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ARCL CALCULATIONS FOR DECOMMISSIONING THE 116-H STACK (132-H-1)

Author

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ARCL CALCULATIONS FOR DECOMMISSIONING THE 116-H STACK

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TABLE OF CONTENTS

i APPROVALS
ii TABLE OF CONTENTS
iii FIGURES & TABLES
iv SUMMARY

Page

1.0 INTRODUCTION TO ALLOWABLE RESIDUAL CONTAMINATION LEVEL METHODOLOGY 1

2.0 116-H STACK LOCATION AND DESCRIPTION 1

3.0 RADIOLOGICAL CHARACTERIZATION 5

3.1 Core Samples 5
3.2 Radiological Instruments Used for Core Sample Analysis ... 9

4.0 DETERMINATION OF THE ALLOWABLE RESIDUAL CONTAMINATION LEVELS (ARCL) FOR THE 116-H STACK 11

4.1 ARCL Methodology 11
4.2 Residential/Construction Exposure Scenario 11
4.3 Assumptions for the ARCL Calculations 12

4.3.1 Concrete Density 12
4.3.2 Depth of Penetration 12
4.3.3 Radioactive Concentrations 12
4.3.4 Exposure Scenario 13

4.4 ARCL Calculation 16

5.0 DETERMINATION OF RESIDUAL CONTAMINATION LEVELS IN THE 116-C RUBBLE 16

6.0 SUMMARY AND CONCLUSION 18

7.0 REFERENCES 18

FIGURES

		Page
FIGURE 1	Hanford 100 Area Site Map	2
FIGURE 2	100-H REactor Area	3
FIGURE 3	Aerial Photograph Showing 116-H Stack Prior to Demolition	4
FIGURE 4	105-H Reactor Facility Showing 116-H Burial Trench	6
FIGURE 5	Photograph of Demolished 116-H Stack in Burial Trench	7
FIGURE 6	North Elevation of 116-H Stack Showing Locations of Core Samples	8
FIGURE 7	Radiological Profile of the 116-H Stack Showing Activities vs. Height of Stack	15
FIGURE 8	Comparison of ARCL Values & Residual Activity - 116-H Stack	19

TABLES

TABLE 1	116-H Core Sample Analytical Data	10
TABLE 2	116-H Core Sample Analytical Data	14
TABLE 3	ARCL Calculation	17

SUMMARY

This document describes how the Allowable Residual Contamination Level (ARCL) methodology and residual activity calculations were used in conjunction with the in situ alternative to decommission the 116-H Stack. The ARCL value for the stack burial site is 196 pCi/g and the residual concentration of the stack rubble is 38 pCi/g. The residual concentration is about 19% of the ARCL value and represents a site dose of approximately 4.8 mrem/year. The total radionuclide inventory in the buried rubble is approximately 12 millicuries.

Application of the ARCL methodology to the 116-H Stack was very straightforward and simplified because the structure contained only one contaminated surface, i.e., the interior surface area of the stack. Specific activity of the contamination was assumed to be uniformly distributed over the inner surface. The depth of penetration of radionuclides into the inner surface of the stack was determined to be about 1 cm, or 3/8-in. Based on the isotopic analysis of the concrete core samples and the assumptions contained in this report, the total curie inventory is considered an estimated quantity and is not meant to be a precise measurement of the radioactivity in the stack. This approach yields a curie inventory slightly higher than would normally be expected and is considered to be conservative and consistent with the ARCL methodology. Therefore, the estimated dose of 4.8 mrem/year represents a theoretical maximum dose to a maximally exposed individual based on the Residential/Construction Exposure Scenario.

The calculations in the document have been prepared in accordance with UNI-2522, Allowable Residual Contamination Levels for Decommissioning Facilities in the 100 Areas of the Hanford Site, and as authorized by the Department of Energy in a letter to Hanford contractors, dated July 3, 1984, from the Manager, DOE-RL.

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1.0 INTRODUCTION TO ALLOWABLE RESIDUAL CONTAMINATION LEVEL METHODOLOGY

The purpose of this report is to document the final radiological characterization and to demonstrate the Allowable Residual Contamination Level (ARCL) methodology resulting in the unrestricted release of the 116-H Stack. The ARCL value is a calculated limit which establishes the amount of radioactive contamination that may remain in a structure when it is demolished and buried in situ. The ARCL value for the 116-H Stack was based on the analytical results of core samples taken from the interior surface of the stack. The inner surface of the stack was contaminated and considered to be one uniform strata. Once demolished, the contaminated strata considered was no longer distinguishable within the mixture of rubble in the burial trench. Therefore, the residual activity in the rubble was calculated separately and compared to the ARCL value for the decommissioned facility site. A residual concentration in the rubble greater than the ARCL value would have indicated that the site dose of 25 mrem/year had been exceeded and that some remedial action would have been necessary prior to demolition. A residual concentration in the rubble that is less than the ARCL value indicates the site dose is less than 25 mrem/year and that no remedial action is required. In the case of the 116-H Stack, residual contamination in the rubble was well below the ARCL value. Residual and ARCL values, calculated separately, are contained in this report.

Calculations consider only the 200-ft concrete stack and the inner floor surface inside the stack. The metal intake plenum, or flue, was disconnected from the stack and disposed of separately. ARCL calculations were based upon an unrestricted use mode at the time of release based on an annual dose rate of less than 25 mrem/year and a contamination condition of 1-4 meters deep in soil. Residual contamination levels in the stack rubble were based on the total mass of concrete (excluding the foundation) and no credit for additional dilution was taken for the 1-4 meters of dirt fill over the site; only that allowed for in the ARCL methodology was considered.

2.0 116-H STACK LOCATION AND DESCRIPTION

The 100-H Area is located within the Hanford Site (Figure 1) on the south bank of the Columbia River, in southeastern Washington State. The 116-H Stack was constructed of concrete and rebar and extended 200 ft above ground level. The stack was located on the south side of the 105-H Reactor Building adjacent to the ventilation wing (Figure 2). Figure 3 is an aerial photograph of the 100-H Reactor complex showing the 116-H Stack prior to demolition.

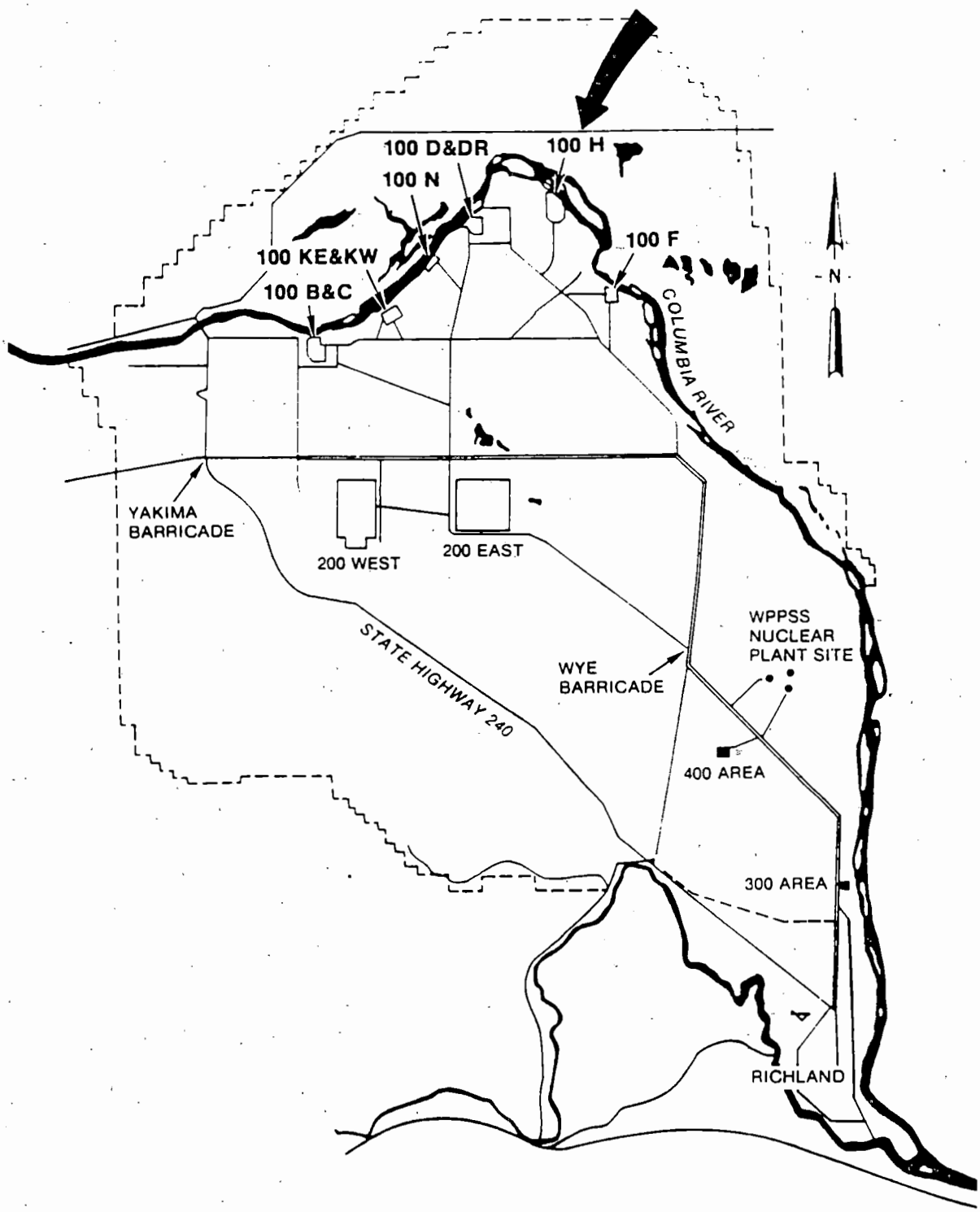

Figure 1. Hanford 100 Area Site Map.

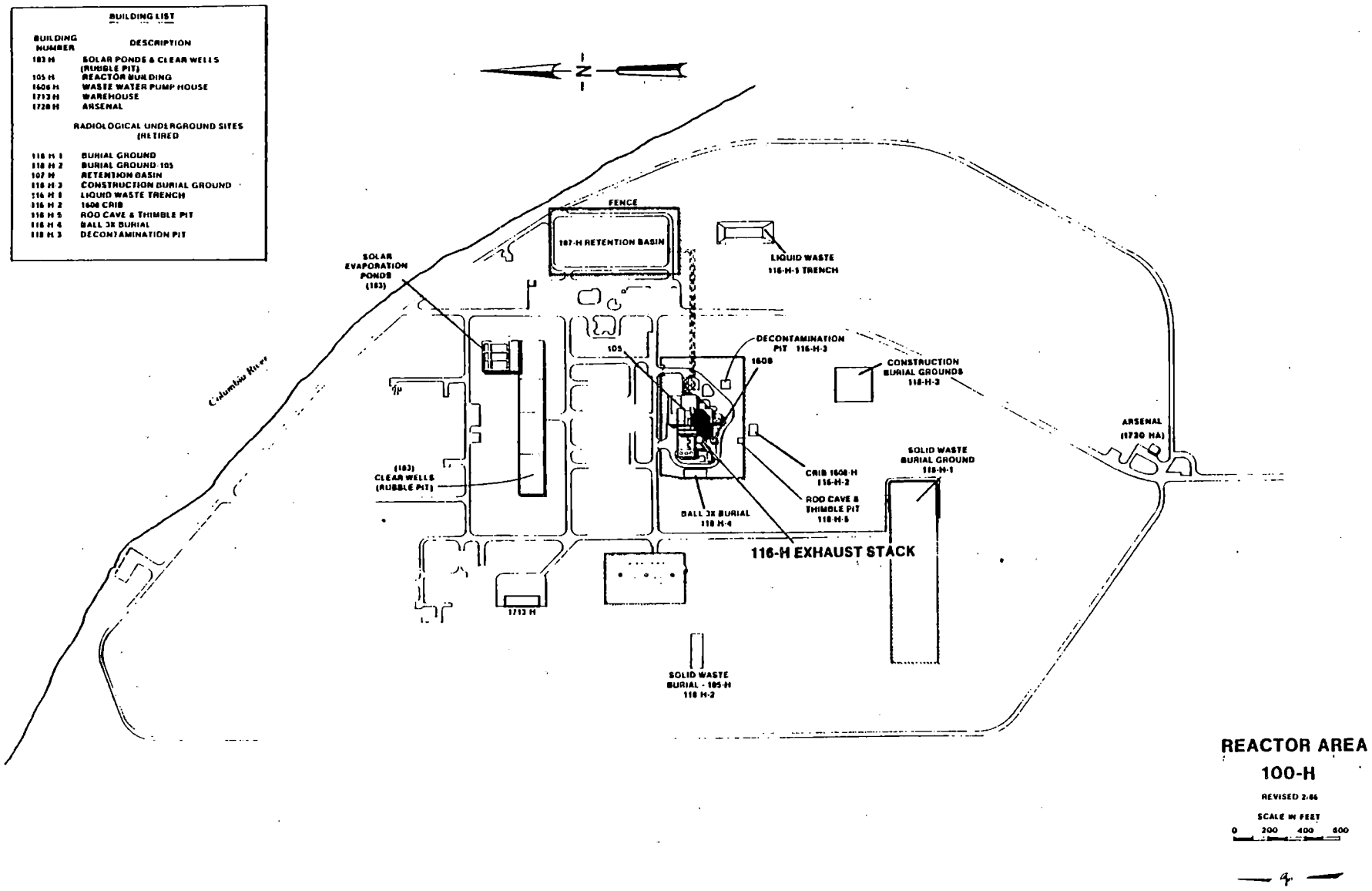

Figure 2. 100-H Reactor Area.

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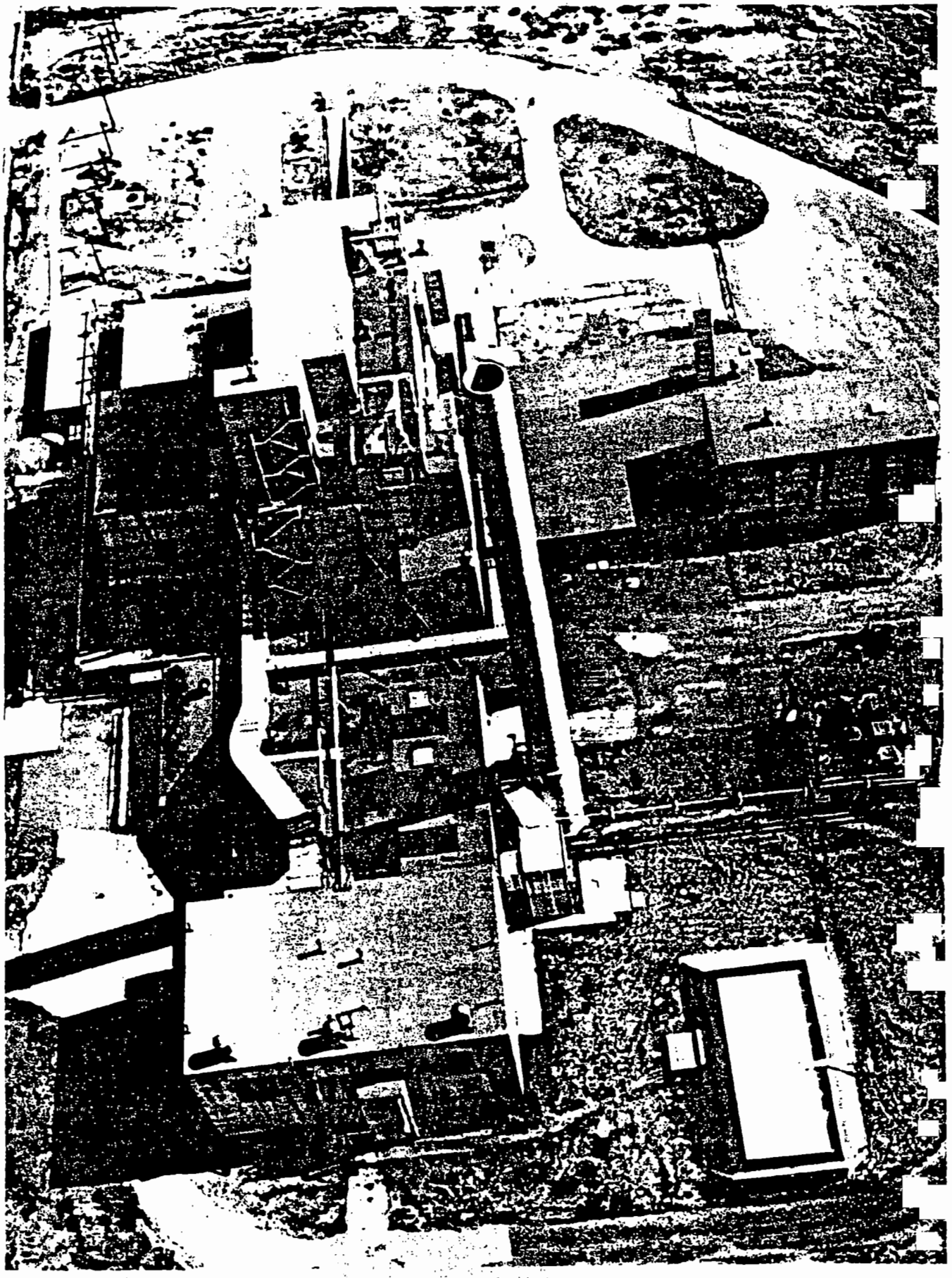

Figure 3. Aerial Photograph Showing 116-H Stack Prior to Demolition

2.0 116-H STACK LOCATION AND DESCRIPTION (Cont'd)

The stack burial trench was excavated in a south by southwesterly direction from the base of the stack, between the 117-H Filter Building and the 1608-H Lift Station Building (Figure 4). The dimensions of the burial trench were approximately 12 ft deep, 30 ft wide, and 200 ft long.

The stack and foundation were demolished by explosives on September 16, 1983 (Reference 1). Demolition charges caused the stack to fall into the excavated trench (Figure 5). After demolition of the foundation, about one third of the foundation rubble was removed and placed in the burial trench. This was partly done to make room for clean fill over the foundation site and to confine rubble associated with the stack floor in the stack burial trench. The remainder of the foundation was buried in place and covered with at least one meter of clean fill. The 116-H demolition site was then graded to conform with the natural area topography.

3.0 RADIOLOGICAL CHARACTERIZATION

3.1 Core Samples

Concrete core samples were collected from the 116-H Stack for the purpose of establishing isotopic inventory and depth of radionuclide penetration into the stack interior surface. Core samples were obtained using a 4-in. diamond concrete core drill and portable drive unit. Cores were drilled from the outside surface of the stack inward. A total of five core samples were obtained: one core sample each from the 15-ft, 19-ft, 30-ft, 56-ft, and 80-ft elevations. Figure 6 shows the 116-H Stack and the locations of the core samples.

Depth of radionuclide penetration was determined by removing three successive layers from the interior surface of the core. First, approximately 1/8 in. of concrete was chipped off the core face (stack inner surface). The core was checked with a portable GM survey meter with P-11 probe and the exposed surface of the core indicated levels of radiation greater than 200 cpm per probe area (probe size 12.5 cm^2.

A second layer was removed from the core comprising about 1/8 in. of concrete. The surface of the core was again checked with the same portable GM instrument and no readings above 200 cpm per probe area were observed. A third layer of about 1/8 in. was also removed from the core, and the core was again surveyed with the portable GM instrumentation. No readings above 200 cpm per probe area (12.5 cm^2) on the surface of the core were observed. Approximately 1 cm of concrete was removed from the inside surface of each core.

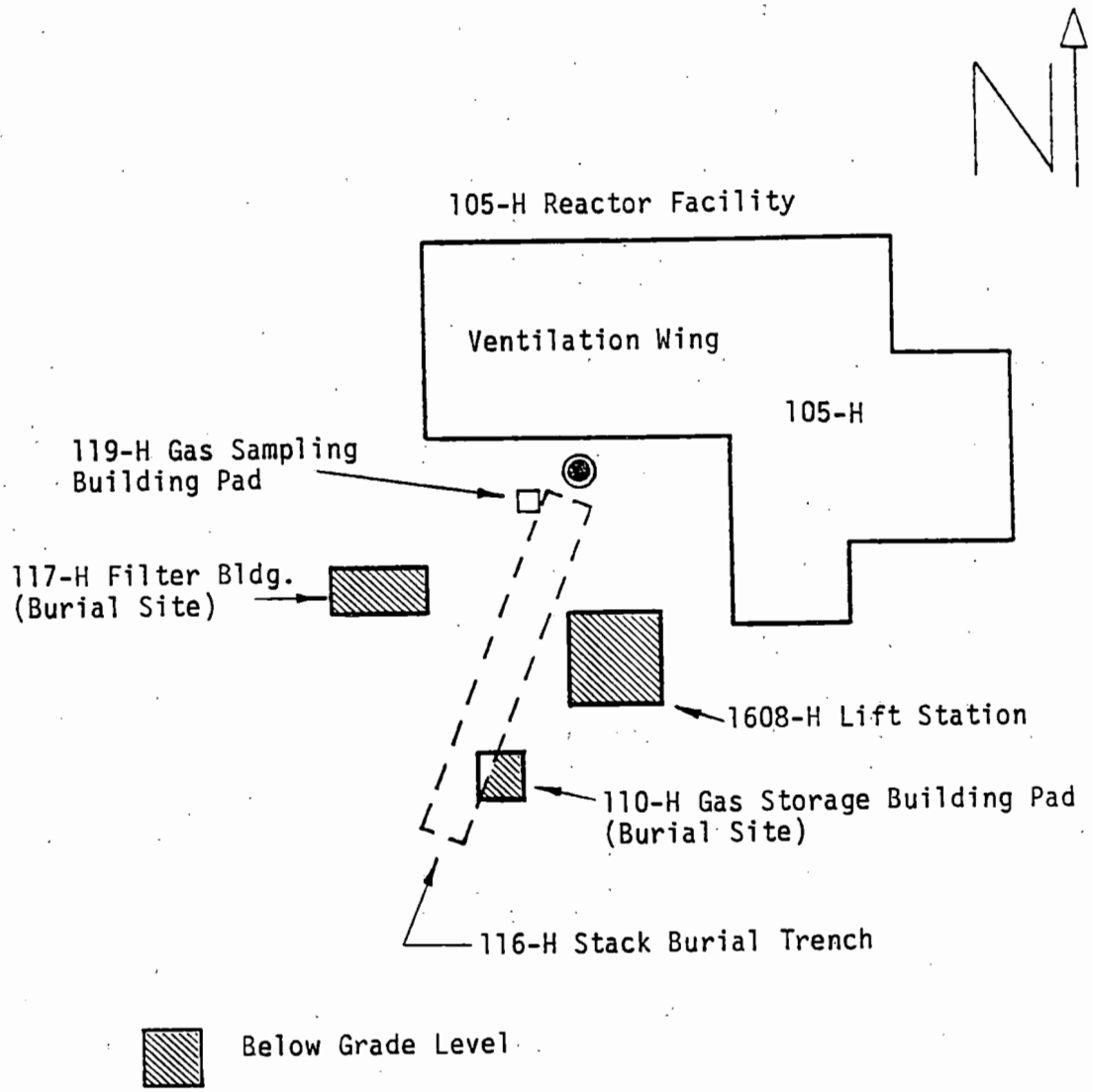

Figure 4. 105-H Reactor Facility Showing 116-H Burial Trench

Figure 5. Photograph of Demolished 116-H Stack in Burial Trench

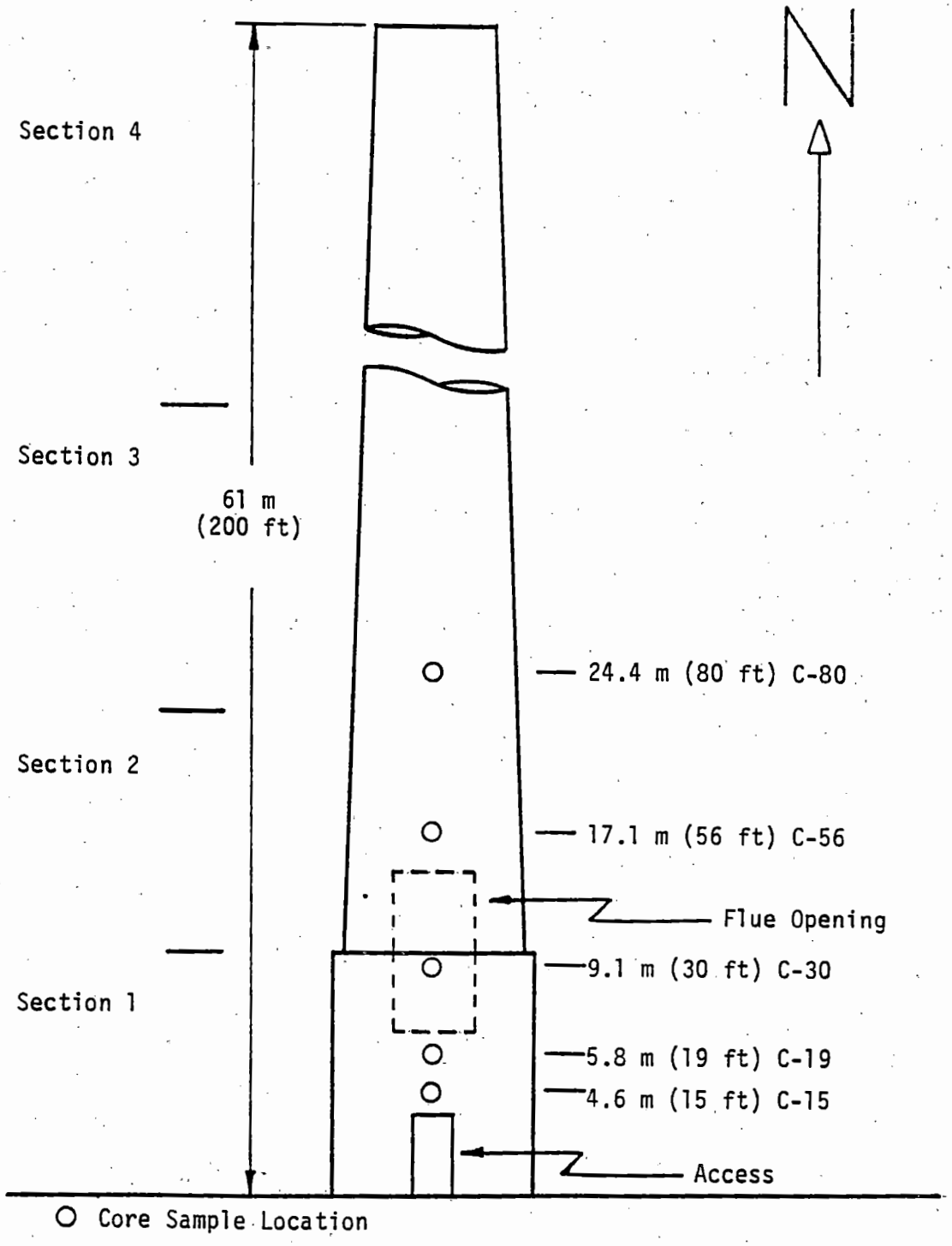

Figure 6. North Elevation of 116-H Stack Showing Locations of Core Samples

3.1 Core Samples (Cont'd)

Every precaution was made to prevent cross contamination of the samples removed from the cores. Each sample was given a unique identification number with reference to its elevation in the stack and distance from the inside surface of the stack. The identification number is composed of three parts consisting of the following notation: C-X-Y. The "C" stands for concrete core, the "X" indicates the elevation of the sample, and "Y" indicates the sequence the sample was removed from the core, e.g., 1 = surface, 2 = second layer, and 3 = third layer. (See Table 1 for analytical results.)

3.2 Radiological Instruments Used for Core Sample Analysis

Radiological Instruments

- Samples from Core 1

  The following analyses were performed by:
  United States Testing Co., Inc.
  2800 George Washington Way
  Richland, Washington 99352

  Gamma scan - July 19, 1983; alpha/beta - July 26, 1983; Carbon-14 - August 5, 1983; strontium-90 - October 5, 1983

- Samples from Cores 2-5.

  Laboratory measurements for cobalt-60, cesium-137, europium-152, and europium-154, were made using the Nuclear Data, Model No. 60, Multi-Channel Analyzer (MCA) located in Room 50, at the 100-N Reactor Facility. The MCA was equipped with a 3 in. x 3 in. High Purity Germanium Scintillation Detector. The MCA is operated and maintained by the Radiation & Water Quality Control Section, 100-N Area. Calibration and Quality Control procedures were conducted in accordance with UNI-M-76 REV1, Effluent Radioanalytical Program (Reference 4).

  Total alpha analyses were made with the Canberra, Model 2404, Low Background Alpha/Beta/Gamma Gas Proportional Counter located at the Decommissioning Services Counting Laboratory, 183-KE, 100-K Area.

- Samples from Core 4

  The three samples (layers) from core 4 were sent to Pacific Northwest Laboratories for strontium-90 analysis in January 1987. The purpose for this was to determine the strontium-90 activity in the core with the highest total activity and to verify the depth penetration of strontium-90 in the concrete.

Table 1. 116-H Core Sample Analytical Data

STACK SECTION	CORE SAMPLE(a)	H-3	C-14	Co-60	Sr-90	Cs-137	Eu-152	Eu-154	GROSS ALPHA
					<----- pCi/g ----->				
	No. 1 (b)								
1	C-15-1	22.4	249	0.617	8.04	12.8	0.637	ND	(c)0.541
	C-15-2	15.7	231	0.197	0.314	2.07	ND	ND	1.08
	C-15-3	15.0	207	(c).055	0.160	0.314	ND	ND	(c)0.541
	No.2								(e)
1	C-19-1	*	*	0.363	*	17.3	ND	ND	15.2
	C-19-2	*	*	ND	*	ND	ND	ND	19.2
	C-19-3	*	*	ND	*	ND	ND	ND	3.2
	No.3								(e)
1	C-30-1	*	*	1.40	*	25.6	ND	ND	6.2
	C-30-2	*	*	0.807	*	0.981	ND	ND	12.2
	C-30-3	*	*	ND	*	ND	ND	ND	0.2
	No.4 (d)								(e)
2	C-36-1	*	*	4.07	9.49	69.4	5.77	ND	21.2
	C-36-2	*	*	1.35	0.92	5.35	ND	ND	6.2
	C-36-3	*	*	ND	0.77	0.768	ND	ND	2.2
	No.5								(e)
3	C-90-1	*	*	1.82	*	30.1	ND	ND	27.2
	C-90-2	*	*	ND	*	3.02	ND	ND	9.2
	C-90-3	*	*	ND	*	ND	ND	ND	ND

(a) Reference Figure 1
(b) Analyses performed by US Testing Co.
(c) Instrument detection limit for isotope.
(d) Strontium-90 analyses performed by PNL.
(e) Counted with Canberra 2400 Gas Proportional Scaler, 183KE HP Lab.
ND Not Detected
* Analysis not performed.

Survey Instruments

Portable survey instruments for beta-gamma and alpha were maintained and calibrated by the Instrument Calibration and Evaluation Section, Pacific Northwest Laboratories, located in the Hanford 300 Area.

Eberline Instrument Corp., Model BNW-1 with P-11 "Pancake" probe (12.5 cm^2).

Eberline Instrument Corp., Model E-140B with alpha scintillation detector.

4.0 DETERMINATION OF THE ALLOWABLE RESIDUAL CONTAMINATION LEVELS (ARCL) FOR THE 116-H STACK

4.1 ARCL Methodology

The objective of the analysis of radionuclides in soil or facilities is the determination of whether radioactively contaminated sites require further decontamination or remedial action prior to demolition and burial in situ. The ARCL value for the 116-H Stack was calculated to be 196 pCi/g. Based on this value and the calculated residual radioactive concentration of the stack rubble, no additional decontamination was required prior to demolition and burial in situ. The ARCL methodology for the 116-H stack was based on the following criteria:

- Residential/Construction Exposure Scenario
- Unrestricted use at time of release based on an annual dose rate of less than 25 mrem/year.
- Contamination condition of confined soil 1 to 4 meters deep.
- Assumed average activity of 851 pCi/g distributed over 100% of the inside surface of the stack. (Section 4.3.3)

4.2 Residential/Construction Exposure Scenario

The residential/construction scenario is based on the intruder/construction scenario developed by the U.S. Nuclear Regulatory Commission in the Draft Environmental Impact Statement in support of 10 CFR Part 61 (U.S. NRC 1981). For this scenario, an individual is assumed to dig a basement for a home into a subsurface radioactive soil (or debris) zone. The radioactive soil is assumed to be 2.5 m from the surface. Typical surface areas for a house are assumed to be 20 m by 10 m, for an area of 200 m^2. This dimension

4.2 Residential/Construction Exposure Scenario (Cont'd)

is assumed for the base of the foundation hole. The foundation hole is assumed to be 3.5 m deep, with surface dimensions of 26 m by 16 m. The total excavation is assumed to involve about 200 m^3 of contaminated rubble mixed with 800 m^3 of clean overburden soil. The resulting 1000 m^3 has a radionuclide concentration that is 20% of the original concentration of contaminated soil. The contaminated soil mixture is assumed to be used as fill around the house and distributed uniformly within a 25-m radius around the house.

For the residential/construction scenario, dose estimates are made for the individual both during and after the construction activities. The most restrictive individual dose resulting from both scenarios for each radionuclide is then used in the ARCL calculation. During construction the individual is assumed to spend 500 hours (over about a three month period) on the site. The individual is assumed to inhale air with a dust concentration of 0.1E-4 g/m^3 and to be exposed to direct radiation for the 500-hour construction period. After the house is constructed, the individual is assumed to reside there and conduct activities similar to those identified by the NRC for the intruder/agriculture scenario.

4.3 Assumptions for the ARCL Calculations

4.3.1 Concrete Density

The density of the concrete was assumed to be 2.1 g/cm^3 based on standard industrial determination procedures. The rebar in the concrete was not considered in the assumption.

4.3.2 Depth of Penetration

For purposes of establishing radionuclide concentrations and isotopic inventory, the maximum penetration depth of all nuclides was assumed to be no greater than 1 cm.

4.3.3 Radioactive Concentrations

Average Core Concentrations

The 116-H Stack was designed and constructed in four sections. Each section represented a change in diameter and wall thickness. Three core samples were taken from stack section 1. One core sample was taken from stack section 2 and one from stack section 3. Stack section 4 was not sampled (Figure 6). Of the three core samples from section 1 (cores No. 1, No. 2 and No. 3), core sample No. 3 had the highest total activity and was assumed to be representative of the activity in section 1.

Average Core Concentrations (Cont'd)

Isotopic concentrations for each core sample were established by averaging the activity of the isotopes in the three layers of concern (Table 2).

It is assumed that isotopic concentrations within each stack section were relatively consistent, and that increases and decreases in isotopic activity are directly related to the abundance of cesium-137. (It is understood that there may not have been any consistent relationship between the isotopic concentrations in the stack. However, for estimating purposes, it is assumed to be reasonable.) The assumption is based on the relatively consistent ratios of cobalt-60 and cesium-137 between the core samples. The mean ratio between cobalt-60 and cesium-137 in core samples No. 1, No. 3, No. 4, and No. 5 is 1:16, with a standard deviation of 3.

Weighted Averages

The isotopic concentrations in Sections 1 through 3 were weighed against the percent surface area of the respective section. Since sample No. 1 from the 15-foot level was analyzed for all isotopes, ratios were calculated for hydrogen-3, and carbon, using cesium-137 as the reference isotope. From these ratios hydrogen-3 and carbon concentrations were calculated for core samples No. 3, No. 4 and No. 5. These calculated concentrations are identified on Table 2 by brackets.

The average concentration for the stack is determined by adding the weighted concentrations of each section of the stack. Section 4, which was not core sampled, was assumed to be contaminated to the same degree as the total of sections 1 through 3. Based on the contamination profile (Figure 7), this assumption appears to be conservative and consistent with the ARCL methodology.

4.3.4 Exposure Scenario

The Residential/Construction scenario assumes that an individual digs a basement for a home into the subsurface radioactive soil (or debris) zone. The radioactive soil is assumed to be 2.5 m from the surface. The surface area for the house is assumed to be 20 m x 10 m. The foundation hole is assumed to be 3.5 m deep. The total excavation is assumed to involve about 200 m^3 of contaminated rubble mixed with

Table 2. Average and Total Concentration for the 116-H Stack

CORE SAMPLE	H-3	C-14	(a) Co-60	Sr-90	(a) Cs-137	(a) Eu-152	GROSS ALPHA	SECTION m	% AREA(b)
	<----- pCi/g ----->								
No.1 Avg(c)	19	230	0.29	2.8	5.1	0.21	0.72		
Ratio	3.5	45			1				
								1	19.39%
No.3 Avg	[31]	[400]	0.74	3.7(d)	8.9	0.00	6.2(e)		
wt. conc	6.0	79	0.14	0.72	1.7	0.00	1.2		
No.4 Avg	[88]	[1125]	1.8	3.7	25	1.9	10(e)	2	15.98%
wt. conc.	14	180	0.29	0.59	4.0	0.30	1.6		
No.5 Avg	[39]	[500]	0.6	3.7(d)	11.0	0	12(e)	3	25.00%
wt. conc.	8.9	120	0.14	0.85	2.5	0	2.8		
AVERAGE CONC.	29	330	0.57	2.2	8.2	0.3	5.6	1-3	58.37%
REMAINDER OF STACK	29	380	0.57	2.2	8.2	0.3	5.6	4	41.63%
TOTAL FOR STACK	58	760	1.1	4.4	16	0.6	11	1-4	100%

(a) Identified by gamma spectrum analysis. Counting errors range from 24 % to 118 %.
(b) Percent interior surface area of stack.
(c) Analyses performed by US Testing Co.
(d) Estimated value from Core Sample 4.
(e) Counted with Canberra 2400 Gas Proportional Scaler, 183KE Hp Lab. Assumed to be Pu-239.
[ ] Calculated concentrations derived from ratios established in Core Sample 1.
Explaination of weighted concentration determination follows in text of Appendix.

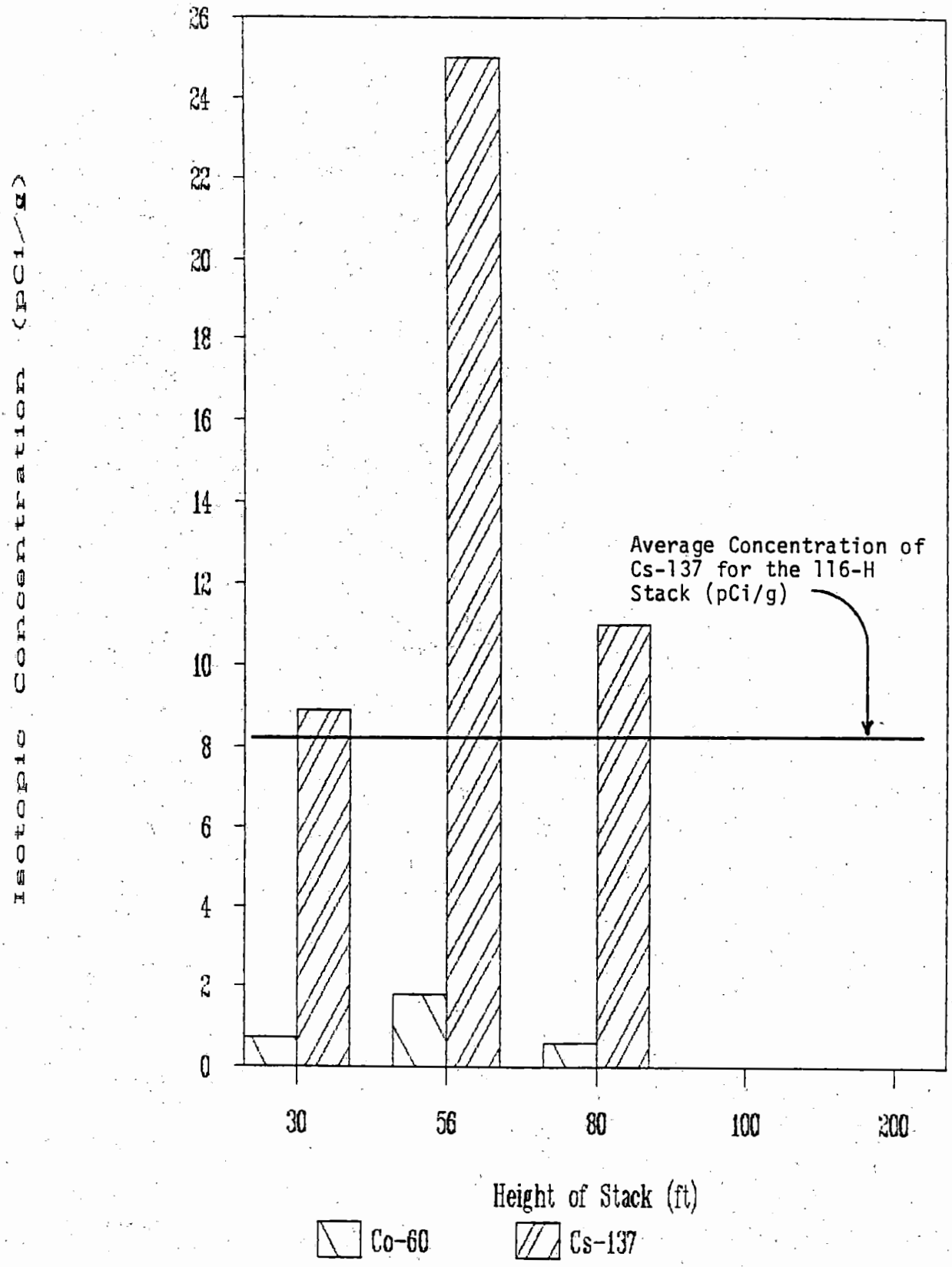

Figure 7. Radiological Profile of the 116-H Stack Showing Concentration vs. Height of Stack

4.3.4 Exposure Scenario (Cont'd)

800 m^3 of contaminated rubble mixed with 800 m^3 of clean overburden. Therefore, based on this scenario, only a fraction of the contaminated stack rubble would be excavated; wherever the 20 m x 10 m foundation hole happened to be located. For the purposes of this estimate of the site dose, it was assumed that the entire inventory of the stack would be excavated from the foundation hole.

4.4 ARCL Calculation

The ARCL calculations for the 116-H Stack are presented in Table 3. The ARCL value is a calculated concentration of radioactive contamination that becomes the controlling level of contamination that must not be exceeded. The ARCL value is 196 pCi/g, and represents a yearly site dose rate of 25 mrem/year to a maximally exposed individual. The residual activity in the stack rubble, buried 1-4 meters deep in soil, is 38 pCi/g. Determination of the residual activity in the rubble is outlined in the following section.

The calculations in the document have been prepared in accordance with UNI-2522, Allowable Residual Contamination Levels for Decommissioning Facilities in the 100 Areas of the Hanford Site, and as authorized by the Department of Energy in a letter to Hanford Contractors, dated July 3, 1984, from the Manager, DOE-RL (References 5 and 6).

5.0 DETERMINATION OF RESIDUAL CONTAMINATION LEVELS IN THE 116-C RUBBLE

Calculations for surface area, volumes, mass and residual contamination in the stack rubble are presented in Appendix A. The following data is a summary of the residual contamination calculations.

STEP 1 Total Surface Area of Stack Interior:

6.4E+6 cm^2

STEP 2 Total Mass of Contaminated Concrete:

1.4E+7 g

STEP 3 Total Mass of Stack and Foundation:

3.2E+8 g

STEP 4 Total Isotopic Inventory (Based on the weighted average concentration of 850 pCi/g x mass in Step 2):

1.2 E+10 pCi

Table 3. ARCL Calculation

FACILTIY NAME: 116-H Stack

CHECKED BY: PW Riffe
DATE: 4/30/87

PREPARER'S NAME: JF Beckstrom JFB

DATE PREPARED: 4-1-87

Determination of ARCL Dose Factors to Enter From Table 5.2.2., UNI-2522. Check one Use Mode and one Contamination Condition.

Use/Contamination Condition	Contaminated Surfaces Ci/m2 or dpm/100cm2	Surface Soil (pCi/gm)	Soil 1-4 m Deep	X	Soil >5 m Deep (pCi/gm)
Restricted Use @ 0.5 rem/yr	Column 1	Column 4	Column 5		Column 6
Controlled Use @ 0.5 rem/yr	Column 2	Column 4	Column 5		Column 6
Unrestricted Use @ 0.025 rem/yr	Column 3	Column 4	Column 5	X	Column 6

5. Radionuclides concerned (list)	6. Radionuclide Concentrations (Available Units)	6a. Radionuclide Concentrations (Ci/m2 or pCi/gm)	7. Scenario-specific ARCL Dose Factors Step 4; (rem/yr)/ [Ci/m2 or pCi/gm])	8. Product of col. 6a. and 7. (rem/yr)/ (pCi/gm)	9. ARCL-product of Column 6a. & Item 8b. (pCi/gm)
H-3	58.00	0.0681	3.40E-11	2.32E-12	13.36
C-14	760.00	0.8930	1.70E-08	1.52E-08	175.10
Co-60	1.10	0.0013	2.20E-03	2.84E-06	0.25
Sr-90	4.40	0.0052	2.20E-02	1.14E-04	1.01
Cs-137	16.00	0.0188	5.30E-04	9.96E-06	3.69
Eu-152	0.60	0.0007	1.00E-03	7.05E-07	0.14
Eu-154	0.00	0.0000	1.10E-03	0.00E+00	0.00
Pu-239	11.00	0.0129	1.80E-05	2.33E-07	2.53
Am-241	0.00	0.0000	3.00E-05	0.00E+00	0.00
		0.0000		0.00E+00	0.00
TOTAL	851.10				

6b. Total: 1.00

8a. Total: 1.27E-04

9a. Total: 196.1

8b. Annual Dose Limit Divided by 8a. (0.025 rem/yr Divided By 8a.) 196.1

ARCL VALUE

COMMENTS:
Concentrations in column 6. are mean values from Table 2. Isotopic Concentrations Used to Estimate Total Inventory in the 116-H Stack.

5.0 DETERMINATION OF RESIDUAL CONTAMINATION LEVELS IN THE 116-C RUBBLE (Cont'd)

STEP 5 Residual Activity of Stack and Foundation Rubble:

38 pCi/g

6.0 SUMMARY AND CONCLUSION

The 116-H Stack was demolished by explosives and buried in situ at a depth of 1-4 meters in soil. The ARCL value for the stack burial site is 196 pCi/g and the residual concentration of the rubble is 38.5 pCi/g. A comparison of these two values can be made by referring to Figure 8, where concentrations are plotted for each isotope identified. The total residual activity for the site is about 19% of the ARCL value and represents a site dose of approximately 4.8 mrem/yr. The total radionuclide inventory in the buried rubble of the 116-H Stack is approximately 12 millicuries.

ARCL calculations were based on the Residential/Construction Exposure Scenario as outlined in Section 4.2 of this report. Based on the calculations contained in this report, the 116-H Stack was decommissioned at a level less than the ARCL value and the dose to a maximally exposed individual would be less than 25 mrem/year to the whole body or to any organ. The 116-H Stack burial site is, therefore, released for unrestricted use and no further remedial action is needed.

7.0 REFERENCES

1. Powers, E. W., and J. M. Steffes, 116-C, -F and -H Reactor Exhaust Ventilation Stack Demolition Hanford Site Individual Facility Report, UNI-3855, UNC Nuclear Industries, Richland, WA, 1986.

2. Dorian, J. J. and V. R. Richards, Radiological Characterization of the Retired 100 Areas, UNI-946, UNC Nuclear Industries, Richland, WA, 1978.

3. Westover, W. G., Radiation Control Manual, UNI-M-38 REV1, UNC Nuclear Industries, Richland, WA, 1982.

4. Diediker, L. D., and T. H. Sunday, Jr., Effluent Radioanalytical Program, UNI-M-76 REV1, UNC Nuclear Industries, Richland, WA.

5. Kennedy, W. D., Jr. and B. A. Napier, Allowable Residual Contamination Levels for Decommissioning Facilities in the 100 Areas of the Hanford Site, PNL-4722/UNI-2522, Pacific Northwest Laboratory, Richland, WA, 1983.

6. Lawrence, M. L., "Radiological Release Criteria for Surplus Contaminated Facilities on the Hanford Site," DOE-RL Letter to Hanford Site Contractors, July 3, 1984.

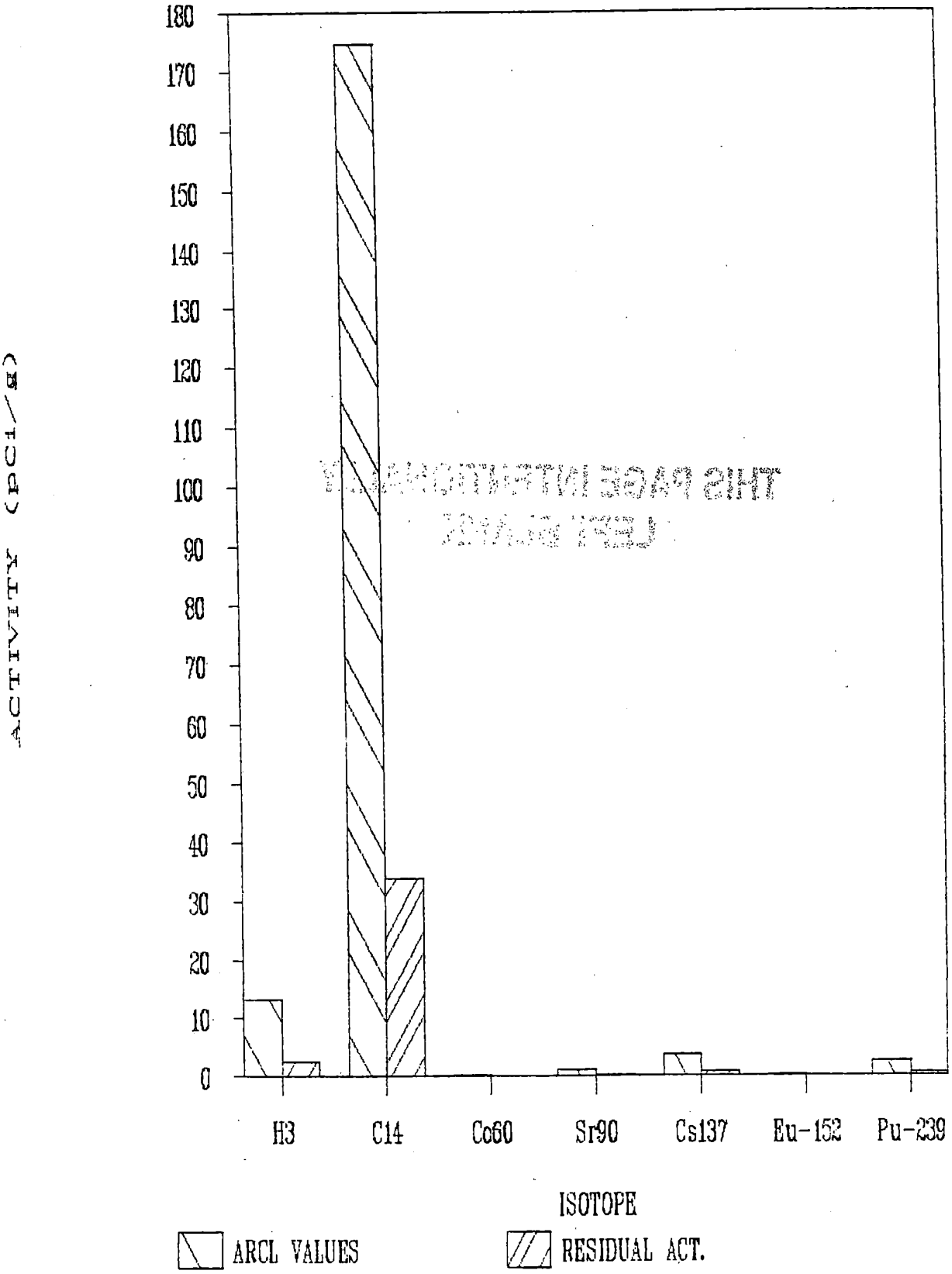

Figure 8. Comparison of ARCL Values and Residual Activity - 116-H Stack

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APPENDIX A

PROJECT: 116-H Stack
TITLE: Surface Area and Isotopic Inventory Calculations.

PREPARED BY: FBeckstrom DATE: 4-29-87
CHECKED BY: RW Huffman DATE: 4/30/87

REFERENCE: Design Analysis, Kaiser Eng., WO B-32086/v248C0, 8/17/83. (Attached)

FORMULA: A=pi(r1+r2) $\sqrt{h^2 + (r1-r2)^2}$ (Truncated Cone)

CALCULATIONS: Performed with Symphony computer program.

PURPOSE: Establish isotopic concentrations for the entire 116-H Stack that can be:

1) Used to calculate the ARCL Value.
2) Used to estimate the isotopic inventory in the 116-H Stack.
3) Used to compare ARCL Value with residual radionuclide concentration in stack rubble.

1. ESTABLISH ISOTOPIC CONCENTRATIONS FOR CALCULATING THE ARCL VALUE.

Table 1 lists the results of radiological analysis from 5 core samples collected from the interior of the 116-H Stack, up to the 80 foot level.

Sample Location

Based on as-built drawings, the 116-H stack was constructed in 4 sections with varying diameters and wall thicknesses. Each section of the stack is identified in Figure 1 along with the locations of the core samples.

Core Samples

Three layers of concrete, each approximately 1/8 inch thick, were removed from the interior end of each core sample to determine the penetration depth of radionuclides. Each layer was labled and analyzed separately.

The three samples (layers) from Core Sample 1 were sent to US Testing for analysis. US Testing analyses consisted of:

Beta analysis- H-3, C-14 and Sr-90.
Complete gamma scan- only Co-60, Cs-137 and Eu-152 were indentified.
Determination for total alpha.

The three sample layers from Core Samples 2-5 were analyzed at UNC facilities.

Complete gamma scan- Room 50, 100-N
Determination for total alpha- 183-KE HP Lab. Facility

The Three sample layers from Core Sample 4 were then sent to PNL for Sr-90 analysis.

Analytical Results

Analytical results showed consistent activity versus depth of penetration in all 5 core samples The highest activity layer in each of the core samples was the surface layer. The activity consistently decreased with each successive layer removed from the core. The individual core sample with the highest activity was Core Sample 4, from the 56 foot level. This was expected since Core Sample 4 was located above and across from where the exhaust air entered into the into the stack. The location of this high activity region in the 116-H stack coincided with the same regions of high activity in the 116-F, 116-C and 108-B stacks, which were characterized and demolished in the same general time frame as the 116-H stack.

Table 1. 116-H Core Sample Analytical Data.

STACK SECTION	CORE SAMPLE(a)	H-3	C-14	Co-60	Sr-90	Cs-137	Eu-152	Eu-154	GROSS ALPHA
		<----- pCi/g ----->							
	No. 1 (b)								
1	C-15-1	22.4	249	0.617	8.04	12.9	0.637	ND	(c)0.541
	C-15-2	15.7	231	0.197	0.314	2.07	ND	ND	1.08
	C-15-3	15.0	207	(c).055	0.160	0.314	ND	ND	(c)0.541
	No.2								(e)
1	C-19-1	*	*	0.363	*	17.8	ND	ND	15.2
	C-19-2	*	*	ND	*	ND	ND	ND	19.2
	C-19-3	*	*	ND	*	ND	ND	ND	3.2
	No.3								(e)
1	C-30-1	*	*	1.40	*	23.6	ND	ND	6.2
	C-30-2	*	*	0.807	*	0.981	ND	ND	12.2
	C-30-3	*	*	ND	*	ND	ND	ND	0.2
	No.4 (d)								(e)
2	C-56-1	*	*	4.07	9.49	69.4	5.77	ND	21.2
	C-56-2	*	*	1.35	0.92	5.35	ND	ND	6.2
	C-56-3	*	*	ND	0.77	0.768	ND	ND	3.2
	No.5								(e)
3	C-80-1	*	*	1.82	*	30.1	ND	ND	27.2
	C-80-2	*	*	ND	*	3.02	ND	ND	5.2
	C-80-3	*	*	ND	*	ND	ND	ND	ND

(a) Reference Figure 1
(b) Analyses performed by US Testing Co.
(c) Instrument detection limit for isotope.
(d) Strontium-90 analyses performed by PNL.
(e) Counted with Canberra 2400 Gas Proportional Scaler, 183KE HP Lab.
ND Not Detected
* Analysis not performed.

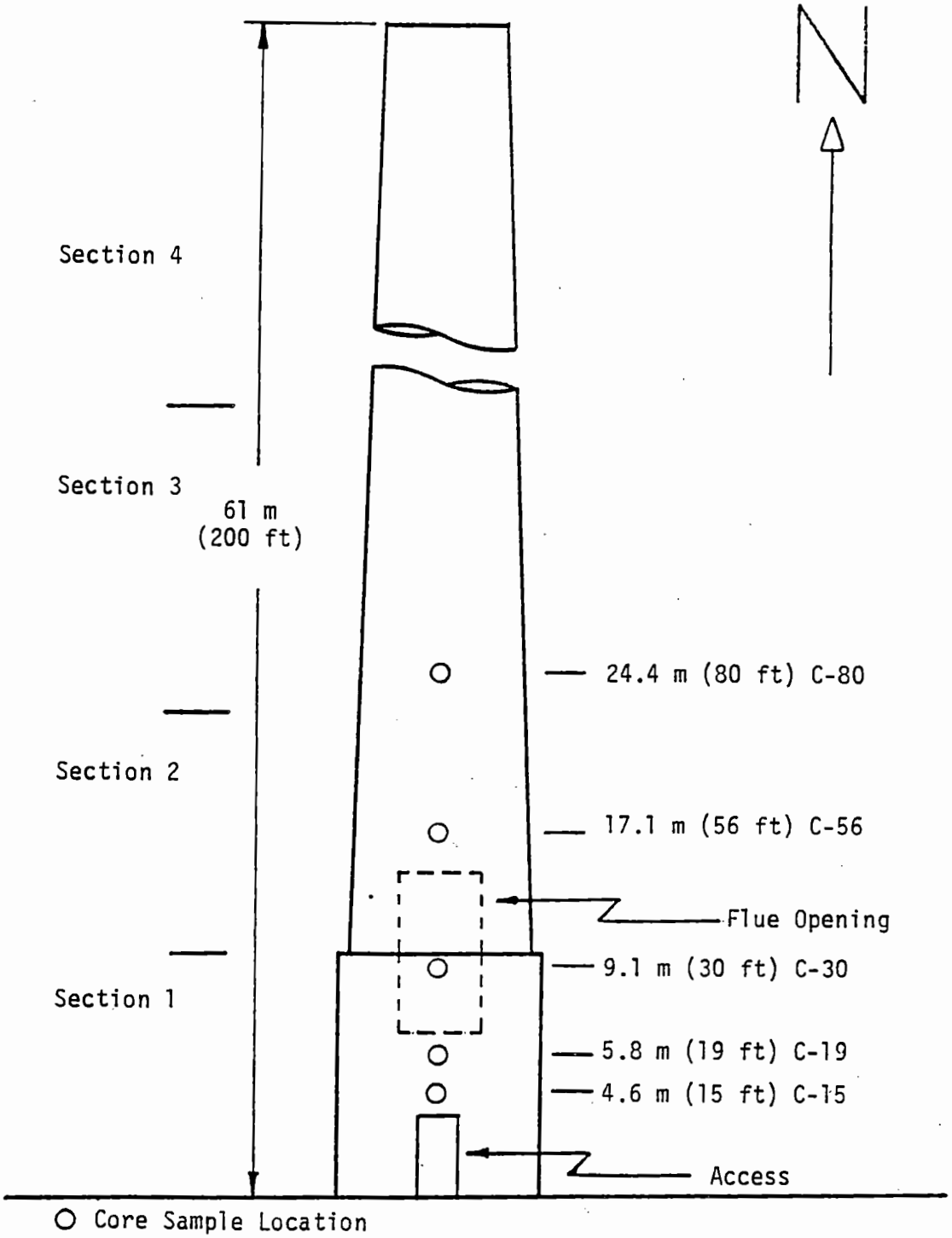


Figure 1. North Elevation of 116-H Stack Showing Locations of Core Samples

Analytical Results Cont'd

Strontium-90 data was obtained from 2 core samples; 1 and 4. Core Sample 1, from the 19 foot level, showed the least total activity of all the core samples. The total Sr-90 activity in core 1 was approximately 6.5 pCi/g. Core Sample 4, from the 56 foot level, showed the highest total activity. The total Sr-90 activity in core sample 4 was approximately 11 pCi/g. The analytical results indicate that the strontium-90 activity is relatively consistent throughout the inner surface to the stack; approximately 6-11 pCi/g. Therefore, the Sr-90 results from Core Sample 4 will be used to estimate the Sr-90 concentration in Core Samples 3 and 5.

Only Core Sample 1 was analyzed for tritium and carbon-14. For purposes of establishing isotopic concentrations and inventories for these nuclides, the levels in the remaining cores will be estimated by calculation.

Isotopic Concentrations

Determination of Weighted Average Concentrations

Isotopic concentrations for each core sample were established by averaging the three core sample layers.

Next, the average concentrations were weighted against the fractional surface area of the stack from which they were collected. (See Table 2)

Surface Area of Stack:

Sample Selection Identification and Location (See Figure 1)

CORE No.	SAMPLE ELEVATION (meters)	STACK SECTION	
1	4.6 m	1	0 - 10.7 m
2	5.9 m		
3	9.1 m		
4	17.1 m	2	10.7 - 19.8 m
5	24.4 m	3	19.8 - 33.5 m
Not Sampled		4	33.5 - 61 m

GIVEN DATA:	Section I (3 Samples)	Radius(r)	r1 =	6.01 ft.	=	183 cm
			r2 =	6.01 ft.	=	183 cm
		Height(h)	h =	35 ft.	=	1067 cm
	Section II (1 Sample)	Radius(r)	r1 =	6.01 ft.	=	183 cm
			r2 =	5.83 ft.	=	178 cm
		Height(h)	h =	30 ft.	=	914 cm
	Section III (1 Sample)	Radius(r)	r1 =	5.83 ft.	=	178 cm
			r2 =	5.53 ft.	=	169 cm
		Height(h)	h =	45 ft.	=	1372 cm
	Section IV (No Samples)	Radius(r)	r1 =	5.53 ft.	=	169 cm
			r2 =	4.75 ft.	=	145 cm
		Height(h)	h =	90 ft.	=	2743 cm

Table 2. Average and Total Concentration for the 116-H Stack.

CORE SAMPLE	H-3	C-14	(a) Co-60	Sr-90	(a) Cs-137	(a) Eu-152	GROSS ALPHA	SECTION m	% AREA(b)
			<----- pCi/g ----->						
No.1 Avg(c)	18	230	0.29	2.8	5.1	0.21	0.72		
Ratio	3.5	45			1				
								1	19.39%
No.3 Avg	[31]	[400]	0.74	3.7(d)	8.9	0.00	6.2(e)		
wt. conc	6.0	78	0.14	0.72	1.7	0.00	1.2		
No.4 Avg	[88]	[1125]	1.8	3.7	25	1.9	10(e)	2	15.98%
wt. conc.	14	180	0.29	0.59	4.0	0.30	1.6		
No.5 Avg	[39]	[500]	0.6	3.7(d)	11.0	0	12(e)	3	23.00%
wt. conc.	8.9	120	0.14	0.85	2.5	0	2.8		
AVERAGE CONC.	29	380	0.57	2.2	8.2	0.3	5.6	1-3	58.37%
REMAINDER OF STACK	29	380	0.57	2.2	8.2	0.3	5.6	4	41.63%
TOTAL FOR STACK	58	760	1.1	4.4	16	0.6	11	1-4	100%

(a) Identified by gamma spectrum analysis. Counting errors range from 24 % to 118 %.
(b) Percent interior surface area of stack.
(c) Analyses performed by US Testing Co.
(d) Estimated value from Core Sample 4.
(e) Counted with Canberra 2400 Gas Proportional Scaler, 183KE Hp Lab. Assumed to be Pu-239.
[ ] Calculated concentrations derived from ratios established in Core Sample 1.
Explaination of weighted concentration determination follows in text of Appendix.

AREA CALCULATION:

Section 1

Area(A) = 1227870 cm^2 = 1.2E+06 cm^2

Access Opening

Height = 6.5 ft. = 198 cm
Width = 3.5 ft. = 107 cm

Area = 21186 cm^2 = 2.1E+04 cm^2 (Access)

Flue Opening

Height = 15 ft. = 457 cm
Width = 7.5 ft. = 229 cm

Area = 104653 cm^2 = 1.0E+05 cm^2 (Flue)

Floor Surface

Radius = 223 cm

Area = 156149 Area = 1.6E+05 cm^2 (Floor)

Net Area of Section 1

Area(Net) = A(stk) - A(access) - A(flue) + A(floor) = 1.3E+06 cm^2

% AREA = 19.39% <-------

Section 2

Area(A) = 1036718 cm^2 = 1.0E+06 cm^2 % AREA = 15.98% <-------

Section 3

Area(A) = 1492039 cm^2 = 1.5E+06 cm^2 % AREA = 23.00% <-------

Section 4

Area(A) = 2700423 cm^2 = 2.7E+06 cm^2 % AREA = 41.63% <-------

AREA (T)= 6487360 cm^2 = 6.5E+06 cm^2 TOTAL 1.00 <=======

Estimation of H-3 and C-14 in Core Samples 3, 4 and 5

ASSUMPTION: Isotopic concentrations on the interior surface of the 116-H Stack are relativily consistent, and that increases and decreases in total activity are directly related to the abundance of Cs-137.

COMMENTS: This assumption is based on the relatively consistent ratios of Co-60 and Cs-137 among the core samples used to determine the overall isotopic inventory of the stack (Core samples 3,4 and 5).

Three core samples were taken in stack section 1; core samples 1, 2 and 3. Core sample 3 contained the highest isotopic activity of the three and , therefore, it was considered to be the worst case and is used to represent the activity in stack section 1. Sample data from Core 2 is completely omitted from the calculations. Since core 1 was the only sample analyzed for H-3 and C-14 a method was needed to to estimate H-3 and C-14 concentrations for samples where there was no data. This was accomplished by determining the ratios of isotopes in core 1 and applying those ratios to core samples 3,4 and 5. After the ratios are established the data from Core Sample 1 will no longer be considered.

Determination of Co-60 and Cs-137 Average Concentration Ratios from data in Table 1:

Sample #	Average Concentration Co-60	Cs-137	Ratio
1	0.29	5.1	1:18
3	0.74	8.9	1:12
4	1.8	25	1:14
5	0.61	11	1:19
Mean			1:16
SD			3

Using Cs-137 as the reference isotope, the ratios of H-3 and C-14 in Core Sample 1 are:

SAMPLE 1	RATIO
Cs-137:H-3	1:3.5
Cs-137:C-14	1:45

Calculated Average Concentrations for H-3 and C-14:

Sample #	H-3	C-14
3	31	400
4	88	1125
5	39	500

From the above ratio values, the weighted concentrations for each section of the stack is calculated. The weighted concentrations are identified in Table 2, by [1]. The Average concentration for the stack is determined by adding the weighted concentrations of each each stack section (Sections 1, 2 & 3). The Average concentration for the stack is presented below and is used to establish the ARCL value.

ASSUMPTION: Section IV of the stack, which was not core sampled, is assumed to be contaminated at the same level as the Average concentration for sections 1-3. Based on the contamination profile (see Figure 2), this assumption appears to be conservative and reasonable for calculating ARCL value and isotopic inventory.

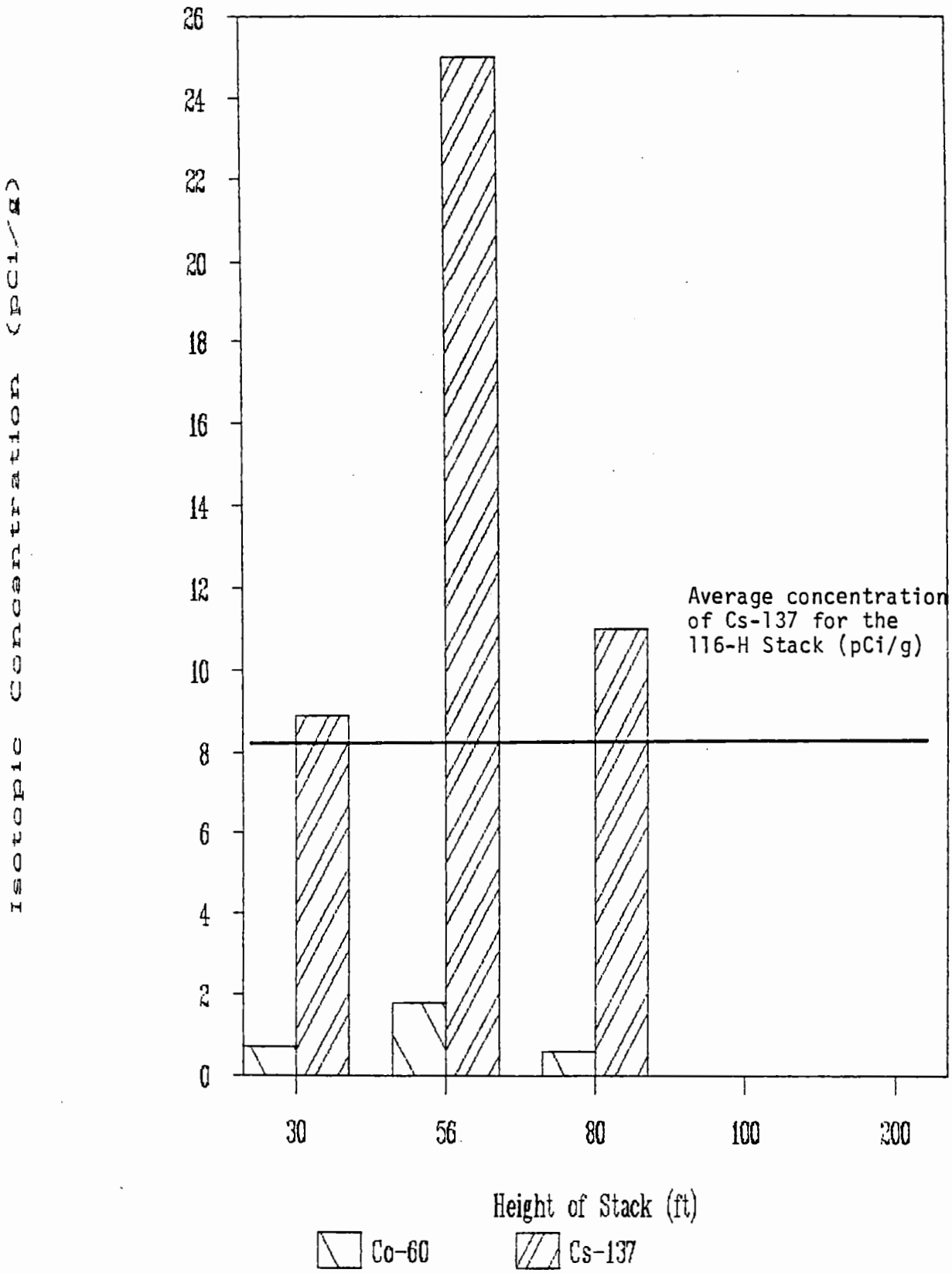


Figure 2. Radiological Profile of the 116-H Stack Showing Activity vs. Height of Stack

AVERAGE CONCENTRATION FOR THE 116-H STACK

	H-3	C-14	Co-60	Sr-90	Cs-137	Eu-152	Pu-239	
SECTIONS 1-3	29	380	0.57	2.2	8.2	0.3	5.6	
SECTION 4	29	380	0.57	2.2	8.2	0.3	5.6	
TOTAL STACK	58	760	1.1	4.4	16.4	0.6	11.2	<==========

ARCL VALUE

Calculations for the ARCL Value are presented in Table 3. Based on the weighted average concentration for each isotope, the ARCL Value was calculated to be: 196 pCi/g or 200 pCi/g <========

2. ESTABLISH THE ISOTOPIC INVENTORY FOR THE 116-H STACK.

Mass of Contaminated Concrete (Interior Surface)

As discussed above, the depth of radionuclide penetration is estimated to be 3/8 inch, or 1.0 cm.

The interior surface area of the stack is : 6.4E+6 cm^2

The density of concrete is : 2.1 g/cm^3

Mass of Contaminated Concrete (g) = $\frac{6.5E+6\ cm^2 \mid 1.0\ cm \mid 2.1\ g}{\mid \mid \mid cm^3}$ = 1.4E+7 g<==========

Isotopic Inventory

Isotope Weighted Average (pCi/g)

H-3	58
C-14	760
Co-60	1.1
Sr-90	4.4
Cs-137	16
Eu-152	0.6
Pu-238	11

Total 851.1 pCi/g or 850 pCi/g

Inventory Calculation

pCi = Total Concentration x Mass of Contaminated Concrete

= $\frac{850\ pCi \mid 1.4E+7\ g}{g \mid}$ = 1.2E+10 pCi

Table 3, ARCL Calculation

FACILTIY NAME: 116-H Stack

CHECKED BY: [illegible]
DATE: 4/30/87

PREPARER'S NAME: JF Beckstrom JFB

DATE PREPARED: 4-1-87

Determination of ARCL Dose Factors to Enter From Table 5.2.2., UNI-2522. Check one Use Mode and one Contamination Condition.

Use/Contamination Condition	Contaminated Surfaces Ci/m2 or dpm/100cm2	Surface Soil (pCi/gm)	Soil 1-4 m Deep	(	Soil >5 m Deep (pCi/gm)
Restricted Use @ 0.5 rem/yr	Column 1	Column 4	Column 5		Column 6
Controlled Use @ 0.5 rem/yr	Column 2	Column 4	Column 5		Column 6
Unrestricted Use @ 0.025 rem/yr	Column 3	Column 4	Column 5	X	Column 6

5. Radionuclides concerned (list)	6. Radionuclide Concentrations (Available Units)	6a. Radionuclide Concentrations (Ci/m2 or pCi/gm)	7. Scenario-specific ARCL Dose Factors Step 4; (rem/yr)/ [Ci/m2 or pCi/gm])	8. Product of col. 6a. and 7. (rem/yr)/ (pCi/gm)	9. ARCL-product of Column 6a. & Item 8b. (pCi/gm)
H-3	59.00	0.0681	3.40E-11	2.32E-12	13.36
C-14	760.00	0.8930	1.70E-08	1.52E-08	175.10
Co-60	1.10	0.0013	2.20E-03	2.84E-06	0.25
Sr-90	4.40	0.0052	2.20E-02	1.14E-04	1.01
Cs-137	16.00	0.0188	5.30E-04	9.96E-06	3.69
Eu-152	0.60	0.0007	1.00E-03	7.05E-07	0.14
Eu-154	0.00	0.0000	1.10E-03	0.00E+00	0.00
Pu-239	11.00	0.0129	1.80E-05	2.33E-07	2.53
Am-241	0.00	0.0000	3.00E-05	0.00E+00	0.00
		0.0000		0.00E+00	0.00
TOTAL	851.10				

6b. Total: 1.00

8a. Total: 1.27E-04

9a. Total: 196.1

8b. Annual Dose Limit Divided by 8a. (0.025 rem/yr Divided By 8a.) 196.1

ARCL VALUE

COMMENTS:
Concentrations in column 6. are mean values from Table 2. Isotopic Concentrations Used to Estimate Total Inventory in the 116-H Stack.

Total Mass of Concrete 116-H Stack

From the referenced document attached, the total calculated mass of the 116-H Stack is:

3.1E+8 g

The mass of the floor is determined assuming a floor thickness of 1 foot.

mass = Area x Thickness x Density

= 1.6E+5 cm^2 x 30.48 cm x 2.1 g = 1.0E+7 g cm^3

Total Mass of Stack = 3.1E+8 g + 1.0E+7 g = 3.2E+8 g <==========

Residual Radionuclide Concentration in Stack Rubble.

pCi = Isotopic Inventory
g Mass of Stack

= 1.2E+10 pCi = 37.5 pCi/g = 38 pCi/g
3.2E+8 g

I. COMPARISON OF ARCL AND RESIDUAL CONCENTRATION

ARCL Value for the 116-H Stack is: 200 pCi/g

Residual Concentration in the 116-H Stack rubble is: 38 pCi/g

The residual conc. is 19 % of the ARCL Value.
This represents a dose to a maximally exposed individual of: 4.8 mrem/year
The total isotopic inventroy left in the site rubble is: 12 millicuries.

9513356.0022

UNI-3827

KAISER ENGINEERS
HANFORD

Page No. 1 of 2

Revision 0

DESIGN ANALYSIS

Client UNC DECOMMISSIONING WO/Job No. B32085/U248 BO

Subject STACK Date 8/23/83 By S.R. STANLEY

116 H Checked 8/31/83 By R G Hollenbeck

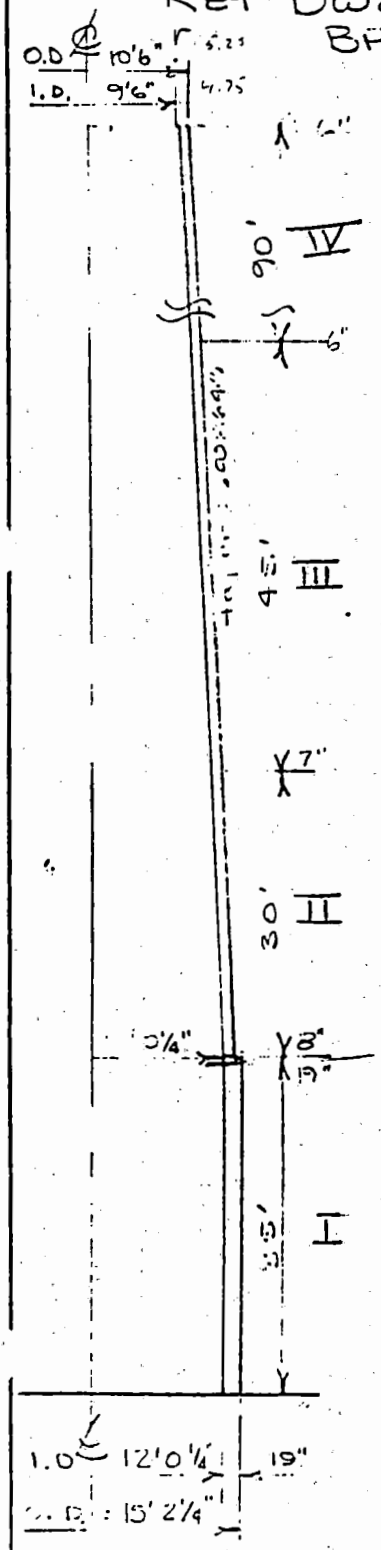
Location 100 H AREA Revised By

STACK VOLUME

Ref Dwg C-5652-B-1 (Rust Engineering) 6-21-43

BPF 50E - Originals Destroyed -

$(D_o^2 - D_I^2)$ .785[illegible]



SECT NO	ELEV.	SECT HEIGHT	OUTSIDE DIAMETER D_o	INSIDE DIAMETER D_I	WALL THICK	$A = \frac{\pi}{4}(D_o^2 - D_I^2)$
	0		15'2¼" / 15.1875	12'0¼" 12.020833	19"	(86.150730) 67.6697
I	35'	35'	15'2¼" / 15.1875	12'0¼" 12.020833	19"	same
II	65'	30'	13'4¼" / 13.359167		8"	(33.833350) 26.5727
III	110'	45'	calc 12.835227	calc / 11.668560	7"	(28.587760) 22.4528
IV	200'	90'	calc 12.056817	calc / 11.056817	6"	(23.115634) 18.1534
			10'6" / 10.5	9'6" / 9.5	6"	(20.0) 15.7080

Assumed outside is uniform taper

VOLUME OF SECTION = $\frac{Area_{bot} + Area_{top}}{2}$ X Height

1226808
1320.569

SECTION I VOLUME

r_1 = 6.01
r_2 = 6.25 35

= 67.6697 ft² x 35' = 2,368.44 ft³

1036680
1115.91

SECTION II VOLUME

r_1 = 6
r_2 = 5.84

= $\frac{26.5727 + 22.4528}{2}$ x 30' = 735.38 ft³

1493306
1607.034

SECTION III VOLUME

r_1 = 5.84
r_2 = 5.53

= $\frac{22.4528 + 18.1534}{2}$ x 45' = 913.64 ft³

2700335
2906.711

SECTION IV VOLUME

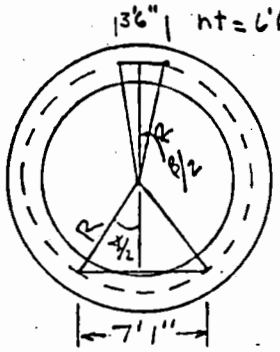
r_1 5.53
r_2 4.75

= $\frac{18.1534 + 15.7080}{2}$ x 10' = 1,523.76 ft³

DESIGN ANALYSIS

Client	UNC DECOMMISSIONING	WO/Job No.	B32085/U248B0
Subject	STACK	Date 8/23/83	By S.R. STANLEY
	116 H	Checked 8/31/83	By R.G. Hollenberk
Location	100 H AREA	Revised	By

STACK VOLUME (CONT)



VOLUME OF OPENINGS (TO BE DEDUCTED)

Ave diameter = 12'0¼" + 19" = 13' 7¼" = 13.604167 R = 6'-9⅝ = 6.802083'

Flue Opening

$\sin \frac{\measuredangle}{2} = \frac{\text{half opening}}{R} = .520674$ $\measuredangle/2 = 31°22'39"$ $\measuredangle = 62.754811$

$\frac{\measuredangle}{360} = \%\text{ Circum} = .1743$ Length = (%circum)(πd) = 7.45

Mat'l Opening

height = 15'0½"
15.041667

$\sin \beta/2 = \frac{\text{half open}}{R} = 0.257274$, $\beta/2 = 14°54'30"$ $\beta = 29.81674$

$\frac{\measuredangle}{360} = \%\text{ circum} = .0828$ Length = (%circum)πd = 3.54'

$V = \underset{\text{Flue}}{L \times H \times T} + \underset{\text{Mat'l}}{L \times H \times T} = (7.45)(\overset{177.43}{15.041667})(1.5833) + (3.54)(\overset{36.43}{6.5})(1.5833)$

$= \underline{213.86\ ft^3}$

TOTAL VOLUME STACK

SECT I	=	2,368.44 ft³
" II	=	735.35 "
" III	=	913.64 "
" IV	=	1,523.76 "
OPENING	=	(-) 213.86 "
		5,327.36 ft³

Cubic Yds = 197.31 yd³

WEIGHT OF STACK

Concrete @ 3500#/yd³	=	690,585
Reinforc Stl @ 150#/yd³	=	29,597
TOTAL	=	720,182

KILOGRAMS (2.2046#/kg)

Conc = 313,247

Steel = 13,425

TOTAL = 326,672 kg

9513356.0023

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Page No. 1 of 2

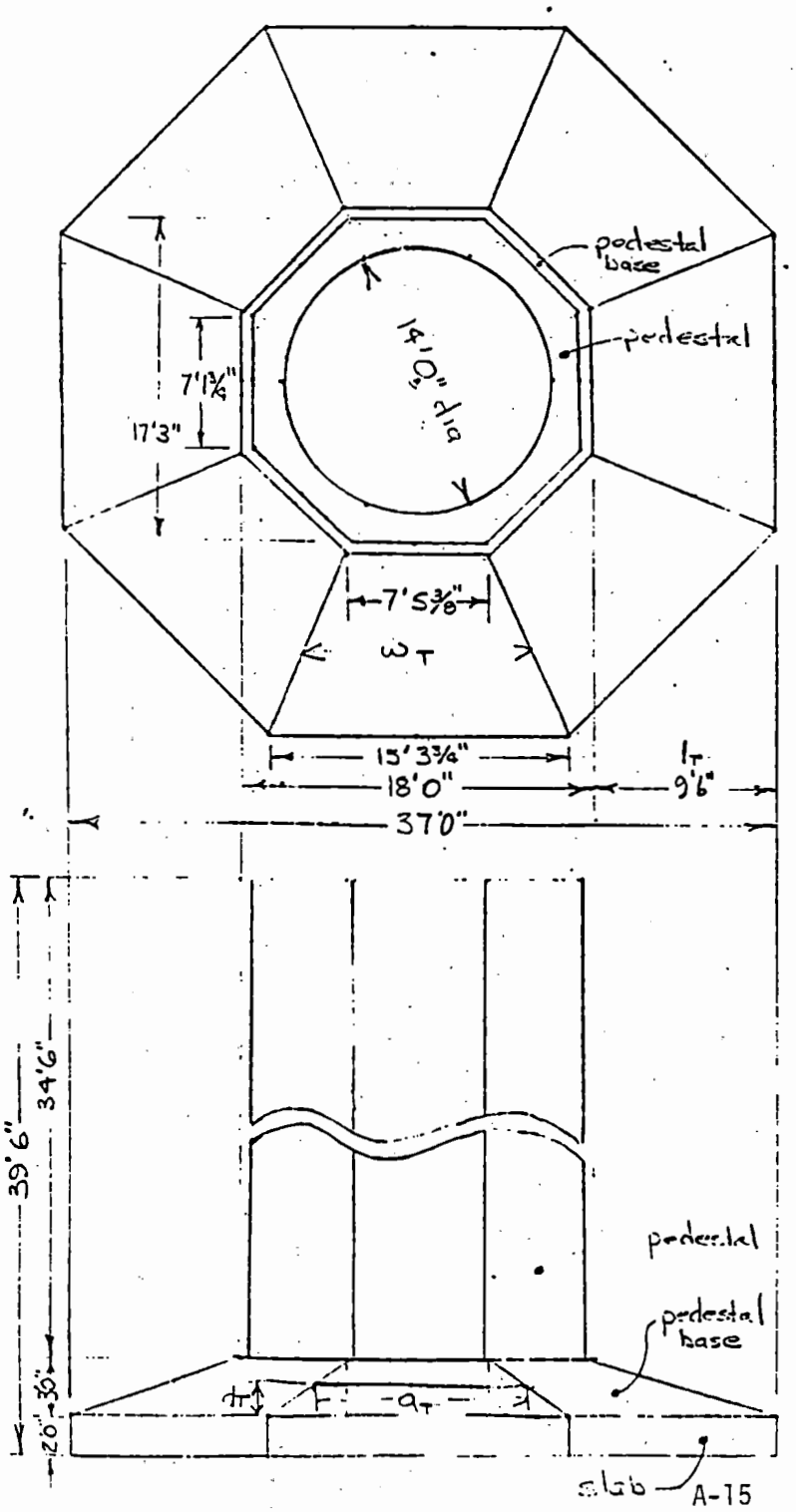
Revision 0

DESIGN ANALYSIS

Client UNC – DECOMMISSIONING	WO/Job No. B32086/U248C0(c)		
Subject STACK FOUNDATION	Date 8/16/83	By S. R. STANLEY	
116C	Checked 9/2/83	By R. G. Hollenbeck	
Location 100C AREA	Revised	By	

FOUNDATION VOLUME

REF DWG C-6396-FA-0 (BPF 3983)



BOTTOM SLAB VOLUME

b_s = base of triangle = 15'3¾"
h_s = height of triangle = 18'6"
d_s = depth of slab = 2'0"

$V = 8(\frac{1}{2} b_s h_s) d_s = 8(\frac{1}{2} \times 15.3125 \times 18.5) 2$

$= \underline{2,266.25 \text{ ft}^3}$

SLAB TO PEDESTAL BASE TRANS. VOLUME

$w_T = \frac{7'5\frac{3}{8}" + 15'3\frac{3}{4}"}{2} = 11.38'$ ave w

$d_T = \frac{3'0" + 0}{2} = 1.5'$

$l_T = 9'6" = 9.5'$

$a_T = w_T d_T$

$V = 8 a_T l_T = w_T d_T l_T = 8(11.38 \times 1.5 \times 9.5$

$= \underline{1297.32 \text{ ft}^3}$

PEDESTAL BASE VOLUME

b_b = base of triangle = 7'5⅜"
h_b = height of triangle = 9'0"
d_b = depth of pedestal base = 3'0"

$V = 8(\frac{1}{2} b_p h_p) d_p = 8(\frac{1}{2} \times 7.4479 \times 9.0) 3.0$

$\underline{804.37 \text{ ft}^3}$

PEDESTAL VOLUME

b_p = base of triangle = 7'1¾" = 7.[illegible]
h_p = height of triangle = 8'5/8" = 8.[illegible]
d_p = depth of pedestal & cylinder = 34'6"
r_c = radius of cylinder = 7'0"

$V = 8(\frac{1}{2} b_p h_p) d_p - (\pi r_c^2) d_p =$
$(4 \times 7.14553 \times 8.625 \times 34.5) - (\pi 7^2 34.5)$
$5505.32 - 5310.87 = \underline{3194.45 \text{ ft}^3}$

DESIGN ANALYSIS

Client UNC DECOMMISSIONING		WO/Job No. B32086 / U248CO (C)	
Subject STACK FOUNDATION 116C		Date 8/17/83	By S.R. STANLEY
		Checked 9/2/83	By R.G. Hollenbeck
Location 100C AREA		Revised	By

FOUNDATION VOLUME (cont)

FLOOR SLAB VOLUME

d_f = diameter of floor slab = 14'6"
t_f = thickness of floor slab = 2'0"

$$V = \pi\left(\frac{d_f}{2}\right)^2 t = \pi\left(\frac{14.5}{2}\right)^2 2.0 = \underline{330.26\ ft^3}$$

TOTAL VOLUME OF STACK FOUNDATION

Bottom Slab	= 2,266.25	ft^3
Transition	= 1,297.32	"
Base	= 804.37	"
Pedestal	= 3,194.45	"
Floor Slab	= 330.26	"

TOTAL = $\underline{\underline{7892.65\ ft^3}}$

Cubic Yds = 292.3 yd^3

FOUNDATION WEIGHT

WEIGHT OF CONCRETE @ 3500#/yd^3 = 1,023,050 #

WEIGHT OF REINFORCING STEEL @ 150#/yd^3 = 43,845 #

TOTAL WEIGHT 1,066,895 #

KILOGRAMS (2.2096#/kg)

Concrete = 464,052
Rebar = 19,888

FOUNDATION TOTAL = 483,940 kg