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7. Abstract

This document provides the technical background information needed to demonstrate that the emission control equipment chosen for the 105-KE Encapsulation activity satisfies the requirement for Best Available Radionuclide Control Technology (BARCT), as defined by Washington Administrative Code (WAC) Chapter 246-247.

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1.0 Executive Summary

The Department of Energy's (DOE) Hanford Site is located northwest of Richland, Washington. The 105 K-East Fuel Storage Basin (105-KE Basin) is located in the northwest portion of the Hanford Site in what is identified as the 100-K East area approximately 40 kilometers (25 miles) northwest of the City of Richland.

The 105-KE Basin currently stores irradiated residual irradiated N Reactor fuel elements. The fuel elements are contained in open canisters which allows fuel surfaces to be exposed to the basin water. Approximately six percent of the fuel cladding material has experienced damage during processing activities in the past. Because the breached cladding material has allowed contact of irradiated metallic uranium nuclear fuel with basin water, the resultant oxide corrosion products have migrated to the basin water.

To prevent further migration of oxide corrosion products, the fuel elements will be encapsulated in new canisters. The encapsulation activity will involve process operations, most of which will be conducted under water. The underwater operations include emptying fuel elements from the existing canisters stored in the 105-KE Basin onto a dump table, filling new canisters with the fuel elements, relocating basin sludge to support encapsulation of the fuel elements, filling new canisters with sludge, capping the new canisters of fuel elements or sludge, cleaning and crushing empty canisters, and returning the canisters of fuel elements or sludge to the storage racks in the basin. Crushed canisters will then be lifted out of the water and packaged for disposal.

Washington Administrative Code 246-247 requires that a notice of construction (NOC) be submitted before the encapsulation activity can proceed. The NOC must include an analysis to determine the best available radionuclide control technology (BARCT) for the reduction of radionuclide emissions resulting from the encapsulation activity.

The Washington State Department of Health (DOH) has determined that high efficiency particulate air (HEPA) filtration of radionuclide particulate matter from gas streams is currently

considered BARCT in cases where no adverse energy, environmental, economic, or other impacts are associated with the application of this control technology. For the encapsulation activity, the baseline option consists of minimization of particulate radionuclide emissions by performing the encapsulation activity under water which is treated by the existing water treatment systems.

Several HEPA filtration options were considered in order to evaluate the most economic application of HEPA filter control technology. Cost estimates for each option were prepared based on past HEPA filter installation experience for the Hanford Site.

The economic impacts due to each HEPA filtration option were evaluated by estimating the total installed capital cost and operating cost for each option. An equivalent amortized capital cost along with the estimated annual operating cost for each unit was then determined. The economic impact to the facility for each control option was then defined in terms of total annual cost per unit reduction in the effective dose equivalent (EDE) to the population (person-rem).

The DOH has related that the U.S. Environmental Protection Agency has indicated an acceptable economic impact for control of radionuclide particulate emissions using HEPA filtration is that control which would have a cost effectiveness less than $12 million per person-rem (WHC 1992b). Since the lowest cost to provide HEPA filtration was $87 million per person-rem, it is clear that all the HEPA filtration options evaluated will have an adverse economic impact on the operation of the facility when considering the EDE to the population.

The low baseline emission rate combined with the construction and operating costs for the HEPA filtration options evaluated in this assessment, present an unacceptable economic impact for the encapsulation activity. Furthermore, air quality analyses reveal that baseline emissions of radionuclides will result in a projected 2.1×10^{-2} person-rem/yr EDE to the population.

BARCT for the encapsulation activity is determined to be the baseline option which consists of minimization of particulate radionuclide emissions by performing the encapsulation activity under water which is treated by the existing water treatment systems.

2.0 Introduction

2.1 Hanford Facility and Location Description

The Department of Energy's (DOE) Hanford Site covers approximately 1,450 square kilometers (560 square miles) of semi-arid land in southeastern Washington, Northwest of Richland. The 105-KE Basin is located in the northwest portion of the Hanford Site in what is identified as the 100 K-East area approximately 40 kilometers (25 miles) northwest of the City of Richland. Figure 2-1 shows the geographical location of the Hanford Site and identifies the 100-K Area within the Hanford Site boundary.

2.2 Background

From 1955 to 1971 the 105-KE Basin was used to store irradiated fuel from KE Reactor until its deactivation. During the years the 105-KE Basin was operated for KE Reactor, it held several hundred metric tons of irradiated fuel which contained millions of curies of fission and activation products from the nuclear operation of the reactor. In 1975 the 105-KE Basin was reactivated for short term storage of N Reactor irradiated fuel. The 105-KE Basin was first upgraded in 1978 with the addition of a cartridge filter cells, and cesium specific zeolite ion exchange system. From 1975-1983 irradiated fuel from N Reactor was added to the 105-KE Basin in open top canisters (WHC 1988a). Approximately six percent of the irradiated fuel from N Reactor exhibited some fuel cladding damage. At present there are currently 3,668 open top canisters filled with N Reactor fuel stored in the 105-KE Basin (1993a).

From 1955-1978, the 105-KE Basin was filled with filtered water which had been purified by flocculation and filtration. Over the years and after many weapons grade fuel campaigns, sludge began to form in the 105-KE Basin. The formation of the sludge was the result of corrosion of the various metals in the 105-KE Basin water. In the early 1970s the sludge was also found to contain radioactivity that had migrated from the irradiated fuel. In 1975 with the addition of irradiated fuel in open top canisters, some of which had damaged fuel cladding, the process of corrosion and sludge formation accelerated. As a result of the damaged irradiated fuel, the concentration of radioactivity in the sludge continued to increase.

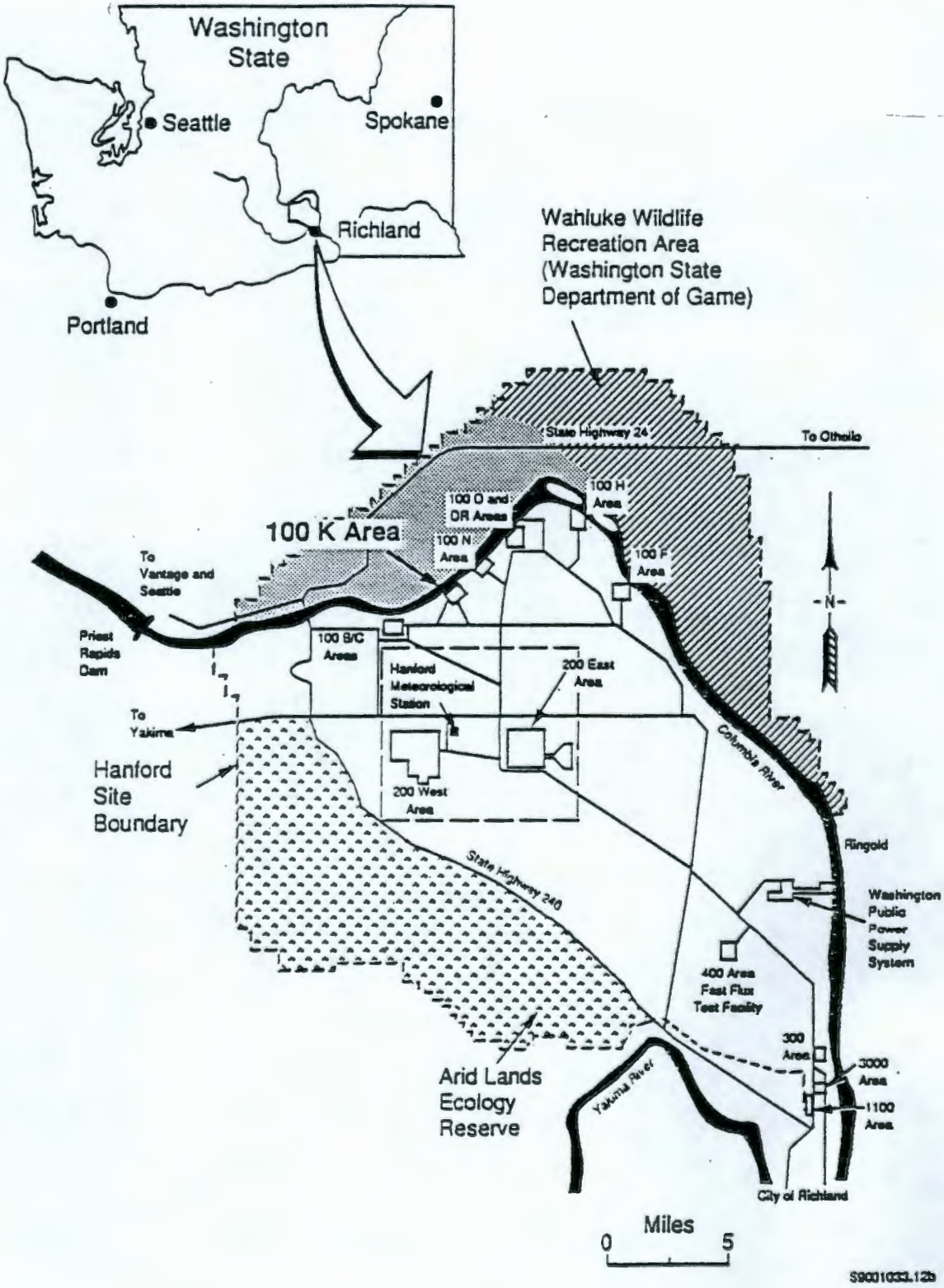

Figure 2-1. Location of the Hanford Site and the 100 K Area.

In 1983 with the addition of a second water treatment system consisting of one sand filter and six ion exchange columns embedded in a concrete shield and disposal container, commonly referred to as an ion exchange module (IXM), the concentration of radioactivity in the basin water decreased significantly. Since 1989, data has shown with the last addition of N Reactor fuel, the concentration of radioactivity in the 105-KE Basin sludge has been decreasing with the continuing corrosion of the metal components present in the 105-KE Basin (WHC 1993a). In contrast, the radioactivity in the 105-KE Basin water increases and decreases with the utilization of water treatment and the operational activities that take place in the 105-KE Basin (WHC 1993a).

In the last fifteen years, the facility has reported that the air in the 105-KE Basin and the air being released to the environment contains small amounts of radioactivity that can only have originated from the damaged irradiated fuel currently stored in the 105-KE Basin. The specific complex mechanisms that transport this small amount of radioactivity from the irradiated fuel to the air are not easily quantified.

The radioactive materials identified in the 105-KE Basin water are in the form of soluble and insoluble radionuclides with respect to their solubility in the basin water. The radioisotopes identified in the basin water from 1979-1987, excluding tritium, were Mn-54, Co-60, Sr-89, Sr-90, Ru-106, Cs-134, Cs-137, Ce/Pr-144, Eu-155, Pu-238, and Pu-239/240 (WHC 1993a). From 1989 to 1992 with the shutdown of N Reactor, the radioisotopes identified in the 105-KE Basin water, excluding tritium, were the long-lived isotopes of Co-60, Sr-90, Ru-106, Sb-125, Cs-137, Pu-238, and Pu-239/240 (WHC 1993a). In late 1992, Am-241 was also identified as being present in the 105-KE basin water.

At the same time, the radionuclides identified in the air released to the environment at 105-KE Basin in 1979-1987, excluding tritium, were Mn-54, Co-60, Sr-90, Ru-106, Cs-134, Cs-137, Ce/Pr-144, Eu-155, Pu-238, and Pu-239/240 (WHC 1993a). Again, from 1989 to 1992, with the shutdown of N Reactor, the radioisotopes identified in the air being released to the environment were identified as the long-lived isotopes of Co-60, Sr-90, Ru-106, Sb-125, Cs-134, Cs-137, Pu-238 Pu-239/240, and Pu-241 (WHC 1993a). In 1992, the significant isotopes present, with respect to their dose contribution, released by the facility were Cs-137, Sr-90, Pu-238, Pu-239/240, and Pu-241. In late 1992, Am-241 was also identified as a significant contributor using data gathered by the fixed head samplers installed in August 1992.

2.3 Scope of the BARCT Analysis

Washington Administrative Code (WAC) 246-247, Radiation Protection -- Air Emissions, requires a notice of construction for the 105-KE Basin Encapsulation Activity which must also include a BARCT analysis (DOH 1990). BARCT is defined by regulation as "technology which will result in a radionuclide emission limitation based on the maximum degree of reduction for radionuclides which would be emitted from any proposed stationary source or modification of a source which the permitting authority on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes or available methods, systems, and techniques" (DOH 1990).

The DOH has determined that high efficiency particulate air (HEPA) filtration has been accepted as BARCT for the control of emissions of radioactive particulate matter (WHC 1992a). For the encapsulation activity, DOH has also determined that this BARCT assessment only needs to evaluate HEPA filtration for particulate air effluent abatement. Controls for radionuclides in a gaseous state do not need to be evaluated (WHC 1992b).

Because DOH has determined that HEPA filtration is BARCT for the control of emissions of radioactive particulate matter, the BARCT assessment proposed the baseline option and three options with different HEPA filtration equipment arrangements. The options were evaluated for technical feasibility. If it was determined that the option was technically feasible, an assessment of the economic, environmental, energy and other impacts was completed. If the impacts of the most effective technology exceeded the impact costs, the technology was eliminated and the next effective technology was considered. The first technology which could not be eliminated is proposed as BARCT.

2.3.1 Identification of Control Options

Since HEPA particulate removal technology is considered BARCT as determined by the DOH, control options identified in this assessment emphasized various equipment arrangements to ensure that BARCT was effectively evaluated.

2.3.2 Technical Feasibility

Evaluation for technical feasibility of the various HEPA equipment control designs involved consideration of the current condition of the basin and its structure, planned encapsulation activities, space limitations, and other technical characteristics. Each conceptual control option was evaluated for technical feasibility. Options which are not feasible were then eliminated from further development.

2.3.3 Economic, Environmental, Energy, and Other Impacts

For each technically feasible option considered, a thorough determination of economic, environmental, energy, and other impacts was completed. Economic impacts involved developing an expected reduction in the EDE to the population expressed in dollars/person-rem based on annualized capital and operating costs. Environmental impacts include waste generation, waste disposal, decontamination, control system construction and other impacts which affect the activity workers and the public. Other additional impacts specific to the 105-KE Basin were also considered.

2.3.4 BARCT Selection Process

Each technically feasible control option was ranked according to cost effectiveness. The control option exhibiting no significant adverse economic, environmental, or other impact was selected as BARCT.

3.0 105-KE Basin Description

3.1 General Description and Layout

The 105-KE Basin was constructed in the 1950s as part of the KE Reactor complex, as shown in Figure 3-1. The 105-KE Basin is a rectangular, reinforced concrete basin (38 m [125 ft.]) long, (20 m [67 ft.]) wide, and (6 m [21 ft.]) deep with a (5 m [16 ft.]) water depth, as shown in Figure 3-2. The 105-KE Basin was modified in 1975 with the addition of a recirculation system, heat exchanger, radiation monitoring system, pool water level monitoring system, cartridge filters cells, and a cesium specific zeolite ion exchange water treatment system (WHC 1988a). A second recirculation water treatment system using sand filters and IXMs was installed in 1983. During this time, the cesium specific zeolite ion exchange resin was replaced with a mixed bed resin containing cation and anion ion exchange material. The main basin floor is covered with fuel storage racks to store the canisters of irradiated fuel elements. Irradiated fuel from KE Reactor and N Reactor was stored in the 105-KE Basin under (5 m [16 ft.]) of filtered water. The storage of the N Reactor irradiated fuel in open top canisters in the fuel storage basin is shown in Figure 3-3.

The heat exchanger circulated river water on the tubeside loop to remove the fuel decay heat from the basin water ciruclated on the shellside loop. In 1984, a water chiller was added to eliminate the seasonal dependence on river water temperature variations in the tubeside loop. The chiller was designed to maintain a water temperature of 10 °C (50 °F), thereby decreasing the rate of corrosion, lowering the solubility of the radionuclides in the basin water, and minimizing the evaporation rate of water.

The 105-KE Basin water consists of demineralized water which is capable of flowing through two different recirculation filtration ion exchange water treatment systems. The first system consists of a cartridge filter cell, a chiller and three ion exchange columns. The second system consists of skimmers, a sand filter and two auxiliary IXMs. Either system can maintain high quality water by removing inorganics and radionuclides. The 105-KE Basin and its water treatment systems are routinely sampled and monitored for flow, conductivity, pH, radionuclides, and, periodically, for inorganic chemicals.

The release of radioactivity to the environment is primarily from the four airborne effluent release points on the roof of the 105-KE Basin, as shown in Figure 3-4.

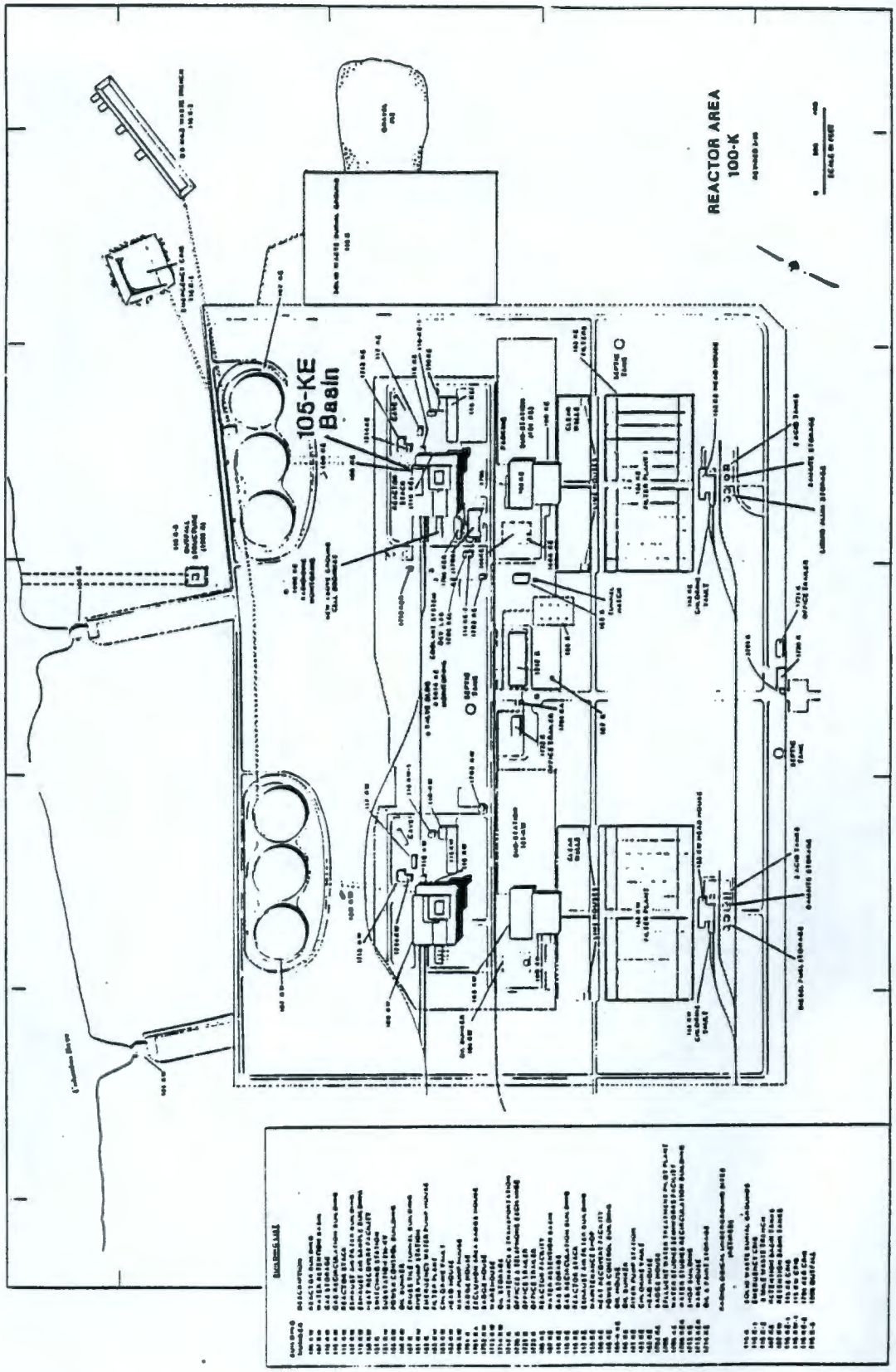

Figure 3-1. Location of the 105-KE Basin within the KE Reactor Complex.

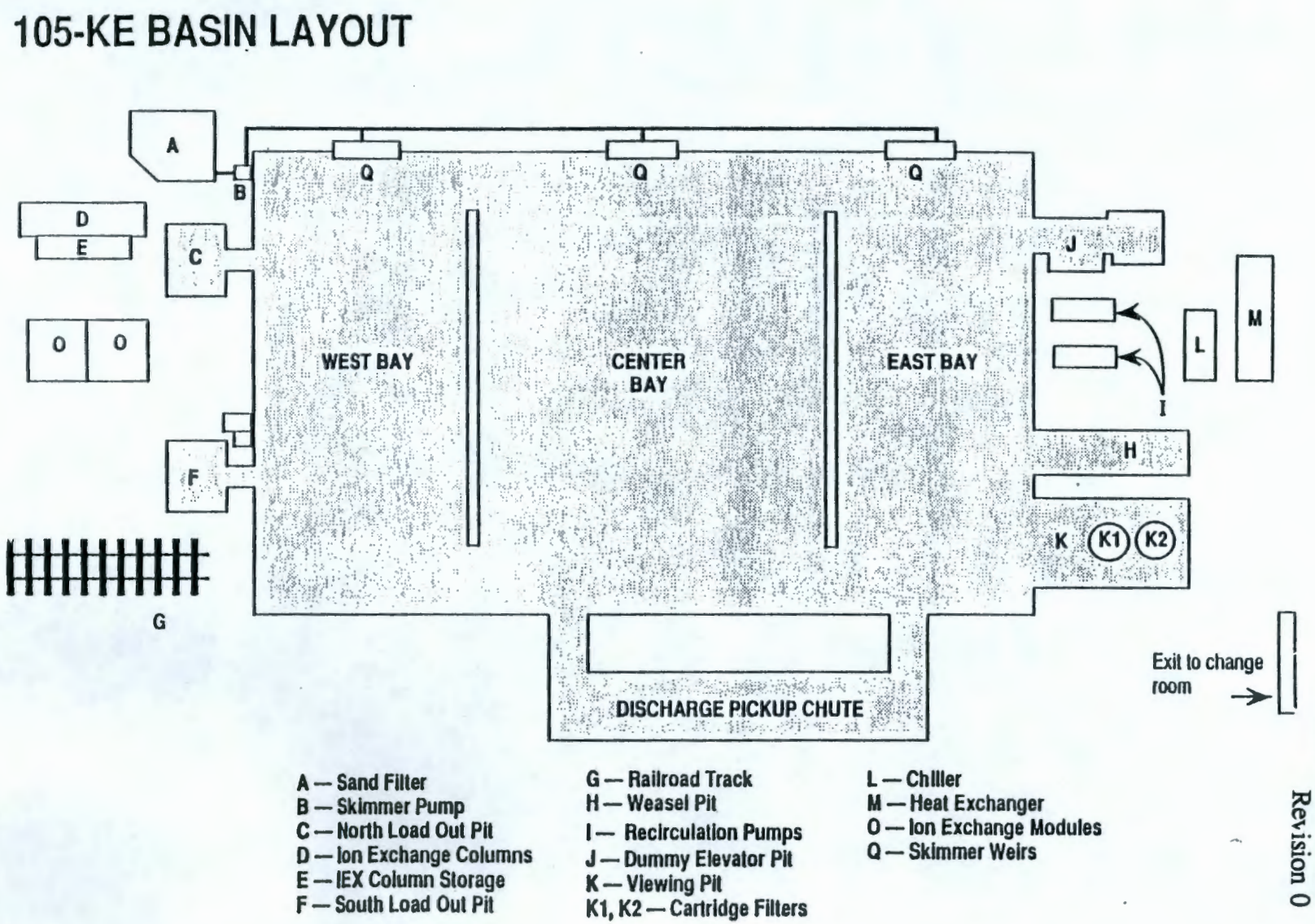

Figure 3-2. 105-KE Basin Layout and its Associated Facilities.

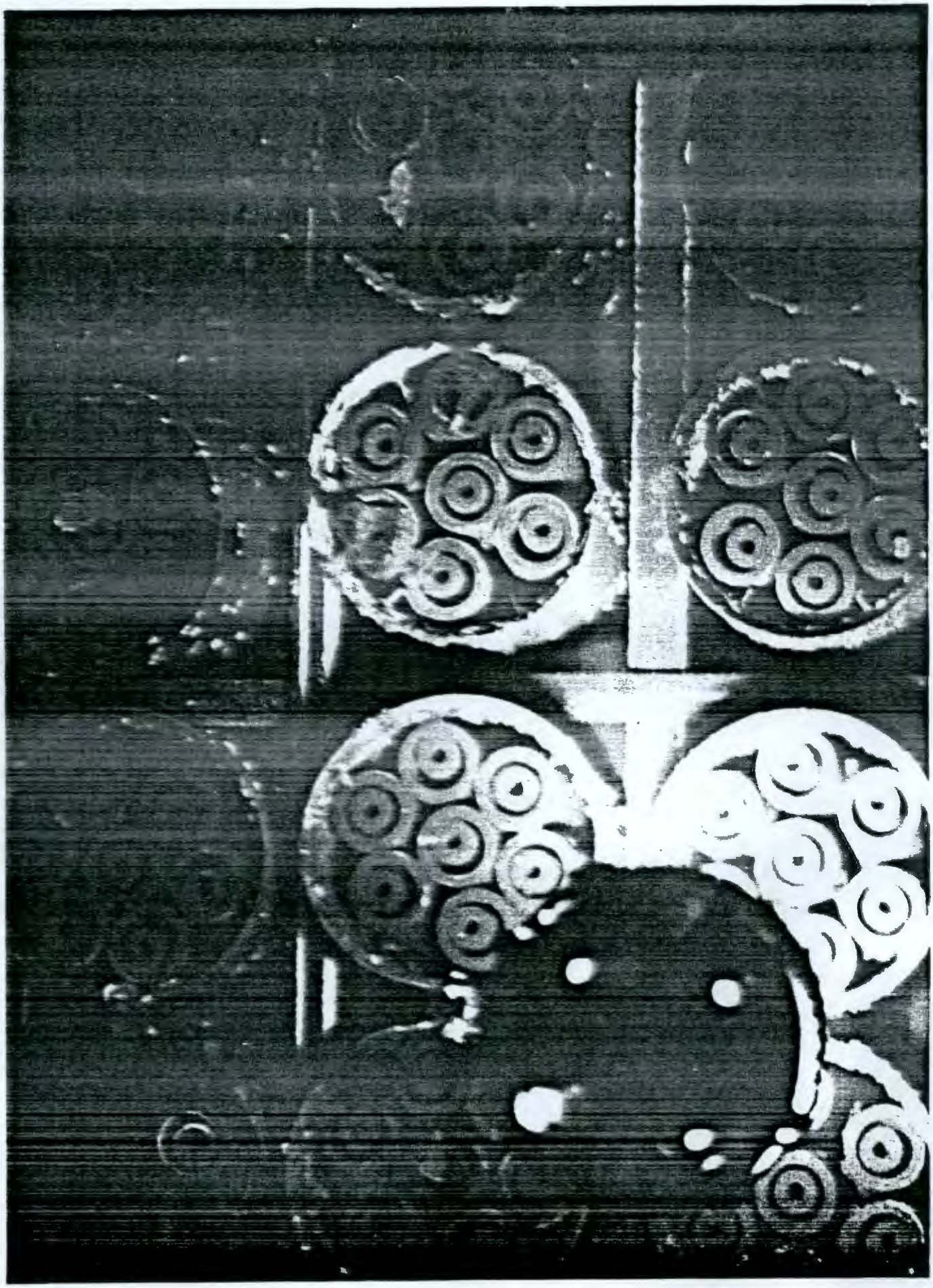

Figure 3-3. N Reator Irradiated Fuel in Open Top Canisters.

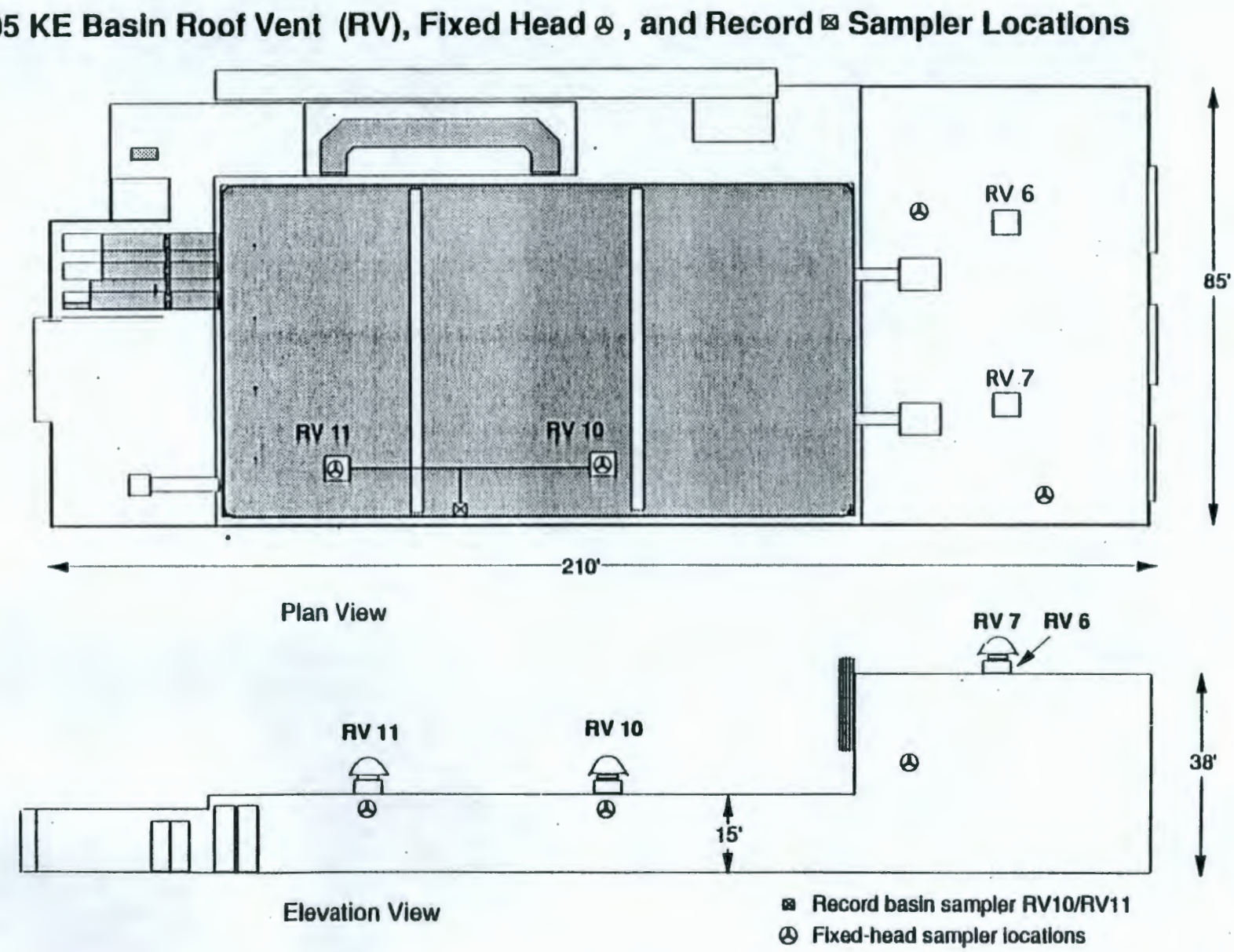

Figure 3-4. 105-KE Basin Roof Vent and Fixed Head Sampler Locations.

3.2 105-KE Basin Water Treatment System

The radionuclide control equipment consists of both passive and active systems directed at controlling the source term. The application of these radionuclide controls are in accordance with ANS-57.7 (ANS 1988).

The passive system consists of the 3.86 X 10^6 liter (L) (1.02 Mgal) of water, which covers the irradiated fuel and sludge. This water not only precludes the radionuclide source term from the irradiated fuel and sludge from becoming directly airborne, but also provides radiation shielding.

The active system consists of two separate water treatment systems shown in Figure 3-5 to reduce radionuclide concentrations in the basin water. The first water treatment system is composed of a cartridge filter cell, a chiller, and three ion exchange columns. The second water treatment system is composed of skimmers, a sand filter, and two auxiliary IXMs.

The first system uses a recirculation pump to draw the basin water through underwater (2.4-m-[8-ft] deep) header pipes in each basin bay. The water passes through a cartridge filter cell at a rate of 1,893 L (500 gal)/min. The cartridge filter cell is composed of 80 individual filter elements and is designed to remove small (i.e., down to 10-micron in diameter) particulates. A backup filter cell and backup pump are available for use as alternates if necessary. Water is then routed through a chiller designed to remove residual decay heat while maintaining the temperature of the basin water at about 10 °C (50 °F). Water temperature in the basin is required by Process Standards to be between 5.5 °C (42 °F) and 32.2 °C (90 °F); in practice the temperature is kept near 10 °C (50 °F) to reduce evaporation and corrosion. After chilling, the water is routed through one of three ion exchange columns receiving flow in parallel operation (at a flow rate of approximately 189 L [50 gal]/min] each) before being returned to the basin. The ion exchange columns will be used only sparingly in the 105-KE Basin to minimize the generation of transuranic waste.

Cartridge filter cells are expected to be changed quarterly during encapsulation activities based on an increase in differential pressure across the filters, normally about 25 lb/in^2. Based on past operations, cartridge filter cells typically remove about 30 Ci of radioactivity before they are changed out.

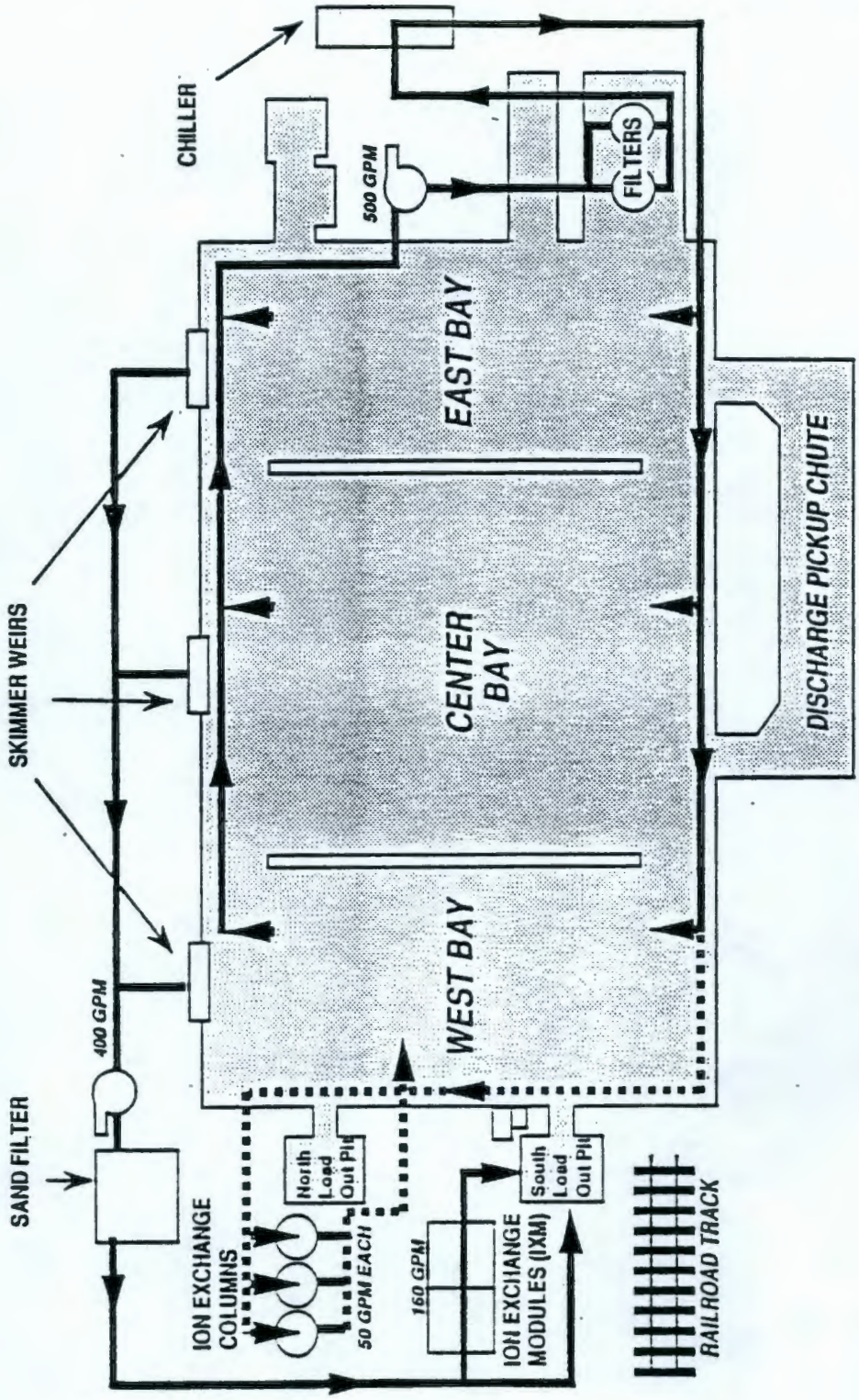

Figure 3-5. 105-KE Basin Water Treatment System.

The second system draws basin water from skimmer weirs along the north wall of the basin and pumps the water at 1,514 L (400 gal)/min. through a large sand filter containing approximately 3,946 kg (8,700 lb) of sand. This water is routinely routed to at least one of two auxiliary IXMs (at approximately 606 L [160 gal]/min each) with the balance bypassing the IXM and returned to the basin. After ion exchange treatment, that portion of the water is discharged to the South Load-Out Pit.

The sand filter is required to be backwashed when an increase in differential pressure occurs. In practice, the pressure limit is not reached and a backwash is performed quarterly in conjunction with sand sampling requirements. The backwash process is performed by first lowering the North Load-Out Pit level by approximately 1.8 m (6 ft). This is accomplished by valving off the skimmers and allowing the skimmer pump to draw directly from the North Load-Out Pit. The North Load-Out Pit (also known as the Sand Filter Backwash Pit) is segregated from the basin by means of a weir. During backwash, the secondary loop valving is changed to reverse flow through the sand filter for approximately 3 minutes discharging filterable solids to the North Load-Out Pit.

Cartridge filter cell changeouts and backwashing of the sand filter to the North Load-Out Pit are routine basin activities. Based upon past occupational monitoring data, the filter element changeouts and sandfilter backwashing represent relatively minor impacts to basin air emissions.

The IXMs are large (218-cm [86-in.] x 178-cm [70-in.] x 202-cm [79.5-in.]) self-contained Duolite[1] mixed bed resin systems. The IXM also serves as the container for disposal. Each IXM uses 21 ft^3 of resin. The IXMs are changed out when the removal efficiency for ^{137}Cs decreases from the initial 99 percent to the 20 percent range. The run times vary depending on basin water quality and changeouts can occur from two to six times per year.

At least one of the water treatment systems with ion exchange capabilities will be kept in service during the encapsulation activity. Outages occur occasionally for equipment failures, repairs, and component changeouts as necessary. Operation of the water treatment systems provides the control necessary to ensure facility air emissions remain within those forecasted in Section 5.1.

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[1]Registered trademark of Rohm and Haas, Inc.

3.2.1 Radionuclide Control Efficiencies

The radionuclide control efficiency for the water treatment system can be estimated based on recent operating history in the 105-KE Basin as explained below. The overall efficiency can be represented as follows:

$$\text{Efficiency} = 1 - \left[\frac{\text{radionuclide inventory with basin water treatment}}{\text{radionuclide inventory without basin water treatment}}\right]$$

To properly assess the efficiency, the above calculation is based upon data taken for time periods when past basin activities were similar to that expected during encapsulation. Accordingly, two time periods were selected.

- October 1992--The water treatment systems were shutdown during the entire month because of chiller installation and resin waste management issues.
- November 1992--One IXM was used for the time period of November 3, 1992 through November 30, 1992 (represents the minimum configuration necessary to provide water treatment).

For the two-month time period above, extensive sludge pumping and sludge debris raking were conducted in the discharge pickup chute area to prepare for encapsulation equipment installation.

Total radionuclides, as calculated from water samples taken from the center of the basin, can be used to calculate the efficiency of the water treatment system (WHC 1993a).

$$\text{Efficiency} = 1 - \frac{(45.9\,\text{Ci [November]})}{(76.5\,\text{Ci [October]})} = 40\%$$

The above represents an estimate of the water treatment system efficiency for removing radionuclides from the basin water, based upon basin water data.

3.2.2 Water Treatment System Radionuclide Removal Efficiencies

The water treatment systems contain ion exchange components for removal of soluble radionuclides and particulate filters for removal of particulate radionuclides. These components can affect emission levels because their operation and basin activities determine the quantity of radionuclides that are present in the water at a given time. Representative operating experience has shown that the operational controls presented in Section 3.2.3 can control radionuclide concentrations in the water so that emissions of radionuclides will not exceed those forecast in Chapter 5.0 for any 12-month period.

Because the primary consideration in effectiveness of control for radionuclide concentrations in the water is water treatment systems operation, the efficiency of the individual components is discussed in the following paragraphs.

The ion exchange columns and IXM radionuclide removal efficiencies vary with time and decrease with increasing run time. The IXMs are run to a plutonium removal efficiency approaching 20 percent. Initial plutonium removal efficiency is 99.6 percent and the average removal efficiency is about 81 percent (WHC 1993a). Radiological controls preclude loading the ion columns to as high a radionuclide content as the IXMs. The average removal efficiencies for plutonium isotopes by the ion exchange columns and IXMs are 74 and 81 percent respectively.

The particulate cartridge filter cell of the primary water treatment system is designed to remove particulates greater than 10 microns. The particulate sand filter is designed to remove particles greater than 100 microns in diameter. The cartridge and sand filters remove approximately 12 percent of the total plutonium concentrations in the inlet stream, indicating some of the plutonium is particulate, but that most of it is either dissolved or very fine. Ion exchange column and IXM plutonium removal efficiencies indicate the majority of plutonium in the water is dissolved. The particulate filters show negligible removal efficiencies for the dissolved cesium and strontium as would be expected. The efficiencies of the individual components in the water treatment systems are presented in Table 3-1.

Table 3-1. Average Radionuclide Removal Efficiencies of Components of the Water Treatment Systems at 105-KE Basin (WHC 1993a)

Radionuclide	Ion exchange column (%)	Ion exchange module (%)	Sand filter (%)	Cartridge filter (%)
Strontium	91	93.5	Negligible	Negligible
Cesium	98	49	Negligible	Negligible
Plutonium	74.3	81	Less than 12	12

3.2.3 Operational Control

The radionuclide control equipment for the 105-KE Basin is operated such that projected emissions will remain within those forecasted in Section 5.1.

At least one of the two water treatment systems is required to be "in service"[2] routinely with the following exceptions:

- An outage of up to 48 hours for changeout of the ion exchange cleanup components (IXMs or Ion Columns).
- An outage of up to 48 hours for changeout or backflushing, as appropriate, of the cartridge filters cells or sand filter, respectively.
- An outage of up to 24 hours for a power failure to the facility.
- An outage of up to 72 hours for a component failure or administrative issue.

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[2] "in service" is defined as follows:

In the water treatment system consisting of a cartridge filter cell, a chiller, and three ion exchange columns, at least one pump will operate; at least one cartridge filter cell is on line; and three ion exchange columns are receiving flow in parallel operation.

In the water treatment system consisting of skimmers, a sand filter, and two auxiliary IXMs, at least one pump will operate; the sand filter will be in service; and at least one IXM will be on line.

If neither system can be returned to operation within the outage durations provided above, no fuel or sludge handling will be permitted until at least one of the two systems is returned to service.

3.3 105-KE Basin Radionuclide Source Term

3.3.1 Fuel Elements

The radionuclide inventory of the irradiated fuel is 9.3 million curies (MCi) (WHC 1993a). The majority of the fuel stored in the 105-KE Basin is 0.95 weight percent (wt%) enriched with the ^{235}U isotope. A small amount of natural uranium fuel (0.71 wt% ^{235}U) is also stored in the 105-KE Basin. Because more highly enriched fuel results in higher radionuclide levels for given irradiation and decay times, radionuclide levels were conservatively based on 0.95 wt% ^{235}U enriched fuel.

Approximately 850 metric tons (MTU) of the 1,150 MTU fuel element inventory was irradiated to fuel grade assay levels where the ^{240}Pu content was allowed to increase to 12 percent of the total plutonium produced. The remaining 300 MTU of fuel was irradiated to levels where the ^{240}Pu build up was limited to 6 percent. Longer irradiation times increase the total radionuclide content of the fuel, so for conservatism, the radionuclide content was based on the longer irradiation time for the fuel grade assay.

A 10-year average decay time was used in establishing the present radionuclide content of the fuel. This is conservative because the average age of the fuel after discharge is slightly greater than 10 years. The radionuclides removed by the water treatment systems have not been removed from the source term.

3.3.2 Sludge

The radionuclide source term in the sludge has been determined conservatively to be 0.70 MCi. This value has been calculated by estimating the total quantity of sludge, which consists of the following.

1. Sludge from present and past inventories existing on all basin floor areas exclusive of the discharge pickup chute area floor.

   Sludge on the basin floor, exclusive of the discharge pickup chute area, has been estimated to be 0.64-centimeters (cm) (0.25-in.) deep over the entire basin floor. This estimate is based on comparing the sludge layer to the canister storage racks and canister dimensions.

2. Sludge on the discharge pickup chute area floor from fuel segregation--a prior activity similar to encapsulation.

   The depth of sludge on the discharge pickup chute area floor (3-meter (m) [10 ft] by 14-m [45-ft]) was estimated at an average depth of 20.32 cm (8 in.) before the sludge was transferred to the Weasel Pit. The depth of sludge (20.32 cm [8 in.]) in the discharge pickup chute (42 square meters (m^2) [450 square feet (ft^2)]) would correspond to 1.09 cm (0.43 in.) if distributed over the entire basin (811 m^2 [8,375 ft^2]). This sludge originated from the fuel segregation effort conducted in 1984 and 1985, involving more than 5,000 canisters of stored fuel.

3. Sludge generated during the encapsulation of existing inventory of fuel elements that are now stored in open canisters.

   The projected volume of sludge to be generated during encapsulation is estimated to be 1.09 cm (0.43 in.) evenly distributed over the basin floor. This is a conservative estimate based upon fuel segregation sludge deposition from 5,000 canisters as compared to 3,700 canisters.

   The estimated total depth of sludge on the basin floor would be:

   0.64 cm (0.25 in.) (1) + 1.09 cm (0.43 in.) (2) + 1.09 cm (0.43 in.) (3) = 2.82 cm (1.11 in.)

Using a density of 4 grams per cubic centimeter (g/cm^3) and the basin dimensions, a total uranium sludge depth of 2.82 cm (1.11 in.) converts to a mass of UO_2 of 87.7 MTU. The amount of oxide formed from corrosion converts to a mass of 77.3 MTU of unoxidized metallic uranium. Based on the fuel radionuclide inventory of 9.3 MCi in 1,150 MTU of fuel

(WHC 1993a), the 77.3 MTU is equivalent to 0.62 MCi. For additional conservatism, the sludge can be estimated to contain 0.70 MCi, equivalent to approximately 86.6 MTU of fuel.

In summary, the conservative nature of the source term evaluation is supported by the following reasons:

- The curie content accounts for no removal of radionuclides by the water treatment systems
- Radionuclide content was based on 0.95 wt% ^{235}U enriched fuel
- The radionuclide content was based on the longer irradiation time for fuel grade assay levels
- A 10-year average decay time was used in establishing the present radionuclide content of the fuel
- The sludge source term represents approximately 86.6 MTU of fuel, larger than that calculated (77.3 MTU) to be present in the volume of the sludge if assumed to be UO_2.

As discussed previously, the total radionuclide inventory of the fuel (9.3 MCi) can be added to that of the sludge (0.70 MCi), to obtain a total of 10 MCi. The 105-KE Basin fuel element and sludge activity is presented in Table 3-2 (WHC 1993c).

Table 3-2[a]. 105-KE Basin Fuel Element and Sludge Activity

Radionuclide	Inventory (curies)
Krypton - 85	2.45E+05
Strontium - 89	2.59E-05
Strontium - 90	2.58E+06
Zirconium - 95	2.66E-02
Niobium - 95	9.27E-11
Ruthenium - 103	5.02E-09
Ruthenium - 106	1.29E+05
Cesium - 134	1.73E+04
Cesium - 137	2.67E+06
Cerium - 144	4.45E+05
Uranium - 234	5.22E+02
Uranium - 235	9.45E+01
Uranium - 238	4.24E+02
Plutonium - 238	2.86E+04
Plutonium - 239[b]	1.75E+05
Plutonium - 241	3.71E+06
Total	1.00E+07

[a] The above source term does not include 565 Ci of Tritium (^3H) (WHC 1993a).
[b] This quantity represents all actinides.

3.3.3 Basin Water

The sludge and fuel is covered by the 3.86 x 10^6 liter (L) (1.02 Mgal) of water in the 105-KE Basin (WHC 1988a). The radionuclides of significance in the airborne emissions are known to be particulates that originate from the basin water. The primary mechanisms responsible for airborne contamination are transport at the water line of the basin, the "bathtub ring", and suspension of surface contamination on basin floors, gratings and tools (WHC 1993a).

3.3.4 Airborne Radionuclide Source Term

The airborne radioactivity source term is the product of the migration of radioactivity contained in the irradiated fuel elements, the sludge that has formed in the 105-KE Basin, the water that fills the 105-KE Basin pool, the surfaces of the pool's concrete walls, structural surfaces such as floors and walls, and on equipment and tools used and stored in the basin. Detailed analysis has been performed on each of these contributory source terms (WHC 1993a).

The average radioactive discharge of the airborne release from 105-KE Basin for 1992 as measured by the fixed head samplers near the 105-KE roof vents is shown in Table 3-3. Because the fixed head samplers were installed in August 1992, an extrapolation was performed on available data for the total system air flow to provide an average of the annual release.

Table 3-3. 105-KE Basin Exhaust Air Concentrations - 1992

Isotope	Average Concentration (μCi/ml)	Estimated Annual Release (Ci)
^{60}Co	1.7E-15	1.3E-06
^{90}Sr	2.1E-13	1.6E-04
^{106}Ru	1.7E-14	1.3E-05
^{125}Sb	1.5E-14	1.1E-05
^{137}Cs	3.1E-13	2.3E-04
^{238}Pu	1.7E-15	1.3E-06
$^{239/240}Pu$	1.1E-14	8.5E-06
^{241}Pu	5.2E-14	3.9E-05
^{241}Am	6.8E-15	5.1E-06
Total		4.3E-04

3.4 Airborne Radioactivity Measurements in the 105-KE Basin

The exhaust system in the basin consists of two exhaust fans over the fuel storage basin (RV 10 and 11) and two in the Transfer Area (RV 6 and RV 7). See Figure 3-4 for the relative locations of the four fixed head samplers.The current airborne radionuclide emissions monitoring system for the 105-KE Basin consists of four fixed head airborne effluent samplers. One fixed head filter assembly is positioned directly in front of the RV 10 and RV 11 exhaust vents. Two fixed head samplers are positioned in the Transfer Area at the mezzanine level in alignment with RV 6 and RV 7.

Each of the four sampling systems utilize a vacuum pump which draws a sample of the 105-KE Basin air through a 47 mm. particulate filter. The particulate sample is collected on 47 mm glass fiber filters. The pumps are equipped with a vacuum gauge for determination of flow rate. The vacuum gauges are checked weekly to verify the flow rate is approximately (0.057 m^3 [2.0 ft^3])/min. The weekly flow checks are documented in a log book for that purpose and maintained at the 105-KE Basin.

The particulate filters from the four sampling systems are collected weekly. The filters are delivered to an off-site laboratory for weekly analysis of gross alpha, beta, and a gamma scan. Weekly filters are composited monthly for ^{90}Sr, Pu isotopic, and ^{241}Am analysis.

In addition to the effluent sampling system described above, a sampling system historically operated in the 105-KE Basin which sampled the exhaust from RV 10 and RV 11 through a common sample line and particulate filter continues to operate. This sampling system is still being operated for information purposes only. All calendar year 1992 sampling results have been reported using the four fixed head sampling systems described above.

4.0 Description of Proposed Encapsulation Activity

4.1 Purpose of Encapsulation Activity

The encapsulation activity will be carried out on the 105-KE Basin floor under a minimum of 3 m (10 ft) of water. The encapsulation activity will include emptying irradiated fuel elements from the existing canisters stored in the 105-KE Basin, packaging these fuel elements in new canisters, packaging sludge from previous fuel inventories and the current inventory in new canisters, capping the canisters of fuel elements and sludge, cleaning and crushing the empty canisters, and returning the new canisters of fuel elements and sludge to the storage racks in the basin. Packaging and disposal of all the crushed canisters will take place above water.

Encapsulation of the 105-KE Basin fuel inventory will provide primary containment for the irradiated fuel, some of which has had its zirconium cladding breached, exposing the uranium fuel to the 105-KE Basin water. This will dramatically reduce environmental concerns associated with the 105-KE Basin. The encapsulation activity will minimize continued release of radionuclides from the damaged fuel elements to the basin water. The lower radionuclide releases to the basin water will reduce basin work place radionuclide concentrations and air emissions from the facility. Lower releases will also reduce worker exposure and minimize waste generated from operation of the water treatment systems. Because the 105-KE Basin is located in close proximity to the Columbia River, the encapsulation activity will greatly reduce environmental risks associated with a leak from the basin.

4.1.1 Encapsulation Activity

The encapsulation activity will be carried out in close proximity to the basin floor such that a minimum of 3 m (10 ft) of water shielding between the worker and the fuel is maintained. The existing hoist and the new encapsulation equipment will be used to accomplish encapsulation of the fuel elements and sludge. The encapsulation activity will include:

- Emptying fuel elements from the existing canisters stored in the 105-KE Basin onto a dump table
- Filling new canisters with the fuel elements
- Relocating sludge to support encapsulation of the fuel elements

- Filling new canisters with sludge
- Capping the new canisters of fuel elements or sludge
- Cleaning and crushing empty canisters
- Returning the canisters of fuel elements or sludge to the storage racks in the basin
- Lifting the crushed canisters out of the water and packaging them for disposal.

4.1.2 Encapsulation of Fuel Elements

The open-top canisters, containing fuel elements, will be moved, one at a time, from the basin to the discharge/pickup chute which is shown in Figure 4-1. The canisters are moved underwater using the existing hoist. The hoist operates on monorails suspended above the basin as shown in Figure 4-2. The fuel elements will be emptied onto a dump table, manually tonged to the repackaging station, and hydraulically inserted into stainless steel canisters.

After the fuel elements are placed into the new stainless steel canisters the lids will be installed and corrosion inhibitor added. The canisters then will be purged with nitrogen. The lid of the stainless steel canisters incorporates a GRAFOIL™[3] sealing surface and a mechanism that applies pressure to affect a lid-to-canister seal. The corrosion inhibitor consists of demineralized water and sodium nitrite. The corrosion inhibitor is designed to minimize fuel degradation rates within the canister. The nitrogen purge establishes an inert gas blanket at the top of canister. The nitrogen isolates the water within the canister from the basin water, preventing the escape of dissolved radionuclides. This, in effect, isolates the canister radionuclide inventory from the basin water.

The new canisters will then be moved back to the basin storage racks via the hoist and monorail system. A process flow diagram of emptying the fuel elements from the old canisters, repackaging the fuel elements into new canisters, and cleaning and crushing the old canisters is shown in Figure 4-3. Figure 4-4 shows the open-top canisters as they are currently stored in the 105-KE Basin and capped canisters, as they are stored in the KW Basin.

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[3]Tradename of the Union Carbide Corporation.

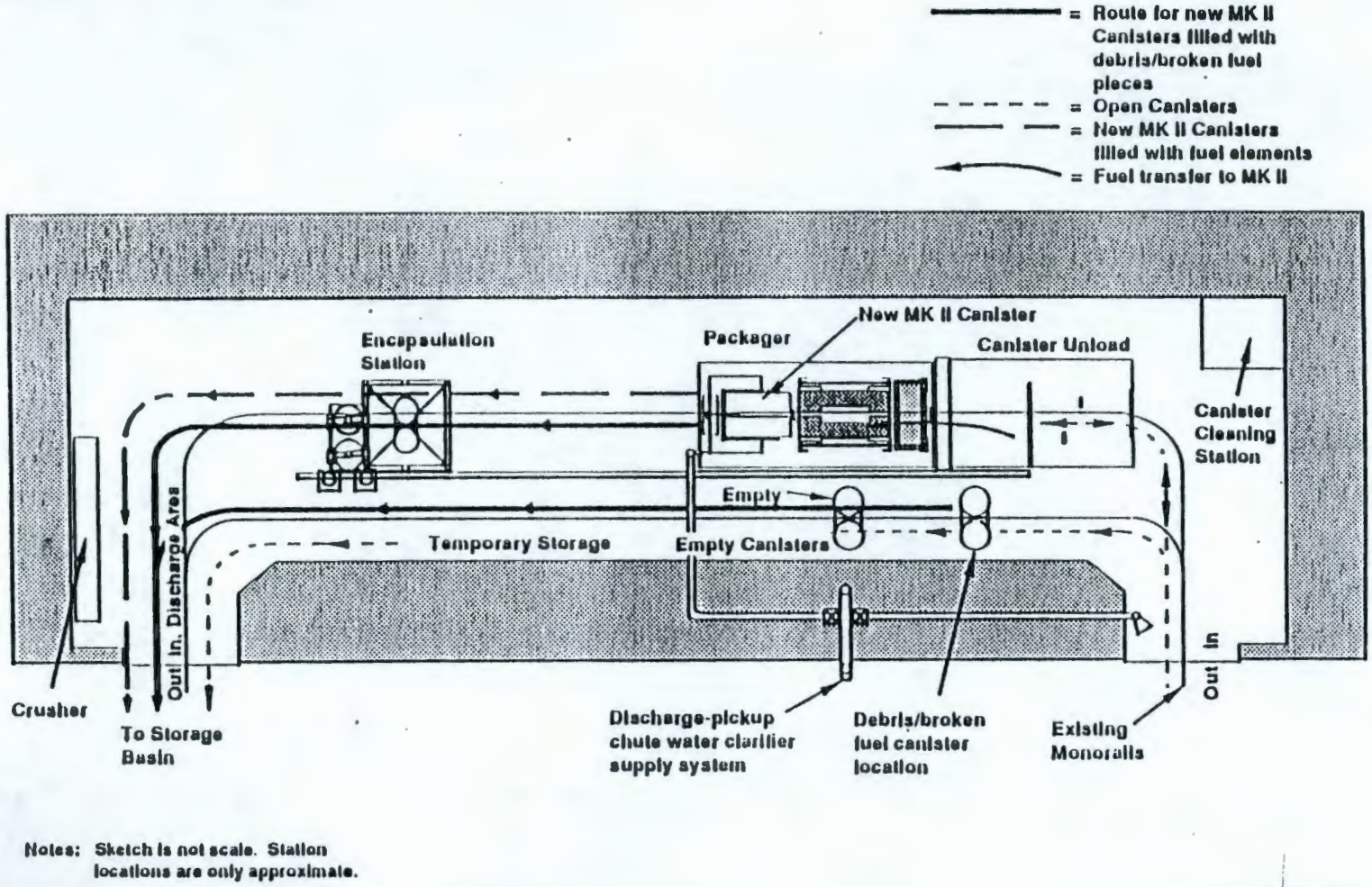

Figure 4-1. 105-KE Basin Discharge/Pickup Chute.

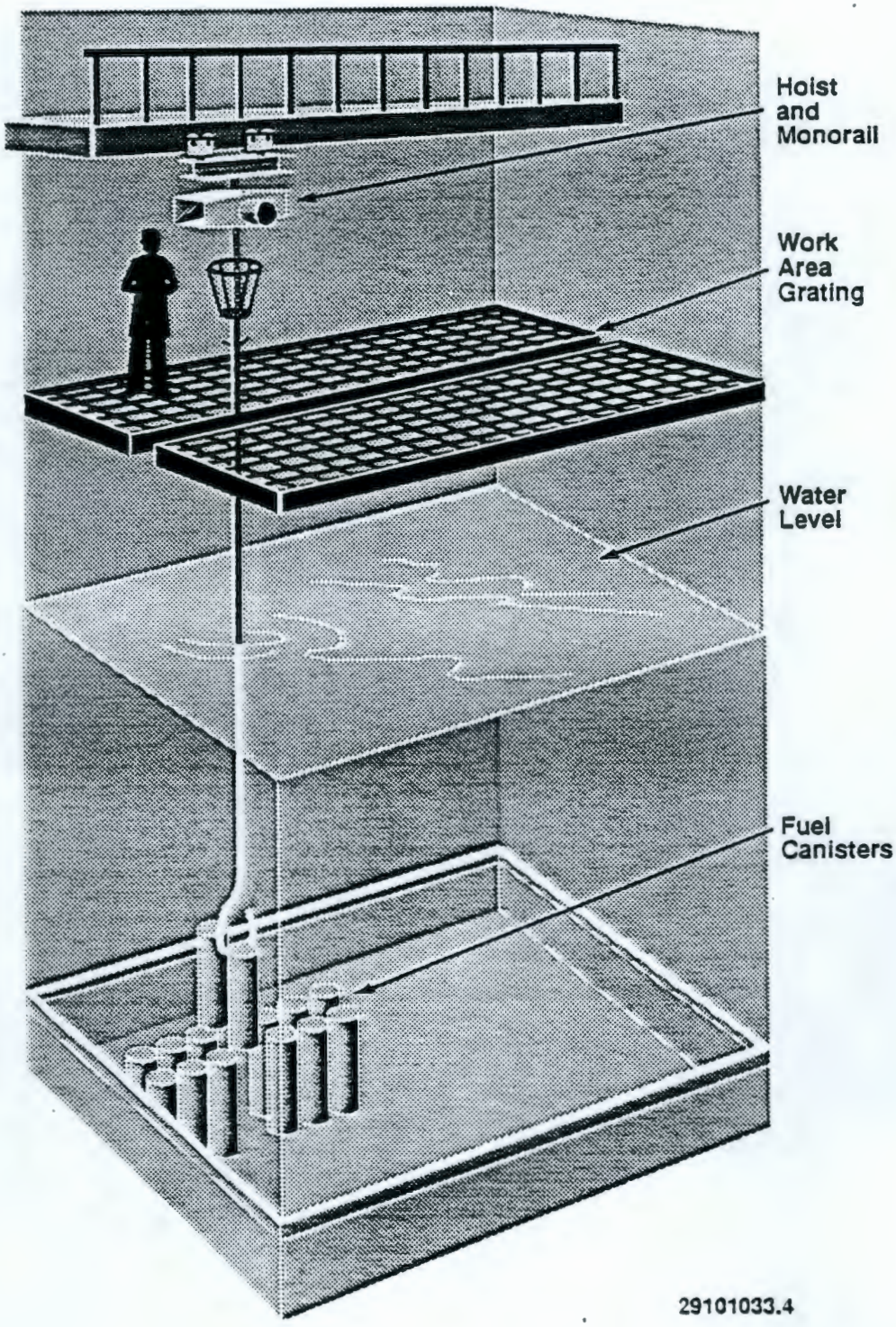

Figure 4-2. 105-KE Basin Monorail and Hoist System.

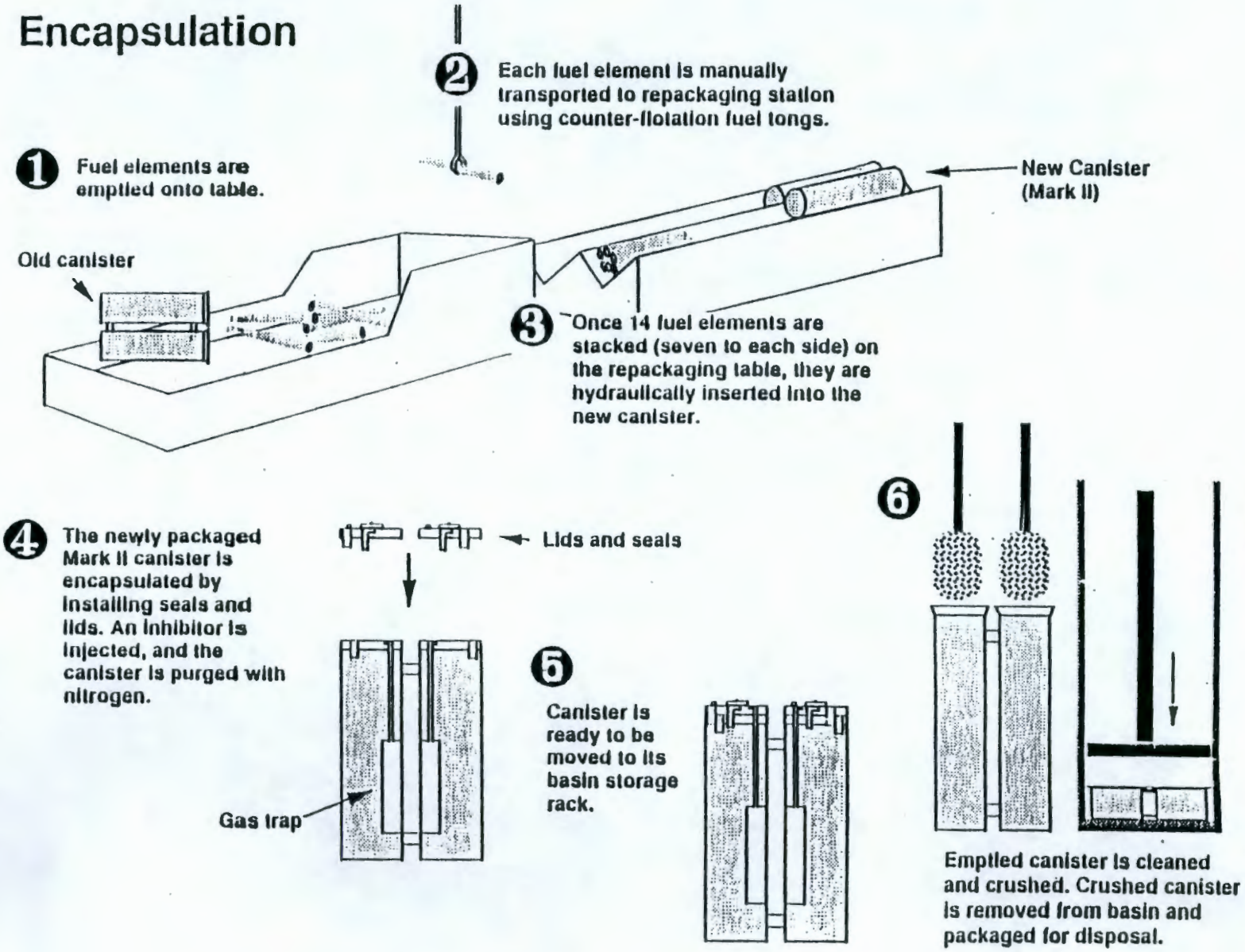

Figure 4-3. Encapsulation Activity Process Diagram.

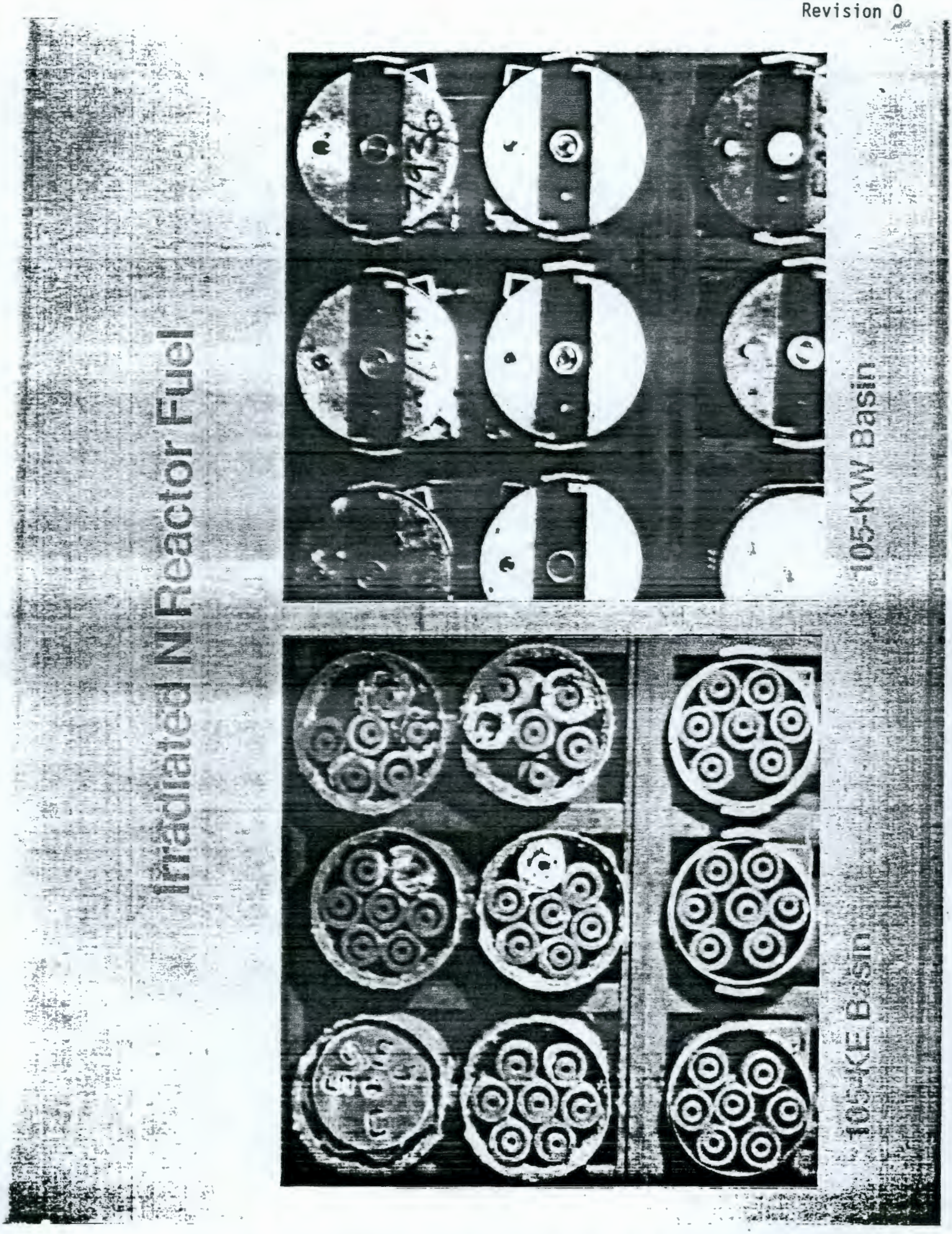

Figure 4-4. Comparison of 105-KW and 105-KE Basin Fuel Canisters

The encapsulation of the fuel elements is estimated to take approximately two years. During periods of encapsulation, the work will be accomplished by operating two shifts per day, five days per week, and encapsulating eight canisters per shift.

4.1.3 Encapsulation of Sludge

Sludge and debris from basin operations has accumulated on the basin floor. The sludge resulted from corrosion of breached fuel elements, which consists of uranium, fission and activation products, along with dirt and sand introduced from the outside environment, and corrosion products of basin structural components. The debris consists of structural parts made of Zircaloy-2 from fuel elements, (i.e., W springs, locking clips, locking stops, end caps, rigid supports, and outer supports) and miscellaneous tools and materials that were left behind. The sludge, which is often finely divided, is distributed loosely and unevenly on the basin floor. Activities performed near the floor of the basin cause the sludge to become re-suspended near the activity. A majority of the sludge eventually settles to the basin floor within hours or days after the activity has ended.

Sludge deposited on the basin storage racks and canisters will likely be re-suspended along the path of canisters being transported by the hoist and monorail system. Additional sludge suspension may occur as canisters with wire mesh bottoms, containing breached cladding, disperse some of their contents. The discharge pickup chute is expected to become clouded during encapsulation, and the basin in general will show an increase in turbidity. Water from the water treatment systems will be introduced into the discharge pickup chute to improve the visibility for operators performing the encapsulation work. Periodic underwater vacuum pumping and water sparging of the discharge pickup chute will be necessary to remove accumulated sludge that will settle to the bottom. The sludge will be vacuum pumped to the Weasel Pit, which is equipped with a fine mesh screen partition. This screen retains the majority of the sludge in the Weasel Pit and allows the liquid to return to the basin.

After the sludge is vacuum pumped, any solid debris greater than 0.64 cm (0.25-in.) in diameter remaining in the discharge pickup chute will be transferred to open-top canisters. These open-top canisters will be retrieved to the dump table and the contents sorted to segregate any fuel element fragments for encapsulation. The remaining debris will be packaged for disposal as

low-level radioactive waste in accordance with WHC-EP-0063-3, "Hanford Site Solid Waste Acceptance Criteria" (WHC 1988b).

The sludge accumulated on the basin floor will be vacuum pumped to the Weasel Pit for consolidation. The sludge in the Weasel Pit will be encapsulated underwater. Encapsulation of sludge will employ operations such as (1) vacuum pumping sludge using a suction nozzle, (2) settling or centrifuging the pumped sludge for removing the suspended solids, and (3) mechanical filtration. Any remaining suspended solids from this process will be discharged to (1) one or both of the basin water treatment systems at the sand filter or cartridge filter cell or (2) the basin. The spent cartridge filters cells are disposed of as low level radioactive waste in accordance with WHC-EP-0063-3 (WHC 1988b). The settled solids from the sand filter backwash will continue to be accumulated and will also be encapsulated.

Because the above process also places the sludge in suspension underwater, but adds the feature of filtering equipment, the sludge encapsulation is expected to result in less sludge suspension in the basin water than that experienced either during the 1984 fuel segregation or the more recent sludge transfers from the discharge pickup chute to the Weasel Pit prior to encapsulation equipment placement.

4.1.4 Crushing of Canisters

The emptied canisters will be moved underwater to the discharge pickup chute area and cleaned by using a high-pressure water jet and wire brushes. Each canister will then be crushed underwater, raised above the water and promptly inserted into a plastic bag. It is estimated that 1,400 aluminum canisters and 2,300 stainless steel canisters will be crushed during encapsulation. Approximately 2,000 empty canisters from basin fuel inventories, previously shipped for processing, also will be cleaned, crushed, bagged, and disposed of. The packaged, crushed canisters will be placed in burial boxes. These burial boxes will be sealed in accordance with WHC-EP-0063-3 (WHC 1988b). It is estimated that one burial box will be loaded and shipped for burial each week.

5.0 Air Quality Analysis

This chapter presents the projected radionuclide emissions and the resultant committed effective dose equivalent (CEDE) to the maximally exposed individual (MEI). The projected radionuclide emissions are based on actual air quality analyses of the 105-KE Basin. The projected dose as a result of the encapsulation activity was derived from the projected radionuclide air emissions.

5.1 Projected Emissions Based on Good Engineering Judgement

Table 5-1 was developed from actual data obtained from the fixed head sampler (RV11). This data was obtained during the sampling period from October through December 1992.

Table 5-1*. Projected Annual Airborne Emissions
Using Fixed Head Sampler (RV11) Data

Radionuclide	Average Concentration (Oct. 92 to Dec. 92) (μCi/ml)	Expected Annual Emissions (Ci/yr)
^{241}Am	1.8 E-14	1.4 E-05
^{60}Co	1.5 E-14	1.1 E-05
^{137}Cs	6.4 E-13	4.8 E-04
^{238}Pu	6.9 E-15	5.2 E-06
$^{239/240}$Pu	4.2 E-14	3.1 E-05
^{241}Pu	5.3 E-14	4.0 E-05
^{106}Ru	3.3 E-14	2.4 E-05
^{90}Sr	7.5 E-13	5.6 E-04
Total		1.2 E-03

*Note: The above expected annual emissions do not include tritium (^{3}H). Multiplying the concentration of tritium in the basin water by the evaporation rate of the basin water yields the amount of tritium released.

Concentration of ^{3}H in basin water (WHC 1993a) = 3.0 E-03 μCi/mL

Evaporation rate of the basin water = 41.6 L/h

The expected annual emissions as reported in Table 5-1 were calculated as follows:

$$\left[3.0 \times 10^{-03} \frac{\mu Ci}{mL}\right]\left[4.16 \times 10^{04} \frac{mL}{h}\right]\left[8{,}760 \frac{h}{year}\right]\left[\frac{10^{-06}\ Ci}{1\ \mu Ci}\right] = 1.2 \frac{Ci}{year}.$$

This sampling period was selected for two reasons. First, the extensive sludge pumping and sludge debris raking during this time period resulted in increased suspension of radionuclides in the basin water similar to that expected during encapsulation. Second, the radionuclides in the water were further elevated by the shutdown of the water treatment system during October and the first two weeks of December 1992. The shutdowns of the water treatment system were necessary to replace the existing water-cooled chiller with a new air-cooled chiller and to minimize the generation of transuranic waste associated with operation of the ion exchange columns. The combination of the increase in suspended sludge and the necessity of the water treatment system shutdowns during this period resulted in radionuclide concentrations in the water that provided a projection of air emissions during encapsulation.

Table 5-1 lists the individual radionuclide concentrations, averaged for the sampling period October through December 1992. The projected annual release for each radionuclide was calculated by multiplying the individual radionuclide concentrations by the anticipated maximum annual flow rate (WHC 1993b) with all four vent fans operating continuously. Formulas for the flow rate and projected annual emissions are as follows:

Annual Flow Rate:

$$\left[60\frac{\text{min.}}{\text{h}}\right]\left[8{,}760\frac{\text{h}}{\text{year}}\right]\left[50{,}273\frac{\text{ft}^3}{\text{min.}}\right]\left[28.32\frac{\text{L}}{\text{ft}^3}\right]\left[1000\frac{\text{mL}}{\text{L}}\right] = 7.5\ \text{E+14}\ \frac{\text{mL}}{\text{year}}.$$

Expected Annual Emission:

$$\left[\text{concentration}\ \frac{\mu\text{Ci}}{\text{mL}}\right]\left[\frac{10^{-06}\text{Ci}}{1\ \mu\text{Ci}}\right]\left[7.5\ \text{E+14}\ \frac{\text{mL}}{\text{year}}\right] = \frac{\text{Ci}}{\text{year}}\ \text{annual emission.}$$

The results of this calculation, 1.2 X 10^{-3} Ci/yr, is the projected annual airborne emissions from the 105-KE Basin during encapsulation activities.

5.2 Projected Dose to the MEI Using Good Engineering Judgement and CAP 88

The projected CEDE to the MEI using good engineering judgement projected emissions is shown in Table 5-2. The dose conversion factors were derived from the EPA-approved code, CAP 88 (Parks 1992). The projected dose from each individual radionuclide was calculated by multiplying the projected annual emission (Table 5-1) by the dose conversion factor.

Table 5-2*. Committed Effective Dose Equivalent to the Maximally Exposed Individual**

Radionuclide	Expected Annual Emissions (From Table 4.2) (Ci/yr)	CAP-88 Dose Conversion Factor	CEDE to MEI (mrem/yr)	Dose, percent of Total
^{241}Am	1.4 E-05	1.94 E+01	2.6 E-04	33.5
^{60}Co	1.1 E-05	4.28 E-02	4.8 E-07	0.1
^{137}Cs	4.8 E-04	3.53 E-02	1.7 E-05	2.2
^{238}Pu	5.2 E-06	1.18 E+01	6.1 E-05	7.8
$^{239/240}$Pu	3.1 E-05	1.28 E+01	4.0 E-04	50.8
^{241}Pu	4.0 E-05	2.03 E-01	8.0 E-06	1.0
^{106}Ru	2.4 E-05	3.08 E-02	7.5 E-07	0.1
^{90}Sr	5.6 E-04	6.45 E-02	3.6 E-05	4.6
Total	1.2 E-03		7.9 E-04	100.0

*Note: The above table does not include tritium (^{3}H). Using 1.2 Ci/yr ^{3}H, as calculated in the note from Table 5-1, and a dose conversion factor of 3.4 E-05, a dose of 4.0 E-05 mrem/yr would result.

** The maximally exposed individual is located 9.9 kilometers west of the 100 Area.

6.0 BARCT Analysis

The baseline control option, as described in Chapter 3, consists of minimizing particulate emissions by submersion in basin water which is treated by the existing water treatment equipment. This particulate radionuclide control technique is currently in operation at the 105-KE basin facility and is considered as reasonably available control technology by the DOH under the conditions of storage of fuel elements. Expected emissions from the encapsulation activity for the baseline case are the projected emissions based on good engineering judgement in Chapter 5.0 (i.e., these emissions will be such that the MEI will receive a CEDE of 7.9×10^{-4} mrem/yr).

6.1 Description of Control Options

The DOH has determined that HEPA filtration has been accepted as BARCT for the control of emissions of radioactive particulate matter (WHC 1992b). For the encapsulation activity, DOH has also determined that this BARCT assessment only needs to evaluate HEPA filtration for particulates. Controls for radionuclides in a gaseous state do not need to be evaluated (WHC 1992b).

The HEPA filtration control concept evaluated was that which would provide filtration to the general basin exhaust air. Three different HEPA filtration options were conceptualized and evaluated for effectiveness. The purpose for evaluating different options was to ensure that the most cost effective HEPA filtration option was developed for the BARCT analysis.

Details of each option, including all assumptions, are contained in reference WHC 1993d. Rough order of magnitude construction costs were estimated for each option only for the basic components required. No attempt was made to provide a detailed design as far as the specific location of the components. Each of the options employed common assumptions and involved a certain amount of common equipment to all options. The items common to all options included a (849.5 m^3 [30,000 ft^3])/min supply air system with evaporative cooling and electric heating located outside the building, airlocks, provision for sealing and insulating the building, and exhaust stack monitoring. Each HEPA unit was assumed to consist of the same general

components. Although the supply air and exhaust air (HEPA) systems were located outside the building, a substantial portion of the ducting was assumed to require installation inside the building to provide adequate distribution of supplied and exhausted air. The following sections contain a brief description of the differences in each HEPA filtration option as well as a technical feasibility determination.

6.1.1 Option 1 - Two Roof Mounted HEPA Units

The first HEPA filtration option considered was the replacement of the four existing roof exhausters over the basin and high bay area with two roof mounted HEPA filter units, each rated at (453.1 m^3 [16,000 ft^3])/min. Provision was included to provide a structural steel support for the equipment that was connected to the building structural beams and columns. Both units were exhausted through a single (15 m [50 ft.]) high stack mounted on the roof.

6.1.2 Option 2 - Ground-level Skid Mounted HEPA Unit

The second HEPA filtration option considered was the mounting at grade level of two HEPA filter units similar to those assumed in Option 1. Although structural modifications to the building superstructure were not required, a concrete pad was included to support the HEPA units. Both units were exhausted through a single (27 m [90 ft.]) high stack mounted on grade.

6.1.3 Option 3 - Four Roof Mounted HEPA Unit

The third HEPA filtration option considered was the roof mounting of four HEPA filter units, each rated at (226.5 m^3 [8,000 ft^3])/min. In effect, this option used twice the number of components rated at one half the capacity of those used in Option 1. Provision was include to provide a structural steel support for the equipment that was connected to the building structural beams and columns. Each two (of the four) units would be exhausted through a (15 m [50 ft.]) high stack mounted on the roof, so two (15 m [50 ft.]) stacks were required. Two supply air units were assumed rated at (424.8 m^3 [15,000 ft^3])/min each.

6.2 Technical Feasibility of Control Strategies

Common devices used for capture of particulate matter emissions consist of hoods, canopies, and gloveboxes. In cases where particulate matter is generated over large areas, use of such capture devices becomes technically infeasible. In these cases, it is advantageous to use the building in which the source is located for containment of air emissions. Emissions are then controlled by maintaining a slight negative pressure within the enclosed building with respect to the atmosphere. This ensures that all particulate matter emissions are contained within the enclosure.

The building which encloses the 105-KE basin was not designed in a manner such that building air can be controlled by means of maintaining a measurable negative building ambient pressure relative to atmospheric pressure. The building construction is a framework of steel beams and columns. The exterior surface transite panels are mechanically attached to the steel framework with bolts, but there is no seal at the bolt holes, the panel overlaps, or the junction of the panels with the foundation. In addition, there are numerous penetrations for hoist trolleys, access doors and three rollup doors for rail and truck traffic. Although the closures at such penetrations are normally closed except as required for basin operations, these closures are not of a hermetically sealed design.

For each option it was assumed that caulking of the gaps in the structure combined with the installation of two airlocks (one for personnel, and one for truck traffic) would be sufficient to allow a negative pressure of 0.3 inches water gauge relative to atmosphere to be attained. The exact amount of effort required to accomplish this is highly uncertain, but considered technically feasible. Construction of airlocks for train traffic might be necessary for fuel shipments but are beyond the scope of the proposed activity and was not considered.

All HEPA filtration options discussed above are technically feasible. However, for purposes of the remaining discussion of the BARCT analysis, the assumption was made, based on applicable DOE design criteria and industry standards, that all radionuclide particulate matter emitted due to the encapsulation activity will be captured and conveyed to the HEPA control unit. In addition, the assumption was made that radionuclide particulate characteristics are such that

99.97 percent (weight) of all such particulate matter will be removed by the HEPA filter units. These assumptions were made in order that the cost effectiveness of each HEPA filtration option would be determined from the most conservative basis.

6.3 Energy, Environmental, and Economic Impacts

This section contains the energy, environmental, and economic impacts relative to all the control systems investigated for the encapsulation activity.

6.3.1 Energy Impacts

Energy impacts due to installation of HEPA filter equipment consist mainly of the energy required to preheat humid air to prevent moisture condensation on filters and the energy required to overcome the gas pressure drop across pre-filters and HEPA filters. These incremental energy requirements do not present any adverse impact to the operations of the facility.

6.3.2 Environmental Impacts

Impacts to the environment due to the installation of HEPA filter equipment will occur because construction debris and used filters must be disposed of as radioactive waste which will require burial storage. Although the environment will be impacted, it does not present an adverse impact to the operations of the facility. An adverse impact would prevent implementation of a control technology.

6.3.3 Economic Impacts

The economic impacts due to each HEPA filtration option were evaluated by estimating the total installed capital cost and operating cost for each option. An equivalent amortized capital cost along with the estimated annual operating cost for each unit was then determined. The economic impact to the facility for each control option was defined in terms of total annual cost to the facility per decrease in EDE to the population (person-rem). The population consisted of 370,000 people located in a (80,463 m [50 mile]) radius from the 100 K area. The dose

estimate was derived from the projected air emissions in Chapter 5.0, Table 5-1. The EDE to the population was calculated to be 2.1 X 10^{-2} person-rem/yr.

No federal guidance on cost estimation for HEPA filtration control could be located. For this reason, cost estimates for each option were prepared by the Westinghouse Hanford Company (WHC) based on past HEPA filter installation project experience. Purchase costs were estimated for major equipment such as prefilter and HEPA filter housings as well as minor equipment such as induced draft fans, air preheaters, ducts, stacks, structural steel, isolation dampers, electrical hardware, etc. The vendor supplied HEPA filter equipment included bag-in-bag-out filter replacement capability and inlet air pre-heat capability. Labor hours for installation of this equipment were estimated. Cost to make roof modifications, training of personnel, demolition and burial of waste material, and engineering services were also estimated by WHC. Complete itemized total capital investment estimates for each option can be found in reference WHC 1993d.

6.3.3.1 Option 1 - Two Roof Mounted HEPA Units

This option consists of adding two roof mounted HEPA housings, each rated at (453.1 m^3 [16,000 ft^3])/min, on the roof of the 105 KE facility and exhausting from a (15 m [50 ft.]) high stack. In addition, a supply air system rated at (849.5 m^3 [30,000 ft^3])/min would be provided at grade level. The cost estimate for this equipment is tabulated in Appendix A-1 of reference WHC 1993d for Option 1 (WHC 1993d).

The purchase price for the exhaust equipment (excluding the sampling system and ducting) was approximately $193K. However, the construction cost including all other materials, labor and overheads was estimated to be approximately $3.233M. After adding engineering and contingency estimates, the total cost for Option 1 was estimated to be approximately $5.94M.

Annual operating costs were estimated as shown in Table 6-1 and are approximately as $87K. Provision was made for preventative maintenance, filter change outs, filter testing as well as the annual electrical usage costs.

The construction costs can be amortized (over four years at ten percent interest) to obtain the annual equipment cost estimate of $1.874 million per year. Total annual costs (capital plus operating) were therefore estimated to be $1.961 million per year.

The system is expected to decrease the EDE due to projected emissions during the encapsulation activity to the population by 2.099 x 10^{-2} person-rem (2.1 X 10^{-2} EDE x 99.97% HEPA filter efficiency). This means that the cost effectiveness of proposed Option 1 is expected to be $93 million per person-rem.

6.3.3.2 Option 2 - Two Grade Mounted HEPA Units

This option consists of adding two HEPA housings, each rated at (453.1 m^3 [16,000 ft^3])/min, on the grade level outside the 105 KE facility and exhausting from a (27 m [90 ft.]) high stack. In addition, a supply air system rated at (849.5 m^3 [30,000 ft^3])/min would be provided at grade level. The cost estimate for this equipment is tabulated in Appendix A-1 of reference WHC 1993d for Option 2 (WHC 1993d).

The purchase price for the exhaust equipment (excluding the sampling system and ducting) was approximately $217K. However, the construction cost including all other materials, labor and overheads was estimated to be approximately $2.984M. After adding engineering and contingency estimates, the total cost for Option 2 was estimated to be approximately $5.48M.

Annual operating costs were estimated as shown in Table 6-1 and are approximately as $87K. Provision was made for preventative maintenance, filter change outs, filter testing as well as the annual electrical usage costs.

The construction costs can be amortized (over four years at ten percent interest) to obtain the annual equipment cost estimate of $1.729 million per year. Total annual costs (capital plus operating) were therefore estimated to be $1.816 million per year.

The system is expected to decrease the EDE due to projected emissions during the encapsulation activity to the population by 2.099 x 10^{-2} rem (2.1 X 10^{-2} EDE x 99.97% HEPA filter

efficiency). This means that the cost effectiveness of proposed Option 2 is expected to be $87 million per person-rem.

6.3.3.3 Option 3 - Four Roof Mounted HEPA Units

This option consists of adding four roof mounted HEPA housings, each rated at (226.5 m^3 [8000 ft^3])/min, on the roof of the 105 KE facility and exhausting from two (15 m [50 ft.]) high stacks. In addition, a supply air system rated at (849.5 m^3 [30,000 ft^3])/min would be provided at grade level. The cost estimate for this equipment is tabulated in Appendix A-1 of reference WHC 1993d for Option 3 (1993d).

The purchase price for the exhaust equipment (excluding the sampling system and ducting) was approximately $251K. However, the construction cost including all other materials, labor and overheads was estimated to be approximately $3.576M. After adding engineering and contingency estimates, the total cost for Option 3 was estimated to be approximately $6.58M.

Annual operating costs were estimated as shown in Table 6-2 and are approximately as $82K. Provision was made for preventative maintenance, filter change outs, filter testing as well as the annual electrical usage costs.

The construction costs can be amortized (over four years at ten percent interest) to obtain the annual equipment cost estimate of $2.076 million per year. Total annual costs (capital plus operating) were therefore estimated to be $2.158 million per year.

The system is expected to decrease the EDE due to projected emissions during the encapsulation activity to the population by 2.099×10^{-2} rem per year (2.1×10^{-2} EDE x 99.97% HEPA filter efficiency). This means that the cost effectiveness of proposed Option 3 is expected to be $103 million per person-rem.

Table 6-1. Annual Operating Cost Estimate for HEPA Ventilation System for Option 1 and 2

Electrical (@ $0.02/Kw-Hr)	No. of Units	Kw each	Percent Use (%)	Annual Cost ($)
Option 1 & 2				
Supply heaters	1	560	25	24,528
HEPA heaters	2	75	50	13,140
Supply Fan 40 hp	1	30	100	5,256
Exhaust Fan 100 hp	1	75	100	13,140
Subtotal				56,064
Maintenance	**Hours/Yr**	**Labor Rate**		
Labor				
Bargaining	292	$42.03		12,273
Exempt	136	$51.10		6,950
Replacement of Supply Air Prefilters (30 filters @ $100/filter, 2 times annually)				6,000
Replacement of Used HEPA filters (36 filters @ $311/filter, once every two years)				5,600
Misc. materials				750
Subtotal				31,573
Total				87,637

Note: Exempt labor estimated at 50% of bargaining labor hours.
WHC current labor rates include overheads.
Filter costs are construction cost estimates.

Table 6-2 Annual Operating Cost Estimate for HEPA Ventilation System for Option 3

Electrical (@ $0.02/Kw-Hr)	No. of Units	Kw each	Percent Use (%)	Annual Cost ($)
Option 3				
Supply heaters	2	300	25	26,280
HEPA heaters	4	25	50	8,760
Supply Fan 20 hp	2	15	100	5,256
Exhaust Fan 40 hp	2	30	100	10,512
Subtotal				50,808
Maintenance	**Hours/Yr**	**Labor Rate**		
Labor				
Bargaining	292	$42.03		12,273
Exempt	136	$51.10		6,950
Replacement of Supply Air Prefilters (30 filters @ $100/filter, 2 times annually)				6,000
Replacement of Used HEPA filters (36 filters @ $311/filter, once every two years)				5,600
Misc. materials				750
Subtotal				31,573
Total				82,381

Note: Exempt labor estimated at 50% of bargaining labor hours.
WHC current labor rates include overheads.
Filter costs are construction cost estimates.

7.0 Selection of BARCT

The DOH has accepted HEPA filtration as BARCT for radionuclide particulate-in-air removal (WHC 1992a). However, for the encapsulation activity, DOH has stated that the baseline option will not be accepted as BARCT without overwhelming evidence that the baseline option will maintain the radionuclide concentration at acceptable levels and the cost of installing HEPA's is extreme (WHC 1992a).

The DOH has indicated that an acceptable facility emission rate is that which would cause any member of the public to receive in any year an CEDE of 1.0×10^{-3} to 1.0×10^{-2} mrem/yr (WHC 1992b). The radionuclide air emissions from the encapsulation activity have been conservatively projected as 1.2×10^{-3} Ci/yr to result in a CEDE to the MEI of 7.9×10^{-4} mrem/yr. Furthermore, the estimated radionuclide air emissions are based on actual air quality analysis for the 105-KE Basin. The estimated radionuclide emissions as a result of the encapsulation activity is below the acceptable facility emission rate which would cause any member of the public to receive in any year a CEDE of 1.0×10^{-3} to 1.0×10^{-2} mrem/yr (WHC 1992b).

No precedent for an acceptable economic impact could be found for the analysis. The DOH has related that the EPA has indicated an acceptable economic impact for control of radionuclide particulate emissions using HEPA filtration is that control which would have a cost effectiveness less than $12 million per person-rem (WHC 1992b). Since the lowest cost to provide HEPA filtration was $87 million per person-rem, it is clear that all the HEPA filtration options evaluated will have an adverse economic impact on the operation of the facility.

Encapsulation activities will be performed over a four year period. Accordingly, equivalent amortized equipment costs for all HEPA filtration options were determined using a four year life.

Table 7-1 contains a summary of the BARCT analysis. Due to the low baseline emission rate for the encapsulation activity, implementation of any of the aforementioned HEPA filtration options for particulate radionuclides emitted due to the encapsulation activity presents an unacceptable economic impact to the 105-KE Basin. The estimated radionuclide air emissions, based on actual air quality analyses of the 105-KE Basin, as a result of the encapsulation activity have been conservatively estimated as 1.2×10^{-3} Ci/yr. The projected population dose as a result of the estimated radionuclide air emissions is 2.1×10^{-2} person-rem/yr. The cost

effectiveness of the most economic HEPA filtration option (option 2) for the projected dose to the population (2.1×10^{-2} person-rem/yr) was $87 million per person-rem. For these reasons, BARCT for the encapsulation activity is determined to be the baseline option which consists of minimization of particulate radionuclide emissions by performing the encapsulation activity under water which is treated by the water treatment systems as discussed in section 3.2.

TABLE 7-1. Summary of BARCT Analysis for Radionuclide Emissions

Control Alternative	AEDE Due to Emissions (person-rem/yr)	AEDE Reduction(a) (person-rem/yr)	Total Capital Investment(b) ($, X10^6)	Economic Impacts: Total Annualized Cost(c) ($/yr, X10^6)	Economic Impacts: Cost Effectiveness(d) ($/person-rem)	Adverse Economic Impact (Yes/No)	Adverse Environmental Impact (Yes/No)	Adverse Energy Impact (Yes/No)
Option 1	6.3E-06	2.099E-02	5.940	1.961	93E+06	Yes	No	No
Option 2	6.3E-06	2.099E-02	5.480	1.816	87E+06	Yes	No	No
Option 3	6.3E-06	2.099E-02	6.580	2.158	103E+06	Yes	No	No
Baseline	2.1E-02	---	---	---	---	---	---	---

a) Emissions reduction below baseline level.
b) Installed capital cost relative to baseline.
c) Includes capital and operating costs. A capital recovery factor was used based on a 4 year equipment life and a 10% annual interest rate.
d) Average Cost Effectiveness is total annualized cost for the control option divided by the emissions reductions resulting from the option.

8.0 References

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