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FINAL REPORT, MEASUREMENT OF NATURALLY OCCURRING RADIONUCLIDES IN CONCRETE FILL MATERIALS - (USED AS A REFERENCE IN OU 3 RI/FS/PP)

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FINAL REPORT

MEASUREMENT OF NATURALLY OCCURRING RADIONUCLIDES IN CONCRETE FILL MATERIALS

by

Dr. Roy Eckart
Dr. Ali Behbahani
Dr. Richard Hagee

JULY 1, 1987

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SECTION 1 - Results

The samples of concrete fill materials (sand, gravel, cement and water) that were collected from each of six major concrete suppliers were analyzed for the natural radionuclides; uranium 238, thorium 232, radium 226 and potassium 40. Summary Table 1 shows the total natural radionuclide content in one cubic yard of a concrete mix called "4000 mix".

SUMMARY TABLE 1

NATURAL RADIONUCLIDE CONTENT IN ONE CUBIC YARD OF 4000 MIX CONCRETE*

	RADIONUCLIDE				
CONCRETE SUPPLIER	Radium 236 (pCi)	Uranium 238 (pCi)	Thorium 232 (pCi)	Potassium 40 (pCi)	TOTAL ACTIVITY (pCi)
Miami Valley Ready Mix	1,049,700	993,582	311,924	7,423,400	9,778,606
Roth Concrete	1,053,140	1,374,382	348,738	8,348,456	10,176,886
Harrison Ready Mix	1,090,197	1,441,400	351,840	8,017,895	10,900,972
Hilltop Basic Resources	693,068	1,023,084	413,838	9,051,918	11,181,908
Ernst Enterprises	710,650	1,391,036	354,889	8,769,536	11,226,111
Plainville Concrete	800,025	2,176,965	316,297	3,204,430	11,497,717

*total content of each natural radionuclide in one cubic yard of concrete containing: 1320 pounds of sand, 1860 pounds of gravel, 564 pounds of cement, 35 gallons of water.

The data in Summary Table 1 was calculated from the actual measured data shown in Tables 4-7 in this summary section and the weight or volume of these materials in one cubic yard of concrete. Tables 4-7 contain the summary data for the natural radionuclide measurements in sand, cement, gravel and water, used to form the concrete.

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1.1 Analysis of Gamma-ray Spectra

Samples of cement, sand and gravel were prepared by techniques described in detail in Section 4 of this report. Gamma rays from these samples were subsequently measured by a high-resolution and high-efficiency intrinsic-Germanium detector. Details of the measurement system are also presented in Section 4. Analysis was required for potassium 40 (^{40}K), radium 226 (^{226}Ra), thorium 232 (^{232}Th) and uranium 238 (^{238}U).

Due to the low activity levels of ^{40}K, ^{226}Ra, ^{232}Th and ^{238}U existing in these samples, an 8 hour counting period was utilized to achieve the sensitivities required. The spectral lines of each sample were evaluated, specific photopeaks being chosen for the analysis of each of the naturally-occuring radionuclides.[1][2] Whenever possible, several photopeaks were utilized for analysis.

The 1460.2 KeV photon is the only gamma ray emitted by ^{40}K. Fortunately, this photopeak has few interferences. The assignment of this photopeak is thus straightforward. There is some activity from ^{40}K in the background measurement which must be corrected for and, in addition, it is necessary to correct for Compton distribution interferences from a number of higher energy photons in both the radium and thorium decay chains.

Three peaks were chosen for analysis of ^{232}Th: 582.7 KeV 910.6 KeV and 968.4 KeV. The 582.7 KeV peak arises in the decay of ^{208}Tl, whereas the other two peaks occur in the decay of ^{228}Ac, the second daughter of ^{232}Th. These peaks were chosen since they were reasonably free of interferences from other nuclides of comparable energy among the naturally occuring radionuclides.

Measurement of ^{238}U by gamma ray spectroscopy is difficult due to the few spectral lines of sufficient intensity which exist in direct ^{238}U decay or from the upper chain members above ^{226}Ra. The two lines selected were the

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63.3 KeV line from ^{234}Th decay and the 1001.04 KeV line from ^{234}Pa decay. The quantum yield of the 63.3 KeV line is higher than the 1001.04 KeV line but is found in a spectral region where many potential interferences exist from low energy photons and X rays. There is also a substantial compton scattering distribution from higher energy photons. Usually the 63.3 KeV photon is the line which is detected above background and Compton interferences.

In the analysis of ^{226}Ra a number of spectral lines were possible candidates. The lines which were chosen were the 185.8 KeV line from ^{226}Ra, the 294.9 KeV and 351.6 KeV lines from ^{214}Pb and the 608.9 KeV line from ^{214}Bi. All of these photons have rather high yields and are resonably free of interferences from photons of comparable energy among the naturally occuring radionuclides.

All of the above mentioned gamma-ray lines were analyzed in each sample. The average of the results from all the lines used for each radionuclide was the value reported for that sample. A detailed compilation of the results for all the samples is given in Appendix I. It will be noted that the results from each spectral line are compiled. Overall the activity values (pCi/gram) obtained were in good agreement for the grouping of lines utilized for each radionuclide.

1.2 Summary of Results

The results of analyses of two samples of sand, gravel and cement from each supplier are shown in Tables 1, 2 and 3. In these tables no attempt has been made to categorize the results by concentration. This is done in Tables 4, 5 and 6 where the average values are reported ranked in order of decreasing concentration. Results of the analysis for each sample are discussed below.

Cement samples

Table 1 summarizes results of the analyses for the cement samples. The agreement between the analyses of the two samples is excellent for ^{226}Ra, ^{232}Th and ^{40}K. The agreement between the values for ^{238}U is not as good since the limits of error of most ^{238}U analyses were higher than for the other nuclides due to significant spectral interferences.

The lowest ^{226}Ra Concentration was found in the cement samples from Ernst Enterprises and Hilltop Basic Resources Concrete. (approximately 0.59 pCi/gm). Samples from the other four suppliers had concentrations of 1 to 2 pCi/gm. Table 4 summarizes these results for each radionuclide in order of decreasing concentration.

The range of activity of ^{232}Th in cement samples was not as large as ^{226}Ra. The cement sample from Plainville Concrete showed the least ^{232}Th concentration and the sample from Ernst Enterprises the highest. The specific acitivity of ^{238}U ranged from approximately 60% of the ^{226}Ra activity in the Miami Valley Concrete cement to slightly greater than the ^{226}Ra activity in other samples.

Tables 1 and 4 show that the activity levels of ^{40}K in cement samples varied by roughly a factor of two from approximately 4 pCi/gm to about 7.5 pCi/gm.

Based upon the total specific activity from ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K the cement samples with the highest activity were from Ernst Enterprises whereas those with the lowest activity were from Miami Valley Ready Mixed Concrete. A large part of the total specific activity is due to ^{40}K.

Gravel samples

Table 2 summarizes results of the analyses for the gravel samples. The agreement between the analyses of the two samples is good for ^{226}Ra, ^{232}Th and ^{40}K, while not as favorable for ^{238}U for reasons previously discussed.

The differences in the values of specific activity for ^{226}Ra were minor in the samples of gravel as borne out by the results shown in Tables 2 and 5. The percent difference in the specific activities of ^{232}Th in gravel samples is greater than for ^{226}Ra. Again the range of specific activities of ^{40}K varies by a factor of two.

The measured specific activities for ^{238}U in gravel samples varied from values comparable to the ^{236}Ra activity to roughly a factor of two higher than ^{226}Ra.

Table 5 shows the total specific activities from ^{40}K, ^{216}Ra, ^{232}Th and ^{238}U for the gravel samples, the results are as shown in Table 5. Hilltop Concrete has the highest total specific activity and Miami Valley Concrete the lowest. Again however, it should be noted that a major part of the activity is due to ^{40}K.

Sand samples

Results of analyses of the sand samples from the six suppliers are summarized in Tables 3 and 6. Again, the agreement between the analyses of the two samples for ^{226}Ra, ^{232}Th and ^{40}K is good, whereas it is not as favorable for ^{238}U.

The ^{226}Ra specific activity shows very little variation between samples (roughly 0.36 to 0.47 pCi/gm). A comparable range of values on a percent basis also was found from ^{232}Th and ^{40}K. The range of specific activity values for ^{40}K was far more uniform in the samples of sand than was the case

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for the other two media.

Specific activities for ^{238}U ranged from values comparable to the specific activity of ^{226}Ra to approximately four times the activitiy of ^{226}Ra.

Table 6 shows a comparison of the total activities from ^{40}K, ^{226}Ra, ^{232}Th and ^{238}U arranged in order of decreasing concentration. Due to the uniformity of analyses of each of the nuclides for the sand samples, there is far greater uniformity for total activity for this medium than for gravel and cement samples. Thus the rank of suppliers is not dominated as significantly by the ^{40}K content for sand samples as for the other two media.

Water samples

The uranium 238 content in the water samples was measured in the WMCO laboratories at the Feed Materials Production Center. These results are shown in Table 7. The uranium content in the water is low. Water is a minor constituent of the finished concrete product. The calculations show that unless the water was extremely contaminated, the radionuclide content of the water will have no effect on the concentration of radionuclides in the final concrete product.

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Table 1

Natural Radionuclides in Cement Samples

	^{226}Ra pCi/gm	^{238}U pCi/gm	^{232}Th pCi/gm	^{40}K pCi/gm
Ernst	0.582	0.680	0.458	7.75
	0.576	0.394	0.542	7.42
Harrison	1.910	2.060	0.397	5.20
	1.830	2.050	0.351	2.83
Hilltop	0.588	0.079	0.511	7.00
	0.583	0.427	0.476	6.86
Miami Valley	1.920	0.304	0.386	5.06
	1.890	1.170	0.385	3.66
Plainville	1.010	1.550	0.379	6.46
	0.974	0.870	0.280	5.31
Roth	1.910	1.810	0.425	4.45
	1.900	1.180	0.398	4.08

Table 2

Natural Radionuclides in Gravel Samples

	^{226}Ra pCi/gm	^{238}U pCi/gm	^{232}Th pCi/gm	^{40}K pCi/gm
Ernst	0.339	0.645	0.129	3.90
	0.341	0.833	0.117	3.51
Harrison	0.394	0.140	0.163	3.70
	0.442	0.798	0.169	2.83
Hilltop	0.330	0.553	0.141	3.07
	0.425	---	0.250	5.37
Miami Valley	0.349	0.462	0.119	2.37
	0.401	0.317	0.100	2.36
Plainville	0.373	0.768	0.173	2.62
	0.327	0.560	0.114	3.19
Roth	0.414	0.439	0.152	3.86
	0.306	0.563	0.125	3.43

Table 3

Natural Radionuclides in Sand Samples

	^{226}Ra pCi/g	^{238}U pCi/g	^{232}Th pCi/g	^{42}K pCi/g
Ernst	0.464	0.214	0.177	6.12
	0.464	0.985	0.239	6.26
Harrison	0.428	0.394	0.208	6.97
	0.425	0.402	0.177	7.19
Hilltop	0.365	0.753	0.217	6.28
	0.367	---	0.192	6.14
Miami Valley	0.410	0.920	0.190	7.07
	0.438	0.303	0.214	7.35
Plainville	0.410	1.910	0.211	7.12
	0.437	0.813	0.174	7.06
Roth	0.476	1.010	0.172	6.73
	0.462	0.892	0.249	7.22

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Table 4

Summary of Analysis of Cement Samples

^{226}Ra [pCi/g]	^{238}U [pCi/g]	^{232}Th [pCi/g]	^{40}K [pCi/g]	Total [pCi/g]
1.90 (4)	2.06 (2)	0.50 (1)	7.59 (1)	9.35 (1)
1.90 (6)	1.50 (6)	0.49 (3)	6.93 (3)	8.44 (3)
1.87 (2)	1.21 (5)	0.41 (6)	5.88 (5)	8.41 (5)
0.99 (5)	1.17 (4)	0.39 (4)	4.36 (4)	8.32 (2)
0.59 (3)	0.68 (1)	0.37 (2)	4.26 (6)	8.07 (6)
0.58 (1)	0.43 (3)	0.33 (5)	4.02 (2)	7.82 (4)

Listed in order of decreasing concentration with numbers in parentheses referring to suppliers.

(1) - Ernst Enterprizes
(2) - Harrison Ready Mix Concrete
(3) - Hilltop Basic Resources
(4) - Miami Valley Ready Mixed
(5) - Plainville Concrete
(6) - Roth Concrete

* Average Value
** Average Value or best value based on sample standard deviation

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Table 5

Summary of Analysis of Gravel Samples

^{226}Ra [pCi/g]	^{238}U [pCi/g]	^{232}Th [pCi/g]	^{40}K [pCi/g]	Total [pCi/g]
0.42 (2)	0.80 (2)	0.20 (3)	4.22 (3)	5.35 (3)
0.38 (3)	0.77 (5)	0.17 (2)	3.70 (1)	4.90 (1)
0.37 (4)	0.74 (1)	0.14 (5)	3.65 (6)	4.65 (6)
0.36 (6)	0.55 (3)	0.14 (6)	3.26 (2)	4.64 (2)
0.35 (5)	0.50 (6)	0.12 (1)	2.91 (5)	4.17 (5)
0.34 (1)	0.39 (4)	0.11 (4)	2.36 (4)	3.23 (4)

Listed in order of decreasing concentration with numbers in parentheses referring to suppliers.

(1) - Ernst Enterprizes
(2) - Harrison Ready Mix Concrete
(3) - Hilltop Basic Resources
(4) - Miami Valley Ready Mixed
(5) - Plainville Concrete
(6) - Roth Concrete

• Average Value
** Average Value or best value based on sample standard deviation

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Table 6

Summary of Analysis of Sand Samples

^{226}Ra* [pci/g]	^{238}U** [pci/g]	^{232}Th* [pci/g]	^{40}K* [pci/g]	Total [pci/g]
0.47 (6)	1.91 (5)	0.21 (6)	7.21 (4)	9.62 (5)
0.46 (1)	0.99 (1)	0.21 (1)	7.09 (5)	8.61 (6)
0.43 (1)	0.95 (6)	0.20 (3)	7.08 (2)	8.45 (4)
0.42 (4)	0.75 (3)	0.20 (4)	6.98 (6)	8.10 (2)
0.42 (5)	0.61 (4)	0.19 (5)	6.21 (3)	7.85 (1)
0.37 (3)	0.40 (2)	0.19 (2)	6.19 (1)	7.53 (3)

Listed in order of decreasing concentration with numbers in parentheses referring to suppliers.

(1) - Ernst Enterprizes
(2) - Harrison Ready Mix Concrete
(3) - Hilltop Basic Resources
(4) - Miami Valley Ready Mixed
(5) - Plainville Concrete
(6) - Roth Concrete

* Average Value
** Average Value or best value based on sample standard deviation

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Table 7

Uranium Content in Water Samples*

Concrete Supplier	Uranium 238 pCi/l
Harrison Ready Mix	0.12 ± 0.02
Ernst Enterprises, Inc.	0.02 ± 0.02
Plainville Concrete	0.18 ± 0.02
Roth Ready Mix Concrete	0.44 ± 0.06
Miami Valley Ready Mixed	0.04 ± 0.02
Hilltop Concrete	0.04 ± 0.02

*measured by WMCO at the Fernald Feed Materials Production Center

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SECTION 2 - Information determined during vendor selection and evaluation

The selection process that led to the identification of six prospective concrete suppliers is described in Section 5 of this report. In summary, the vendors were selected on the basis of dependability, size of the firm, quality of the product, reliability and experience. A University of Cincinnati Civil Engineering faculty member (Dr. Boyd Ringo), who is an expert in concrete, was consulted during the initial phase of this work.

In order to determine sources of the component materials for concrete, we interviewed each of the major concrete suppliers that were identified as prospective vendors. It was expected that there might be a few limited suppliers in the Cincinnati area of the constituent materials; sand, gravel and cement. For example, if there were only two or three major suppliers of sand in the area, then we planned to go directly to these suppliers for the sand.

Based on discussions with each major supplier, it was determined that there are no common suppliers of cement, sand or gravel in the Cincinnati area. The cement is obtained from various suppliers around the country. The gravel is obtained from local suppliers or from the concrete supplier's own facility (property). The sand is also obtained from a variety of local sources or the concrete supplier's own property.

It was expected that the water used to make the concrete would be municipal water that had been filtered and treated. This is not the way water is obtained. All the concrete vendors obtain water from an on-site well. Some of the water looked discolored, but the WMCO radiological analysis showed the water to be low in content of radionuclides. Also, water is not a major constituent in concrete.

In summary, the information gained during the initial task, which was to determine sites around the area from which concrete fill materials are obtained, was that there are no common sources of cement, sand, gravel or water. Each concrete supplier (vendor) uses different sources of cement. Sand and gravel are obtained from the vendor's own property or a local source. Water is obtained from the concrete supplier's own property. It is not municipal water.

The major suppliers selected for the natural radionuclide measurements in concrete materials are listed below:

(1) Harrison Ready Mix Concrete
I74 and Dry Fork Road
Harrison, OH
367-0234

(2) Ernst Enterprises, Inc.
10093 Princeton-Glendale Road
Fairfield, OH
874-8300

(3) Plainville Concrete
P.O. Box 44160
Cincinnati, OH 45244
724-7000

(4) Roth Ready Mix Concrete Co.
900 Kieley Place
Cincinnati, OH
242-8400

(5) Miami Valley Ready Mixed Concrete
7466 New Haven Road
Fernald, OH
739-2616

(6) Hilltop Concrete
511 West Water Street
Cincinnati, OH
621-1500

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SECTION 3 - Quality assurance

This section will provide a description of procedures used both to efficiency calibrate the Intrinsic Germanium Detector and to energy calibrate and assess slight gain shifts in the gamma spectrometer system throughout the period when samples were being routinely measured for radionuclide content.

3.1 Efficiency Calibration of Gamma-Ray Spectrometer

The efficiency of the gamma-ray spectrometer for ^{40}K, ^{226}Ra, ^{232}Th and ^{238}U was determined by utilizing standards containing known concentrations of these radionuclides and prepared geometrically in an identical fashion to samples of sand, gravel and cement.

Foremost of these standards was the National Bureau of Standards, Standard Reference Material 4353 - Rocky Flats Soil Number 1. As may be seen from Table 3.1, this standard contains known concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K in addition to a number of other radionuclides. Approximately 190 grams of this material was obtained from National Bureau of Standards (NBS).

As recommended by NBS, the material was prepared for use by air drying at 40°C for at least 24 hours. This was done in the same type sample container as employed for all building materials samples. Following final weighing of the sample, the lid was sealed to initiate the ingrowth of ^{222}Rn in the ^{226}Ra. No definitive measurements of this standard were made until after a minimal 21 day ingrowth period.

To provide additional efficiency calibration data for ^{238}U, two other standards were obtained on loan from the Environmental Protection Agency (EPA), Office of Radiation Programs, Las Vegas Laboratory. These standards, designated EPA-3DP and EPA-F, contain the concentration of ^{238}U, ^{232}Th and

^{226}Ra shown in Table 3.1.[3] It will be noted that the radionuclide concentrations of the EPA Standards is substantially higher than for NBS Standard Reference Material 4353. This was of particular value for the ^{238}U calibration since it permitted a more favorable peak to background ratio to be obtained for the ^{238}U calibration. Both EPA standards had been prepared by EPA utilizing the same container as used for materials in this investigation. Agreement between the NBS and EPA standards was very good.

Measurements of these standards were carried out prior to the initiation of measurements on building-materials samples and several times throughout the period during which these samples were being counted. The replicate measurements made were found to be in good agreement and served both as a check of data quality throughout this time period and as a basis for calibration of the gamma spectrometer for each of the radionuclides analyzed in this investigation.

3.2 Energy Calibration of Gamma Ray Spectrometer

Although many of the gamma-ray photopeaks from the known constituents in the NBS and EPA Standards identified above in Part 3.1 serve as energy reference lines, it was more convenient to utilize a higher activity multicomponent source for energy calibration. The source selected for this purpose was obtained from Isotope Products Laboratories, Burbank, California. It contains NBS traceable quantitites of the nine radionuclides shown in Table 3.2.

The gamma-ray energy standard was measured two or three times per week during the period of measurement of the samples analyzed in this study. Slight gain adjustments were sometimes necessary at those times. The adjustment necessary was seldom greater than 2 or 3 channels at 8192 channels.

TABLE 3.1

Radionuclides Content of Standards Used for

Efficiency Calibration of Germanium Detector

Table 3.1(A)

National Bureau of Standards, Standard Reference
Material 4353 - Rocky Flats Soil Number 1

Radionuclide	Activity Concentration pCi/g	Total* Uncertainty (percent)
^{40}K	1.95	9.6
^{90}Sr	0.206	10.2
^{137}Cs	0.476	4.5
^{226}Ra	1.16	6.6
^{228}Ac	1.89	5.1
^{228}Th	1.91	5.1
^{230}Th	1.20	5.1
^{232}Th	1.89	5.1
^{234}U	1.06	3.6
^{238}U	1.05	5.1
^{238}Pu	0.0045	11.0
$^{239}Pu + ^{240}Pu$	0.217	7.5
^{241}Am	0.0338	7.3

*The random and systematic uncertainties have been combined in quadratise at a level corresponding to a standard deviation of the mean. The stated overall uncertainties are three times this value.

Table 3.1(B)

Standards from Environmental Protection Agency -

Office of Radiation Programs - Las Vegas, Nevada

Radionuclide	Activity Concentration pCi/g	Standard Deviation (percent)
Standard EPA - 3DP		
^{226}Ra	234	5
^{238}U	234	5
Standard EPA - F		
^{226}Ra	26.7	5
^{232}Th	14.5	5
^{238}U	26.7	5

TABLE 3.2

Radionuclide Content of Energy Calibration Standard

Radionuclide	Principal Gamma-rays(s) (MeV)	Activity (uCi)	Date
^{109}Cd	0.088	0.521	March 15, 1987
^{57}Co	0.122, 0.1365	0.0158	"
^{139}Ce	0.1659	0.0198	"
^{203}Hg	0.279	0.0610	"
^{113}Sn	0.392	0.0725	"
^{137}Cs	0.662	0.0690	"
^{60}Co	1.173, 1.332	0.0814	"
^{88}Y	0.848, 1.836	0.173	"
^{85}Sr	0.514	0.0962	"

Some typical gamma spectra for the standard samples are shown in Figures 3.1 through 3.3.

3.3 Propagation of error due to Statistics

Since most of the isotopes under investigation in the building materials also exist in the background, a method to correct for this and for determining the statistical error has to be established. Let the area under the entire photopeak be S_g (counts) and the net area in the peak be S_n. A second subscript "s" or "b" can be added to indicate wheather the peak is obtained from counting a sample or the background (S_{gs} and S_{ns}, or S_{gb} and S_{nb}). These areas are shown in Fig. 3.4.

If we assume the standard deviation of counting time is approximately equal to zero, the count rate due to the source only can be calculated by:

$$\dot{x} = \dot{S}_{ns} - \dot{S}_{nb} = \frac{S_{ns}}{t_1} - \frac{S_{nb}}{t_2} \qquad \text{eq. 3.1}$$

where: t_1 and t_2 are counting time for the source and background

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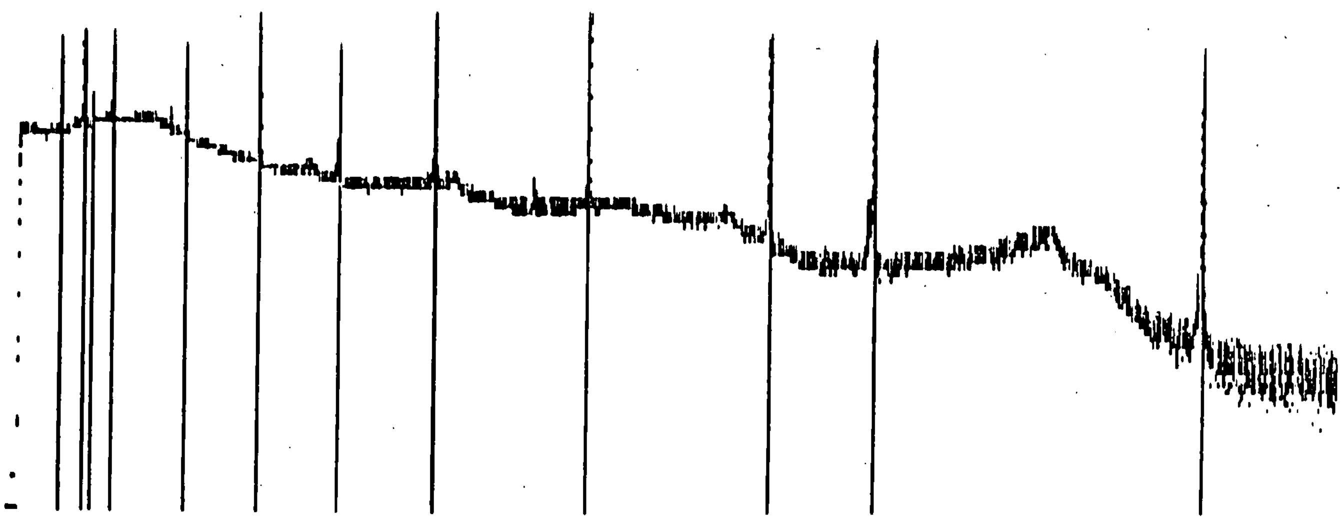
MAY 16 1987 09:09:51 PM MODES: PHA SUB % DEAD TIME: 00

GROUP: F VS: LOG CTS GAIN: 8192 CHLS OFFSET: 0000 CHLS ID: CAL 3

FUNCTION KEY

F1 MORE	F2 IDENT
F3 STORE	F4 LOAD
F5 [illegible]	F6 USER
F7 CTRD	F8 FWHM
F9 DOS	F10 MAIN

FIGURE 3.1 a,b,c
GAMMA SPECTRA FOR THE NBS STANDARD WITH
1) REGION OF INTEREST
2) PEAKS IDENTIFIED



ENERGY: 1836.06 KEV COUNTS: 00012402* ROI #1: OFF ROI #2: ON

PK #: 12 CTRD: 1836.06 KEV FWHM: 0.00000 KEV GROSS: 000012402 NET: 000001269

TIME LIVE PRESET: 028800 ELAPSED: 003600 REMAINING: 028800 SECONDS

7599

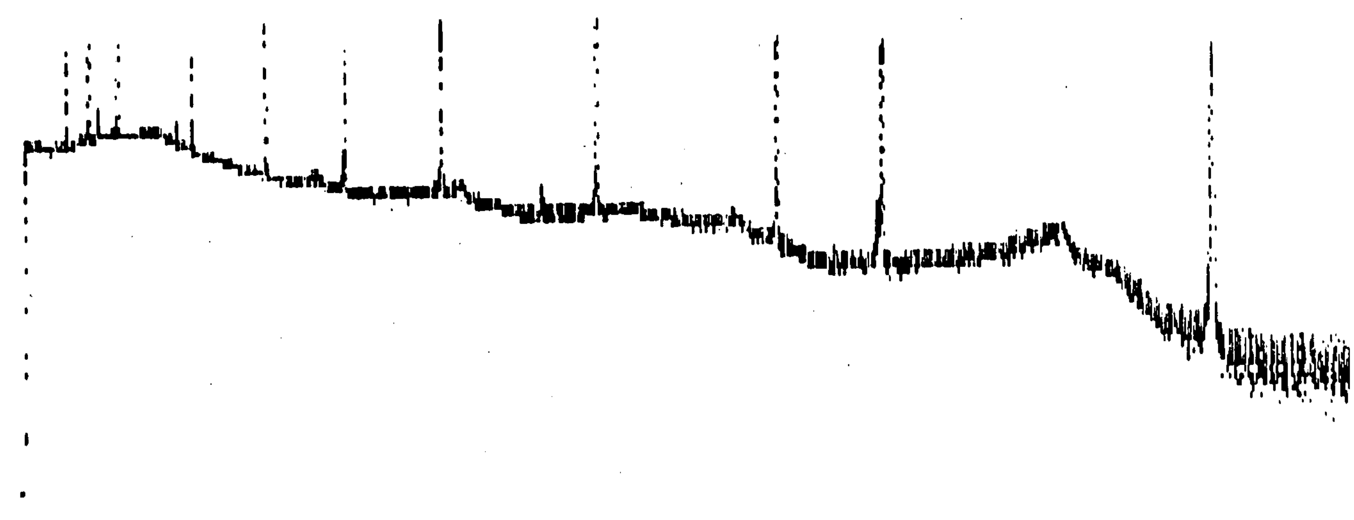
000022

MAY 16 1987   09:09:51 PM   MODES: PHA SUB   % DEAD TIME: 00
GROUP: F   VS: LOG CTS   GAIN: 8192 CHLS   OFFSET: 0000 CHLS   ID: CAL 3

FIGURE 3.1(b)

FUNCTION KEY

F1 MORE	F2 IDENT
F3 STORE	F4 LOAD
F5	F6 USER
F7 CTRD	F8 FWHM
F9 DOS	F10 MAIN



ENERGY: 186.732 KEV   COUNTS: 00002588   ROI #1: OFF   ROI #2: OFF
PK #: 00   CTRD: 0.00000 KEV   FWHM: 0.00000 KEV   GROSS: 000000000   NET: 00000000
TIME   LIVE   PRESET: 028800   ELAPSED: 003600   REMAINING: 028800   SECONDS

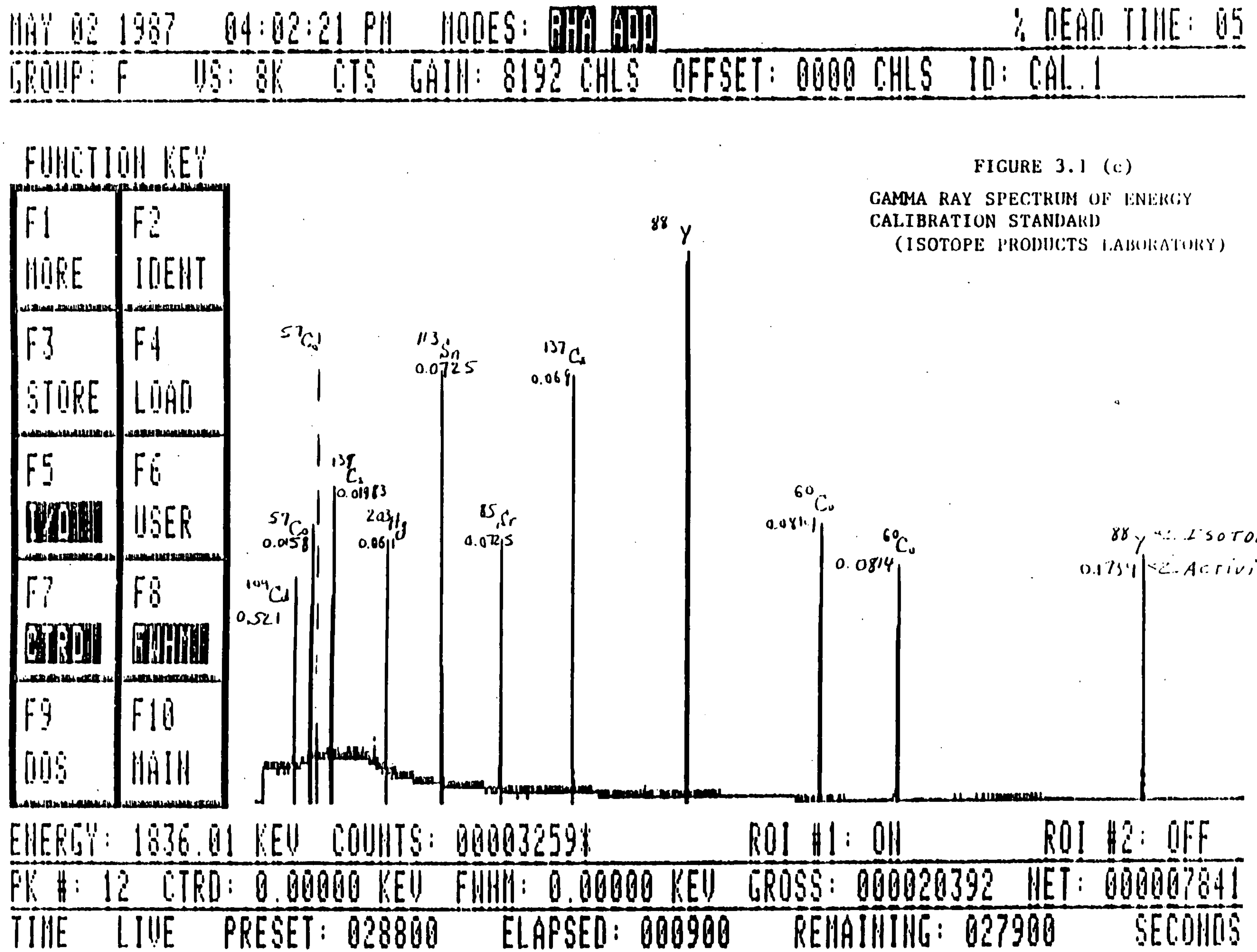


FIGURE 3.1 (c)

GAMMA RAY SPECTRUM OF ENERGY CALIBRATION STANDARD (ISOTOPE PRODUCTS LABORATORY)

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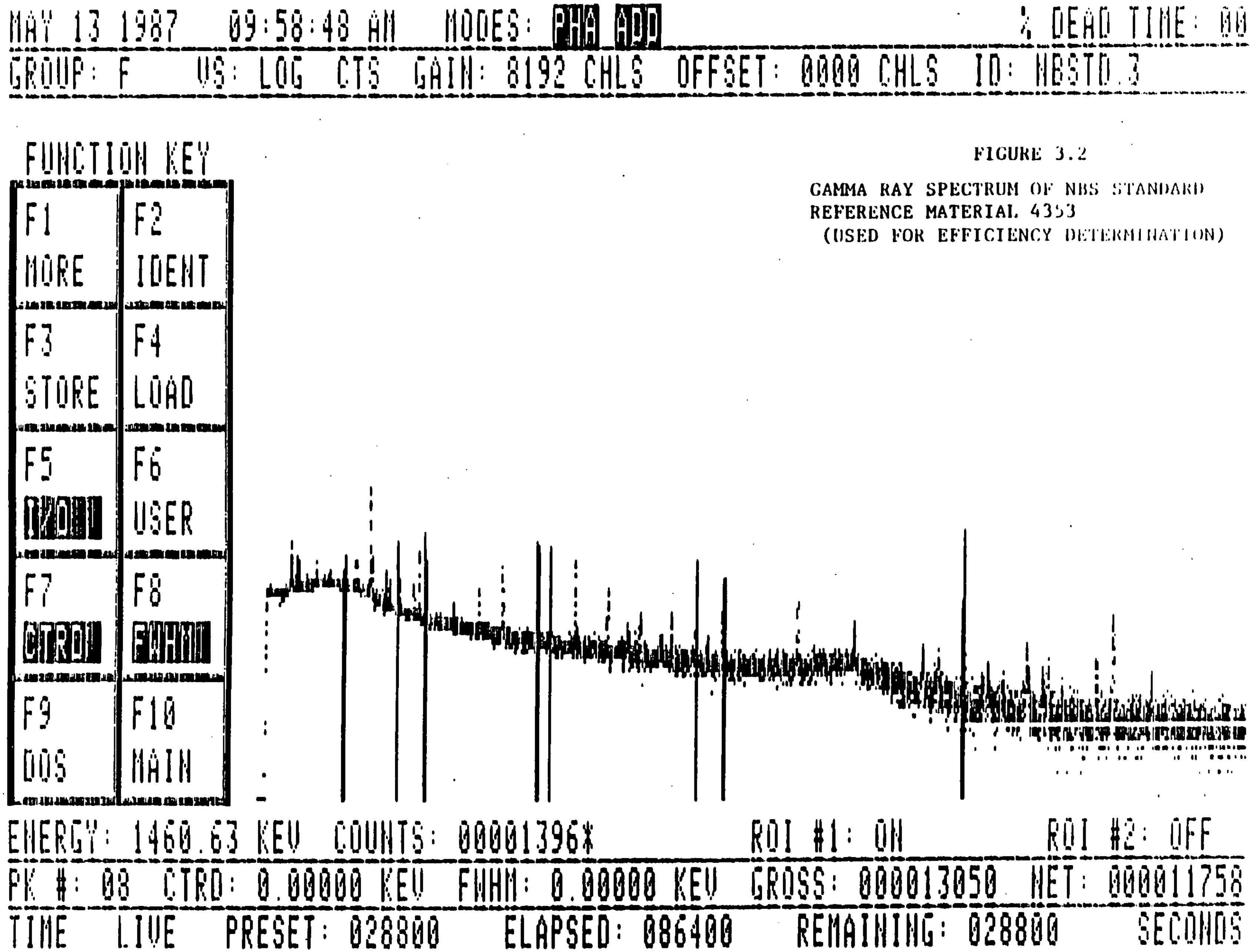


FIGURE 3.2

GAMMA RAY SPECTRUM OF NBS STANDARD
REFERENCE MATERIAL 4353
(USED FOR EFFICIENCY DETERMINATION)

000025

MAY 25 1987 11:30:50 PM MODES: PHA ADD % DEAD TIME: 00

GROUP: F VS: LOG CTS GAIN: 8192 CHLS OFFSET: 0000 CHLS ID: F193.2

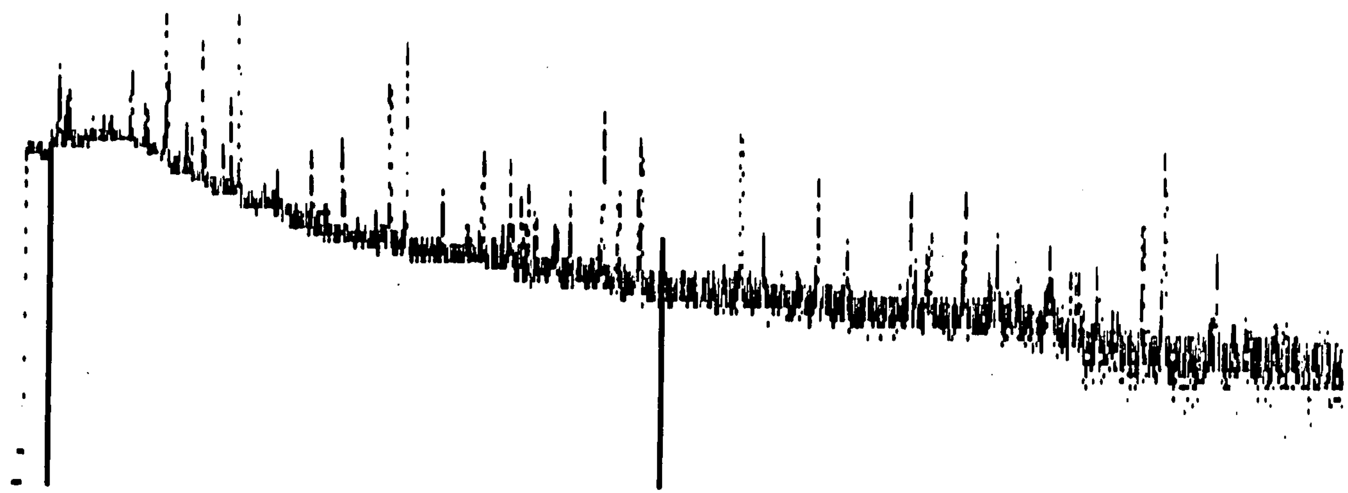
FIGURE 3.3

GAMMA RAY SPECTRUM OF EPA STANDARD EPA F

(USED FOR URANIUM 238 EFFICIENCY DETERMINATION)

FUNCTION KEY

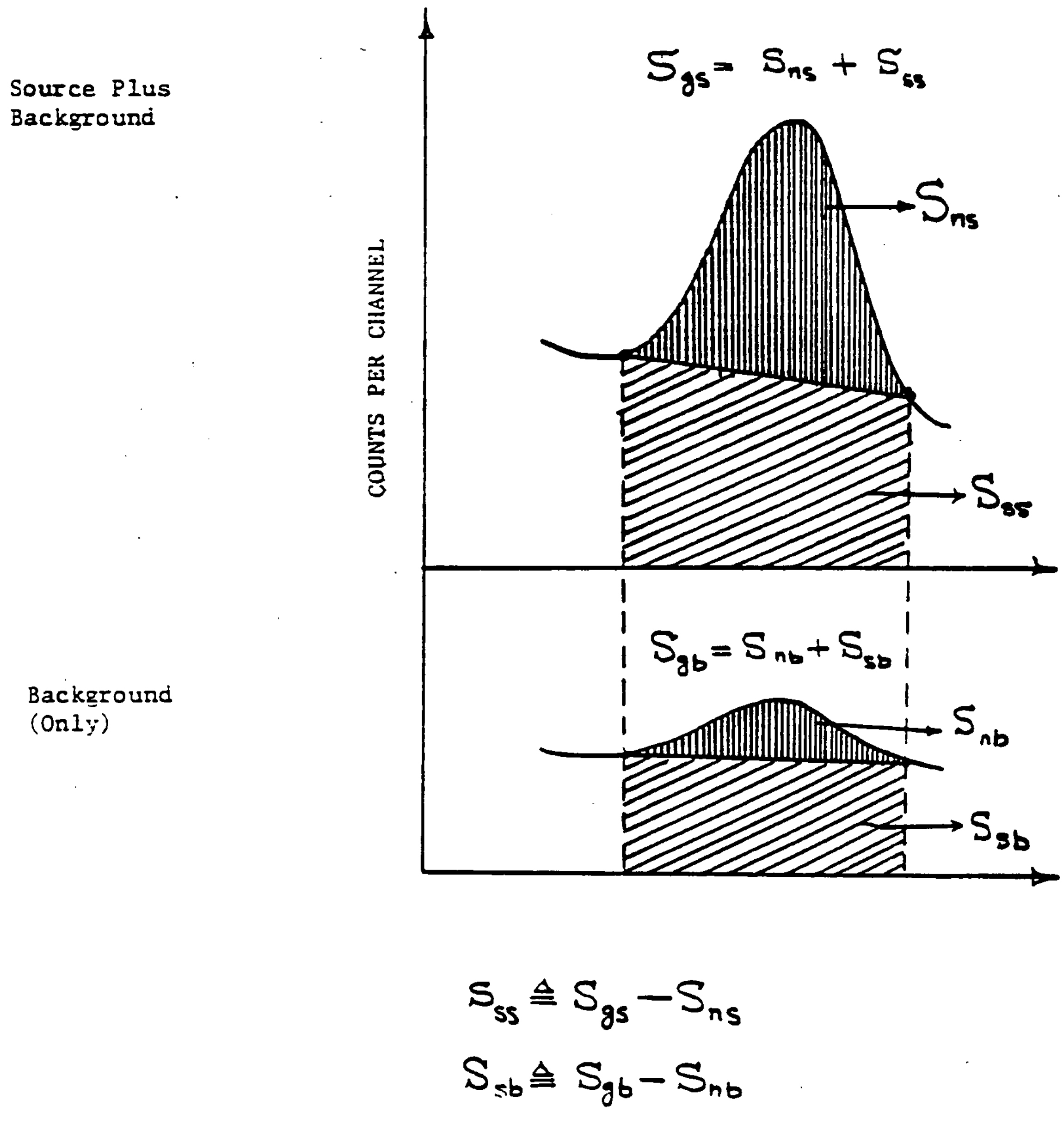
F1 MORE	F2 IDENT
F3 STORE	F4 LOAD
F5 [illegible]	F6 USER
F7 CTRD	F8 FWHM
F9 DOS	F10 MAIN



ENERGY: 63.0384 KEV COUNTS: 00001116* ROI #1: OFF ROI #2: ON

PK #: 01 CTRD: 63.1842 KEV FWHM: 0.56576 KEV GROSS: 000009188 NET: 000000881

TIME LIVE PRESET: 028800 ELAPSED: 028800 REMAINING: 028800 SECONDS



$$S_{ss} \triangleq S_{gs} - S_{ns}$$

$$S_{sb} \triangleq S_{gb} - S_{nb}$$

FIGURE 3.4 NET AND GROSS COUNTS FOR BACKGROUND AND SAMPLE PLUS BACKGROUND

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respectively. The standard deviation of the net count rate can be calculated from

$$\sigma_{\dot{x}} = (\sigma_{\dot{S}ns}^{2} + \sigma_{\dot{S}nb}^{2})^{1/2} \qquad \text{eq. 3.2}$$

The Standard Deviation of the net count rate of the source plus background ($\sigma_{\dot{s}_{ns}}$) can be calculated by obtaining the net counts under the peak. In finding the net area's (S_{nG} and S_{nb}) most software routines first obtain the number of counts for the entire peak area, then the area in the lower portion of the peak (includes the background and compton continuum), and finally subtract these two numbers. The summation of the counts for the entire peak and the summation of the counts below the peak both follow Poisson statistics, the net count is $S_{ns} = S_{gs} - (S_{gs} - S_{ns})$

Defining $S_{gs} - S_{ns} \triangleq S_{ss}$, the standard deviation of the net count <u>rate</u> due the source plus background is

$$\sigma_{\dot{S}_{ns}} = (\sigma^{2}_{\dot{S}_{gs}} + \sigma^{2}_{\dot{S}_{ss}})^{1/2} \qquad \text{eq. 3.3}$$

$$= (\frac{\dot{S}_{gs}}{K_{s}t_{s}} + \frac{\dot{S}_{gs} - \dot{S}_{ns}}{K_{s}t_{s}})^{1/2}$$

$$= (\frac{2\dot{S}_{gs} - \dot{S}_{ns}}{K_{s}t_{s}})^{1/2}$$

$$\sigma_{\dot{S}_{ns}} = (\frac{2S_{gs} - S_{ns}}{K_{s}t_{s}^{2}})^{1/2} \qquad \text{eq. 3.4}$$

where K_s = number of measurements and t_s is the counting time for the source plus background.

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The standard deviation of the "best value" of the net background count rate is defined as

$$\sigma_{\dot{S}nb} = \Delta\sigma_{<b>},$$

based on the weighting technique (shown in section 3.6).

Since the source counts even in the peak (upper peak area) contain some counts due to the background one must correct for this by subtracting the net contribution of that peak in the background from the net peak area of source containing background. See Section 3.4 for a detailed description. Therefore, the net count rate due to the net sample is

$$\dot{X} = \dot{S}_{ns} - \dot{S}_{nb}. \qquad \text{eq. 3.5}$$

This is identical to subtracting the background from the spectrum and then finding the net counts in the photopeak as shown in section 3.4. This is necessary to reduce the counting time. The standard deviation of the net sample count rate is then

$$\sigma_{\dot{X}} = (\sigma^2_{\dot{S}_{ns}} + \sigma^2_{\dot{S}_{nb}})^{1/2}$$

$$\sigma_{\dot{X}} = (\frac{2S_{gs} - S_{ns}}{t_s^2} + \sigma^2_{<b>})^{1/2} \qquad \text{eq. 3.6}$$

In calculating the standard deviation of the net count rate, if a standard with known activity is used, one must use the "best value" for the net source count rate based on the weighting technique. Use $\sigma_{<S>}$ in place of $\sigma^2_{\dot{S}ns}$. For the case where the errors in counting the standard are

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approximately equal, one must use the usual averaging technique. For example, for the EPA standard, two counts of 8 hours each were made. Thus

$$\sigma^2_{\bar{S}_{ns}} = \frac{\bar{S}_{gs} - \bar{S}_{ns}}{(2)(480 \text{ min})} \qquad \text{eq. 3.7}$$

where $\bar{S}_{gs}$ and $\bar{S}_{ns}$ are the average gross and net count rate from the two measurements.

In calculating the activity, one must find a calibration factor for each peak as:

$$C \pm \sigma_c (\text{pCi/gm per cpm/gm}) \qquad \text{eq. 3.8}$$

where σ_c represents the standard deviation of the calibration factor, C, used to convert the count rate to activity (pci).

Assuming the error in measuring the weight of the sample and the time are to be negligible the calibration factors can be calculated as:

$$C \pm \sigma_c = \frac{A + \sigma_A}{\dot{X}' \pm \sigma_{\dot{X}'}} \qquad \text{eq. 3.9}$$

where: A is the known activity of the NBS standard or EPA standard per gram and $\dot{X}'$ is the best value of the count rate per gram shown below

$$\dot{X}' \pm \sigma_{\dot{X}'} = \frac{\bar{X} \pm \sigma_{\bar{X}}}{\text{Sample weight (gm)}} \qquad \text{eq. 3.10}$$

The standard deviation of the calibration factor, σ_c, can be found from

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$$\sigma_C = \frac{A}{\dot{X}'} \left(\left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{\dot{X}'}}{\dot{X}'}\right)^2 \right)^{1/2} \qquad \text{eq. 3.11}$$

and the percent error for the calibration factor is

$$\frac{\sigma_C}{C} = 100 \left(\left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{X'}}{X'}\right)^2 \right)^{1/2} \qquad \text{eq. 3.12}$$

The standard error of the activity is given in Table 3.3.

TABLE 3.3

Standard Errors of NBS and EPA Standards

	Isotope	$3\sigma A/A(\%)$	$\sigma/A(\%)$
NBS	K - 40	9.6	3.2
NBS	P_a - 226	6.6	2.2
NBS	Th - 232	5.1	1.7
EPA	U - 238	-	5

The activity of the unknown sample is defined as $B \pm \sigma_B$, and can be calculated from:

$$B \pm \sigma_B = (C \pm \sigma_C)\ (\dot{Y}' + \sigma\ \dot{Y}') \qquad \text{eq. 3.13}$$

where: C is the calibration factor (pCi/gm per cpm/gm)

and $\dot{Y}'$ is the best value of the net count rate (cpm) of a photopeak for a sample.

Therefore the activity can be calculated from

$$B \pm \sigma_B = C\ \dot{Y}' \pm \sigma_B \qquad \text{eq. 3.14}$$

and the Standard Deviation is

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$$\sigma_B = C\dot{Y}' \quad \left(\left(\frac{\sigma_C}{C}\right)^2 + \left(\frac{\sigma_{\dot{Y}'}}{\dot{Y}'}\right)^2\right)^{1/2}, \qquad \text{eq. 3.15}$$

where $C\dot{y}'$ = Activity in pci/gm.

$$\sigma_B = B\left(\left(\frac{\sigma_A}{A}\right)^2 + \left(\frac{\sigma_{\dot{X}'}}{\dot{X}'}\right)^2 + \left(\frac{\sigma_{\dot{Y}'}}{\dot{Y}'}\right)^2\right)^{1/2} \qquad \text{eq. 3.16}$$

where $\frac{A}{A}$, is given in Table 3.3

The standard deviation of the unknown sample count rate per gram can be calculated from

$$\dot{Y} \pm \sigma_{\dot{y}'} = \frac{Y' \pm \sigma_{Y'}}{\text{weight of the sample}} \qquad \text{eq. 3.17}$$

and the percent propagated error (standard error) can be calculated from:

$$\frac{\sigma_B}{B} = 100\left(\left(\frac{\sigma_C}{C}\right)^2 + \frac{\left(\frac{2S_{gs} - S_{nA}}{(480)^2} + \sigma^2_{<b>}\right)}{(\text{Net sample count rate (cpm)} - <b>)^2}\right)^{1/2} \qquad \text{eq. 3.18}$$

Other possible Errors

Factors not considered in this experiment which are believed to add negligible error in the experiments were: deadtime, peaksumming, self absorption, etc.

The dead time of about 1-2% has very little effect on the results. The error due to photopeak summing is also small. Self absorption is believed to be negligible.

Self absorption was investigated by comparing the calculated activity resulting from photopeaks of different energy present in the decay of a radionuclide such as ^{226}Ra. Results indicate that the lower energy gamma rays do not result in lower activity which one might expect if significant self absorption were present.

The error due to weight is very small. The balance used was accurate to ± 0.001 grams.

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Every effort was made to keep the geometry the same. Each standard sample and each vendor sample was filled to the exact same height in the sample container can.

3.4 Technique To Obtain the Net Counts Due A Specific Isotope When the Same Isotope is Present in the Background

In order to establish a technique to find the net counts without obtaining background for each sample, one must look at the area under a photopeak.

Let the g_i represent the gross count at each channel in the peak area in a region of interest (where $i = 1, \ldots n$ is channel number) and b_i be the gross background count containing the same source (identical channel numbers and region of interest), as shown in the figure 3.5.

Assuming there are eleven channels in the region of interest, the gross counts under the entire peak $G_g = g_1 + g_2 + \ldots g_{11} = \sum_{(i=1)}^{11} g_i$, and the scattering counts (below the peak) are

$$G_s = \left(\frac{g_1 + g_{11}}{2}\right)(c_{11} - c_1 + 1) \qquad \text{eq. 3.19}$$

similarly, the background counts under the entire peak are $B_g = b_1 + b_2 + \ldots + b_{11} = \sum_{i=1}^{11} b_i$, and the scattering counts are:

$$B_s = \left(\frac{b_1 + b_{11}}{2}\right)(c_{11} - c_1 + 1) \qquad \text{eq. 3.20}$$

The net counts due to the source under the entire photopeak is then

$$N = Gg - Bg = \sum_{i=1}^{11}(g_i - b_i) \qquad \text{eq. 3.21}$$

000033

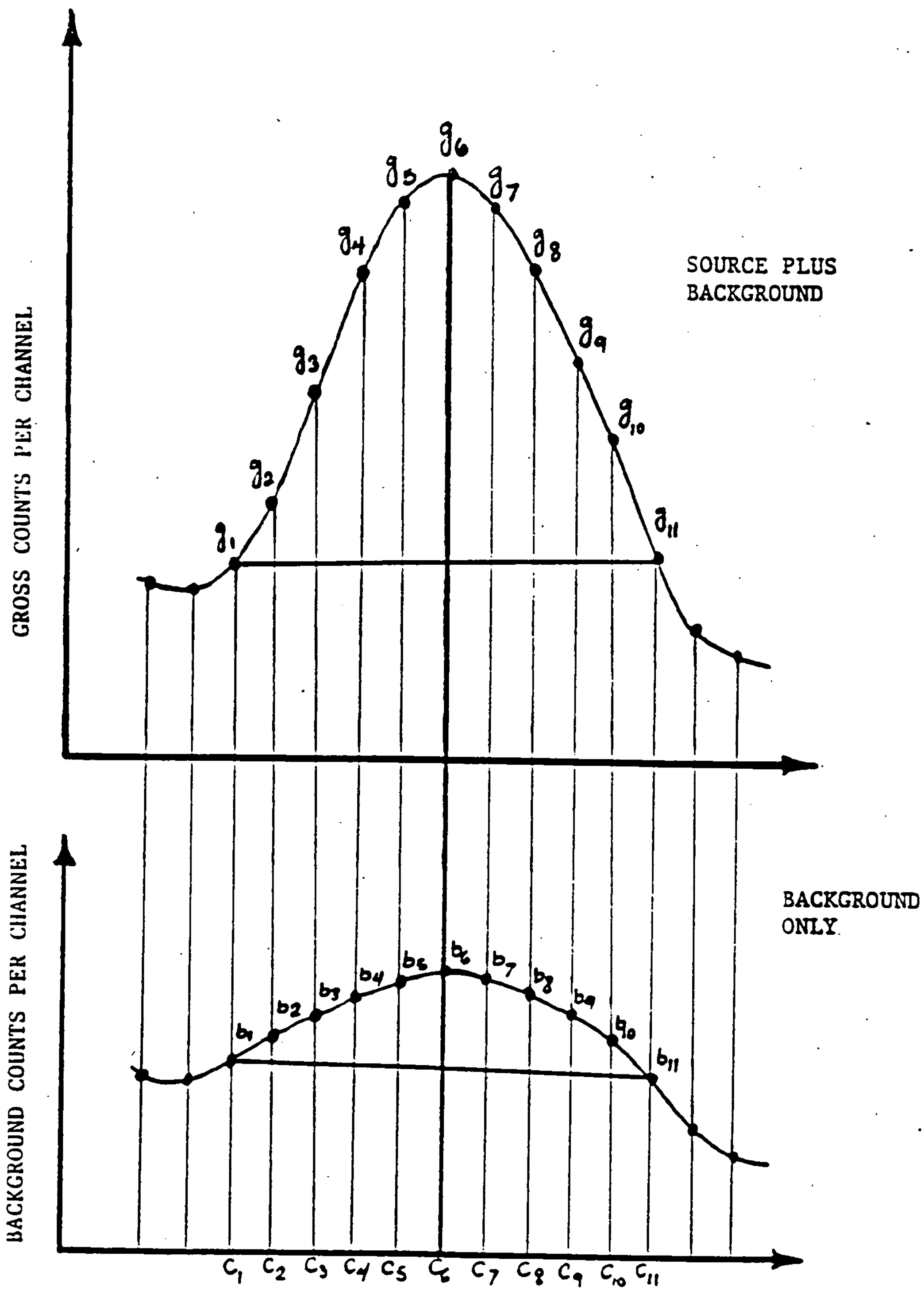

FIGURE 3.5 NET COUNT DETERMINATION

The net counts due to the source only is given by subtracting the net counts from the source plus background and the background as shown below:

$$Net = G_g - G_s - (B_g - B_s) \qquad \text{eq. 3.22}$$

or

$$Net = \sum_{i=1}^{11} g_i - \left[\frac{(g_1 + g_{11})}{2}(c_{11} - c_1 + 1)\right] - \left[\sum_{i=1}^{11} b_i - \left[\frac{(b_1 + b_{11})}{2}(C_{11} - C_1 + 1)\right]\right]$$

$$Net = \sum_{i=1}^{11} (g_i - b_i) - \left[\frac{(g_1 - b_1) + (g_{11} - b_{11})}{2}\right](C_{11} - C_1 + 1). \qquad \text{eq. 3.23}$$

If one subtracts the background, channel by channel, the result will be the same.

$$Net = [(g_1 - b_1) + (g_2 - b_2) + \cdots + (g_{11} - b_{11})] - \left[\frac{(g_1 - b_1) + (g_{11} - b_{11})}{2}\right](c_{11} - c_1 + 1)$$

$$Net = \sum_{i=1}^{11} (g_i - b_i) - \left[\frac{(g_1 - b_1) + (g_{11} - b_{11})}{2}\right](c_{11} - c_1 + 1). \qquad \text{eq. 3.24}$$

Therefore, they are equal.

3.5 Minimum Detectable Activity Calculation

Minimum Detectable Activity (MDA) or the Lower Limit of Detection (LLD) of the Germanium spectroscopy system may be defined as the smallest amount of sample activity that will yield a net count that can be distinguished as different from background with a specified confidence limit. As is evident in the results; the concentrations and statistical error obtained by the gamma spectroscopy technique for building material having the lowest radioactivity and hence highest standard error leads to the definition of the Lower Limit of Detection[8] as follows:

$$LLD_i = (K_\alpha + K_\beta)\ SE_i, \qquad \text{eq. 3.25}$$

where:

K_α is the value for the upper percentile of the standarized normal variate corresponding to the preselected risk for concluding falsely that activity is present (σ), type I error.

K_β is the corresponding value for the predetermined degree of confidence for detecting the presence of activity (1- β), type II error.

SE_i is the estimated standard error for a specific photopeak in the background corresponding to a radionuclide in a sample.

For simplicity $K_\sigma = K_G$. Further we assume the probability of type I and type II errors are chosen to be 5%.

Several techniques have been used to estimate the standard errors (SE) for calculating the LLD limits. One technique, described in U.S. DOE Report - HASL 300[5] (Harley, 1976) uses the standard errors of the background count rates for different photopeaks in the gamma spectra.

The LLD's for each peak can be estimated by assuming that a sample containing extremely low activity has the same count rates as the background. The LLD value for various photopeaks can then be calculated from:

$$LLD_i \cong (K_\sigma + K_\beta)\ So_i \cong (3.29)\ So = 3.29\ \left(\frac{\sigma_{<b>i}}{\bar{w}}\right)(ci) \qquad \text{eq. 3.26}$$

where:

S_o is the standard error of the net activity when no activity is present (background),

$K_\alpha = K_\beta = 1.645$, indicates 5% error of type I and II,

$\sigma_{\langle b \rangle i}$ = Standard deviation of the best value of the background for a given photopeak

$\bar{w}$ = Average weight of all the samples analyzed.

C_i = calibration factor to convert cpm/g to pci/g for a photopeak corresponding to an isotope.

The results are shown in Table 3.4.

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Table 3.4

Estimated LLD Based on Background Data

Nuclide	energy (kev)	Best Value for Background (cpm) <b>	(cpm) (S.D.) σ<b>	Calibration Factor C pCi/g per cpm/g	(S.E.) σc/c	LLD $3.29(\frac{\sigma}{\bar{\omega}}$ Lower Li[mit] of Dete[ction]
	185	0.178880	0.023407	259.7800071	0.065909269	0.07
^{226}Ra	294	0.068370	0.020698	87.68610599	0.030532708	0.02
	351	0.091048	0.019291	49.72126954	0.025830012	0.01
	608	0.181449	0.016374	77.54667278	0.028261468	0.01
	63	0.089009	0.022265	2.67451E+03	0.112860067	0.66
^{238}U						
	1001	0.013847	0.007439	1.27794E+04	0.493722583	1.05
	582	0.135035	0.016766	111.1009177	0.023641907	0.02
^{232}Th	910	0.109886	0.013998	202.2826691	0.030576341	0.03
	968	0.062434	0.012625	372.2303575	0.041826461	0.05
^{40}K	1460	1.270950	0.025979	517.4817867	0.033543802	0.15

$\bar{\omega}$ = Average weight of all the samples = 298.04 ± 43.27 gram.

*contract requirements for LLD were:
^{226}Ra = 0.6
^{238}U = 0.6
^{232}Th = 1.0
^{40}K = 2.5

000038

The second method to estimate the LLD's involves the use of a "blank" sample containing very little activity. To do this, a sample was made with Drierite desiccant materials ($CaSO_4$ 10-20 mesh). The sample was canned and then counted for 8 hrs. The activities of the pertinent radionuclides in of the sample were calculated (the background data were not subtracted), and the standard error's of the activities were calculated. The LLD's were then calculated based on the following equation:

$$LLD_i = 3.29 \left(\frac{\sigma_i}{w}\right) (C_i), \qquad \text{eq. 3.27}$$

where:

σ_i = standard error of the activity

C_i = calibration factor pci/g/cpm/g

w = sample weight = 232.90 g.

The results are shown in Table 3.5. It is believed that this calculation is not an accurate estimate of the LLD's, since the error for the one measurement is very high. If the counting time were to be increased, the standard error of the count rate would be reduced.

The LLD limits for a gamma spectroscopy system depend on the activities of different radioisotopes present in the sample. This includes all the isotopes present in the sample. This problem was analyzed extensively by Pasternack and Harley(8). Their conclusion was the LLD increases with the standard error (SE) of a radionuclide concentration estimate, and SE increases with additional nuclide spectra in the samples. This indicates that the LLD for ^{238}U will increase if the concentration of ^{40}K increases in the sample

Table 3.6 shows the LLD's in the last column for a typical sample.

000039

TABLE 3.[illegible]

LLD VALUES FOR THE CaS_{04} STANDARD

University of Cincinnati
Nuclear Engineering

Ra-226, U-238, Th-232, and K-40 Activity in Concrete [illegible] Materials
Westinghouse Material Company Project

Sample Name:CaSO4
Sample Weight: [illegible] grams
Date Collected: [illegible]
Date Sealed: [illegible]
Data File Name: [illegible]
Date Counted: [illegible]
Counting Time: [illegible] sec.
Sample Geometry: Aluminum Can, Size [illegible]
Region: [illegible]
Detector: Intrinsic Germanium Coaxial Detector, PGT Model IGC [illegible], P Type
Analyzer: MCA/IBM PC, Nucleus PCA-8000 and IBM Personal Computer

Nuclide	Energy Expected [keV]	Energy Meas. [keV]	[illegible] Sample Gross Integral [counts]	[illegible] Sample Net Integral [counts]	[illegible] [s/t] Count Rate [cpm]	[illegible]/g Source Count Rate/gram [cpm/g]
Ra-226	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U-238	63.34	63.0442	[illegible]	[illegible]	[illegible]	[illegible]
	1001.04	1001.74	[illegible]	5	[illegible]	[illegible]
Th-232	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K-40	1460.[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

000040

R' Standard Count Rate/gram [cpm/g]	R/R'	Standard pCi/g per cpm/g	Sample Activity per gram [pCi/g]	SD Sample Activity --[%]	Sample Activity per gram [Bq/g]	LLD [pCi/g]	Nuclide
[illegible]	[illegible]	[illegible]	0.07953	[illegible]	[illegible]	[illegible]	Ra-226
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	13.33	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	0.06709	[illegible]	[illegible]	[illegible]	
		Avg	[illegible]				
[illegible]	[illegible]	[illegible]	1.06737	44.50	[illegible]	[illegible]	U-238
[illegible]	[illegible]	[illegible]	0.58598	144.10	[illegible]	[illegible]	
		Avg	0.87599				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Th-232
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		Avg	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	K-40

000041

7599

TABLE 3.6

LLD VALUES FOR A TYPICAL CEMENT SAMPLE

University of Cincinnati
Nuclear Engineering

Ra-226, U-238, Th-232, and K-40 Activity in Concrete Fill Materials
Westinghouse Material Company Project

Sample Name: [illegible] Basic Resources Concrete, Cement Sample [illegible]
Sample Weight: [illegible] grams
Date Collected: [illegible]
Date Sealed: [illegible]
Data File Name: [illegible]
Date Counted: [illegible]
Counting Time: [illegible] sec.
Sample Geometry: Aluminum Can, Size [illegible]
Region: Full
Detector: Intrinsic Germanium Coaxial Detector, PGT Model IGC 4021, P Type
Analyzer: MCA/IBM PC, Nucleus PCA-8000 and IBM Personal Computer

Nuclide	Energy Expected [keV]	Energy Meas. [keV]	G Gross Integral Source [cts]	s Net Integral Source [cts]	b/t Bkg Count Rate [cpm]	r [s/t-b/t] Count Rate [cpm]	R = r/g Source Count Rate/gram [cpm/g]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	45	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	ND	1.3247E-02	ND	ND
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

000042

R' Standard Count Rate/gram [cpm/g]	R/R'	Standard pCi/g per cpm/g	Sample Activity per gram [pCi/g]	SD Sample Activity --[%]	Sample Activity per gram [Bq/g]	LLD [pCi/g]	Nuclide
[illegible]	[illegible]	[illegible]	[illegible]	10.12	[illegible]	[illegible]	Pa-[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	4.53	[illegible]	[illegible]	
[illegible]	0.50	[illegible]	0.59363	[illegible]	[illegible]	[illegible]	
		Avg	0.59941				
[illegible]	0.00	[illegible]	0.07939	1059.35	[illegible]E-03	[illegible]	[illegible]-239
[illegible]	ND	[illegible]	ND		ND		
		Avg	0.07939				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Th-[illegible]
[illegible]	[illegible]	[illegible]	0.42339	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.27	
		Avg	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	K-40

000043

Best Values for Background and Standrd Count Rates:

Since the background and the NBS calibrated sources were counted independently, they do not all have the same statistical errors (because the counting time is different). Then, a simple average is no longer the optimum way to calculate the best representation of the two quantities. A better technique is calculating their "best values" by a coefficient weighting method. In this method, the best value $\langle x \rangle$ can be computed from the linear combination of individual measurements (x_1, x_2, ...x_i), and using a weighting factor a_i (a_1, a_2,...a_i) as shown in the following:

$$\langle x \rangle = \frac{a_1x_1+a_2x_2...+a_ix_i}{a_1+a_2...+a_i} \qquad \text{eq. 3.28}$$

where, a_i is inversly related to square of its own error as shown in the following

$$a_i = \frac{1}{\sigma_{x_i}^2}\left(\frac{1}{\sigma_{x_1}^2} + \frac{1}{\sigma_{x_2}^2} + \ldots + \frac{1}{\sigma_{x_i}^2}\right)^{-1}. \qquad \text{eq. 3.29}$$

For the optimum weighting, the value of varience can be calculated from:

$$\sigma_{\langle x \rangle}^2 = \left(\frac{1}{\sigma_{x_1}^2} + \frac{1}{\sigma_{x_2}^2} + \ldots + \frac{1}{\sigma_{x_i}^2}\right)^{-1} \qquad \text{eq. 3.30}$$

The standard deviation for the net counts above the continuum area for a photopeak in the gamma spectra (assuming poission statistics) can be calculated from:

$$\sigma_{net} = \left(\frac{2g-n}{t}\right)^{1/2} \qquad \text{eq. 3.31}$$

000044

where, g= Gross count rate of a photopeak area,

n= Net count rate in the peak above continuum area

t= Counting time

Applying the weighting coefficient technique and using the above standard deviation results in

$$a_1 = \frac{t_1}{(2g-n)_{b1}} (B), \qquad \text{eq. 3.32}$$

$$a_2 = \frac{t_1}{(2g-n)_{b2}} (B), \qquad \text{eq. 3.33}$$

$$a_3 = \frac{t_2}{(2g-n)_{b3}} (B), \qquad \text{eq. 3.34}$$

$$\text{and } a_4 = \frac{t_1}{(2g-n)_{b4}} (B). \qquad \text{eq. 3.35}$$

where:

$$B \triangleq \left(\frac{t_1}{(2g-n)_{b1}} + \frac{t_1}{(2g-n)_{b2}} + \frac{t_2}{(2g-n)_{b3}} + \frac{t_1}{(2g-n)_{b4}}\right)^{-1} \qquad \text{eq. 3.36}$$

t_1= counting time for background = 480 min

t_2= counting time for background = 960 min

Then, the best value for the net background count rate in the background can be calculated from:

$$\langle b \rangle = \frac{a_1(b1)+a_2(b2)+a_3(b3)+a_4(a_4)}{a_1+a_2+a_3+a_4} \qquad \text{eq. 3.37}$$

where, bi's represent the net background court rates in the photopeak aeras (above continuum).

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And, the standard deviation of the best value for the background count rate is

$$\sigma_{<b>}=(B)^{1/2} \qquad \text{eq. 3.38}$$

Similarly, the calibrated NBS standard can be calculated from:

$$a_1=\frac{t_1}{(2g-n)_{s1}}(S), \qquad \text{eq. 3.39}$$

$$a_2=\frac{t_1}{(2g-n)_{s2}}(S), \qquad \text{eq. 3.40}$$

and $$a_3=\frac{t_2}{(2g-n)_{s3}}(S). \qquad \text{eq. 3.41}$$

where: $$S\triangleq\frac{t_1}{(2g-n)_{s1}}+\frac{t_1}{(sg-n)_{s2}}+\frac{t_2}{(sg-n)_{s3}} \qquad \text{eq. 3.42}$$

t1= counting time for NBS source= 480 min

t2= counting time for NBS source = 1440 min

The best value for the net NBS standard count rate can be calculated from:

$$<s>=\frac{a_1(s_1)+a_2(s_2)+a_3(s_3)}{a_1+a_2+a_3} \qquad \text{eq. 3.43}$$

where, s_i's represent the net source (plus background) count rate in the photopack areas (above continuam). And the standard deviation of the best value of the NBS standard can be calculated from

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$$\sigma_{<s>} = (S)^{1/2} \quad \text{or} \quad \sigma_{<s>}^{2} = S. \qquad \text{eq. 3.44}$$

For the EPA standard, since the counting error for both measurements are nearly the same, the simple averaging technique for the best value is adequate. The average counts for the net and gross counts under a photopeak are as following:

$$\bar{S}_{ns} = \frac{S_{ns1} + S_{ns2}}{2} \qquad \text{eq. 3.45}$$

$$\bar{S}_{gs} = \frac{S_{gs1} + S_{gs2}}{2} \qquad \text{eq. 3.46}$$

The average count rate for the net and the gross count rate is

$$\bar{\dot{S}}_{ns} = \frac{\bar{S}_{ns}}{t} \quad \text{and} \quad \bar{\dot{S}}_{gs} = \frac{\bar{S}_{gs}}{t} \qquad \text{eq. 3.47}$$

where t= counting time for the source = 480 min.

The standard deviation of the average net count rate is

$$\sigma_{\dot{s}} = \frac{2\,\bar{\dot{S}}_{gs} - \bar{\dot{S}}_{ns}}{(2)\,(t)} \qquad \text{eq. 3.48}$$

where, t=480 min.

In order to reduce the statistical errors due to background, estimate its best values in different regions, and evaluate its stability, several measurements of background at different dates were made.

Figures 3.6 - 3.10 show data in various spectral regions from several 8 hour background counts. The best values of background (<b>) along with <b> $\pm$ $2\sigma_{<b>}$ are indicated on the figures (95% confidence levels).

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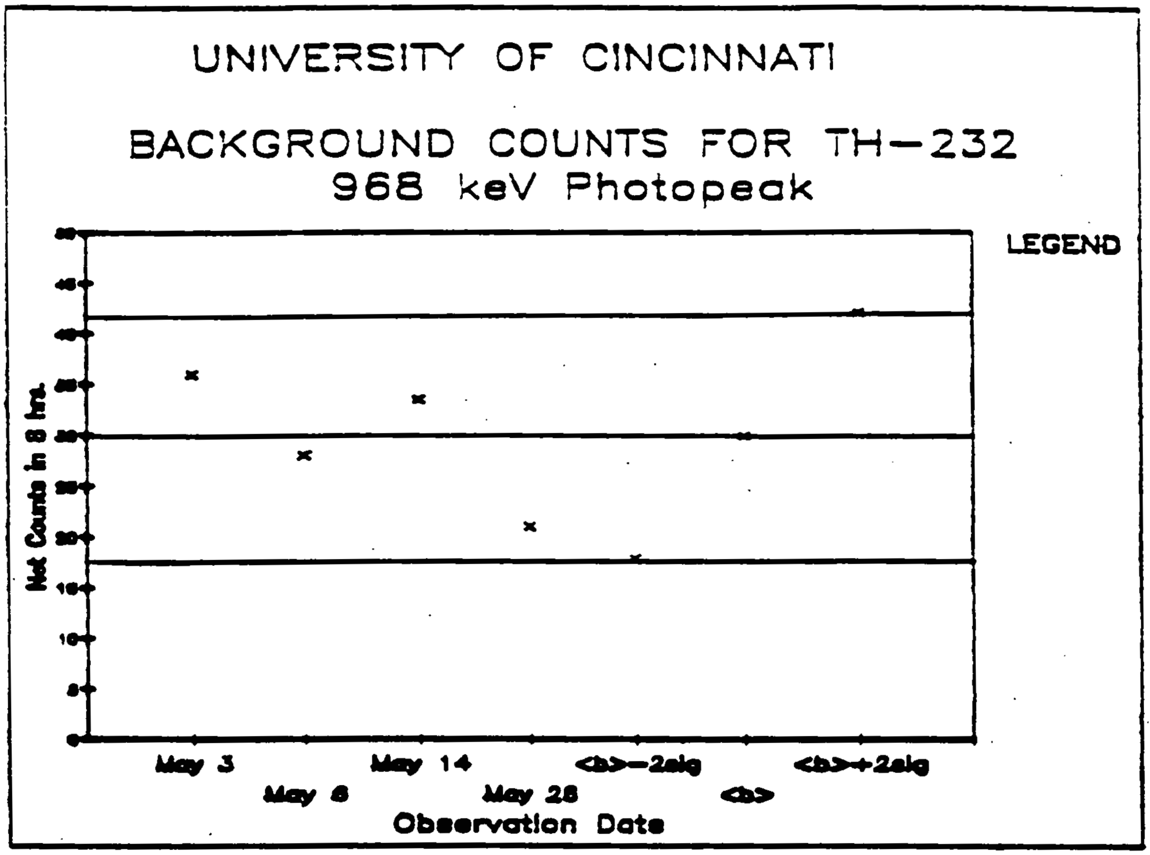

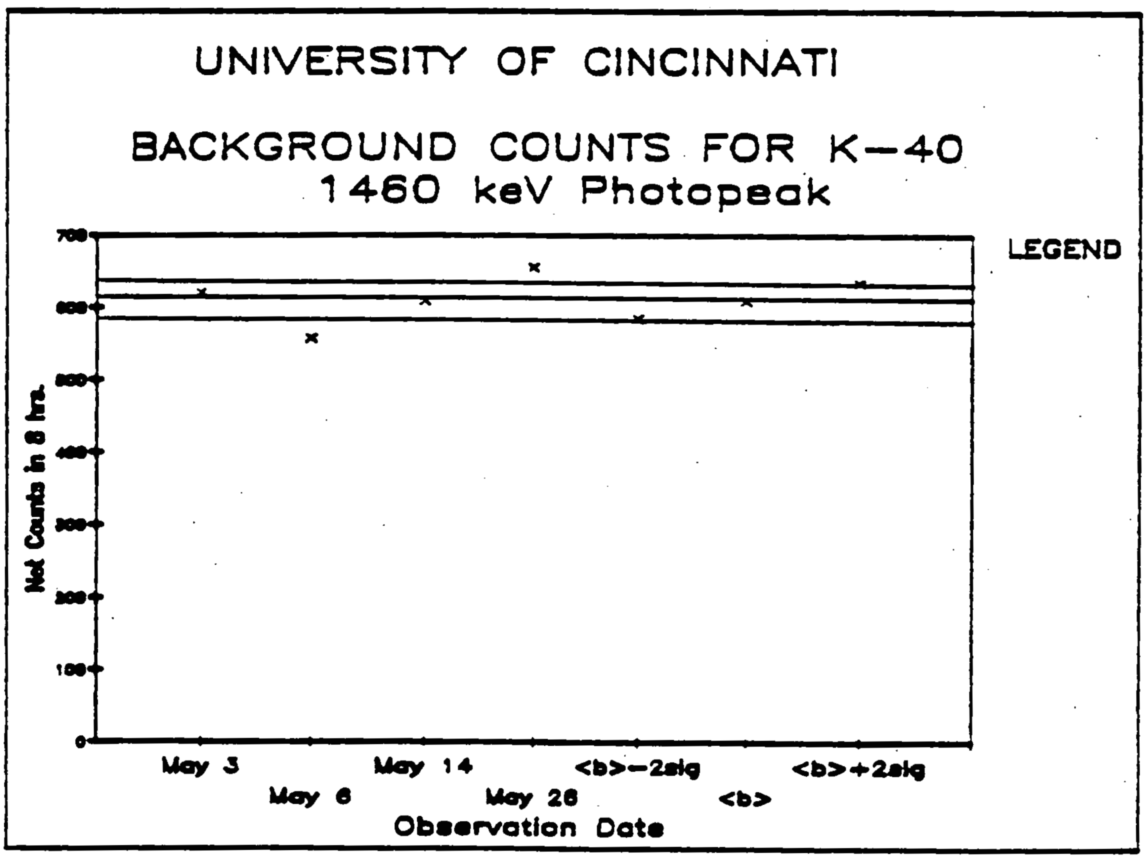

FIGURE 3.6

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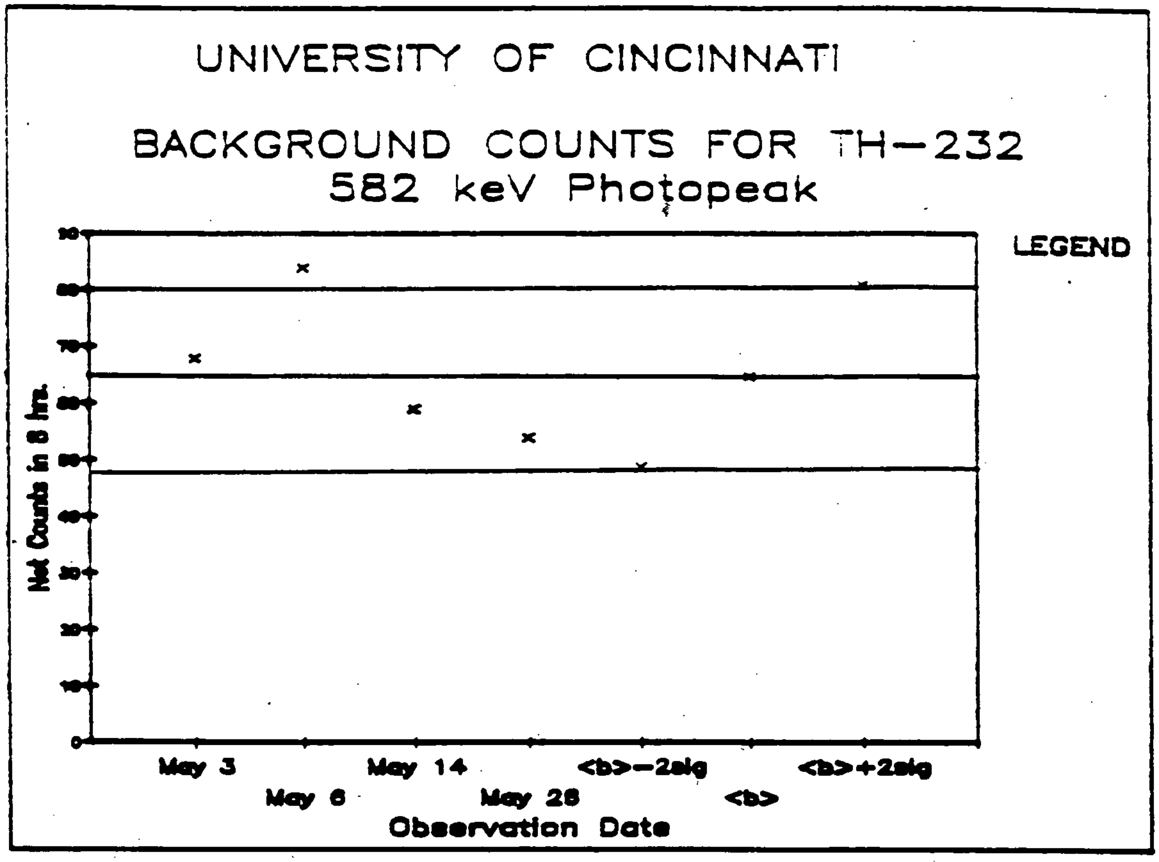

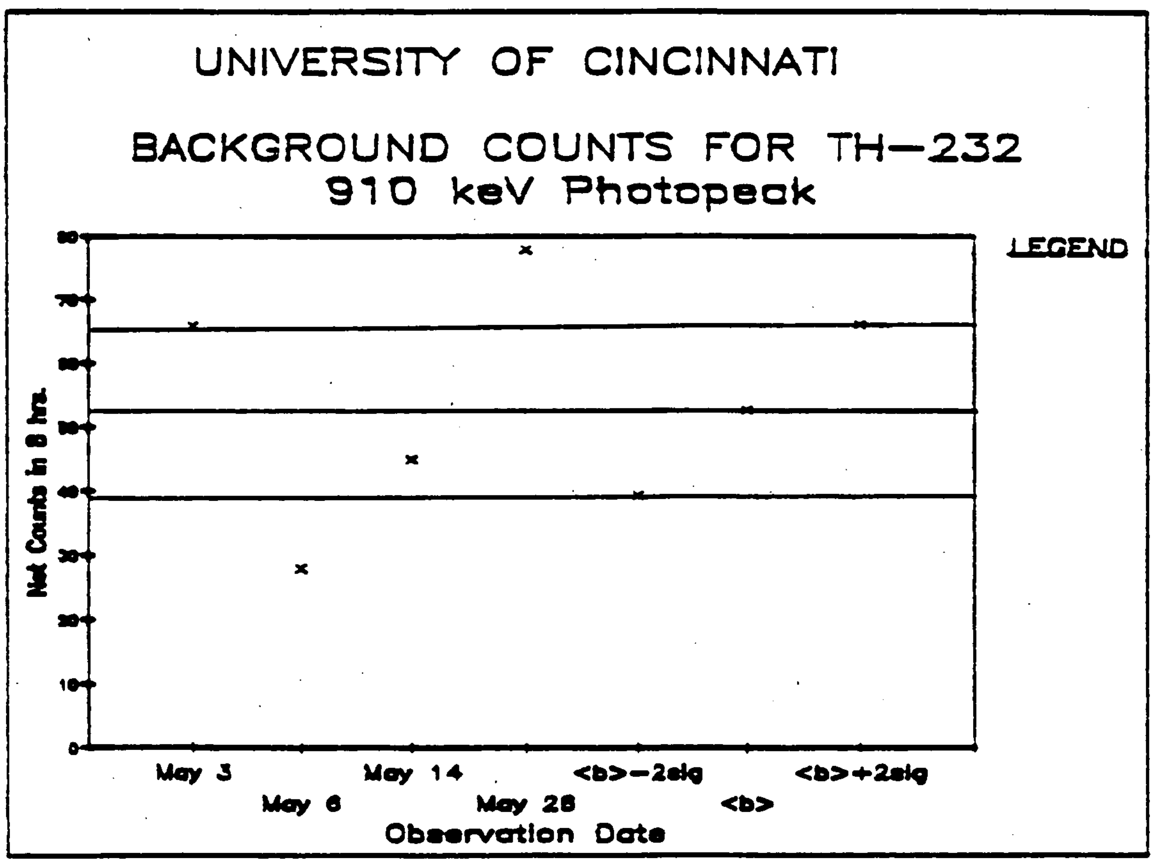

FIGURE 3.7

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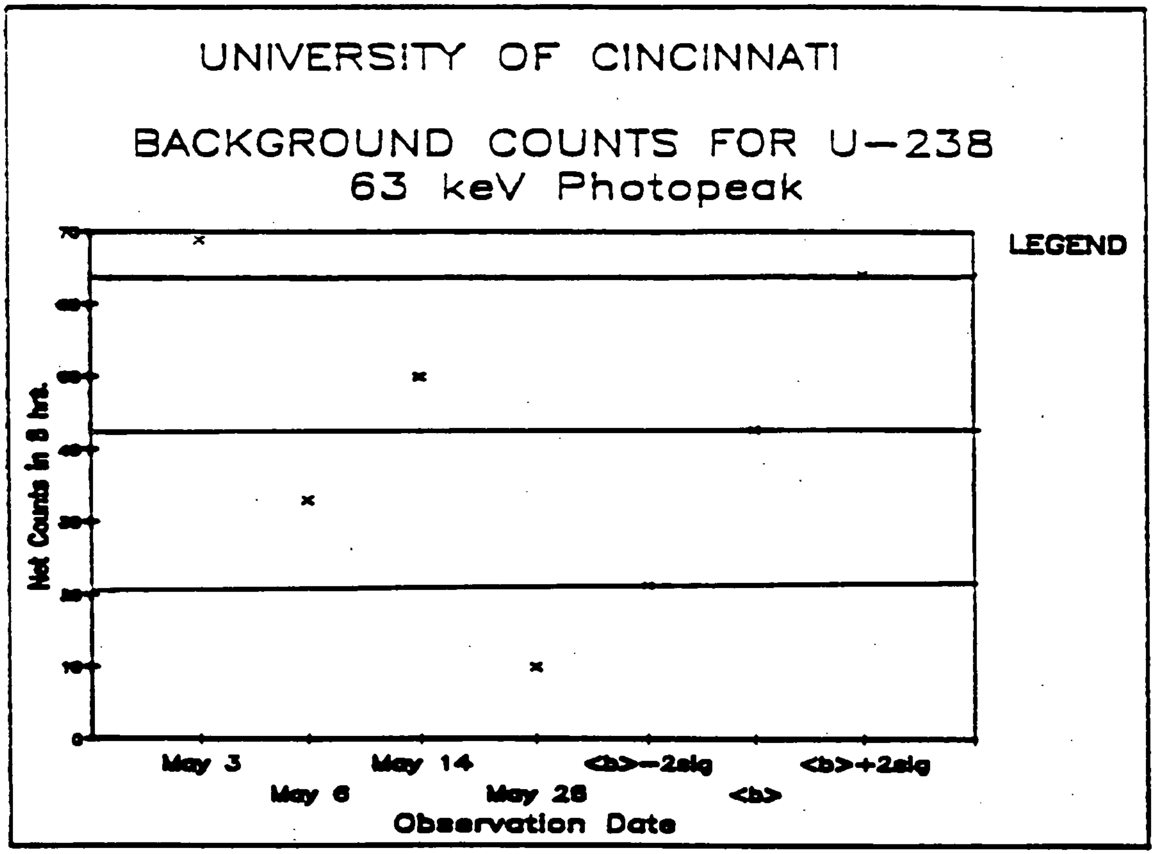


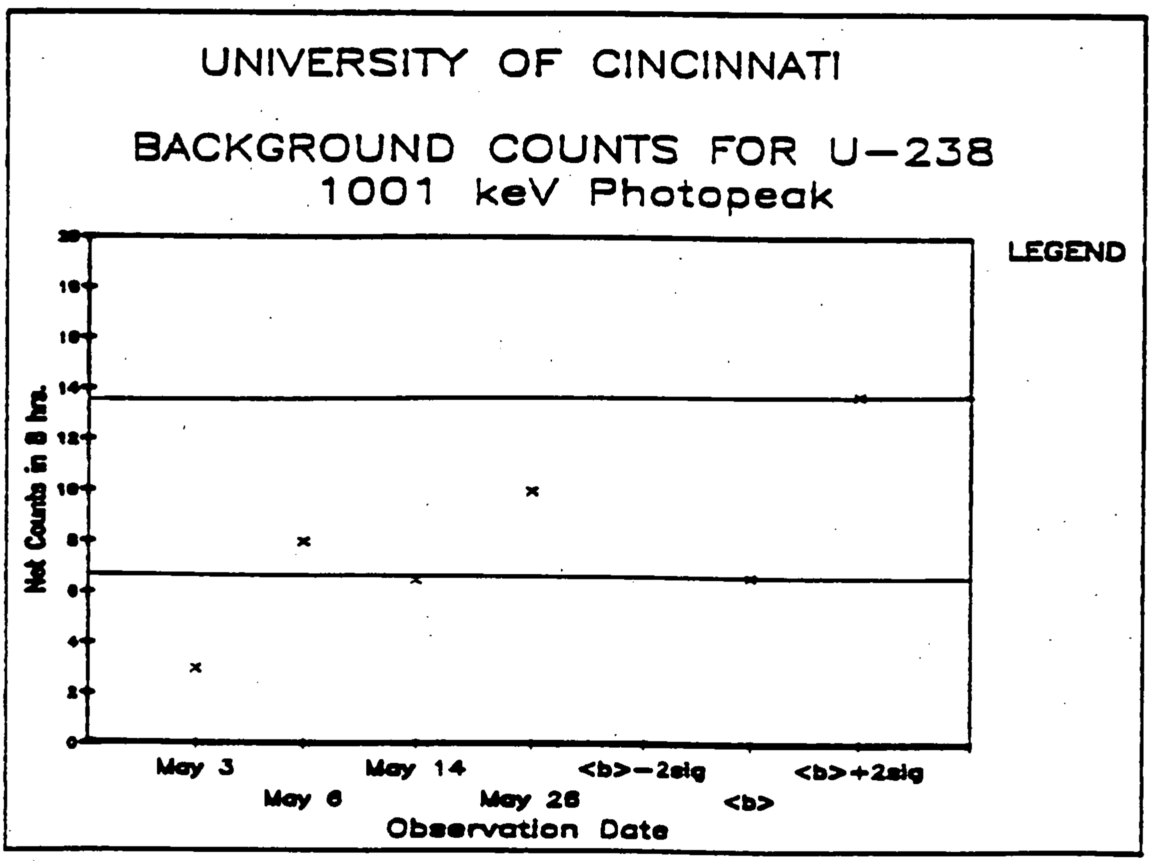
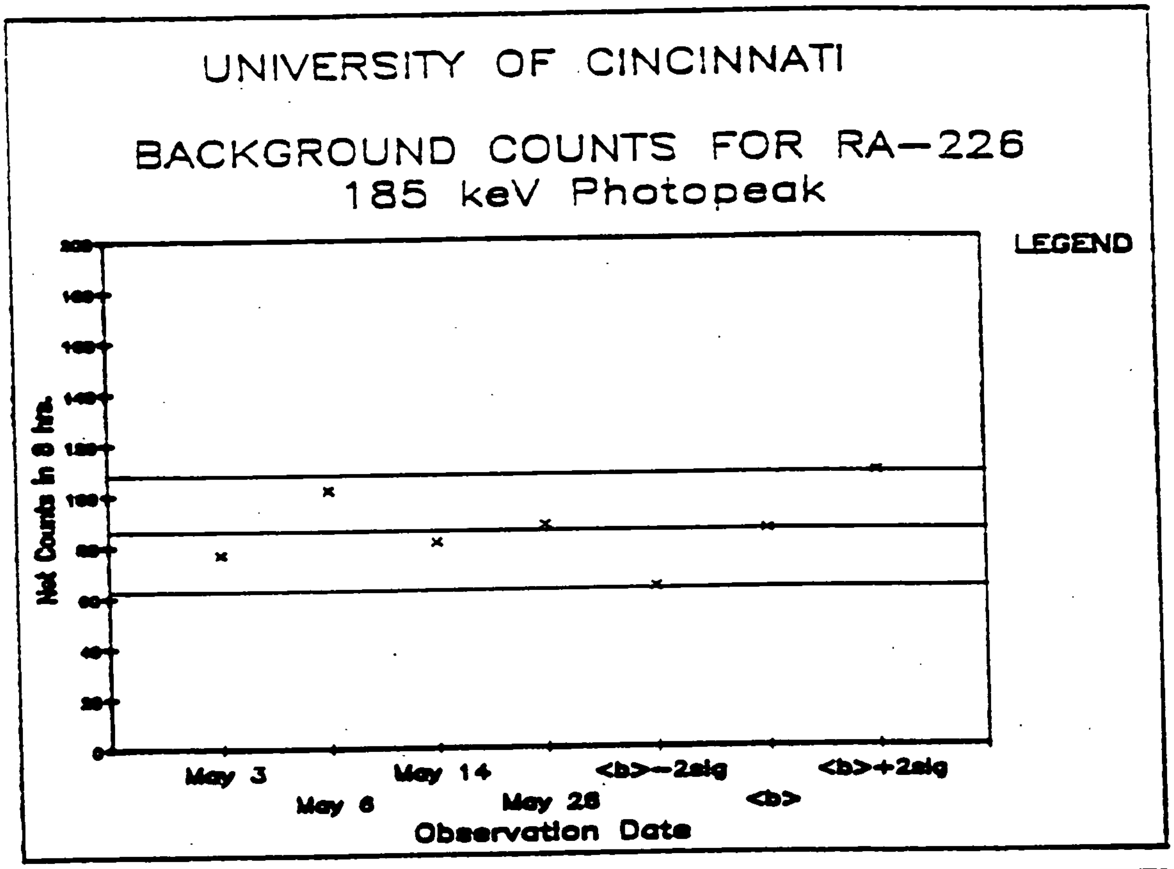


FIGURE 3.8

000050



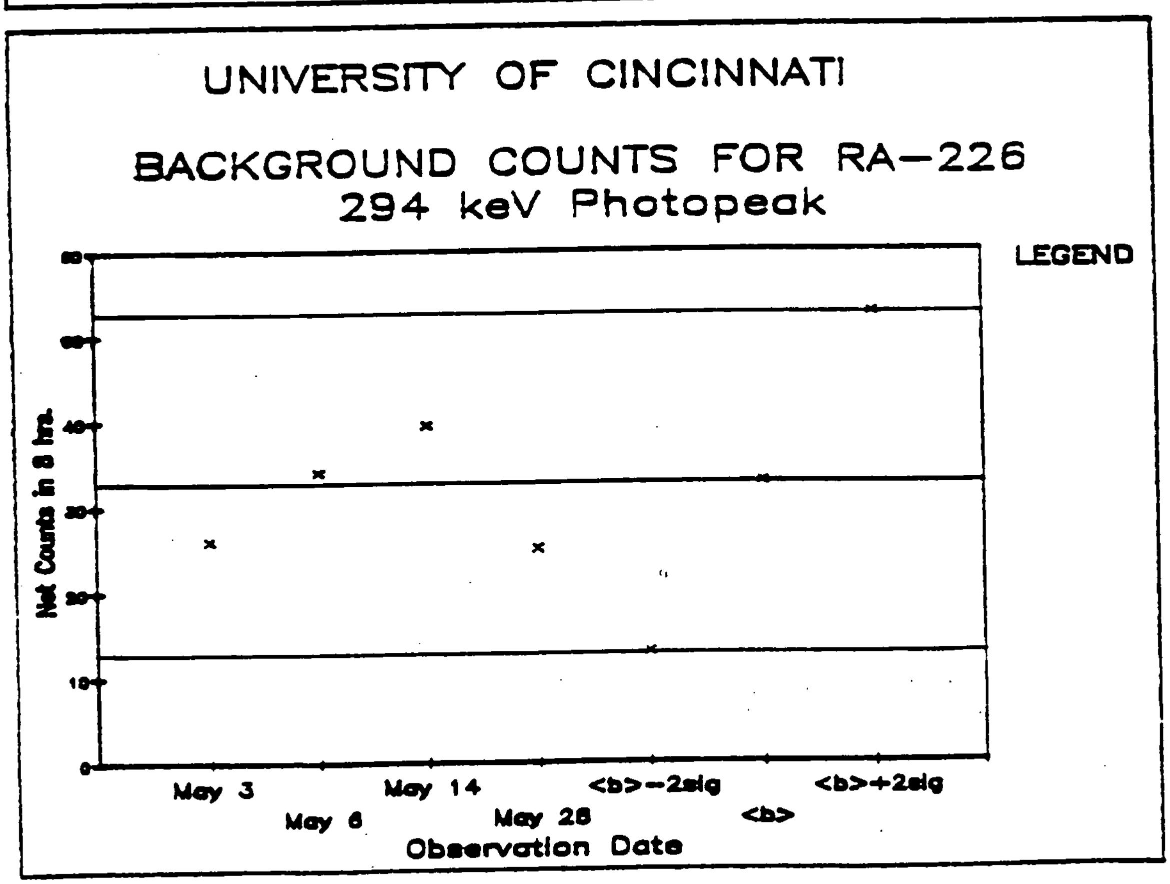


FIGURE 3.9

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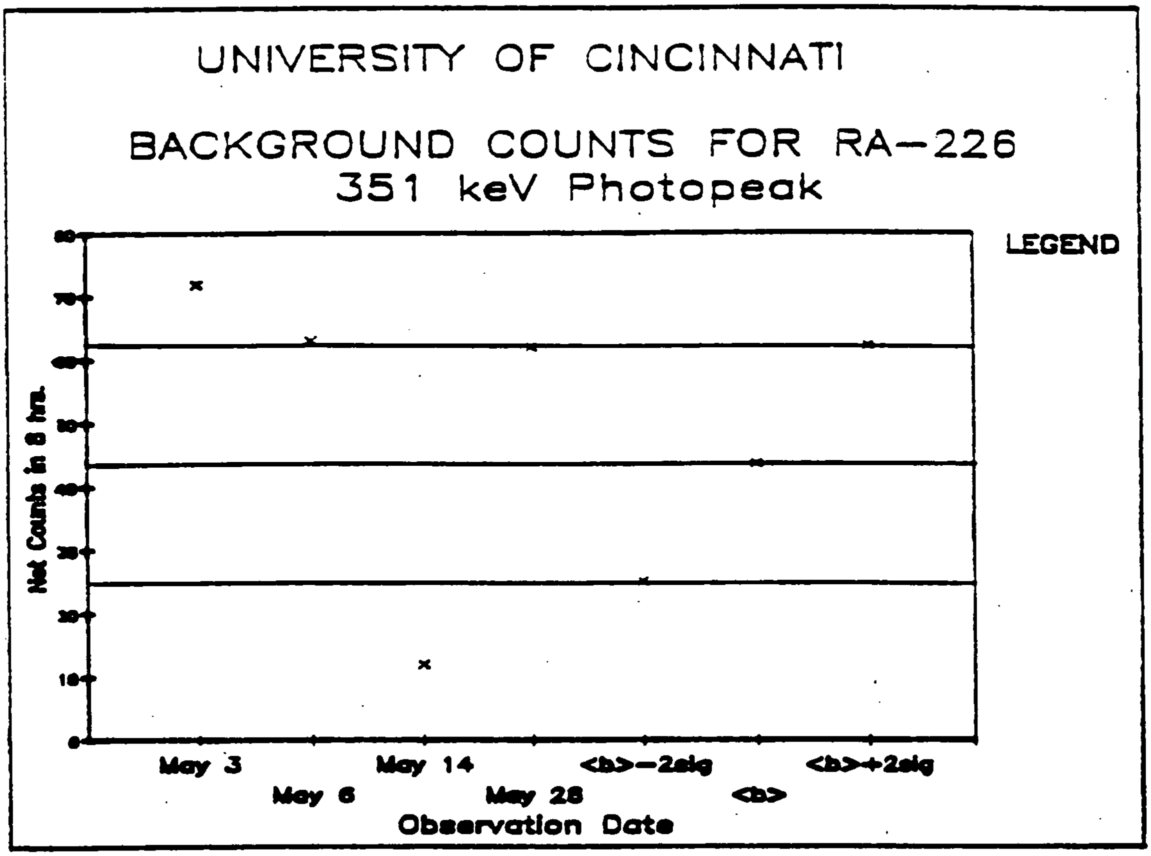

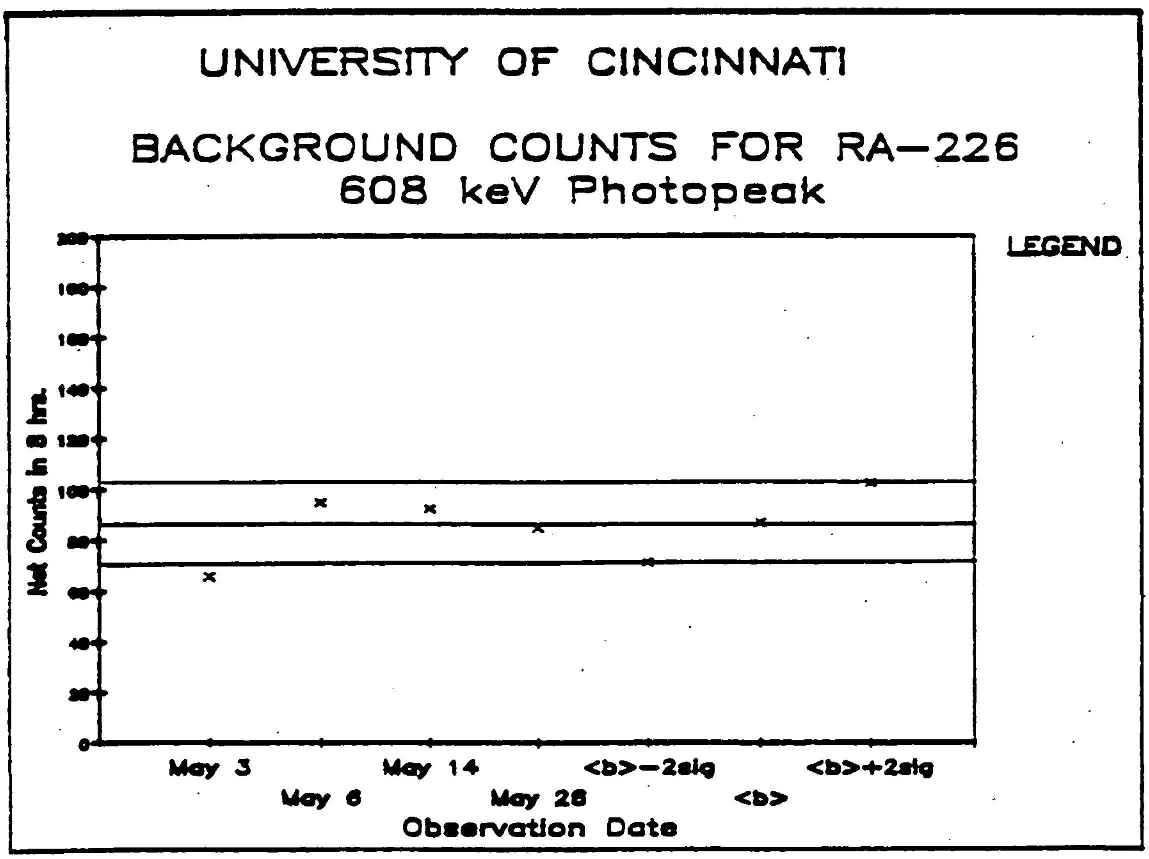

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FIGURE 3.10

SECTION 4 - Analytical procedures

4.1 Site Selection for Equipment Setup

The laboratory that houses the Low-Level Counting Facility was carefully selected by a radiation survey prior to setting up the gamma spectrometry system. Gamma spectra were acquired, and integral counts in the following four regions were compared at different sites:

Channel (#)		Energy (Kev)	
From	To	From	To
20	511	30	766.5
513	1023	769.5	1534.5
1025	1535	1537.5	2302.5
1537	2047	2305.5	3070.5

Based on the analysis of the count rates at different regions and sites, location with lowest background was selected. The laboratory chosen is temperature controlled and has a high air turnover (flow) to avoid Radon build-up.

4.2 Equipment

The Gamma Spectroscopy System used in this project is composed of a Germanium detector (with its cryostat, dewer, and pre-amplifier), a spectroscopy amplifier, a high voltage power supply with automatic liquid nitrogen monitor, a lead/cadmium/copper shield assembly, and a multichannel analyzer. The multichannel analyzer is linked to an IBM Microcomputer with a graphic printer. The system is shown in Figs. 4.1 (a and b). The important components are described in detail in the following paragraphs.

Intrinsic Germanium Detector

A principal component of the low level spectrosocpy system used in this project is the Germanium detector. The type of detector used is a P-type

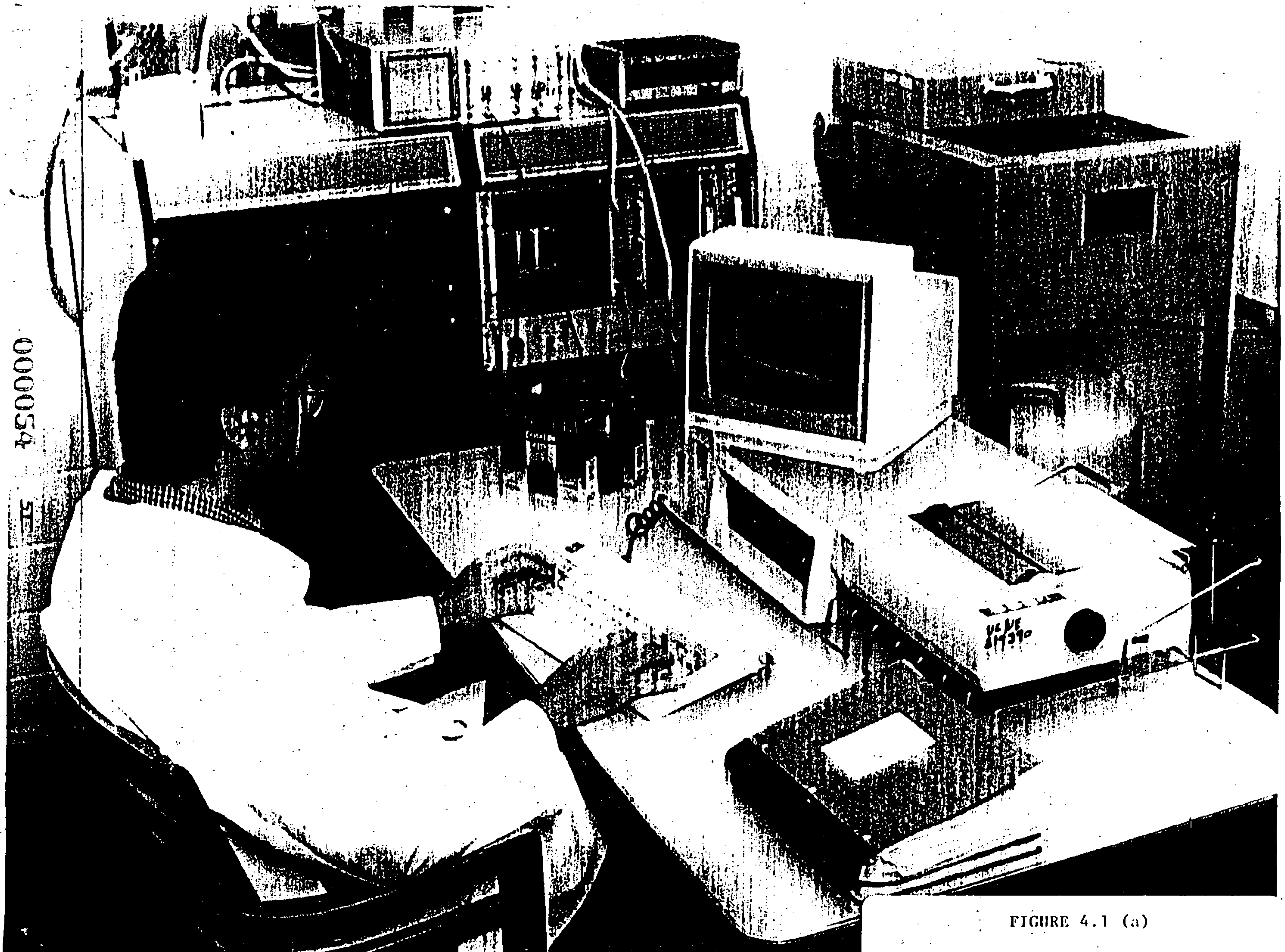

FIGURE 4.1 (a)

LOW LEVEL COUNTING EQUIPMENT

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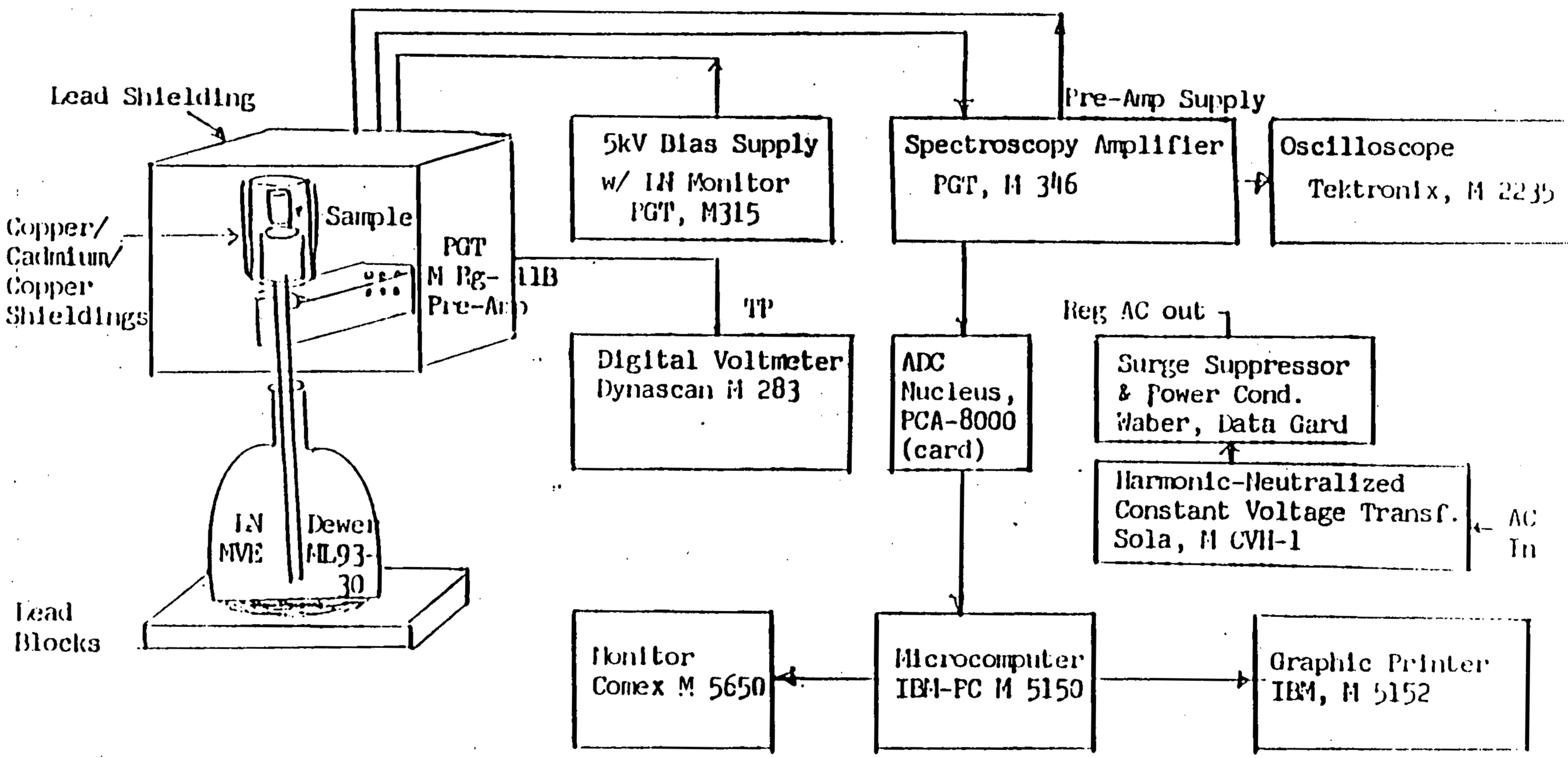

FIGURE 4.1 (b) Block Diagram of the Instrumentation used for Low-Level Counting of Building Materials

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coaxial intrinsic (high purity) germanium detector. The detector specifications are shown in Fig. 4.2. Several important detector specifications were carefully considered to be useful for low level counting.

The detector efficiency was one of the prime factors that was considered in selecting a detector. The detector used in this project has a relative efficiency of 41.8%. The Germanium detector resolution is 1.95 keV for the 1332 KeV photon of Co-60, and 0.917 keV for the 122 keV of photon Co-57. The peak to compton ratio for the 1332 KeV photon is 63:1.

Spectroscopy Amplifier

The Model 346 Spectroscopy Amplifier (Princeton Gamma-Tech) used in this project is a state-of-the-art instrument, designed to optimize energy resolution in spectroscopy application with the Germanium detector. It has a wide choice of selectable shaping time constants (shaping time of 4 microseconds used) and a baseline restorer.

Multichannel and Personal Computer Analyzer

The Multichannel and Personal Computer Analyzer is composed of an MCA card containing an 8192 Channel Analog to Digital Converter (ADC), an upgraded microcomputer system, and an graphic printer. The microcomputer consists of dual floppy Disk Drives, 640 kilobit RAM, a graphic card, and a monochrome monitor. In addition to the standard microcomputer system, a multilfunction card, and a PCA1-8000 multichannel card were added. The computer system was supported by IBM DOS 3.00, Lotus 1-2-3, and the Nucleus software.

The ADC card used in conjunction with the microcomputer meets certain specifications desirable for low-level gamma spectroscopy, namely high conversion gain (8192 channels), high clock frequency (100 Mhz), and good

TECHNICAL DATA
INTRINSIC GERMANIUM COAXIAL DETECTOR

Model Number: IGC 4021 Cryostat: SD/4" Serial Number: 1925

Type: IGC P ☒ N ☐ Well ☐ Other ☐ ______

Measured Performance:

Operating Bias: +4500 **VDC** **Polarity** Positive

at 1.33 MeV, ^{60}Co, with 4 **microseconds amplifier shaping time:**

Efficiency: 41.8 % **(Full energy peak relative to that of 3" x 3" NaI, 25 cm source-to-detector distance)**

Resolution: 1.95 **keV FWHM (full width half maximum)**

3.75 **keV FWTM (full width tenth maximum)**

Peak/Compton: 63.7/1 **(Ratio of peak height to Compton plateau height)**

at 122 keV, ^{57}Co, with 4 **microseconds amplifier shaping time:**

Resolution: 0.917 **keV FWHM (full width half maximum)**

Other: ______

Characteristics:

Diameter: 58 **mm** **Length:** 60 **mm** **Nominal active volume:** 170 **cm³**

Detector-to-window distance: 5 **mm** **Face dead layer thickness:** 0.6 **mm**

Capacitance: – **picofarads at operating bias**

Leakage current: <0.1 **nanoamperes at operating bias**

Test point voltage: -0.20 **VDC without radiation sources**

Preamplifier FET: Cooled ☑ Room temperature ☐

Test equipment: Amplifier PGT 347

Bias supply PGT 314

Tested by: C. Pezalo

Date: 4/30/87

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PRINCETON GAMMA-TECH

linearity and stability. A summary of the specifications is shown in Appendix B. Data reduction and analysis are performed by computer programs purchased for this purpose.

Bias Supply for Detector (with LN Monitor)

The bias supply (PGT, Model 315) for the Germanium detector has a voltage range of 0-5 KeV with noise and ripple of less than 3 mV peak-to-peak. The voltage drift is less than 0.05% per hour. In addition to the bias supply, the unit has the capability to monitor the liquid nitrogen in the dewer that cools the detector and the pre-amplifier and shut off the bias supply due to lack of liquid nitrogen or detector malfunction (excessive leakage current).

Shielding

To reduce the background counts several shielding configurations were designed, built, and tested. The final shield configuration is shown in Figure 4.3. Four inches of lead brick surround a cylinderical chamber made from copper and cadmium fitted around the detector assembly. Figure 4.4 shows a picture of the detector and sample, surrounded by the shield. The background gamma ray spectra obtained before and after shielding are shown in Figures 4.5 and 4.6. An estimated improvement of 65:1 was observed. The energy calibration curve for the system is shown in Figure 4.7.

4.3 Sample Collection and Preparation

Sample Selection

Three samples of sand, gravel and cement were collected from each of the six concrete suppliers. A liter of water was also collected from each vendor for analysis. At the suggestion of Mr. Bill Hayes, the analysis of the water

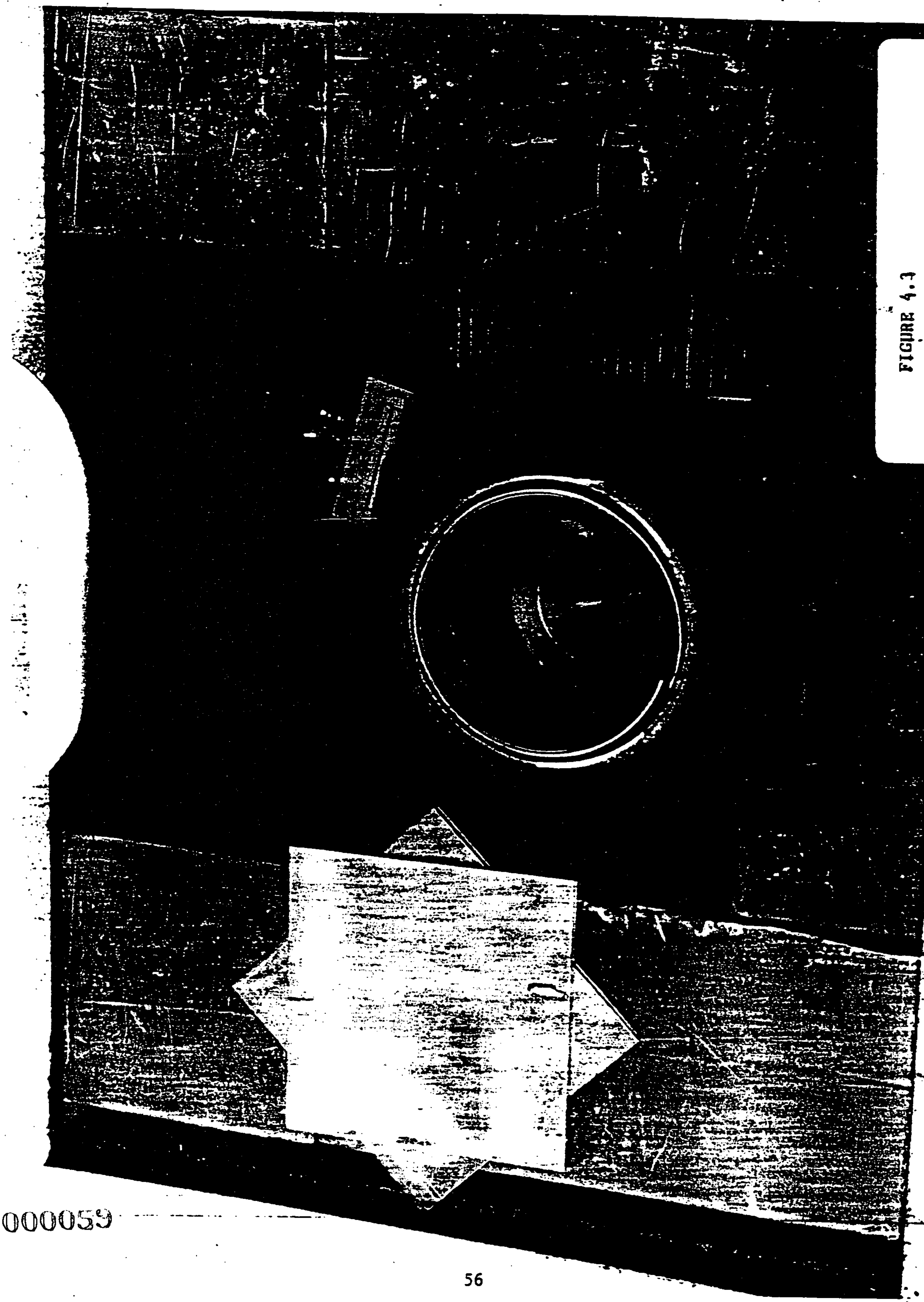


FIGURE 4.3

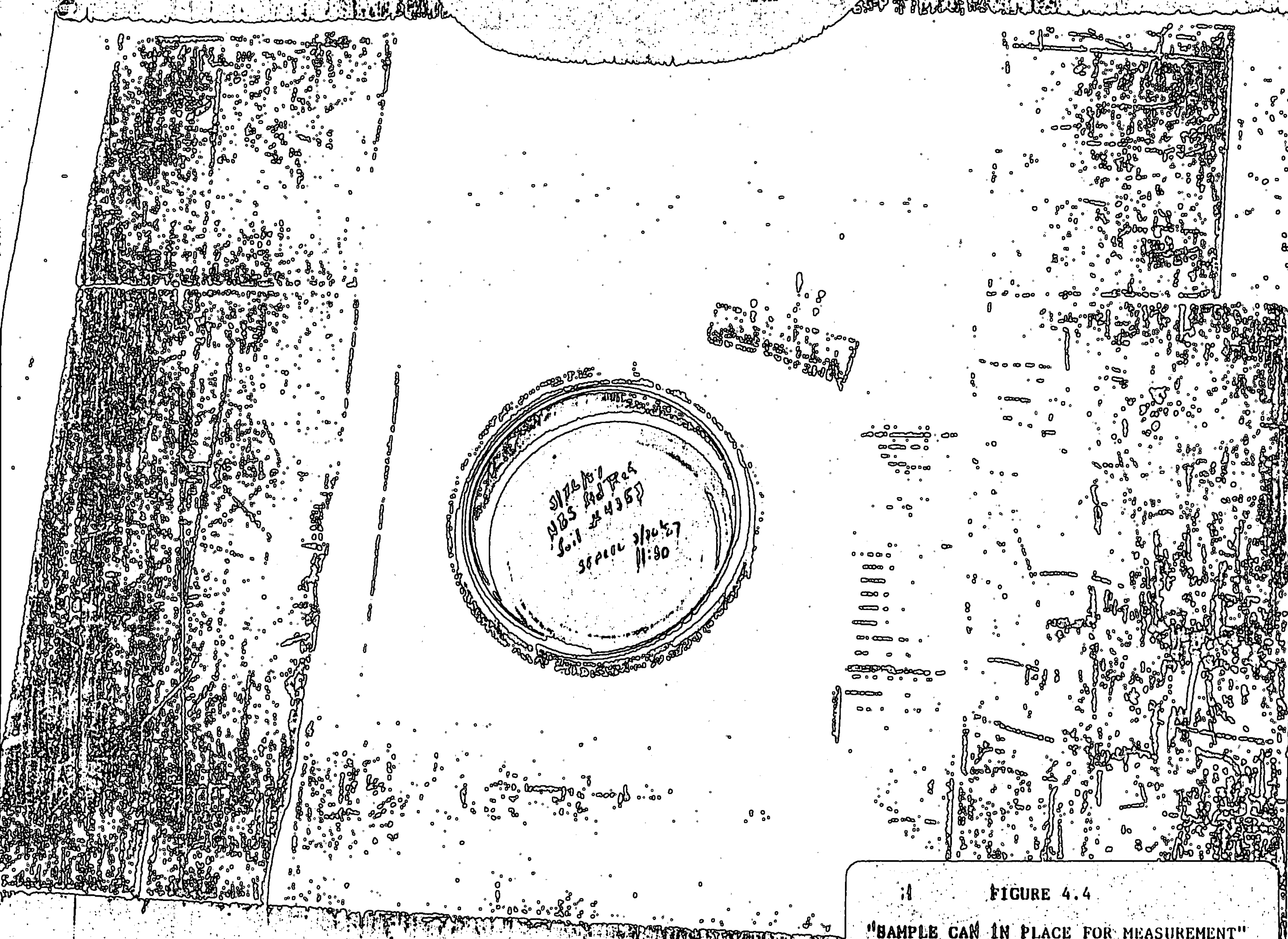


FIGURE 4.4

"SAMPLE CAN IN PLACE FOR MEASUREMENT"

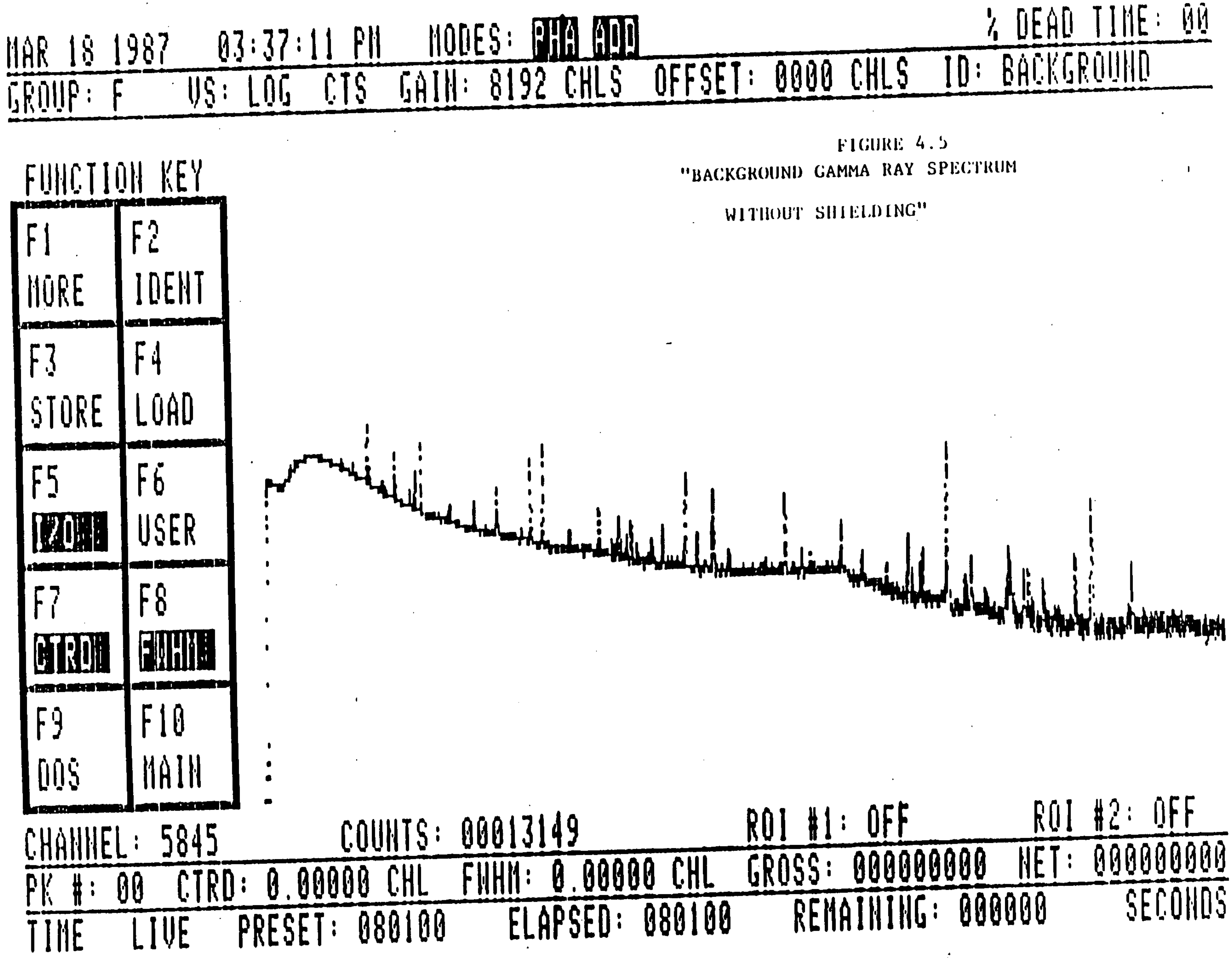


FIGURE 4.5
"BACKGROUND GAMMA RAY SPECTRUM
WITHOUT SHIELDING"

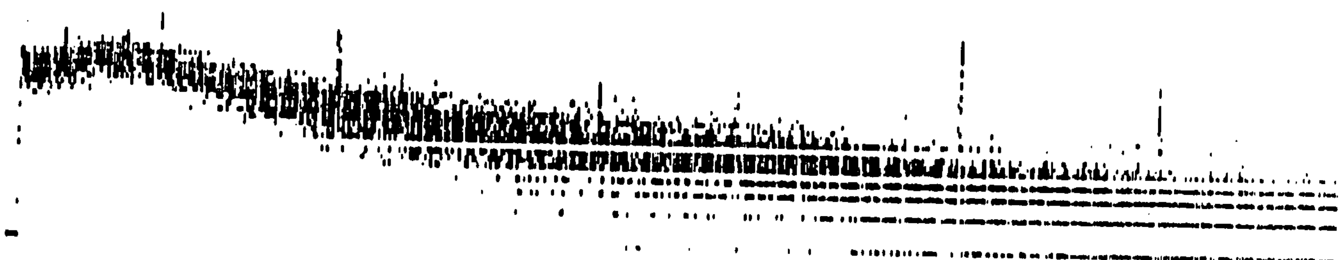
MAY 26 1987 01:25:03 PM MODES: PHA SUB % DEAD TIME: 00
GROUP: F VS: LOG CTS GAIN: 8192 CHLS OFFSET: 0000 CHLS ID: BG 4

FUNCTION KEY

F1 MORE	F2 IDENT
F3 STORE	F4 LOAD
F5 [illegible]	F6 USER
F7 CTRD	F8 FWHM
F9 DOS	F10 MAIN

FIGURE 4.6

"BACKGROUND GAMMA RAY SPECTRUM WITH SHIEDLING"



ENERGY: 1460.39 KEV COUNTS: 00000076 ROI #1: OFF ROI #2: OFF
PK #: 00 CTRD: 0.00000 KEV FWHM: 0.00000 KEV GROSS: 000000000 NET: 000000000
TIME LIVE PRESET: 028800 ELAPSED: 028800 REMAINING: 028800 SECONDS

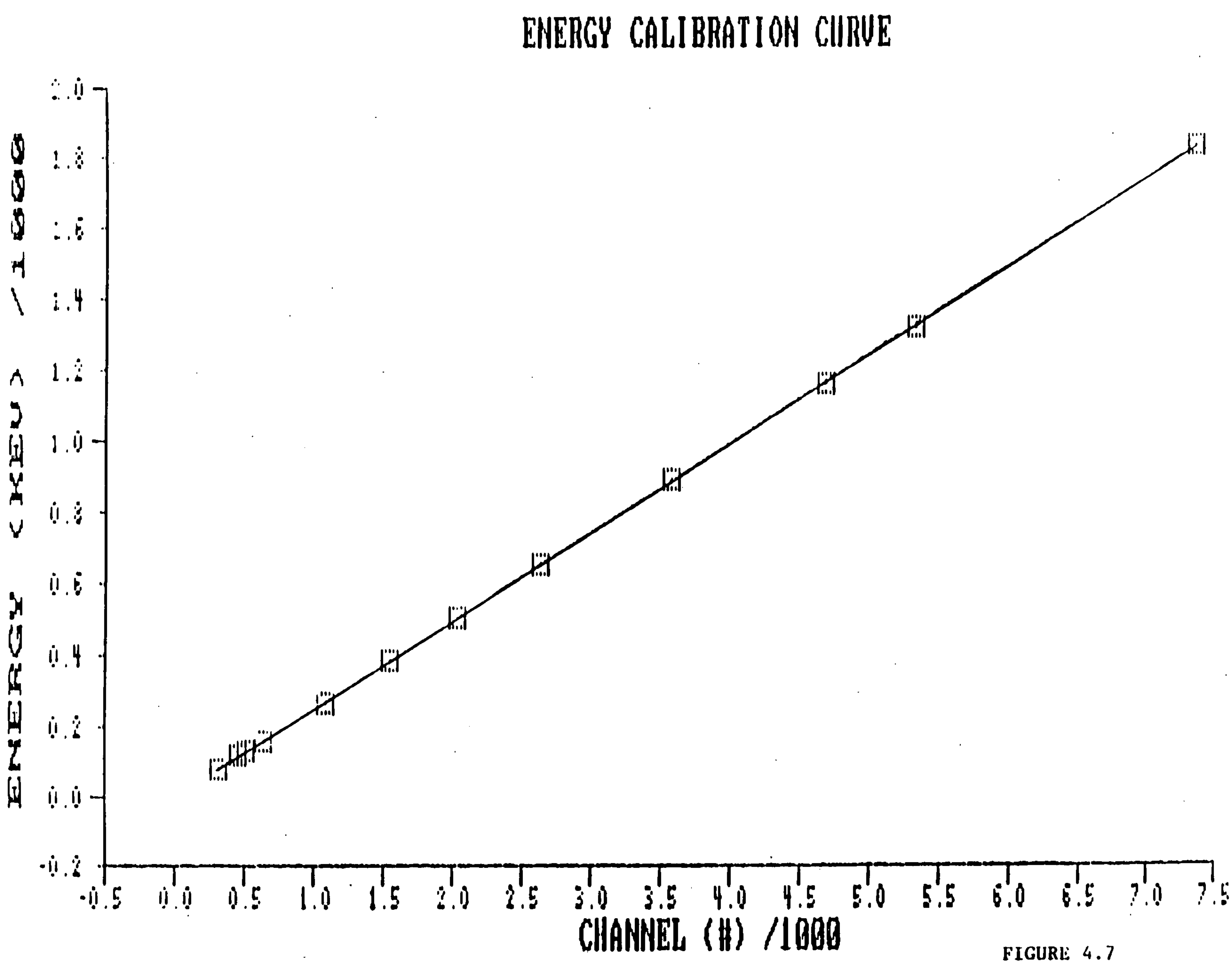


FIGURE 4.7

ENERGY CALIBRATION CURVE

samples was performed at WMCO.

The concrete fill material samples (sand, cement, gravel and water) were collected from each vendor's site and were placed in large plastic containers. All solid material samples were marked with vendor name, location of the sample, and type of sample (sand, gravel or cement). The water samples were collected in a one liter plastic bottle and identified in the same manner.

All of the samples were collected using a procedure that would insure homogeneous samples. Each vendor maintains a large sand pile. Sand samples were collected in the large container by obtaining a large number of small samples from various locations in the sand pile. The same procedure was used to collect the cement and gravel samples.

Sample Containers

The container slected for preparation of samples for measurement was an aluminum can approximately 3 7/16" diameter by 2 1/8" high (Type 307 x 202) obtained from Central States Can Co., Massilon, Ohio. The matching lid could be hermetically sealed for containment of ^{222}Rn during ingrowth from ^{226}Ra. The lid sealing tool was a Model 225 Master Can Sealer (Wisconsin Aluminum Foundry, Manitowse, Wisconsin). A sample can is shown in Figure 4.8.

Selection of the sample container was made following an evaluation of what was available from various suppliers and discussions with persons doing similar work at other laboratories. The container selected matches the diameter of the intrinsic germanium detector very closely, is inexpensive, convenient to use and is similar to those in use in laboratories doing related work.

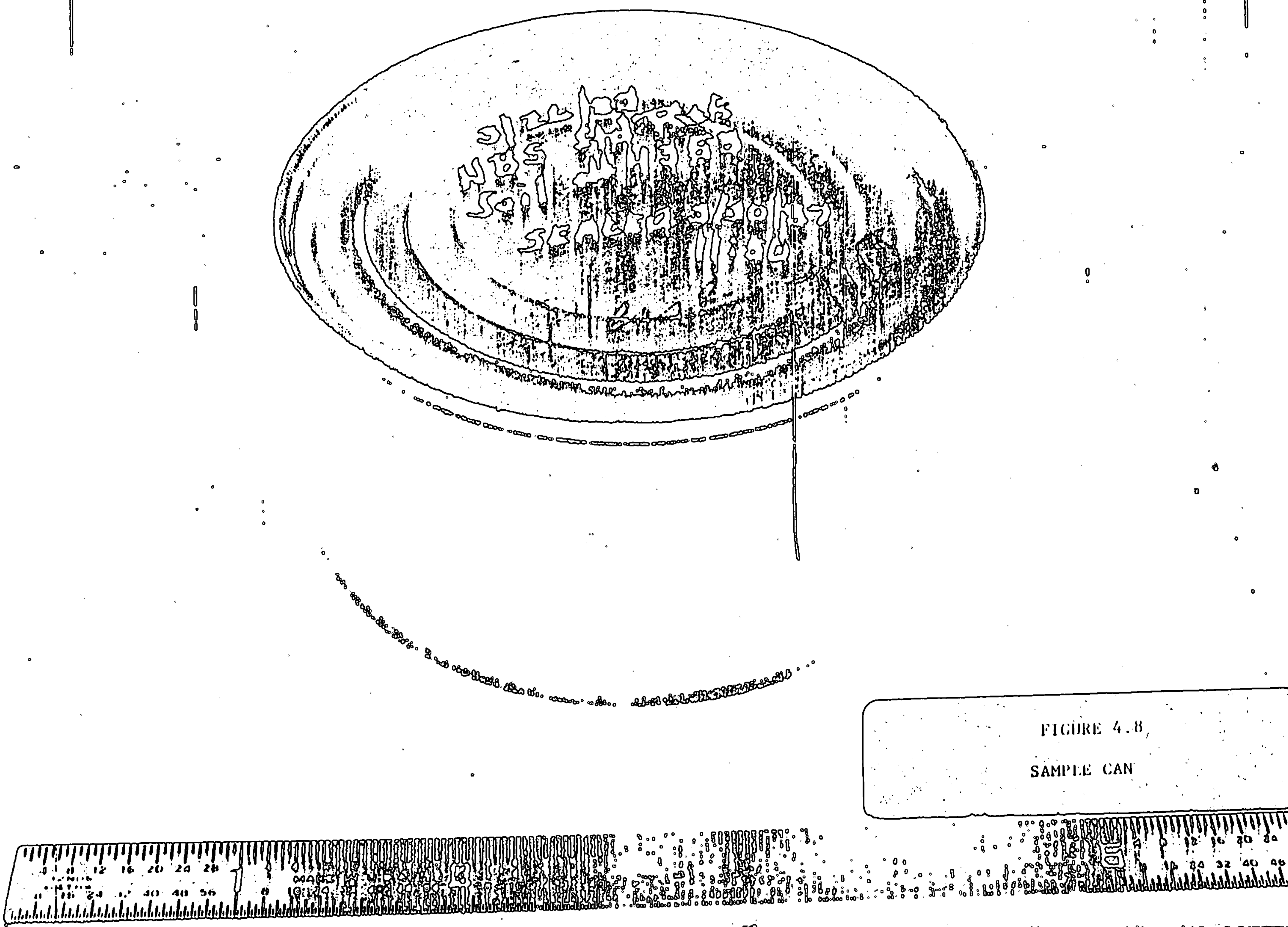


FIGURE 4.8

SAMPLE CAN

Sample Preparation

Part of the fill material samples which were collected in the large plastic containers were transferred to the aluminum sample holding can. Each can was marked and identified with the vendor name and data about the sample. Each sample was prepared for counting in an identical fashion to the standard samples.

Two sample cans and lids were appropriately marked and weighed on a digital balance. Sample material (i.e. sand, gravel and cement) was removed from the field container by means of a spatula and placed in each of the cans to approximately 80% of capacity. Each container and lid was re-weighed with the sample inside it.

Cans with sample and lids were placed in an oven at 120°C and dried for a minimum of 16 hours. This period was extended to 24 to 48 hours whenever possible. Upon removal from the oven, samples were placed in a desiccator and permitted to come to room temperature in this atmosphere in order to prevent the samples from picking up moisture while cooling off.

The samples were then re-weighed. A considerable loss of weight and settling occurred during drying (particularly in sand and cement samples). Thus a portion of the contents of one can was removed by spatula and placed in the second can to a height of 3.4 centimeters, as measured from the inside bottom surface of the can. A final weighing of the sample, contents and lid was made to obtain the total sample mass. There was a slight difference in the masses of samples of a given medium but the volume occupied in the container was constant.

Following the final weighing the lid was sealed on the can. Date and time of this operation was recorded for purposes of assessing the ingrowth of ^{222}Rn into ^{226}Ra. Data on all the weighing and drying operations described above, including times and dates were also appropriately logged.

The minimum ingrowth period of ^{222}Rn into ^{226}Ra prior to measurement was 21 days. In most cases this ingrowth period was considerably longer and thus ^{222}Rn was within 1-2% of equilibrium in most samples prior to counting. Since the deviation from a true secular equilibrium was small and well below measurement errors, no correction for ingrowth was included in the calculation.

4.4 Counting Procedures

Using the Germanium spectroscopy system described earlier, all samples were counted for an 8 hour measurement period. The time and date of the count was recorded in a laboratory notebook. Other pertinent information such as: sample name, date, calibration checks, or any other relevent information was also logged in the book. Every attempt was made to maintain the same geometry for all the measurements. A typical Gamma spectrum is shown in Fig. 4.9. In the gamma spectra analysis, the peaks were identified based on their photopeak energies, and the regions-of-interest were established. Fig. 4.10 shows two peaks with pertinent regions of interests. The first samples analyzed were the NBS and the EPA standards to obtain the calibration factors.

4.5 Photopeak Identification and Determination of Photopeak Areas

Identification of gamma ray photopeaks from the radionuclides measured in this study was accomplished predominantly by accurate energy measurements and measurements of relative photopeak counts. The gamma spectrometer system was energy calibrated as shown previously by Figure 4.7. The energy calibration was accomplished through the use of the multiple nuclide standard source described in Section 4.2. This procedure assured that photopeak energy could

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MAY 17 1987 03:04:54 PM MODES: PHA SUB % DEAD TIME: 00

GROUP: F VS: LOG CTS GAIN: 8192 CHLS OFFSET: 0000 CHLS ID: MIC2A.1

FIGURE 4.9

TYPICAL GAMMA SPECTRA

SHOWING PHOTO PEAK IDENTIFIED

FUNCTION KEY

F1 MORE	F2 IDENT
F3 STORE	F4 LOAD
F5 [illegible]	F6 USER
F7 CTRD	F8 FWHM
F9 DOS	F10 MAIN

ENERGY: 1461.01 KEV COUNTS: 00000195 ROI #1: OFF ROI #2: OFF

PK #: 00 CTRD: 0.00000 KEV FWHM: 0.00000 KEV GROSS: 000000000 NET: 000000000

TIME LIVE PRESET: 028800 ELAPSED: 028800 REMAINING: 028800 SECONDS

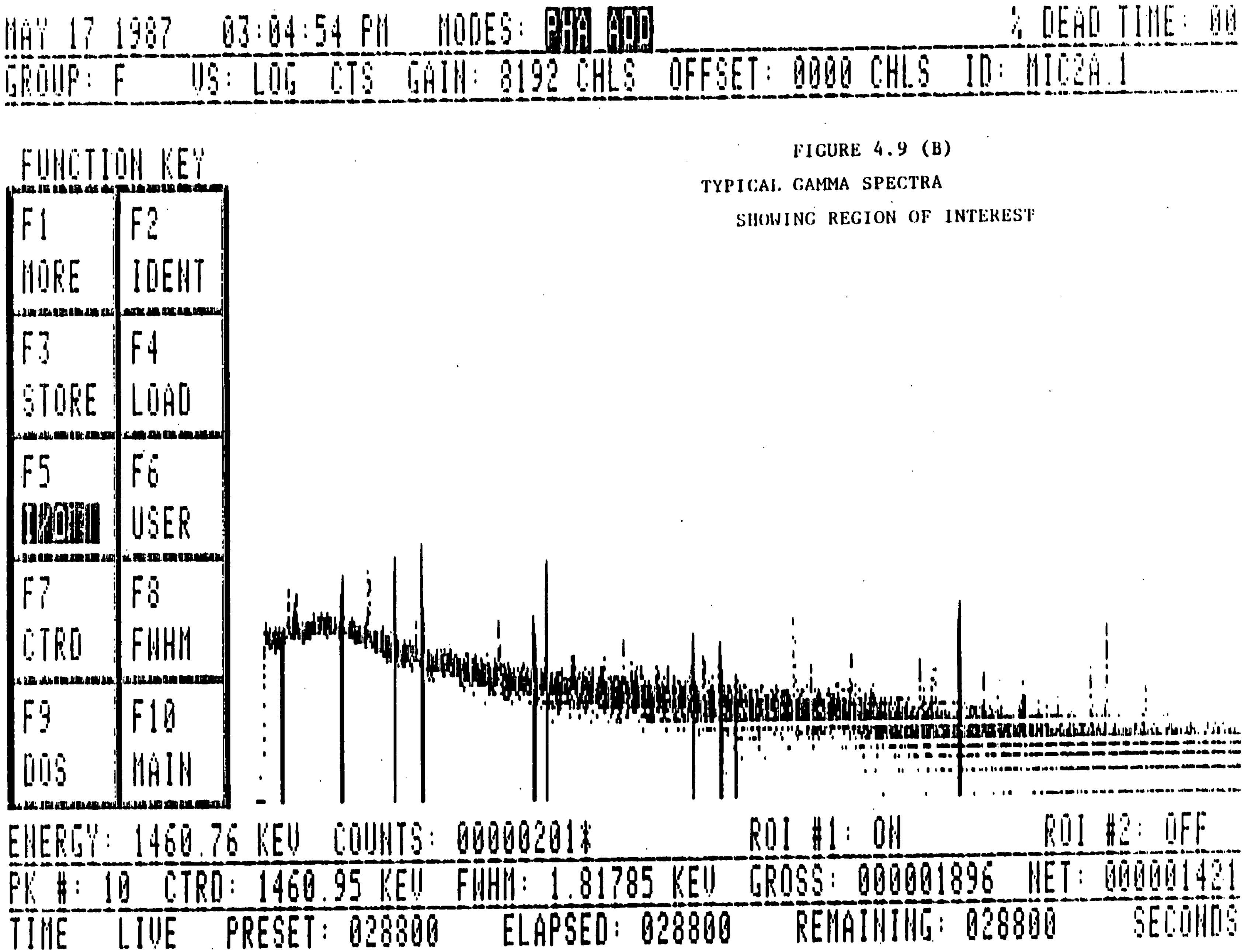

FIGURE 4.9 (B)
TYPICAL GAMMA SPECTRA
SHOWING REGION OF INTEREST

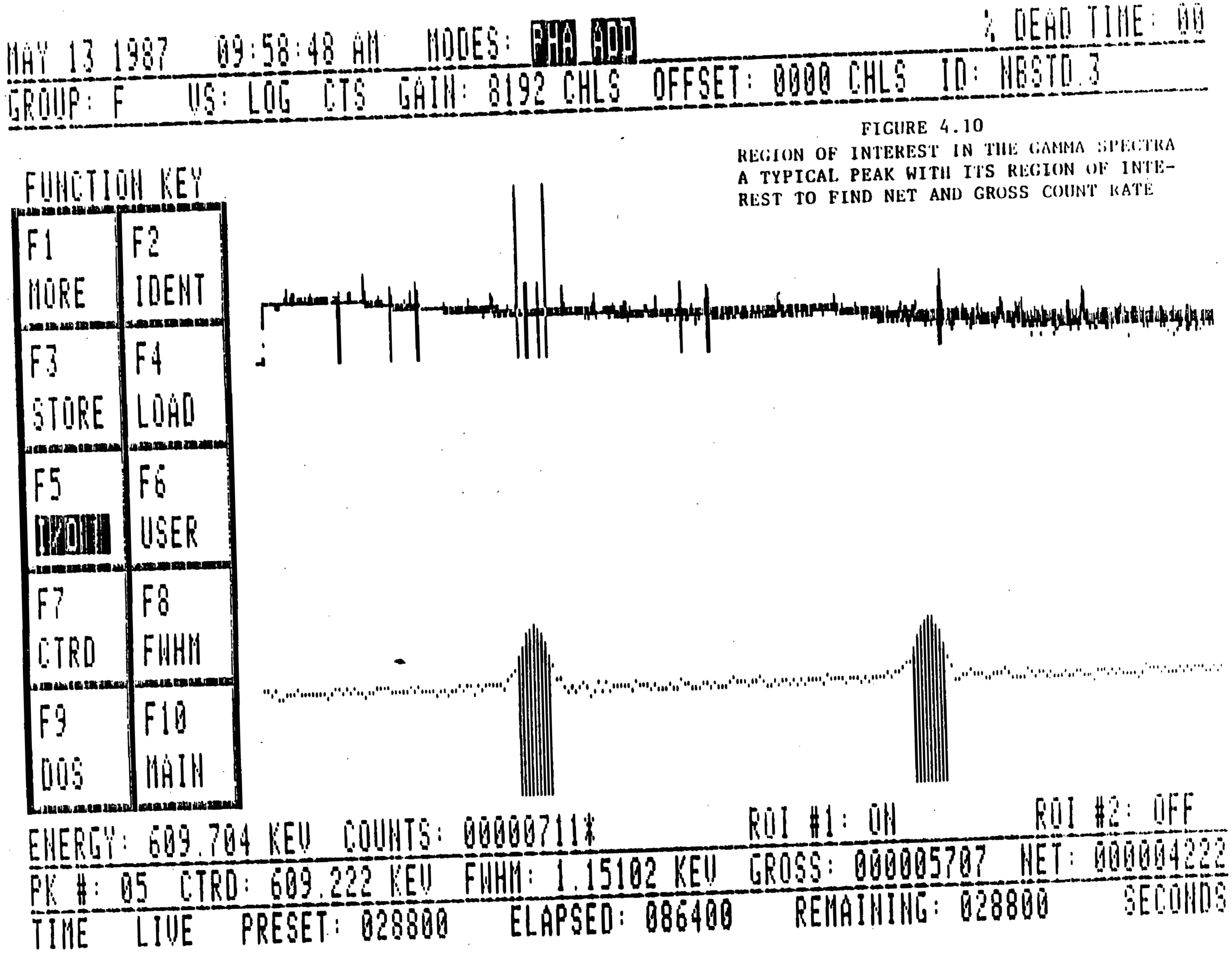

FIGURE 4.10
REGION OF INTEREST IN THE GAMMA SPECTRA
A TYPICAL PEAK WITH ITS REGION OF INTEREST TO FIND NET AND GROSS COUNT RATE

be measured to ± 1 KeV. Relative numbers of counts in the photopeak were calculated by obtaining net photopeak areas. By comparison of energies with nuclear data tables[10] and relative net counts with standard data such as the NBS standard soil data and with tabular values, it was possible to confirm assignments.

The identification of the specific peaks used for the analysis of each radionuclide in the study was essentially unambigous. These peaks are listed in Table 4.1 below.

Table 4.1

Photopeaks Used For Measurement

Radionuclide	Peak Energy (keV)
^{226}Ra	185.755
^{226}Ra	294.909
^{226}Ra	351.566
^{226}Ra	608.930
^{238}U	63.34
^{238}U	766.28
^{238}U	1001.04
^{232}Th	582.749
^{232}Th	910.653
^{232}Th	968.39
^{40}K	1460.21

To determine the activity of the isotopes listed above, one needs to find the absolute intensity of a particular gamma energy. This requires the determination of the net area under the peak, and this is not as straight forward as assignment of energy. Because the area under thepeak includes contributions from other gamma rays, many methods have been developed to determine this area.

One simple method (which was described in Section 3.4) to estimate the area (Gross) under the peak by simple integration between the limits set at the shoulder of the peak (adding the counts from all the channels in the region of the peak) and subtract a "base background" which is the background plus the compton continuum. This is shown in Figure 4.11.

In the PCA-8000 Personal Computer Analyzer a more advance algorithm is used to calculate the net area of the peak. This is the method used to calculate the net area in the peaks for quantitative analysis of the building materials. The net areas of the peak is determined by averaging the beginning Region of Interest (ROI) channel contents and three previous channels and drawing a straight line from there to the average of the ending ROI channel contents and the three following channels. All counts above that line are considered to be the net area. It is believed that this technique would give a better estimate of the net counts in the peak area than the simple integration technique. The pertinent areas used are shown in Figure 4.11.

FIGURE 4.11 DETERMINATION OF NET AREA UNDER A PHOTOPEAK

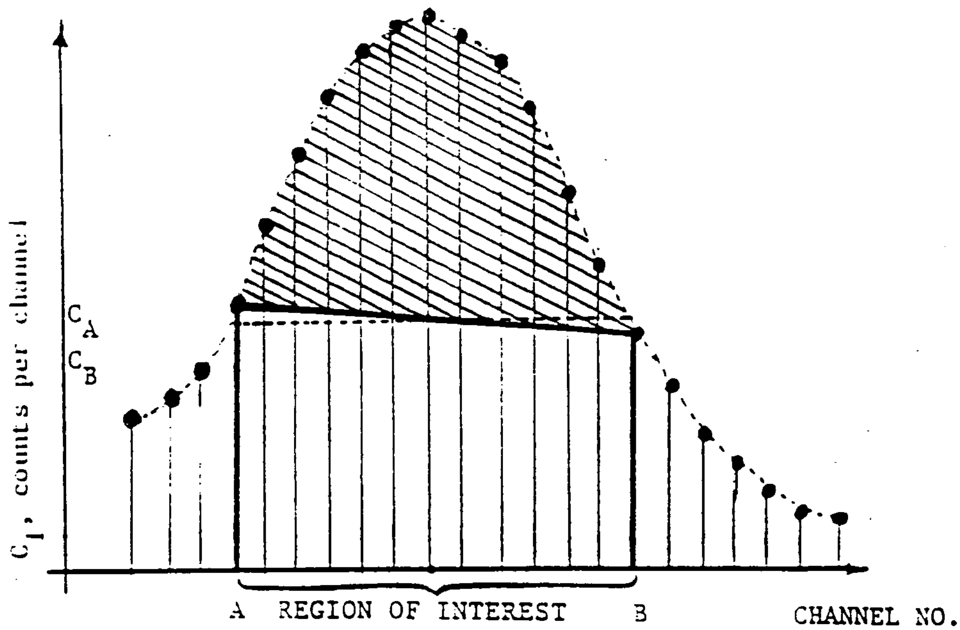

FIGURE 4.11 (a) SIMPLE INTEGRATION TECHNIQUE

$$\text{Net peak area} = \sum_{A}^{B} C_i - (B - A+1)((C_A - C_B)/2)$$

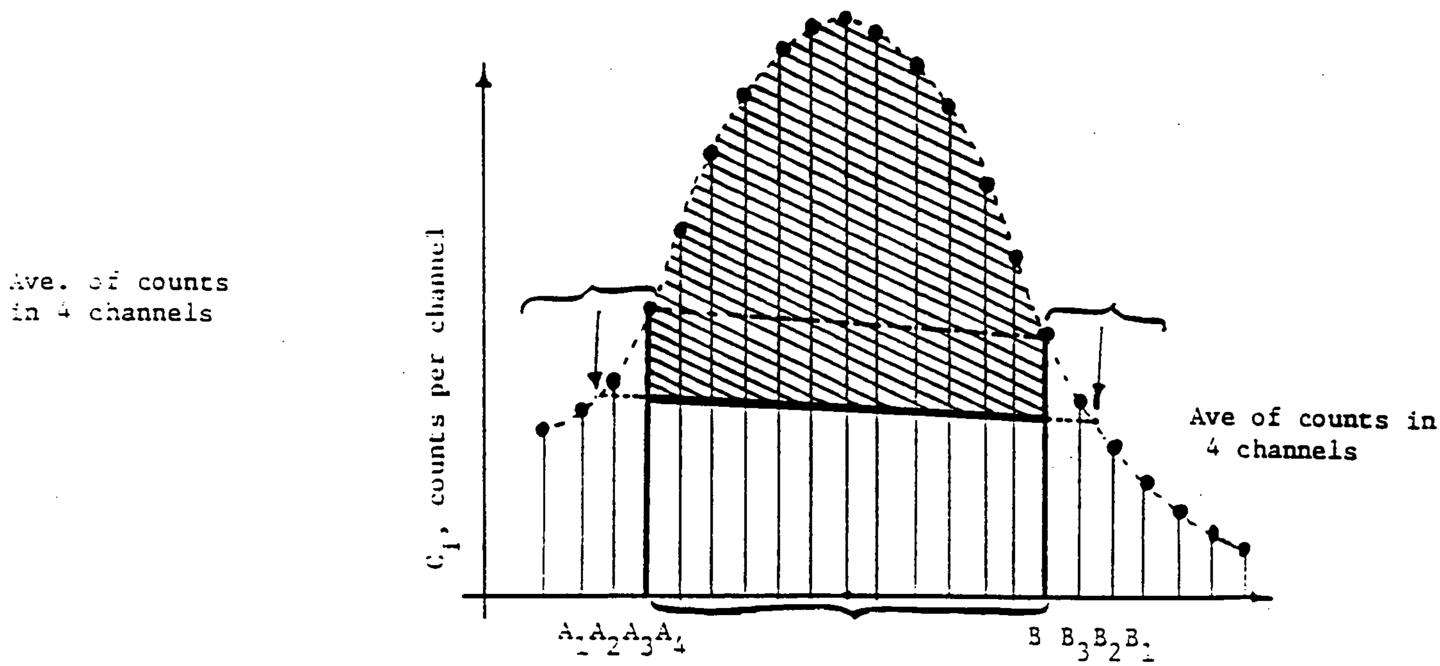

FIGURE 4.11 (b) TECHNIQUE USED BY PCA-8000

$$\text{Net peak area} = \sum_{A}^{B} C_i - (B - A+1)((C_{\bar{A}} - C_{\bar{B}})/2)$$

where: $C_{\bar{A}} = (C_{A1} + C_{A2} + C_{A3} + C_{A4})/4$

$C_{\bar{B}} = (C_{B1} + C_{B2} + C_{B3} + C_{B4})/4$

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SECTION 5 - Description of the Project

The primary objective of this project was to measure the level of naturally occurring radionuclides in concrete fill materials from major suppliers in the greater Cincinnati area.

A low radioactive background whole-body counting facility is being constructed by the Westinghouse Materials Company of Ohio (WMCO) at the Fernald Feed Materials Production Center (FMPC). In order to achieve this low radioactive background, the concrete material that is used to construct the facility must not only provide good shielding, but must contain as little as possible of the naturally occurring radionuclides: uranium 238, thorium 232, radium 226 and potassium 40. Concrete consists of sand, gravel and cement. These naturally occurring radionuclides are present in each of these constituents.

Dr. Boyd Ringo, Professor of Civil Engineering, was contacted to provide information on the local concrete suppliers. Dr. Ringo is a nationally recognized expert on concrete. Discussions with Dr. Ringo led to the identification of five concrete materials suppliers in the greater Cincinnati area. The basis of the selection was: quality of the product, reliability and dependablility of the vendor and past experience with these vendor. The five companies selected by the University of Cincinnati evaluation were:

Harrison Ready Mix

Ernst Enterprises, Inc.

Plainville Concrete

Roth Ready Mix Concrete Co.

Hilltop Concrete

The contract allowed for the selection of six supplier. Westinghouse was allowed a "wild card": any other concrete supplier of their choice. Mr. Bill

Hays requested evaluation of:

Miami Valley Ready Mixed Concrete

Samples of sand, gravel, cement and water were collected from each of these prospective vendors. The samples were properly marked and prepared for measurement as described in Section 4 of the report. All samples were weighed carefully after drying and sealed in the sample containers. Sealed sample containers were stored for 21 days prior to measurement to allow for ingrowth of radioactive daughter products.

A gamma spectrometry system was used to measure the naturally occurring radionuclides in the concrete fill materials. The system is described in considerable detail in Section 4. The focus of the system is a new 41% efficient intrinsic Germanium detector in a well shielded facility. A personal computer software package was purchased to assist in searching for gamma photopeaks and correctingfor decay. Both NBS and EPA standard samples were used to energy calibrate and efficiency calibrate the system. This procedure was also previously described in this report.

In order to insure reasonable statistical variations, all samples were measured for eight hours. The sample data runs proceeded over a three week period during which the gamma spectrometry system was periodically checked for quality control and quality assurance.

A picture of the system is shown in Figure 4.1(a). Figure 4.1(b) is a schematic diagram of the gamma spectrometry system. Figure 4.1(a) shows the detector inside the shield cave in the upper right hand corner. The personal computer supporting the system is shown in the foreground. Figures 4.3 and 4.4 (in Section 4) show the shielding configuration and the sample can and detector arrangement.

SECTION 6 - Literature Review

A literature search was conducted to determine previous work which has been done in the measurement of naturally occurring radionuclides in building materials. The literature search was also useful to help to determine the anticipated results.

The results of the ltierature search indicated that very few studies have been conducted on this topic. Many of the studies that were performed were used to predict Radon gas emanation rates from building materials. Very little relevant work has been done using high efficiency Germanium detectors. Only a handfull of articles were found. The most useful articles found were:

(1) J. Ingersoll, "A Survey of Radionuclide Contents and Radon Emanation Rates in Building Materials Used in the U.S.", Health Physics, Vol. 45, No. 2, Aug. 83.

(2) T. Myrick, et. al., "Determination of Concentrations of Selected Radioncuclides in Soils", Health Physics, Vol. 45, No. 3, Sept. 83.

(3) M. Momeni, "Analysis of Uranium Gamma Spectra in Environmental Contamination", Nuclear Instruments and Methods", Vol. 193, 1982.

(4) A. Toth, "Gamma Spectrometric Method for Measuring Natural Radioactivity of Building Materials", Hungarian Academy of Sciences, Central Institute for Physics, Report KFKI-76-80, (1980).

(5) G. Badie, "Radioactivity in Construction Materials - A Literature Review", U.S.-EPA Office of Radiation Programs PB-242983, April 1975.

(6) E. Hamilton, "Relative Radioactivity of Building Materials", J. Am. Ind. Hygene Association, Vol. 32, pgs. 398-403, 1971.

(7) J. McKlveen, "Natural Radioactivity in Building Materials", MS Thesis, Arizona State University, 1970.

(8) H. Wollenberg, et. al., "Earth Materials for Low-Background Radiation Shielding", Univ. of California, UCRL 9970, 1962.

(9) H. Wollenberg, et. al., "Portland Cement for a Low-Background Counting Facility", Univ. of California, UCRL-10475, 1962.

These articles all pertain to the quantities of the naturally occurring radionuclides in earth and building materials. Relative to this initial contract, the information on concrete materials was condensed and summarized in Table 6.1 below. The data were taken by many different systems, in different countries over a 25 year time period.

Table 6.1

Summary of Results from the Literature Search For Natural Radionuclides in Concrete Materials

Constituent Material	^{238}U pCi/g min-max	^{232}Th pCi/g min-max	^{226}Ra pCi/g min-max	^{40}K pCi/g min-max
cement	0.21-3.5	0.3-1.2	0.21-3.9	1.0-9.7
sand	0.15-4.5	0.10-2.8	0.15-2.7	0.7-8.5
gravel	.25-1.75	0.10-2.5	0.10-1.8	1.0-10.2
water*	.01-1.5	no data	no data	no data

*pCi/liter

The values obtained from this study are within the range of values obtained.

000077

References

(1) "Analysis of Uranium Gamma Spectra: An Application to Measurements of Environmental Contamination" By Momeni, M. H. Nuclear Instruments and Methods, 193, 185-190, (1982).

(2) "Determination of Concentration of Selected Radionuclides in Surface Soil in the U.S." By Myrich, T. E. et al. Health Physics 45, No3, 631-42, (1983).

(3) "Environmental Protection Agency, Las Vegas, Private Communication. Mr. Hahn Pasternak.

(4) "Radiation Detection and Measurement", By Glenn F. Knoll, John Wiley & Sons, 1979.

(5) HASL-300, "EML Procedure Manual", Environmental Measurement Laboratory, U.S. Dept. of Energy, 26th Edition, PPD-07-01.

(6) "Radiochemical Analytical Procedures for Analysis of Environmental Samples" E MSL-LV-0539-17, Environmental Monitoring and Support Laboratory, U.S.EPA, March 1979, Edited by: F. B. Johns, et. al.

(7) Levels and Transitions in Rn-219 populated by Alpha Decay of ^{223}Ra", M.S. Thesis, Air Force Institute of Technology U.S.A.F. By Ronald L. Holton, GNE/PH/70-6, Sep. 1970.

(8) "Detection limits for Radionuclides in the analysis of multi-component gamma ray spectrometer data" By: Pasternak and N. H. Harley., Nuclear Instruments and Methods 91 (1971) p533-540.

(9) "Measurement and Detection of Radiation", by Nicholas Soulfanids, McGraw Hill Book Company, 1983

(10) "Gamma-Ray Spectrum Catalogue", Ge (Li) and Si (Li) Spectrometry", By R. L. Heath National Technical Information Service, ANCR-1000-2, Physics TID-4500, March 1984

(11) "Table of Isotopes", Seven Edition, By C.M. Leaderer and V. S. Shirley John Wiley & Sons, 1978.

Appendix A

Typical Data Sheets Obtained From Sample Measurements

University of Cincinnati
Nuclear Engineering

Ra-226, U-238, Th-232, and K-40 Activity in Concrete Fill Materials
Westinghouse Material Company Project

Sample Name: Harrison Ready Mix, Gravel Sample [illegible]
Sample Weight: [illegible] grams
Date Collected: [illegible]/97
Date Sealed: 3/20/97
Data File Name: [illegible]
Date Counted: 5/07/97
Counting Time: [illegible] sec.
Sample Geometry: Aluminum Can, Size 307-307X200
Region: Full
Detector: Intrinsic Germanium Coaxial Detector, PGT Model IGC 4021, P Type
Analyzer: MCA/IBM PC, Nucleus PCA-8000 and IBM Personal Computer

Nuclide	Energy Expected [keV]	Energy Meas. [keV]	S Gross Integral Source [cts]	s Net Integral Source [cts]	b/t Bkg Count Rate [cpm]	r [s/t-b/t] Count Rate [cpm]	R = r/g Source Count Rate/gram [cpm/g]
Ra-226	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]840E+00	[illegible]
	[illegible]	609.421	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
U-238	[illegible]	63.5925	337	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	1000.94	[illegible]	3	1.3847E-02	ND	ND
Th-232	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	148	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
K-40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

000081

R' Standard Count Rate/gram [cpm/g]	R/R'	Standard pci/g per cpm/g	Sample Activity per gram [pci/g]	SD Sample Activity +-[%]	Sample Activity per gram [Bq/g]	LLD [pci/g]	Nuclide
[illegible]	[illegible]	[illegible]	[illegible]	20.29	1.27E-02	[illegible]	Ra-226
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	4.52	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	5.62	[illegible]	0.03	
		Avg	[illegible]				
9.9831E-03	0.01	2.5745E+03	0.14048	407.92	[illegible]	[illegible]	U-238
2.0893E-03	ND	1.2779E-04	ND		ND		
		Avg	[illegible]				
[illegible]	[illegible]	[illegible]	0.16302	12.13	6.02E-03	0.07	Th-232
[illegible]	[illegible]	[illegible]	[illegible]	24.37	4.52E-03	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	24.26	7.52E-03	[illegible]	
		Avg	[illegible]				
[illegible]	[illegible]	[illegible]	[illegible]	5.43	[illegible]	[illegible]	[illegible]

000082

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Nuclear Engineering

Ra-226, U-238, Th-232, and K-40 Activity in Concrete Fill Materials
Westinghouse Material Company Project

Sample Name: Harrison Ready Mix, Cement Sample 1A
Sample Weight: 239.15 grams
Date Collected: 4/07/87
Date Sealed: 4/08/87
Data File Name: HAC1A.1
Date Counted: 5/11/87
Counting Time: 23800 sec.
Sample Geometry: Aluminum Can, Size 307-307X202
Region: Full
Detector: Intrinsic Germanium Coaxial Detector, PGT Model IGC 4021, P Type
Analyzer: MCA/IBM PC, Nucleus PCA-3000 and IBM Personal Computer

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Nuclide	Energy Expected [keV]	Energy Meas. [keV]	S Gross Integral Source [cts]	s Net Integral Source [cts]	b/t Bkg Count Rate [cpm]	r [s/t-b/t] Count Rate [cpm]	R = r/g Source Count Rate/gram [cpm/g]
Ra-226	185.755	185.7[illegible]	[illegible]	392	1.7338E-01	1.7303E-00	[illegible]
	294.909	295.1[illegible]	3400	2962	5.3370E-02	5.4775E+00	2.0394E-02
	351.998	351.939	[illegible]	4434	2.1049E-02	9.1455E+00	3.8240E-02
	609.30	609.095	[illegible]	2293	1.0145E-01	5.7956E-00	2.4034E-02
U-238	63.34	63.2089	901	118	9.9009E-02	1.5582E-01	6.5579E-04
	1001.04	1001.33	39	28	1.3847E-02	4.4486E-02	1.8602E-04
Th-232	583.149	583.292	772	484	1.3503E-01	3.7330E-01	3.5517E-03
	910.553	911.305	515	253	1.0989E-01	4.3303E-01	1.8219E-03
	968.99	968.924	339	158	5.2434E-02	2.5673E-01	1.1153E-03
K-40	1460.81	1461.13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

000083

R' Standard Count Rate/gram [cpm/g]	R/R'	Standard pci/g per cpm/g	Sample Activity per gram [pci/g]	SD Sample Activity --[%]	Sample Activity per gram [Bq/g]	LLD [pci/g]	Nuclide
[illegible]E-03	1.53	[illegible]E-02	1.24936	3.55	[illegible]E-02	[illegible]	Ra-226
[illegible]E-02	1.70	[illegible]E-01	2.00935	3.32	[illegible]E-02	[illegible]	
[illegible]E-02	1.34	[illegible]E-01	1.00152	[illegible]	[illegible]E-02	[illegible]	
[illegible]E-02	1.52	[illegible]E-01	1.07909	[illegible]	[illegible]E-02	[illegible]	
		Avg	1.30906				
9.9831E-03	0.07	[illegible].6745E-03	1.75333	57.45	6.49E-02	[illegible]	U-238
[illegible]E-03	0.09	[illegible]E+04	2.37721	[illegible]	8.80E-02	[illegible]	
		Avg	2.06552				
[illegible]E-02	0.22	[illegible]E+02	0.40570	[illegible]	1.50E-02	[illegible]	Th-230
[illegible]E-03	[illegible]	[illegible]E-02	[illegible]	12.39	[illegible]E-02	[illegible]	
[illegible]E-03	[illegible]	[illegible]E-02	[illegible]	10.86	[illegible]E-02	[illegible]	
		Avg	[illegible]				
[illegible]E-02	[illegible]	[illegible]E-02	[illegible]	5.45	[illegible]E-01	[illegible]	K-40

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Nuclear Engineering

Ra-226, U-238, Th-232, and K-40 Activity in Concrete Fill Materials
Westinghouse Material Company Project

Sample Name: Hilltop Basic Resources Concrete, Sand Sample [illegible]
Sample Weight: 354.89 grams
Date Collected: 3/13/97
Date Sealed: 3/25/97
Data File Name: [illegible]
Date Counted: [illegible]
Counting Time: [illegible]300 sec.
Sample Geometry: Aluminum Can, Size [illegible]
Region: Full
Detector: Intrinsic Germanium Coaxial Detector, PGT Model [illegible], [illegible] Type
Analyzer: MCA/IBM PC, Nucleus PCA-8000 and IBM Personal Computer

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Nuclide	Energy Expected [keV]	Energy Meas. [keV]	S Gross Integral Source [cts]	s Net Integral Source [cts]	b/t Bkg Counts Rate [cpm]	r [s/t-b/t] Count Rate [cpm]	R = r/g Source Count Rate/gram [cpm/g]
Ra-226	185.755	185.397	397	[illegible]	[illegible]E-01	[illegible]E-01	[illegible]E-03
	[illegible]	[illegible]	[illegible]	702	[illegible]E-02	[illegible]E+00	[illegible]E-03
	351.[illegible]	351.397	1304	1335	[illegible]E-02	[illegible]E-00	[illegible]E-03
	609.[illegible]	609.[illegible]	[illegible]	391	[illegible]E-01	[illegible]E+00	[illegible]E-03
U-238	[illegible]	[illegible].2765	[illegible]	94	[illegible]E-02	[illegible]E-01	[illegible]E-04
	1001.04	1000.5[illegible]	[illegible]	[illegible]6	[illegible].3947E-02	[illegible].3486E-02	[illegible].4908E-05
Th-232	[illegible]	[illegible].309	[illegible]	[illegible]	[illegible]E-01	[illegible].3036E-01	[illegible]E-03
	[illegible]	[illegible]	[illegible]	229	[illegible]E-01	[illegible]E-01	[illegible]E-03
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]E-02	[illegible]E-01	[illegible]E-04
K-40	1460.[illegible]	1461.[illegible]	[illegible]	[illegible]	[illegible]E-02	[illegible]E-02	[illegible]E-02

R' Standard Count Rate/gram [cpm/g]	R/R'	Standard pci/g per cpm/g	Sample Activity per gram [pci/g]	SD Sample Activity +-[%]	Sample Activity per gram [Bq/g]	LLD [pci/g]	Nuclide
[illegible]	0.03	2.5379E+02	0.32361	19.74	1.20E-02	0.21	Ra-226
[illegible]	0.03	3.7635E+01	0.33564	5.36	1.43E-02	0.03	
[illegible]	0.22	1.9721E+01	0.27720	4.56	1.40E-02	0.06	
1.4337E-02	0.21	7.7547E+01	0.36596	5.92	1.35E-02	0.07	
		Avg	0.36450				
3.9831E-03	0.03	2.5745E+03	0.80505	67.94	[illegible]	1.90	U-238
2.2393E-03	0.03	1.2779E+04	0.70169	135.23	[illegible]	3.12	
		Avg	0.75337				
1.5358E-02	0.10	1.1110E+02	0.18795	10.59	6.95E-03	0.07	Th-232
[illegible]	0.11	2.0223E+02	0.20930	14.21	7.74E-03	0.10	
[illegible]	0.14	3.7023E+02	0.25354	19.16	9.38E-03	0.16	
		Avg	0.21693				
[illegible]	[illegible]	[illegible]	[illegible]	4.40	[illegible]	[illegible]	K-40

Appendix B

Technical Specifications

for Multichannel Analyzer

Memory

8192 channel acquisition memory. (Optional 1024, 2048, and 4096 channel).

Capicity

2^{24} -1, (16,777,215) maximum counts per channel.

Time Base

1 MHz crystal controlled. Preset live and real acquisition time selectable to 999,999 seconds maximum.

Memory Group

Selectable in binary increments 256 channel to 8192 maximum.

ADC

8192 channel, 100 MHz clock frequency Wilkinson type. (Optional 1024, 2048, 4096 channel available). 0 to +8 volts unipolar or positive leading.

Conversion Gain

Selectable from 256 to 8192 channels in binary increments.

Digital Offset

Selectable in 256 channel blocks to 7936 channels.

Linearity

Integral: ± 0.1% over top 98% of range
Differential: ± 1% over top 98% of range

Temperature Stability

Gain: ± 0.01%/C
Zero Level: ± 0.01%/C

Lower Level Discriminator

15-turn screwdriver adjustment (rear panel)
Range: 0.5 to 105%

000087

Upper Level Discriminator

15-turn screwdriver adjustment (rear panel)
Range: 0.5 to 105%

Zero Level

15-turn screwdriver adjustment (rear panel)
Range: -4 to +8%

Input Polarity

Positive or positive leading bipolar.

Inputs

ADC: 0 to 8.2V nominal, positive pulse
GATE: TTL low gates off ADC
BUSY: TTL low gates off live timer
MCS: TTL positive pulse
MCS DWELL: TTL negative pulse
EXT. SYNC.: TTL positive pulse starts MCS pass

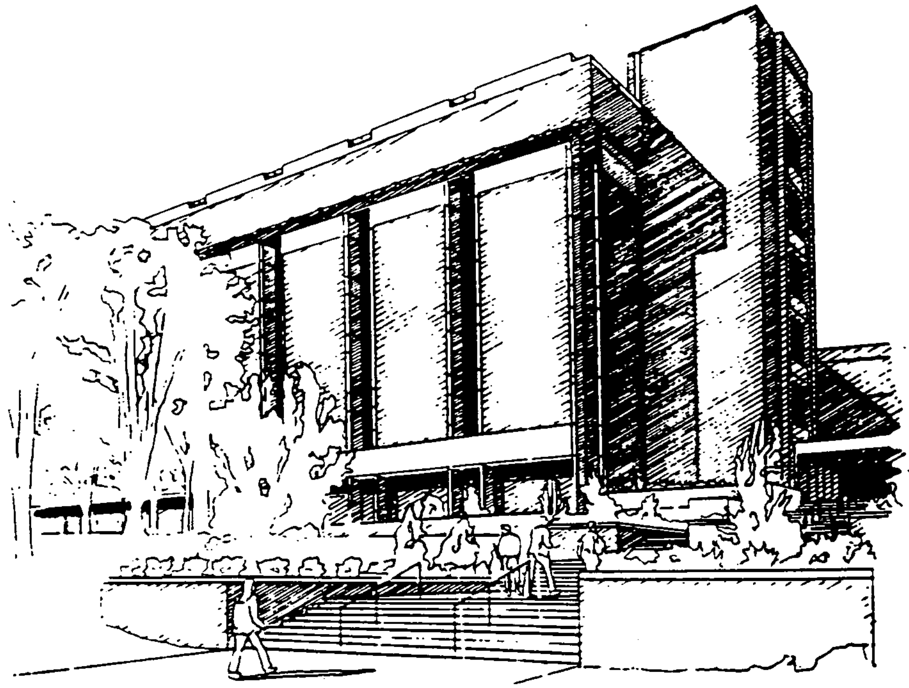
Outputs

ROI: TTL pulse for x-ray mapping (Optional)
SCA: TTL pulse

Power Requirements

+5V, 1.2 A.
+12V 65 Ma.
-12V 65 Ma.

000089



UNIVERSITY OF CINCINNATI
COLLEGE OF ENGINEERING

Final Report

GAMMA SPECTROSCOPY ANALYSIS OF THE CONSTRUCTION MATERIALS USED FOR THE IN-VIVO MONITORING FACILITY AT THE FMPC

R. Eckart
A. Motahamelian

January 1989

Volume 2

7599

Final Report

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VOLUME 2

REMARKS

This is the second volume of a two-volume report on gamma spectroscopy analysis of radionuclide concentration in construction materials used for the In-Vivo Monitoring Facility at the Feed Materials Production Center (FMPC).

Volume 1 contains descriptions of the technical aspects of sample analysis, as well as figures, tables and a summary of the results.

Volume 2 is devoted entirely to final results of all the samples processed. Results for each sample are listed clearly and separately. These results, with comments of page 103, should be self-explanatory. A complete list of all samples, as well as a complete table of MDA values, is also provided.

It must be emphasized that most samples were analyzed in a somewhat accelerated manner, so as to meet deadlines set by WMCO. A copy of the results of sample analysis was sent to WMCO upon completion of such analysis. This manner allowed the construction of the whole-body counting facility to proceed without any delay caused by us. The revised version of the results are represented here in a new format. Some inconsistency has, however, existed in the manner in which the results were previously represented. For record-keeping purposes, it should be emphasized that these results are to be considered final and complete.

R. Eckart
A. Motahamelian

University of Cincinnati

January 1989

List of L_D and MDA Values
List of Samples
Results of Sample Analysis

Table B : Limits of Detection and
Minimum Detectable Activities

Energy, KeV	L_D, Counts/10 hrs	MDA, pCi/g
92.8	67	.013
186.2	83	.009
238.6	77	.009
352.0	77	.010
583.1	45	.008
609.3	50	.009
911.2	35	.008
1460.6	58	.019

Table C : Complete List of the Samples
(Gamma Spectroscopy Analysis)

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
1	10/23/87	COPPER C001	C001.100	11/07/87	11/24/87
2	10/23/87	COPPER C002	C002.100	11/09/87	11/24/87
3	10/23/87	COPPER C003	C003.100	11/10/87	11/24/87
4	10/23/87	COPPER C004	C004.100	11/11/87	11/24/87
5	10/23/87	COPPER C005	C005.100	11/12/87	11/24/87
6	10/23/87	COPPER C006	C006.100	11/12/87	11/24/87
7	10/23/87	STEEL W006	W006.100	11/15/87	11/24/87
8	10/23/87	STEEL W009	W009.100	11/16/87	11/24/87
9	11/02/87	STEEL 62472	S62472.SPM	11/24/87	12/17/87
10	11/02/87	STEEL 62658	S62658.SPM	11/25/87	12/17/87
11	11/02/87	STEEL 63200	S63200.SPM	11/25/87	12/17/87
12	11/02/87	STEEL 63284	S63284.SPM	11/26/87	12/17/87
13	11/02/87	STEEL 63347	S63347.SPM	11/26/87	12/17/87
14	11/02/87	STEEL 60883	S60883.SPM	11/27/87	12/17/87
15	11/02/87	STEEL 63370	S63370.SPM	11/27/87	12/17/87
16	11/02/87	STEEL 62804	S62804.SPM	11/28/87	12/17/87
17	11/02/87	STEEL 62693	S62693.SPM	11/28/87	12/17/87
18	11/02/87	STEEL 63386	S63386.SPM	11/29/87	12/17/87
19	11/02/87	ALUMINUM 36915	AL36915.SPM	11/29/87	12/17/87
20	11/06/87	IRON REBAR3	REBAR3.SPM	11/19/87	11/20/87
21	11/06/87	IRON REBAR4	REBAR4.SPM	11/19/87	11/20/87
22	11/06/87	IRON REBAR5	REBAR5.SPM	11/18/87	11/20/87

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
23	11/06/87	IRON REBAR6	REBAR6.SPM	11/20/87	11/20/87
24	11/06/87	SAND	SAND#1.SPM	11/21/87	11/25/87
25	11/06/87	CEMENT	CMT#1.SPM	11/21/87	11/25/87
26	11/06/87	AGGREGATE GRAVEL	GRAVEL.SPM	11/23/87	11/25/87
27	11/06/87	WATER	WATER1.SPM	11/23/87	11/25/87
28	11/20/87	RUBBER(#7-#11)	RBS2.SPM	11/24/87	11/25/87
29	11/20/87	RUBBER(#1-#6)	RBS1.SPM	11/24/87	11/25/87
30	11/20/87	PAPER FILTER	PAPER.SPM	11/22/87	11/25/87
31	11/20/87	SOIL #4353	NBSOIL.SPM	11/22/87	11/25/87
32	11/30/87	ANCHOR BOLT 4-1312	BOLT1312.SPM	12/02/87	12/17/87
33	11/30/87	LEVEL PLATE S/C284	STEEL.SPM	12/03/87	12/17/87
34	11/30/87	CONCRETE BRICK 4-310	CMT310.SPM	12/03/87	12/17/87
35	11/30/87	LEAD #1	LEAD#1.SPM	12/04/87	12/17/87
36	11/30/87	LEAD #2	LEAD#2.SPM	12/04/87	12/17/87
37	11/30/87	LEAD #3	LEAD#3.SPM	12/05/87	12/17/87
38	11/30/87	LEAD #4	LEAD#4.SPM	12/05/87	12/17/87
39	11/30/87	LEAD #5	LEAD#5.SPM	12/06/87	12/17/87
40	11/30/87	LEAD #6	LEAD#6.SPM	12/06/87	12/17/87
41	11/30/87	LEAD #7	LEAD#7.SPM	12/07/87	12/17/87
42	11/30/87	LEAD #8	LEAD#8.SPM	12/07/87	12/17/87
43	11/30/87	CADMIUM #1	CD#1.SPM	12/08/87	12/17/87
44	11/30/87	CADMIUM #2	CD#2.SPM	12/09/87	12/17/87
45	11/30/87	CADMIUM #3	CD#3.SPM	12/09/87	12/17/87
46	11/30/87	CADMIUM #4	CD#4.SPM	12/10/87	12/17/87

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
47	11/30/87	CADMIUM #5	CD#5.SPM	12/10/87	12/17/87
48	11/30/87	CADMIUM #6	CD#6.SPM	12/11/87	12/17/87
49	11/30/87	CADMIUM #7	CD#7.SPM	12/11/87	12/17/87
50	11/30/87	CADMIUM #8	CD#8.SPM	12/12/87	12/17/87
51	12/10/87	RUBBER 85296(SC284)	R296.SPM	12/13/87	12/17/87
52	12/10/87	RUBBER 100835(SC284)	R835.SPM	12/14/87	12/17/87
53	12/10/87	IRON PIPE(SC284)	SC284.SPM	12/14/87	12/17/87
54	12/10/87	SAND(SC284)	SA284.SPM	12/15/87	12/17/87
55	12/31/87	WELD JOINT 4-310AC	4-310AC.SPM	1/03/88	1/07/88
56	12/31/87	WALL TIES 4-310PR	4-310PR.SPM	1/04/88	1/07/88
57	12/31/87	RADON BARRIER 83394	RN-83394.SPM	1/05/88	1/07/88
58	12/31/87	RADON BARRIER 85262	RN-85262.SPM	1/06/88	1/07/88
59	1/12/88	THREADED ROD	THREADED.SPM	1/13/88	1/27/88
60	1/12/88	IRON PIPE(SC40)	SC40PIPE.SPM	1/14/88	1/27/88
61	1/12/88	SAND(SC284)	SAND#1.SPM	1/16/88	1/27/88
62	1/12/88	SAND(SC284)	SAND#2.SPM	1/16/88	1/27/88
63	1/12/88	SAND(SC284)	SAND#3.SPM	1/17/88	(SPARE)
64	1/19/88	HOT SAND(SC284)	HSAND#1.SPM	1/22/88	2/02/88
65	1/19/88	HOT SAND(SC284)	HSAND#2.SPM	1/23/88	2/02/88
66	1/19/88	HOT SAND(SC284)	HSAND#3.SPM	1/23/88	2/02/88
67	1/19/88	HOT SAND(SC284)	HSAND#4.SPM	1/24/88	2/02/88
68	1/19/88	HOT SAND(SC284)	HSAND#5.SPM	1/24/88	SPARE
69	1/19/88	STEEL PIPE(1 in.)	P1IND.SPM	1/25/88	2/04/88
70	1/19/88	STEEL PIPE(3 in.) (thick)	P3IND#1.SPM	1/26/88	2/04/88

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
71	1/19/88	STEEL PIPE(3 in.)	P3IND#2.SPM	1/27/88	2/04/88
72	1/19/88	STEEL PIPE(2 in.)	P2IND.SPM	1/27/88	2/08/88
73	1/19/88	STEEL PIPE(2.5 in.)	P25IND.SPM	1/28/88	2/08/88
74	1/29/88	RADON BARRIER 84832	R84832.SPM	1/30/88	2/08/88
75	1/29/88	THREADED ROD 85329	T85329.SPM	2/01/88	2/08/88
76	1/29/88	RUBBER SEAL 38060A	RS38060A.SPM	1/31/88	2/08/88
77	1/29/88	ALUMINIUM WALL 38060	AL38060.SPM	2/03/88	2/08/88
78	1/29/88	AL CHANNEL(2") 38056	A38056.SPM	2/02/88	2/08/88
79	1/29/88	AL CHAN(3/4") 38056A	A38056A.SPM	2/03/88	2/08/88
80	2/11/88	2" EMT CONDUIT	EMT2CON.SPM	2/13/88	2/19/88
81	2/11/88	1" EMT CONDUIT	EMT1CON.SPM	2/13/88	2/19/88
82	2/11/88	1/2" FLEX CONDUIT	FLX05CON.SPM	2/14/88	2/19/88
83	2/11/88	3/4" EMT CONDUIT	EMT34CON.SPM	2/14/88	2/19/88
84	2/11/88	3/4" FLEX CONDUIT	FLX34CON.SPM	2/15/88	2/19/88
85	2/11/88	WELDING ROD	WELROD.SPM	2/15/88	2/19/88
86	2/18/88	1.5" EMT CONDUIT	EMTCON12.SPM	2/22/88	2/29/88
87	2/18/88	2x2x3/8" ANGLE	ANG2212.SPM	2/22/88	2/29/88
88	2/18/88	3x3x1/4" ANGLE (MECH. P. T.)	ANG33M12.SPM	2/23/88	2/29/88
89	2/18/88	3x3x1/4" ANGLE (FOYER ROOF)	ANG33F12.SPM	2/24/88	2/29/88
90	2/18/88	4x4x1/4" ANGLE	ANG4412.SPM	2/24/88	2/29/88
91	2/18/88	1x1/4"LID SUPPORT	LIDSUP12.SPM	2/25/88	2/29/88
92	2/18/88	1x1/8" STRAP	STRAP12.SPM	2/25/88	2/29/88
93	3/04/88	CEMENT W01028	W01028.CE1	3/05/88	3/07/88

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
94	3/04/88	SAND W01028	WO1028.SA1	3/06/88	3/07/88
95	3/04/88	GRAVEL W01028	WO1028.GR1	3/06/88	3/07/88
96	3/04/88	WATER W01028	WO1028.WT1	3/07/88	3/14/88
97	3/07/88	GUTTER	GUTTER.GU1	3/08/88	3/14/88
98	3/07/88	BASE PLATE	BASEPL.BP1	3/09/88	3/14/88
99	3/07/88	GIRT FRAME	GIRTFR.GF1	3/09/88	3/14/88
100	3/07/88	PARAPIT WALL	PARAPITW.PW1	3/10/88	3/14/88
101	3/07/88	STEEL STRAP	STEELST.SS1	3/11/88	3/14/88
102	3/09/88	CEMENT LOT3	LOT3.CE1	3/10/88	3/14/88
103	3/09/88	POLY TUBE 2205	2205PT.PT1	3/12/88	3/14/88
104	3/09/88	3/8" Cu TUBE 2205	2205C.CT1	3/11/88	3/14/88
105	3/31/87	E. E. CEMENT	EECEMENT.CE3	3/12/88	3/14/88
106	4/07/87	M. V. CEMENT	MVCEMENT.CE3	3/13/88	3/14/88
107	3/16/88	CAST IRON PIPE	CAST6IP.IP1	3/18/88	3/23/88
108	3/16/88	WIRE MESH 2.9"	WMESH29.WM1	3/20/88	3/23/88
109	3/16/88	WIRE MESH 1.4"	WMESH14.WM1	3/21/88	3/23/88
110	3/18/88	COPLAY CEMENT	COPCEM.CE1	3/19/88	3/21/88
111	3/18/88	DUNDEE CEMENT	DUNCEM.DC1	3/19/88	3/21/88
112	3/18/88	CLAKSVILLE CEMENT	CLKCEM.CC1	3/20/88	3/21/88
113	3/18/88	CONCRETE WALL1	CONWALL.CW1	3/22/88	3/23/88
114	3/18/88	CONCRETE WALL2	CONWALL.CW2	3/23/88	3/28/88
115	3/18/88	N2 PAD CONCRETE	CON2PAD.CNP	3/23/88	3/28/88
116	3/18/88	DRAIN CONCRETE	CONDRAIN.CD1	3/24/88	3/28/88
117	3/21/88	READY MIX HAR3000	HAR3000.RM1	3/21/88	3/23/88

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
118	3/21/88	READY MIX HAR4000	HAR4000.RM1	3/22/88	3/23/88
119	4/15/88	METAL STUDS & TRACK	MSTRACK.MS1	4/17/88	4/22/88
120	4/15/88	METAL STUDS & TRACK	MSTRACK.MS2	4/18/88	4/22/88
121	4/15/88	METAL STUDS & TRACK	MSTRACK.MS3	4/20/88	4/22/88
122	4/15/88	METAL STUDS & TRACK	MSTRACK.MS4	4/20/88	4/22/88
123	4/15/88	METAL STUDS & TRACK	MSTRACK.MS5	4/21/88	4/22/88
124	4/15/88	DUCT SHEET METAL	DUCTSH.DS1	4/16/88	4/22/88
125	4/15/88	DUCT SHEET METAL	DUCTSH.DS2	4/16/88	4/22/88
126	4/15/88	6" REBAR	6INREBAR.6RB	4/17/88	4/22/88
127	4/15/88	DRY WALL	DRYWALL.DW1	4/18/88	4/22/88
128	4/15/88	CONCRETE/SOUTH	CONSOUTH.CS	4/19/88	4/22/88
129	4/15/88	CONCRETE/NORTH	CONNORTH.CN1	4/19/88	4/22/88
130	4/27/88	1" PIPE	1INPIPE.427	4/27/88	5/06/88
131	4/27/88	5/4" PIPE	54INPIPE.428	4/28/88	5/06/88
132	4/27/88	T-FITT(LARGE)	LTFITT.429	4/29/88	5/06/88
133	4/27/88	T-FITT(SMALL)	STFITT.430	4/30/88	5/06/88
134	4/27/88	AL CABLE TRAY	ALTRAY1.430	4/30/88	5/06/88
135	4/27/88	AL CABLE TRAY	ALTRAY2.501	5/01/88	5/06/88
136	4/27/88	2" PIPE	2INPIPE.501	5/01/88	5/06/88
137	4/27/88	5/2" PIPE	52INPIPE.502	5/02/88	5/06/88
138	4/27/88	4" PIPE	4INPIPE.DAT	5/03/88	5/06/88
139	4/27/88	3" PIPE	3INPIPE.DAT	5/04/88	5/06/88
140	6/21/88	VINYL WALL COV.	VINYLWC.01A	6/22/88	6/30/88
141	6/21/88	FLOOR TILE	FTILE.01A	6/23/88	6/30/88
142	6/21/88	BASE TILE	BTILE.01A	6/23/88	6/30/88

SAMPLE ID NUMBER	DATE RECEIVED BY U. C.	WMCO SAMPLE ID	UC FILE NAME	DATE COUNTED	RESULTS TO WMCO
143	6/21/88	3/4" DRY WALL	34DRYW.D1A	6/25/88	7/07/88
144	6/21/88	1/2"MR DRY WALL	12DRYW.D1A	6/26/88	7/07/88
145	6/21/88	1/2"VINYL COVER D. W.	12VCDRYW.D1A	6/27/88	7/07/88
146	6/21/88	1 3/4"AL STUD	134ALDS.D1A	6/27/88	7/07/88
147	6/21/88	AL DEM.TRACK	ALDT.D1A	6/28/88	7/07/88
148	6/21/88	AL DEM.SPACER	ALDS.D1A	6/28/88	7/07/88
149	6/21/88	3/4"AL CONDUIT	34ALCON.D1A	6/30/88	7/07/88
150	6/21/88	112"MR DRY WALL	12MRDRYW.C1B	6/30/88	7/04/88
151	6/21/88	"	12MRDRYW.C2B	7/01/88	7/04/88
152	7/25/88	RUBBER COVER	RCB4.D1A	7/25/88	8/01/88
153	7/25/88	CARPET	CARP1.D1A	7/26/88	8/01/88

RESULTS OF SAMPLE ANALYSIS

COMMENTS

1. U-238: It is assumed that U-238 and Th-234 are in secular equilibrium.

2. RA-226: It is assumed that Ra-226 is in secular equilibrium with Pb-214 and Bi-214. Reported activity of Ra-226 is obtained by averaging activities of Pb-214 and Bi-214.

3. Th-232: It is assumed that Th-232 and Ac-228 are in secular equilibrium.

4. Th-228: It is assumed that Th-228 is in secular equilibrium with Pb-212 and Tl-208. Reported activity of Th-228 is obtained by averaging activities of Pb-212 and Tl-208.

5. ND: When sample's net count rate is zero, or activity is less than 0.0005 pCi/g, "ND" is recorded, indicating that the radioactivity was "not detectable."

6. MDA(X): An "X" in the MDA column indicates that activity is less than or equal to the "Minimum Detectable Activity."

7. C.D./ Al Can: "Circular Disk"/"Aluminum Can" geometry.

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: C001 (Copper)	U-238	0.024	
GEOMETRY: C.D.	Ra-226	0.016	
MASS: 91 g	Th-232	0.034	
COUNTING TIME: 10 hr	Th-228	0.003	X
DATE: 11/07/87	K-40	ND	X
FILE: C001.100			
ID: C002 (Copper)	U-238	0.023	
GEOMETRY: C.D.	Ra-226	0.010	X
MASS: 91 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/09/87	K-40	ND	X
FILE: C002.100			
ID: C003 (Copper)	U-238	0.004	X
GEOMETRY: C.D.	Ra-226	0.016	X
MASS: 91 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.004	X
DATE: 11/10/87	K-40	ND	X
FILE: C003.100			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: C004 (Copper)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.022	X
MASS: 91 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.003	X
DATE: 11/11/87	K-40	ND	X
FILE: C004.100			
ID: C005 (Copper)	U-238	0.045	
GEOMETRY: C.D.	Ra-226	0.022	
MASS: 91 g	Th-232	0.005	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 11/12/87	K-40	ND	X
FILE: C005.100			
ID: C006 (Copper)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.021	X
MASS: 91 g	Th-232	0.008	X
COUNTING TIME: 10 hr	Th-228	0.005	X
DATE: 11/12/87	K-40	ND	X
FILE: C006.100			

000105

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: W006 (Steel)	U-238	0.004	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 379 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/15/87	K-40	ND	X
FILE: W006.100			
ID: W009 (Steel)	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 370 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/16/87	K-40	ND	X
FILE: W009.100			
ID: 62472 (Steel)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 194.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/24/87	K-40	ND	X
FILE: S62472.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 62658 (Steel)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 163.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/25/87	K-40	0.013	X
FILE: S62658.SPM			
ID: 63200 (Steel)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 313.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/25/87	K-40	0.001	X
FILE: S63200.SPM			
6328A ?			
ID: 63248 (Steel)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 319.9 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/25/87	K-40	0.004	X
FILE: S63248.SPM			
= 63284.SPM ?			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 63347 (Steel)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.003	X
MASS: 123.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/26/87	K-40	0.014	X
FILE: S63347.SPM			
ID: 60883 (Steel)	U-238	0.004	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 73.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/27/87	K-40	ND	X
FILE: S60883.SPM			
ID: 63370 (Steel)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 119.2 g	Th-232	0.003	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/27/87	K-40	0.014	X
FILE: S63370.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 62804 (Steel)	U-238	0.005	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 49 g	Th-232	0.010	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 11/28/87	K-40	ND	X
FILE: S62804.SPM			
ID: 62693 (Steel)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 63.5 g	Th-232	0.005	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 11/28/87	K-40	0.014	X
FILE: S62693.SPM			
ID: 63386 (Steel)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.005	X
MASS: 40.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.003	X
DATE: 11/29/87	K-40	0.004	X
FILE: S63386.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 36915 (Steel)	U-238	0.003	X
GEOMETRY: C.D.	Ra-226	0.005	X
MASS: 47.5 g	Th-232	0.007	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 11/29/87	K-40	0.031	X
FILE: AL36915.SPM			
ID: J7-277-3 REBAR	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 87.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/19/87	K-40	ND	X
FILE: REBAR3.SPM			
ID: C6-5822-4 REBAR	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 92.3 g	Th-232	0.007	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 11/19/87	K-40	0.004	X
FILE: REBAR4.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: K8-0077-5 REBAR	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.007	X
MASS: 81.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 11/18/87	K-40	0.046	X
FILE: REBAR5.SPM			
ID: K8-0043-6 REBAR	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	0.008	X
MASS: 76.8 g	Th-232	0.007	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 11/20/87	K-40	0.022	X
FILE: REBAR6.SPM			
ID: 110587-S3 (Sand)	U-238	0.524	
GEOMETRY: Al Can	Ra-226	0.492	
MASS: 351:5 g	Th-232	0.199	
COUNTING TIME: 10 hr	Th-228	0.175	
DATE: 11/21/87	K-40	8.040	
FILE: SS1.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 110587-C4 (Cement)	U-238	1.946	
GEOMETRY: Al Can	Ra-226	2.167	
MASS: 262.8 g	Th-232	0.429	
COUNTING TIME: 10 hr	Th-228	0.482	
DATE: 11/21/87	K-40	5.349	
FILE: CS1.SPM			
ID: 119587-A2 (Gravel)	U-238	0.252	
GEOMETRY: Al Can	Ra-226	0.404	
MASS: 295.7 g	Th-232	0.229	
COUNTING TIME: 10 hr	Th-228	0.240	
DATE: 11/23/87	K-40	4.727	
FILE: GS1.SPM			
ID: 110587-W1 (Water)	U-238	0.267	
GEOMETRY: C.D.	Ra-226	0.322	
MASS: 0.55 l (dried)	Th-232	0.255 *	
COUNTING TIME: 10 hr	Th-228	0.255	
DATE: 11/23/87	K-40	2.373	
FILE: WATER1.SPM	Cs-137	0.344	

* Estimated

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: RBS2 Rubber	U-238	0.011	
GEOMETRY: C.D.	Ra-226	0.033	
MASS: 21.6 g	Th-232	0.028	
COUNTING TIME: 10 hr	Th-228	0.020	
DATE: 11/24/87	K-40	0.308	
FILE: RBS2.SPM			
ID: RBS1 Rubber	U-238	0.020	
GEOMETRY: C.D.	Ra-226	0.017	
MASS: 25.5 g	Th-232	0.022	
COUNTING TIME: 10 hr	Th-228	0.019	
DATE: 11/24/87	K-40	0.075	
FILE: RBS1.SPM			
ID: 4-1312	U-238	ND *	X
GEOMETRY: (Anchor Bolt)	Ra-226	0.011*	X
MASS: N.A.	Th-232	0.002*	X
COUNTING TIME: 10 hr	Th-228	0.004*	X
DATE: 12/02/87	K-40	0.012*	X
FILE: BOLT1312.SPM			

* cps

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: S1C284 ST	U-238	ND *	X
GEOMETRY: (Level Plate)	Ra-226	0.006*	X
MASS: N.A.	Th-232	ND *	X
COUNTING TIME: 10 hr	Th-228	0.001*	X
DATE: 12/03/87	K-40	0.010*	X
FILE: STEEL.SPM			
		* cps	
ID: 4-310 (Cement Mix)	U-238	0.464	
GEOMETRY: Al Can	Ra-226	0.448	
MASS: 263.8 g	Th-232	0.240	
COUNTING TIME: 10 hr	Th-228	0.221	
DATE: 12/03/87	K-40	6.231	
FILE: CMT310.SPM			
ID: PB #1 (Lead)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 136.5 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/04/87	K-40	0.035	X
FILE: LEAD#1.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PB#2 (Lead)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 135.4 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/04/87	K-40	0.008	X
FILE: LEAD#2.SPM			
ID: PB#3 (Lead)	U-238	0.003	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 136.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/05/87	K-40	0.007	X
FILE: LEAD#3.SPM			
ID: PB #4 (Lead)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 134.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/05/87	K-40	0.005	X
FILE: LEAD#4.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PB#5 (Lead)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 136.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/06/87	K-40	0.003	X
FILE: LEAD#5.SPM			
ID: PB#6 (Lead)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 137.1 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/06/87	K-40	0.045	X
FILE: LEAD#6.SPM			
ID: PB#7 (Lead)	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 135.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/07/87	K-40	0.008	X
FILE: LEAD#7.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PB#8 (Lead)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 134.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/07/87	K-40	0.003	X
FILE: LEAD#8.SPM			
ID: CD#1 (Cadmium)	U-238	0.021	X
GEOMETRY: C.D.	Ra-226	0.003	X
MASS: 48.5 g	Th-232	0.003	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/08/87	K-40	ND	X
FILE: CD#1.SPM			
ID: CD#2 (Cadmium)	U-238	0.036	
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 47.2 g	Th-232	0.004	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/09/87	K-40	0.013	X
FILE: CD#2.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: CD#3 (Cadmium)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.005	X
MASS: 48.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/09/87	K-40	0.060	X
FILE: CD#3.SPM			
ID: CD#4 (Cadmium)	U-238	0.006	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 47.4 g	Th-232	0.005	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/10/87	K-40	0.093	
FILE: CD#4.SPM			
ID: CD#5 (Cadmium)	U-238	0.003	X
GEOMETRY: C.D.	Ra-226	0.007	X
MASS: 48.6 g	Th-232	0.003	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 12/10/87	K-40	0.071	
FILE: CD#5.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: CD#6 (Cadmium)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 49.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 12/11/87	K-40	0.007	X
FILE: CD#6.SPM			
ID: CD#7 (Cadmium)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 48.0 g	Th-232	0.006	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 12/11/87	K-40	0.063	
FILE: CD#7.SPM			
ID: CD#8 (Cadmium)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 46.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 12/12/87	K-40	ND	X
FILE: CD#8.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 85296RB (Rubber)	U-238	ND	
GEOMETRY: C.D.	Ra-226	0.058	
MASS: 4.3 g	Th-232	ND	
COUNTING TIME: 10 hr	Th-228	0.012	
DATE: 12/13/87	K-40	0.630	
FILE: R296.SPM			
ID: 100835RB (Rubber)	U-238	ND	
GEOMETRY: C.D.	Ra-226	0.083	
MASS: 4.7 g	Th-232	0.072	
COUNTING TIME: 10 hr	Th-228	0.032	
DATE: 12/13/87	K-40	0.427	
FILE: R835.SPM			
ID: SC284 (Iron Pipe)	U-238	0.012	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 83.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 12/14/87	K-40	0.022	
FILE: SC284.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: SA284 (Sand)	U-238	0.335	
GEOMETRY: Al Can	Ra-226	0.465	
MASS: 321.8 g	Th-232	0.187	
COUNTING TIME: 10 hr	Th-228	0.215	
DATE: 12/16/87	K-40	7.630	
FILE: SA284.SPM			
ID: 4.310 ACC (Weld Joints)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.004	X
MASS: 61.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 01/03/88	K-40	ND	X
FILE: 4-310AC.SPM			
ID: 4.310 PR (Wall Ties)	U-238	0.014	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 65.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 01/04/88	K-40	ND	X
FILE: 4-310PR.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 83394 (Rn Barrier)	U-238	0.013	
GEOMETRY: C.D.	Ra-226	0.031	
MASS: 38.0 g	Th-232	0.016	
COUNTING TIME: 10 hr	Th-228	0.015	
DATE: 01/05/88	K-40	0.111	
FILE: RN-83394.SPM			
ID: 85262 (Rn Barrier)	U-238	ND	
GEOMETRY: C.D.	Ra-226	0.018	
MASS: 38.5 g	Th-232	0.034	
COUNTING TIME: 10 hr	Th-228	0.013	
DATE: 01/06/88	K-40	0.133	
FILE: RN-85262.SPM			
ID: Threaded Rod	U-238	0.007	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 69.5 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 01/13/88	K-40	ND	X
FILE: THREADED.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: SC40 (Pipe)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.023	X
MASS: 101.0 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.003	X
DATE: 01/14/88	K-40	ND	X
FILE: SC40PIPE.SPM			
ID: SC284-1 (Sand)	U-238	0.404	
GEOMETRY: Al Can	Ra-226	0.405	
MASS: 389.4 g	Th-232	0.164	
COUNTING TIME: 10 hr	Th-228	0.162	
DATE: 01/16/88	K-40	4.575	
FILE: SAND#1.SPM			
ID: SC284-2 (Sand)	U-238	0.410	
GEOMETRY: Al Can	Ra-226	0.437	
MASS: 375.9 g	Th-232	0.093	
COUNTING TIME: 10 hr	Th-228	0.143	
DATE: 01/16/88	K-40	4.323	
FILE: SAND#2.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: H.SAND	U-238	0.380	
GEOMETRY: Al Can	Ra-226	0.426	
MASS: 363.7 g	Th-232	0.176	
COUNTING TIME: 10 hr	Th-228	0.186	
DATE: 01/22/88	K-40	6.577	
FILE: HSAND#1.SPM			
ID: H.SAND	U-238	0.530	
GEOMETRY: Al Can	Ra-226	0.437	
MASS: 352.4 g	Th-232	0.176	
COUNTING TIME: 10 hr	Th-228	0.190	
DATE: 01/23/88	K-40	6.254	
FILE: HSAND#2.SPM			
ID: H.SAND	U-238	0.384	
GEOMETRY: Al Can	Ra-226	0.413	
MASS: 341.8 g	Th-232	0.105	
COUNTING TIME: 10 hr	Th-228	0.191	
DATE: 01/23/88	K-40	6.031	
FILE: HSAND#3.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: H.SAND GEOMETRY: Al Can MASS: 365.1 g COUNTING TIME: 10 hr DATE: 01/24/88 FILE: HSAND#4.SPM	U-238 Ra-226 Th-232 Th-228 K-40	0.256 0.447 0.168 0.206 6.306	
ID: H.SAND GEOMETRY: Al Can MASS: N.A. COUNTING TIME: 10 hr DATE: N.A. FILE: HSAND.AVG	U-238 Ra-226 Th-232 Th-228 K-40	0.388 0.428 0.155 0.193 6.292	
ID: PIPE (1") GEOMETRY: C.D. MASS: 135.0 g COUNTING TIME: 10 hr DATE: 01/26/88 FILE: P1IND.SPM	U-238 Ra-226 Th-232 Th-228 K-40	0.002 0.002 ND ND 0.011	X X X X X

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PIPE (3" Thick)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 164.6 g	Th-232	0.002	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 01/27/88	K-40	ND	X
FILE: P3IND#1.SPM			
ID: PIPE (3" Thin)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 32.6 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 01/27/88	K-40	0.053	
FILE: P3IND#2.SPM			
ID: PIPE (2")	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 98.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 01/28/88	K-40	ND	X
FILE: P2IND.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PIPE (2.5")	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 114.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 01/28/88	K-40	ND	X
FILE: P25IND.SPM			
ID: R84832 (Rn Barrier)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 26.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.006	X
DATE: 01/31/88	K-40	ND	X
FILE: R84832.SPM			
ID: T85329 (Threaded Rod)	U-238	0.011	X
GEOMETRY: C.D.	Ra-226	0.004	X
MASS: 118.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 02/02/88	K-40	ND	X
FILE: T85329.SPM			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: RS38060A (Rubber Seal)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 14.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 02/01/88	K-40	ND	X
FILE: RS38060A.SPM			
ID: AL38060 (Al Wall)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.010	X
MASS: 25.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/04/88	K-40	ND	X
FILE: AL38060.SPM			
ID: A308056 (Al Channels 2")	U-238	0.029	
GEOMETRY: C.D.	Ra-226	0.041	
MASS: 12.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 02/03/88	K-40	0.319	
FILE: A38056.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: A308056A (Al Channel, 3/4")	U-238	0.011	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 20.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 02/04/88	K-40	0.048	X
FILE: A38056A.SPM			
ID: EMTCOND (2")	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 89.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 02/13/88	K-40	0.019	X
FILE: EMT2CON.SPM			
ID: EMTCOND (1")	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 76.2 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/13/88	K-40	0.013	X
FILE: EMT1CON.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: FLXCIBD (0.5")	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 42.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 02/14/88	K-40	ND	X
FILE: FLX05CON.SPM			
ID: EMTCOND (3/4")	U-238	0.004	X
GEOMETRY: C.D.	Ra-226	0.003	X
MASS: 64.3 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 02/14/88	K-40	ND	X
FILE: EMT34CON.SPM			
ID: FLXCOND (3/4")	U-238	0.021	
GEOMETRY: C.D.	Ra-226	0.011	
MASS: 44.5 g	Th-232	0.005	X
COUNTING TIME: 10 hr	Th-228	0.004	X
DATE: 02/15/88	K-40	0.030	X
FILE: FLX34CON.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: WELD ROD	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.009	X
MASS: 48.5 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 02/15/88	K-40	0.526	
FILE: WELROD.SPM			
ID: EMTCOND (1.5")	U-238	0.008	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 96.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/22/88	K-40	0.006	X
FILE: EMTCON12.SPM			
ID: ANG2212 (Mech Pt.)	U-238	0.002	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 190.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/23/88	K-40	ND	X
FILE: ANG2212.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: ANG33M12 (Mech Pl/Rail)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 64.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 02/24/88	K-40	ND	X
FILE: ANG33M12.SPM			
ID: ANG33F12 (Foyer Support)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 150.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/24/88	K-40	ND	X
FILE: ANG33F12.SPM			
ID: ANG4412 (Mech Pt.)	U-238	0.001	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 144.6 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/25/88	K-40	ND	X
FILE: ANG4412.SPM			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: LIDSUP12 (Lid Support)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 160.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/26/88	K-40	0.012	X
FILE: LIDSUP12.SPM			
ID: STRAP 12	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 69.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 02/26/88	K-40	0.007	X
FILE: STRAP12.SPM			
ID: W01028 (Cement)	U-238	2.044	
GEOMETRY: Al Can	Ra-226	2.231	
MASS: 250.02 g	Th-232	0.376	
COUNTING TIME: 10 hr	Th-228	0.440	
DATE: 03/06/88	K-40	4.867	
FILE: W01028.CE1			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: W01028 (Sand)	U-238	0.502	
GEOMETRY: Al Can	Ra-226	0.345	
MASS: 326.2 g	Th-232	0.150	
COUNTING TIME: 10 hr	Th-228	0.178	
DATE: 03/06/88	K-40	6.750	
FILE: W01028.SA1			
ID: W01028 (Gravel)	U-238	0.180	
GEOMETRY: Al Can	Ra-226	0.347	
MASS: 361.9 g	Th-232	0.087	
COUNTING TIME: 10 hr	Th-228	0.107	
DATE: 03/07/88	K-40	2.135	
FILE: W01028.GR1			
ID: W01028 (Water)	U-238	ND	X
GEOMETRY: Al Can	Ra-226	ND	X
MASS: (1 liter)	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/08/88	K-40	ND	X
FILE: W01028.WA2			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: GUTTER	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 25.8 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/09/88	K-40	ND	X
FILE: GUTTER.GU1			
ID: BASE PLATE	U-238	0.012	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 41.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/09/88	K-40	ND	X
FILE: BASEPL.BP1			
ID: GIRT FRAMING	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 70.5 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/10/88	K-40	ND	X
FILE: GIRTFR.GF1			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: PARAPIT WALL	U-238	0.017	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 13.5 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/11/88	K-40	ND	X
FILE: PARAPITW.PW1			
ID: STEEL STRAP	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 23.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/11/88	K-40	ND	X
FILE: STEELST.SS1			
ID: LOT3 (Cement)	U-238	1.964	
GEOMETRY: Al Can	Ra-226	2.190	
MASS: 277.0 g	Th-232	0.361	
COUNTING TIME: 10 hr	Th-228	0.429	
DATE: 03/10/88	K-40	5.603	
FILE: LOT3.CE1			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: COPPER TUBE 3/8"	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 22.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 03/12/88	K-40	ND	X
FILE: 2205C.CT1			
ID: POLYTUBE	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.028	X
MASS: 3.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.026	X
DATE: 03/12/88	K-40	ND	X
FILE: 2205P.PT1			
ID: E.E. CEMENT	U-238	0.682	
GEOMETRY: Al Can	Ra-226	0.646	
MASS: 229.7 g	Th-232	0.392	
COUNTING TIME: 10 hr	Th-228	0.481	
DATE: 03/13/88	K-40	7.271	
FILE: EECEMENT.CE3			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: M.V. CEMENT	U-238	1.658	
GEOMETRY: Al Can	Ra-226	2.188	
MASS: 252.9 g	Th-232	0.325	
COUNTING TIME: 10 hr	Th-228	0.362	
DATE: 03/13/88	K-40	5.268	
FILE: MVCEMENT.CE3			
ID: IRON PIPE 6"	U-238	21.049 *	
GEOMETRY: N.A.	Ra-226	7.453 *	
MASS: N.A.	Th-232	2.953 *	
COUNTING TIME: 10 hr	Th-228	3.421 *	
DATE: 03/18/88	K-40	20.178 *	
FILE: 6CASTIP.IP1			
		* pCi/Sample	
ID: WIRE MESH (2.9")	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 50.4 g	Th-232	0.004	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 03/21/88	K-40	ND	X
FILE: WMESH29.WM1			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: WIRE MESH (1.4")	U-238	0.027	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 37.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 03/22/88	K-40	ND	X
FILE: WMESH14.WM1			
ID: COPLAY CEMENT	U-238	1.940	
GEOMETRY: Al Can	Ra-226	2.140	
MASS: 253.3 g	Th-232	0.353	
COUNTING TIME: 10 hr	Th-228	0.475	
DATE: 03/19/88	K-40	6.072	
FILE: COPCEM.CE1			
ID: DUNDEE CEMENT	U-238	1.832	
GEOMETRY: Al Can	Ra-226	1.735	
MASS: 235.4 g	Th-232	0.436	
COUNTING TIME: 10 hr	Th-228	0.498	
DATE: 03/20/88	K-40	6.571	
FILE: DUNCEM.DC1			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: CLARKSVILLE CEMENT	U-238	0.632	
GEOMETRY: Al Can	Ra-226	0.803	
MASS: 287.7 g	Th-232	0.371	
COUNTING TIME: 10 hr	Th-228	0.388	
DATE: 03/20/88	K-40	4.958	
FILE: CLKCEM.CC1			
ID: CONCRETE WALL1	U-238	0.637	
GEOMETRY: Al Can	Ra-226	0.349	
MASS: 259.0 g	Th-232	0.253	
COUNTING TIME: 10 hr	Th-228	0.200	
DATE: 03/23/88	K-40	4.964	
FILE: CONWALL.CW1			
ID: CONCRETE WALL2	U-238	0.486	
GEOMETRY: Al Can	Ra-226	0.467	
MASS: 288.0 g	Th-232	0.178	
COUNTING TIME: 10 hr	Th-228	0.189	
DATE: 03/23/88	K-40	5.068	
FILE: CONWALL.CW2			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: CONCRETE N2 PAD	U-238	0.612	
GEOMETRY: Al Can	Ra-226	0.483	
MASS: 291.7 g	Th-232	0.160	
COUNTING TIME: 10 hr	Th-228	0.175	
DATE: 03/24/88	K-40	5.354	
FILE: CON2PAD.CNP			
ID: CONCRETE DRAIN	U-238	0.814	
GEOMETRY: Al Can	Ra-226	0.462	
MASS: 276.6 g	Th-232	0.231	
COUNTING TIME: 10 hr	Th-228	0.187	
DATE: 03/25/88	K-40	5.916	
FILE: CONDRAIN.CD1			
ID: HARRISON 3000 Psi (Concrete)	U-238	0.434	
GEOMETRY: Al Can	Ra-226	0.413	
MASS: 238.4 g	Th-232	0.220	
COUNTING TIME: 10 hr	Th-228	0.253	
DATE: 03/22/88	K-40	6.632	
FILE: HAR3000.RM1			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: HARRISON 4000 Psi (Concrete)	U-238	0.702	
GEOMETRY: Al Can	Ra-226	0.484	
MASS: 264.3 g	Th-232	0.218	
COUNTING TIME: 10 hr	Th-228	0.176	
DATE: 03/22/88	K-40	6.015	
FILE: HAR4000.RM1			
ID: METAL STUDS/TRACK	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.006	X
MASS: 28.1 g	Th-232	0.010	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 04/17/88	K-40	0.133	
FILE: MSTRACK.MS1			
ID: METAL STUDS/TRACK	U-238	0.028	X
GEOMETRY: C.D.	Ra-226	0.009	X
MASS: 28.4 g	Th-232	0.004	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 04/18/88	K-40	0.126	
FILE: MSTRACK.MS2			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: METAL STUDS/TRACK	U-238	0.025	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 28.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 04/20/88	K-40	0.067	
FILE: MSTRACK.MS3			
ID: METAL STUDS/TRACK	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 28.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 04/21/88	K-40	0.085	
FILE: MSTRACK.MS4			
ID: METAL STUDS/TRACK	U-238	0.005	X
GEOMETRY: C.D.	Ra-226	0.001	X
MASS: 29.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 04/22/88	K-40	0.069	
FILE: MSTRACK.MS5			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: DUCT SHEET	U-238	0.014	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 37.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 04/16/88	K-40	ND	X
FILE: DUCTSH.DS1			
ID: DUCT SHEET	U-238	0.021	X
GEOMETRY: C.D.	Ra-226	0.002	X
MASS: 35.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.004	X
DATE: 04/17/88	K-40	ND	X
FILE: DUCTSH.DS2			
ID: REBAR (6")	U-238	0.019	X
GEOMETRY: C.D.	Ra-226	0.003	X
MASS: 38.3 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 04/18/88	K-40	0.081	
FILE: 6INREBAR.6RB			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: DRYWALL	U-238	0.013	X
GEOMETRY: C.D.	Ra-226	0.005	X
MASS: 36.3 g	Th-232	0.001	X
COUNTING TIME: 10 hr	Th-228	0.003	X
DATE: 04/19/88	K-40	0.195	
FILE: DRYWALL.DW1			
ID: CONCRETE SOUTH	U-238	0.472	
GEOMETRY: Al Can	Ra-226	0.415	
MASS: 280.3 g	Th-232	0.169	
COUNTING TIME: 10 hr	Th-228	0.192	
DATE: 04/19/88	K-40	6.365	
FILE: CONSOUTH.CS1			
ID: CONCRETE NORTH	U-238	0.446	
GEOMETRY: Al Can	Ra-226	0.465	
MASS: 304.8 g	Th-232	0.091	
COUNTING TIME: 10 hr	Th-228	0.159	
DATE: 04/20/88	K-40	5.138	
FILE: CONNORTH.CN1			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 1" PIPE	U-238	27 *	X
GEOMETRY: (Tube)	Ra-226	77 *	X
MASS: 129.5 g	Th-232	ND *	X
COUNTING TIME: 10 hr	Th-228	52 *	X
DATE: 04/28/88	K-40	ND *	X
FILE: 1INPIPE.427			
		* Counts/10 hr	
ID: 5/4" PIPE	U-238	23 *	X
GEOMETRY: (Tube)	Ra-226	22 *	X
MASS: 181.4 g	Th-232	ND *	X
COUNTING TIME: 10 hr	Th-228	20 *	X
DATE: 04/29/88	K-40	ND *	X
FILE: 5/4INPIPE.428			
		* Counts/10 hr	
ID: T-FITTING (Large)	U-238	ND *	X
GEOMETRY: (L-Shaped Tube)	Ra-226	36 *	X
MASS: 428.6 g	Th-232	ND *	X
COUNTING TIME: 10 hr	Th-228	ND *	X
DATE: 04/30/88	K-40	ND *	X
FILE: LTFITT.429			
		* Counts/10 hr	

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: T-FITTING (Small)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 242.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 04/30/88	K-40	ND	X
FILE: STFITT.430			
ID: ALUMINUM TRAY 1	U-238	0.089	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 16.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.002	X
DATE: 05/01/88	K-40	ND	X
FILE: ALTRAY1.430			
ID: ALUMINUM TRAY 2	U-238	0.021	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 17.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.006	X
DATE: 05/01/88	K-40	0.079	
FILE: ALTRAY2.501			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 2" TUBE	U-238	ND	X
GEOMETRY: (Tube)	Ra-226	ND	X
MASS: 287.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 05/02/88	K-40	ND	X
FILE: 2INPIPE.501			
ID: 5/2" PIPE	U-238	ND	X
GEOMETRY: (Tube)	Ra-226	ND	X
MASS: 435.1 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 05/03/88	K-40	ND	X
FILE: 5/2INPIPE.502			
ID: 4" PIPE	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 143.2 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 05/04/88	K-40	ND	X
FILE: 4INPIPE.DAT			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 3" PIPE	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 124.4 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 05/05/88	K-40	ND	X
FILE: 3INPIPE.DAT			
ID: VINYL WALL COVER	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 6.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/22/88	K-40	ND	X
FILE: VINYLWC.01C			
ID: FLOOR TILE	U-238	0.489	
GEOMETRY: C.D.	Ra-226	0.207	
MASS: 65.6 g	Th-232	0.139	
COUNTING TIME: 10 hr	Th-228	0.037	
DATE: 06/23/88	K-40	1.662	
FILE: FTILE.0IC			

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SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: BASE TILE	U-238	0.478	
GEOMETRY: C.D.	Ra-226	0.170	
MASS: 61.8 g	Th-232	0.136	
COUNTING TIME: 10 hr	Th-228	0.090	
DATE: 06/23/88	K-40	1.654	
FILE: BTILE.0IC			
ID: 3/4" DRY WALL	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 50.8 g	Th-232	0.036	X
COUNTING TIME: 10 hr	Th-228	0.004	X
DATE: 06/25/88	K-40	0.018	X
FILE: 34DRYW.D1B			
ID: 1/2" DRY WALL (MR)	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 33.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/26/88	K-40	ND	X
FILE: 12MRDRYW.DIB			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: 1/2" DRY WALL	U-238	ND	X
GEOMETRY: C.D.	Ra-226	0.005	X
MASS: 34.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.001	X
DATE: 06/27/88	K-40	ND	X
FILE: 12VCDRYW.DIB			
ID: 1-3/4" AL STUD	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 20.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/28/88	K-40	ND	X
FILE: 134ALDS.DIB			
ID: AL TRACK	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 20.0 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/28/88	K-40	ND	X
FILE: ALDT.DIB			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: AL SPACE	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 21.9 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/29/88	K-40	ND	X
FILE: ALDS.DIB			
ID: 3/4" AL CONDUIT	U-238	ND	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 30.6 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	ND	X
DATE: 06/30/88	K-40	ND	X
FILE: 34ALCON.D18			
ID: 1/2" MR DRYWALL	U-238	0.362	
GEOMETRY: Al Can	Ra-226	0.141	
MASS: 125.5 g	Th-232	0.047	
COUNTING TIME: 20 hr	Th-228	0.045	
DATE: 07/02/88	K-40	0.481	
FILE: 12MRDRYW.C2B			

SAMPLE SPECIFICATIONS	RADIONUCLIDE	ACTIVITY, pCi/g	MDA
ID: RCB-4 BASE	U-238	0.081	
GEOMETRY: C.D.	Ra-226	0.044	
MASS: 29.5 g	Th-232	0.094	
COUNTING TIME: 20 hr	Th-228	0.066	
DATE: 07/26/88	K-40	ND	
FILE: RCB4.DIA			
ID: CARPET-1	U-238	0.009	X
GEOMETRY: C.D.	Ra-226	ND	X
MASS: 6.7 g	Th-232	ND	X
COUNTING TIME: 10 hr	Th-228	0.004	X
DATE: 07/27/88	K-40	ND	X
FILE: CARP1.D1A			

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