IPR-R1 TRIGA RESEARCH REACTOR DECOMMISSIONG PLAN:
STRUCTURE AND GENERAL ASPECTS (Draft)

1. **INTRODUCTION**

2. **OBJECTIVE**

3. **TRIGA IPR-R1 DESCRIPTION**

3.1. **Historical aspects**

- Description of the nuclear reactor, the site and the surrounding area that could affect, and be affected by decommissioning

3.2. **Operational Data Recovery**

- Recover the operational life history of the nuclear reactor, reasons for taking it out of service, and the planned use of the nuclear installation and the site during and after decommissioning

3.3. **Properties and construction aspects**

- Identification of structural characteristics, alterations, restructuration and significant plant modifications

3.4. **Location and using area description**

3.5. **Drawings and maps**

4. **DRIVERS TO DETERMINE THE DECOMMISSIONING - LIFETIME ESTIMATION**

4.1. **Maximum Fuel Element Burn-up**

The MCNP transport code, the ORIGEN 2.1 burn-up code and MONTEBURNS radioactive decay code were applied to evaluate the total fuel (235U) burn-up throughout 48 years of operation [DALLE, H.M. Simulação do Reator TRIGA- IPR – R1 Utilizando Métodos de Transporte por Monte Carlo. Tese de Doutorado, Universidade Estadual de Campinas, São Paulo (2005)]. The results indicate a reduction of 96 g of 235U mass, regarding to initial inventory of 63 elements, and a total burn-up near to 4%. Each rod has approximately 37 g that results a total mass 2.3 kg of 235U inside the core. The total heat generated until June 2008 was evaluated in 2000 MWh.

The estimated lifetime for the IPR-R1 is of more 34 years with a total burn-up of 3500 MWh. This estimation was performed by numerical simulations considering the following parameters: 68 fuel elements inserted on TRIGA core (note: there are 5 fresh stainless-steel elements that have never been used); operation at 250 kW (conservative hypothesis); and an average work demand based on the past 48 operation years. The thermal power calibration since 2000 is based on the energy balance and presents an assign uncertainty of 7.5 % [MESQUITA, A.Z., Investigação Experimental da Distribuição de Temperaturas no Reator Nuclear de Pesquisa TRIGA IPR-R1, Tese de Doutorado, Universidade Estadual de Campinas, São Paulo (2005)]. In this assessment a relative small burn-up of 12.1 % (mean of 68 elements) were observed, indicating a reduction of 307 g of

235U mass. Even for the central elements the total burn-up would be less than 20% as recommend by the manufacturer.

The IPR-R1 Research reactor could operate at least 3 decades by the actual work demand. Other factors must be considered as structural integrity of mechanical devices and fuel cladding, obsolescence of the instrumentation for measurement and control of operational parameters. All this factors can be managed and corrected by corrective and predictive maintenance, periodic inspections, acquiring new instrumentations and changing suspected or denied fuels.

Assessment of Radionuclide Inventory

An attempt to assess the radionuclide inventory was made simulating the end of life of fuel elements (spent fuel) [INTERNATIONAL ATOMIC ENERGY AGENCY, "Planning and management for the decommissioning of research reactors and other small nuclear facilities", (IAEA-TRS-351), Vienna, Austria (1993)]. The radionuclide inventory assessment for the spent fuel, considering 68 fuel elements and final burn-up of 6000 MWh (maximum without core reconfiguration) was calculated by CDTN's experts [DALLE, H.M.; JERAJ, R.;TAMBOURGI, E.B., Characterization of Burned Fuel of the TRIGA IPR – R1 Research Reactor Using Monteburns Code, 2002], where the lifetime is a function of: power, released energy and operation schedule (Table 1).

Table 1 – Inventory of Fuel Elements at the End of IPR-R1 Lifetime

Nuclídeo	Massa (gramas)	Atividade (Ci)	Calor de decaimento (W)	Radiotoxic. inalação (m^3 de ar)	Radiotoxic. ingestão (m^3 de água)
Zircônio93	1,34E+01	3,07E–02	3,57E–06	7,69E+06	3,84E+01
Tecnécio99	6,72E+00	9,46E–02	4,75E–05	1,35E+06	3,16E+02
Iodo129	9,50E–01	1,39E–04	6,44E–08	6,95E+06	2,32E+03
Césio135	8,65E+00	8,30E–03	2,77E–06	nd	nd
Césio137	7,04E+00	4,81E+02	5,33E–01	2,41E+11	2,41E+07
Promécio147	5,20E–01	1,37E+02	4,92E–02	nd	nd
Samário149	1,02E–01	1,50E–15	0,00E+00	nd	nd
Samário151	2,73E–01	4,63E+00	5,42E–04	nd	nd
Urânio235	2,04E+03	4,41E–03	1,16E–04	2,21E+08	1,47E+02
Urânio236	4,82E+01	3,11E–03	8,43E–05	1,56E+08	1,04E+02
Urânio238	9,49E+03	3,19E–03	8,08E–05	1,06E+09	7,97E+01
Netúnio237	2,57E–01	1,81E–04	5,53E–06	1,81E+09	6,04E+01
Netúnio239	5,14E–11	1,19E–05	2,89E–08	nd	nd
Plutônio239	2,27E+01	1,42E+00	4,35E–02	2,35E+13	2,83E+05
Plutônio240	1,12E+00	2,56E–01	7,97E–03	4,27E+12	5,12E+04
Plutônio241	7,72E–02	7,96E+00	2,47E–04	2,65E+12	3,98E+04
Plutônio242	2,29E–03	8,73E–06	2,58E–07	1,46E+08	1,75E+00
Plutônio244	4,55E–10	8,05E–15	2,34E–16	nd	nd
Amerício241	2,59E–02	8,89E–02	2,95E–03	4,44E+11	2,22E+04
Amerício243	5,99E–05	1,19E–05	3,83E–07	5,97E+07	2,98E+00
Cúrio242	3,19E–05	1,06E–01	3,89E–03	2,64E+10	5,28E+03
Cúrio243	2,62E–07	1,35E–05	4,96E–07	6,76E+07	2,71E+00
Cúrio244	1,41E–06	1,14E–04	3,99E–06	3,79E+08	1,63E+01
Cúrio245	4,24E–09	7,28E–10	2,42E–11	nd	nd
Cúrio246	4,98E–11	1,53E–11	5,00E–13	nd	nd
Cúrio247	2,27E–14	2,11E–18	6,75E–20	nd	nd
Actinídeos total	1,16E+04	3,89E+03	3,97E+00	1,95E+14	1,52E+08

In the same way they can carry out the inventory assessment for the activation of the structures and shielding can be carried out by the same group, using e.g. Monte Carlo Simulation.

4.2. Assessment of Structural and Operational Safety Conditions

4.3. Institutional and National Strategies for Nuclear Facilities

5. DECOMMISSIONING STRATEGY AND END STATE

5.1. Rationale for the preferred decommissioning option

- IAEA: Selection of decommissioning strategies: Issues and factors http://www-pub.iaea.org/MTCD/publications/PDF/TE_1478_web.pdf
- NEA: Selecting strategies for the decommissioning of nuclear facilities http://www.nea.fr/html/rwm/reports/2006/nea6038-decommissioning.pdf

5.2. End State of Decommissioning

Expected End States

- Free release of buildings and sites
- Reuse of buildings and sites (nuclear or industrial)
- Restricted release of buildings and sites (institutional control)

Important Factors to end state decisions

- Planned use for the IPR-R1 Reactor site
- Proper characterization of buildings and sites
- Assessment of the decontamination capabilities
- Comparison to the release requirements
- Analyses of the costs / financial benefits (land price)
- Policy and socio-economic factors: politicians, pressure groups, public may heavily oppose restricted release. Be prepared to deal with scientific and all types of non-scientific matter

6. RESPONSIBILITIES, ACTIVITIES AND ORGANIZATION CHART

6.1. Project Management

- description of the experience, resources, responsibilities and structure of the decommissioning organization, including the technical qualification/skills of the staff

6.2. Health & Safety

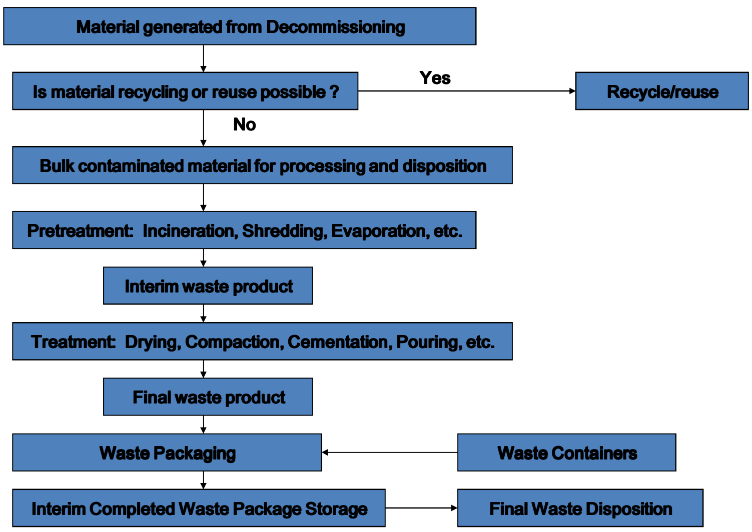
- Assessment and control of any abnormal events and incidents
- description of other applicable important technical and administrative considerations such as safeguards, physical security arrangements and details of emergency preparedness
- physical protection and safeguards

- Reporting of abnormal occurrences, incidents and accidents

6.3. Radiological Protection

- Personnel Training
- Radiological Survey Report
- Control of occupational and public doses
- Safety assessments, including the radiological and non-radiological hazards to workers and the public including a description of the proposed radiation protection procedures to be used during decommissioning
- Planning of process considering the ALARA principle
- On-site and off-site radiation and contamination surveys
- Explicit requirements for appropriate radiological criteria for guiding decommissioning
- Release criteria measurement/verification methods
- Description of the monitoring programme, equipment and methods to be used to verify that the site will comply with the release criteria
- Final confirmatory radiological survey at the end of decommissioning

6.4. Waste Management



- Identification and characterization of sources, types and volumes of waste
- Criteria for segregating materials
- Proposed treatment, conditioning, transport, storage and disposal methods
- Identification of potential to reuse and recycle materials, and related criteria
- Define anticipated discharges of radioactive and hazardous non-radioactive materials to the environment (airborne, liquid effluent and solid waste discharges)
- Application of size reduction techniques and waste minimization as: Chemical decontamination, Abrasive- blasting techniques, Melting (not applied), Techniques for Concrete, Pneumatic breaker, Diamond drill/ burst Expanding

grout, Hydraulic crusher, Diamond Wire (Diamond wire maximum removal rates), Contaminated concrete, Scrabble, Shave, Breakout.

- Treatment systems required:
  - Solidification, Removal of water
  - Immobilization of the contaminants
  - Preparation for subsequent treatment
  - Reduction of waste volume
  - Purification of water for reuse/discharge
  - Separation of a contaminant from a bulk matrix

6.5. Reactor Operation Team

- Record keeping
- Involvement in all activities

6.6. Laboratory Analyses

- Gross measurements (alpha and beta)
- Gamma spectroscopy
- Alpha spectroscopy
- Beta spectroscopy (liquid scintillation)
- Radiochemical analysis
- Autoradiography
- Activation analysis
- Other measurement techniques
- Definition of “scaling factors”, “fingerprints”, radionuclide vectors or radionuclide relationships (an immediate dismantling allows the use of Co60 and Cs measurements as a probe to define the radionuclide relationships)

6.7. Reactor Engineering

- Life time estimation: maximum fuel element burn-up and safety conditions of the reactor structures.
- Radionuclide inventory
- Structure and Components Activation
- Assessment of the amount, type and location of residual radioactive and hazardous non-radioactive materials in the nuclear reactor installation, including calculational methods and measurements used to determine the inventory of each

6.8. Infra-structure & General Maintenance

6.9. Administrative and Financial

6.10. Legal

6.11. Environmental

- environmental impact assessments
- description of the proposed environmental monitoring programme to be implemented during decommissioning

6.12. Audit and Quality Assurance Program

- description of the quality assurance programme
- establishment of Audit processes

6.13. Communication

- Interaction with Stakeholders
- Communication: local community, decision makers and general public

7. FINANCIAL ASPECTS, COST ESTIMATES AND FUNDING

- Details of the estimated cost of decommissioning, including waste management, and the source of funds required to carry out the work
- Estimate costs for decommissioning options (part of the "optioneering" /decision making process, No funds – No safety!) considering the safety requirements and types of waste generation.
- Calculate detailed costs during the final planning - Total costs and cost breakdown for individual elements (prepare a detailed time table)
- Build inflation into the cost calculations
- Allow a margin for uncertainties
- Include the costs for waste and materials management, e.g. conditioning, storage, disposal of radioactive waste; nuclear fuel; release of materials, buildings, site(s), considering the tasks:

(a) Pre-decommissioning actions, e.g. decommissioning planning;
(b) Facility shutdown activities, e.g. removal of the spent fuel, system reconfiguration and retirement, decontamination and immobilization of residual contamination;
(c) (Limited) procurement of equipment and materials;
(d) (Limited) dismantling activities and characterization of radioactive inventory;
(e) Waste processing, storage and disposal (including hazardous waste);
(f) Site security, surveillance and maintenance;
(g) Transition project management;
(h) Other costs, including asset recovery.

- IAEA: Financial Aspects of Decommissioning
  http://www-pub.iaea.org/MTCD/publications/PDF/te_1476_web.pdf
- NEA: Decommissioning Funding: Ethics, Implementation, Uncertainties
  http://www.nea.fr/html/rwm/reports/2006/nea5996-decommissioning.pdf
- NEA: Decommiss. Nuclear Power Plants: Policies, Strategies and Costs
  http://213.253.134.43/oecd/pdfs/browseit/6603221E.PDF
- **STANDARDIZED COST ITEMS FOR DECOMMISSIONING PROJECTS**

8. QUALITY ASSURANCE PROGRAM

9. LEGAL AND REGULATORY FRAMEWORK AND ASSIGN DOCUMENTATION

(description of the legal and regulatory framework applied to RR Decommissioning)

Federal Standards
CNEN Standards and Procedures
CDTN Procedures
Environmental Standards
AEA Recommendations
Other supporting documents:

- Characterization Plan
- Characterization Report
- Public Relations Plan
- Final Survey Plan
- Final Survey Report
- Final Report for the Decommissioning Project

10. CHARACTERIZATION PROGRAM

10.1. Maps of the installation

10.2. Maps of the installation

10.3. Contamination Level Approach

10.4. Gridding for Sampling and number of samples to be taken

10.5. Clearance Values (Safety Standards Series No. RS-G-1.7 : Application of the Concepts of Exclusion, Exemption and Clearance)

10.6. Definition of scaling factors, radionuclide vectors, "fingerprints"

10.7. Analysis and Results (Standard Values)

10.8. Destiny of the samples (release or stored as witness)

10.9. Classification of the material as non-radioactive or radioactive waste, recyclable, reusable material

11. EQUIPMENT AND INSTRUMENT FILE

SIMPLE MONITORING INSTRUMENTS			
Application	**Detector**	**Characteristics**	**Remarks**
Alpha emitters	proportional – various windows sizes	0.4 to 3 Bq/100 cm^2 sensitivity for scanning	Sensitivity depending on type of surface
	scintillation	3 Bq/100 cm^2 sensitivity for scanning	Sensitivity depending on type of surface
Beta emitters	proportional – various windows sizes	3 Bq/100 cm^2 sensitivity for scanning	Sensitivity depending on type of surface
	Geiger-Muller	3 Bq/100 cm^2 sensitivity for scanning	Sensitivity depending on type of surface
Gamma emitters	Geiger-Muller	Measurement at 50% above background	Better sensitivity with time integration
	proportional	Measurement at 50% above background	Better sensitivity with time integration
	scintillation	Measurement at 50% above background	Better sensitivity with time integration
Note: These instruments can be used for scanning or in a time integration mode for increased precision during direct measurements			

FIELD RADIATION DETECTORS FOR NUCLIDE-SPECIFIC MEASUREMENTS			
Application	**Detector**	**Characteristics**	**Remarks**
Alpha emitters	Sealed –large area proportional counter	Minimum deectable activity (MDA) of 0.3 Bq/g or 2 Bq/100 cm^2	Used as X ray spectrometer
	FIDLER (Field Instrument for Determination of Low Energy Radiation)	MDA of 70 Bq/100 cm^2 for Pu mix	Can be used for scanning, detects X rays
	Array of Si or Ge crystals	MDA of 0.03 Bq/g for Pu mix in 1 hour	Detects X rays or 60 keV line of ^{241}Am
Beta emitters	Scintillating fibres	MDA of 0.2 Bq/g for ^{90}Sr in 1 minute	Provides some nuclide / energy discrimination
Gamma emitters	NaI gamma spectrometer	10×10 cm crystall measures background nuclide concentrations in minutes	Low energy resolution
	Ge gamma spectrometer	Larger types can measure 0.004 Bq/g in 10 minutes	High energy resolution

RADIATION DETECTORS FOR DOSE RATE MEASUREMENTS			
Application	**Detector**	**Characteristics**	**Remarks**
Active	pressurised ionisation chamber	<100 nSv/h sensitivity	high precision
	Geiger-Muller	100 nSv/h sensitivity	Energy compensation needed
	proportional	100 nSv/h sensitivity	Energy compensation needed
	scintillator	<100 nSv/h sensitivity	Dual phosphor or tissue for flat energy response (used in current mode)
Passive	Thermoluminescence dosemeter	<50 nSv/h in 1 month	Good for wide area deployment
	Film badge	100 µSv/month	Sensitivity not sufficient for background measurements
	Electret ionisation chamber		Measures radon as well
Active/passive	Electronic dosemeter		Good for personal monitoring

12. ROUTES

12.1. Personnel

12.2. Wastes

12.3. Other Materials

13. EMERGENCY PLAN

- Develop, implement and maintain procedures to cope with abnormal occurrences
- Contingency procedures (deal with accidents and incidents involving the fuel, such as the potential loss of coolant for the fuel if it is in a fuel pool)

14. DECOMMISSIONING TIMETABLE (TIME SCHEDULE) AND FLOW SHEET

15. STEPS, PROCESSES AND CRITICAL TASKS OF DECOMMISSIONING

15.1. Initial Characterization of the Installation

Field measurements with radiological survey methods:

- Scanning - Moving a detector across or through an area to detect the presence of radiation
- Measurement - Determining the quantity (and quality) of radiation or radioactive material at a location, based on direct response of a detection system
- Sampling - Selecting a portion of the medium being evaluated for analysis

Sample collection and analysis of:

- Concrete
- Steel, equipment and components
- Paint
- Floor and ceiling tile
- Drains, pipes and ducts
- Surface and subsurface soil
- Biota
- Foodstuffs
- Water and sediments
- Airborne contamination

Laboratory analyses

15.2. Transition Phase

15.3. Fuel Removal (transfer, storage)

- Revision of important assign documents: "Developed Devices for Dismantling and Maintenance of IPR-R1 Research Reactor" (NI-AT4-004/95) 39 p. 1995.
- Consolidation or off-site transfer to country of origin – Spent fuel shipment
- Dry storage - cask
- Wet storage – pool
- On-site storage
- Storage on National Repository for Spent Fuel Elements

15.4. Removal of Absorbers, Containment and Safety Systems including Maintenance, Modification and Refurbishment of remain systems to assure the safety requirements in case of a extended period of surveillance

15.5. Removal of the Water

15.6. Decontamination of the Plant and equipments - Strategies

Draining and decontamination of pipes, tanks and other wet systems

Techniques for metal

Chemical decontamination

- Concentrated or diluted chemical reagents
- Effective for complex geometry
- Requires efficient recycling of the chemical
- Unless the site has a process for either solidifying liquid waste or processing it, avoid liquid decontamination methods
- They produce large volumes of secondary wastes
- Equally so electrochemical methods

Abrasive- blasting techniques

- Wet techniques
- Dry techniques
- Provided secondary wastes are controlled can be efficient.

Melting (not applied)

Techniques for Concrete

Free release concrete removal

- Pneumatic breaker
- Diamond drill/ burst
- Expanding grout
- Hydraulic crusher
- Diamond Wire (Diamond wire maximum removal rates)

Contaminated concrete

- Scrabble
- Shave
- Breakout
- All methods worthy of consideration (Consider minimization of airborne contamination)

15.7. Extended period of Surveillance and Maintenance

- Reasons for extend period of surveillance
- Necessity of refurbish of the reactor and ventilation systems
- Creation of museum of nuclear science (IPR-R1 Reactor and TRIGA Technology) accessible for public tours
- Revision of aspects assign to a extended period of surveillance as intended site or land use, feasibility of the museum of nuclear science, technologies for decommissioning, institutional and national strategies

15.8. Dismantling of the Facility

- Work Breakdown Structure (WBS)
- Removal of radioactive and other wastes

15.9. Final Radiological Survey

15.10. License Termination

15.11. Release of Site from Regulatory Control

15.12. Reduction to a green field site or reuse of the facilities

16. CONCLUSIONS

The decommissioning plan should take part of the documentation presented to commission nuclear installations. In the initial IPR-R1 licensing, the decommissioning aspects were not considered and no decommissioning plan was developed during the commissioning activities. Nowadays, the reactor operating at CDTN/CNEN is being commissioned for operation in 250 kW. The decommissioning plan for it is being written and will take part of this new licensing documentation.

This documentation, as [21], regarding to the decommissioning planning can be used as a guide for other radioactive installation for licensing future processes or for revision of existent documentation.

16.1. Final Radiological Survey Report

16.2. Inventory of Residual Radioactive and Non-Radioactive Wastes

16.3. Summary of any abnormal events and incidents

16.4. Summary of occupational and public doses

16.5. Lessons Learned

17. REFERENCES

IAEA Publications

A. Code of Conduct on the Safety of Research Reactors

B. Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management

C. Handbook on Nuclear Law

D. Safety Fundamentals

1. Draft Safety Fundamental DS298
   Principles of Nuclear, Radiation, Radioactive Waste and Transport Safety

E. Safety Requirements

1. Safety Series No. 115
   International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources

2. [Safety Standards Series No. GS-R-1]
   Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety
3. [Draft Safety Requirement DS333]
   Decommissioning of Nuclear Facilities
4. [Safety Standards Series No. NS-R-2]
   Safety of Nuclear Power Plants: Operation
5. [Safety Standards Series No. WS-R-2]
   Predisposal Management of Radioactive Waste, Including Decommissioning

F. Safety Guides

1. [Safety Standards Series No. RS-G-1.7]
   Application of the Concepts of Exclusion, Exemption and Clearance
2. [Safety Standards Series No. WS-G-1.1]
   Safety Assessment for Near Surface Disposal of Radioactive Waste
3. [Safety Standards Series No. WS-G-2.1]
   Decommissioning of Nuclear Power Plants and Research Reactors
4. [Safety Standards Series No. WS-G-2.2]
   Decommissioning of Medical, Industrial and Research Facilities
5. [Safety Standards Series No. WS-G-2.3].
   Regulatory Control of Radioactive Discharges to the Environment.
6. [Safety Standards Series No. WS-G-2.4]
   Decommissioning of Nuclear Fuel Cycle Facilities
7. [Safety Series No. 111-G-1.1]
   Classification of Radioactive Waste
8. [Draft Safety Guide DS332]
   Release of Sites from Regulatory Control Upon the Termination of Practices

G. Safety Reports

1. [Safety Reports Series No. 26]
   Safe Enclosure of Nuclear Facilities During Deferred Dismantling.
2. [Safety Reports Series No. 36]
   Safety Considerations in the Transition from Operation to Decommissioning of Nuclear Facilities
3. [Safety Reports Series No. 44]
   Derivation of Activity Concentration Values for Exclusion, Exemption and Clearance
4. [Safety Reports Series No. 45]
   Standard Format and Content for Safety Related Decommissioning Documents

H. Technical Reports

1. [Technical Reports Series No. 395]
   State of the Art Technology for Decontamination and Dismantling of Nuclear Facilities
2. [Technical Reports Series No. 399]
   Organization and Management of Decommissioning of Large Nuclear Facilities
3. [Technical Reports Series No. 411]
   Record Keeping for the Decommissioning of Nuclear Facilities: Guidelines and Experience
4. [Technical Reports Series No. 420]
   Transition from Operation to Decommissioning of Nuclear Installations

I. TECDOCS

1. [IAEA-TECDOC-1124]
   On-Site Disposal as a Decommissioning Strategy

2. IAEA-TECDOC-1394
Planning, Managing and Organizing the Decommissioning of Nuclear Facilities: Lessons Learned
3. IAEA-TECDOC-1478
Selection of Decommissioning Strategies: Issues and Factors

J. Proceedings
1. Research Reactor Utilization, Safety, Decommissioning, Fuel and Waste Management
Proceedings of an International Conference, Santiago, Chile, 10-14 November 2003. STI/PUB/1212.
2. Safe Decommissioning for Nuclear Activities
Proceedings of an International Conference in Berlin, Germany, 14-18 October 2002. STI/PUB/1154.

CNEN and CDTN Documents and Standards

i. CDTN/CNEN, “Relatório de Análise de Segurança do Reator TRIGA IPR-R1” RASIN/TRIGA-IPR-R1/CDTN, Belo Horizonte, (2007).
ii. DALLE, H.M. Simulação do Reator TRIGA- IPR – R1 Utilizando Métodos de Transporte por Monte Carlo. Tese de Doutorado, Universidade Estadual de Campinas, São Paulo (2005).
iii. MESQUITA, A.Z., Investigação Experimental da Distribuição de Temperaturas no Reator Nuclear de Pesquisa TRIGA IPR-R1, Tese de Doutorado, Universidade Estadual de Campinas, São Paulo (2005).
iv. INTERNATIONAL ATOMIC ENERGY AGENCY, “Planning and management for the decommissioning of research reactors and other small nuclear facilities”, (IAEA-TRS-351), Vienna, Austria (1993).
v. National Report of Brazil for the Joint Convention on the safety of spent fuel management and on the safety of radioactive waste management, 2005.
vi. CNEN 1.04 (Nuclear Facilities Licensing)
vii. CNEN-NE-1.08.
viii. CNEN-NE-1.09.
ix. CNEN-NE-1.11.
x. “Brazil: A Country Profile on Sustainable Energy Development”.
xi. CNEN 3.01 (Basic Instructions for Radiation Protection)
xii. CNEN 6.02 (Licensing of Radioactive Installations)
xiii. CNEN 6.05 (Management of Radioactive Wastes)
xiv. AMORIM, V.A.; OLIVEIRA, P.F.,Developed Devices for Dismantling and Maintenance of IPR-R1 Research Reactor (NI-AT4-004/95) 39 p. 1995.
xv. DALLE, H.M.; TAMBOURGI, E.B., Shielding and Criticality Safety Analyses of a Latin American Cask for Transportation and Interim Storage of Spent Fuel From Research Reactors, 2003.
xvi. DALLE, H.M.; JERAJ, R.;TAMBOURGI, E.B., Characterization of Burned Fuel of the TRIGA IPR – R1 Research Reactor Using Monteburns Code, 2002.
xvii. TELLO, C. C. O; GROSSI, P. A; MESQUITA, A. Z., “Ipr-r1 triga research reactor decommissioning: preliminary plan”. In: International Nuclear Atlantic Conference, 2005. Anais. Santos: INAC 2007.
xviii. GROSSI, P. A; TELLO, C. C. O; MESQUITA, A. Z., “IPR-R1 TRIGA Research Reactor Decommissioning Plan” IRPA 12 – Buenos Aires, Argentina, October 2008.

18. TABLE OF REVISION

19. ANNEXES