The PRR-1 Characterization Survey Plan

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- Contents of this presentation:
  - Objectives of characterization survey
  - Considerations in preparing the Characterization Survey Plan
  - Approaches to be adopted in doing the characterization survey
  - Equipment needed
  - Preparatory work
  - Survey work flow in a typical location
  - The Characterization Survey Report

Objectives of Characterization Survey

- The objective of performing a hazards characterization survey of the PRR-1 is to obtain reliable data on the quantity, type, location, distribution, and physical and chemical states of radionuclides and other hazards in the facility

- The data generated should be appropriate as input for the following aspects of creating a decommissioning plan:
  - Choosing efficient decontamination and dismantling procedures and techniques
  - Properly providing for the safety of the workers and the public during decommissioning and afterwards
  - Properly disposing of or managing the hazardous waste generated by decommissioning
  - Properly estimating decommissioning costs
  - Meeting regulatory requirements

- Radiological hazards are expected to dominate in the PRR-1, but non-radiological hazards that may be encountered during decommissioning will also be identified
  - Common industrial safety hazards such as electrocution and falls
  - Lead and phenolic paint that may be present
  - Fortunately, asbestos and PCBs are not known to be present in the PRR-1

Considerations in Preparing the Characterization Survey Plan

- Regulations
  - Clearance levels
    - Code of PNRI Regulations: CPR Part 3, *Standards for Protection Against Radiation*
    - IAEA Safety Requirement: Safety Series No. 115, *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*
    - IAEA Safety Guide: Safety Standards Series No. RS-G-1.7, *Application of the Concepts of Exclusion, Exemption and Clearance*

  - Radiation protection levels
    - Radiation exposure limits given by CPR Part 3 and IAEA Safety Series No. 115 will apply to the entire PRR-1 decommissioning project, including the characterization survey
    - More conservative limits voluntarily adopted in the spirit of ALARA in Appendix D, *Administrative Limits*, of the application for the current PRR-1 license will apply to the characterization survey
  - Overlap in regulations?
    - No basic conflict between norms because CPR is based on IAEA Safety Standards
    - Where different limits are given, more conservative value will apply to comply with both requirements

- Radionuclides of interest
  - Radionuclides that are significant to decommissioning are given in Section 5 of IAEA Technical Reports Series No. 389, *Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes*
  - List of radionuclides may be reduced based on PRR-1 reactor type and history
    - Long shutdown time has eliminated short-lived radionuclides
    - Targets of some activation products low or absent in the PRR-1

- Low contamination level expected
  - PRR-1 relatively low-powered and lightly used
    - Neutron flux at 1 MW only about 1.0×10^{13} in core and several orders of magnitude lower in biological shield concrete
    - Total burnup only 617 MWd
  - Coolant water quality always high during entire reactor life
    - Conductivity kept between 0.1 and 1.0 µS and pH always slightly less than 7, even during long shutdown

- No known fuel cladding failure
  - Significant fission products never detected in coolant
  - Visual inspection has never detected significant corrosion in any fuel element
- Only small amounts of radionuclides processed in laboratories, all short-lived or producing little long-lived waste and contamination
  - Typical radionuclides produced were P-32, Br-82, Na-24, Au-198
  - No radioisotope production using fissionable targets was done

- Long decay period
  - Last day of operation at any power was in 1988
  - Last day of significant megawatt-level operation was in 1977
- All spent fuel shipped back to the U.S.A. under its take-back program in 1999
- Some cleaning up already done in the 1980s and 1990s
  - Some laboratory rooms have been decontaminated
  - Reactor pool has been drained and cleaned
  - Some irradiation facilities have been dismantled
  - Old reactor building ventilation system ductwork and filters have been removed

- Survey results must be reliable and complete
  - Must be good enough to base decommissioning plan on, especially costing
  - Must pass review by regulator
  - Must assume need to convince public as well

- Limited manpower, equipment and funding available
  - Characterization survey needs a range of skills not usually available in reactor operations personnel
  - Field survey and lab equipment at PNRI not suitable, too old, or already committed to other uses
  - No money in regular PNRI budget to cover survey expenses

Approaches to be Adopted in Doing the Characterization Survey

- Tap entire PNRI for manpower
  - Use remaining reactor staff (~10 people), with some additional training
  - Draft a few more people (~10) with appropriate training from PNRI research and radiation protection units
- Use the IAEA to obtain equipment and training
  - Technical Assistance program for equipment
  - R2D2P for training

- Get operational funding from extra-budgetary sources and savings
  - Use grants-in-aid program of the Department of Science and Technology (DOST)
  - Re-target some of maintenance and operational items in PNRI's annual budget

- Make Quality Assurance a fundamental part of the survey plan
  - Needed to assure that the data generated will have sufficient completeness and reliability
  - Design a QA Program to ensure that:
    - All significant hazards will be identified and characterized
    - Characterization methods and techniques used will be appropriate and will be performed according to plan
    - Instruments used will be appropriate, in good working order and accurate during use
    - The safety of the workers and the public will always be preserved

- QA Program should have the following features:
  - Policies will be stated in writing unambiguously
  - Work will be done according to written procedures
  - Procedures will have a clear preparation, review, approval and revision path
  - Performance of procedures will be documented
  - All numerical data produced will be traceable to a certified calibration standard

- Pre-classify areas based on expected level of contamination and vary survey method accordingly
  - Areas with very low likelihood of contamination will receive only wide-area survey, designed to be sensitive enough to detect anomalies from background in case of unexpected contamination
  - Identifying and mapping radionuclides in relation to clearance levels will be concentrated on areas which could actually be contaminated
  - Where there are radiation exposure doses that are significant in comparison with occupational doses, emphasis will shift to taking measurements for radiation protection

- Category 1: Low Likelihood of Contamination
  - Locations in which radionuclides are not known to have been produced, processed, conveyed or stored, and into which there is very little likelihood of migration of radionuclides from contaminated areas
    - Includes spaces that were used exclusively as offices or for the storage of non-radioactive materials
  - Characterization approach is to do wide-area radiation scan to determine if higher than background radiation level is present in the area; precise criteria to be established with regulator
    - Requires that reference scans of similar but uncontaminated locations be available; such scans to be obtained in consensus with regulator
  - If location fails wide-scan background level criteria, location will be reclassified Category 2

- Category 2: Some Likelihood of Contamination
  - Locations not definitely known to be contaminated but where radionuclides were processed, conveyed, or stored, or have some likelihood of having been contaminated by migration of radionuclides
    - Includes rooms believed clean now but where radionuclides were used in the past, passages through which radionuclides were carried, and places where liquid spills could have spread

- Characterization approach is to do wide-area scan as in Category 1, supplemented with close-in manual scanning and sampling of spots where contamination is most likely
  - Spot levels will be compared with those of similar but uncontaminated spots; comparison criteria to be established in advance with regulator
  - Requires that reference measurements be available; such measurements to be obtained in advance in consensus with regulator
- If location fails any spot measurement, location will be reclassified Category 3

- Category 3: High Likelihood of Contamination
  - Locations that were not directly neutron-irradiated, but into which neutron activation products have a direct migration path, or otherwise have a high probability of being contaminated
    - Includes parts of the concrete biological shield that were remote from the reactor core but were reached by leaking water, the interior of the primary coolant piping that may have deposits, and the underground piping that drains the sump of the Reactor Building
  - Characterization approach is to identify spots where the clearance level is exceeded (if any) by surveying the entire location in a grid
    - Manual scanning and sampling will be done along the entire grid
  - If the clearance level is exceeded in any spot, the location will be reclassified Category 4

- Category 4: Known to be Contaminated
  - Locations and items that are assumed or known to be contaminated above clearance level
    - Includes locations and items that were irradiated with neutrons, those containing known radioactive sources, and the locations of known spills
    - Specific examples are biological shield concrete close to the core, thermal column, beam tubes, and the ion-exchange column of the coolant purification system
  - Primary objective is to provide input for contamination removal
    - Survey must identify radionuclides and determine spatial distribution, including possible migration along cracks
    - In addition to surface survey, drilled core samples will be taken for detailed laboratory analysis where subsurface contamination could exist

- Category 5: Known Occupational Hazard
  - Items that are assumed or known to produce radiation doses that are significant in comparison with limits on occupational exposure
    - Specific examples are the core box, the fuel elements, the start-up neutron sources, in-core irradiation rigs and baskets, and Co-60 gamma irradiation sources that were stored in the reactor pool
    - These items will generally be moved whole to waste storage
  - Primary objective is to provide data for radiation protection during removal
    - Accurately measure radiation fields
    - Assess possible mobilization of contaminants
    - Will provide input data for specifying dismantling procedures, protective equipment and shielding

Equipment Needed

- *In-situ* survey equipment
  - Portable coarse-resolution gamma spectrometer with sensitive detector for wide-area radiation measurements
  - Portable scaler/rate meters with appropriate detectors for scanning for alpha, beta and gamma contamination of surfaces
- Sample-taking equipment
  - Core drill capable of taking subsurface samples from concrete and metals
  - Surface sampling tools

- Laboratory analysis equipment
  - High-resolution gamma spectrometer for the identification and measurement of gamma emitters
  - Liquid scintillation counter for the measurement of alpha and beta emitters and low-energy gamma emitters
  - Alpha/beta/gamma counter for the measurement of gross radioactivity in smear/swipe samples
  - Basic physical and chemical laboratory equipment for sample preparation

- Radiation protection equipment
  - Personal dosimeters
  - Protective clothing
- Record-keeping equipment
  - Digital cameras
  - Barcode makers and readers for samples
  - Computers for databases

Preparatory Work

- Organize and train personnel
  - Hazards characterization survey to be performed by the PRR-1 Decommissioning Task Force (created January 2007)
    - Task force members are remaining PRR-1 personnel and specialists in radiation protection, radiation detection and laboratory analysis from other PNRI units (approximately 20 people total)
  - Form work teams for:
    - *In-situ* survey (more than one team)
    - Sample-taking with special tools
    - Laboratory analysis
    - Instrument maintenance
    - Radiation protection

- Team leaders and specialists will orient and train team members
- Assign QA Manager

- Create QA Program, policies and procedures for:
  - *In-situ* surveys
  - Sample-taking
  - Laboratory analysis
  - Radiation protection
  - Equipment calibration and maintenance
  - Record management

- Categorize locations and items to be surveyed
  - Based on layout drawings and history of usage of the facility
  - Update according to present conditions and new information

- Obtain and set up equipment and workplaces
  - Portable counting equipment
  - Laboratory counting equipment
  - Calibration sources
  - Sample-taking equipment
  - Record-keeping equipment
  - Counting and sample-preparation rooms

- Determine natural-radiation references
  - Identify reference locations
  - Do measurements
  - Obtain consensus with regulator
- Obtain approval to do survey
  - Do operator-side review and approval
  - Submit characterization survey plan with application to modify reactor authorization to regulator

Survey Work Flow in a Typical Location

- Perform an initial visual inspection and radiation protection survey of the location
  - Intended to reveal occupational radiation and physical hazards
  - Will determine the radiation and physical protection measures (if any) that will be used
  - Also intended to reveal preliminary measures that may be necessary, such as clearing trash and extraneous materials in the location

- Prepare an action plan specific to the location
  - Will contain details such as coordinate system and sample numbering for the location
- Perform an *in-situ* wide-area gamma survey
  - Use stationary coarse gamma spectrometer
  - If location is Category 1 and result not significantly different from natural radiation, location is considered not contaminated and no further test is necessary
    - otherwise, reclassify location as Category 2

- Examine spots where contamination is likely to be concentrated
  - Manually scan selected spots with portable alpha, beta and gamma detectors
  - Take samples of selected spots for lab analysis
  - If location is Category 2 and results not significantly different from natural radiation, location is considered not contaminated and no further test is necessary
    - otherwise, reclassify location as Category 3

- Examine entire surface (Category 3 or higher)
  - Manually scan all surfaces with portable alpha, beta and gamma detectors
  - Take samples on a grid and in spots highlighted by scan for lab analysis
  - If location is Category 3 and no radioactivity is detected above clearance level, location is considered not contaminated and no further test is necessary
    - otherwise, reclassify location as Category 4

- Delineate, identify radionuclides, and compare contamination to clearance level (Category 4 or higher)
  - Use portable detectors and take samples for lab analysis as in Category 3
  - Take subsurface samples of porous materials
  - Take very deep core samples of concrete biological shield along construction pour joints, following water leakage paths
  - Identify and characterize possible debris and airborne contamination for radiation protection during future dismantling

- Characterize radiological hazards for radiation protection measures and waste handling measures during future dismantling (Category 5)
  - Map direct exposure radiation field
  - Do Category 4 surveys too

The Characterization Survey Report

- Will describe the radionuclides, quantity, location, distribution, and physical and chemical form of all materials found with radioactive contamination above clearance level in the PRR-1
- Will describe radiological and other occupational hazards that should be expected during the dismantling and decontamination phase of decommissioning
- Will describe the methods and techniques used to perform the characterization survey and their scientific validity
- Will be an essential input to the preparation of the Decommissioning Plan