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TITLE: "Radiological Survey of Buildings T373 and T375."

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ABSTRACT

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

1) Building T373;
2) Building T374;
3) Building T375; and
4) surrounding areas.

Building T373 was used for SNAP critical tests. Building T374 was used for testing liquid metal heat transfer loops. Building T375 was used as a control room for testing SNAP control rod assemblies. All facilities were cleared of SNAP components at the completion of the program. A radiological survey performed then cleared these facilities for non-nuclear use. These facilities are currently abandoned and dilapidated. The surrounding areas are mostly natural terrain and in certain locations cluttered with debris. No known contamination incidents occurred at any of these 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 areas. This plan resulted in over 400 gamma measurements. Throughout the course of this survey, further inspection and investigation because of increased exposure rates was not necessary. Smear samples collected inside Buildings T373 and T374 were analyzed to measure removable alpha/beta activity. Collection of smears in every 3-m square grid and in sinks,

drains, showers, exhaust systems, and filter plenums resulted in 213 samples. In those same locations, total beta surface activity was measured "for indication."

Results of this survey, analysis, and interpretation show that all locations are not contaminated with 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 topography changes), pass acceptance criteria for unrestricted use. Removable activity values analyzed in the same statistical manner also pass acceptance criteria for unrestricted use by a wide margin. Removable activity is statistically insignificant. Total beta surface activity measurements show No Detectable Activity. No further investigation is necessary in these locations.

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1.0 INTRODUCTION

Three facilities and surrounding fence-line areas 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. The outside areas which surround these facilities are primarily natural terrain and have been used for various functions: storing excess salvageable materials and scrap components; holding equipment; and possibly for storing drums and barrels. These facilities and areas supported AEC, ERDA, and DOE nuclear-related programs and include:

1. Building T373 (formerly SNAP Critical Facility);
2. Building T374; and
3. Building T375 (formerly a tower for testing SNAP control rod assemblies).

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 5.4.23, and 5.4.24).

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 on what is now the northern boundary of the Energy Technology Engineering Center (ETEC) area was used in the 1960s for developing, assembling, and testing SNAP reactors for the AEC. A few satellite facilities located outside of the ETEC area were used to support SNAP component testing. Facilities were used for critical testing SNAP reactors, testing various heat transfer loops, and testing control rod assemblies. These tests were performed in Buildings

T373, T374, and T375. These buildings and surrounding areas 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. T373, T374, and T375 are currently abandoned.

Residual radioactive material existing in these survey locations is not likely. No significant radioactivity releases from Building T373 are known to have occurred. Furthermore, when T373 was reassigned for non-nuclear use, a radiological survey was performed to ensure that the area was clean. It is not known for certain that radioactive material was handled at either Building T374 or T375. Because of its proximity to Building T373 (which was a critical facility), Building T374 may have been used as a support facility during critical testing. Consequently, activation foils and other radioactive materials may have been introduced to T374. Most radioactive materials handled at T373 were totally encapsulated or in a condition which would not release radioactivity to the environment. Building T375 was used for non-nuclear testing of SNAP components.

Building T373 was used for testing SNAP critical assemblies at low power. Fully encapsulated highly enriched uranium was handled here. Activation foils were used for flux mapping. Liquids were not used here. No releases or significant neutron activation of facility materials occurred. Building T374, located just a few feet north of T373, was used for testing liquid metal heat transfer loops. These loops were non-nuclear related. Building T375 was used as a control center for testing SNAP control rod assemblies. That test project was non-nuclear. After T375 was abandoned, barrels were stored in the surrounding area. Some of these barrels may have contained radioactive material, but this is not known for certain. No known incidents occurred in these facilities or surrounding areas which would have spread contamination. 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, sections 5.4.23 and 5.4.24), 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, removable alpha/beta surface activity and total beta surface activity was assessed inside Buildings T373 and T374. 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. Removable alpha/beta activity was analyzed statically. Surface beta activity measurements were made "for indication." Statistically

All ambient gamma exposure rate data 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 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. Then the average "background" exposure rate of the three "natural background" distributions is subtracted from each data set to compare the results against the 5 μR/h above background criteria.

2.0 IDENTIFICATION OF FACILITY PREMISES

2.1 Location

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

1. Building T373, (Section 5.4.23); and
2. Building T375, (Section 5.4.24).

Building T374, which is separate from T373, was actually used as a support facility for T373. It is located a few yards from T373 but within the boundary fence-line. Because of its proximity to Building T373, Building T374 was included with this survey.

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 two 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 area locations. The buildings are Rockwell owned, and are located on the west side of 22nd Street, south of "G" Street. These facilities are not within the 90.26-acre Government-Optioned Area.

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

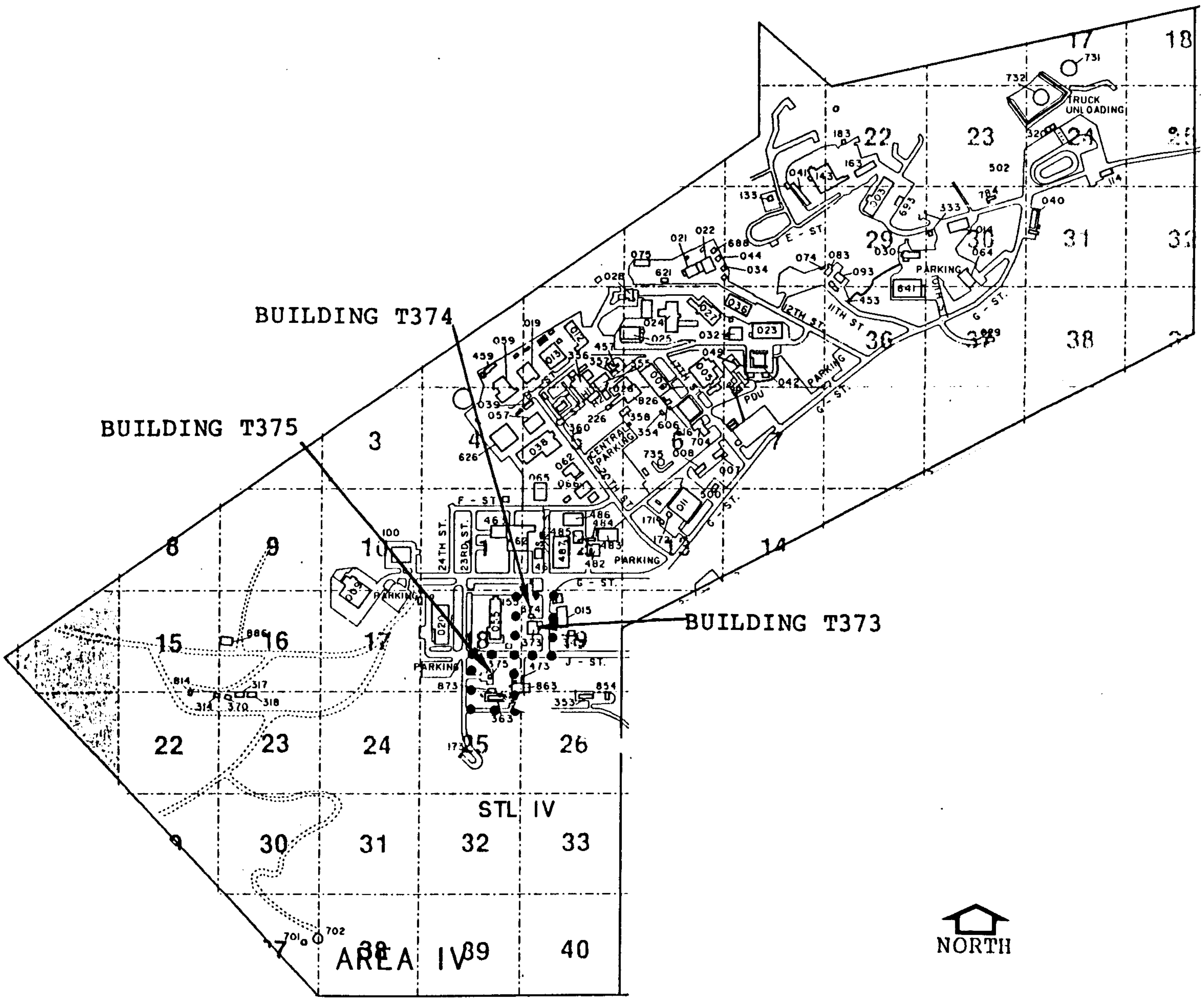


Figure 2.3 SSFL Layout, Showing Locations of
Buildings T373 ·74, and T375

level patches. Outcroppings of Chico sandstone formation are numerous in some areas. Local surrounding areas of these facilities are mostly natural terrain covered with natural vegetation.

The general slope of Area IV, including these facilities and surrounding areas, is in an easterly 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.

Building T373 was constructed in 1956 by the Rocketdyne Division as a solid propellant mixing and casting facility. The building has a total enclosed area of 3030 sq ft. The facility consists of five test bays, three of which are enclosed with 12-in. thick concrete walls. The remainder of the building is steel frame construction with the siding and roof using transite, plywood, and sheet metal. The facility was turned over to the Atomics International Division in 1957, at which time one of the test cells was modified for critical assembly research and development testing by adding 2 ft of additional concrete shielding to two walls. A layout of Building T373 is shown in Figure 2.5.

Located just a few feet from T373, is Building T374. The building is constructed of steel framing with steel siding and roof; a Butler-type building. It is no more than 600 sq ft in area. This facility currently houses an old mercury test-loop.

Building T375 was constructed in 1959 as a test shelter for an outside control-rod test tower. The building is 400 sq ft in size, 20 ft x 20 ft. It has a steel frame with steel roof and siding. A layout of T375 is shown in Figure 2.6. Parts of the surrounding area are cluttered with debris and metal components, as shown in Figure 2.8, a recent photograph.

Figure 2.4 Topographic Map of Areas Surveyed

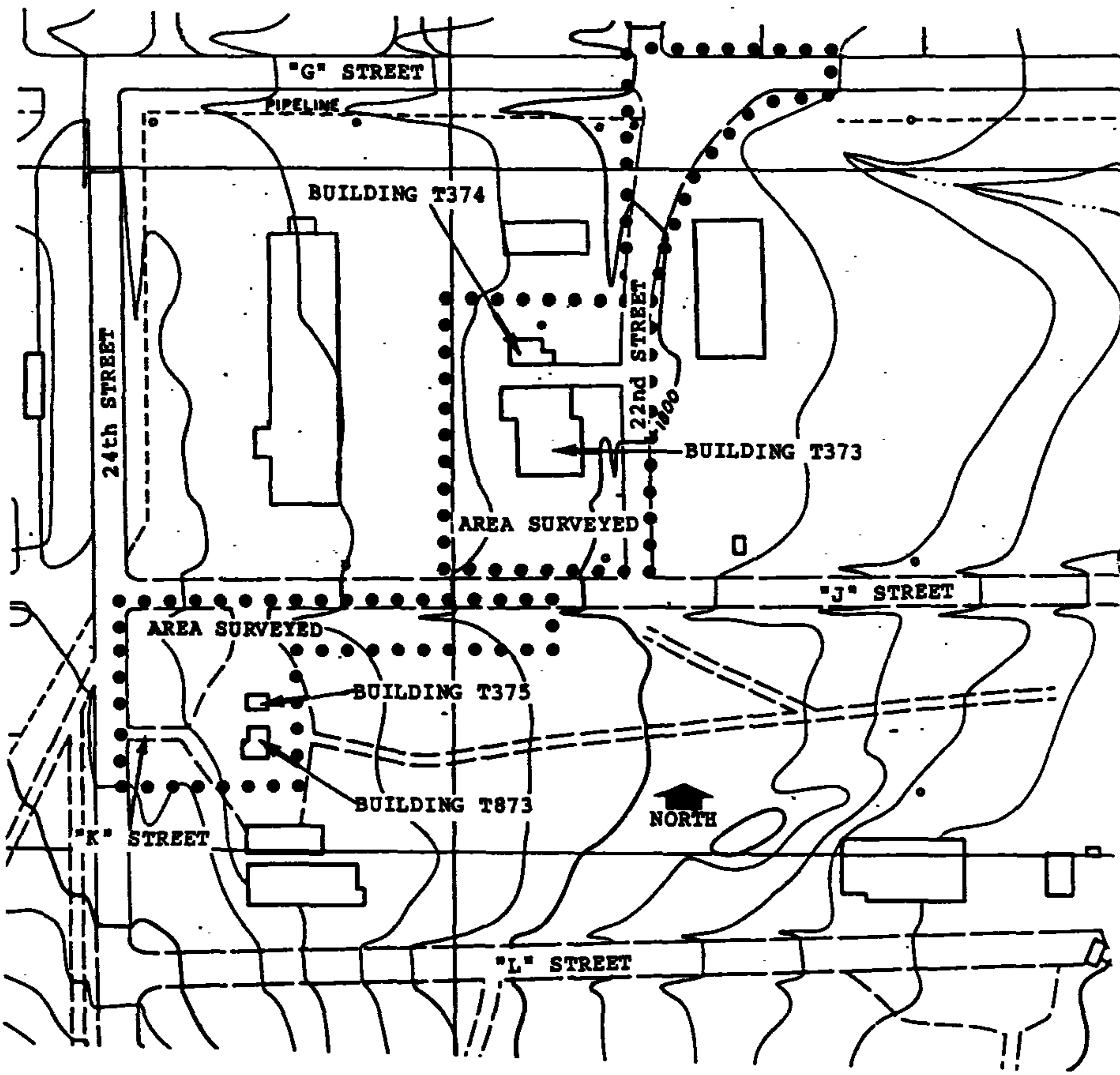


Figure 2.5 Plot Plan of Building T373

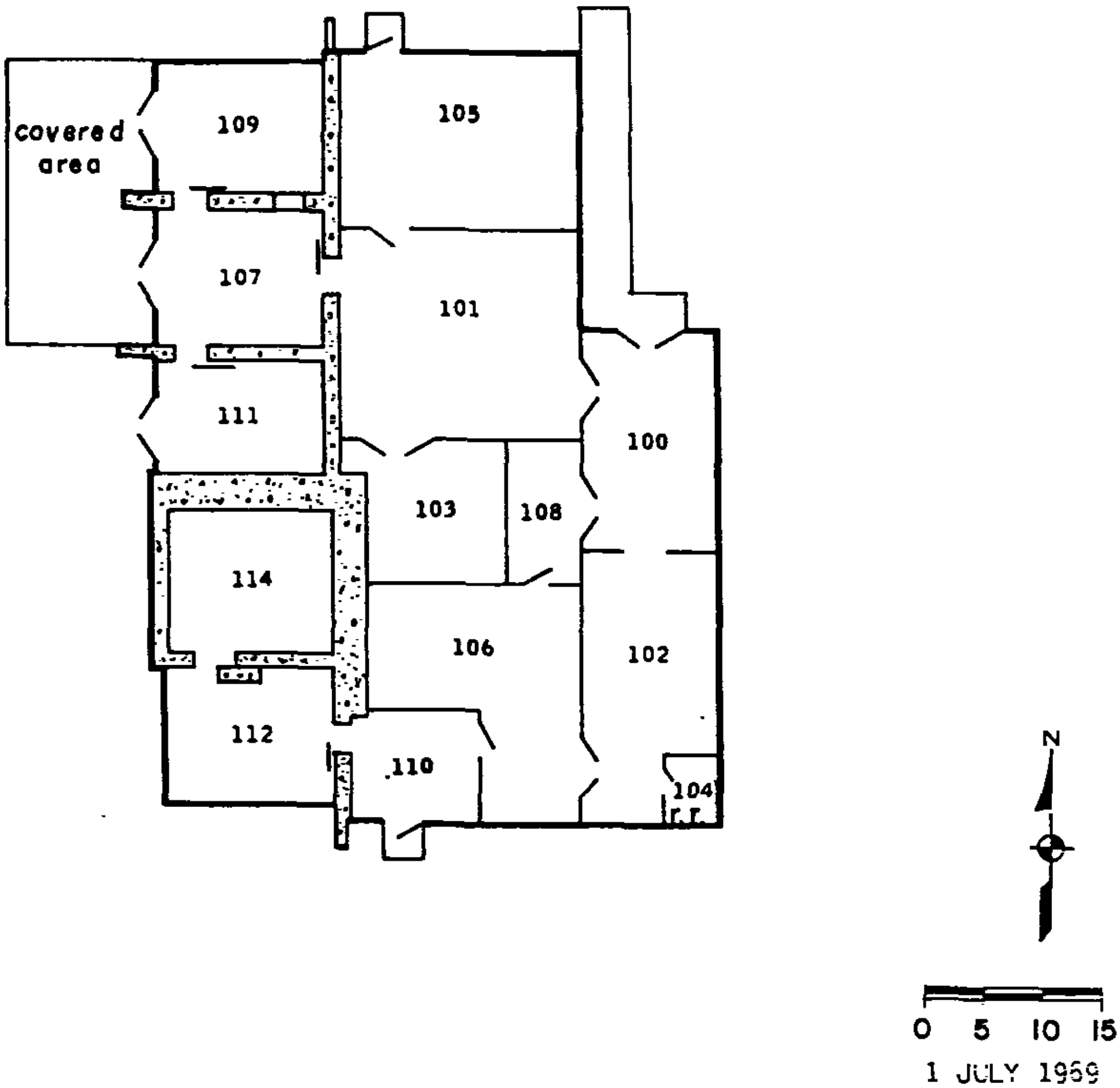
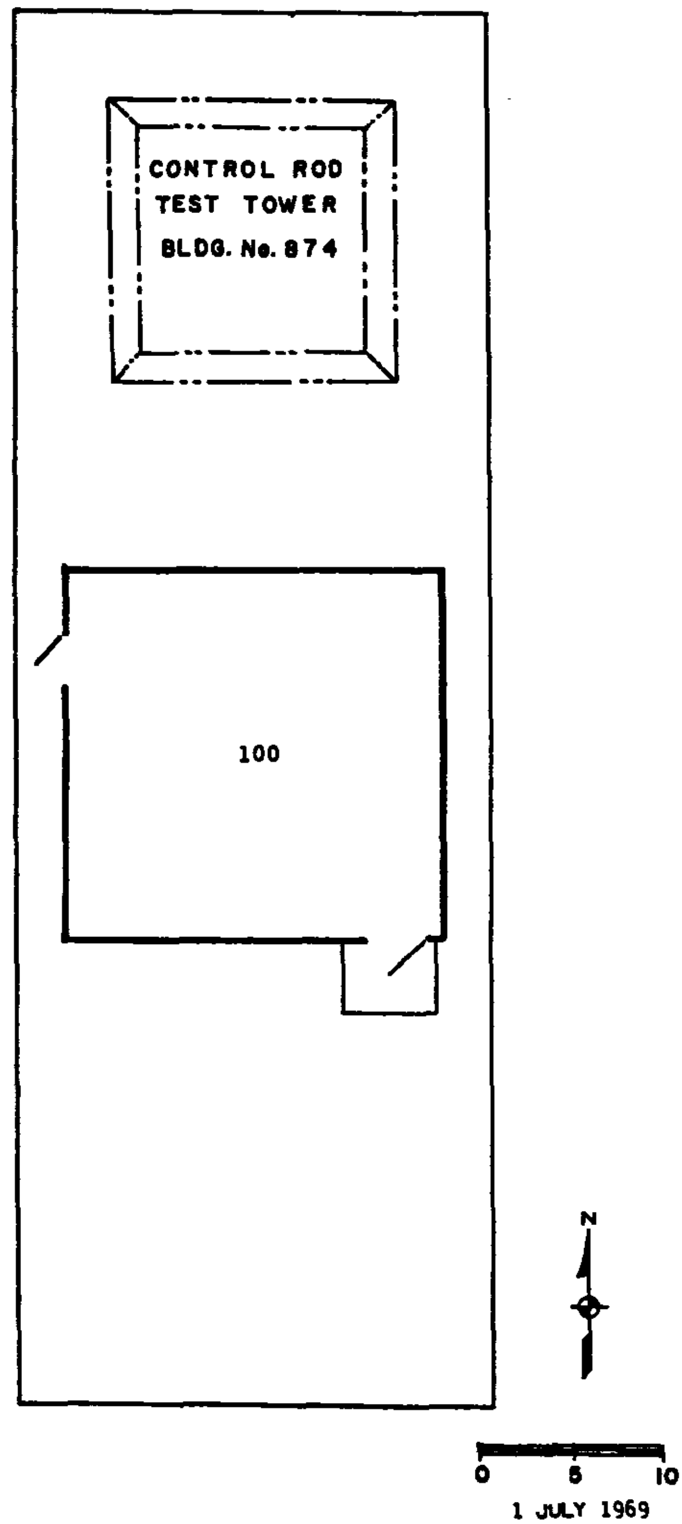


Figure 2.6 Plot Plan of Building T375



2.3 Facility Utilization and Present Radiological Condition

Buildings T373, T374, and T375 were used 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. Several designs of SNAP were developed and tested in this location of SSFL, Area IV. 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.

These facilities were designated either nuclear-related or non-nuclear-related based on whether radioactive or nuclear materials were handled there or not. Building T373 was nuclear-related. Buildings T374 and T375 were non-nuclear-related; however, because of the proximity of T374 to T373, radioactive and/or nuclear materials might have been handled there. These facilities that supported SNAP were reassigned and modified for other non-nuclear DOE programs. Currently, they are abandoned.

2.3.1 Building T373

As originally designed and constructed by Rocketdyne, Building T373 was to be used as a cast and melt facility for solid propellants. Structures of this kind were made with three solid walls and a fourth wall made to break away should an explosion occur. There is no evidence to suggest that this building was ever used in that capacity.

In 1956 or 1957, the building was modified to house several critical assemblies as part of the SNAP program. T373 was called the SNAP Critical Facility. The weak fourth wall was replaced with a poured-in-place concrete wall to produce an enclosed vault-like structure. In addition, an absolute (HEPA) filter bank was installed to reduce releases of airborne particulate radioactivity. It was anticipated that only low levels of radioactivity would be present from fissile material and activation foils. No liquid radioactive waste was produced.

The SNAP critical assembly (SCA) had a pseudospherical shape with fixed hydrogen moderator, highly enriched U-235 fuel, and a beryllium and graphite reflector. The first SCA used unclad fuel while the fuel in the last three assemblies was clad. Each assembly was limited to a power level of one watt or less, which is a fission rate of 3×10^{10} fissions per second.

Several critical experiments and tests on critical assemblies are thought to have been completed in T373. A brief description of these tests and critical assemblies are listed below, (Reference 25):

1. SCA-1. Initiated October 1957. This assembly consisted of a pseudo sphere of zirconium hydride-enriched uranium dioxide blocks. Basic reactor parameters of the SNAP-2 reactor concept were determined.

2. S2ER Critical Experiment. Initiated June 1959. The S2ER components were assembled and preliminary tests conducted at zero power.

3. SCA-2. Initiated about September 1960. A clean, cylindrical geometry core was studied, using the core and reflector components from the conduction-cooled SNAP 10 reactor.

4. SCA-3. Initiated October 1961. An assembly of about a 1 ft^3 core volume was built to study the characteristics of the SNAP 4 reactor. Plate-type fuel elements and a water coolant were used.

5. SCA-4C. This assembly used prototype SNAP 2/10A core and reflector components, as a final design check on the flight reactor system. Thought to have been performed in mid-1962.

6. S8ER Critical Experiment. The S8ER components were used to determine the nuclear parameters of the SNAP 8 reactor design. Final adjustments were made on the reflector shims prior to installation of the reactor in the power test facility (Building 010). Thought to have been performed in late 1962.

At the conclusion of SNAP critical tests in 1962, the facility was modified and reassigned for non-nuclear use. A small non-nuclear liquid metal NaK test loop was installed in the facility for research and development testing in support of the first SNAP Experimental Reactor (SER). The small test loop was used to pretest a NaK/NaK heat exchanger, EM pumps, electrical heaters, valves, piping, and instrumentation. Other non-nuclear projects associated with T373 were rubidium-potassium test loops, boiling mercury test loops (T374), and MHD boiling potassium loops, (Reference 25).

Building T373 has remained idle most of the time since this initial SNAP activity, except for intermittent periods when it was used for various storage activities. Buildings T373 and T374 are currently abandoned. An old mercury loop is still housed in T374. Both facilities are dilapidated inside with many of the interior walls removed. Conduit and miscellaneous debris are scattered about and hanging from the ceiling. Both facilities are a mess. Building demolition by Rockwell is planned since the highly specialized configuration does not lend itself to general industrial use. A photograph of Building T373 is presented in Figure 2.7.

Most nuclear or radioactive materials handled here were fully encapsulated. Only low levels of radioactivity were produced from fissile material or activation foils. No liquid radioactive waste was produced. Facility activation by neutrons was negligible. No fission product releases or contamination incidents are known to have occurred. When the facility

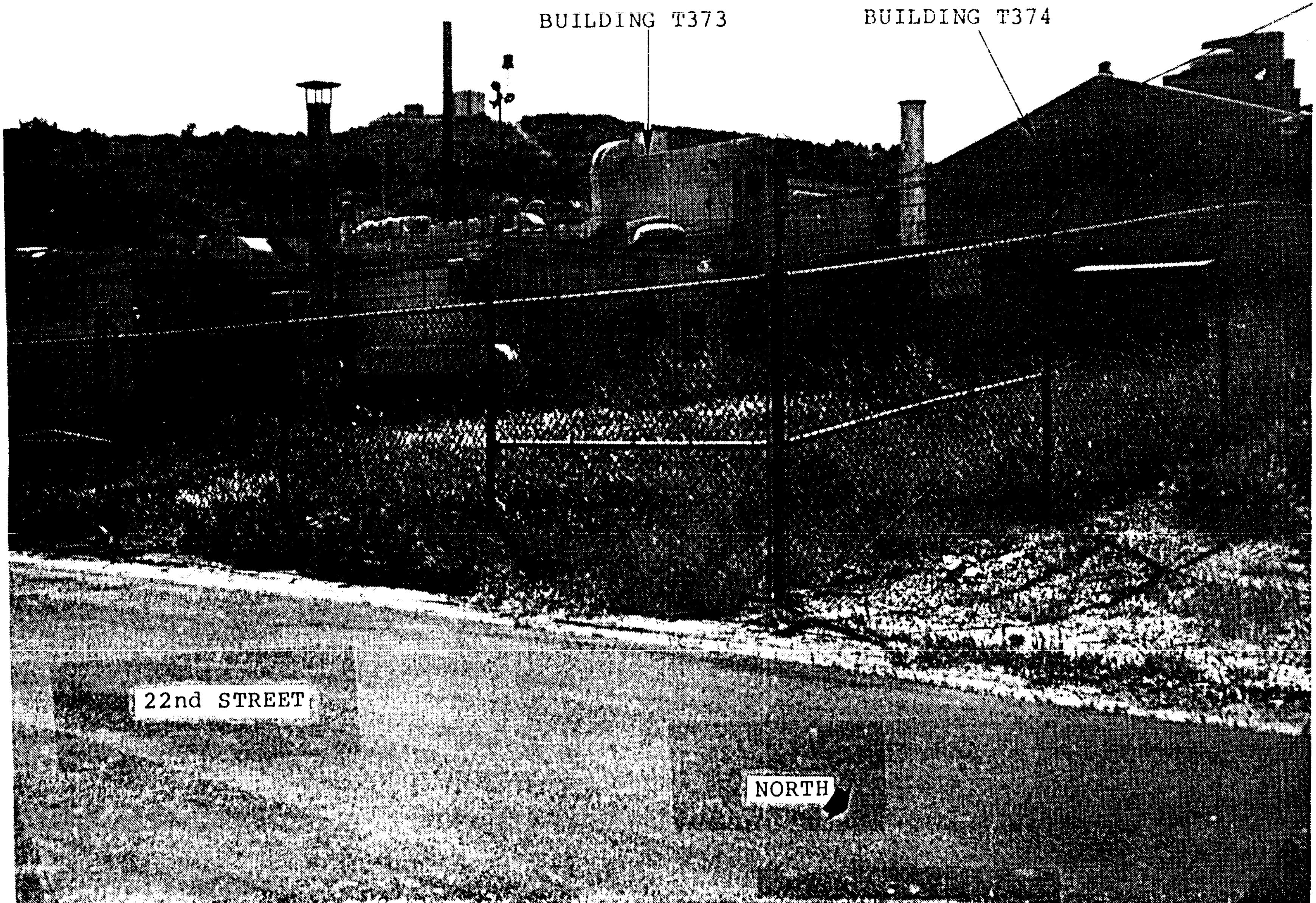


Figure 2.7 Photograph (1988) of Buildings T373 and T374

was reassigned for non-nuclear use, a radiological survey was performed to ensure that the facility was not contaminated. Residual radioactivity is not suspect in Building T373, and its nearby support facility, Building T374.

2.3.2 Building T375

Control rod assemblies were tested in an area installation that included Building T375 as a test shelter. Testing proceeded through 1968. Following completion of testing, the outside test tower was dismantled and equipment including tanks, piping, valves, instrumentation, controls, etc. were removed from the installation. There were no radioactive materials used in the building during its use as a control shelter for outside loop testing. Subsequent to the loop testing, the adjacent ground area at "K" and 24th Streets was used for barrel storage (some may have contained radioactive materials), and some barrels may have been stored in Building T375. This is not documented. A view of Building T375 from the east is shown in Figure 2.8. Note the debris and piping scattered about the surrounding area.

No contamination incidents are known to have occurred. Residual radioactivity is not suspect at this facility or surrounding area.

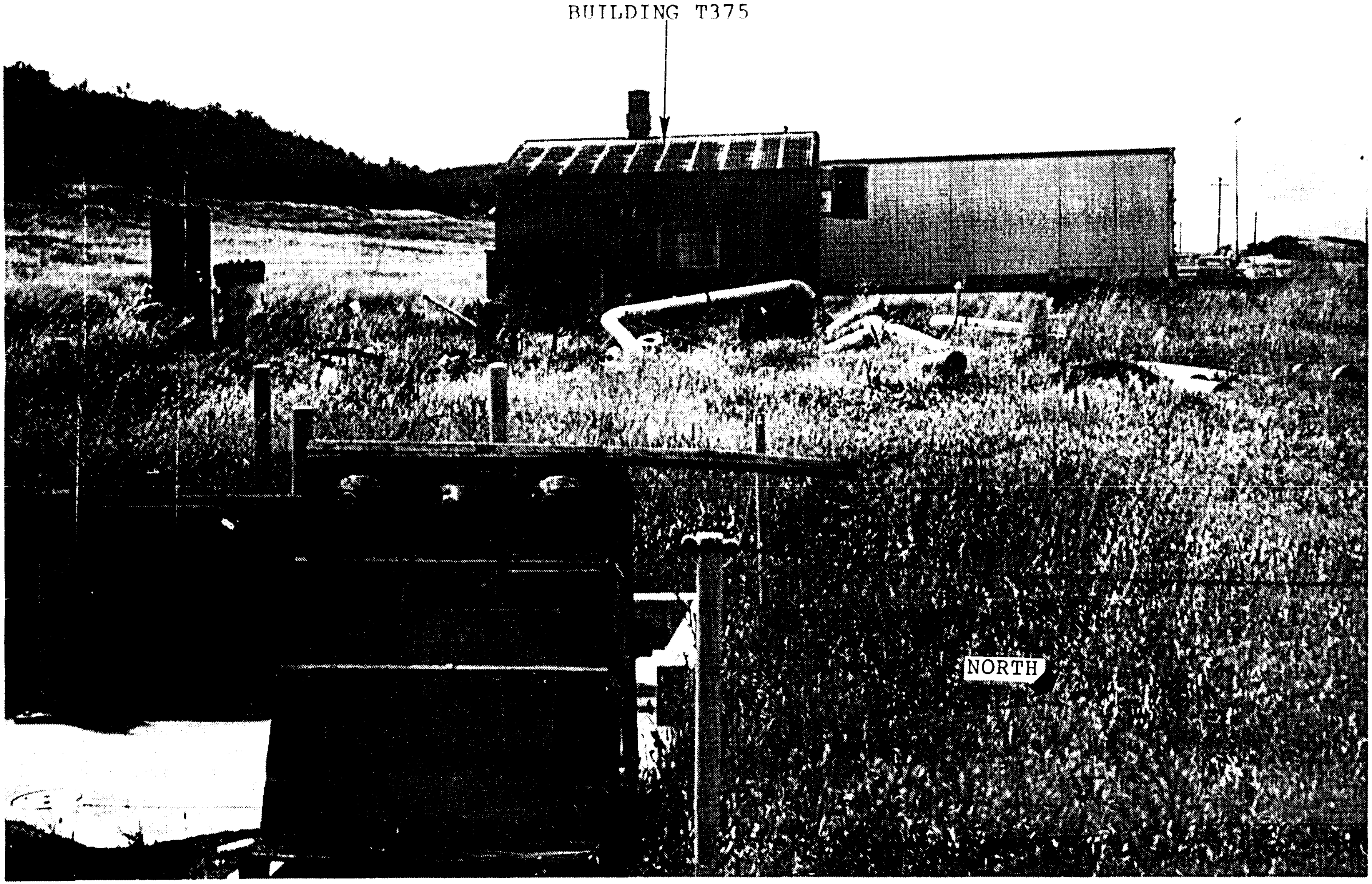


Figure 2.8 Photograph 8) of Building T375

3.0 SURVEY SCOPE

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

1. Building T373 (Reference 4, Section 5.4.23)

   * Survey floors, drains, and exhaust systems.
   * Survey the surface between "G" Street and "J" Street and from 22nd Street to the west fence for gamma exposure rate.
   + Include Building T374 with this survey.

2. Building T375 (Reference 4, Section 5.4.24)

   * Survey the surface of building and grounds from "J" to "L" Streets and from 24th to 22nd Streets for gamma exposure rate.

These facilities are shown in Figure 2.4.

Interior building areas of T373 and T374 were radiologically inspected by measuring removable alpha/beta contamination and ambient gamma exposure rate. Total beta surface activity was also measured "for indication" on selected grids and special building features. Surrounding areas were radiologically inspected by measuring ambient gamma exposure rates 1 meter above the surface. If this gamma measurement indicated contamination, surface soil samples were to be acquired and analyzed by gamma spectrometry and for gross alpha/beta activity. About 190 smears were collected inside Building T373 for assessment of removable alpha/beta contamination; these smears included miscellaneous items and building features. About 25 smears were collected inside Building T374. Exhaust vents, filter plenums, sinks, drains, showers, and similar systems were surveyed for residual removable alpha/beta activity and total beta contamination.

Gamma exposure rate measurements were made in about 370 locations: 89 inside T373; 20 inside T374; 9 inside T375; 170 in the area surrounding T373 and T374; and 79 in the area surrounding T375. This corresponded to one measurement per 3-m square grid inside facilities and one measurement per 6-m square grid outside facilities. Soil samples were not collected and analyzed because no indication of contamination was found. Ambient gamma exposure rates are reported in micro-roentgens per hour (μR/h). Removable alpha/beta activity is reported in disintegrations per minute per 100 cm^2 (dpm/100 cm^2). Beta activity measurements are reported as No Detectable Activity (NDA), or less than 50 counts per minute (cpm), 60 cpm, ...etc. These 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

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***	$1x10^{-4}$ μCi/ml	$1x10^{-5}$ 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.

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.

3.2 Sample Lots

For purposes of this radiological survey, two sample lots were established for radiologic characterization and data interpretation. Interior and exterior radiological measurements from the total of all buildings were each treated as separate sample lots. Interior exposure rate measurements from Buildings T373, T374, and T375 were treated as one sample lot because facility characteristics are similar. Removable alpha/beta activity was also measured for that sample lot. Likewise, surrounding areas to each facility are similar, and gamma exposure rate measurements made there were combined into one sample lot. Since beta activity measurements were performed "for indication," no statistical tests apply.

3-m square grids were superimposed within each subject facility. 6-m square grids were superimposed over outdoor terrain. One ambient gamma exposure rate measurement was made in each 9-m^2 or 36-m^2 cell, whichever applies. Location (1,1) was the northwestern-most grid in each area. Because of the dilapidated state of these facilities, grids were established differently than in the past. Location (1,1) was the northwestern-most floor area of the entire facility. Floor smears were marked as F(x,y), corresponding to the matrix notation from (1,1). Wall smears were marked W(x,y), where x,y corresponds to the nearest floor grid. Most walls were torn out or terribly in shambles. 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. Physical surroundings fell into two categories: 1) Inside buildings; or 2) Natural terrain. These two presumably uniform areas formed the basis for establishing sample lots for evaluating gamma exposure rate measurements and removable alpha/beta activity measurements.

3.3 Ambient Gamma Exposure Rate Measurements

In each cell, 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 μR/h. The measurement location and exposure rate were recorded in tabular form. 370 1-min. measurements were acquired over the total inspection area.

3.4 Removable Alpha/Beta Contamination Measurements

Measurements of removable alpha and beta surface activity 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.

For surface contamination measurements of alpha and beta activity, data included sample location, counts recorded in a five minute count of each smear, instrument background for five minutes, and efficiency factor.

Special structural features and miscellaneous items were surveyed in a similar manner. Additionally, total beta surface activity was measured "for indication."

3.5 Surface Soil Samples and Surface Beta Radioactivity Measurements

Soil sampling and measurements of beta surface activity were required by the Site Survey Plan (Reference 4) for better characterization of radiological condition only if gamma exposure rate measurements indicated possible radioactivity. No increased exposure rate measurements indicated possible radioactivity, so no soil samples were collected and analyzed, and no beta surface activity measurements were made on that basis. However, a thorough survey for beta 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 for several reasons:

1. Most nuclear materials handled at T373 (and T374, if at all) were fully encapsulated. No releases ever occurred;

2. Activation of building materials at T373 was negligible; the test reactors were operated for short periods and low power;

3. When T373 was reassigned, a thorough radiation survey was performed to ensure no residual radioactivity remained undetected; and

4. T375 was never known to handle nuclear or radioactive material, although drums containing radioactive material might have been stored in the surrounding area. 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 probability of existing residual enriched uranium is highly unlikely. Furthermore, no uranium powders or grinding fines were handled here. It is highly unlikely that any subsurface debris is currently in natural terrain areas; they were never used as dumping grounds or landfills. Subsurface transport of contaminants is also considered negligible. If any contaminants do exist on-site, they are most likely still on the surface.

Because of the large area surveyed, outdoor exposure rates were measured every 36 m^2. This sampling plan is sufficient for two reasons:

1) Gamma measurements made on a 6-m square 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 the greatest separation distance of 6 meters. These sensitivities meet the requirements of this survey; and

2) 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; and

2. Any relatively intense gamma-emitting debris is buried (see Section 5.4.4).

We cannot conclude whether:

1. Any slight subsurface migration has occurred; or if

2. Any buried debris with low intensity radiation is present.

The likelihood for occurrence of the above two conditions is small. First, migration periods of contaminants below the surface are typically very long. It is much easier for surface water flowing downslope to carry with it any contaminants. The settling out of these contaminants into the subsurface also takes a long time. Second, no known burial or dumping activities took place in any of these areas.

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, $(x = \overline{x} = m)$. 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:

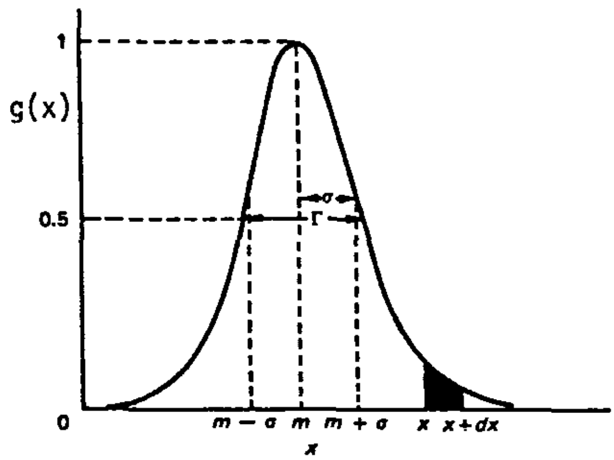


Figure 4.1 The Gaussian Probability Density Function

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:

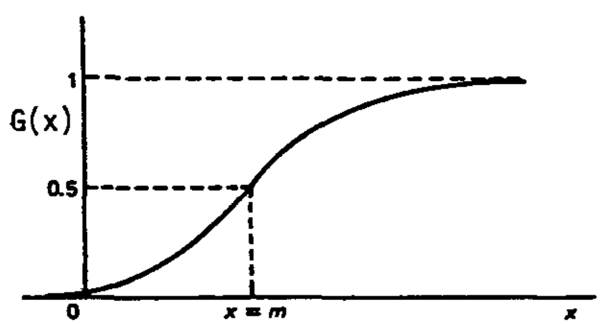


Figure 4.2 The Gaussian Cumulative Distribution Function

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:

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

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.

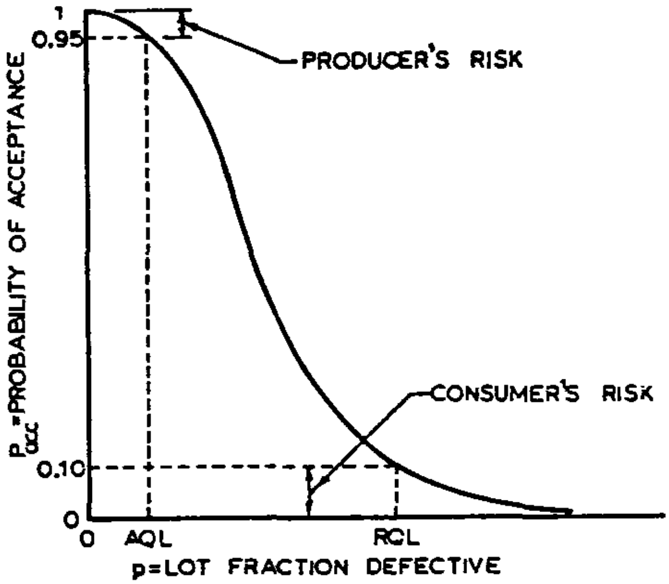


Figure 4.3 Operating Characteristics Curve

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):

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

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_β 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 $\bar{x}$ + 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.

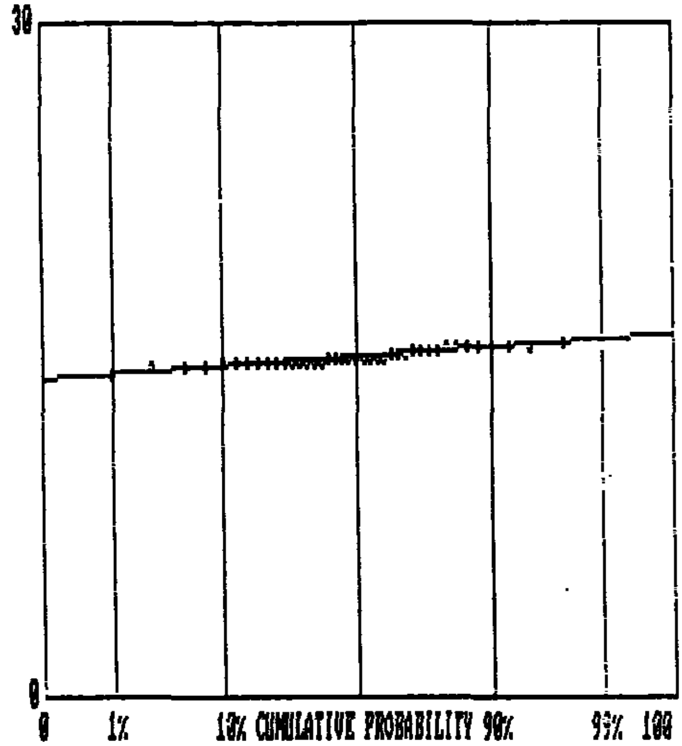


Figure 4.4 Gaussian cdf Plotted on Probability-Grade Paper

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

3) Rejection: If the test statistic ($\bar{x}$ + ks) is greater than the limit (U) and $\bar{x}$ >= 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, that judgement is based on three types of radiological measurements:

1) Ambient gamma exposure rate;
2) Removable alpha and beta contamination; and
3) Total beta surface activity.

For exterior locations and surrounding areas, ambient gamma exposure rate measurements were made.

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 square grid inside T373 and T374, 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.

In each designated 6-m square grid in Building T375 and in all surrounding areas, 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 the soil; or a low settling spot for surface water runoff. 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 of the data was not required. 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 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 (probability 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:

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

Output for Gaussian Plots of inside measurements:

1. Alpha removable activity and standard deviation (dpm/100 cm^2);
2. Beta removable activity and standard deviation (dpm/100 cm^2); and
3. Ambient gamma exposure rate and standard deviation (μR/h).

Input for data reduction of outside 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, $\bar{x}$ + 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, $\bar{x}$ + 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 ± 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 μR/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, $\bar{x}$ + 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 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. During the survey we observed significant deviations in "natural background" radiation as a function of landscape geometry. For example, 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. "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 left behind in some of these areas. Fortunately, no secondary influence of gamma exposure rate occurred in these sampling locations. Instrument noise is fairly uniform.

The best solution for evaluating the potential or existence of residual contamination in an area where the radiation field varies naturally by swings as large as the acceptance limit, is to 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, similar to conditions of each test-area. Additionally, an assessment of other contributors to "ambient background" should be performed. These quantities should be estimated.

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, $\bar{X}$ + 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 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, or buried several feet below (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.

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

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	

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 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. Smears were acquired in sinks, drains, showers, filter plenums, exhaust vents, and suspect-looking cracks and crevices. Each smear sample was placed in a gas-flow proportional counter for analysis.

5.5.1 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.

5.5.2 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 5-3 and 5-4. Conversion from gross counts to dpm/100 cm^2 is given by:

$$SA = \frac{(C - B)(EF)}{5} \quad (dpm/100\ cm^2) \qquad \text{(Eq. 5-3)}$$

where: SA = removable surface activity
C = total counts in 5 min.
5 = count time, min.
B = background counts in 5 min. (generally 0-2 for alpha and about 40-50 for beta for a 5 min. time period)
EF = Efficiency factor, dpm/cpm (averages about 3.5 for alpha and about 3.9 for beta)

The standard deviation of this measurement is:

$$s = \frac{\sqrt{C + B}\ (EF)}{5} \quad (dpm/100\ cm^2) \qquad \text{(Eq. 5-4)}$$

5.5.3 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, $\bar{x}$ + 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.

6.0 PROCEDURES

The following radiological procedures were used in performing this survey.

6.1 Sample Selection Gridding

Two sample lots should be established; one for facility interior radiological measurements, and one for exterior radiological measurements. Superimpose 3-meter square grids on each interior surface to be radiologically characterized, and 6-meter square grids on outside surrounding areas. Designate each square meter in matrix notation with location (1,1) being the northwestern-most square in a facility or area. From this northwestern-most location, mark a location off every 3 or 6 meters (whichever applies) east, and south. Where it is not convenient to make a measurement because of rock outcroppings or facility components, 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 are calibrated and checked every morning, noon, and evening for the duration of the project as follows.

Portable Ludlum 2220-ESG Survey Instruments coupled to a 1 in. x 1 in. NaI crystal:

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

2) Check high voltage (800V gamma).

3) Check threshold (400 gamma).

4) Set window in/out switch to "out."

5) Check battery (greater than 500).

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

7) Take and record a 1 min. background count in an uncontaminated area which typifies the area to be surveyed. Verify that ambient background falls within ± 20% of daily-averaged background measurements.

8) 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).

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) Take at least 30, 1-min. counts in an area of similar topography where no radioactive materials were ever handled, stored, or used. This is the background distribution. Enter data in SMART SPREADSHEET.

6.3.2 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.

6.3.3 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 three facilities was performed using the survey plan previously described:

1. Building T373 (T374, and surrounding area included); and
2. Building T375 and surrounding area.

Sample lots for analyzing and interpreting radiological data were selected based on similar building conditions and local topography. Uniform 3-m square grids were established to measure indoor gamma exposure rate 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 removable alpha/beta contamination measurements show that all areas are uncontaminated. Variability of gamma-radiation "natural background" was observed for all test-areas. All total beta 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 removable alpha/beta measurement results are presented according to this format. Each sampling lot is discussed separately.

7.1 Statistical Results Format

Gamma exposure rate data collected for this survey are displayed as Gaussian cumulative distribution functions in Figures 7.1 through 7.7. 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. Figures 7.4, and 7.6 are distributions of gross-total gamma exposure rates for indoor and outdoor gamma measurements, respectively. Figures 7.5, and 7.7 are distributions of the same two data sets corrected for "natural background" based on the median value of the gross-total measurements presented in Figures 7.4 and 7.6. 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 significantly greater than exposure rate measurements made in these subject areas. Subtraction of "natural background" would be an overestimate of "ambient background" in these test areas. Figures 7.8 and 7.9 show the removable alpha and beta contamination results, respectively. 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.

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 the NRC acceptance limit of 5 μR/h. The value of k used in the inspection test is very nearly 1.5 for each case; thus, the Test Statistic (TS) line ($\bar{x}$ + 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 removable 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 example, 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 was 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 381 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.

Descriptive statistics presented in Table 7.1 show that average exposure rates calculated for each test-area are all significantly less than the three "natural background," control-group areas. Standard deviations of each test-area are in general 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 appear uncontaminated. 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.

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 T373	89	10.3	0.22	1.32	6.81
Interior of T374 and T375	29	9.3	0.21	0.79	3.35
Surrounding Area of T373 and T374	170	12.6	0.24	0.61	4.64
Roof of T373	14	9.4	0.21	1.00	3.06
Surrounding Area of T375	79	13.7	0.25	1.27	5.84
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.

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 similar in characteristics and topography to the outdoor inspected areas for this report. A minor difference is that the terrain of the surrounding areas is very flat and covered with natural vegetation and pavement -- no outcroppings. Additionally, scrap materials are scattered about the area surrounding T375. The purpose these "background" distributions serve is to show "natural" variability of gamma radiation on natural terrain at SSFL.

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 unaffected 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.

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

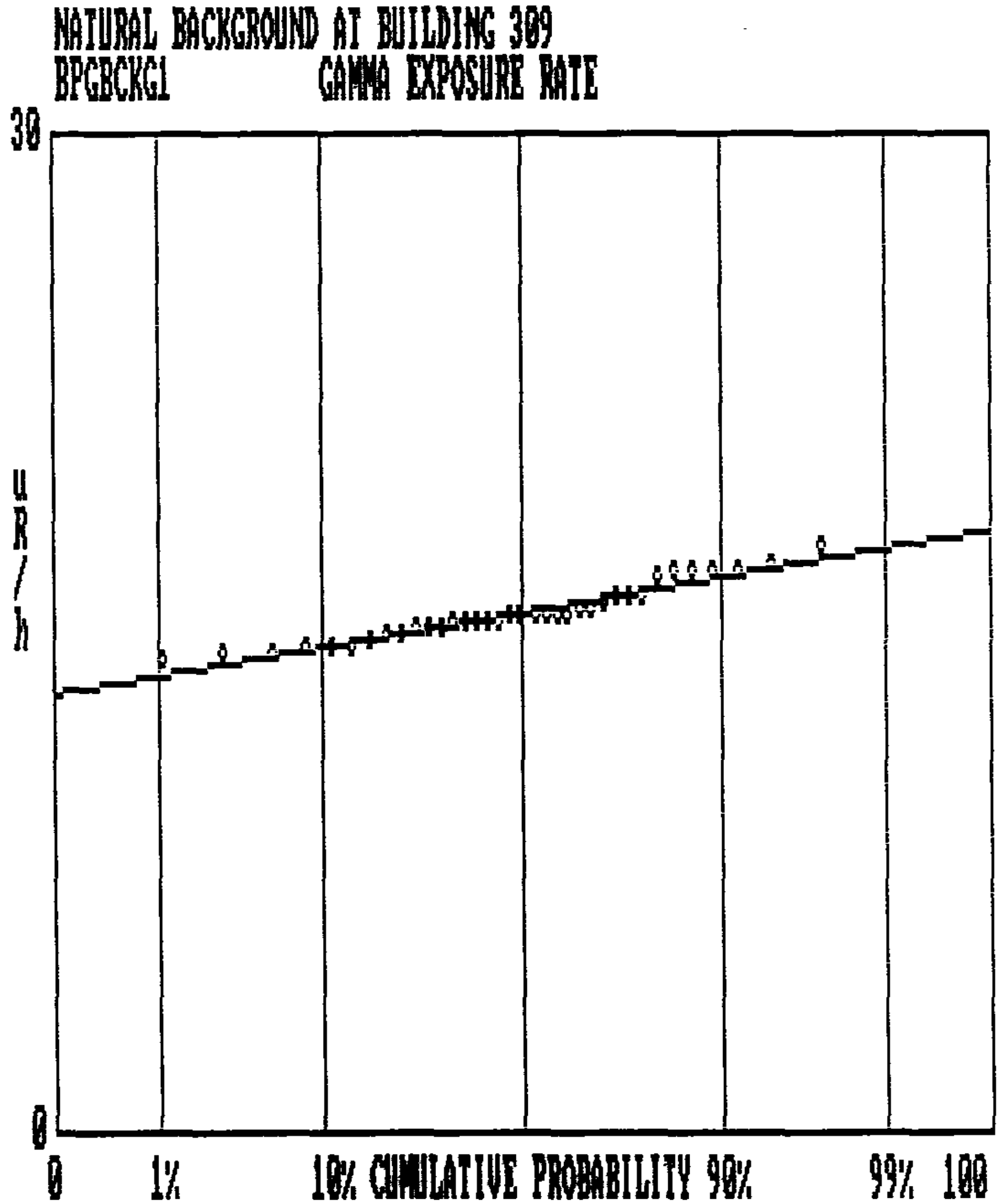


Figure 7.2 Ambient Gamma Radiation at Area Well #13 Road
(Background Distribution)

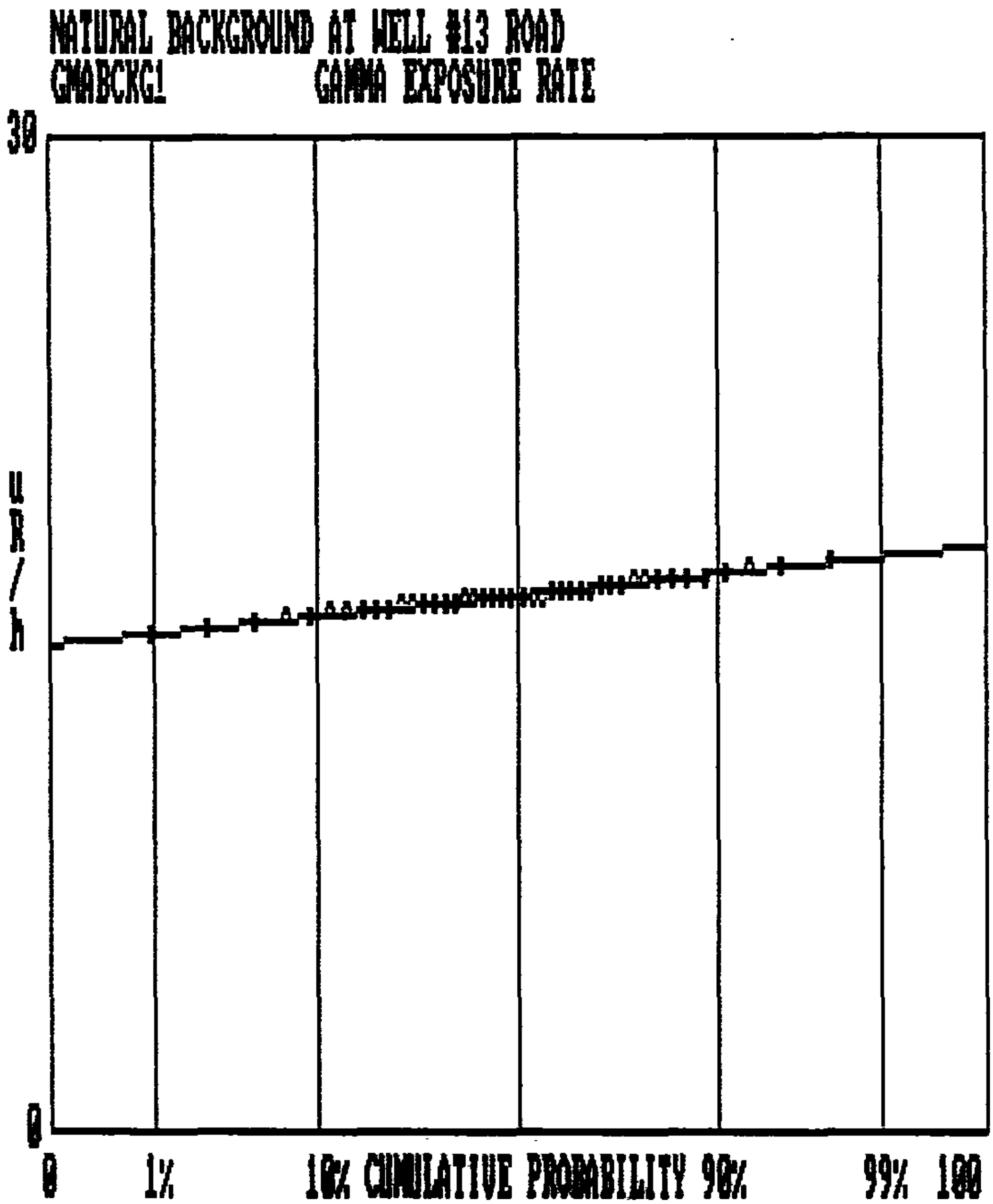
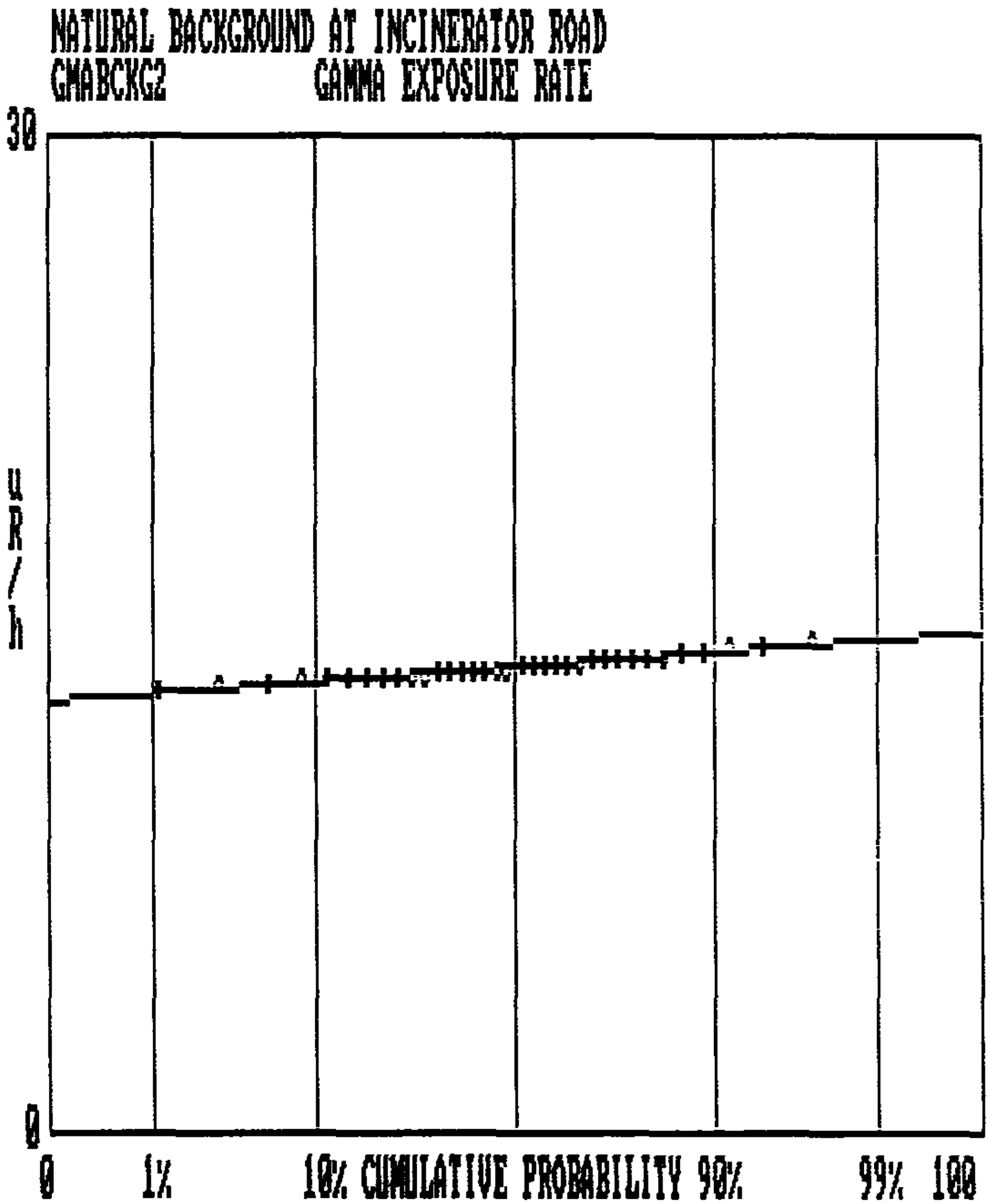


Figure 7.3 Ambient Gamma Radiation at Incinerator Road
(Background Distribution)



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 three test-area measurements presented in this report.

7.2.2 Measurements Made in Interior of Buildings T373, T374, and T375

Figure 7.4 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for interior locations of T373, T374, and T375. This test-area was all indoors, and the facilities were of similar construction. Exposure rate measurements were acquired in every 3-m square. A few outliers at the high end and inliers at the low end of the distribution are not significant. These are normal expected deviations. The data follow a well-fitted Gaussian distribution with a mean value of 10.04 ± 1.27 μR/h, less than "natural background." No trends indicating a contaminated area are observed.

Figure 7.5 shows the same data set, in which case a correction for "natural background" was made uniformly to each measurement value. 9.7 μR/h was used for "background" subtraction, corresponding to the median exposure rate of the gross-total data set measurements in Figure 7.4.

Deviations observed in the measurements, although slight, are pronounced in this figure because the ordinate scale has been expanded. Four measurement values exceed our 50% Reinspection action level. The three greatest measurements were made in the same general area of T373: grids 10-9, 9-9, and 9-10, (see map in Appendix D.1). These greatest values were 13.97, 13.78, 12.98, and 12.91 μR/h uncorrected for background. These are all less than "natural background" as determined by averages at the three "background" locations. As part of the reinspection effort, this area was surveyed for beta activity: no detectable activity was found. A background-corrected exposure rate average of -0.028 ± 1.21 μR/h is less than the

Figure 7.4 Total-Gross Ambient Gamma Exposure Rates
Measured Inside Buildings T373, T374, and T375

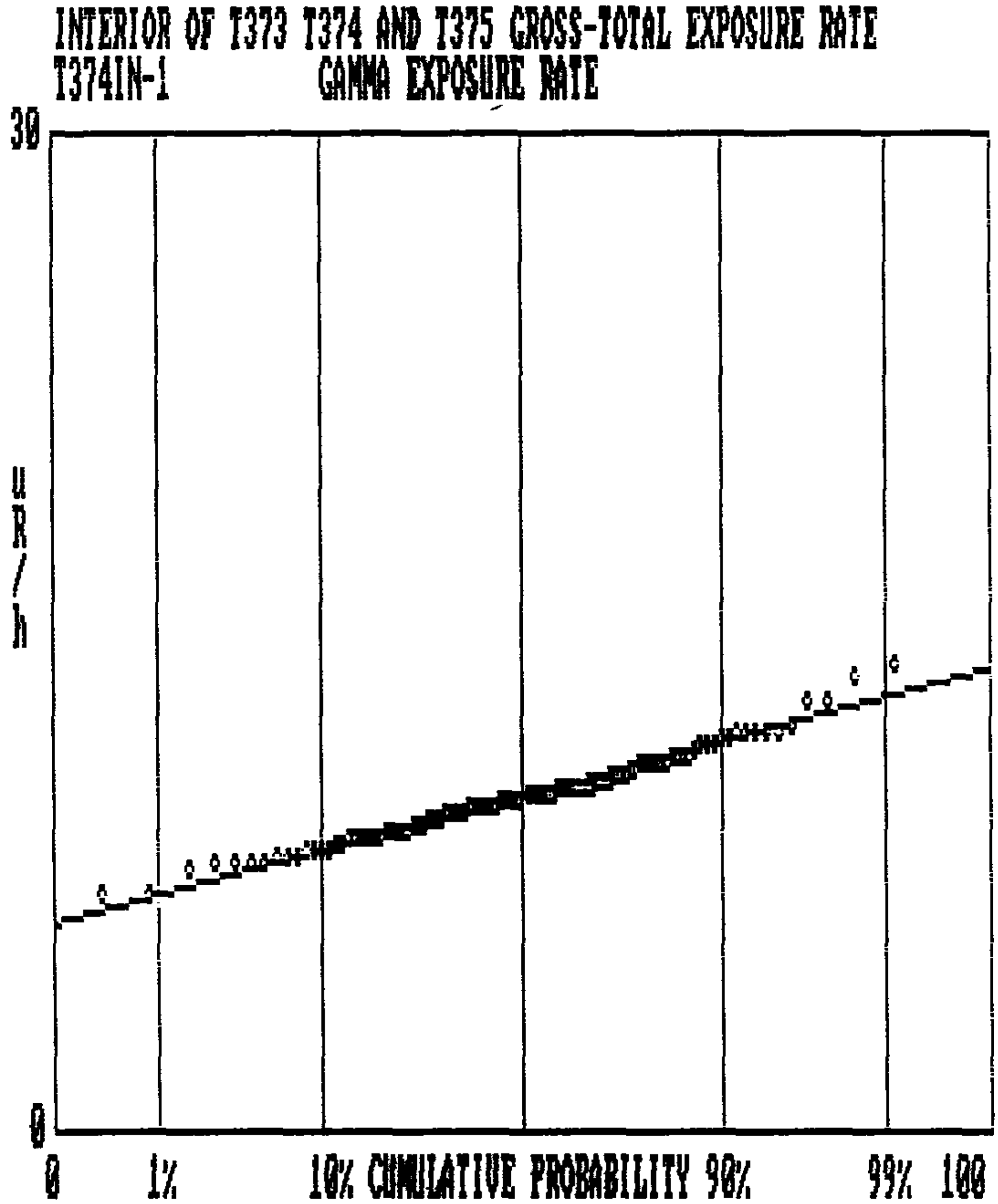
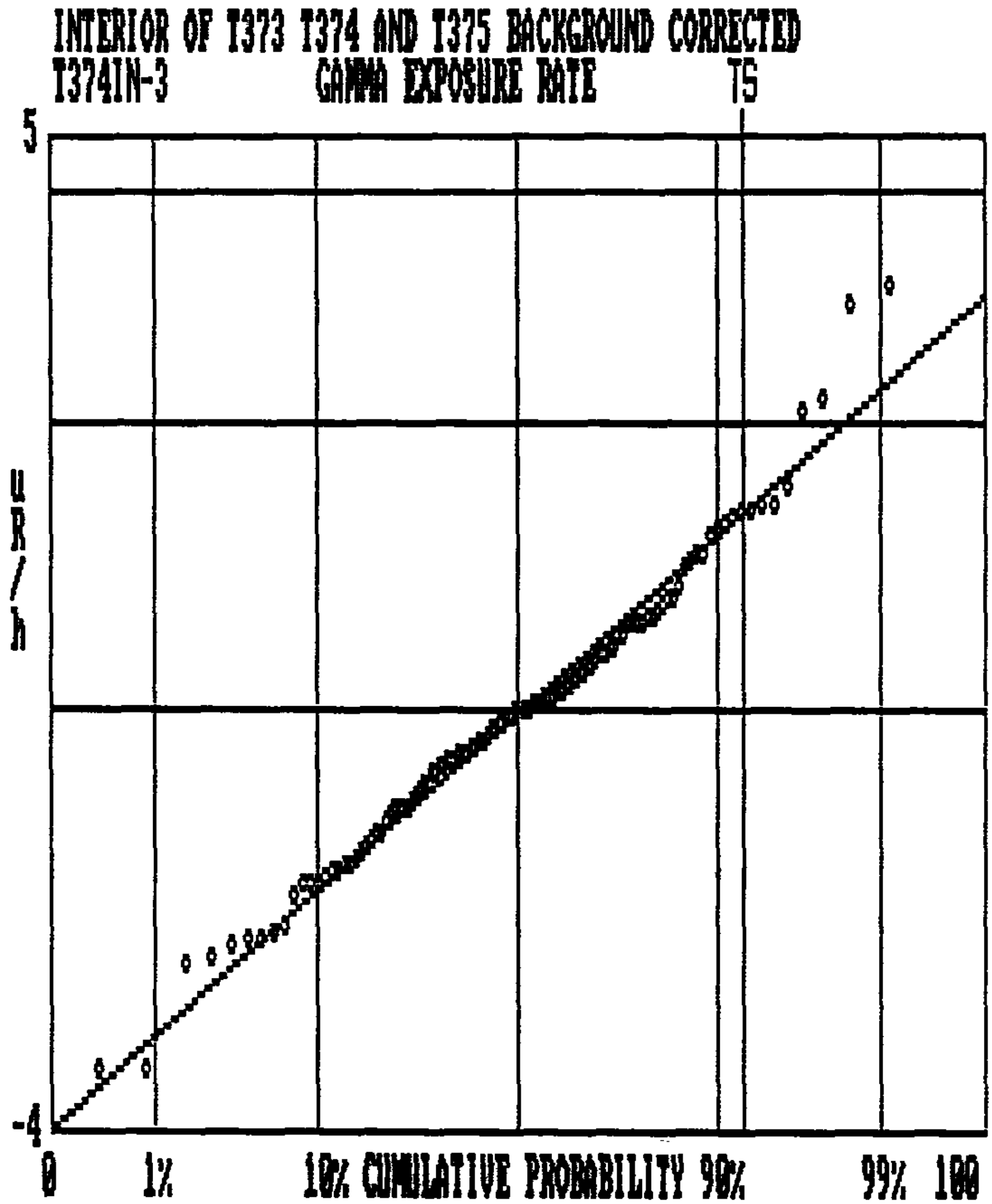


Figure 7.5 Background-Corrected Ambient Gamma Exposure Rates Measured Inside Buildings T373, T374, and T375



5 μR/h acceptance limit and all action levels. The inspection test statistic, 1.73 μR/h, is less than 5 μR/h. We accept this area as uncontaminated by this inspection method. No further investigation is required.

7.2.3 Measurements Made in Surrounding Areas of T373, T374, and T375

Figure 7.6 shows the statistical distribution of gross-total gamma exposure rate measurements plotted against cumulative probability for the surrounding area. Measurements were acquired in each 6-m square. This test-area is all outdoors, with various surfaces: natural terrain, asphalt concrete roadways, roofing (T373), and cement slabs. Some locations are cluttered with old system components and junk. These objects perturb ambient exposure rates; the sample lot is not uniform. Even though the sample lot is not uniform, the data follow a fairly well represented Gaussian distribution. No trends indicating a contaminated area are observed.

Figure 7.7 shows the same data set, in which case a correction for "natural background" was made uniformly to each measurement value. 13.40 μR/h was used for "background" subtraction, corresponding to the median exposure rate of the gross-total data set measurements in Figure 7.6.

Deviations observed in exposure rate measurements because of stored scrap materials and surface obstructions are pronounced in this figure because the ordinate scale has been expanded. The deviations, primarily in the low end, are due to roof measurements made at T373, with an average of 9.4 μR/h, and to variances in the terrain at T375. An average of -0.18 ± 0.90 μR/h is less than the 5 μR/h acceptance limit and all action levels. The inspection test statistic, 1.08 μR/h, is less than 5 μR/h. We accept this area as uncontaminated by this inspection method.

Figure 7.6 Total-Gross Ambient Gamma Exposure Rates Measured in Surrounding Areas At T373, T374, and T375

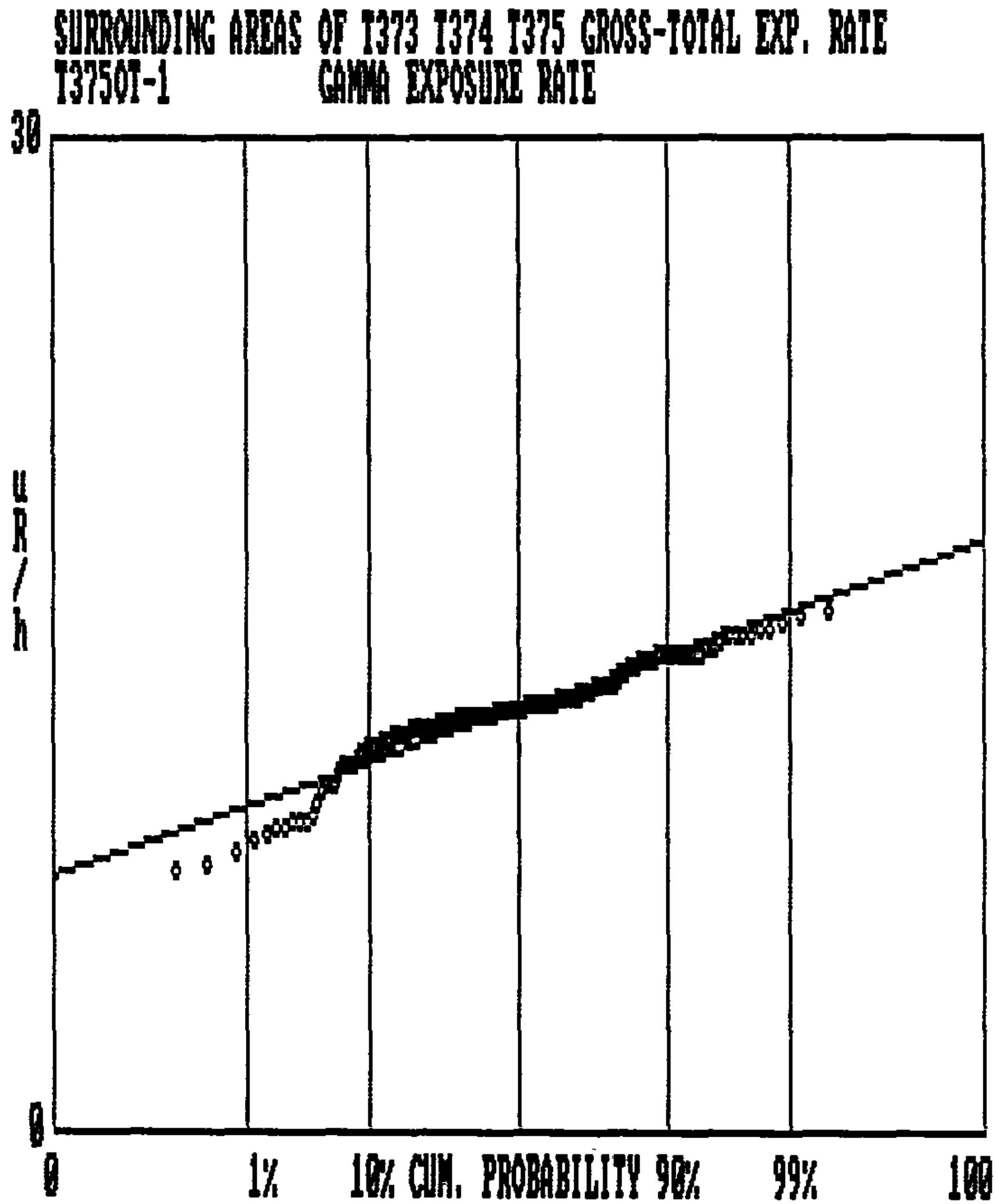
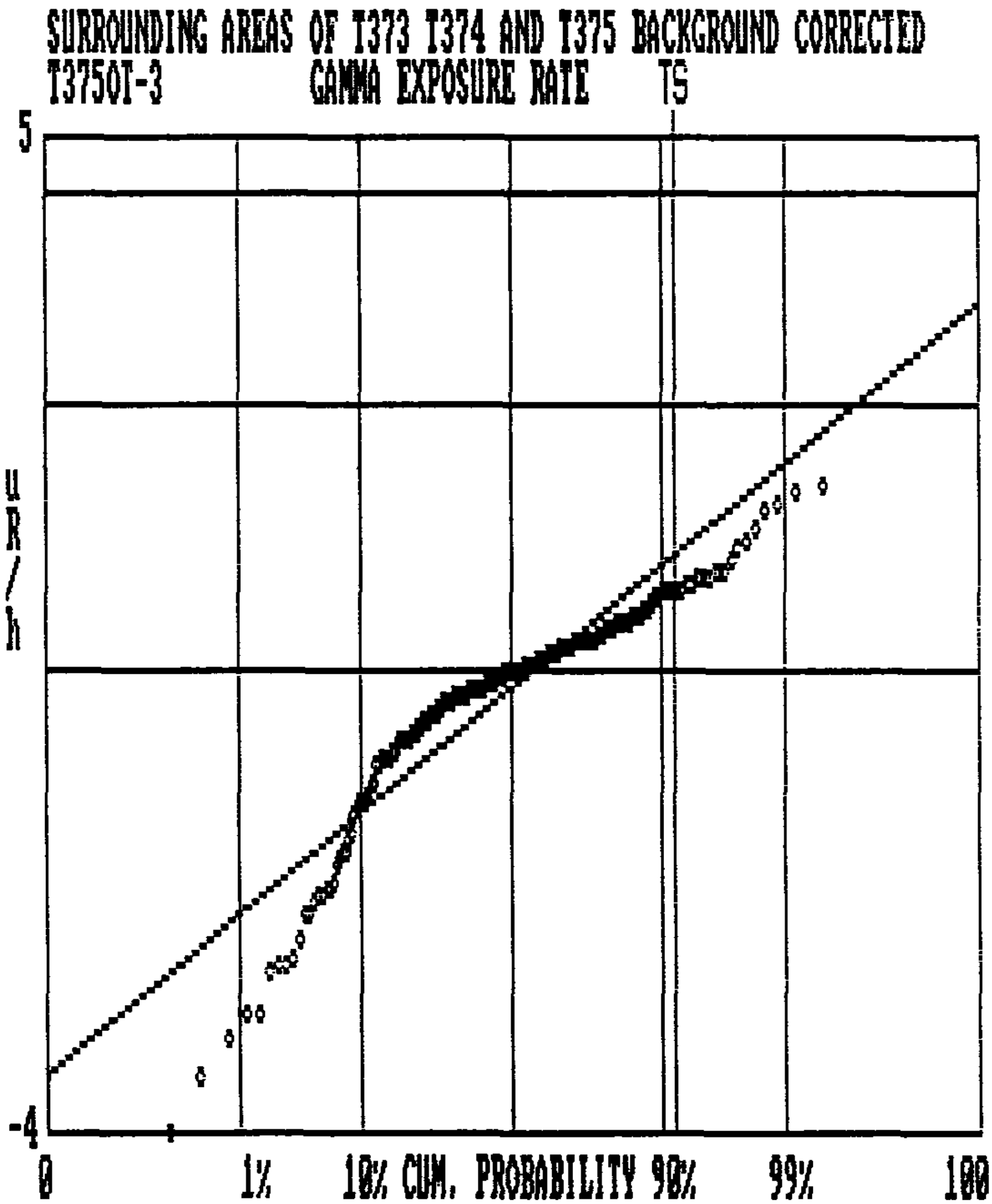


Figure 7.7 Background-Corrected Ambient Gamma Exposure Rates Measured in Surrounding Areas of T373, T374, and T375



7.3 Removable Alpha/Beta Measurements Inside Buildings T373 and T374

Removable alpha and beta measurements were made in each 3-m square grid and on many miscellaneous building features inside Buildings T373 and T374. Miscellaneous features included drains, sinks, showers, exhaust vents, blowers, and filter banks. These measurements were evaluated by analytical interpretation using Gaussian statistics. Removable contamination was assessed in 213 locations. Table 7.2 shows the results of this assessment. Figures 7.8 and 7.9 show the statistical distributions of removable beta measurements plotted against cumulative probability, respectively. In both cases, the measured activity was far less than the acceptance limit of 1000 dpm/100 cm^2. Based on this inspection method, we accept the area as uncontaminated.

Table 7.2 Removable Activity Inside Buildings T373 and T374

Measurement	Number of Locations	Average Value	Maximum Value	Inspection Test Statistic	Limit
Removable alpha (dpm/100 cm^2)	213	-0.063	2.8	0.96	1,000
Removable beta (dpm/100 cm^2)	213	-0.47	10.1	5.3	1,000

7.4 Beta Surface Activity Measurements

Beta surface activity measurements were made in specified grids, and on various special structural features, in the same locations as smear tests were collected. Results of this "search and find" survey were in all cases No Detectable Activity.

Figure 7.8 Removable Alpha Activity Inside Buildings T373 and T374

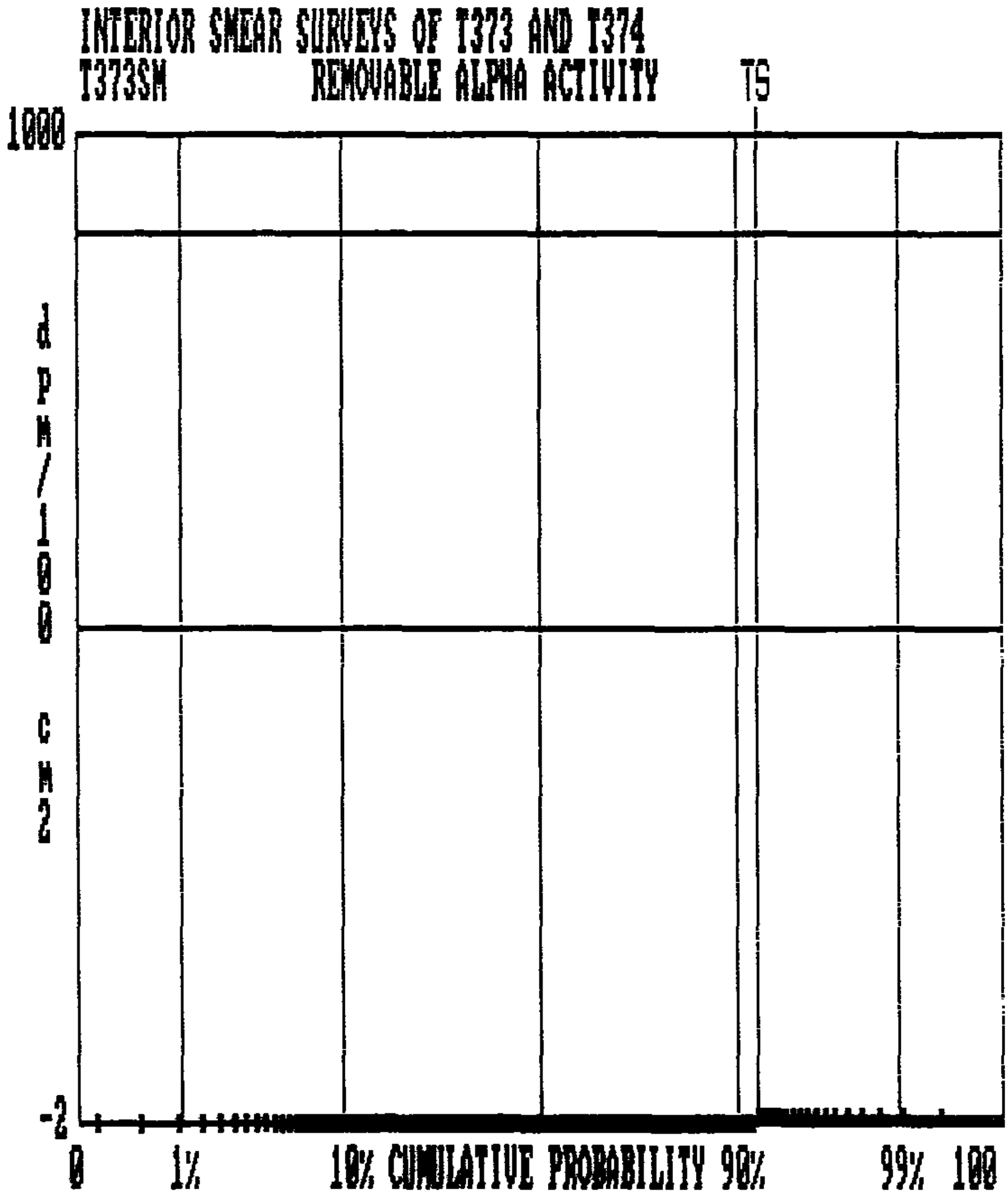
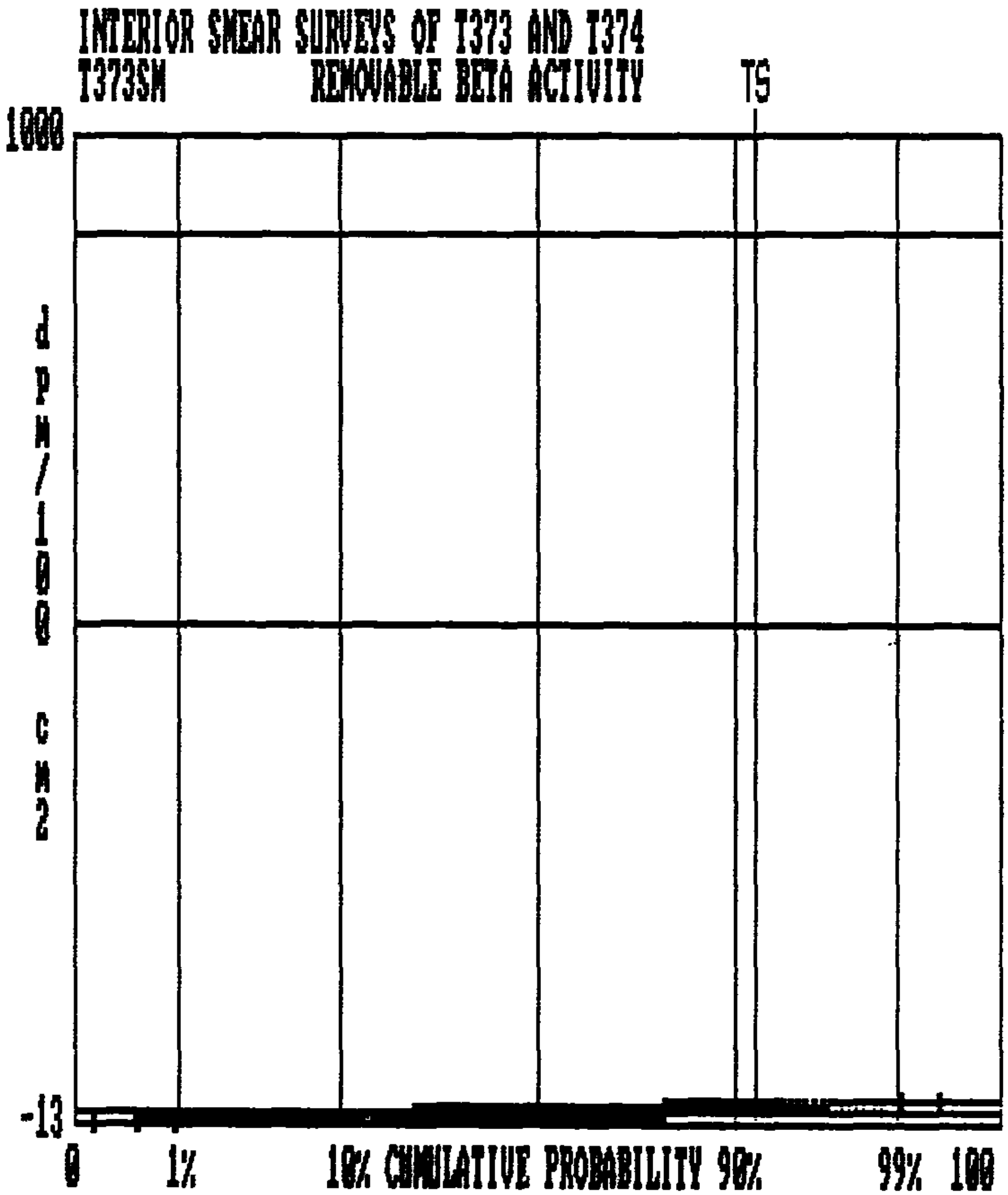


Figure 7.9 Removable Beta Activity Inside Buildings T373 and T374



7.5 Assessment of Radiological Condition

A comprehensive radiological survey testing for exposure rate, removable alpha/beta contamination, and total beta activity was performed to assess present radiological condition of these subject facilities. Statistical analyses of these measurements show that all sampled areas are acceptably clean. A summary of background-corrected gamma exposure rate statistics for data sets is presented in Table 7.3. Removable alpha/beta activity results show no statistically significant activity. All areas pass criteria for unrestricted use. We are confident that the sensitivity and sampling frequency of exposure rate measurements, removable alpha/beta activity measurements, and total beta activity measurements are sufficient for identifying suspect contamination.

Table 7.3 Summary of Gamma Exposure Rate Data Corrected for Background and Statistically Tested Against Acceptance Limits

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 Buildings T373, T374, and T375	9.70*	-0.028	1.21	3.7	1.73	5
Surrounding Area of T373, T374, and T375	13.40*	-0.177	0.90	1.6	1.08	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.

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8.0 CONCLUSIONS

Buildings T373, T374, T375, and surrounding areas were inspected for radioactive contaminants. Gamma exposure rate measurements were made on a 3-m square sampling grid inside T373 and T374; and a 6-m square sampling grid everywhere else, according to the Site Survey Plan (Reference 4). Inside Buildings T373 and T374, over 200 smears were collected in each 3-m square and on special building features to assess the extent of removable alpha/beta activity. In those same interior locations, total beta surface activity was checked "for indication." Smears and beta surveys were performed on sinks, drains, exhaust vents, ventilation systems, and filter banks -- these systems are more likely to have retained residual contamination. Exposure rate measurements plotted against cumulative probability show that "natural background" radiation in these areas varies depending on local topography, natural landscape conditions, and vicinity of buildings, equipment, or scrap components. 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 "natural background," the distributions show no trends indicating possible contamination. Removable alpha/beta activity measurements plotted against cumulative probability show no statistically significant activity. All beta surface activity measurements show No Detectable Activity above ambient background. These locations pass as acceptably clean by our test criteria.

Based on these statistical distributions of exposure rate measurements corrected for what we found to be "ambient background" in each sample lot and on 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%. Reinspection during performance of this survey was not necessary. No further inspection is required in these locations.

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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

A Ludlum model 2220-ESG portable scaler/ratemeter was coupled to a Ludlum model 44-10 NaI gamma scintillator 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

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

MAR 05 1985

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:

02067RL

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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, Jr.

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

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.

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.

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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.

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 cm²)†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.

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 <u>Long-Term Management</u>

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.

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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

H. REFERENCES

International Commission on Radiological Protection. 1977. Recommendations of the International Commission on Radiological Protection (Adopted January 17, 1977). ICRP Publication 26. Pergamon Press, Oxford. [As modified by "Statement from the 1978 Stockholm Meeting of the ICRP." Annals of the ICRP, Vol. 2, No. 1, 1978.]

International Commission on Radiological Protection. 1978. Limits for Intakes of Radionuclides by Workers. A Report of Committee 2 of the International Commission on Radiological Protection. Adopted by the Commission in July 1978. ICRP Publication 30. Part 1 (and Supplement), Part 2 (and Supplement), Part 3 (and Supplements A and B), and Index. Pergamon Press, Oxford.

U.S. Environmental Protection Agency. 1983. Standards for Remedial Actions at Inactive Uranium Processing Sites; Final Rule (40 CFR Part 192). Fed. Regist. 48(3):590-604 (January 5, 1983).

U.S. Department of Energy. 1984. Formerly Utilized Sites Remedial Action Program. Summary Protocol: Identification - Characterization - Designation - Remedial Action - Certification. Office of Nuclear Energy, Office of Terminal Waste Disposal and Remedial Action, Division of Remedial Action Projects. April 1984.

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U.S. Department of Energy. 1985. Supplement to U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites. A Manual for Implementing Residual Radioactivity Guidelines. Prepared by Argonne National Laboratory, Los Alamos National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory for the U.S. Department of Energy. (In preparation.)

U.S. Nuclear Regulatory Commission. 1982. Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC. July 1982. [See also: U.S. Atomic Energy Commission. 1974. Regulatory Guide 1.86. Termination of Operating Licenses for Nuclear Reactors. Table I.]

APPENDIX C. RADIOLOGICAL SURVEY DATA

C.1 Interior of T373 Exposure Rates Sorted by Location

T373IN.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-1	2300	10.65	0.22
	2-1	2422	11.22	0.23
	2-4	2027	9.39	0.21
	2-5	2100	9.73	0.21
	2-7	2215	10.26	0.22
	2-8	2237	10.36	0.22
	2-10	2561	11.86	0.23
	2-11	2516	11.65	0.23
	2-12	2485	11.51	0.23
	3-2	2182	10.11	0.22
	3-5	2056	9.52	0.21
	3-9	2590	12.00	0.24
	3-10	2550	11.81	0.23
	3-12	2608	12.08	0.24
	4-7	2231	10.33	0.22
	4-9	2385	11.05	0.23
	4-10	2638	12.22	0.24
	5-2	2168	10.04	0.22
	5-4	2049	9.49	0.21
	5-5	2038	9.44	0.21
	5-6	2080	9.63	0.21
	5-8	2240	10.38	0.22
	5-9	2385	11.05	0.23
	5-11	2571	11.91	0.23
	6-3	1979	9.17	0.21
	6-6	1892	8.76	0.20
	6-7	1775	8.22	0.20
	6-9	2402	11.13	0.23
	6-11	2362	10.94	0.23
	6-12	2161	10.01	0.22
	7-2	2168	10.04	0.22
	7-3	1962	9.09	0.21
	7-5	1805	8.36	0.20
	7-7	1898	8.79	0.20
	7-9	2381	11.03	0.23
	7-10	2322	10.76	0.22
	7-11	2270	10.51	0.22
	7-12	2233	10.34	0.22
	8-4	1945	9.01	0.20
	8-5	1544	7.15	0.18
	9-3	1808	8.37	0.20
	9-5	1751	8.11	0.19
	9-6	1793	8.31	0.20
	9-7	1545	7.16	0.18
	9-9	2976	13.78	0.25
	9-10	2803	12.98	0.25
	9-11	2580	11.95	0.24
	10-2	2199	10.19	0.22
	10-4	2125	9.84	0.21
	10-6	2138	9.90	0.21

T373IN.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	10-7	2438	11.29	0.23
	10-8	1927	8.93	0.20
	10-9	3015	13.97	0.25
	10-10	2610	12.09	0.24
	10-12	2498	11.57	0.23
	11-5	2192	10.15	0.22
	11-6	2383	11.04	0.23
	11-12	2387	11.06	0.23
	12-2	2246	10.40	0.22
	12-7	2206	10.22	0.22
	12-10	2435	11.28	0.23
	12-12	2509	11.62	0.23
	13-4	1959	9.07	0.21
	13-5	2118	9.81	0.21
	13-6	2396	11.10	0.23
	13-8	2322	10.76	0.22
	13-9	2321	10.75	0.22
	13-13	2788	12.91	0.24
	13-14	2202	10.20	0.22
	13-15	2143	9.93	0.21
	14-7	2257	10.45	0.22
	14-10	1740	8.06	0.19
	14-11	2258	10.46	0.22
	14-12	2344	10.86	0.22
	14-14	2135	9.89	0.21
	14-15	2143	9.93	0.21
	15-4	1791	8.30	0.20
	15-5	1896	8.78	0.20
	15-9	2236	10.36	0.22
	15-10	1906	8.83	0.20
	15-13	2169	10.05	0.22
	16-6	2273	10.53	0.22
	16-7	2037	9.44	0.21
	16-10	2109	9.77	0.21
	16-11	1919	8.89	0.20
	16-12	1987	9.20	0.21
	16-13	2128	9.86	0.21
	16-14	2217	10.27	0.22
	16-15	2221	10.29	0.22

NUMBER OF MEAS.	89	
AVERAGE/SQRT(SUMSQ)	10.27	2.06
STD. DEV.	1.32	
MAXIMUM	13.97	
MIMIMUM	7.15	
RANGE	6.81	

Interior of T373 Sorted by Exposure Rate

T373IN.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	10-9	3015	13.97	0.25
	9-9	2976	13.78	0.25
	9-10	2803	12.98	0.25
	13-13	2788	12.91	0.24
	4-10	2638	12.22	0.24
	10-10	2610	12.09	0.24
	3-12	2608	12.08	0.24
	3-9	2590	12.00	0.24
	9-11	2580	11.95	0.24
	5-11	2571	11.91	0.23
	2-10	2561	11.86	0.23
	3-10	2550	11.81	0.23
	2-11	2516	11.65	0.23
	12-12	2509	11.62	0.23
	10-12	2498	11.57	0.23
	2-12	2485	11.51	0.23
	10-7	2438	11.29	0.23
	12-10	2435	11.28	0.23
	2-1	2422	11.22	0.23
	6-9	2402	11.13	0.23
	13-6	2396	11.10	0.23
	11-12	2387	11.06	0.23
	5-9	2385	11.05	0.23
	4-9	2385	11.05	0.23
	11-6	2383	11.04	0.23
	7-9	2381	11.03	0.23
	6-11	2362	10.94	0.23
	14-12	2344	10.86	0.22
	7-10	2322	10.76	0.22
	13-8	2322	10.76	0.22
	13-9	2321	10.75	0.22
	1-1	2300	10.65	0.22
	16-6	2273	10.53	0.22
	7-11	2270	10.51	0.22
	14-11	2258	10.46	0.22
	14-7	2257	10.45	0.22
	12-2	2246	10.40	0.22
	5-8	2240	10.38	0.22
	2-8	2237	10.36	0.22
	15-9	2236	10.36	0.22
	7-12	2233	10.34	0.22
	4-7	2231	10.33	0.22
	16-15	2221	10.29	0.22
	16-14	2217	10.27	0.22
	2-7	2215	10.26	0.22
	12-7	2206	10.22	0.22
	13-14	2202	10.20	0.22
	10-2	2199	10.19	0.22
	11-5	2192	10.15	0.22
	3-2	2182	10.11	0.22

T373IN.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	15-13	2169	10.05	0.22
	5-2	2168	10.04	0.22
	7-2	2168	10.04	0.22
	6-12	2161	10.01	0.22
	13-15	2143	9.93	0.21
	14-15	2143	9.93	0.21
	10-6	2138	9.90	0.21
	14-14	2135	9.89	0.21
	16-13	2128	9.86	0.21
	10-4	2125	9.84	0.21
	13-5	2118	9.81	0.21
	16-10	2109	9.77	0.21
	2-5	2100	9.73	0.21
	5-6	2080	9.63	0.21
	3-5	2056	9.52	0.21
	5-4	2049	9.49	0.21
	5-5	2038	9.44	0.21
	16-7	2037	9.44	0.21
	2-4	2027	9.39	0.21
	16-12	1987	9.20	0.21
	6-3	1979	9.17	0.21
	7-3	1962	9.09	0.21
	13-4	1959	9.07	0.21
	8-4	1945	9.01	0.20
	10-8	1927	8.93	0.20
	16-11	1919	8.89	0.20
	15-10	1906	8.83	0.20
	7-7	1898	8.79	0.20
	15-5	1896	8.78	0.20
	6-6	1892	8.76	0.20
	9-3	1808	8.37	0.20
	7-5	1805	8.36	0.20
	9-6	1793	8.31	0.20
	15-4	1791	8.30	0.20
	6-7	1775	8.22	0.20
	9-5	1751	8.11	0.19
	14-10	1740	8.06	0.19
	9-7	1545	7.16	0.18
	8-5	1544	7.15	0.18

NUMBER OF MEAS.	89	
AVERAGE/SQRT(SUMSQ)	10.27	2.06
STD. DEV.	1.32	
MAXIMUM	13.97	
MIMIMUM	7.15	
RANGE	6.81	

C.2 Interior of T374 and T375 Exposure Rates Sorted by Location

T374IN.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
T374	1-1	1948	9.02	0.20
T374	1-2	1859	8.61	0.20
T374	1-3	2076	9.62	0.21
T374	1-4	1835	8.50	0.20
T374	2-1	2120	9.82	0.21
T374	2-2	2034	9.42	0.21
T374	2-3	2070	9.59	0.21
T374	2-4	1894	8.77	0.20
T374	2-5	1690	7.83	0.19
T374	2-6	1862	8.62	0.20
T374	3-1	2168	10.04	0.22
T374	3-2	2117	9.81	0.21
T374	3-3	2103	9.74	0.21
T374	3-4	1974	9.14	0.21
T374	3-4	1744	8.08	0.19
T374	3-5	1748	8.10	0.19
T374	3-6	1940	8.99	0.20
T374	4-1	2413	11.18	0.23
T374	4-4	2189	10.14	0.22
T374	4-6	2230	10.33	0.22
T375	1-1	2109	9.77	0.21
T375	1-2	2153	9.97	0.21
T375	1-3	1975	9.15	0.21
T375	2-1	2044	9.47	0.21
T375	2-2	2273	10.53	0.22
T375	2-3	2125	9.84	0.21
T375	3-1	1909	8.84	0.20
T375	3-2	2047	9.48	0.21
T375	3-2	1809	8.38	0.20

NUMBER OF MEAS.	29	
AVERAGE/SQRT(SUMSQ)	9.34	1.12
STD. DEV.	0.79	
MAXIMUM	11.18	
MINIMUM	7.83	
RANGE	3.35	

Interior of T374 and T375 Sorted by Exposure Rate

T374IN.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
T374	4-1	2413	11.18	0.23
T375	2-2	2273	10.53	0.22
T374	4-6	2230	10.33	0.22
T374	4-4	2189	10.14	0.22
T374	3-1	2168	10.04	0.22
T375	1-2	2153	9.97	0.21
T375	2-3	2125	9.84	0.21
T374	2-1	2120	9.82	0.21
T374	3-2	2117	9.81	0.21
T375	1-1	2109	9.77	0.21
T374	3-3	2103	9.74	0.21
T374	1-3	2076	9.62	0.21
T374	2-3	2070	9.59	0.21
T375	3-2	2047	9.48	0.21
T375	2-1	2044	9.47	0.21
T374	2-2	2034	9.42	0.21
T375	1-3	1975	9.15	0.21
T374	3-4	1974	9.14	0.21
T374	1-1	1948	9.02	0.20
T374	3-6	1940	8.99	0.20
T375	3-1	1909	8.84	0.20
T374	2-4	1894	8.77	0.20
T374	2-6	1862	8.62	0.20
T374	1-2	1859	8.61	0.20
T374	1-4	1835	8.50	0.20
T375	3-2	1809	8.38	0.20
T374	3-5	1748	8.10	0.19
T374	3-4	1744	8.08	0.19
T374	2-5	1690	7.83	0.19

NUMBER OF MEAS.	29	
AVERAGE/SQRT(SUMSQ)	9.34	1.12
STD. DEV.	0.79	
MAXIMUM	11.18	
MINIMUM	7.83	
RANGE	3.35	

C.3 T373 and T374 Surrounding Area Sorted by Location

T373OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	2-11	2749	12.73	0.24
	2-12	2719	12.59	0.24
	2-13	2730	12.65	0.24
	3-10	2652	12.28	0.24
	3-11	2518	11.66	0.23
	3-12	2792	12.93	0.24
	3-13	2791	12.93	0.24
	4-10	2710	12.55	0.24
	4-11	2800	12.97	0.25
	4-12	2708	12.54	0.24
	4-13	2743	12.71	0.24
	5-10	2702	12.52	0.24
	5-11	2767	12.82	0.24
	5-12	2685	12.44	0.24
	5-13	2824	13.08	0.25
	6-10	2688	12.45	0.24
	6-11	2704	12.52	0.24
	6-12	2695	12.48	0.24
	6-13	2710	12.55	0.24
	7-10	2733	12.66	0.24
	7-11	2716	12.58	0.24
	7-12	2662	12.33	0.24
	7-13	2744	12.71	0.24
	8-10	2710	12.55	0.24
	8-11	2693	12.47	0.24
	9-11	2757	12.77	0.24
	9-12	2790	12.92	0.24
	10-10	2765	12.81	0.24
	10-11	2721	12.60	0.24
	11-10	2720	12.60	0.24
	11-11	2765	12.81	0.24
	12-1	2595	12.02	0.24
	12-2	2652	12.28	0.24
	12-3	2620	12.14	0.24
	12-4	2504	11.60	0.23
	12-5	2605	12.07	0.24
	12-6	2614	12.11	0.24
	12-7	2641	12.23	0.24
	12-8	2694	12.48	0.24
	12-9	2757	12.77	0.24
	12-10	2570	11.90	0.23
	12-11	2666	12.35	0.24
	13-1	2634	12.20	0.24
	13-2	2734	12.66	0.24
	13-3	2497	11.57	0.23
	13-4	2248	10.41	0.22
	13-5	2249	10.42	0.22
	13-6	2608	12.08	0.24
	13-7	2747	12.72	0.24
	13-8	2704	12.52	0.24

T373OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	13-9	2798	12.96	0.25
	13-10	2577	11.94	0.24
	13-11	2709	12.55	0.24
	14-1	2803	12.98	0.25
	14-2	2711	12.56	0.24
	14-3	2555	11.83	0.23
	14-6	2005	9.29	0.21
	14-7	2778	12.87	0.24
	14-8	2737	12.68	0.24
	14-9	2612	12.10	0.24
	14-10	2679	12.41	0.24
	14-11	2622	12.15	0.24
	15-1	2859	13.24	0.25
	15-2	2820	13.06	0.25
	15-3	2673	12.38	0.24
	15-4	2680	12.41	0.24
	15-5	2418	11.20	0.23
	15-6	2372	10.99	0.23
	15-7	2690	12.46	0.24
	15-8	2692	12.47	0.24
	15-9	2598	12.03	0.24
	15-10	2659	12.32	0.24
	15-11	2656	12.30	0.24
	16-1	2799	12.96	0.25
	16-2	2908	13.47	0.25
	16-3	2582	11.96	0.24
	16-8	2674	12.39	0.24
	16-9	2642	12.24	0.24
	16-10	2517	11.66	0.23
	16-11	2752	12.75	0.24
	17-1	2745	12.71	0.24
	17-2	2860	13.25	0.25
	17-3	2844	13.17	0.25
	17-4	2565	11.88	0.23
	17-8	2660	12.32	0.24
	17-9	2661	12.33	0.24
	17-10	2556	11.84	0.23
	17-11	2740	12.69	0.24
	18-1	2848	13.19	0.25
	18-2	2852	13.21	0.25
	18-3	2775	12.85	0.24
	18-4	2903	13.45	0.25
	18-8	2699	12.50	0.24
	18-9	2690	12.46	0.24
	18-10	2623	12.15	0.24
	18-11	2744	12.71	0.24
	19-1	2850	13.20	0.25
	19-2	2905	13.46	0.25
	19-3	2840	13.15	0.25
	19-4	2804	12.99	0.25

T373OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	19-8	2582	11.96	0.24
	19-9	2843	13.17	0.25
	19-10	2817	13.05	0.25
	19-11	2713	12.57	0.24
	20-1	2731	12.65	0.24
	20-2	3006	13.92	0.25
	20-3	2791	12.93	0.24
	20-4	2927	13.56	0.25
	20-8	2710	12.55	0.24
	20-9	2809	13.01	0.25
	20-10	2683	12.43	0.24
	20-11	2793	12.94	0.24
	21-1	2647	12.26	0.24
	21-2	2780	12.88	0.24
	21-3	2826	13.09	0.25
	21-4	2789	12.92	0.24
	21-5	2932	13.58	0.25
	21-6	2852	13.21	0.25
	21-7	2567	11.89	0.23
	21-8	2828	13.10	0.25
	21-9	2736	12.67	0.24
	21-10	2717	12.59	0.24
	21-11	2830	13.11	0.25
	22-1	2743	12.71	0.24
	22-2	2840	13.15	0.25
	22-3	2805	12.99	0.25
	22-4	2941	13.62	0.25
	22-4	2739	12.69	0.24
	22-5	2830	13.11	0.25
	22-6	2802	12.98	0.25
	22-7	2805	12.99	0.25
	22-8	2903	13.45	0.25
	22-9	2839	13.15	0.25
	22-10	2741	12.70	0.24
	23-1	2608	12.08	0.24
	23-2	2773	12.84	0.24
	23-3	2882	13.35	0.25
	23-4	2808	13.01	0.25
	23-5	2770	12.83	0.24
	23-6	2924	13.54	0.25
	23-7	2854	13.22	0.25
	23-8	2879	13.34	0.25
	23-9	2932	13.58	0.25
	23-10	2783	12.89	0.24
	23-11	2748	12.73	0.24
	24-1	2641	12.23	0.24
	24-2	2868	13.28	0.25
	24-3	2858	13.24	0.25
	24-4	2810	13.02	0.25
	24-5	2849	13.20	0.25

T373OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	24-6	2634	12.20	0.24
	24-7	2830	13.11	0.25
	24-8	2797	12.96	0.24
	24-9	2917	13.51	0.25
	24-10	2692	12.47	0.24
	24-11	2792	12.93	0.24
	25-1	2649	12.27	0.24
	25-2	2759	12.78	0.24
	25-3	2737	12.68	0.24
	25-4	2716	12.58	0.24
	25-5	2724	12.62	0.24
	25-6	2715	12.58	0.24
	25-7	2861	13.25	0.25
	25-8	2908	13.47	0.25
	25-9	2849	13.20	0.25
	25-10	2821	13.07	0.25
	26-9	2718	12.59	0.24
	26-10	2894	13.41	0.25
	27-9	2803	12.98	0.25
	27-10	2912	13.49	0.25

NUMBER OF MEAS.	170	
AVERAGE/SQRT(SUMSQ)	12.65	3.16
STD. DEV.	0.61	
MAXIMUM	13.92	
MIMIMUM	9.29	
RANGE	4.64	

T373 and T374 Surrounding Area Sorted by Exposure Rate

T373OUT.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	20-2	3006	13.92	0.25
	22-4	2941	13.62	0.25
	21-5	2932	13.58	0.25
	23-9	2932	13.58	0.25
	20-4	2927	13.56	0.25
	23-6	2924	13.54	0.25
	24-9	2917	13.51	0.25
	27-10	2912	13.49	0.25
	16-2	2908	13.47	0.25
	25-8	2908	13.47	0.25
	19-2	2905	13.46	0.25
	18-4	2903	13.45	0.25
	22-8	2903	13.45	0.25
	26-10	2894	13.41	0.25
	23-3	2882	13.35	0.25
	23-8	2879	13.34	0.25
	24-2	2868	13.28	0.25
	25-7	2861	13.25	0.25
	17-2	2860	13.25	0.25
	15-1	2859	13.24	0.25
	24-3	2858	13.24	0.25
	23-7	2854	13.22	0.25
	18-2	2852	13.21	0.25
	21-6	2852	13.21	0.25
	19-1	2850	13.20	0.25
	24-5	2849	13.20	0.25
	25-9	2849	13.20	0.25
	18-1	2848	13.19	0.25
	17-3	2844	13.17	0.25
	19-9	2843	13.17	0.25
	19-3	2840	13.15	0.25
	22-2	2840	13.15	0.25
	22-9	2839	13.15	0.25
	21-11	2830	13.11	0.25
	22-5	2830	13.11	0.25
	24-7	2830	13.11	0.25
	21-8	2828	13.10	0.25
	21-3	2826	13.09	0.25
	5-13	2824	13.08	0.25
	25-10	2821	13.07	0.25
	15-2	2820	13.06	0.25
	19-10	2817	13.05	0.25
	24-4	2810	13.02	0.25
	20-9	2809	13.01	0.25
	23-4	2808	13.01	0.25
	22-3	2805	12.99	0.25
	22-7	2805	12.99	0.25
	19-4	2804	12.99	0.25
	14-1	2803	12.98	0.25
	27-9	2803	12.98	0.25

T373OUT.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	22-6	2802	12.98	0.25
	4-11	2800	12.97	0.25
	16-1	2799	12.96	0.25
	13-9	2798	12.96	0.25
	24-8	2797	12.96	0.24
	20-11	2793	12.94	0.24
	3-12	2792	12.93	0.24
	24-11	2792	12.93	0.24
	20-3	2791	12.93	0.24
	3-13	2791	12.93	0.24
	9-12	2790	12.92	0.24
	21-4	2789	12.92	0.24
	23-10	2783	12.89	0.24
	21-2	2780	12.88	0.24
	14-7	2778	12.87	0.24
	18-3	2775	12.85	0.24
	23-2	2773	12.84	0.24
	23-5	2770	12.83	0.24
	5-11	2767	12.82	0.24
	10-10	2765	12.81	0.24
	11-11	2765	12.81	0.24
	25-2	2759	12.78	0.24
	9-11	2757	12.77	0.24
	12-9	2757	12.77	0.24
	16-11	2752	12.75	0.24
	2-11	2749	12.73	0.24
	23-11	2748	12.73	0.24
	13-7	2747	12.72	0.24
	17-1	2745	12.71	0.24
	7-13	2744	12.71	0.24
	18-11	2744	12.71	0.24
	4-13	2743	12.71	0.24
	22-1	2743	12.71	0.24
	22-10	2741	12.70	0.24
	17-11	2740	12.69	0.24
	22-4	2739	12.69	0.24
	14-8	2737	12.68	0.24
	25-3	2737	12.68	0.24
	21-9	2736	12.67	0.24
	13-2	2734	12.66	0.24
	7-10	2733	12.66	0.24
	20-1	2731	12.65	0.24
	2-13	2730	12.65	0.24
	25-5	2724	12.62	0.24
	10-11	2721	12.60	0.24
	11-10	2720	12.60	0.24
	2-12	2719	12.59	0.24
	26-9	2718	12.59	0.24
	21-10	2717	12.59	0.24
	7-11	2716	12.58	0.24

T373OUT.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	25-4	2716	12.58	0.24
	25-6	2715	12.58	0.24
	19-11	2713	12.57	0.24
	14-2	2711	12.56	0.24
	20-8	2710	12.55	0.24
	8-10	2710	12.55	0.24
	6-13	2710	12.55	0.24
	4-10	2710	12.55	0.24
	13-11	2709	12.55	0.24
	4-12	2708	12.54	0.24
	6-11	2704	12.52	0.24
	13-8	2704	12.52	0.24
	5-10	2702	12.52	0.24
	18-8	2699	12.50	0.24
	6-12	2695	12.48	0.24
	12-8	2694	12.48	0.24
	8-11	2693	12.47	0.24
	15-8	2692	12.47	0.24
	24-10	2692	12.47	0.24
	15-7	2690	12.46	0.24
	18-9	2690	12.46	0.24
	6-10	2688	12.45	0.24
	5-12	2685	12.44	0.24
	20-10	2683	12.43	0.24
	15-4	2680	12.41	0.24
	14-10	2679	12.41	0.24
	16-8	2674	12.39	0.24
	15-3	2673	12.38	0.24
	12-11	2666	12.35	0.24
	7-12	2662	12.33	0.24
	17-9	2661	12.33	0.24
	17-8	2660	12.32	0.24
	15-10	2659	12.32	0.24
	15-11	2656	12.30	0.24
	3-10	2652	12.28	0.24
	12-2	2652	12.28	0.24
	25-1	2649	12.27	0.24
	21-1	2647	12.26	0.24
	16-9	2642	12.24	0.24
	24-1	2641	12.23	0.24
	12-7	2641	12.23	0.24
	13-1	2634	12.20	0.24
	24-6	2634	12.20	0.24
	18-10	2623	12.15	0.24
	14-11	2622	12.15	0.24
	12-3	2620	12.14	0.24
	12-6	2614	12.11	0.24
	14-9	2612	12.10	0.24
	23-1	2608	12.08	0.24
	13-6	2608	12.08	0.24

T373OUT.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	uR/h STD DEV
	12-5	2605	12.07	0.24
	15-9	2598	12.03	0.24
	12-1	2595	12.02	0.24
	19-8	2582	11.96	0.24
	16-3	2582	11.96	0.24
	13-10	2577	11.94	0.24
	12-10	2570	11.90	0.23
	21-7	2567	11.89	0.23
	17-4	2565	11.88	0.23
	17-10	2556	11.84	0.23
	14-3	2555	11.83	0.23
	3-11	2518	11.66	0.23
	16-10	2517	11.66	0.23
	12-4	2504	11.60	0.23
	13-3	2497	11.57	0.23
	15-5	2418	11.20	0.23
	15-6	2372	10.99	0.23
	13-5	2249	10.42	0.22
	13-4	2248	10.41	0.22
	14-6	2005	9.29	0.21

NUMBER OF MEAS.	170	
AVERAGE/SQRT(SUMSQ)	12.65	3.16
STD. DEV.	0.61	
MAXIMUM	13.92	
MIMIMUM	9.29	
RANGE	4.64	

C.4 Exposure Rates on Roof of T373

T373ROOF.WS — SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-3	2000	9.26	0.21
	1-4	2006	9.29	0.21
	2-2	2329	10.79	0.22
	2-3	1831	8.48	0.20
	2-4	1917	8.88	0.20
	3-2	2372	10.99	0.23
	3-3	1719	7.96	0.19
	3-4	1976	9.15	0.21
	4-2	2379	11.02	0.23
	4-3	1741	8.06	0.19
	4-4	2060	9.54	0.21
	5-2	1942	9.00	0.20
	5-3	2009	9.31	0.21
	5-4	2211	10.24	0.22
	NUMBER OF MEAS.		14	
	AVERAGE/SQRT(SUMSQ)		9.43	0.78
	STD. DEV.		1.00	
	MAXIMUM		11.02	
	MINIMUM		7.96	
	RANGE		3.06	

T373ROOF.WS — SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	4-2	2379	11.02	0.23
	3-2	2372	10.99	0.23
	2-2	2329	10.79	0.22
	5-4	2211	10.24	0.22
	4-4	2060	9.54	0.21
	5-3	2009	9.31	0.21
	1-4	2006	9.29	0.21
	1-3	2000	9.26	0.21
	3-4	1976	9.15	0.21
	5-2	1942	9.00	0.20
	2-4	1917	8.88	0.20
	2-3	1831	8.48	0.20
	4-3	1741	8.06	0.19
	3-3	1719	7.96	0.19

C.5 T375 Surrounding Area Sorted by Location

T375OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-1	3399	15.74	0.27
	1-2	3233	14.98	0.26
	1-3	3228	14.95	0.26
	1-4	3220	14.92	0.26
	1-5	3064	14.19	0.26
	1-6	3129	14.49	0.26
	1-7	3125	14.48	0.26
	1-8	3321	15.38	0.27
	1-9	3143	14.56	0.26
	1-10	3046	14.11	0.26
	1-11	3099	14.35	0.26
	1-12	3026	14.02	0.25
	1-13	3022	14.00	0.25
	1-14	2890	13.39	0.25
	1-15	3121	14.46	0.26
	1-16	3089	14.31	0.26
	1-17	3064	14.19	0.26
	1-18	3082	14.28	0.26
	1-19	3225	14.94	0.26
	2-1	3354	15.54	0.27
	2-2	3239	15.00	0.26
	2-3	3291	15.24	0.27
	2-4	3267	15.13	0.26
	2-5	3131	14.50	0.26
	2-6	3215	14.89	0.26
	2-7	3102	14.37	0.26
	2-8	3135	14.52	0.26
	3-1	3148	14.58	0.26
	3-2	3110	14.41	0.26
	3-3	3087	14.30	0.26
	3-4	3133	14.51	0.26
	3-5	2926	13.55	0.25
	3-6	2924	13.54	0.25
	3-7	3030	14.03	0.25
	3-8	3172	14.69	0.26
	4-1	3124	14.47	0.26
	4-2	3073	14.23	0.26
	4-3	3019	13.98	0.25
	4-4	2887	13.37	0.25
	4-5	2461	11.40	0.23
	4-6	2482	11.50	0.23
	4-7	2527	11.71	0.23
	4-8	2380	11.02	0.23
	5-1	3084	14.29	0.26
	5-2	3102	14.37	0.26
	5-3	2961	13.72	0.25
	5-4	2615	12.11	0.24
	5-5	2257	10.45	0.22
	5-6	2138	9.90	0.21
	5-7	2380	11.02	0.23

T375OUT.WS SORTED BY LOCATION

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	5-8	2470	11.44	0.23
	6-1	3084	14.29	0.26
	6-2	3097	14.35	0.26
	6-3	3022	14.00	0.25
	6-4	3110	14.41	0.26
	6-7	2598	12.03	0.24
	6-8	2492	11.54	0.23
	7-1	3097	14.35	0.26
	7-2	3098	14.35	0.26
	7-3	3010	13.94	0.25
	7-4	2638	12.22	0.24
	7-7	2706	12.53	0.24
	7-8	2693	12.47	0.24
	8-1	2787	12.91	0.24
	8-2	2933	13.59	0.25
	8-3	3001	13.90	0.25
	8-4	2807	13.00	0.25
	8-5	2609	12.08	0.24
	8-6	2623	12.15	0.24
	8-7	2627	12.17	0.24
	8-8	2732	12.65	0.24
	9-1	3104	14.38	0.26
	9-2	3132	14.51	0.26
	9-3	3084	14.29	0.26
	9-4	2929	13.57	0.25
	9-5	3010	13.94	0.25
	9-6	2997	13.88	0.25
	9-7	2808	13.01	0.25
	9-8	2676	12.40	0.24

NUMBER OF MEAS.	79	
AVERAGE/SQRT(SUMSQ)	13.68	2.24
STD. DEV.	1.27	
MAXIMUM	15.74	
MIMIMUM	9.90	
RANGE	5.84	

T375 Surrounding Area Sorted by Exposure Rate

T375OUT.WS

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	1-1	3399	15.74	0.27
	2-1	3354	15.54	0.27
	1-8	3321	15.38	0.27
	2-3	3291	15.24	0.27
	2-4	3267	15.13	0.26
	2-2	3239	15.00	0.26
	1-2	3233	14.98	0.26
	1-3	3228	14.95	0.26
	1-19	3225	14.94	0.26
	1-4	3220	14.92	0.26
	2-6	3215	14.89	0.26
	3-8	3172	14.69	0.26
	3-1	3148	14.58	0.26
	1-9	3143	14.56	0.26
	2-8	3135	14.52	0.26
	3-4	3133	14.51	0.26
	9-2	3132	14.51	0.26
	2-5	3131	14.50	0.26
	1-6	3129	14.49	0.26
	1-7	3125	14.48	0.26
	4-1	3124	14.47	0.26
	1-15	3121	14.46	0.26
	3-2	3110	14.41	0.26
	6-4	3110	14.41	0.26
	9-1	3104	14.38	0.26
	2-7	3102	14.37	0.26
	5-2	3102	14.37	0.26
	1-11	3099	14.35	0.26
	7-2	3098	14.35	0.26
	6-2	3097	14.35	0.26
	7-1	3097	14.35	0.26
	1-16	3089	14.31	0.26
	3-3	3087	14.30	0.26
	5-1	3084	14.29	0.26
	6-1	3084	14.29	0.26
	9-3	3084	14.29	0.26
	1-18	3082	14.28	0.26
	4-2	3073	14.23	0.26
	1-5	3064	14.19	0.26
	1-17	3064	14.19	0.26
	1-10	3046	14.11	0.26
	3-7	3030	14.03	0.25
	1-12	3026	14.02	0.25
	6-3	3022	14.00	0.25
	1-13	3022	14.00	0.25
	4-3	3019	13.98	0.25
	7-3	3010	13.94	0.25
	9-5	3010	13.94	0.25
	8-3	3001	13.90	0.25
	9-6	2997	13.88	0.25

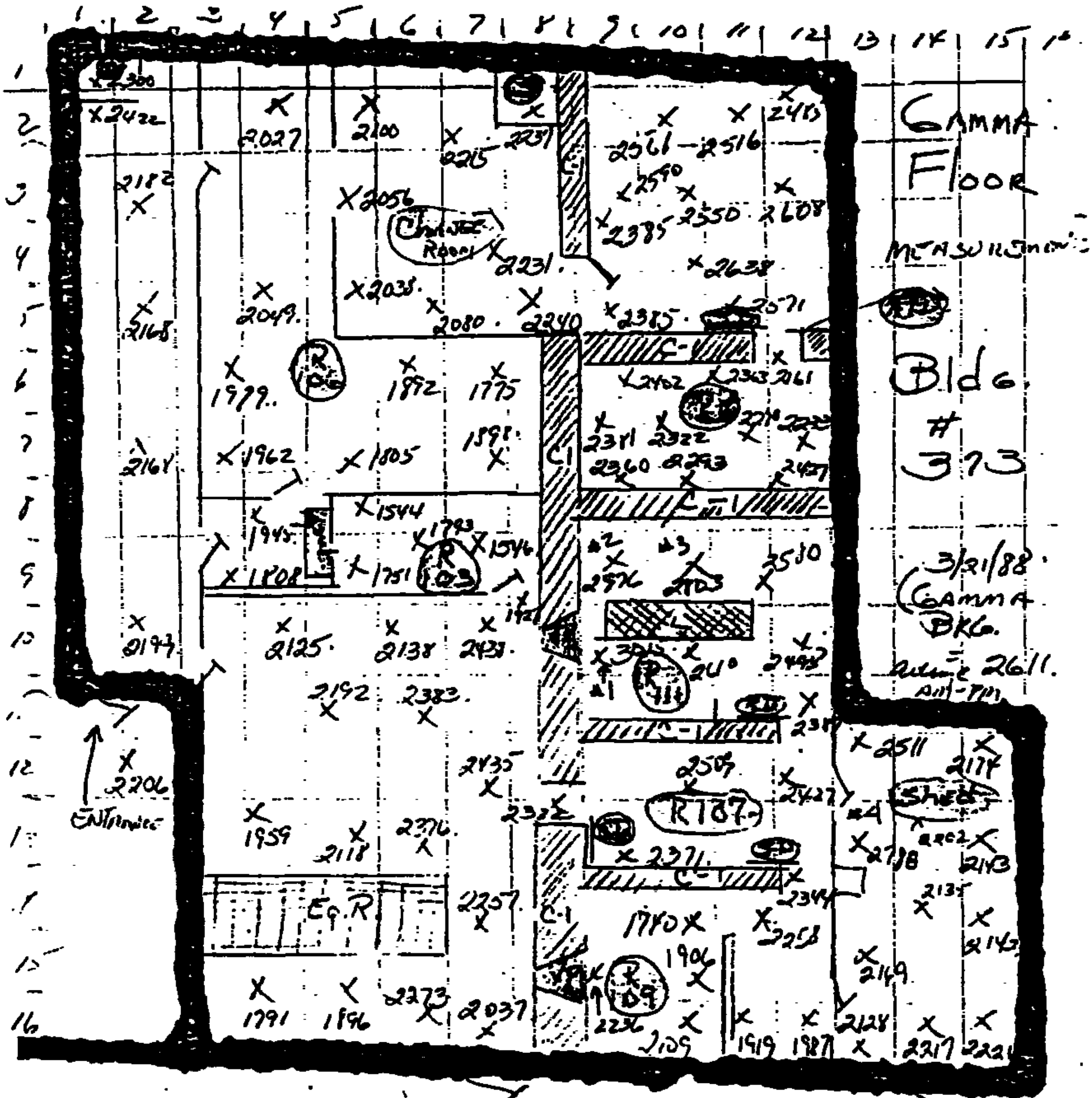
T375OUT.WS SORTED BY EXPOSURE RATE

ROOM NUMBER	GRID NAME	GAMMA TOTAL	uR/h TOTAL	STD DEV
	5-3	2961	13.72	0.25
	8-2	2933	13.59	0.25
	9-4	2929	13.57	0.25
	3-5	2926	13.55	0.25
	3-6	2924	13.54	0.25
	1-14	2890	13.39	0.25
	4-4	2887	13.37	0.25
	9-7	2808	13.01	0.25
	8-4	2807	13.00	0.25
	8-1	2787	12.91	0.24
	8-8	2732	12.65	0.24
	7-7	2706	12.53	0.24
	7-8	2693	12.47	0.24
	9-8	2676	12.40	0.24
	7-4	2638	12.22	0.24
	8-7	2627	12.17	0.24
	8-6	2623	12.15	0.24
	5-4	2615	12.11	0.24
	8-5	2609	12.08	0.24
	6-7	2598	12.03	0.24
	4-7	2527	11.71	0.23
	6-8	2492	11.54	0.23
	4-6	2482	11.50	0.23
	5-8	2470	11.44	0.23
	4-5	2461	11.40	0.23
	5-7	2380	11.02	0.23
	4-8	2380	11.02	0.23
	5-5	2257	10.45	0.22
	5-6	2138	9.90	0.21

NUMBER OF MEAS.	79	
AVERAGE/SQRT(SUMSQ)	13.68	2.24
STD. DEV.	1.27	
MAXIMUM	15.74	
MIMIMUM	9.90	
RANGE	5.84	

APPENDIX D. SURVEYOR MAPS USED DURING RADIOLOGICAL SURVEY

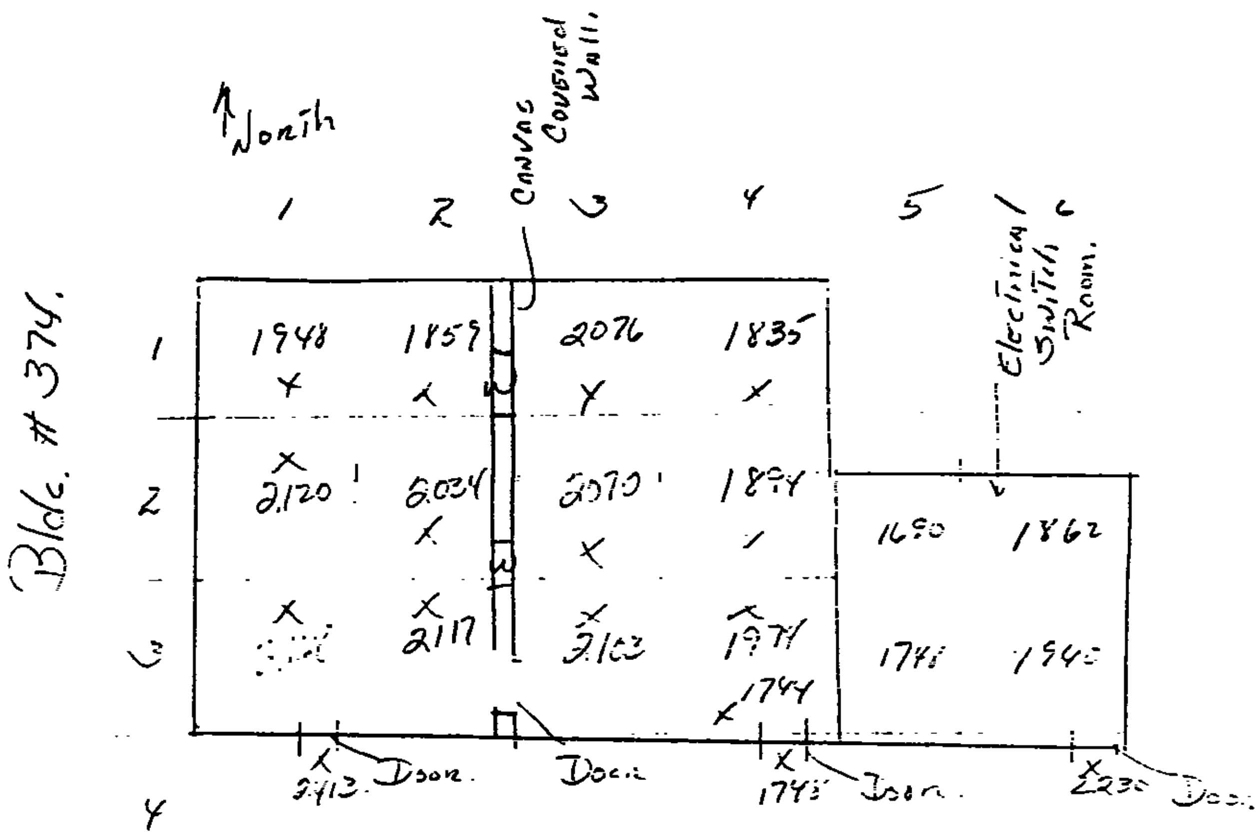
D.1 <u>Interior of Building T373</u>



C-1 = Concrete Wall 1 Foot Thick.
V.P. - View Port
S.D - Sliding Metal Door.
ATD = Air Tight Door.
T = Toilet.
(Gamma Counts / Min).

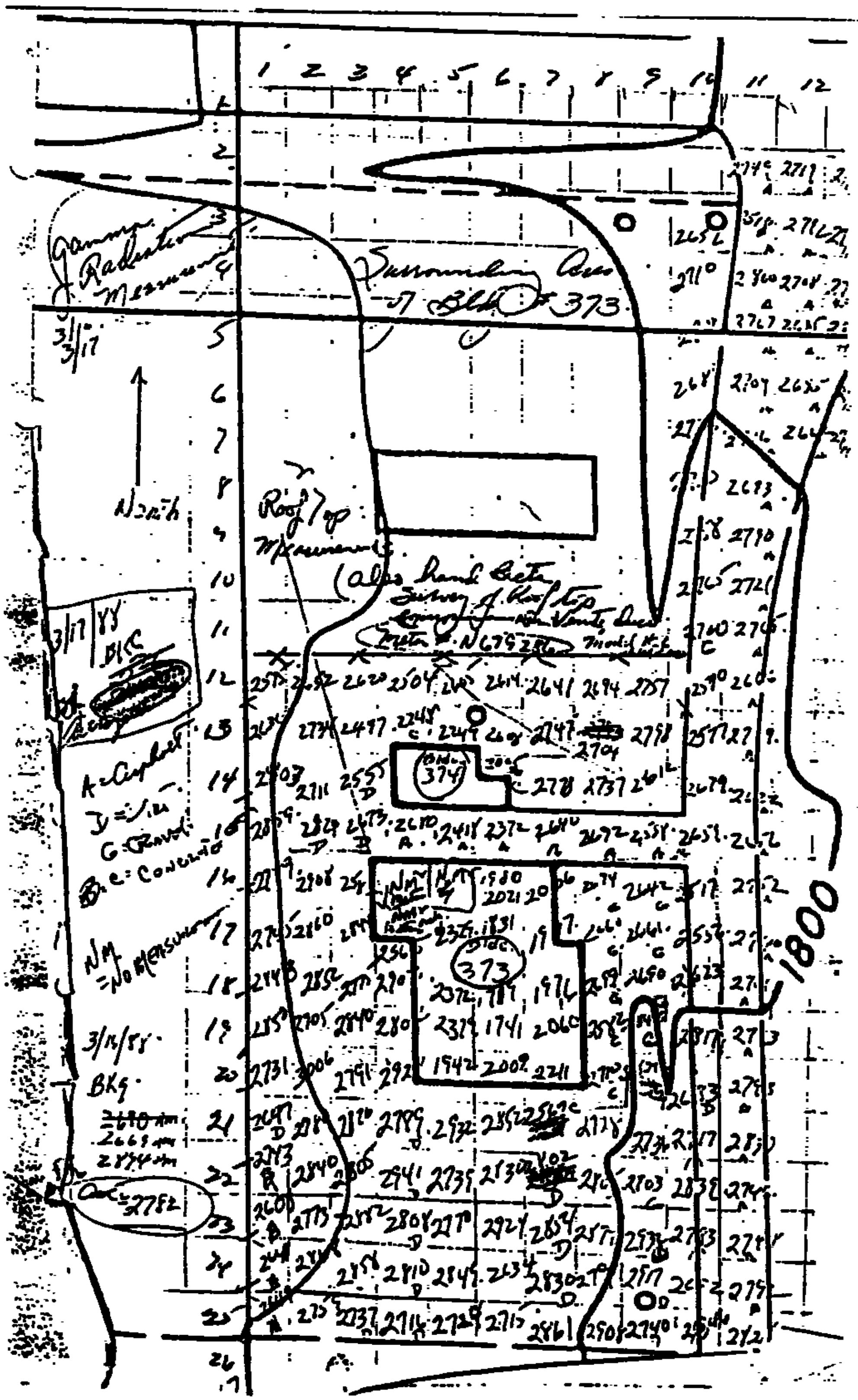
S = Shower.
L = Alkali Metal Loop.
North.
EqR. = Equipment Rack.
Each Square ~ 3 meters
RV - Reactor Vault.

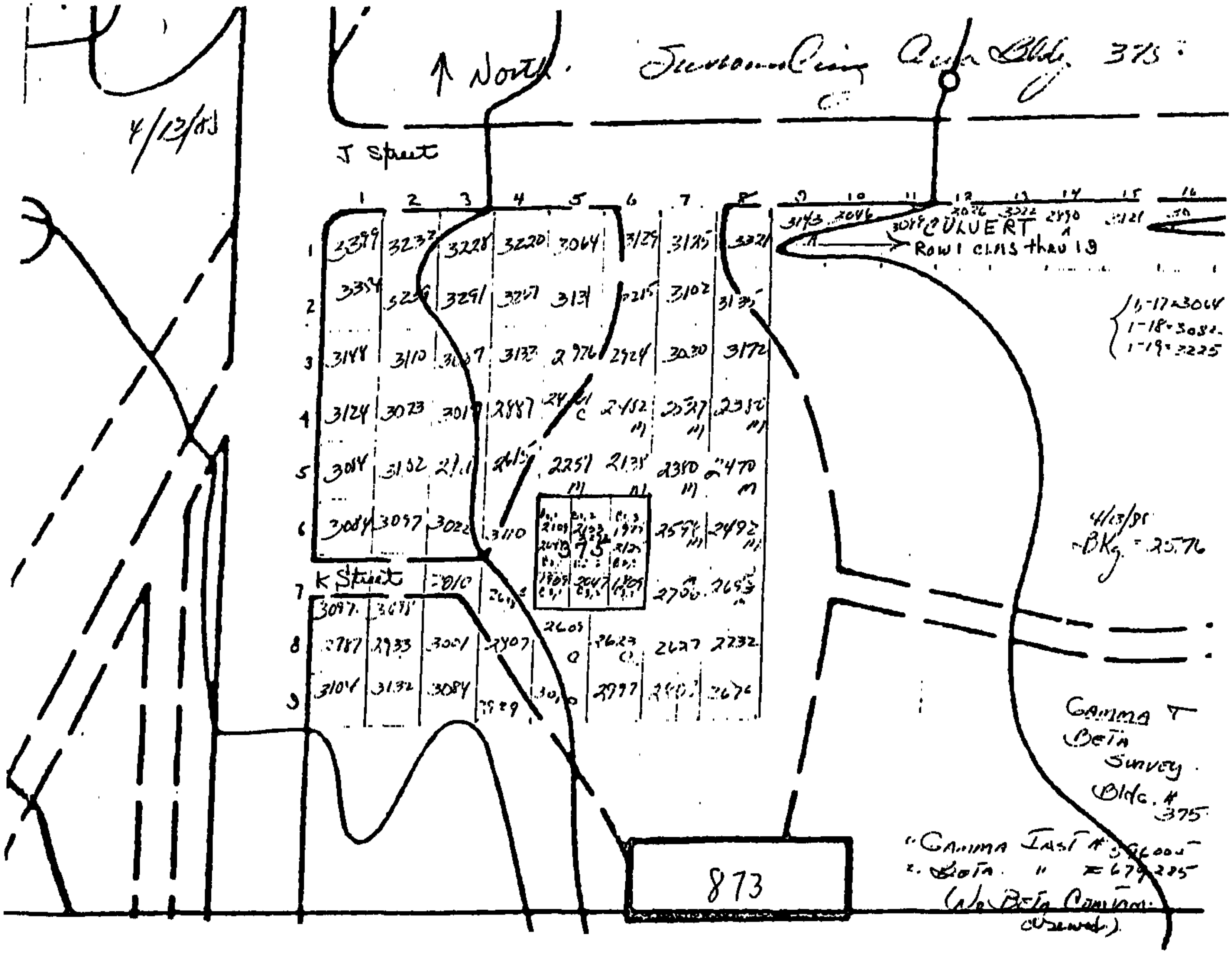
D.2 Interior of Building T374



GAMMA & BETA SURVEY 3/21/88
(No Beta Contamination Detected

D.3 Surrounding Area of T373 and T374





D.4 Interior and Surrounding Area of T375