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Energy Technology Engineering Center

Operated for the U.S. Department of Energy
Rocketdyne Division, Rockwell International

No. GEN-ZR-0013 Rev. ___
Page 1 of 179
Orig. Date 8/26/88
Rev. Date ______

DRR 23/88 SC

TITLE: "Radiological Survey of Buildings T049, T042, T027, T032, and T025."

-APPROVALS-

Written by: Jeffrey A. Chapman *Jeff A. Chapman*

Approved by: Robert J. Tuttle *RJTuttle*

Kenneth T. Stafford *[signature]*

REV. LTR.	REVISION	APPROVAL/DATE

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ABSTRACT

A radiological survey was performed in five SSFL facilities which were used in the 1950s and 1960s to support the Systems for Nuclear Auxiliary Power (SNAP) program. These facilities are located in the government-optioned portion of Area IV and include:

1) Building T049;
2) Building T042;
3) Building T027;
4) Building T032; and
5) Building T025, (including the adjacent parking lot/storage yard.

These facilities, except for Building T049, were used as engineering development and test sites for SNAP. Tests performed were all non-nuclear related, and included heat transfer loop performance, vibration and shock tests, space environment assessment, and some casting work. In interim periods, areas of these facilities were used for storing materials. Building T049 was a small facility used as a control center. Radioactive materials may have been handled only at Buildings T042 and T027, but this is not known for certain. No known contamination incidents occurred at any nearby facilities to such a magnitude that would result in contaminating these areas. Residual radioactivity is not suspect. This radiological survey was performed to determine if any radioactive material has been accidentally left behind to such an extent that further surveying or decontamination is warranted.

Ambient gamma exposure rate measurements were performed on a 3-m square plot plan inside the buildings and a 6-m square plan in the outside area of T025. This plan resulted in the acquisition of 450 gamma measurements, and 56 total and removable alpha/beta activity measurements. Further inspection and investigation because of increased exposure rates was

necessary during this survey primarily because of changes in ambient conditions due to gamma radiation emitted from the nearby RMDF. Smear samples collected inside Buildings T049 and T042 were analyzed to measure removable alpha/beta activity. Total alpha/beta activity was measured in these same locations. Smears were also collected in sinks, drains, showers, exhaust systems, and outside a glove box in T042. In those same locations, total beta surface activity was measured "for indication."

Results of this survey, analysis, and interpretation show that no locations are contaminated with significant residual radioactivity. Gamma exposure rate measurements plotted against cumulative probability show Gaussian distributions with slightly greater variability than expected from counting statistics alone. This greater variability is attributed to variations in "ambient background." All sample lots, when corrected independently for "ambient background," (this includes background variations due to natural phenomena, instrument noise, geometry changes, and increased gamma radiation from the RMDF), pass acceptance criteria for unrestricted use. Total and removable alpha/beta activity values analyzed in the same statistical manner also pass acceptance criteria for unrestricted use by a wide margin. Total beta surface activity measurements show No Detectable Activity, except for a drip pan found in Building T032 which was slightly contaminated at a level of about 25,000 dpm/100 cm^2 beta activity. This stainless steel pan had evidently been activated; Co-60 was the contaminant. This radioactivity was fixed in the steel and did not spread to surrounding areas. Although not a hazard, this pan was dispositioned as radioactive waste. No further investigation is necessary in these locations.

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1.0 INTRODUCTION

Five facilities located in Area IV of Rockwell International's Santa Susana Field Laboratories (SSFL) were inspected and analyzed for residual radioactive material. These facilities supported Atomics International's Systems for Nuclear Auxiliary Power (SNAP) program in the 1950s and 1960s. An outside area surrounding Building T025 is currently in use as a storage yard for salvageable materials and scrap components. These facilities supported AEC, ERDA, and DOE nuclear-related programs and include:

1. Building T049 (formerly a Hydraulic Test Facility control center);
2. Building T042 (formerly the SNAP Shield Casting Facility);
3. Building T027 (formerly the SNAP Vibration and Shock Laboratory);
4. Building T032 (formerly the Space Environmental Test Facility); and
5. Building T025 (formerly the SNAP Remote Mock-up Facility).

Each location was inspected for radioactivity to determine whether any radioactive material has been accidentally left behind and if further investigation is necessary or remedial action is required. This radiological survey was conducted as prescribed in the "Radiological Survey Plan for SSFL," (Reference 4, Sections 5.4.10, 5.4.11, 5.4.12, 5.4.13, and 5.4.14).

Located in Ventura County, California, Area IV of Rockwell International's SSFL has been used to develop and test nuclear powered reactors; fabricate nuclear reactor fuels; and disassemble irradiated nuclear fuel elements. A cluster of buildings located in what is now the Energy Technology Engineering Center (ETEC) area was used in the 1960s for developing, assembling, and testing SNAP reactors for the AEC. Several of these buildings and one surrounding storage yard area are the subject of this radiological survey. The SNAP program has ended, and the facilities that supported this program were reassigned and modified for other non-nuclear DOE programs. T049 is currently abandoned. T042 is in limited use for testing liquid metal systems. T027 is a storage facility. T032 is an active sodium test loop. T025 is a storage facility.

Residual radioactive material existing in these survey locations is not likely. No loose radioactive material was handled at any of these facilities. Building T049 could only possibly be contaminated from operations performed at nearby Building T005, a uranium carbide fuel facility. Uranium may have been used at Building T042 for a short test program (less than a week), but this is not confirmed. And, Building T027 may have been used for storing totally sealed radiography sources. Buildings T032 and T025 were never known to contain radioactive or nuclear materials.

No known incidents occurred in these or surrounding facilities which would have spread contamination to the inspected areas. Although some minor radiological contamination incidents might have occurred, it was common practice to decontaminate and return an affected location to its natural condition. No residual contamination is suspect. The purpose of this survey was to detect any radioactive material accidentally left behind from these operations.

As part of the DOE SSFL Site Survey (Reference 4) a radiation survey was performed in these areas to determine if any residual contamination exists. Ambient gamma exposure rates were measured outdoors on a 6-m by 6-m grid and indoors on a 3-m by 3-m grid. These radiation measurements are sensitive to radiations emitted from the radioactive materials handled or produced at the SNAP facilities: enriched uranium, mixed fission products, and activation products. If radioactive contamination was indicated during performance of the gamma measurements, samples were to be collected and analyzed for radioactivity, and beta surface activity measurements were to be performed. Sample collection was not required for this particular survey. In addition to exposure rate measurements, total and removable alpha/beta surface activity was assessed inside Buildings T049 and T042. These inspections were performed in each 3-m square grid and on special facility features: wall coving, miscellaneous horizontal surfaces, cracks, crevices, sinks, drains, showers, exhaust systems, and filter banks. These measurements were analyzed statistically. Surface beta activity measurements were made "for indication" on miscellaneous facility features.

All ambient gamma exposure rate data, and total and removable alpha/beta contamination data were input into a Personal Computer (PC) graphics program which plots the radiation measurement value against its cumulative probability. The software also calculates a test statistic using inspection by variables techniques. This test statistic is that value greater than the mean value of the distribution, which corresponds to a consumer's risk of acceptance of 10% probability with a Lot Tolerance Percent Defective (LTPD) of 0.10. This method assumes the data follow a Gaussian probability density function. Inspection by variables techniques allows a thorough, understandable, and conclusive study for assessing the contamination level in an area.

Radiation measurements are compared against DOE residual radioactivity limits specified in "Guidelines for Residual Radioactivity at FUSRAP and Remote SFMP Sites," (Reference 1). This guide generally agrees with previously published guides and standards, including ANSI Standard N13.12 (Reference 7), Regulatory Guide 1.86, and USNRC License SNM-21 (Reference 2). Limits for total and removable alpha/beta activity agree between standards. Limits for acceptable ambient gamma exposure rates differ between the DOE and NRC. DOE specifies 20 μR/h above background while NRC specifies 5 μR/h above background as acceptable gamma exposure rate limits. "Natural background" at SSFL is very difficult to determine because of a large observed variability in the measurements. Because of this large variation, total-gross gamma measurements made in a survey area are plotted and compared against three independent "natural" background distributions. If the average "background" exposure rate of the three "natural background" distributions (which is 15 μR/h) represents similar ambient conditions in a test-area, then this value is used to correct gross test-area values for background. If "ambient" conditions are dissimilar, then the best estimate for "ambient background" is the median value of gross-total measurements made in a sample lot. "Ambient" conditions are assessed on a sample lot by sample lot basis in order to compare gamma measurements against acceptance limits "above background."

2.0 IDENTIFICATION OF FACILITY PREMISES

2.1 Location

The facilities covered in this report are identified in the "Radiological Survey Plan for SSFL,"(Reference 4) as follows:

1. Building T049, (Section 5.4.10);
2. Building T042, (Section 5.4.11);
3. Building T027, (Section 5.4.12);
4. Building T032, (Section 5.4.13); and
5. Building T025, (Section 5.4.14).

These buildings are adjacent to each other, and are located within Rockwell International's Santa Susana Field Laboratory (SSFL) in the Simi Hills of southeastern Ventura County, California. The site is adjacent to the Los Angeles County line, and is approximately 29 miles northwest of downtown Los Angeles. The SSFL location relative to the Los Angeles area and surrounding vicinity is shown in Figure 2.1. Figure 2.2 is an enlarged map of neighboring SSFL communities.

The five facilities covered in this report are located in the western portion of SSFL, which is referred to as Area IV. Figure 2.3 is a plot plan of Area IV showing the subject facility locations. The buildings are located along "B" Street, south of 12th Street and west of "G" Street. These facilities are within the 90.26-acre Government-Optioned land area. Most facilities in this area are part of the Energy Technology Engineering Center (ETEC), which is government-owned, and operated by Rocketdyne. This is the case for these subject facilities.

2.2 Local Area Topography and Facility Characteristics

These sites are located on an irregular plateau in a mountainous area of recent geological age sprinkled with outcroppings above the more

Figure 2.1 Map of Los Angeles Area

Figure 2.2 Map of Neighboring SSFL Communities

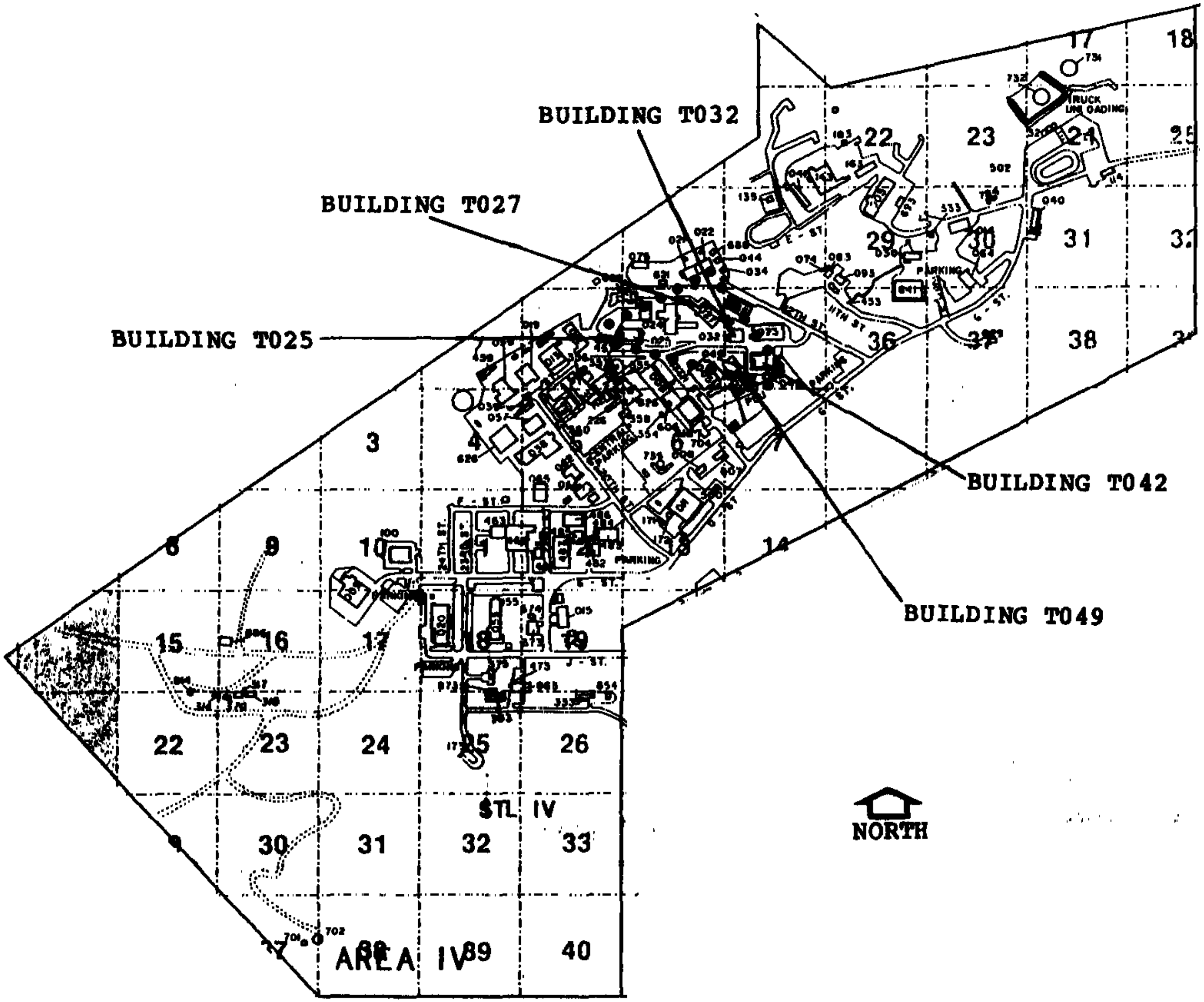


Figure 2.3 SSFL Layout, Showing Locations of Buildings T049, T042, T027, T032, and T025

level patches. Asphalt concrete pavement used for access to each facility and for equipment holding and staging. The vicinity of these facilities is relatively heavily populated with nearby test facilities.

The general slope of Area IV, including these facilities and surrounding areas, is in a southerly direction. Water runoff is directed to the retention reservoirs which are part of the SSFL industrial effluent control system. Liquid effluent discharge from the final retention pond into the Bell Canyon drainage occurs only after controlled effluent hold-up and sampling. Figure 2.4 is a topographic map of this area. The entire area is paved.

Building T049 was built in 1959 as a control center for an outside vertical test stand. The total installation was build as a hydraulic test facility. Building T049 was constructed as a block house with block frame and siding and a built-up roof. Ceiling height is 10.5 ft with a 2-ton jib crane. The building has 800 sq ft. A layout of Building T049 is shown in Figure 2.5.

Building T042 was constructed in 1963 as a general test and lithium hydride shield fabrication building in support of the SNAP program. The building was constructed with a steel frame, and steel siding and roofing. The building has a 4,269 sq ft area of which 4,117 sq ft is laboratory space. The ceiling height is 38 ft with a 5-ton bridge crane. A layout of Building T042 is shown in Figure 2.6.

Building T027 was constructed in 1961 as a vibration and shock test facility in support of the SNAP programs launch schedule. The building has 9,240 sq ft total area with 4,589 sq ft of high bay laboratory area, and the remaining area, office and shop support. The building is steel frame with steel siding and roof. The high bay is 37 ft high with a 6-ton bridge crane. The walls of the high bay have acoustical insulation. A layout of the building is shown in Figure 2.7.

Figure 2.4 Topographic Map of Areas Surveyed

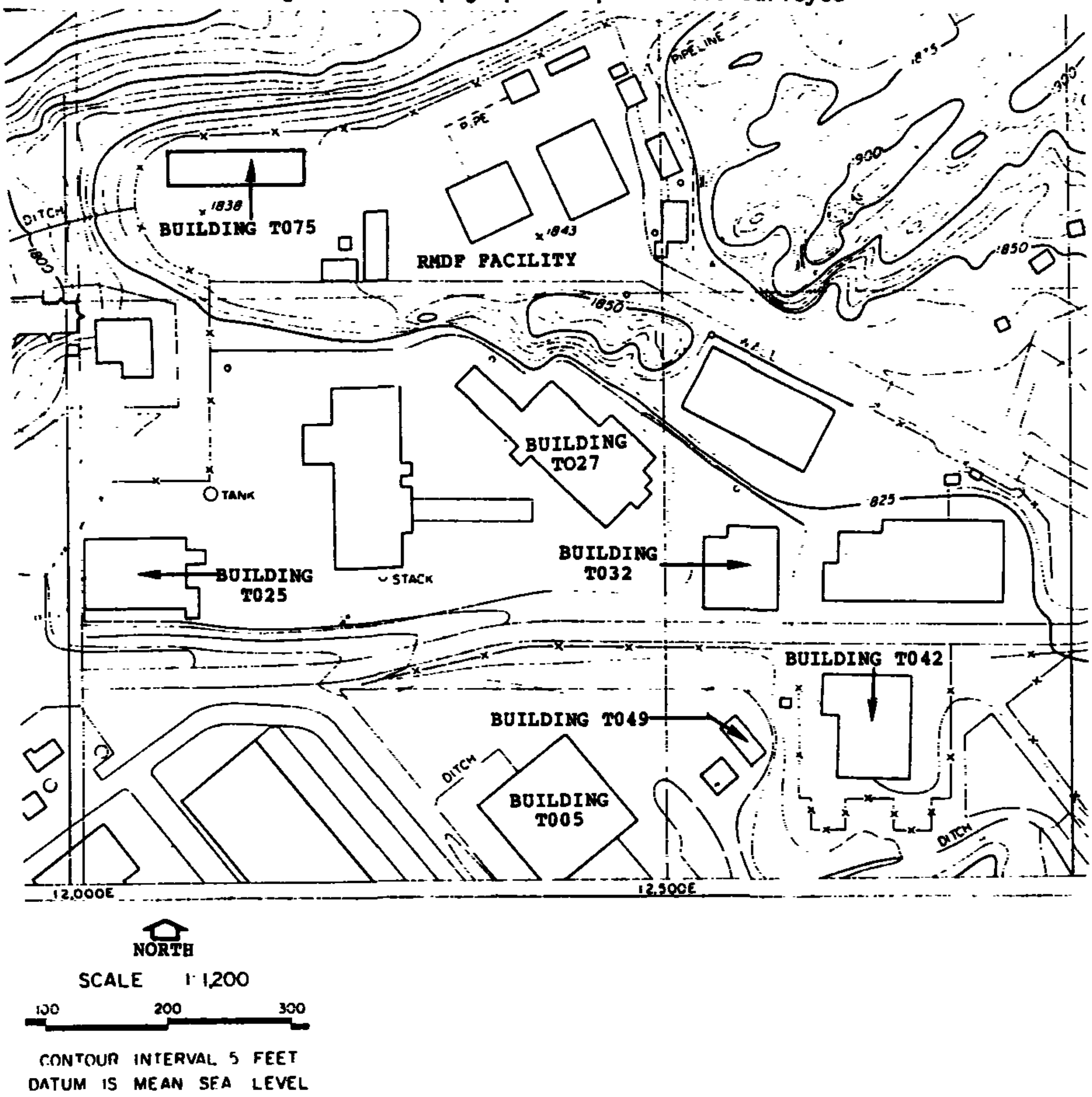


Figure 2.5 Plot Plan of Building T049

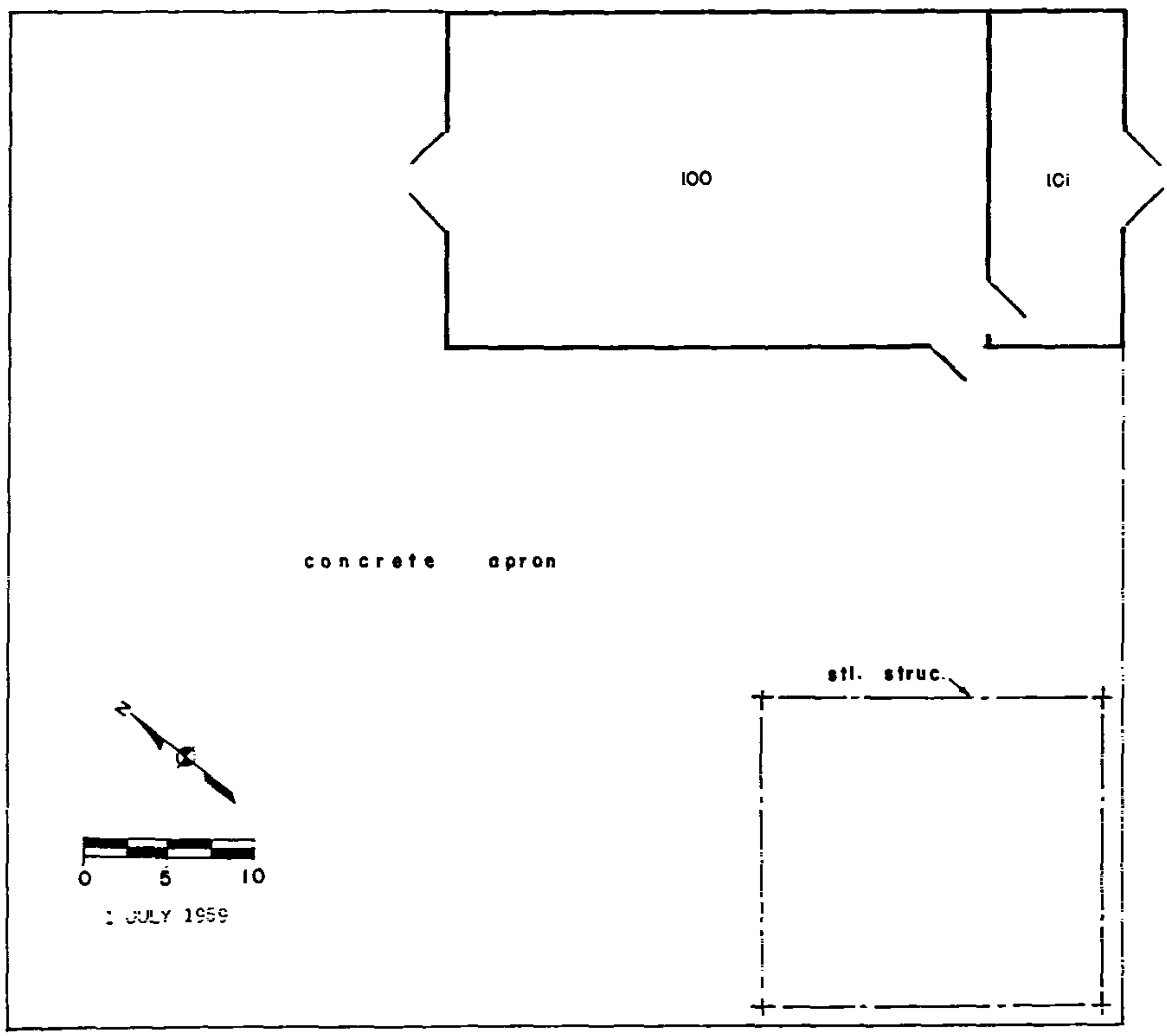
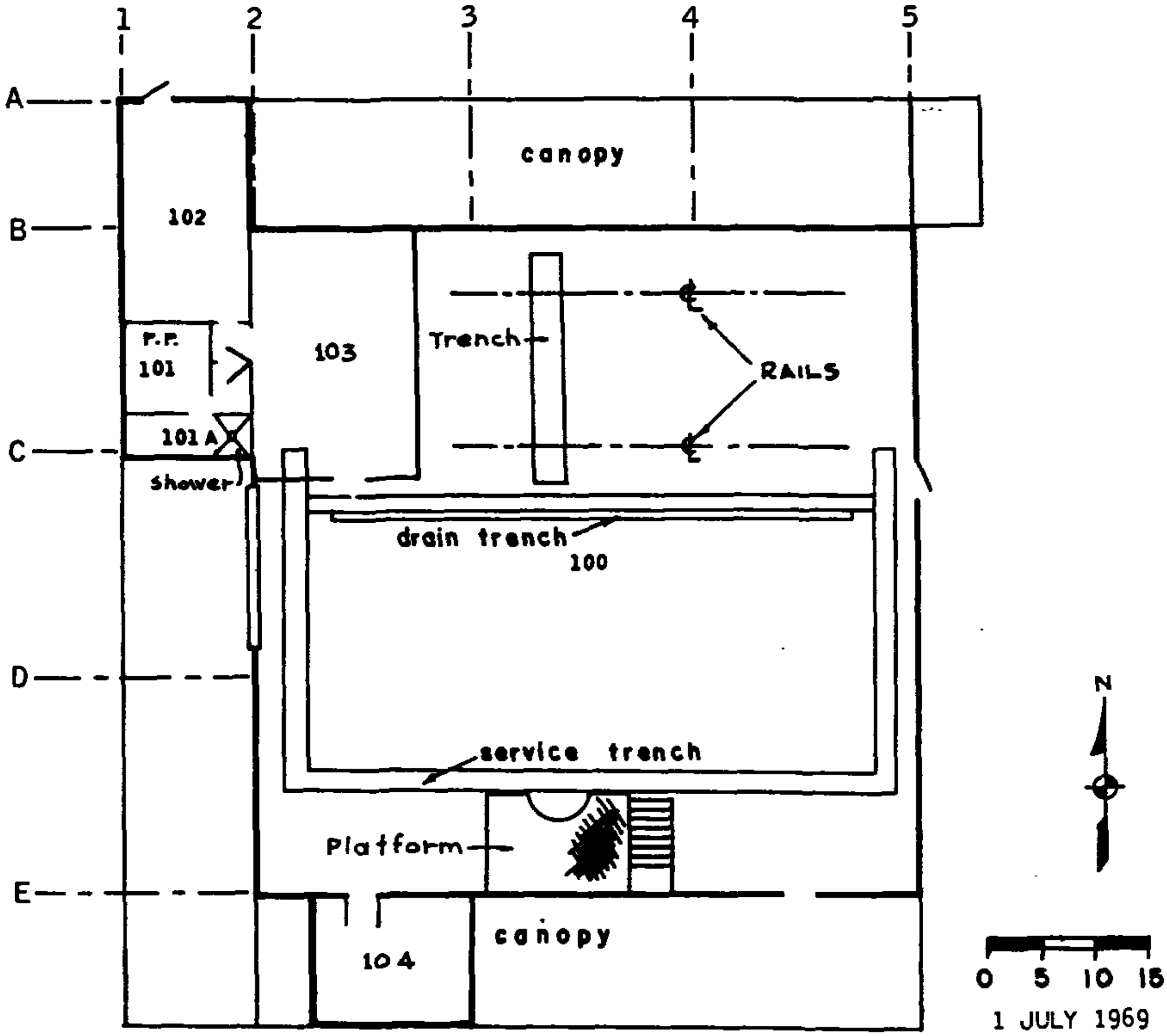


Figure 2.6 Plot Plan of Building T042



SHIELD CASTING FACILITY

BUILDING NO. 042

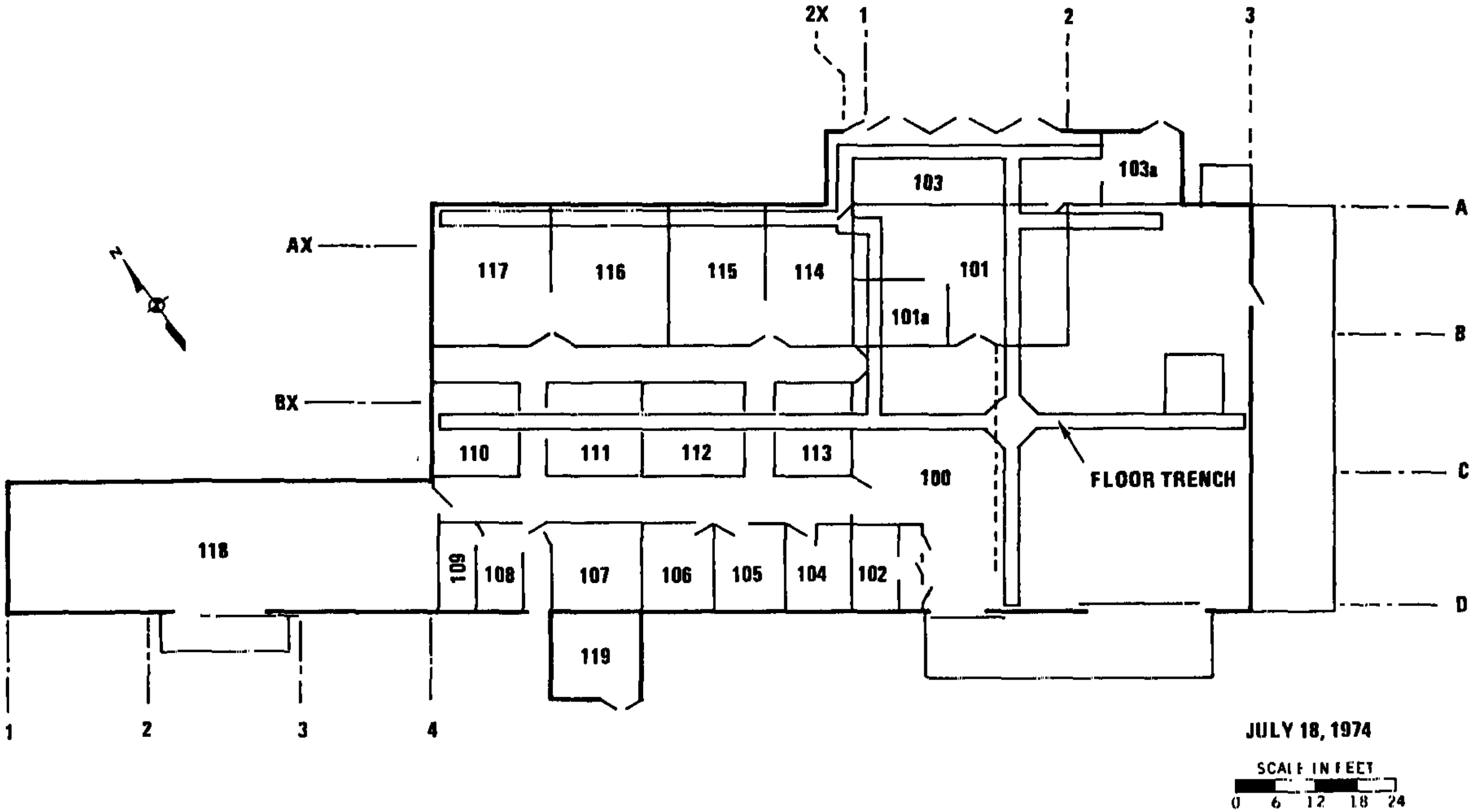


Figure 2.7 Plot Plan of Building T027

Building T032 was built in 1962 as a space environmental test facility for thermal vacuum systems. The building has 4,580 sq ft of space of which 4,200 sq ft is laboratory. The building is a steel frame structure with steel siding and roof. The ceiling height is 32 ft with a 5-ton bridge crane. A layout of the building is shown in Figure 2.8.

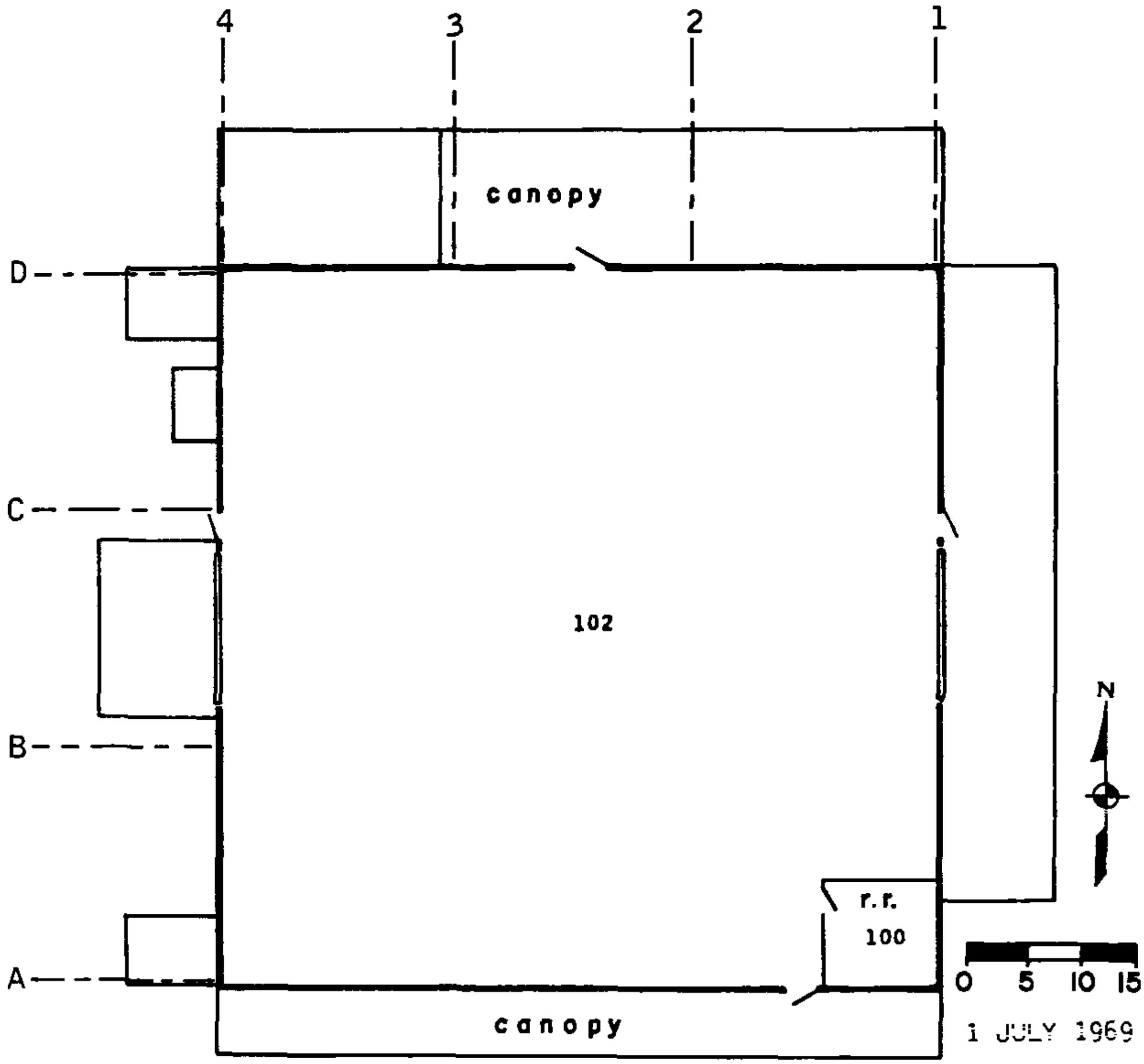
Building T025 was constructed in 1959 for the purpose of supporting the SNAP nuclear reactor tests. The structure consists of a steel frame with steel siding and roof. The building has 5,595 sq ft with a low bay, middle bay, and high bay. Ceiling heights are 9 ft, 20 ft and 35.5 ft. The building has two, 2-ton bridge cranes. A layout of the building is shown in Figure 2.9.

Several of these facilities are located in close proximity to the Radioactive Materials Disposal Facility (RMDF), where radioactive materials are packaged and staged for off-site disposition. Direct radiation and skyshine from the RMDF affects ambient radiation conditions in these locations.

2.3 Facility Utilization and Present Radiological Condition

Buildings T042, T027, T032, and T025 were built to support Atomic International's Systems for Nuclear Auxiliary Power (SNAP) program. The SNAP program began in about 1955 and facilities were constructed shortly thereafter. Figure 2.10 is a mid-1960s photograph showing the SNAP Building Complex. Several designs of SNAP were developed and tested in Area IV of SSFL. SNAP-2 was a reactor-heated electrical power plant to produce 3 kW. SNAP-10A was a SNAP-2 reactor, with a thermoelectric generator to produce 500 watts. Fuel for these reactors was highly enriched uranium as a zirconium hydride alloy, clad in Hastelloy. The subject facilities of this report were not used for critical testing or for SNAP tests involving the use of radioactive material; these were support facilities for other engineering tests.

Figure 2.8 Plot Plan of Building T032



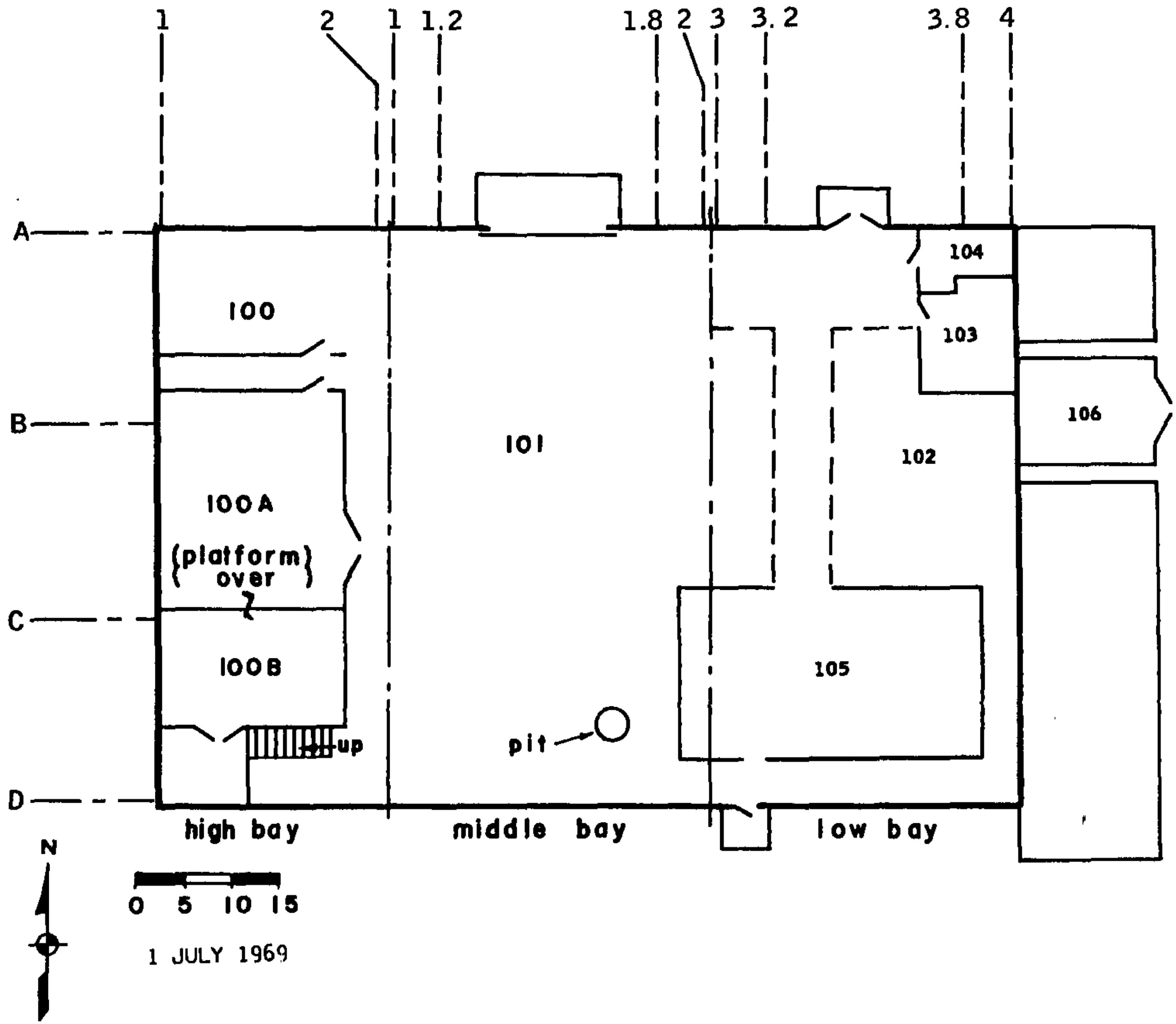


Figure 2.9 Plot Plan of Building T025

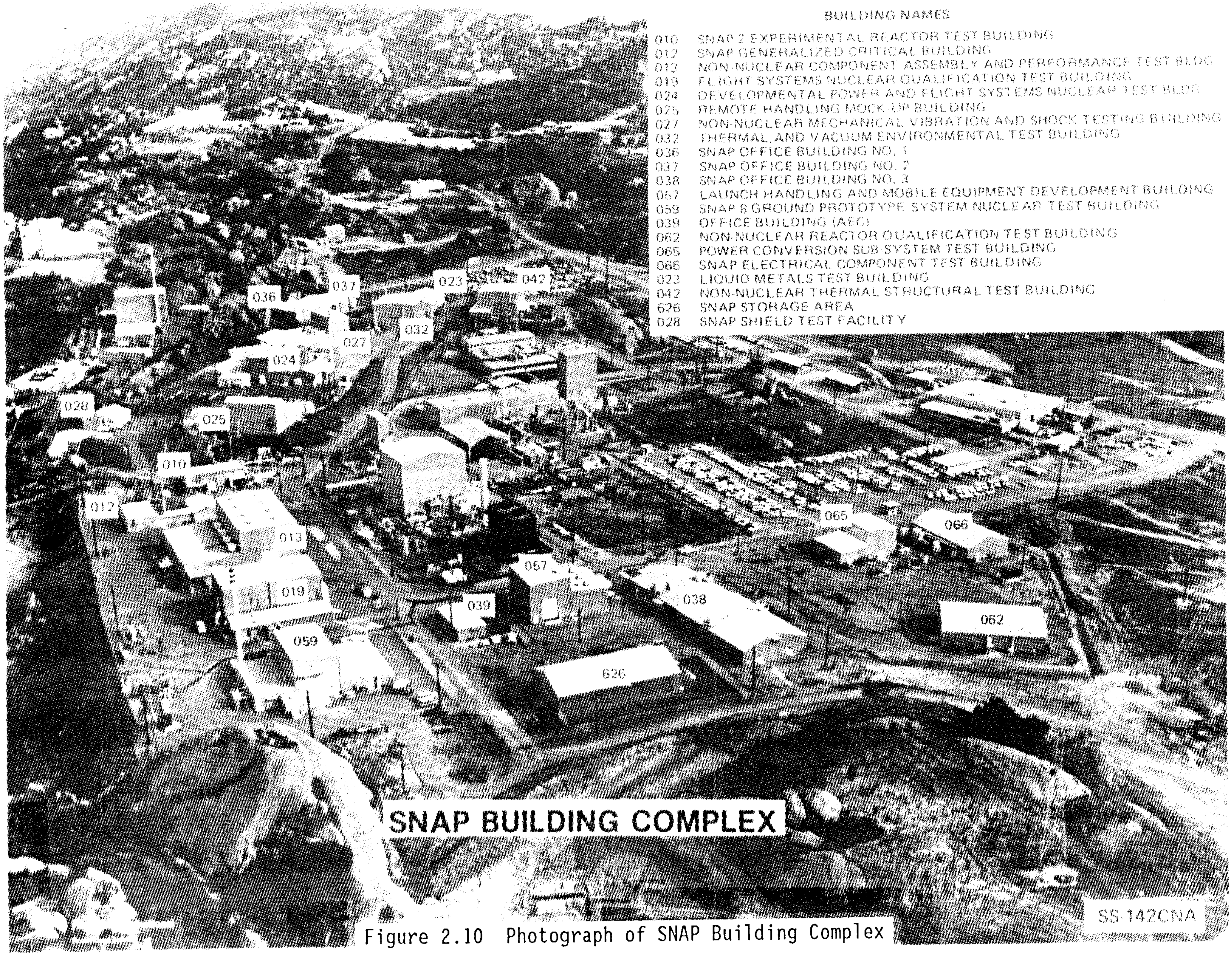


Figure 2.10 Photograph of SNAP Building Complex

SNAP facilities were designated either nuclear-related or non-nuclear-related based on whether radioactive or nuclear materials were handled there or not. All of these subject facilities were non-nuclear-related; however, depleted uranium may have been used at T042 for a short 5-day experiment, but this is not confirmed. In the Site Survey Plan (Reference 4), Building T042 was incorrectly listed as having a contaminated sodium test loop; this loop was in Building T023 -- which is not part of this radiological survey. These facilities that supported SNAP have been reassigned and modified for other non-nuclear DOE programs. They are currently in use.

Building T049 is the only building which was not associated with the SNAP program. It was in use as a control center for a non-nuclear test bed. It is however, located within the boundary fence-line of Building T005, the old Uranium Carbide Pilot Fuel Facility (UCPFF), which is known to be contaminated in certain locations (Reference 16). Because of its proximity to Building T005, it was included as part of the DOE Site Survey.

2.3.1 Building T049

Building T049 commenced operations as a hydraulic test facility control center in 1960. The outside test stand was used for tests with terphenyl organics and finned sintered-aluminum-product cladding materials, sodium-water reaction tests, and a variety of sodium and NaK hydraulic tests. During the time frame from 1968-1977 the facility was used as a control center for Piqua Test Loops. In 1977 the installation was redesignated as a control and test center for the PDU coal gasification process. Currently, the facility is secured and inactive. Figure 2.11 is a photograph of T049.

Radioactive materials were not handled at T049. The only possibility for radioactive material being there would be if it was spread from nearby Building T005. This is highly unlikely. Residual radioactivity is not suspect in this facility.

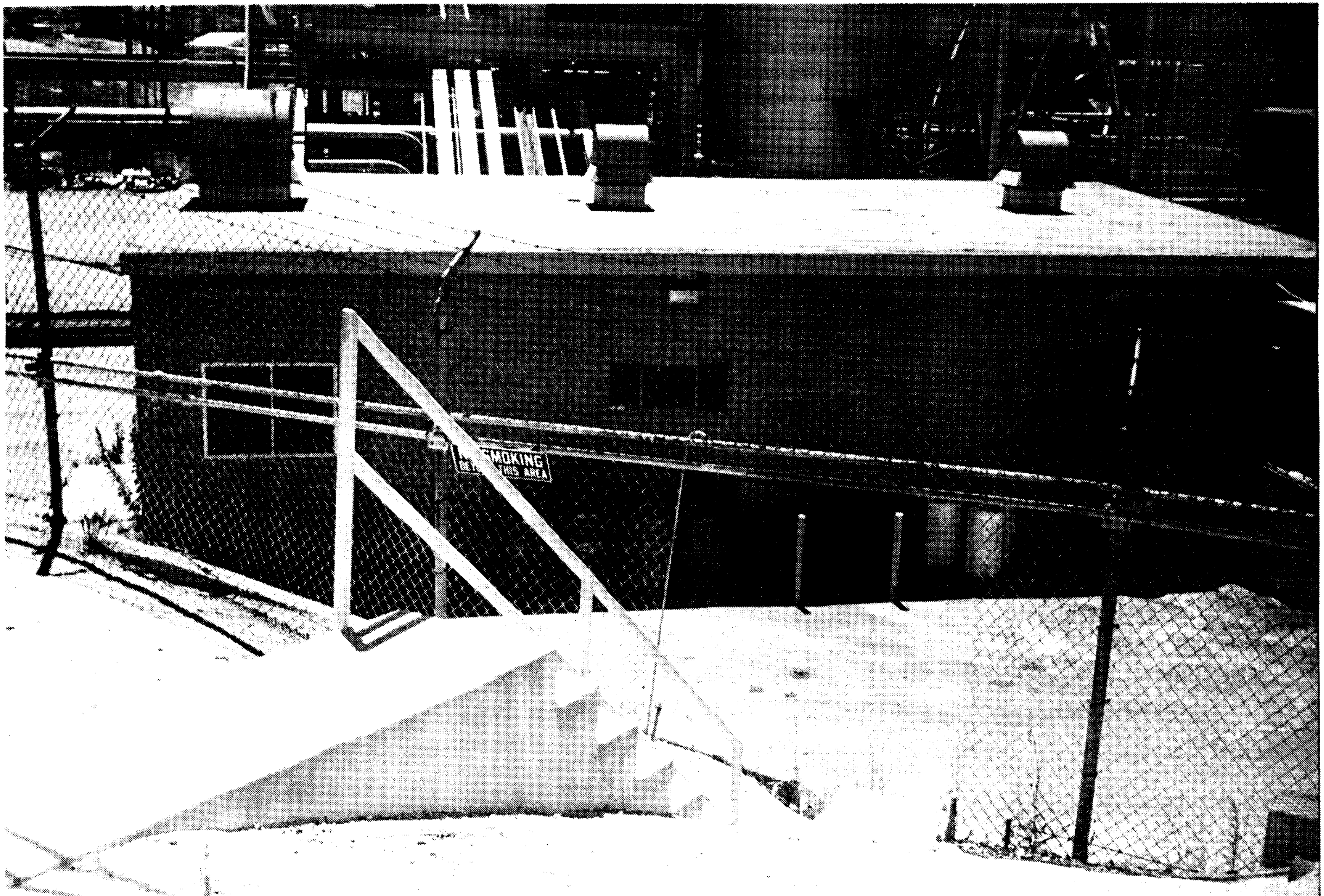


Figure 2.11 Photograph of Building T049 Looking West
Toward Building T005

2.3.2 Building T042

Following construction, Building T042 was designated a lithium hydride, Shield Casting Facility. Shields were fabricated for the SNAP reactors for the ground tests and, in addition, the SNAP 10 FS-3 that was launched into space in 1965. Through the 1960s, this building was also used for sodium-aerosol, and related technology tests. With the cancellation of the SNAP program in 1970, only a limited amount of hydride fabrication work was conducted, and for the most part, liquid metal technology work continued. This has been the case to the present time.

The only possible (but undocumented) radioactive material handled at T042 is depleted uranium. An unknown experiment using this material may have occurred. No incidents are known to have occurred. Residual radioactivity is not suspect in this facility. Figure 2.12 is a photograph of T042.

2.3.3 Building T027

Vibration and shock tests were performed in Building T027 in 1962 for the SNAP program. Launch vehicle simulation testing was conducted at this facility through 1968. The equipment was removed from the building in 1970, and the facility has subsequently been used for quality assurance, and materials and components acceptance. As part of the QA function, radiography equipment and perhaps sealed sources were stored here. At the present time the building is used for storage. Figure 2.13 is a photograph of T027.

No loose radioactive or nuclear material were handled at T027. Sealed, fully-encapsulated, radiography sources may have been stored there several years ago. Radiography sources were always leak tested every 6 months. No incidents are known. Residual radioactivity is not suspect at T027.

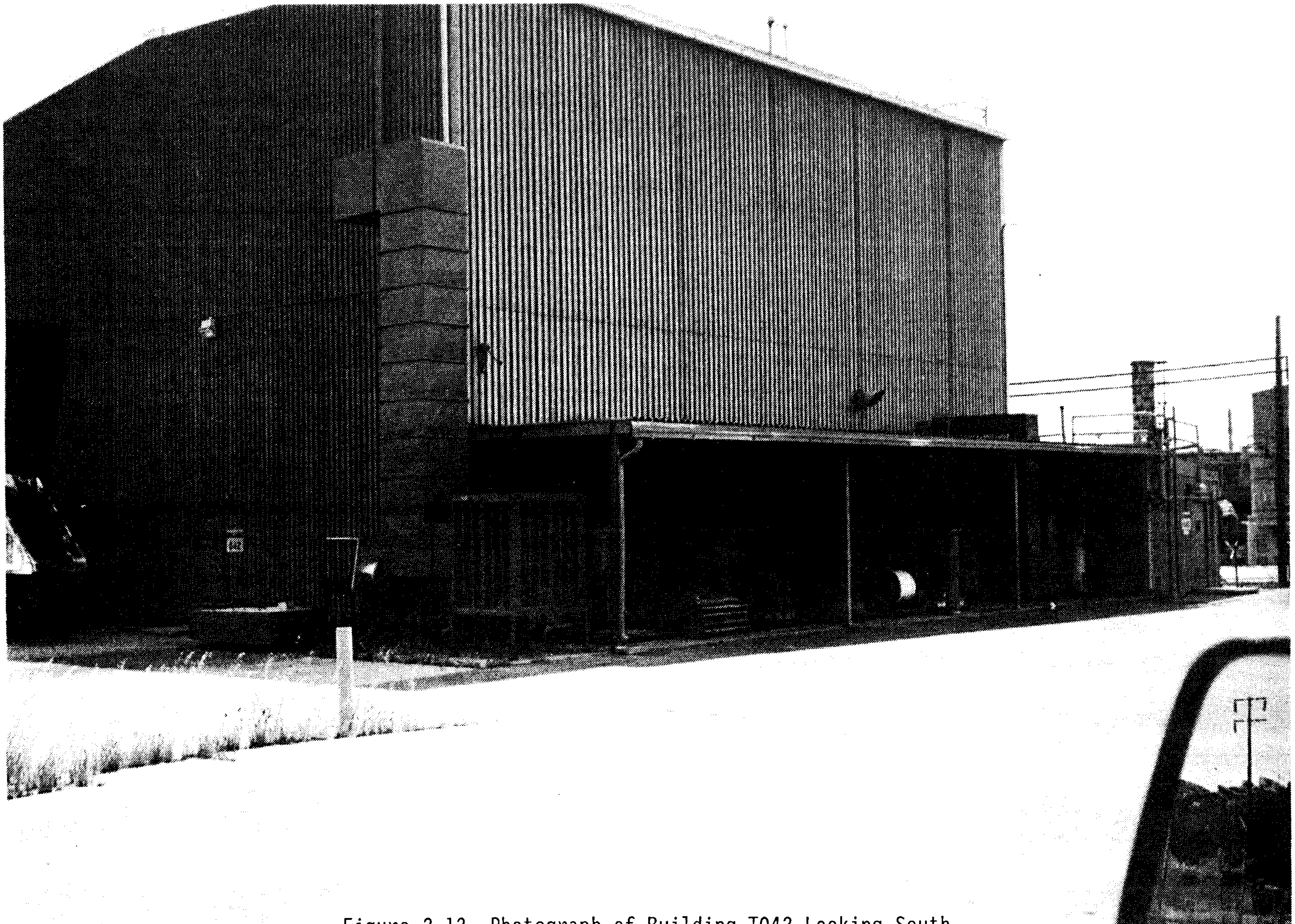


Figure 2.12 Photograph of Building T042 Looking South

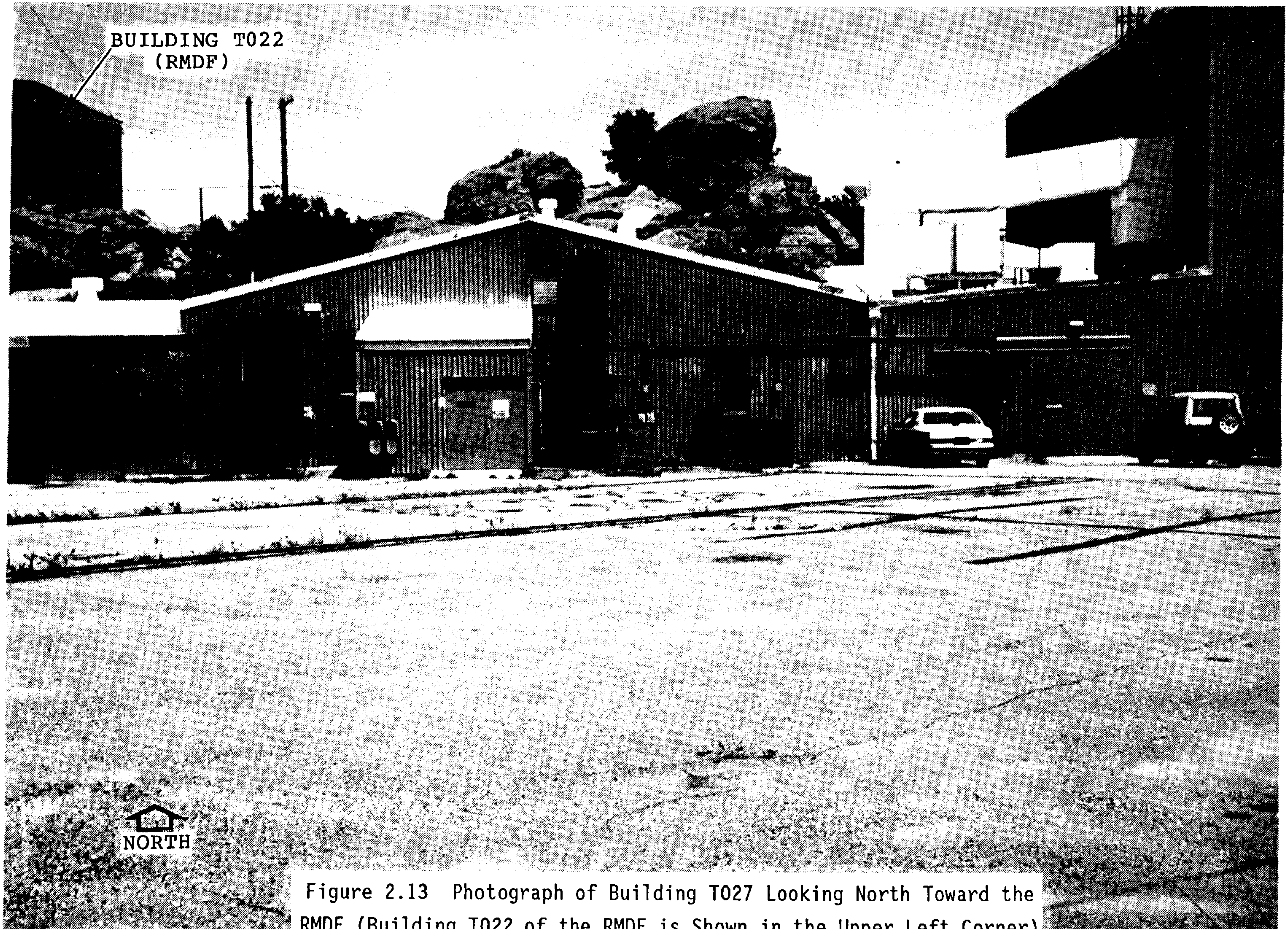


Figure 2.13 Photograph of Building T027 Looking North Toward the RMDF (Building T022 of the RMDF is Shown in the Upper Left Corner)

2.3.4 Building T032

Building T032 was designated the Space Environmental Test Facility following its construction in 1962. Vacuum chamber equipment was installed in the building; and heaters were used for SNAP system's thermal simulation testing. Following completion of thermal vacuum testing in 1970, the vacuum equipment was removed and the facility was redesignated as an ETEC General Test Building. The facility has been used for sodium component and instrumentation testing since that time. Figure 2.14 is a photograph of T032.

No radioactive or nuclear materials are known to have been handled here. Residual radioactivity is not suspect at T032.

2.3.5 Building T025

Building T025 was designated the Remote Handling Mock-up Facility following construction. The building was used through 1970 for nuclear reactor, remote handling and viewing mockup work in support of the SNAP 2/10A, and SNAP 8 tests. Extensive mockup work was conducted for work at Building T025, the "Developmental Power and Flight Systems Test Facility." Following cancellation of the SNAP program in 1970, Building T025 was designated the ETEC Instrumentation and Inventory Building, and has been used for component assembly, storage and instrumentation work since that time. Figures 2.15 and 2.16 are current photographs of T025.

No radioactive or nuclear materials are known to have been handled or stored here. Residual radioactivity is not suspect in T025.

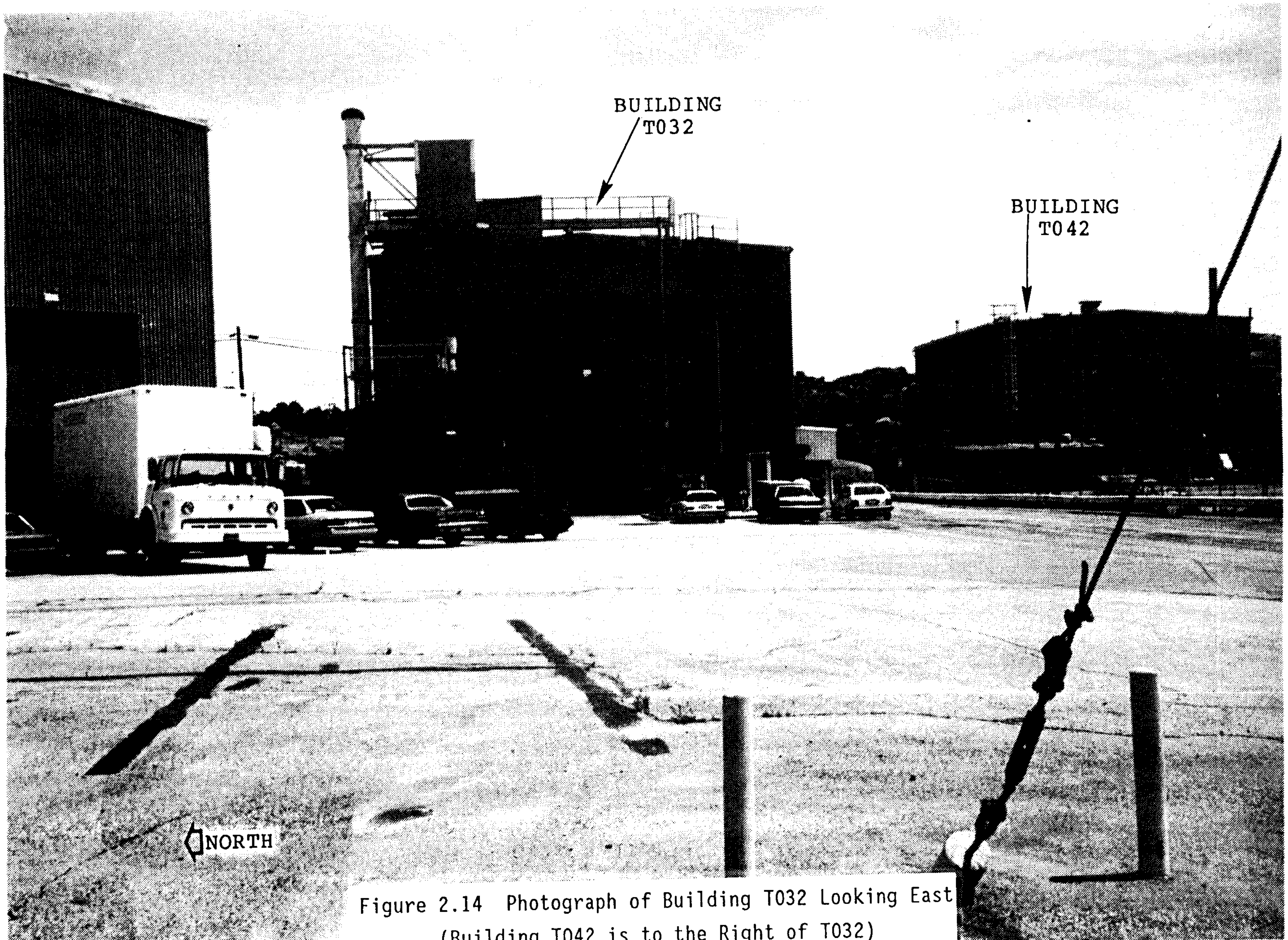


Figure 2.14 Photograph of Building T032 Looking East
(Building T042 is to the Right of T032)

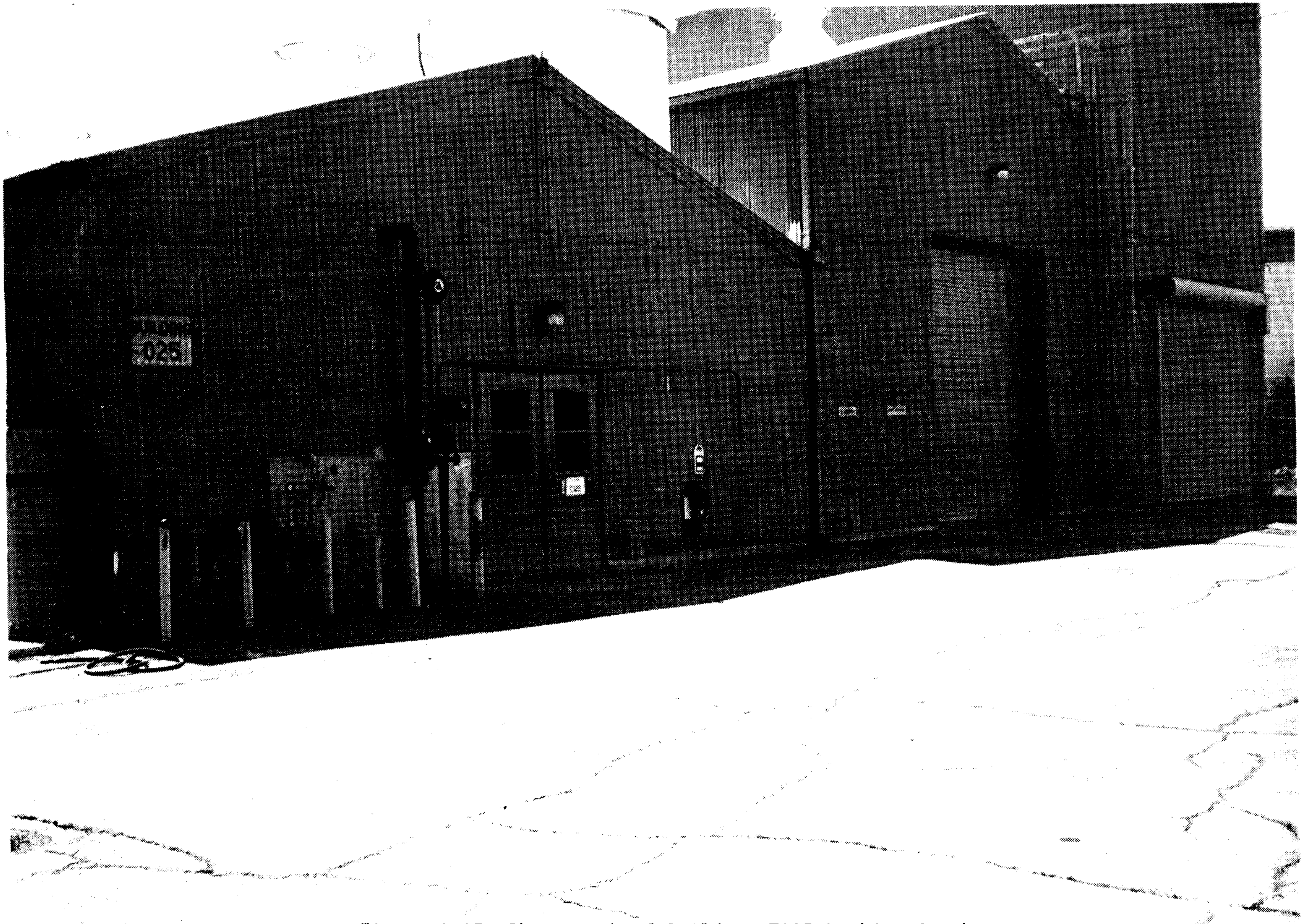


Figure 2.15 Photograph of Building T025 Looking South

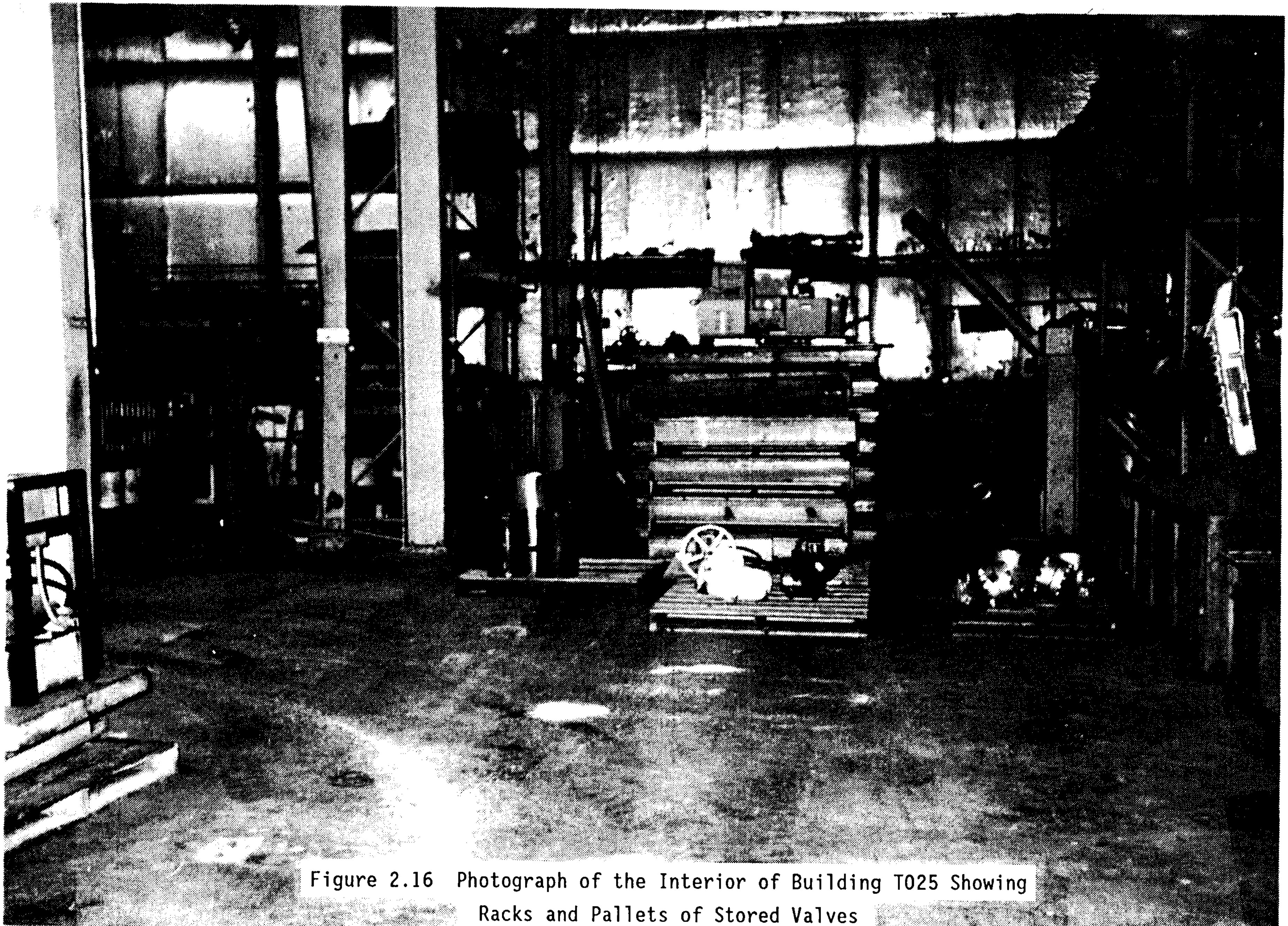


Figure 2.16 Photograph of the Interior of Building T025 Showing Racks and Pallets of Stored Valves

3.0 SURVEY SCOPE

The following facilities were radiologically inspected as specified by the "Radiological Survey Plan for SSFL," (Reference 4):

1. Building T049 (Reference 4, Section 5.4.10)

   * Surface survey floors and ledges for mixed fission products and uranium.

2. Building T042 (Reference 4, Section 5.4.11)

   * Surface survey inside building for uranium. (Although the plan specifies that Co-60 and Na-22 are possible suspect radionuclides, it has been determined that this suspicion was in error. The only possible radionuclides at T042 are U-235, and U-238.)

3. Building T027 (Reference 4, Section 5.4.12)

   * Surface survey high bay and the north/northwest annex (room 118).

4. Building T032 (Reference 4, Section 5.4.13)

   * Surface survey for gamma exposure rate and then for surface beta activity (on indication).

5. Building T025 (Reference 4, Section 5.4.14)

   * Surface survey building and surrounding parking lot/storage area.

These locations are shown in Figure 2.4, a topographic map, and Figure 2.10, an aerial photograph.

The scope of this radiological survey was based on the likelihood that radioactive contaminants could remain in these facilities, and was established on a facility-by-facility basis. Within all facilities, gamma exposure rate measurements were made on a pre-determined 2- or 3-m square sampling grid. Also within every facility, beta surface activity measurements were made in suspect-looking areas "for indication." Suspect areas include, but not limited to, chemical stains or residues on surfaces; facility corners, cracks, or crevices; ventilation returns; sinks, filters; and entrance ways. In the two facilities where uranium is suspect, i.e. Buildings T049 and T042, total and removable alpha/beta activity measurements were made in pre-determined grids and on suspect building features. Special sample collection for radioactivity analysis was not required unless indication of radioactivity warranted further inspection. Soil sample collection and analysis was not applicable to this survey because no natural terrain areas exist; this area of SSFL is completely paved. No contaminated components or equipment are known to exist in any of these facilities. The sodium test loop which, in the Site Survey Plan (Reference 4), was indicated as being contaminated in T042, is in error. Building T042 does not contain a sodium test loop. This contaminated test loop is located in Building T023, which was not included as part of the survey plan.

Gamma exposure rate measurements were made at 418 locations in the combined survey area: 23 inside T049; 160 inside T042; 85 inside T027; 63 inside T032; 82 inside T025; and 33 in a storage area surrounding T025. Exposure rate measurements are reported in micro-roentgens per hour (μR/H). Total alpha/beta activity was measured in 42 locations, 1 m^2 each: 8 inside T049; and 34 inside T042. Removable alpha/beta activity was measured in those same locations plus 26 special locations: 14 inside T049; and 12 inside T042. Alpha/beta activity is reported in disintegrations per minute per 100 square centimeters (dpm/100 cm^2). Beta surface activity measurements made in miscellaneous locations are reported as No Detectable Activity

(NDA), or less than 20 counts per minute (cpm), 30, 40, 50 cpm,...etc. These measurement data were analyzed statistically by sampling inspection by variables techniques against appropriate residual contamination acceptance limits.

3.1 Unrestricted-use Acceptable Contamination Limits

A sampling inspection plan using variables, discussed in Section 4.2, was used to compare radiological contamination quantities against unrestricted-use acceptable contamination limits prescribed in DOE guidelines (Reference 1), Regulatory Guide 1.86, NRC license SNM-21, and other references. The limits shown in Table 3.1 below have been adopted by Rocketdyne and are based on enriched uranium used for SNAP. Measurements of average surface alpha/beta contamination are averaged over an area of no more than 1 m^2. The maximum allowable alpha/beta contamination level applies for a single area of not more than 100 cm^2 in that 1 m^2. Allowable removable alpha/beta contamination is based on a surface wipe with area equal to 100 cm^2.

Three specific action levels were established for the survey. These are proactive action levels initiated when the surveyor detects radiation according to the following criteria:

1. Characterization Level - that level of radioactivity which is below 50% of the maximum acceptable limit. This level is typical of natural background levels, or slightly above, and requires no further action.

2. Reinspection Level - that level of radioactivity which is above 50% of the maximum acceptable limit. A general resurvey of the area and a few additional samples are required in this case.

3. Investigation Level - that level of radioactivity which exceeds 90% of the maximum acceptable limit. Specific investigation of the occurrence is required in this case.

Table 3.1 Maximum Acceptable Contamination Limits

Criteria	Alpha (dpm/100 cm^2)	Beta (dpm/100 cm^2)
Total Surface, averaged over 1 m^2	5000	5000
Maximum Surface, in 1 m^2	15000	15000
Removable Surface, over 100 cm^2	1000	1000
Ambient Gamma Exposure Rate*	5 μR/h above background	
Soil Activity Concentration**	46 pCi/g	100 pCi/g
Water Activity Concentration***	1×10^{-4} μCi/ml	1×10^{-5} μCi/ml

* Although DOE Guide (Reference 1) recommends a value of 20 μR/h above background for ambient gamma exposure rate, NRC has required 5 μR/h. For conservatism, we use 5 μR/h above background to compare survey results.

** Alpha activity concentration limit for enriched uranium is 30 pCi/g (Reference 26) plus that contribution from naturally occurring radioactivity, (about 16 pCi/g from Reference 17, p. 93). The total beta activity concentration limit is 100 pCi/g, including background which is about 24 pCi/g.

*** The most restrictive alpha/beta water radioactivity concentrations for a restricted area taken from DOE Order 5480.1 Chapter XI, Table 1, Column 2. Alpha corresponds to Pu-239, beta to Sr-90.

3.2 Sample Lots

For purposes of this radiological survey, sample lots were established for radiologic characterization and data interpretation based on facility characteristics. Buildings T049, T042, and T032 were each individually treated as single sample lots. All measurements for these facilities were made indoors, in areas of similar construction and characteristics. Buildings T027 and T025 each had to be split into two separate sample lots because of variation in ambient radiation from the Radioactive Materials Disposal Facility (RMDF) located nearby. The high bay and room 118 in T027 were treated as separate sample lots. Inside and outside measurements at T025 were also treated as separate sample lots. In total, seven sample lots were established. Results for each sample lot are treated and presented separately.

3-m square grids and in a few cases, 2-m square grids, were superimposed within each subject facility. 6-m square grids were superimposed over the outdoor parking lot/storage area at T025. One ambient gamma exposure rate measurement was made in each cell. Location (1,1) was the northwestern-most grid in each facility or room, whichever was easier. Each measurement location was marked on a map with its corresponding two figure Cartesian coordinate indicating the location from a local benchmark. Refer to the surveyor maps in Appendix D. The sampling inspection plan used was based upon a uniform square grid superimposed on a uniform inspection area. Although the basis for statistical treatment corresponds to a uniform survey area, these facilities were packed with operating test loops and components. It's difficult to imagine a uniform survey area in these facilities. Deviations from an expected distribution of measurements (even if contamination was present), are pronounced because of non-uniformities in the inspection lot.

3.3 Ambient Gamma Exposure Rate Measurements

In each cell established by the sampling lot plan, a gamma exposure rate measurement was made 1 m from the surface. The particular location in each cell was chosen randomly, and identified on a map. A tripod was used to support a 1 in. x 1 in. NaI crystal coupled to a photomultiplier tube and fed to a Ludlum 2220-ESG scaler, at 1 m from the ground. In each cell, a 1-min. count was collected and converted to $\mu R/h$. The measurement location and exposure rate were recorded in tabular form. 418 1-min. measurements were acquired over the inspected areas covered in this report.

3.4 Alpha and Beta Contamination Measurements

Measurements for alpha/beta radiation were made in Buildings T049 and T042. In order to determine alpha/beta contamination in each square meter surveyed per 9-m^2 area, four radiological characteristics were measured: total-average alpha surface activity, total-average beta surface activity, removable alpha surface activity, and removable beta surface activity. The location of the 1-m^2 area was left to the surveyor's judgement: it was to be the area that, in his judgement, was most likely to have retained the most residual contamination of any similar area within the 3-m square grid. The surveyor was instructed to do this conscientiously to assure that any significant residual contamination would be detected. The use of a predetermined grid with discretion for the exact location provides a uniform survey biased towards the high end of the distribution. An alpha probe and beta probe were each connected to a Ludlum Model 2220-ESG portable scaler.

Measurements of the average alpha surface activity were made by use of a large-diameter (9.5 cm) alpha scintillation detector, sensitive only to alpha particles with energy exceeding about 1.5 MeV. This detector was calibrated using a Th-230 alpha source. The energy of Th-230 alpha particles (4.6 MeV) is similar to that of the uranium isotopes handled at, or near these facilities; U-235, U-234, and U-238.

Measurements of total average beta surface activity were made by use of a thin-window pancake Geiger-Mueller tube. While this detector is sensitive to alpha and beta particles and slightly sensitive to X- and gamma-rays, it is so predominately used to measure beta-activity that it is generally called a "beta-detector." This detector was calibrated by use of a Tc-99 beta source. The energy of the Tc-99 beta particles (maximum 0.3 MeV) is close to those from U-238 daughters. The measurements were made over the same area as was used for each measurement of total average alpha surface activity.

In order to ease the survey method, alpha and beta probes were connected by a face-plate such that the separation distance between probes was no greater than a couple of centimeters. Each square-meter was surveyed using the assembly for 5 minutes; this corresponds to a transit velocity of no greater than 3.3 cm/sec (ANSI draft standard N13.12). The standard states that the transit velocity (in cm/sec) when surveying for alpha contamination, shall not exceed one-third the numerical value of the detector window dimension (in cm) in the direction of the scan. The diameter of the Ludlum model 43-1 alpha probe is 10 cm. The number of counts registered by the instrument in a five minute scan was recorded by location. If a contaminated spot was detected during the course of the "average scan" survey, the location was identified; subsequently, a five minute stationary survey of that specific location was conducted. The average surface activity of the square meter, the maximum surface activity of one spot located within the square meter, and the removable surface activity of 100 cm^2 in the square meter were recorded. No maximum "hot spots" were detected during performance of this survey.

Because the results must be reported in disintegrations per minute per 100 square-centimeters (dpm/100 cm^2), conversion factors were applied as follows. First, "background" radiation levels of the alpha and beta probes were determined for each facility surveyed. Background levels were determined in areas of similar characteristics to the area under study. Second, an efficiency factor of the survey instrument was calculated by comparing the number of counts recorded by the instrument to the number of disintegrations yielded by a calibration source. These determinations were made three times each day; first thing in the morning, at noon, and just before quitting time in the evening. Third, an area correction factor of the window was calculated in order to present results per 100 cm^2.

Measurements of removable surface activity (alpha and beta) were made by wiping approximately 100 cm^2 of surface area, using a cloth disk (NPO cloth sampling smears, 2 in diameter). The activity on the disk was measured using a thin-window gas-flow proportional counter, calibrated with Th-230 and Tc-99 disk sources. Detector "background" and efficiency was determined to convert the results to dpm/100 cm^2.

Thus, for surface contamination measurements of alpha and beta activity, data included sample location, total counts recorded in a five minute scan, maximum hot spot if present, natural background for one minute, efficiency factor, and area factor. The same data were recorded for removable contamination measurements except area factor, which is not applicable for the gas proportional detector since the measurement area refers to the area smeared.

Special structural features and miscellaneous items were surveyed in a similar manner, for removable alpha/beta activity and total beta surface activity. These measurements were "for indication" of radioactivity.

3.5 Surface Beta Radioactivity Measurements

Measurements of beta surface activity "for indication" were required by the Site Survey Plan (Reference 4) for better characterization of radiological condition only if gamma exposure rate measurements indicated possible radioactivity. Slight increases of exposure rate measurements indicated possible radioactivity, so beta surface activity measurements were made on a limited basis. A thorough survey for beta surface activity was performed at all facilities in suspect-looking areas. Beta surveys were performed on sinks, drains, showers, exhaust vents, filter banks, cracks, wall-to-floor joints, miscellaneous horizontal surfaces, and various residual test components. Beta measurements were made using a Ludlum 44-9 pancake Geiger-Mueller probe (active area = 20 cm^2) coupled to a Ludlum model 12 count rate meter. This detector was calibrated using a Tc-99 source.

3.6 Goals and Limitations of Survey Scope

The scope and detail of this radiological survey is based on the likelihood for residual radioactivity occurring in these areas from the nuclear operations which were performed. These facilities are not suspect of containing residual radioactivity because no nuclear or radioactive materials are known to have been handled at T049, T027, T032, or T025. Building

T049 was a maintenance building for Building T005 (UCPFF), located nearby and known to be contaminated. Buildings T027, T032, and T025 were non-nuclear SNAP support and maintenance facilities. Building T042 is thought to have been used for less than a week for some special test involving the use of uranium; however, this use is not confirmed. No incidents are known.

The scope of this survey was established in Reference 4 based on an unlikely occurrence of residual radioactivity being accidentally left behind from previous operations. The goal of this survey is to determine if contamination exists to such an extent that further surveying or remedial action is warranted.

Ambient gamma exposure rate measurements are sensitive enough to detect contaminants left behind. Most probable contaminants are mixed-fission products and activation products. The possibility of residual uranium is more likely in Buildings T049 and T042 than in other facilities. For this reason, alpha/beta contamination was assessed there.

This sampling plan is sufficient for three reasons:

1) Gamma measurements made on a 6-m square (the maximum separation distance) would detect Cs-137 at 100 pCi/g (the beta activity limit) if the surface layer was thicker than 1 cm. A 1 mCi Cs-137 source would be detectable at this greatest separation distance. These sensitivities meet the requirements of this survey;

2) Alpha/beta radiation measurements made every 9 m^2 in most suspect areas corresponds to an 11% sampling plan. A 3-m square grid has been adopted to be consistent with NRC and State of California guidance for releasing a facility for unrestricted use; and

3) By applying Lot Tolerance Percent Defective techniques, we can determine with a statistical confidence of 0.90, that there is a probability of 90% that radioactive contamination does not

exceed some predetermined acceptance limit. This determination varies inversely to the number of samples taken. This technique, along with the graphical representations of cumulative distribution functions will identify trends, anomalies, outliers, and perturbations in the radiation levels.

We are able to conclude whether:

1. Any surface deposition, migration, or dispersion of radioactive materials has occurred.

We cannot conclude whether:

1. Radioactive material emitting low intensity radiation is present.

4.0 STATISTICS

4.1 Counting Statistics

The emission of atomic and nuclear radiation obeys the rules of quantum theory. As a result of this, only the probability that an emission will occur is determined. The absolute number of particles emitted by a radioactive source in a unit of time, is not constant in time; it has a statistical variability because of the probabilistic nature of the phenomenon under study. The number of particles emitted per unit time is different for successive units of time. Therefore, only the average number of particles emitted per unit time and per unit area or mass can be determined. The number of particles, x, emitted by a radiation source in time, T, obeys the Poisson distribution:

$$P_x = \frac{m^x e^{-m}}{x!} \qquad \text{(Eq. 4-1)}$$

where m is the average number of emissions in that time. x is what we measure each time an area or sample is surveyed. The standard deviation is the square root of the average squared deviation of x from its mean, m. For the Poisson distribution, the standard deviation is given by:

$$s = \sqrt{x}\ , \qquad \text{(Eq. 4-2)}$$

the square root of the counts observed, $(x = \bar{x} = m)$. Since background radiation is always inherent in a given sample measurement, propagation of errors tells us that the total standard deviation is:

$$s = \frac{\sqrt{C + B}}{T} \qquad \text{(Eq. 4-3)}$$

where C = the number of counts recorded in time, T, of the sample

B = the number of counts recorded in time, T, of the background radiation environment

Equal values of the time, T, must be used for the sample and background counts for equation 4-3 to apply. This Poisson distribution and standard deviation applies for single radiation measurements, of the discrete random variable, x, and is applicable only when the observation times are short compared with the half-life. This is the case for the site survey.

Because of the probabilistic nature of particles emitted by radioactive elements, repeated measurements of the average number of emissions per unit time shows a distribution approximated by the Gaussian (or normal) probability density function (pdf); this is known as the central limit theorem. This theorem holds for any random sample with finite standard deviation. If measurements are made at many similar locations, these measurements will show a greater variability, but the distribution will remain adequately represented by a Gaussian function. This Gaussian approximation is good when the number of samples collected is at least 30. Thus the number of occurrences of particular mean radiological contamination values, g(x), shows a Gaussian pdf relative to the contamination value, and the data can be plotted accordingly. Subsequently, based on the results of the data analysis, a conclusion can be made regarding the amount of radioactive material in an area, and any anomalous values can be identified.

The Gaussian probability density function, g(x), is given by:

$$g(x)dx = \frac{1}{(\sqrt{2\pi})\sigma} \exp\left(\frac{-(x-m)^2}{2\sigma^2}\right) dx \qquad \text{(Eq. 4-4)}$$

where g(x)dx = probability that the value of x, lies between x and x+dx

m = average, or mean of the population distribution

σ = standard deviation of the population distribution.

A graph of x vs. g(x) gives the following bell-shaped curve:

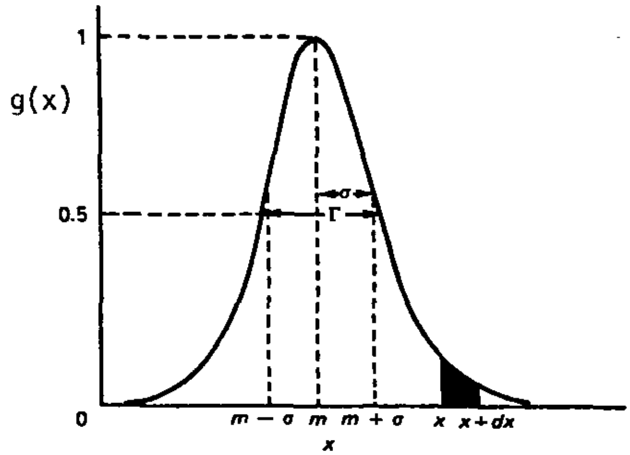


Figure 4.1 The Gaussian Probability Density Function

The cumulative distribution function (cdf), G(x), is equal to the integral of the pdf, for a continuous random variable, hence:

$$G(x) = \int_{\infty}^{X} g(x)dx \qquad \text{(Eq. 4-5)}$$

$$= P(x < X)$$

This function is commonly referred to as the error function, (erf). The graph of the Gaussian cdf is:

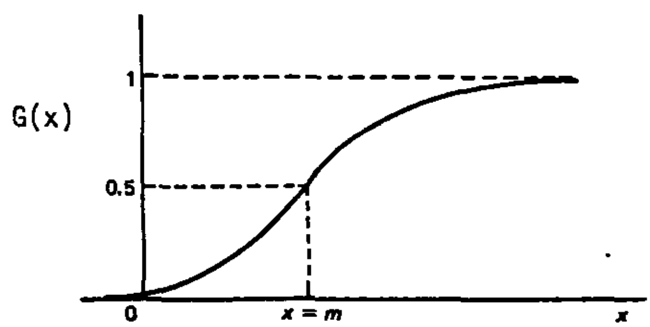


Figure 4.2 The Gaussian Cumulative Distribution Function

By plotting multiple measurements we make in the field; i.e. the average contamination values approximated by the Poisson distribution, as a cdf of the Gaussian distribution, we can identify whether the entire area is unacceptably contaminated, part of the area is contaminated more than the rest, or further radiological measurements are necessary. Furthermore, by making use of the Gaussian approximation, we can easily calculate the mean contamination value with its associated standard deviation, and apply inspection by variables techniques to either accept the area as clean or reject the area as contaminated.

This statistical summary presents fundamental principles used to reduce and analyze radiological measurement data from the site survey.

4.2 Sampling Inspection

4.2.1 By Variables

Acceptance inspection by variables is a method of judging whether a lot of items is of acceptable quality by examining a sample from the lot, or population. In the case of determining the extent of contamination in an area, it would be unacceptably time consuming and not cost effective to measure 100% of the population. However, by applying sampling inspection by variables methods, the accuracy of the conclusion made about the level of contamination is not sacrificed because of a decrease in number of sampling locations. We estimate the level of contamination in an area by making at least 30 measurements. This allows us to approximate a Gaussian distribution through the Central Limit Theorem. The entire area must have similar radiological characteristics and physical attributes. In acceptance inspection by variables, the result is recorded numerically and is not treated as a Boolean statistic, so fewer areas need to be inspected for a given degree of accuracy in judging a lot's acceptability.

4.2.2 By Attributes

By contrast, in acceptance inspection by attributes, the radiation measurement in a given area is recorded and classified as either being defective or nondefective, according to the acceptance criteria. A defect means an instance of a failure to meet a requirement imposed on a unit with respect to a single quality characteristic. Second, a decision is made from the number of defective areas in the sample whether the percentage of defective areas in the lot is small enough for the lot to be considered acceptable. More areas need to be inspected to obtain the same level of accuracy using this method. Consequently, we use inspection by variables.

4.3 Sampling Inspection by Variables

4.3.1 Calculated Statistics of the Gaussian Distribution

The test statistic for each sample area, $\bar{x} + ks$, is compared to the acceptance limit U, where:

$\bar{x}$ = average (arithmetic mean of measured values) of sample
s = observed sample distribution standard deviation
k = tolerance factor calculated from the number of samples to achieve the desired sensitivity for the test
U = acceptance limit.

The sample mean is given by:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad \text{(Eq. 4-6)}$$

where: x_i = individual measurement values
n = number of measurement values

The standard deviation, s is given by:

$$s = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}} \qquad \text{(Eq. 4-7)}$$

The sample mean, standard deviation, and acceptance limit are easily calculable quantities; the value of k, the tolerance factor, bears further discussion. Of the various criteria for selecting plans for acceptance sampling by variables, the most appropriate is the method of Lot Tolerance Percent Defective (LTPD), also referred to as the Rejectable Quality Level (RQL). The LTPD is some chosen limiting value of percent defective in a lot. Associated with the LTPD is a parameter referred to as consumer's risk (β), the risk or probability of accepting a lot with a percentage of defective items equal to the LTPD. It has been standard practice to assign a value of 0.10 for consumer's risk (β). Conventionally, the value assigned to the LTPD has been 10%. These a priori determinations are consistent with the literature and regulatory position, and are the same values used by the State of California (Reference 2). Thus, based on sampling inspection, we are willing to accept the hypothesis that the probability of accepting a lot as not being contaminated which is in fact 10 percent defective (i.e. above the test limit, U) is 0.10. The value of k, which is a function of the a priori determinations made for β and LTPD is given by equation 4-8.

Figure 4.3 demonstrates this principle. The operating characteristics curve of a Gaussian sample distribution shows the principles of consumer's and producer's risk, LTPD (or RQL), and acceptable quality level, (AQL). The criteria for acceptance of a lot are presented in section 4.3.3.

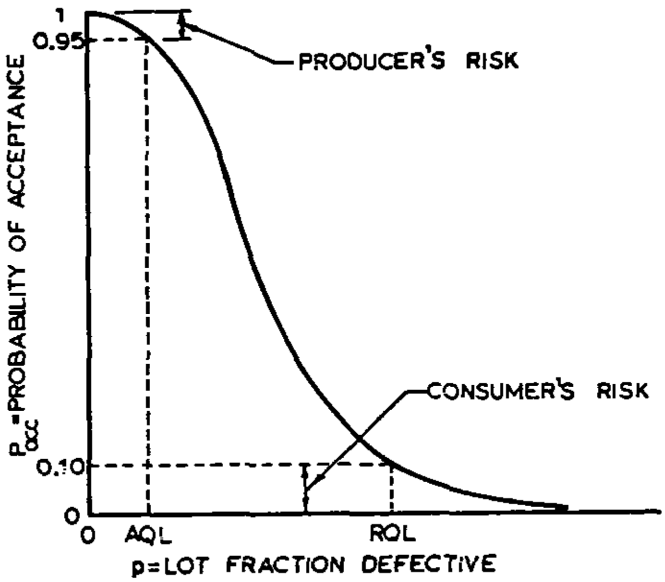


Figure 4.3 Operating Characteristics Curve

The value of k, and thus the value of $\overline{x}$ + ks, on which ultimately a decision is made whether the area is acceptably clean, is based on the conditions chosen for the test. k is calculated in accordance with the following equations, (Reference 8):

$$k = \frac{K_2 + \sqrt{K_2^2 - ab}}{a} \; ; \; a = 1 - \frac{K_\beta^2}{2(n-1)} \; ; \; b = K_2^2 - \frac{K_\beta^2}{n} \qquad \text{(Eq. 4-8)}$$

where:

k = tolerance factor

K_2 = the normal deviate exceeded with probability of β, 0.10 (from tables, K_2 = 1.282)

K_β = The normal deviate exceeded with probability equal to the LTPD. 0.10 (from tables, K_β = 1.282)

n = number of samples

As mentioned previously, the State of California has stated that the consumer's risk of acceptance (β) at 10% defective (LTPD) must be 0.1. For these choices of β and LTPD, $K_\beta = K_2 = 1.282$.

The coefficients $K\beta$ and K_2 are equal because of the choice for the values of both β and LTPD as 0.10. Refer to statistics handbooks listed in the reference section for additional description of this sampling principle. The values chosen for the sampling coefficients are consistent with industrial sampling practice and regulatory guidance.

4.3.2 Graphical Display of Gaussian Distribution

When the cdf G(x), the integral of the Gaussian pdf, (Eq. 4-4), is plotted against x, the measurement value, a graph of the error function is generated (Figure 4.2) on a linear-grade scale. For convenience of this survey and for readability, G(x) is plotted as the abscissa (x-axis) on a probability grade scale and the measurement value, x, is plotted as the ordinate (y-axis). G(x) values arranged in order of magnitude from left to right form a straight line on probability-grade paper, when the sample lot contamination is normally distributed. Figure 4.4 shows this output.

The power of this graphical display is that it permits identification of values with significantly greater contamination than expected for that lot. Calculated statistics numerically indicate the average and dispersion of the distribution, but are not effective for identifying trends or anomalies. For instance, identification of an isolated area in a sample lot which is contaminated at levels significantly greater than the fitted Gaussian line are easily observable in the plot, but $\overline{x}$ + ks may still show acceptability. Upon further inspection and analysis, these graphical displays are used to show contamination level differences between areas or structures in a sample lot. The power of the fitted Gaussian graphical display is important in assessing significant variations in the contamination levels within sample lots.

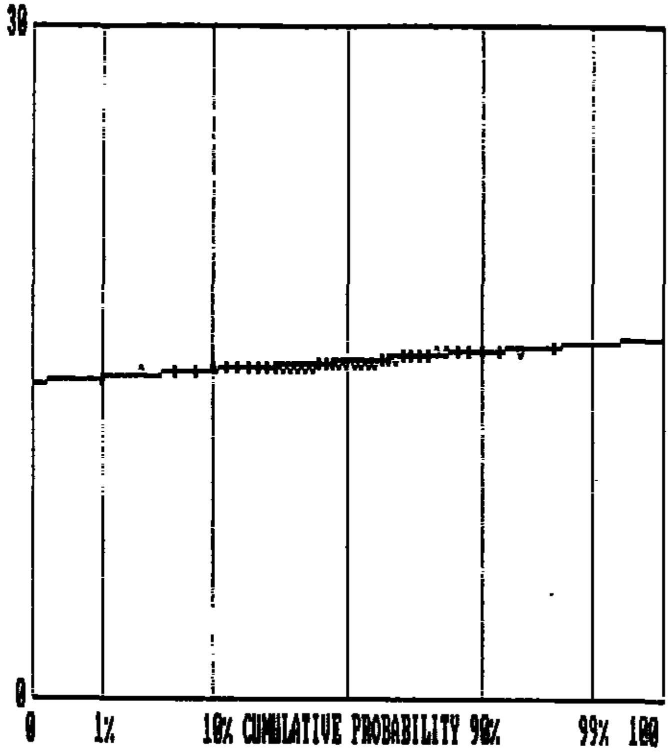


Figure 4.4 Gaussian cdf Plotted on Probability-Grade Paper

4.3.3 Acceptance Criteria for an Uncontaminated Area

Once the test statistic, $\overline{X} + ks$, is calculated and the Gaussian cdf probability plot is generated, a decision is made as to the extent of contamination in the area. Is the area clean? Is part of the area contaminated? Is the entire area contaminated? Are additional measurements necessary to make a determination?

First, the Gaussian distribution will identify significant variations in the radiological measurements. The sample output, if it represents the entire area well, should approximate a straight line. Measurements made which represent radiological conditions in a separate population from the one assumed, are easily observable as severe deviations in the straight line. The location of these anomalous measurements can be determined and subsequent follow-up is applied.

Second, the test statistic, $\overline{x}$ + ks, is calculated for the distribution. The criteria for acceptance are presented as a plan of action. The action plan is:

1) Acceptance: If the test statistic ($\overline{x}$ + ks) is less than or equal to the limit (U), accept the region as clean. (Any single value, x, less than 50% of the limit is considered the Characterization Level, which requires no further action. If any single measured value, x, exceeds 50% of the limit, reinspect that location and take a few additional samples in the immediate area for the analysis. This is the Reinspection Level. If any single measured value, x, exceeds 90% of the limit, investigate the source of occurrence. This is the Investigation Level. These proactive action levels were presented in section 3.1.)

2) Collect additional measurements: If the test statistic ($\overline{x}$ + ks) is greater than the limit (U), but $\overline{x}$ itself is less than U, independently resample and combine all measured values to determine if $\overline{x} + ks <= U$ for the combined set; if so, accept the region as clean. If not reject the region.

3) Rejection: If the test statistic ($\overline{x}$ + ks) is greater than the limit (U) and $\overline{x} >= U$, reject the region. Investigate the source of occurrence.

5.0 ANALYTICAL TECHNIQUES

Statistical methods presented in Section 4.0 were used to judge whether a sampling area is not contaminated, slightly contaminated, contaminated above acceptance limits, or whether additional investigation is required. That decision is based on several radiological measurements. For interior surfaces and selected special building features of T049 and T042, that judgement is based on four types of radiological measurements:

1) Ambient gamma exposure rate;
2) Total alpha/beta surface activity;
3) Removable alpha/beta activity; and
4) Total beta surface activity "for indication."

For exterior locations and inside Buildings T027, T032, and T025, ambient gamma exposure rate measurements and beta surface activity measurements "for indication" were made; total and removable alpha/beta radioactivity was not measured.

Analytical techniques used to acquire, evaluate, and interpret these radiological measurements are presented in detail in this section. These techniques include instrument calibration, determinations of "ambient background" radiation, and computerized data analysis through inspection by variables.

5.1 Data Acquisition

In each designated 3-m, or 2-m square grid inside Buildings T049 and T042, total and removable alpha/beta contamination, and gamma exposure rates were measured. Each square grid was outlined and marked with its coordinates. The exact location within that square grid where the samples were collected was left to the surveyor's judgement: it was to be the area that, in his judgement, was most likely to have retained the greatest amount of contamination in that square grid. This decision is based on surface discoloration, debris, crevices or cracks in the building structure; chemical residues; or debris. Total beta surface activity was measured "for indication" on special structural features and miscellaneous components.

In each designated 3-m square grid in Buildings T027, T032, and T025; and in each 6-m square grid outside T025, ambient gamma exposure rate was measured. Each square grid was stepped-off from a local benchmark and marked with its coordinates. As before, the exact location within that square grid where the measurement was made was left to the surveyor's judgement: it was to be the area that, in his judgement, was most likely to have retained the greatest amount of contamination in that square grid. This decision is based on discoloration, debris, crevices, or cracks in concrete; low settling spots for surface water runoff, or chemical residues. In both cases, the use of a predetermined grid with discretion for the exact location provides a uniform survey biased towards the high end of the distribution. Locations of noticeably greater exposure rates were to be reinspected; however, for this survey, reinspection was not required on that basis. Use of a predetermined grid with discretion for exact location provides a uniform survey biased towards the high end of the distribution. Locations of noticeably greater radioactivity were always noted and surrounding locations, then surveyed.

5.2 Data Reduction Software Program

Each radiological measurement characteristic data value was input into SMART SPREADSHEET. This is an off-the-shelf computer software package which allows multiple computations to be performed on raw data values. Columns were established to calculate alpha/beta total-average, and removable contamination per 1 m^2 in dpm/100 cm^2, and surface ambient gamma exposure rate in $\mu R/h$. The standard deviation of each measurement was also calculated. Software was developed in a program language called Quick Basic by Microsoft to read data from a SMART file into a graphics program which plots the radiological measurements against a Gaussian cdf. For convenience, the distribution function, $G(x)$ is plotted as the abscissa (prob-

ability grades), and x, the measurement value, is plotted as the ordinate (linear grades), see Figure 4.4.

Input for this data reduction was, for inside measurements of T049 and T042:

1. Room number;
2. Grid location; ex. W(1,3), wall, nearest floor grid 1,3;
3. Alpha total activity, averaged over 1 m^2 (counts in 5 min.);
4. Alpha removable activity from 100 cm^2 smear (counts in 5 min.);
5. Beta total activity, averaged over 1 m^2 (counts in 5 min.);
6. Beta removable activity from 100 cm^2 smear (counts in 5 min.);
7. Alpha gas-proportional detector background (5 min.) and efficiency factor (dpm/cpm);
8. Beta gas-proportional detector background (5 min.) and efficiency factor (dpm/cpm).
9. Ambient Gamma Exposure Rate (counts in 1 min.; cpm);
10. Gamma survey instrument background (1 min.); and
11. Gamma survey instrument efficiency factor (μR/h/cpm).

Output for Gaussian Plots of these measurements:

1. Alpha total activity averaged over 1 m^2 with standard deviation (dpm/100 cm^2);
2. Alpha removable activity and standard deviation (dpm/100 cm^2);
3. Beta total activity averaged over 1 m^2 with standard deviation (dpm/100 cm^2);
4. Beta removable activity and standard deviation (dpm/100 cm^2); and

5. Ambient gamma exposure rate and standard deviation (μR/h).

Input for data reduction of all other measurements was:

1. Ambient gamma exposure rate (counts in 1 min.; cpm);
2. Gamma survey instrument background (1 min.); and
3. Efficiency factor (μR/h/cpm).

Output for Gaussian plots of these measurements:

1. Ambient gamma exposure rate and standard deviation (μR/h).

5.3 Data Analysis

An arithmetic mean and standard deviation of the radiological measurement values is calculated for each data set. The test statistic, $\overline{x}$ + ks, based on a consumer's risk of acceptance of 0.10 at 10% defective, is also calculated for distributions being tested against an acceptance limit. The acceptance criteria presented in Section 4.3.3 is applied to each sampling distribution. Gamma exposure rate data is always handled differently than alpha/beta activity data because "background" is quite variable. The specifics are covered in detail in Section 5.4.

From the plot of measurement values vs. cumulative probability, the mean radiological value of the lot is the point on the ordinate axis where the fitted-distribution intersects the 50% cumulative probability. In test cases where an acceptance limit has been established for acceptably clean, a vertical line is plotted corresponding to the test statistic, $\overline{x}$ + ks. When an acceptance limit is applied to a test case, horizontal lines are displayed on the graph at 0 (zero), 50% of the acceptance limit (Reinspection), 90% of the acceptance limit (Investigation), and at the acceptance limit. The figures display the results on an expanded scale so that the variations in the data can be seen in detail.

5.4 Ambient Gamma Exposure Rate

Measurements of ambient gamma exposure rate were made by use of a 1 in. x 1 in. NaI scintillation crystal coupled to a Ludlum Model 2220 portable scaler, (Appendix A). This device was mounted on a tripod so that the sensitive crystal was 1 meter from the ground. The detector is nearly equally sensitive in all directions, i.e. 4-π geometry, and can show variations in exposure rate down to one-half of a μR/h, using the digital scaler for a 1-min. count time. Because of the natural variability of ambient radiation, however, a 3 to 5 μR/h exposure rate above "background" is considered the instrument sensitivity in practice. At this level, a surveyor would decide to collect additional measurements.

5.4.1 Instrument Calibration

This detector is calibrated quarterly by the calibration laboratory using Cs-137 as the calibration source. A voltage plateau is plotted and the voltage is set at a nominal 800 V. The detector is placed on a calibration range and readings taken at 5, 2, 1, 0.9, 0.5, 0.4, 0.3, and 0.2 mR/hr. A detector efficiency plot as a function of exposure rate is generated in this regard, (μR/h/cpm).

Because of an exposure rate-dependent effect and because our calibration range does not read less than 200 μR/h (0.2 mR/h), this instrument was cross-calibrated against a Reuter Stokes High Pressure Ion Chamber (HPIC). Count rates were converted to exposure rates by the relationship that about 215 cpm = 1 μR/h, at background exposure rates. This calibration was performed several times.

Instrument response was checked three times a day using a Ra-226 source. The source was placed 1 ft from the detector and counted for 1 min. If the scaler reading fell within $\pm$ 5% of the nominal value, then the instrument was qualified as operable for the day, under the calibration conditions previously described. Recalibration because of "instrument out of tolerance" was never necessary.

5.4.2 Data Acquisition and Reduction

Each location where a gamma measurement was made was identified on a map and in matrix notation. The gross number of counts recorded in 1 min. along with the matrix notation location was input into SMART SPREADSHEET. Columns were established to calculate the total exposure rate (μR/h) and its standard deviation according to equations 5-1 and 5-2. Gamma scintillations produced by a NaI detector were converted from gross counts to exposure rate (μR/h) by:

$$R = \frac{(C) * (EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-1)}$$

where R = exposure rate (μR/h)
C = gross counts in 1 min.
EF = efficiency factor (0.0047 μR/h/cpm) based on cross calibration with HPIC.

The standard deviation of a single measurement then becomes by Eq. 4-3:

$$s = \frac{\sqrt{C} *(EF)}{1 \text{ min.}} \qquad \text{(Eq. 5-2)}$$

5.4.3 Data Analysis

Analysis and interpretation of gamma exposure rate data is a five step process:

1. Plot, in order of magnitude from left to right, total-gross exposure rates in μR/h against cumulative probability for three independent areas considered to be "natural background" at SSFL. These survey locations should be from areas where no

radioactive material has ever been used, handled, stored, or disposed. These areas should be of similar geologic characteristics to those of the inspected areas. Calculate the average, standard deviation, and range for each distribution. These three distributions give the baseline for "natural" variability of exposure rate as a function of SSFL terrain.

2. Plot total-gross exposure rates in $\mu R/h$ against cumulative probability for each subject sampling lot. Calculate the average, standard deviation, and range for each distribution. Compare these statistics and probability distributions against "natural background" distributions.

3. Determine if there are any trends indicated by the probability plots of each subject sampling lot which show a potentially contaminated area. If necessary, explain elevated measurements and/or trends in the distribution.

4. Determine whether the "natural background" distributions adequately represent "ambient background" for the tested areas. Determine if any nuclear-related operations in the local area are influencing "ambient background" in the test-areas. If so, make corrections.

5. Subtract "natural background" from each test-area measurement and compare the results against acceptance criteria in Table 3.1 and Section 4.3.3. Use inspection by variables techniques to test for acceptance. Calculate the average, standard deviation, and test statistic, $\overline{x}$ + ks, for each test-area distribution. If "ambient background" in the test-areas differs from "natural background," correct the data accordingly and retest. Often, "ambient background" is less than "natural background." When this is the case, a better estimate of "ambient background" is the median gross-total

exposure rate value from the same uncorrected data set. The median is an unbiased estimator of "ambient background."

The most critical step in the analysis of gamma exposure rate measurements is assessing what true "ambient background" radiation is for a test area. "Ambient background" accounts for three effects which result in the production of an electronic pulse of the gamma instrument (a count), which under ideal measurement conditions would not occur:

1. "Natural background" radiation from the cosmos, and primordial radionuclides;

2. Secondary influence of gamma exposure rate due to nearby facilities which handle radioactive materials or radiation producing machines; and

3. Instrument noise.

These individual contributions to "ambient background" complicate data interpretation against acceptable limits because both the NRC and DOE criteria for acceptance for unrestricted use are given in μR/h above background, 5 and 20, respectively. Because these gamma measurements were made indoors or on planar (paved) surfaces outdoors, we did not observe significant deviations in "natural background" radiation as a function of landscape geometry. For example, in natural-terrain areas, when the detector is placed near a large sandstone outcropping, the exposure rate may increase by almost 4 μR/h. This increase is due to primordial radionuclides in the sandstone, and a change in source geometry, from a planar 2π-steradian surface to a rocky 3π-steradian surface. Fortunately, this deviation was not observed here. "Natural background" is also more variable when measurements are made over, at, or near large metal pieces, scrap components, and other objects -- such as those stored in some of these areas. "Natural background" is also different indoors and varies with construction materials. The most important factor which influences ambient radiation conditions is the close proximity of T027 and T025 to the Radioactive Material Disposal Facility (RMDF), which stores high levels of radioactive material. This exposure rate contribution must be evaluated as appropriate. Finally, instrument noise fortunately, is fairly uniform.

The best solution for evaluating the potential or existence of residual contamination in an area where the ambient radiation field varies naturally by swings as large as the acceptance limit, is to first compare test-area total-gross exposure rates against "natural background" total-gross exposure rates. "Natural background" measurements were taken on flat and rugged terrain, with Chico Formation sandstone. It would have been better to measure "natural background" inside a facility of similar characteristics but one was not available.

The most significant component of "ambient background" must also be assessed: that contribution resulting from nearby operations using radioactive material or radiation-producing machines. These operations can significantly increase local area "ambient background." This is the case in several SSFL locations, particularly T027 and T025, located near the RMDF. If the test-area distribution is well-represented by a Gaussian at a uniformly greater value than the "natural background" distributions, then one of two conditions exist:

1. The area is uniformly contaminated; or

2. Contribution to "ambient background" from nearby facilities is elevating test-area "background."

This determination is made on a case by case basis. Because condition 1 is unlikely for these surveys, condition 2 is addressed. A correction for facility-influenced gamma "background" is made when a facility known to emit radiation is clearly visible from the test-area. An estimate for direct radiation and skyshine is made based on fence-line measurements and the median value of the test area distribution. This assessment is more of a qualitative analysis rather than a detailed analytical model.

Best corrections for "ambient background" radiation for this survey, then, fall into three categories:

1. "Natural background" inside a Butler-type building with concrete slab floor. Exposure rate is typically 6 to 7 μR/h. The best estimate of "background" for a typical facility is the median gross-total exposure rate measurement value for that facility;

2. "Natural background" of a planar landscape composed of asphalt concrete. This is typical of equipment staging areas and storage yards. Exposure rates are not highly variable, unless many large equipment items are stored there. Expect 13 to 15 μR/h;

3. "Ambient background" which includes the variability of "natural background" plus that contribution from nearby radiation sources (e.g. RMDF). These effects are highly variable and depend on current operations (this can be largely time dependent), and measurement location. At locations considered here, this contribution could add an additional 5 to 15 μR/h above "natural background."

Once all the best corrections for "ambient background" have been made, resulting distributions are compared against the 5 μR/h above "background" acceptance limit. The test statistic, x + ks, is calculated for each distribution. Statistical acceptance criteria presented in section 4.3.3 apply.

5.4.4 Sensitivity of Gamma Exposure Rate Measurements

The analysis for instrument sensitivity developed in this section relates to soil activity and radioactive debris buried below surfaces. Although these surveyed areas were all paved, the sensitivities presented here still apply and can be adjusted to fit a particular situation.

The purpose of performing these exposure rate measurements is to detect any significant quantity of gamma-emitting radionuclides. Operational history and surveys performed years ago show that the most probable radiological contaminant in these areas is Cs-137, associated mixed-fission-products, and activation products. Since Cs-137 is a gamma emitter, it is detectable with the NaI detector.

The sensitivity of these measurements, or rather, the amount of contamination which could be there and which would not be detected, is based on two possibilities:

1) A uniformly contaminated region of soil; a layer on the surface, or a layer several feet below the surface; (this scenario is unlikely in these inspected areas); or

2) A piece of contaminated debris located on the surface, (this is the more credible scenario for residual radioactivity in these areas).

Our acceptance criteria specify that no soil activity exceeding 100 pCi/g-beta is acceptable for unrestricted-use. In comparison, 10 μCi of Cs-137, total, is the limit for exempt quantity according to 10CFR30, Schedule B. If only Cs-137 were contained in the soil, 10 μCi of activity would be present in 100 kg of soil, or about 70,000 cm^2 of surface area, if the layer were 1 cm thick.

Table 5.1 Exposure Rates of Cs-137 Contaminated Soil and Debris

(1) Contaminated Soil (100 pCi/g)	Exposure Rate (μR/h) 1 meter above surface	
Infinite Slab on the Surface		
0.3 meters thick	72	
1 meter thick	74	
Infinite Slab, 20 cm thick/10 cm thick		
at Surface	68	55
at 5 cm depth	32	25
at 10 cm depth	17	13
at 15 cm depth	9	7
at 30 cm depth	2	1
Rectangular Volume, 20 cm thick/10 cm thick		
1 square meter, surface	6.5	4.2
36 square meters, surface	47	34
(2) Contaminated Debris, (1 mCi total activity)		
at Surface	155	
at 15 cm depth	36	
at 30 cm depth	8	

Natural ambient gamma "background" radiation is about 12-16 μR/h at 1 meter from the ground, so the radioactive material would have to produce an exposure rate of about 3 μR/h above background in order to detect it to such an extent that further investigation would commence. Table 5.1 shows theoretical exposure rates calculated for some uniformly contaminated soil and miscellaneous contaminated debris. The contaminant is assumed to be Cs-137. Condition (1) assumes a uniformly distributed layer of soil with 100 pCi/g Cs-137. Condition (2) assumes a point source of Cs-137 with total activity equal to 1 mCi.

For condition (1), 100 pCi/g Cs-137 layer of contaminated soil, these measurements would detect a surface layer greater than one cm thick, but would not detect a small thickness of soil (10 cm) buried much more than a half-foot from the surface. This is very good sensitivity, particularly since the likelihood of a thin layer of contaminated soil located more than 6 in. below the surface is small. For condition (2), contaminated debris, whose activity exceeded 1 mCi Cs-137 activity could be seen if it wasn't buried much deeper than about a foot. 10 mCi could probably be seen down to 2 feet. The likelihood of buried or scattered debris occurring in these areas is very small; however, this is probably the most likely scenario of the two for residual contamination. Concerning suspect activation products and their sensitivity levels, Co-60 is the most significant activation product. It is more easily detectable than Cs-137 because of higher energy gamma rays. Thus, this Cs-137 analysis gives the most conservative sensitivities for suspect contaminants.

5.5 Direct Alpha/Beta Contamination Measurements

Direct alpha/beta contamination measurements were made by using Ludlum model 2220-ESG portable scalers to detect pulses from a Ludlum 43-1 alpha probe and Ludlum 44-9 beta probe, respectively. These surveys were only performed in Buildings T049 and T042.

5.5.1 Instrument Calibration

Each detector was calibrated three times daily. The alpha detector was calibrated with Th-230; the beta detector with Tc-99. Background levels were determined specifically for each facility.

5.5.2 Data Acquisition and Reduction

Each location where a measurement was made was identified on a map and in matrix notation. The gross number of alpha and beta counts recorded in 5 min. along with the matrix notation location was input into SMART SPREADSHEET. Columns were established to calculate total-average alpha and beta surface activity and the standard deviation (in dpm/100 cm^2) according to equations 5-3 and 5-4. Conversion from gross counts observed to dpm/100 cm^2 is given by:

$$SA = \frac{(C - B)}{5}\,\frac{(EF)(100)}{A} \qquad \text{(Eq. 5-3)}$$

where:
- SA = surface activity
- C = total counts in 5 min.
- 5 = count time, min.
- B = background count in 5 min. (generally 0-5 for alpha and about 440-460 for beta)
- EF = Efficiency factor, dpm/cpm (averages about 4.8 for alpha and about 3.7 for beta)
- 100 = 100 cm^2 standard area
- A = probe sensitive area (71 cm^2 for Ludlum model 43-1 circular alpha scintillator; 20 cm^2 for Ludlum model 44-9 pancake G-M)

Note that the analysis is done using counts rather than count rates. The standard deviation of the measurement in dpm/100 cm^2 is given by:

$$s = \frac{\sqrt{C + B}\;(100)(EF)}{(5)(A)} \qquad \text{(Eq. 5-4)}$$

5.5.3 Data Analysis

Total-average alpha/beta radioactivity in dpm/100 cm^2 per square meter were plotted, in order of magnitude from left to right, against cumulative probability, as in Figure 4.4. The test statistic, $\bar{x}$ + ks, was also calculated for the lot. $\bar{x}$ + ks is compared against the acceptance limits presented in section 3.1. Criteria for accepting the area as uncontaminated is presented in section 4.3.3.

If the measurements taken are represented by a Gaussian distribution, the data will be arranged in a straight line. If large breaks or changes in slope are observed in the distribution, then some specific area is contaminated to a greater level.

5.6 Removable Alpha/Beta Contamination Measurements

A 100 cm^2 area of selected interior locations was sampled for removable alpha/beta contamination. Sampling locations were chosen based on its likelihood to retain the greatest amount of contamination with the square meter surveyed for total alpha/beta contamination. Smears were also collected from suspect building features and components. Each smear sample was placed in a gas-flow proportional counter for analysis.

5.6.1 Instrument Calibration

The Canberra Model 2201 gas-flow proportional counter was calibrated twice daily. Alpha efficiencies were determined by using a Th-230 calibration source. Beta efficiencies were determined by using a Tc-99 calibration source. A "clean" smear-paper was used to determine background radiation levels.

5.6.2 Data Acquisition and Reduction

Each location where a smear was collected was identified on a map and in matrix notation. Gross alpha and beta counts for each smear were entered into SMART SPREADSHEET. Columns were established to calculate removable surface activity (in dpm/100 cm^2) according to equations 5-5 and 5-6. Removable surface activity is converted to dpm/100 cm^2 by:

$$SA = \frac{(C - B)(EF)}{5} \quad (\text{dpm}/100\ \text{cm}^2) \qquad (\text{Eq. } 5\text{-}5)$$

where the appropriate alpha and beta backgrounds and efficiency factors were used. Backgrounds (B) are typically 0-2 counts for alpha and 15-20 counts for beta in a five minute time period. Efficiency factors (EF) are about *3.5 for alpha and 3.9 for beta.*

The standard deviation of this measurement is:

$$s = \frac{\sqrt{C + B}\ (EF)}{5} \quad (\text{dpm}/100\ \text{cm}^2) \qquad \text{(Eq. 5-6)}$$

5.6.3 Data Analysis

Removable alpha/beta radioactivity in dpm/100 cm^2 per square meter were plotted, in order of magnitude from left to right, against cumulative probability, as in Figure 4.4. The test statistic, $\overline{X}$ + ks, was also calculated for the lot. $\overline{X}$ + ks is compared against the acceptance limits presented in section 3.1. Criteria for accepting the area as uncontaminated is presented in section 4.3.3.

If the measurements taken are represented by a Gaussian distribution, the data will be arranged in a straight line. If large breaks or changes in slope are observed in the distribution, then some specific area is contaminated to a greater level.

6.0 PROCEDURES

The following radiological procedures were used in performing this survey.

6.1 Sample Selection Gridding

Seven sample lots should be established; one each for the interior of Buildings T049, T042, and T032; one for the high bay in T027; one for room 118 in T027; one for the interior of T025; and one for the parking lot/storage area of T025. Superimpose 3-meter square grids on each interior surface to be radiologically characterized, and 6-meter square grids on outside areas. Designate each square meter in matrix notation with location (1,1) being the northwestern-most square in a facility or area, whichever is more convenient. From this northwestern-most location, mark a location off every 3 or 6 meters (whichever applies) east, and south. Select 1 m^2 out of each 9 m^2 on which to perform measurements of alpha/beta contamination (Buildings T049 and T042 only) and gamma exposure rate. In the T025 parking lot select 1 m^2 out of each 36 m^2 on which to take a gamma exposure rate measurement. Where it is not convenient to make a measurement because of facility components or stored material, step to the nearest clear area.

For special structural features, gridding is not necessary. Survey randomly for detectable beta contamination. Smear the item for analysis of removable contamination. Special features include accessible coving, wall-to-floor joints, light fixtures, vertical I-beam supports, fire extinguishers, cracks, filters, sinks, drains, showers, exhaust vents, and miscellaneous items.

6.2 Calibration and Instrument Checks

Instruments were calibrated and checked every morning, noon, and evening for the duration of the project as follows.

Portable Ludlum 2220-ESG Survey Instruments:

1) Turn the instrument 'ON' and allow to warm up for 5 min.

2) Check high voltage (600-750V alpha, 800-950V beta, 800V gamma).

3) Check threshold (140-190 alpha, 250-350 beta, 400 gamma).

4) Window in/out switch is set to out.

5) Check battery (greater than 500).

6) Set range selector to 1, response to fast, and count time to 5 min. for alpha and beta measurements. For ambient gamma exposure rate measurements, set time to 1 min.

7) Take and record a 5 min. background count in an uncontaminated area which typifies the area to be surveyed.

8) Take and record a 5 min. count of known alpha and beta standards; an electroplated Th-230 and electroplated Tc-99 source, respectively. The efficiency factor (dpm/cpm) is calculated as the ratio of 2 times the 2π emission rate of the source (dpm) to the net count rate of the instrument. The radioactivity of the calibration sources is traceable to NBS. Similarly, use a Ra-226 check source located 1 ft from the NaI detector to check operability of the gamma instrument. The count rate should not vary by more than ± 5% from the initially established standard. The gamma calibration efficiency factor is determined by comparison against a Reuter Stokes High Pressure Ion Chamber (HPIC).

9) Calculate the area of the alpha and beta end windows and record value. This is performed only once.

Gas-flow Proportional:

1) Equipment is to be left in the 'ON' position at all times.

2) Using uncontaminated planchets, take four 5 min. background counts to determine the detector background for smear samples.

3) Take and record 5 min. counts of known alpha and beta standards; 1 in. Th-230 and Tc-99 sources, respectively. Calculate efficiency factors for smear samples.

Average the daily results:

Calculate the average background and efficiency factor of each instrument for morning and afternoon. The morning value should be the average of the 7:00 am and 11:30 am measurements; the afternoon value should be the average of the 11:30 am and 4:00 pm measurements.

6.3 Radiological Measurements

6.3.1 Ambient Gamma Exposure Rate Measurements

1) Mount the detector on a tripod which centers the detector 1 meter from the ground.

2) Set the count time to 1 min. and take a measurement at each applicable location for that length of time.

3) If any single reading exceeds about 400 cpm above normal readings, recount.

4) Record the location, total counts, background, and efficiency factor (μR/h/cpm).

5) Enter the data into SMART SPREADSHEET.

6.3.2 Total-Average Alpha/Beta Contamination Measurements

1) Identify 1-m^2 area to be measured; 1 m^2 per 9 m^2 surface should be surveyed to be consistent with a minimum 11% sampling plan.

2) With portable scaler instrumentation (Ludlum 2220-ESG) set for a 5-min. count time, use an alpha probe (Ludlum Model 43-1) on one instrument and a beta probe (Ludlum 44-9) on another, then uniformly scan the area. The probe transit velocity should be slow; less than one-third the numerical detector window diameter (in cm). This corresponds to a transit velocity not exceeding 3 cm/sec. The 5 min. count time per square meter was adopted based on this transit velocity limit for alpha contamination. (Watch and listen for "hot spots" where radioactivity may exceed the average limit. These spots are to be resurveyed later).

3) In an area of similar construction, determine the 5 min. background rate and the efficiency for each instrument as covered in Section 6.2 (7) and (8).

4) Record the location, total count, background, efficiency factor, area factor, and date/time.

5) Enter the data into SMART spreadsheet.

6.3.3 Maximum Alpha/Beta Contamination Measurements

1) Return to any area identified as having a spot which measures considerably greater than the average contamination value for that area.

2) Repeat the scan of only the hot spot area, covering approximately 100 cm^2 with the probe.

3) Record the location, total count, background, efficiency factor, area factor, and date/time, as a maximum contamination value.

4) Enter the data into SMART spreadsheet.

6.3.4 Removable Alpha/Beta Contamination Measurements

1) Using an NPO 2" diameter - cloth swipe, wipe an "S" pattern, with legs approximately 6 in long, so as to sample removable contamination from an area of approximately 100 cm^2 within the 1-m^2 grids identified and sampled with the survey meters.

2) Place smear in envelope kit and record the location of the sample grid on the envelope. Save until ready for counting.

3) Count radioactivity using gas-flow proportional counter (Canberra Model 2201) for 5 min. (see Appendix A).

4) Record the location, total alpha and beta counts, background and efficiency factors for each.

5) Enter the data into SMART spreadsheet.

6.3.5 Surveys of Special Structural Features and Components

1) Using a Ludlum Model 12 count rate meter in connection with a Ludlum Model 43-1 pancake GM beta probe, survey various building features and components which are suspect of containing residual contamination.

2) Perform an instrument calibration check three times daily using the Tc-99 source mentioned above.

3) Record the gross count rate in a generalized manner as NDA (No Detectable Activity) or less than 20 cpm, 30 cpm, 100 cpm, etc., as applicable.

4) Smear the special structural features and analyze for removable radioactivity. Follow the procedure in section 6.3.2.

7.0 SURVEY RESULTS

A radiological survey of five facilities was performed using the survey plan previously described:

1. Building T049;
2. Building T042;
3. Building T027;
4. Building T032; and
5. Building T025.

Sample lots for analyzing and interpreting radiological data were selected based on similar building conditions and local characteristics. Uniform 3-m square grids were established to measure indoor gamma exposure rate, and total and removable alpha/beta activity. Uniform 6-m square grids were established to measure outdoor ambient gamma exposure rates. Analytical interpretation of gamma exposure rate measurements, and total and removable alpha/beta contamination measurements show that all areas are uncontaminated. Variability of gamma-radiation "ambient background" was observed for all test-areas. Except for a drain pan found in T032, all total beta surface activity surveys of indoor areas, vents, pipes, filters, sinks, and drains showed no detectable activity above naturally-occurring "background."

In this section, the format used for presenting data, analyzing probability plots, and interpreting results is presented first. Then the gamma exposure rate, and total and removable alpha/beta measurement results are presented according to this format. After a summary of ambient gamma exposure rate results made in all test-areas, each sampling lot is discussed separately. Seven sampling lots were established; one for each facility (T049, T042, and T032); and two each for T027 and T025.

7.1 Statistical Results Format

Gamma exposure rate, and total and removable alpha/beta activity data collected for this survey are displayed as Gaussian cumulative distribution functions in Figures 7.1 through 7.20. Figures 7.1 through 7.3 are distributions of gamma exposure rate measurements made at 3 independent SSFL locations to demonstrate the variability of "natural background" radiation. These distributions are a guide for comparing test-area exposure rate results. Figures 7.4, 7.5, 7.11, 7.13, 7.15, 7.17, and 7.19 are distributions of gross-total gamma exposure rates for the seven sampling inspection lots. Figures 7.6, 7.12, 7.14, 7.16, 7.18, and 7.20 are distributions of the same exposure rate data sets (except for T049) corrected for "ambient background" based on the median value of the gross-total measurements. The median value is an unbiased estimator for "ambient background" in a sampling area. Normally, an average of the results presented in Figures 7.1 through 7.3, (i.e. the "natural background" data) is used for background correction, but those "background" measurements were from natural terrain areas -- different from these inspected areas. Subtraction of "natural background" would be an overestimate of "ambient background" in most of these test areas. Figures 7.7, 7.8, 7.9, and 7.10 show the total and removable alpha and beta contamination results for Building T042. These figures show each measurement value, arranged in order of magnitude from left to right, and a straight line representing the derived fitted-Gaussian distribution. Although alpha/beta contamination measurements were made in T049, the facility was so small that less than 30 measurements were acquired. At least 30 measurements are required to be considered statistically significant for representing a Gaussian.

The mean of each distribution is approximately that value of the fitted-Gaussian on the ordinate which corresponds to a 50% cumulative probability on the abscissa. The measurement value at 50% cumulative probability is the median. For a theoretical Gaussian, the median is equal to the mean. For a well-fitted Gaussian, the median is very close to the mean. One, two, and three standard deviations above the mean correspond to

84%, 97.7%, and 99.8% cumulative probability for a one-sided test, respectively. Inspection by variables is used to test only "background-corrected" data sets against acceptance limits. The value of k used in the inspection test is very nearly 1.5 for each case; thus, the Test Statistic (TS) line ($\overline{X}$ + ks) will run perpendicular to the abscissa corresponding to about a 93.3% cumulative probability. The Gaussian distribution line must pass below the intersection of the "TS" line (about 93%) and the horizontal line showing the acceptance limit at that point in order to accept the lot as being uncontaminated. "k" and thus the "TS" line increase as the number of samples in a lot decrease.

At the top left hand corner of each output is the data file name for the sample lot. For "uncorrected" gamma exposure rate data sets, 30 μR/h is normally used for convenience, as the maximum ordinate value. If gamma measurements exceed 30 μR/h, then the greatest measurement value is the upper bound of the ordinate axis. In cases where gamma measurements have been corrected for "natural background," 5 μR/h (the NRC acceptance limit) is used as the maximum ordinate value. The lower bound of the ordinate is either the smallest measured value (minus background, if applicable) or the smallest value calculated for a Gaussian fit. Negative numbers result when the measured value is less than background. Cumulative probability (abscissa) is plotted in probability grades, i.e. the distance between any two successive points increases as the distance from the 50% cumulative probability line increases. If an acceptance limit is applicable, four horizontal lines extending across each plot show, from top to bottom, 100% of the test limit, 90% of the test limit (Investigation), 50% of the test limit (Reinspection), and zero; see Section 4.3.3.

For total and removable alpha/beta activity measurements, an acceptance limit is applicable in all cases. The test statistic is calculated and compared against the appropriate limit.

In cases where an acceptance limit is not appropriate, for instance, gamma exposure rate measurements not corrected for "natural background," the four horizontal lines are not shown. Furthermore, a test statistic is not calculated because we were not testing the data against an acceptance limit. Since the variability in naturally occurring ambient gamma exposure rates at SSFL is wide, background was not subtracted at first. In these cases, the mean is calculated and the shape of the distribution is observed to identify any areas of increased radioactivity. Then the shape of the curve is compared against three "background" distributions. Finally, "natural background" and contributions to "ambient background," if applicable, are subtracted and inspection by variables techniques are applied to prove or disprove the hypothesis that the area is not contaminated.

Surveys of total beta activity on selected building surfaces and materials were performed "for indication." Statistical interpretation is not applicable. Results are presented as No Detectable Activity (NDA), or less than 20 counts per minute (cpm), 30, 40, 50,...etc. above background. If this survey was to determine a contaminated area, further investigation was to commence.

7.2 Ambient Gamma Exposure Rates

Ambient gamma exposure rate measurements were made at 446 locations. Appendix C shows the data sets. Appendix D shows measurement locations. Table 7.1 shows the computed statistics for each data set compared against data from three independent outdoor areas where no radioactive material was ever handled, used, or stored. These outdoor areas are considered "natural background" at SSFL. This type of comparison is necessary for two reasons: 1) to demonstrate variability of "natural background" gamma radiation at SSFL; and 2) to estimate "natural background" at SSFL because the limits for unrestricted-use by which we use to demonstrate an "acceptable" area are based on above "background" criteria. So, unless we confidently know what "ambient background" is, the area under study may be found incorrectly acceptable if the background used was too high, or incorrectly unacceptable if the background used was too low. For this survey, it would have been better to measure "ambient background" inside a facility of similar characteristics, but one was not available.

Table 7.1 Natural Background Gamma Radiation at SSFL Compared to Survey Data

Location	No. of Measurements	Mean Exposure Rate (μR/h)	Expected Standard Deviation at the Mean (μR/h)*	Standard Deviation of the Distribution (μR/h)**	Range μR/h
Interior of T049	23	9.3	0.21	1.02	4.6
Interior of T042	160	7.2	0.18	1.38	6.9
Interior of T027 (High Bay)	36	9.6	0.21	1.38	5.9
Interior of T027 (Room 118)	49	16.1	0.27	2.30	10.0
Interior of T032	63	7.6	0.18	1.49	6.4
Interior of T025	82	11.4	0.23	2.34	8.6
Exterior of T025	33	23.9	0.33	2.18	8.0
Background					
Building 309 Area (1/19/88)	36	15.6	0.27	0.82	3.4
Well #13 Road (Dirt) (4/29/88)	43	16.2	0.27	0.49	2.2
Incinerator Road (Dirt) (4/29/88)	35	14.0	0.25	0.36	1.4

* The expected standard deviation at the mean is calculated based on counting statistics, equation 4.2.

** The standard deviation of the data points accounts for dispersion in the measurements, equation 4.7.

Descriptive statistics presented in Table 7.1 show that average exposure rates calculated for each test-area are all, except the exterior of T025, significantly less than the three "natural background," control-group areas. Standard deviations of each test-area are greater than that observed for "natural background" in natural terrain. Greater variability observed in these test-areas is attributed to interference of exposure rate due to equipment items and nearby building materials. These properties make for a non-uniform inspection lot. The range of measurements observed for these test cases is also greater than "natural background." Again, this observation is due to non-uniform deviations in exposure rate as a function of location, e.g. near a wall, indoors, partially indoors with an over-hang, outdoors, or near miscellaneous components. By observation of these descriptive statistics, these test-areas, except for the exterior of T025, appear uncontaminated. The exterior storage yard of T025 is located less than 250 ft from Building T075, where large quantities of radioactive material are stored (RMDF). Direct radiation and skyshine affect ambient gamma conditions. However, before any judgments can be made about the existence of residual contamination, we must investigate the probability plots to determine outliers in each distribution and to formulate an understanding of the greater variations and ranges observed in some test-cases.

7.2.1 Non-Radiological Areas

Because the "natural background" gamma-radiation environment is quite variable at SSFL and because the limits for unrestricted use are based on limits above background, further demonstration of this natural variability is necessary. For comparison against test-area measurements, three independent areas were surveyed, all in locations where no radioactive material was ever handled, used, stored, or disposed. All three areas are located on the eastern side of SSFL: (1) Area surrounding building 309 on Area I Road; (2) well #13 Road; and (3) Incinerator Road. Table 7.1 shows the results of these measurements. These "natural background" areas are not similar in characteristics and topography to the outdoor inspected areas for this report. The purpose these "background" distributions serve is to show "natural" variability of gamma radiation on natural terrain at SSFL to be used as a guide for comparing sample lot results.

Figures 7.1 through 7.3 are probability plots of these three independent "background" areas. At least 30 measurements were made in each area on the same day. In the plots, a uniform background rate (unbiased by spatial effects), would appear as a straight line with a minimal slope. That slope would show that 1 standard deviation from the mean of values would be equivalent to the mean-value standard deviation (i.e. the square root of the counts of the mean multiplied by an appropriate efficiency factor). If this was the case, the values in columns 4 and 5 of Table 7.1 would be equivalent. Obviously, this ideal condition is impossible to achieve in this terrain at SSFL. All three plots show model Gaussian distributions, but with greater variability than would be expected from ideal laboratory-level measurements. Variability is greatest near Building 309.

Measurements from the area surrounding Building 309 show the most variability of all three background areas. This is attributed to large sandstone outcroppings in the area; the spatial dependency of each measurement is observable in this case. The variability of each distribution depends on the number of measurements made directly against the rock versus the number made many feet from the rock. Also of importance here is the range of measurement values with a maximum of 3.4 μR/h. "Natural background" variability approaches the NRC limit.

This "natural background" analysis shows the great difficulty in assessing whether an area is contaminated based on the NRC acceptance limit of 5 μR/h above background. The DOE limit of 20 μR/h is more reasonable. Natural gamma radiation is significantly variable at SSFL. We'll now compare this "natural" variability against the test-area measurements presented in this report. We'll see that "natural" variability is even more significant inside and near facilities.

Figure 7.1 Ambient Gamma Radiation at Area Surrounding Building 309
(Background Distribution)

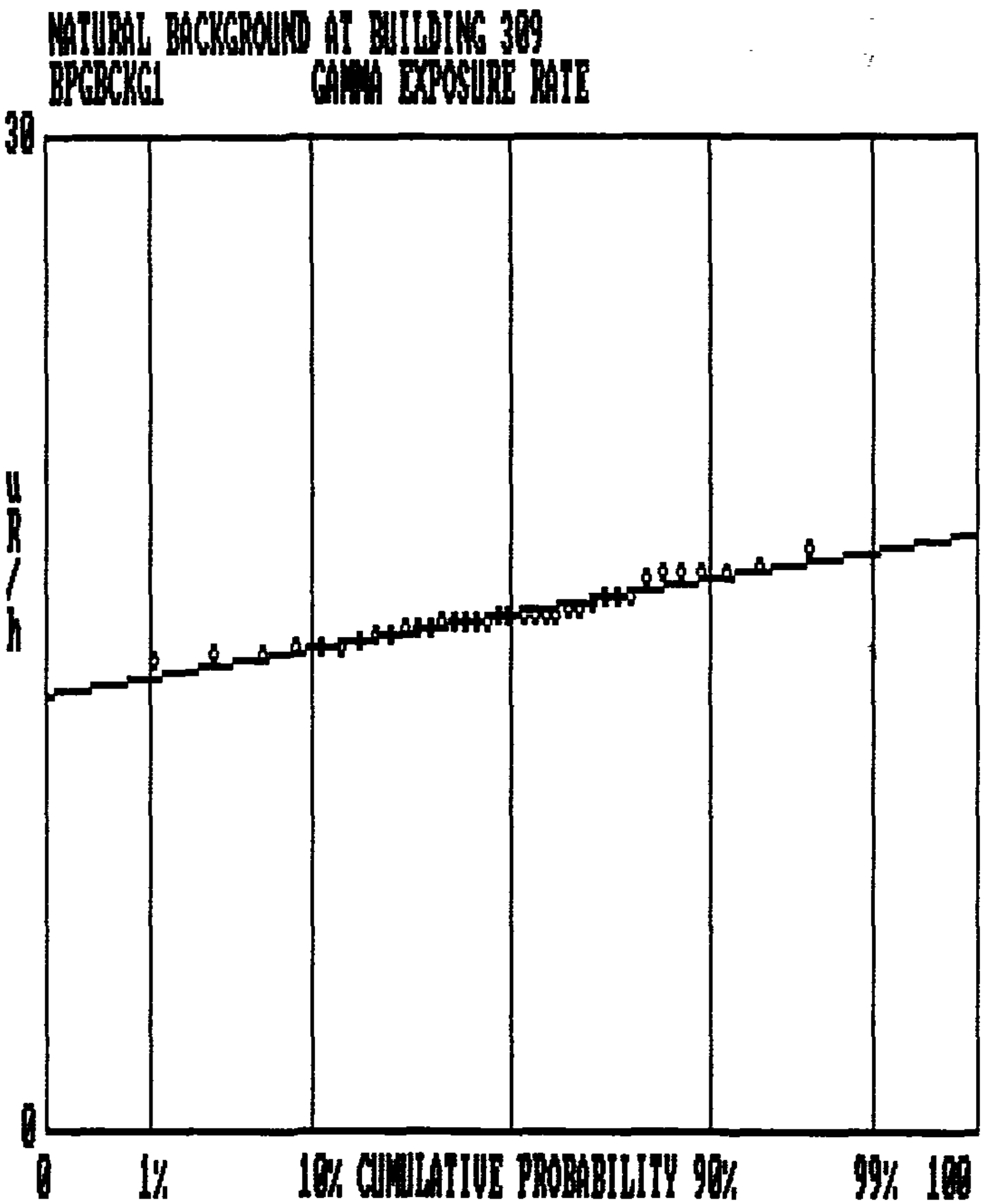


Figure 7.2 Ambient Gamma Radiation at Area Well #13 Road
(Background Distribution)

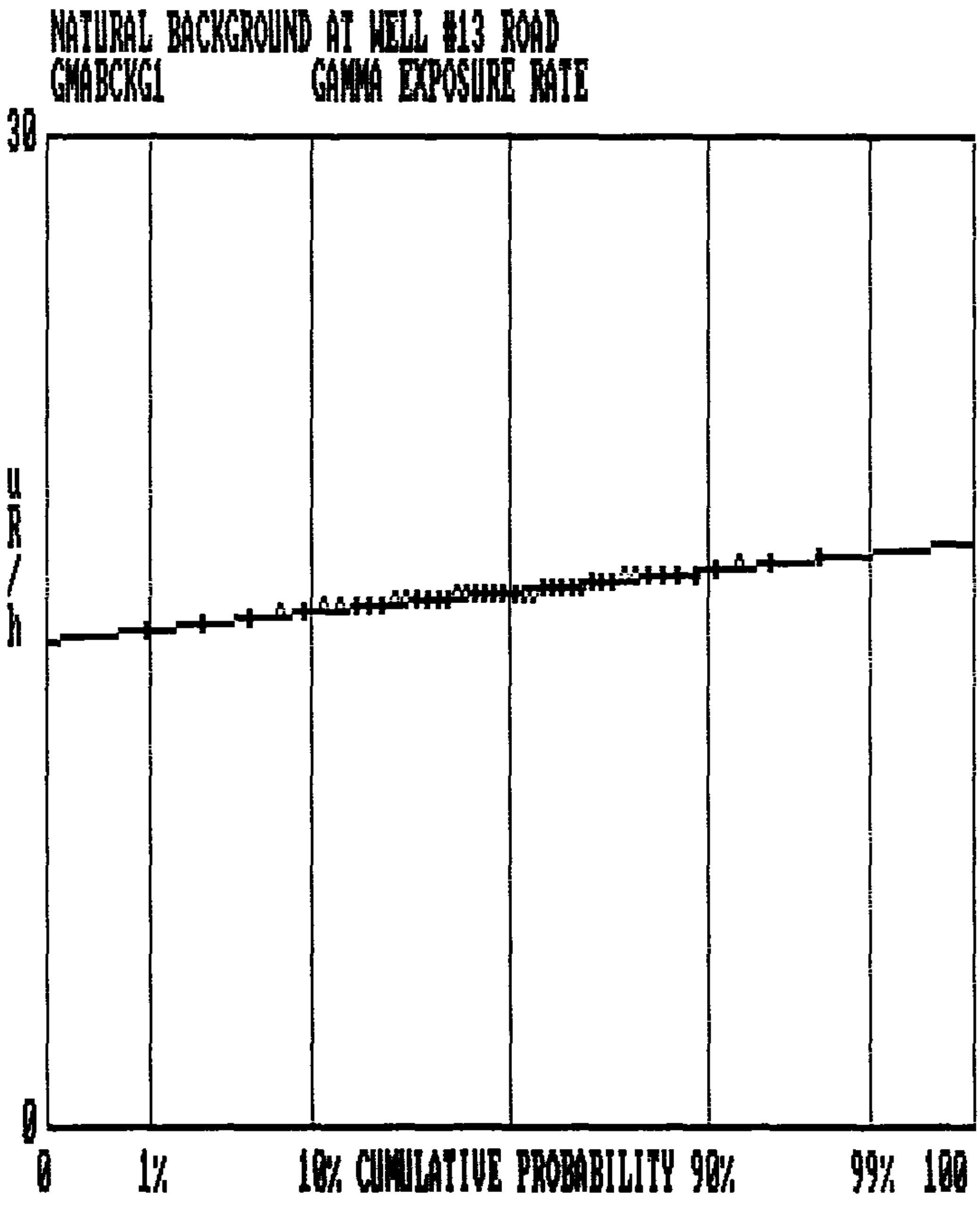
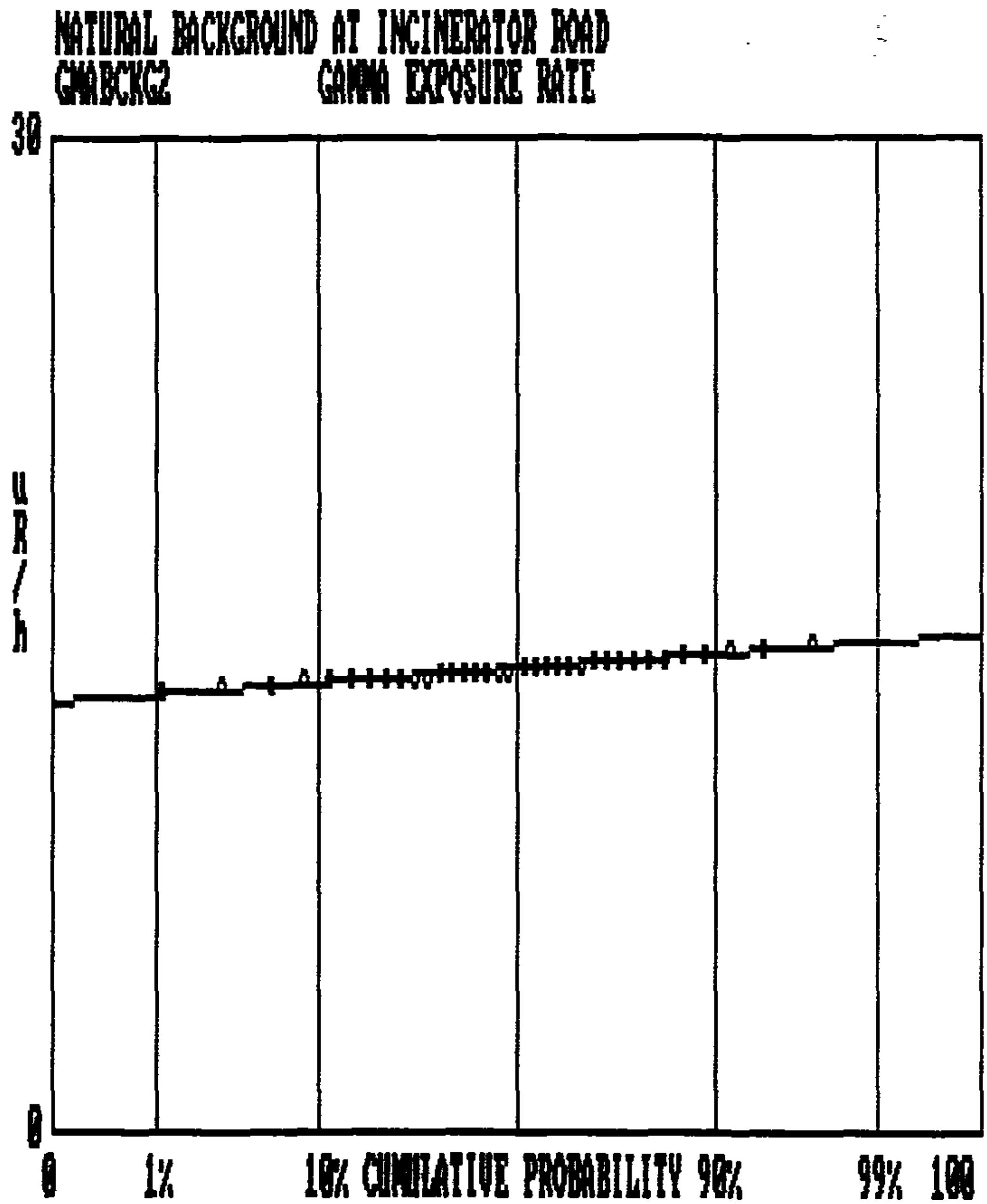


Figure 7.3 Ambient Gamma Radiation at Incinerator Road
(Background Distribution)



7.3 Building T049

Building T049 was inspected for radioactive contaminates based on its proximity to Building T005, where enriched uranium contamination is known. This enriched uranium is presumably the suspect contaminant in T049. Building T049 was a control room and no radioactive or nuclear materials were handled there. It is located about 100 ft east of Building T005, (see Figure 2.4). Building T049 is very small (20 ft x 40 ft) and contains large control panels on several walls. Radiation surveys performed on a 3-m square plot plan resulted in few measurements. Gamma radiation was measured in just about every accessible square meter; this resulted in 23 measurements. Total-average alpha/beta activity per 1 m^2 was measured in 8 locations, and removable alpha/beta activity was assessed on 14 special facility features. Exposure rate measurements were evaluated by analytical interpretation using Gaussian statistics and inspection by variables. Assessment of alpha/beta contamination was performed in too few areas to be statistically significant for inspection by variables techniques. Results are presented in tabular format. Miscellaneous building features were surveyed "for indication" of beta activity; no statistical tests apply. Appendix C.1 shows the specific measurement values and Appendix D.1 shows measurement locations within T049.

Table 7.2 shows the survey results for Building T049. A correction of 9.1 μR/h was made for "ambient gamma background" at T049, corresponding to the median value of the 23 exposure rate measurements made there. Using a value of 15.3 μR/h for background subtraction (which is an average of the three "background" areas) would overestimate ambient conditions. Figure 7.4 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability. Exposure rate measurements were acquired in just about every accessible square meter. The data follow a well-fitted Gaussian distribution with a mean total-gross value of 9.3 ± 1.02 μR/h, less than "natural background." No trends indicating a contaminated area are observed by these gamma measurements. *The "background-corrected" average of 0.08 ± 1.83 μR/h and the inspection* test statistic, 1.81 μR/h, are less than the acceptance limit and all action levels.

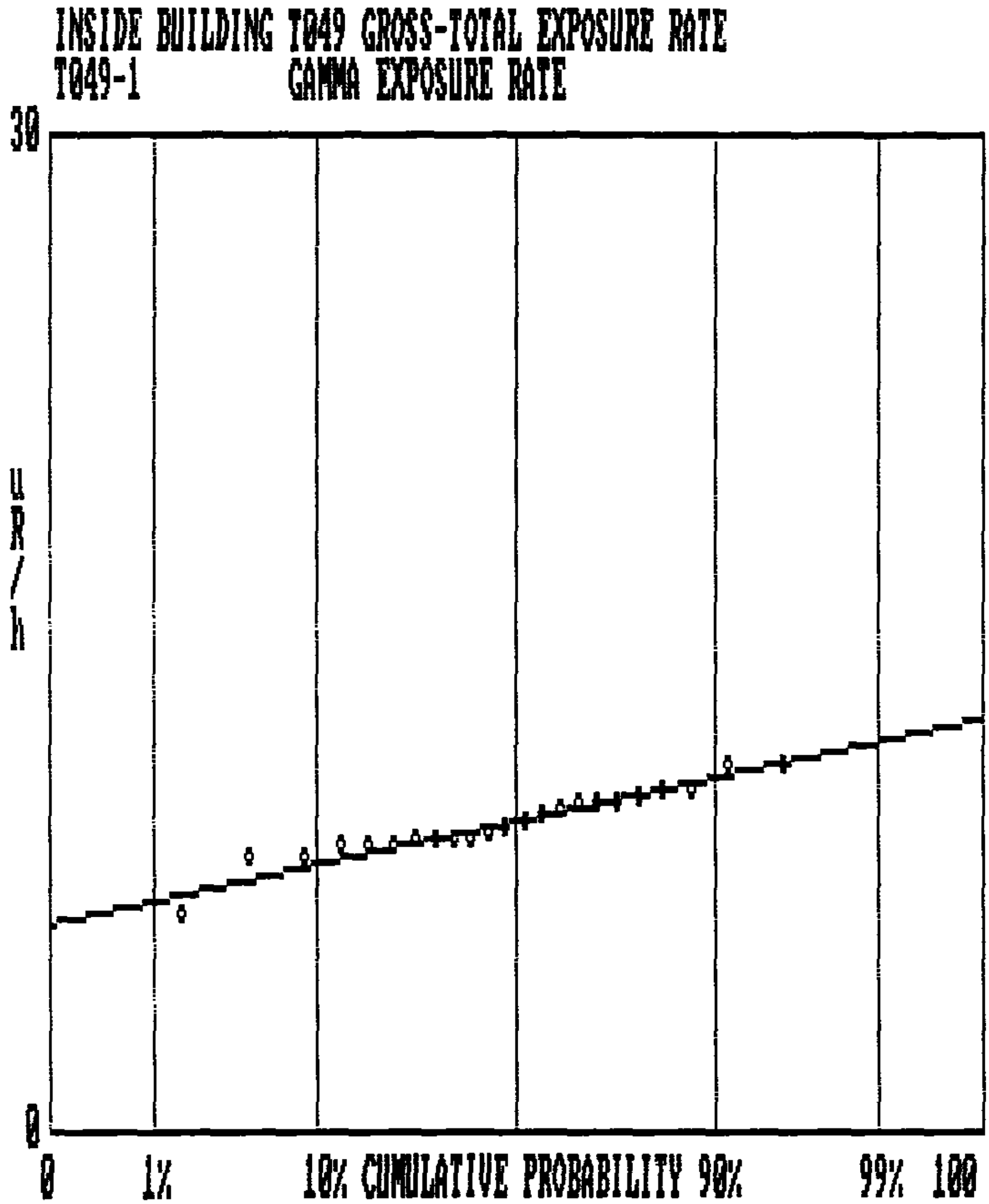
Table 7.2 Survey Results for Building T049

Measurement	Number of Locations	Average Value	Maximum Value	Inspection Test Statistic	Limit
Ambient Gamma Exposure Rate Corrected for Background (μR/h)*	23	0.8	1.83	1.81	5
Total-Average alpha (dpm/100 cm^2)	8	8.9	17.5	N/T	5,000
Removable alpha (dpm/100 cm^2)	14	0.4	1.7	N/T	1,000
Total-Average beta (dpm/100 cm^2)	8	855	1080	N/T	5,000
Removable beta (dpm/100 cm^2)	14	2.5	7.1	N/T	1,000

Note: No maximum alpha/beta activity spots were found.
N/T: Not Tested - too few measurements for statistical significance.
* Gamma exposure rate corrected for background of 9.2 μR/h.

Total-average and removable alpha/beta contamination measurements show in all cases that the averages and maximum values are far below the 50% reinspection level. However, the total-beta measurements are greater than what is normally expected. These measurement values, shown in Appendix D, are corrected for a background of 434 counts per 5 min. time frame. These values suggest that the concrete floor surface is most likely naturally radioactive. This behavior has been observed in similar "clean" areas. Beta surface activity measurements made "for indication" in cracks, crevices, and on special features such as light fixtures, control panels, and ventilation returns, show in all cases No Detectable Activity above naturally occurring background. Removable activity results are presented in Table 7.2 and show no statistically significant activity. We accept Building T049 as uncontaminated by this inspection method. No further inspection is warranted in this facility.

Figure 7.4 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Building T049



7.4 Building T042

Building T042 was inspected for radioactive contaminants based on its affiliation with the SNAP program and the short test thought to have been performed there using uranium. The uranium handled there is thought to have been encapsulated; no problems occurred. Gamma exposure rate measurements, and total-average and removable alpha/beta measurements were made per square meter on a 3-m square sampling grid. 160 exposure rate measurements were acquired; 34 square meters were surveyed for total-average alpha/beta activity; and 46 locations were smeared for removable alpha/beta activity. Smears were made in designated square meters and on special features, including the outside of a glove box. These radiological measurements were evaluated by analytical interpretation using Gaussian statistics and inspection by variables. Miscellaneous building features were surveyed "for indication" of beta activity; no statistical tests apply. Appendix C.2 shows specific measurement values and Appendices D.2 and D.3 show measurement locations within T042.

Table 7.3 shows the survey results for Building T042. A correction of 7.1 $\mu R/h$ was made for "ambient gamma background" at T042, corresponding to the median value of the 160 exposure rate measurements made there. Using a value of 15.3 $\mu R/h$ for background subtraction (which is an average of the three "background" areas) would overestimate ambient conditions. Figure 7.5 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability. The data follow a well-fitted Gaussian distribution with a mean total-gross value of 7.2 $\pm$ 1.38 $\mu R/h$, less than "natural background." The outliers at the high and low ends of the distribution are expected deviations due to changes in measurement conditions. The sixteen outliers at the high end correspond to measurements acquired outdoors under a canopy on the north and south sides of the facility (see Appendix D.2 for these locations). No trends indicating a contaminated area are observed by these gamma measurements. Figure 7.6 shows the same data set, corrected for "ambient background." Deviations observed in the measurements are pronounced in this figure because the

Table 7.3 *Survey Results for Building T042*

Measurement	Number of Locations	Average Value	Maximum Value	Inspection Test Statistic	Limit
Ambient Gamma Exposure Rate Corrected for Background (μR/h)*	160	0.1	4.4	2.10	5
Total-Average alpha (dpm/100 cm^2)	34	4.0	12.6	9.9	5,000
Removable alpha (dpm/100 cm^2)	46	0.5	5.9	2.2	1,000
Total-Average beta (dpm/100 cm^2)	34	775	1200	1209	5,000
Removable beta (dpm/100 cm^2)	46	2.8	15.4	10.4	1,000

Note: No maximum alpha/beta activity spots were found.
* Gamma exposure rate corrected for background of 7.1 μR/h.

ordinate scale has been expanded. The measurements exceeding our 50% of the limit Reinspection level were all made outdoors and were less than "natural background" measurements, as determined by averages of the 3 "background" locations. The "background-corrected" average of 0.1 $\pm$ 1.38 μR/h and the inspection test statistic, 2.10 μR/h, are less than the acceptance limit and all action levels.

Total-average and removable alpha/beta contamination measurements show in all cases that the averages, maximum values, and inspection test statistics are far below acceptance limits and, more conservatively, the 50% Reinspection action level. 34 square meters were surveyed in the test areas (see Appendix D.3), corresponding to an 11% survey plan. The office areas and restrooms were not surveyed for alpha/beta activity because of a negligible possibility that contamination would exist there. Removable activity was assessed in these same locations plus many special features, including a glove box. These special smear measurements were included with

Figure 7.5 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Building T042

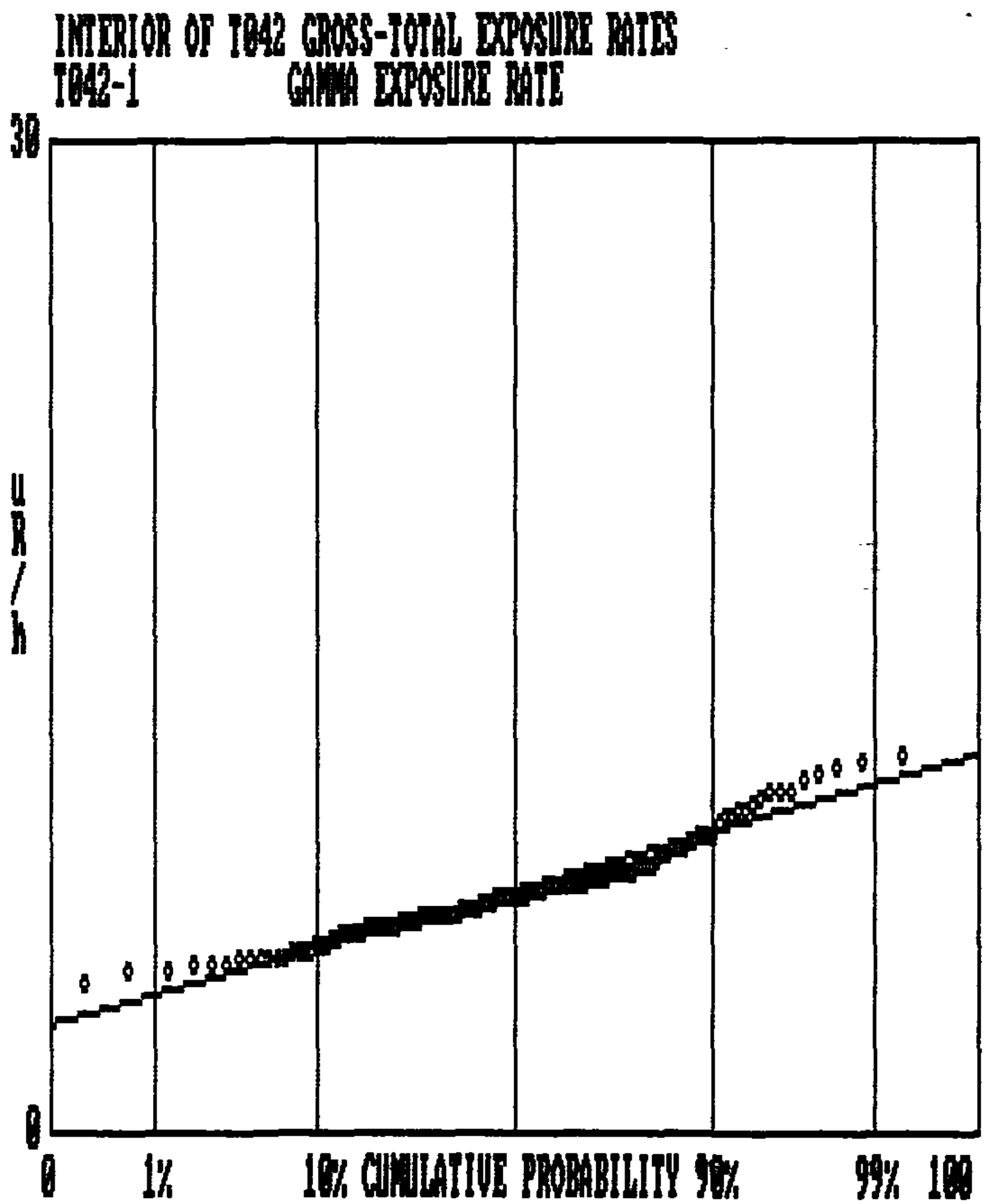
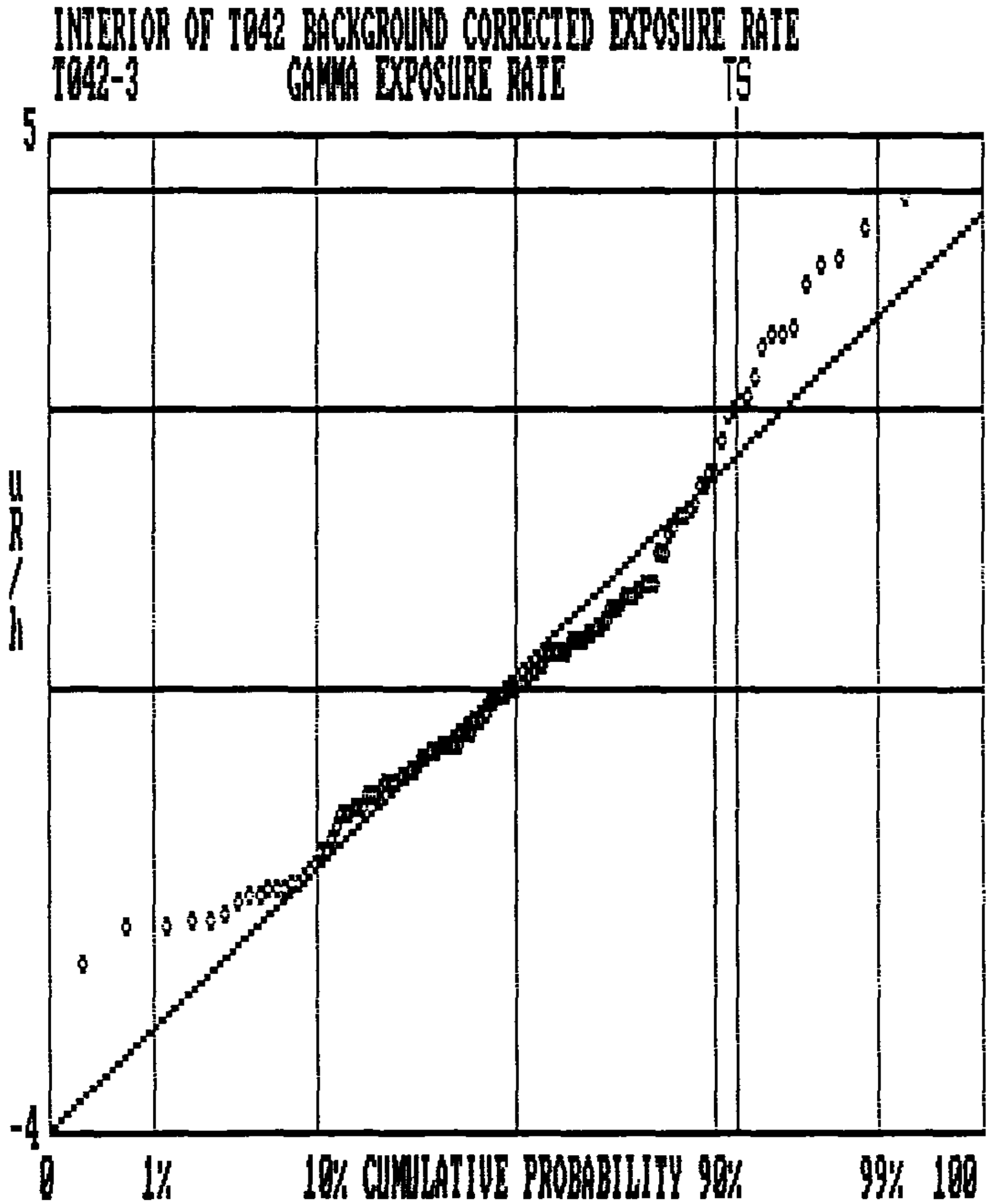


Figure 7.6 Background-Corrected Ambient Gamma Exposure Rate Measured Inside Building T042



the results in Table 7.3 and Figures 7.8 and 7.10. Specific smear survey locations and measurement values are presented in Appendix C.2. Figures 7.7, 7.8, 7.9, and 7.10 show total-average alpha activity, removable alpha activity, total-average beta activity, and removable beta activity, respectively, plotted against cumulative probability. No outliers exist. The distributions show well-fitted Gaussian distributions. As observed before in Building T049, concrete used for the floor is "naturally" radioactive, with an average beta surface activity of 775 dpm/100 cm^2. This is not an alarming result, nor is it unacceptable; it shows that "natural" primordial radioactivity can complicate data interpretation and evaluation. Beta surface activity measurements made "for indication" on various components and systems show in all cases No Detectable Activity above naturally occurring background. We accept Building T042 as uncontaminated by this inspection method. No further inspection is warranted in this facility.

7.5 Building T027

Building T027 was inspected for radioactive contaminants because of its affiliation with the SNAP program. Only gamma exposure rate measurements were acquired in order to assess radiological condition because no radioactive or nuclear materials are known to have been handled here. Exposure rate measurements were made on a 2- to 3-m square plot plan in the high bay (test area) and room 118 (a storage area). Each of these areas was handled as an individual sample lot because of variations in "ambient background." The remainder of T027 is primarily office space and was not surveyed for radioactivity because of the unlikely possibility that residual contamination would exist. Exposure rate measurements were evaluated by analytical interpretation using Gaussian statistics and inspection by variables. Miscellaneous building features were surveyed "for indication" of beta activity; no statistical tests apply. Appendix C.3 shows specific measurement values and Appendices D.4 and D.5 show measurement locations.

Table 7.4 shows the "background-corrected" results of exposure rate measurements acquired in each sample lot. Using the appropriate

Figure 7.7 Total-Average Alpha Activity Inside Building T042

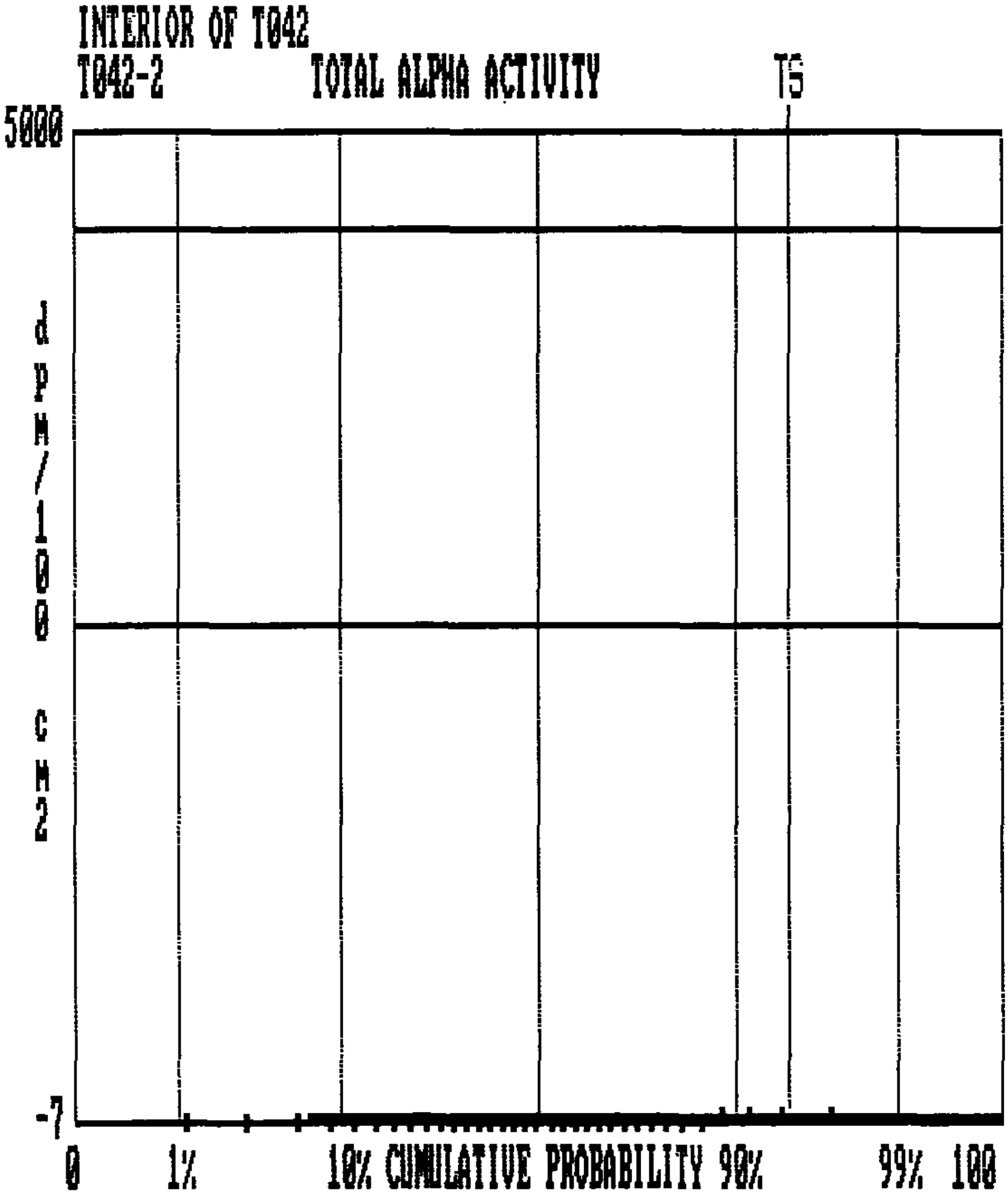


Figure 7.8 Removable Alpha Activity Inside Building T042

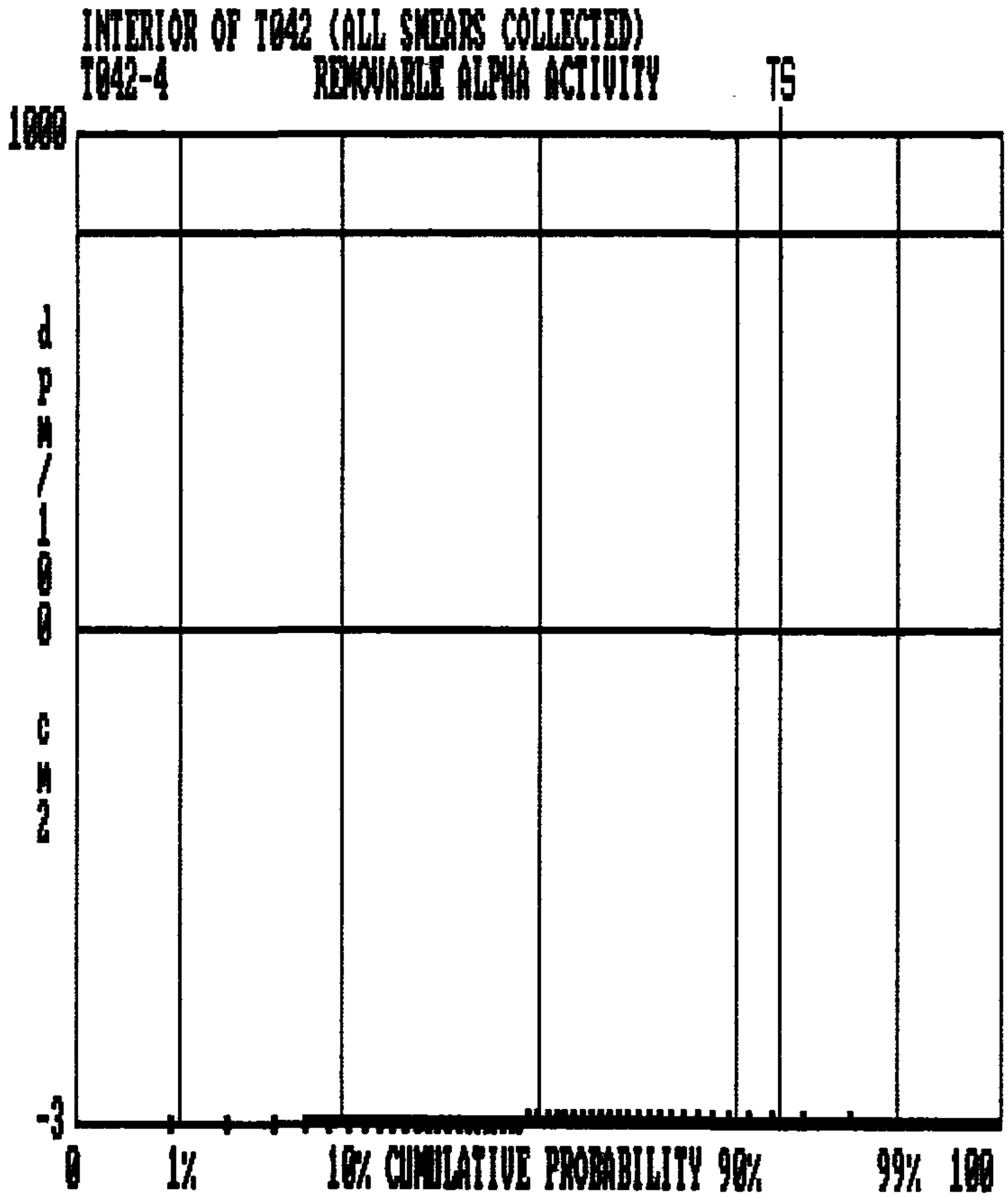


Figure 7.9 Total-Average Beta Activity Inside Building T042

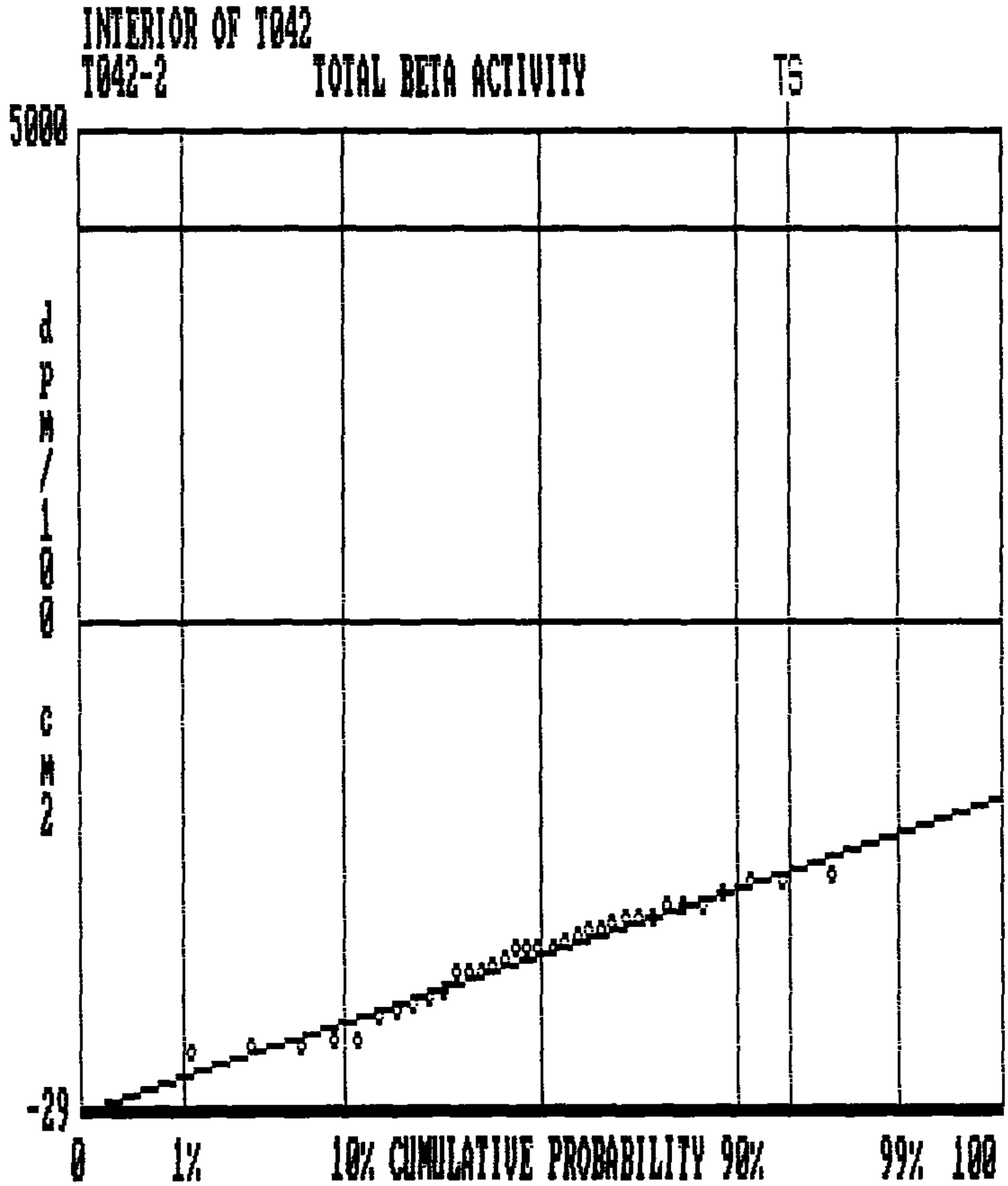


Figure 7.10 Removable Beta Activity Inside Building T042

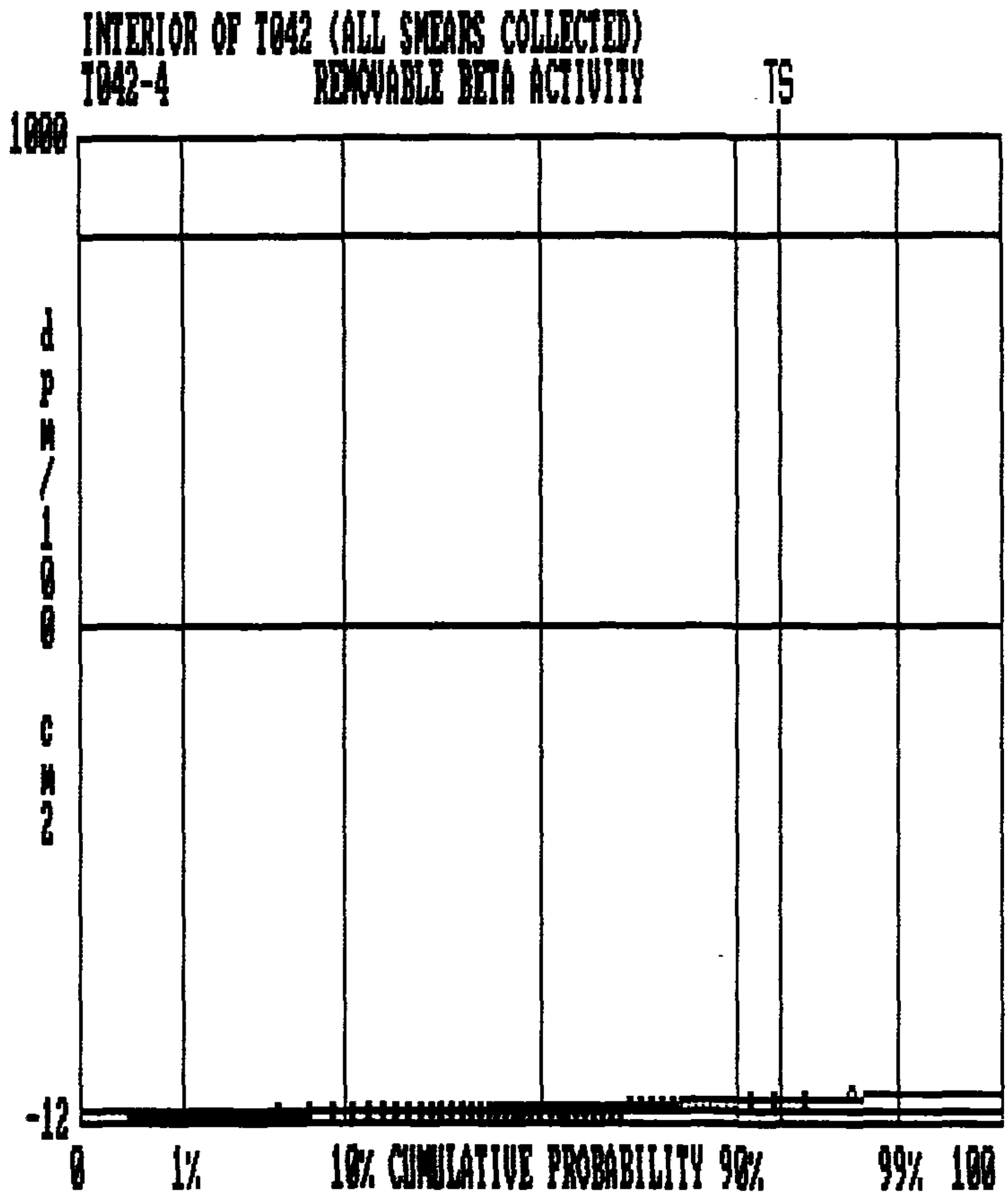


Table 7.4 Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits for Building T027

Sample Lot	Ambient Background Value (μR/h)	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
High Bay	9.09*	0.46	1.37	3.8	2.68	5
Room 118	17.40*	-1.26	2.30	2.8	2.31	5

*Ambient background based on median value of exposure rate measurements acquired in that test-area. The median value is an unbiased estimator of the Gaussian mean "ambient background" of a sample lot.

background values listed in the table, these areas pass our inspection criteria. However, to understand the basis for varying "ambient" conditions, further explanation is required.

Figure 7.11 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the High Bay of T027. Deviations from a Gaussian are observed, but these deviations are well within expected variations for exposure rate measurements in a facility of this sort. No trends indicating contamination are observed by these gamma measurements. A mean "uncorrected" exposure rate of 9.6 $\pm$ 1.38 μR/h is less than "natural background," as determined by averaging the 3 "natural background" areas.

Figure 7.12 shows the same data set (High Bay of T027), in which case a correction for "ambient background" was made uniformly to each measurement value. 9.09 μR/h was used for "background" subtraction, corresponding to the median value of gross-total measurements shown in Figure 7.11. Deviations observed in the measurements because of changes in ambient conditions (i.e. stored equipment, facility walls, etc.) are pronounced in this figure because the ordinate scale has been expanded. The single measurement value exceeding 50% Reinspection level was made in floor

Figure 7.11 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Building T027 High Bay

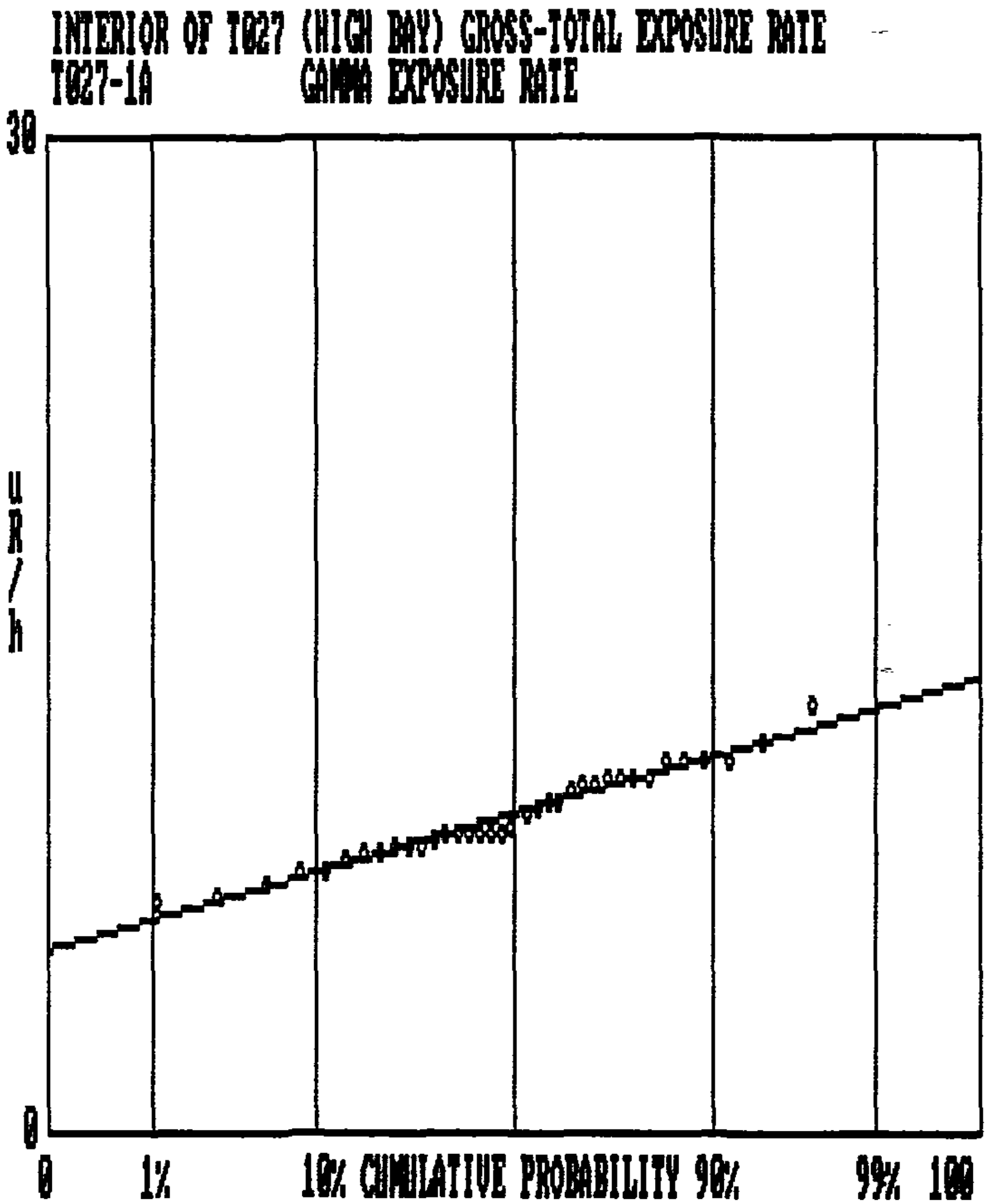
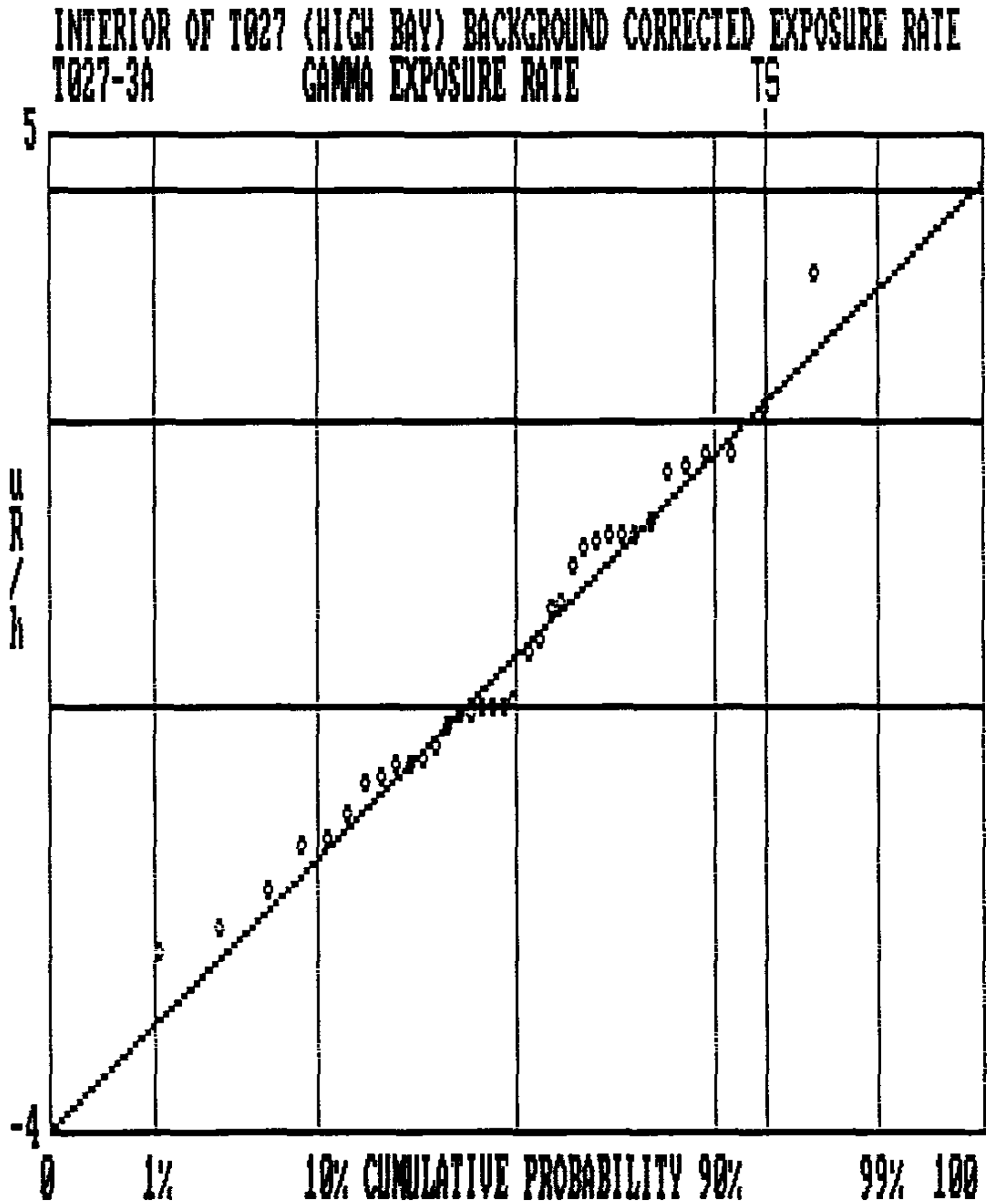


Figure 7.12 Background-Corrected Ambient Gamma Exposure Rates Measured Inside Building T027 High Bay



grid 4,2 (see Appendices C.3 and D.5). Several nearby locations were measured and a survey for beta surface activity was performed, but no indication of contamination was discovered. This value is a bona fide outlier in the distribution.

Figure 7.13 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for room 118 of Building T027. A small fluctuation from an ideal Gaussian distribution is observed at 50% cumulative probability and probably reflects some variation in ambient conditions. The distribution, however, is uniformly greater than the "background" distributions (Figure 7.1, 7.2, and 7.3) and is more variable (slope is greater). The average exposure rate is 16.1 $\pm$ 2.30 μR/h. One of three conditions is applicable to this sample lot:

1. A radiation source is located in the room;
2. The area is uniformly contaminated; or
3. "Ambient background" is greater in this location.

Additional surveys did not identify any contamination within the facility. Since the RMDF is in line-of-sight, about 100 ft from the back door of room 118, and fence-line exposure rates measure at least 34 μR/h, it is very likely that "ambient background" is greater than normal in room 118. This is due to direct radiation and skyshine from the RMDF. No trends indicating a specific contaminated location are observed.

Figure 7.14 shows the same data set for room 118 of Building T027, corrected for "ambient background" based on the median value (17.40 μR/h) of total gross measurements shown in Figure 7.13. The Gaussian is well represented, but deviations observed in the measurements are pronounced in this figure because the ordinate scale is expanded. The greatest measurements (including the one above the 50% Reinspection level) were all made along the north wall nearest the RMDF. Accepting an average "ambient" exposure rate of 17.4 μR/h, the average corrected exposure rate becomes-1.26 $\pm$ 2.3 μR/h and the test statistic is 2.31 μR/h. An unusually large standard deviation of 2.3 μR/h indicates a non-uniform sample lot. Both are less than acceptance limits and action levels.

Figure 7.13 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Building T027, Room 118

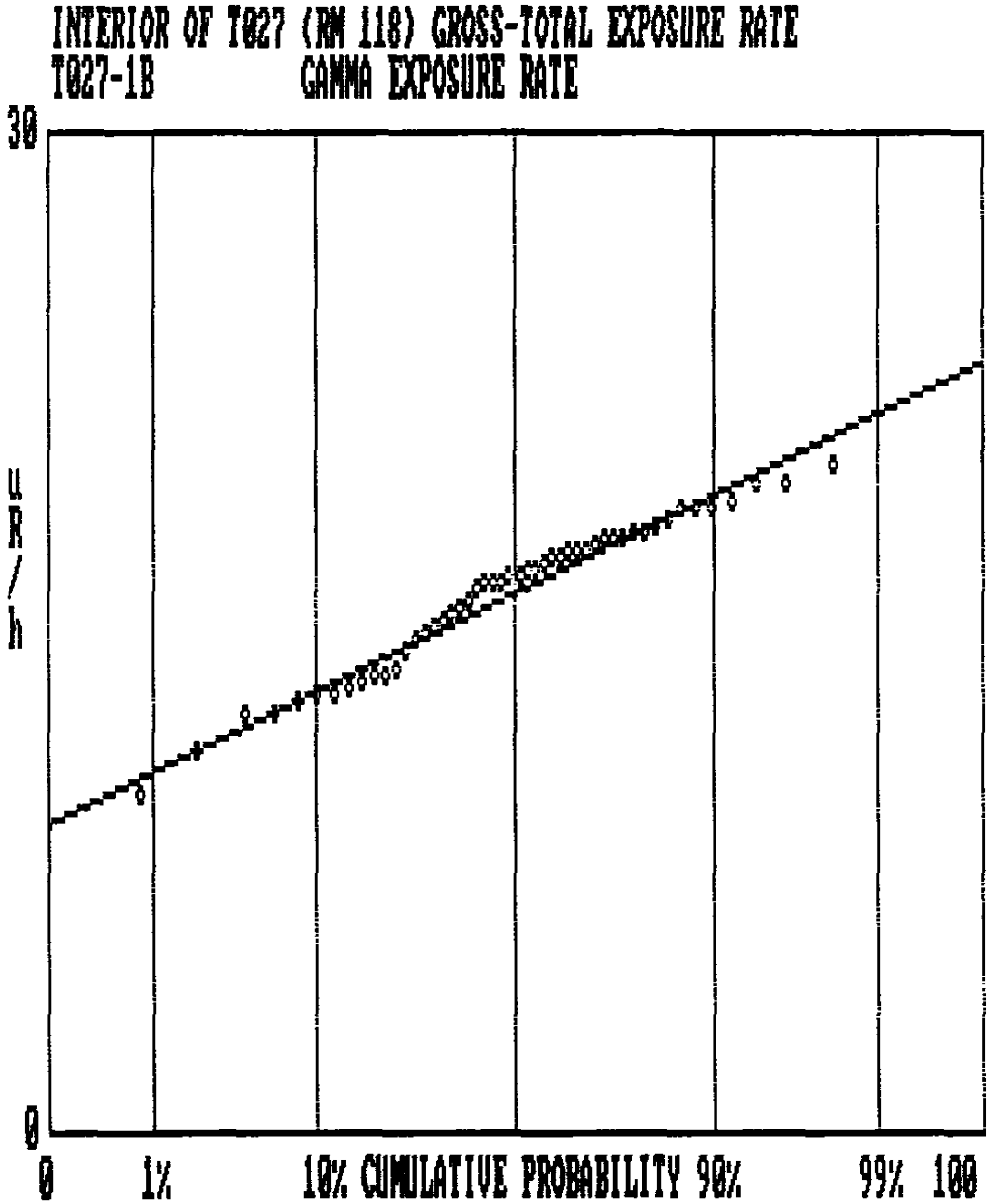
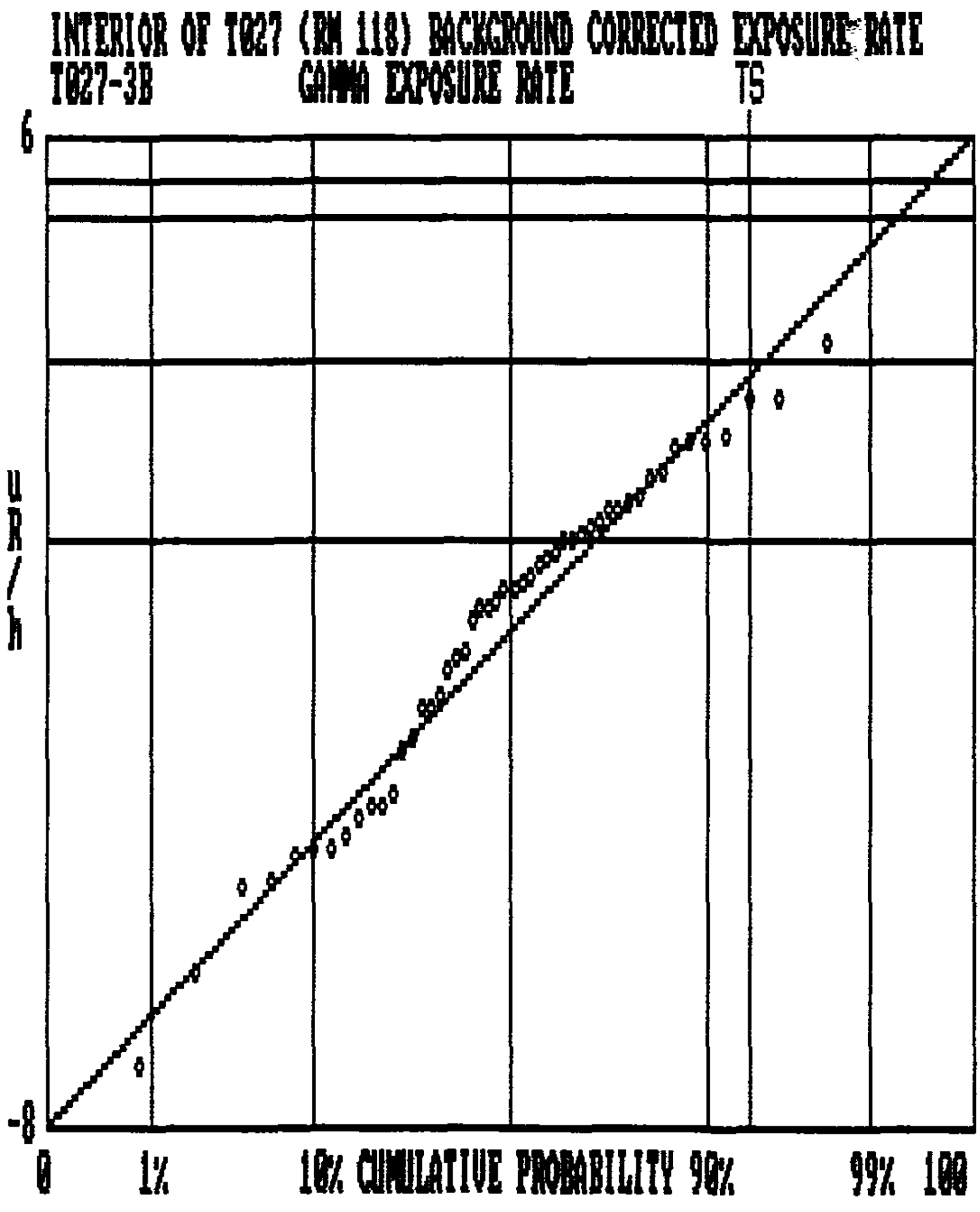


Figure 7.14 Background-Corrected Ambient Gamma Exposure Rates Measured Inside Building T027, Room 118



Surveys of surface beta activity performed "for indication" on all special building features and miscellaneous stored items, show in all cases, No Detectable Activity. Results of these statistical analyses show that Building T027 is not contaminated. We accept this facility as "clean." No further inspection is required in this facility.

7.6 Building T032

Building T032 was inspected for radioactive contaminants because of its affiliation with the SNAP program. Only gamma exposure rate measurements were acquired in this facility. No radioactive or nuclear materials are known to have been handled here. Exposure rate measurements were made on a 3-m square sampling plan. Because this facility is an active sodium test loop, with many pipes occupying the premises, it was necessary to modify the rigid 3-m square policy in many cases -- many locations were simply not accessible. Exposure rate measurements were evaluated by analytical interpretation using Gaussian statistics and inspection by variables. Miscellaneous building features and test components were surveyed "for indication" of beta activity; no statistical tests apply. Appendix C.4 shows specific measurement values and Appendix D.6 shows measurement locations.

Figure 7.15 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for Building T032. A slight change in slope is present at about the 60% cumulative probability line, indicating two possible Gaussian distributions. Further evaluation of the data and measurement locations (Appendices C.4 and D.6) shows that 18 of the 20 greatest measurements were made in or near outdoor locations. Appendix D.6 shows that these locations include equipment pads, a pit, and canopy-covered areas. The greatest exposure rate measured was 11.71 μR/h, well below "natural background" of 15.3 μR/h. No trends indicating a contaminated area are observed.

Figure 7.15 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Building T032

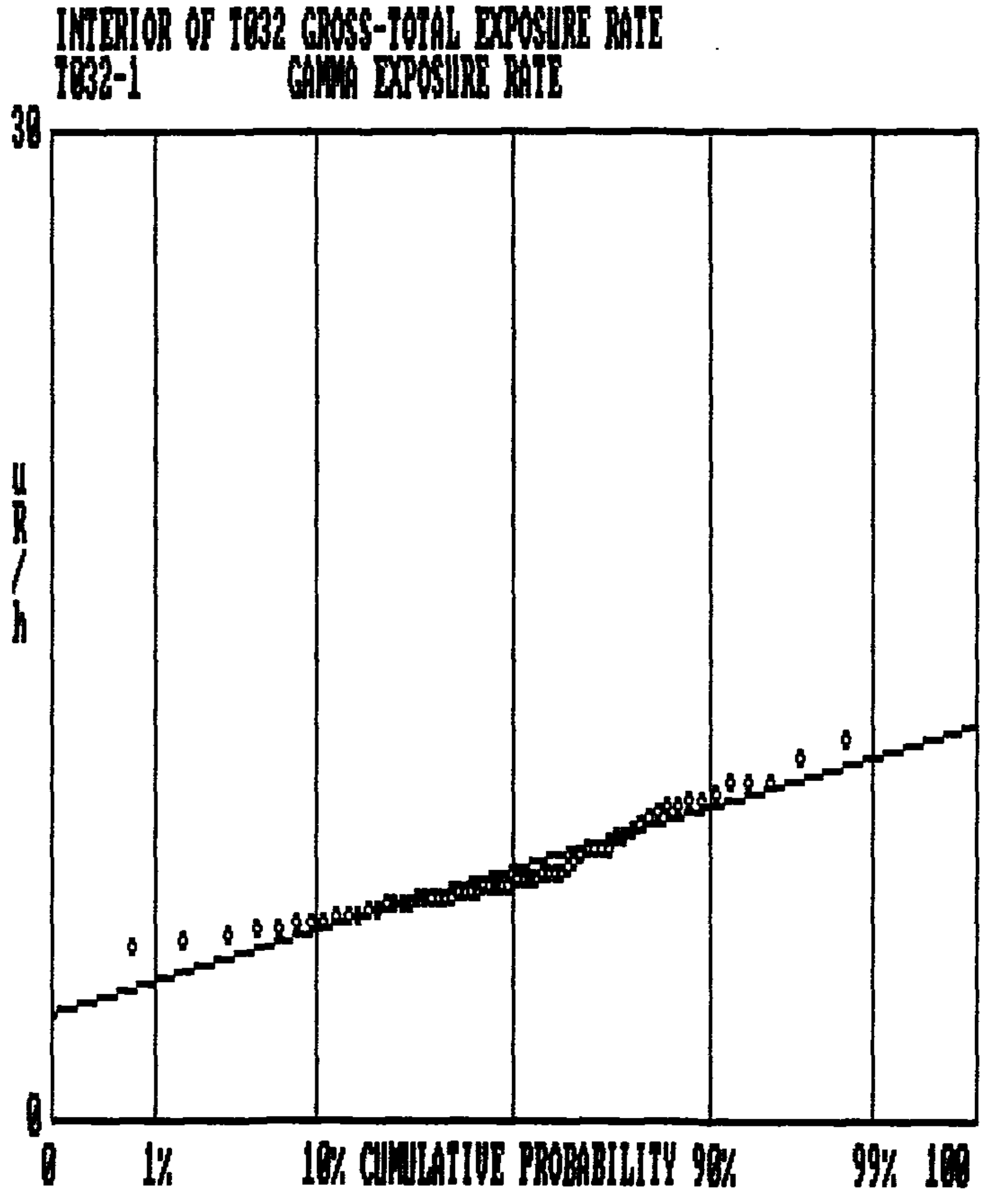


Figure 7.16 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 7.27 μR/h was used for "background" subtraction, corresponding to the median exposure rate of the gross-total data set measurements in Figure 7.15. Deviations observed in the measurements because of changes in "ambient" conditions are pronounced in this figure because the ordinate scale has been expanded. Again, the greatest measurements (particularly above our 50% Reinspection level) are clearly distinguished and represent outdoor measurement locations. These values do not indicate radioactivity. Even with these elevated measurements, an average of 0.43 μR/h is less than the 5 μR/h acceptance limit and all action levels. The inspection test statistic, 2.69 μR/h, is less than 5 μR/h.

Beta surface activity measurements were made on various building features and test components "for indication." All surveys, except for one location, showed No Detectable Activity. A stainless steel catch pan (about 2 ft x 3.5 ft) was found to be radioactive in about a 100 cm^2 area. The greatest count rate observed was 1000 β cpm above background. The pan was removed from the facility and dispositioned accordingly. The contaminant was Co-60, an activation product in stainless steel. The total activity was less than 20 nCi. This amount of activity produces a negligible exposure rate. None of the radioactive material spread to surrounding areas -- it was not loose, so it was not an internal hazard. This piece of activated or contaminated metal is not hazardous. The origin of the drip pan is unknown, but was probably used in some capacity associated with SNAP, possibly at Building T059. Following removal of this pan from T032, additional surveys were performed to ensure that no contamination was left behind.

Table 7.5 below shows the exposure rate results for Building T032. Now that the contaminated drip pan has been removed from T032, we accept this facility as uncontaminated by this inspection method. No further investigation is required.

Figure 7.16 Background-Corrected Ambient Gamma Exposure Rates Measured Inside Building T032

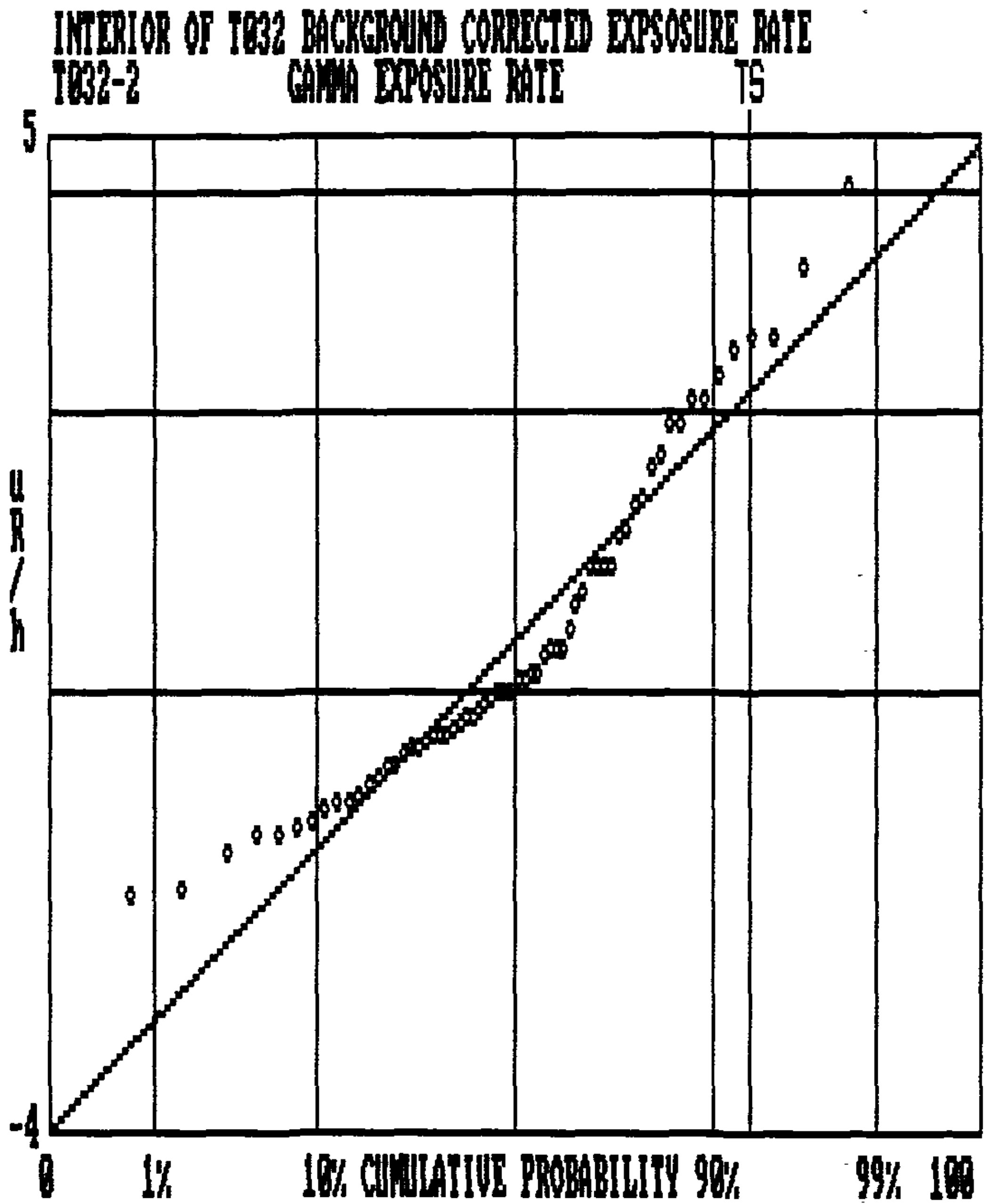


Table 7.5 Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits for Building T032

Sample Lot	Ambient Background Value (μR/h)	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
Building T032	7.27*	0.43	1.49	4.4	2.69	5

*Ambient background based on median value of exposure rate measurements acquired in that test-area. The median value is an unbiased estimator of the Gaussian mean "ambient background" of a sample lot.

7.7 Building T025

Building T025 was inspected for radioactive contaminants because of its association with the SNAP program. It has also been used more recently as a storage and warehouse facility. Exposure rate measurements were made on a 3-m square plot plan inside, and on a 6-m square plot plan outside in the surrounding storage yard. Each of these areas was handled as an individual sample lot because of variation in "ambient background;" indoors versus outdoors and RMDF influence. Exposure rate measurements were evaluated by analytical interpretation using Gaussian statistics and inspection by variables. Miscellaneous components and building features were surveyed "for indication" of beta activity; no statistical tests apply. Appendix C.5 shows specific measurement values and Appendices D.7, D.8, and D.9 show measurement locations.

Figure 7.17 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the inside of Building T025. Fluctuations observed in the distribution show that "ambient" radiation conditions must be changing from location to location. No distinguishable pattern is evident relative to the greatest exposure rates as a function of location. The average indoor total-gross exposure rate is 11.4 μR/h, far below "natural background" of 15.3 μR/h, but slightly greater than exposure rates observed in similar facilities. No trends indicating a contaminated area are observed.

Figure 7.17 Total-Gross Ambient Gamma Exposure Rates Measured Inside Building T025

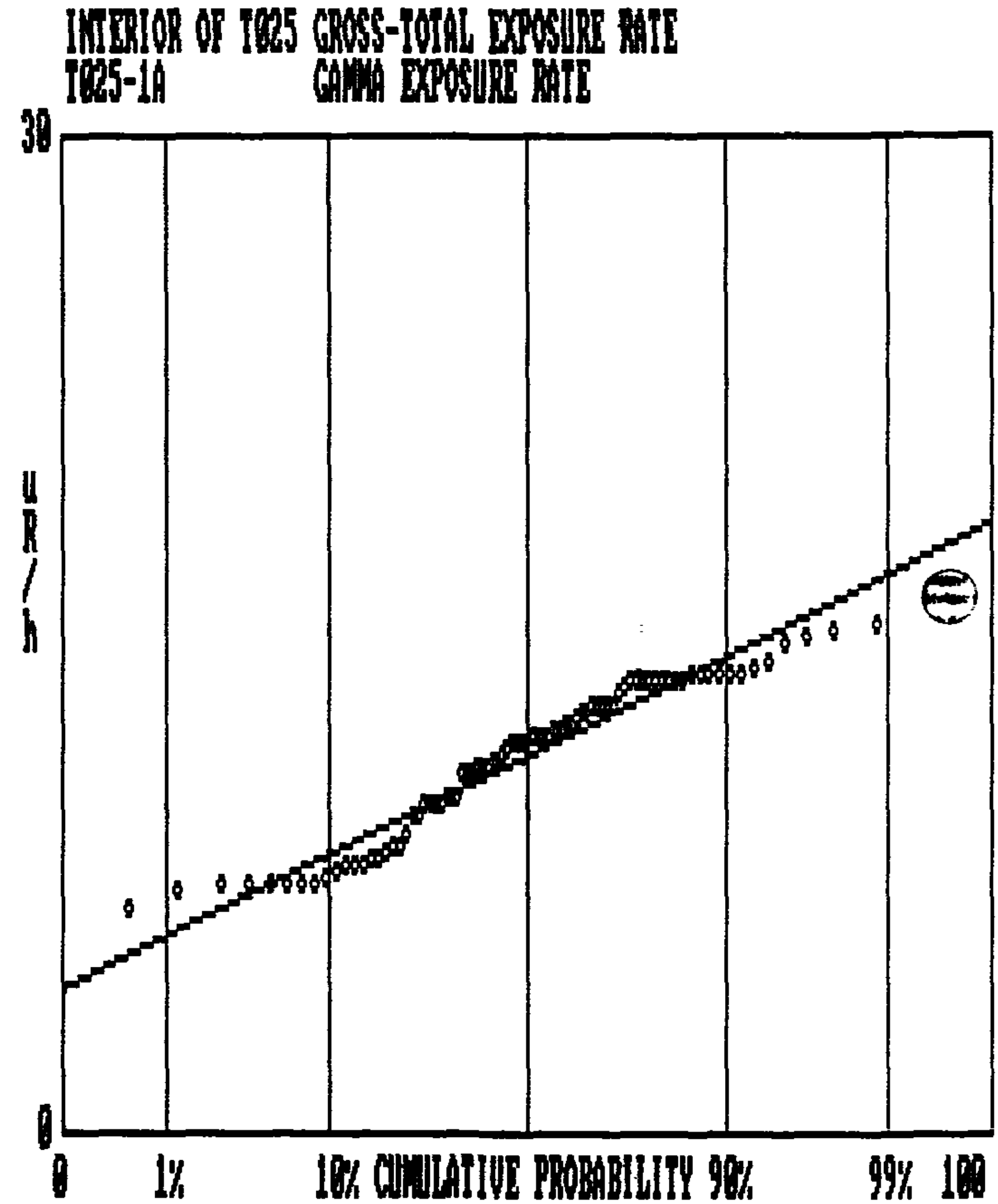


Figure 7.18 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 11.8 μR/h was used for "background" subtraction, corresponding to the median exposure rate of the gross-total data set measurements in Figure 7.17. Deviations observed in the measurements are pronounced in this figure because the ordinate scale has been expanded. A few underliers at the high end of the distribution exceed our 50% Reinspection level. Further inspection produced no explanation -- these values are anomalous. By the non-linearity exhibited by these measurements and the large standard deviation of 2.34 μR/h, we know that a secondary factor is influencing ambient radiation conditions; the area is not a uniform sampling lot. Fortunately, no contamination is indicated. The accepted idea is that RMDF direct radiation and skyshine is affecting conditions indoors, and this is location dependent -- near cracks, doors, or vents. An average of -0.43 μR/h is less than the 5 μR/h acceptance limit and all action levels. The inspection test statistic, 305 μR/h, is less than 5 μR/h. Beta surface activity measurements made "for indication" show in all cases No Detectable Activity. We accept this area as uncontaminated by this inspection method. No further investigation is required.

Outdoor measurements were treated as a separate sample lot from the indoor measurements made at T025. Figure 7.19 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the outside storage yard. This test-area is paved and cluttered with stored materials. No outliers or trends indicating a contaminated area are observed. The "S" shape at 50% cumulative probability, however, may indicate a change in ambient radiation conditions. The distribution, however, is uniformly greater than the "background" distributions (Figures 7.1, 7.2, and 7.3) and is much more variable (greater slope). The average exposure rate in this area is 24 μR/h with a maximum of 28 μR/h. This test-area is either uniformly contaminated or "ambient background" is greater in this location. Since Building T075 at the RMDF is located about 200 ft from this storage yard (see Figure 2.4), most likely, direct radiation and skyshine is affecting "ambient" conditions. Depending on the

Figure 7.18 Background-Corrected Ambient Gamma Exposure Rates Measured Inside Building T025

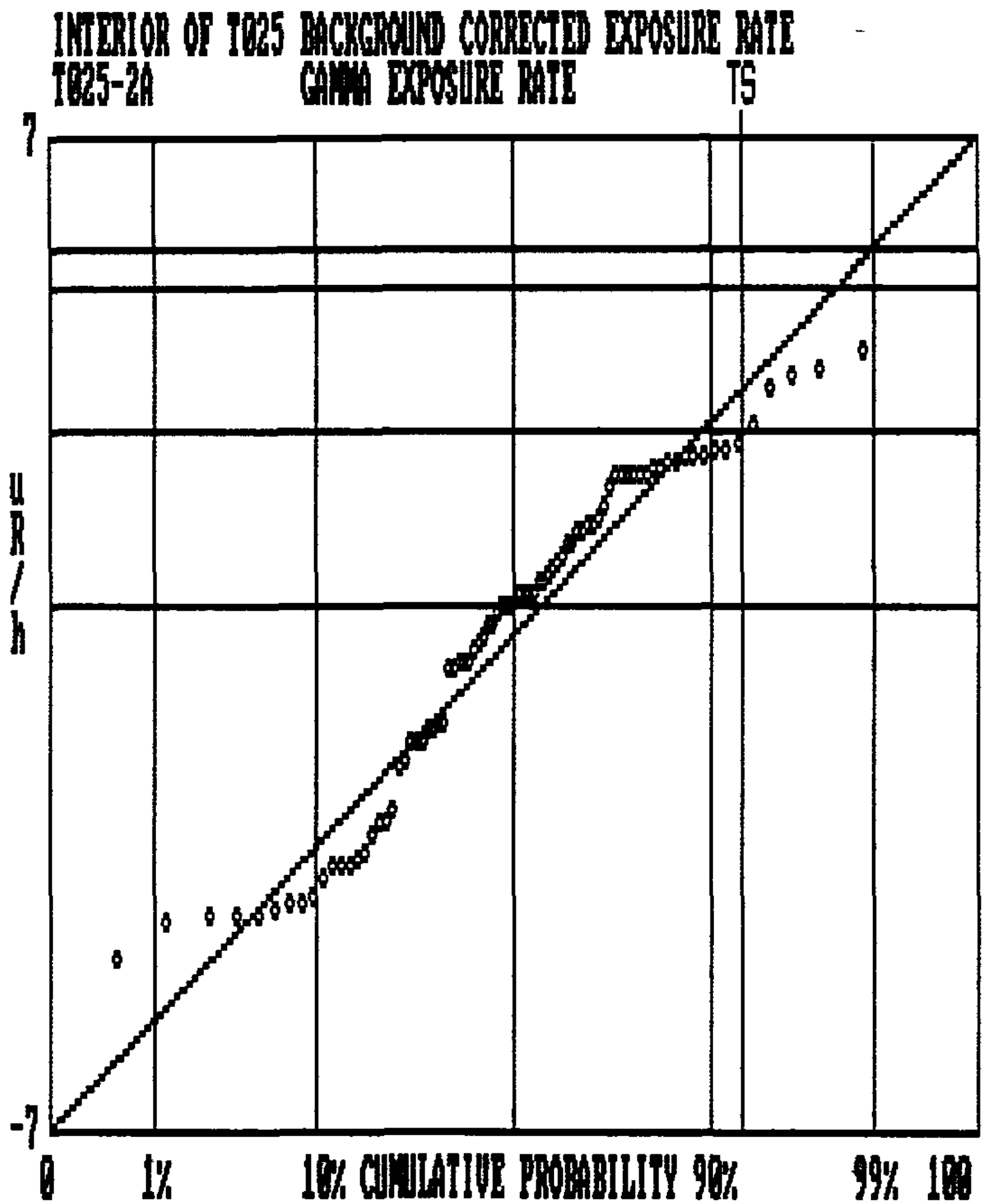
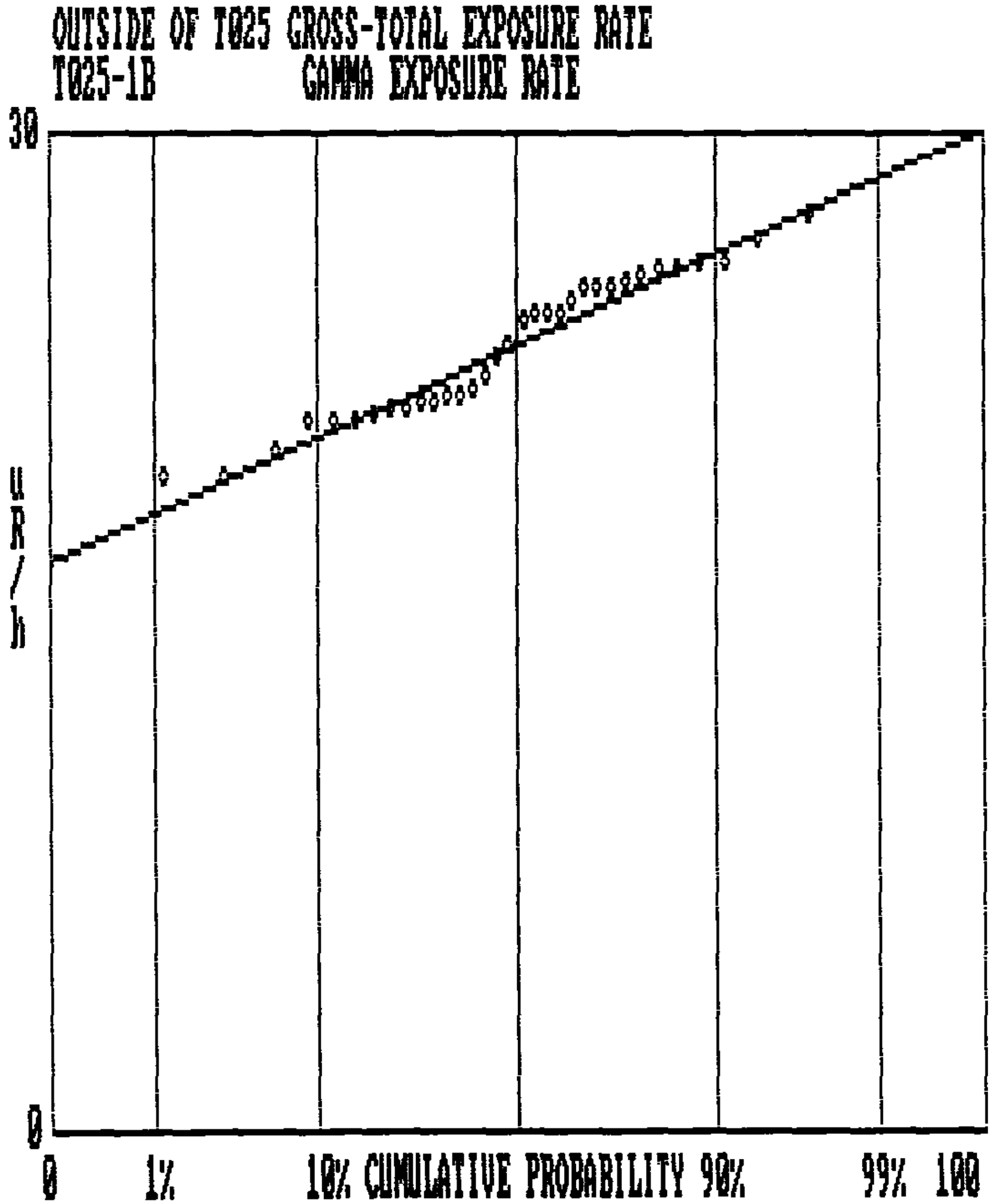


Figure 7.19 Total-Gross Ambient Gamma Exposure Rates Measured in the Storage Yard Surrounding Building T025



operations being performed at the RMDF, fence-line measurements in the direction of T025 can approach 35 to 40 μR/h for extended time periods (normally not exceeding a few days). The fence-line is only 100 ft or so from the location of some of these measurements. Also, skyshine probably contributes significantly to ambient exposure rate in this particular location. It is not credible that the entire storage yard is uniformly contaminated to this measured level.

Figure 7.20 shows the same data set, in which case a correction for "ambient background" was made uniformly to each measurement value. 24.0 μR/h was used for "background" subtraction, corresponding to the median exposure rate of the gross-total data set measurements in Figure 7.19. Using the "natural background" value of 15.3 μR/h for background subtraction would be an underestimate of true "ambient" conditions here. Deviations observed in the measurements because of these RMDF influences, (which are location dependent) are pronounced in this figure because the ordinate scale has been expanded. An average of -0.14 ± 2.18 μR/h is less than the 5 μR/h acceptance limit and all action levels. The inspection test statistic, 3.39 μR/h, is less than 5 μR/h. We accept this facility as uncontaminated by this inspection method. However, after the RMDF has been decommissioned, a check for "ambient" gamma radiation at the fence-line and in surrounding areas should be made to ensure that in fact radioactive material stored at the RMDF was significantly influencing gamma background.

Table 7.6 below shows the exposure rate results for both sample lots at Building T025. The standard deviations observed by the data sets are greater than expected -- this shows variation in "ambient" conditions. The extremely large value of "ambient background" used for the outside area is justified because of nearby RMDF operations involving the use of intense radioactive materials. All inspection tests pass our criteria for unrestricted use. Building T025 is not contaminated. No further investigation is required.

Figure 7.20 Background-Corrected Ambient Gamma Exposure Rates Measured In the Storage Yard Surrounding Building T025

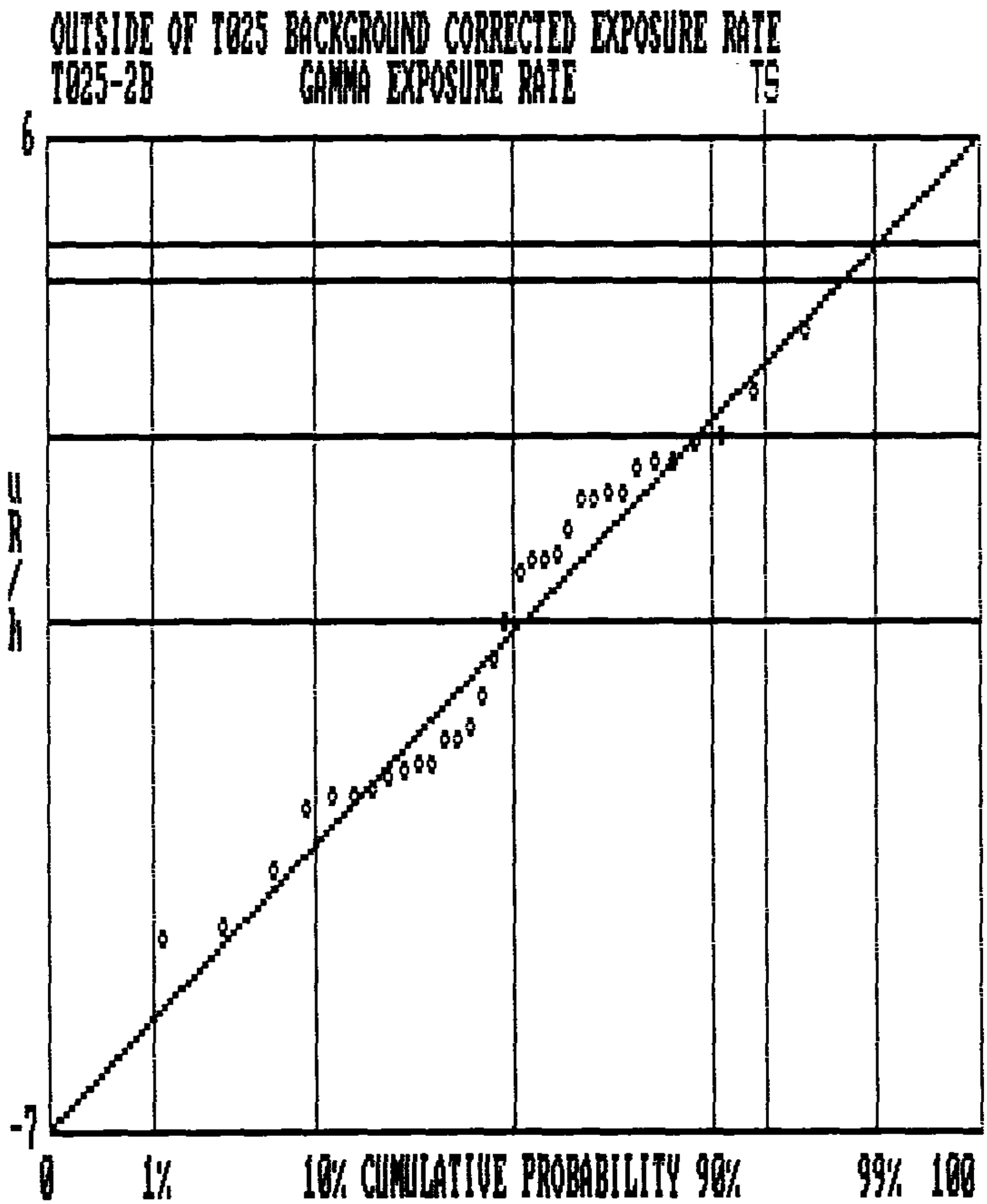


Table 7.6 Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits for Building T025

Sample Lot	Ambient Background Value (μR/h)	Average Value (μR/h)	Standard Deviation (μR/h)	Maximum Value (μR/h)	Inspection Test Statistic (μR/h)	Acceptance Limit (μR/h)
Inside T025	11.8*	-0.43	2.34	3.6	3.05	5
Outside in Surrounding Storage Yard	24.0*	-0.14	2.18	3.9	3.39	5

*Ambient background based on median value of exposure rate measurements acquired in that test-area. The median value is an unbiased estimator of the Gaussian mean "ambient background" of a sample lot.

7.8 Assessment of Radiological Condition

Analysis and interpretation of exposure rate measurements collected for this radiological survey became an exercise in assessing variability of "ambient background" at SSFL, and the factors which influence these measurements. A culmination of various factors affected ambient exposure rate for this survey:

1) Indoor versus outdoor changes in "ambient background;"
2) Stored large metal equipment items on-site; and
3) Nearby RMDF, where radioactive materials are stored.

Best-estimate corrections which account for these ambient variations were applied specifically to each sample lot. Outliers in each distribution were reinspected. Exposure rate mapping was performed to show the effects of ambient changes in gamma background.

Analysis of alpha and beta contamination measurements showed clearly that no contamination was found inside Buildings T049 and T042. The concrete used in these facilities, however, was found to contain more natural radioactivity than is usually found for similar material. Comprehensive surveys of beta surface activity "for indication" on miscellaneous facility features showed in one case an irradiated or contaminated stainless steel drip pan. The amount of radioactivity found was small and not hazardous.

Application of best corrections for "ambient gamma background" and resulting statistical analyses show that all sampled areas are acceptably uncontaminated. All areas pass criteria for unrestricted use. We are confident that the sensitivity and sampling frequency of exposure rate and alpha/beta measurements is sufficient for identifying suspect contamination even though the "noise" level was greater than usual.

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8.0 CONCLUSIONS

Buildings T049, T042, T027, T032, and T025 were inspected for radioactive contaminants. Gamma exposure rate measurements were made on a 3-m square sampling grid inside the facilities; and a 6-m square sampling grid in the storage yard of T025, according to the Site Survey Plan (Reference 4). Inside Buildings T049 and T042, smears were collected in each 3-m square and on special building features to assess the extent of removable alpha/beta activity. Total alpha/beta activity was also measured in those indoor locations. Total beta surface activity was checked "for indication" on interior features of all buildings. Smears and beta surveys were performed on sinks, drains, exhaust vents, ventilation systems, a glove box and filter banks -- these systems are more likely to have retained residual contamination. Exposure rate measurements plotted against cumulative probability show that "ambient background" radiation in these areas can vary by as much as 20 μR/h. This variation depends on local topography; vicinity of buildings, equipment, or scrap components; and proximity to the RMDF. The deviations observed in exposure rate data collected for these inspected areas are attributed to ambient radiation conditions. When proper adjustments are made to the data to account for "ambient background," the distributions show no trends indicating possible contamination. Total and removable alpha/beta activity measurements plotted against cumulative probability are far less than acceptance limits. All beta surface activity measurements show No Detectable Activity above ambient background, except for a stainless steel drip pan (3.5 ft x 2 ft) with a 100 cm^2 area reading 1000 β cpm. The contaminant was fixed Co-60. The pan was disposed of as radioactive waste. These locations pass as acceptably clean by our test criteria.

During performance of this particular survey, further reinspection and investigation were required and performed. First, several gamma measurements were recorded in outdoor areas which exceeded the 50% Reinspection level. These increased values are attributed to direct radiation and skyshine from the RMDF. The process of adjusting for "ambient background" as a non-uniform occurrence as a function of measurement location was required and estimated. Second, uniformly increased readings of beta surface activity on floor grids in T049 and T042 was observed. Reinspection showed natural radioactivity in the concrete.

Based on these statistical distributions of exposure rate measurements corrected for what we found to be "ambient background" in each sample lot, and on total and removable alpha/beta activity, we conclude through inspection by variables, that all locations surveyed do not contain residual radioactivity. This statistical test assumes a consumer's risk of acceptance of 0.1 at an LTPD of 10%. No further inspection is required in these locations.

9.0 REFERENCES

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18. "Radiological Survey of the Source and Special Nuclear Material Storage Vault - Building T064", GEN-ZR-0005, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988.

19. "Radiological Survey of the Old Calibration Facility - Building T029", GEN-ZR-006, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988.

20. "Radiological Survey of Shipping/Receiving and Old Accelerator Area - Building T641 and T030", GEN-ZR-0007, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988.

21. "Radiological Survey of the Old ESG Salvage Yard, Rocketdyne Barrel Storage Yard, and New Salvage Yard (T583)", GEN-ZR-0008, J. A. Chapman, Rocketdyne/Rockwell International, August, 1988.

22. "Radiological Survey of the T513 Parking Lot; Old R/A Laundry Area; Plot 333; and Areas Between the SRE-to-RMDF, and KEWB-to-RMDF", GEN-ZR-0009, J. A. Chapman, Rocketdyne/Rockwell International, September, 1988.

23. "Radiological Survey of Building T019 and T013; An Area Northwest of T059, T019, T013, and T012; and A Storage yard West of Buildings T626 and T038", GEN-ZR-0010, J. A. Chapman, Rocketdyne/Rockwell International, September, 1988.

24. "Radiological Survey of the T056 Landfill; Area from 23rd Street to Building T100; and an Area Across from Building T011", GEN-ZR-0011, J. A. Chapman, Rocketdyne/Rockwell International, September 1988.

25. "Disposal or Onsite Storage of Thorium or Uranium Wastes from Past Operations", Federal Register Vol. 46, No. 205, October 31, 1981

26. "Radiological Survey of Buildings T373 and T375", GEN-ZR-0012, J. A. Chapman, Rocketdyne/Rockwell International, September, 1988

APPENDIX A. DESCRIPTION OF NUCLEAR INSTRUMENTATION

During the radiological survey, smear-test wipes from interior surfaces were analyzed for radioactivity content by the following nuclear instrumentation system. Direct beta and gamma radiation measurements were made by using portable instruments.

A.1 Gross Alpha/Beta Automatic Proportional Counter

Smear-test wipes were analyzed for gross alpha and gross beta radioactivity with a Canberra Industries Model 2201 Ultra Low Level Counting System. Model 2201 consists of a highly efficient gas-flow sample detector operating in the proportional gas amplification region. The system detects radiation in a 2π geometry using P-10 gas (90% methane, 10% argon). A cosmic-ray detector provides coincidence event cancellation to reduce instrument background. The two detectors operate in an anticoincidence mode to reduce the count rate due to cosmic-ray events. When cosmic-ray or background events occur, the input circuit to the count integrator is gated off and the simultaneous event is discarded. Thus, only true alpha and/or beta radiation events are recorded. The detectors are coupled through dual Model 2006A preamplifiers to a Model 2015A system amplifier then through a Model 2209A coincidence analyzer to the alpha or beta event scaling unit. The Series 2201 has a sample capacity of 99 samples contained in a magazine designed to accept sample planchets having a 2-inch diameter. Calibration of the sample detector for alpha and for beta radiation on smear-wipes is done with NBS traceable certified thorium-230 (alpha) and technicium-99 (beta) radiation sources having a configuration essentially equivalent to that of the smear wipes.

A.2 Portable Instruments

Ludlum model 2220-ESG portable scaler/ratemeters coupled to alpha, beta, and gamma probes were used during the course of this survey. The 2220-ESG has a six decade LCD readout; combination four decade linear and log rate meter; adjustable HV threshold, and window positions, with readouts on digital display; audio provided by unimorph speaker with pitch change in relation to count rate; and preset electronic timer. Three 2220-ESGs were connected to separate probes; alpha, beta, and gamma.

A Ludlum model 43-1 alpha scintillation detector was coupled to one 2220 for alpha contamination measurements. The scintillator is ZnS(Ag). The window (0.8 mg/cm^2) is aluminized mylar with an active area of about 72 cm^2. Background for this probe is less than 2 counts per 5 minutes. Efficiency for Pu-239 or Th-230 alpha particles is between 25% and 30%.

A Ludlum model 44-9 pancake Geiger-Mueller detector was coupled to another 2220 for beta contamination measurements. The window (1.7 mg/cm^2) is mica with a nominal active area of 20 cm^2. Background for this probe is about 80 to 100 cpm. Efficiency for Tc-99 beta particles is between 25% and 20%.

A Ludlum model 44-10 NaI gamma scintillator was used for detecting gamma radiation. The NaI(Tl) crystal is extremely sensitive to changes in gamma flux. The probe efficiency varies with exposure rate. At background ambient gamma exposure rates, the efficiency is about 215 cpm/(μR/h). This determination was made by calibrating the 2220-ESG against a Reuter Stokes High-Pressure Ion Chamber (HPIC). The HPIC displays a digital readout every 3 to 4 seconds in μR/h.

A Ludlum model 12 count-ratemeter was coupled to a Ludlum model 44-9 pancake G-M beta probe to measure beta radiation. The probe active area is 20 cm^2. Instrument calibration is performed using Tc-99. This instrument is best suited "for indication" determinations.

APPENDIX B. COPY OF DOE REPORT,

"GUIDELINES FOR RESIDUAL RADIOACTIVITY AT

FUSRAP AND REMOTE SFMP SITES," March, 1985

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

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RECEIVED
CORRESPONDENCE

Addressees

GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

The attached guidelines, "U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites," (January 1985) have been issued by the Division of Remedial Action Projects for implementation by FUSRAP and SFMP in order to establish authorized limits for remedial actions. While these Guidelines are specifically intended for "remote" SFMP sites (those located outside a major DOE R&D or production site), they should be taken into consideration when developing authorized limits for remedial actions on major DOE reservations. The guidelines provide specific authorized limits for residual radium and thorium radioisotopes in soil, for airborne radon decay products, for external gamma radiation, and for residual surface contamination levels on materials to be released for unrestricted use. These guidelines will be supplemented in the near future by a document providing the methodology and guidance to establish authorized limits for residual radioisotopes other than radium and thorium in soil at sites to be certified for unrestricted use. The supplement will provide further guidance on the philosophies, scenarios, and pathways to derive appropriate authorized limits for residual radionuclides and mixtures in soil. These guidelines are based on the International Commission on Radiation Protection (ICRP) philosophies and dose limits in ICRP reports 26 and 30 as interpreted in the draft revised DOE Order 5480.1A. These dose limits are 500 mrem/yr for an individual member of the public over a short period of time and an average of 100 mrem/yr over a lifetime.

The approval of authorized limits differing from the guidelines is described in Section D, last sentence of the attached document. If the urgency of field activity makes DRAP concurrence not cost effective, a copy of the approval and backup analysis should be furnished to DRAP as soon as possible, although not necessarily prior to beginning field activities. This does not remove the requirement for approval by SFMPO.

As a result of a recent court decision, the Environmental Protection Agency (EPA) has issued airborne radiation standards applicable to DOE facilities. These final standards, issued as revisions to 40 CFR 61, are:

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- 25 mrem/yr-whole body
- 75 mrem/yr-organ
- waiver of these standards will be granted if DOE demonstrates that no individual would receive 100 mrem/yr continuous exposure whole body dose equivalent from all sources within 10 km radius, excluding natural background and medical procedures
- radon and radon daughters are excluded (these standards are covered in 40 CFR 192)

The attached guidelines were written to be consistent with the revision of the DOE Order 5480.1A now in draft at Headquarters and have received the concurrence of the Public Safety Division, Office of Operational Safety. The guidelines will be included in the SFMP Program Plan beginning with the next revision (for FY 1986-1990).

Please refer any questions to Paul F. X. Dunigan, Jr. (FTS 444-6667), of my staff.

Clarence E. Miller

Clarence E. Miller, Jr., Director
Surplus Facilities Management
Program Office

SFMPO:PFXD

Attachment:
As stated

cc: R. N. Coy, UNC
E. G. DeLaney, NE-24, HQ

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U.S. DEPARTMENT OF ENERGY GUIDELINES FOR RESIDUAL RADIOACTIVITY AT FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

(February 1985)

A. INTRODUCTION

This document presents U.S. Department of Energy (DOE) radiological protection guidelines for cleanup of residual radioactive materials and management of the resulting wastes and residues. It is applicable to sites identified by the Formerly Utilized Sites Remedial Action Program (FUSRAP) and remote sites identified by the Surplus Facilities Management Program (SFMP).* The topics covered are basic dose limits, guidelines and authorized limits for allowable levels of residual radioactivity, and requirements for control of the radioactive wastes and residues.

Protocols for identification, characterization, and designation of FUSRAP sites for remedial action; for implementation of the remedial action; and for certification of a FUSRAP site for release for unrestricted use are given in a separate document (U.S. Dept. Energy 1984). More detailed information on applications of the guidelines presented herein, including procedures for deriving site-specific guidelines for allowable levels of residual radioactivity from basic dose limits, is contained in a supplementary document--referred to herein as the "supplement" (U.S. Dept. Energy 1985).

"Residual radioactivity" includes: (1) residual concentrations of radionuclides in soil material,** (2) concentrations of airborne radon decay products, (3) external gamma radiation level, and (4) surface contamination. A "basic dose limit" is a prescribed standard from which limits for quantities that can be monitored and controlled are derived; it is specified in terms of the effective dose equivalent as defined by the International Commission on Radiological Protection (ICRP 1977, 1978). Basic dose limits are used explicitly for deriving guidelines for residual concentrations of radionuclides in soil material, except for thorium and radium. Guidelines for

*A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE research and development or production area.

**The term "soil material" refers to all material below grade level after remedial action is completed.

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residual concentrations of thorium and radium and for the other three quantities (airborne radon decay products, external gamma radiation level, and surface contamination) are based on existing radiological protection standards (U.S. Environ. Prot. Agency 1983; U.S. Nucl. Reg. Comm. 1982). These standards are assumed to be consistent with basic dose limits within the uncertainty of derivations of levels of residual radioactivity from basic limits.

A "guideline" for residual radioactivity is a level of residual radioactivity that is acceptable if the use of the site is to be unrestricted. Guidelines for residual radioactivity presented herein are of two kinds: (1) generic, site-independent guidelines taken from existing radiation protection standards, and (2) site-specific guidelines derived from basic dose limits using site-specific models and data. Generic guideline values are presented in this document. Procedures and data for deriving site-specific guideline values are given in the supplement.

An "authorized limit" is a level of residual radioactivity that must not be exceeded if the remedial action is to be considered completed. Under normal circumstances, expected to occur at most sites, authorized limits are set equal to guideline values for residual radioactivity that are acceptable if use of the site is not be restricted. If the authorized limit is set higher than the guideline, restrictions and controls must be established for use of the site. Exceptional circumstances for which authorized limits might differ from guideline values are specified in Sections D and F. The restrictions and controls that must be placed on the site if authorized limits are set higher than guidelines are described in Section E.

DOE policy requires that all exposures to radiation be limited to levels that are as low as reasonably achievable (ALARA). Implementation of ALARA policy is specified as procedures to be applied after authorized limits have been set. For sites to be released for unrestricted use, the intent is to reduce residual radioactivity to levels that are as far below authorized limits as reasonable considering technical, economic, and social factors. At sites where the residual radioactivity is not reduced to levels that permit release for unrestricted use, ALARA policy is implemented by establishing controls to reduce exposure to ALARA levels. Procedures for implementing ALARA policy are described in the supplement. ALARA policies, procedures, and actions must be documented and filed as a permanent record upon completion of remedial action at a site.

B. BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 500 mrem/yr for a period of exposure not to exceed 5 years and an average of 100 mrem/yr over a lifetime. The committed effective dose equivalent, as defined in ICRP Publication 26 (ICRP 1977) and calculated by dosimetry models described in ICRP Publication 30 (ICRP 1978), shall be used for determining the dose.

C. GUIDELINES FOR RESIDUAL RADIOACTIVITY

C.1 Residual Radionuclides in Soil Material

Residual concentrations of radionuclides in soil material shall be specified as above-background concentrations averaged over an area of 100 m^2. If the concentration in any area is found to exceed the average by a factor greater than 3, guidelines for local concentrations shall also be applicable. These "hot spot" guidelines depend on the extent of the elevated local concentrations and are given in the supplement.

The generic guidelines specified below are for concentrations of individual radionuclides occurring alone. If mixtures of radionuclides are present, the concentrations of individual radionuclides shall be reduced so that the dose for the mixture would not exceed the basic dose limit. Explicit formulas for calculating residual concentration guidelines for mixtures are given in the supplement.

The generic guidelines for residual concentrations of Th-232, Th-230, Ra-228, and Ra-226 are:

- 5 pCi/g, averaged over the first 15 cm of soil below the surface

- 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface

The guidelines for residual concentrations in soil material of all other radionuclides shall be derived from basic dose limits by means of an environmental pathway analysis using site-specific data. Procedures for deriving these guidelines are given in the supplement.

C.2 Airborne Radon Decay Products

Generic guidelines for concentrations of airborne radon decay products shall apply to existing occupied or habitable structures on private property that are intended for unrestricted use; structures that will be demolished or buried are excluded. The applicable generic guideline (40 CFR 192) is: In any occupied or habitable building, the objective of remedial action shall be, and reasonable effort shall be made to achieve, an annual average (or equivalent) radon decay product concentration (including background) not to exceed 0.02 WL.* In any case, the radon decay product concentration (including background) shall not exceed 0.03 WL. Remedial actions are not required in order to comply with this guideline when there is reasonable assurance that residual radioactive materials are not the cause.

C.3. External Gamma Radiation

The level of gamma radiation at any location on a site to be released for unrestricted use, whether inside an occupied building or habitable structure or outdoors, shall not exceed the background level by more than 20 μR/h.

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*A working level (WL) is any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

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C.4 Surface Contamination

The following generic guidelines, adapted from standards of the U.S. Nuclear Regulatory Commission (1982), are applicable only to existing structures and equipment that will not be demolished and buried. They apply to both interior and exterior surfaces. If a building is demolished and buried, the guidelines in Section C.1 are applicable to the resulting contamination in the ground.

	Allowable Total Residual Surface Contamination (dpm/100 cm^2)†[1]		
Radionuclides†[2]	Average†[3],†[4]	Maximum†[4],†[5]	Removable†[6]
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

†[1] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

†[2] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

†[3] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

†[4] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

†[5] The maximum contamination level applies to an area of not more than 100 cm^2.

†[6] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.

D. AUTHORIZED LIMITS FOR RESIDUAL RADIOACTIVITY

The remedial action shall not be considered complete unless the residual radioactivity is below authorized limits. Authorized limits shall be set equal to guidelines for residual radioactivity unless: (1) exceptions specified in Section F of this document are applicable, in which case an authorized limit may be set above the guideline value for the specific location or condition to which the exception is applicable; or (2) on the basis of site-specific data not used in establishing the guidelines, it can be clearly established that limits below the guidelines are reasonable and can be achieved without appreciable increase in cost of the remedial action. Authorized limits that differ from guidelines must be justified and established on a site-specific basis, with documentation that must be filed as a permanent record upon completion of remedial action at a site. Authorized limits differing from the guidelines must be approved by the Director, Oak Ridge Technical Services Division, for FUSRAP and by the Director, Richland Surplus Facilities Management Program Office, for remote SFMP--with concurrence by the Director of Remedial Action Projects for both programs.

E. CONTROL OF RESIDUAL RADIOACTIVITY AT FUSRAP AND REMOTE SFMP SITES

Residual radioactivity above the guidelines at FUSRAP and remote SFMP sites must be managed in accordance with applicable DOE Orders. The DOE Order 5480.1A requires compliance with applicable federal, state, and local environmental protection standards.

The operational and control requirements specified in the following DOE Orders shall apply to both interim storage and long-term management.

a. 5440.1B, Implementation of the National Environmental Policy Act

b. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations

c. 5480.2, Hazardous and Radioactive Mixed Waste Management

d. 5480.4, Environmental Protection, Safety, and Health Protection Standards

e. 5482.1A, Environmental, Safety, and Health Appraisal Program

f. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities

g. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements

h. 5484.2, Unusual Occurrence Reporting System

i. 5820.2, Radioactive Waste Management

E.1 Interim Storage

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 50 years and, in any case, at least 25 years.

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b. Above-background Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not exceed: (1) 100 pCi/L at any given point, (2) an annual average concentration of 30 pCi/L over the facility site, and (3) an annual average concentration of 3 pCi/L at or above any location outside the facility site (DOE Order 5480.1A, Attachment XI-1).

c. Concentrations of radionuclides in the groundwater or quantities of residual radioactive materials shall not exceed existing federal, state, or local standards.

d. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These control features should be designed to ensure, to the extent reasonable, an effective life of at least 25 years. The federal government shall have title to the property.

E.2 Long-Term Management

a. Control and stabilization features shall be designed to ensure, to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years.

b. Control and stabilization features shall be designed to ensure that Rn-222 emanation to the atmosphere from the waste shall not: (1) exceed an annual average release rate of 20 $pCi/m^2/s$, and (2) increase the annual average Rn-222 concentration at or above any location outside the boundary of the contaminated area by more than 0.5 pCi/L. Field verification of emanation rates is not required.

c. Prior to placement of any potentially biodegradable contaminated wastes in a long-term management facility, such wastes shall be properly conditioned to ensure that (1) the generation and escape of biogenic gases will not cause the requirement in paragraph b of this section (E.2) to be exceeded, and (2) biodegradation within the facility will not result in premature structural failure in violation of the requirements in paragraph a of this section (E.2).

d. Groundwater shall be protected in accordance with 40 CFR 192.20(a)(2) and 192.20(a)(3), as applicable to FUSRAP and remote SFMP sites.

e. Access to a site should be controlled and misuse of onsite material contaminated by residual radioactivity should be prevented through appropriate administrative controls and physical barriers--active and passive controls as described by the U.S. Environmental Protection Agency (1983--p. 595). These controls should be designed to be effective to the extent reasonable for at least 200 years. The federal government shall have title to the property.

F. EXCEPTIONS

Exceptions to the requirement that authorized limits be set equal to the guidelines may be made on the basis of an analysis of site-specific aspects of a designated site that were not taken into account in deriving the guidelines. Exceptions require approvals as stated in Section D. Specific situations that warrant exceptions are:

a. Where remedial actions would pose a clear and present risk of injury to workers or members of the general public, notwithstanding reasonable measures to avoid or reduce risk.

b. Where remedial actions--even after all reasonable mitigative measures have been taken--would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

c. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and where the residual radioactive materials do not pose a clear present or future risk after taking necessary control measures. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this risk. Remedial actions will generally not be necessary where only minor quantities of residual radioactive materials are involved or where residual radioactive materials occur in an inaccessible location at which site-specific factors limit their hazard and from which they are costly or difficult to remove. Examples are residual radioactive materials under hard-surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. In order to invoke this exception, a site-specific analysis must be provided to establish that it would not cause an individual to receive a radiation dose in excess of the basic dose limits stated in Section B, and a statement specifying the residual radioactivity must be included in the appropriate state and local records.

d. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be effected by remedial action, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of remedial actions that would be less costly than removal of the residual radioactive materials. A statement specifying the residual radioactivity must be included in the appropriate state and local records.

e. Where there is no feasible remedial action.

G. SOURCES

Limit or Guideline	Source
Basic Dose Limits	
Dosimetry Model and Dose Limits	International Commission on Radiological Protection (1977, 1978)
Guidelines for Residual Radioactivity	
Residual Radionuclides in Soil Material	40 CFR 192
Airborne Radon Decay Products	40 CFR 192
External Gamma Radiation	40 CFR 192
Surface Contamination	U.S. Nuclear Regulatory Commission (1982)
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	DOE Order 5480.1A; 40 CFR 192

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APPENDIX C. RADIOLOGICAL SURVEY DATA

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C.1 Building T049 Exposure Rates Measurements (Sorted by Location)

T049.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
100	1-1	2135	9.89	0.21
100	1-2	1903	8.81	0.20
100	1-4	2107	9.76	0.21
100	1-6	2041	9.45	0.21
100	1-8	2374	11.00	0.23
101	1-9	2078	9.63	0.21
101	1-10	2388	11.06	0.23
101	2-10	1938	8.98	0.20
100	3-1	2225	10.31	0.22
100	3-2	1850	8.57	0.20
100	3-4	1900	8.80	0.20
100	3-6	1864	8.63	0.20
100	3-8	2227	10.32	0.22
101	3-10	1877	8.69	0.20
101	4-9	1770	8.20	0.19
101	4-10	1906	8.83	0.20
100	5-1	1795	8.31	0.20
100	5-2	1404	6.50	0.17
100	5-4	1908	8.84	0.20
100	5-6	1991	9.22	0.21
100	5-8	2157	9.99	0.22
101	5-9	2135	9.89	0.21
101	5-10	2204	10.21	0.22
	NUMBER OF MEAS.		23	
	AVERAGE/SQRT(SUMSQ)		9.30	1.00
	STD. DEV.		1.02	
	MAXIMUM		11.06	
	MINIMUM		6.50	
	RANGE		4.56	

Building T049 Exposure Rate Measurements (Sorted by Exposure Rate)

T049.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
101	1-10	2388	11.06	0.23
100	1-8	2374	11.00	0.23
100	3-8	2227	10.32	0.22
100	3-1	2225	10.31	0.22
101	5-10	2204	10.21	0.22
100	5-8	2157	9.99	0.22
100	1-1	2135	9.89	0.21
101	5-9	2135	9.89	0.21
100	1-4	2107	9.76	0.21
101	1-9	2078	9.63	0.21
100	1-6	2041	9.45	0.21
100	5-6	1991	9.22	0.21
101	2-10	1938	8.98	0.20
100	5-4	1908	8.84	0.20
101	4-10	1906	8.83	0.20
100	1-2	1903	8.81	0.20
100	3-4	1900	8.80	0.20
101	3-10	1877	8.69	0.20
100	3-6	1864	8.63	0.20
100	3-2	1850	8.57	0.20
100	5-1	1795	8.31	0.20
101	4-9	1770	8.20	0.19
100	5-2	1404	6.50	0.17
	NUMBER OF MEAS.		23	
	AVERAGE/SQRT(SUMSQ)		9.30	1.00
	STD. DEV.		1.02	
	MAXIMUM		11.06	
	MINIMUM		6.50	
	RANGE		4.56	

Building T049 Alpha/Beta Radioactivity Measurements

SMEARS OF FEATURES (BUILDING T049)	ALPHA REMOVABLE dpm/100cm2		BETA REMOVABLE dpm/100cm2	
	VALUE	STD DEV	VALUE	STD DEV
LIGHT FIXT. PANEL A	1.68	1.33	5.31	4.42
TOP PANEL A	1.68	1.33	-0.99	3.72
TOP DOUBLE DOORS	-0.42	0.54	3.51	4.23
LIGHT FIXT. PANEL A	0.98	1.13	6.21	4.51
TOP OF PANEL G	-0.42	0.54	-3.69	3.38
LIGHT FIXT. PANEL G	0.98	1.13	-0.99	3.72
TOP OF PANEL C	0.28	0.89	0.81	3.93
LIGHT FIXT. PANEL C	0.28	0.89	5.31	4.42
VENT NORTH WALL 100	-0.42	0.54	7.11	4.60
BELOW AC DUCT E. WAL	-0.42	0.54	1.71	4.03
VENT NORTH WALL 101	0.98	1.13	-0.99	3.72
TOP RELIANC #2 101	0.28	0.89	0.81	3.93
TOP OF PANEL E	0.28	0.89	4.41	4.33
LP-58LP-6 TOP PANEL	-0.42	0.54	6.21	4.51
NUMBER OF MEAS.	14		14	
AVERAGE/SQRT(SUMSQ)	0.38	3.46	2.48	15.42
STD. DEV.	0.77		3.40	
MAXIMUM	1.68		7.11	
MINIMUM	-0.42		-3.69	
RANGE	2.10		10.80	

ALPHA/BETA MEAS. (T049)		TOTAL ALPHA (dpm/100cm2)		TOTAL BETA (dpm/100cm2)	
ROOM	GRID	VALUE	STD DEV	VALUE	STD DEV
100	1-6	4.4	3.9	1080	123.0
100	2-1	8.7	4.6	936	120.9
100	2-9	17.5	5.8	929	120.8
100	3-11	1.5	3.3	788	118.7
100	4-4	8.7	4.6	648	116.5
100	4-8	11.6	5.0	900	120.4
100	5-1	11.6	5.0	860	119.8
100	6-11	7.3	4.4	698	117.3
NUMBER OF MEAS.		8		8	
AVERAGE/SQRT(SUMSQ)		8.92	13.10	855.00	338.55
STD. DEV.		4.89		139.64	
MAXIMUM		17.47		1080.00	
MINIMUM		1.46		648.00	
RANGE		16.02		432.00	

C.2 Building T042 Exposure Rates Measurements (Sorted by Location)

T042.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
101 NW	4-1	1696	7.86	0.19
101 MID	4-1	1898	8.79	0.20
101 SW	4-1	1605	7.43	0.19
101 ENTRY	4-2	1568	7.26	0.18
101 ENTRY	4-2	1547	7.17	0.18
101A SHWR	5-1	1468	6.80	0.18
101A DOOR	5-1	1309	6.06	0.17
101A DRAN	5-2	1128	5.22	0.16
102	1-1	1801	8.34	0.20
102	1-2	1651	7.65	0.19
102	1-3	1301	6.03	0.17
102	1-4	2221	10.29	0.22
102	1-5	2137	9.90	0.21
102	1-6	2080	9.63	0.21
102	1-7	2094	9.70	0.21
102	1-8	2198	10.18	0.22
102	1-9	2232	10.34	0.22
102	1-10	2241	10.38	0.22
102	1-11	2489	11.53	0.23
102	2-1	1674	7.75	0.19
102	2-2	1625	7.53	0.19
102	2-3	1804	8.36	0.20
102	2-4	1937	8.97	0.20
102	2-5	1883	8.72	0.20
102	2-6	1666	7.72	0.19
102	2-7	1647	7.63	0.19
102	2-8	1379	6.39	0.17
102	2-9	1602	7.42	0.19
102	2-10	1954	9.05	0.20
102	2-11	2432	11.27	0.23
102	3-1	1850	8.57	0.20
102	3-2	1618	7.49	0.19
103	3-2	1337	6.19	0.17
103	3-3	1347	6.24	0.17
103	3-4	1133	5.25	0.16
103	3-5	1295	6.00	0.17
103	3-6	1300	6.02	0.17
103	3-7	1323	6.13	0.17
103	3-8	1403	6.50	0.17
103	3-9	1446	6.70	0.18
103	3-10	1875	8.69	0.20
103	4-2	1480	6.86	0.18
103	4-3	1146	5.31	0.16
103	4-4	1196	5.54	0.16
103	4-5	1220	5.65	0.16
103	4-8	1246	5.77	0.16
103	4-9	1560	7.23	0.18
103	4-10	1954	9.05	0.20
103	5-2	1115	5.16	0.15
103	5-3	1348	6.24	0.17

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T042.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
103	5-3	1165	5.40	0.16
103	5-4	1177	5.45	0.16
103	5-4	1359	6.29	0.17
103	5-5	1411	6.54	0.17
103	5-6	1356	6.28	0.17
103	5-7	1420	6.58	0.17
103	5-8	1421	6.58	0.17
103	5-9	1514	7.01	0.18
103	6-3	1288	5.97	0.17
103	6-3	1605	7.43	0.19
103	5-9	1544	7.15	0.18
103	5-10	1698	7.87	0.19
103	6-4	1570	7.27	0.18
103	6-5	1537	7.12	0.18
103	6-6	1605	7.43	0.19
103	6-7	1626	7.53	0.19
103	6-8	1536	7.11	0.18
103	6-9	1522	7.05	0.18
103	6-10	1331	6.17	0.17
103	6-10	1554	7.20	0.18
103	7-3	1633	7.56	0.19
103	7-4	1642	7.61	0.19
103	7-5	1580	7.32	0.18
103	7-6	1607	7.44	0.19
103	7-7	1375	6.37	0.17
103	7-8	1477	6.84	0.18
103	7-9	1487	6.89	0.18
103	7-10	1524	7.06	0.18
103	8-3	1580	7.32	0.18
103	8-3	1743	8.07	0.19
103	8-4	1806	8.37	0.20
103	8-5	1715	7.94	0.19
103	8-6	1656	7.67	0.19
103	8-7	1539	7.13	0.18
103	8-8	1410	6.53	0.17
103	8-9	1091	5.05	0.15
103	8-10	1145	5.30	0.16
103	9-3	1420	6.58	0.17
103	9-4	1697	7.86	0.19
103	9-5	1636	7.58	0.19
103	9-6	1587	7.35	0.18
103	9-7	1404	6.50	0.17
103	9-8	1390	6.44	0.17
103	9-10	1155	5.35	0.16
103	10-3	1450	6.72	0.18
103	10-4	1512	7.00	0.18
103	10-5	1478	6.85	0.18
103	10-6	1366	6.33	0.17
103	10-6	1266	5.86	0.16
103	10-8	1420	6.58	0.17

T042.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
103	10-9	1527	7.07	0.18
103	10-10	1418	6.57	0.17
103	10-5	1067	4.94	0.15
103	10-6	992	4.59	0.15
103	10-6	1088	5.04	0.15
103	10-7	1066	4.94	0.15
103	10-7	1088	5.04	0.15
104	11-3	1711	7.93	0.19
104	11-4	1605	7.43	0.19
104	11-5	1450	6.72	0.18
104	11-5	1453	6.73	0.18
104	11-5	1476	6.84	0.18
104	11-6	1869	8.66	0.20
104	11-7	1564	7.24	0.18
104	11-8	1832	8.49	0.20
104	11-9	2024	9.38	0.21
104	11-10	1601	7.42	0.19
104	11-10	1727	8.00	0.19
104	11-10	1739	8.06	0.19
104	11-10	1727	8.00	0.19
104	12-5	2359	10.93	0.22
104	12-6	2105	9.75	0.21
104	12-7	2073	9.60	0.21
104	12-8	2375	11.00	0.23
104	12-9	2321	10.75	0.22
104	12-10	1937	8.97	0.20
100	F2-5	1633	7.56	0.19
100	F2-8	1743	8.07	0.19
100	F3-1	1348	6.24	0.17
100	F3-11	1450	6.72	0.18
100	F4-4	1642	7.61	0.19
100	F5-8	1697	7.86	0.19
100	F5-10	1512	7.00	0.18
100	F6-2	1537	7.12	0.18
100	F7-7	1715	7.94	0.19
100	F9-1	1356	6.28	0.17
100	F9-4	1607	7.44	0.19
100	F9-10	1366	6.33	0.17
100	F10-7	1656	7.67	0.19
100	F11-11	1420	6.58	0.17
100	F12-2	1626	7.53	0.19
100	F12-5	1375	6.37	0.17
100	F13-7	1410	6.53	0.17
100	F14-11	1420	6.58	0.17
100	F15-2	1522	7.05	0.18
100	F16-10	1527	7.07	0.18
100	F18-1	1331	6.17	0.17
100	F18-5	1145	5.30	0.16
100	F18-8	1155	5.35	0.16
RAILS	F1-7	1411	6.54	0.17

T042.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RAILS	F2-4	1220	5.65	0.16
RAILS	F3-2	1295	6.00	0.17
RAILS	F6-2	1323	6.13	0.17
RAILS	F7-6	1420	6.58	0.17
RAILS	F9-2	1403	6.50	0.17
RAILS	F12-2	1875	8.69	0.20
RAILS	F12-6	1696	7.86	0.19
104	F2-2	1711	7.93	0.19
104	F3-3	1739	8.06	0.19
104	F4-2	1605	7.43	0.19
	NUMBER OF MEAS.		160	
	AVERAGE/SQRT(SUMSQ)		7.25	2.32
	STD. DEV.		1.38	
	MAXIMUM		11.53	
	MINIMUM		4.59	
	RANGE		6.93	

Building T042 Exposure Rate Measurements (Sorted by Exposure Rate)

T042.WS		SORTED BY EXPOSURE RATE		
ROOM	GRID	GAMMA	uR/h	
NUMBER	NAME	TOTAL	TOTAL	STD DEV
102	1-11	2489	11.53	0.23
102	2-11	2432	11.27	0.23
104	12-8	2375	11.00	0.23
104	12-5	2359	10.93	0.22
104	12-9	2321	10.75	0.22
102	1-10	2241	10.38	0.22
102	1-9	2232	10.34	0.22
102	1-4	2221	10.29	0.22
102	1-8	2198	10.18	0.22
102	1-5	2137	9.90	0.21
104	12-6	2105	9.75	0.21
102	1-7	2094	9.70	0.21
102	1-6	2080	9.63	0.21
104	12-7	2073	9.60	0.21
104	11-9	2024	9.38	0.21
102	2-10	1954	9.05	0.20
103	4-10	1954	9.05	0.20
102	2-4	1937	8.97	0.20
104	12-10	1937	8.97	0.20
101 MID	4-1	1898	8.79	0.20
102	2-5	1883	8.72	0.20
103	3-10	1875	8.69	0.20
RAILS	F12-2	1875	8.69	0.20
104	11-6	1869	8.66	0.20
102	3-1	1850	8.57	0.20
104	11-8	1832	8.49	0.20
103	8-4	1806	8.37	0.20
102	2-3	1804	8.36	0.20
102	1-1	1801	8.34	0.20
103	8-3	1743	8.07	0.19
100	F2-8	1743	8.07	0.19
104	11-10	1739	8.06	0.19
104	F3-3	1739	8.06	0.19
104	11-10	1727	8.00	0.19
104	11-10	1727	8.00	0.19
103	8-5	1715	7.94	0.19
100	F7-7	1715	7.94	0.19
104	11-3	1711	7.93	0.19
104	F2-2	1711	7.93	0.19
103	5-10	1698	7.87	0.19
103	9-4	1697	7.86	0.19
100	F5-8	1697	7.86	0.19
101 NW	4-1	1696	7.86	0.19
RAILS	F12-6	1696	7.86	0.19
102	2-1	1674	7.75	0.19
102	2-6	1666	7.72	0.19
103	8-6	1656	7.67	0.19
100	F10-7	1656	7.67	0.19
102	1-2	1651	7.65	0.19
102	2-7	1647	7.63	0.19

T042.WS

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
		SORTED BY EXPOSURE RATE		
103	7-4	1642	7.61	0.19
100	F4-4	1642	7.61	0.19
103	9-5	1636	7.58	0.19
103	7-3	1633	7.56	0.19
100	F2-5	1633	7.56	0.19
103	6-7	1626	7.53	0.19
100	F12-2	1626	7.53	0.19
102	2-2	1625	7.53	0.19
102	3-2	1618	7.49	0.19
103	7-6	1607	7.44	0.19
100	F9-4	1607	7.44	0.19
103	6-6	1605	7.43	0.19
103	6-3	1605	7.43	0.19
104	11-4	1605	7.43	0.19
101 SW	4-1	1605	7.43	0.19
104	F4-2	1605	7.43	0.19
102	2-9	1602	7.42	0.19
104	11-10	1601	7.42	0.19
103	9-6	1587	7.35	0.18
103	7-5	1580	7.32	0.18
103	8-3	1580	7.32	0.18
103	6-4	1570	7.27	0.18
101 ENTRY	4-2	1568	7.26	0.18
104	11-7	1564	7.24	0.18
103	4-9	1560	7.23	0.18
103	6-10	1554	7.20	0.18
101 ENTRY	4-2	1547	7.17	0.18
103	5-9	1544	7.15	0.18
103	8-7	1539	7.13	0.18
103	6-5	1537	7.12	0.18
100	F6-2	1537	7.12	0.18
103	6-8	1536	7.11	0.18
103	10-9	1527	7.07	0.18
100	F16-10	1527	7.07	0.18
103	7-10	1524	7.06	0.18
103	6-9	1522	7.05	0.18
100	F15-2	1522	7.05	0.18
103	5-9	1514	7.01	0.18
103	10-4	1512	7.00	0.18
100	F5-10	1512	7.00	0.18
103	7-9	1487	6.89	0.18
103	4-2	1480	6.86	0.18
103	10-5	1478	6.85	0.18
103	7-8	1477	6.84	0.18
104	11-5	1476	6.84	0.18
101A SHWR	5-1	1468	6.80	0.18
104	11-5	1453	6.73	0.18
104	11-5	1450	6.72	0.18
103	10-3	1450	6.72	0.18
100	F3-11	1450	6.72	0.18

T042.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
103	3-9	1446	6.70	0.18
103	5-8	1421	6.58	0.17
103	9-3	1420	6.58	0.17
103	10-8	1420	6.58	0.17
100	F11-11	1420	6.58	0.17
100	F14-11	1420	6.58	0.17
RAILS	F7-6	1420	6.58	0.17
103	5-7	1420	6.58	0.17
103	10-10	1418	6.57	0.17
103	5-5	1411	6.54	0.17
RAILS	F1-7	1411	6.54	0.17
103	8-8	1410	6.53	0.17
100	F13-7	1410	6.53	0.17
103	9-7	1404	6.50	0.17
RAILS	F9-2	1403	6.50	0.17
103	3-8	1403	6.50	0.17
103	9-8	1390	6.44	0.17
102	2-8	1379	6.39	0.17
103	7-7	1375	6.37	0.17
100	F12-5	1375	6.37	0.17
100	F9-10	1366	6.33	0.17
103	10-6	1366	6.33	0.17
103	5-4	1359	6.29	0.17
103	5-6	1356	6.28	0.17
100	F9-1	1356	6.28	0.17
100	F3-1	1348	6.24	0.17
103	5-3	1348	6.24	0.17
103	3-3	1347	6.24	0.17
103	3-2	1337	6.19	0.17
103	6-10	1331	6.17	0.17
100	F18-1	1331	6.17	0.17
RAILS	F6-2	1323	6.13	0.17
103	3-7	1323	6.13	0.17
101A DOOR	5-1	1309	6.06	0.17
102	1-3	1301	6.03	0.17
103	3-6	1300	6.02	0.17
RAILS	F3-2	1295	6.00	0.17
103	3-5	1295	6.00	0.17
103	6-3	1288	5.97	0.17
103	10-6	1266	5.86	0.16
103	4-8	1246	5.77	0.16
RAILS	F2-4	1220	5.65	0.16
103	4-5	1220	5.65	0.16
103	4-4	1196	5.54	0.16
103	5-4	1177	5.45	0.16
103	5-3	1165	5.40	0.16
100	F18-8	1155	5.35	0.16
103	9-10	1155	5.35	0.16
103	4-3	1146	5.31	0.16
100	F18-5	1145	5.30	0.16

T042.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
103	8-10	1145	5.30	0.16
103	3-4	1133	5.25	0.16
101A DRAN	5-2	1128	5.22	0.16
103	5-2	1115	5.16	0.15
103	8-9	1091	5.05	0.15
103	10-6	1088	5.04	0.15
103	10-7	1088	5.04	0.15
103	10-5	1067	4.94	0.15
103	10-7	1066	4.94	0.15
103	10-6	992	4.59	0.15

NUMBER OF MEAS.	160	
AVERAGE/SQRT(SUMSQ)	7.25	2.32
STD. DEV.	1.38	
MAXIMUM	11.53	
MINIMUM	4.59	
RANGE	6.93	

Building T042 Alpha/Beta Radioactivity Measurements

T042.WS		<---- ALPHA					---->	<---- BETA			----
ROOM	GRID	DPM/100CM2						DPM/100CM2			
NUMBER	NAME	TOTAL	STD DEV	MAX	STD DEV	REM	STD DEV	TOTAL	STD DEV	REM	STD DEV
100	F2-5	6.0	5.2	0	0	1.1	1.2	608	116	-2.2	3.4
100	F2-8	-0.7	3.0			-0.4	0.5	503	99	4.8	4.2
100	F3-1	2.1	3.6			-0.4	0.5	473	99	2.2	3.9
100	F3-11	5.0	4.2			-0.4	0.5	925	106	6.6	4.4
100	F4-4	0.0	4.3			1.9	1.4	1176	126	2.2	3.9
100	F5-8	10.6	5.9			-0.4	0.5	916	122	2.2	3.9
100	F5-10	7.9	4.6			-0.4	0.5	898	106	-0.4	3.6
100	F6-2	7.9	4.6			-0.4	0.5	864	105	-4.8	3.0
100	F7-7	5.0	4.2			-0.4	0.5	830	105	2.2	3.9
100	F9-1	-1.5	4.0			-0.4	0.5	320	111	-2.2	3.4
100	F9-4	4.5	5.0			0.4	0.9	816	120	1.3	3.8
100	F9-10	2.1	3.6			1.1	1.2	823	105	4.0	4.1
100	F10-7	9.3	4.8			-0.4	0.5	986	107	-0.4	3.6
100	F11-11	6.4	4.4			0.4	0.9	819	105	0.4	3.7
100	F12-2	3.0	4.8			1.1	1.2	1172	126	3.1	4.0
100	F12-5	4.5	5.0			0.4	0.9	1052	124	-0.4	3.6
100	F13-7	3.0	4.8			0.4	0.9	932	122	0.4	3.7
100	F14-11	6.0	5.2			-0.4	0.5	972	123	4.0	4.1
100	F15-2	7.6	5.5			-0.4	0.5	1088	124	5.7	4.3
100	F16-10	0.0	4.3			0.4	0.9	1200	126	2.2	3.9
100	F18-1	9.1	5.7			1.9	1.4	340	112	-1.3	3.5
100	F18-5	4.5	5.0			-0.4	0.5	288	111	7.5	4.4
100	F18-8	6.0	5.2			-0.4	0.5	328	112	1.3	3.8
RAILS	F1-7	5.6	4.8			0.4	0.9	525	98	-1.3	3.5
RAILS	F2-4	0.0	4.0			0.4	0.9	571	99	-0.4	3.6
RAILS	F3-2	1.4	4.2			0.4	0.9	749	102	0.4	3.7
RAILS	F6-2	0.0	4.0			-0.4	0.5	696	101	-0.4	3.6
RAILS	F7-6	2.8	4.4			-0.4	0.5	340	95	4.8	4.2
RAILS	F9-2	1.4	4.2			-0.4	0.5	703	101	1.3	3.8
RAILS	F12-2	1.4	4.2			-0.4	0.5	723	101	-0.4	3.6
RAILS	F12-6	2.8	4.4			1.1	1.2	683	101	-1.3	3.5
104	F2-2	4.2	4.6			1.1	1.2	974	105	11.0	4.8
104	F3-3	-2.8	3.4			1.1	1.2	1033	106	1.3	3.8
104	F4-2	12.6	5.8			0.4	0.9	1030	106	3.1	4.0
		34		NUMBER OF MEAS.		34		34		34	
		4.06	26.86	AVERAGE/SQRT(SUMSQ)		0.22	4.91	775.09	641.40	1.66	22.30
		3.62		STD. DEV.		0.70		267.98		3.15	
		12.60		MAXIMUM		1.85		1200.00		11.00	
		-2.80		MINIMUM		-0.37		288.00		-4.84	
		15.40		RANGE		2.22		912.00		15.84	

Building T042 Removable Alpha/Beta Activity Around Glove Box

SPECIAL SMEAR RM 100 (T042.WS)	ALPHA REMOVABLE (dpm/100cm2) VALUE	STD DEV	BETA REMOVABLE (dpm/100cm2) VALUE	STD DEV
PLATFORM FLOOR	-0.4	0.5	11.0	4.8
BELOW GLOVE BOX	3.3	1.7	15.4	5.2
BELOW GLOVE BOX	-0.4	0.5	-1.3	3.5
OPENING OF GLOVE BOX	1.1	1.2	6.6	4.4
BELOW GLOVE BOX	4.8	2.0	21.6	5.7
BELOW GLOVE BOX	2.6	1.6	7.5	4.4
FRONT OF GLOVE BOX	1.9	1.4	1.3	3.8
BEHIND GLOVE BOX	-0.4	0.5	3.1	4.0
EXTERIOR GLOVE BOX	-0.4	0.5	4.8	4.2
GLOVE BOX WINDOE (R)	1.1	1.2	2.2	3.9
GLOVE BOX BEHIND CHA	1.1	1.2	4.8	4.2
CAPITAL W. UNIT	-0.4	0.5	-4.0	3.1
NUMBER OF MEAS.	12		12	
AVERAGE/SQRT(SUMSQ)	1.17	4.12	6.09	14.91
STD. DEV.	1.71		7.12	
MAXIMUM	4.81		21.56	
MIMIMUM	-0.37		-3.96	
RANGE	5.18		25.52	

C.3 Building T027 Exposure Rate Measurements (Sorted by Location)

T027.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
HIGH BAY	1-1	1706	7.90	0.19
HIGH BAY	1-1	1770	8.20	0.19
HIGH BAY	1-2	1834	8.50	0.20
HIGH BAY	1-3	1627	7.54	0.19
HIGH BAY	1-5	1504	6.97	0.18
HIGH BAY	2-1	1894	8.77	0.20
HIGH BAY	2-2	2076	9.62	0.21
HIGH BAY	2-3	2321	10.75	0.22
HIGH BAY	2-5	1554	7.20	0.18
HIGH BAY	3-1	1821	8.43	0.20
HIGH BAY	3-2	2295	10.63	0.22
HIGH BAY	3-3	2294	10.63	0.22
HIGH BAY	3-4	1961	9.08	0.21
HIGH BAY	3-5	1719	7.96	0.19
HIGH BAY	4-1	1962	9.09	0.21
HIGH BAY	4-2	2786	12.90	0.24
HIGH BAY	4-4	2533	11.73	0.23
HIGH BAY	5-2	2446	11.33	0.23
HIGH BAY	5-5	2157	9.99	0.22
HIGH BAY	6-1	1962	9.09	0.21
HIGH BAY	6-3	2410	11.16	0.23
HIGH BAY	6-5	2444	11.32	0.23
HIGH BAY	7-2	1856	8.60	0.20
HIGH BAY	7-4	2284	10.58	0.22
HIGH BAY	8-1	1925	8.92	0.20
HIGH BAY	8-4	1864	8.63	0.20
HIGH BAY	8-5	1867	8.65	0.20
HIGH BAY	9-1	2161	10.01	0.22
HIGH BAY	9-2	2266	10.50	0.22
HIGH BAY	9-4	1959	9.07	0.21
HIGH BAY	9-5	1973	9.14	0.21
HIGH BAY	10-1	1949	9.03	0.20
HIGH BAY	10-2	2241	10.38	0.22
HIGH BAY	10-3	2425	11.23	0.23
HIGH BAY	10-4	2293	10.62	0.22
HIGH BAY	10-5	2096	9.71	0.21
118	1-1	3793	17.57	0.29
118	1-2	3869	17.92	0.29
118	1-3	4351	20.15	0.31
118	1-3	3617	16.75	0.28
118	1-4	4195	19.43	0.30
118	1-4	4200	19.45	0.30
118	1-5	4064	18.82	0.30
118	1-5	3777	17.50	0.28
118	1-6	3647	16.89	0.28
118	1-7	3689	17.09	0.28
118	1-9	2731	12.65	0.24
118	2-1	3177	14.72	0.26
118	2-2	3856	17.86	0.29
118	2-3	3961	18.35	0.29

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T027.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
118	2-4	4045	18.74	0.29
118	2-5	3553	16.46	0.28
118	2-6	3304	15.30	0.27
118	2-7	2865	13.27	0.25
118	2-8	2926	13.55	0.25
118	2-9	2837	13.14	0.25
118	3-1	3613	16.74	0.28
118	3-2	3252	15.06	0.26
118	3-3	3705	17.16	0.28
118	3-4	3522	16.31	0.27
118	3-5	3262	15.11	0.26
118	3-6	2961	13.72	0.25
118	3-8	2460	11.39	0.23
118	3-9	2189	10.14	0.22
118	4-1	3627	16.80	0.28
118	4-2	3722	17.24	0.28
118	4-4	3555	16.47	0.28
118	4-5	3008	13.93	0.25
118	4-6	2810	13.02	0.25
118	4-7	2833	13.12	0.25
118	4-8	2965	13.73	0.25
118	4-9	2720	12.60	0.24
118 FENCE	1-1	4084	18.92	0.30
118 FENCE	1-2	3942	18.26	0.29
118 FENCE	1-3	3579	16.58	0.28
118 FENCE	2-1	3417	15.83	0.27
118 FENCE	2-2	3764	17.43	0.28
118 FENCE	2-3	3369	15.61	0.27
118 FENCE	2-4	3425	15.86	0.27
118 FENCE	2-5	3128	14.49	0.26
118 FENCE	4-1	3830	17.74	0.29
118 FENCE	4-2	3850	17.83	0.29
118 FENCE	4-3	4059	18.80	0.30
118 FENCE	4-4	3892	18.03	0.29
118 FENCE	4-5	3758	17.41	0.28

NUMBER OF MEAS.	85	
AVERAGE/SQRT(SUMSQ)	13.35	2.29
STD. DEV.	3.81	
MAXIMUM	20.15	
MIMIMUM	6.97	
RANGE	13.19	

NOTES: HIGH BAY IS ON EAST SIDE AWAY FROM RMDF READINGS TAKEN EVERY 2-M SQUARE. NOTICED DIFFERENCE OF 3 uR/h WITH DOOR OPEN VS. CLOSED IN RM118 (RMDF) ROOM 118 HAS A FENCED-IN STORAGE AREA

Building T027 Exposure Rate Measurements (Sorted by Exposure Rate)

T027.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
118	1-3	4351	20.15	0.31
118	1-4	4200	19.45	0.30
118	1-4	4195	19.43	0.30
118 FENCE	1-1	4084	18.92	0.30
118	1-5	4064	18.82	0.30
118 FENCE	4-3	4059	18.80	0.30
118	2-4	4045	18.74	0.29
118	2-3	3961	18.35	0.29
118 FENCE	1-2	3942	18.26	0.29
118 FENCE	4-4	3892	18.03	0.29
118	1-2	3869	17.92	0.29
118	2-2	3856	17.86	0.29
118 FENCE	4-2	3850	17.83	0.29
118 FENCE	4-1	3830	17.74	0.29
118	1-1	3793	17.57	0.29
118	1-5	3777	17.50	0.28
118 FENCE	2-2	3764	17.43	0.28
118 FENCE	4-5	3758	17.41	0.28
118	4-2	3722	17.24	0.28
118	3-3	3705	17.16	0.28
118	1-7	3689	17.09	0.28
118	1-6	3647	16.89	0.28
118	4-1	3627	16.80	0.28
118	1-3	3617	16.75	0.28
118	3-1	3613	16.74	0.28
118 FENCE	1-3	3579	16.58	0.28
118	4-4	3555	16.47	0.28
118	2-5	3553	16.46	0.28
118	3-4	3522	16.31	0.27
118 FENCE	2-4	3425	15.86	0.27
118 FENCE	2-1	3417	15.83	0.27
118 FENCE	2-3	3369	15.61	0.27
118	2-6	3304	15.30	0.27
118	3-5	3262	15.11	0.26
118	3-2	3252	15.06	0.26
118	2-1	3177	14.72	0.26
118 FENCE	2-5	3128	14.49	0.26
118	4-5	3008	13.93	0.25
118	4-8	2965	13.73	0.25
118	3-6	2961	13.72	0.25
118	2-8	2926	13.55	0.25
118	2-7	2865	13.27	0.25
118	2-9	2837	13.14	0.25
118	4-7	2833	13.12	0.25
118	4-6	2810	13.02	0.25
HIGH BAY	4-2	2786	12.90	0.24
118	1-9	2731	12.65	0.24
118	4-9	2720	12.60	0.24
HIGH BAY	4-4	2533	11.73	0.23
118	3-8	2460	11.39	0.23

T027.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
HIGH BAY	5-2	2446	11.33	0.23
HIGH BAY	6-5	2444	11.32	0.23
HIGH BAY	10-3	2425	11.23	0.23
HIGH BAY	6-3	2410	11.16	0.23
HIGH BAY	2-3	2321	10.75	0.22
HIGH BAY	3-2	2295	10.63	0.22
HIGH BAY	3-3	2294	10.63	0.22
HIGH BAY	10-4	2293	10.62	0.22
HIGH BAY	7-4	2284	10.58	0.22
HIGH BAY	9-2	2266	10.50	0.22
HIGH BAY	10-2	2241	10.38	0.22
118	3-9	2189	10.14	0.22
HIGH BAY	9-1	2161	10.01	0.22
HIGH BAY	5-5	2157	9.99	0.22
HIGH BAY	10-5	2096	9.71	0.21
HIGH BAY	2-2	2076	9.62	0.21
HIGH BAY	9-5	1973	9.14	0.21
HIGH BAY	4-1	1962	9.09	0.21
HIGH BAY	6-1	1962	9.09	0.21
HIGH BAY	3-4	1961	9.08	0.21
HIGH BAY	9-4	1959	9.07	0.21
HIGH BAY	10-1	1949	9.03	0.20
HIGH BAY	8-1	1925	8.92	0.20
HIGH BAY	2-1	1894	8.77	0.20
HIGH BAY	8-5	1867	8.65	0.20
HIGH BAY	8-4	1864	8.63	0.20
HIGH BAY	7-2	1856	8.60	0.20
HIGH BAY	1-2	1834	8.50	0.20
HIGH BAY	3-1	1821	8.43	0.20
HIGH BAY	1-1	1770	8.20	0.19
HIGH BAY	3-5	1719	7.96	0.19
HIGH BAY	1-1	1706	7.90	0.19
HIGH BAY	1-3	1627	7.54	0.19
HIGH BAY	2-5	1554	7.20	0.18
HIGH BAY	1-5	1504	6.97	0.18

NUMBER OF MEAS.	85	
AVERAGE/SQRT(SUMSQ)	13.35	2.29
STD. DEV.	3.81	
MAXIMUM	20.15	
MIMIMUM	6.97	
RANGE	13.19	

NOTES: HIGH BAY IS ON EAST SIDE AWAY FROM RMDF
READINGS TAKEN EVERY 2-M SQUARE. NOTICED
DIFFERENCE OF 3 uR/h WITH DOOR OPEN VS.
CLOSED IN RM118 (RMDF) ROOM 118 HAS A
FENCED-IN STORAGE AREA

C.4 Building T032 Exposure Rate Measurements (Sorted by Location)

T032.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
102	2-4	1322	6.12	0.17
102	2-6	1369	6.34	0.17
102	2-8	1462	6.77	0.18
102	2-9	1231	5.70	0.16
102	3-4	1399	6.48	0.17
102	3-5	1160	5.37	0.16
102	3-6	1262	5.85	0.16
102	3-7	1282	5.94	0.17
102	3-8	1478	6.85	0.18
102	3-9	1580	7.32	0.18
102	4-4	1399	6.48	0.17
102	4-5	1449	6.71	0.18
102	4-6	1338	6.20	0.17
102	4-7	1454	6.73	0.18
102	4-9	1460	6.76	0.18
102	5-3	1867	8.65	0.20
102	5-4	1742	8.07	0.19
102	5-5	1140	5.28	0.16
102	5-6	1496	6.93	0.18
102	5-7	1492	6.91	0.18
102	5-8	1424	6.60	0.17
102	5-9	1429	6.62	0.18
102	6-3	1632	7.56	0.19
102	6-4	1784	8.26	0.20
102	6-5	1323	6.13	0.17
102	6-6	1514	7.01	0.18
102	6-7	1261	5.84	0.16
102	6-8	1474	6.83	0.18
102	6-9	1631	7.55	0.19
102	7-4	1628	7.54	0.19
102	7-5	1550	7.18	0.18
102	7-6	1362	6.31	0.17
102	7-7	1585	7.34	0.18
102	7-9	1717	7.95	0.19
102	8-3	1545	7.16	0.18
102	8-5	1527	7.07	0.18
102	8-6	1281	5.93	0.17
102	8-7	1570	7.27	0.18
100	8-9	1574	7.29	0.18
W. DOORWAY	2-2	1787	8.28	0.20
W. DOORWAY	2-2	1783	8.26	0.20
N. CANOPY	1-3	1542	7.14	0.18
N. CANOPY	1-4	1308	6.06	0.17
N. CANOPY	1-6	1928	8.93	0.20
N. CANOPY	1-7	2006	9.29	0.21
N. CANOPY	1-8	1848	8.56	0.20
N. CANOPY	1-9	1980	9.17	0.21
W. PIT	2-1	2237	10.36	0.22
W. PIT	3-1	2111	9.78	0.21
W. PIT	4-1	2166	10.03	0.22

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T032.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
E. CANOPY	3-10	1794	8.31	0.20
E. CANOPY	5-10	2123	9.83	0.21
E. CANOPY	7-10	1914	8.87	0.20
W. SLAB	5-2	2244	10.39	0.22
W. DOOR	6-2	2378	11.01	0.23
W. SLAB	8-2	2528	11.71	0.23
S. CANOPY	9-3	2065	9.57	0.21
S. CANOPY	9-4	1620	7.50	0.19
S. CANOPY	9-5	1439	6.67	0.18
S. CANOPY	9-6	1519	7.04	0.18
S. CANOPY	9-7	1670	7.74	0.19
S. CANOPY	9-8	2073	9.60	0.21
S. CANOPY	9-9	2210	10.24	0.22
	NUMBER OF MEAS.		63	
	AVERAGE/SQRT(SUMSQ)		7.61	1.49
	STD. DEV.		1.49	
	MAXIMUM		11.71	
	MIMIMUM		5.28	
	RANGE		6.43	

Building T032 Exposure Rate Measurements (Sorted by Exposure Rate)

T032.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
W. SLAB	8-2	2528	11.71	0.23
W. DOOR	6-2	2378	11.01	0.23
W. SLAB	5-2	2244	10.39	0.22
W. PIT	2-1	2237	10.36	0.22
S. CANOPY	9-9	2210	10.24	0.22
W. PIT	4-1	2166	10.03	0.22
E. CANOPY	5-10	2123	9.83	0.21
W. PIT	3-1	2111	9.78	0.21
S. CANOPY	9-8	2073	9.60	0.21
S. CANOPY	9-3	2065	9.57	0.21
N. CANOPY	1-7	2006	9.29	0.21
N. CANOPY	1-9	1980	9.17	0.21
N. CANOPY	1-6	1928	8.93	0.20
E. CANOPY	7-10	1914	8.87	0.20
102	5-3	1867	8.65	0.20
N. CANOPY	1-8	1848	8.56	0.20
E. CANOPY	3-10	1794	8.31	0.20
W. DOORWAY	2-2	1787	8.28	0.20
102	6-4	1784	8.26	0.20
W. DOORWAY	2-2	1783	8.26	0.20
102	5-4	1742	8.07	0.19
102	7-9	1717	7.95	0.19
S. CANOPY	9-7	1670	7.74	0.19
102	6-3	1632	7.56	0.19
102	6-9	1631	7.55	0.19
102	7-4	1628	7.54	0.19
S. CANOPY	9-4	1620	7.50	0.19
102	7-7	1585	7.34	0.18
102	3-9	1580	7.32	0.18
100	8-9	1574	7.29	0.18
102	8-7	1570	7.27	0.18
102	7-5	1550	7.18	0.18
102	8-3	1545	7.16	0.18
N. CANOPY	1-3	1542	7.14	0.18
102	8-5	1527	7.07	0.18
S. CANOPY	9-6	1519	7.04	0.18
102	6-6	1514	7.01	0.18
102	5-6	1496	6.93	0.18
102	5-7	1492	6.91	0.18
102	3-8	1478	6.85	0.18
102	6-8	1474	6.83	0.18
102	2-8	1462	6.77	0.18
102	4-9	1460	6.76	0.18
102	4-7	1454	6.73	0.18
102	4-5	1449	6.71	0.18
S. CANOPY	9-5	1439	6.67	0.18
102	5-9	1429	6.62	0.18
102	5-8	1424	6.60	0.17
102	4-4	1399	6.48	0.17
102	3-4	1399	6.48	0.17

(1 of 2)

T032.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
102	2-6	1369	6.34	0.17
102	7-6	1362	6.31	0.17
102	4-6	1338	6.20	0.17
102	6-5	1323	6.13	0.17
102	2-4	1322	6.12	0.17
N. CANOPY	1-4	1308	6.06	0.17
102	3-7	1282	5.94	0.17
102	8-6	1281	5.93	0.17
102	3-6	1262	5.85	0.16
102	6-7	1261	5.84	0.16
102	2-9	1231	5.70	0.16
102	3-5	1160	5.37	0.16
102	5-5	1140	5.28	0.16

NUMBER OF MEAS.	63	
AVERAGE/SQRT(SUMSQ)	7.61	1.49
STD. DEV.	1.49	
MAXIMUM	11.71	
MIMIMUM	5.28	
RANGE	6.43	

C.5 Building T025 Exposure Rate Measurements (Sorted by Location)

T025.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
HIGH BAY	1-1	2951	13.67	0.25
HIGH BAY	1-2	3210	14.87	0.26
HIGH BAY	1-3	2962	13.72	0.25
HIGH BAY	1-5	2946	13.65	0.25
HIGH BAY	1-6	3240	15.01	0.26
HIGH BAY	1-7	2981	13.81	0.25
HIGH BAY	1-8	2949	13.66	0.25
HIGH BAY	2-1	2555	11.83	0.23
HIGH BAY	2-2	2949	13.66	0.25
HIGH BAY	2-3	2350	10.89	0.22
HIGH BAY	2-5	2627	12.17	0.24
HIGH BAY	2-6	2995	13.87	0.25
HIGH BAY	2-7	3276	15.17	0.27
HIGH BAY	3-1	2742	12.70	0.24
HIGH BAY	3-2	3049	14.12	0.26
HIGH BAY	3-3	2407	11.15	0.23
HIGH BAY	3-5	2959	13.71	0.25
HIGH BAY	3-6	3325	15.40	0.27
HIGH BAY	3-7	2993	13.86	0.25
HIGH BAY	4-1	2742	12.70	0.24
HIGH BAY	4-2	2788	12.91	0.24
HIGH BAY	4-3	2540	11.77	0.23
HIGH BAY	4-4	3090	14.31	0.26
HIGH BAY	4-5	3013	13.96	0.25
HIGH BAY	4-6	3013	13.96	0.25
HIGH BAY	4-7	2577	11.94	0.24
HIGH BAY	5-1	2531	11.72	0.23
HIGH BAY	5-2	2487	11.52	0.23
HIGH BAY	5-3	2500	11.58	0.23
HIGH BAY	5-4	2975	13.78	0.25
HIGH BAY	5-5	2955	13.69	0.25
HIGH BAY	5-6	2626	12.16	0.24
HIGH BAY	6-1	2367	10.96	0.23
HIGH BAY	6-2	2132	9.88	0.21
HIGH BAY	6-3	1923	8.91	0.20
HIGH BAY	6-4	2175	10.07	0.22
HIGH BAY	6-5	2777	12.86	0.24
HIGH BAY	6-6	2785	12.90	0.24
HIGH BAY	7-4	2382	11.03	0.23
HIGH BAY	7-5	2180	10.10	0.22
HIGH BAY	7-6	2788	12.91	0.24
HIGH BAY	8-4	2580	11.95	0.24
HIGH BAY	8-5	2446	11.33	0.23
HIGH BAY	8-6	2360	10.93	0.23
HIGH BAY	9-4	2996	13.88	0.25
HIGH BAY	9-5	2426	11.24	0.23
HIGH BAY	9-6	2129	9.86	0.21
RM 102	1-1	2809	13.01	0.25
RM 102	1-2	2908	13.47	0.25
RM 102	1-3	2694	12.48	0.24

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T025.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
RM 102	2-1	2585	11.97	0.24
RM 102	2-2	2858	13.24	0.25
RM 102	2-3	2059	9.54	0.21
RM 102	2-4	2674	12.39	0.24
RM 102	3-1	2545	11.79	0.23
RM 102	3-2	2953	13.68	0.25
RM 102	3-3	2643	12.24	0.24
RM 102	3-4	2161	10.01	0.22
RM 102	4-1	2381	11.03	0.23
RM 102	4-2	2580	11.95	0.24
RM 102	4-3	2661	12.33	0.24
RM 102	4-4	2187	10.13	0.22
RM 102	5-4	2071	9.59	0.21
RM 102	6-4	1613	7.47	0.19
RM 102	7-4	1838	8.51	0.20
RM 105	1-2	1714	7.94	0.19
RM 105	1-3	2133	9.88	0.21
RM 105	1-4	1745	8.08	0.19
RM 105	1-5	1607	7.44	0.19
RM 105	2-1	1632	7.56	0.19
RM 105	2-3	1775	8.22	0.20
RM 105	2-5	1780	8.24	0.20
RM 105	3-1	1751	8.11	0.19
RM 105	3-2	1876	8.69	0.20
RM 105	3-3	1655	7.67	0.19
RM 105	3-4	1600	7.41	0.19
RM 105	3-5	1634	7.57	0.19
RM 105	4-1	1468	6.80	0.18
RM 105	4-2	1760	8.15	0.19
RM 105	4-3	1876	8.69	0.20
RM 105	4-4	1607	7.44	0.19
RM 105	4-5	1578	7.31	0.18
I	NUMBER OF MEAS.		82	
N	AVERAGE/SQRT(SUMSQ)		11.36	2.08
D	STD. DEV.		2.34	
O	MAXIMUM		15.40	
O	MINIMUM		6.80	
R	RANGE		8.60	
OUTSIDE	1-3	4972	23.03	0.33
OUTSIDE	1-5	4482	20.76	0.31
OUTSIDE	1-8	5701	26.41	0.35
OUTSIDE	1-11	5851	27.10	0.35
OUTSIDE	1-14	5460	25.29	0.34
OUTSIDE	1-17	5716	26.48	0.35
OUTSIDE	1-19	6028	27.92	0.36
OUTSIDE	2-2	4861	22.52	0.32
OUTSIDE	2-4	4892	22.66	0.32
OUTSIDE	2-6	5335	24.71	0.34

T025.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
OUTSIDE	2-9	5380	24.92	0.34
OUTSIDE	2-12	5372	24.88	0.34
OUTSIDE	2-16	5556	25.74	0.35
OUTSIDE	2-18	5540	25.66	0.34
OUTSIDE	2-20	5643	26.14	0.35
OUTSIDE	3-2	4710	21.82	0.32
OUTSIDE	3-4	4663	21.60	0.32
OUTSIDE	3-6	4854	22.48	0.32
OUTSIDE	3-9	5083	23.54	0.33
OUTSIDE	3-12	5361	24.83	0.34
OUTSIDE	3-14	5540	25.66	0.34
OUTSIDE	3-17	5562	25.76	0.35
OUTSIDE	3-19	5643	26.14	0.35
OUTSIDE	5-19	5185	24.02	0.33
OUTSIDE	5-20	5624	26.05	0.35
OUTSIDE	7-19	4786	22.17	0.32
OUTSIDE	7-20	4757	22.03	0.32
OUTSIDE	9-19	4786	22.17	0.32
OUTSIDE	9-20	4691	21.73	0.32
OUTSIDE	11-19	4744	21.97	0.32
OUTSIDE	11-20	4689	21.72	0.32
OUTSIDE	13-19	4290	19.87	0.30
OUTSIDE	13-20	4323	20.02	0.30

O	NUMBER OF MEAS.		33	
U	AVERAGE/SQRT(SUMSQ)		23.87	1.91
T	STD. DEV.		2.18	
S	MAXIMUM		27.92	
I	MINIMUM		19.87	
D	RANGE		8.05	
E				

T	NUMBER OF MEAS.		115	
O	AVERAGE/SQRT(SUMSQ)		14.95	2.82
T	STD. DEV.		6.13	
A	MAXIMUM		27.92	
L	MINIMUM		6.80	
	RANGE		21.12	

Building T025 Exposure Rate Measurements (Sorted by Exposure Rate)

T025.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
HIGH BAY	3-6	3325	15.40	0.27
HIGH BAY	2-7	3276	15.17	0.27
HIGH BAY	1-6	3240	15.01	0.26
HIGH BAY	1-2	3210	14.87	0.26
HIGH BAY	4-4	3090	14.31	0.26
HIGH BAY	3-2	3049	14.12	0.26
HIGH BAY	4-5	3013	13.96	0.25
HIGH BAY	4-6	3013	13.96	0.25
HIGH BAY	9-4	2996	13.88	0.25
HIGH BAY	2-6	2995	13.87	0.25
HIGH BAY	3-7	2993	13.86	0.25
HIGH BAY	1-7	2981	13.81	0.25
HIGH BAY	5-4	2975	13.78	0.25
HIGH BAY	1-3	2962	13.72	0.25
HIGH BAY	3-5	2959	13.71	0.25
HIGH BAY	5-5	2955	13.69	0.25
RM 102	3-2	2953	13.68	0.25
HIGH BAY	1-1	2951	13.67	0.25
HIGH BAY	1-8	2949	13.66	0.25
HIGH BAY	2-2	2949	13.66	0.25
HIGH BAY	1-5	2946	13.65	0.25
RM 102	1-2	2908	13.47	0.25
RM 102	2-2	2858	13.24	0.25
RM 102	1-1	2809	13.01	0.25
HIGH BAY	4-2	2788	12.91	0.24
HIGH BAY	7-6	2788	12.91	0.24
HIGH BAY	6-6	2785	12.90	0.24
HIGH BAY	6-5	2777	12.86	0.24
HIGH BAY	4-1	2742	12.70	0.24
HIGH BAY	3-1	2742	12.70	0.24
RM 102	1-3	2694	12.48	0.24
RM 102	2-4	2674	12.39	0.24
RM 102	4-3	2661	12.33	0.24
RM 102	3-3	2643	12.24	0.24
HIGH BAY	2-5	2627	12.17	0.24
HIGH BAY	5-6	2626	12.16	0.24
RM 102	2-1	2585	11.97	0.24
HIGH BAY	8-4	2580	11.95	0.24
RM 102	4-2	2580	11.95	0.24
HIGH BAY	4-7	2577	11.94	0.24
HIGH BAY	2-1	2555	11.83	0.23
RM 102	3-1	2545	11.79	0.23
HIGH BAY	4-3	2540	11.77	0.23
HIGH BAY	5-1	2531	11.72	0.23
HIGH BAY	5-3	2500	11.58	0.23
HIGH BAY	5-2	2487	11.52	0.23
HIGH BAY	8-5	2446	11.33	0.23
HIGH BAY	9-5	2426	11.24	0.23
HIGH BAY	3-3	2407	11.15	0.23
HIGH BAY	7-4	2382	11.03	0.23

(1 of 3)

T025.WS		SORTED BY EXPOSURE RATE		
ROOM	GRID	GAMMA	uR/h	
NUMBER	NAME	TOTAL	TOTAL	STD DEV
RM 102	4-1	2381	11.03	0.23
HIGH BAY	6-1	2367	10.96	0.23
HIGH BAY	8-6	2360	10.93	0.23
HIGH BAY	2-3	2350	10.89	0.22
RM 102	4-4	2187	10.13	0.22
HIGH BAY	7-5	2180	10.10	0.22
HIGH BAY	6-4	2175	10.07	0.22
RM 102	3-4	2161	10.01	0.22
RM 105	1-3	2133	9.88	0.21
HIGH BAY	6-2	2132	9.88	0.21
HIGH BAY	9-6	2129	9.86	0.21
RM 102	5-4	2071	9.59	0.21
RM 102	2-3	2059	9.54	0.21
HIGH BAY	6-3	1923	8.91	0.20
RM 105	3-2	1876	8.69	0.20
RM 105	4-3	1876	8.69	0.20
RM 102	7-4	1838	8.51	0.20
RM 105	2-5	1780	8.24	0.20
RM 105	2-3	1775	8.22	0.20
RM 105	4-2	1760	8.15	0.19
RM 105	3-1	1751	8.11	0.19
RM 105	1-4	1745	8.08	0.19
RM 105	1-2	1714	7.94	0.19
RM 105	3-3	1655	7.67	0.19
RM 105	3-5	1634	7.57	0.19
RM 105	2-1	1632	7.56	0.19
RM 102	6-4	1613	7.47	0.19
RM 105	1-5	1607	7.44	0.19
RM 105	4-4	1607	7.44	0.19
RM 105	3-4	1600	7.41	0.19
RM 105	4-5	1578	7.31	0.18
RM 105	4-1	1468	6.80	0.18
I	NUMBER OF MEAS.		82	
N	AVERAGE/SQRT(SUMSQ)		11.36	2.08
D	STD. DEV.		2.34	
O	MAXIMUM		15.40	
O	MINIMUM		6.80	
R	RANGE		8.60	
OUTSIDE	1-19	6028	27.92	0.36
OUTSIDE	1-11	5851	27.10	0.35
OUTSIDE	1-17	5716	26.48	0.35
OUTSIDE	1-8	5701	26.41	0.35
OUTSIDE	2-20	5643	26.14	0.35
OUTSIDE	3-19	5643	26.14	0.35
OUTSIDE	5-20	5624	26.05	0.35
OUTSIDE	3-17	5562	25.76	0.35
OUTSIDE	2-16	5556	25.74	0.35
OUTSIDE	2-18	5540	25.66	0.34

T025.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
OUTSIDE	3-14	5540	25.66	0.34
OUTSIDE	1-14	5460	25.29	0.34
OUTSIDE	2-9	5380	24.92	0.34
OUTSIDE	2-12	5372	24.88	0.34
OUTSIDE	3-12	5361	24.83	0.34
OUTSIDE	2-6	5335	24.71	0.34
OUTSIDE	5-19	5185	24.02	0.33
OUTSIDE	3-9	5083	23.54	0.33
OUTSIDE	1-3	4972	23.03	0.33
OUTSIDE	2-4	4892	22.66	0.32
OUTSIDE	2-2	4861	22.52	0.32
OUTSIDE	3-6	4854	22.48	0.32
OUTSIDE	7-19	4786	22.17	0.32
OUTSIDE	9-19	4786	22.17	0.32
OUTSIDE	7-20	4757	22.03	0.32
OUTSIDE	11-19	4744	21.97	0.32
OUTSIDE	3-2	4710	21.82	0.32
OUTSIDE	9-20	4691	21.73	0.32
OUTSIDE	11-20	4689	21.72	0.32
OUTSIDE	3-4	4663	21.60	0.32
OUTSIDE	1-5	4482	20.76	0.31
OUTSIDE	13-20	4323	20.02	0.30
OUTSIDE	13-19	4290	19.87	0.30
O	NUMBER OF MEAS.		33	
U	AVERAGE/SQRT(SUMSQ)		23.87	1.91
T	STD. DEV.		2.18	
S	MAXIMUM		27.92	
I	MINIMUM		19.87	
D	RANGE		8.05	
E				
T	NUMBER OF MEAS.		115	
O	AVERAGE/SQRT(SUMSQ)		14.95	2.82
T	STD. DEV.		6.13	
A	MAXIMUM		27.92	
L	MINIMUM		6.80	
	RANGE		21.12	

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APPENDIX D. SURVEYOR MAPS USED DURING RADIOLOGICAL SURVEY

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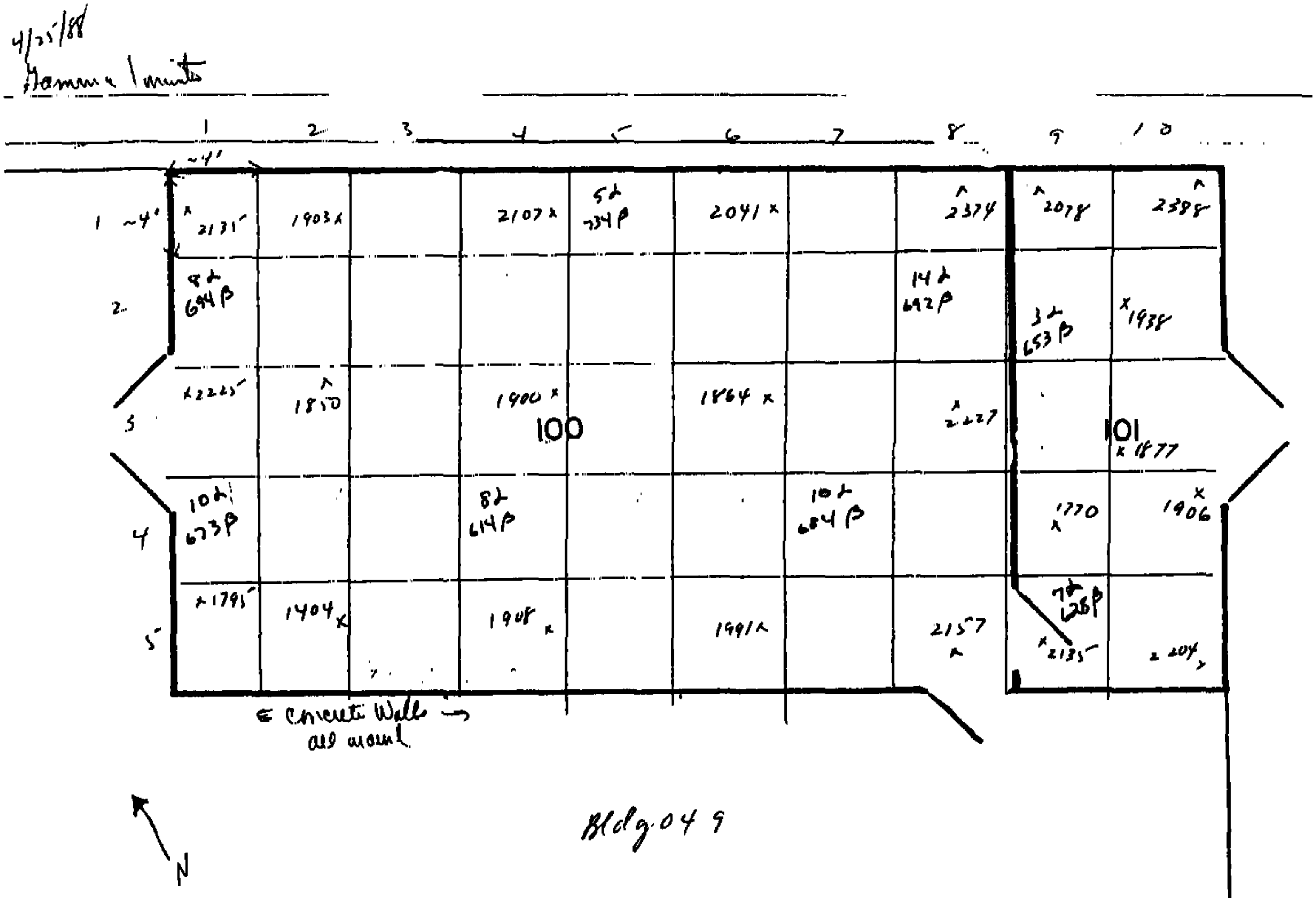
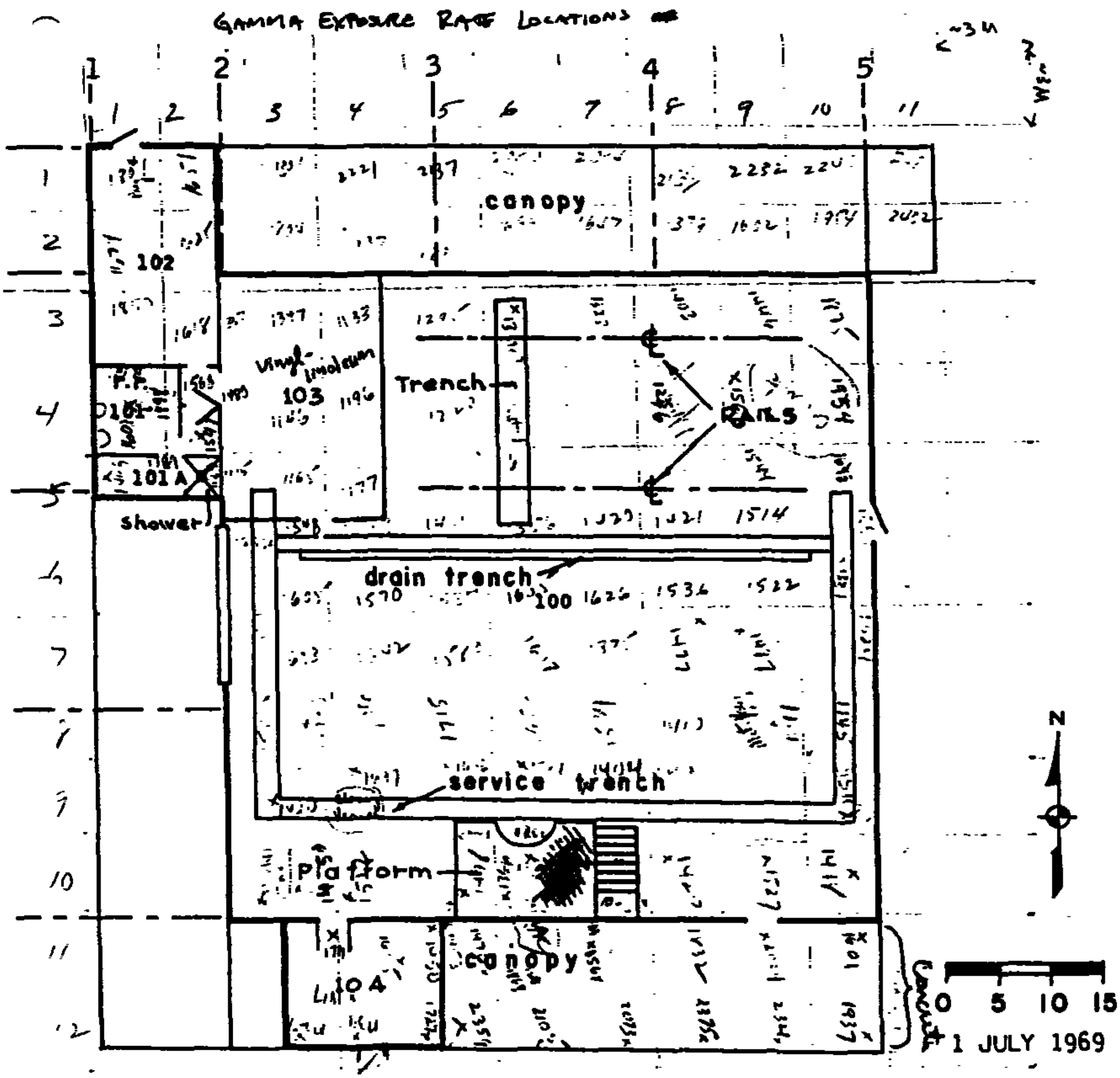


D.1 Building T049 Sampling Lot

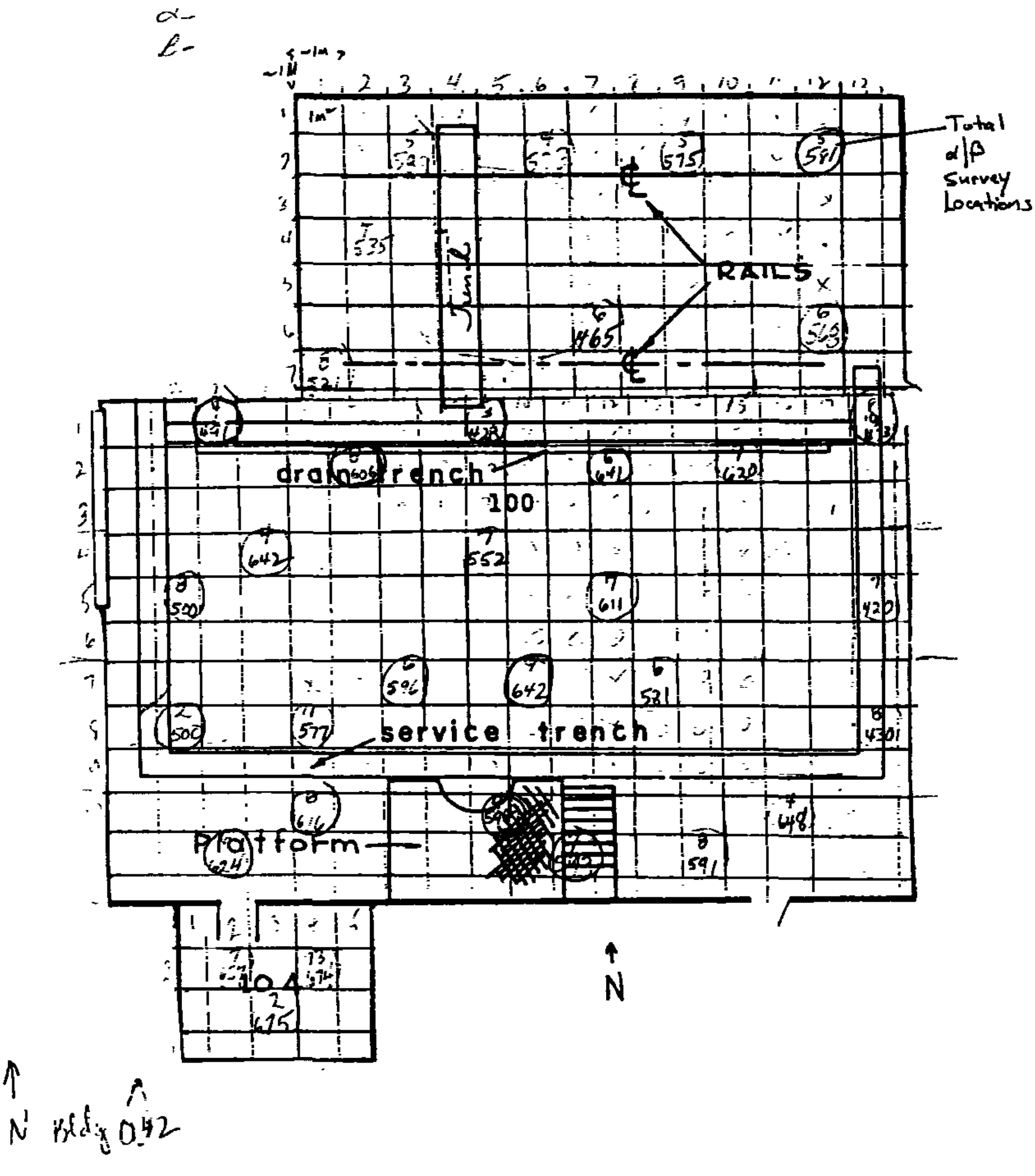
D.2 Building T042 Sampling Lot (Gamma Exposure Rate)

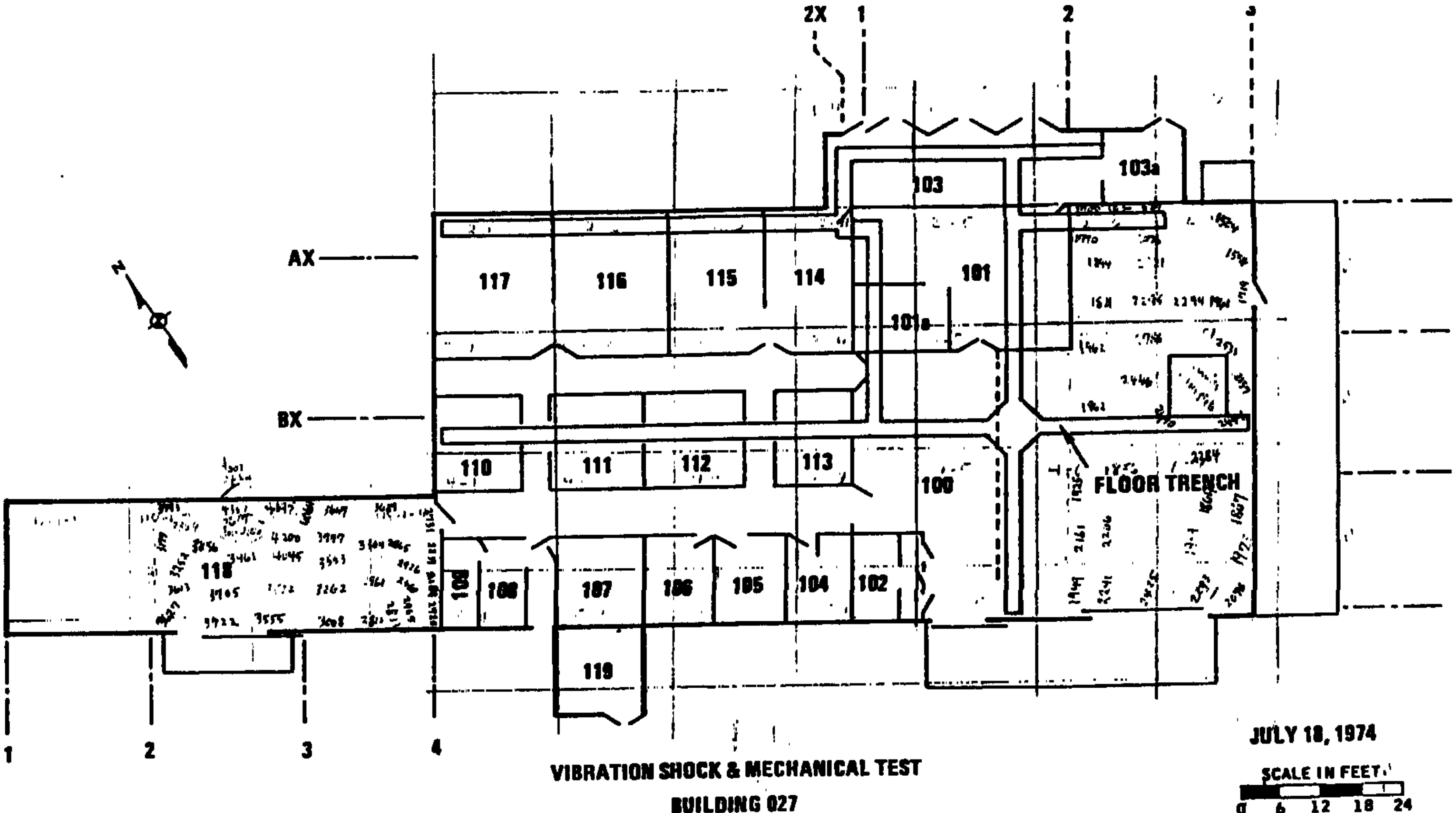


SHIELD CASTING FACILITY

BUILDING NO. 042

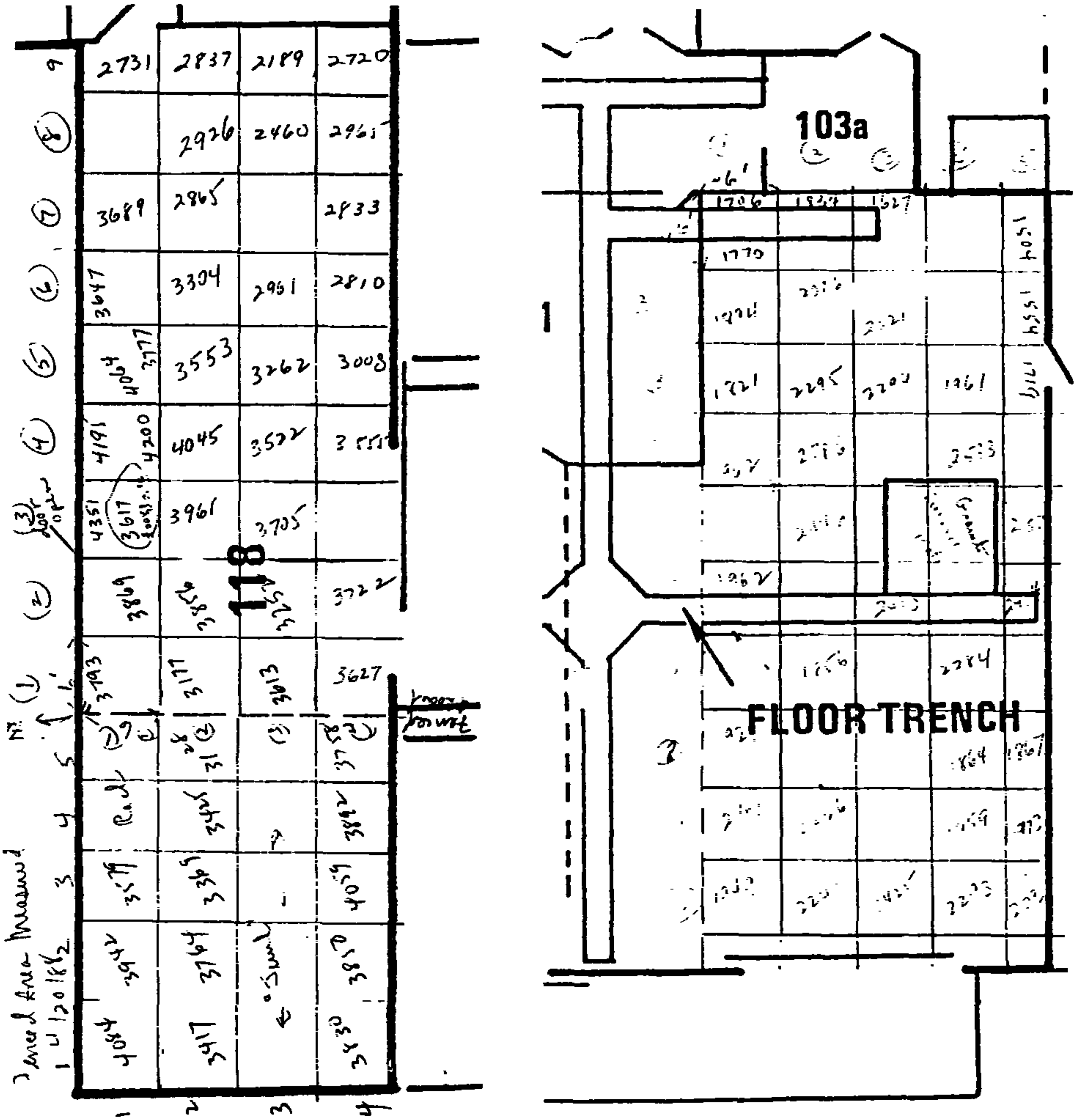
D.3 Building T042 Sampling Lot (Alpha/Beta Radioactivity)



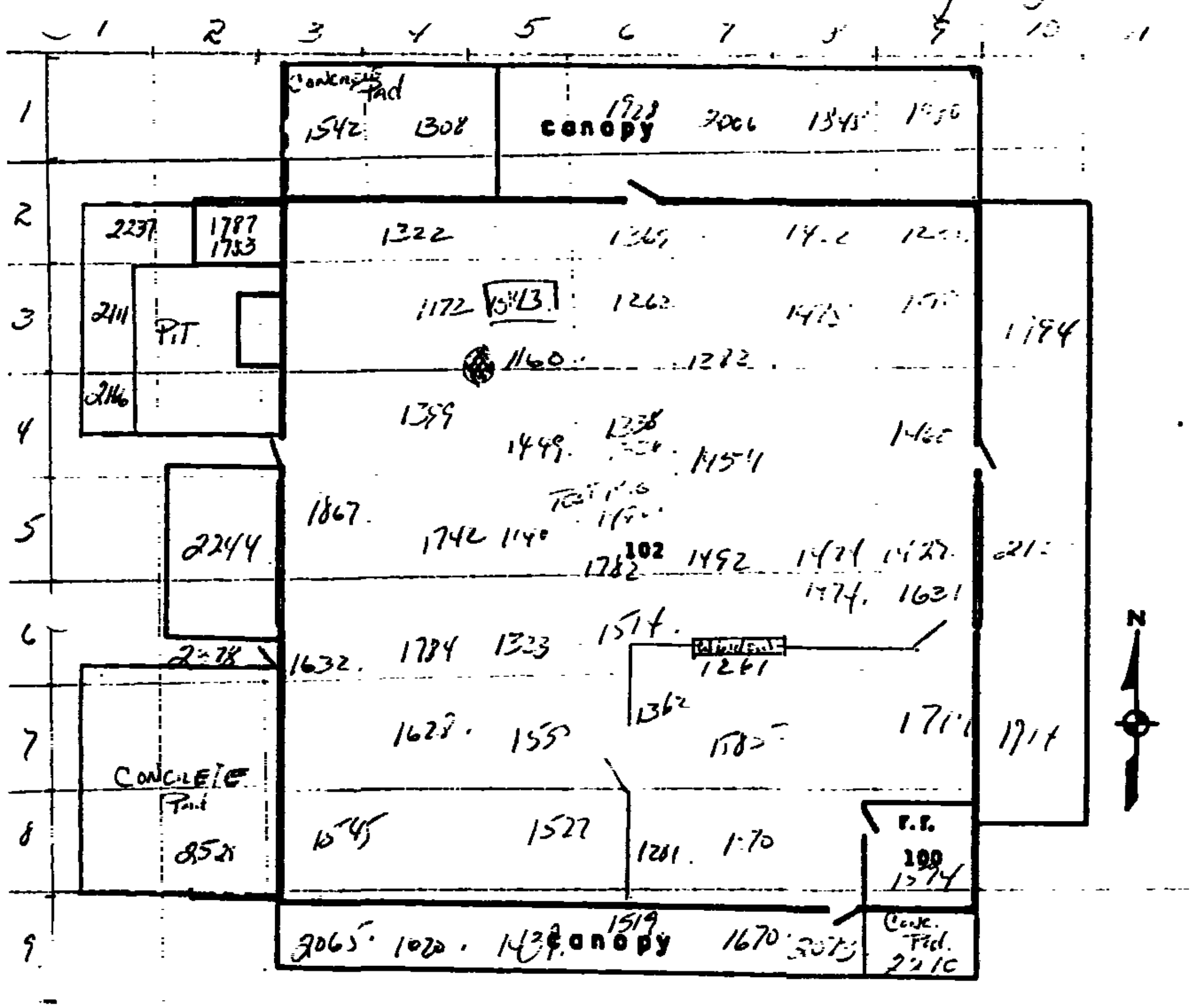


D.4 Building T027 Radiation Measurement Locations

D.5 Building T027 High Bay and Room 118



D.6 <u>Building T032</u>

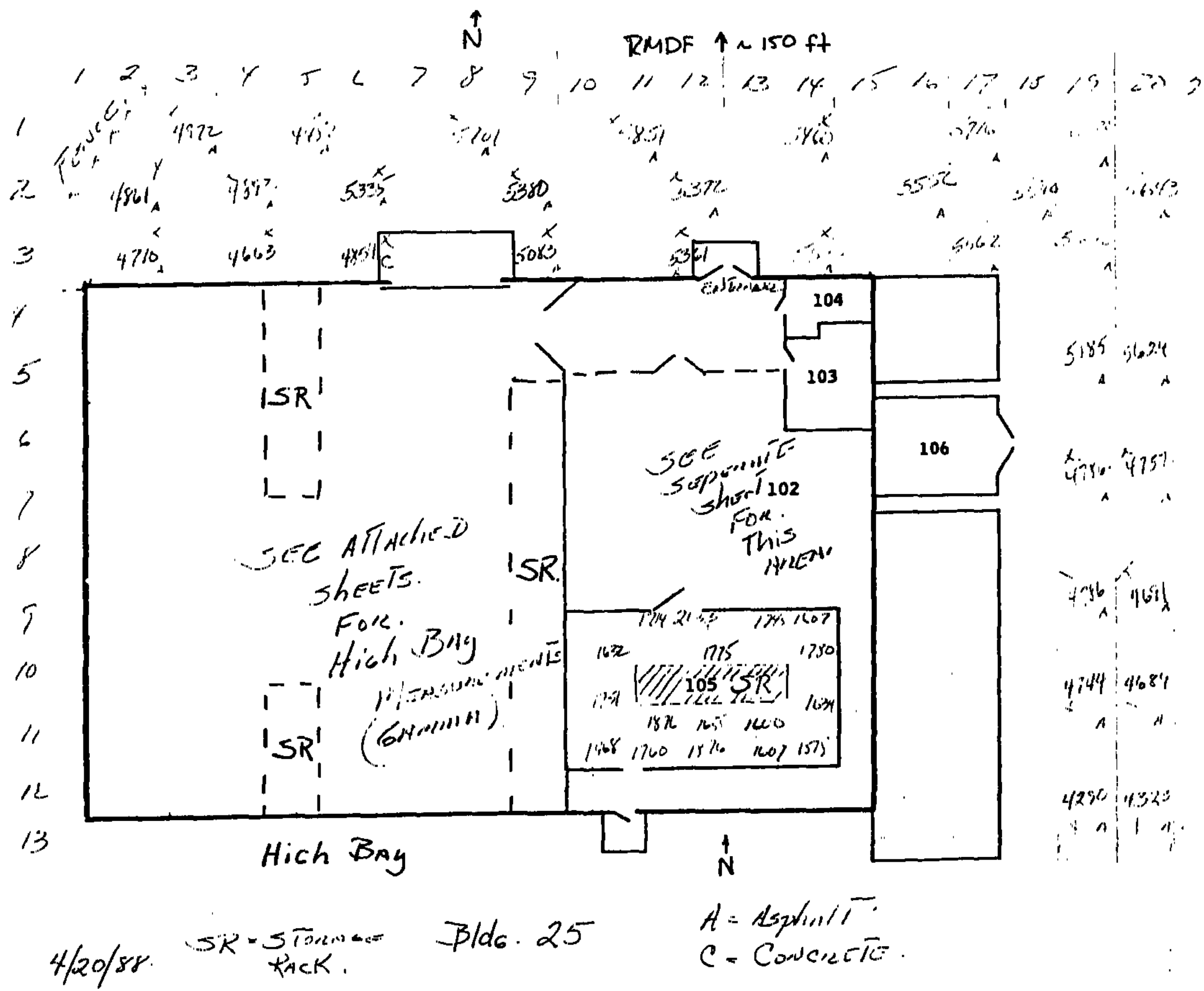


4/18/88 - Gamma

SPACE ENVIRONMENTAL TEST

BUILDING No. 032

353662



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D.7 Building T025 and Surrounding Area Layout

D.8 Building T025 (High Bay)

By WAM/PO.

North

	1	2	3	4	5	6	7	8
1	2951	Pullup Door. 3210	2962		2546	#3 3240	2981	Door way. 2949.
2	2555	#4 2549	2350 M	STORAGE RACK.	2627	2995	#2 3271	
3	2742	#6 3049	2407 M	(Metal Part.	2959	#1 3325	2993	Metal Parts
4	2742	2788	2540 M	#5 3090	#6 3013	#7 3013	2077 M	Rack
5	2531	2487	2500	2975	2955	2626	Metal Racks With Metal parts And Valves	
6	2367	2132 M	1923 M	2175	2777	2785		
7				2372	2180	2788.		
8			STORAGE	2580	2446	2360		
9	LARGE Metal Pipe pieces NO ACCESS		RACK (Metal parts.	#8 2996	2426	2129.		

Concrete Floor. Surface. (1 min Count) Inst #59000

Bldg T025 STORAGE AREA. High Bay.

4/14/88 1 min. [illegible] BK. 02532

D.9 Building T025 (Room 102)

↑ North

Main Entrance to Bldg.

To High Bay (Double Door) ⇐

	1	2	3	4
1	2809	2908	2684	Roof Room
2	2585	2858	2059	2674
3	2545	2553	2643	2161
4	2381	2580	2661	2187
5				2071
6				1613 m
7				1838 m

Bldg. T025 (Parts Room)

4/14/88
Surveyors
by J. Olsen + W. McCollum

Gamma
1 Min Count.
Bkg. 2532
Inst. # 596005

Gamma. Floor Measurements.
Room 102
Bldg. T025

m = Metal Surroundings.

4/14/88 Bkg. 2532.