

Design for Decommissioning

Report No. PEC-DFD-2006

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Revision 2, March 2010

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Revisions

I welcome comments and suggestions for inclusion in future revisions of this document, with the understanding that they will be reviewed for inclusion with the following criteria:

- Any material included will be in the public domain, as is this report, and is released from any copyright restrictions.
- The focus is technical aspects of design. Of course there are many other types of lessons important to decommissioning. This document is not intended to address other subjects or provide general advice.
- We have not included topics that relate primarily to operations unless they also are useful for post-operational deactivation, cleanup, equipment removal, decontamination, demolition, dismantling, etc.

Chuck Negin
January 2006

Record of Changes

Version	Date	Changes
Revision 0	November 2006	Original Issue
Revision 1	January 2007	Incorporate comments from A. Szilagyi of DOE
Revision 2	March 2010	Incorporate discussion of In Situ Decommissioning

1. INTRODUCTION

1.1 Purpose

Decommissioning activities for almost any type of facility are well within the technological state-of-the-art¹. The major impact for complications resulting from insufficient consideration during design of a new facility that involves radioactive processes and/or material is the cost of: a) gaining access to high radiation areas and b) dealing with high levels of contamination. For this reason, this document has been assembled as a way of raising the awareness of designers and design reviewers to features that can both impact and facilitate ultimate decommissioning. The intent is that this can be used in the early stages of design development when requirements are being assembled.

The focus is on types of facilities that contain nuclear and/or radioactive processes and materials. The level of detail presented herein is more specific than would be found in most decommissioning plans prepared for regulatory purposes.

1.2 Advice to Keep Design for Decommissioning in the Proper Context

Two cautions are advised in applying the recommendations herein:

- Designing for the operational mission of the facility is a higher priority than accommodating ease of decommissioning. The recommendations here should be considered as preferable design practices when they can be accommodated without compromising the primary design objectives.
- The content of this document should be considered as guidance and *not* design requirements. It is noted that some will become requirements because they are incorporated in modern building codes. (An example is prohibition on the use of a variety of hazardous materials such as asbestos.)

1.3 Report Organization

Sections 2 through 5 are topically organized. Section 6 provides a general example of how a checklist can be created to use this information. It also includes the results of how the general checklist was modified for the first application of this report.

¹ Although within the state of the art, there is always room for improvement in decommissioning technologies.

1.4 Sources

Primary Sources

The information in this document combines the authors' experience² with selected information from the following two documents:

1. Headquarters, Department of the Army, TM 5-801-10, *General Design Criteria To Facilitate The Decommissioning of Nuclear Facilities*, <http://www.army.mil/usapa/eng/index.html>, 3 April 1992.
2. International Atomic Energy Agency, Technical Report Series No. 382, *Design and Construction of Nuclear Power Plants to Facilitate Decommissioning*, 1997. (Only available in paper copy.)

Thanks go to Michel Laraia of the IAEA for providing Reference 2 above.

PEC-DFD-2006 is a public domain report. There are no licensing or copyright restrictions for replicating its content by others for use in their own reviews. When so used, C. A. Negin and C. S. Urland should be acknowledged as authors. We encourage users to read the above two references and acknowledge them as appropriate.

Many of the requirements from the Army and IAEA references have not been included where the authors consider them to be nuclear facility design requirements *regardless* of decommissioning considerations. It is anticipated that these omitted requirements will be addressed in the course of other reviews, such as for operability, maintenance, and radiation protection for workers.

It is noted that the two references have heavy emphasis on decontamination. However, decontamination is complex, expensive, and time consuming. Experience indicates that decontaminating to the point of free release of materials or equipment is generally not economically feasible and can severely impact decommissioning schedules. Decontamination is selectively conducted for very specific reasons of dose reduction or waste disposal cost reduction. However, much of the decontamination information in these references has been included because incorporation of design features for decontamination activities that will occur during the facility's operational life cycle will also be of value during decommissioning. Where operational radiation levels will be very high, there is high value in the ability to decontaminate surfaces exposed to minor leakages and releases.

Other Sources

In addition to the content of the above two references, there are many other references that can provide insights to technical planners and facility designers. A few examples that provide guidance specific to deactivation and decommissioning of the U.S. Department of Energy facilities are³:

- DOE G 430.1-2, Implementation Guide for Surveillance and Maintenance during Facility Transition and Disposition
- DOE G 430.1-3, Deactivation Implementation Guide

² C. Negin and C. Urland have been involved in planning and execution of nuclear and radioactive facility decommissioning projects since the early 1980s.

³ located at <http://www.directives.doe.gov/directives/current.html#number>

- DOE G 430.1-5, Transition Implementation Guide
- DOE G 430.1-4, Decommissioning Implementation Guide

These four guides are not focused on design, but rather planning various phases of decommissioning. Similarly, much decommissioning guidance can also be found in IAEA documents⁴. Look in the nuclear fuel cycle and waste management section.

1.5 Decommissioning Phases

Two major phases of decommissioning during which there is significant physical modifications to a facility are: a) deactivation; that is, shutting down and deactivating for a term of inactivity prior to demolition, and b) demolition. A brief perspective for these phases is provided below because they are part of the basis for the content in this report.

Deactivation Phase

When a facility is shut down, stabilization occurs to reduce or eliminate high energy sources, remove hazardous and nuclear materials, immobilize contamination to prevent uncontrolled migration, and otherwise create a set of facility conditions that are safe and stable.

Deactivation proceeds further to establish minimum surveillance and maintenance in a stable set of conditions, preferably without continuous occupancy. When a facility is deactivated, systems and major components will be viewed in three ways:

- Many will be permanently shutdown, isolated, made inoperable, and abandoned in place.
- Some will need to remain operational (typical examples are listed later in the systems section)
- A few may be mothballed for later use. The primary example is major cranes that may be useful when equipment is removed prior to demolition.

The main emphasis for design review of new facilities is the ability to power systems that are likely to remain operable while much of the electrical system is deenergized.

In addition to systems, deactivation also considers facility spaces and areas as follows:

- Those accessed periodically for surveillance and maintenance; this would apply to walkthrough areas for checking on building integrity and areas that contain systems remaining active, such as ventilation fans and filters.
- Those that will rarely or never be entered until demolition; for example hot cells or other highly contaminated areas.
- Those exterior to the main facility, such as cooling towers, valve stations, storage buildings, etc.

The main emphasis for accessibility design in consideration of deactivation is an understanding of the habitability of areas most likely to be accessed in a deactivated condition.

⁴ <http://www-pub.iaea.org/MTCD/publications/SubjectAreas.asp>

Demolition Phase

Demolition is characterized by the following general sequence of activities:

- Selected decontamination, if any for contamination control, dose reduction, and/or waste management.
- Modifications if there are adjacent facilities that would otherwise be affected by the demolition (e.g., structural integrity, utilities that pass through to other buildings, etc.)
- Abatement of materials hazardous to workers (e.g., asbestos, mercury, beryllium, etc.)
- Isolation of buildings from active site services and utilities
- Removal of equipment prior to demolition (note that for contaminated facilities, much equipment may remain in place during demolition to be disposed to local approved landfills in bulk as part of the demolition waste)
- Demolition of buildings and foundations
- Backfill and grading of foundations holes

Understanding this sequence of activities provides input to developing the recommendations herein.

1.6 In Situ Decommissioning

In situ decommissioning; also referred to as entombment, is an approach in which the main buildings are not demolished. This method of decommissioning is most applicable to massive reinforced concrete structures such as reactor buildings/containments, processing canyons, and other heavily shielded facilities that will become contaminated

If there is precedent at the site, reviewing the design for compatibility with an in situ decommissioning should be considered. It can also be considered at other sites if agreed to. As can be seen in Section 6 herein, such reviews do not substantially add to what is already in this report. A comprehensive description of in situ decommissioning is in “DOE EM Strategy and Experience for In Situ Decommissioning,” published in September 2009. It should appear on the EM web site sometime in early 2010.

It must be kept in mind that in situ decommissioning does not mean one walks away from the facilities without any decommissioning activities. There will be requirements for removal of some equipment that is contaminated and removal of structures that will eventually fail; for example, steel superstructures. Therefore, this report should be used accordingly.

2. YARD AND EXTERIOR SPACES

2.1 Yard Areas

The area surrounding buildings that will contain contamination or large buildings in general should be reviewed for the following.

- Sufficient yard space should be available for mobile cranes and lifting equipment for:
 - placing and removing temporary equipment
 - waste container management; containers can be as large as 200 cubic feet and weigh as much as 20,000 pounds
 - removing roof or wall sections for access to large contaminated equipment that cannot reasonably be size-reduced within the facility
- Space should be available in the immediate area of the facility for waste operations that include survey, sorting, packaging, and staging for transport. This may be external (e.g., yard or nearby warehouse) or internal to the facility (e.g., large truck bay). Features include:
 - can be readily secured by fencing or other barrier
 - placement of temporary shielding
 - access for transport vehicles and cranes
 - not be a low point for area drainage
- Access will also be required for various types of equipment and vehicles such as heavy-duty trucks, demolition excavators, and earthmovers.

2.2 Underground Tunnels and Vaults

Removal of tunnels and underground vaults generally requires an amount of excavation and backfill work disproportionate to their size. However, depending on the facility layout and local area constraints, such features may be necessary in the design to enclose piping or ventilation ducting that contains contaminated fluids.

The overall recommendation is that designers should take a prudent approach of avoiding excessive placement of large below-grade tunnels and vaults.

2.3 Roofs and Siding

Layout of roofs, roof hatches, and building walls is a consideration for the ability to remove contaminated equipment and tanks to minimize the need to conduct in-situ size reduction (See Section 3.3. below).

Roof and siding materials should not contain asbestos containing materials (ACM), which is prohibited by current standards. This will avoid the cost of abatement during demolition and will also increase safety by not requiring workers to remove ACM roofing prior to demolition.

3. STRUCTURES AND INTERIOR SPACES

3.1 Interior Spaces

Interior space within buildings during decommissioning is of interest for the following reasons:

- Placement of cleanup and/or waste processing equipment. Processing examples include size reduction of large metal components, water wash and flushing, and decontamination systems, and others. Contamination control barriers and HEPA ventilation support will create a need for adjacent space.
- Waste staging and packaging, removal of existing equipment (i.e., lay-down space or fork-lift maneuvering), room for temporary processing skids, etc.

If there is insufficient interior space available during demolition, alternatives include addition of ante-rooms and air locks to allow egress of large equipment into contaminated areas, construction of tents and enclosures, etc.

3.2 Use of Hazardous Materials

A major challenge prior to demolition is removing construction materials that have been classified as hazardous waste; examples include asbestos, mercury containing switches, PCB light ballasts, lead-based paint, PCB-based paint, and various lubricants and coolants. Such materials that become radioactively contaminated become a mixed-waste, which is very costly to dispose. For these reasons, such materials should be avoided.

This may not be an issue for new designs because Modern building codes eliminate the use of most of these materials. Design requirements should stress the used of standards that prohibit their use unless absolutely necessary.

3.3 Placement of Large or Heavy Equipment

Wherever feasible, large or heavy equipment should be arranged for relative ease of removal or dismantling:

- For safety during bulk demolition, large or very heavy equipment must first be removed from elevated stories of a multi-story structure. The lifts are difficult, requiring large cranes and often hands-on demolition to gain access for removal. To the extent feasible, such equipment should be placed on ground level or basement floors.
- Large equipment that is installed by constructing the building around it should have removable wall or floor/ceiling panels to provide access for removal.
- Arrangement of large or very heavy equipment such as main ventilation fans and large pumps should have paths which allows for straight lifts and runs for removal with the understanding that during demolition, it is acceptable to remove walls and ceilings.
- Large equipment should be isolated from contamination to the extent practicable. In particular, electrical equipment such as transformers, switchgear, and motor control centers should not be installed in potentially contaminated areas.

3.4 Shield Walls & Floors

Demolition of shield walls and floors is expensive and difficult when they are contaminated or are extremely thick. Therefore:

- Rooms that are likely to be surface contaminated to significant levels (see hot cells discussion later) should have a removable liner or coating on floors and wall. Ceilings are less important except in small rooms and enclosures (i.e., a few feet or less in characteristic dimension).
- Concrete walls greater than 4 feet thick up to the first floor above grade and 3 feet thick on upper floors present challenges for conventional demolition equipment such as processor jaws and pneumatic hammers mounted on excavators. Clearly when deciding wall thickness the need for shielding during operation is more important than the ease of demolition. However, designers should be aware that if wall thickness greater than these can be avoided without compromising the design, such is preferred.

4. SYSTEMS AND EQUIPMENT

4.1 Systems for Deactivation

When a facility is deactivated, more often than not, several systems and equipment will remain operational. These are likely to be:

- Fire detection and fire suppression if a significant combustible loading remains following deactivation
- Exhaust ventilation (supply may be shut down and exhaust operated at a lower capacity to avoid too high a negative pressure in the buildings)
- Heating for freeze protection, especially if wet-pipe fire suppression remains operational
- Condensate drains if heating is with steam
- Sump pumping and level control system
- Low voltage circuits for lighting to support a periodic walk-through, or for connection of lighting strings.

The specific systems that need to remain operable depend very much on the type of facility, its geographical location, and the conditions of contamination within the facility.

The primary design consideration for systems deactivation is that it would be beneficial if the building electrical power systems are configured to allow these systems to be energized while everything else in the building is de-energized.

4.2 Service and Utility Systems Isolation

The ability to isolate piping and electrical systems at locations external to the facility from outside will facilitate demolition.

- For piping systems an external location should be provided that can be readily accessed (e.g., at a manhole or exterior building) for permanent isolation by installation of a blind flange, welded cap, or other means. For drains and sanitary effluent, a location where a permanent plug can be installed is important.
- Avoid routing *permanent* electrical power or fluid systems through a building to other buildings unless the buildings would clearly be demolished together.
- Avoid multiple points of connection to the extent possible for each utility, understanding that in some cases redundancy is needed for reliability. This will simplify the ability to render a facility ‘cold and dark’ or otherwise to a state requiring minimum surveillance and maintenance.

4.3 Pipes and Ducts

Design and placement of fluid system pipes and ventilation ducts should allow access for characterization, cleaning (e.g., flushing), injection of a fixative (e.g., grout or foam), and removal.

- Pipes, ducts, and equipment that carry contaminated fluids should not be embedded in walls, floors, or ceilings. They should not be run below concrete slabs on grade unless placed in chases or tunnels that are accessible through removable hatches or panels.

- Similarly, outdoor underground piping systems that contain contaminated fluids should be placed in enclosures, tunnels, or double walled pipe.
- Locations for connection of equipment for flushing or injection of fixative should be provided on highly radioactive systems. The entire radioactive portions of such should be able to be treated with such connections.

4.4 Tanks

Tank Placement and Arrangements

Tanks containing contaminated fluids should be placed in above-grade rooms. If below-grade placement is the only option, acceptable alternatives are:

- Tanks can be placed in a buried concrete vault with a sump that allows remote pumpout. The vault surfaces should be coated, sealed, or lined to prevent both in and out leakage. Access should be provided to allow decontamination of the interior surface of the vault.
- Direct burial of double-walled tanks may also be used; however, these will be much more difficult to remove. Buried tanks should not be tied to other structures.

Tank Cleanout

The need to gain access during decommissioning to the interior of large tanks that contained contaminated fluids or process media is a one-time occurrence that is nevertheless quite important for purposes of dose reduction. This is accomplished with pressure washing equipment, removal of sludge, and alternate pumping of contents. To accommodate the need for these types of operations:

- The ability to access tanks near their top with an opening large enough to insert equipment for operations such as power washing or applying fixatives. Because such openings may *not* be required during the normal operating life of the facility, there is reluctance to include a large flanged opening that will be used only once and is a potential source of leakage during the facility's life. To accommodate these conflicting needs/concerns, consideration should be given to a manway-sized flanged opening that can remain closed for the operational lifetime and perhaps seal welded to prevent leaks.
- A related need is sufficient overhead space above the tank and below the ceiling of its enclosure for placement of shielding, access by personnel, placement and operation of cutting equipment, insertion of equipment for visual inspection of the tank interior, and cleanout equipment such as high pressure water washers. This translates to at least 5 feet of overhead clearance or ability to remove panels or plugs from the ceiling to gain access from the floor immediately above the tank.
- Similar considerations apply to lateral clearance between tanks and walls of their enclosed space.
- For cleanout of tanks that contain solids or are likely to accumulate sludge, conical bottoms are preferable to flat or dished bottoms.

4.5 Crud Traps

Crud traps are locations in radioactive fluid systems that promote the accumulation of sediment or sludge. These should be eliminated to the greatest degree possible. Design methods to minimize crud traps include:

- Instrument taps should not be from the bottom of piping
- Drain connections should minimize collection or have the ability to be periodically flushed to the liquid waste system
- Unavoidable dead legs can be flushed via a valved path
- Piping sloped in the direction of flow; and to drain points
- Long radius bends on radioactive systems and resin-transfer systems
- Orifices located in vertical runs of pipe rather than in horizontal runs
- Tanks provided with sloped bottoms and a bottom drain
- Thermal expansion loops are above their piping
- Butt-welded piping to the extent practicable; avoid socket welds
- Valves with minimum internal dead spots and crevices where residues can accumulate

Depending on location, elimination of crud traps can reduce personnel exposure during operation and maintenance as well as during decommissioning

4.6 Laboratories

Cleanout of labs is made easier with the following considerations:

- Work Stations – Countertops should be designed to contain spills and prevent loss off the counter. The countertop design should, in particular, prevent radioactive liquids from seeping between the counter and wall. A sealed perimeter lip to contain spills is appropriate. Work stations shall be modular to allow removal and disposal of contaminated units.
- Surfaces – Nonporous, impermeable materials should be used on work surfaces. Countertops, walls, floors, or any surface on which contaminants could collect should be nonporous, sealed, lined, or coated in order to prevent the migration of contaminants into the materials of construction and to facilitate the cleanup of these surfaces.

4.7 Gloveboxes

Many of the standard design features for gloveboxes facilitate cleanup and removal; such requirements are not listed here. The following features are specifically to support removal prior to demolition:

- Avoid internal compartments, such as ventilation plenums, that are not readily accessible via the gloveports. Such features significantly complicate characterization and decontamination for removal and disposal.
- Glovebox lines longer than 8 feet should be able to be separated for size reduction and/or packaging for disposal.
- Pipes, ducts, and other attachments open to the glove box should be readily accessible for disconnection.

- Gloveboxes should not use a structural room wall as part of its containment envelope.
- Glovebox support legs, whether bolted or welded, should be accessible close to where they connect to the box for purposes of separation.
- Enclosed conveyor systems should be connected to gloveboxes in a manner that will allow removal from one end or the other. Alternately, an intermediate location should be provided where the conveyor enclosure can be separated for conveyor disassembly.
- When possible, glovebox shielding greater than one inch thickness should not be an integral part of the wall. That is, so that it can be separated from the glovebox without breaching the interior.
- Interior surfaces that can be decontaminated are especially important if:
 - they will contain solutions with high gamma radiation content
 - they will have materials with high transuranic radionuclide content

4.8 Hot Cells

Because of their basic function hot cells are likely to be very contaminated. This presents a challenge as they are not designed with a consideration that some sort of entry will be required preceding removal for decontamination and/or placement of a fixative coating. Another complication for demolition occurs when highly contaminated hot cell boundaries are an integral part of the building structure.

As a result the following should be considered in design:

- Avoid hot cell boundaries being integral to the building structural integrity; e.g., hot cell walls should not be building bearing walls.
- Consideration should be given to a removable wall or ceiling panel or shield plug that can remain sealed throughout the facility's operating life, but would be readily removed later. The size should be several feet in each dimension and sufficient for access by decontamination equipment and personnel.
- Avoid internal compartments, such as ventilation plenums, that are not directly accessible from within the cell. Such features significantly complicate characterization and decontamination for removal and disposal.
- Interior surfaces or surface coatings should be readily decontaminated.
- Penetrations should be provided for connecting external sources of decontamination fluids and fixatives. The ability to maneuvering of the nozzles inside the cell does not need to be addressed in design if a removable panel or plug as noted above is provided.

5. CONTAMINATION CONTROL

Readers need to be aware that decontaminating to a free release condition is often impossible to achieve within reasonable cost. For this reason, applying fixatives and disposing of contaminated materials of construction as radioactive waste is a common practice during equipment removal and building demolition.

The primary recommendation with regard to designing for the ability to decontaminate is that the purpose should be to support ALARA during a facility's primary mission; not decommissioning. There are two notable exceptions that are important to decommissioning. These are:

- Where there are processes in which contamination is a high gamma radiation source, the ability to decontaminate is important to reduce the source strength and exposure to decommissioning workers. This is more the case where leaks can contaminate open areas and not inside pipes.
- Bulky equipments such as gloveboxes that are contaminated with transuranics (i.e., TRU) are sometimes decontaminated to reduce the total volume that must be packaged and transported to WIPP⁵, a consideration in the USA. This situation will become less important in the next year or so when the ability to ship relatively large volumes to WIPP will be available using the TRUPAC III cask with the Standard Large Box 2 (SLB2) container.

Because contamination control and the ability to decontaminate are important subjects for operations, this section contains contamination control requirements from the reference documents. To the degree they are built into the design, they will also be of benefit for decommissioning.

5.1 Walls, Floors, and Ceilings

In spaces where there is a potential for radioactive contamination from leaks, surfaces should be smooth and coated, sealed, or provided with a surface liner to minimize penetration of the materials of construction. The following practices are recommended *in areas of potential contamination*:

- Floor covering should be totally seamless, if possible. If not, the number of seams must be kept to a minimum. The use of tile segments should be avoided.
- Coatings and sealers should comply with the specifications of ANSI N512 of the American National Standards Institute and be selected for high impermeability.
- Cracks, crevices, and joints should be sealed to prevent the entrapment or spread of contaminants.
- Curbs, dikes, or other barriers should be provided to contain potential releases of radioactive liquids. The net containment volume should be at least 125 percent of the total volume of liquid contained in the area.
- Repeated decontamination during operations of covered or sealed surfaces should not reduce the effectiveness of the barrier (coating, liner, etc). The barrier should be capable of being returned to its original effectiveness or be replaced after decontamination.

⁵ Waste Isolation Pilot Plant

- Layered or porous materials that could entrap radioactive materials should not be used.
- Materials used on walls, floors, or ceilings that cannot be easily decontaminated should be easy to remove and dispose.
- The edges of the floors where they meet the walls should be well sealed and easily maintained to prevent dust or liquid seepage into construction joints.
- Concrete or tile block walls should not be used unless it can be ensured that the finished surface is sealed and maintained to be smooth, nonporous, and readily decontaminated.
- Dropped ceilings should not be used. Void spaces open to the area should not be allowed.

5.2 Sumps and Drains

Design and placement of sumps and drains should prevent the spread of radioactive contaminants and facilitate cleanup.

- Contaminated sumps walls should not be bolted. Seams should be minimized and welds ground flush.
- Connections should be provided at appropriate locations to ensure complete drainage of a system after shutdown. Vents should be provided to permit draining.
- Equipment drains can be equipped with quick disconnects for hoses to direct liquids to a contaminated sump in lieu of permitting radioactive liquids to run across the floor to a drain.
- Pumps should be equipped with collection pans for leakage.
- Loop seals and/or backflow preventers should be provided in drains where they enter a sump.
- Drains which enter sumps should be designed so that piping extends below the minimum water level to ensure that air-borne activity will not pass to other areas through the drain system.

5.3 Ability to Decontaminate

The decontamination of fluid systems may be necessary to support both deactivation and demolition. Fluid system flushing and decontamination may be required to support hazardous chemical regulations as well as ALARA. An approach for design review is:

- Based on the processes in the various fluid systems, identify the types of decontamination processes that are most likely to be used; such as:
 - Water flushing, pressure washing, or hydrolasing
 - Concentrated chemical
 - Dilute chemical concentration
 - Mechanical brushing, scraping, or course media blasting
- When chemical decontamination is likely, the system should be segmented accordingly. It may only be necessary to segment the system into a few sections. Judiciously add valves if needed to accomplish the desired segmenting.

- For consideration of mechanical decontamination for decommissioning, consider only large diameter pipe. It will be more efficient to remove and dispose of small diameter pipe as waste.

If the potential need for built-in decontamination capability is high, the following support requirements are offered. These do not provide all the requirements. They serve to identify space provisions that should be included during design that would be almost impossible to provide once a facility is constructed. Similarly, the fittings called for here are easier to install during construction rather than after the system has been installed and is contaminated.

Support Requirements for Mechanical Decontamination of Fluid Systems

Provisions that should be considered for the in-place mechanical cleaning of fluid systems are as follows:

- Necessary fittings to allow the insertion and removal of mechanical decontamination tools such as pigs, brushes, or scrapers
- Pipe bends should be smooth with large radius bends
- The ability to collect and process flush water

Support Requirements for Chemical Decontamination of Fluid Systems

Space or fittings should be provided for the future installation of equipment and temporary piping for in-place chemical cleaning of contaminated fluid systems. Examples of the types of equipment, temporary piping tie-ins, and process capabilities that will be required are:

- Facilities to mix and prepare the chemical solutions. These may be temporary skid-mounted assemblies.
- Adequate space for recirculation pumps, motor control centers, instrumentation, and control panels.
- Fittings to fill and drain the system being decontaminated.
- Heaters to raise the solution to the proper temperature.
- The ability to bring the entire fluid system being decontaminated to the proper process temperature.
- Fittings to allow feed and bleed to and from the system being decontaminated.
- The ability to purge, with demineralized water, any component that might be adversely attacked by the chemicals and thus fail during the decontamination process. For example, reactor coolant pumps may use stellite seals. During decontamination, these pumps would be used to recirculate the chemical solution. However, the chemicals would attack the seals. The seals can be protected by a water purge past the seals.
- The ability to collect and process waste. (The requirements depend on the chemical process selected.)
- The ability to rapidly drain the system to deal with possible upsets.

6. IN SITU DECOMMISSIONING

6.1 Placement of Grout or Other Fill Materials Within Building Spaces

Grout and other fill materials are considered for filling open spaces and voids within a facility as preparation for in situ decommissioning. All below grade spaces should be reachable from concrete pumpers via sluicing hoses without the need for remote equipment for placement to avoid excessive exposure to workers. If the above grade structure is also of robust construction, the same considerations apply.

When grout is pumped, a vent path is required to ensure complete filling of the space. It is preferred that a vertical opening to serve as an air vent path be atop such spaces. Where such spaces have a roof without openings, the ability to place a vertical core drilling machine above the space should be reviewed. The location must be accessible and not overly constrained by walls and ceiling.

6.2 Placement of Grout or Other Fill Materials Within Tanks, Vessels and Large Pipes

Tanks, vessels and large pipes are also a consideration for filling, especially if they are below grade within the structure or buried in close proximity to the facility. Those with characteristic dimensions greater than xx feet should be reviewed for the ability to pump grout and vent, as described above.

Above grade components of this nature in a non-radiation area where workers would not be exposed if they are to be removed or vented during in situ decommissioning do not have to be reviewed. Such decisions can be left to future technical planning for in situ decommissioning.

7. CHECKLIST TOOL

This section first shows a generic checklist that reflects the foregoing information. It is provided as a tool for those reviewing designs for decommissioning. This is followed by a variation used for the first time on a specific project. Note that on our first use, we modified it considerably to suit our review. You should do the same.

Section	Topic	Subjects Addressed	Conclusions
2.	Yard and Exterior Spaces		
2.1	Yard Areas		
	Space for cranes		
	Space for Waste Management		
	Access for large equipment		
2.2	Underground Tunnels and Vaults		
2.3	Roofs and Siding		
3.	Structures and Interior Spaces		
3.1	Interior Spaces		
	Space for cleanup & waste processing equipment		
	Space for waste management and equipment removal		
3.2	Use of Hazardous Materials		
3.3	Placement of Large or Heavy Equipment		
	Above first floor		
	Removal through walls or ceilings/floors		
	Removal pathways		
	In contaminated areas		
3.4	Shield Walls & Floors		
	Ability to decontaminate		
	Wall thickness		
4.	Systems and Equipment		
4.1	Systems for Deactivation		

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Section	Topic	Subjects Addressed	Conclusions
4.2	Service and Utility Systems Isolation		
	Piping system external isolability		
	Pass through to other facilities		
	Multiple isolation locations		
4.3	Pipes and Ducts		
	Embedded or below the slabs		
	Underground contaminated fluid systems		
	Flushing connections		
4.4	Tanks		
	Placement		
	Cleanout		
4.5	Crud traps		
4.6	Laboratories		
	Workstations		
	Countertops		
4.7	Gloveboxes		
4.8	Hot cells		
5.	Contamination control		
5.1	Walls, Floors, and Ceilings		
5.2	Sumps and Drains		
5.3	Ability to decontaminate		
6.	In Situ Decommissioning		
6.1	Placement of grout or other fill materials within building spaces		
6.2	Placement of grout or other fill materials within tanks, vessel and large pipes		

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This checklist is the one used for the first application of this Report. Note that we have omitted several of the conclusions for reasons of not identifying the specific project. Of those omitted, two were considered to be “findings,” although not major ones. There are a sufficient number of conclusion statements remaining to see how it was used.

Topic	Subjects Addressed	Conclusions
Yard and Exterior Spaces		
Yard Areas		
Space for cranes	Sufficient yard space should be available for mobile cranes and lifting equipment	There is sufficient area in what is now the temporary construction area west of the main building as well as east of the main building and south of the admin building.
Space for Waste Management	Space should be available in the immediate area of the facility for waste operations	Parking lots will suffice.
Access for large equipment	Access will also be required heavy-duty trucks, demolition excavators, and earthmovers	Northern access road satisfies this.
Underground Tunnels and Vaults	Avoid excessive placement of large below-grade tunnels and vaults	There are none that are covered by slabs.
Roofs and Siding	Roof and siding materials should not contain asbestos containing materials (ACM)	There is no ACM in the design.
Structures and Interior Spaces		
Interior Spaces		
Space for cleanup & waste processing equipment	Where are interior locations where decontamination and local HVAC can be staged?	<i>Comment deleted for reasons of non-disclosure.</i>
Space for waste management and equipment removal	Where is there space for loading and staging of waste containers?	
Use of Hazardous Materials	Do the design requirements prohibit asbestos, mercury containing switches, PCB light ballasts, lead-based paint, PCB-based paint, and other similar materials	<ul style="list-style-type: none"> • Random check of liquid filled transformers specs confirmed prohibition of PCBs. • Wall panel specs prohibited asbestos fibers. • Equipment and materials with these types of constituents are generally no longer available.
Placement of Large or Heavy Equipment		
Above first floor	Is there large or heavy equipment above the grade floor that would be difficult to remove?	<i>Comment deleted for reasons of non-disclosure.</i>
Removal through walls or ceilings/floors	Will the building be constructed around heavy equipment and if so are there panels or shield plugs by which it can be removed.	<i>Comment deleted for reasons of non-disclosure.</i>
Removal pathways	Is there a clear removal pathway for large fans and pumps?	Yes; fans and pumps are designed for replacement.

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Topic	Subjects Addressed	Conclusions
In contaminated areas	Is all large electrical distribution equipment not in contaminated areas?	There is no large distribution or switchgear equipment within contaminated areas.
Shield Walls & Floors		
Ability to decontaminate	Rooms that are likely to be surface contaminated to significant levels should have a removable liner or coating on floors and wall	We were verbally informed that “epoxy coatings for decontamination would be used on all wall and floor surfaces in the process areas and on the ceilings in the alpha area as well.” However, this could not be found in any design requirements that would ensure consistency among designers.
Wall thickness	Concrete walls greater than 4 feet thick up to the first floor above grade and 3 feet thick on upper floors present challenges for conventional demolition equipment	Walls generally do not exceed these dimensions.
Systems and Equipment		
Systems for Deactivation		
Service and Utility Systems Isolation	Can exhaust ventilation, sump pumps, fire protection remain energized when most of the building is deenergized?	Discussion with electrical system independent reviewer indicates that it will be straightforward to isolate all but necessary equipment for post-deactivation surveillance and maintenance.
Piping system external isolability	For piping systems an external location should be provided that can be readily accessed.	This is ok for domestic water, sanitary sewer, fire water.
Pass through to other facilities	Avoid routing <i>permanent</i> electrical power or fluid systems through a building to other buildings	There are no such situations for this facility.
Multiple isolation locations	Avoid multiple points of connection to the extent possible for each utility	This is not an issue for this project.
Pipes and Ducts		
Embedded or below the slabs	Pipes, ducts, and equipment that carry contaminated fluids beneath grade floor slabs should be in chases or tunnels and not embedded.	There are none in this design.
Underground contaminated fluid systems	Underground piping systems that contain contaminated fluids should be placed in enclosures, tunnels, or double walled pipe	<i>Comment deleted for reasons of non-disclosure.</i>
Flushing connections	Locations for connection of equipment for flushing or injection of fixative should be should be provided on highly radioactive systems.	<i>Comment deleted for reasons of non-disclosure.</i>
Tanks		
Placement	Tanks containing contaminated fluids should be placed in above-grade rooms.	There are no buried tanks. Most contaminated fluid tanks are above grade.

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Topic	Subjects Addressed	Conclusions
Cleanout	It is desirable to have sufficient space near their top for access within tanks and with an opening large enough to insert equipment for inspection, cleanout, and applying fixatives.	<i>Comment deleted for reasons of non-disclosure.</i>
Crud traps	Does the design have requirements to avoid accumulation of sediment and sludge in crevices and other locations?	<i>Comment deleted for reasons of non-disclosure.</i>
Laboratories		
Workstations and Countertops	Countertops, walls, floors, or any surface should be nonporous, sealed, lined, or coated.	<i>Comment deleted for reasons of non-disclosure.</i>
Gloveboxes and Conveyor Enclosure	Ability to cleanout and remove internal components	This detail has not been developed at this design stage.
	Ability to remove	Longest section is 8 feet, which is the reasonable maximum for separation for removal.
Hot cells	Ability to decontaminate	<i>Comment deleted for reasons of non-disclosure.</i>
	Ability to demolish	<i>Comment deleted for reasons of non-disclosure.</i>