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MAINTENANCE AND OPERATIONS STUDY FOR K BASINS SLUDGE TREATMENT

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Abstract: This study evaluates maintenance and operating concepts for the chemical treatment of sludge from the 100 K Basins at Hanford. The sludge treatment equipment that will require remote operation or maintenance was identified. Then various maintenance and operating concepts used in the nuclear industry were evaluated for applicability to sludge treatment. A hot cell or cells is recommended as the best maintenance and operating concept for a sludge treatment facility.

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MAINTENANCE AND OPERATIONS STUDY FOR K BASINS SLUDGE TREATMENT

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November 1998

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MAINTENANCE AND OPERATIONS STUDY FOR K BASIN SLUDGE TREATMENT

1. Executive Summary

This study evaluates various maintenance and operating concepts for a facility for chemical treatment of K Basin sludge. Preliminary dose rate and shielding calculations were used to determine which pieces of equipment can be contact operated and maintained and which ones will require remote operation and maintenance.

The primary conclusion of this study is that a hot cell is the best maintenance and operation concept for the processing vessels that will require remote operation and maintenance. It will provide the capability for vessel heel inspections, filter changeout, and remote maintenance of mechanical equipment in a timely manner while protecting personnel from high radiation fields. Hot cells have been built and operated for many years so they are a well developed and proven technology. The compact processing unit (CPU) concept should be considered for neutralization/precipitation of the dissolved sludge if this step is done separate from the rest of sludge treatment.

The two remote operations that will be the most time consuming and difficult to perform are inspecting vessels for heels and changing out cartridge filters. Alternatives to these two operations should be pursued.

2. Introduction

2.1 Purpose

The purpose of this document is to evaluate operating and maintenance concepts that could be used in a facility for chemically treating the K Basin sludge. This study will screen out concepts that are not feasible and recommend the best concept or concepts to be considered during design. Which operating and maintenance concepts are feasible for the sludge treatment facility will impact both the cost and the schedule.

2.2 Background

The KE and KW basins are used to store spent nuclear fuel (SNF) from Hanford reactors. The floor and pits of the basins contain sludge from fuel corrosion, concrete spalling, and sand infiltration. The SNF will be removed from the basins, overpacked, vacuum dried, and stored in the Canister Storage Building (CSB). During and/or following fuel removal, the sludge will be removed from the basins and transferred to a sludge treatment facility. Sludge from the canisters and fuel washing will also be transferred to the sludge treatment facility. There the sludge will be chemically treated to meet waste tank acceptance criteria and then transferred to a double shell waste tank. Process flow diagrams and a process description for sludge treatment have been issued. This maintenance and operation study is needed prior to selecting a site for the sludge treatment facility.

2.3 Scope

The scope of this document includes the transfer of the sludge from the 100 K Basins to the treatment facility, the sludge treatment process, the packaging of the solids for transfer to the Environmental Restoration Disposal Facility (ERDF), but not the transport of the treated sludge to a double shell waste tank.

3. Process Description

A flow diagram of the sludge treatment process is shown in Figure 1. The sludge will be transferred from the KE and KW basins to the treatment facility in a shielded critically safe transport container. The sludge will be pumped from the transport container into the lag storage tank where it will be held until it can be moved on through the process. Sludge treatment will be done by dissolving the fuel constituents in nitric acid, separating the insoluble material, adding neutron absorbers for criticality safety, and then reacting the solution with caustic to co-precipitate the uranium, plutonium, and absorbers. The resulting slurry will be transported to an underground storage tank (most likely 105-AW) in a shielded transport container.

Sludge treatment will include the following steps:

- Sludge transfer from transport container to lag storage vessel
- Resin bead separation by screening and elutriation
- Acid addition to the dissolver
- Sludge transfer from lag storage vessel to dissolver
- Sludge dissolution
- Solution transfer from dissolver
- Solids/liquid separation by a centrifuge and cartridge filter
- Addition of depleted U and FeNO_3 absorbers (after sampling)
- Neutralization/precipitation with NaOH
- Slurry transfer to tank farm by truck

The portion of the sludge that is not dissolved will go through the following steps:

- Solids/liquid separation and washing in a centrifuge
- Chemical treatment of solids for Cs-137 and TRU removal

- Solids/liquid separation and washing in a centrifuge
- Stabilization in grout

The resin beads that are separated upstream from the dissolver will go through the following steps:

- Chemical leaching for Cs-137 and TRU removal
- Solids/liquid separation and washing in a centrifuge
- Stabilization in grout along with undissolved solids from the dissolver

The dissolver off gas system will consist of the following:

- Condenser
- NO_x absorber
- Mist eliminator
- Heater
- HEPA filters
- Activated carbon cartridge for PCB removal
- Sampling/monitoring system
- Stack

A more detailed description of the sludge treatment process can be found in the K Basin Sludge Treatment Process Description (Westra, et. al., 1998).

4. Assumptions

Listed below are major assumptions that affect operation and maintenance of the sludge treatment facility:

- The sludge treatment facility will use the chemical process and unit operations summarized in the previous section and described in the K Basin Sludge Treatment Process Description (Westra, et. al., 1998).
- The radiation dose rate from the cartridge filter will be high enough to preclude manual change out of the filter elements. The unshielded direct contact dose rate from a batch of basin sludge is expected to be in the order of magnitude of 500 Rad/hr.

- The cartridge filter elements will be placed in drums and either stabilized in grout for disposal at ERDF, or stored for future incineration.
- Mechanical pumps and agitators will be used to transfer and suspend the sludge.
- Mass limits will be used for criticality control so internal inspections of the lag storage vessel, dissolver feed tank, and dissolver will be necessary to verify that there is not a buildup of fissile material.

If the above assumptions are changed as the sludge treatment process is further defined, it may invalidate the conclusions of this study.

The sludge treatment facility must meet the requirements of 10 CFR 835, *Occupational Radiation Protection* as implemented by the Hanford Site Radiological Control Manual, HSRCM-1. The design objective for external exposure shall be that no individual worker will receive a dose equivalent in excess of 0.01 Sv (1 rem) per year.

Dose rate limits are 2 mrem/hr for less than 1 hr/day exposure and 0.25 mrem/hr for full time work in a controlled area.

Dose rate goals in areas requiring routine personnel access should not exceed 0.5 mrem/hr.

The results of preliminary dose rate and shielding calculations (Pili-Vincens, 1998) indicate that much of the processing equipment will need to be shielded to meet the above requirements.

5. Methodology

This section describes the methodology that was used in this study to determine which operating and maintenance concepts are best to use for K Basin sludge processing.

The process equipment that will be needed for sludge processing as described in the K Basin Sludge Treatment Process Description (Westra, et. al., 1998) was divided into categories based on the function of the piece of equipment and the expected radiation dose. The results of preliminary dose rate and shielding calculations (Pili-Vincens, 1998) were used to help categorize the individual pieces of equipment.

The equipment was divided into the following categories:

- Equipment that will require little or no shielding and is suitable for manual, hands-on operation and maintenance.

- Equipment that will require substantial shielding to protect operating personnel from radiation, but is suitable for manual, hands-on operation and maintenance.
- Equipment that will require substantial shielding to protect operating personnel from radiation and will require remote operation and maintenance.

The reasoning that was used to place equipment in each category is described. For the first category, the reasoning was based on the preliminary dose rate and shielding calculations. For the second and third categories, the function of the equipment and the source term that could be released in an accident were also considered since both of these have an impact on whether or not the equipment should be operated remotely. Some equipment that requires shielding is best operated manually due to the function it performs. On the other hand, the source term present in some equipment may require remote operation for containment reasons when the equipment otherwise could best be operated and maintained manually if shielded.

Equipment in the last category was then evaluated to identify operating steps that will require a manipulator or in-cell crane. The equipment in this category was also evaluated to identify which pieces of equipment are most likely to require maintenance or replacement during the course of the operating campaign.

Finally operation and maintenance concepts that have been used in nuclear reprocessing plants were evaluated for applicability to a sludge processing facility. The following concepts were evaluated:

- Canyon facility
- Hot cell
- Contact maintenance facility
- Pump and valve maintenance corridor adjacent to cell
- Skid-mounted modular facility installed in the CVD
- Compact processing unit

The following criteria were used to evaluate the different maintenance and operating concepts:

- The facility must provide the capability for repair or replacement of equipment likely to fail during the sludge treatment campaign.
- Equipment repairs or replacement must not result in extended shutdowns that will jeopardize completing sludge treatment in the scheduled processing window.

- The likelihood of plugging transfer lines with sludge must be minimized. The most direct route between vessels should be used as much as possible.
- The facility must have the capability to remotely inspect the interior of some vessels and to remotely replace filter cartridge elements.

6. Manually Operated/Maintained vs Remotely Operated/Maintained Equipment

This section describes how the sludge processing equipment was divided into the three categories described in the previous section based on the equipment function and the expected radiation dose rate.

Category 1: Equipment that will require little or no shielding and is suitable for manual, hands-on operation and maintenance.

The chemical makeup tanks and off-gas system downstream from the condenser fall into this category. The chemical make up tanks will handle only non-radioactive chemicals with the exception of depleted uranium. There will not be a significant beta/gamma dose rate from the depleted uranium so neither shielding nor remote operation will be necessary. The dose rate from the off gas equipment downstream from the condenser is expected to be low enough to allow manual/hands-on operation and maintenance, if necessary.

Category 2: Equipment that will require shielding to protect operating personnel from radiation, but is suitable for manual, hands-on operation and maintenance.

The transport container that will be used to transfer the sludge from the basins to the treatment facility, the solids collection tank and the grout containers fit into this category. The transport container must be heavily shielded due to the radiation dose rate from the sludge, but the connections for the transfer line can probably be done manually if the line is flushed after each sludge transfer. Although, nearly all of the fission products and Am-241 will be removed from the undissolved solids during treatment, the solids collection tank and grout containers most likely will require some shielding to reduce the dose rate from residual Cs-137. Preliminary calculations indicate that the source term in the solids collection tank and grout containers will be low enough that the vessels can be non safety class with no containment other than the vessels themselves.

Category 3: Equipment that will require substantial shielding to protect operating personnel from radiation and will require remote operation.

The equipment that will handle the undissolved sludge, ion exchange resin, and the dissolved fuel components falls into the third category. This includes the main processing equipment consisting of the lag storage tank(s), elutriation column, resin buffer tank, dissolver feed tank, dissolver,

condenser, centrifuge, leach tank, clarified liquid tank, cartridge filter, adjustment tank(s), and neutralization tank. The preliminary dose rate and shielding calculations (Pili-Vincens, 1998) indicate that all of the above vessels will need approximately the same shielding.

7. Manually Operated/Maintained Equipment

The section discusses the sludge processing equipment that will be operated and maintained manually. This includes the equipment in the first two categories in the previous section (manual operation/maintenance with no shielding and manual operation/maintenance with shielding).

7.1 Off Gas System

Operation of the stack monitoring system is the only routine manual operation anticipated for the off gas system. Changeout of the HEPA filters and granulated activated charcoal filter should not be required during the short operating campaign (less than one year). Operation of the NO_x absorption system may also involve some hands-on operation. However, it is anticipated that it will be operated remotely from the control area using pump switches and flow controllers. A manual valve line up prior to startup and after shutdown may be required.

7.2 Chemical Makeup

The chemical make up tanks will handle only non-radioactive chemicals with the exception of depleted uranium. There will not be a significant beta/gamma dose rate from the depleted uranium so neither shielding nor remote operation will be necessary. However, contamination control measures will be needed due to the alpha radiation associated with the uranium.

The valves and pumps associated with the chemical makeup tanks may be operated either manually or with remote switches and controllers. If remote switches and controllers are selected, the decision will be made based on operating efficiency and process control, not for radiation protection.

7.3 Transport Container Unloading and Loading

The transport container that will be used to transfer sludge from the KE and KW basins to the sludge treatment facility will be shielded to reduce the dose rate to personnel. The line that will be used to transfer the sludge from the transport container to the lag storage vessel in the sludge treatment facility will have a flexible section on the end to facilitate hookup to the transport container. The flex line will be shielded so that the connections between the transport container and the line to the lag storage vessel can be done manually. The transfer line can be flushed with water following sludge transfer to reduce the radiation dose rate prior to making or breaking connections on the transfer line. The piping connections to the transport container are expected to be quick disconnect fittings with automatic shutoff to prevent spillage of any liquid that may be held up in the line. The design

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and operation of the transfer line is expected to be very similar to the design and operation that will be used to transfer sludge from the K Basins into the transport container. Operation of the valves on the transfer line can probably be done manually if the valves are shielded and have extension handles. However, valve operators and remote switches appear to be a better alternative and also provide the capability for interlocks.

A shielded transport container or tank truck will also be used to transfer the neutralized waste from the neutralization tank to the AW tank farm. It is assumed that the line used to load out this solution will be similar to the line used to load in the sludge. The line will be shielded as necessary so that connections can be done manually.

A shielded cask truck (model LR56, built in France and purchased through Numatec) is available on the Hanford site and could possibly be used for the transfers from the sludge treatment facility to AW tank farm. The hose connections for transferring into and out of the cask truck must be connected manually. The valves on the loading and unloading lines must also be manually operated.

7.4 Solids Collection Tank

The solids collection (reception) tank will be the largest vessel in the sludge treatment facility with a capacity of over 50 m³ according to the K Basins Sludge Treatment Process Description (Westra, et.al., 1998). If this large tank can be located outside the shielded cell, the size and cost of the cell can be reduced. The results of preliminary dose rate and shielding calculations (Pili-Vincens, 1998) indicate that the shielding thickness required for the solids collection tank will be 25-40% less than the shielding thickness required for the vessels that handle sludge or resin. Since the solids collection tank will only be used to accumulate undissolved solids during the sludge treatment campaign, there is not expected to be any need for maintenance. The tank will be equipped with an agitation system to suspend and mix the solids and with one or two transfer pumps. The pumps and agitation system will not be used until the solids are grouted at the end of the sludge treatment campaign. Therefore, any maintenance problems with the agitation system or pumps for the solids collection tank will not impact sludge removal from the basins.

7.5 Solids Grouting

Grouting of the undissolved solids for disposal at ERDF will be done at the end of the sludge processing campaign. The proposed grout container is the Chem Nuclear L14-170 cask liner having a capacity of 4.8 m³. Approximately 7 of the cask liners will be needed for disposal of all of the undissolved solids. It is assumed that the solids will be grouted by transferring a batch to the grout container, decanting off any excess water, and then adding grout-forming chemicals. The cask liner can be shielded, if necessary, during the grouting operation. Replacing a full grout container with an empty one will probably be done using a mobile crane. The dose rate is expected to be low

enough that connecting, disconnecting, and rigging the fill head to the grout container can be done manually.

During the grouting of N Basin sludge, the grout container was shielded in a section of concrete culvert. The fill head containing sludge addition, grout addition, and vent lines was manually connected to the grout container by operators. After grouting was completed, the fill head was manually disconnected and a lid installed on the grout container. Following confirmation that the contact dose rates were in compliance with DOT requirements, the grout container was placed on a flatbed trailer using the 60 ton basin crane. The flatbed trailer was used to transfer the grout container to ERDF for disposal (Logan, 1998).

7.6 Filter Grouting

If individual filter elements are changed out from the cartridge filter, the elements will be placed in drums as they are transferred out of the processing area. Most of the filter elements are expected to be non TRU based on the process flow diagrams and will be grouted for disposal at ERDF. It is assumed that if the filter elements are washed with water prior to removal from the process, the dose rate will be low enough that filter grouting can be a manual operation with shielding to reduce the radiation dose to personnel. The drums can be shielded if necessary during the grouting operation.

If the filter housing is changed out along with the filter, then a larger container than a drum will be required to grout the filter and housing. Even if multi-cartridge housings are used, it is assumed that filter grouting can be done as a manual operation with shielding around the grout container.

7.7 Sample Shipment

Once samples are taken and placed in a shielded pig, decontamination and transfer of the sample to the sample truck for shipment to the laboratory will be done manually.

8. Remotely Operated and Maintained Equipment

This section describes sludge treatment equipment that will require either remote operation or maintenance. Subsection 8.1 covers remote operations and subsection 8.2 covers remote maintenance.

8.1 Remote Operations Requiring a Crane or Manipulators

Most of the sludge processing equipment that will require heavy shielding can be operated and monitored remotely from outside of the processing area. However, some operations will need to be done inside a shielded area using cranes and manipulators. Following is a list of operations that will need to be done with cranes or manipulators because they involve mechanical operations such as opening vessels or changing out equipment.

- Dissolver heel inspection
- Lag storage tank heel inspection
- Dissolver feed tank heel inspection
- Filter element changeout
- Sampling

8.1.1 Dissolver Heel Inspection

The inside of the dissolver will need to be inspected on a regular basis to verify that there is not a buildup of fissile material. This will probably require removing a flange and using a remote TV camera and light to view the interior of the dissolver. A crane or manipulator will be required to remove the vessel flange and position the camera and light for inspecting the inside of the dissolver vessel.

8.1.2 Lag Storage Tank Heel Inspection

Inspection of the lag storage tank will be similar to inspection of the dissolver as described above.

8.1.3 Dissolver Feed Tank Heel Inspection

Inspection of the dissolver feed tank will be similar to inspection of the dissolver as described above.

8.1.4 Filter Element Changeout

A cartridge filter will be used downstream from the centrifuge as a polishing filter to remove fine particulate material that passes through the centrifuge. The fine particulate material will plug the filter media over time so the filter cartridges will need to be replaced periodically (approximately 47 times during the course of the sludge treatment campaign).

It is assumed that the filter will be designed so that the filter elements can be replaced remotely by either of the two following methods:

- 1) The filter housing will remain in place with only the filter elements replaced. Removing the filter elements will require remotely removing the lid from the filter housing and then removing and packaging the filter elements. The steps would be reversed to install the new filter element.

lines to the filter housing and then replacing the entire filter housing.

Replacement of the cartridge filters as describe above will require a crane or manipulator.

The current baseline is to place the filter elements in 55-gal drums for disposal. If this is done, it is assumed that an air lock will be used to transfer the filters out of the processing area. This could be done by moving a shielded drum into the air lock and then remotely lowering a filter cartridge through a hatch into the drum. Then the hatch will be closed and the drum brought out of the air lock. Movement of the drums into and out of the air lock could be done using a small forklift, a drum dolly, or a trolley system similar to the ones used at the WRAP facility.

Changeout of the filters could be done more efficiently by installing two or more cartridge filters in parallel. This will allow processing to continue while a filter cartridge is being replaced, or alternately allow changeout of more than one filter during the same process interruption.

The non TRU filter elements will be grouted for disposal at the ERDF. Several of the filter cartridges are expected to be TRU and will be stored in the drums for final disposal at the Waste Isolation Pilot Plant (WIPP) or an incineration facility.

8.1.5 Sampling

Samples of the solution in the adjustment tank will be required for every batch of sludge processed. Samples may also be needed from other vessels from time to time. The radiation dose from the samples is expected to be high enough that remote handling of the samples will be required until the samples are placed in a shielded container. This could be relatively simple using simple manipulators or extension tools in a small shielded cave adjacent to the main cell.

8.2 Remote Equipment Most Likely to Require Maintenance

The sludge processing campaign is projected to last less than a year so equipment failures are less likely than in a plant designed for a 20-30 year lifetime. However, the characteristics of the sludge may cause equipment to fail sooner than it would in normal service. The 6.4 mm uranium metal fragments that will be present in some sludge streams can be expected to shorten the life of pumps, valves, flow meters, and agitators. Other mechanical equipment that will be needed for the sludge treatment facility are a centrifuge and a continuous sludge feed system for the dissolver.

8.2.1 Continuous Sludge Feed System to Dissolver

The equipment that will be used to continuously feed sludge to the dissolver has not been determined at this time. Development and testing work is planned to ensure that a reliable concept is selected. One concept that has been suggested is a small head tank with a rotating "water wheel" that scoops up some of the agitated sludge solution and feeds it by gravity to the dissolver. A feed system like this would probably need an electric motor to drive the rotating wheel. The motor and rotary feeder may require maintenance.

8.2.2 Pumps and Agitators

The number and type of pumps and agitators that will be needed has not been determined at this time. However, it is estimated that there will be a minimum of 9 pumps and 8 agitators in the shielded cell (assuming pumps are used for all the transfers). Most pumps and agitators have electric motors which may fail and require repair or replacement. There is the possibility that air operated pumps will be used which may be more reliable than electric pumps. The probability of an agitator failing is considered to be significantly lower than a pump failure.

Pulse jet agitation is being considered as an alternative to mechanical agitators. If this type of agitation is used, the moving parts can be located outside the cell where they can be repaired using contact maintenance.

The pump design(s) that will be used to transfer sludge have not been determined. Some of the sludge streams will contain pieces of 6.4 mm uranium metal in addition to uranium oxides, silica, and other components of K Basin sludge. The pieces of uranium metal are likely to result in a short operating life for the pumps upstream from the dissolver, depending on the pump design selected. If fluidic transfer is used instead of mechanical pumps, the moving parts can be located outside the cell where they can be repaired using contact maintenance. Once the uranium in the sludge is dissolved in the dissolver, most of the residual solids will consist of silica. The silica may still be erosive to pumps, but less so than the pieces of uranium metal.

8.2.3 Valves and Flow Meters

Remotely operated valves and flow meters will probably be required at various locations in the sludge processing facility. The facility must have the capability to replace these valves and flow meters if they fail.

8.2.4 Centrifuge

The centrifuge will have an electric motor which may fail and require repair or replacement. The Robatel centrifuge recommended for the sludge treatment facility includes shielding between the centrifuge bowl and the motor to allow contact maintenance of the motor if the background dose rate in the area is not excessive. The facility should be designed to shield the area around the centrifuge motor to reduce background radiation to the point that contact

maintenance can be performed on the centrifuge motor. This could be done by installing the centrifuge so that the motor is located above the cell with the shaft extending down through the shielding to the bowl and housing which would be located inside the cell.

9. Maintenance and Operation Concepts

The following design principles are recommended to facilitate operation and maintenance in a radioactive environment:

- 1) Minimize mechanical and electrical equipment in a radioactive environment.
- 2) Use welded fittings on piping as much as possible to minimize the potential for leaks.
- 3) Dip legs or submerged pumps (turbine, cantilevered centrifugal, etc.) are preferred to bottom outlets for transferring liquid out of vessels. This minimizes the potential for leaks and the need for most isolation valves.
- 4) Redundant pumps and transfer lines in critical areas decrease the need for maintenance or replacement of pumps and valves. It also reduces down time due to plugged transfer lines.
- 5) The use of fluidics technology to transfer and agitate solutions can reduce the number of moving parts located in a shielded cell. Fluidics technology employs compressed air as the motive force for transferring or agitating solutions. Moving parts can be located in a cold area where contact maintenance can be used.
- 6) Steam jets are generally preferred to pumps if steam is available and the flow rate does not need to be closely controlled. The steam jet operating valves can be located in a cold area where contact maintenance can be employed. However, abrasive solids in a solution will erode and possibly plug the throat of jets. To prevent the back flow (suck back) of radioactivity into cold areas, jets need to be purged with air and vented following transfers. Locating the jet control valves high above the steam jets also helps to prevent back flow.

The following subsections describe several maintenance and operating concepts that have been used or considered in the nuclear industry, and evaluates those concepts for a sludge treatment facility.

9.1 Canyon

The canyon concept was used for nuclear fuel processing plants built at Hanford (T, U, B, Redox, and PUREX) and the Savannah River Plant during the 1940s and 1950s. The canyons consisted of a series of shielded cells with

processing equipment connected by pipe jumpers with remote connectors. Electrical jumpers with remote connectors were used to supply power and transmit electrical signals for in-cell instrumentation. Pneumatic jumpers were used to supply process air and instrument air to equipment in the canyon. An overhead bridge crane was used to remove cell cover blocks when access to the cells was needed for equipment replacement. An impact wrench and hoists on the crane were used to disconnect and replace failed equipment when necessary. The crane was also used to change piping routes, and perform some operating functions such as charging fuel elements to dissolvers. The crane operator rode in a cab that was separated from the canyon area by a shielding wall. The cranes were equipped with periscope type optics to view the equipment in the canyon. The optics were later supplemented by closed circuit TV systems.

The Process Facility Modification project (canceled prior to start of construction) included a canyon as well as a hot cell in the design. The canyon crane in the PFM project was designed for remote operation from a control room using a closed circuit TV system. The crane at the 244-AR vault also was operated from a control room using TV cameras and a periscope. The 244-AR vault is a small canyon facility located near the AW tank farm.

The canyon concept adds considerably to the initial cost of the plant. This increment is not materially altered by the size of the plant since the cost of various devices required for remote maintenance remains the same. Therefore, it is difficult to justify the canyon concept for a small plant (Stoller and Richards, 1961).

Advantages and disadvantages of the canyon concept are listed below.

Advantages:

- Operating flexibility if properly designed
- Designed for remote equipment replacement
- Minimal downtime needed for replacement of pumps, agitators, and other equipment.
- Proven technology

Disadvantages:

- High initial cost
- Requires more cell space than other concepts to accommodate equipment removal. If equipment is stacked, upper equipment must be removed to gain access to lower equipment for remote maintenance.
- Yokes and specialized tools are needed to enable remote maintenance and equipment replacement to be performed by the crane.

- Tight tolerances are required on floor elevations and wall positions to ensure that rigid pipe jumpers will fit properly.

Applicability of canyon concept to sludge treatment:

The canyon concept allows a great deal of flexibility for process modifications since large pieces of equipment can be replaced remotely and routes between vessels can be changed easily using alternate jumper arrangements. However, the flexibility comes at a high initial cost and is not needed for sludge processing. The canyon concept is more suited to a large processing plant with a long mission than to a small process that will be operated for a short time.

The operating and maintenance requirements of a sludge processing facility can be met using the canyon concept. A canyon crane with impact wrench and hoists could be used to change out the filters and replace valves, pumps, and agitators if needed. A camera on the crane could be used to inspect the interior of the dissolver, lag storage vessel, and dissolver feed tank. If maintenance is required on the centrifuge, the crane could also be used to replace the centrifuge or move it to a maintenance area.

The canyon concept does not appear to be a viable option for the sludge processing facility unless an existing canyon facility can be used. The flexibility provided by a canyon facility is not needed for the well defined mission and relatively short operating time needed for sludge processing. However, the use of an existing canyon could save a large investment in capital cost over a new facility that has a very limited mission.

9.2 Hot Cell with Overhead Crane and/or Manipulators

Hot cells generally consist of shielded cells with viewing windows, manipulators, and in-cell cranes. The manipulators and cranes can be used to perform both maintenance and operating functions. Crane or wall mounted power manipulators appear to be more useful than master/slave manipulators for the sludge processing facility since they are more versatile and mobile. One crane mounted manipulator and hoist combination may be all that is necessary to perform the remote maintenance and operating functions that are required.

A closed circuit TV system can be used to minimize the number of viewing windows necessary to operate wall mounted and overhead manipulators and hoists.

The UP3 reprocessing plant at La Hague, France has hot cells designed for remote replacement of equipment likely to fail. Standard process equipment such as valves and pumps can be remotely replaced using a mobile cask (Bernard et. al., 1984). This is commonly called flasking. Specialized valves and pumps are located near the top of the cell and isolated from the cell environment by an enclosure. Pump motors and valve actuators are located in the maintenance area above the cell with a shaft extending down through the

shielding to the wetted part of the pump or valve. Contact maintenance can be used to service or replace motors or actuators since they are located outside the cell. If the wetted parts of a pump fail, it can be replaced using a mobile equipment replacement cask (MERC) system. Remote replacement of the equipment does not contaminate either the cell or the maintenance area above it. Coupled doors with a special connecting gasket are used to make an airtight seal between the mobile cask and the hatch cover of the cell to ensure containment. Then the hatch cover and coupled doors are opened and a gripping device is used to lift the pump into the cask. Once the pump is inside the cask, the hatch cover and coupled doors are closed and the cask can be moved to a maintenance area. The process is reversed to install a replacement pump. Valves, filters, ejectors, etc. can be replaced in a similar manner.

Other equipment requiring remote maintenance at the UP3 plant was designed to facilitate remote maintenance through the replacement of complete subassemblies. Subassemblies considered to be the most unreliable, such as motors and monitoring devices, were designed to be removed using the MERC system. In-cell cranes, master-slave manipulators, and power manipulators are used to perform remote maintenance on larger subassemblies. Some large components can be removed using an airlock equipped with decontamination and packaging capabilities.

The in-cell cranes and power manipulators are stored in special crane maintenance cells during normal operation to limit contamination.

Reprocessing plants in the United Kingdom use a transfer cask technique similar to the French design to remotely replace valves and pumps (Boomer, et. al, 1996).

Advantages and disadvantages of a hot cell facility are listed below.

Advantages:

- Remote changeout capability for high maintenance equipment
- Remote operations capability
- Operational flexibility
- Proven technology

Disadvantages:

- Higher initial cost than a contact maintenance facility

Applicability of the hot cell concept to sludge treatment:

The operating and maintenance requirements of a sludge treatment facility can be met using a hot cell. An in-cell crane and manipulators could be used to change out the filters and replace valves, pumps and agitators, if needed. The crane also could be used to remove flanges on the dissolver, lag storage vessel, and dissolver feed tank for heel inspections. The crane or manipulators could be used to position a TV camera for the heel inspections.

The centrifuge could be installed with the motor located above the cell shielding with the shaft extending down through the shielding to the bowl located inside the cell.

The mobile cask (flasking) system used for equipment replacement at nuclear facilities in France and the United Kingdom would probably be too expensive to use at a sludge treatment hot cell since sludge treatment is a small process with an operating life of less than one year.

A hot cell for sludge treatment could be pre-fabricated offsite, and then shipped to Hanford and assembled at the construction site. Windows, manipulators, and shielding would be installed at the site. This technique was used to build the last hot cells installed at the 222 S laboratory. Depending on size, this type of the hot cell could possibly be relocated after the sludge treatment campaign is completed.

9.3 Contact Maintenance and Operation

The contact maintenance concept was used for the nuclear fuel reprocessing plants built at the Idaho National Engineering and Environmental Lab (INEL) and the Oakridge National Lab during the 1950s. In a contact maintenance and operation plant, personnel enter the shielded processing area to perform maintenance and operating functions on processing equipment while it is in place. None of the equipment is designed to be replaced remotely. If the equipment has handled dissolved fuel elements or high level waste, extensive flushing and decontamination may be necessary to reduce the dose rate prior to performing maintenance work on the equipment. This requires down time, corrodes equipment, and generates liquid waste. Nearby equipment generally must be flushed and/or shielded to reduce the radiation dose to the personnel involved in the maintenance work.

The initial cost of a contact maintenance plant is lower than a remote maintenance plant, but operating and maintenance costs can be high due to the down time and waste generation associated with flushing and decontamination. The reduction in exposure limits and the emphasis on the ALARA concept have made contact maintenance for the high radiation areas of nuclear fuel reprocessing plants less feasible in recent years.

Contact maintenance is the most feasible and economical concept to use in plant areas that require some shielding, but where the radiation dose rate is relatively low. Processing plants that use the canyon or hot cell concept for

high radiation dose areas generally use contact maintenance for equipment that has a relatively low radiation dose rate.

Advantages and disadvantages of a strictly contact maintenance facility are listed below.

Advantages:

- Low initial cost compared to canyon or hot cell
- Efficient use of in-cell space by stacking equipment vertically
- Proven technology

Disadvantages:

- Very limited operational flexibility
- Sufficient spares for critical items must be installed to allow continued operation in case of equipment failure
- Decontamination and manned entry needed for all maintenance in high dose rate areas
- Cell equipment must be designed to withstand repeated exposure to decontamination solutions
- Scaffolding and ladders resistant to decontamination solutions must be installed in the cells for personnel access to in-cell equipment.

Applicability of contact maintenance concept to sludge treatment:

The current baseline process for sludge treatment includes a cartridge filter that will need to have the filter elements replaced periodically as they plug with solids. Even if the filters are flushed with water to remove the radionuclides from the liquid held up in the filter cake and filter media, the radiation dose rate is expected to be too high to allow manual changeout of the filter elements. The baseline process will need to be changed to eliminate the need for filter changeout if a strictly contact maintenance plant is to be used. This still leaves the need to inspect the interior of the dissolver and other vessels for heel buildup. This could not be done in a contact maintenance plant.

There is not enough time in the sludge treatment processing window to perform the flushing and decontamination necessary for contact maintenance. The liquid waste from flushing and decontamination would have to be trucked to the 200 E area for disposal.

For the above reasons, the contact maintenance concept is not acceptable for the main processing equipment needed for sludge treatment.

9.4 Pump and Valve Maintenance Corridor Adjacent to Cell

The New Waste Calcining Facility at INEEL used a modified contact maintenance concept. The large processing vessels that were unlikely to need maintenance were hard piped in place and required manned entrance in the unlikely event that maintenance was required. Equipment that was more likely to fail such as control valves and pumps were designed with remote connectors and located in a shielded maintenance corridor adjacent to the main cells. The maintenance corridor was equipped with an electro-mechanical manipulator and an overhead crane for replacing the valves and pumps if needed. A combination of TV cameras and viewing windows were used for viewing the interior of the cells and maintenance corridor.

A similar concept was used for the Fluorine and Storage (FAST) reprocessing plant at INEEL. Equipment requiring frequent maintenance such as valves and pumps were designed with remote connectors and located so they could be replaced using a crane or manipulators (Christian, 1998). The crane was used to move the failed equipment to a maintenance cell where it could be decontaminated and repaired using contact maintenance. Viewing windows and TV cameras were used for viewing the interior of the cells.

Advantages and disadvantages of the maintenance corridor adjacent to processing cells are listed below.

Advantages:

- Low initial cost compared to a canyon facility
- Remote changeout capability for high maintenance equipment

Disadvantages:

- Decontamination and manned entry needed for maintenance on large pieces of equipment
- Higher initial cost than contact maintenance facility
- Limited operational flexibility
- Only used in two facilities

Applicability to sludge treatment:

If this type of facility was built for sludge treatment, the pumps, valves and filter could be located in the maintenance corridor so that they could be replaced remotely. This would require much longer piping runs and more elbows than a direct route between vessels. The longer piping runs and additional elbows would increase the likelihood of pipe plugging when transferring sludge between vessels. A crane or manipulator would still be required in the main cell to inspect the interior of the dissolver and other vessels for heel

buildup. Replacement of mechanical agitators in the sludge treatment vessels also would require a crane or manipulator in the main cell.

In a small facility with a short operating life such as required for sludge treatment, the maintenance corridor would add to the complexity and size of the facility.

For the above reasons, the maintenance corridor concept is not recommended.

9.5 Skid Mounted Modules in the CVD

The sludge treatment preconceptual design document prepared by Fluor Daniel Northwest (Chang, 1997) was based on fabricating the sludge treatment facility as six skid mounted modules. Three of the skid mounted modules could then be moved into the spare bay in the Cold Vacuum Drying (CVD) facility or some other building. The other modules could be located outside the facility. After the modules were set in place, they would be connected together to form an integrated sludge processing facility. The liquid processing equipment was grouped together in one module on skid #1 and the off gas treatment equipment was grouped together on skid #2. The design included removable shielding that would be placed around these two skids to reduce the radiation dose to operating personnel. The stack and stack monitoring system would be located on skid #3. Skid #4 would contain cooling towers and heaters for heating and cooling water. Skid #5 would contain the chemical makeup tanks. Skid #6 would contain the control room and electrical switchgear. Skids 3, 4, and 5 could be located outside the facility.

The preconceptual design was based on the contact maintenance concept and included connections for water flush lines to flush piping and vessels to reduce the radiation dose rate. The design included redundant pumps that could be valved into the process in case of a pump failure. This would reduce the downtime for decontamination and maintenance to repair or replace a pump. However, the additional valves needed to switch the routing between the pumps also adds additional mechanical equipment in the high radiation area. The valves could be avoided by adding redundant transfer lines along with the pumps. The design did not include any details about how maintenance personnel would gain access to the shielded modules if maintenance was required.

Advantages and disadvantages of the preconceptual modular design:

Advantages:

- Self-contained except for utilities (compressed air, electrical power, water, steam)
- Modular concept allows flexibility in location
- Modular concept would facilitate decontamination and decommissioning after completion of sludge processing

Disadvantages:

- Decontamination and manned entry needed for maintenance
- Downtime needed for decontamination prior to maintenance
- No remote filter changeout capability
- Very limited operational flexibility
- New technology for radioactive processing facility

Applicability to sludge treatment:

Since the modular concept described in the preconceptual design depended on contact maintenance, it has many of the same drawbacks as the contact maintenance concept described earlier. It did not have any provision for remote maintenance or remote operating functions such as filter replacement and heel inspections. (The need for a cartridge filter and heel inspections was not identified when the preconceptual design was done.) Decontamination and contact maintenance would be used if maintenance was required in the high radiation area.

There is not enough time in the processing window for sludge treatment to perform the flushing and decontamination necessary for contact maintenance.

For the above reasons, the modular concept described in the preconceptual design is not acceptable for the main processing equipment needed for sludge treatment. However, the modular concept could be used for the off-gas system and chemical makeup tanks. The modules would be easier to move for reuse or decommissioning after the sludge treatment campaign than permanently installed equipment.

9.6 Compact Processing Unit

The compact processing unit (CPU) concept was developed by PNNL in the early 1990s as part of the effort to pretreat Hanford tank waste prior to vitrification. The concept involves building process equipment in small modules that can be manufactured offsite by commercial vendors and moved into place using conventional transport methods such as the transporter used to move deactivated submarine reactor compartments from Richland to the 200 E area. In some ways this is quite similar to the prefabricated hot cells discussed at the end of section 9.2. Different unit operations could be built on separate modules and then linked together onsite. Support services such as offgas treatment, chemical makeup, utilities, and process control would be provided by separate modules.

The basic philosophy underlying the CPU concept is that facility costs can be reduced if the following items of the design and construction process can be separated (Richmond, 1998):

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- Safety and process
- Process testing and construction
- Site selection and schedule

The idea was that safety and processing aspects can be separated by building compact processing units that are housed in a safety/containment enclosure so that none of the equipment needs to be safety class or safety significant. If the units are designed so that no maintenance or operating functions need to be done inside the unit, then no provisions for personnel access are required. Approximately 30% of the construction cost for a nuclear facility is to accommodate people. Equipment inside the units can be located more compactly and the ventilation does not need to meet personnel access requirements. A chiller would be used to remove the heat generated by the process since little heat would be removed by the low ventilation flows.

PNNL produced a conceptual design for a single CPU demonstration module for pretreatment of Hanford tank waste based on cesium ion exchange. The purpose of the design was to demonstrate the processing of radioactive waste from a single Hanford tank over a 12 month period. The supernate would be transferred from a waste tank to the processing unit where it would be treated by ion exchange and then transferred to a different waste tank. The CPU included two 5000 gal tanks, four ion exchange columns, and five pumps as well as valves and transfer lines. The equipment would be installed in a stainless steel framework which would then be placed inside a concrete vault for shielding and containment. There was no maintenance capability for most of the pumps and valves inside the CPU. All controls for the valves and electrical equipment were designed to be located in a control station separated from the processing unit but connected by a cable bundle.

Before the PNNL CPU project proceeded past conceptual design, the mission changed and Ebasco/BNFL was given an expanded charter to produce a conceptual design of a CPU facility for extended radioactive operation (Ebasco/BNFL, 1994). This was called the Initial Pretreatment Module Cesium Demonstration Unit (CDU). The CDU equipment was designed to fit into compact stainless steel modules of various dimensions. The modules would be connected together to make up the entire processing facility. The equipment could be fabricated off site as soon as the design was finished and then tested before transfer to Hanford. Site selection and permitting could proceed parallel to the testing. The enclosure and shielding could be built later and the equipment assembly placed inside after testing was completed.

The CDU conceptual design placed valves near the top of the CPU modules with the actuators outside the module shielding. The design included the capability to replace valve bodies, pumps, and filters remotely from outside the CPU modules using a transfer cask. This is the flasking technique used in nuclear plants in France and the United Kingdom.

Advantages and disadvantages of the CPU concept:

Advantages:

- Low capital cost
- Modular concept allows flexibility in location
- Modular concept would facilitate decontamination and decommissioning after completion of sludge processing
- Accelerated schedule

Disadvantages:

- Limited equipment replacement capability with a transfer cask if specialized valves and pumps are used
- Transfer cask needed for filter changeout
- No operational flexibility
- New technology - the CPU concept has only been used for a few small radioactive processes

Applicability of the CPU concept to sludge treatment:

The remotely operated portion of the sludge treatment facility will contain a minimum of eight vessels (with agitators), a centrifuge, a cartridge filter, and approximately nine pumps.

Any processing equipment expected to fail would need to be designed so that it could be maintained from outside the containment enclosure. Agitator and centrifuge motors could be located on top of the containment enclosure with shafts extending down through the shielding and containment enclosure to the equipment inside. Designing the pumps and cartridge filter so that they can be maintained and operated from outside the containment enclosure presents more difficult problems.

The filter elements in the cartridge filter will need to be replaced frequently (approximately every four batches). There does not appear to be an easy way to replace the filter elements in a CPU. One possible way would be to place the filter housing against the top of the containment enclosure so that the filter elements could be removed from outside the containment enclosure. This would require removing a shielded plug in the containment enclosure or opening a hatch to gain access to the top of the filter housing. Then the filter housing would need to be opened and the elements removed and placed into a drum or other container. It is assumed that this would need to be a remote operation using a small crane or extension tools. A secondary containment enclosure would be necessary to prevent the spread of

contamination and to protect workers in inclement weather. A transfer cask could also be used.

Pumps could be located in shielded niches outside the main containment where they could be decontaminated and repaired, or replaced, in a contact operation. However, locating the pumps in niches would require much longer piping runs and more elbows than if the transfer routes go directly from vessel to vessel. The additional piping and elbows would increase the probability of plugging the lines with the solids present in the sludge.

The CPU concept appears to be more applicable to a smaller operation than sludge treatment. If neutralization of the dissolved sludge is separated from the rest of the sludge treatment process in order to avoid shipping solids from 100 K to the AW tank farm, then the CPU concept looks very attractive for the neutralization process. The neutralization process inside the CPU would consist of one agitated tank and a pump to transfer the neutralized slurry to waste tank AW-105. Redundant pumps could be used to minimize the need for pump maintenance. The heat generated by the neutralization reaction would need to be removed. This is not considered a big problem since the past design effort on the CPU concept included provisions for heating and cooling vessels inside the containment enclosure.

Chemical makeup tanks for the NaOH and NaNO₂ used in the neutralization process could be located outside the containment enclosure and pumped from there directly into the neutralization tank. The chemical makeup tanks and transfer lines would need freeze protection. Tank trucks or bulk containers could possibly be used instead of chemical makeup tanks.

The CPU concept may also be the best alternative for the solids storage tank. Since this large tank will need less shielding than the main processing vessels, it may be advantageous to place it in a CPU to reduce the size and cost of the processing cell.

10. Conclusions

The primary conclusion reached as a result of this study is that a hot cell is the best maintenance and operating concept for the main processing equipment needed in a sludge treatment facility. It will provide the capability for vessel heel inspections, filter changeout, and remote maintenance of mechanical equipment in a timely manner while protecting personnel from high radiation fields. Hot cell technology is well developed and has been used for many years in the nuclear industry.

Secondary conclusions from the study are listed below:

- Preliminary dose rate and shielding calculations indicate that a shielded facility will be needed for the lag storage tank, elutriation system, dissolver feed tank, resin buffer tank, dissolver, centrifuge,

leach tank, clarified liquid tank, cartridge filter, adjustment tank, and neutralization tank.

- Contact maintenance and operation can be used for the transport container, chemical makeup tanks, off-gas system downstream from the condenser, and undissolved solids grouting.
- A crane and/or manipulators will be needed to remove flanges from vessels for heel inspections, to replace failed pumps and agitators, and to change out filter cartridges. The crane can be located outside the processing cell if a canyon facility is used or inside the cell if a hot cell is used. Alternatives to the heel inspections and cartridge filter should be pursued to simplify operation of the sludge treatment facility.
- If an alternative to cartridge filters is not found, installation of several cartridge filters in parallel should be considered to reduce the number of process interruptions needed for filter changeouts.
- A strictly contact maintenance facility is not feasible for the main processing equipment in a K Basin sludge treatment facility. Radiation dose rates will be too high to enter the cell unless it is preceded by flushing and decontamination. There is not enough time in the processing window to perform the flushing and decontamination necessary for contact maintenance.
- Fabricating the sludge processing equipment as skid-mounted modules is not feasible for the main processing equipment unless it can incorporate some remote maintenance and operations capabilities. Skid mounted modules are appropriate for the off-gas system and chemical makeup tanks.
- The CPU concept should be considered for the neutralization tank if it is located separate from the main sludge treatment facility.
- Equipment likely to require maintenance should be designed to facilitate replacement - incorporate features of canyon design philosophy.
- The design principles listed at the beginning of section 9.0 should be incorporated into the design if feasible and cost effective.

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