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RESULTS OF THE RADIOLOGICAL SURVEY OF THE CARPENTER STEEL FACILITY, READING, PENNSYLVANIA

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ABSTRACT

In 1944, experimental uranium-forming work was conducted by Carpenter Technology Corporation at the Carpenter Steel Facility in Reading, Pennsylvania, under contract to the Manhattan Engineer District (MED). The fabrication method, aimed at producing sounder uranium metal and improving the yields of rods from billets, was reportedly soon discarded as unsatisfactory. As part of the Department of Energy's (DOE) efforts to verify the closeout status of facilities under contract to agencies preceding DOE during early nuclear energy development, the site was included in the Formerly Utilized Sites Remedial Action Program (FUSRAP).

At the request of DOE, the Measurement Applications and Development Group of the Health and Safety Research Division of Oak Ridge National Laboratory performed a radiological assessment survey in July and August 1988. The purpose of the survey was to determine if past operations had deposited radioactive residues in the facility, and whether those residuals were in significant quantities when compared to DOE guidelines. The survey included (1) gamma scanning; (2) direct measurements of alpha activity levels and beta-gamma dose rates; (3) sampling for transferable alpha and beta-gamma residuals on selected surfaces; and (4) sampling of soil, debris and currently used processing materials for radionuclide analysis.

All survey results were within DOE FUSRAP guidelines derived to determine the eligibility of a site for remedial action. These guidelines are derived to ensure that unrestricted use of the property will not result in any measurable radiological hazard to the site occupants or the general public.

RESULTS OF THE RADIOLOGICAL SURVEY OF THE CARPENTER STEEL FACILITY, READING, PENNSYLVANIA *

INTRODUCTION

The Carpenter Steel Division Facility is located in an industrial complex at 101 West Bern Street, Reading, Pennsylvania. The facility, owned and operated by Carpenter Technology Corporation, was under contract to the Manhattan Engineer District (MED) to conduct experimental uranium metal-forming work in 1944. Historical information is sparse, however, available records indicate that the large-scale uranium hot rolling tests conducted here were similar to those performed by the Joslyn Manufacturing Company in Fort Wayne, Indiana. Accounts also suggest that the product was intended for the Hanford Engineer Works. The fabrication method, aimed at producing sounder uranium metal and improving the yields of rods from billets, was reportedly soon discarded as unsatisfactory.[1] As part of the Department of Energy's (DOE) efforts to verify the closeout status of facilities under contract to agencies preceding DOE during early nuclear energy development, the site was included in the Formerly Utilized Sites Remedial Action Program (FUSRAP).

A preliminary radiological survey performed on a limited portion of the site by Argonne National Laboratory (ANL) in June 1981 revealed several slightly elevated gamma readings near furnaces in the south end of Building 1.[2] Because past operations at the facility may have caused the elevated levels, and because the heating and/or melting of uranium can generate aerosols that may deposit on overhead structures, a radiological assessment was recommended. Although the 16-in. mill located in Building 1 is believed to have been the primary processing equipment for the experiments, the exact location of the milling of the uranium billets is not known. For this reason, the survey team performed scan measurements over the complete interior of the facility (i.e., in Buildings 1, 2, and 3). Because survey data from both the 1981 ANL survey and the scan conducted during this survey confirmed that Building 3 contained no radioactive residuals, the collection of more detailed data was restricted to Buildings 1 and 2, the areas most likely to have been impacted by past activities involving radioactive materials. The survey was conducted in July and August 1988.

Figure 1 shows a layout of the buildings surveyed. Buildings 1, 2, and 3 are under one roof. The floor surface is composed of concrete and steel plates laid directly over the ground surface. In some locations, the soil surface is exposed.

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*The survey was performed by members of the Measurement Applications and Development Group of the Health and Safety Research Division of Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

SURVEY PROCEDURES

The radiological survey included: (1) scanning to obtain directly measured gamma exposure rate ranges inside Buildings 1, 2, and 3 and on the roof; (2) scan measurements over the outdoor area north and east of the buildings; (3) determination of removable alpha and beta-gamma activity levels, and total alpha levels and surface dose rate measurements in selected areas of Buildings 1 and 2 and on the roof; and (4) sampling of soil, dust, and process materials for radionuclide analysis. A comprehensive description of the survey methods and instrumentation has been presented in another report.[3]

Using a portable gamma scintillation (NaI) survey meter, surfaces inside Buildings 1, 2, and 3 were scanned to determine ranges of exposure rates. Gamma levels were also measured at selected locations on the roof and in the open areas immediately north of all buildings and east of Building 1. On the roof and on surfaces such as overhead beams where aerosols may have deposited radioactive residuals during past operations, beta-gamma dose rate measurements and alpha activity levels were systematically determined. Smears were also obtained from selected surfaces to establish removable alpha and beta-gamma activity levels. In addition, systematic soil and debris samples were taken without regard to gamma exposure rates, and biased samples of debris and process material were collected at selected locations. The samples were analyzed for radionuclide content.

SURVEY RESULTS

Applicable DOE guidelines for sites included within the FUSRAP are summarized in Table 1. Typical radiation background levels in the Reading, Pennsylvania, area are presented in Table 2. These data are provided for comparison with the survey results presented in this section. With the exception of measurements of removable activity, which are reported as net disintegration rates, all direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations in soil, debris, and other samples.

OUTDOOR SURVEY RESULTS

Ground Surface Survey

Gamma levels were 2 to 8 μR/h, the same as typical background (Table 2), in the open areas north of Buildings 1 and 3 and east of Building 1 (Fig. 2). The lower end of the range was measured over the asphalt that covered most of the area.

Roof Survey

Gamma exposure rates. Surface measurements were taken at 25 individual locations on the roof. Figure 3 shows a representation of the configuration of the roof and the approximate locations of the measurements relative to each other and to the roof's architectural details. (The figure is not drawn to scale.) Results are listed in Table 3. Gamma levels ranged from 2 to 7 μR/h, values within the range of background for the southeastern Pennsylvania area.

Surface contamination. Total directly measured alpha activity levels ranged from <25 to 900 dpm/100 cm^2 while beta-gamma dose rates were 0.02 to 0.10 mrad/h. Alpha levels were somewhat higher than background; however, all results are below the DOE guidelines for alpha-emitting ^{238}U residuals and for beta-gamma dose rates (Table 1). Values such as those found might be expected on roof surfaces impacted by dust or aerosol deposits from the type of process materials being used at this site. Furthermore, because results of analysis show that the ^{226}Ra and ^{238}U from the process materials are in equilibrium, the enhanced alpha activity levels are undoubtedly of natural origin.

Smears were obtained from the surface of the roof at 33 separate locations. All removable alpha and beta-gamma activity levels were below the respective MDA's of 10 and 200 dpm/100 cm^2.

Radionuclide analysis of samples. Analysis of a sample of debris from the roof (Table 4, sample B1) revealed concentrations (pCi/g) of 0.32, 0.34, and 0.30 for ^{226}Ra, ^{232}Th, and ^{238}U, respectively. These values are below background concentrations of these radionuclides typically found in southeastern Pennsylvania (Table 2).

INDOOR SURVEY RESULTS

Gamma Exposure Rates

Gamma measurements over floor and structural surfaces inside the Buildings revealed exposure rates generally ranging from 2 to 8 μR/h as shown on Figs. 2 (Building 3) and 4 (Buildings 1 and 2). Two areas of slightly elevated levels were detected. A spot measuring 12 μR/h was found on contact with the floor in the south end of Building 3 and another spot of 24 μR/h was located inside the brick housing of furnace 501 (F-501) at the south end of the 16-in. mill conveyor in Building 1. Exposure rates were very low (1 to 2 μR/h) on surfaces inside mill housings, along mill trains, and in service pits where steel structures provided shielding. Multiple measurements were obtained along the length of beams that extend east and west through Buildings 1 and 2. The locations of the beams, designated 1W–13W and 13E–20E, are indicated on Fig. 4. Exposure rates were 1 to 6 μR/h as shown in Table 5. The maximum measurement, 24 μR/h, found inside an oven, was the result of

gamma radiation emanating from the fire brick lining of the oven. Increased gamma levels are normally found on the surfaces of fire bricks because they contain elevated concentrations of naturally occurring radioactive materials.

Surface Contamination

Results of directly measured alpha activity levels and surface beta-gamma dose rates taken at intervals from east to west along the surfaces of overhead beams are listed in Table 5. Alpha activity levels ranged from less than the minimum detectable activity (25)* to 110 dpm/100 cm^2. Beta-gamma dose rates ranged from 0.01 to 0.05 mrad/h.

Smears obtained from beam surfaces indicated removable alpha activity levels of <10 dpm/100 cm^2. Removable beta-gamma activity levels were all less than the MDA.* All results are below the DOE surface contamination guidelines for uranium (Table 1).

Seven smears were taken on the surfaces of mill housings to determine levels of removable contamination. The smear from the 16-in. housing showed an alpha activity level of 10 dpm/100 cm^2, equalling the MDA.* All others were less than the MDA.* Beta-gamma activity levels on the housings were all less than 200 dpm/100 cm^2. All results are below the DOE surface contamination guidelines for uranium (Table 1).

Radionuclide Analysis of Samples

Samples of soil from accessible dirt floor areas, dust and debris from beams, and samples from bags of materials used in ongoing processes were collected for radionuclide analyses. Results are listed in Table 4 with locations shown on Fig. 5.

In systematic soil samples collected from depths of 0–15 cm, concentrations of ^{226}Ra ranged from 0.06 to 2.0 pCi/g. In subsurface (15–45 cm) samples, ^{226}Ra was found in concentrations of 0.09 to 1.3 pCi/g. Thorium-232 concentrations in systematic samples ranged from 0.06 to 2.2 pCi/g in surface soil, and from 0.08 to 1.4 pCi/g in subsurface soil. These results are well below the DOE criteria of 5 and 15 pCi/g for surface and subsurface soil (Table 1). Concentrations of ^{238}U above MDA in systematically collected surface and subsurface samples were 0.17 to 1.7 pCi/g (averaging 0.66 pCi/g) and 1.0 to 2.2 pCi/g, respectively, (averaging 1.6 pCi/g). The average concentrations approximate background values typically found in southeastern Pennsylvania (Table 2) and are well below uranium guidelines established for FUSRAP sites.

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*The instrument-specific minimum detectable activities (MDAs) for directly measured and removable alpha radiation levels are 25 and 10 dpm/100 cm^2, respectively. For directly measured and removable beta-gamma radiation, the respective MDAs are 0.01 mrad/h and 200 dpm/100 cm^2.

Samples from bagged materials used in ongoing processes (Utracast® and Kaocrete D®) were collected and analyzed for radionuclide content. The two biased samples (B3 and B4) contained 3.8 and 2.3 pCi/g ^{226}Ra, 2.5 and 4.5 pCi/g ^{232}Th, and 4.9 and 2.3 pCi/g ^{238}U, respectively (Table 4). Concentrations of ^{226}Ra and ^{238}U in the samples are approximately equal indicating that the slightly elevated concentrations are in secular equilibrium (i.e., present in approximately equal concentrations); thus they are of natural origin and are not related to uranium metal processing. Enhanced concentrations of naturally occurring radionuclides are frequently found in such materials.

Samples (S13–S17) of dust and debris were collected from overhead beams to determine whether or not radioactive aerosols had been deposited there during uranium processing. Concentrations of ^{238}U in those samples ranged from 0.68 to 2.5 pCi/g and averaged 1.5 pCi/g. These values are no higher than uranium concentrations found in materials being used in on-going processes (see above) and likely originated from these materials. In any case, these concentrations are well below applicable guidelines established for FUSRAP sites.

SIGNIFICANCE OF FINDINGS

Survey results establish that no significant levels of radioactive residuals from former MED operations remain at the Carpenter Steel Facility. All radiation levels and radionuclide concentrations are below DOE guidelines.

With one exception, all gamma exposure rates both indoors and outdoors approximated typical background levels found in the southeastern Pennsylvania area (Table 2). The maximum measurement (24 μR/h) was found inside a furnace and is consistent with typical naturally enhanced radiation levels associated with the type of fire brick with which the furnace is lined.

Analysis of all soil and debris samples, and samples of materials used in ongoing processes, demonstrated radionuclide concentrations well below DOE guidelines. Radium-226 and ^{238}U were found in concentrations slightly elevated above typical background (Table 2) in process materials Ultracast® and Kaocrete D® (samples B3 and B4). Alpha activity directly measured on the roof surface was also found at levels slightly above background. This slight elevation is typical of deposition where such process materials are being used and is probably due to dust and/or aerosols from ongoing operations. The fact that the two radionuclides are in secular equilibrium indicates that the residual material is of natural origin and not the result of former MED activities. Materials comparable to Ultracast® or Kaocrete D® typically contain augmented concentrations of ^{226}Ra and ^{238}U. All measurements were within guidelines.

In summary, all survey measurements in Buildings 1, 2, and 3 at the Carpenter Steel Facility are within DOE FUSRAP criteria. These guidelines are derived to ensure that unrestricted use of the property will not result in any measurable hazard to the site occupants or the general public.

REFERENCES

1. A. Wallo III, The Aerospace Corporation, Germantown, Maryland, letter to W. E. Mott, Environmental Control Technology, U.S. Department of Energy, Germantown, Maryland, September 29, 1980.

2. P. M. Neeson, interdepartmental memo to W. D. Shipp, Director, U.S. Department of Energy, Operational and Environmental Safety Division, Germantown, Maryland, July 14, 1981.

3. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program,* Oak Ridge National Laboratory, Oak Ridge, Tennessee, ORNL/TM-8600 (April 1987).

4. T. E. Myrick and B. A. Berven, *State Background Radiation Levels: Results of Measurements Taken During 1975-1979,* Oak Ridge National Laboratory, ORNL/TM-7343 (November 1981).

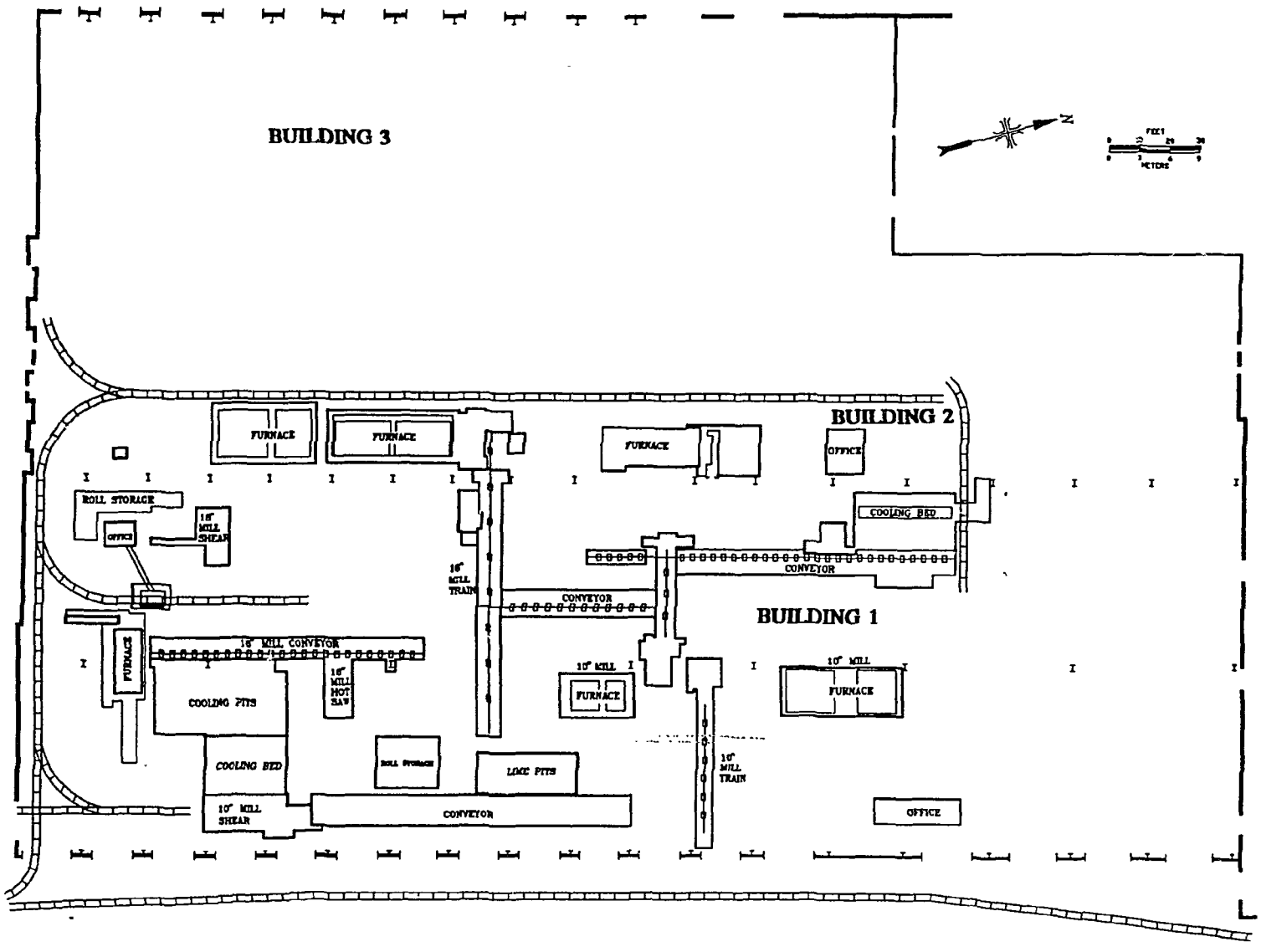


Fig. 1. Diagram of Buildings 1, 2, and 3 at the Carpenter Steel Facility.

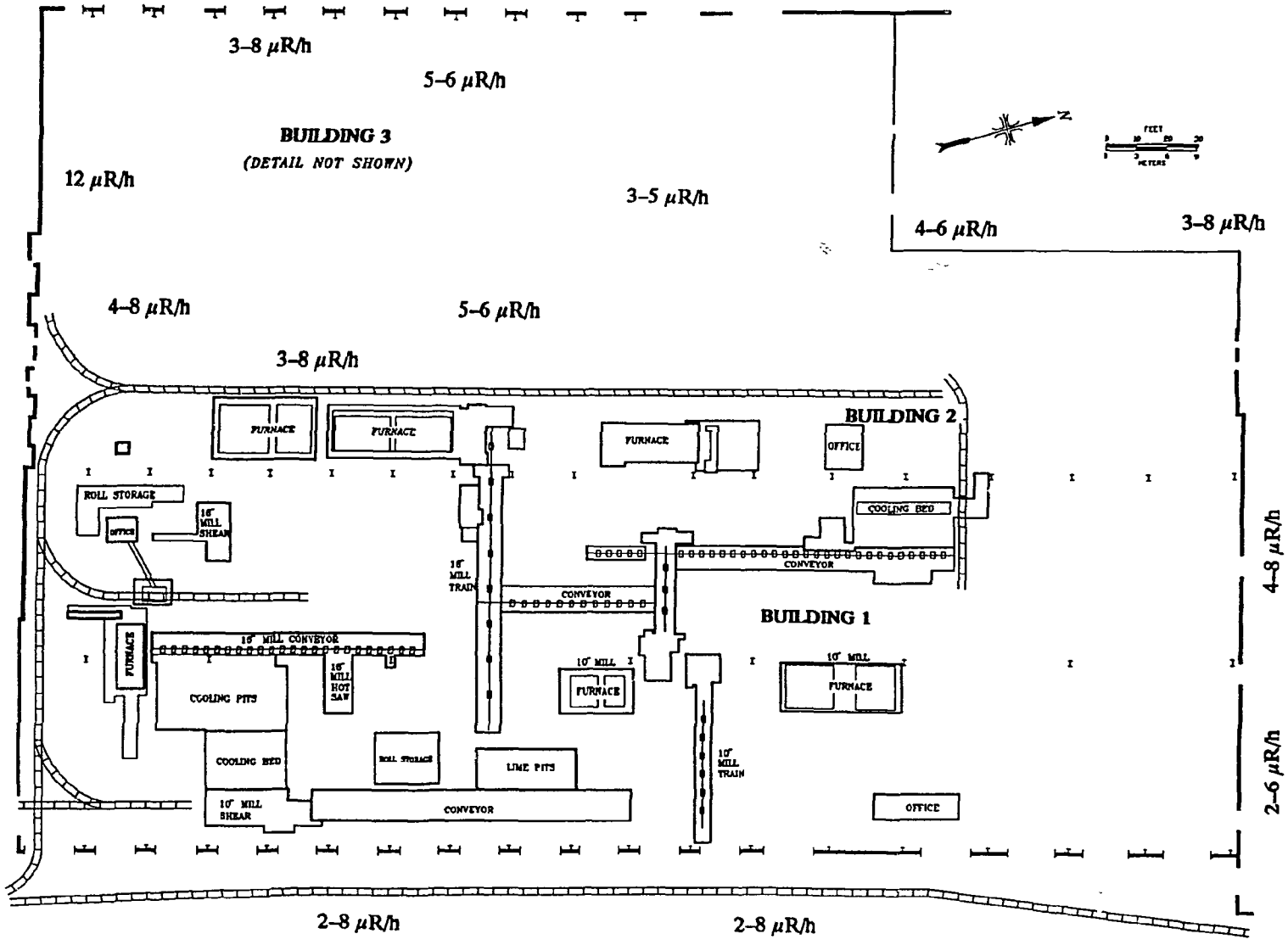
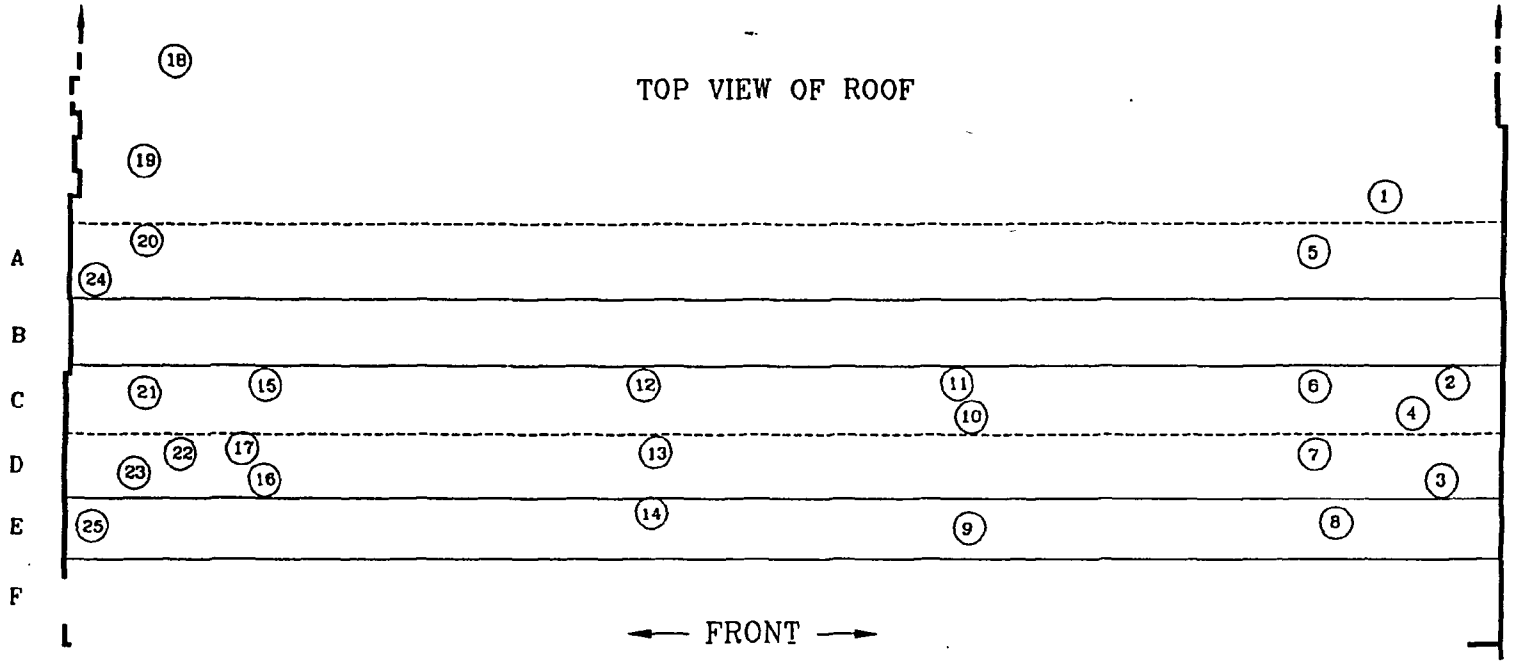
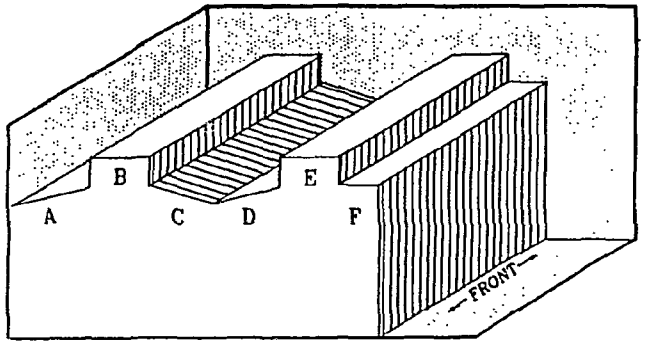


Fig. 2. Gamma exposure rates measured outdoors and inside Building 3.





Cross sectional view of building

Fig. 3. Locations of direct measurements taken on the surface of the roof. [Figure is not drawn to scale].

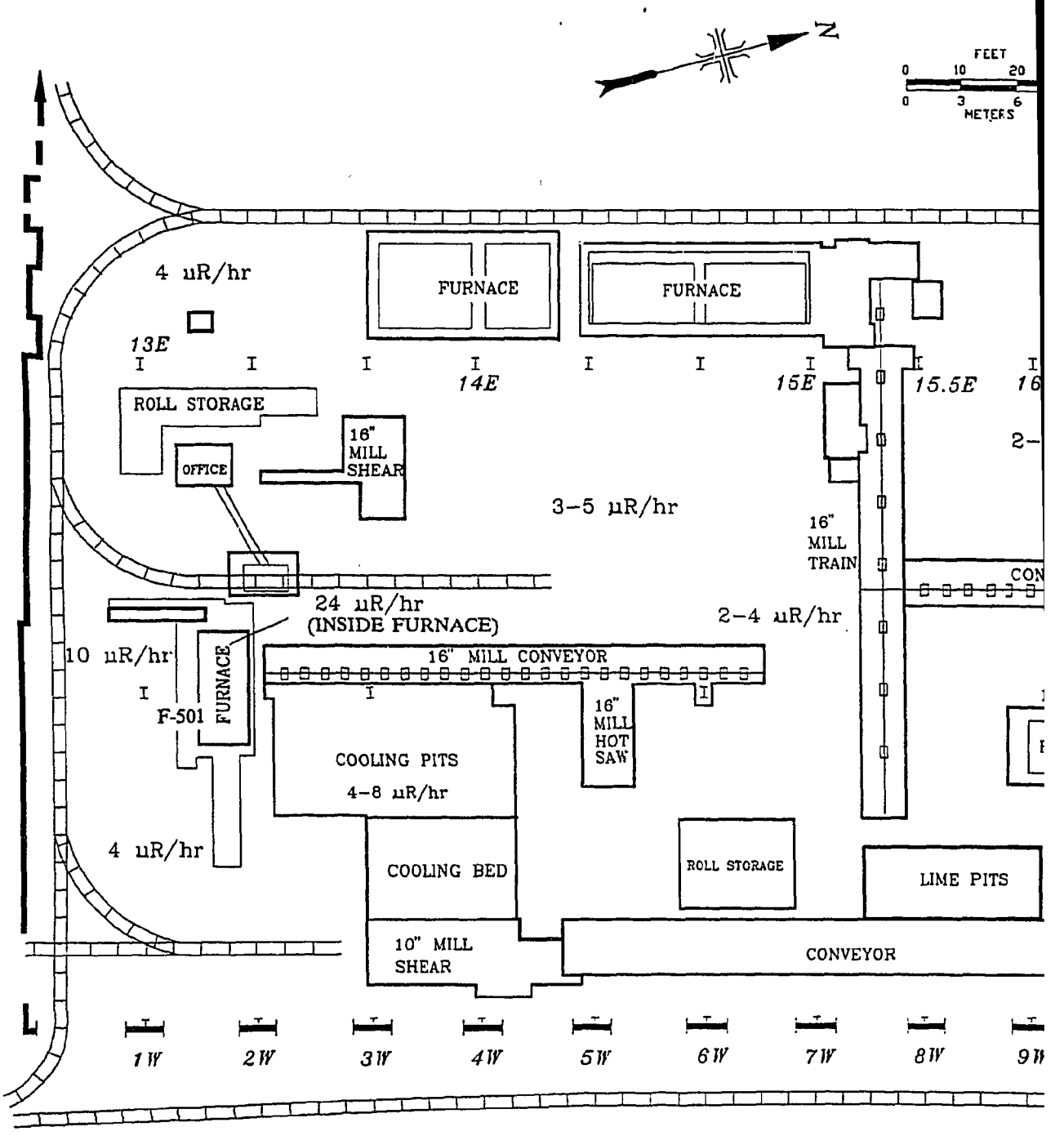
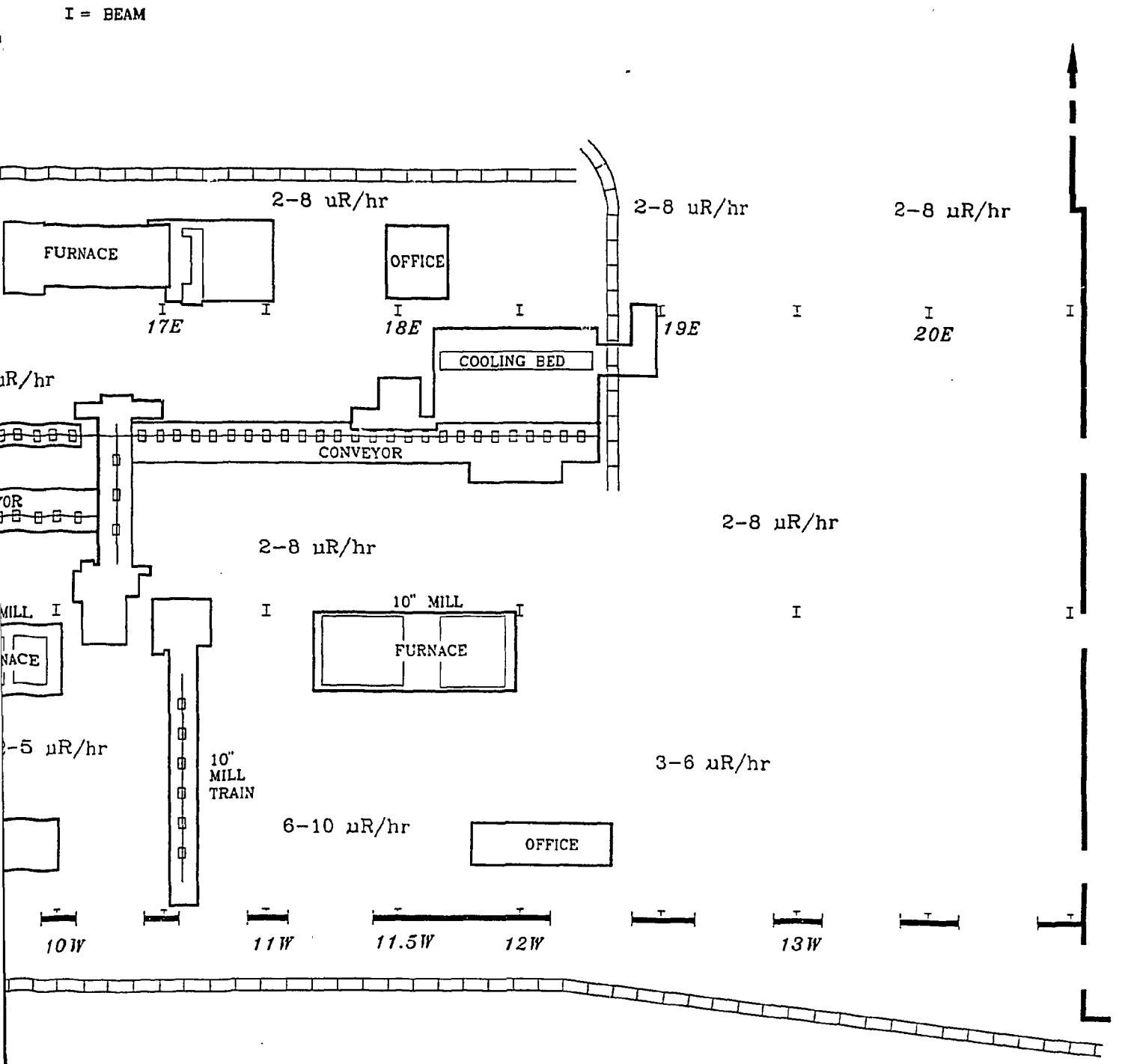


Fig. 4. Gamma exposure rates inside Building



and 2, and locations of beams 1W–13W and 13E–20E.

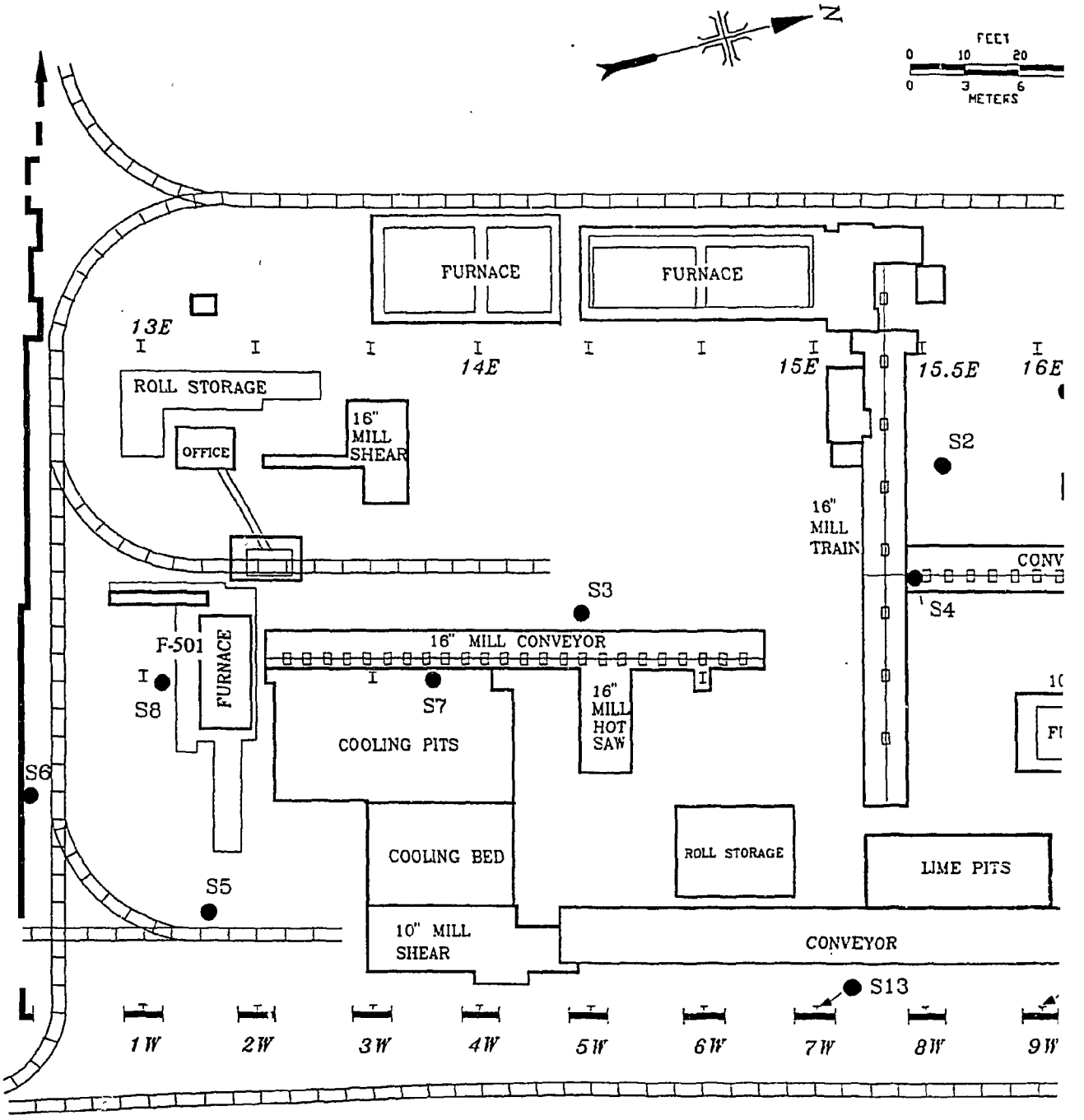
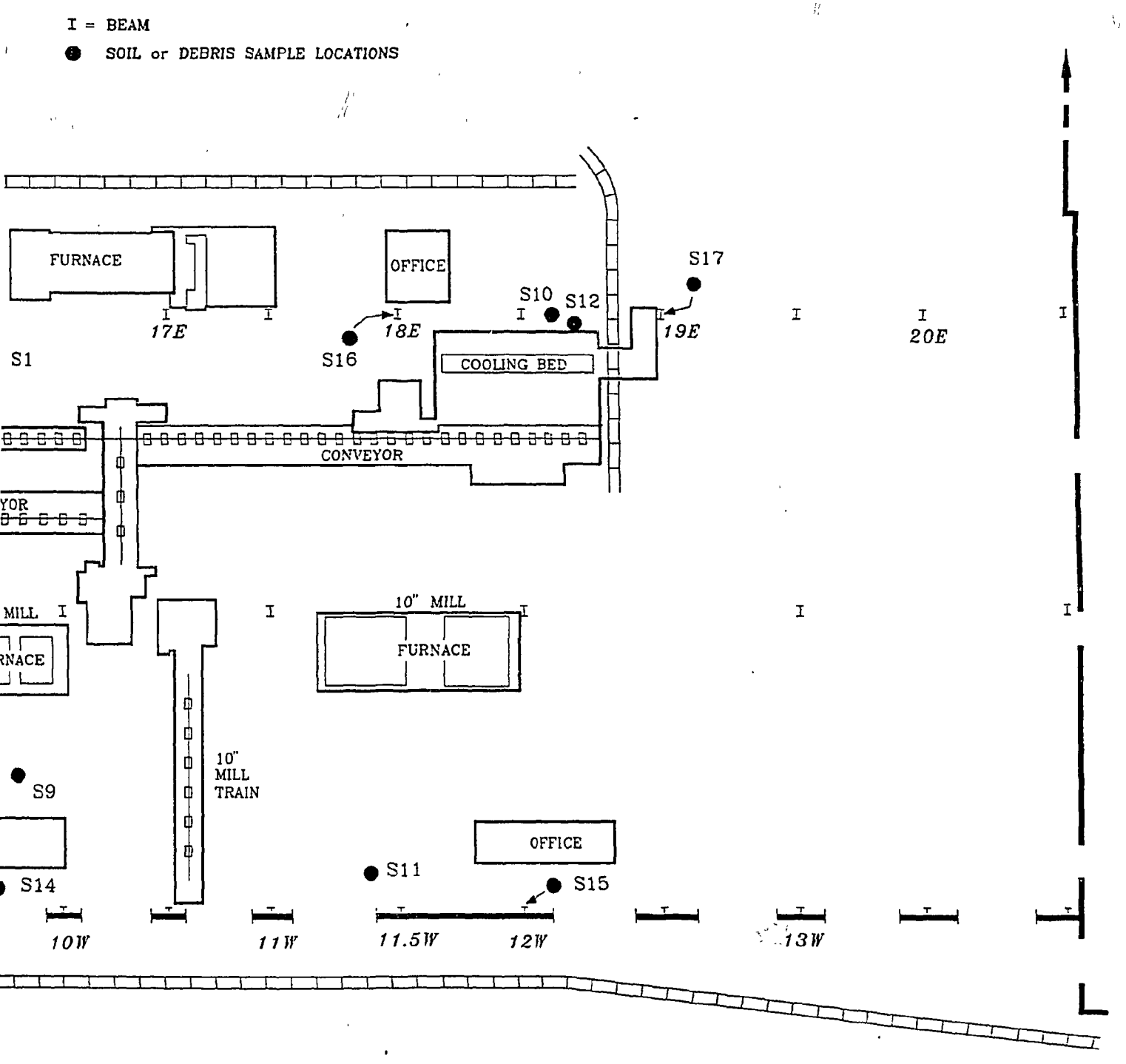


Fig. 5. Locations of systematic soil and debris



mples collected inside Building 1 at the Carpenter Steel Facility.

Table 1. Applicable guidelines for protection against radiation[a]

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h
Surface alpha contamination	^{238}U, U-natural	
	Fixed on surfaces	5000 dpm/100 cm^2
	Removable	1000 dpm/100 cm^2
	^{232}Th, Th-natural	
	Fixed on surfaces	1000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra	
	Fixed on surfaces	100 dpm/100 cm^2
	Removable	20 dpm/100 cm^2
Surface beta contamination[b]	Removable beta–gamma emitters	1,000 dpm/100 cm^2
Beta-gamma dose rates	Surface dose rate averaged over not more than 1 m^2	0.20 mrad/h
	Maximum dose rate in any 100 cm^2	1.0 mrad/h
Radionuclide concentrations in soil	Maximum permissible concentration of the following radionuclides in soil above background levels averaged over 100 m^2 area	5 pCi/g averaged over the first 15-cm of soil below the surface; 15 pCi/g when averaged over 15-cm thick soil layers more than 15 cm below the surface
	^{232}Th	
	^{230}Th	
	^{228}Ra	
	^{226}Ra	
	^{238}U	Derived (site specific)

[a]U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites (April 1987).
[b]Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr, ^{228}Ra, ^{223}Ra, ^{227}Ac, ^{133}I, ^{131}I, ^{129}I, ^{126}I, ^{125}I.

Table 2. Background radiation levels and concentrations of selected radionuclides in soil samples taken in southeastern Pennsylvania

Type of radiation measurement or sample[a]	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above ground surface (μR/h)	2–8	6
Concentration of radionuclides in soil (pCi/g dry wt)		
^{232}Th	0.69–1.2	1.0
^{226}Ra	0.81–0.96	0.87
^{238}U	0.63–1.1	0.91

[a]Values were obtained from 3 locations in southeastern Pennsylvania.[4]

Table 3. Gamma exposure rates and directly measured alpha and beta-gamma surface contamination on the roof

Location I.D.[a]	Gamma exposure rates at surface (μR/h)	Directly measured surface contamination: Alpha (dpm/100 cm^2)[b]	Directly measured surface contamination: Beta-gamma dose rates (mrad/h)
1	2	90	0.02
2	7	300	0.07
3	6	340	0.05
4	6	410	0.10
5	7	720	0.07
6	7	540	0.06
7	6	360	0.06
8	7	600	0.06
9	6	360	0.05
10	6	540	0.06
11	7	180	0.10
12	2	360	0.04
13	2	540	0.06
14	2	126	0.02
15	3	200	0.03
16	3	130	0.04
17	3	900	0.05
18	3	90	0.03
19	2	340	0.04
20	2	<25	0.02
21	2	190	0.02
22	3	450	0.07
23	3	300	0.04
24	3	110	0.03
25	4	90	0.02

[a]Location shown on Fig. 5.

[b]The instrument-specific minimum detectable activity is 25 dpm/100 cm^2.

Table 4. Concentrations of radionuclides in soil, debris, and process material samples at the Carpenter Steel Facility, Reading, Pennsylvania

Sample[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
		^{226}Ra[b]	^{232}Th[b]	^{238}U[b]
		Systematic samples[c]		
S1A	0–15	0.45 ± 0.01	0.44 ± 0.02	0.25 ± 0.2
S1B	15–30	0.80 ± 0.02	0.77 ± 0.02	<1.2
S2A	0–15	0.17 ± 0.006	0.18 ± 0.01	0.17 ± 0.1
S2B	15–30	1.2 ± 0.04	1.1 ± 0.08	<3.6
S2C	30–45	1.2 ± 0.07	1.2 ± 0.1	<2.1
S3A	0–15	0.99 ± 0.02	1.0 ± 0.04	<1.6
S3B	15–30	1.3 ± 0.04	1.2 ± 0.07	2.2 ± 1.4
S3C	30–45	1.3 ± 0.06	1.3 ± 0.08	<4.4
S4A	0–13	0.14 ± 0.04	0.16 ± 0.10	1.3 ± 0.74
S4B	13–30	0.10 ± 0.03	0.10 ± 0.05	1.1 ± 0.52
S4C	30–36	0.26 ± 0.05	0.22 ± 0.09	1.0 ± 0.93
S5	0–8	0.19 ± 0.00	0.19 ± 0.02	<0.66
S6	0–10	0.20 ± 0.008	0.20 ± 0.01	<0.65
S7	0–10	0.37 ± 0.02	0.38 ± 0.04	<1.7
S8	0-5	1.6 ± 0.03	2.2 ± 0.06	1.7 ± 0.4
S9A	0–5	0.53 ± 0.02	0.60 ± 0.02	0.32 ± 0.3
S9B	5-20	1.2 ± 0.04	1.3 ± 0.08	1.8 ± 1.0
S10	0–15	1.4 ± 0.02	1.4 ± 0.04	<1.4
S11	0–15	0.95 ± 0.02	1.2 ± 0.05	0.9 ± 0.6
S12A	0–15	2.0 ± 0.06	1.9 ± 0.01	<5.4
S12B	15–30	1.4 ± 0.04	1.4 ± 0.07	<3.3
S12C	30–45	1.4 ± 0.04	1.4 ± 0.06	1.4 ± 1.1
S13	*d*	0.41 ± 0.02	0.42 ± 0.03	2.5 ± 1.0
S14	*d*	0.31 ± 0.02	0.30 ± 0.02	0.89 ± 0.2
S15	*d*	0.24 ± 0.02	0.31 ± 0.04	<2.0
S16	*d*	0.37 ± 0.02	0.40 ± 0.04	1.5 ± 0.6
S17	*d*	0.46 ± 0.01	0.49 ± 0.02	0.68 ± 0.3
		Biased samples[e]		
B1	*f*	0.32 ± 0.02	0.34 ± 0.02	0.30 ± 0.3
B3	*f*	3.8 ± 0.06	2.5 ± 0.09	4.9 ± 2
B4	*f*	2.3 ± 0.02	4.5 ± 0.04	2.3 ± 0.8

[a]Locations of systematic samples are shown on Fig. 4.
[b]Indicated counting error is at the 95% confidence level ($\pm 2\sigma$).
[c]Systematic samples are taken at selected locations irrespective of gamma exposure rates.
[d]Samples of dust and debris from overhead beams.
[e]Biased samples are taken from areas shown to have elevated gamma exposure rates.
[f]Samples of roof debris, and the process materials Ultracast® and Kaocrete D®, respectively.

Table 5. Gamma exposure rates and directly measured alpha and beta–gamma surface contamination on overhead beams

Overhead beam I.D.[b]	Gamma exposure rate(s) (μR/h)	Directly measured surface contamination[a]	
		Alpha (dpm/100 cm^2)[c]	Beta-gamma dose rates (mrad/h)
1W	1-3	<25–30	0.02–0.03
2W	1-2	25	0.02
3W	1-2	<25	0.02–0.04
4W	1-2	25	0.02
5W	1-2	<25	0.01
6W	1-2	<25	0.02
7W	1-2	<25	0.03
8W	1-3	<25	0.02
9W	1-3	<25	0.02–0.03
10W	1-2	<25	0.02
11W	1-2	<25	0.02
12W	1-3	<25	0.01
13W	2-3	<25	0.02–0.03
13E	2	<25	0.02
14E	1-2	<25	0.02
15E	1-2	<25	0.02
15.5E	2	<25	0.04
16E	1-2	25	0.02
17E	1-2	25	0.02
18E	1-2	<25	0.02
19E	2-4	25	0.02
20E	6	110	0.05

[a]Number of measurements determined by accessibility.
[b]Location shown on Fig. 3.
[c]The instrument-specific minimum detectable activity is 25 dpm/100 cm^2.