Decommissioning

Chapter XVII

Introduction

- **The decommissioning of a nuclear facility signifies:**

  "the measures taken at the end of its operating life to cease its operation without endangering the health or the safety of personnel or the public, nor compromising the integrity of the environment."

- **The term decommissioning refers to administrative and technical actions taken to allow removal of some or all of the regulatory controls from a nuclear facility (except for a repository).**

Introduction (Contd.)

- **These actions involve:**
  - **Decontamination,**
  - **Dismantling and**
  - **Removal of radioactive materials, waste, components and structures.**
- **Decommissioning of nuclear facilities comprise:**
  - ✓ **preparation and approval of a decommissioning plan;**
  - ✓ **the actual decommissioning operations; and**
  - ✓ **the management of waste resulting from the decommissioning activities.**

Introduction (Contd.)

- **The time period to the decommissioning activities for nuclear power plants and research reactors may typically range from a few years to decades (for example, to allow for radioactive decay).**
- **Decommissioning may be carried out in one continuous operation following shutdown or in a series of discrete operations over time (i.e. phased decommissioning).**

Regulatory Framework

- **The regulatory framework of a country should include provision for the decommissioning of nuclear installations, in particular nuclear reactors.**
- **National regulatory authorities should:**
  - ✓ **provide guidance on radiological criteria for the removal of regulatory controls over the decommissioned installations and sites; and**
  - ✓ **ensure that an adequate system is in place for properly managing the removal of controls.**

Stages of Decommissioning

- **By definition, there are three stages of decommissioning but are not intended to be rigid and can be varied to suit each case.**
- **These stages are defined by two characteristics:**
  - ✓ **the physical state of the plant and equipment**
  - ✓ **the surveillance, inspections and tests necessitated by that state.**

Stages of Decommissioning (Contd.)

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❑ Stage 1 (Storage with surveillance)

❖ State of the plant and equipment

- ✓ **First contamination barrier is kept as it was during operation**
- ✓ **mechanical opening systems are permanently blocked and sealed (valves, plugs, etc.)**
- ✓ **The atmosphere inside the containment building is subject to appropriate control**
- ✓ **Access to the inside of the containment building is subject to monitoring and surveillance procedures**

Stages of Decommissioning (Contd.)

- **Stage 2 (Restricted site release)**
  - **State of the plant and equipment**
    - ✓ **First contamination barrier is reduced to minimum size (all parts easily dismantled or removed)**
    - ✓ **Decontamination to acceptable levels**
    - ✓ **containment building and the nuclear ventilation system may be modified or removed**
    - ✓ **access to the containment building can be permitted**

Stages of Decommissioning (Contd.)

- **Stage 3 (Unrestricted site release)**
  - **all materials, equipment and parts of the plant are removed**
  - **contamination has been reduced to acceptable levels**
  - **the plant is decommissioned (released) with out restriction**
  - **no further surveillance, inspections or tests are necessary.**

Decommissioning Options

- **There are 3 primary decommissioning options:**
  - **Immediate Dismantling**
    - ✓ **all components and structures that are radioactive are cleaned or dismantled, packaged and shipped to a low-level waste disposal site, or they are stored temporarily on site.**
    - ✓ **this task may take five or more years for its completion**
    - ✓ **that portion of the site can be reused for other purposes.**

Decommissioning Options (Contd.)

❑ Deferred Dismantling

- ✓ **The plant is kept intact and placed in protective storage for tens of years (20 to 150).**
- ✓ **This method involves locking that part of the plant containing radioactive materials and monitoring it with an on-site security force and uses time as a decontaminating agent.**
- ✓ **If a plant is allowed to sit idle for 30 years, for example, the radioactivity from cobalt-60 will be reduced to 1/50th of its original level; after 50 years, the radioactivity will be just 1/1,000th of its original level.**
- ✓ **Once radioactivity has decayed to lower levels, the unit is taken apart similar to Immediate Dismantling.**

Decommissioning Options (Contd.)

❑ Entombment

- ✓ This option involves encasing radioactive structures, systems and components in a long-lived substance, such as concrete.
- ✓ The encased plant would be appropriately maintained, and surveillance would continue until the radioactivity decays to acceptable level.
- ✓ To date, no facility owner have proposed the entombment option for any nuclear power plants undergoing decommissioning.

Decommissioning Options (Contd.)

- **Factors that influence decommissioning options are:**
  - ✓ national nuclear strategy, including waste handling policy
  - ✓ condition of the plant from the safety point of view
  - ✓ Owner's interest including planned use of site
  - ✓ availability of decommissioning technology
  - ✓ post-operational cost
  - ✓ social consideration
  - ✓ availability of funds
  - ✓ optimization of decommissioning plan

Decommissioning Options (Contd.)

- **Factors to be considered in selection of preferred decommissioning option:**
  - ✓ **compliance with laws and regulations;**
  - ✓ **characterization of the installation, including the design and operational history as well as the radiological inventory;**
  - ✓ **safety assessment of the radiological and non-radiological hazards;**
  - ✓ **the physical status of the nuclear installation;**
  - ✓ **adequate arrangements for waste management;**

Decommissioning Options (Contd.)

- ✓ **adequacy and availability of financial resources;**
- ✓ **availability of experienced personnel and proven techniques, including decontamination, cutting and dismantling, as well as remote operating capabilities;**
- ✓ **lessons learned from previous, similar decommissioning projects;**
- ✓ **the environmental and socioeconomic impact;**
- ✓ **the anticipated development and use of the installation and the area adjacent to the site.**

Facilitating Decommissioning

- **To facilitate decommissioning consideration should be given:**
  - ✓ **at the design stage for a new reactor installation, or**
  - ✓ **as soon as possible to existing installations**
- **A thorough review of design features, from the viewpoint of facilitating decommissioning, should be performed during the design stage of the reactor installation.**
- **In general, design features which assist maintenance and inspection during the operational lifetime of the reactor will also assist decommissioning.**

Facilitating Decommissioning (Contd.)

- **The design features which may assist are:**

a) Careful selection of materials to:

- ✓ **reduce activation;**
- ✓ **minimize the spread of activated corrosion products;**
- ✓ **ensure that surfaces are easy to decontaminate; and**
- ✓ **minimize the use of potentially hazardous substances (e.g. oils, flammable and chemically hazardous materials and fibrous insulations);**

Facilitating Decommissioning (Contd.)

b) Optimization of the plant's design, layout and access routes to facilitate:

- ✓ **the removal of large components;**
- ✓ **easy detachment and remote removal of significantly activated components;**
- ✓ **future installation of decontamination and waste handling equipment;**
- ✓ **decontamination or removal of embedded components such as pipes and drains; and**
- ✓ **control of radioactive material within the installation.**

Decommissioning Techniques

- **Decommissioning operations are based on the use of a variety of techniques, the most important are:**

❑ **Radioactivity Measuring Techniques**

➢ **They are useful for:**

- ✓ **choosing the decontamination processes,**
- ✓ **sorting materials and wastes into categories,**
- ✓ **batching wastes and packaging them,**
- ✓ **making arrangements for worker protection, and**
- ✓ **checking on completion of the work that no significant trace of radioactivity remains.**

Decommissioning Techniques (Contd.)

❑ Decontamination Techniques

- **These are various chemical, mechanical, electrical or mixed processes for removing contamination from metal, concrete or other surfaces.**

❑ Cutting Techniques

- **It is frequently desirable to cut the piping and sometimes the equipment in to pieces sized approximately to facilitate either:**
  - ✓ **decontamination in a centralized decontamination facility or**
  - ✓ **packaging in a container for disposal as radioactive waste.**

Decommissioning Techniques (Contd.)

- These cutting operations can be performed either under water or in air by using:
  - ✓ remotely- operated or
  - ✓ directly - operated devices;
- Cutting operations depends upon the:
  - ✓ location of the material to be cut;
  - ✓ levels of radioactivity present; and
  - ✓ nature of the material to be cut.

Decommissioning Techniques (Contd.)

❑ Remote Control Techniques

- **Remotely controlled devices are used in presence of radiation fields and/or contamination to protect operating personnel from radiation exposure.**
- **These devices needs to be capable of functioning under water as well.**
- **These devices may require lighting and viewing equipments to aid the operators in seeing and controlling the work.**

Decommissioning Techniques (Contd.)

❑ Techniques for Worker and Environmental Protection

- **These contribute to protecting workers against irradiation and contamination, and the environment against the spread of contamination. They involve:**
  - ✓ **temporary moveable shields**
  - ✓ **airlocks and temporary cells,**
  - ✓ **mobile ventilation and filtration systems,**
  - ✓ **a variety of special clothing (breathing air suits, masks,…)**

Decommissioning Techniques (Contd.)

- **Each of these techniques involves a great variety of tools or equipment items, each of which has well defined fields of application and conditions of use.**
- **The problem is to find the most suitable tool for a particular operation.**
- **The choice of any technique must always take into account to the secondary wastes produced (liquid or gaseous).**

Planning for Decommissioning

- **A decommissioning plan should be prepared for each reactor.**
- **The extent of such plans, their content and degree of detail required may differ, depending on the complexity and hazard potential of the nuclear installation, but it should be consistent with national regulations.**
- **The operating organization should plan for adequate financial resources to ensure the decommissioning of a nuclear reactor.**

Planning for Decommissioning (Contd.)

- **Three stages of planning are envisaged:**
  - ✓ **Initial**
  - ✓ **Ongoing**
  - ✓ **Final**
- The degree of detail will increase from the initial to the final decommissioning plan.

❑ Initial Planning

- An initial plan for decommissioning should be prepared and submitted to regulatory body.

Planning for Decommissioning (Contd.)

- **The initial plan may address:**
  - ✓ Feasibility of decommissioning;
  - ✓ Costs of decommissioning; and
  - ✓ Means of financing the decommissioning work.

❑ Ongoing Planning

- **During the operation of a reactor, the decommissioning plan should be reviewed, updated and made more comprehensive with respect to:**
  - ✓ Technological developments in decommissioning;
  - ✓ Incidents that may have occurred, including abnormal events;

Planning for Decommissioning (Contd.)

- ✓ Amendments in regulations and government policy; and
- ✓ Cost estimates and financial provisions, where applicable.

❑ Final Planning

- ➢ **Final decommissioning plan is prepared when the final shutdown of a nuclear reactor is known.**
- ➢ **The experience from previous decommissioning should be appropriately taken into account.**
- ➢ **The following list of items to be considered for the final decommissioning plan:**
  - ✓ **description of the nuclear reactor, the site and the surrounding area that could affect and be affected by decommissioning;**

Planning for Decommissioning (Contd.)

- ✓ the life history of the nuclear reactor;
- ✓ the planned use of the site during and after decommissioning;
- ✓ legal and regulatory framework;
- ✓ description of the proposed decommissioning activities, including a time schedule;
- ✓ safety assessments and environmental impact assessments;
- ✓ proposed environmental monitoring programme;
- ✓ availability of special services, engineering and decommissioning techniques;
- ✓ quality assurance programme;
- ✓ waste management practices;
- ✓ physical security arrangements and details of emergency preparedness;

Financial Assurance for Decommissioning

- **The cost of decommissioning is based on the following factors:**
  - ✓ **The sequence of decommissioning stages chosen;**
  - ✓ **The timing of each decommissioning stage;**
  - ✓ **The decommissioning activities accomplished in each stage; and**
  - ✓ **The site-specific factors:**
    - **type of reactor;**
    - **waste management;**
    - **disposal practices; and**
    - **labor rates.**

Critical Tasks of Decommissioning

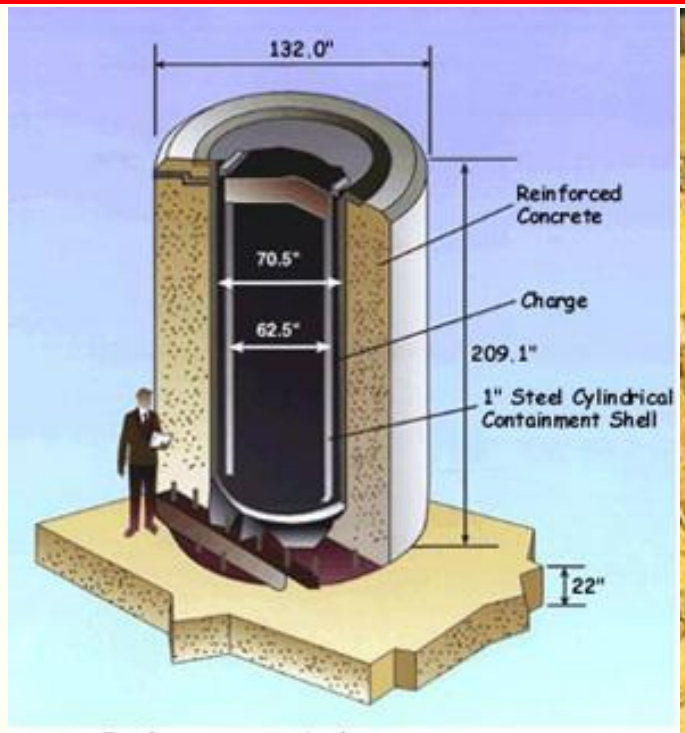
1. Fuel Removal
2. Containment maintenance and modification
3. Decontamination
4. Dismantling
5. Maintenance
6. Final radiological survey

Critical Tasks of Decommissioning (Contd.)

1. Fuel Removal

- The removal of spent fuel from the reactor installation at the end of its operational lifetime can be performed:
  - ✓ as part of operations or
  - ✓ as one of the initial activities in decommissioning.
- The time for fuel removal will vary considerably, depending upon:
  - ✓ the type and size of the reactor,
  - ✓ the condition of the fuel, and
  - ✓ the constraints for its transport and
  - ✓ off-site management.

Critical Tasks of Decommissioning (Contd.)



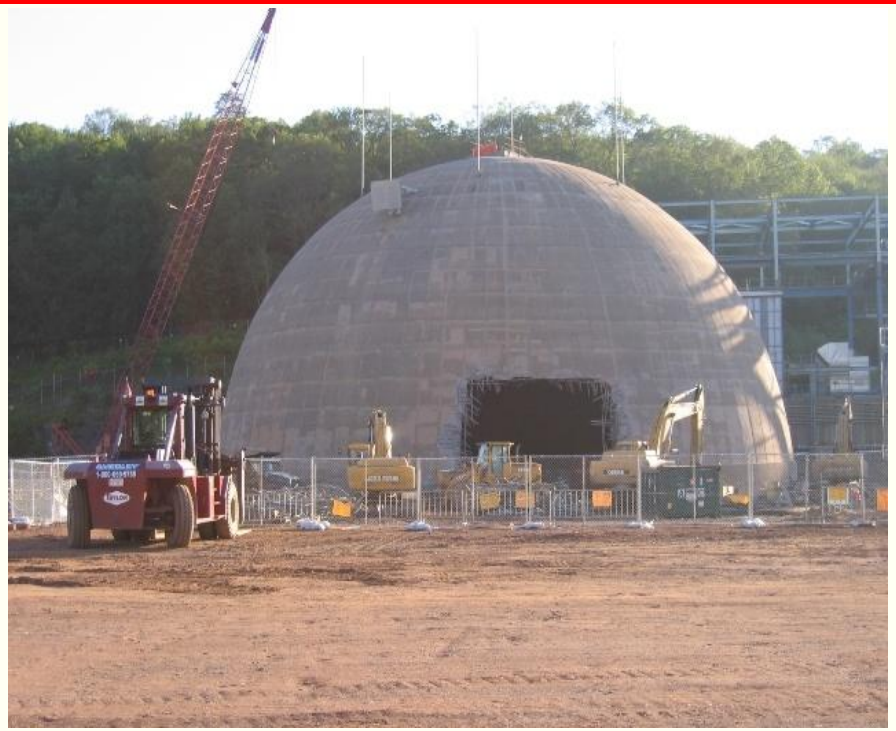
Spent Fuel Storage Cask

Critical Tasks of Decommissioning (Contd.)

2. Containment maintenance and modification

- Containment is an important element of defense in depth to prevent the movement of residual radionuclides.
- Care should be taken to retain containment systems as long as necessary and feasible.
- The containment may require changes during decommissioning as:
  - ✓ **radioactive materials (spent fuel and operational waste) are removed from the installations; or**
  - ✓ **the installation is modified, for example, in order to increase accessibility.**

Critical Tasks of Decommissioning (Contd.)



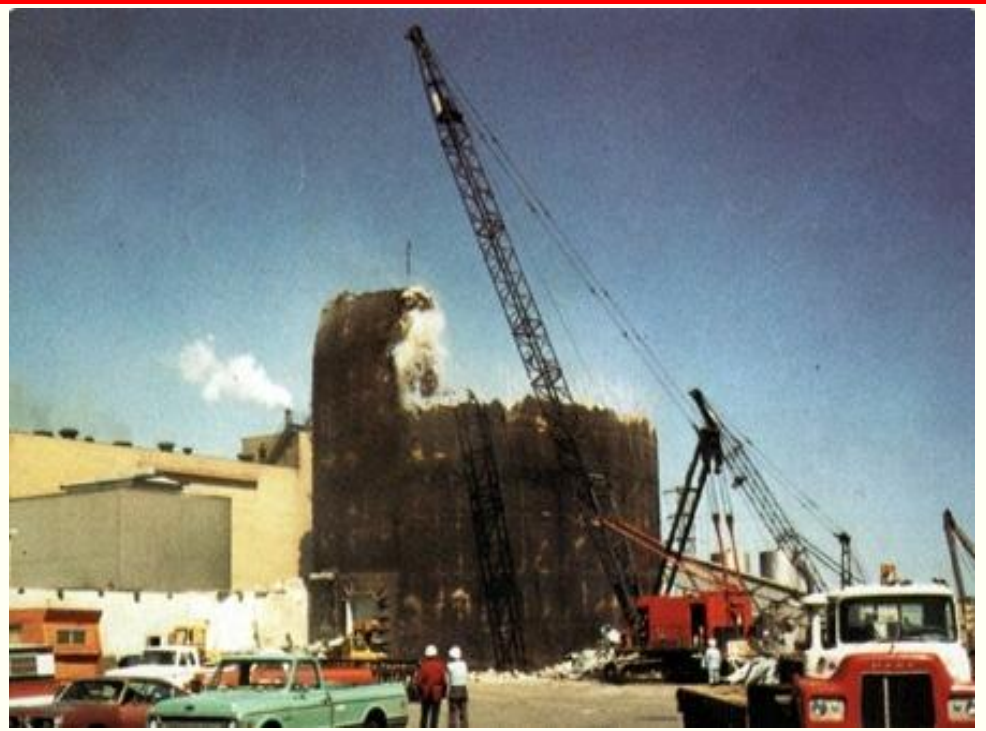


Figure: Demolition of Containment Building

Critical Tasks of Decommissioning (Contd.)

3. Decontamination

- **The term decontamination covers the broad range of activities directed to the removal or reduction of radioactive contamination in or on materials, structures and equipment at a nuclear installation.**
- **The objectives of decontamination include:**
  - ✓ **A reduction of exposures during decommissioning activities;**
  - ✓ **A minimization of the volume of the categories of material to be classified or disposed of as solid radioactive waste; and**
  - ✓ **The increase of the possibility of recycle and reuse of equipment, materials or premises.**

Critical Tasks of Decommissioning (Contd.)

4. Dismantling

- Dismantling refers to all the operations using disassembling, cutting and demolition techniques to remove contaminated or activated materials and structures.
- Selection of methods and techniques to be used in safe dismantling should take into account such aspects as:
  - ✓ **the types and characteristics (e.g. size, shape and accessibility) of materials, equipment and systems to be dismantled;**
  - ✓ **the availability of proven equipment;**
  - ✓ **the radiation hazards to the worker and the general public;**

Critical Tasks of Decommissioning (Contd.)

- ✓ the environmental conditions of the workplace;
- ✓ the radioactive waste produced; and
- ✓ the non-radioactive waste produced;

➢ Each dismantling task should be analysed to determine the most effective and safe method for its performance. Some considerations are as follows:

- ✓ equipment should be simple to operate, decontaminate and maintain;
- ✓ effective methods for controlling airborne radionuclides should be implemented;
- ✓ effective control of discharges to the environment;

Critical Tasks of Decommissioning (Contd.)

- ✓ when underwater dismantling and cutting is used, provision should be made for water processing to ensure good visibility and assist in effluent treatment;
- ✓ the effect of each task on adjacent systems and structures and on other work in progress should be evaluated; and
- ✓ waste containers, handling systems and routes should be defined before the start of dismantling work.

Critical Tasks of Decommissioning (Contd.)

5. Maintenance

- **Maintenance is important during deferred decommissioning;**
- **Part of the safety of the installation may rely on systems that have to retain their capability to perform for extended periods of time.**
- **Periodical monitoring of all the safety related components of the installation should be incorporated into the decommissioning plan.**

Critical Tasks of Decommissioning (Contd.)

6. Final Radiological Survey

- **At the completion of the decontamination or dismantling activities, a survey of the residual radionuclides at the reactor site should be performed to demonstrate that:**
  - ✓ **the residual activity complies with the criteria set by the national regulatory authority; and**
  - ✓ **the decommissioning objectives have been fulfilled.**
- **This survey may be carried out in phases, as decommissioning work is completed, to enable parts of the site to be released from regulatory control.**

Critical Tasks of Decommissioning (Contd.)

- The survey data should be documented in a final survey report and submitted to the regulatory body.
- The report should form one of the bases for:
  - ✓ reuse of the site or
  - ✓ its release from regulatory control.
- The report should include:
  - ✓ criteria used;
  - ✓ methods and procedures to ensure that the criteria were met; and
  - ✓ measurement data, including appropriate statistical analysis and systematic approaches used.
- The results of the survey should be included in the final decommissioning report.

Completion of Decommissioning

- **A final decommissioning report should be prepared, sustained by the records assembled and containing the following information:**
  - ✓ **description of the installation;**
  - ✓ **decommissioning objectives;**
  - ✓ **radiological criteria used as a basis for the removal of the equipment, buildings or site from regulatory controls;**
  - ✓ **description of the decommissioning activities;**
  - ✓ **description of any remaining buildings or equipment not decommissioned or partially decommissioned;**
  - ✓ **final radiological survey report;**

Completion of Decommissioning (Contd.)

- ✓ **inventory of radioactive materials, including:**
  - **amounts and types of waste generated during decommissioning; and**
  - **location for storage and/or disposal;**
- ✓ **inventory of materials, equipment and premises released from regulatory control;**
- ✓ **summary of any abnormal events and incidents that occurred during decommissioning;**
- ✓ **summary of occupational and public doses received during the decommissioning; and**
- ✓ **lessons learned.**

➢ **<u>This report provides confirmation of the completion of decommissioning.</u>**

Thanks