long irradiation periods, fluences up to 10^{22} cm^{-2}, elevated temperatures, and lack of space for extended monitor sets, including covers. C. Heimbach (Aberdeen Proving Ground) explained the use of diodes and transistors in neutron fluences up to 10^{16} cm^{-2}. He showed a survey of response regions in relation to the conventional activation monitors [*3*].

References

[*1*] Alevra, A. V., "Accurate Neutron Fluence Measurements Using Bonner Spheres," this publication, pp. 290–299.
[*2*] Stanka, M. B., "Proton-Recoil Spectroscopy 400 Meters from a Fission Neutron Source," this publication, pp. 300–309.
[*3*] Heimbach, C. R., "Intercomparison of Neutron Test Facilities for Equivalent Damage to Electronics," this publication, pp. 509–514.

Appendixes

APPENDIX I

Symposium Organization

Sponsors

- ASTM Committee E-10 on Nuclear Technology and Applications
- The Commission of the European Communities, Joint Research Centre

Co-Sponsors

- American National Standards Institute (ANSI)
- American Nuclear Society (ANS)
- U.S. Department of Energy (DOE)
- U.S. Nuclear Regulatory Commission (NRC)
- U.S. National Institute for Standards and Technology (NIST)
- Electric Power Research Institute (EPRI)
- Institute of Electrical and Electronics Engineers (IEEE)—Nuclear Power Engineering Committee
- The Symposium was held in cooperation with the International Atomic Energy Agency (IAEA) and the American Society of Mechanical Engineers (ASME)

ASTM Symposium Committee

General Chairman:	*Harry Farrar IV,* Consultant, Bell Canyon, California
Executive Chairman:	*W. N. McElroy,* CTS, Richland, Washington
Vice Chairman:	*F. H. Ruddy,* Westinghouse Science and Technology Center, Pittsburgh, Pennsylvania
Program Chairman:	*E. P. Lippincott,* Westinghouse Electric, Pittsburgh, Pennsylvania
Program Vice Chairman:	*J. G. Williams,* University of Arizona, Tucson, Arizona
Scientific Secretary:	*D. W. Vehar,* Sandia, Albuquerque, New Mexico
Members:	*S. L. Anderson,* Westinghouse Electric, Pittsburgh, Pennsylvania
	S. C. Apple, Arkansas Tech, Russellville, Arkansas
	J. Butler, UKAEA, Winfrith, United Kingdom
	L. R. Greenwood, PNL, Richland, Washington
	P. J. Griffin, Sandia, Albuquerque, New Mexico
	F. B. K. Kam, ORNL, Oak Ridge, Tennessee
	S. Q. King, BWNT, Lynchburg, Virginia
	K. Kobayashi, Kyoto University, Osaka, Japan
	G. P. Lamaze, NIST, Gaithersburg, Maryland
	A. L. Lowe, Jr., BWNT, Lynchburg, Virginia
	T. F. Luera, Sandia, Albuquerque, New Mexico
	G. C. Martin, GE, Pleasanton, California
	R. J. McElroy, AEA, Harwell, United Kingdom
	E. D. McGarry, NIST, Gaithersburg, Maryland
	L. Petrusha, BWNT, Lynchburg, Virginia
	JW Rogers, EG&G, Idaho Falls, Idaho

Copyright© 1994 by ASTM International www.astm.org

W. L. Server, ATI, San Ramon, California
M. H. Sparks, White Sands, New Mexico
F. W. Stallmann, Knoxville, Tennessee
A. Taboada, USNRC, Washington, D.C.
J. J. Wagschal, Hebrew University, Jerusalem, Israel
C. West, ORNL, Oak Ridge, Tennessee
M. Williams, Tucson, Arizona

Euratom Programme Committee

Chairman: *R. Dierckx,* JRC, Ispra, Italy
Vice Chairman: *W. G. Alberts,* Braunschweig, PTB, Germany

Members: *A. Alberman,* CEN, Saclay, France
P. d'hondt, CEN/SCK, Mol, Belgium
A. J. Fudge, AERE, Harwell, United Kingdom
F. Hegedüs, PSI, Villigen, Switzerland
N. P. Kocherov, IAEA, Vienna, Austria
H. J. Nolthenius, ECN, Petten, Netherlands
B. Ošmera, NRI, Rez, Czech Republic
M. Petilli, ENEA, Rome, Italy

APPENDIX II

Attendees of Eighth ASTM-Euratom Symposium

Stefano Agosteo
Politecnico di Milano
Via Ponzio 34/3
Milano 20133 Italy
Phone: (+39)-2-2399-6318
Fax: (+39)-2-2399-6309

Hamid Ait Abderrahim
CEN/SCK Fuel Research
Boeretang 200
Mol, B-2400 Belgium
Phone: (32) 14-33 2277
Fax: (32) 14 33 25 84

Alain Alberman
CEA/CEN Saclay
Nuclear Reactors Directorate
DRE/SRO
F 91191 Gif-sur-Yvette, France
Phone: (33) 1 6908 4538
Fax: (33) 1 6908 9008

Raymond Alcouffe
Los Alamos National Laboratories
PO Box 1663
Los Alamos, NM 87545 USA
Phone: (505) 667-5756
Fax: (505) 665-5538

Alexandru Alevra
Lab 7.22
Physiklisch Technische Bundesanstalt
Bundesalle 100
D-38116 Braunschweig, Germany
Phone: + + 49-531-592 7221
Fax: + + 49 -531-592 9292

Dick Amato
Room 211
Westinghouse - Bettis
PO Box 79
Pittsburgh, PA 15122 USA
Phone: (412) 476-5445
Fax: (412) 476-5115

Stan Anderson
Westinghouse Electric
456 Rainier Drive
Pittsburgh, PA 15239 USA
Phone: (412) 374-5165
Fax: (412) 374-4697

Stanton Apple
Arkansas Tech University
#2 Black Oak Court
Russellville, AR 72801 USA
Phone: (501) 968-0629
Fax: (501) 968-0677

Bruno L. Baers
Technical Research Centre of Finland
Reactor Laboratory
Otakaari 3A, FIN-02150 Espoo, Finland
Phone: (358) 0 456 6340
Fax: (358) 0 456 6390

Charles Baldwin
Oak Ridge National Laboratory
PO Box 2008, MS-6295
Oak Ridge, TN 37831-6360 USA
Phone: (615) 574-6552
Fax: (615) 576-3894

Cloyd Beasley
Oak Ridge National Laboratory
PO Box 2008
Oak Ridge, TN 37831-6360 USA
Phone: (615) 576-3913
Fax: (615) 576-2760

Daniel Beretz
CEA (C.E.N.G.)
SRS/SAPR - C.E.N.G. 85X
38041 Grenoble Cedex, France
Phone: 76251249

Philippe Bioux
EDF/DER/PHR
1 Av, du General de Gaulle
92141 Clamart Cedex, France
Phone: (1) 4765 3908
Fax: (1) 4765 3499

Juan Bros
Tecnatom, S.A.
Av Montes de Oca, 1
28709-S. Sebastian Reyes
Madrid, Spain
Phone: (1) 651-6700
Fax: (1) 654-1532

Richard Cacciapouti
Yankee Atomic Electric Company
580 Main Street
Bolton, MA 01740 USA
Phone: (508) 779-6711
Fax: (508) 779-6730

Allan Carlson
NIST
RADP C311
Gaithersburg, MD 20899 USA
Phone: (301) 975-5570
Fax: (301) 869-7682

Jacques Chevallier
CEA
Is Sur Tille, 21120 France
Phone: 80235122
Fax: 80235107

Bradley Clark
Los Alamos National Laboratory
MS-B226
Los Alamos, NM 87545 USA
Phone: (505) 667-6287
Fax: (505) 665-5538

Jimmy L. Coor
B&W Nuclear Environmental Services
PO Box 11165
Lynchburg, VA 24506-1165 USA
Phone: (804) 522-6059
Fax: (804) 522-6860

Francois Coninckx
CERN
Commission TIS
CH-1211 Geneva 23 Switzerland
Phone: (41) 227674780
Fax: (41) 227852208

Charles de Raedt
SCK/CEN
Boeretang 200
B-2400 Mol, Belgium
Phone: 32 14 33 22 71
Fax: 32 14 31 91 81

Pierre D'hondt
SCK/CEN
Boeretang 200
B-2400 Mol, Belgium
Phone: 14 - 332200
Fax: 14 31 91 81

Francesco d'Errico
Universita' di Pisa
Via Diotisalvi 2, Pisa, 56126 Italy
Phone: +39 50 585 223
Fax: (39) 50 585 265

Ronald Dierckx
EFC/JRC Ispra
I-21020 Ispra, Italy
Phone: 0039/332/789438
Fax: 0039/332/785072

Roger de Wouters
Tractebel
Av Ariane 7
B-1200 Brussels, Belgium
Phone: (32) 2-773 7349
Fax: (32) 2-773 9900

Ernie Eason
Modelling & Computing Services
39675 Cedar Blvd., Suite 290
Newark, CA 94560 USA
Phone: (510) 226-1183
Fax: (510) 226-1073

Charles Eisenhauer
National Institute of Standards and Technology
Gaithersburg, MD 20899 USA
Phone: (301) 975-6204
Fax: (301) 926-1604

Cetin Ertek
IAEA
Wagramerstr 5, Box 200
Vienna, A-1400 Austria
Phone: (43) 1-23606262

Harry Farrar IV
18 Flintlock Lane
Bell Canyon, CA 91307-1127 USA
Phone: (818) 340-1227
Fax: (818) 340-2132

T. Michael Flanders
Nuclear Effects Laboratory
STEWS-NE-R
WSMR, NM 88002-5158 USA
Phone: (505) 679-9484
Fax: (505) 678-8495

Phillip D. Ferguson
University of MO–Rolla
112 Fulton Hall
Rolla, MO 64501
Phone: (314) 341-6552

Christian Garat
Framatome
Tour Fiat–Cedex 16
Paris-la-Defense, 92084 France
Phone: 33-1-47961906
Fax: 33-1-47963031

Henry Gerstenberg
AFRRI
Bethesda, MD 20889 USA
Phone: (301) 295-0424

David Gilliam
NIST
REACT/A-155
Gaithersburg, MD 20899 USA
Phone: (301) 975-6206
Fax: (301) 926-1604

Bogdan Glumac
Jozef Stefan Industries
Jamova 39, POB 100
Ljubljana, 61111 Slovenia
Phone: (386) (1) 371 321
Fax: (386) (1) 374 919

Raymond Gold
Metrology Control Corp.
1982 Greenbrook Blvd.
Richland, WA 99352 USA
Phone: (508) 627-2527

Larry Greenwood
Battelle–Pacific Northwest Laboratory
PO Box 999, MS P7-22
Richland, WA 99352 USA
Phone: (509) 376-6918
Fax: (509) 376-1297

Patrick Griffin
Sandia National Laboratories
PO Box 5800, Dept. 6514
Albuquerque, NM 87185 USA
Phone: (505) 845-9121
Fax: (505) 845-3115

James Grundl
Department of Commerce
NIST
Gaithersburg, MD 20899
USA
Phone: (301) 975-6201
Fax: (301) 926-1604

Ayman Hawari
The University of Michigan
Ann Arbor, MI 98109
USA
Phone: (313) 764-0338
Fax: (313) 762-5450

Frank Hegedüs
Paul Scherrer Institute
Villigen PSI, 5332
Switzerland
Phone: ..41 56992473
Fax: ..41 56982327

Craig Heimbach
Combat Systems Test Activity
Bldg. 860 STECS-NE
Aberdeen Proving Ground, MD 21005 USA
Phone: (410) 278-4881
Fax: (410) 278-8517

John Helm
Columbia University
202 Mudd Bldg.
New York, NY 10027
USA
Phone: (212) 854-2972

William Hopkins
Bechtel Corp.
9801 Washington Blvd.
Gaithersburg, MD 20878-5356 USA
Phone: (301) 417-8802
Fax: (301) 738-7967

Chris Ingelbrecht
IRMM
Retieseweg
Geel, B-2440 Belgium
Phone: +32 14 571211
Fax: +32 14 584273

Dan Ingersoll
Oak Ridge National Laboratory
PO Box 2008
Oak Ridge, TN 37831
USA
Phone: (615) 574-6102
Fax: (615) 574-9619

Shin Iwasaki
Tohoku University
Aobaku-Aza-Aoba
Sendai, 980 Japan
Phone: (022) 222-1800, ext. 4674
Fax: (022) 268-1539

Albin Janett
Paul Scherrer Institute
5232 Villigen PSI
Switzerland
Phone: (41) 56/99 23 17
Fax: (41) 56/99 23 09

Francis Kam
Oak Ridge National Laboratory
PO Box 2008
Oak Ridge, TN 37831
USA
Phone: (615) 574-7000
Fax: (615) 574-4018

Mark Kawchak
Westinghouse Electric
PO Box 158
Madison, PA 15663 USA
Phone: (412) 722-5219
Fax: (412) 722-5919

Jake (John) Kelly
Sandia National Laboratories, Dept. 6514
Box 5800
Albuquerque, NM 87185
USA
Phone: (505) 845-3021
Fax: (505) 845-3117

Isuro Kimura
Kyoto University
Kyoto, Japan 606-01
Phone: (81) 75-753-5824
Fax: (81) 75-753-5845

Quinton King
BWNT
Route 5, Box 213
Amhurst, VA 24521 USA
Phone: (804) 385-2594
Fax: (804) 385-3736

Katsuhei Kobayashi
Kyoto University
Kumatori-Cho Sennan-Gum
Osaka, 590-04 Japan
Phone: (+81) 724-52-0901
Fax: (+81) 724-53-0360

Nikolai Kocherov
IAEA
Wagramerstr 5, Box 100
Vienna, A-1400 Austria
Phone: (43) 1-23-60-17-18

William Kohlroser
Virginia Power
5000 Dominion Blvd.
Glen Allen, VA 23060
USA
Phone: (804) 273-2257

Trevor Lewis
Nuclear Electric
Berkeley Technology Center
Berkeley GL13 9PB, United Kingdom
Phone: 453-812353
Fax: 453-812096

Robert Lidstone
AECL Research
Whiteshell Laboratories
Pinawa, MB ROEILO
Canada
Phone: (208) 753-2311
Fax: (204) 753-2455

E. Parvin Lippincott
Westinghouse Electric
PO Box 355
Pittsburgh, PA 15230 USA
Phone: (412) 374-4191
Fax: (412) 374-4697

Raoul Lloret
CEA-CEN-SAPR
85X
Grenoble Cedex 38041
France
Phone: (33) 76 88 47 63
Fax: (33) 76 88 51 78

Arthur L. Lowe, Jr.
BW Nuclear Technologies
PO Box 10935
Lynchburg, VA 24506-0935 USA
Phone: (804) 385-3276
Fax: (804) 385-3663

Ted Luera
Sandia National Laboratories
Department 6500B, PO Box 5800
Albuquerque, NM USA
Phone: (505) 845-3026
Fax: (505) 845-3115

Richard Maerker
724 Bristol Circle
Knoxville, TN 37923 USA
Phone: (615) 593-4956

Michael Manahan
MPM Research and Consulting
915 Pike St., PO Box 840
Lemont, PA 16851 USA
Phone: (814) 234-8860
Fax: (814) 234-0248

Duane Marr
Los Alamos National Laboratory
PO Box 1663
Los Alamos, NM 87545 USA
Phone: (505) 665-2305
Fax: (505) 665-5538

Gerald Martin
General Electric Co.
Vallecitos Nuc. Cen. M/C V04
Pleasanton, CA 94566 USA
Phone: (510) 657-6920
Fax: (510) 862-4515

Gilles Martin
CEA/DREC
CEA Cadarache BP1
13108 St. Paul-lez-Durance, France
Phone: (33) 42 25 46 34
Fax: (33) 42 25 62 33

Manfred Matzke
Physikalisch–Technische Bundesanstalt
Postfach 3345
D-38023 Braunschweig, Germany
Phone: (49) 531 592 7320
Fax: (49) 531 592 7015

Ron McElroy
AEA Technology, Harwell
Harwell Laboratory
Didcot, Oxon, OX11ORA, United Kingdom
Phone: (235) 434184
Fax: (235) 436305

William McElroy
CTS
113 Thayer Drive
Richland, WA USA
Phone: (509) 943-5953
Fax: (509) 946-4770

David McGoff
U.S. Department of Energy (DOE)
NE-40; GTN
Washington, D.C. 20585 USA
Phone: (301) 903-5447
Fax: (301) 903-5588

William Miller
University of Missouri
E2433 EBW
Columbia, MO 65211 USA
Phone: (314) 882-9692
Fax: (314) 884-4801

Gary Mueller
University of Missouri
203 Fulton Hall, Nuclear Engineering
Rolla, MO 65401 USA
Phone: (314) 341-4348
Fax: (314) 341-6309

Markina Natalia V
RTAR
433510 Dimitrovgrad
Ulianovsk Region, Russia
Phone: 84235 32921
Fax: 84235 35698

Martin Nelson
USNA
NAOME Dept.
Annapolis, MD 21432 USA
Phone: (410) 267-3871

Henk Nolthenius
Netherlands Energy Research Foundation
Post Bus 1
Petten, 1755 ZG The Netherlands
Phone: (31) 2246-4296
Fax: (31) 2246-3490

Brian Oliver
Rockwell International
6633 Canoga Ave.
Canoga Park, CA 91309 USA
Phone: (818) 586-2724
Fax: (818) 586-1983

Mark Oliver
USACSTA Army Pulse Radiation Facility
Aberdeen Proving Ground, MD 21005 USA
Phone: (410) 278-4881
Fax: (410) 278-8517

Bohumil Osmera
Nuclear Research Institute
Rez u Prah, 250.68 Czech Republic
Phone: (422) 685 8351
Fax: (422) 685 7156

Joe V. Pace III
Bldg. 6025, MS-6363
Oak Ridge National Laboratory (MMES)
Oak Ridge, TN 37831-6363 USA
Phone: (615) 574-5285
Fax: (615) 574-9619

Kent Parsons
Los Alamos National Laboratory
MS-B226
Los Alamos, NM 87545 USA
Phone: (505) 667-3513
Fax: (505) 665-5538

Reuven L. Perel
Racah Institute of Physics
The Hebrew Univ. of Jerusalem
Jerusalem, 91904 Israel
Phone: 972-2-584521
Fax: 972-2-584437

Eckhard Polke
Siemens
Frauenauracher Str 85
Erlangen, D 91050 Germany
Phone: 499 131 18 6391
Fax: 499 131 18 68 35

Bernard Ponsard
CEN/SCK
Boeretang 200
Mol, B2400 Belgium
Phone: (32) 14 33 2430
Fax: (32) 14 32 0513

Rob Radulovich
Consumer Power
Palisades Nuclear Power
Blue Star Hwy.
Covert, MI 49043-9530 USA
Phone: (616) 764-8913, ext. 0153
Fax: (616) 764-8196

Graham Raw
AEA Technology
B220 Harwell
Didcot, Oxforshire OX11 SRA United Kingdom
Phone: 0235 434635
Fax: 0235 434522

Igor Remec
ORAU/ORNL
PO Box 2009
Oak Ridge, TN 37831 USA
Phone: (615) 574-7076
Fax: (615) 574-4018

Jeremy Rich
U.S. Naval Academy
Annapolis, MD 21412 USA
Phone: (410) 267-3551

JW Rogers
INEL–EG&G Idaho
PO Box 1625
Idaho Falls, ID 83415 USA
Phone: (208) 526-4252
Fax: (208) 526-5450

A. David Rossin
American Nuclear Society
555 N. Kensington Avenue
La Grange Park, IL 60525 USA
Phone: (708) 352-6611
Fax: (708) 352-0499

Frank Ruddy
Westinghouse Science Technology Center
1310 Beulah Road
Pittsburgh, PA 15235-5098 USA
Phone: (412) 256-1064
Fax: (412) 256-1007

Mark Rutherford
B&W Nuclear Technologies
3315 Old Forest Road
Lynchburg, VA 24506 USA
Phone: (804) 385-3270
Fax: (808) 385-3736

Jean-Pierre Rozain
CEA
BP 14
Is-Sur-Tille, 21120 France
Phone: 80234778
Fax: 80234703

Wesley Sallee
White Sands Missile Range
PO Box 333
WSMR, NM 88002 USA
Phone: (505) 679-9478
Fax: (505) 678-8495

Vincenzo Sangiust
Via Ponzio 34/3
Milano, 20124 Italy
Phone: (02) 23996390
Fax: (02) 23996309

Douglas Selby
Oak Ridge National Laboratory
708 Andover Blvd.
Knoxville, TN 37922 USA
Phone: (615) 966-7437

Tom Seren
Technical Research Centre of Finland
Reactor Laboratory, POB 200
FIN-02151 Espoo, Finland
Phone: (358) - 0 - 456 6340
Fax: (358) - 0 - 456 6390

William Server
ATI Consulting
2010 Crow Canyon Pl., Suite 140
San Ramon, CA 94583 USA
Phone: (510) 866-7100
Fax: (510) 866-6162

Robert Simons
Westinghouse Hanford Co., HO-35
PO Box 1970
Richland, WA 99352 USA
Phone: (508) 376-8244

Ross Snuggerud
Consumers Power Company
Palisades Nuclear Plant
Blue Star Hwy.
Covert, MI 49043-9530 USA
Phone: (616) 764-8913, ext. 0703
Fax: (616) 764-8196

Walt Sommer
Los Alamos National Laboratory
PO Box 1663, MS E546
Los Alamos, NM USA
Phone: (505) 667-1269
Fax: (505) 665-1712

Mary Sparks
White Sands Missile Range
STEWS-NE-R
WSMR, NM 88002 USA
Phone: (505) 679-9478
Fax: (505) 678-8495

Keith Spinney
Yankee Atomic Electric Co.
580 Main Street
Medway, MA 02053 USA
Phone: (508) 779-6711
Fax: (508) 779-6732

Fred Stallmann
ORNL
140 Sunrise Drive
Knoxville, TN 37919 USA
Phone: (615) 588-9347

Michael Stanka
U.S. Army Pulse Radiation Facility
STECS-NE Bldg. 860
Aberdeen Proving Ground, MD USA
Phone: (410) 278-4881
Fax: (410) 278-8517

Coenraad Stoker
Atomic Energy Corp of South Africa
Pelindaba, PO Box 582
Pretoria, 001 South Africa
Phone: (012) 3166039
Fax: (012) 3165925

James Stubbins
University of Illinois
214 NEL, 103 S. Goodwin Ave.
Urbana, IL 61801 USA
Phone: (217) 333-6474
Fax: (217) 333-2906

Roy L. Squires
S.M.E.
14 Granville Close
Duffield, Derby, DE2 8BJ England
Phone: 44-0332-840569
Fax: 44-0332-840569

Al Taboada
USNRC
Washington, D.C. 20555 USA
Phone: (301) 492-3838
Fax: (301) 492-3586

Ian Thomson
Thomson & Nielsen Electronics Ltd.
1050 Baxter Road
Ottawa K2C 3P1 Canada
Phone: (613) 596-4563
Fax: (613) 596-5243

Milos Tichy
Seven
Slezska 7 PO Box 146
Prague 2, CZ 120 00 Czech Republic
Phone: (422) 25 35 24
Fax: (422) 2424 7597

Hiroyuki Toyokawa
Nagoya University
Dept. of Nuclear Engineering
Nagoya 964-01, Japan
Phone: (81) 52-781-5111, ext. 4695
Fax: (81) 52-782-3810

Makoto Tsuneda
Nikkiso Co., Ltd.
498-1, Shiztani Haibaracho Haibara-Gun
Shizuoka, 421-04 Japan
Phone: 0548-22-5889
Fax: 0548-22-5857

William T. Urban
Los Alamos National Laboratory
MS B226
Los Alamos, NM 87545 USA
Phone: (505) 667-4024
Fax: (505) 665-5538

David Vehar
Sandia National Laboratories
Department 6521, PO Box 5800
Albuquerque, NM 87185 USA
Phone: (505) 845-3414
Fax: (505) 845-3115

Ramkumar Venkataraman
University of Michigan
2301 Bonisteel Blvd.
Ann Arbor, MI 48109 USA
Phone: (313) 764-5285

William Voorbraak
Netherlands Energy Research Foundation
PO Box 1
Petten, 1755 ZG, The Netherlands
Phone: (31) 2246-4295
Fax: (31) 2246 3490

J. J. Wagschal
Hebrew University/Racah Inst. of Physics
Jerusalem, IL-91904 Israel
Phone: (972) 2-584-521
Fax: (972) 2-584-437

Frank Walters
B&W Nuclear Service Co.
3315 Old Forest Rd., PO Box 10935

Lynchburg, VA 24506-0935 USA
Phone: (804) 385-2208
Fax: (804) 385-3662

Monroe Wechsler
North Carolina State University
106 Hunter Hill Place
Chapel Hill, NC 27514 USA
Phone: (919) 929-5193
Fax: (919) 515-5115

Charles Wemple
INEL-EG&G Idaho
PO Box 1625
Idaho Falls, ID 83415-3885 USA
Phone: (208) 526-7667
Fax: (208) 526-6971

Colin West
Oak Ridge National Laboratory
114 Union Valley Road
Oak Ridge, TN 37831 USA
Phone: (615) 574-0370
Fax: (615) 574-3041

John R. White
Chemical & Nuclear Engineering
University of Massachusetts-Lowell
Lowell, MA 01854 USA
Phone: (508) 934-3165

John E. White
Oak Ridge National Laboratory
MS 6362
PO Box 2008
Oak Ridge, TN 37831-6362 USA
Phone: (615) 574-6176
Fax: (615) 574-6182

John Williams
University of Arizona
Dept. of Nuclear Engineering
Tucson, AZ 85721 USA
Phone: (602) 621-9729
Fax: (602) 621-8096

Hitoshi Yamamoto
Suitomo Special Metals America, Inc.
23326 Hawthorne Blvd.
Torrance, CA 90505 USA
Phone: (310) 378-7886
Fax: (310) 378-0108

Konstantin Zolotarev
Russian Nuclear Data Center
Institute of Physics and Power Engineering
Ploschad Bondarenko
249020 Obinsk, The Russian Federation
Phone: (007) 08439 9-54-98
Fax: (007) 95 230 2326