MASTER

SURVEY OF DECONTAMINATION
AND
DECOMMISSIONING TECHNIQUES

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Geologic Storage Engineering Section
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Research and Engineering Division

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FOREWARD

Literature from 1944 on has been reviewed for information pertaining to decontamination and decommissioning radioactively contaminated facilities. Results will be used in developing criteria for use by DuPont as part of the, "Alternate Fuel Technology Program," in preparing a conceptual plan design for closing the light water reactor fuel cycle.

Successful experience in decommissioning facilities has been demonstrated at several Energy Research and Development Administration sites. In general, standard techniques normally used by maintenance in maintaining and repairing equipment have been used. Special equipment and techniques have been developed in a few specific instances and are briefly reviewed. These include a remotely operated plasma torch and use of special shaped charges for cutting pipes and concrete.

Included in this review are reports summarizing results from references to over 500 reports on decontamination and decommissioning. Also included in the appendix are criteria and recommendations for design of new plutonium facilities as developed by Rockwell International and Mound Laboratory.

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SURVEY OF DECONTAMINATION
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I. INTRODUCTION

A review has been made of decommissioning studies and reports as part of the General Project for the Savannah River Laboratory (SRL) program to develop a conceptual design of a commercial reprocessing plant for fuel from Light Water Reactors (LWR). This program on decommissioning is being performed for SRL by Atlantic Richfield Hanford Company (ARHCO) to provide information for the nuclear fuel reprocessing industry.

This report contains a summary of articles and reports on plant decommissioning techniques. This is not an evaluation of the data, rather it is a brief summary of data that can be used as a reference source in studying and evaluating decommissioning activities. Specific details and limitations associated with each type of technology or technique require further detailed study.

The volume of material that has been written on decontamination and decommissioning is large. An example over 500 reports are referenced in two reports. The Battelle Northwest Report (1) includes 429 references which are arranged in chronological order with a brief summary of each reference. A subject and author index are also included as a cross reference source. In addition, this data has been computerized to simplify future additions and also for ease in preparing subject or author listings.

Paschall⁽²⁾ includes a compilation of 88 references including a brief summary statement for each report. Results of this particular listing were used to prepare criteria for use in design of new plutonium facilities. A brief summary of the criteria is listed in Appendix A.

The report from the first conference on decontamination and decommissioning of the Energy Research and Development Administration (ERDA) facilities held at Idaho Falls, August 1975, provides a good overall review of past decommissioning activities.⁽³⁾ Also, included in this conference report are NRC and ERDA plans regarding future implementing of regulations concerning decommissioning.

A detailed summary of techniques and procedures used to decommission the Special Metallurgical Building at Mound Laboratory are summarized by Harris.⁽⁴⁾ Included are radiological exposure data of individuals engaged in decommissioning the facility. Also health physics data concerning sampling techniques and results are provided. A discussion is included on techniques and equipment which were evaluated and found to be unsuitable for planned operations. Recommendations for construction of new facilities are summarized in Appendix B.

II. REVIEW OF LITERATURE

1. Decontamination Literature

A wide variety of decontamination techniques and procedures have been successfully developed in the past and are being used on a routine basis in maintenance operations associated with radioactive equipment or facilities. Details of past experience have been well documented by Ayres (5) who has compiled a thorough review of techniques which are oriented towards beta-gamma decontamination. Gerding and Steindler (6) of Argonne National Laboratory (ANL) and Christensen (7) of Los Alamos Scientific Laboratory (LASL) have compiled extensive data on techniques used in decontaminating plutonium contamination materials.

The following summary of decontamination experience is extracted from the, "Resource Book - Disposition of Retired Contaminated Facilities at Hanford," and review methods being considered for decontaminating contaminated facilities at Hanford. (8)

2. The Decontamination of Metal Surfaces

A wide variety of procedures can be used to clean metal surfaces contaminated with alpha activity (and beta-gamma activity as well). The optimum method for a given situation will depend on a number of factors including:

- the types and amounts of contamination present,
- accessibility of the contaminated surface,
- the degree of decontamination required,
- the methods available for disposing of contaminated wastes generated by the decontamination operations.

The decontamination of metal surfaces normally involves the use of liquid decontamination solutions. This requires, however, that facilities for disposing of the contaminated liquid wastes be available. If disposal facilities are not available, dry decontaminating procedures must be used (this can include the use of wet rags and swabs, which can be disposed of as solid waste).

Experience at various nuclear facilities has shown that the removal of alpha emitters from exposed metal surfaces is more readily accomplished by manual techniques. Vacuuming of the surface to remove loose contamination followed by mopping, wiping, or brushing with an appropriate cleaning solution has proved very practical for removing alpha activity. The cleaning solution used will depend on the particular situation, but complexed acid solutions or commercial decontaminating solutions have proved quite effective. (9-12) Sequential cleaning steps using two or more cleaning agents provide even better decontamination. Steam cleaning or foam spraying

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followed by mopping or wiping has also proved effective. (10) Since the metal being cleaned will normally be scrapped, corrosive solutions which attack the metal surface can be used effectively. (7) Using these procedures it should be possible to decontaminate most metal surfaces to levels where respirators (assault masks) are no longer required by those working in the facility.

In those cases where manual techniques are not effective, abrasive procedures such as sandblasting or mechanical abrasion (wire brushing, sanding, etc.) can be used. (5-11) These techniques generate airborne contamination which must be controlled. They also remove a portion of the metal and may not be applicable to all situations. Vacuum blasting can be used to reduce airborne contamination; or water sprays or mists can be used to hold down the particulates.

Inaccessible metal surfaces, such as the inner surface of process equipment and piping, can be cleaned in place by flushing with the appropriate decontaminating solutions. The cleaning agents used are similar to those used in the manual operation. Again, corrosive cleaners can be used if the metal is to be disposed of. Sequential flushing with two or more different decontaminating solutions improves the activity removal.

Complex metal equipment, such as lathes and other machine tools, may have to be disassembled or cut up prior to decontamination. The individual parts can then be decontaminated manually or in cleaning baths, (i.e., ultrasonic cleaner, electrolytic cell, agitated bath). Similarly, process equipment and piping can be disassembled (and segmented if necessary) and treated in the same way.

The degree of decontamination required for a particular item will depend on its ultimate use or disposal. If the metal is considered excess, it would be desirable to decontaminate it to a sufficiently low level that retrievable storage of the material would not be required. If this is not possible, then there is little incentive to remove more than the gross contamination.

3. Decontamination of Nonmetallic Surfaces

Effective decontamination of nonmetallic surfaces depends largely on the type of surface to be cleaned. Relatively nonporous surfaces such as glass, plexiglass and other plastics can be cleaned quite easily, while porous surfaces such as wood, transite and masonite present much more difficult problems (concrete is discussed in a subsequent section). Nonporous surfaces can be effectively decontaminated manually, using the appropriate cleaning solutions. Materials such as glass and lucite can be decontaminated to quite low levels by wiping the surfaces with dilute nitric acid, or nitric acid-hydrofluoric acid mixtures, and flushing with water. (7)

Effective decontamination of porous surfaces depends on the depth to which the activity has penetrated. If the activity is mainly at the surface, it may be possible to partially decontaminate by vacuuming the surface and then scrubbing with a mild detergent solution or solvent. If the activity has penetrated into the material, it will probably be necessary to remove the contaminated layer. This can be done by various methods including sandblasting, vacuum blasting, flame spalling, or sanding, depending on the material.

Painted surfaces can also be a problem. Paints are normally applied to protect the surface. If the activity has penetrated the paint, it will be necessary to remove the paint layer. This can be done by the judicious use of solvents or by abrasion, (i.e., sandblasting, sanding, scraping, etc.).

4. Decontamination of Concrete

It is difficult to decontaminate concrete effectively, especially if the surface has been exposed to radioactivity for long periods or to radioactive solutions. The more porous the concrete surface, the more difficult the problem. Concrete exposed to radioactive solutions will be contaminated to greater depths than concrete exposed only to radioactive solids or slurries.

Concrete surfaces which have been exposed only to radioactive solids or slurries, where the activity has not penetrated significantly, can be decontaminated reasonably well by the following sequence of operations: (13)

- vacuum the surface to remove loose contamination,
- mop or wipe the surface with a mild detergent solution or solvent to remove any oil, grease or adherent dirt. A minimum of liquid should be used, and the contact time should be as short as possible. Alternatively, dry steam could be used,
- vacuum the surface again after it has dried.

This approach or modifications thereof will remove most of the surface contamination.

If the radioactivity has penetrated into the concrete, effective decontamination requires removal of the contaminated surface layer. The amount of concrete which must be removed will depend on the depth to which the activity has penetrated and on the level of residual activity which can be tolerated. If the concrete is to be disposed of, it is highly desirable that the alpha activity level be less than 10 nCi/g so that retrievable storage would not be required for the total volume of concrete.

Several methods for removing the contaminated surface layer from concrete have been used with varying degrees of success. They include:

- dry sandblasting (5, 12, 14) or shot blasting,
- vacuum blasting, (5,11)

- mechanical abrasion (i.e., pneumatic hammers, sanders, grinders, wire brushes, rock splitters, etc.),
- abrasive sawing,
- flame spalling, (14)
- explosive spalling. (15,16)

All of these methods except vacuum blasting create substantial amounts of airborne contamination. Special precautions must be taken to minimize the spread of airborne contamination and prevent recontamination of clean surfaces.

Sandblasting and mechanical abrasion using pneumatic hammers and chisels are probably the most widely used methods for removing contaminated concrete surfaces. Vacuum blasting, which reduces the problem of airborne contamination, can be used effectively over large areas if the depth of concrete to be removed is not too great. It can also be used to remove a considerable depth of concrete over a small area, but the operating time required can become excessive if the area to be cleared is large. Rock splitters can be used effectively to remove a considerable depth of concrete over large areas.

Explosives can be used to remove concrete to various depths. Their use, however, is limited to certain applications which can tolerate the side effects (pressurization, airborne contamination, structural damage to the concrete, etc.). Because of the possibility of structural damage, explosives can not be used effectively with thin concrete sections which must retain their structural integrity. Explosives were used successfully during demolition of the Elk River Reactor to remove contaminated layers from massive concrete sections. (15,16)

Flame spalling and abrasive sawing have found only limited use in decontaminated concrete. Flame spalling by itself is only partially successful in removing contaminated layers from concrete, but a combination of flame spalling and mechanical abrasion has been used successfully.

Battelle Northwest Laboratories is currently investigating the use of rock splitters and water cannon for removing contaminated concrete. Additional work is needed, however, before the procedures potential can be fully evaluated.

Depending on the method selected for surface removal, control of airborne contamination is a key factor. Water sprays, mists and heavy mats can be used to reduce airborne particulates. No data was found that quantifies the total amount of waste generated in removing contaminated concrete.

5. Metal Cutting

Contaminated equipment, piping and structural sections have generally been removed using standard metal cutting equipment. Special equipment and techniques have been developed for a few specific applications due to high exposure, work space limitations or restrictions on spread of fumes. The plasma torch is one tool that has received considerable development effort in order to cut remotely under water or in air. Oak Ridge developed the initial unit which was successfully used in the decommissioning operations at the Elk River Reactor (ERR) site. (3)

Cuts of one and one-half inch thick stainless steel were made under water on the inner thermal shield. The pressure vessel, which was 3 1/8-inch thick carbon steel with a 0.109 inch stainless steel overlay, was cut in air. The outer thermal shield, consisting of carbon steel and lead, was cut with an oxyacetylene torch in air. Vessels were approximately seven feet in diameter and had contact readings of 1500 and 250, and 1R/ hour respectively. All of the equipment performed reliably and accurately. It was rugged, easy to learn to operate, and did not require set up times.

The hardware components of this system consist of the plasma equipment, the manipulator, the control package, and an assortment of long handled mechanical tools. The plasma equipment consists of the torch, torch hoses, cables, power supplies, cutting gases, and accessories that are available from the welding equipment industry. the Linde PT-7 plasma torch was used because it had the highest capacity rating of any torch on the market. For this application a number of minor modifications to the hardware as purchased were made.

The torch is mounted on and moved by a manipulator. This is a special purpose, moderately sophisticated, one of a kind device. It's design was heavily influenced by the accuracy and rigidity requirements of the plasma cutting process. It weights almost 4,000 pounds and is 28 feet long. It has a 20 foot travel vertically and rotates 360 degrees. In the radial direction the torch is forces outward to bear against the metal to be cut, or it is completely withdrawn. Two arms, or torch holders, are used. One driven hydraulically for underwater work and an electrically driven arm for in-air cutting. The design of each arm reflects the criteria imposed by the cutting situation.

A control system controls the position and movement of the manipulator (thereby the torch), all of the cutting process parameters, and a special sequence of operations. Included in this bundle are the following: air to keep water out of the torch, torch cooling water, nitrogen cutting gas, argon starting gas, dc power to the torch, and to the drive motors, tachometer and position potentiometer signals, etc.

The cutting equipment is augmented with long handled tools for supporting and moving the cut segments and various other functions. Specially designed platforms, stands, and tool supports are also required and maintenance provisions have to be considered. In addition to the

mechanical hardware, it is necessary to test the components both separately and assembled and to develop by trial and error the cutting parameters that give the most satisfactory results. The development work of this type for ERR was done on small samples wherever possible.

With the equipment described and the general techniques used at the ERR, the Sodium Reactor Experiment (SRE) near Los Angeles is being dismantled. Atomics International (AI) has through additional work extended the remote handling capability of the torch. (3) Radial cutting capability, as well as the capability of cutting sections having small radii, such as the base of the tank, have been added. A special development facility has been established in which full scale mockup tanks of the SRE reactor have been successfully dismantled. The development facility would be available for additional testing and demonstration of cutting other configuration and materials.

Explosives have been used for years in demolition work and this experience has been applied recently in decommissioning several reactors. The use of shaped charges in particular has been used successfully in cutting contamination pipes and structural components. Experience gained in the petroleum industry in cutting pipes underwater has proved to be very valuable.

The most recent application of shaped charges in decommissioning is work being conducted by Atomics International in decommissioning the Sodium Reactor Experiment (SRE). Schedule 40 pipes up to ten inches in diameter have been successfully cut.

Shaped charges were also used in decommissioning the Battelle Reactor. (18) Stainless steel and aluminum pipes up to six inches in diameter and the aluminum pool liner were all cut using shaped charges.

Their conclusions were:

1. There was no measurable contamination spread due to the cutting operation.
2. There was no activity due to vaporization of the material being cut.
3. The task spanned about two weeks and require about 20 percent of the man-hours anticipated for any other removal technique.

Shaped charges were also successfully used by Aerojet Nuclear Company in decommissioning a stainless steel storage tank - 32 feet in diameter and 40 feet in height. The specific application consisted of cutting four 30-inch diameter legs used to support the tanks at an overall height of 193 feet. (3)

A limited amount of development work has been done in the past at Hanford to demonstrate the capability of using shaped charges to cut "H" beams, 24-inch pipe and solids steel rods. (19) It was also demonstrated that shaped charges can be equipped and placed remotely thereby reducing exposure of personnel to high radiation levels.

6. Material Handling

Techniques used to remove and package contaminated material depend on the radioactivity level of the item being handled. Concrete rubble, as an example, has been removed using a standard tractor with a bucket attachment. When materials containing high levels of radioactivity are encountered the approach generally has been to decontaminate to a level where shielding is not required. This increases the volume of contaminated wastes to be processed. Another alternate that has not been explored in any detail in past decommissioning activities has been the use of shielded remotely operated and controlled equipment. Several elaborate pieces of equipment were developed for remote maintenance use during the early days of the Aircraft Nuclear Propulsion program which could have possible use in a large scale decommissioning program involved several buildings. (20)

III. CONCLUSIONS

Reports and articles on decommissioning have been reviewed to determine the current technology status and also attempt to identify potential decommissioning problem areas. It is concluded that technological road blocks, which limited decommissioning facilities in the past have been removed. In general, techniques developed by maintenance in maintaining the facility have been used to decommission facilities.

Some of the more promising development underway which will further simplify decommissioning activities are: electrolytic decontamination which simplifies some decontaminating operations; arc saw and vacuum furnace which reduce the volume of metallic contaminated material by a factor of 10; remotely operated plasma torch which reduces personnel exposure; and shaped charges, water cannon and rock splitters which simplify concrete removal.

Areas in which published data are limited are detailed costs identifying various components included in the total cost and also the quantity of waste generated during the decommissioning activities.

With the increased awareness of decommissioning requirements as specified by licensing requirements, design criteria for new facilities are taking into consideration final decommissioning of buildings. Specific building design features will evolve as designs are evaluated and implemented.

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V. APPENDIX ABRIEF SUMMARY OF DESIGN CRITERIA
FOR PLUTONIUM FACILITIES
(Proposed by Paschall (2))

Interior Walls (may also apply to exterior walls, ceilings, and floors).

1. The surface of the walls shall be smooth and flat.
2. The surface shall be easy to clean and decontaminated.
3. Contamination should not penetrate far into the surface.
4. Contamination which does penetrate the surface shall be easily removed. This may require removing part of the surface.
5. No sandwich material shall be used.
6. Repeated decontamination shall not reduce the effectiveness of the surface for future decontamination; or, surface can be reprepared to return them to original effectiveness.
7. The number of wall penetrations shall be minimized.
8. Penetrations through the walls shall be sealed around.
9. Penetrations into the walls shall be sealed around.
10. Walls with interior spaces shall be sealed.
11. The surface should be decontaminated to levels determined by final disposition criteria, or the walls can be easily disposed of.
12. The walls should be easily disposed of if they cannot be decontaminated to levels required for decommissioning.

Exterior Walls

1. Surfaces shall be easy to decontaminate or have removable liners.

Ceilings

1. Surfaces shall be easy to decontaminate, light fixtures flush, and false ceilings avoided.

Floors

1. The surface shall be smooth but not slippery.
2. The edges of the floors where they meet the walls shall be easy to clean and decontaminate.
3. The floors shall have drains and slope toward the drains.
4. Floor drains shall be smooth and easy to decontaminate.
5. Curbs shall be provided around all the floors.

Glove Boxes

1. Glove boxes shall be sized for ease of disposal or rearrangement.
2. Glove boxes shall be designed so that they are easy to separate.
3. Pipes, ducts, conduits, other attachments to the glove box shall be easy to disconnect from the glove box.

Glove Box Materials

1. The box shall be designed for ease of decontamination inside and out.
2. Glove box windows shall be made of glass wherever possible.
3. Materials used in gloves shall be designed for long life.
4. Glove ports shall be covered when the gloves are not in use.
5. Connecting areas between glove boxes shall be minimized.
6. The size of glove box windows shall be small as practical.
7. Glove box shielding shall be designed so that it is easy to clean and decontaminate exposed surfaces.
8. Glove boxes shall have lighting fixtures which are flush with the top of the glove box and sealed.
9. Ventilation in the glove box shall be of the down-draft type.
10. The glove box shall have rounded edges.

11. The surface of glove boxes shall be such that corrosion does not affect them.
12. The boxes shall be designed to minimize the effects of scraping, scratching, gouging, and damaging of the surface while in use.
13. Use of special self-contained enclosures within the glove box enclosures shall be considered.

Conveyers and Conveyer Enclosures

1. Enclosed conveyers may be used to connect short glove box trains together.
2. Enclosed conveyers shall be used to connect long glove box segments.
3. Conveyer systems shall be connected to glove boxes in a manner for easy removal.

Ventilation

1. Ventilation shall be the primary means by which contamination spreading is minimized and controlled.
2. Intake filters on glove boxes shall include prefilters and HEPA filters.
3. The exhaust filters on glove boxes shall contain prefilters and HEPA filters.
4. The glove box shall be provided with pressure regulation to prevent inside overpressurization.
5. Hot rooms or corridors shall have separate prefilters and HEPA filters both on the inlet supply air system and the outlet exhaust system.
6. Cold areas, such as offices, corridors, and cold laboratories, shall have prefilters and HEPA filters on the inlet air supply system. The exhaust air shall go directly to the large filter plenums.
7. Down-draft flow shall be used for all ventilation systems in the glove boxes, hot room areas, and cold room areas.

7. Sufficient room shall be provided in the building arrangement for easy movement of glove boxes and equipment.

Compartment Arrangements

1. Compartments which are hot, or may possibly become hot, should be arranged such that they are as void as possible.
2. Room ventilation ducts should be minimized and easy to clean and clean around.
3. There shall be minimal protuberances from the walls, floors and ceilings.
4. There should be sufficient room in each compartment for moving glove boxes and equipment.

Effluents and Wastes

1. The exhaust stack leading from the ventilation system shall be separable into small segments.
2. Pipes containing radioactive liquid wastes shall be as short as possible.
3. The liquid waste pipes and holdup tanks shall be doubly encased.
4. Liquid waste holdup tanks shall be designed for ease of decontamination and decommissioning.
5. Pipes carrying radioactive liquid waste to waste disposal facilities outside of the plutonium facility shall be easily accessible and doubly contained.

Special Rooms

1. Plutonium facilities shall have one or more decontamination rooms.
2. The plutonium facility shall have one or more rooms provided for size reduction.
3. Combustible wastes shall be reduced to a minimum by incineration or other methods.
4. The facility shall have the capability of size reduction of liquid disposable wastes.

APPENDIX B

SUMMARY OF MOUND LABORATORY RECOMMENDATIONS

1. All walls should be seamless and have smooth durable walls.
2. Sandwich walls should be avoided because of decontamination problems.
3. Processing areas should be compartmentalized to control the movement of any release of radioactivity.
4. Sealed off access areas shall be provided behind processing lines to provide a work area for maintenance and installation work in contaminated hoodlines.
5. Building and glovebox services which contain radioactive materials should not be located overhead but should be located either beneath the floor level or in some area away from laboratories.
6. Complete building systems, such as house vacuum, corrosive vapor removal systems, and glove box exhaust systems should be located in isolated areas.
7. Once a decommissioning effort has been started, it is important that the same individuals stay with the project.