50-320

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

March 16, 1995

Mr. T. Gary Broughton
Vice President
GPU Nuclear Corporation
Post Office Box 480
Middletown, Pennsylvania 17057-0191

SUBJECT: RESULTS OF PNL RADIOLOGICAL SURVEY OF TMI-2

Dear Mr. Broughton:

The U.S. Nuclear Regulatory Commission staff, in their oversight of the Three Mile Island Nuclear Station, Unit 2 (TMI-2) cleanup, requested that the Pacific Northwest Laboratory (PNL) perform a study to independently verify GPU Nuclear surface contamination levels and general area radiation levels in the Reactor Building and the Auxiliary and Fuel Handling Buildings (AFHB) as reported in your Post-Defueling Safety Analysis Report. The survey was conducted in November 1993. PNL has completed the analysis and the results of their investigation is summarized in the enclosed copy of the report entitled "Verification of Dose Rate and Radioactive Contamination Levels in the Three Mile Island-Unit 2 Facility".

The measurements of general area gamma dose rates found that in November 1993, PNL recorded higher gamma dose rates than those reported by the licensee in 5 out of the 20 locations, approximately the same dose rates in 4 of the 20 locations and lower dose rates in 11 out of the 20 locations. Of the 14 locations where beta dose rates were determined, PNL found higher dose rates in 2, approximately equal dose rates in 2, and lower beta dose rates in 11 of the locations. In all locations surveyed, the licensee reported dose rates well below the goals for the locations. PNL surveys confirmed that the dose rates were below the goals.

The PNL study measured lower contamination levels than those measured by the licensee in 19 of the 20 areas sampled. In one location the PNL measurements averaged about 50 percent higher than the licensee's measurements. The licensee had determined that 4 of 20 locations sampled had contamination levels higher than the stated goals. These 20 locations were the reactor building, the makeup and purification pump room 1B, the seal injection valve room, and the makeup tank room. The PNL study confirmed that contamination levels in the reactor building and the makeup and purification pump room 1B were higher than the stated goals, however, PNL found lower levels of contamination than the licensee found in the seal injection valve room and the makeup tank room. PNL determined that the licensee met the stated goals for these 2 locations.

The results of the alpha surveys indicated that alpha-emitting contamination was a very minor component of the contamination in the areas surveyed and within regulatory limits.

PNL found that within the variation associated with instrumentation, methodology, and assumptions, the dose rate and contamination level measurements made in November 1993 provided reasonable confirmation of the measurements made by the licensee. The PNL study verified that the licensee conducted adequate and sufficiently accurate assessments of dose rates and contamination levels in the Reactor Building and the AFHB.

Sincerely,

Original signed by: Michael Masnik for:

Lee H. Thonus, Project Manager
Non-Power Reactors and Decommissioning
Project Directorate
Division of Project Support
Office of Nuclear Reactor Regulation

Docket No. 50-320

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Sincerely,

Michael T. Masnik for

Lee H. Thonus, Project Manager
Non-Power Reactors and Decommissioning
Project Directorate
Division of Project Support
Office of Nuclear Reactor Regulation

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GPU Nuclear Corporation Unit No. 2

Three Mile Island Nuclear Station
Docket No. 50-320

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Letter Report

VERIFICATION OF DOSE RATE AND RADIOACTIVE CONTAMINATION LEVELS IN THE THREE MILE ISLAND-UNIT 2 FACILITY

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October 1994

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EXECUTIVE SUMMARY

The Three Mile Island, Unit 2 nuclear power reactor experienced a loss of reactor coolant on March 29, 1979 and the subsequent distribution of radioactive contamination throughout the reactor coolant system, the Reactor Building and the Auxiliary and Fuel-Handling Buildings (AFHB). Since the accident, cleanup activities have included decontamination of much of the AFHB as well as parts of the Reactor Building. Approximately 99% of the fuel has been removed from the reactor vessel and the remainder of the facility. On August 16, 1988, the licensee, General Public Utilities Nuclear Corporation (GPUN) formally proposed placing the facility in a storage mode after the completion of the defueling process to allow decay of the radionuclides remaining in the facility. This storage mode, referred to as "post-defueling monitored storage" (PDMS), was approved by the NRC on December 28, 1993.

Before placement of the facility into PDMS the licensee had set specific decontamination goals (dose rate and surface contamination levels) for all areas of the facility and had performed measurement surveys to determine the degree of success in meeting these goals. The NRC staff, as part of their oversight of the TMI-2 facility and the cleanup process, requested that the Pacific Northwest Laboratory (PNL)[a] perform a study to independently verify the licensee's measurements. PNL selected 19 locations or cubicles in the AFHB and one location in the Reactor Building to perform general area dose rate and surface contamination measurements. The general area beta and gamma dose rates were measured using ionization chambers that were similar to those used by the licensee. The beta surface contamination measurements were made using instruments provided by the licensee, the same instruments that the licensee used for their measurements. Alpha surface contamination was also measured by both the licensee and PNL using the same scintillation alpha counter. The PNL and the GPUN procedures used to survey the locations for general area dose rate measurements and the surface contamination measurements were similar but not identical.

The measurements of general area gamma dose rates show that PNL found higher gamma dose rates than those reported by the licensee in five out of the 20 locations, approximately the same dose rates in 4 of the 20 locations and lower dose rates in 11 out of the 20 locations. Of the 14 cubicles where beta dose rates were determined, PNL found higher dose rates in 2, approximately equal dose rates in 2, and lower beta dose rates in 11 of the cubicles. In all locations surveyed, the licensee reported dose rates well below the goals that they had initially set. PNL surveys confirmed that the dose rates were below the licensee goals.

The PNL study measured lower contamination levels than those measured by the licensee in 19 of the 20 areas. In one location the PNL measurements averaged about 50% higher than the licensee's measurements. The licensee had determined that four of the twenty locations in this study had contamination levels higher than the stated goals.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

The PNL study confirmed that contamination levels in the Reactor Building and in Makeup and Purification Pump Room 1B were higher than the stated goals, however, in the Seal Injection Valve Room and in the Makeup Tank Room, the PNL survey found lower levels of contamination than did the licensee, which did not exceed the stated goal.

The results of the alpha surveys indicated that alpha-emitting contamination was a very minor component of the contamination in the areas surveyed and within the regulatory limits.

PNL found that within the variation associated with instrumentation, methodology, and assumptions, the dose rate and contamination level measurements made in November 1993 provided reasonable confirmation of the measurements made by the licensee. The PNL study verified that the licensee conducted adequate and sufficiently accurate assessments of dose rates and contamination levels in the Reactor Building and the AFHB.

CONTENTS

INTRODUCTION

Three Mile Island, Unit 2 (TMI-2) is a nuclear power reactor located on the banks of the Susquehanna River in Dauphin County, Pennsylvania. TMI-2 is a pressurized water reactor with a Babcock and Wilcox (B&W) nuclear steam supply system, which was designed to generate 890 MW (megawatts) of electric power (2770 MW thermal). Between issuance of its operating license on February 8, 1978 and March 28, 1979, TMI-2 operated about 95 effective full-power days. Operation ceased on March 28, 1979 after an incident occurred that involved a loss of reactor coolant and resulted in serious damage to the reactor fuel. When coolant was restored, radioactive contamination was distributed throughout the reactor coolant system and into the reactor building basement. Exposed surfaces and equipment in the Reactor Building and the Auxiliary and Fuel-Handling Buildings (AFHB) were contaminated with radioactive material contained in the water and steam that escaped from the reactor coolant system.

Since the accident, the water released into the facility has been removed, extensively processed (to remove radionuclides), and evaporated. In addition to removing the contaminated water, cleanup activities included decontamination of much of the AFHB as well as the Reactor Building. Approximately 99% of the fuel has been removed from the reactor vessel and the remainder of the facility.

On August 16, 1988, General Public Utilities Nuclear Corporation (GPUN), the licensee for TMI-2, proposed placing the facility into long term storage after the completion of the defueling process. This would allow decay of the radionuclides remaining in the facility and thus workers would be exposed to lower levels of radioactivity during future decontamination and decommissioning. This storage mode, during which the facility is monitored by the licensee, is referred to as "post-defueling monitored storage" (PDMS). Following an in-depth review, the NRC approved GPUN's request for post-defueling monitored storage on December 28, 1993.

Before TMI-2 entered PDMS, the licensee determined that it would be appropriate to set specific decontamination goals for all areas of the facility and perform measurement surveys to determine the degree of success in meeting those goals. In addition the general area dose rate and contamination measurements could be used to characterize to the extent possible, the remaining loose surface contamination and general area radiation levels. This characterization would allow the licensee to monitor changes in the levels of surface contamination or in the general area radiation levels over time.

The licensee has surveyed each area in the Reactor Building and each cubicle in the AFHB to determine whether the general area dose rates and contamination levels are below the goals and to provide a baseline for monitoring changes during PDMS. These surveys have been performed at various time periods during the decontamination process. The

results of each study have been published in the licensee's Safety Analysis Report (SAR) for PDMS (GPU 1988, as supplemented).[a]

The Nuclear Regulatory Commission (NRC) staff as part of their oversight of the TMI-2 facility and the cleanup process, determined that confirmatory measurements of the licensee's results should be made. The NRC requested that the Pacific Northwest Laboratory (PNL) perform a study that would independently verify the efforts of the licensee in assessing the loose surface contamination levels and the general area dose rates in the facility. Pacific Northwest Laboratory selected 19 cubicles (or areas) in the Auxiliary and Fuel Handling Buildings (AFHB) and one area in the Reactor Building to perform general area dose rates and surface contamination measurements that were equivalent but not identical, to the methods employed by the licensee. The results of the measurements were then compared to the licensee's measurement results.

This report documents the instruments and techniques used by the PNL researchers in performing this study, presents the data that was collected and compares the PNL survey data to the licensee's data.

(a) The August 16, 1988, SAR was supplied by information contained in letters dated January 9, 1989 (GPU 1989a); February 9, 1989 (GPU 1989b); March 31, 1989 (GPU 1989c); June 26, 1989 (GPU 1989d); October 10, 1989 (GPU 1989e); November 22, 1989 (GPU 1989f); June 21, 1990 (GPU 1990a); October 15, 1990 (GPU 1990b); November 7, 1990 (GPU 1990c); February 19, 1991 (GPU 1991a); April 19, 1991 (GPU 1991b); June 21, 1991 (GPU 1991c); August 28, 1991 (GPU 1991d); October 9, 1991 (GPU 1991e); January 13, 1991 (GPU 1991f); January 18, 1993 (GPU 1993a); and May 28, 1993 (GPU 1993b).

PROCEDURES

The purpose of the verification study is to perform general area dose rate and surface contamination level measurements in the TMI-2 facility that are independent of the measurements performed by the licensee, and then to compare the results with the measurements made by the licensee. The general area dose rate and surface contamination levels provide an indication of the amount of radioactive material located in each area. This in turn is indicative of the extent of the decontamination in each area when compared to pre-decontamination level readings.

There were five major components to this study: 1) selection of the areas for survey, 2) selection of the instruments to be used to perform the survey, 3) calibration of the instruments, 4) procedures for the use of the instruments in the actual survey, and 5) analysis of the data. This section describes the first four components. The analysis of the data is discussed in the "Measurement Results" section.

SELECTION OF LOCATIONS FOR SURVEY

After the extensive cleanup efforts performed at TMI-2, most of the contamination concerns were focused on the Reactor Building and the AFHB. Other buildings were either sufficiently uncontaminated to be released for unrestricted use, or the contamination was considered to be well-understood and suitably contained.

For the purpose of contamination characterization and control, the Reactor Building was divided into a number of areas, and appropriate goals were set for the general area dose rates and contamination levels of each area. In some areas, such as the Reactor Building basement, due to the very high general area radiation levels and extensive contamination, it was recognized that there was no reasonable alternative to maintaining the contamination level "as is". In other areas it was considered reasonable to set general area dose rate and contamination level goals, and work to achieve these goals.

The Auxiliary Building was divided into 99 "cubicles" (in many cases, a cubicle was a room; in others it was a general area such as the open area at the bottom of a stairwell). The Fuel Handling Building was divided into 37 cubicles. A small number of cubicles were considered to be left "as is"; for most cubicles the following goals were set:

- General area dose rate (mR/h)
- Surface contamination for surfaces below 7 ft overhead (dpm/100 cm^2)
- Surface contamination for surfaces above 7 ft overhead (dpm/100 cm^2).

Chapter 5 of the PDMS SAR (GPU Nuclear, 1988, as supplemented) describes the contamination goals and the measurements that were subsequently performed.

The selection of areas for the verification survey was based on the need to survey a variety of locations with varying levels of contamination in order to minimize systematic bias. The licensee's summary reports of contamination levels that had been previously

measured in the AFHB were given in the PDMS SAR. These reports were used to select several cubicles with varying amounts of contamination including several with low levels of contamination, several with high levels and several with intermediate levels. Locations were also chosen to provide a variety of expected dose rates. Floor plans were inspected to ensure that a variety of room configurations would be chosen. Accessibility was also an issue in location selection. Since PNL staff were not respirator-qualified, cubicles or areas with high airborne contamination were ruled out. The one exception was the measurement made in the TMI-2 reactor building where the actual measurements were performed by NRC personnel who were respirator-qualified.

The initial list of candidate cubicles was sent to the licensee for additional information regarding the status of the selected areas. The licensee indicated that three of the chosen cubicles required the use of respirators or additional protective clothing due to high airborne concentrations, or were inaccessible due to the presence of water in the cubicle. Because of the additional expense and dose required to survey these areas, the decision was made to chose three alternate cubicles to complete the list.

Table 1 lists the cubicles in the Auxiliary and Fuel Handling Buildings that were surveyed in this study. It also lists the area in the reactor building that was studied. For each cubicle or area, Table 1 lists an identifying code that is used in the presentation of the data in this report.

INSTRUMENT SELECTION

This section contains a description and comparison of the instruments used by both the licensee and PNL to measure general area dose rates, beta radiation from the surface contamination and alpha radiation from surface contamination.

General Area Dose Rate Measurements

The beta and gamma general area dose rates measured by the licensee were obtained using an Eberline RO-2 (or RO-2A) ionization chamber. The RO-2 and RO-2A have approximately 800 to 1000 mg/cm^2 wall and window covering. The scale of the RO-2 or RO-2A measures in units of mR/h (milliroentgen per hours) and has a sensitive range of a few tenths of an mR/h to 5000 mR/h.

PNL used a different version of ionization chamber, called the "CP" ("Cutie Pie" or "QT-π"), an Eberline RO-3B. The CP has a 400 mg/cm^2 wall and window covering. The CP also has a scale that measures in units of mR/h with a sensitive range from a few tenths of an mR/h to 5000 mR/h.

The side and back walls of both the Eberline RO-2's and the CP's cylindrical chamber are constructed of a material that stops most beta radiations. The entrance window of each detector chamber is made of thin mylar to allow betas to enter. There is a removable plastic shield for the detector entrance window that will stop low- and medium-energy betas. Thus a survey is performed by making two readings, one with the window open and one with it closed. These two readings can be used to obtain separate readings for penetrating and non-penetrating radiation.

Table 1. Rooms Surveyed

Auxiliary Building - Basement (280-ft Level)

AX001	Reactor Building Emergency Cooling Booster Pump Area
AX004	Seal Injection Valve Room
AX005	Makeup and Purification Pump #1C
AX006	Makeup and Purification Pump #1B
AX007	Makeup and Purification Pump #1A
AX011	Auxiliary Building Sump Tank, Pumps and Valve Room
AX013	Evaporator Condensate Tank Pumps
AX018	Waste Transfer Pump Room
AX021	Reactor Coolant Bleed Holdup Tank #1A

Auxiliary Building - Ground Floor (305-ft Level)

AX102	Reactor Building Sump Pump Filter
AX103	Motor Control Center
AX113	Waste Gas Analyzer Room
AX116	Makeup Tank Room
AX118	Spent Fuel Coolers and Pumps

Fuel Handling Building - Ground Floor (305-ft Level)

FH103	Sample Room
FH105	Model Room
FH112	Annulus

Auxiliary Building - First Floor (328-ft Level)

AX218	Concentrated Waste Storage Room

Auxiliary Building - Operating Floor (347-ft Level)

FH304	Annulus

Reactor Building (305-ft Level)

RB305	Area in front of Equipment Hatch

The use of both the CP and the RO-2 or RO-2A involves a few approximations that should be clarified. Non-penetrating and penetrating radiation usually are assumed to correspond to betas and photons respectively, but some low-energy photons can be stopped by the front shield and some high-energy betas can penetrate the shield. A fraction of the betas emitted by ^{90}Sr have energies high enough to penetrate the shield, so they will contribute to the "penetrating" component of the measurement. In this report we use the convention of specifying gamma versus beta radiation (the licensee also used this convention in survey reports), but it should be remembered that a small percentage of the "gamma" dose was actually produced by betas.

Another approximation is that the CP (like the RO-2 or RO-2A) actually measures exposure (measured in roentgens (R) or milliroentgens (mR)), and not dose (rad or mrad) or dose equivalent (rem or mrem). For the types of radiation encountered at TMI-2, 1 R is nearly equal, numerically, to 1 rad and to 1 rem, so this report will refer to dose rates while it is understood that the quantity actually measured was exposure rate.

Beta Surface Contamination

Surface contamination was measured by taking smear samples of the contaminated area, then counting betas emitted by the sample. For counting PNL used instruments provided by the licensee (the same instruments as those used by the licensee for their surveys). Beta radiation measurements were made with a Ludlum 2000 counter. The Ludlum 2000 is a self-contained counting instrument that can work with several different detectors. Both the licensee and PNL used an Eberline HP-210 probe (a "pancake" GM tube with a thin mica window) for the beta measurements. The probe was positioned at the top of a small lead cave to reduce background counts. The lead cave contained a drawer with a stainless steel planchet for holding the smear sample. This arrangement provided a low background count with a reproducible geometry.

Although the desired counting time could be varied, the scaler in the Ludlum 2000 was set to record counts over a 1 minute interval so that the recorded counts would be equivalent to counts per minute (cpm). These values were converted to disintegrations per minute (dpm) using an efficiency value that is appropriate for the beta-emitting nuclides present at TMI-2. The ratemeter's accuracy deteriorated at approximately 30,000 to 50,000 cpm due to dead time[a] losses. Thus, procedures called for recounting high-count rate samples (greater then 50,000 cpm) with an RM-14 meter equipped with an HP-210 probe.

(a) Dead time is the amount of time required for the instrument to recover from a count. Because a specific interval of time is required for the instrument to recover following a count, the greater the number of counts, the greater the chance that some counts are being missed. Dead time does not affect the number of counts at low count rates.

Alpha Surface Contamination

Alpha radiation from smear samples were measured by both the licensee and PNL using an Eberline SAC-4 counter (Scintillation Alpha Counter) provided by the licensee. The SAC-4 utilizes a 2-inch scintillation crystal for particle detection. The detector is self-contained in the instrument which provides for shielding of the sample, thus allowing the sample to be counted in a lower background environment. The sample to be evaluated is placed in a drawer that slides into the detector. This setup allows the sample to be positioned directly under the detector and provides a reproducible geometry so that the sample can be recounted in the same manner. The counter displays total counts, which could be converted to cpm by dividing by the counting time period.

INSTRUMENT CALIBRATION

The measurement results depend heavily on the methods used to calibrate the instruments. The methods used by the licensee and by PNL for each of the instruments discussed above, are given in this section.

RO-2 Survey Meters

The licensee's procedures for calibration of radiological instruments calls for the use of photon and beta sources traceable to the National Institute of Standards and Testing (NIST). Calibration of dose rate measuring instruments (such as the RO-2's) is required at a minimum of quarterly to assure consistent, reliable and predictable response to radiation levels. Calibration is also required if an instrument does not pass a source check, or following repair. Calibration accuracy is required to meet the manufacturer's specifications as a minimum.

CP Survey Meters

The CP instruments used by PNL staff were calibrated by the PNL calibration staff according to methods and procedures traceable to the NIST two weeks before the measurements were taken at TMI-2. The calibration of the instruments was checked again the week after the measurements were performed, and both instruments were found to be exactly within specifications. Thus, there is strong assurance that the instruments were responding properly and giving reliable dose rate readings during the TMI-2 contamination study.

Dose rates for penetrating radiation are found by making a reading with the window closed (that is, covered by the protective shield). The dose rate for non-penetrating radiation is found by taking a reading at the same location with the window open, subtracting the window-closed reading, and multiplying the difference by a correction factor. The correction factor varies depending on the shape and size of the beta-emitting source, the beta energy, and the distance of the source from the detector. For all measurements made in this study, a correction factor of 2.5 was used, which corresponds to a large-area source of ^{90}Sr or ^{137}Cs positioned more than 6 inches away from the face of the detector.

Ludlum 2000 Beta Smear Counters

Three different Ludlum 2000 units were used in this study. The probes for all three units were carefully selected so that their responses would be similar. These counters presented data in units of cpm. In order to determine the desired units of dpm, a counter efficiency was applied. The efficiency can be mathematically defined by the following equation:

$$c = \epsilon d,$$

where c = count rate (cpm)
ϵ = efficiency
d = radionuclide activity (dpm).

The detector efficiency depends on the geometry of the smear and the detector, on the energy of the betas, and on the number of betas emitted per disintegration. The geometry is constant for all smears, so the selection of an appropriate efficiency value is based on the mix of radionuclides present on the counted smear. At TMI-2, beta radiation is produced almost exclusively by two isotopes, ^{137}Cs and ^{90}Sr.

The licensee performed calibration studies for ^{137}Cs and ^{90}Sr and found that the efficiency for beta radiation was 0.20. The licensee's calibration study involved the collection of samples of ^{137}Cs and ^{90}Sr. The samples were obtained by collecting air samples in the reactor containment building on thirteen different air filters. These filters were counted on a germanium detector to determine the ^{137}Cs and ^{90}Sr contents. The values were converted to units of dpm. They were then measured using three different Ludlum-2000 units to read cpm. The ratios of cpm to dpm were all very close to 0.20, so this value was adopted as the efficiency value.

The PNL staff used a different approach to determine the instrument's efficiency. Initially, PNL obtained eight smears from TMI-2, and had them sent to one of PNL's laboratories to determine the relative fractions of these two nuclides in the smearable contamination. The smears were placed on a beta spectrometer, and the recorded spectra were analyzed to determine the relative fractions of ^{137}Cs and ^{90}Sr. A complete description of this study is presented in Appendix A. The study showed that the two smears taken from the Reactor Building had 74% to 78% ^{137}Cs with the balance consisting of ^{90}Sr. A smear taken from the fuel handling building was similar, with 67% ^{137}Cs. The five smears taken from the Auxiliary Building showed wide variability: two of the smears had very high ^{137}Cs components (89% and 99%); one smear was similar to the Reactor Building smears (73% ^{137}Cs); and two smears had very low ^{137}Cs components (8% and 13%). The fact that Cs/Sr ratios varied from location to location would appear to dictate customized efficiency factors for counting smears in each individual room. However, because the following analysis indicated that the efficiencies for ^{90}Sr and ^{137}Cs on the Ludlum 2000 counter are similar (0.44 versus 0.40), the error would be small if a single efficiency were used for any mixture of the nuclides. The uncertainty resulting from this error would certainly be far less than the other uncertainties associated with collecting smear samples.

In order to determine a single efficiency, well-characterized sources, with radioactivity traceable to NIST, were used in the Ludlum 2000 counters. Count rates, in cpm, were determined for several repetitive counts. Background count rates were subtracted from these to give net cpm values. These count rates could then be divided by the NIST-traceable values of dpm for the efficiencies. Separate measurements were made for ^{137}Cs and ^{90}Sr sources. A complete description of the calibration of these detectors is presented in Appendix B. The PNL measurements determined that appropriate efficiencies for these counters were 0.44 for counting ^{90}Sr and 0.40 for counting ^{137}Cs.

The detector efficiency determined by PNL is significantly greater than the value determined by the licensee. The reason for this discrepancy can be traced to a difference in convention for specifying activity in a beta source. PNL uses the convention of specifying activity only in terms of the parent nuclide. Strontium-90, however, decays to a radioactive progeny, ^{90}Y, which is also a beta emitter, whereas the licensee uses the convention of reporting the activity of the parent plus the activity of the progeny nuclides. For the case of ^{90}Sr this leads to a factor of two difference in the dpm that would be reported. For example, a ^{90}Sr smear reported by the licensee to contain 1000 dpm of beta activity would be reported as 500 dpm under the PNL scheme. In the experience of PNL health physicists, the convention leading to higher efficiencies and lower reported activities is consistent with standard usage in the nuclear industry. Thus, the use of an efficiency of 0.40 is not inappropriate for this study. However, the licensee's method leads to more conservative estimates of contamination. For this reason, and in order to compare the contamination estimates, the efficiency used by the licensee was adopted for the PNL measurements.

Eberline SAC-4 Counter

The licensee calibrated the Eberline SAC-4 by using a certified alpha source, either a ^{238}Pu source or a suitable equivalent. The procedures for calibrating the Eberline SAC-4 also call for using a pulser to calibrate the timing.

PNL also calibrated the Eberline SAC-4 counts by counting a well-characterized source. A ^{230}Th alpha calibration source was used, and the efficiency was found to be 0.24. This efficiency factor can be used to convert recorded cpm to dpm in the same way that the efficiencies are used in the analysis of beta smears.

PROCEDURES FOR ROOM SURVEY

The procedures for the room surveys for both general area dose rates, and surface contamination are discussed here for both the licensee's, and PNL's measurement teams.

Procedures for General Area Dose Rate Measurements

The licensee's general area radiation surveys, for beta and gamma measurements were taken by positioning the instrument such that a 360 degree unshielded indication was observed. Measurements were taken at approximately 1 foot, 3 feet, and 6 feet above the floor for approximately every 25 square feet of floor area and not less than four survey points per cubicle or area. In addition the area was scanned for "hot spots," points of

significantly higher radiation levels than general areas. The detector was centered 1 inch from the surface and also at approximately 1 foot (if practicable) and the component or system was scanned.

PNL's procedures for general area dose rate measurements involved the use of a CP to measure dose rates in each cubicle sampled. Upon entry into a room, PNL staff used the CP to measure dose rates in a number of locations. The locations for these measurements were chosen to map the general area dose rates over the entire room and to measure dose rates in the vicinity of items of interest in the room such as tanks, pipes or valves. In some cases "contact" dose rates were taken. Contact dose rates were found by holding the instrument within an inch of the surface of the item. For all dose rate measurements, readings were made by the CP with the window open. In most cases, readings were also taken with the window closed to find the nonpenetrating and penetrating components of the dose. When the CP was used to find the nonpenetrating component of the dose, the instrument was pointed in all directions (at chest height) to find the highest reading. This was necessary to account for the many cases where betas came from a specific direction. In all cases, the highest reading at a location was recorded.

Procedures for Surface Contamination Measurements

The licensee took loose surface contamination smears every 25 square feet of floor area and 35 square feet of wall area below the 7-foot mark. At least 16 smears were taken per area or cubicle. Representative surface contamination surveys were also taken of the walls above 7 feet and of the overheads. Smears encompassed 100 cm^2 and were taken using "moderate pressure" typically using long "S" shaped wiping motions. Smears were also taken at locations where the build-up of radioactive contamination was expected, such as valves, pumps, drains, pump drip pans, etc. The smears were placed in envelopes or plastic bags, and transported to the counting room, where they were counted using the Ludlum 2000 Beta Smear Counter. In the event of a high count rate smear sample, the licensee's procedures called for recounting the sample on a RM-14 meter equipped with a HP-210 probe. This instrument is a ratemeter that shows readings directly in cpm, which can be converted to dpm. However, because this technique did not improve the dead time problem, it did not improve the measurement capability.

PNL collected between 30 and 100 smear samples in each room or cubicle. In most cubicles this was between one-fourth and one-half the number of locations sampled by the licensee. Locations for surface smears were selected based on either of two criteria:

- approximating the locations that had been previously smeared by the licensee
- selecting new locations that could potentially harbor contamination.

In actual practice, there were very few locations selected that had not been surveyed by the licensee. It was apparent that the licensee had been thorough in selecting the most important locations for smearing. The selection of smear locations was guided by studying maps of the cubicles. These maps indicated the locations previously sampled by the

licensee. PNL smear locations could not exactly duplicate the licensee's locations because of the level of detail in the maps. Furthermore, it was undesirable to wipe precisely the same area that had previously been wiped, since the previous wiping would have had a decontaminating effect.

The smear was collected by wiping the area to be sampled with a 1.75-inch-diameter filter paper. The filter paper was wiped in a circular motion covering approximately 100 cm^2. The PNL staff who collected the smears practiced their wiping motions before collecting actual samples to ensure that a 100 cm^2 area was correctly covered. The smears were placed into paper coin envelopes that had been labeled with the smear location, and then transported to the smear counting room.

The smears were counted on the Ludlum 2000 counters for one minute, so that the recorded number of counts was numerically the same as cpm. The timer on the counter's scaler was a simple timer with no dead time correction, so for accuracy it was important that count rates be low enough to produce insignificant dead time. Count rates below about 30,000 cpm needed no dead time correction, but at higher count rates dead time effects reduced the accuracy of the measurement. Conversely, some of the smears had low count rates (30 to 40 counts) which resulted in a larger standard deviation relative to the count.

Thirty-nine of the smears with the highest activities were also counted for alphas. Each of these smears was counted in the SAC-4 counter for one minute, so the number of counts recorded on the scaler corresponded to cpm.

MEASUREMENT RESULTS

This section presents the results of the general area dose rate measurements and contamination smear measurements. Summary data tables are presented in this section, and the detailed measurement results are provided in appendices.

GENERAL AREA DOSE RATE MEASUREMENTS

A summary of the general area, gamma and beta, dose rates measured in the twenty cubicles is listed in Table 2. These are the results of measurements made by PNL using a CP and measurements made by the licensee using an RO2. The first column provides the list of rooms or cubicles where the measurements were performed. The second column labeled "Licensee Goal" is the value published in Chapter 5 of the licensee's PDMS SAR (GPU 1988, as supplemented) as the licensee's goal for each room or cubicle. The measurements were performed to determine the degree of success in meeting this goal. The column labeled "GPU PDMS" is the measured dose rate recorded by the licensee in its routine survey, and published in Chapter 5 of the SAR (GPU 1988). This value is the average for all locations measured in a given room. The columns labeled "PNL Avg" (PNL's Average) and "GPU Avg" (Licensee's Average) are the two values that should be compared to each other. The "GPU Avg" value was averaged over just the locations that were used for the PNL measurements (the PNL measurements did not usually check all the locations that were used in the original pre-PDMS survey as previously discussed). Thus each "GPU Avg" value is averaged over a set of measurements that constitute a subset of the measurements used to find the "GPU PDMS" value. The columns labeled "Ratio" give the ratio of either the PNL gamma measurement to the licensee's gamma measurement, or the ratio of PNL's and the licensee's beta measurements.

There were several cubicles where a beta dose rate was not measured. In these cubicles, general dose rates were so low that taking separate window-open and window-closed measurements would not give statistically significant data. It should also be noted that the dose rate measurements listed in Table 2 were only for general area dose rates and not for contact dose rates. Contact dose rates are much harder to duplicate, since the precise positioning is important, so these measurements were not included in this report.

PNL found higher gamma dose rates than those reported by the licensee in five of the 20 cubicles studied. PNL reported approximately the same gamma dose rates in 4 of the 20 cubicles, and PNL reported lower gamma dose rates in 11 of the 20 cubicles. Of the 4 cubicles where beta dose rates were determined, PNL found higher dose rates in 2, approximately equal dose rates in 2, and lower beta dose rates in the other 11 cubicles. In cases where PNL measured higher dose rates than the licensee, the highest reported ratio of measured dose rates was 1.3.

A complete set of dose rates measured by the PNL survey is presented in Appendix C. This appendix contains maps of the twenty cubicles with measured dose

rates shown at the location of each measurement. It also contains tables comparing the PNL dose rates at each location with dose rate measurements made by the licensee.

BETA SURFACE CONTAMINATION MEASUREMENT RESULTS

The smears from the locations in each of the 20 cubicles that were surveyed, were counted and the counts were converted to dpm using a counter efficiency of 0.20 as previously discussed. Table 3 presents a summary of the smear results for betas, with an average dpm presented for each cubicle. The average dpm listed for the licensee is the value presented in Chapter 5 of the PDMS SAR (GPU 1988, as supplemented). The average dpm listed for PNL is the average of the smears taken by PNL staff. Detailed listings of all smear results for each cubicle are given in Appendix D.

In 19 of the 20 cubicles, the PNL study measured lower contamination levels than those measured by the licensee. In one room (the Evaporator Condensate Tank Pump Room (AX013) the PNL measurements averaged about 50% higher than the licensee's measurements. At the other extreme, there were four cubicles where PNL evaluated the contamination levels to be less than 10% of the values determined by the licensee.

ALPHA SURFACE CONTAMINATION MEASUREMENT RESULTS

Of the 39 smears that were counted for alpha contamination, 30 of them recorded 0 counts, 6 of them recorded 1 count and 3 of them recorded higher counts. Table 4 lists the non-zero counts. The complete listing of all the alpha smears is given in Appendix D.

Most smears that gave 1 count are likely due to background, and are probably not indications of definite alpha activity. The licensee performed alpha counts on smears corresponding to two of the locations listed in Table 4: the Makeup and Purification Pump #1C Cubicle (AX005) and the Makeup Tank Room (AX116). The licensee found that the Makeup Tank Room (AX116) smear was below the minimum detectable concentration, but the Makeup and Purification Pump #1C Cubicle (AX005) smear was measured at 30 dpm. Thus, the licensee found a higher alpha activity at the Makeup and Purification Pump #1C Cubicle (AX005) location than measured by PNL.

Three locations, one in the waste Gas Analyzer Room (AX113) and two in the reactor building, gave alpha counts that are sufficiently above background to indicate definite alpha activity.

Table 2. Measured Dose Rates

Room	Licensee Goal mR/h[a]	GPU PDMS mR/h[b]	Gamma PNL Avg mR/h[c]	Gamma GPU Avg mR/h[d]	Gamma Ratio PNL/GPU[e]	Beta PNL Avg mR/h[c]	Beta GPU Avg mR/h[d]	Beta Ratio PNL/GPU[e]
Reactor Building Emergency Cooling Booster Pump Area (AX001)	<2.5	1.5	0.3	0.5	0.6	N/A	N/A	N/A
Seal Injection Valve Room (AX004)	<1000.0	116	94	80	1.2	48	44	1.1
Makeup and Purification Pump #1C (AX005)	<500.0	8	4	5	0.8	15	17	0.9
Makeup and Purification Pump #1B (AX006)	<500.0	58	76	61	1.2	47.	99.	0.5
Makeup and Purification Pump #1A (AX007)	<500.0	37	30	34	0.9	6	34	0.2
Auxiliary Building Sump Tank, Pumps and Valve Room (AX011)	<50.0	8	7.7	7.4	1.0	2.2	2.8	0.8
Evaporator Condensate Tank Pumps (AX013)	<500.0	5	2.8	2.3	1.2	48	40	1.2
Waste Transfer Pump Room (AX018)	<500.0	10	4.2	8.2	0.5	6.9	11	0.6
Reactor Coolant Bleed Holdup Tank #1A (A2X021)	<500.0	18	6.2	6.6	0.9	1.4	2.2	0.6
Reactor Building Sump Pump Filter (AX102)	<1000.0	48	51	57	0.9	19	46	0.4
Motor Control Center (AX103)	<2.5	0.2	<0.2	<0.2	1.0	N/A	N/A	N/A
Waste Gas Analyzer Room (AX113)	<50.0	19	3.7	8.0	0.5	2.6	5.2	0.5
Makeup Tank Room (AX116)	<500.0	60	50	38	1.3	N/A	44	N/A
Spent Fuel Coolers and Pumps (AX118)	<2.5	1.1	0.8	0.7	1.1	0.0	0.0	1.0
Sample Room (FH103)	<50.0	1.2	0.5	0.5	1.0	0.0	3	0.0

Table 2. (continued)

Room	Licensee Goal mR/h[a]	GPU PDMS mR/h[b]	Gamma PNL Avg mR/h[c]	Gamma GPU Avg mR/h[d]	Gamma Ratio PNL/GPU[e]	Beta PNL Avg mR/h[c]	Beta GPU Avg mR/h[d]	Beta Ratio PNL/GPU[e]
Model Room (FH105)	<2.5	0.2	0.2	0.2	1.0	N/A	N/A	N/A
Annulus (FH112)	<100.0	19	6.4	9.1	0.7	1.0	5.5	0.2
Concentrated Waste Storage Room (AX218)	<500.0	15	6.0	7.5	0.8	2.0	2.1	1.0
Annulus (FH304)	<500.0	0.6	0.5	0.6	0.8	0.8	0.0	N/A
Reactor Building Area in front of Equipment Hatch (RB305)	<100.0	150	69	84	0.8	N/A	N/A	N/A

(a) The licensee goal for general dose rates following decontamination of each cubicle or room are published in the PDMS SAR (GPU 1988, as supplemented).

(b) Average of the measured dose rate recorded by the licensee in its routine survey [published in the PDM SAR (GPU 1988, as supplemented)].

(c) Average of PNL measurements.

(d) Average of the licensee's measurements at the locations measured by PNL.

(e) Ratio of the PNL measurements and the licensee's measurements.

Table 3. Summary of Beta Smear Results

Room	Licensee's Smear Goal (dpm)	Licensee # Smears	Licensee Average (dpm)	PNL # Smears	PNL Average (dpm)	PNL/Licensee Ratio
Reactor Building Emergency Cooling Booster Pump Area (AX001)	<1,000	165	592	63	110	0.18
Seal Injection Valve Room (AX004)	<50,000	26	68385	30	30000	0.44
Makeup and Purification Pump #1C (AX005)	<50,000	57	39982	29	6500	0.16
Makeup and Purification Pump #1B (AX006)	<50,000	45	87533	36	83000	0.95
Makeup and Purification Pump #1A (AX007)	<50,000	41	9195	30	2200	0.24
Auxiliary Building Sump Tank, Pumps and Valve Room (AX011)	<5,000	30	3233	29	850	0.26
Evaporator Condensate Tank Pumps (AX013)	<1,000	84	133	30	200	1.48
Waste Transfer Pump Room (AX018)	<50,000	60	17233	30	5200	0.30
Reactor Coolant Bleed Holdup Tank #1A (AX021)	<50,000	195	1805	67	160	0.09
Reactor Building Sump Pump Filter (AX102)	<50,000	22	9264	25	4200	0.45
Motor Control Center (AX103)	<1,000	23	469	24	13	0.03
Waste Gas Analyzer Room (AX113)	<50,000	71	22380	30	6600	0.29
Makeup Tank Room (AX116)	<50,000	69	313652	27	2600	0.01
Spent Fuel Coolers and Pumps (AX118)	<1,000	60	1000	28	60	0.06
Sample Room (FH103)	<50,000	34	4029	30	3000	0.74
Model Room (FH105)	<1,000	60	101	72	19	0.19
Annulus (FH112)	<50,000	53	3524	30	1700	0.48
Concentrated Waste Storage Room (AX218)	<50,000	50	1860	29	480	0.26
Annulus (FH304)	<50,000	22	2205	25	720	0.33
Reactor Building Area in front of Equipment Hatch (RB305)	<50,000	47	288577	26	75000	0.26

Table 4. Recorded Alpha Counts on Smears

Cubicle	Location	Licensee Activity (dpm)	PNL Count Rate (cpm)	PNL Activity (dpm)
Makeup and Purification Pump #1C (AX005)	Motor support of pump	30	1	4
Makeup and Purification Pump #1B (AX006)	Floor	NT [1]	1	4
Waste Transfer Pump Room (AX018)	Floor	NT	1	4
Waste Gas Analyzer Room (AX113)	On shielding	NT	15	62
Makeup Tank Room (AX116)	Instrument line	< MDC [2]	1	4
Reactor Building (RB305)	Floor	NT	19	79
Reactor Building (RB305)	On cart	NT	1	4
Reactor Building (RB305)	Floor	NT	1	4
Reactor Building (RB305)	Floor	NT	26	108

(1) NT: No alpha count taken at this point
(2) MDC: Minimum detectable counts

DISCUSSION

Descriptions of the instrumentation, the procedures and the results of the measurements were given in previous sections. A discussion of the variations in the instrumentation and procedures used by PNL and the licensee that had or may have been significant in this study is given below. An analysis of the similarities and variations between PNL's results and the licensee's results is also given.

INSTRUMENTATION

PNL staff analyzed the instruments used by the licensee, and in many cases used the same instruments as the licensee. PNL staff also studied the licensee's procedures and determined that the instruments and procedures used by the licensee for measuring contamination levels and dose rates in the plant were appropriate and adequate for the intended purpose. The two major differences between the licensee and the PNL instrumentation were in the use of instruments for measuring the general area dose rates, and in the calibration of the beta smear counters.

Instruments for Measuring General Area Dose Rates

PNL staff used a different instrument for measuring general area dose rates than the instrument used by the licensee. PNL used a CP, which is routinely used for surveys at the Hanford site. The licensee used the RO2 (or RO2A), which is another industry standard instrument. Both instruments are similar, except that the CP has a larger ionization chamber than the RO2. This difference did not affect the non-contact measurements of dose rate, but it may have lead to differences in the measured contact dose rates. Since the effective center of the ionization chamber is positioned at a greater distance behind the mylar window in the CP than in the RO2, beta dose rates for contact readings would not be expected to be identical, with lower readings expected for the CP.

Calibration of Beta Smear Counters

The PNL study performed an independent calibration of the Ludlum 2000 beta smear counter, and determined counter efficiencies that were roughly double the efficiencies used by the licensee. The reason for this disagreement is a difference in convention for specifying activity in a beta source. If the nuclide decays into a radioactive progeny, reporting the activity so that it is clearly understood is difficult. PNL uses the convention of specifying activity only in terms of the parent nuclide, whereas the licensee used the convention of reporting the activity of the parent plus the activity of the progeny nuclides. In the case of ^{90}Sr, which decays to ^{90}Y (also a beta emitter), this leads to a factor of two difference in the dpm that would be reported: a smear reported by the licensee to contain 1000 dpm of beta activity would be reported as 500 dpm under the PNL scheme. In the experience of PNL health physicists, the convention leading to higher efficiencies and lower reported activities is consistent with standard usage in the nuclear industry. In addition, the licensee's reported activities are conservatively higher than PNL's.

The disagreement in the counter efficiencies is probably inconsequential as far as the comparison of the licensee's contamination surveys to the decontamination goals set for entry into PDMS. These goals were stated in terms of surface activity, expressed in units of dpm. The convention of including parent/progeny activity in the decontamination goals was the same as the convention used in calibrating the counter. Thus the determination of smear activity was consistent with the convention used in setting the goals. In relation to the goal of characterizing the amount of contamination remaining in the facility, the licensee's reported activities are conservatively higher than those estimated by PNL using methods that are standard usage in the nuclear industry.

GENERAL AREA DOSE RATE MEASUREMENTS

The dose rate survey gave good confirmation of the general area dose rates measured by the licensee (see Table 2). In all cubicles surveyed, the licensee had reported dose rates well below the goal, and the PNL surveys confirmed that the dose rates were below the goal. PNL found higher gamma dose rates in five cubicles and dose rates approximately equal to the licensees in four others. The highest reported ratio of PNL's dose to the licensee's dose was 1.3. The methods used by PNL to obtain the general area dose rate measurements were very similar to those used by the licensee.

BETA/SURFACE CONTAMINATION MEASUREMENTS

The PNL study measured lower contamination levels than the licensee in 19 of the 20 cubicles. In the Evaporator Condensate Tank Pump Room (AX013), the PNL measurements averaged about 50% higher than the licensee's measurements.

It is, in general, particularly difficult to replicate smear surveys. PNL staff chose smear locations based on maps that showed the locations previously smeared by the licensee. In many cases, it is likely that the location smeared by PNL was a foot or two away from the location smeared by the licensee. Contamination levels can vary significantly over this distance due to the mechanism of contamination deposition or due to subsequent disturbances. Some time had passed since the previous smearing, and it is possible that the contamination was disturbed; and that the first smearing itself was a small-scale decontamination activity, so there were opportunities for the contamination level to undergo some changes.

Subtle variations in the smearing techniques of individuals, such as pressure on the smear paper or the size of the smeared area, can lead to large differences in the quantity of material collected on the paper. PNL staff wiped the smears using a circular pattern, whereas the licensee's staff typically used long S-shaped wiping motions. Both techniques are common practices in the industry. It is likely that the two smearing techniques resulted in different quantities of collected material.

There is also an opportunity for inaccuracy in transporting the smear samples from the surveyed cubicle to the counting instrument. Both PNL staff and the licensee deposited the smears into paper envelopes, and it is possible that some of the

contamination may have been inadvertantly dislodged from the paper during transit, or during insertion into the envelope or removal from it.

In some cases, the counter caused some differences. All of PNL's smear samples were counted in the Ludlum 2000, but for some cubicles the licensee had counted smears with an RM-14 frisker. The count in the Ludlum 2000 always lasted for 60 seconds, but since the RM-14 is a rate meter the count times are shorter. The geometry of source-to-detector is also more difficult to keep constant with the RM-14, so it is possible that this could lead to differences in the counting. In some cases where the licensee used the RM-14 in low-contamination areas, the recorded average dpm could be larger than the actual true value because the lowest value on the rate meter dial was 1000 dpm. GPU recorded that a number of smears contained 1000 dpm, which actually may have contained substantially less than 1000 dpm, whereas the PNL survey using the Ludlum 2000 would have the capability for reporting far lower readings. This accounted for PNL's tendency to report lower contamination levels in several cubicles. However, since the PNL study found lower contamination levels than the licensee's surveys in 19 out of 20 cubicles, it is probable that there were other differences in techniques which accounted for the variation in recorded contamination levels.

The licensee had determined that four of the twenty cubicles surveyed in this study had contamination levels higher than the goals. Three of these locations were in the Auxiliary Building, and one was in the Reactor Building. The PNL study also found that the contamination levels in the Reactor Building were higher than the goal (PNL found the average to be 75,000 dpm/100 cm^2, where the goal was stated as 50,000). In the Makeup and Purification Pump #1B cubicle (AX006), the licensee had estimated the contamination level to be 87,533 dpm, exceeding the goal of 50,000. PNL's survey again supported the licensee's result, finding an average of 83,000 dpm, which also exceeds the goal.

There were two cubicles in the Auxiliary Building, the Seal Injection Valve Room (AX004) and the Makeup Tank Room (AX116), where the licensee's survey concluded that contamination levels exceeded the goal (50,000 for both), but the PNL survey found lower levels that did not exceed the goal. In the Seal Injection Valve Room (AX004), the licensee evaluated an average of 68,385 dpm while the PNL survey found an average of 30,000 dpm. A partial explanation for the differences was the use of the RM-14 rather than the Ludlum 2000 to count smears. However, the difference in the counters does not fully explain the variation on the readings, since there were a few locations where the licensee used the RM-14 and PNL used the Ludlum 2000 in which the PNL reading was higher or in which the two surveys found the same value.

In the Makeup Tank Room (AX116), the licensee found a contamination level that was much higher than the goal: 313,652 dpm versus 50,000. The PNL survey, on the other hand, found a far lower value of 2618 dpm. The licensee's survey had included 69 locations; of these, 42 smears were at or near background and only 8 were above the goal. The PNL survey had smeared only 27 of these locations, including 6 of the locations found to be above the goal by the licensee. Of these 6 high locations, PNL only found one with a higher than expected count rate, and it was also below the goal. For the locations where the dose rates were closer to the background dose rate, PNL typically counted

below 200 dpm whereas the licensee recorded the values as 1000 dpm using the RM-14 rate meter as discussed previously. Thus the PNL evaluation arrived at a much lower average contamination level than the licensee found in this cubicle.

In summary, the results of the PNL survey show that some contamination levels may be lower than those reported by the licensee. In a few cases the licensee's levels could have been lower if the smears would have been counted on the Ludlum 2000 rather than the RM-14 frisker. It is possible that one or two cubicles may have been classified as meeting the contamination goal rather than exceeding it if a different counter had been used. The PNL survey did not, however, see any indication that any rooms were improperly identified as meeting the contamination goals.

ALPHA CONTAMINATION MEASUREMENTS

Alpha activity is associated with residual fuel, and since cleanup of residual fuel has been thorough in most areas, alpha activity was rarely seen. Of the 39 smears counted by PNL for alphas, 30 recorded 0 counts, 6 recorded 1 count and 3 recorded higher. The samples registering 1 count probably contain no alpha-emitters; the counts were likely due to background. Of the three samples showing definite alpha activity, one was in the Auxiliary Building (AX113), on shielding in the Waste Gas Analyzer Room, with an activity of 62 dpm/100 cm^2. The other two smears showing alpha activity were on the Reactor Building floor, one with 79 and the other with 108 dpm/100 cm^2. The results of the alpha survey indicate that alpha-emitting contamination constitutes a very minor component of the contamination in the TMI-2 facility and that either fuel was not present in the cubicles measured, that it was well contained in equipment or components in the cubicles, or that it had been removed during cleanup.

CONCLUSIONS

The PNL study confirmed that within the variation associated with the instrumentation, methodology, and assumptions, the licensee performed adequate and accurate assessments of the dose rate and surface contamination levels in the TMI-2 building. There were no cases in which the PNL measurements could be used to demonstrate that the goals set by the licensee were improperly reported as being met. In addition, the general area dose rates measured by PNL were similar to the values reported by the licensee and were below the dose rate goals set for entry into PDMS. The contamination levels as measured by PNL looked generally lower than those found by the licensee. Some of the disagreement was due to technique or choice of instrumentation. It is unlikely that in a study of this type that the numbers obtained by two different groups, or even from the same group surveying on two separate days would be identical. Differences that were consistently on the order of one or two levels of magnitude would be suspect, however, the results of this study did not give any cause for doubting the measurements made by the licensee.

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APPENDIX A

MEASUREMENT OF RELATIVE FRACTIONS OF $^{90}Sr/^{90}Y$ AND ^{137}Cs IN TMI SMEARS

APPENDIX A

MEASUREMENT OF RELATIVE FRACTIONS OF $^{90}Sr/^{90}Y$ AND ^{137}Cs IN TMI SMEARS

The surface contamination present at Three Mile Island (TMI) Unit-2 is known to consist primarily of ^{137}Cs and $^{90}Sr/^{90}Y$. Removable surface contamination levels are typically determined by obtaining smear samples, counting the samples in a fixed geometry using a GM-frisker probe coupled to a digital scaler, and applying a predetermined efficiency factor to the net counts. The actual efficiency of the detector system is dependent on the relative fractions of ^{137}Cs and $^{90}Sr/^{90}Y$ present in the sample. Therefore, to determine contamination levels it is important to have an estimate of the relative fractions.

A method was developed by Pacific Northwest Laboratory (PNL) to estimate the relative fractions of ^{137}Cs and $^{90}Sr/^{90}Y$ on smear samples from TMI Unit-2. This method uses a prototype instrument capable of measuring a beta spectrum in the presence of gamma radiation. The instrument uses a coincidence technique implementing two detectors (a gas-flow proportional counter attached to the front of a plastic scintillator detector) to separate the beta and gamma components from a mixed radiation field. Beta particles entering the system generate a signal as they pass through the proportional counter and deposit their remaining energy in the scintillator. Gating circuitry routes either a beta or gamma scintillator pulse to a multichannel analyzer, which records the type of interaction and the deposited energy.

Calibration of the instrument was performed by measuring twelve simulated smear samples having known quantities of both ^{137}Cs and $^{90}Sr/^{90}Y$. These sources were traceable to the National Institute of Standards and Technology (NIST) and the activities were known to within 3% in all cases. The total activity on the simulated smears ranged from 1.5×10^4 dpm (6.8 nCi) to 5.0×10^5 dpm (230 nCi). The fraction of the total activity attributable to ^{137}Cs ranged from 20% to 95%. The radioactive material was in discrete locations deposited on the simulated smears within a one-inch diameter circle. It is important to note the difficulty in preparing calibration sources that perfectly model smear samples because the method of collecting a smear sample affects the uniformity of distribution of the radioactive material on the filter paper. This introduces a geometry dependency to the calibration. For purposes of estimation, the geometry dependence in these measurements was ignored.

Estimating the relative fractions of the radionuclides was possible using the beta spectrometer system because of the dissimilarity between a ^{137}Cs and $^{90}Sr/^{90}Y$ beta spectrum. ^{137}Cs emits two beta particles, one with a frequency of 94.6% of the time and an average energy of 157 keV, and the other with a frequency of 5.4% and an average energy of 415 keV. The primary daughter product, ^{137m}Ba, emits several conversion electrons, the most frequent of which occurs following 7.9% of the ^{137}Cs disintegrations and has an energy of 624.2 keV. Because conversion electrons are monoenergetic, a ^{137}Cs beta emission spectrum contains a highly-discernible peak at an energy of 624 keV. In

contrast, ^{90}Sr emits a beta particle having a frequency of 100% and an average energy of 196 keV, and its daughter, ^{90}Y, emits a beta particle having a frequency of 100% and an average energy of 935 keV. Neither radionuclide emits conversion electrons. Therefore, a beta spectrum of a source consisting mainly of ^{137}Cs is characterized by a discernible peak at an energy of 624 keV and few counts beyond that energy, while a beta spectrum of a source consisting of $^{90}Sr/^{90}Y$ contains no discernible peak at 624 keV and many counts at energies higher than 624 keV.

Based on analysis of the calibrated samples, a methodology was developed to estimate the relative fractions of ^{137}Cs and $^{90}Sr/^{90}Y$ in smear samples containing unknown quantities of both radionuclides. This methodology is based on the comparison of the number of counts obtained in two distinct regions of interest (ROIs) on the beta spectra. The first ROI (ROI-A) corresponds to energies near the conversion electron peak from ^{137}Cs, and includes counts in the energy range from 609 keV to 639 keV, as shown in Figures A.1, A.2 and A.4 through A.11, by a dark bar labeled "ROI A". This region brackets the expected energy peak of the ^{137}Cs conversion electron[a]. The second ROI (ROI-B) ranges in energy from approximately 1000 keV to 1030 keV (shown in Figures A.1 and A.2 as a dark bar labeled "ROI B") and is of high enough energy to essentially exclude counts from ^{137}Cs yet low enough to result in a statistically significant number of counts from small quantities of $^{90}Sr/^{90}Y$. The dark bar designating "ROI A" is more pronounced in Figure A.1 then in Figure A.2, because the mixture being measured contains 95% ^{137}Cs, while the mixture displayed in Figure A.2 contains only 5% ^{137}Cs. The opposite is true for $^{90}Sr/^{90}Y$.

A comparison of the number of counts in the two ROIs in each of the beta spectra obtained from the calibrated sources was used to estimate a relationship between the two ROIs and the relative fractions of ^{137}Cs and $^{90}Sr/^{90}Y$ present in the samples. Figure A.3 illustrates the estimated relationship between the ROI Ratio (defined as the number of net counts in ROI-B divided by the number of net counts in ROI-A) and the relative activity fractions of ^{137}Cs and $^{90}Sr/^{90}Y$ in the calibration sources. This figure also shows the ROI ratios and estimated relative fractions for eight locations in the reactor and auxiliary and fuel handling buildings. Beta spectra of the smears from these eight areas are illustrated in Figures A.4 through A.11.

Results from the analysis of smears obtained from TMI Unit-2 are listed in Table A.1. The relative fractions of $^{90}Sr/^{90}Y$ and ^{137}Cs for the Reactor Building Sump Pump Filter Room (AX102 (3)) and the Makeup and Purification Pump #1B Cubicle (AX006 (45)) are estimated from an extrapolation of the calibration data. As indicated in the table, the smear from the Makeup and Purification Pump #1B Cubicle (AX005 (57)) did not appear to contain significant quantities of $^{90}Sr/^{90}Y$.

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[a] The difference between the position of the region of interest under the ^{137}Cs conversion electron peak and observed centroid of the peak results from the differences between the measurement conditions during energy calibration and the conditions present during measurement of the smears. (The energy calibration discussed here is in contrast to the calibration performed to determine the relative fractions of $^{90}Sr/^{90}Y$.) The radioactive source used to calibrate the spectrometer was significantly different in construction than the smears

Table A.1. Results of TMI-2 Smear Sample Analysis

Sample	Estimated % $^{90}Sr/^{90}Y$	Estimated % ^{137}Cs
Makeup and Purification Pump #1B Room AX005 (57)	1	99
Seal Injection Valve Room AX004 (26)	11	89
Reactor Building RB100 (33)	22	78
Waste Gas Analyzer Room AX113 (12)	27	73
Reactor Building RB100 (56)	26	74
Annulus - Fuel Handling Building FH112 (49)	33	67
Reactor Building Sump Pump Filter Room AX102 (3)	87	13
Makeup and Purification Pump #1B Room AX006 (45)	92	8

collected at TMI-2, since the geometry and construction of each smear is unique. Each smear has a different arrangement of radionuclides and varies in the amount and location of dust or other attenuating materials. The differences between the calibration source and the smears results in a variation in the attenuation of the beta particles. The variation in attenuation (energy loss) results in a variation in the location of the centroid of the ^{137}Cs conversion electron peak. Thus, the location of the centroid varies between the calibration sources and the smears and between the individual smears as expected.

One solution to this problem would be to center the region of interest about the centroid of the conversion electron peak for each individual smear based on visual analysis. A sum of the counts obtained in the region of interest would then be a maximum and statistical variation would be at a minimum. As a result, no two smears would have the same energy range for the selected region of interest. The difficulty occurs, in the case where a conversion electron peak is not apparent or when measuring the background radiation. In these situations selection of the region of interest would be arbitrary and therefore not defendable. Instead, a constant definition of the region of interest is more scientifically justifiable and serves as a satisfactory rudimentary approximation if the limitations are fully appreciated.

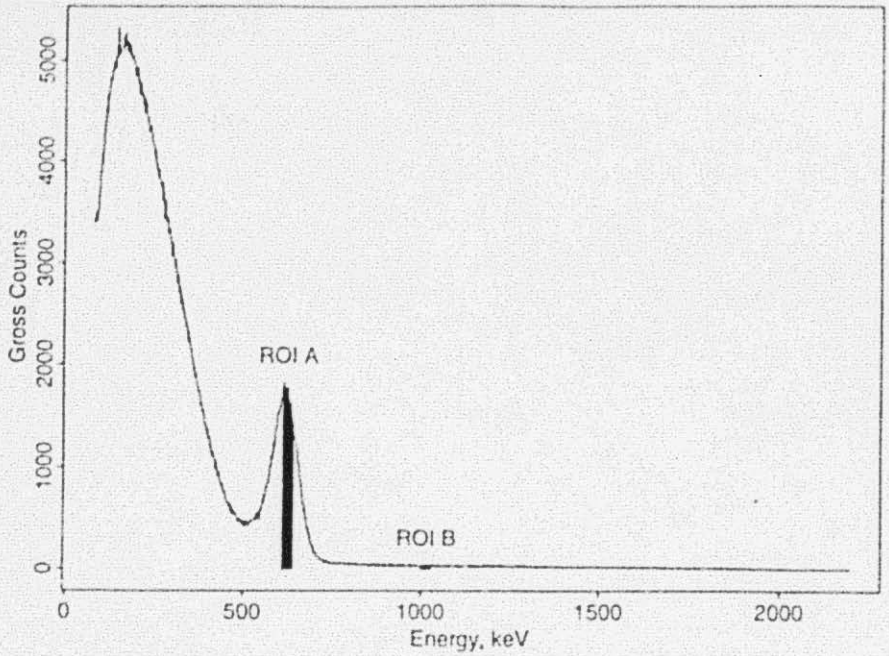

Figure A.1. Calibration Source with 5% $^{90}Sr/^{90}Y$ and 95% ^{137}Cs

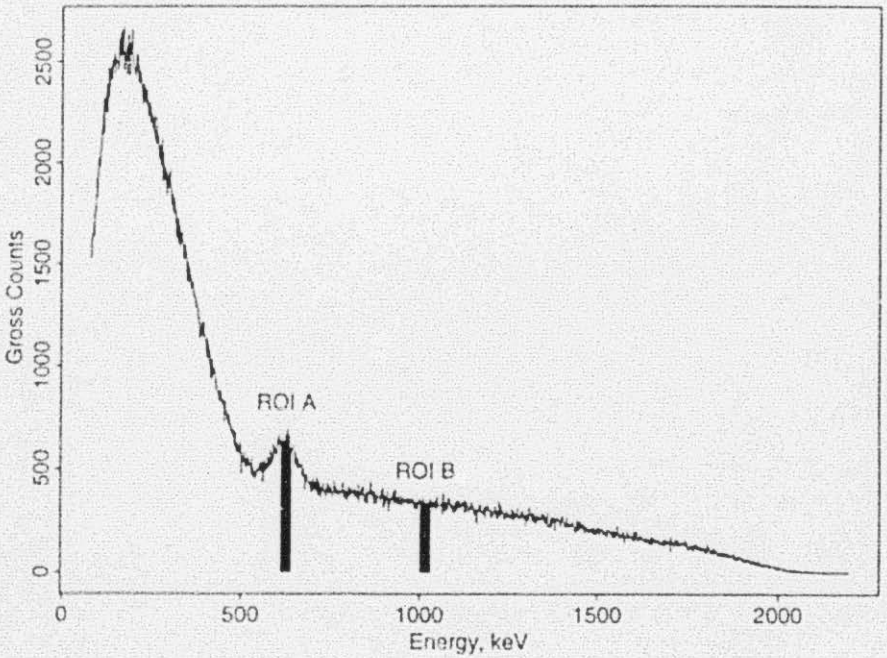

Figure A.2. Calibration Source with 80% $^{90}Sr/^{90}Y$ and 20% ^{137}Cs

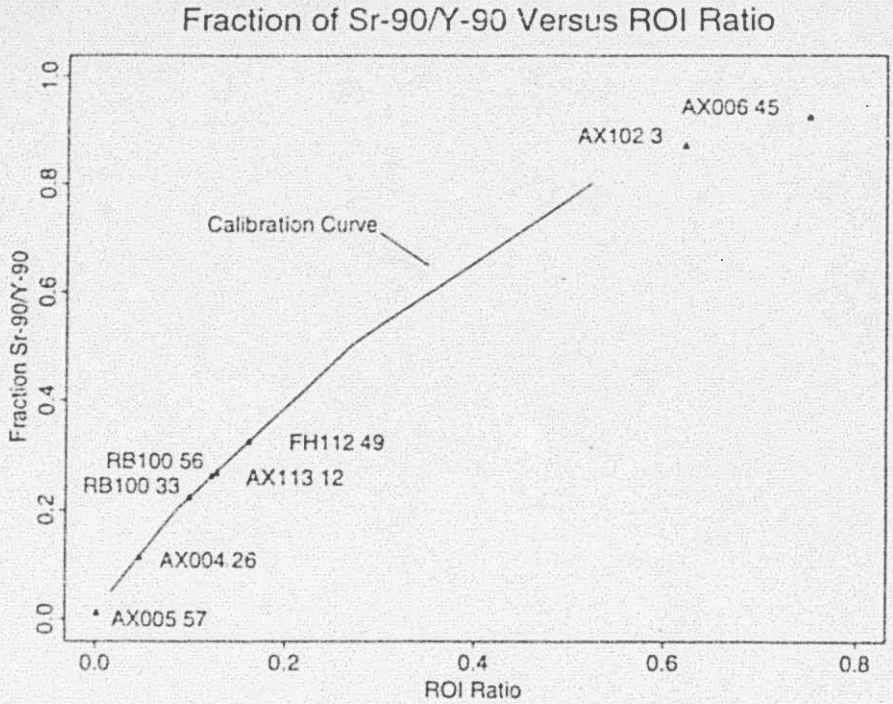

Figure A.3. Fraction of $^{90}Sr/^{90}Y$ Versus ROI Ratio

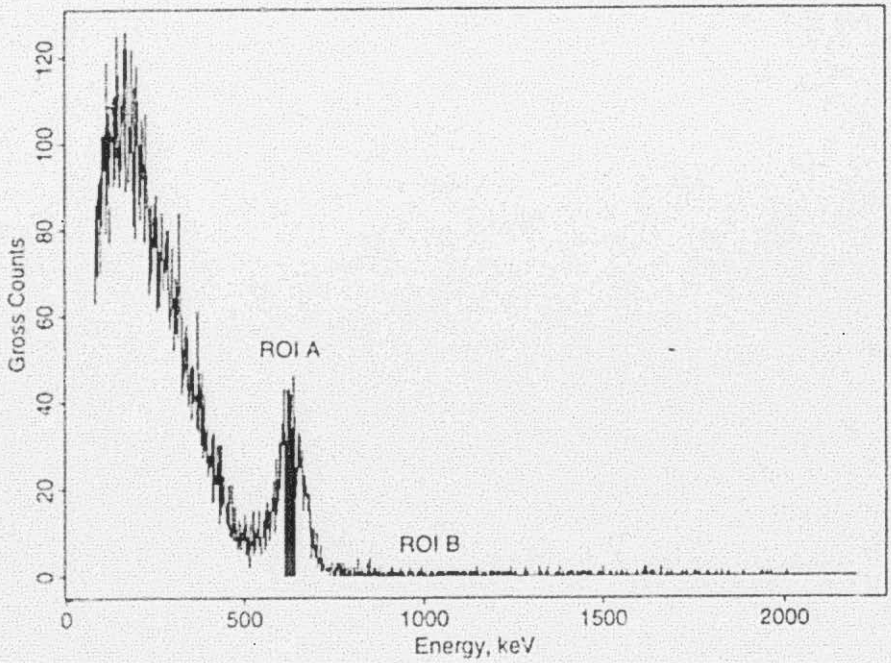

Figure A.4. Makeup and Purification Pump Room (AX005-57)

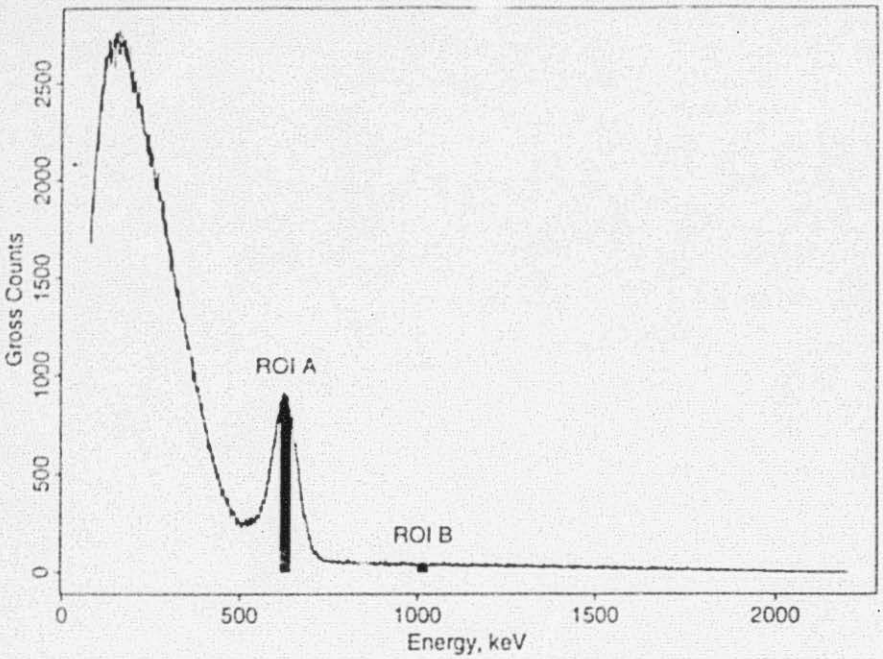

Figure A.5. Seal Injection Valve Room (AX004-26)

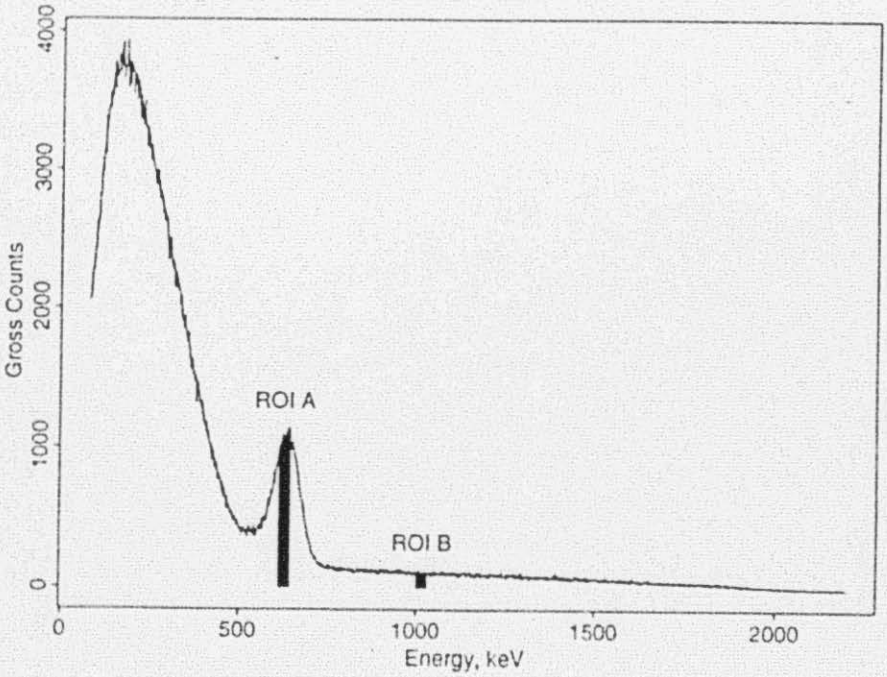

Figure A.6. Reactor Building (RB100-33)

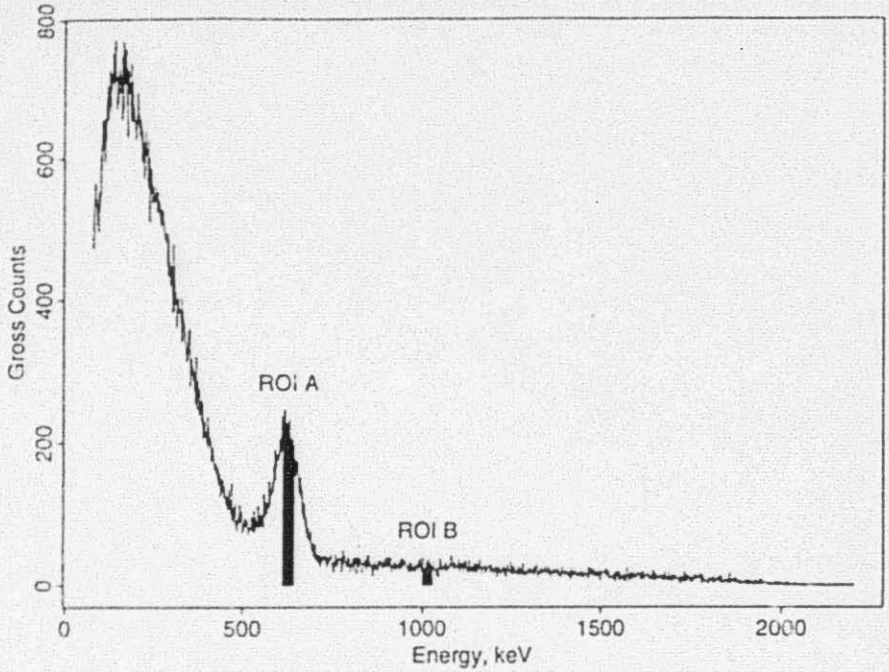

Figure A.7. Waste Gas Analyzer Room (AX113-12)

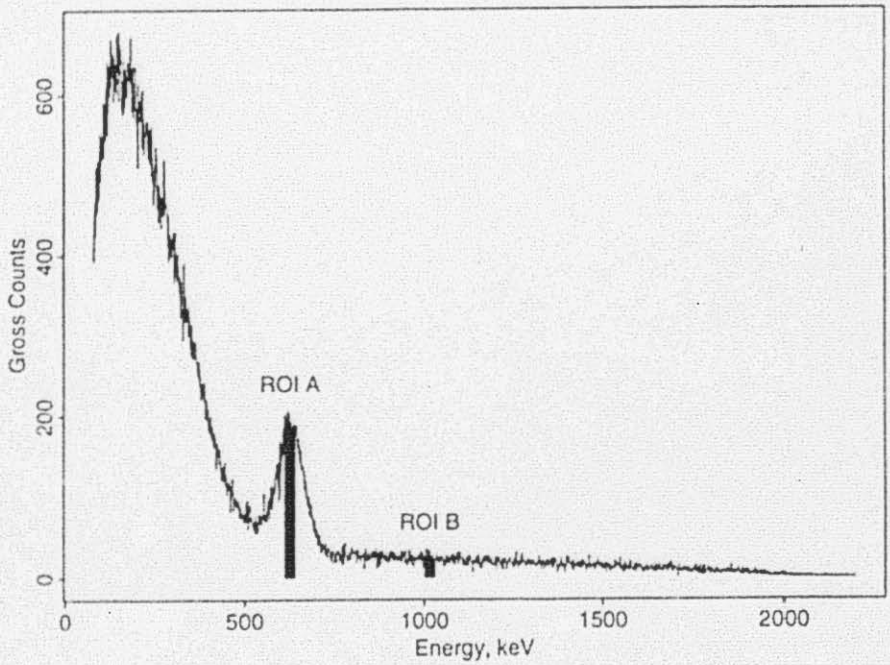

Figure A.8. Reactor Building (RB100-56)

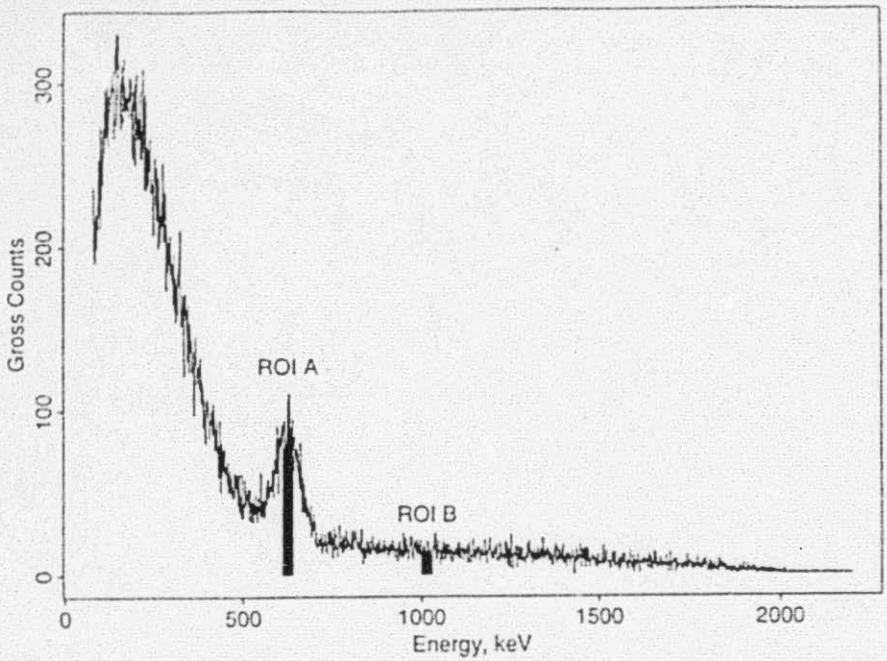

Figure A.9. Annulus - Fueling Handling Building (FH112-49)

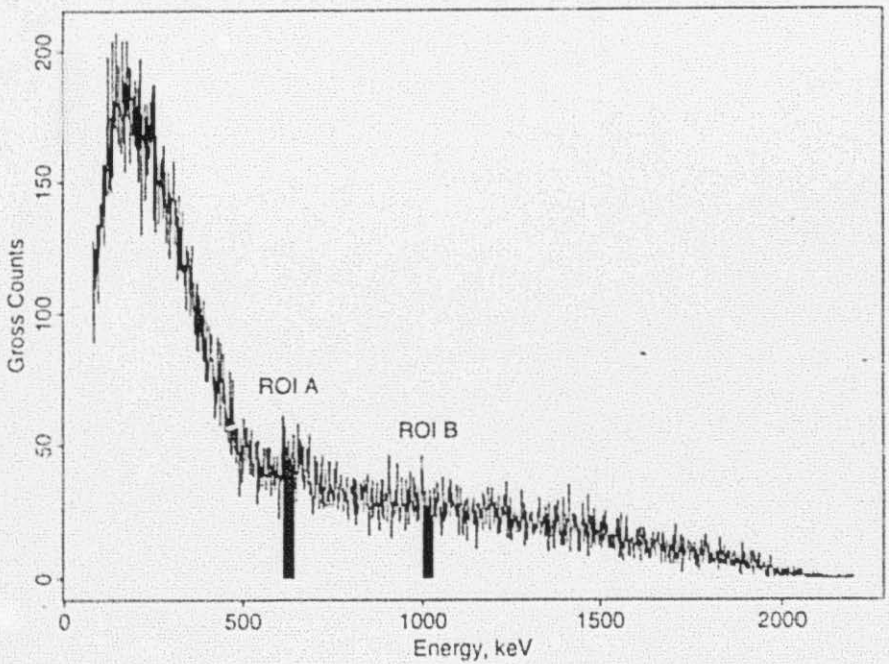

Figure A.10. Reactor Building Sump Pump Filter Room (AX102-3)

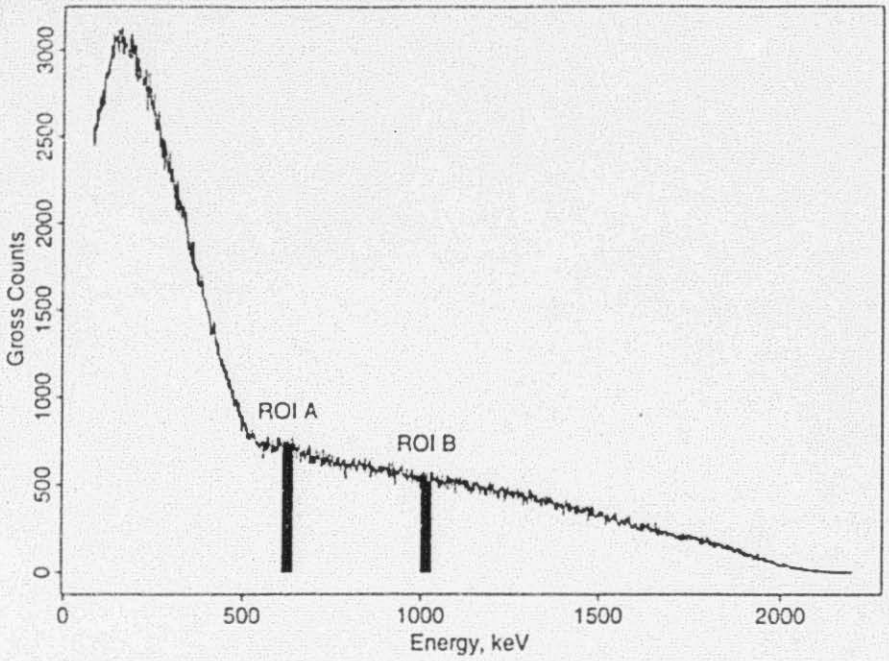

Figure A.11. Makeup and Purification Pump #1B Room (AX006-45)

APPENDIX B

CALIBRATION OF LUDLUM 2000 DETECTOR

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CALIBRATION OF LUDLUM 2000 DETECTOR

Two sources were used for this calibration study, a $^{90}Sr/^{90}Y$ source with serial number S-2103 and a $^{137}Cs/^{137m}Ba$ source with serial number S-2029. The sources were provided by the licensee.

For the ^{90}Sr source, a Report of Calibration was provided by the supplier, Eberline, which certified that its total disintegration rate was 10410 dpm on November 8, 1979. This value was found by counting the "2π" beta emission rate and correcting for 40% backscatter. It was therefore derived using betas that were emitted by both ^{90}Sr decays and ^{90}Y decays.

By industry convention, the activity of a source is specified in terms of the parent nuclide decays only, not including the decays of progeny nuclides. In the case of $^{90}Sr/^{90}Y$, it would seem to be straightforward to specify activity in terms of both parent and progeny nuclides, since the parent half life is long, the progeny half life is short, and 100% of the parent decays produce the progeny. However, many decay chains are more complex, and the assumption of equilibrium is not necessarily valid, so the nuclear industry generally references only parent nuclide decays. Thus a "1 microcurie ^{137}Cs" source contains 1.0 μCi of ^{137}Cs and 0.95 μCi of ^{137m}Ba. Following this convention, the source activity of 10410 dpm was divided by 2 (since there are two betas emitted for every disintegration of ^{90}Sr) to get a reference activity of 5205 dpm ^{90}Sr on the calibration date. This reference dpm was then decayed to the measurement date in November 1993 using ^{90}Sr's half life of 28.6 years, to get a value of 3705 dpm on the measurement date.

For the ^{137}Cs source, a similar Report of Calibration listed an activity of 7410 dpm on July 12, 1979. To correct this value to the measurement date, an emission rate of 1.1 betas per disintegration and a half life of 30.2 years were applied to arrive at a value of 5328 dpm on the measurement date.

The SAC-4 Counter was calibrated using the ^{230}Th source.

For each nuclide, once the appropriate activity value was known, the efficiency of the detector was determined by making measurements of the count rate, correcting for background, and finding the ratio of the count rate to the activity. The following Tables show the determination of efficiencies for the ^{137}Cs source (using one measurement), the ^{90}Sr source (using 11 sets of measurements), and the ^{230}Th source.

Table B.1 Summary of Cesium-137 Calibrations

Counter Identification 102761
Measurement Date 11/16/93
Measured Efficiency - .4021

Measurements on Cesium-137 Source No. S202911

Ludlum 2000 Detector - #102761		Background
Counts per minute		Counts per minute
	1998	14
	1996	13
	1927	16
	1920	
	1970	
Average	1962.2	14.3

Net cpm: 1947.9

Source:	6736.36 dpm on	07/12/79	
	Decay Time =	14.3	yrs
	Cs-137 Halflife =	30.17	yrs
	Decay Fraction =	0.72	
	Decayed dpm =	4850	
	Efficiency =	0.40	

Table B.2 - Summary of Strontium/Yttrium-90 Calibrations

Ludlum 2000 Counter - Identification No. 12159

Measurement Date	Measured Efficiency
11/16/93	0.4349
11/17/93	0.4416
11/19/93	0.4470
Average	0.4412

Measurements on Sr/Y-90 Source No. S2103 on 11/16/93

Measurements (counts per minute)

	1560
	1664
	1604
	1679
	1656
	1621
Average =	1631
Background =	193 counts/10 minutes
=	19.3 cpm
Net cpm =	1611.0

Source =	5205	dpm on	11/08/79
Decay Time =	14.0	yrs	
Sr-90 Halflife =	28.6	yrs	
Decay Fraction =	0.71		
Decayed dpm =	3705		
Efficiency =	0.43		

Measurements on Sr/Y-90 Source No. S2103 on 11/17/93

Measurements (counts per minute)

	1658
	1600
	1672
	1653
	1687
Average =	1654
Background =	177 counts/10 minutes
=	17.7 cpm
Net cpm =	1636.0

Source =	5205	dpm on	11/08/79
Decay Time =	14.0	yrs	
Sr-90 Halflife =	28.6	yrs	
Decay Fraction =	0.71		
Decayed dpm =	3705		
Efficiency =	0.44		

Measurement on Sr/Y-90 Source No. S2103 on 11/19/93

Measurements (counts per minute)

	1654
	1779
	1666
	1608
	1670
Average =	1675
Background =	196 counts/10 min.
=	19.6 cpm
Net cpm =	1656.0

Source =	5205	dpm on	11/08/79
Decay Time =	14.0	yrs	
Sr-90 Halflife =	28.6	yrs	
Decay Fraction =	0.71		
Decayed dpm =	3705		
Efficiency =	0.45		

Table B.2 - Summary of Strontium/Yttrium-90 Calibrations (Continued)

Ludlum 2000 Counter - Identification No. 102761

Measurement Date	Measured Efficiency
11/16/93	0.4393
11/17/93	0.4062
11/18/93	0.4196
11/19/93	0.4382
Average	0.4258

Measurements on Sr/Y-90 Source No. S2103 on 11/16/93

Measurements (counts per minute)

	1609	Source =	5205	dpm on	11/08/79
	1597	Decay Time =		14.0	yrs
	1666	Sr-90 Halflife =		28.6	yrs
	1655	Decay Fraction =		0.71	
	1657	Decayed dpm =		3705	
Average =	1642	Efficiency =		0.44	
Background =	14 cpm, 13 cpm and 16 cpm				
=	14.3 cpm				
Net cpm =	1627.7				

Measurement on Sr/Y-90 Source No. S2103 on 11/17/93

Measurements (counts per minute)

	1585	Source =	5205	dpm on	11/08/79
	1595	Decay Time =		14.0	yrs
	1624	Sr-90 Halflife =		28.6	yrs
	1548	Decay Fraction =		0.71	
	1587	Decayed dpm =		3705	
Average =	1520	Efficiency =		0.41	
Background =	149 counts/10 min.				
=	14.9 cpm				
Net cpm =	1505.1				

Measurements on Sr/Y-90 Source No. S2103 on 11/18/93

Measurements (counts per minute)

	1551	Source =	5205	dpm on	11/08/79
	1588	Decay Time =		14.0	yrs
	1581	Sr-90 Halflife =		28.6	yrs
	1588	Decay Fraction =		0.71	
	1588	Decayed dpm =		3705	
Average =	1579.2	Efficiency =		0.42	
Background =	28 cpm and 21 cpm				
=	24.5 cpm				
Net cpm =	1554.7				

Table B.2 - Summary of Strontium/Yttrium-90 Calibrations (Continued)

Measurements on Sr/Y-90 Source No. S2103 on 11/19/93

Measurements (counts per minute)

	1636	Source =	5205	dpm on	11/08/79
	1579	Decay Time =		14.0	yrs
	1548	Sr-90 Halflife =		28.6	yrs
	1649	Decay Fraction =		0.71	
	1612	Decayed dpm =		3705	
Average =	1642	Efficiency =		0.44	
Background =	187 counts/10 minutes				
=	18.7 cpm				
Net cpm =	1623.3				

Ludlum 2000 Counter - Identification No. 10079

Measurement Date	Measured Efficiency	
11/16/93	0.4599	
11/17/93	0.4394	
11/19/93	0.4629	
11/19/93	0.4174	(filter paper over source)
Average	0.4449	

Measurements on Sr/Y-90 Source No. S2103 on 11/16/93

Measurements (counts per minute)

	1676	Source =	5205	dpm on	11/08/79
	1778	Decay Time =		14.0	yrs
	1798	Sr-90 Halflife =		28.6	yrs
	1749	Decay Fraction =		0.71	
	1595	Decayed dpm =		3705	
	1714	Efficiency =		0.46	
Average =	1718				
Background =	14 cpm, 13 cpm, and 16 cpm				
=	14.3 cpm				
Net cpm =	1704.0				

Measurements on Sr/Y-90 Source No. S2103 on 11/17/93

Measurements (counts per minute)

	1688	Source =	5205	dpm on	11/08/79
	1656	Decay Time =		14.0	yrs
	1688	Sr-90 Halflife =		28.6	yrs
	1612	Decay Fraction =		0.71	
	1681	Decayed dpm =		3705	
Average =	1642	Efficiency =		0.44	
Background =	16 cpm and 12 cpm				
=	14 cpm				
Net cpm =	1628.0				

Table B.2 - Summary of Strontium/Yttrium-90 Calibrations (Continued)

Measurements on Sr/Y-90 Source No. S2103 on 11/19/93
Measurements (counts per minute)

	1807	Source =	5205	dpm on	11/08/79
	1717	Decay Time =		14.0	yrs
	1704	Sr-90 Halflife =		28.6	yrs
	1709	Decay Fraction =		0.71	
	1721	Decayed dpm =		3705	
Average =	1732	Efficiency =		0.46	
Background =	167 counts/10 minutes				
=	16.7 cpm				
Net cpm =	1714.9				

Measurements on Sr/Y-90 Source No. S2103 on 11/19/93
(Filter Paper on top of source)
Measurements (counts per minute)

	1579	Source =	5205	dpm on	11/08/79
	1575	Decay Time =		14.0	yrs
	1543	Sr-90 Halflife =		28.6	yrs
	1579	Decay Fraction =		0.71	
	1538	Decayed dpm =		3705	
Average =	1563	Efficiency =		0.42	
Background =	167 counts/10 minutes				
=	16.7 cpm				
Net cpm =	1546.1				

APPENDIX C

GENERAL AREA DOSE RATE RESULTS

APPENDIX C

GENERAL AREA DOSE RATE RESULTS

Tables comparing the PNL measurements to the licensee's measurements are presented in this appendix with comparisons made location-by-location. The tables show in detail how the individual measurements made by the PNL study compare to those made by the licensee in its pre-PDMS survey. The PNL gamma measurements should be compared to the GPU gamma measurements and the PNL measurements should be compared to the GPU beta measurements. The "PNL Open Window" measurement values were used to calculate the "Betas PNL" and "Gammas PNL" values. They are listed in the tables for completeness; however, because they are "intermediate" values, the average of the open window readings are meaningless and are not provided.

Maps of the surveyed cubicles are also included in this appendix, with the measured dose rates printed at the location of each measurement. The dose rates measured at each location are presented in units of mR/h. Readings made on contact (with a wall, pipe, tank, or other item) are presented inside a circle; readings not circled correspond to general area dose rates. If a location had a gamma reading but no beta reading, only one number is presented, corresponding to the gamma reading. If a location had both a gamma and a beta reading, two numbers will be presented, with the gamma reading above a short line and the beta reading below it.

Table C.1 Reactor Building Emergency Cooling Booster Pump Area (AX001)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h
General area	0.1	0.2
General area	0.1	0.5
Over Open Vault	0.5	0.8
General area	0.5	0.8
Near Door	0.5	1.0
General area	0.7	1.4
by Vault AX503	0.5	1.5
General area	0.4	0.5
General area	1.0	0.4
General area	0.4	0.4
General area	0.4	0.2
General area	0.0	0.2
General area	0.1	0.1
General area	0.1	0.2
General area	0.1	0.1
General area	0.1	0.1
General area	0.1	0.1
General area	0.1	0.2
General area	0.1	0.2
General area	0.1	0.2
General area	0.5	1.2
General area	0.8	1.0
Averaged mR/h	0.33	0.51
PDMS Result:		1.5
PDMS Goal:		< 2.5

Table C.2 Seal Injection Valve Room (AX004)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General Area	24	22	50	65	40
General Area	35	46	50	38	28
General Area	80	46	75	0	28
General Area	75	50	90	38	60
General Area	170	120	200	75	40
General Area	120	140	130	25	40
General Area	150	140	150	0	40
General Area	130	80	180	125	40
General Area	120	120	130	25	80
General Area	35	38	70	88	44
Averaged mR/h	94	80		48	44
PDMS Result:		116			
PDMS Goal:		< 1000			

Table C.3 Makeup and Purification Pump Room #1C (AX005)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General area	5	NMT	NMT	NMT
General area	3	5	38	40
General area	4	6	37	36
General area	4	5	14	18
General area	4	6	7	8
General area	6	6	3	4
General area	5	6	18	8
General area	4	4	8	12
General area	4	5	22	26
General area	4	4	16	8
General area	3	NMT	1	NMT
General area	3	4	8	12
General area	4	NMT	10	NMT
Averaged mR/h	4	5	15	17
PDMS Result:		8		
PDMS Goal:		< 500		

NMT = No Measurement Taken

Table C.4 Makeup and Purification Pump Room #1B (AX006)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General area	30	28	13	80
General area	50	80	25	200
General area	8	6	33	40
General area	7	12	10	16
General area	40	40	75	80
General area	110	100	125	200
General area	300	160	11750 *	600
General area	60	60	50	80
Averaged mR/h	76	61	47	99
PDMS Result:		58		
PDMS Goal:		< 500		

* Open Window reading offscale, measurements not included in beta average

Table C.5 Makeup and Purification Pump Room #1A (AX007)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General area	11	16	8	12
General area	20	16	5	8
General area	60	70	NMT	60
Averaged mR/h	30	34	6	34
PDMS Result:		37		
PDMS Goal:		< 500		

NMT = No Measurement Taken

Table C.6 Auxiliary Building Sump Tank, Pumps and Valve Room (AX011)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General area	0.8	1.6	1.5	0.8
General area	4.1	4.0	1.8	1.4
General area	11.0	10.0	NMT	NMT
General area	6.0	8.0	NMT	NMT
General area	8.0	8.0	2.5	4.0
General area	12.0	10.0	2.5	4.0
General area	12.0	10.0	2.5	4.0
Averaged mR/h	7.7	7.4	2.2	2.8
PDMS Result:		8		
PDMS Goal:		< 50		

NMT = No Measurement Taken

Table C.7 Evaporator Condensate Tank Pumps (AX013)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General Area	0.2	0.2	NMT	NMT
General Area	0.3	0.2	NMT	NMT
General Area	0.3	0.2	NMT	NMT
General Area	0.3	0.2	NMT	NMT
General Area	9.0	10.0	47.5	40.0
General Area	0.2	0.2	NMT	NMT
General Area	0.2	0.2	NMT	NMT
General Area	0.2	0.2	NMT	NMT
General Area	0.2	0.2	NMT	NMT
General Area	0.4	0.2	NMT	NMT
General Area	0.2	0.2	NMT	NMT
General Area	0.6	0.6	NMT	NMT
General Area	0.8	0.8	NMT	NMT
General Area	0.4	0.4	NMT	NMT
General Area	0.6	0.6	NMT	NMT
General Area	0.8	0.8	NMT	NMT
General Area	1.7	2	NMT	NMT
General Area	1.4	1.8	NMT	NMT
General Area	2	1.5	NMT	NMT
General Area	10	10	NMT	NMT
General Area	34	20	NMT	NMT
General Area	3	3	NMT	NMT
General Area	2.5	2.5	NMT	NMT
General Area	1.5	2	NMT	NMT
General Area	0.2	0.4	NMT	NMT
Averaged mR/h	2.8	2.3	47.5	40.0
PDMS Result:		5.0		
PDMS Goal:		< 500		

NMT = No Measurement Taken

Table C.8 Waste Transfer Pump Room (AX018)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	Betas PNL mR/h	Betas GPU mR/h
General area	0.6	1.0	0.3	0.0
General area	0.3	0.4	0.0	0.0
General area	0.3	0.4	0.4	0.0
General area	1.0	1.8	3.8	0.4
General area	6.0	10.0	2.5	20.0
General area	5.0	16.0	5.0	28.0
General area	10.0	20.0	20.0	20.0
General area	8.0	20.0	22.5	40.0
General area	10.0	NMT	12.5	NMT
General area	5.0	10.0	10.0	4.0
General area	5.0	12.0	12.5	16.0
General area	3.3	4.0	1.9	8.0
General area	2.8	NMT	3.1	NMT
General area	3.2	6	4.5	4.0
General area	2.8	5	4.4	6.0
Averaged mR/h	4.2	8.2	6.9	11.3
PDMS Result:		10		
PDMS Goal:		< 500		

NMT = No Measurement Taken

Table C.9 Reactor Coolant Bleed Holdup Tank #1A (AX021)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
Storage Cage	6.0	6.0	NMT	NMT	NMT
Storage Cage	6.0	10.0	NMT	NMT	NMT
Storage Cage	5.0	6.0	NMT	NMT	NMT
Storage Cage	4.0	NMT	NMT	NMT	NMT
Storage Cage	4.1	NMT	NMT	NMT	NMT
Storage Cage	4.0	3.5	NMT	NMT	NMT
Storage Cage	1.8	4.4	NMT	NMT	NMT
Storage Cage	2.5	4.6	NMT	NMT	NMT
Storage Cage	1.9	1.6	2.5	1.5	0.8
Storage Cage	3.1	4.0	3.8	1.8	2.2
Storage Cage	2.6	4.0	3.0	1.0	NMT
Storage Cage	1.7	1.8	NMT	NMT	5.4
Storage Cage	1.2	1.4	NMT	NMT	0.4
Storage Cage	2.9	4.0	NMT	NMT	NMT
Main room	17.0	15.0	NMT	NMT	NMT
Main room	10.0	10.0	NMT	NMT	NMT
Main room	15.0	15.0	NMT	NMT	NMT
Main room	10.0	8.0	NMT	NMT	NMT
Main room	7.5	8.0	NMT	NMT	NMT
Main room	9.0	7.0	NMT	NMT	NMT
Main room	6	6	NMT	NMT	NMT
Main room	4.5	4.6	NMT	NMT	NMT
Main room	7	8	NMT	NMT	NMT
Main room	8.0	6.0	NMT	NMT	NMT
Main room	6.0	6.0	NMT	NMT	NMT
Main room	9.0	10.0	NMT	NMT	NMT
Main room	11.0	10.0	NMT	NMT	NMT
Main room	7.0	6.0	NMT	NMT	NMT
Main room	5.0	6.0	NMT	NMT	NMT
Averaged mR/h	6.2	6.6	None	1.4	2.2
PDMS Result:		18			
PDMS Goal:		< 500			

NMT = No Measurement Taken

Table C.10 Reactor Building Sump Pump Filter Room (AX102)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	40	50	50	25	60
General area	50	60	55	13	60
General area	33	38	38	13	24
General area	80	80	90	25	40
Averaged mR/h	51	57	None	19	46
PDMS Result:		48			
PDMS Goal:		< 1000			

Table C.11 Motor Control Center (AX103)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
General area	< 0.2	< 0.2
Averaged mR/h	< 0.2	< 0.2
PDMS Result:		0.2
PDMS Goal:		< 2.5

Table C.12 Waste Gas Analyzer Room (AX113)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	0.9	0.4	1.0	0.3	NMT
General area	1.8	1.8	2.0	0.5	0.8
General area	2.5	2.6	3.0	1.3	6.8
General area	6.0	8.0	7.0	2.5	8.0
General area	4.0	6.0	6.0	5.0	NMT
General area	4.0	6.0	6.0	5.0	NMT
General area	10.0	42.0	13.0	7.5	NMT
General area	1.0	1.8	1.0	0.0	NMT
General area	3.5	3.4	4.0	1.3	NMT
Averaged mR/h	3.7	8.0		2.6	5.2
PDMS Result:		19			
PDMS Goal:		< 50			

NMT = No Measurement Taken

Table C.13 Makeup Tank Room (AX116)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	15	15	NMT	NMT	NMT
General area	38	38	NMT	NMT	44
General area	47	35	NMT	NMT	NMT
General area	70	50	NMT	NMT	NMT
General area	50	41	NMT	NMT	NMT
General area	60	45	NMT	NMT	NMT
General area	60	53	NMT	NMT	NMT
General area	60	20	NMT	NMT	NMT
General area	50	45	NMT	NMT	NMT
Averaged mR/h	50	38	None	None	44
PDMS Result:		60			
PDMS Goal:		< 500			

NMT = No Measurement Taken

Table C.14 Spent Fuel Coolers and Pumps (AX118)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	0.2	0.2	0.0	0.0	0.0
General area	0.2	0.2	0.0	0.0	0.0
General area	1.0	1.0	0.0	0.0	0.0
General area	0.8	0.8	0.0	0.0	0.0
General area	2.0	1.0	0.0	0.0	0.0
General area	1.6	1.6	0.0	0.0	0.0
General area	1.0	1.0	0.0	0.0	0.0
General area	0.6	0.6	0.0	0.0	0.0
General area	0.6	0.6	0.0	0.0	0.0
General area	0.3	0.3	0.0	0.0	0.0
General area	0.5	0.5	0.0	0.0	0.0
General area	0.5	0.5	0.0	0.0	0.0
Averaged mR/h	0.8	0.7	None	0.0	0.0
PDMS Result:		1.1			
PDMS Goal:		< 2.5			

Table C.15 Sample Room (FH103)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	0.5	0.5	0.0	0.0	2.0
General area	0.2	0.2	0.0	0.0	2.0
General area	0.2	0.2	0.0	0.0	NMT
General area	0.2	0.2	0.0	0.0	NMT
General area	0.4	0.4	0.0	0.0	2.0
General area	< .2	< .2	0.0	0.0	NMT
General area	0.5	0.5	0.0	0.0	8.0
General area	0.5	0.5	0.0	0.0	3.0
General area	0.7	0.7	0.0	0.0	2.0
General area	1.5	1.5	0.0	0.0	2.0
Averaged mR/h	0.5	0.5	None	0.0	3.0
PDMS Result:		1.2			
PDMS Goal:		< 50			

NMT = No Measurement Taken

Table C.16 Model Room (FH105)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h
General area	0.5	0.5
General area	0.3	0.2
General area	0.5	0.4
General area	0.4	0.4
General area	0.3	0.2
General area	0.2	0.2
General area	0.4	0.2
General area	0.4	0.2
General area	0.4	0.2
General area	0.3	0.2
General area	0.3	0.2
General area	0.3	0.2
General area	0.0	0.0
General area	0.0	0.0
General area	0.1	0.1
General area	0.2	0.1
General area	0.3	0.2
General area	0.2	0.2
General area	0.3	0.3
General area	0.4	0.4
General area	0.3	0.2
General area	0.1	0.1
General area	0.1	0.1
General area	0.2	0.2
General area	0.1	0.1
General area	0.1	0.1
General area	0.1	0.1
General area	0.2	0.1
General area	0.1	0.1
General area	0.1	0.1
General area	0.1	0.1
Averaged mR/h	0.2	0.2
PDMS Result:		0.2
PDMS Goal:		< 2.5

Table C.17 Annulus (FH112)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	20.0	16.0	25.0	12.5	12.0
General area	15.0	15.0	15.0	0.0	6.0
General area	7.0	7.0	7.0	0.0	0.0
General area	3.0	3.0	3.0	0.0	0.0
General area	1.7	1.7	1.7	0.0	0.0
General area	1.5	1.5	1.5	0.0	0.0
General area	1.1	1.1	1.1	0.0	0.0
General area	1.0	1.0	1.0	0.0	0.0
General area	1.0	1.0	1.0	0.0	0.0
General area	2.0	2.5	2.0	0.0	0.0
General area	2.5	2.5	2.5	0.0	0.0
General area	8.0	15.5	8.0	0.0	3.0
General area	20.0	50.0	20.0	0.0	60.0
Averaged mR/h	6.4	9.1	None	0.96	5.5
PDMS Result:		19			
PDMS Goal:		< 100			

Table C.18 Concentrated Waste Storage Room (AX218)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	2.0	2.0	2.8	2.0	0.2
General area	6.0	7.0	6.0	0.0	1.6
General area	9.0	8.0	7.0	0.0	2.0
General area	5.0	6.0	5.0	0.0	4.0
General area	8.0	8.0	9.0	2.5	2.0
General area	5.0	8.0	7.0	5.0	2.0
General area	7.0	10.0	10.0	7.5	2.0
General area	5.0	NMT	5.0	0.0	NMT
General area	7.5	12.0	7.5	0.0	4.0
General area	6.0	8.0	6.0	0.0	2.0
General area	6.0	6.0	8.0	5.0	1.2
Averaged mR/h	6.0	7.5	None	2.0	2.1
PDMS Result:		15			
PDMS Goal:		< 500			

NMT = No Measurement Taken

Table C.19 Annulus (FH304)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h	PNL Open Window	Betas PNL mR/h	Betas GPU mR/h
General area	0.1	0.1	NMT	NMT	0.0
General area	0.2	0.4	NMT	NMT	0.0
General area	0.2	0.3	0.3	0.3	0.0
General area	0.5	0.5	0.7	0.5	0.0
General area	0.5	0.6	NMT	NMT	0.0
General area	0.8	0.7	1.4	1.6	0.0
General area	0.8	0.8	NMT	NMT	0.0
General area	0.5	0.8	NMT	NMT	0.0
General area	0.8	1.0	NMT	NMT	0.0
Averaged mR/h	0.5	0.6	None	0.8	0.0
PDMS Result:		0.6			
PDMS Goal:		< 500			

NMT = No Measurement Taken

Table C.20 Reactor Building: Area In Front Of Equipment Hatch (RB305)

MEASURED DOSE RATES

Location	Gammas PNL mR/h	Gammas GPU mR/h
General area	60	100
General area	130	100
General area	50	80
General area	60	80
General area	50	80
General area	80	100
General area	80	100
General area	50	80
General area	50	80
General area	50	60
General area	100	60
Averaged mR/h	69	84
PDMS Result:		150
PDMS Goal:		<100

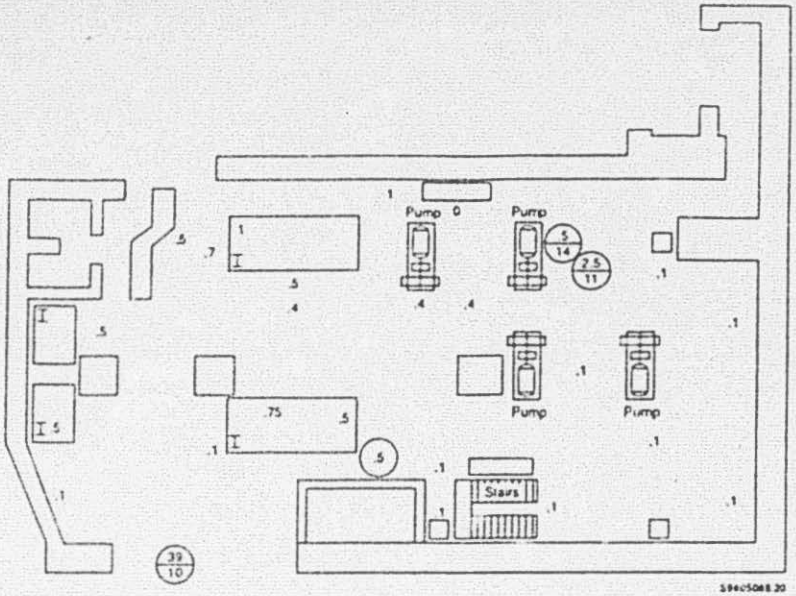

Figure C.1. Reactor Building Emergency Cooling Booster Pump Area (AX001)

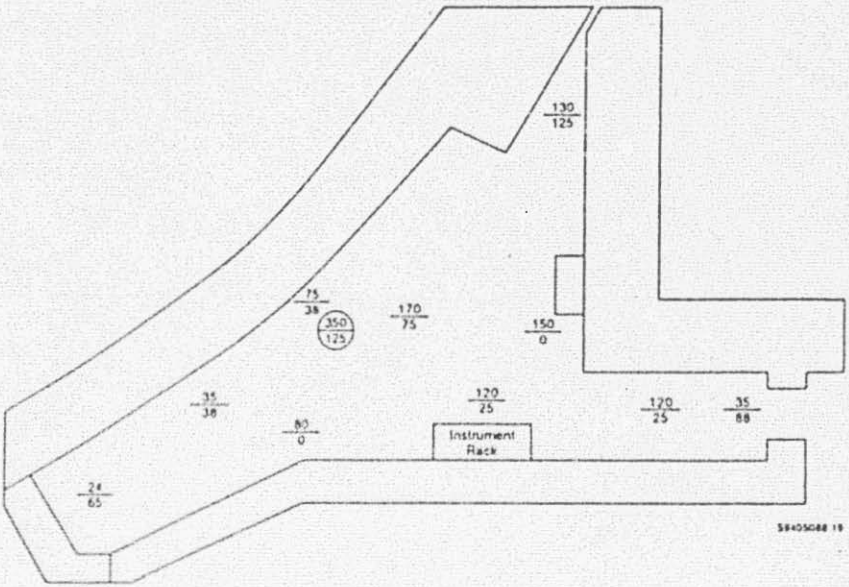

Figure C.2. Seal Injection Valve Room (AX004)

* An explanation of the symbols used in Figures C.1 through C.20 is located on page C.1

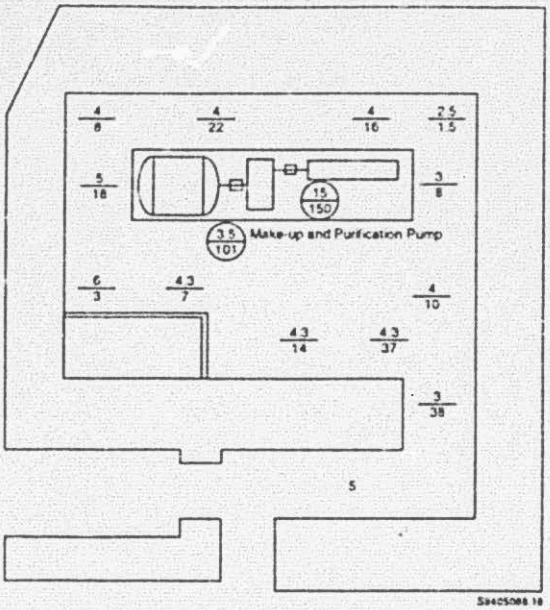

Figure C.3. Makeup and Purification Pump 1C (AX005)

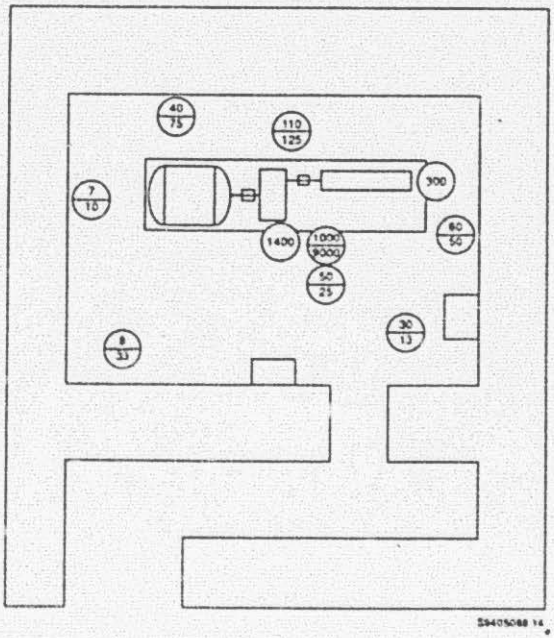

Figure C.4. Makeup and Purification Pump 1B (AX006)

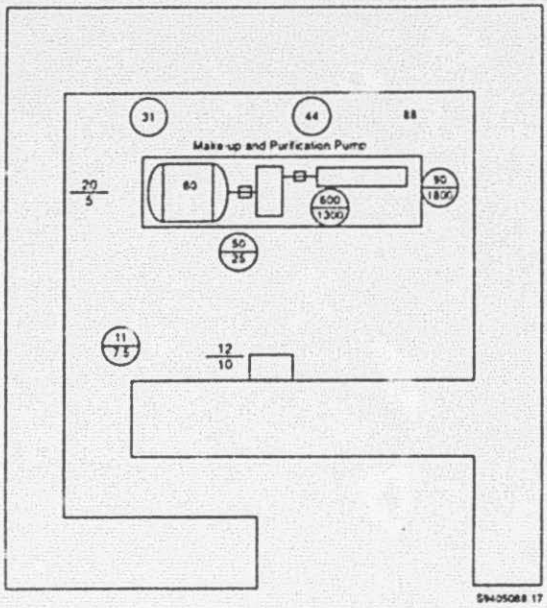

Figure C.5. Makeup and Purification Pump 1A (AX007)

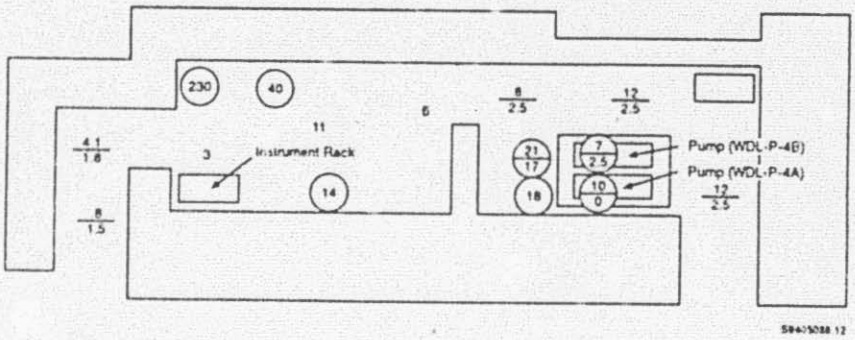

Figure C.6. Auxiliary Building Sump Tank, Pumps and Valve Room (AX011)

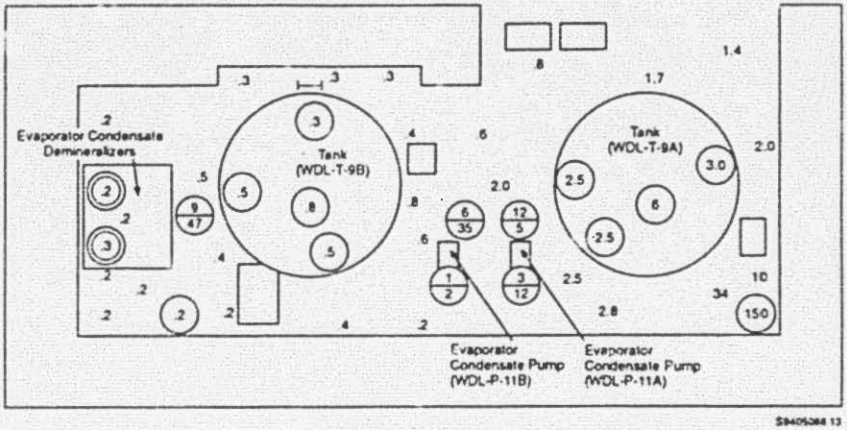

Figure C.7. Evaporator Condensate Tank Pump Room (AX013)

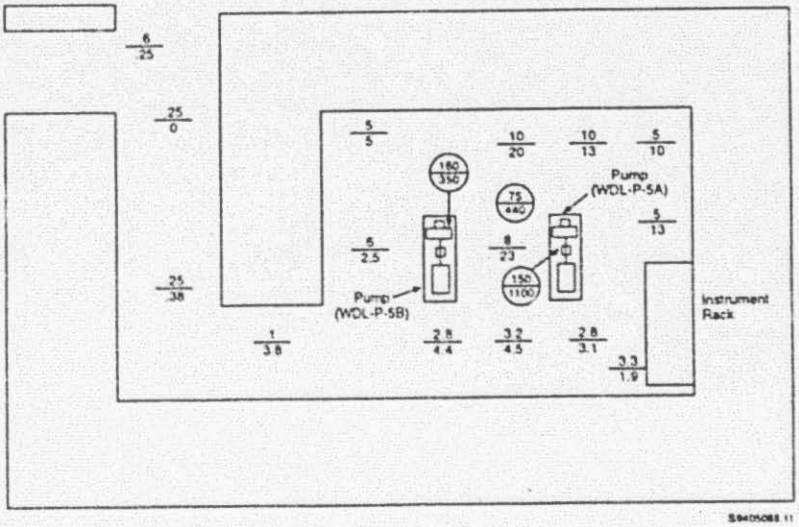

Figure C.8. Waste Transfer Pump Room (AX018)

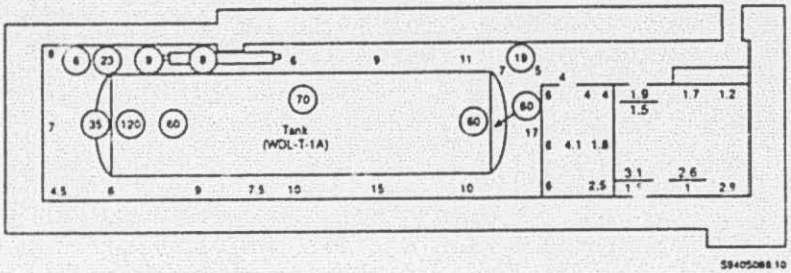

Figure C.9. Reactor Coolant Bleed Holdup Tank 1A

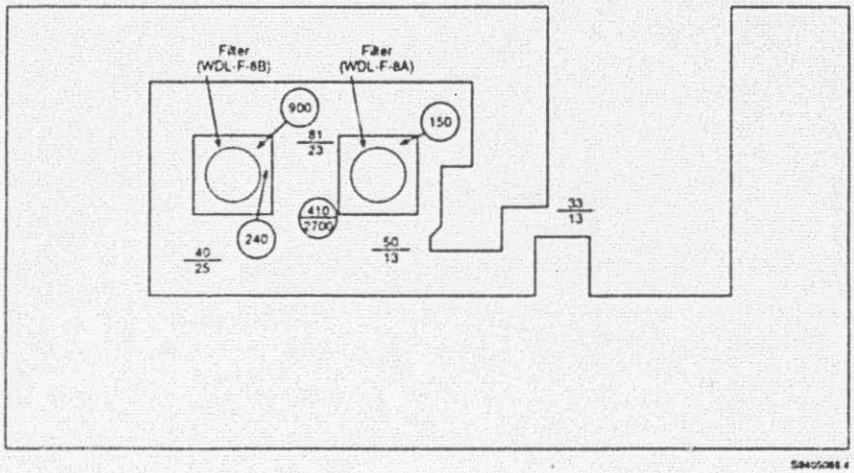

Figure C.10. Reactor Building Sump Pump Filter Room (AX102)

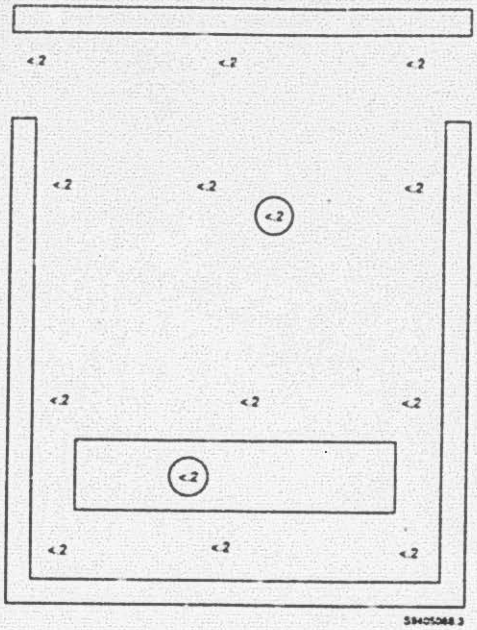

Figure C.11. Motor Control Center (AX103)

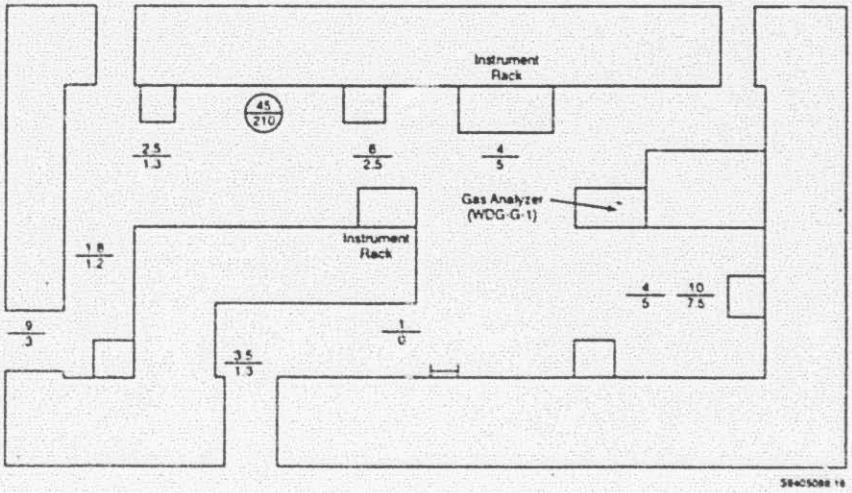

Figure C.12. Waste Gas Analyzer Room (AX113)

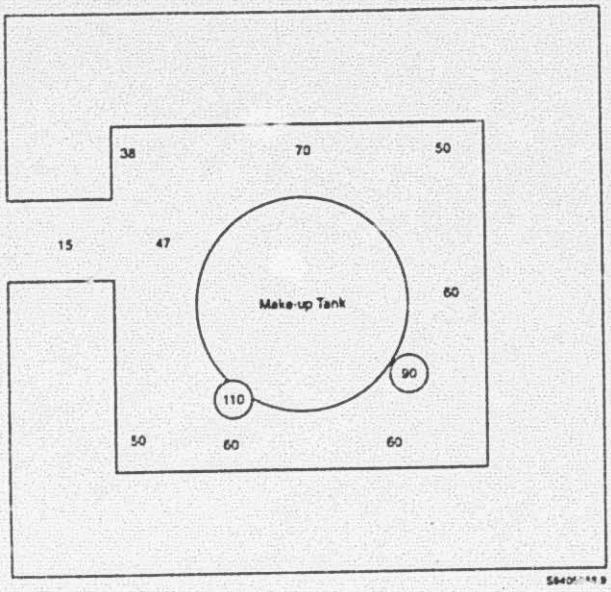

Figure C.13. Makeup Tank Room (AX116)

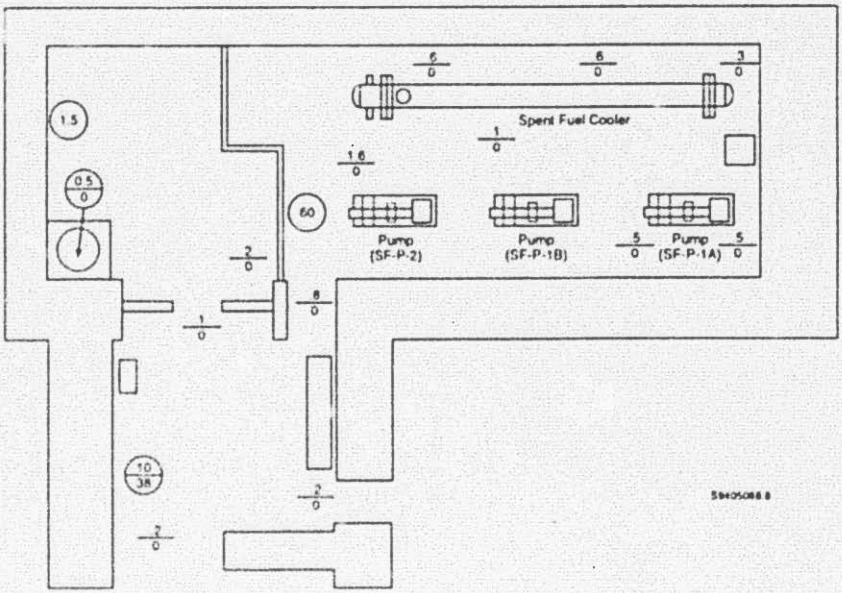

Figure C.14. Spent Fuel Coolers and Pump Room (AX118)

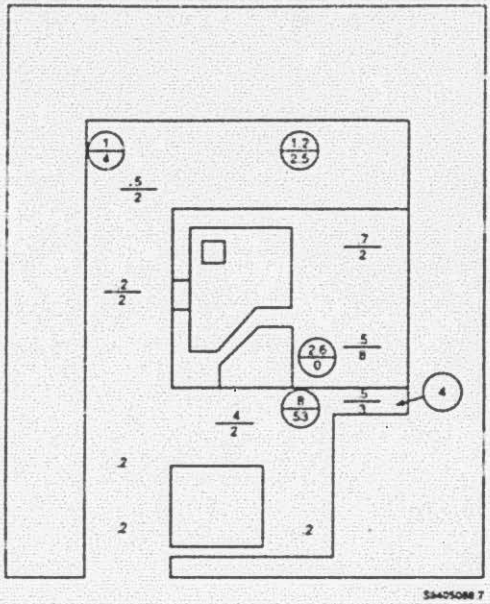

Figure C.15. Sample Room (FH103)

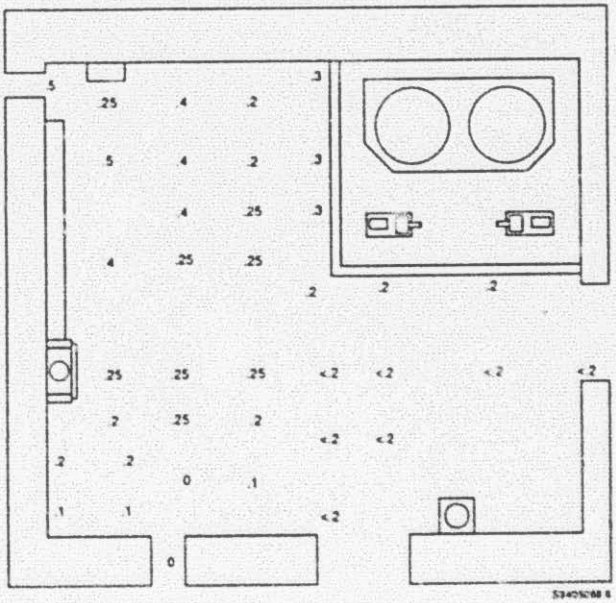

Figure C.16. Model Room (FH105)

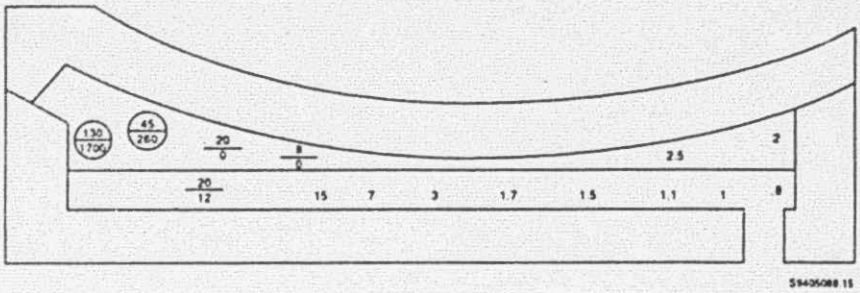

Figure C.17. Annulus - Elevation 305 Ft. (FH112)

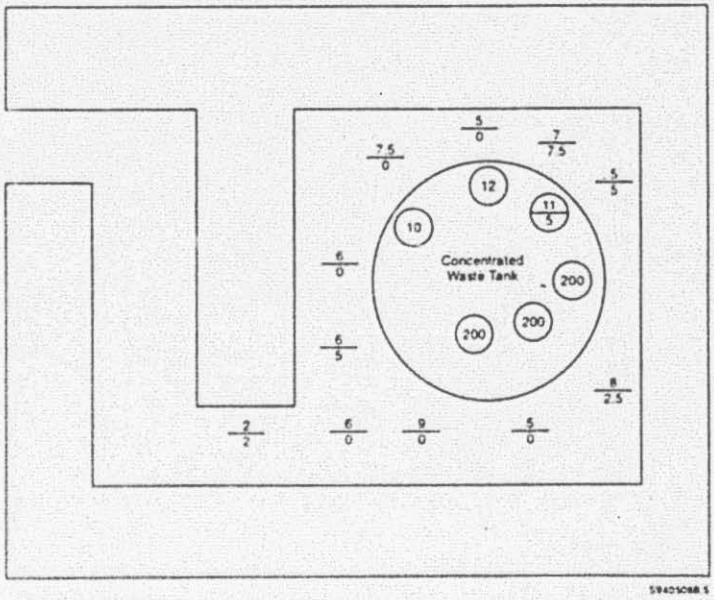

Figure C.18. Concentrated Waste Storage Room (AX218)

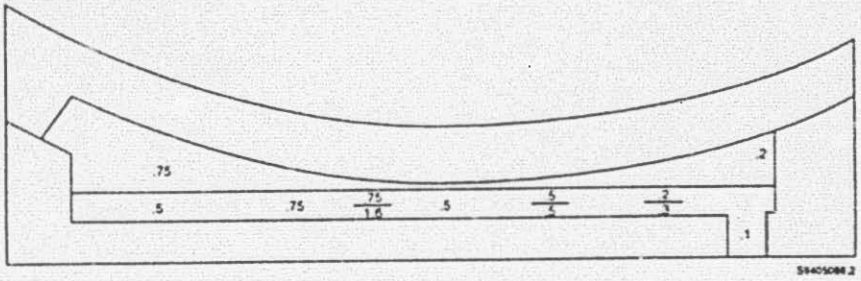

Figure C.19. Annulus - Evaluation 347 Ft. (FH304)

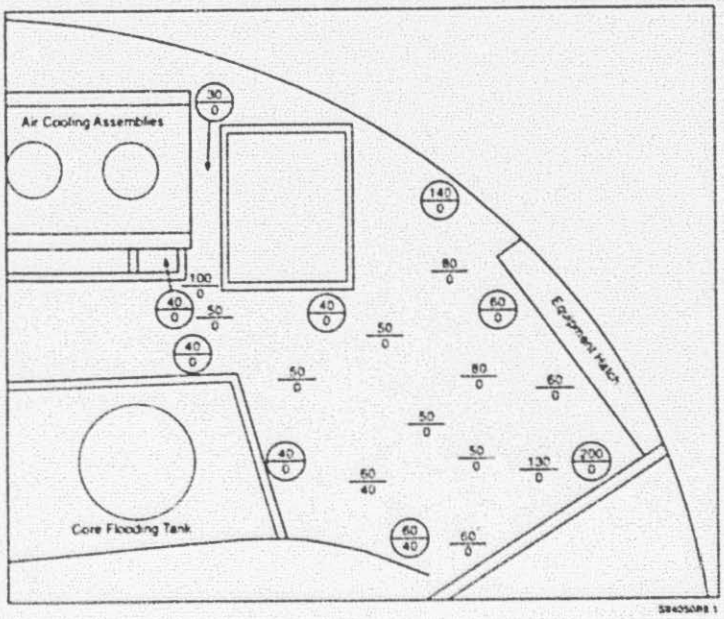

Figure C.20. Reactor Building 305 Elevation (Area in front of Equipment Hatch)

APPENDIX D

CONTAMINATION SMEAR RESULTS

APPENDIX D

CONTAMINATION SMEAR RESULTS

Tables of the contamination smear results are presented in this appendix for each of the cubicles surveyed by PNL. The tables list the sample number, the counts per minute (cpm), including gross counts and net counts (after subtraction of the background dose rate), the efficiency of the instrument (0.2), and the number of disintegrations per minute (dpm). In addition, the measurements made by GPU are also listed for each location. The background dose rate, and the average of the smear results are given for both PNL and GPU. The average results are compared against the goal that was set by GPU for each cubicle.

Table D.1 Reactor Building Emergency Cooling Booster Pump Area (AX001)

Background Count Rate = 18.7 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
3	20	1.3	0.2	7	<MDC
6	182	163.3	0.2	817	100
8	24	5.3	0.2	27	<MDC
10	21	2.3	0.2	12	<MDC
12	19	0.3	0.2	2	<MDC
15	25	6.3	0.2	32	<MDC
17	16	0	0.2	0	<MDC
20	17	0	0.2	0	<MDC
23	30	11.3	0.2	57	<MDC
25	41	22.3	0.2	112	<MDC
27	27	8.3	0.2	42	730
29	19	0.3	0.2	2	<MDC
30	31	12.3	0.2	62	970
32	86	67.3	0.2	337	340
33	26	7.3	0.2	37	880
35	51	32.3	0.2	162	670
37	28	9.3	0.2	47	1,530
40	143	124.3	0.2	622	4,730
41	254	235.3	0.2	1177	11,560
44	96	77.3	0.2	387	9,020
47	254	235.3	0.2	1177	13,750
48	16	0	0.2	0	<MDC
50	11	0	0.2	0	<MDC
52	26	7.3	0.2	37	<MDC
54	28	9.3	0.2	47	<MDC
56	17	0	0.2	0	<MDC
61	18	0	0.2	0	<MDC
62	13	0	0.2	0	<MDC
65	28	9.3	0.2	47	<MDC
68	21	2.3	0.2	12	<MDC
69	63	44.3	0.2	222	2,130
71	54	35.3	0.2	177	580
73	40	21.3	0.2	107	3,100
75	147	128.3	0.2	642	910
77	18	0	0.2	0	<MDC
80	16	0	0.2	0	<MDC
82	31	12.3	0.2	62	100
87	18	0	0.2	0	110
92	22	3.3	0.2	17	<MDC
94	30	11.3	0.2	57	130
97	20	1.3	0.2	7	<MDC
99	16	0	0.2	0	<MDC

MDC = Minimum Detectable Counts

Table D.1 Reactor Building Emergency Cooling Booster Pump Area (AX001) (Continued)

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
101	16	1.3	0.2	7	<MDC
102	12	0	0.2	0	<MDC
105	19	0.3	0.2	2	<MDC
110	19	0.3	0.2	2	<MDC
113	26	7.3	0.2	37	<MDC
116	30	11.3	0.2	57	<MDC
121	17	0	0.2	0	<MDC
125	21	2.3	0.2	12	110
127	18	0	0.2	0	130
128	14	0	0.2	0	100
129	20	1.3	0.2	7	<MDC
131	17	0	0.2	0	<MDC
132	18	0	0.2	0	<MDC
135	14	0	0.2	0	170
138	19	0.3	0.2	2	100
147	28	9.3	0.2	47	620
150	21	2.3	0.2	12	440
155	17	0	0.2	0	440
163	28	9.3	0.2	47	410
170	116	97.3	0.2	487	3,800
176	50	31.3	0.2	157	500

PNL Average Disintegrations/minute =	111
GPU Average Disintegrations/minute =	592
GPU Goal - Disintegrations/minute	<1,000

MDC = Minimum Detectable Counts

Table D.2 Seal Injection Valve Room (AX004)

Background Count Rate =
22.1 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	1280	1258	0.2	6290	180,000
2	1314	1292	0.2	6460	80,000
3	949	927	0.2	4635	40,000
4	4002	3980	0.2	19900	10,000
5	379	357	0.2	1785	8,000
6	555	533	0.2	2665	10,000
7	466	444	0.2	2220	10,000
8	361	339	0.2	1695	14,000
9	2409	2387	0.2	11935	14,000
10	2494	2472	0.2	12360	60,000
11	2993	2971	0.2	14855	24,000
12	4588	4566	0.2	22830	38,000
13	2661	2639	0.2	13195	100,000
14	2241	2219	0.2	11095	60,000
15	2852	2830	0.2	14150	42,000
16	1596	1574	0.2	7870	120,000
17	4449	4427	0.2	22135	38,000
18	5236	5214	0.2	26070	100,000
19	4047	4025	0.2	20125	22,000
20	3931	3909	0.2	19545	20,000
21	2879	2857	0.2	14285	34,000
22	1483	1461	0.2	7305	24,000
23	2471	2449	0.2	12245	50,000
24	2579	2557	0.2	12785	100,000
25	405	383	0.2	1915	24 *mrad
26	77715	77693	0.2	388465	200,000
27	12831	12809	0.2	64045	180,000
28	14822	14800	0.2	74000	30 *mrad
29	811	789	0.2	3945	300,000
30	14950	14928	0.2	74640	380,000

PNL Average Disintegrations/minute =	29848
GPU Average Disintegrations/minute =	68385
GPU Goal - Disintegrations/minute =	< 50000

* Measurement performed with a ratemeter; licensee did not convert reading to dpm

Table D.3 Makeup and Purification Pump Room - 1C (AX005)

Background Count Rate =
23.7 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	302	278	0.2	1392	10000
3	96	72	0.2	362	2000
4	137	113	0.2	567	3000
6	111	87	0.2	437	5000
8	163	139	0.2	697	6000
9	225	201	0.2	1007	1500
11	326	302	0.2	1512	6000
14	54	30	0.2	152	6000
18	1148	1124	0.2	5622	3000
20	161	137	0.2	687	2000
23	61	37	0.2	187	3000
25	83	59	0.2	297	3000
27	238	214	0.2	1072	2000
29	418	394	0.2	1972	6000
32	468	444	0.2	2222	4000
35	NMT	NMT	0.2	NMT	3000
37	150	126	0.2	632	2000
40	709	685	0.2	3427	60000
42	51	27	0.2	137	4000
44	115	91	0.2	457	60000
45	965	941	0.2	4707	100000
48	133	109	0.2	547	34000
50	11632	11608	0.2	58042	120000
51	178	154	0.2	772	80000
53	1001	977	0.2	4887	50000
54	260	236	0.2	1182	260000
55	78	54	0.2	272	22000
57	18029	18005	0.2	90027	200000
58	614	590	0.2	2952	15000
60	243	219	0.2	1097	6000

PNL Average Disintegrations/minute = 6459
GPU Average Disintegrations/minute = 39982
GPU Goal - Disintegrations/minute = <50000

NMT = No Measurement Taken

Table D.4 Makeup and Purification Pump Room - 1B (AX006)

Background Count Rate =
18.25 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	138	120	0.2	599	8,000
3	74	56	0.2	279	1,000
4	945	927	0.2	4,634	20,000
7	675	657	0.2	3,284	6,000
9	189	171	0.2	854	4,000
10	422	404	0.2	2,019	1,000
11	2052	2034	0.2	10,169	10,000
12	2582	2564	0.2	12,819	38,000
13	1442	1424	0.2	7,119	12,000
14	1064	1046	0.2	5,229	14,000
15	160	142	0.2	709	4,000
16	61	43	0.2	214	2,000
17	37	19	0.2	94	<1,000
18	329	311	0.2	1,554	8,000
20	1757	1739	0.2	8,694	6 *mrad
23	1920	1902	0.2	9,509	60,000
26	482	464	0.2	2,319	8,000
28	436	418	0.2	2,089	14,000
29	545	527	0.2	2,634	12,000
30	417	399	0.2	1,994	6,000
31	452	434	0.2	2,169	18,000
32	225	207	0.2	1,034	26,000
33	25	7	0.2	34	6 *mrad
34	35	17	0.2	84	60,000
37	153	135	0.2	674	8,000
38	3491	3473	0.2	17,364	2,000
39	286	268	0.2	1,339	20,000
40	115	97	0.2	484	16,000
41	1926	1908	0.2	9,539	40 *mrad
42	1000	982	0.2	4,909	16 *mrad
43	5909	5891	0.2	29,454	60,000
44	7408	7390	0.2	36,949	3 *mrad
45	462472	462453	0.2	2,312,266	60,000
46	26517	26498	0.2	132,491	6,000
47	28123	28105	0.2	140,524	40,000
48	47237	47219	0.2	236,094	40,000

PNL Average Disintegrations/minute = 83,395
GPU Average Disintegrations/minute = 87,533
GPU Goal - Disintegrations/minute = <50,000

* Measurement performed with a ratemeter; licensee did not convert reading to dpm

Table D.5 Makeup and Purification Pump Room - 1A (AX007)

Background Count Rate =
22 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	391	369	0.2	1845	2,000
3	77	55	0.2	275	3,000
4	105	83	0.2	415	2,000
5	119	97	0.2	485	40,000
6	63	41	0.2	205	2,000
8	90	68	0.2	340	4,000
9	572	550	0.2	2750	8,000
11	129	107	0.2	535	6,000
12	151	129	0.2	645	12,000
13	140	118	0.2	590	1,000
15	345	323	0.2	1615	15,000
17	172	150	0.2	750	2,000
19	63	41	0.2	205	1,000
20	35	13	0.2	65	<1,000
21	58	36	0.2	180	1,000
22	173	151	0.2	755	2,000
24	335	313	0.2	1565	32,000
25	108	86	0.2	430	2,000
27	43	21	0.2	105	<1,000
28	96	74	0.2	370	3,000
29	54	32	0.2	160	14,000
30	186	164	0.2	820	4,000
31	7734	7712	0.2	38560	1,000
33	467	445	0.2	2225	4,000
34	1079	1057	0.2	5285	6,000
35	796	774	0.2	3870	2,000
36	64	42	0.2	210	12,000
37	50	28	0.2	140	16,000
39	212	190	0.2	950	40,000
41	239	217	0.2	1085	4,000

PNL Average Disintegrations/minute = 2248
GPU Average Disintegrations/minute = 9195
GPU Goal - Disintegrations/minute = < 50,000

Table D.6 Auxiliary Building Sump Tank, Pumps and Valve Room (AX011)

Background Count Rate =
24.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	43	18.5	0.2	93	<1,000
2	29	4.5	0.2	23	<1,000
3	33	8.5	0.2	43	<1,000
4	27	2.5	0.2	13	<1,000
6	23	0	0.2	0	<1,000
7	32	7.5	0.2	38	1,000
8	306	281.5	0.2	1408	<1,000
9	35	10.5	0.2	53	<1,000
11	80	55.5	0.2	278	<1,000
12	47	22.5	0.2	113	<1,000
13	33	8.5	0.2	43	<1,000
16	32	7.5	0.2	38	<1,000
18	24	0	0.2	0	<1,000
19	40	15.5	0.2	78	1,000
21	34	9.5	0.2	48	<1,000
22	57	32.5	0.2	163	<1,000
23	23	0	0.2	0	20,000
25	126	101.5	0.2	508	22,000
26	27	2.5	0.2	13	<1,000
27	33	8.5	0.2	43	<1,000
29	140	115.5	0.2	578	6,000
30	1550	1525.5	0.2	7628	18,000
31	380	355.5	0.2	1778	2,000
33	62	37.5	0.2	188	6,000
34	103	78.5	0.2	393	10,000
36	300	275.5	0.2	1378	6,000
37	998	973.5	0.2	4868	4,000
39	640	615.5	0.2	3078	6,000
40	393	368.5	0.2	1843	2,000

PNL Average Disintegrations/minute = 852
GPU Average Disintegrations/minute = 3233
GPU Goal - Disintegrations/minute = < 5,000

Table D.7 Evaporator Condensate Tank Pumps (AX013)

Background Count Rate =
21.4 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	21	0	0.2	0	<MDC
4	23	1.6	0.2	8	< MDC
8	22	0.6	0.2	3	< MDC
12	24	2.6	0.2	13	< MDC
15	18	0	0.2	0	< MDC
19	17	0	0.2	0	< MDC
20	12	0	0.2	0	< MDC
23	16	0	0.2	0	< MDC
25	49	27.6	0.2	138	< MDC
30	40	18.6	0.2	93	270
33	13	0	0.2	0	< MDC
36	16	0	0.2	0	< MDC
38	18	0	0.2	0	< MDC
42	11	0	0.2	0	< MDC
47	61	39.6	0.2	198	< MDC
50	17	0	0.2	0	< MDC
51	17	0	0.2	0	< MDC
56	20	0	0.2	0	< MDC
57	16	0	0.2	0	< MDC
60	24	2.6	0.2	13	< MDC
61	23	1.6	0.2	8	< MDC
64	22	0.6	0.2	3	< MDC
66	20	0	0.2	0	< MDC
70	28	6.6	0.2	33	< MDC
73	25	3.6	0.2	18	< MDC
77	28	6.6	0.2	33	< MDC
81	990	968.6	0.2	4843	2,150
84	114	92.6	0.2	463	250
86	16	0	0.2	0	< MDC
88	30	8.6	0.2	43	250

PNL Average Disintegrations/minute = 197
GPU Average Disintegrations/minute = 133
GPU Goal - Disintegrations/minute = <1000

MDC = Minimum Detectable Counts

Table D.8 Waste Transfer Pump Room (AX018)

Background Count Rate =
18.7 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	13	0	0.2	0	< 1000
3	24	5.3	0.2	27	< 1000
5	17	0	0.2	0	< 1000
7	36	17.3	0.2	87	< 1000
9	62	43.3	0.2	217	2000
10	26	7.3	0.2	37	< 1000
12	27	8.3	0.2	42	< 1000
16	29	10.3	0.2	52	< 1000
18	93	74.3	0.2	372	< 1000
20	49	30.3	0.2	152	< 1000
22	24	5.3	0.2	27	< 1000
24	304	285.3	0.2	1427	3000
28	40	21.3	0.2	107	< 1000
30	29	10.3	0.2	52	< 1000
32	93	74.3	0.2	372	14000
33	70	51.3	0.2	257	< 1000
34	91	72.3	0.2	362	8000
37	181	162.3	0.2	812	2000
41	677	658.3	0.2	3292	20000
43	1492	1473.3	0.2	7367	160000
44	374	355.3	0.2	1777	10000
45	171	152.3	0.2	762	8000
49	212	193.3	0.2	967	6000
51	20419	20400	0.2	102002	6000
52	428	409.3	0.2	2047	4000
53	204	185.3	0.2	927	80000
54	4269	4250.3	0.2	21252	140000
56	832	813.3	0.2	4067	12000
58	691	672.3	0.2	3362	20000
60	565	546.3	0.2	2732	400000

PNL Average Disintegrations/minute = 5165
GPU Average Disintegrations/minute = 17233
GPU Goal - Disintegrations/minute = < 50,000

Table D.9 Reactor Coolant Bleed Holdup Tank 1A (AX021)

Background Count Rate =
20.3 counts per min

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
Storage Cages:					
1	19	0	0.2	0	< 1000
6	31	10.7	0.2	54	< 1000
8	25	4.7	0.2	24	< 1000
12	31	10.7	0.2	54	< 1000
15	17	0	0.2	0	< 1000
18	22	1.7	0.2	9	< 1000
20	28	7.7	0.2	39	< 1000
22	18	0	0.2	0	< 1000
23	19	0	0.2	0	< 1000
31	24	3.7	0.2	19	< 1000
32	25	4.7	0.2	24	< 1000
34	14	0	0.2	0	< 1000
35	25	4.7	0.2	24	< 1000
36	14	0	0.2	0	< 1000
37	18	0	0.2	0	< 1000
41	16	0	0.2	0	< 1000
47	55	34.7	0.2	174	< 1000
Main Room:					
	Background Dose Rate = 19.3 cpm for 11/17/94 readings				
1	24	4.7	0.2	24	< 1000
3	14	0	0.2	0	< 1000
6	20	0.7	0.2	4	< 1000
7	27	7.7	0.2	39	< 1000
10	46	26.7	0.2	134	< 1000
17	29	9.7	0.2	49	< 1000
20	21	1.7	0.2	9	< 1000
23	28	8.7	0.2	44	< 1000
25	16	0	0.2	0	< 1000
27	21	1.7	0.2	9	< 1000
30	19	0	0.2	0	< 1000
37	20	0.7	0.2	4	< 1000
39	18	0	0.2	0	< 1000
41	23	3.7	0.2	19	< 1000
54	83	63.7	0.2	319	< 1000
58	55	35.7	0.2	179	< 1000
67	48	28.7	0.2	144	1,000
69	127	107.7	0.2	539	< 1000
71	34	14.7	0.2	74	2,000
73	23	3.7	0.2	19	< 1000

Table D.9 Reactor Coolant Bleed Holdup Tank 1A (AX021) (Continued)

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
76	39	19.7	0.2	99	< 1000
82	41	21.7	0.2	109	< 1000
86	33	13.7	0.2	69	< 1000
90	35	15.7	0.2	79	< 1000
92	39	19.7	0.2	99	2,000
94	35	15.7	0.2	79	2,000
96	81	61.7	0.2	309	1,000
102	508	488.7	0.2	2,444	2,000
103	126	106.7	0.2	534	4,000
111	39	19.7	0.2	99	2,000
115	31	11.7	0.2	59	1,000
116	28	8.7	0.2	44	< 1000
122	42	22.7	0.2	114	< 1000
127	206	186.7	0.2	934	3,000
128	266	246.7	0.2	1,234	6,000
129	422	402.7	0.2	2,014	12,000
	Background Dose Rate = 17.7	cpm for 11/17/94 readings			
15	15	0	0.2	0	< 1000
34	18	0.3	0.2	2	< 1000
42	18	0.3	0.2	2	< 1000
43	11	0	0.2	0	< 1000
45	17	0	0.2	0	< 1000
48	16	0	0.2	0	< 1000
50	17	0	0.2	0	1000
52	16	0	0.2	0	< 1000
56	20	2.3	0.2	12	< 1000
75	18	0.3	0.2	2	< 1000
79	17	0	0.2	0	< 1000
83	41	23.3	0.2	117	< 1000
105	45	27.3	0.2	137	1000
108	86	68.3	0.2	342	1000

PNL Average Disintegrations/minute = 181.2
GPU Average Disintegrations/minute = 1805
GPU Goal - Disintegrations/minute = < 50,000

Table D.10 Reactor Building Sump Pump Filter Room (AX102)

Background Count Rate =
31.6 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	273	241.4	0.2	1207	3910
2	850	818.4	0.2	4092	27080
3	4008	3976.4	0.2	19882	19580
4	459	427.4	0.2	2137	19410
5	831	799.4	0.2	3997	5270
6	236	204.4	0.2	1022	14630
7	228	196.4	0.2	982	1010
8	196	164.4	0.2	822	16940
9	223	191.4	0.2	957	2940
10	1027	995.4	0.2	4977	13260
11	3501	3469.4	0.2	17347	7280
12	159	127.4	0.2	637	420
13	318	286.4	0.2	1432	6360
14	1464	1432.4	0.2	7162	15010
15	140	108.4	0.2	542	650
16	78	46.4	0.2	232	630
17	70	38.4	0.2	192	1410
18	155	123.4	0.2	617	570
19	3623	3591.4	0.2	17957	19270
20	2953	2921.4	0.2	14607	25410
21	126	94.4	0.2	472	1330
22	140	108.4	0.2	542	1430
23	349	317.4	0.2	1587	2360
24	187	155.4	0.2	777	5730
25	74	42.4	0.2	212	5230

PNL Average Disintegrations/minute =	4176
GPU Average Disintegrations/minute	9264
GPU Goal - Disintegrations/minute =	< 50,000

Table D.11 Motor Control Center (AX103)

Background Count Rate =
15.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	15	0	0.2	0	<MDC
2	16	0.5	0.2	3	< MDC
3	14	0	0.2	0	< MDC
4	16	0.5	0.2	3	< MDC
5	21	5.5	0.2	28	< MDC
6	22	6.5	0.2	33	< MDC
7	16	0.5	0.2	3	< MDC
8	12	0	0.2	0	< MDC
9	23	7.5	0.2	38	< MDC
10	19	3.5	0.2	18	< MDC
11	20	4.5	0.2	23	< MDC
12	6	0	0.2	0	< MDC
13	14	0	0.2	0	< MDC
14	17	1.5	0.2	8	< MDC
15	12	0	0.2	0	< MDC
16	17	1.5	0.2	8	< MDC
17	22	6.5	0.2	33	< MDC
18	23	7.5	0.2	38	< MDC
19	20	4.5	0.2	23	< MDC
20	17	1.5	0.2	8	< MDC
21	9	0	0.2	0	< MDC
22	25	9.5	0.2	48	330
23	16	0.5	0.2	3	370
24	17	1.5	0.2	8	< MDC

PNL Average Disintegrations/minute = 13
GPU Average Disintegrations/minute = 469
GPU Goal - Disintegrations/minute = < 1000

MDC = Minimum Detectable Counts

Table D.12 Waste Gas Analyzer Room (AX113)

Background Count Rate =
21.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	1437	1415.5	0.2	7078	10,000
3	40	18.5	0.2	93	< 1000
5	87	65.5	0.2	328	8,000
8	25	3.5	0.2	18	10,000
9	318	296.5	0.2	1483	15,000
12	34120	34099	0.2	170493	160,000
14	578	556.5	0.2	2783	140,000
15	238	216.5	0.2	1083	50,000
17	104	82.5	0.2	413	5,000
18	91	69.5	0.2	348	< 1000
20	73	51.5	0.2	258	< 1000
21	38	16.5	0.2	83	6,000
23	155	133.5	0.2	668	6,000
25	220	198.5	0.2	993	< 1000
26	20	-1.5	0.2	0	< 1000
29	22	0.5	0.2	3	< 1000
32	90	68.5	0.2	343	< 1000
35	23	1.5	0.2	8	< 1000
37	19	-2.5	0.2	0	< 1000
40	29	7.5	0.2	38	< 1000
41	24	2.5	0.2	13	< 1000
43	34	12.5	0.2	63	< 1000
45	69	47.5	0.2	238	< 1000
46	431	409.5	0.2	2048	1,000
48	703	681.5	0.2	3408	< 1000
51	32	10.5	0.2	53	< 1000
53	1058	1036.5	0.2	5183	5,000
55	43	21.5	0.2	108	< 1000
57	43	21.5	0.2	108	< 1000
60	25	3.5	0.2	18	< 1000

PNL Average Disintegrations/minute = 6591
GPU Average Disintegrations/minute = 22380
GPU Goal - Disintegrations/minute = < 50000

Table D.13 Makeup Tank Room (AX116)

Background Count Rate =
15 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	61	46	0.2	230	1,000
2	24	9	0.2	45	< 1000
5	150	135	0.2	675	1,000
8	33	18	0.2	90	< 1000
11	97	82	0.2	410	< 1000
14	37	22	0.2	110	< 1000
17	43	28	0.2	140	< 1000
20	79	64	0.2	320	< 1000
24	39	24	0.2	120	1,000
28	371	356	0.2	1780	8,000
33	138	123	0.2	615	20,000
37	34	19	0.2	95	10,000
40	1265	1250	0.2	6250	50,000
44	31	16	0.2	80	1,000
47	94	79	0.2	395	< 1000
50	37	22	0.2	110	1,000
53	159	144	0.2	720	6,000
54	205	190	0.2	950	4,000
56	31	16	0.2	80	< 1000
58	419	404	0.2	2020	10,000
60	71	56	0.2	280	< 1000
61	28	13	0.2	65	4,000
68	348	333	0.2	1665	50,000
71	338	323	0.2	1615	200,000
72	419	404	0.2	2020	50,000
75	9509	9494	0.2	47470	200,000
76	483	468	0.2	2340	100,000

PNL Average Disintegrations/minute = 2618
GPU Average Disintegrations/minute = 313,652
GPU Goal - Disintegrations/minute = < 50,000

Table D.14 Spent Fuel Coolers and Pumps (AX118)

Background Count Rate =
19.9 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	23	3.1	0.2	16	< 1000
3	16	0.0	0.2	0	< 1000
5	23	3.1	0.2	16	< 1000
6	25	5.1	0.2	26	< 1000
8	21	1.1	0.2	6	< 1000
10	20	0.1	0.2	1	< 1000
12	21	1.1	0.2	6	< 1000
15	15	0.0	0.2	0	< 1000
19	26	6.1	0.2	31	< 1000
20	17	0.0	0.2	0	< 1000
21	19	0.0	0.2	0	< 1000
22	32	12.1	0.2	61	< 1000
23	26	6.1	0.2	31	< 1000
24	18	0.0	0.2	0	< 1000
25	15	0.0	0.2	0	< 1000
27	19	0.0	0.2	0	< 1000
29	13	0.0	0.2	0	< 1000
33	26	6.1	0.2	31	< 1000
37	28	8.1	0.2	41	< 1000
41	20	0.1	0.2	1	< 1000
44	21	1.1	0.2	6	< 1000
47	19	0.0	0.2	0	< 1000
50	30	10.1	0.2	51	< 1000
53	21	1.1	0.2	6	< 1000
56	22	2.1	0.2	11	< 1000
58	277	257.1	0.2	1286	6,000
62	30	10.1	0.2	51	< 1000
64	19	0.0	0.2	0	< 1000

PNL Average Disintegrations/minute = 60
GPU Average Disintegrations/minute = 1000
GPU Goal - Disintegrations/minute = < 1000

Table D.15 Concentrated Waste Storage Room (AX218)

Background Count Rate =
19.6 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	50	30.4	0.2	152	1000
2	247	227.4	0.2	1137	2000
5	82	62.4	0.2	312	< 1000
7	190	170.4	0.2	852	< 1000
9	51	31.4	0.2	157	2000
11	341	321.4	0.2	1607	20000
13	81	61.4	0.2	307	1000
14	49	29.4	0.2	147	1000
17	943	923.4	0.2	4617	< 1000
20	41	21.4	0.2	107	2000
21	247	227.4	0.2	1137	< 1000
23	47	27.4	0.2	137	< 1000
25	58	38.4	0.2	192	< 1000
26	47	27.4	0.2	137	< 1000
28	78	58.4	0.2	292	< 1000
30	44	24.4	0.2	122	< 1000
32	30	10.4	0.2	52	< 1000
33	40	20.4	0.2	102	< 1000
35	37	17.4	0.2	87	< 1000
38	61	41.4	0.2	207	< 1000
40	28	8.4	0.2	42	< 1000
42	40	20.4	0.2	102	< 1000
45	38	18.4	0.2	92	< 1000
46	35	15.4	0.2	77	2000
49	63	43.4	0.2	217	2000
52	41	21.4	0.2	107	10000
55	43	23.4	0.2	117	2000
57	58	38.4	0.2	192	1000
61	244	224.4	0.2	1122	NMT

PNL Average Disintegrations/minute = 480
GPU Average Disintegrations/minute = 1860
GPU Goal - Disintegrations/minute = < 50,000

NMT = No Measurement Taken

Table D.16 Sample Room (FH103)

Background Count Rate =
24.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	33	8.5	0.2	43	1,000
2	31	6.5	0.2	33	< 1000
3	44	19.5	0.2	98	< 1000
4	45	20.5	0.2	103	1,000
5	24	0	0.2	0	< 1000
6	15	0	0.2	0	< 1000
7	22	0	0.2	0	< 1000
8	23	0	0.2	0	< 1000
9	22	0	0.2	0	< 1000
10	24	0	0.2	0	< 1000
11	21	0	0.2	0	< 1000
12	19	0	0.2	0	< 1000
13	23	0	0.2	0	< 1000
14	18	0	0.2	0	2,000
15	116	91.5	0.2	458	2,000
16	60	35.5	0.2	178	< 1000
17	46	21.5	0.2	108	1,000
18	31	6.5	0.2	33	< 1000
19	33	8.5	0.2	43	2,000
20	45	20.5	0.2	103	2,000
21	62	37.5	0.2	188	< 1000
22	96	71.5	0.2	358	2,000
23	28	3.5	0.2	18	30,000
24	195	170.5	0.2	853	4,000
25	82	57.5	0.2	288	2,000
26	16966	16942	0.2	84708	60,000
27	81	56.5	0.2	283	3,000
28	38	13.5	0.2	68	< 1000
29	33	8.5	0.2	43	< 1000
30	268	243.5	0.2	1218	5,000

PNL Average Disintegrations/minute = 2974
GPU Average Disintegrations/minute = 4029
GPU Goal - Disintegrations/minute = < 50,000

Table D.17 Model Room (FH105)

Background Count Rate = 15.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	19	3.5	0.2	18	<MDC
2	17	1.5	0.2	8	<MDC
3	20	4.5	0.2	23	<MDC
4	17	1.5	0.2	8	<MDC
5	14	0	0.2	0	<MDC
6	24	8.5	0.2	43	<MDC
7	13	0	0.2	0	<MDC
8	22	6.5	0.2	33	<MDC
9	19	3.5	0.2	18	<MDC
10	17	1.5	0.2	8	<MDC
11	13	0	0.2	0	<MDC
12	22	6.5	0.2	33	<MDC
13	18	2.5	0.2	13	<MDC
14	20	4.5	0.2	23	<MDC
15	16	0.5	0.2	3	<MDC
16	25	9.5	0.2	48	<MDC
17	18	2.5	0.2	13	<MDC
18	20	4.5	0.2	23	<MDC
19	23	7.5	0.2	38	<MDC
20	18	2.5	0.2	13	<MDC
21	13	0	0.2	0	<MDC
22	23	7.5	0.2	38	<MDC
23	13	0	0.2	0	<MDC
24	24	8.5	0.2	43	<MDC
25	25	9.5	0.2	48	<MDC
26	15	0	0.2	0	<MDC
27	20	4.5	0.2	23	<MDC
28	13	0	0.2	0	<MDC
29	26	10.5	0.2	53	<MDC
30	24	8.5	0.2	43	<MDC
31	16	0.5	0.2	3	<MDC
32	20	4.5	0.2	23	<MDC
33	28	12.5	0.2	63	<MDC
34	18	2.5	0.2	13	<MDC
35	14	0	0.2	0	<MDC
36	14	0	0.2	0	<MDC
36	23	7.5	0.2	38	<MDC
37	18	2.5	0.2	13	<MDC
38	21	5.5	0.2	28	<MDC
39	18	2.5	0.2	13	<MDC
40	16	0.5	0.2	3	<MDC
41	19	3.5	0.2	18	<MDC

MDC = Minimum Detectable Counts

Table D.17 Model Room (FH105) (Continued)

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
42	24	8.5	0.2	43	<MDC
43	16	0.5	0.2	3	<MDC
44	17	1.5	0.2	8	<MDC
45	18	2.5	0.2	13	<MDC
46	18	2.5	0.2	13	<MDC
47	25	9.5	0.2	48	<MDC
48	16	0.5	0.2	3	<MDC
49	17	1.5	0.2	8	<MDC
50	16	0.5	0.2	3	<MDC
51	10	0	0.2	0	<MDC
52	13	0	0.2	0	<MDC
53	16	0.5	0.2	3	<MDC
54	26	10.5	0.2	53	<MDC
55	13	0	0.2	0	<MDC
57	13	0	0.2	0	<MDC
58	20	4.5	0.2	23	<MDC
59	10	0	0.2	0	<MDC
60	12	0	0.2	0	<MDC
61	23	7.5	0.2	38	<MDC
62	15	0	0.2	0	<MDC
63	14	0	0.2	0	<MDC
64	27	11.5	0.2	58	<MDC
65	24	8.5	0.2	43	<MDC
66	42	26.5	0.2	133	<MDC
67	20	4.5	0.2	23	<MDC
68	9	0	0.2	0	<MDC
70	18	2.5	0.2	13	<MDC
101	15	0	0.2	0	<MDC
102	18	2.5	0.2	13	<MDC
103	14	0	0.2	0	<MDC

PNL Average Disintegrations/minute = 19
GPU Average Disintegrations/minute = 101
GPU Goal - Disintegrations/minute = < 1,000

MDC = Minimum Detectable Counts

Table D.18 Annulus (FH112)

Background Count Rate =
24.5 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	17	0	0.2	0	550
3	27	2.5	0.2	13	<MDC
5	43	18.5	0.2	93	< MDC
7	40	15.5	0.2	78	< MDC
9	30	5.5	0.2	28	< MDC
11	37	12.5	0.2	63	1,590
14	88	63.5	0.2	318	610
17	98	73.5	0.2	368	660
20	63	38.5	0.2	193	600
21	65	40.5	0.2	203	2,200
23	98	73.5	0.2	368	1,340
25	51	26.5	0.2	133	1,010
27	56	31.5	0.2	158	420
28	10	0	0.2	0	1,080
31	37	12.5	0.2	63	< MDC
33	43	18.5	0.2	93	< MDC
36	214	189.5	0.2	948	4,940
43	102	77.5	0.2	388	640
46	134	109.5	0.2	548	1,890
47	3740	3715.5	0.2	18578	87,720
49	3053	3028.5	0.2	15143	6,660
50	1161	1136.5	0.2	5683	7,900
52	265	240.5	0.2	1203	4,320
54	405	380.5	0.2	1903	2,850
55	130	105.5	0.2	528	3,020
56	54	29.5	0.2	148	2,290
57	693	668.5	0.2	3343	4,880
58	67	42.5	0.2	213	330
59	76	51.5	0.2	258	450
60	46	21.5	0.2	108	5,030

PNL Average Disintegrations/minute = 1705
GPU Average Disintegrations/minute = 3524
GPU Goal - Disintegrations/minute = < 50,000

MDC = Minimum Detectable Counts

Table D.19 Annulus (FH304)

Background Count Rate =
19.6 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
1	81	61.4	0.2	307	19,000
2	40	20.4	0.2	102	<1000
3	40	20.4	0.2	102	1,000
4	108	88.4	0.2	442	2,000
5	84	64.4	0.2	322	2,000
6	100	80.4	0.2	402	<1000
7	188	168.4	0.2	842	<1000
8	122	102.4	0.2	512	1,500
9	193	173.4	0.2	867	<1000
10	114	94.4	0.2	472	1,000
11	120	100.4	0.2	502	<1000
12	138	118.4	0.2	592	<1000
13	48	28.4	0.2	142	1,000
14	311	291.4	0.2	1457	7,000
15	36	16.4	0.2	82	<1000
16	48	28.4	0.2	142	<1000
17	49	29.4	0.2	147	<1000
18	52	32.4	0.2	162	<1000
19	31	11.4	0.2	57	<1000
20	38	18.4	0.2	92	<1000
21	33	13.4	0.2	67	<1000
22	29	9.4	0.2	47	<1000
23	693	673.4	0.2	3367	3,000
24	177	157.4	0.2	787	2,000
25	1224	1204.4	0.2	6022	1,500

PNL Average Disintegrations/minute = 721
GPU Average Disintegrations/minute = 2205
GPU Goal - Disintegrations/minute = <50000

Table D.20 Reactor Building: Area in Front of Equipment Hatch (RB305)

Background Count Rate =
16.7 counts per minute

Sample Number	Gross counts per minute	Net counts per minute	Efficiency	PNL measured disintegrations per minute	GPU measured disintegrations per minute
31	454	437	0.2	2187	20000
32	98	81	0.2	407	18000
33	54639	54622	0.2	273112	210000
34	7631	7614	0.2	38072	40000
35	119	102	0.2	512	60000
36	7645	7628	0.2	38142	50000
37	8746	8729	0.2	43647	90000
38	6286	6269	0.2	31347	50000
39	1261	1244	0.2	6222	24000
40	2333	2316	0.2	11582	150000
41	4887	4870	0.2	24352	60000
42	10870	10853	0.2	54267	200000
43	4071	4054	0.2	20272	12000
44	2785	2768	0.2	13842	40000
45	3538	3521	0.2	17607	15000
46	4629	4612	0.2	23062	8000
47	7540	7523	0.2	37617	26000
48	10720	10703	0.2	53517	30000
49	13401	13384	0.2	66922	10000
50	21495	21478	0.2	107392	8000
51	19966	19949	0.2	99747	50000
52	22956	22939	0.2	114697	210000
53	2431	2414	0.2	12072	20000
54	5361	5344	0.2	26722	100000
55	59026	59009	0.2	295047	10000
56	106429	106412	0.2	532062	5992000

PNL Average Disintegrations/minute = 74785
GPU Average Disintegrations/minute = 288577
GPU Goal - Disintegrations/minute = < 50,000