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Oak Ridge Associated
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and
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and Safeguards,
Emergency
Preparedness and
Radiological
Protection Branch

CONFIRMATORY RADIOLOGICAL SURVEY OF THE BERKELEY RESEARCH REACTOR FACILITY UNIVERSITY OF CALIFORNIA AT BERKELEY BERKELEY, CALIFORNIA

T. J. VITKUS

Environmental Survey and Site Assessment Program
Energy/Environment Systems Division

FINAL REPORT
NOVEMBER 1990

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CONFIRMATORY RADIOLOGICAL SURVEY OF THE BERKELEY RESEARCH REACTOR FACILITY UNIVERSITY OF CALIFORNIA AT BERKELEY BERKELEY, CALIFORNIA

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CONFIRMATORY RADIOLOGICAL SURVEY
OF THE
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

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INTRODUCTION

The University of California at Berkeley (UCB) operated a 1 MW TRIGA Mark III Reactor from August 1966 through December 1987, with a total power output during this period of 292.5 MWd. The Berkeley Research Reactor (BRR) was located in Etcheverry Hall on the UCB campus in Berkeley, California (Figures 1 - 3). The unit was a General Atomics heterogenous pool-type reactor (Figure 4) and provided a source of ionizing radiation and neutrons for research projects as well as a training mechanism for students in reactor operation principles. Operation was in accordance with AEC/NRC License No. R-101 (Docket No. 50-224).

Reactor operation activities resulted in the activation of core components, surfaces of the exposure room, ends of beam ports closest to the reactor, and concrete around beam ports and thermal columns. Other reported localized contamination, within the reactor bay, was the result of past experimental work with tritium and natural uranium. These experiments were conducted under a California Radioactive Materials License.

After shutdown of the reactor in 1987, the fuel was removed and shipped off-site during June and July of 1989. This was followed by the issuance of the NRC order, on September 12, 1989, authorizing reactor dismantlement. The reactor was decommissioned by removing the water from the tank followed by dismantlement and disposal of activated reactor components and support equipment, and scarification of activated concrete within the reactor tank.

Once decommissioning was completed, a survey of the reactor environs, conducted by the licensee's agent, demonstrated that the residual radiation levels satisfy the established NRC guidelines. The Region V Office of the NRC requested that the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities (ORAU) conduct a survey of the facility to confirm those findings.

FACILITY DESCRIPTION

Etcheverry Hall is a six story brick structure comprised of classrooms, laboratories, and offices with the reactor facility located on the basement level (Figure 5). The reactor facility is constructed with concrete floors, block and reinforced concrete walls and ceilings. The following areas were included as part of the ORAU survey: the high-bay reactor room (Room 1140) measuring approximately 924 m^2, an emergency egress measuring 30 m^2, the reactor operators office (15 m^2), the personnel decontamination facility (22 m^2), an airlock, a rabbit fume hood terminus located in Room 1110B, and adjacent corridors (Figure 6). Room 1140 is divided, by means of temporary confinement barriers, into a DECON area and an adjacent State of California Radioactive Materials licensed area which was not included in this survey. Additional coverage of the California Radioactive Materials License 1333-62 includes sealed neutron sources contained in a storage well in Room 1140 and Room 1110B exclusive of the previously described hood.

PROCEDURES

Objective

On July 16 - 18, 1990 ORAU conducted a confirmatory survey of the Berkeley Research Reactor (BRR) facility. The purpose of the survey was to verify the adequacy

and accuracy of the licensee's final survey and to confirm the radiological condition of the facility relative to decommissioning guidelines.

Document Review

ORAU reviewed the licensees's final survey report supporting the decommissioning of the reactor.

Survey Procedures

1. The reference grid established by the licensee was utilized by ORAU during the course of the survey. The grid consisted of 1 m x 1 m blocks in areas designated as high contamination potential areas. These areas included the reactor itself and immediate area, operators office, emergency egress, and personnel decontamination room. The remainder of the facility was divided into 3 m x 3 m blocks.

2. Gamma radiation scans to identify locations of residual activity were performed on lower walls and floors of Room 1140, the reactor operators office, personnel decontamination room, airlock, basement corridors, the hood in Room 1110B, the roof, storm and sanitary sewers, and immediate exterior grounds of Etcheverry Hall. Scans were performed using NaI(Tl) gamma scintillation detectors coupled to countrate meters with audible indicators.

3. Large-area and/or 100 cm^2 hand-held gas proportional detectors were used to scan floors, lower walls, and equipment for alpha plus beta activity. Accessible ceilings, pipes, ducts and other overhead structures were scanned with thin-window GM detectors. All detectors were coupled to countrate meters/scalers with audible indicators.

4. Gamma radiation exposure rate measurements were obtained at one meter above surfaces at various locations in and around Etcheverry Hall (Figures 7, 8, and 9). Background measurements were obtained at locations within Etcheverry Hall that have similar construction but no history of radiological usage.

5. Measurements to determine surface activity levels were performed on randomly selected grid blocks located on the floors, lower walls, and hoods (Figures 9 - 30). Measurements were performed at the center and four points equidistant from the center and grid block corners. Gas proportional detectors for identifying alpha plus beta activity were utilized for these measurements. Single-point measurements were performed on upper walls and accessible ceilings within Room 1140, the reactor operators office, and the airlock floors and walls using gas proportional and or GM detectors (Figures 9 - 30). All detectors were coupled to countrate meters/scalers. During the course of the survey, the radiological condition of the facility was determined to be such that extensive upper wall and ceiling measurements were not required. Additionally, established release criteria as well as site radiological history did not necessitate discrimination of alpha and beta activity levels in the absence of elevated measurements.

6. Smear samples, for determining removable activity levels, were collected from the location within each surveyed grid block with the highest total direct measurement, from each single point measurement location, drains, sewers, and hoods.

7. Soil samples were collected from areas with elevated gamma radiation levels.

8. Concrete samples were collected from within the reactor monolith.

FINDINGS AND RESULTS

Surface Scans

Surface scans for alpha plus beta activity did not identify any areas of elevated contact radiation levels. Gamma scans inside Etcheverry Hall identified one location with elevated activity. This area was associated with a laboratory bench, situated along the north wall of Room 1140. Further investigation revealed an encapsulated check-source which was removed and returned to appropriate UCB personnel; gamma radiation returned to background levels following source removal. Gamma scans of the exterior of Etcheverry Hall identified two areas of elevated activity located in the west alley adjacent to the building (Figure 31).

Exposure Rate Measurements

Exposure rate measurements and locations are given in Table 1. Background measurements were 7 μR/h to 9 μR/h at one meter above surfaces. Final exposure rate measurements for the reactor facility and immediate environs ranged from 8 μR/h to 10 μR/h.

Surface Activity Levels

The results of total and removable surface activity measurements are summarized in Table 2. Most of the measurements were below the lower limits of detection for the procedure. The highest grid block average for total alpha plus beta activity was 440 dpm/100 cm^2. Removable activity measured in grid blocks was $<$8 dpm/100 cm^2 for alpha and $<$18 dpm/100 cm^2 for beta. Total activity levels for single point measurements

were <250 to 1700 dpm/100 cm^2 for alpha plus beta and <840 dpm/100 cm^2 for beta-gamma. Removable activity levels were <8 dpm/100 cm^2 for alpha and <18 dpm/100 cm^2 for beta. Removable tritium activity levels were <22 dpm/100 cm^2 to 43 dpm/100 cm^2.

Radionuclide Concentrations in Concrete

Concentration levels of anticipated activation and fission products are presented in Table 4. All radionuclides were below the minimal detectable activity for the analysis, with the exception of Co-60 which had a concentration range of 0.4 ± 0.4 pCi/g to 2.3 ± 1.6 pCi/g.

No guideline levels for Co-60 in building materials have been established for this site. The exposure pathway for Co-60 is direct gamma radiation. Although there is evidence of low levels of this activation product in the concrete, exposure rates in the facility are well below 5 μR/h above background, and therefore the measured concentrations of Co-60 are considered such that the basic release criteria is satisfied.

Elevated Area Synopsis

The elevated contact gamma radiation levels detected were located in the west alley adjacent to Etcheverry Hall (Figure 31). The alley is a public access area and is outside the NRC license jurisdiction. The anomalies identified were the result of a surface layer of a light brown material with a consistency of fine sand that appeared to have been placed over the indigenous soils.

Gamma exposure rate measurements were performed and surface samples collected from three (3) locations. Exposure rates ranged from 10 μR/h to 13 μR/h at one meter above the surface. UCB personnel excavated the material and the area was resurveyed by collecting confirmatory soil samples and performing a gamma exposure rate measurement from the area exhibiting the highest contact gamma activity.

Concentrations of radionuclides in samples collected from the alley are summarized in Table 3. Concentrations of radionuclides in the post-remediation sample are as follows: U-235, 0.5 ± 0.2 pCi/g; U-238, 4.4 ± 1.3 pCi/g; Total U, 17 pCi/g; Th-232, 1.2 ± 0.4 pCi/g; Ra-226, 3.8 ± 0.4 pCi/g.

The radionuclides present and their respective concentrations, indicate that the material contains natural unprocessed uranium including daughter products. The NRC license for the Reactor Facility did not include the possession and use of unprocessed uranium. Based on this information and the location of the material in a public area, the material is likely a commercial product such as blasting grit and is not associated with NRC licensed activities.

The final maximum gamma exposure rate measurement for the remediated areas was 9 μR/h which is within the 7 to 9 μR/h site background levels.

COMPARISON OF RESULTS WITH GUIDELINES

The NRC guidelines for surface activity, established for release of the Berkeley Research Reactor to unrestricted use, are based on the following:

U-nat, U-235, U-238 and
associated decay products

15,000 dpm/100 cm^2 (maximum in a 100 cm^2 area)
5,000 dpm/100 cm^2 (averaged over 1 m^2)
1,000 dpm/100 cm^2, removable

Residual Beta-Gamma Emitters
15,000 dpm/100 cm^2 (maximum in a 100 cm^2 area)
5,000 dpm/100 cm^2 (averaged over 1 m^2)
1,000 dpm/100 cm^2, removable

All measurements conducted during this survey were well within these guideline levels.

The guideline for gamma exposure rate is 5 μR/h above background at 1 m from surfaces. The maximum level measured in the facility was 9 μR/h; the maximum level outside the facility was 10 μR/h. These levels are less than 5 μR/h above the area background level of 7 to 9 μR/h which meets the established guideline.

SUMMARY

On July 16 - 18, 1990 Oak Ridge Associated Universities performed a confirmatory radiological survey of the Berkeley Research Reactor located in Etcheverry Hall on the University of California, Berkeley Campus, in Berkeley, California. The survey included surface alpha plus beta, beta-gamma, and gamma scans, direct and removable activity level

measurements, and soil and concrete sampling. The findings support the close-out survey performed by the licensee, and confirm that the radiological conditions of the BRR facility satisfy the NRC guidelines for release to unrestricted use.

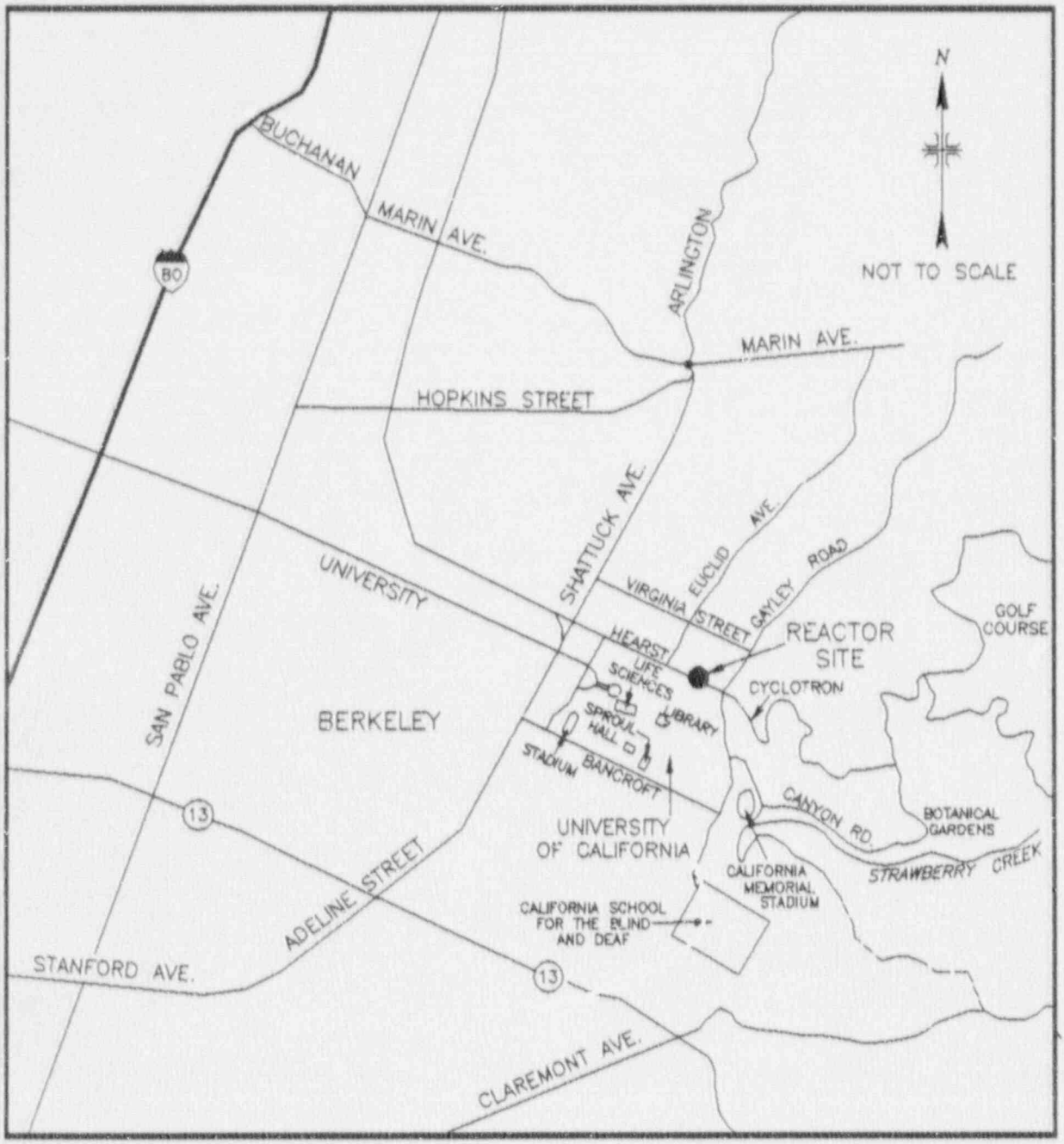


FIGURE 1: City of Berkeley, CA Showing Campus Area

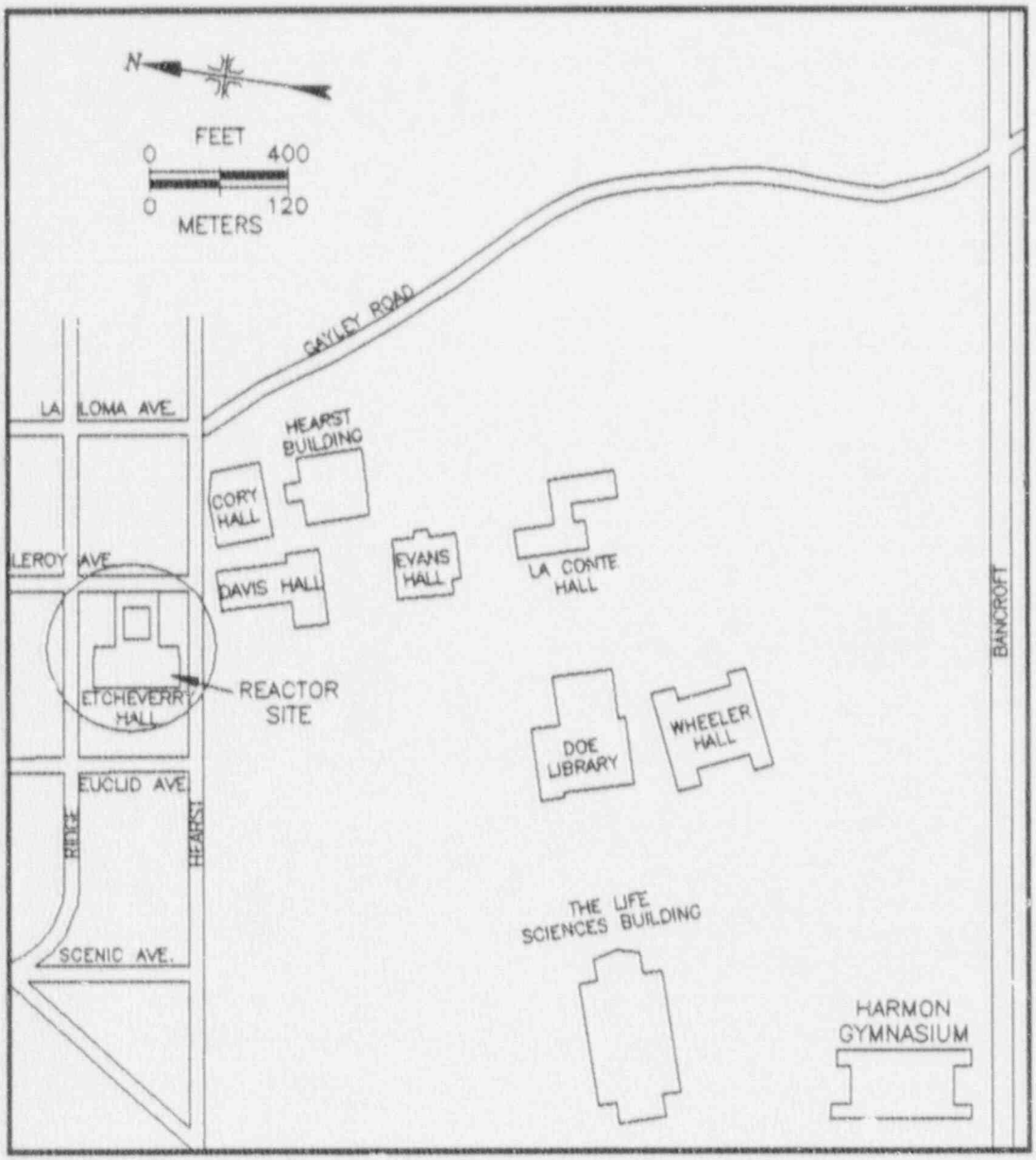


FIGURE 2: Plot Plan Showing Campus Area and Etcheverry Hall

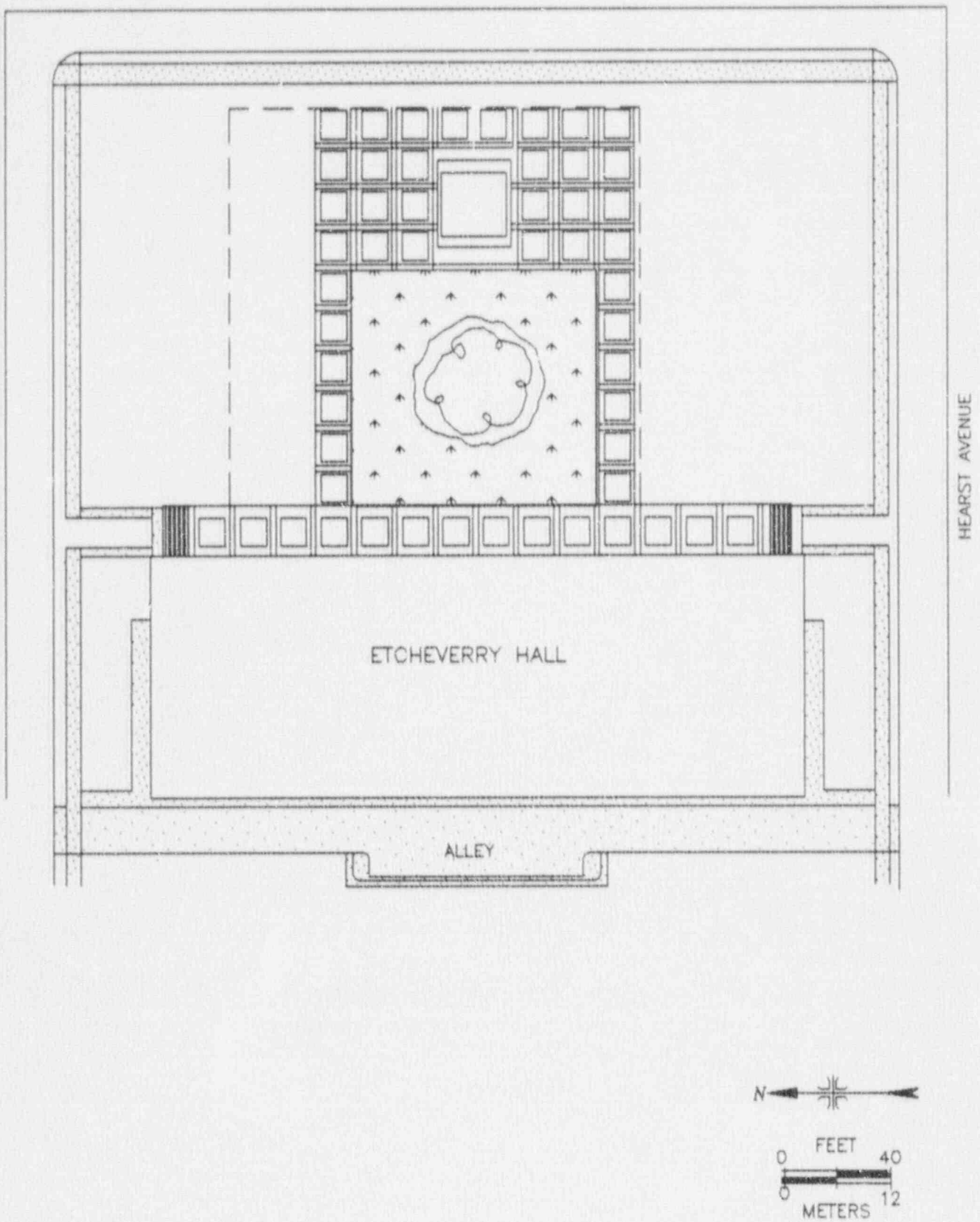


FIGURE 3: UC Berkeley–Etcheverry Hall

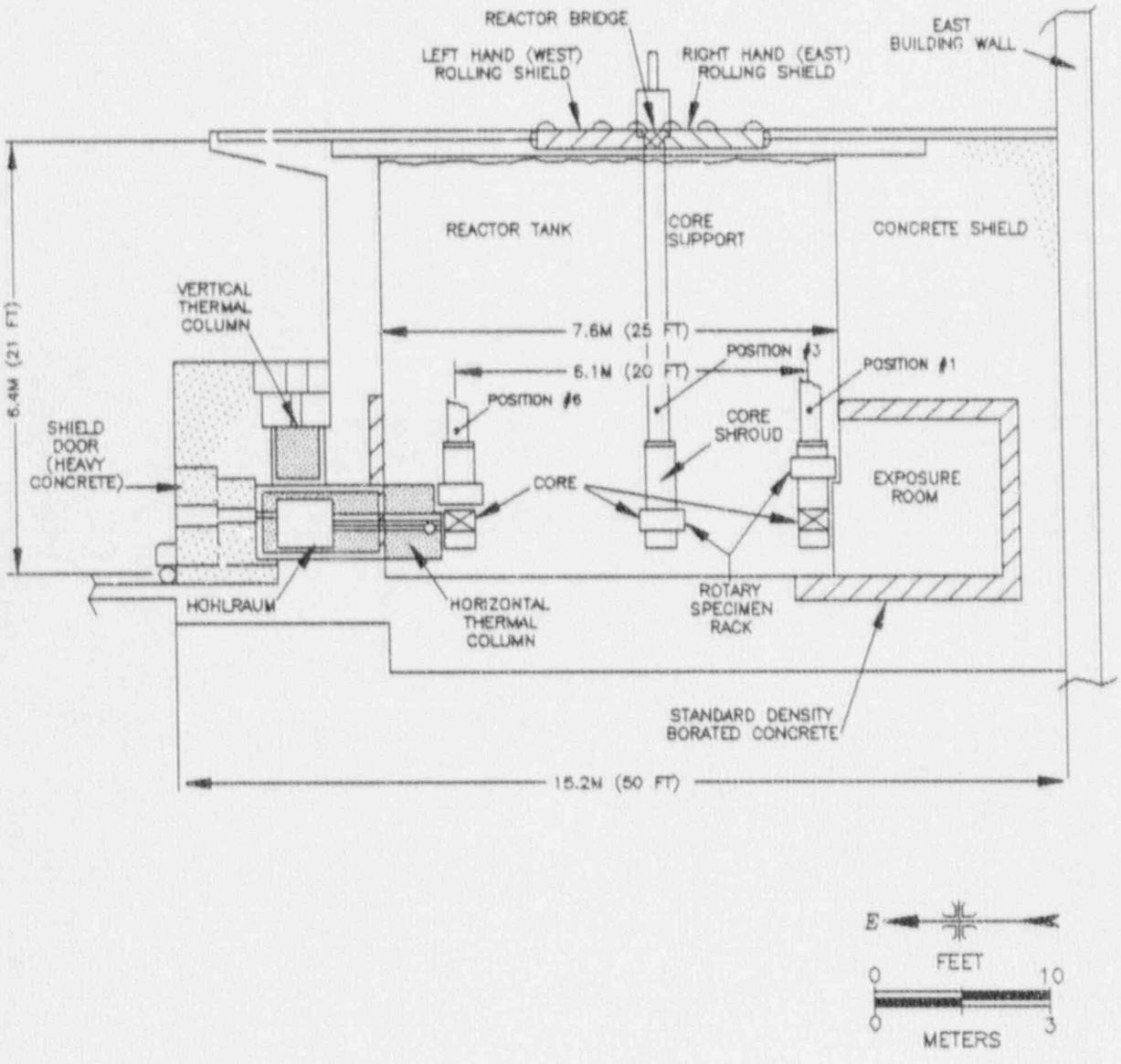


FIGURE 4: Vertical Section–Berkeley Research Reactor

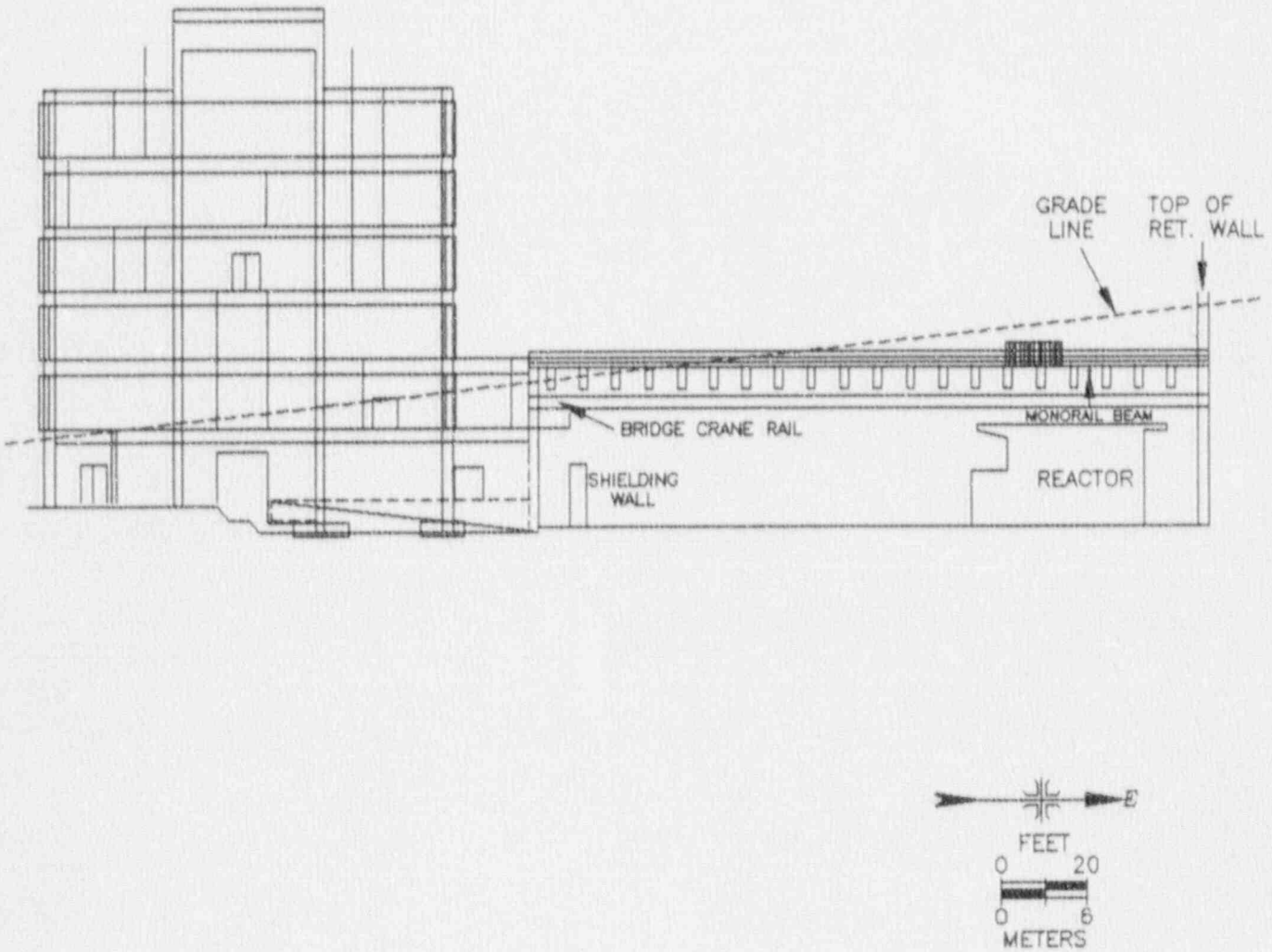


FIGURE 5: Section Through Etcheverry Hall

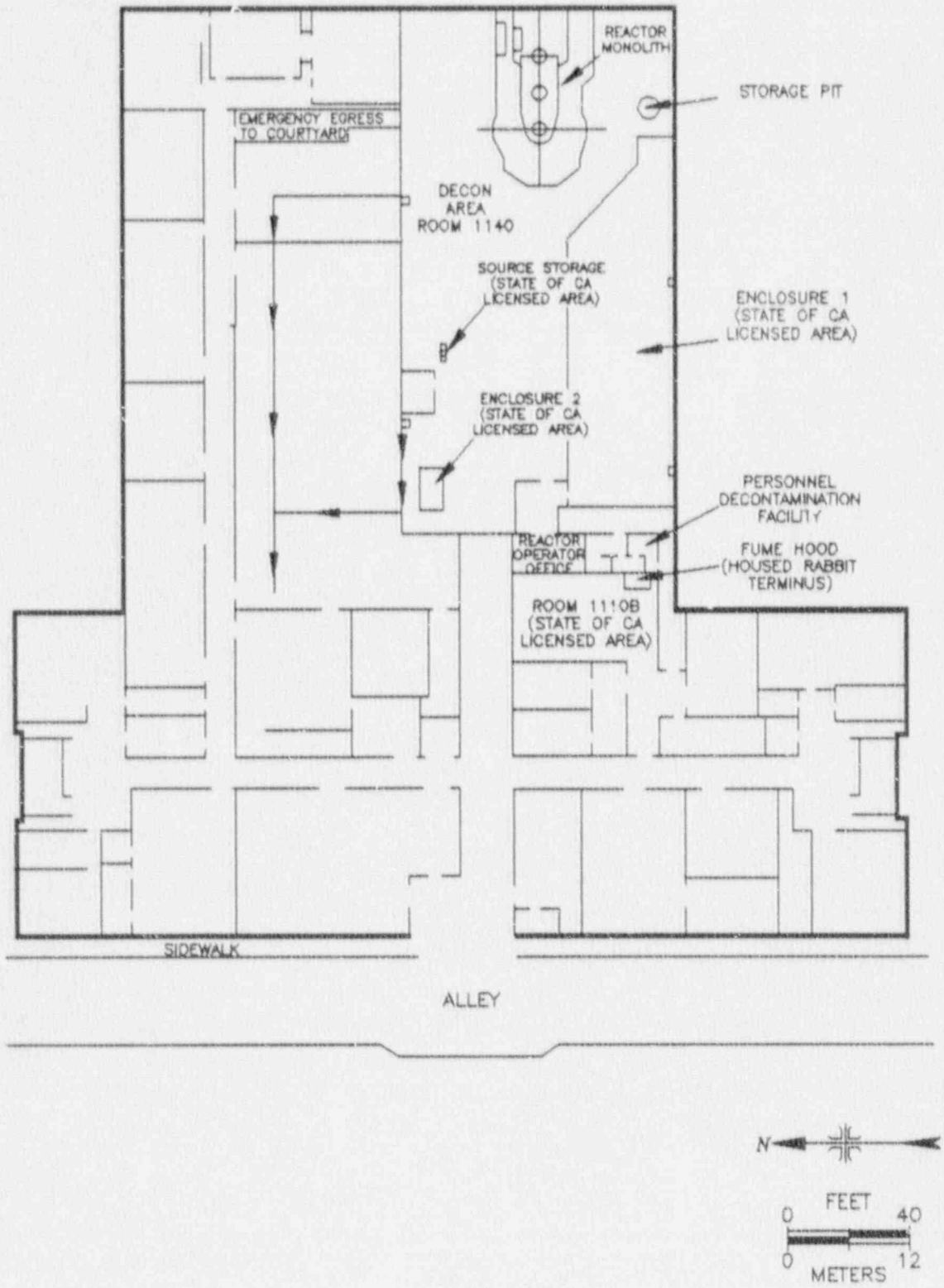


FIGURE 6: UC Berkeley–Etcheverry Hall
Ground Floor–Nucleonic Lab and Environs

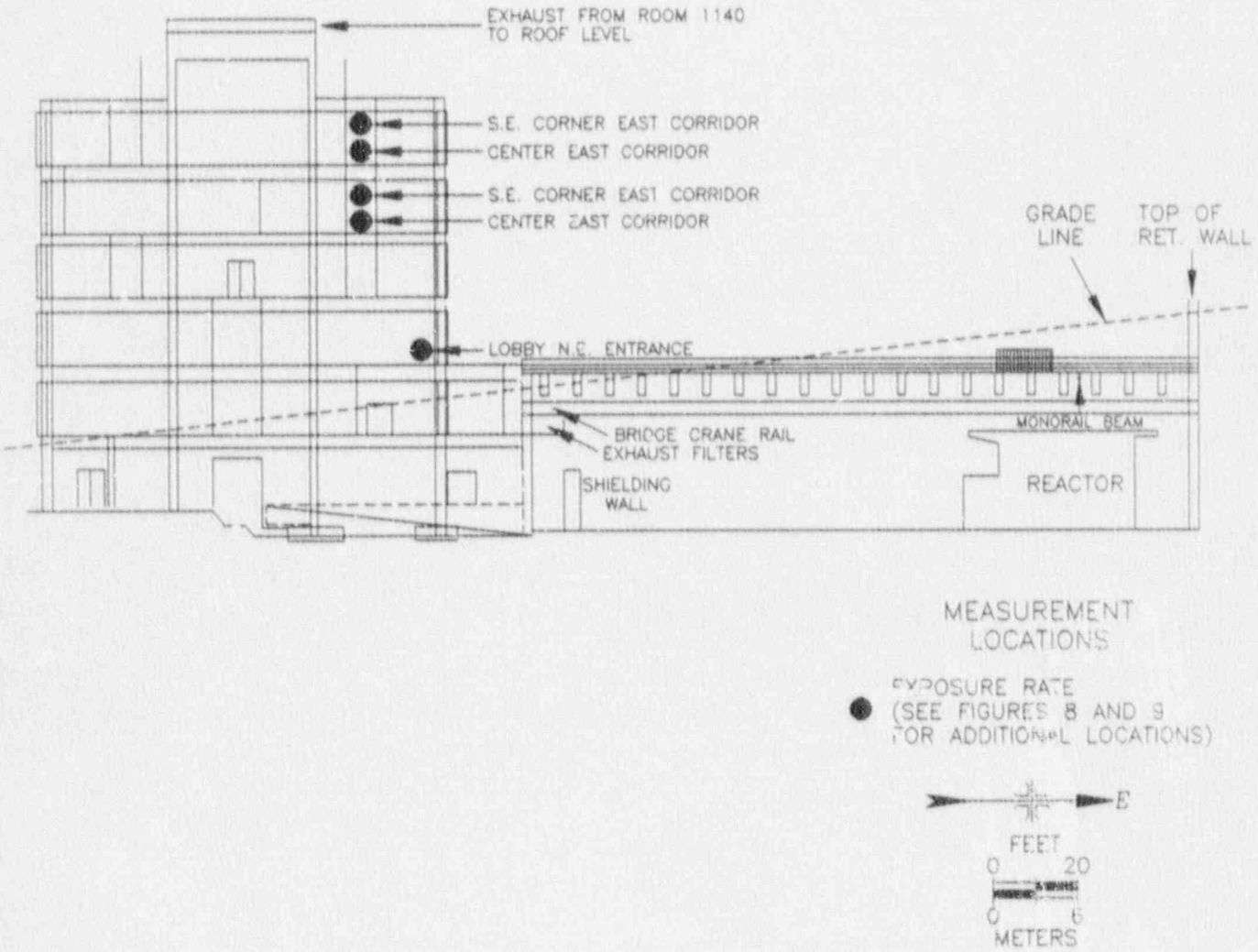


FIGURE 7: Section Through Etcheverry Hall Showing Background Exposure Rate Measurement Locations

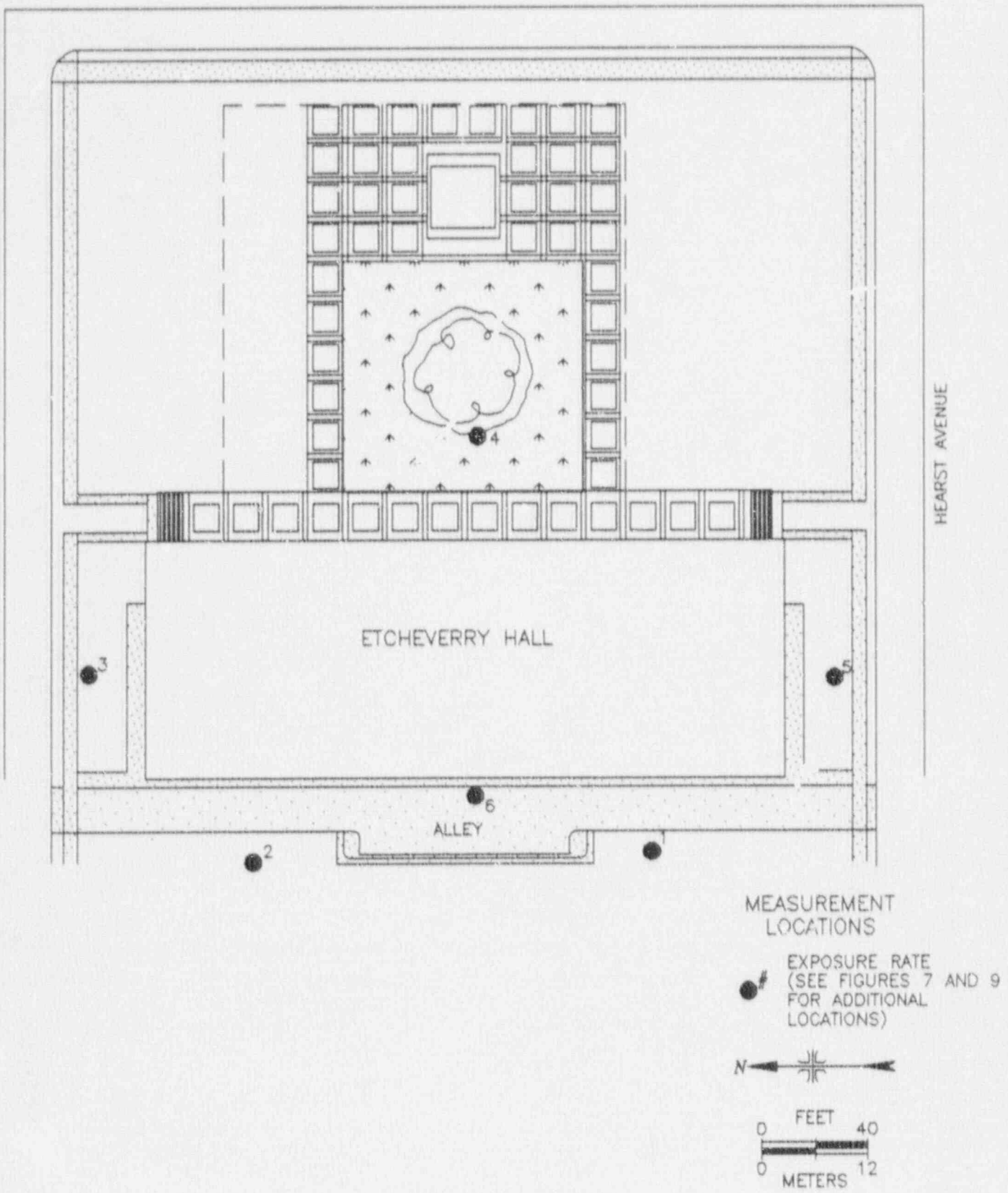


FIGURE 8: UC Berkeley–Etcheverry Hall Showing Exposure Rate Measurement Locations

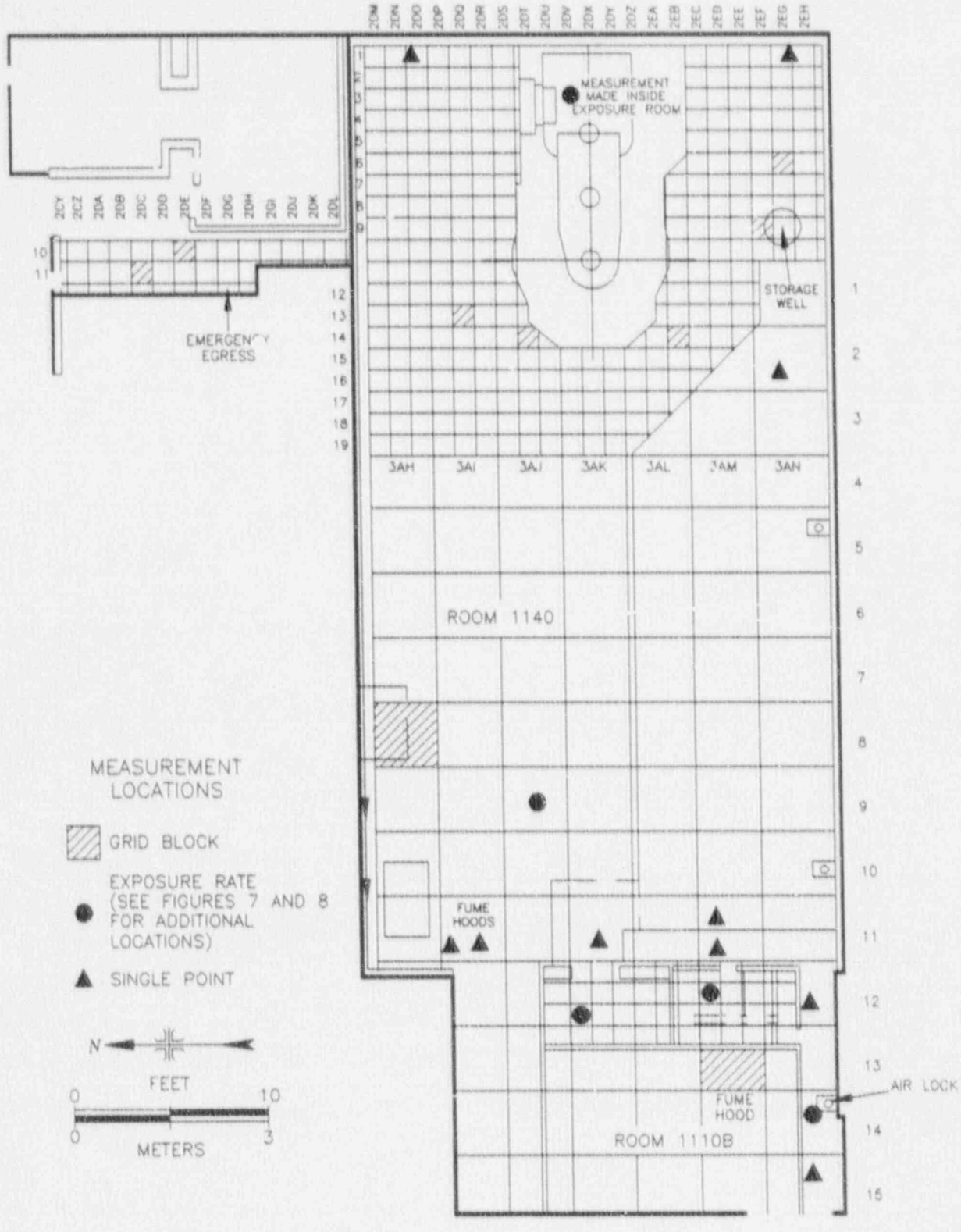


FIGURE 9: Room 1140, Emergency Egress, and Room 1110B Direct Measurement Locations and Ground Floor Exposure Rate Measurement Locations

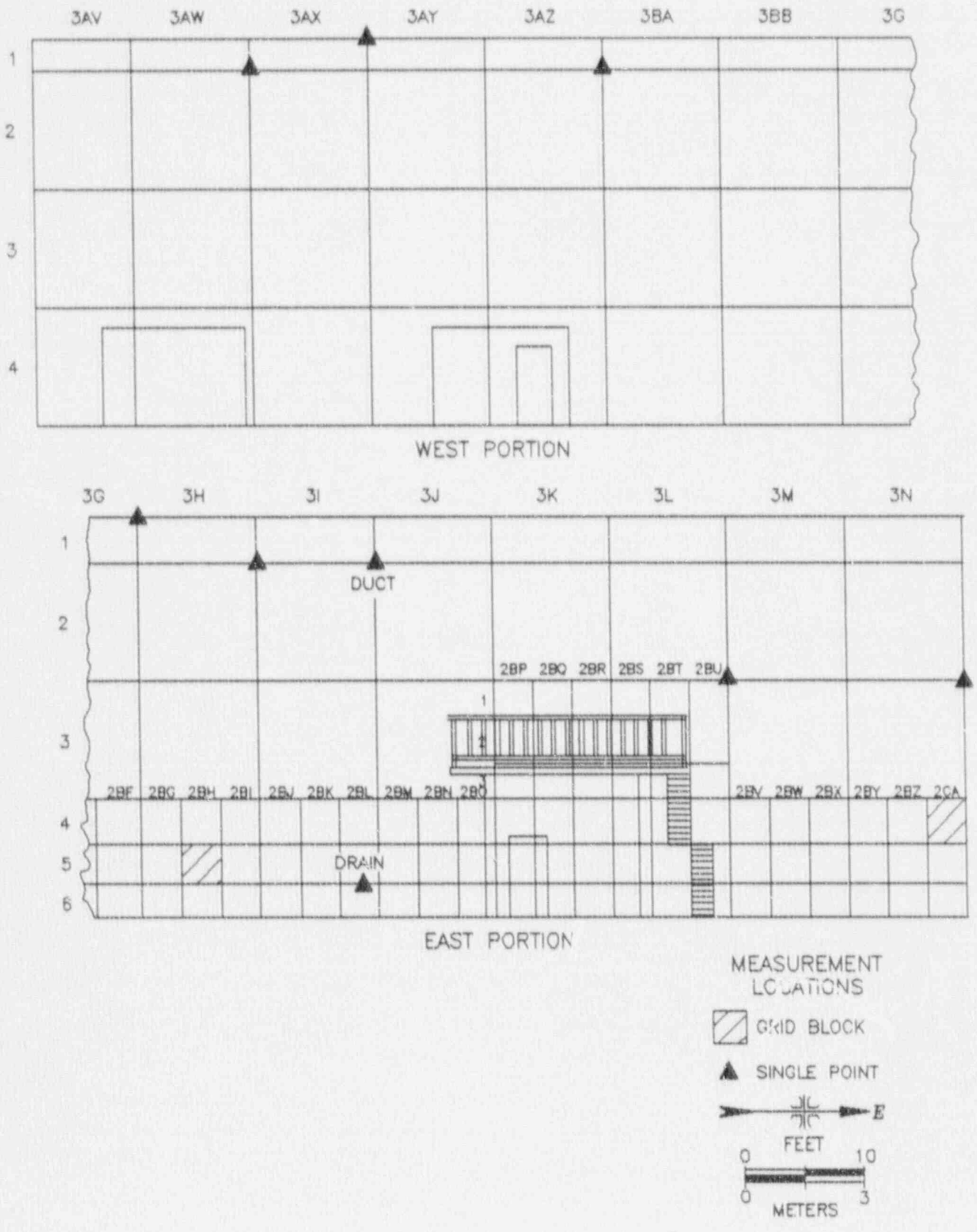


FIGURE 10: Elevation North Wall, Room 1140

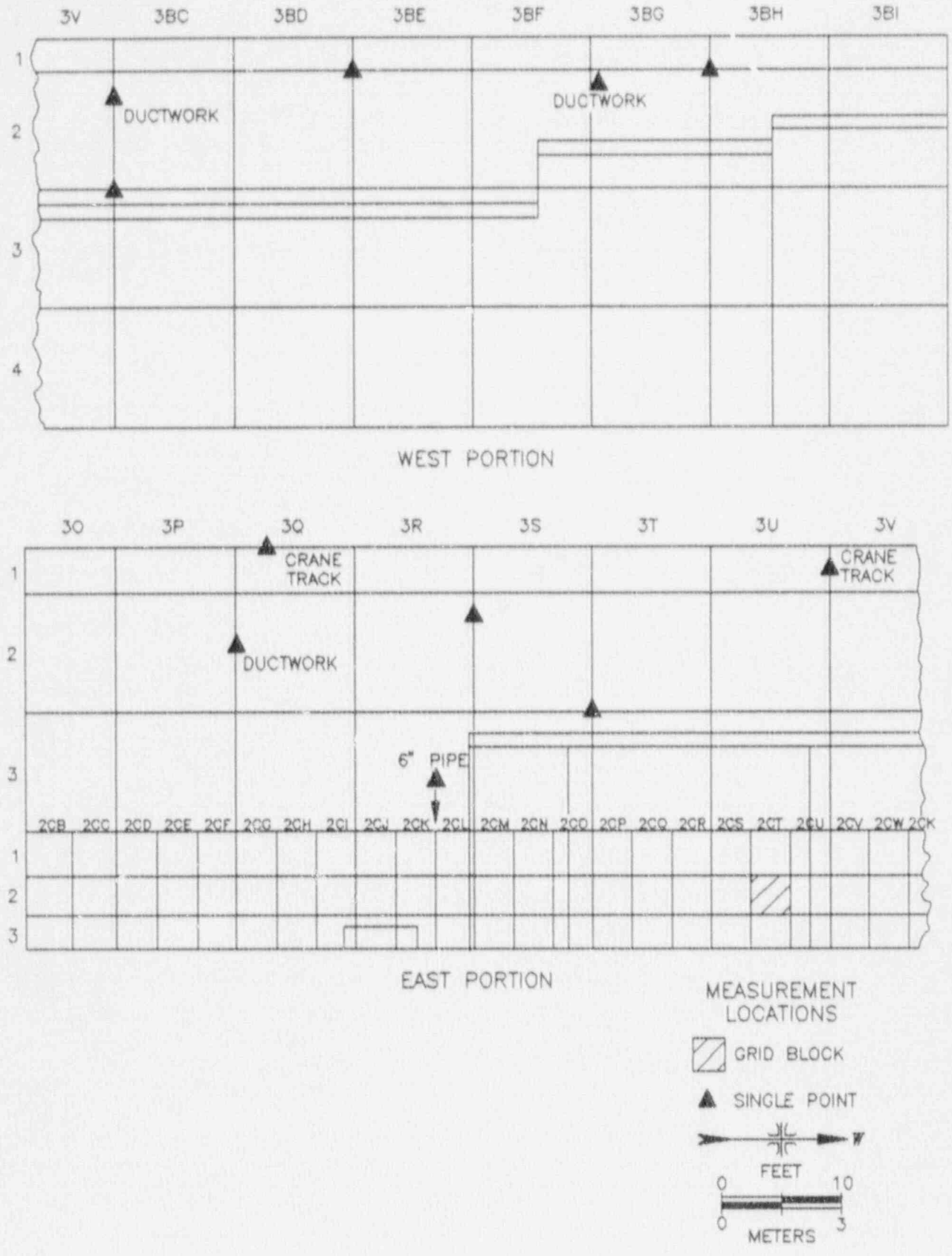


FIGURE 11: Elevation South Wall, Room 1140

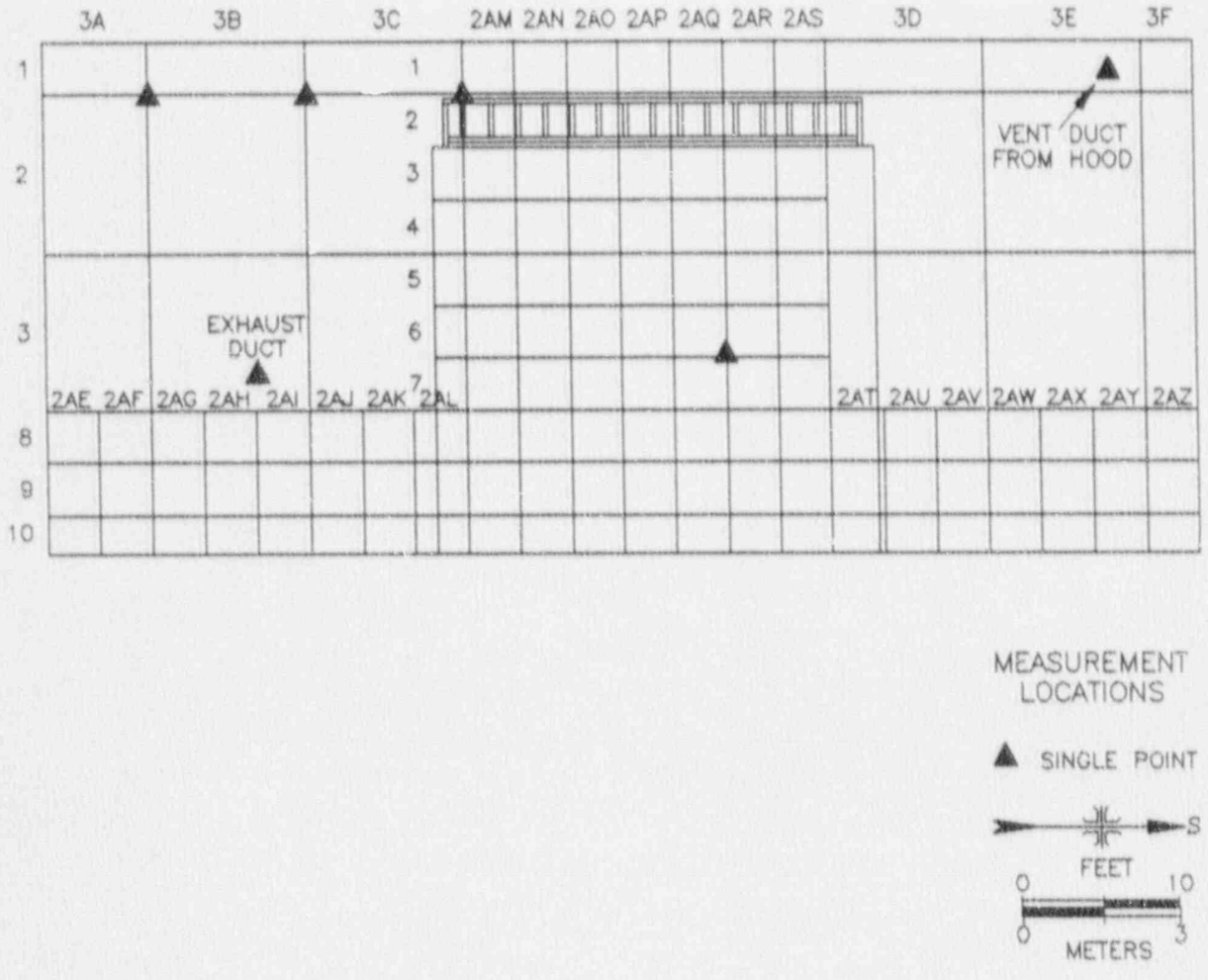


FIGURE 12: Elevation East Wall, Room 1140

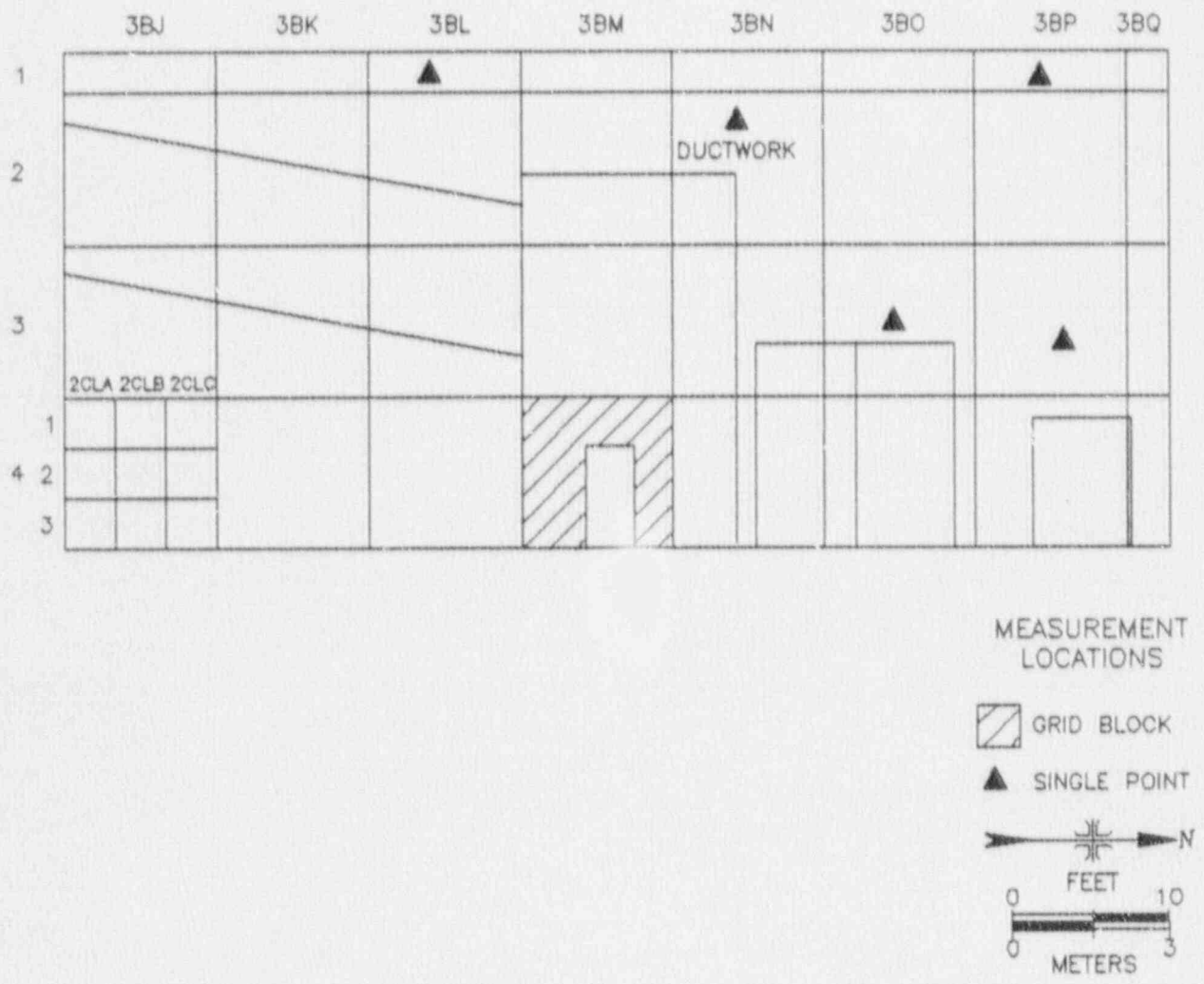


FIGURE 13: Elevation West Wall, Room 1140

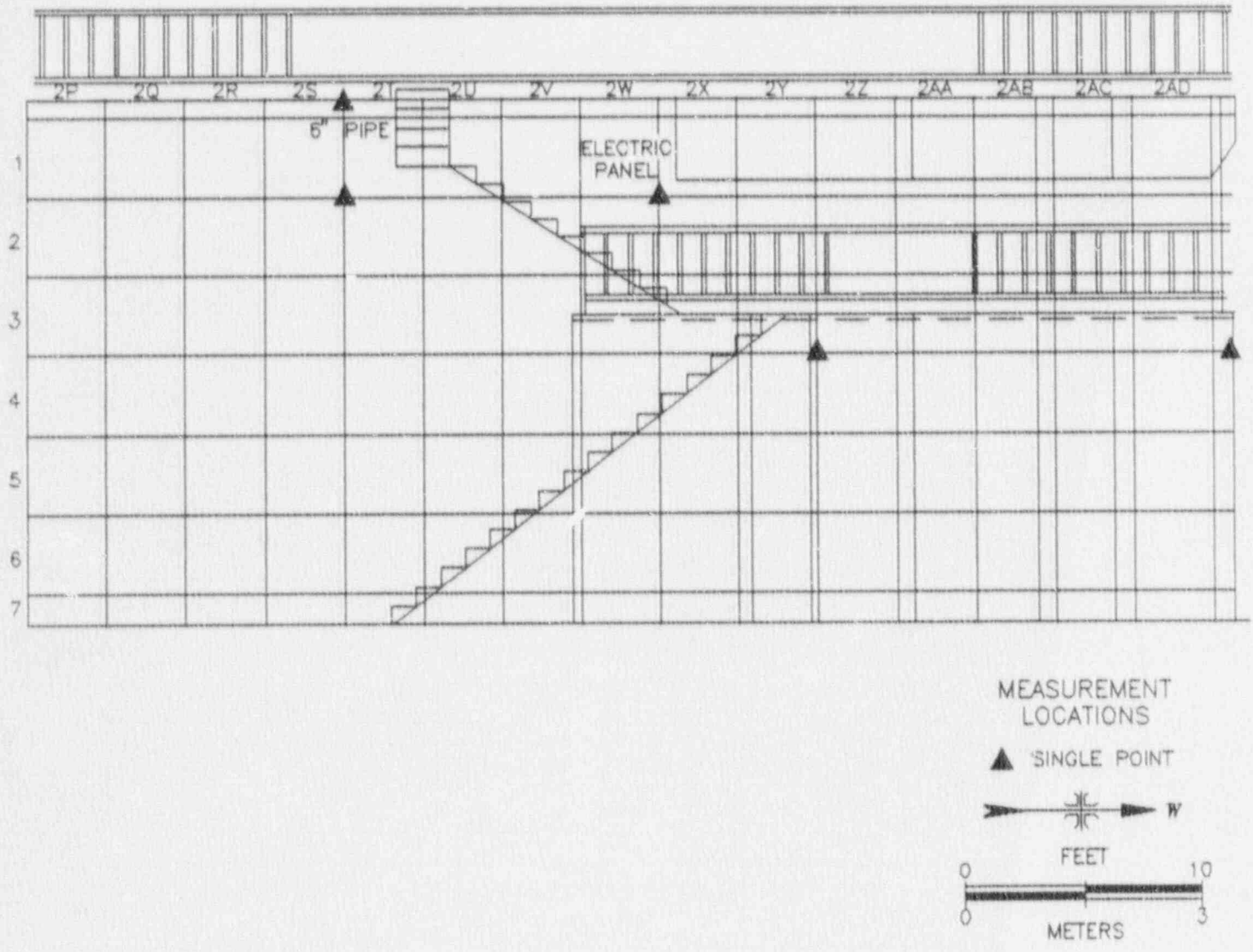


FIGURE 14: North Wall, Reactor Monolith Exterior

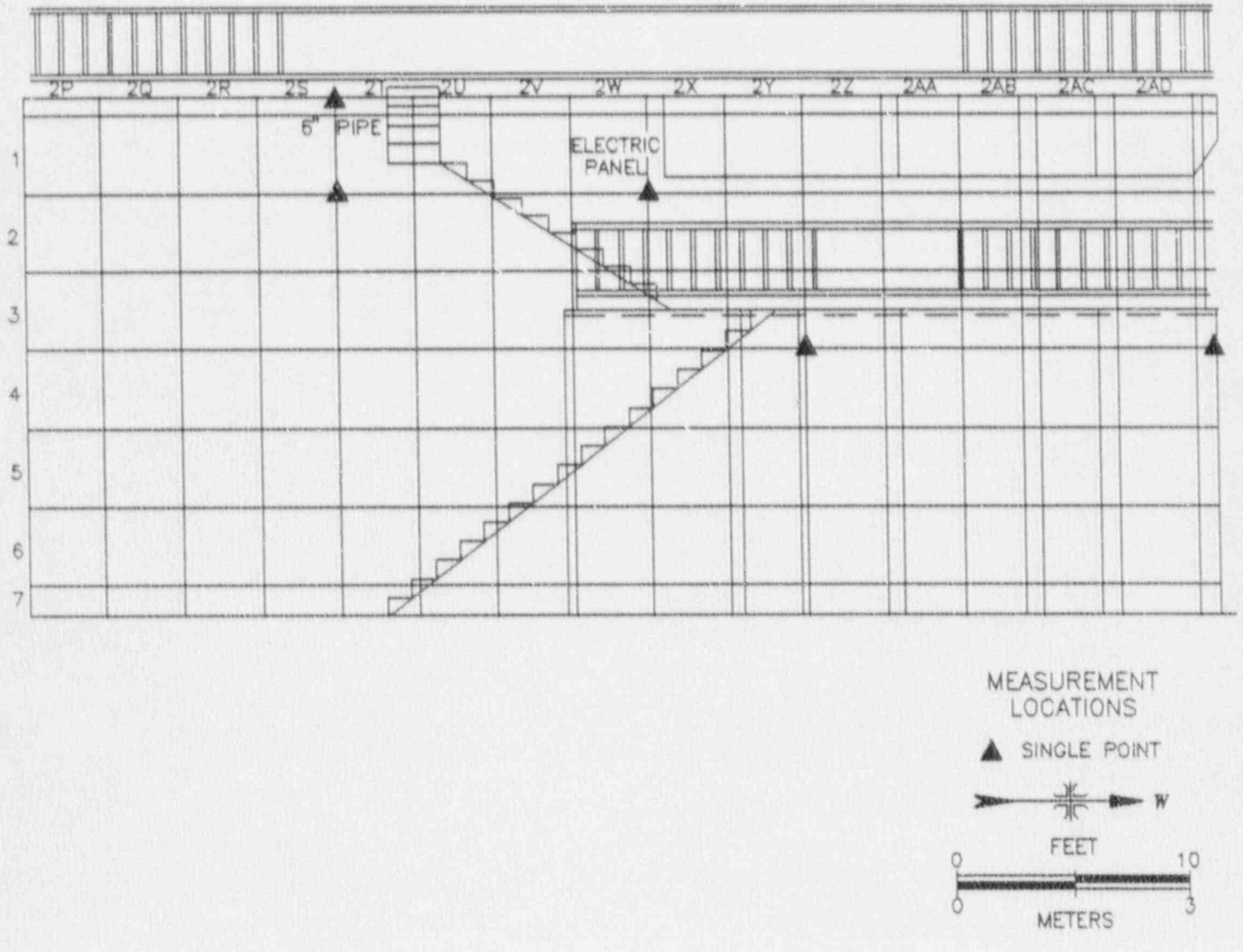


FIGURE 14: North Wall, Reactor Monolith Exterior

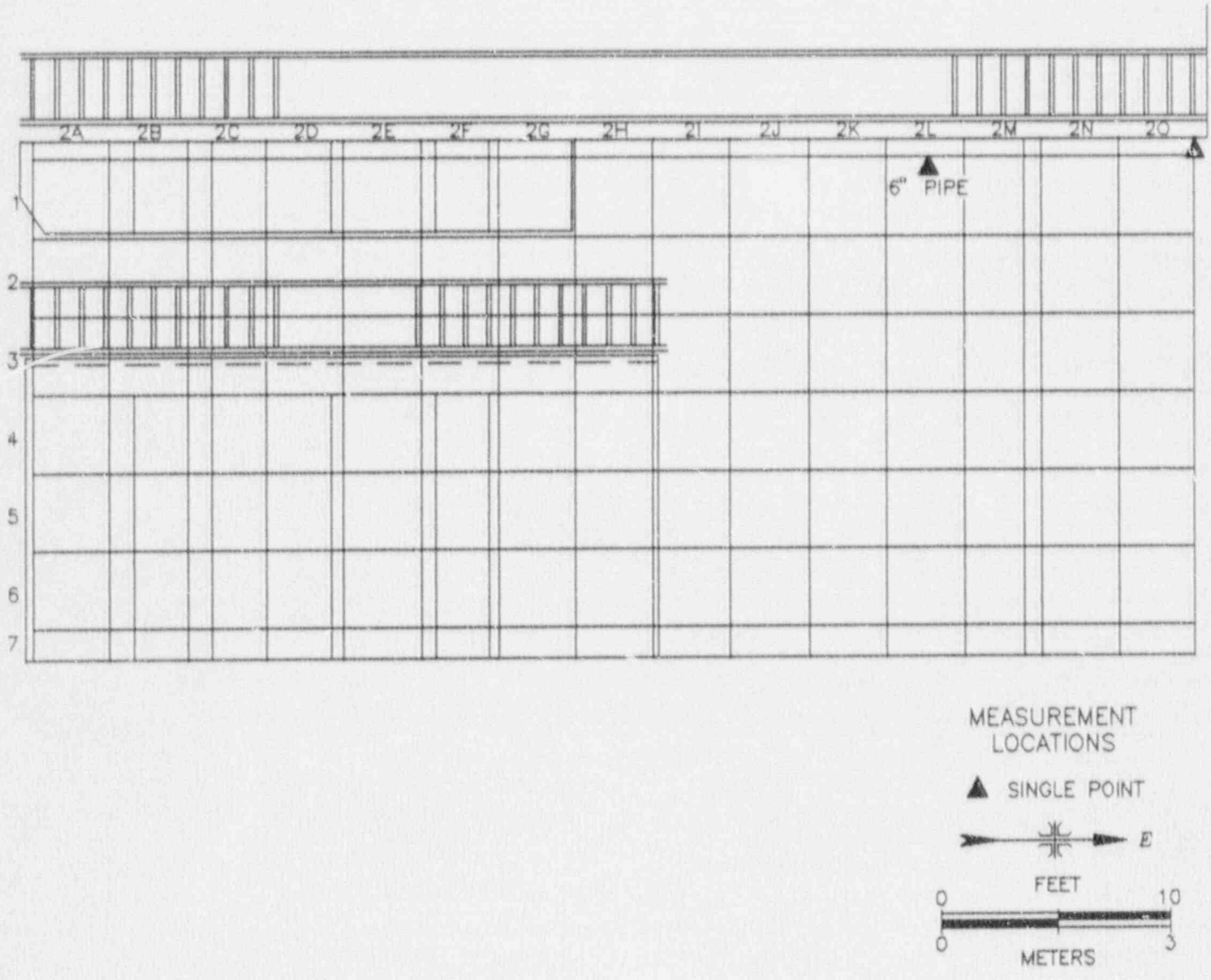


FIGURE 15: South Wall Reactor, Monolith Exterior

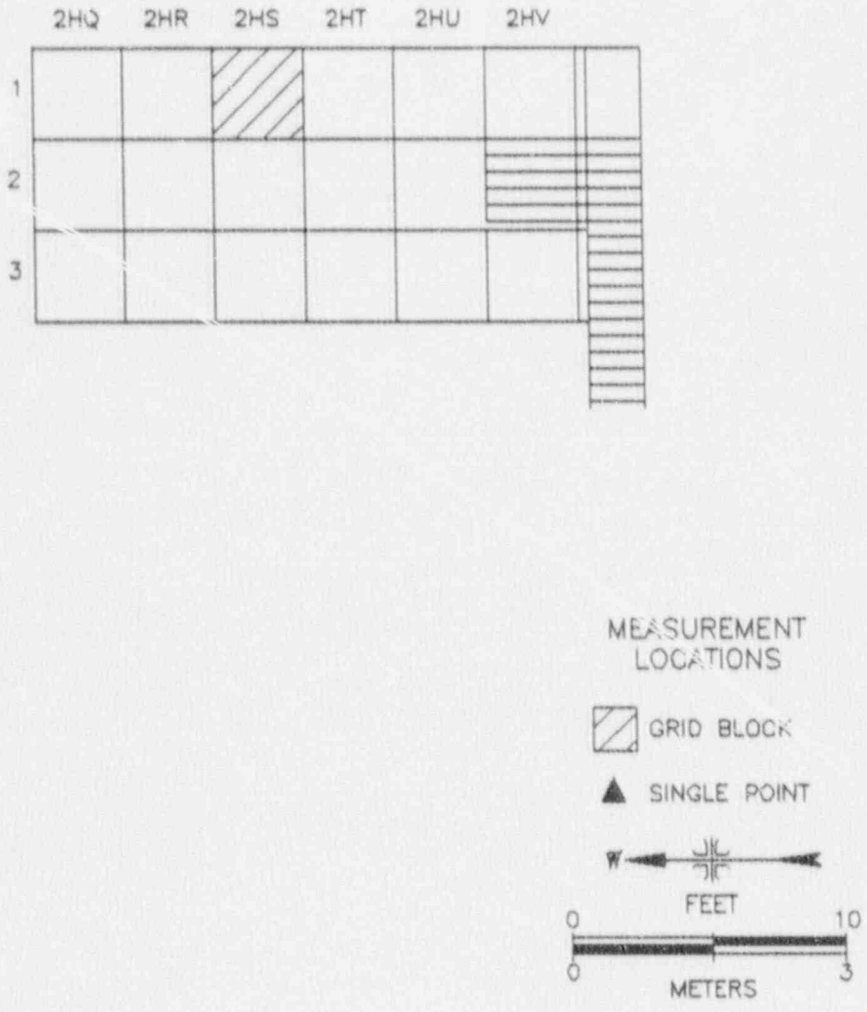


FIGURE 16: Operator's Platform Walking Surface

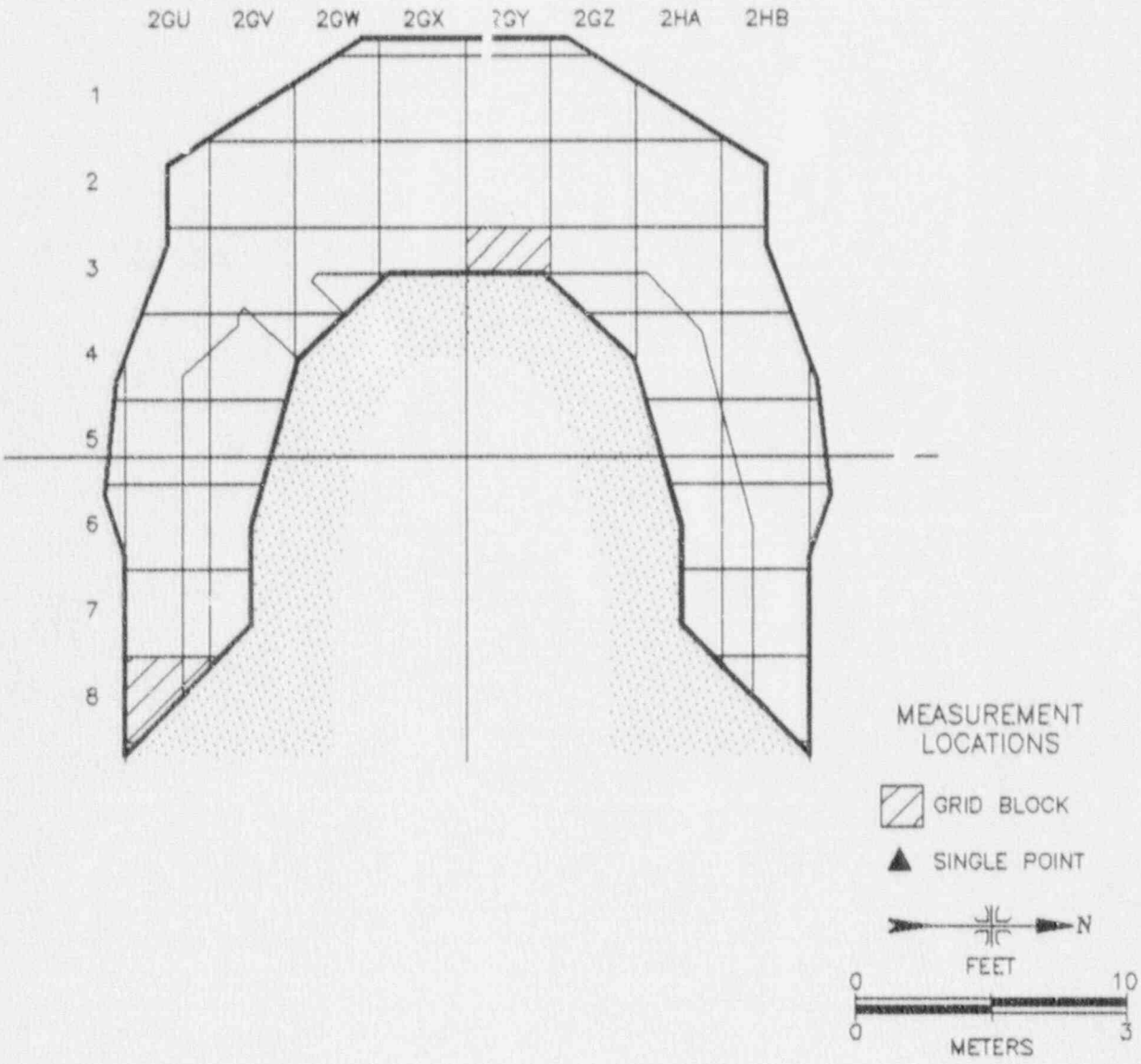


FIGURE 17: Monolith Mezzanine

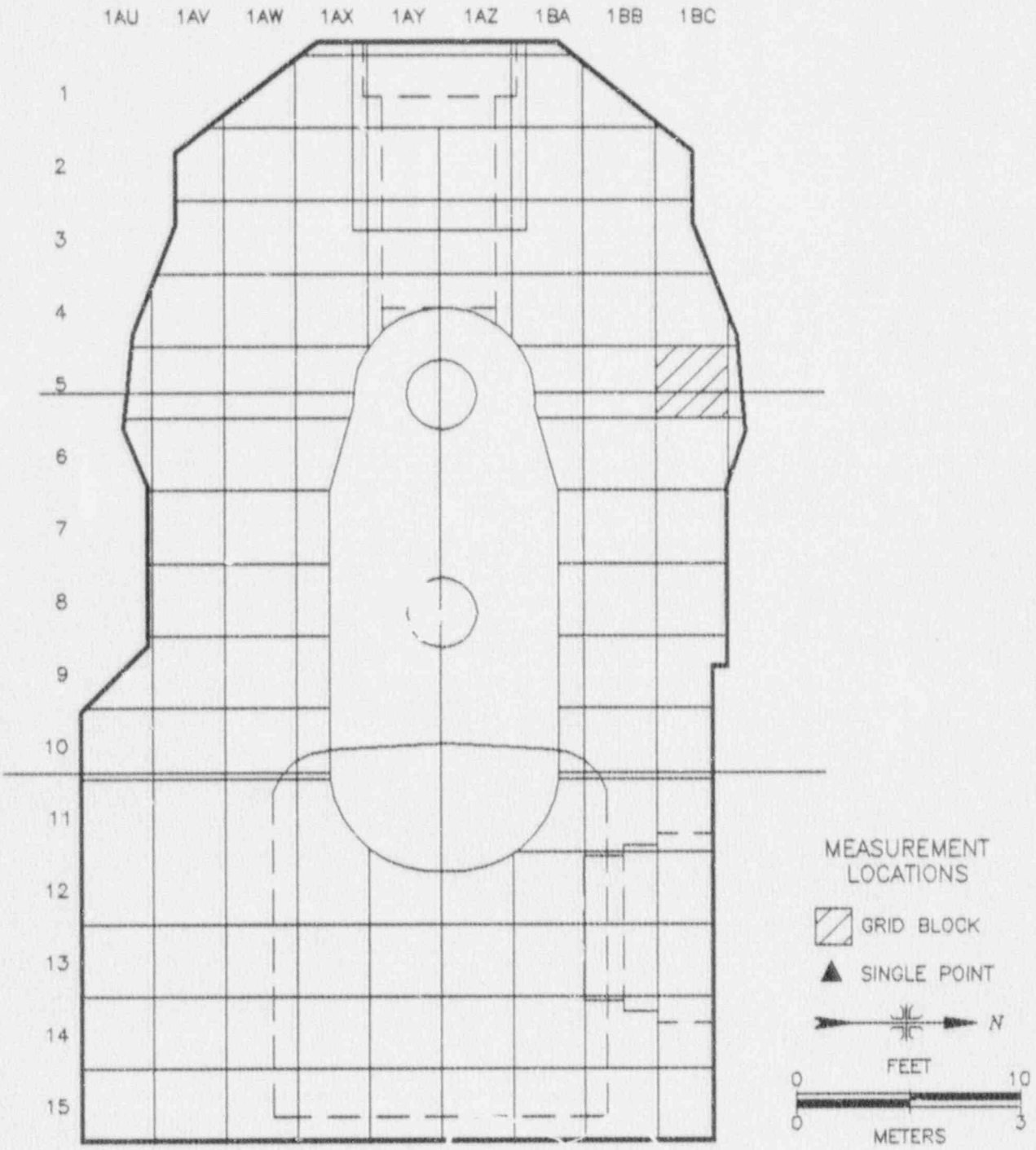


FIGURE 18: Reactor Monolith Walking Surface

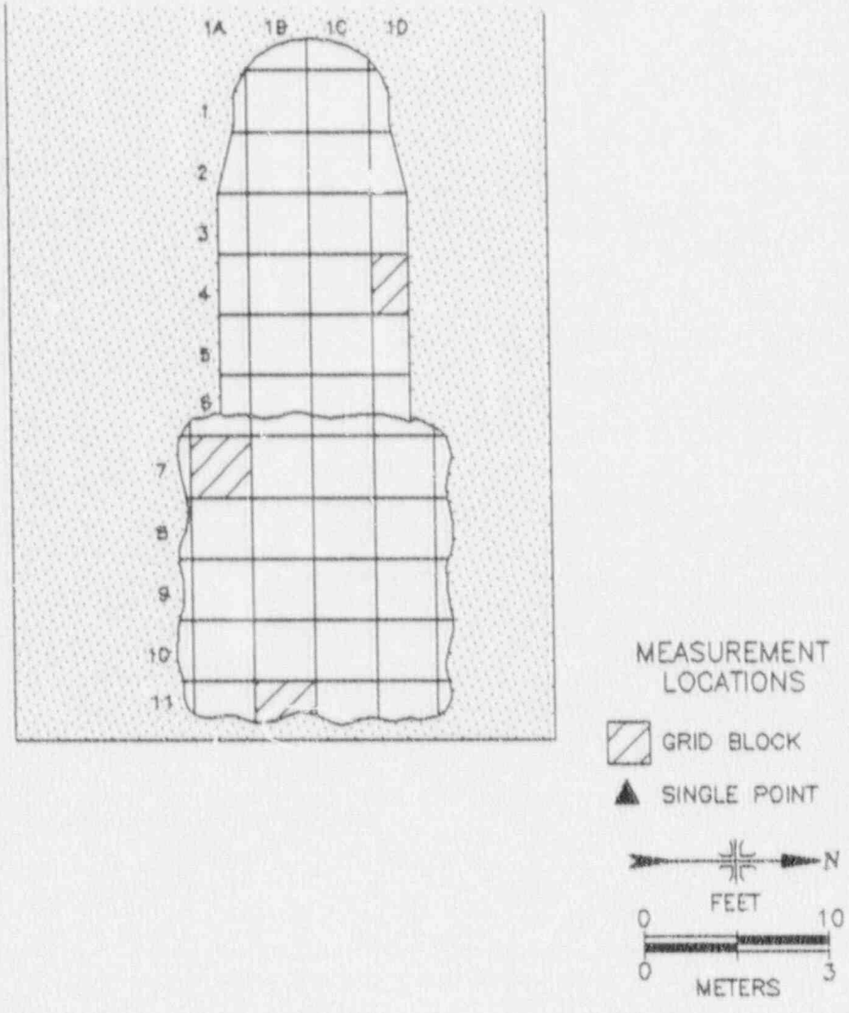
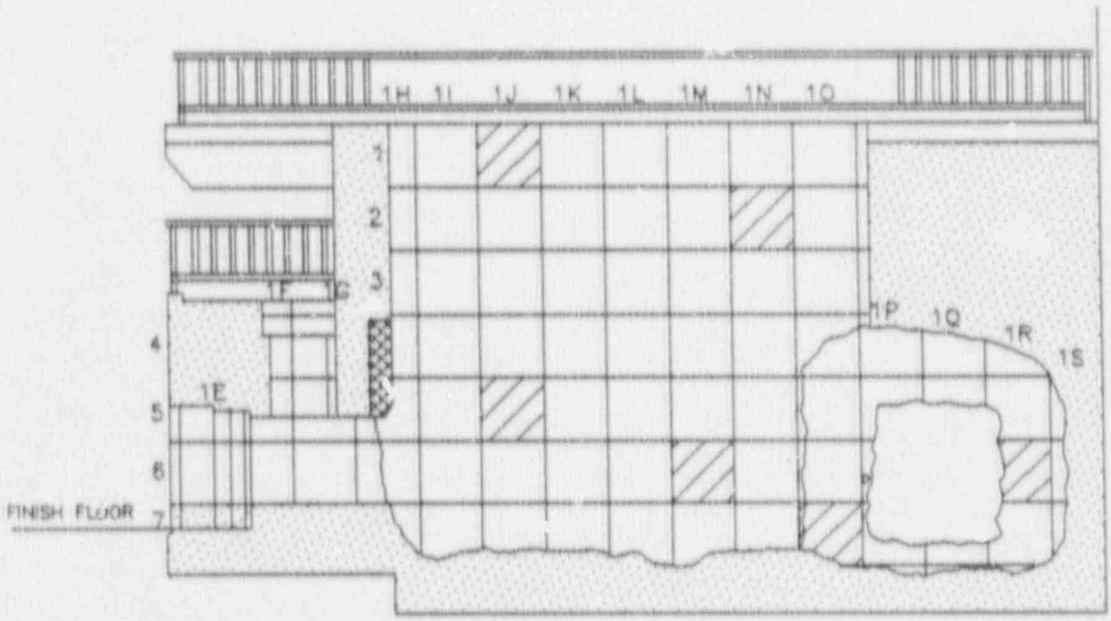


FIGURE 19: Reactor Monolith Exposure Room and Pool Floor



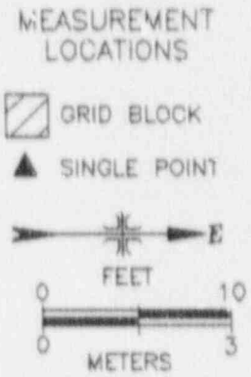


FIGURE 20: Reactor Monolith Interior–North Wall

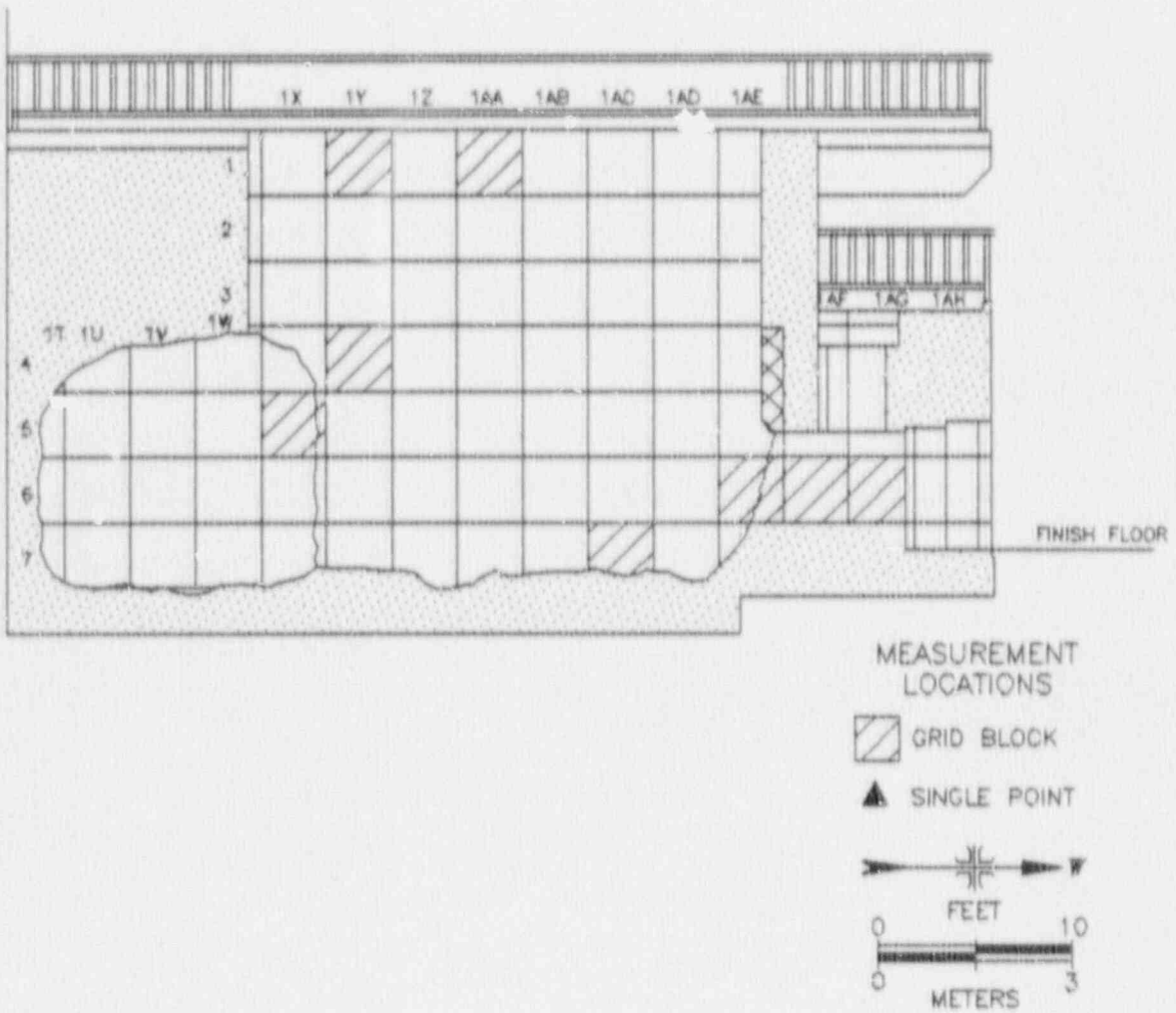


FIGURE 21: Reactor Monolith Interior--South Wall

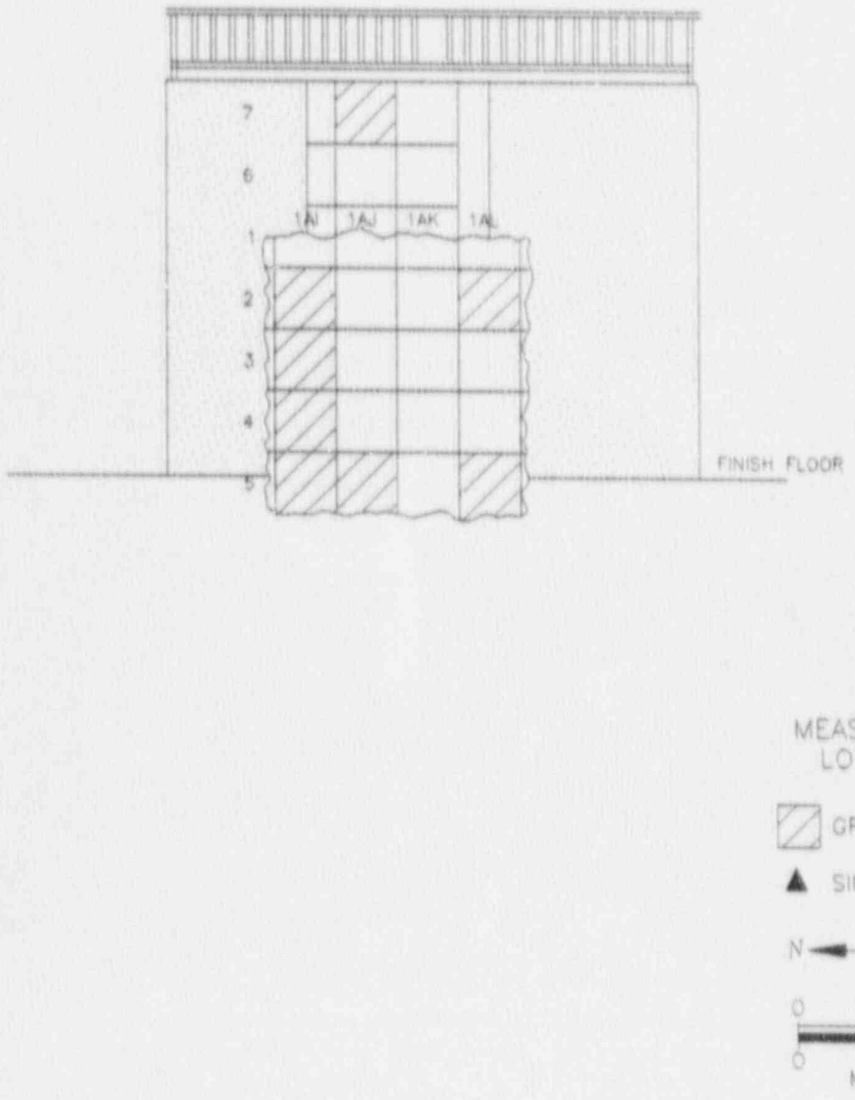
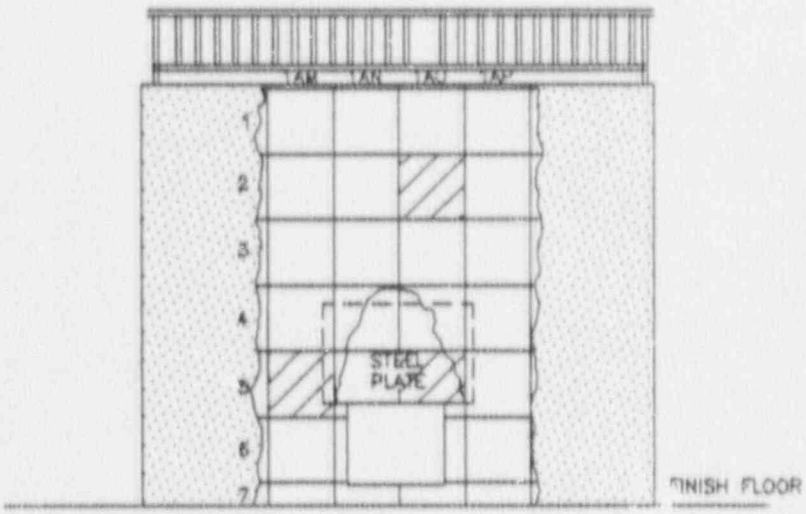


FIGURE 22: Reactor Monolith Interior–East Wall



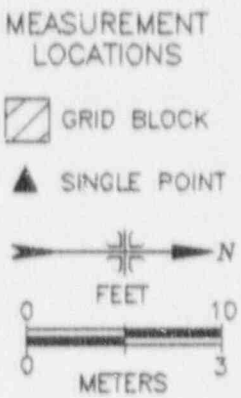
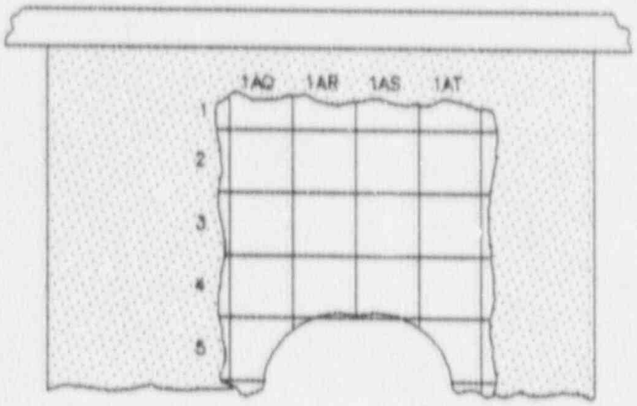


FIGURE 23: Reactor Monolith Interior–West Wall



MEASUREMENT LOCATIONS

GRID BLOCK

SINGLE POINT

N

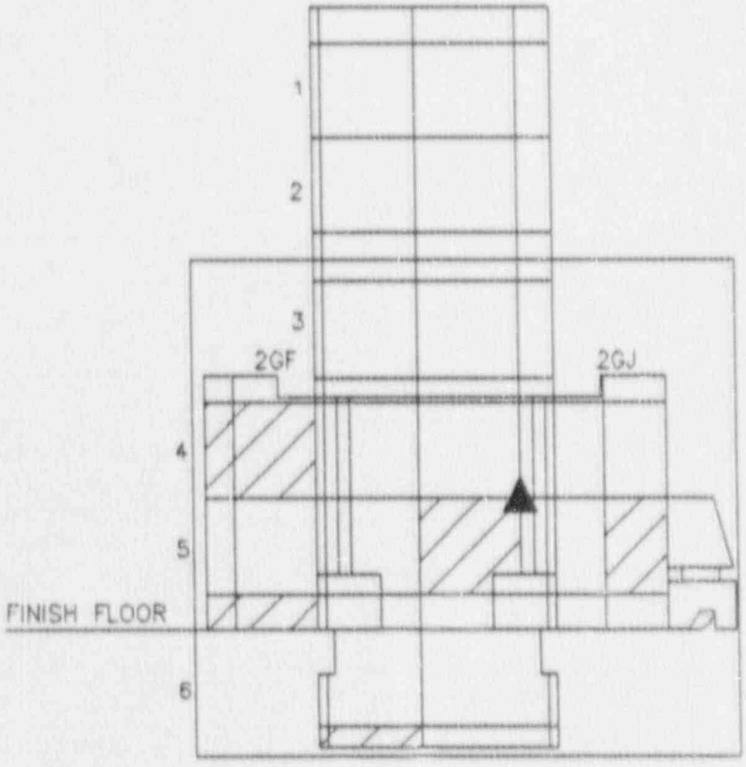
FEET

0 10

0 3

METERS

FIGURE 24: Reactor Monolith Exposure Room Ceiling



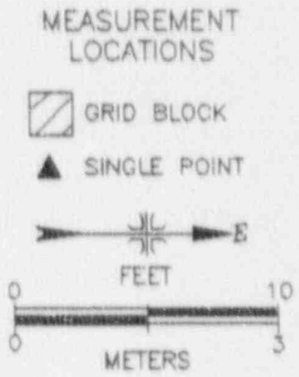


FIGURE 25: BRR Exposure Room Door

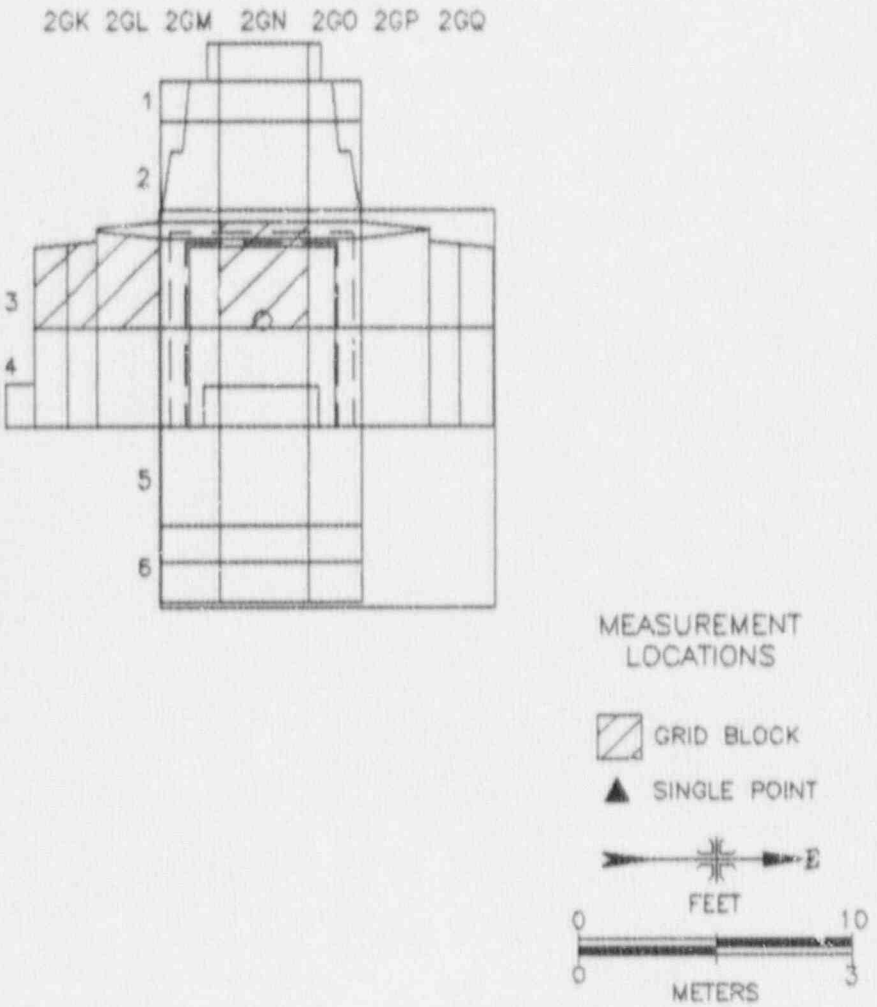


FIGURE 26: BRR Thermal Column Door

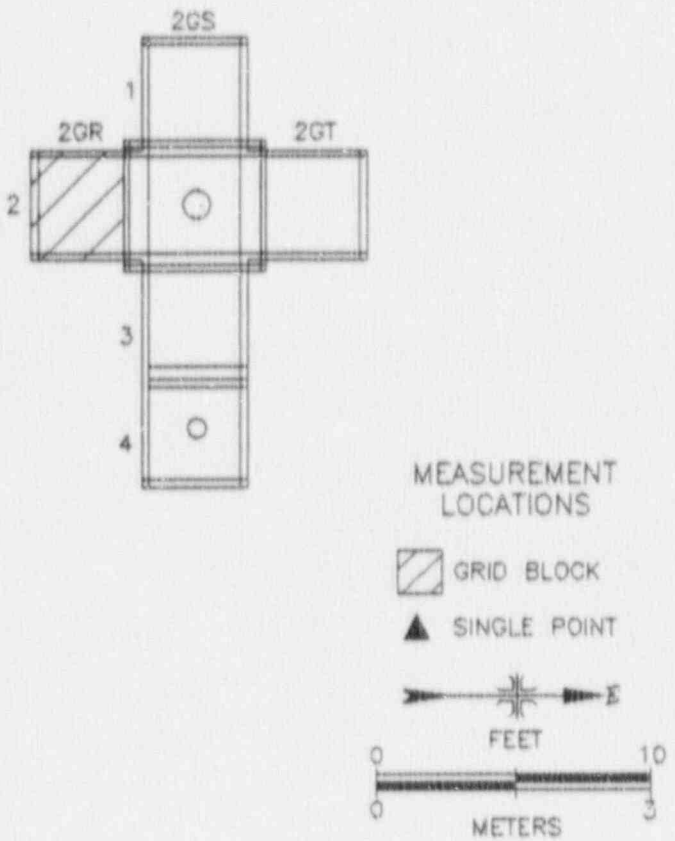


FIGURE 27: Vertical Thermal Column Plug

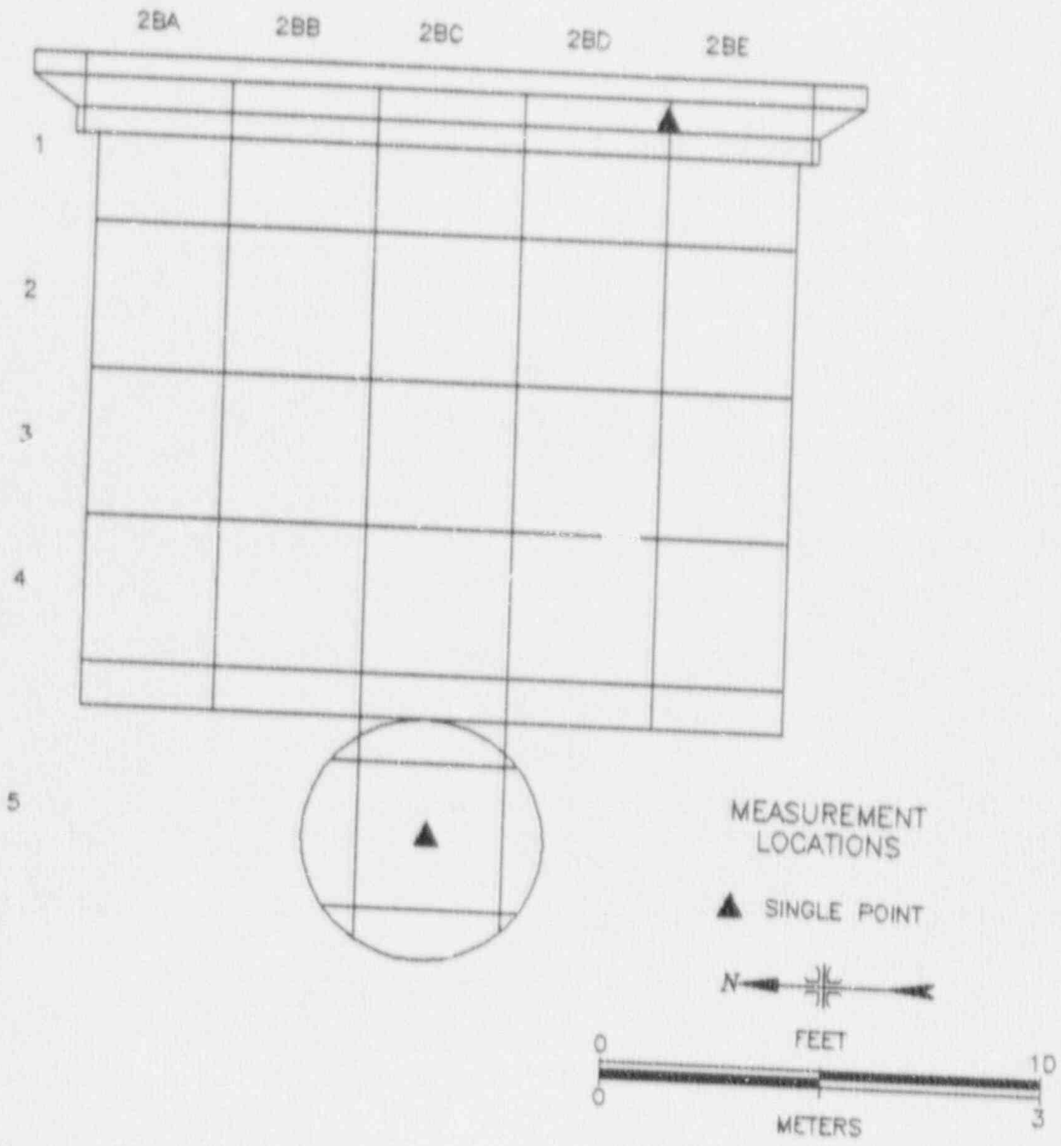


FIGURE 2B: Developed View of Storage Well Room 1140

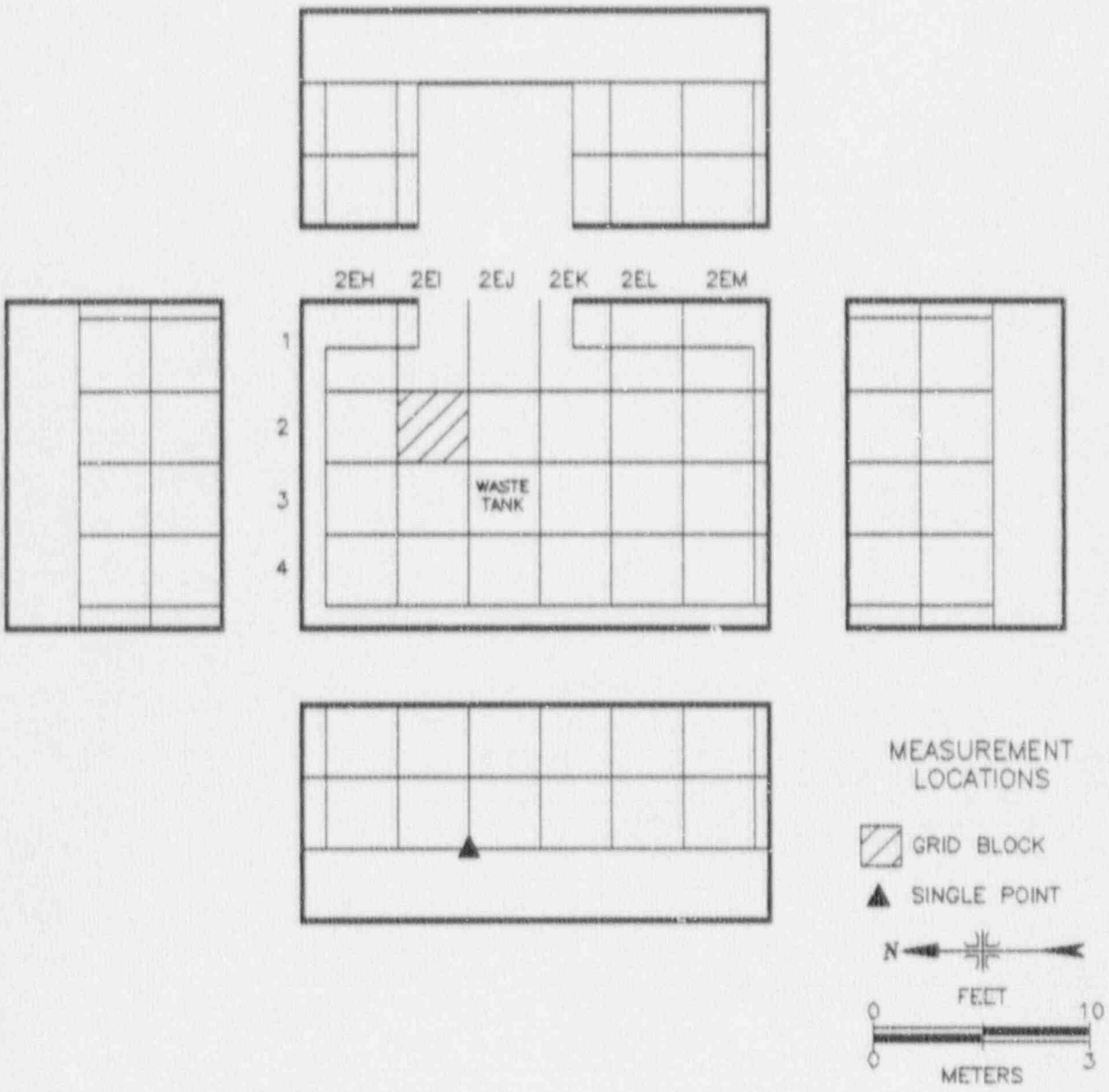


FIGURE 29: Reactor Operator's Office

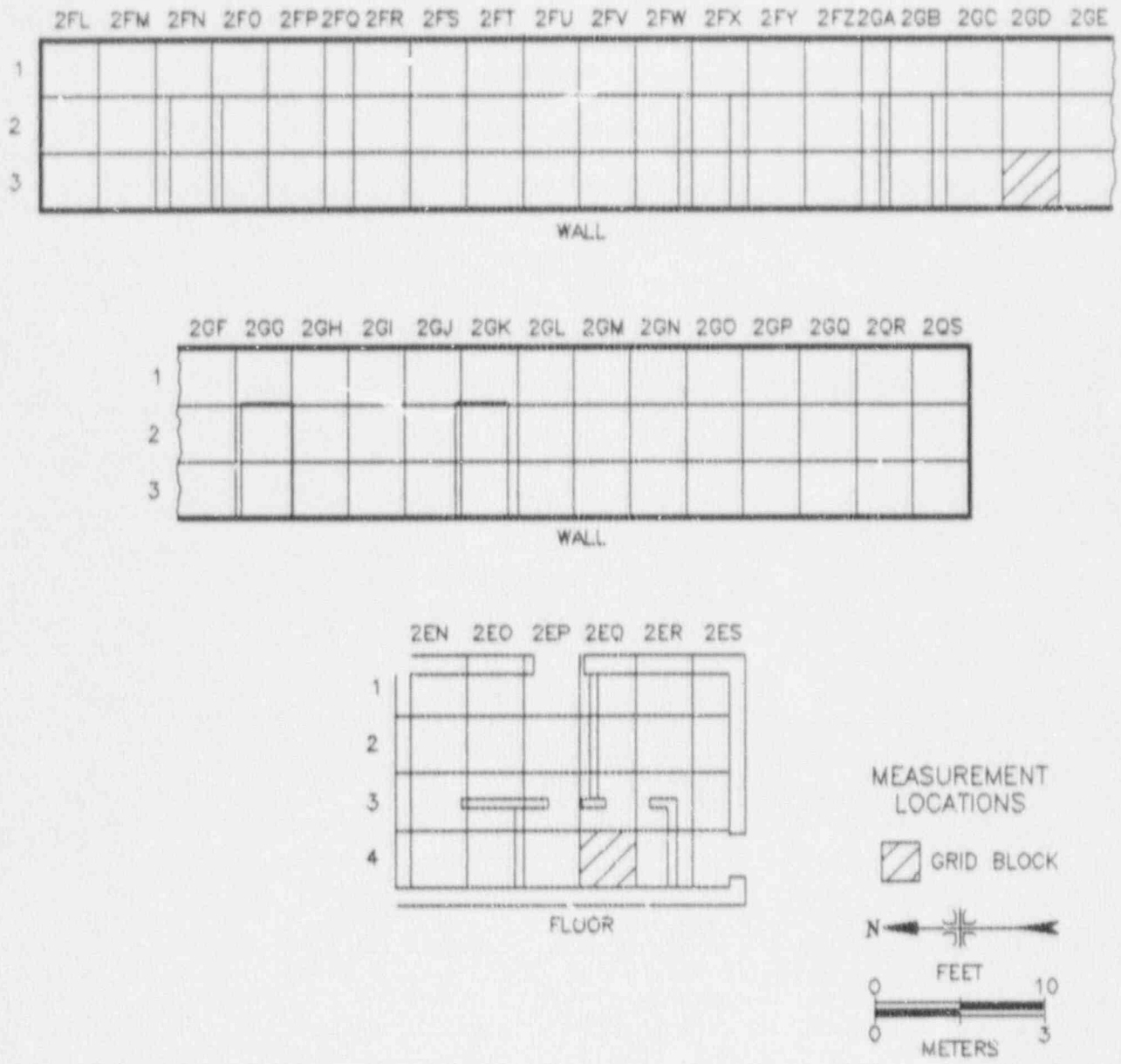


FIGURE 30: Decontamination Facility Floor and Walls

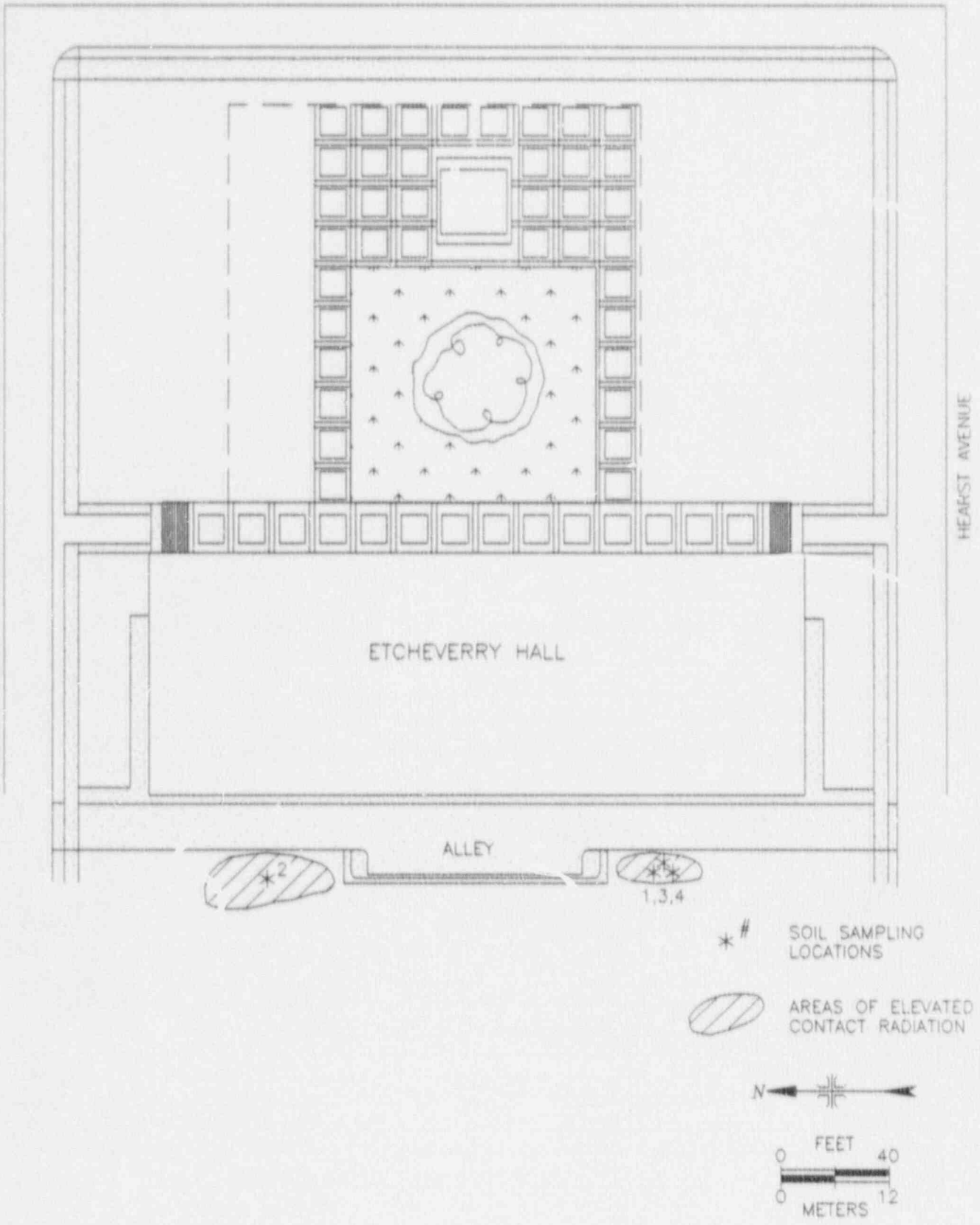


FIGURE 31: UC Berkeley–Etcheverry Hall Showing Soil Sampling Locations

TABLE 1

EXPOSURE RATE MEASUREMENTS
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

Location		Exposure Rate (μR/h) at 1 m Above Surface
Background Measurements		
Exterior[a]	North Etcheverrey Hall	8
Exterior[a]	East Etcheverrey Hall	9
Exterior[a]	South Etcheverrey Hall	7
Exterior[a]	West Alley Etcheverrey Hall	8
Interior[b]	Third Floor Lobby	8
Interior[b]	Fifth Floor/Center of East Corridor	8
Interior[b]	Fifth Floor/South End of East Corridor	9
Interior[b]	Sixth Floor/Center of East Corridor	8
Interior[b]	Sixth Floor/South End East Corridor	9
Reactor Facility & Elevated Location Measurements		
Exterior[a]	West Alley Etcheverrey Hall	12
Exterior[a]	West Alley Etcheverrey Hall	10
Exterior[a,d]	West Alley Etcheverrey Hall	9
Interior[c]	Reactor Monolith	10
Interior[c]	Reactor Bay (Room 1140)	9
Interior[c]	Reactor Operators Office	9
Interior[c]	Airlock	9
Interior[c]	Personnel Decontamination Room	8

[a]Refer to Figure 8.
[b]Refer to Figure 7.
[c]Refer to Figure 9.
[d]Measurement taken following remediation.

TABLE 2

SUMMARY OF SURFACE ACTIVITY
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

Room	Location	# Measured Locations	Highest Grid Block Avg. (dpm/100 cm^2) Alpha plus Beta	Total Activity (dpm/100 cm^2) Alpha plus Beta Range	Removable Activity (dpm/100 cm^2) Alpha Range	Removable Activity (dpm/100 cm^2) Beta Range	Tritium (Removable) (dpm/100 cm^2)
1140	Lower Walls and Floor	14	<240	<240 - 280	<8	<18	<22
	Upper Walls & Ceiling	45	N/A	<840	<8	<18	—
	Equipment & Drains	5	N/A	<840	<8	<18	<22 - 43
Reactor Pool & Exposure Room	Walls and Floor	27	440	<240 - 660	<8	<18	<22
	Ceiling	1	<250	<250	<8	<18	<22
Exposure Room Door	Door	4	<250	<250 - 610	<8	<18	<22
	Single Point	1	N/A	1700			
Personnel Decon	Walls and Floor	1	<240	<240	<8	<18	<22
Reactor Operators Office	Lower Walls and Floors	1	<250	<250	<8	<18	<22
	Upper Walls and Ceilings	1	—	<270	<8	<18	—

TABLE 2 (Continued)

SUMMARY OF SURFACE ACTIVITY
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

Room	Location	# Measured Locations	Highest Grid Block Avg. (dpm/100 cm^2) Alpha plus Beta	Total Activity (dpm/100 cm^2) Alpha plus Beta Range	Removable Activity (dpm/100 cm^2) Alpha Range	Removable Activity (dpm/100 cm^2) Beta Range	Tritium (Removable) (dpm/100 cm^2)
Airlock & Hall To Reactor Room	Walls and Floor	4	—	<250	<8	<18	—
Vertical Thermal Column	Walls	1	<250	<250	<8	<18	<22
Horizontal Thermal Column Door	Door	2	<250	<250 - 420	<8	<18	<22
Emergency Egress	Walls and Floor	1	<240	<240	<8	<18	<22
11108 Hood		1	<250	<250	<8	<18	<22
Storm & Sanitary Sewers		2	—	—	<8	<18	<22

TABLE 3

RADIONUCLIDE CONCENTRATIONS IN SOIL
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

Sample Location[a]	Radionuclide Concentration (pCi/g)				
	U-235	U-238	Total U[c]	Th-232	Ra-226
1	2.9 ± 0.4[d]	77 ± 12	138	12 ± 0.3	73 ± 1
2	1.3 ± 0.3	36 ± 10	63	4.9 ± 0.2	30 ± 0.3
3	0.1 ± 0.1	2.7 ± 1.7	5.3	1.0 ± 0.5	0.9 ± 0.2
4[b] Post Remediation	0.5 ± 0.2	4.4 ± 1.3	17	1.2 ± 0.4	3.8 ± 0.4

[a]Refer to Figure 31 for sample points.
[b]Sample collected from area with highest contact gamma radiation level following excavation.
[c]Calculated, utilizing U-234/U-235 activity ratio of 21.
[d]Uncertainties represent the 95% confidence level, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN CONCRETE
BERKELEY RESEARCH REACTOR FACILITY
UNIVERSITY OF CALIFORNIA AT BERKELEY
BERKELEY, CALIFORNIA

NUCLIDE	RANGE OF CONCENTRATIONS (pCi/g)[a]
Co-57	<1.2
Co-60	0.4 ± 0.4 to 2.3 ± 1.6
Cs-137	<2.8
Eu-152	<5.8
Eu-154	<12
Eu-155	<3.7
Mn-54	<2.4

[a]Relatively high measurement sensitivities were the result of limited sample quantity.

REFERENCES

1. Decommissioning Final Report and Termination Radiation Survey Results, University of California at Berkeley, Berkeley Research Reactor Decommissioning Project, Biscraft Northeast Inc., April 1990.

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

I. Direct Radiation Measurement

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, OH)

Eberline "Rascal"
Portable Ratemeter-Scaler
Model PRS-1
(Eberline, Santa Fe, NM)

Eberline Beta-Gamma "Pancake" Detector
Model HP-260
(Eberline, Santa Fe, NM)

Ludlum Alpha-Beta Floor Monitor
Model 239-1
(Ludlum, Sweetwater, TX)

Ludlum Ratemeter-Scaler
Model 2221
(Ludlum, Sweetwater, TX)

Ludlum Alpha-Beta Gas Proportional Detector
Model 43-68
(Ludlum, Sweetwater, TX)

Reuter-Stokes Pressurized Ion Chamber
Model RSS-111
Reuter-Stokes, Cleveland, OH)

II. Laboratory Analytical Equipment

Low BKG Alpha-Beta Counter
Model LB-5110
(Tennelec, Oak Ridge, TN)

Tri-Carb Liquid Scintillation Anal.
Model 1900CA
(Packard Instrument Co., Meridan, CT)

High-Purity Germanium Coaxial Well Detector
Model GWL-110210-PWS-S, 23% Eff.
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield Model G-16
(Applied Physical Technology, Atlanta, GA)

High-Purity Germanium Detector
Model IGC25, 25% Eff.
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield
(Nuclear Data, Schaumburg, IL)

Multichannel Analyzer
ND66/MicroVax
(Nuclear Data, Schaumburg, IL/Digital
Equipment, Maynard, MA)

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

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MEASUREMENT AND ANALYTICAL PROCEDURES

Surface Scans

Surface scans were performed by passing the probes slowly over the surface; the distance between the probe and the surface was maintained at a minimum - nominally about 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument. Scans of large surface areas of the floor of the facility were accomplished by use of a gas proportional floor monitor, with a 550 cm^2 sensitive area. The detector was slowly moved in a systematic pattern to cover 100% of the accessible areas. Other surfaces were scanned using smaller, hand-held detectors. Combinations of detectors and instruments for the scans were:

Beta-Gamma	-	Pancake GM probe with PRS-1 scaler/ratemeter.
Gamma	-	NaI scintillation detector (3.2 cm x 3.8 cm crystal) with PRM-6 ratemeter.
Alpha-Beta	-	Gas Proportional Floor Monitor with Ludlum Model 2220 Scaler/ratemeter.
Alpha-Beta	-	Gas Proportional 100 cm^2 probes with Ludlum Model 2221 Scaler/ratemeter.

Surface Activity Measurements

Measurements of total alpha plus beta activity levels were performed using Ludlum Model 2221 portable scaler/ratemeters with Model 43-68 hand held gas proportional probes. Count rates (cpm) were converted to disintegration rates (dpm/100 cm^2) by dividing the net rate by the 4 π efficiency and correcting for the active area of the detector. The background count rate for the 100 cm^2 proportional detectors averaged approximately 250 cpm; the average background count rate was approximately 40 cpm for the GM detectors.

Removable Activity Measurement

Smears for determination of removable activity levels were performed using numbered filter paper disks, 47 mm in diameter; smears were placed in labeled envelopes with the location and other pertinent information recorded. The smears were counted on a low background gas-proportional counter for gross alpha and gross beta activity.

Smears were cut up and placed into scintillation vials containing a commercial "cocktail"; vials were analyzed by liquid scintillation counting for tritium activity.

Gamma Exposure Rate Measurements

Measurements of gamma exposure rates were performed using a Reuter-Stokes pressurized ionization chamber. The chamber was placed 1 meter above the surface at several locations throughout the facility.

Gamma Spectrometry

Samples were placed in an appropriate container, chosen to reproduce the calibrated counting geometry. Net weights were determined and the samples counted using a high purity germanium detector coupled to a Nuclear Data Model ND-66/MicroVaxII pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Co-57	0.136 MeV
Co-60	1.173 MeV
Cs-137	0.661 MeV
Eu-152	0.344 MeV
Eu-154	0.723 MeV

Eu-155	0.105 MeV
Mn-54	0.834 MeV
U-238	1.00 MeV from Pa-234
U-235	0.143 MeV
Th-232	0.911 MeV from Ac-228
Ra-226	0.609 MeV from Bi-214

Spectra were reviewed for other identifiable photopeaks.

Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report, represent the 95% confidence levels for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net samples count was less .han the 95% statistical deviation of the background count, the sample concentration was reported as less than the detection limits of the measurement procedure. Because of variations in background levels, sample volumes or weights, measurement efficiencies, and Compton contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument. Additional uncertainties of + 6 to 10%, associated with sampling and laboratory procedures, have not been propagated into the data presented in this report.

Calibration and Quality Assurance

The Environmental Survey and Site Assessment Program conducted the survey and analytical activities in accordance with field survey and laboratory procedures which are documented in manuals developed specifically for the Oak Ridge Associated Universities' ESSAP to meet the requirements of ANSI/ASME Nuclear Quality Assurance-1 (NQA-1).

The specific manuals and procedures applicable to this survey were the "Quality Assurance Manual," February 1990, Revision 3; "Survey Procedures Manual," March 1990, Revision 5; and the "Laboratory Procedures Manual," February, 1990, Revision 5.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NIST-traceable standards.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and EML Quality Assurance Programs.