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Results of the Independent Radiological Verification Survey at B&T Metals, 425 West Town Street, Columbus, Ohio (CO001V)

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ABSTRACT

In the mid-1940s, B&T Metals, 425 West Town Street, Columbus, Ohio became one of the first commercial firms to provide extrusion of uranium billets into rods in support of Manhattan Engineer District (MED) operations. The U.S. Department of Energy conducted radiological surveys of these sites to evaluate current radiological conditions as part of the 1974 Formerly Utilized Sites Remedial Action Program (FUSRAP).

In 1988 and 1989, a preliminary radiological survey was conducted by ORNL on the commercial property of B&T Metals. Results of the survey indicated that limited and localized residual radioactive material found in the main building and in one area outdoors exceeded current DOE guidelines, and the site was recommended for remediation.

In the spring of 1996, a radiological verification survey of this property was conducted by ORNL, the independent verification contractor, in conjunction with decontamination operations conducted under the supervision of Bechtel National, Incorporated. The verification survey included gamma scans of the main building and parts of the grounds, limited beta-gamma scans of the building and roof, limited alpha scans of inside overhead structures, smear sampling, and the collection of samples for radionuclide analysis. This report describes the results of the radiological verification survey of the commercial property of B&T Metals, Columbus, Ohio.

Based on the results of the post remedial action survey and verification data reported in this document, all radiological measurements fall below the limits prescribed by DOE radiological guidelines established for this site, and the B&T Metals property successfully meets the DOE radiological guidelines for unrestricted use.

Results of the Independent Radiological Verification Survey at B&T Metals, 425 West Town Street, Columbus, Ohio (CO001V) *

INTRODUCTION

The B&T Metals Company in Columbus, Ohio was one of many companies performing work during the 1940s associated with the development of nuclear energy for defense-related projects for the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). As a result of these activities, equipment, buildings, and land at some of the sites became radiologically contaminated with small amounts of the material resulting in low levels of contamination on the properties. In 1974, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established by the U. S. Department of Energy (DOE) to identify and reevaluate the radiological status of these sites and assist in the assessment and cleanup activities.[1]

B&T Metals, located at 425 West Town Street on the southwest side of Columbus, Ohio, was one of the first commercial firms to provide extrusion of uranium billets into rods in support of the MED operations. Measurements taken in March and April of 1943 confirmed excessive amounts of airborne metals found in the main building near the rolling table, extrusion trough, and furnace. The extrusion and machining activities were relatively small scale and occurred over a period of approximately ten months.

The buildings and property cover most of a city block and include three buildings: the main building, a storage building, and an extrusion building (Fig. 1). The extrusion building did not exist at the time of the MED-sponsored activities . The work performed for MED occurred in the northwest corner of the main building, the largest of these three structures. Reportedly, shavings from these activities may have been dumped outside in what is now a parking area, west of the main building.[2]

In August 1988 and April 1989, preliminary radiological surveys were conducted by members of the Measurement Applications and Development (MAD) Group of the Oak Ridge National Laboratory (ORNL) on the commercial property at B&T Metals, Columbus, Ohio.[3] The preliminary survey included surface gamma scans of the main building and most of the property outdoors, collection of dust and debris and soil samples,

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*The survey was performed by members of the Measurement Applications and Development Group of the former Health Sciences Research Division (now the Life Sciences Division) of Oak Ridge National Laboratory under DOE contract DE-AC05-96OR22464.

direct and transferable measurements of alpha and beta-gamma activity levels inside and on the roof, and air sampling inside the main building.

The survey report, published in 1990, concluded that limited residual radioactive material was found in localized areas of the main building and in the drain system beneath the floor, and in one area outdoors east of the storage building (south of the substation, Fig. 1), where shavings from the former MED operations were reportedly dumped. Although an examination of the "present-use conditions" for this site suggested that no significant radiation exposures would result, the property exceeded current DOE guidelines, and was scheduled for remedial action.

Decontamination of the facility was conducted by subcontractor personnel under the direction of Bechtel National, Incorporated (BNI), the project management contractor for FUSRAP.

The independent radiological verification survey detailed in this report was performed during the period from April to June 1996 under the FUSRAP program by members of the Measurement Applications and Development Group at ORNL at the request of DOE. The DOE's policy to assign an independent verification contractor (IVC) ensures the effectiveness of remedial actions performed within FUSRAP and confirms the site's compliance with DOE guidelines.

VERIFICATION PROCEDURES

OBJECTIVES

The objective of the verification activities was to confirm (1) that available documentation adequately and accurately describes the post-remedial action of the facility that is to be verified, and (2) that the remedial action reduced contamination levels to within authorized limits. Applicable DOE residual radioactivity guidelines for protection of the general public are summarized in Table 1.

SURVEY METHODS

Although spot checks were made in areas not directly in the contaminated area, most of the radiological verification survey of the site was concentrated in an area of approximately 50 x 150 ft on the first floor of the northwest corner of the main building, including the floors, overhead structures, the roof, and roof gutters. On the outside, the area at the west end of the main building south of the substation, as well as the sewer manholes on the south side of the building (Fig. 1) were surveyed. The building was deteriorated, cluttered, and dirty. Soil and other samples were taken outside on the west side of the building, inside from crumbling concrete "trenches" in the floor, and from the

gutters on the roof. In some places the floor had badly deteriorated and the crumbling concrete had been removed down to the soil. In another area, a 3-4 in. layer of concrete covered the original floor. Materials (such as bricks, vats, and drums) left on site but moved out of the remediated northwest corner of the building (see Fig. 2), were also checked for contamination. The survey covered ~10-20 % of the floor area in the building, in addition to any areas of likely contamination inside and outside.

The verification survey of the site included: (1) a gamma scan of the floors in the entire building at the surface and at one meter above the surface using Bicron microrem detectors, and a gamma scan of a suspected contaminated area in the alley outside the west end of the main building with the Field Instrument for Detection of Low-Energy X-Rays (FIDLER); (2) beta-gamma scans of the floors and overhead structures indoors in the northwest corner of the building, and outdoors of the roof and roof gutters, and two sewer manholes south of the building with "pancake" GM detectors; (3) limited alpha scans on overhead structures with a ZnS scintillation probe; (4) selective smear sampling for transferable alpha and beta-gamma activity on overhead structures and roof gutters; and (5) radionuclide analysis of soil samples taken outside on the west end of the main building and from under the concrete floor inside the building, and samples of the material from the roof gutters.

Survey methods followed guidelines for a generic site as outlined in References 4 and 5. The northwest area of the main building was divided into a series of 6-m^2 survey blocks, with the southwest corner of the building used as the origin (N0,E0), and the first block at N40,E0 (Fig. 2). Instrument calibrations were verified and background checked daily.

VERIFICATION SURVEY AND ANALYSIS

Current guidelines for sites included within FUSRAP are summarized in Table 1. Typical background radiation levels for the Columbus, Ohio area are presented in Table 2. These data are provided for comparison with the survey results presented in this section. Gamma 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.

Beta-gamma contamination levels were recorded in gross counts per minute (cpm), background adjusted and converted to disintegrations per minute (dpm/100 cm^2) using standard geometry factors for beta-gamma pancake probe/Bicron ratemeter combination. Transferable radioactivity levels (smears) are reported as net counts with background subtracted.

LOCATIONS OF REMEDIATION ACTIVITIES

The areas remediated involved (1) a soil area west of the main building and south of the substation, (2) the northwest corner of the main building and the rain gutters above this area, and (3) three outside man-holes near the building (see Fig. 1).

The small area of soil just west of the building was identified during the initial survey in 1988 (Ref. 3) and again in April 1996 during the independent verification survey. The 1996 survey was performed using FIDLER instruments taking timed measurements on a 2-m grid. The extent of the contamination was defined by BNI.

The northwest corner of the building (~5000 ft^2) required remediation of the floors, walls, overhead structures, outside rain gutters, some floor drains, and limited subsurface soil. The extent of the affected drains and associated piping was identified as part of the remediation. BNI investigated the drain system from all endpoints and determined the scope of possible contamination. The ORNL staff concurred with the BNI assessment since their approach was reasonable, and concluded that a more detailed analysis was unjustified.

Three manholes contained residual material: two on Walnut Street and one on Town Street.

DIRECT AND REMOVABLE RADIOACTIVITY LEVELS

Gamma Radiation Levels

Gamma exposure rates ranged from 6 to 9 μR/h at 1 m above the floor while surface exposure rates ranged from 6 to 8 μR/h on the first and second floors of the main building (Fig. 3). These values are comparable to the typical range of background levels for the area of 7 to 9 μR/h (Table 2). Gamma levels at accessible floor and wall surfaces were slightly higher on contact with bricks, concrete, and other materials that contain naturally occurring radioactivity.

Alpha and Beta-Gamma Measurements

Direct and transferable beta-gamma levels were measured over selected and accessible areas of the floor, walls, ceiling structures, beams and trusses, and rooftop gutters in the northwest corner of the building. Two sewer manholes on the south side of the main building were also surveyed (Fig. 1). Alpha levels were measured at selected locations where beta-gamma levels were elevated.

Direct measurements. Direct beta-gamma activity levels were measured on accessible overhead beams and trusses and on dry areas of the floors in the northwest corner of the

building where contamination was found in the first survey. Direct beta-gamma activity levels measured on floors generally ranged from 1500 to 4800 dpm/100 cm^2. Higher activity of up to 6000 dpm/100 cm^2 was detected on contact with red brick walls and concrete joints. Two spots of contamination were found on the floor where the area was badly deteriorated that measured from 2000 to 5700 dpm/100 cm^2 beta-gamma activity. Some activity above guidelines was found on the floor in spots during the initial survey by the verification team but were remediated and again surveyed and the area verified below guidelines.

Direct beta-gamma levels on the overhead structure surfaces generally ranged from 1500 to 6000 dpm/100 cm^2, and up to 9000 dpm/100 cm^2 on the upper surfaces of a small (1 m x 8 cm) section of an "I" beam where individual spots of up to 3450 dpm/100 cm^2 were detected. Generally, alpha levels on overhead structures ranged from 45 to 900 dpm/100 cm^2 when measured over selected locations with elevated gamma levels. Smears were taken in areas with elevated measurements.

Spotty contamination was also found on some overhead structures. Small spots measuring up to 6000 dpm/100 cm^2 beta-gamma, and to 1842 dpm/100 cm^2 alpha activity were found in scattered areas on beams, trusses, ledges, drains, drainpipes, window sills and other overhead structures. A beta-gamma scan of the floors under these beams showed no beta-gamma measurements above guidelines.

Two manholes outside the south side of the main building (Fig. 1) were surveyed for beta-gamma activity. Several spots along the southern sides of the manholes were found that ranged from 1250 to 1500 dpm/100 cm^2 above background. The third manhole, located on Town Street, was not surveyed by ORNL; however, ORNL staff reviewed the BNI survey data and found it to reasonably demonstrate compliance.

The gutters running east to west on the roof (Fig. 4) were surveyed for residual activity. Spots ranging from 240 to 320 dpm/100 cm^2 were measured on the center and south gutters. Samples were taken of the tar-like material in the gutters and analyzed for radionuclide concentrations. Results of the analysis are shown on Table 3.

The general scan range of the north gutter was 1500 to 4500 dpm/100 cm^2 beta-gamma, with spots ranging from 1500 to 2750 dpm/100 cm^2. The north gutters did not have the tar base, therefore no samples could be taken at the elevated spots. Even though the direct measurements were less than the guidelines for fixed contamination, smears were taken from the north gutter at these spots to ensure the guidelines for transferrable contamination were satisfied.

Transferable measurements. Smears were collected at selected locations in the north gutter on the roof and from selected areas inside on overhead structures to ensure that remedial efforts left no residual transferable radioactivity above established guidelines.

The locations of the smears are shown on Figs. 4 and 5. Results from the smear analyses indicate no removable beta-gamma or alpha activity above guidelines. Results of the smear analyses are presented on Table 4. With the exception of one smear sample taken from an overhead truss which measured 42 dpm/100 cm^2 alpha activity (sample VT7), all other measurements were less than the instrument-specific critical detection level (L_c).*

SOIL AND TAR SAMPLES

Systematic and biased samples of soil and other material were taken outdoors west of the main building between the substation and the storage building, and on the roof from the gutters. Samples were taken indoors under the concrete floor where trenches had formed in the crumbling concrete. Sample locations are shown on Figs. 4 and 5.

All samples were analyzed to determine the concentrations of ^{238}U, ^{226}Ra, and ^{232}Th. Results of the radionuclide analysis are shown in Table 3. The site specific guidelines for total uranium concentrations of 35 pCi/g (~17.5 pCi/g ^{238}U) have been applied at this site (Table 1).

Results of the analyses show that concentrations of ^{226}Ra and ^{232}Th were low, ranging from 0.13 to 2.3 pCi/g both outside and inside the building and in the gutter material. All these values are comparable to background levels in the area, and well below DOE guidelines.

Uranium concentrations were slightly higher. Concentrations of ^{238}U ranged from 1.8 to 7.0 pCi/g in the gutter material and from 0.85 to 6.5 pCi/g outside the building, and up to 29 pCi/g in the material taken from inside the building (Table 3). Five biased samples (VB4 to VB8, Fig. 5) were collected from the small area (~25 m^2) where subsurface contamination was found under drain pipes that were removed during the remediation. The average concentration was 14 pCi/g, which is less than the allowable guidelines. For an area of this size the allowable concentration is 70 pCi/g total uranium.

CONCLUSIONS

Prior to remedial efforts, uranium residuals exceeded current DOE radiological guidelines in some spots in the main building and outside on the west end of the building. Decontamination of the facility was performed under the direction of BNI. Initially, spotty contamination on parts of the floor was identified by the ORNL verification team; these residuals were removed and the areas resurveyed by the ORNL team.

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* The critical detection levels (L_c) for transferable alpha and beta activity are 5 and 168 dpm/100 cm^2, respectively.

Results of this independent radiological verification survey of the main building at B&T metals in Columbus, Ohio confirm that residual uranium contamination in the northwest corner inside and on the roof of the building has been remediated to levels meeting the DOE guidelines for this site. While some spotty contamination was measured in scattered areas, this contamination is imbedded in the concrete and metal, and because of the irregular shapes of beams, trusses and other structures, the average contamination per square meter meets the guidelines. The overall results of the direct scans and the removable smear analyses showed that direct and transferable activity on the floors, overhead structures and roof are below applicable guidelines. The results of analyses of samples on the roof and outside on the west side of the building indicate that all radionuclide concentration measurements are below the limits prescribed by DOE radiological guidelines.

Based on the results of the post remedial action survey and verification data in this report, this site has no residual contamination above the DOE radiological guidelines established for this site. Therefore it should be released without any radiological restrictions.

REFERENCES

1. U. S. Department of Energy, *A Background Report for the Formerly Utilized Manhattan Engineer District/Atomic Energy Commission Sites Program*, DOE/EV-0097, September 1980.

2. Personal communication, Vic Sharp, retired employee of B&T Metals, to J. L. Quillen, Oak Ridge National Laboratory, August 22, 1988.

3. W. D. Cottrell, J. L. Quillen, and J. W. Crutcher, *Results of the Preliminary Radiological Survey at B&T Metals, 425 West Town Street, Columbus, Ohio (CO001)*, ORNL/RASA-89/1, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., October 1990.

4. 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*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.

5. Oak Ridge National Laboratory, Health Sciences Research Division, *Measurement Applications and Development Group Guidelines*, ORNL-6782, Martin Marietta Energy Systems, Inc., January 1995.

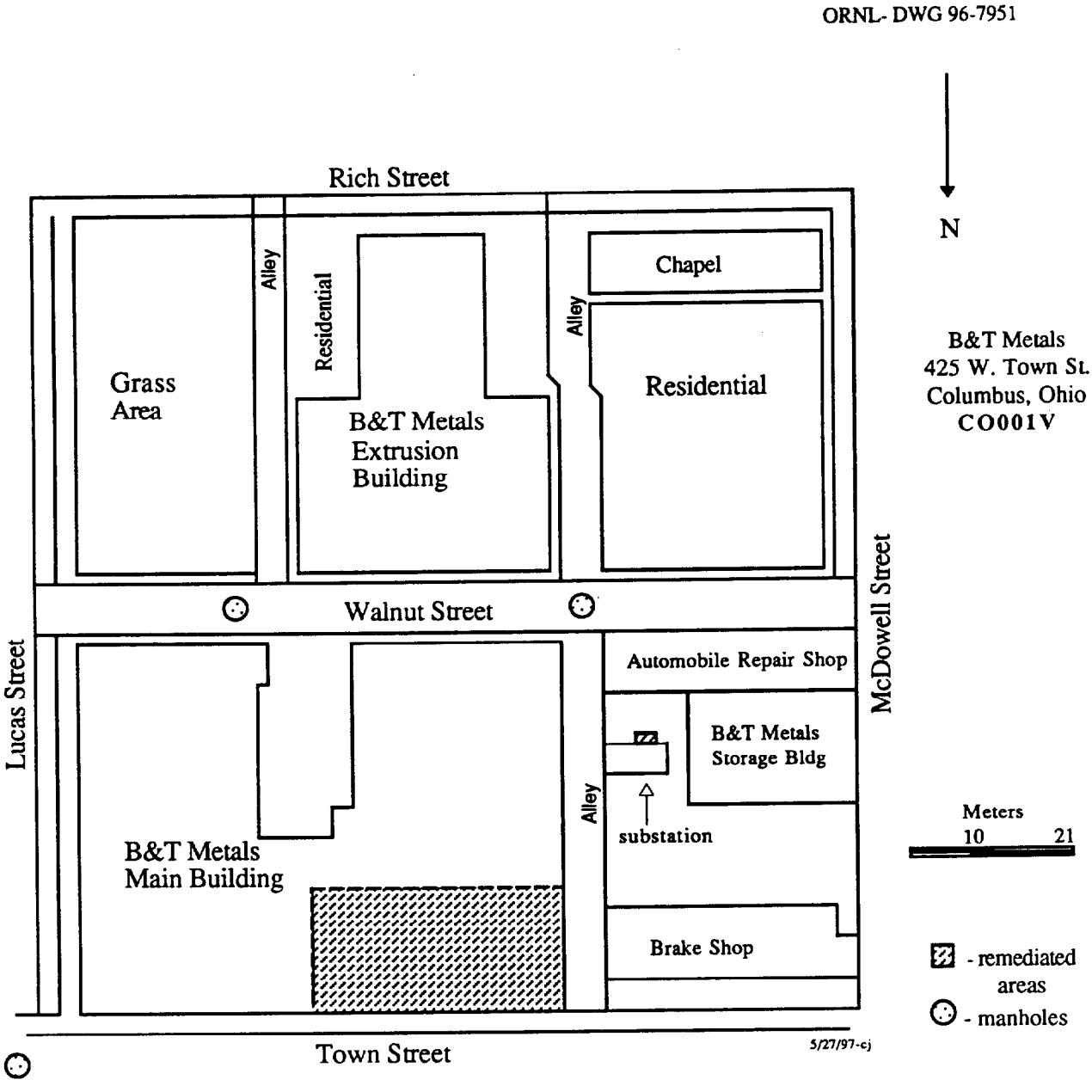

Fig. 1. Drawing of the buildings on the B&T Metals property, Columbus, Ohio. The two manholes on the south side of the main building were also surveyed.

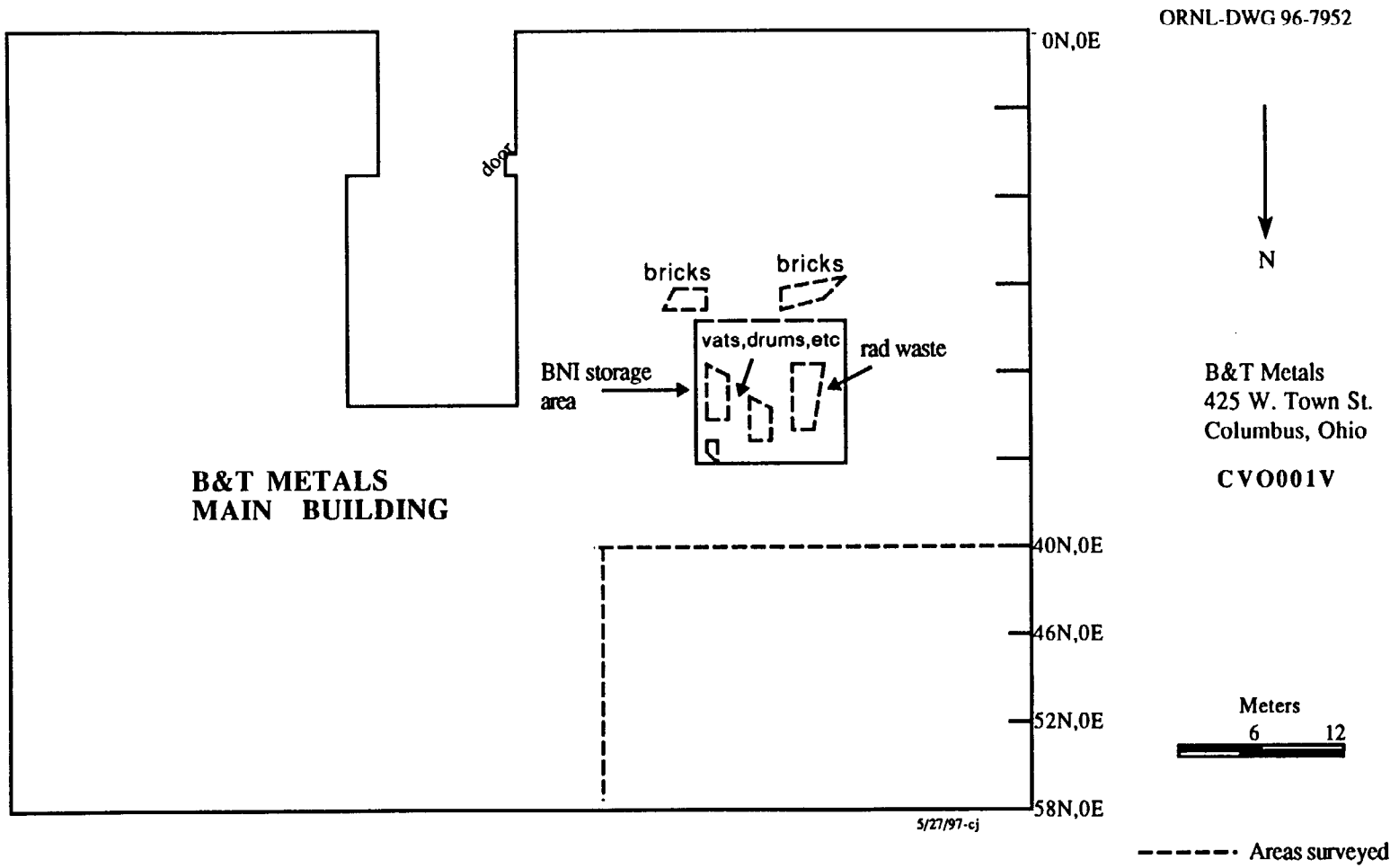

Fig. 2. Drawing showing the general location of materials surveyed and left in the BNI storage area in the main building of the B&T Metals Company.

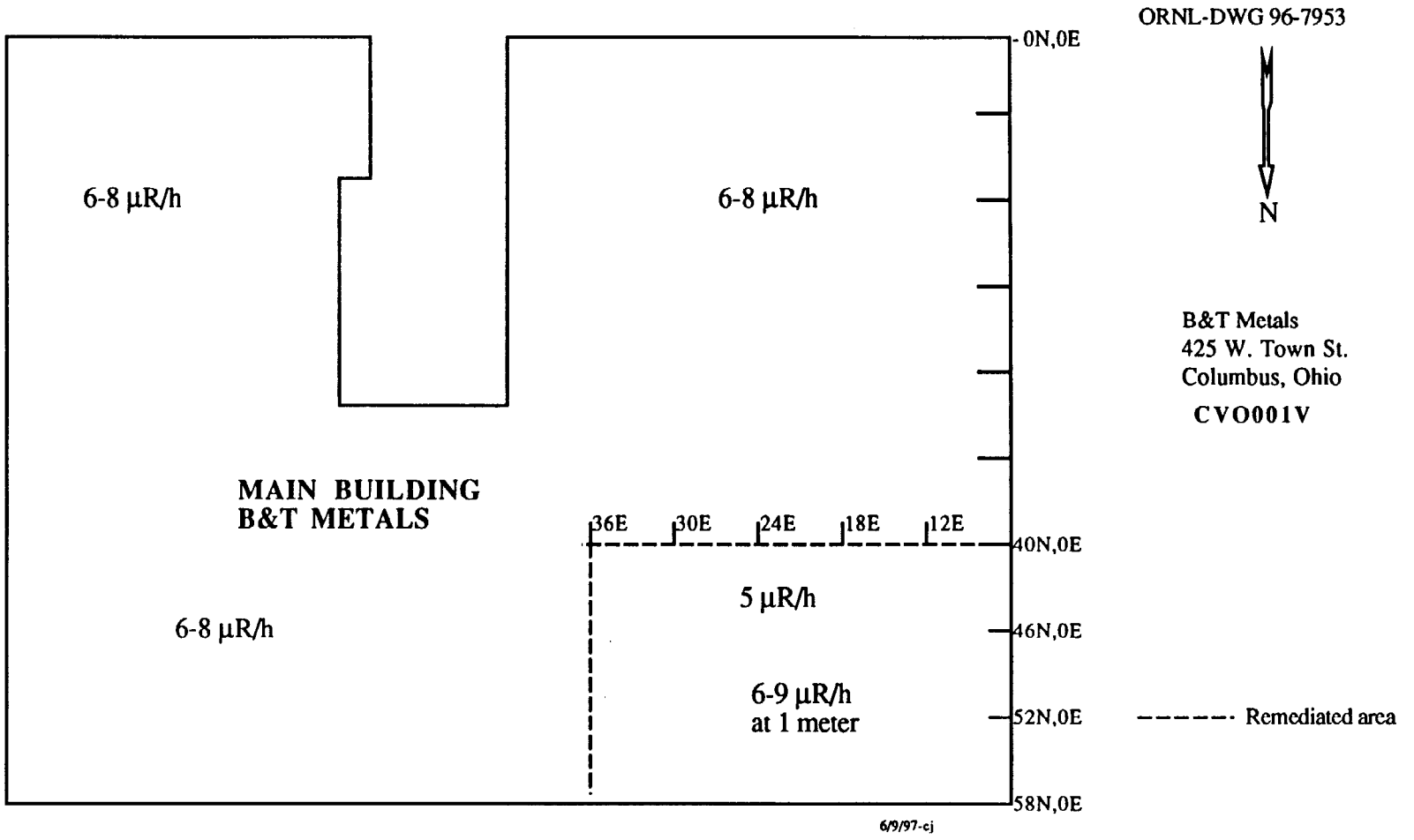

Fig. 3. Drawing showing gamma measurements taken throughout the main building on the property of the B&T Metals Company. The northwest corner of the building (remediated area) is marked off in 6-m grids.

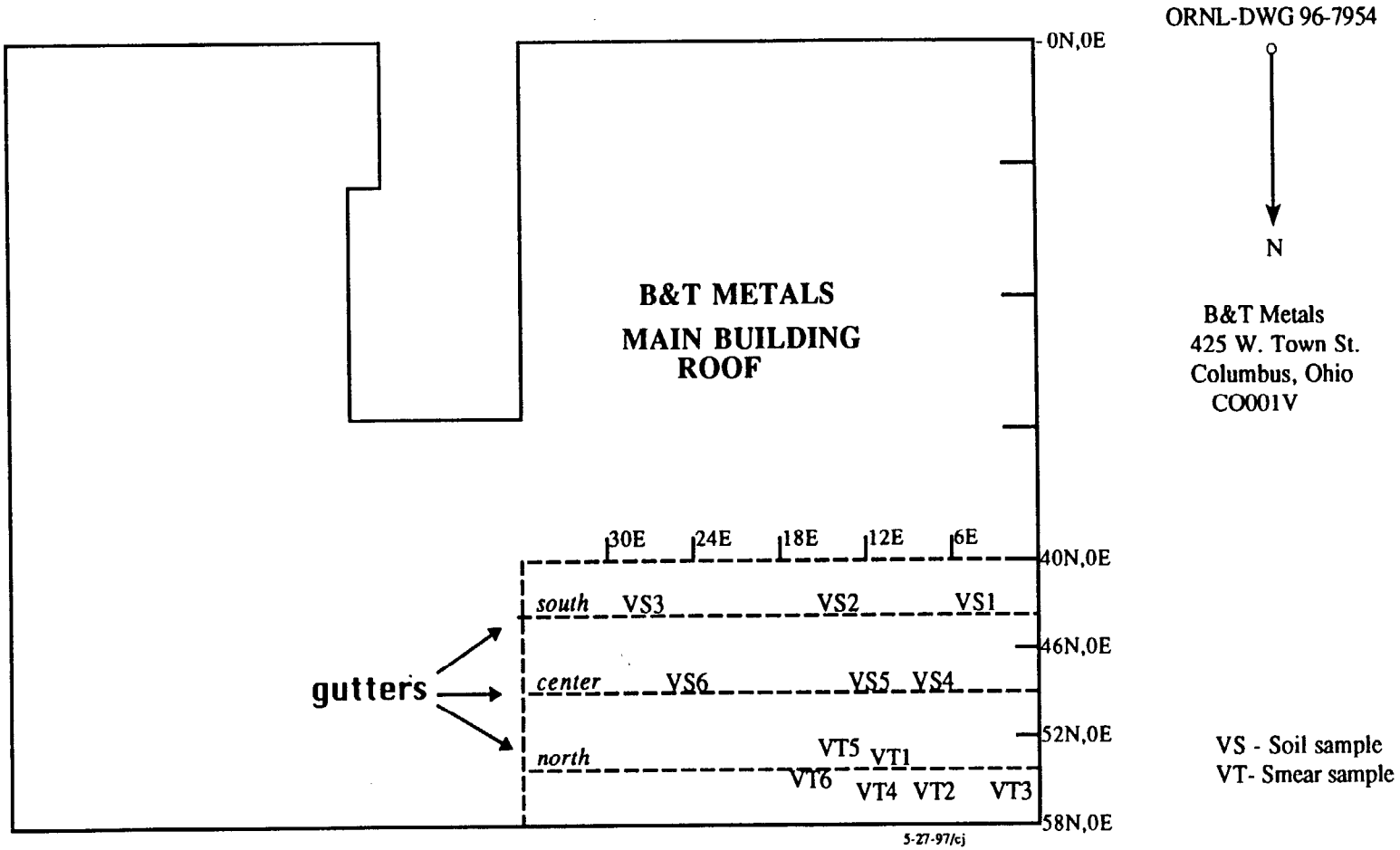

Fig. 4. Drawing showing the northwest corner of the roof of the main building where the north, south, and center gutters lie east to west. Approximate locations of the soil and smear samples taken from the gutters are indicated. The results of the analyses are shown in Tables 3 and 4. (Drawing not to scale)

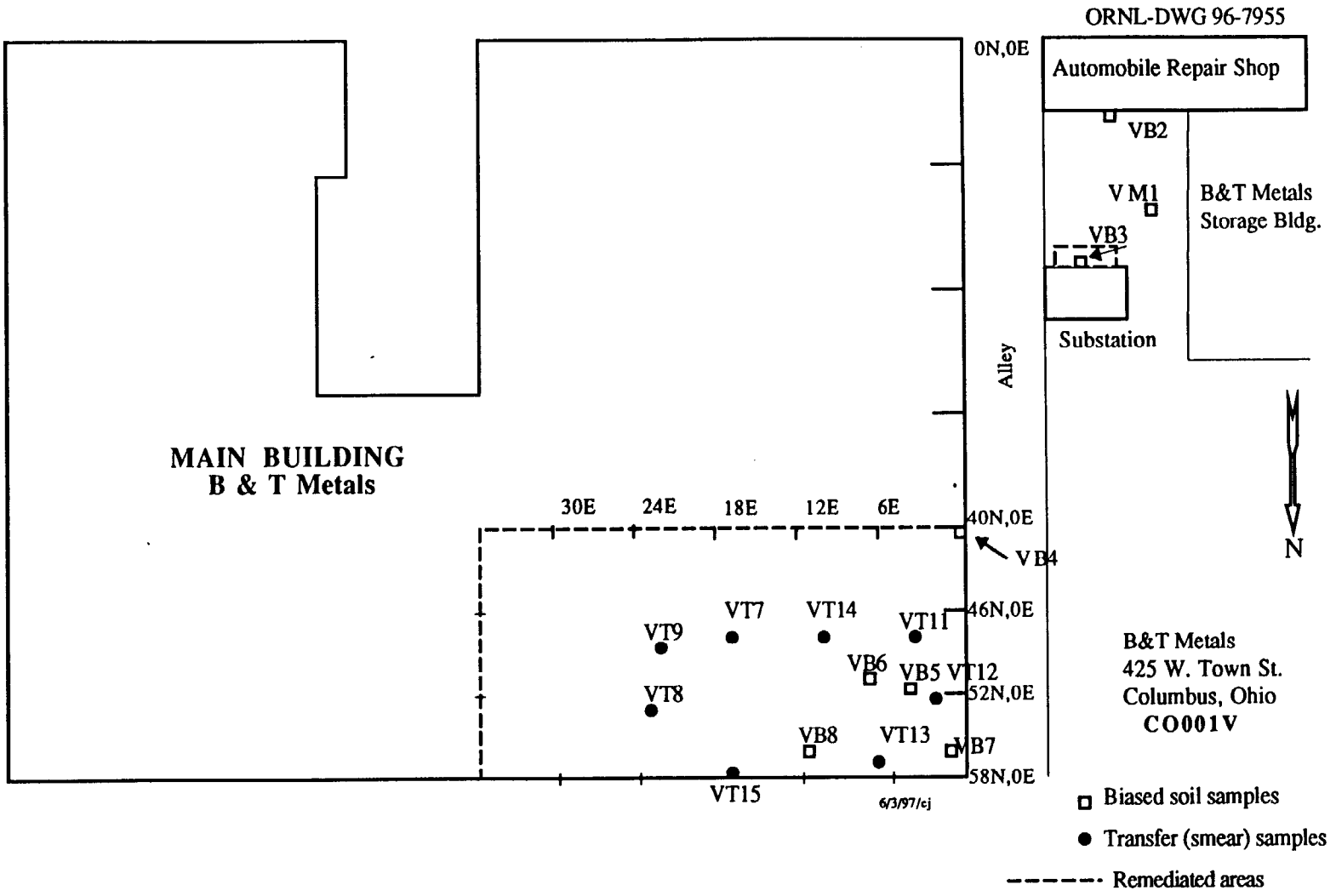

Fig. 5. Locations of smears taken inside on overhead structures, and soil samples taken both inside and outside the main building. Results of analyses are shown on Tables 3 and 4. (Drawing not to scale)

Table 1. Applicable guidelines for protection against radiation
(Limits for uncontrolled areas)

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h[a]
Total residual surface contamination[b]	^{238}U, ^{235}U, U-natural (*alpha emitters*) or Beta-gamma emitters[c]	
	Maximum	15,000 dpm/100 cm^2
	Average	5,000 dpm/100 cm^2
	Removable	1,000 dpm/100 cm^2
Radionuclide concentrations in soil (generic)	Maximum permissible concentration of the following radionuclides in soil above background levels, averaged over a 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 > 15 cm below the surface
	^{226}Ra	
	^{232}Th	
	^{230}Th	
Derived concentrations	Total uranium	35 pCi/g[d]
Guideline for non-homogeneous contamination (used in addition to the 100-m^2 guideline)[e]	Applicable to locations with an area ≤25 m^2, with significantly elevated concentrations of radionuclides ("hot spots")	$G_A = G_i(100/A)^{1/2}$, where G_A = guideline for "hot spot" of area (A) G_i = guideline averaged over a 100-m^2 area

[a]The 20 μR/h shall comply with the basic dose limit (100 mrem/yr) when an appropriate-use scenario is considered.

[b]DOE surface contamination guidelines are consistent with *NRC Guidelines for Decontamination at Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material*, May 1987.

[c]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, ^{129}I, ^{126}I, ^{125}I.

[d]DOE guidelines for uranium are derived on a site-specific basis. The guideline of 35 pCi/g total uranium has been applied at this FUSRAP site. *Sources*: Adler, D. G., *Baker Brothers and B and T Metals Sites-Uranium Soil Guidelines, Memorandum from Adler to J. W. Wagoner (CCN 131598)*, June 27, 1994. Argonne National Laboratory, *Derivation of Guidelines for Uranium Residual Radioactive Material in Soil at the B&T Metals Company Site, Columbus, Ohio (Draft)*, 1995.

[e]DOE guidelines specify that every reasonable effort shall be made to identify and to remove any source that has a concentration exceeding 30 times the guideline value, irrespective of area (adapted from *Revised Guidelines for Residual Radioactive Material at FUSRAP and Remote SFMP Sites, April 1987).*

Sources: Adapted from U.S. Department of Energy, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5, April 1990, and U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Rev. 2, March 1987; and *U. S. Department of Energy Radiological Control Manual*, DOE N 5480.6 (DOE/EH-256T), June 1992.

Table 2. Background radiation levels and concentrations of selected radionuclides in soil in the Columbus, Ohio, area[a]

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above ground surface (μR/h)[b]	7-9	8
Concentration of radionuclides in soil (pCi/g)[c]		
^{226}Ra	1.5 – 2.5	2.0
^{232}Th	0.71– 1.0	0.82
^{238}U	1.3 – 2.2	1.7

[a]*Source:* T. E. Myrick, B. A. Berven, and F. F. Haywood, *State Background Radiation Levels: Results of Measurements Taken During 1975-1979,* ORNL/TM-7343, Union Carbide Corp., Oak Ridge Natl. Lab., November 1981.

[b]Values obtained from 2 locations in the Columbus, Ohio, area.

[c]Values obtained from 3 locations in the Columbus, Ohio, area.

Table 3. Concentrations of radionuclides in soil and other materials at B&T Metals, Columbus, Ohio (CO001V)

Sample number[a]	Grid location	Depth[a] (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
		Systematic samples[c]			
VS1	6E, south gutter		2.9±3	2.3 ±1	2.2 ±2
VS2	16E, south gutter		<2.0	0.30±0.10	<0.29
VS3	27E, south gutter		4.3±1	0.30±0.2	0.40±0.20
VS4	9E, center gutter		7.0±1	<0.30	<0.40
VS5	12.5E, center gutter		2.9±1	0.90±0.5	<0.60
VS6	25E, center gutter		1.8±0.7	0.29±0.06	<0.30
		Biased soil samples[d]			
Outdoors					
VB2A	N8.6, E(-8)	0-15	2.1 ±1	1.7±0.1	1.0 ±0.1
VB2B		15-31	2.7 ±1	1.7±0.1	0.91±0.2
VB2C		31-46	2.2 ±0.4	2.1± 0.1	1.0 ±0.1
VB3A	N14.5, E(-8)	0-15	4.8 ±0.7	1.3± 0.09	0.72±0.1
VB3B		15-31	6.5 ±2	1.7±0.1	1.0 ±0.1
VB3C		31-46	4.1 ±1	1.6±0.09	0.95±0.1
Indoors[e]					
VB4	N41,E(-0.5)	0-15	0.85±0.3	0.83±0.07	0.13±0.07
VB5	N52, E6	0-5	15 ±5	1.2 ±0.08	0.51±0.1
VB6	N51, E6.5	0-5	5.0 ±2	1.4 ±0.08	0.62±0.07
VB7	N54.5,E3.7	0-5	29 ±1	1.4 ±0.09	0.74±0.1
VB8	N54.5,E13.0	0-5	20 ±5.0	1.8 ±0.2	0.85±0.2
		Miscelleanous sample			
VM1[f]	N14.5,E(-8)	0-15	8.0±3	1.7±0.1	0.91±0.1

[a]Locations of soil and gutter material samples are shown on Figs. 4 and 5. Gutter samples are all surface samples.

[b]Indicated counting error is at the 95% confidence level (± 2σ).

[c]Systematic samples are taken at locations irrespective of gamma exposure rates.

[d]Biased samples were taken from areas with elevated gamma exposure rates inside the building and outdoors.

[e]Samples taken from trench made in concrete floor (under concrete pad), 12-18 in. below floor level.

[f]BNI split sample from same area as sample VB3.

Table 4. Transferable alpha and beta levels in north roof gutter and ceiling overhead structures at B&T Metals, Columbus, Ohio (CO001V)

Sample number	Grid location	Location description	Alpha[a] (dpm/100 cm^2)	Beta-gamma[a] (dpm/100 cm^2)
		Smears from north gutter[b]		
VT1	9.5E	[c]	[0]	[-17]
VT2	8.9E	[c]	[0]	[-5.7]
VT3	2.25E	[c]	[0]	[29]
VT4	11.5E	[c]	[0]	[-17]
VT5	12.2E	[c]	[0]	[-17]
VT6	13E	[c]	[0]	[6]
		Smears from overhead structures[d]		
VT7	N46.5,E18	overhead truss	42	[34]
VT8	N52,E24	overhead I beam	[0]	[17]
VT9	N49.5,E24	overhead line	[0]	[-6]
VT10	N57,E24	overhead truss	[0]	[-46]
VT11	N46,E5	overhead I beam	[0]	[11]
VT12	N52,E2	upper surface switchgear box	[0]	[29]
VT13	N52,E6	overhead I beam	[0]	[17]
VT14	N46, E6	truss, I beam connection	[0]	[11]
VT15	N58,E16	wall ledge	[0]	[-23]

[a]Brackets indicate the value calculated is less than the L_c value of 5 dpm/100 cm^2 alpha, or 168 dpm/100 cm^2 beta.

[b]Locations of smears from gutter material are shown on Fig. 4.

[c] Locations of smears from gutter (lying in east-west direction on the roof) are measured in meters east of the west wall.

[d]Locations of smears from ceiling overhead structures are shown on Fig. 5.

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