Recent Accelerator Experiments Updates in SINBAD (Shielding INtegral Benchmark Archive Database)

I. Kodeli[a*], E. Sartori[b] and B. Kirk[c]

[a]*IAEA representative at OECD/NEA Data Bank, 12 bd. des Iles, 92130 Issy-les-Moulinaux, France*
[b]*OECD Nuclear Energy Agency, 12 bd des Iles, 92130 Issy les Moulineaux, France*
[c]*RSICC, Oak Ridge National Laboratory, POB 2008, Oak Ridge, TN 37831-6362, USA*

Abstract

SINBAD is an internationally established set of radiation shielding and dosimetry data relative to experiments relevant in reactor shielding, fusion blanket neutronics and accelerator shielding. In addition to the characterization of the radiation source, it describes shielding materials and instrumentation and the relevant detectors. The experimental results, be it dose, reaction rates or unfolded spectra are presented in tabular ASCII form that can easily be exported to different computer environments for further use. Most sets in SINBAD contain also the computer model used for the interpretation of the experiment and, where available, results from uncertainty analysis. The set of primary documents used for the benchmark compilation and evaluation are provided in computer readable form. SINBAD is available free of charge from RSICC and from the NEA Data Bank.

Keywords: benchmark experiments; accelerator shielding; radiation transport;

1. Introduction

SINBAD is an international effort between the OECD/NEA Data Bank (Organization for Economic Cooperation and Development, Nuclear Energy Agency Data Bank http://www.nea.fr/html/databank/) and ORNL/RSICC (Oak Ridge National Laboratory, Radiation Safety Information Computational Center http://www-rsicc.ornl.gov/). Cooperation from many organizations, authors, and benchmark analysts (see Table 1) have helped SINBAD become a 'living database' incorporating now over 70 benchmark experiments. The database is divided in three main parts covering both low and inter-mediate energy particles applications:

- reactor shielding, pressure vessel dosimetry (35 experiments)
- fusion blanket neutronics (26)
- accelerator shielding (13)

The accelerator shielding part, although in number of experiments still smaller than the reactor shielding and fusion areas, was recently increased by several new experiments, and others are to be added in this and the coming years. Among experiments in preparation are also the aviation route dose and medical experiments.

* Corresponding author. Tel.: +33-1-4524-1074; fax: +33-1-4524-1128; e-mail: ivo.kodeli@oecd.org

SINBAD is available at no charge from RSICC and from the NEA Data Bank. Since its beginnings in 1996 there have been many different users, including US, European, and Japanese establishments, government programs, universities, and private companies. SINBAD was distributed to 67 research and industry establishments worldwide.

Table 1: Contributing institutions.

- AEA Technology (AEAT),
- Comissariat a l'Energie Atomique (CEA),
- EC Joint Research Centre (ISPRA),
- Ente per le Nuove Technologie, L'Energia e l'Ambiente (ENEA),
- Forschungszentrum Karlsruhe (FZK),
- Forschungszentrum Rossendorf e.V. (FZR),
- Georgia Institute of Technology (GIT),
- High Energy Accelerator Research Organization (KEK),
- Institute of Nuclear Techniques, Technical University of Budapest (TUB),
- Institute of Physical and Chemical Research (RIKEN), Japan
- Institute of Physics and Power Engineering (IPPE), Obninsk,
- Interfaculty Reactor Institute (IRI), Delft University of Technology,
- Japan Atomic Energy Institute (JAERI),
- Jožef Stefan Institute (IJS),
- Lawrence Berkeley National Laboratory (LBNL),
- Los Alamos National Laboratory (LANL),
- Michigan State University (MSU),
- National Institute of Radiological Sciences (NIRS) of Japan,
- National Institute of Standards and Technology, Gaithersburg (NIST),
- Oak Ridge National Laboratory (ORNL),
- Paul Scherrer Institute (PSI),
- Research Centre Mol (SCK-CEN)
- Rutherford Application Laboratory (RAL, UK
- Scientific and Engineering Center for Nuclear and Radiation Safety (SEC NRS) of GOSATOMNADZOR,
- Stanford Linear Accelerator Center (SLAC),
- Technische Universitaet Dresden (TUD),
- Tohoku University,
- University of Illinois,
- University of Osaka,
- University of Pavia,
- University of Tokyo,
- CERN SPS (Super Proton Synchrotron), Geneva

and many experts who have contributed to the compilation, validation and review of the data.

2. Recent developments

The objective of the *SINBAD* data-base [1- 5] is to store and make available the information on high quality benchmark experiments for validation of radiation transport codes and nuclear data. A short description of accelerator shielding relevant experiments included in the present version of SINBAD is given in Table 2. New benchmark experiments are regularly added to the database, and the existing data are updated with feedback received from the users and when supplementary information becomes available. A list of experiments which are planned to be included in the near future is given in Table 3.

The ANS-6 standard on formats for benchmark problem description have been followed. SINBAD data include benchmark information on (1) the experimental facility and the source; (2) the benchmark geometry and composition; and (3) the detection system, measured data, and an error analysis. A full reference section is included with the data. Relevant graphical information, such as experimental geometry or spectral data, is included. All information that is compiled for inclusion with SINBAD has been verified for accuracy and reviewed by two scientists. The set of primary documents used for the benchmark compilation and evaluation are provided in computer readable form.

3. Conclusions

Information on some valuable shielding experiments has been saved together with the primary documents. Many new experiments were added in the last years, and SINBAD incorporates at present over 70 benchmark experiments, 13 of them covering accelerator applications. Further data is being processed and much data is waiting to be processed. These experiments have been identified of being of high relevance for validation of radiation transport and shielding methods and codes. Close cooperation with other projects like the Expert Group on Shielding Aspects for Accelerators, Targets and Irradiation Facilities (SATIF) [5] was established.

SINBAD is available at no charge from RSICC and from the NEA Data Bank.

Table 2: Accelerator Shielding Experiments in SINBAD

Title	Shielding material	Projectile	Measured quantity	Organisation
Transmission Through Shielding Materials of Neutrons and Photons Generated by 52 MeV Protons	C (up to 64.5 cm thick), Fe (up to 57.9 cm), H_2O (up to 101 cm), concrete (up to 115 cm)	52 MeV protons on C target	Neutron and gamma spectra by NE213 scintillation	FM cyclotron of University of Tokyo
Transmission Through Shielding Materials of Neutrons and Photons Generated by 65 MeV Protons	concrete, iron, lead and graphite (10 to 100 cm thick)	65 MeV protons on Cu target	Neutron and gamma spectra by NE213 scintillation	AVF cyclotron, Osaka University
TIARA 40 and 65 MeV Neutron Transmission Through Iron, Concrete and Polyethylene	Fe (130 cm thick), concrete (up to 200 cm), and polyethylene (up to 180 cm)	43 and 68 MeV protons on Li7 target	Neutron spectra and reaction rates by BC501Ascintillator, Bonner ball counter, fission counters, TLD and SSNTD	TIARA/JAERI
ROESTI I and III	Fe and Pb (100 cm thick)	200 GeV/c positive hadrons (2/3 protons and 1/3 positive pions)	In, S, Al, C activation detectors, radiophotoluminescent dosimeters (RPL)	CERN SPS (Super Proton Synchrotron)
ROESTI II	Fe (100 cm thick)	24 GeV/c protons	In, S, Al, C activation detectors, RPL	CERN PS (Proton Synchrotron)
RIKEN Quasi-monoenergetic Neutron Field in 70-210 MeV Energy Range		70 – 210 MeV protons on ^{7}Li target	TOF neutron spectra (NE213 scintillator)	RIKEN
HIMAC He, C, Ne, Ar, Fe, Xe and Si ions on C, Al, Cu and Pb targets	C, Al, Cu and Pb targets	100-800 MeV/nucleon He, C, Ne, Ar, Fe, Xe and Si ions	Angular neutron spectra by NE213 and NE102A scintillators	HIMAC/NIRS
HIMAC/NIRS High Energy Neutron (up to 800 MeV) Measurements in Iron	Fe (up to 100 cm)	400 MeV/nucleon C ions on Cu target	Neutron spectra by Self-TOF, NE213	HIMAC/NIRS
HIMAC/NIRS High Energy Neutron (up to 800 MeV) Measurements in Concrete	Concrete (up to 250 cm)	400 MeV/nucleon C ions on Cu target	Neutron spectra by Self-TOF, NE213, Bi and C activation detectors	HIMAC/NIRS
BEVALAC Experiment with Nb Ions on Nb & Al Targets	Nb (0.51 and 1 cm thick) and Al (1.27 cm thick)	272 and 435 MeV/nucleon Nb ions	Angular neutron spectra by NE-102 scintillator	LBNL
MSU experiment with He and C ions on Al target	Al (13.34 cm)	155 MeV/nucleon He and C ions	Angular neutron spectra by TOF method (BC-501 or NE213), charged particles	National Superconducting Cyclotron Laboratory (NCSL) at MSU
PSI - High Energy Neutron Spectra Generated by 590-MeV Protons on Pb Target	Pb target (60 cm)	590 MeV protons	Angular proton and neutron spectra by TOF method (NE213)	Swiss Institute for Nuclear Research, PSI
ISIS Deep Penetration of Neutrons through Concrete and Iron	Concrete (120 cm) and Fe (60 cm)	800 MeV protons on Ta target	C, Bi, Al, In_2O_3 activation detectors, neutron and gamma dose meters	ISIS, RAL, UK
TEPC-FLUKA Comparison for Aircraft Dose		Co60 (photons), 0.5 MeV neutron source, AmBe mixed source, CERN/CERF (120 GeV protons & pions on Cu target)	Neutron and photon absorbed dose by TEPC	ARC Seibersdorf Research GmbH

Table 3: SINBAD accelerator benchmarks - work in progress, (2005 and following years).

Title	**Organisation**
Transmission of Medium Energy Neutrons Through Concrete Shields	AVF Osaka University
Neutron Production from Thick Target of C, Fe, Cu, and Pb by 30- and 52-MeV Protons	INS Tokyo University
68 MeV proton on thick Cu target	JAERI
Neutron Yields from Stopping-Length C, Al, Fe and Depleted U Targets for 256-MeV Protons	LAMPF LANL
Neutron Angular and Energy Distributions from 710-MeV Alphas Stopping in H_2O, C, Steel and Pb	SREL (1980)
Photoproduction of High-Energy Neutrons in Thick Lead Targets Irradiated by 150 to 270 MeV Electrons	e-Linac, University of Mainz (1973)
Secondary Neutron Fluxes inside and around Iron Beam Stop Irradiated by 500 MeV Protons	p-synchrotron KEK
Reaction rate distribution inside thick concrete shield irradiated by 6.2 GeV protons	Bevatron (LBL)
Radioactivity induced by 2.83 and 24 GeV protons and spallation neutrons using AGS accelerator	Alternative Gradient Synchrotron at BNL
Shielding experiment using 4 m concrete at KENS/KEK 500 MeV Proton Accelerator Facility	KENS/KEK
Cosmic ray induced neutron spectrum at the summit of the Zugspitze 2660m & Chacaltaya 5240m ; measurements at the CERF utility	GSF, Neuherberg
TOF neutron spectra at angles 0 to 110 deg. and radioactivity induced in the accelerator material (Li, Be, Cu, C, Al, etc.) for 25 - 40 MeV deuterons	Tohoku University AVF Cyclotron
Neutron transmission spectra from 20cm iron slab, $D_2O(^3He,xn)$ reaction at 40 MeV	Fast Neutron Facility of NPI Rez
Yields of Residual Product Nuclei Produced in Thin Targets Irradiated by 100-2600 MeV Protons	ITEP, Moscow
SLAC experiment using 28.7 GeV electrons	SLAC

Acknowledgments

NEA Data Bank would like to thank the following persons for their input and valuable work to process the experiments into SINBAD: Takashi Nakamura, Michiya Sasaki and Alberto Fassò.

References

[1] OECD Nuclear Energy Agency Data Bank SINBAD http://www.nea.fr/html/science/shielding/sinbad/sinbadis.htm

[2] Radiation Safety Information Computational Center (RSICC) http://www-rsicc.ornl.gov/rsiccnew/BENCHMARKS.htm

[3] M. Salvatores, P. Miller, P. Nagel, E. Sartori, "Shielding Experimental Benchmark Data Base at the Nuclear Energy Agency Data Bank, " 7th International Conference on Radiation Shielding (ICRS7), Bournemouth, UK, 12 - 16 September 1988.

[4] I. Kodeli , H. Hunter, E. Sartori, Radiation Shielding and Dosimetry Experiments Updates in the SINBAD Data base, to be published in Radiation Protection Dosimetry (2005)

[5] E. Sartori, I. Kodeli, J.M. Galán, B.L. Kirk, Acquisition of Computer Codes, Cross-Section Libraries and Accelerator Shielding Experiments - Status 2004, Shielding Aspects of Accelerators, Targets and Irradiation Facilities – SATIF7, Workshop Proceedings, Sacavem, Portugal, 17-18 May 2004, OECD 2005, NEA No. 6005.

[6] T. Nakamura, et al., Handbook on Secondary Particle Production and Transport by High Energy Heavy Ions, this conference.