ATTACHMENT 2
ESTABLISHING THE MINIMUM DETECTABLE CONCENTRATIONS OF DEPLETED URANIUM PENETRATOR FRAGMENTS AT EGLIN AFB RANGES USING THE FIELD INSTRUMENT FOR THE DETECTION OF LOW ENERGY RADIATION (FIDLER)

ESTABLISHING THE MINIMUM DETECTABLE CONCENTRATIONS OF DEPLETED URANIUM PENETRATOR FRAGMENTS AT EGLIN AFB RANGES USING THE FIELD INSTRUMENT FOR THE DETECTION OF LOW ENGERGY RADIATION (FIDLER)

CONTRACT NO. DACW45-94-D-0002
DELIVERY ORDER NO. 15

Prepared For
Eglin Air Force Base
Air Armament Center
Air Force Materiel Command
Eglin AFB, Florida

Prepared By
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Fort Walton Beach, Florida

Under Contract To
U.S. Army Corps of Engineers
Omaha, Nebraska

August 2000

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF PHOTOGRAPHS

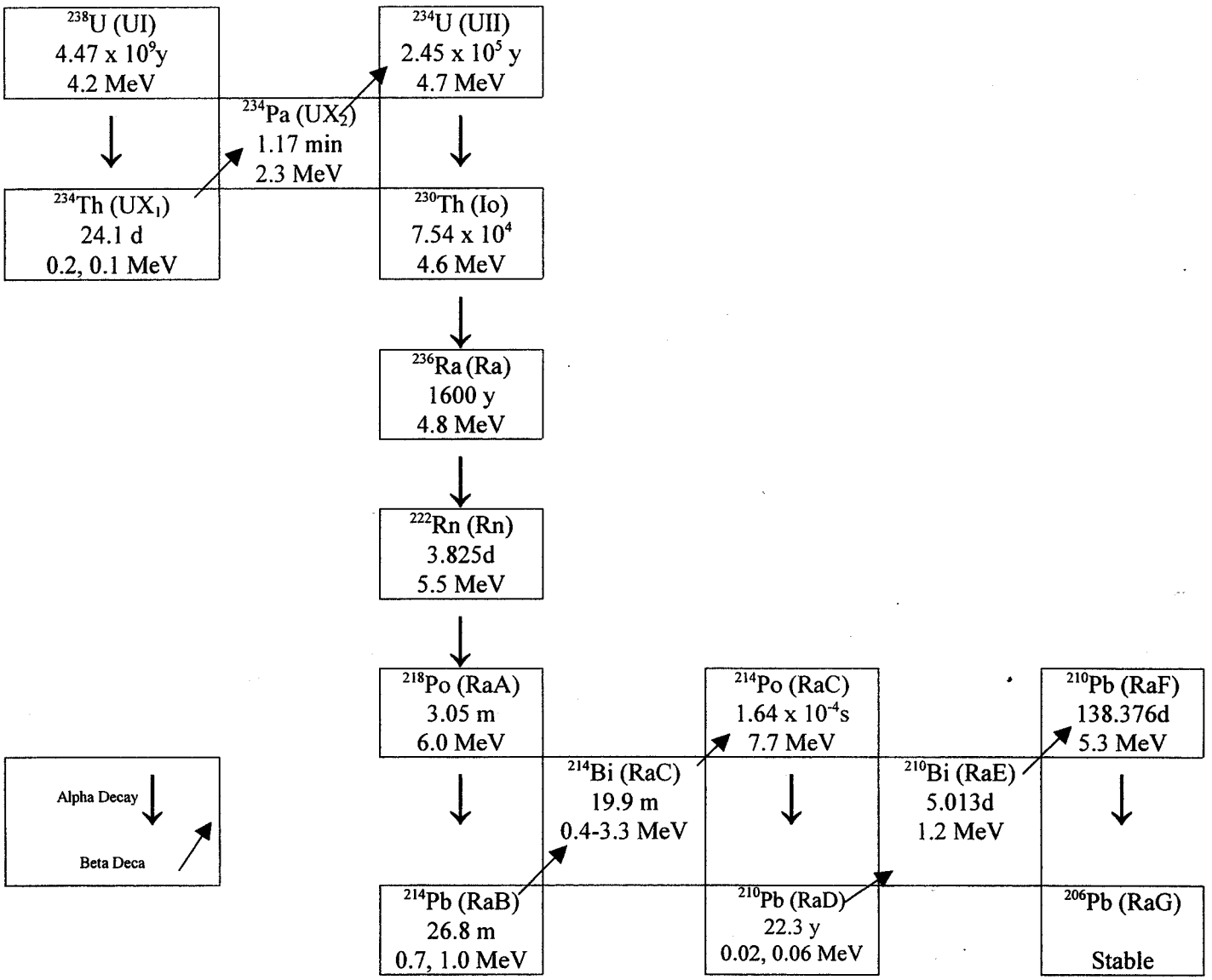
LIST OF ACRONYMS

bls	below land surface
Ci/g	Curies per gram
CPM	Counts per minute
Cs^{137}	Cesium 137
DCGL	Derived Concentration Guideline Limit
dpm	disintegration per minute
DU	Depleted Uranium
Earth Tech	Earth Tech Environment & Infrastructure, Inc.
Eglin	Eglin Air Force Base
emc	Elevated Measurement Comparison
FIDLER	Field Instrument for the Detection of Low Energy Radiation
g	grams
kcpm	Kilocounts per minute
LLRM	Low-Level Radioactive Materials
m/s	meters per second
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimal detectable concentration
MDCR	minimal detectable count rate
MFP	mean free path
MDA	Minimum Detectable Activity
NaI	Sodium Iodine
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulation
pCi/g	picoCuries per gram
ug/g	micrograms per gram
RESRAD	residual radioactivity
REI	Rust Environment & Infrastructure, Inc.
RSO	Radiation Safety Officer
SI	Site Investigation
USACE	U.S. Army Corps of Engineers
^{238}U	Uranium 238
µCi	microCuries
µR/hr	Micro-R per hour

CONVERSION FACTORS

TO CONVERT FROM	TO	MULTIPLY BY
acre	hectare	0.405
	sq.meter (m^3)	4,050
	sq. feet (ft^3)	43,600
becquerel (Bq)	Curie (Ci)	$2.7x10^{-11}$
	dps	1
	pCi	27
Bq/kg	pCi/g	0.027
Bq/m^2	dpm/100 cm^2	1.67
Bq/m^3	Bq/L	0.001
	pCi/L	0.027
centimeter (cm)	inch	0.394
Ci	Bq	$3.7x10^{-10}$
	pCi	$1x10^{-12}$
dps	dpm	0.0167
	pCi	27
dpm	dps	60
	pCi	2.22
gray (Gy)	rad	100
hectare	acre	2.47
meter (m)	inch	39.4
	mile	0.00621
sq. meter (m^2)	acre	0.000247
	hectare	0.0001
	sq. feet (ft^2)	10.8
	sq. mile	$3.86x10^{-7}$
mrem	mSv	0.01
mrem/y	mSv/y	0.01
mSv	mrem	10
mSv/y	mrem/y	100
pCi	Bq	0.037
	dpm	0.45
pCi/g	Bq/kg	37
pCi/L	Bq/m^3	37
rad	gy	0.01
rem	mrem	1,000
	MSv	10
	Sv	0
seivert (Sv)	Mrem	100,000
	MSv	1,000
	Rem	100

PRINCIPAL MEMBERS OF THE URANIUM SERIES



1.0 ABSTRACT

The purpose of this study was to describe and quantify the sensitivity of the Eberline ASP2e Ratemeter and Bicron's G5 NaI probe Field Instrument for the Detection of Low Energy Radiation (FIDLER, rate meter and probe) in detecting Depleted Uranium (DU) fragments in white sand and red clay found on Eglin Air Force Base (Eglin). The results of this study were also used to recommend a Derived Concentration Guideline Limit Elevated Measurement Comparison ($DCGL_{emc}$) based on FIDLER measurements.

The study concludes that the FIDLER is capable of detecting DU metal fragments and oxides DU particles from 0-12 inches in red clay and white sand common on the test sites at Eglin AFB, Florida at 10-50 percent of the Derived Concentration Guideline Limit (DCGL) as recommended in the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM).

2.0 INTRODUCTION

The U.S. Army Corps of Engineers, Omaha District (USACE) has retained Earth Tech Environment & Infrastructure, Inc. (Earth Tech), formerly Rust Environment & Infrastructure, Inc. (REI), to perform Preliminary Assessments (PAs) and Site Investigations (SIs) for depleted uranium (DU) contamination at several ranges on Eglin Air Force Base (Eglin), Florida. Although Eglin must adhere to the Installation Restoration Program, the Eglin Low-level Radioactive Material (LLRM) Partnering Team determined that for the best interest of all regulatory agencies involved, the MARSSIM approach should be followed as practical for the investigation and potential cleanup of the LLRM sites identified at Eglin.

The LLRM Partnering Team approved the FIDLER as the primary field instrument for conducting surface scans and in identifying potential soil sampling locations. Since discrete DU fragments were considered the source of the contamination on the ranges the FIDLER was chosen for its ability to locate elevated hot spots from surface to subsurface depths and to determine the horizontal extent of contamination. Soil samples were used to determine the vertical extent of the DU contamination potentially requiring remediation.

During the early stages of the characterization survey it was realized that the capabilities of the FIDLER in detecting DU fragments weren't fully understood. The FIDLER had been used as the primary field instrument without knowledge of the instruments Minimum Detectable Concentrations (MDC) in white sand and red clay at depth ranging from zero to 12 inches below land surface (bls). Furthermore, the FIDLER was used without verification of its ability to detect ten to fifty percent of the DCGL as recommended in Nuclear Regulation (NUREG)-1575, MARSSIM. In order to quantify the ability of the FIDLER in detecting metal DU fragments and oxidized DU particles a test was proposed and submitted to the Eglin AFB partnering team. This test was developed with the goal of verifying the FIDLER ability to meet MARSSIM requirements, establish an MDC and recommend a DCGL based on small areas of elevated activity.

3.0 DU TEST METHODOLOGY

A test to demonstrate the ability of the ASP-2e/G5 FIDLER, to quantify the FIDLER response to the soil DCGL and to established the MDC was devised by Earth Tech and presented to the LLRM partnering team during the December 2, 1999 meeting (Eglin, December 1999). The team approved the concept and gave approval to complete the test. The test was set up as follows:

3.1 TEST PROCEDURE

Several measurements at various depths using several instruments and different size DU fragments were used in the test. The instruments were placed in contact with the surface or held 3 foot above the surface during the test. The testing involved the following procedures:

- Collected ten scaler readings in the 95% confidence mode with two FIDLERs;
- Collected ten readings with two Micro-R meters;
- Collected three-foot readings with two Micro-R meters above the fragments while the fragments were on the surface and below surface level; and
- The FILDER scaler and Micro-R meter readings were taken with the DU fragments at the following depths:
  - 0 inches
  - 2 inches
  - 4 inches
  - 6 inches
  - 9 inches
  - 12 inches
  - 3 feet above soil surface (Micro-R meter only)

The following equipment was used in the DU test:

- One 55-gallon drum containing white sand
- Scales to weigh DU fragments
- Shovels
- Two FIDLERS
- Nitrile gloves
- Fragments of DU:
  1 gram fragment
  50 gram fragment
  101 gram fragment
  300 gram fragment
  Soil containing oxidized DU fragments (189 μR/hr) A Bag
  Soil containing oxidized DU fragments (8.25 μR/hr) B Bag
- One 55-gallon drum containing red clay
- Tape Measure
- One Pancake Probe
- Two Micro-R Meters
- Plastic bags
- Stop watch or Clock

Before beginning the DU test, each DU fragment was weighed and labeled as follows:

- F1 = 1 gram DU (0.36 μCi)
- B1 = 50 gram DU (18 μCi)
- Z1 = 101 gram DU (36.36 μCi)
- R1 = 300 gram DU (108 μCi)

All instruments were pre-calibrated and inspected. Background measurements were collected of the two drums, one with 18 inches of red clay and other with 18 inches of white sand.

The following specific parameters were used in the DU test:

- Specific Activity of DU = 3.6×10^{-7} Ci/g
  (40 CFR Part 20) = 0.36 μCi/g (or 360,000 pCi/g)
- $DCGL_w$ = 600 pCi/g (Earth Tech, March 1999; Eglin, March 1999)
- Background of white sand = 0.06 pCi/g ^{238}U
- Background of red clay = 0.7 pCi/g ^{238}U

Please refer to Tables 2 through 13, and Figures 1 through 12.

4.0 INSTRUMENT PRE/POST CALIBRATION PROCEDURES

Daily pre/post calibration checks were performed on all the equipment that was utilized in the DU test to determine if they were operating properly and to provide quality control.

4.1 FIDLER CALIBRATION PROCEDURES

To verify the statistical validity of the FIDLER data, daily pre/post calibration checks were completed using a 50-gram DU fragment in a reproducible geometry. The LLRM Eglin Standard Operating Procedures (ESOP) No. 15 requires that the measurements be within ±10% of the initial calibration value (Eglin, April 1999). The methodology used to source check the instrument included:

- One background measurement was taken to ensure the absence of contamination on the probe face;
- Measurements were taken in the 95% confidence scaler mode;
- Measurements were taken with a 0.25-inch plastic cover over the instrument probe face (e.g.,field measurements were taken with a plastic cover over the instrument probe face);
- Measurements were taken at a constant distance and geometry using a wood jig;
- Ten individual counts (one count is completed when the rate meter reaches the 95% confidence level) were performed. The average of these counts was used as the source check measurement.

The FIDLER data was sufficient to statistically validate the collected data.

4.2 MICRO-R METER CALIBRATION PROCEDURES

To verify the statistical validity of the Micro-R meter data, daily pre/post source checks were completed using the same 50 gram DU source. The pre/post calibration sheets required that the measurements were within ±10% of the initial calibration value. The methodology used to source check the instrument included:

- One background measurement was taken to ensure the absence of contamination on the instrument;
- Measurements were taken in the slow response mode;
- Measurements were taken at a constant distance and geometry;
- One five-minute count was performed and used as the source check measurement.

The Micro-R meter data was sufficient to statistically validate the collected data.

4.3 AMBIENT BACKGROUND

The DU test was conducted in two different locations:

The white sand DU test was conducted at the EarthTech Office Parking Lot (11 Racetrack Road, Fort Walton Beach, Florida). The measured backgrounds for the FIDLER and the Micro-R meter were 3.34kcpm and 3.5μR/hr, respectively. The Earth Tech Parking Lot was the original location of the DU

test. This ideal location was selected due to the low background levels, but was open to the unpredictable weather.

The second phase of the testing involved the red clay DU test that was performed inside the Earth Tech Field House (4 Skipper Avenue, Fort Walton Beach, Florida). The red clay portion of the DU test was moved to the new location because of weather and time constraints. The measured backgrounds for the FIDLER and the Micro-R meter were 7.63kcpm and 8.75μR/hr, respectively. This increased background level masked some of the low level gamma energy produced by the DU fragments. The cinder block walls and concrete floors inside of the Earth Tech Field House measured 10.5 μR/hr and 7.63 kcpm. These levels affected the red clay test results, notably the measurements taken at 3 feet above the test sources. However, it has been determined that the FIDLER and the Micro-R meter data are of sufficient quality to support the test. The elevated background readings do not adversely affect the overall test results. The background count rates from red clay and white sand were obtained using the same instrument that was used to determine the ambient background in both locations.

5.0 VARIABLES AFFECTING THE FIDLER MDC

5.1 EFFICIENCY

Before the overall effectiveness for the FIDLER could be determined, instrument and source efficiency needed to be calculated. This determination was based on three factors: (1) the common soil types present at Eglin, (2) various sized DU fragments, and (3) different source depths. Efficiency and the MDC would need to be established for each type of soil to meet the 95% confidence level required by MARSSIM.

5.1.1 Soil Types

During the LLRM investigative surveys conducted at Eglin in 1999, two primary types of soil, red clay and white sand, with a density of 1.5 and 2.0 mg/cm^3 respectively were identified. These two soil types common on the ranges at Eglin AFB have significantly different background radiation levels. Background uranium concentrations in the soils at the sites range from 0.06 – 0.7 pCi/g. As a result, the initial investigation level (two times background) used at each site to guide field decisions were dependent on the dominant type of soil at the site. This caused problems during the survey when grass covering or mixed soil types were encountered during the FIDLER surface scans due to the varying background levels. The investigation levels could change significantly within 50 ft during the surface scanning; a more consistent value was needed.

5.1.2 DU Fragment Size

Four actual DU fragments and two bags of oxides DU fragments mixed with soil (labeled A bag and a B bag) were used during the test. The fragments were actual DU penetrators that were discovered during the CS at IRP Site No. RW-41 Test Area C-74L. The fragments, which had activities ranging from 0.36 - 108 µCi, were buried at varying soil depths typical of contamination found at RW-41. The following fragments were used during the testing:

- 1 gram flake of DU
- 50 gram DU fragment
- 101 gram DU fragment
- 300 gram DU round (complete round)

In addition to the DU fragments, two bags containing either white sand or red clay mixed with DU fragments were collected. These bags were collected from IRP Site No. RW-41 Test Area C-74L at zero to two inches bls and were considered worst case concentrations. These bags were used to compare instrument efficiency using a non-point source (distributed source) to see what effects source geometry played in FIDLER measurements with discrete fragment versus distributed contamination (Tables 10 through 13 and Figures 5, 6, 11, and 12). The A bag's activity averaged 189 µR/hr and the B bag averaged readings of 8.25 µR/hr using the Ludlum 19 Micro R meter.

5.1.3 Source Depths

The depth of the DU fragments and the soil density were the primary factors that affected the instrument efficiency as shown by Figures 21 and 22. The depth ranges of zero to twelve inches used in the study were selected based on actual DU fragments locations encountered during fieldwork. All measurements were made with the FIDLER in the 95 percent confident scaler mode, usually resulting in one-minute counts being taken. All Micro-R meter readings were conducted for five minutes in slow response mode at each depth with the meter in contact with the soil and at three feet above the ground surface.

5.2 TOTAL EFFICIENCY

The instrument efficiency and source efficiency (total efficiency) was determined by using data collected from the DU test and the pre/post calibration checks. A 50-gram DU fragment (activity of 18 μCi) was used as the daily check source to calculate the instrument efficiency. This particular weight fragment was used as a check source because it was representative of discrete small areas of elevated activity typically found at the sites under investigation.

A total of 120 measurements were made using the 50 gram source over a six day period with 2 FIDLERs and 2 Micro R meters in a fixed reproducible geometry in contact with the source while in a wooded jig. Measurements were also taken at various depths during the testing of fragments in the metal drums, See figure 21 & 22.

Calibration Averages

	MICRO-R sn#156485	MICRO-R sn#156461	FIDLER sn#550	FIDLER sn#471
DAY 1	201.00 μR/hr	194.00 μR/hr	175.44 kcpm	186.85 kcpm
DAY 2	200.00 μR/hr	198.00 μR/hr	180.20 kcpm	190.76 kcpm
DAY 3	202.00 μR/hr	200.00 μR/hr	178.09 kcpm	190.74 kcpm
DAY 4	208.00 μR/hr	198.00 μR/hr	180.69 kcpm	188.30 kcpm
DAY 5	205.00 μR/hr	190.00 μR/hr	179.50 kcpm	192.72 kcpm
DAY 6	191.00 μR/hr	202.00 μR/hr	178.74 kcpm	192.48 kcpm
AVERAGE	201.17 μR/hr	197.00 μR/hr	178.78 kcpm	190.31 kcpm
TOTAL AVERAGE NET COUNTS	**199.08 μR/hr**		**184.54 kcpm**	

Source: Micro-R meter and FIDLER calibration sheets for 6 days. A total of 20 measurements per instrument were taken each day.

The average gross counts were then divided by the activity of the 50 gram DU fragment (0.36 μCi/g) counts/disintegrations equals efficiency, (c/d=e):

$$\frac{184.54 \text{ kcpm}}{39{,}960{,}000 \text{ dpm}} = 4.62\text{E-}3 \text{ or } 0.46\ \% \text{ efficiency}$$

note: 1 pCi = 2.22 dpm

5.2.1 Source Efficiency

The source efficiency, E_s, is defined as the ratio between the number of particles of a given type emerging from the front face of a source and the number of particles of the same type created or released within the source per unit time (ISO 7503-1). The source (or surface) efficiency takes into account the increased particle emission due to backscatter effects, as well as the decreased particle emission due to self-absorption losses. For an ideal source (no backscatter or self-absorption), the value of E_s, is 0.5. Many real sources will exhibit values of E_s, less than 0.5, although values greater than 0.5 are possible, depending on the relative importance of the absorption and backscatter processes. Source efficiencies must be determined experimentally.

The experiment process was used to calculate the source efficiency of a DU fragment. The FIDLER counts per minute average calculated over several days was lower than expected for a field instrument capable of detecting radiation at levels necessary to meet MARSSIM standards. This was primarily due to the self-absorption effects of a DU fragment with a density of 18.75 g/cm^3. Uranium (DU) is an excellent radiation shield, which gives rise to the most serious complication, self absorption. That is, some if not all of the gamma rays produced in a piece of depleted uranium never escape to be detected. For example, the mean free path in uranium for the 93 keV photon from ^{234}Th is only 0.2 mm, but the 1001 keV photon from ^{234}Pa has a mean free path of 7 mm. Therefore, the 93 keV photons only come from the oxides DU fragments and/or the paper thin surface of the DU fragment facing the detector. The 1001 keV photons will originate from the outer 2 cm of the DU fragment facing the detector. Thus the detectability of DU depends on the size and shape of the fragments present, the soil type and geometry, (source efficiency factors).

5.2.2 Instrument Efficiency

The instrument efficiency is defined as the ratio between the net count rate of the instrument and the surface emission rate of a source for a specified geometry. The surface emission rate, $q_{2\pi}$, is defined as the " number of particles of a given type above a given energy emerging from the front face of the source per unit time" (ISO 7503-1). The surface emission rate is the 2-pi particle fluence that embodies both the adsorption and scattering processes that affect the radiation emitted from the source. Thus, the instrument efficiency is determined by the following equation.

$$E = \frac{Rs + b - Rb}{q}$$

The instrument efficiency is determined during calibration by obtaining a static count with the detector over a calibration source that has a traceable activity or surface emission rate or both. In many cases, it is the source surface emission rate that is measured by the manufacturer and certified as National Institutes of Standards and Technology (NIST) traceable. The source activity is then calculated from the surface emission rate based on assumed backscatter and self-absorption properties of the source. The maximum value of instrument efficiency is 1.

The method for determining instrument efficiency during the DU test took into account source efficiency factors that would be encountered during the field survey by performing the measurements in the white sand and red clay at a LLRM site (NUREG-1507, 5.2.2 recommends using experimental data for each surface encountered for a more realistic instrument response). Figures 21 and 22 show the trendline

developed during the efficiency testing at various soil depths. However, a correction factor had to be developed to accurately account for the loss of photons due to self-absorption, and geometry. This was done using the following method:

50 gram DU fragment 0.36 μCi/g or 18E6 pCi total activity

1pCi = 2.22 dpm therefore;

18E6 pCi = 39,960,000 dpm

Using the following formula

Counts per minute (cpm)/dpm = instrument efficiency

Set efficiency to 50% or 0.5, cpm equal 19,980,000 cpm

This value is the number of photons that would be detected if every photon were counted by the probe in a 2-pi source geometry. This calculated value, (199.9E6) did not match the daily calibration readings equal to an average of 184,540 cpm, that's a 1083 times difference requiring a correction factor to account for the self absorption. Using the correction factor the calculated total activity should be 199 E6 cpm. This is the maximum number of photons measured if none were lost due to self absorption. This equals an efficiency of 49% using actual test in the following equation;

$$\frac{184{,}540 \text{ cpm} \times 108.3}{39{,}960{,}000 \text{ dpm}} = 0.5 \times 100\% = 50\%$$

This would be the efficiency of the FILDER probe on contact with a DU fragment in a fixed geometry which is not the case in the field. As to be expected, the low energy gamma detection drops as the depth of the soil increases. Although the FIDLER can detect DU fragments down to twelve inches, the efficiency drops greatly after four inches bls in the white sand and red clay. This drop was expected considering the ^{232}Th (63 keV and 93 keV). They are produced by 8% of the uranium decays, suffer very strong self-absorption, but travel 3.4 cm in soil. Therefore, they can be effectively used to map the distribution and migration of the weathered oxides in the top 5 cm of soil. However, they have little value for mapping large fragments of uranium metal, particularly if buried. But the pair of gamma's emitted from ^{234m}Pa, (765 keV and 1001 keV), these are produce by very few decays (<0.9%), but their high energy permits them to avoid total self-absorption. More importantly, they have a mean free path of 10 cm in soil so they can be detected from small pieces of DU buried by a foot of soil or more. These photons are useful for locating fragments of uranium metal, but not as good as the ^{232}Th photons to map oxides, because they are too weakly produced by decays.

Another technique, and one use during the field survey, is to measure all photons regardless of the energy.

This was accomplished using the FILDER in the gross operating mode. Many of the photons described above will be Compton scattered by the soil to lower energy where they cannot be recognized. By including all photons, (gross mode) will increase your chances of detection by increasing sensitivity, therefore increasing instrument efficiency.

6.0 DETERMINATION OF MINIMAL DECTABLE COUNT RATE

6.1 SCANNING

The ability to identify small areas of elevated radioactivity during surface scanning is dependent upon the surveyor's skill in recognizing an increase in the audible and/or display of the instrument as well as the instrument's sensitivity. MARSSIM and NUREG –1507 discuss human performance and scanning sensitivity and their affect on the Minimal Detectable Count Rate (MDCR) in detail (NUREG 1575, NRC, 1997; NRC, 1995). MARSSIM also provides an equation for determining the MDCR.

The framework for calculating the MDCR is based on the premise that there are two stages of scanning: continuous monitoring and stationary sampling. These two stages are summarized below.

6.1.1 Continuous Monitoring

During continuous surface monitoring, the FIDLER is swung side to side with the probe kept at approximately four to six inches above the ground while the surveyor walks at a pace of 0.5 meters per second (m/s). As the surveyor walks and swings the FIDLER, the surveyor listens for an audible increase in the rate of FIDLER clicks. The difficulties of the detection decision are dependent on the magnitude of the increase in count rate, visibility of the instrument's display, and the surveyor's attention to the task at hand. The surveyor has to make the decision that the audible increase is greater than normal background and that a scaler measurement is necessary.

6.1.2 Stationary Sampling

The stationary sampling as it applies to the Eglin LLRM project is based on taking a scaler measurement at each predetermined grid intersection. During the investigations performed in the summer and fall of 1999, the FIDLER was switched to the scaler mode and an integrated reading in the 95 percent confidence mode was performed (at ground contact) at 30-foot grid intervals laid out by a professional surveyor. These readings along with any suspect continuous readings greater than two times background were recorded for use in the survey as a suspected hot spot.

6.2 SCAN MDC DETERMINATION

Since the scanning is divided into two stages, the calculation in MARSSIM for scan MDC is also a two step process. Typically, observation intervals during the first stage are on the order of one or two seconds, while the second stage, (stationary sampling) pause may be several seconds long. The greater calculated value of MDCR from each of the scanning stages is used to determine the scanning sensitivity for the surveyor. Another factor that must be taken into account is that the sites have two different types of soil that greatly affect the two-stage calculation. The average background measurements for white sand and red clay were used in the calculation with the most conservative value was used as the MDCR.

I. Calculate MDCR

	Formula:	$MDCR = d^1 \sqrt{b_1}$	
Given:	$d^1 = 1.38$	Given:	$d^1 = 2.48$
	$b_1 = \frac{(5000\ cpm)(1\ second)}{60\ minutes}$		$b_1 = \frac{(5000\ cpm)(4\ second)}{60\ minutes}$
	$= 83.333$		$= 333.33$
Formula:	$MDCR = 1.38\sqrt{83.33}$	Formula:	$MDCR = 2.48\sqrt{333.33}$
	$= 12.597$		$=45.278$
	$= 12.597 \times 60$		$=45.2788 \times 60$
	$MDCR = 755.82$ cpm		$MDCR = 679.17$ cpm

Next the surveyor's actual performance and experience must be taken into consideration in the calculation. This number is based on actual confidence rating experiments, the surveyor efficiency (p) was estimated to be between 0.5 and 0.75 (this value is based on actual tests conducted by the NRC and published in NUREG-1507). MARSSIM recommends assuming a surveyor efficiency (p) at the lower end of the observed range (i.e., 0.5) when making MDC estimates.

Given: Use the larger number of 755.82 cpm for MDCR

$\sqrt{p} = 0.5$

Formula:

$$MDCR_{surveyor} = \frac{MDCR}{\sqrt{p}}$$

$$= \frac{755.82\ cpm}{\sqrt{0.5}}$$

$$MDCR_{surveyor} = 1068.89\ cpm$$

Using the more conservative number, it is recommended that the MDCR surveyor (red clay) of 1070 cpm value be used for all sites. It is too difficult to know exactly what soil types or mix will be encountered under vegetation at each survey site. The MDCR surveyor value for white sand equals 1058 cpm using the same calculation.

7.0 MINIMUM DETECTABLE SOIL CONCENTRATION

Once the process has been completed to determine the MDCR, the minimum detectable soil concentration must be calculated to determine the relationship between the FIDLER's MDCR and the depleted uranium concentration in soil. Before this can be accomplished two questions must be answered. The relationship between the FIDLER's net count rate to the Ludlum 19 Micro-R meter net exposure rate had to be established (cpm/μR/hr). Second, the relationship between the radionuclide contamination and exposure rate must be determined using a modeling program. For this study, the Eglin LLRM Partnering Team agreed to use MicroShield™ modeling program to make the soil contamination to radiation exposure rate correlation (Eglin, December, 1999).

7.1 MINIMUM DETECTABLE EXPOSURE RATE

In making the comparison between the Micro-R meter (μR/hr) and the FIDLER (cpm), MARSSIM recommends referring to the manufacture specification data. Due to the fact that most μR/hr to cpm comparisons are made using Cesium^{137} in a controlled reproducible geometry, it was decided to use the daily data collected from daily instrument calibrations using a fifty-gram DU source. This eliminated the need for a corrective factor and resulted in more accurate results. The minimum detectable exposure rate is calculated by dividing 1078 cpm (MDCR survey count rate) by 930 cpm per μR/hr (exposure rate). This calculation yields 1.16 μR/hr minimum detectable exposure rate.

Calculate the ratio: $\frac{184.54 \text{ kcpm}}{X} = \frac{199.08 \mu R/hr}{1}$

$$X = 926 \text{ cpm}/\mu R/hr$$

$$\frac{1070 \text{ cpm}}{926 \text{ cpm}/\mu R/hr} = 1.16 \ \mu R/hr$$

7.2 MICRO-SHIELD DOSE RATE CALCULATION

It is recommended in MARSSIM Section 6.7.2.1 to use a modeling program for small areas of elevated activity to determine the net exposure rate produced by a radionuclide concentration in the soil. The modeling performed in this study followed the example presented in MARSSIM. The objective of this model was to determine the radionuclide concentration in the soil (pCi/g) that correlates the minimum detectable net exposure rate of the FIDLER (kcpm) and Micro-R meter (μR/hr).

The following parameters were used in the model:

- *Radionuclide of interest:* ^{238}U and all gamma emitters in the decay chain.
- *Expected concentration of the radionuclide of interest*: The same DU fragment concentrations used during the DU test were used in the Micro-shield calculation in order to make a correlation between the DU test and the model. Once the nuclide and its activity was entered into MicroShield, the

program calculated the energy and probability of decay for each photon associated with each nuclide. The decay was set for 1,000 years.

- *Dose Points above the Source:* Four inches and three feet.
- *Aerial dimensions of the area of elevated activity:* The cylinder geometry was used based on the diameter of the FIDLER probe face.
- *Depth of the area of elevated activity*: The same depths used in the DU test were used for comparison.
- *Location of dose point NaI (Tl) scintillation detector height above the surface)*: The position above the surface was chosen to be 10 cm (4 inches) because this is the approximate height of the FIDLER probe as it swings during a field survey.
- *Density of Soil*: Red clay 2 mg/m^3; White sand 1.5mg/m^3.
- *Information on Energy Groups*: The MicroShield modeling program breaks down the decay products' energy into 20 groups with 37% of the energy from the decay process being less than 100 keV. The FIDLER is most efficient at energies less than 100 keV. It was noted during several MicroShield™ model runs that 0.04 MeV had the greatest potential contributing to exposure.

Refer to Table 1 for the results of the MicroShield model and the DU test comparison.

8.0 FIDLER BASED DCGL

The development of DCGLs are based on exposure pathway models which assume a relatively uniform distribution of contamination. However, this is not the case with small areas of elevated activity, such as with discrete DU fragments. MARSSIM 2.5.1.1 addresses the small area of elevated activity by using a simple comparison to an investigation level as an alternative to statistical methods. This elevated measurement comparison (EMC) represents the conservative approach in which every measurement is below the action level. The investigation level for this comparison is called the $DCGL_{emc}$, which is the $DCGL_w$ modified to account for the smaller area of elevated activity.

One of the objectives of this study was to make a correlation between the existing $DCGL_w$ in pCi/g with the FIDLER's counts per minute and to recommend a $DCGL_{emc}$ based on counts per minute.

A review of the MicroShield model data shows that a relationship can be made between the scan MDC and the uranium soil concentration in pCi/g. Table 1 shows the relationship between various size fragments and different soil depths using the MicroShield model and the DU test.

Based on the $MDCR_{surveyor}$ scan value of 1078 CPM, the DU concentration necessary to yield the minimum detectable exposure rate (1.16μR/hr) for red clay would be 14.17 pCi/g 12 inches bls and white sand would be 7.04 pCi/g at 12-inches bls. Using the more conservative value of 14.17 pCi/g, a correlation was made to the DU test value of 1.61 kcpm (FIDLER) at the same depth. The next step was to determine the FIDLER's cpm value using the Eglin LLRM Partner Team $DCGL_w$ value of 600 pCi/g (industrial scenario; Eglin, March 1999). Using the ratio of 14.17 pCi/g equals = 1070 CPM, 600 pCi/g would equal 45.31 kcpm.

Scan MDC = [(1 pCi/g)(1.16 μR/hr)]/(0.0818 μR/hr) = 14.17 pCi/g

(Note: The value of 0.0818 is found in Table 1)

Following that logic we recommend that the $DCGL_{emc}$ be based on FIDLER readings in kcpm and not the current 600 pCi/g.

8.1 AREA FACTORS

The area factor is the magnitude by which the concentration within the small area of elevated activity can exceed the $DCGL_w$, while maintaining compliance with the release criteria of 600 pCi/g. The area factor is determined based on specific regulatory agency guidance. MARSSIM Table 5.6 gives examples of area factors generated using exposure pathway models. The outdoor area factors listed in the table were calculated using RESRAD 5.6 and are based on a radionuclide concentration of 1 pCi/g and risk factors based on a land area of 10,000 m^2.

The minimum detectable concentration (MDC) of the scan procedure needed to detect an area of elevated activity at the limit determined by the area factor is calculated as follows:

scan MDC (required) = $(DCGL_w)$ x (Area Factor) or written as

$DCGL_{emc}$ = $(DCGL_w)$ x (Area Factor)

Following this method results in:

Scan MDC = 14.17 pCi/g/ 600pCi/g

Area Factor = 0.0236

Note the area factor is less than one; however this is not a recommend value. MARSSIM (paragraph 5.5.2.4) used RESRAD 5.6 with a conservative concentration of 1pCi/g resulted in an area factor of 1. Using a value less than 1 will create problems later in determining sample size. Therefore a value less than one is not recommended.

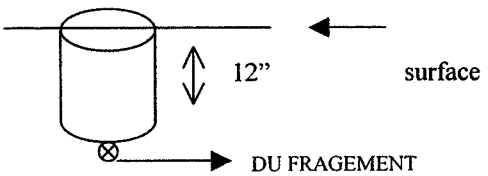
If an area factor of 1 is used, a scan MDC of 600 pCi/g results. Using our data from the MicroShield™ test, MDCR surveyor of 1078 cpm and scan MDC of 14.7 pCi/g, the relationship can then be made that the scan MDC of 600 pCi/g equals a new scan MDC based on a FIDLER reading of 46 kcpm to use as the $DCGL_{emc}$.

8.2 AREA FACTOR BASED ON THE FIDLER SIZE

Another method is to recommend to the regulators that the $DCGL_{emc}$ be based on the size of the area that the field instrument can "see". This method results in a very conservative value.

Determine volume under the FIDLER:

Given: FIDLER "sees" up to 12 inches bls within a cylinder with a diameter of five inches (radius of 2.5 inches)



Formula:

$V = \pi \times R^2 \times H$

$R = 2.5 \text{ in.} = 6.35\text{cm}$

$H = 12 \text{ in.} = 30.48\text{cm}$

$V = (3.14159) \times (6.35)^2 \times 30.48$

$= 3{,}861.10 \text{ cm}^3$

Mass of white sand:

Given: white sand density = 1.5 g/cm^3

Formula: M = dv

= (1.5 g/cm^3) x (3,861.10 cm^3)

= 5,791.65 g of white sand under the probe

$DCGL_{emc}$ Determination:

Given: Assume area factor (A_F) of 1 meter^2 (MARRSIM Table 5.6). For ^{238}U, this will equal an A_F of 30.6:

A_F = 30.6

$DCGL_w$ = 600 pCi/g

Formula: $DCGL_{emc}$ = $DCGL_w$ x A_F

= (600 pCi/g) x (30.6)

= 18,360 pCi/g

Correlation:

Given: A (activity) = 0.36 μCi/g = 108 uCi or 108,000,000 pCi

M = 5,791.65 g of white sand under the probe

Formula: DU activity in soil (pCi/g) = A/M

= 108,000,000 pCi/5,791.65g

= 18,647.5 pCi/g

Comparison from DU test:

Given: DU test has shown that a 300-gram DU round is equal to 9.28 kcpm

Area of the FIDLER probe = 1.266e-02 m^2

Comparison: $DCGL_{emc}$ = 18,360 pCi/g

300 Gram round = 18,647.5 pCi/g

Therefore, can assume = 9.28 kcpm (approximately)

This is a comparison between the DU test and a proposed area factor based on FILDER probe size. The recommended method would be to use the one square meter area factor value of 30.6. This example was designed to illustrate some of the challenges in trying to quantify smaller areas of elevated activity.

9.0 CONCLUSION

9.1 DU TEST RESULTS

Red Clay:

- 1 gram fragment of DU can not be detected below four inches of soil with the FIDLER.
- The FIDLER can detect fragments greater than 50 grams in 12 inches of soil:
- 1 gram fragment of DU can not be detected at the ground surface with the Micro-R meter.
- The Micro-R meter can detect fragments greater than 50 grams in 9 inches of soil:
- The FIDLER and Micro-R meter can detect the A bag in 12 inches of soil.
- The B bag can not be detected after 4 inches of soil with the FIDLER or the Micro-R meter.

White Sand:

- A 1 gram fragment of DU can not be detected below four inches of sand with the FIDLER.
- A 1 gram fragment of DU can not be detected below two inches of sand with the Micro-R meter.
- The FIDLER can detect fragments greater than 50 grams in 12 inches of white sand.
- The Micro-R meter can detect fragments greater than 50 grams in 12 inches of white sand.
- The FIDLER and Micro-R meter can detect the A bag, (189 μR/hr) in 12 inches of soil.
- The B bag, (8.25 μR/hr) can not be detected under 4 inches of soil with the FIDLER or the Micro-R meter.

9.2 MICROSHIELD CONCLUSIONS

A total of 72 models were calculated with MicroShield™ using various depths, geometry, soils, densities, dose points and fragment sizes to try to determine an average scan MDC for the FIDLER.

The white sand/DU fragment exposure rate model ranged from 0.0008 to 6.2850 μR/hr at a dose point of 10 cm above the surface of the ground six to twelve inches bls. This dose rate equals scan MDCs ranging from 0.1846 to 1386.89 pCi/g (Table 1). This range of contamination is the scanning minimum detectable concentration level for fragments ranging in size from 1 gram to 300 grams.

The red clay/DU fragment exposure rate model ranged from 0.0020 to 4.66 μR/hr at a dose point of 10 cm above the surface of the ground from six to twelve inches bls. This dose rate equals scan MDCs ranging from 0.2488 to 568.90 pCi/g (Table 1). This range of contamination is the scanning minimum detectable exposure rate of 1.16 μR/hr for fragments ranging in size from 1 gram to 300 grams.

The Micro-Shield calculation with twelve inches of red clay (average density of 2.0 g/cm$^{3)}$, a 50 gram DU fragment produced an exposure rate of 0.0818 uR/hr at 10 cm above the surface (Figures 29-34). This is equal to the scan MDC of 14.17 pCi/g needed to yield the minimum detectable exposure rate of 1.16 uR/hr. This value is the recommended scan MDC that should be used for the FIDLER during field activities.

9.3 $DCGL_{EMC}$ CONCLUSION

Three methods were shown for determining the $DCGL_{emc}$. It's imperative for NFA approval, future surveys, Final Status approval and risk based decisions, (extending the grid) that one of these values or methods be approved. After completion of the DU test, and completion of the MicroShield modeling program, the FIDLER is capable of detecting average size fragments in 12" of soil within 10 –50% of the DCGL as recommended by MARRSIM. Therefore, we recommend that the FIDLER base value of 44 kcpm be used as the $DCGL_{emc}$ for a 1meter area. This value should be used as direct comparison value for hot spots risk determination.

10.0 REFERENCES

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TABLES

TABLE 1
MICROSHIELD AND DU TEST COMPARISON
LLRM INVESTIGATION
EGLIN AFB, FLORIDA

	1 GRAM FRAGMENT		50 GRAM FRAGMENT					300 GRAM FRAGMENT				
WHITE SAND	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	FIDLER DU TEST RESULTS[3] kCPM	EXPOSURE RATE TOTAL AT 3 FEET[4] uR/hr	MICRO-R DU TEST RESULTS[5] uR/hr	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	FIDLER DU TEST RESULTS[3] kCPM	EXPOSURE RATE TOTAL AT 3 FEET[4] uR/hr	MICRO-R DU TEST RESULTS[5] uR/hr
6"	0.0053	217.5544	1.0460	1.1090	11.4300	0.0604	6.80 uR/hr	6.2850	0.1846	54.7200	0.3632	29.0000
12"	0.0008	1386.8962	0.1646	7.0474	2.6100	0.0182	1.51 uR/hr	0.9893	1.1725	9.2800	0.1095	6.2500
	RANGE 217.55 - 1386.90		*Range 1.10 - 7.07*					*RANGE 0.18 - 1.17*				

	1 GRAM FRAGMENT		50 GRAM FRAGMENT					300 GRAM FRAGMENT				
RED CLAY	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	FIDLER DU TEST RESULTS[3] kCPM	EXPOSURE RATE TOTAL AT 3 FEET[4] uR/hr	MICRO-R DU TEST RESULTS[5] uR/hr	EXPOSURE RATE TOTAL uR/hr[1]	SCAN MDC[6] pCi/g [2]	FIDLER DU TEST RESULTS[3] kCPM	EXPOSURE RATE TOTAL AT 3 FEET[4] uR/hr	MICRO-R DU TEST RESULTS[5] uR/hr
6"	0.0192	60.5744	0.7758	1.4952	10.86 kCPM	0.0451	6.0000	4.6630	0.2488	49.13	0.2709	28.75
12"	0.0020	568.9063	0.0818	14.1775	1.61 kCPM	0.0818	<BKG	0.4918	2.3587	9.16	0.05468	5.25
	RANGE 60.57 - 568.91		*RANGE 1.50 - 14.18*					*RANGE 0.25 - 2.36*				

[1] MICROSHIELD MODEL (WITH BUILDUP) EXPOSURE RATE AT 4 INCHES

[2] RADIONUCLIDE CONCENTRATION OF U^{238} (SCAN MDC) NECESSARY TO YIELD THE MINIMUM DETECTABLE RATE (1.13 Ur/hr)
CALCULATION: $\frac{(1\ pCi/g \times 1.16 uR/hr)}{\text{MICROSHIELD EXPOSURE RATE}}$

[3] DU TEST RESULT VALUE (FIDLER) ON CONTACT WITH SOIL

[4] MICROSHIELD MODEL (WITH BUILDUP) EXPOSURE RATE AT 3 FEET

[5] DU TEST RESULT VALUE (MICRO-R) ON CONTACT WITH SOIL

[6] THE SCAN MDC WHILE SWINGING THE FIDLER (CONTINUOUS MONITORING)

TABLE 2
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

1 GRAM DU FRAGMENT, WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM
0"	4.33	3.97	4.15	3.50	3.50	3.50	3.50
2"	1.52	1.34	1.43	0.38	0.50	0.44	3.10
4"	0.49	0.38	0.44	<BKG	<BKG	<BKG	<BKG
6"	<BKG	0.11	0.06	<BKG	<BKG	<BKG	<BKG
9"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
12"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 3
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

50 GRAM DU FRAGMENT, WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3'
0"	192.10	204.96	198.53	188.50	198.50	193.50	-
2"	51.57	55.71	53.64	34.70	35.10	34.90	4.00
4"	26.98	26.66	26.82	15.70	15.00	15.35	3.40
6"	10.93	11.92	11.43	7.00	6.60	6.80	3.00
9"	3.33	3.44	3.38	2.10	1.70	1.90	3.00
12"	2.66	2.57	2.61	1.50	1.50	1.50	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 4
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

101 GRAM DU FRAGMENT, WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3'
0"	332.90	381.86	357.38	325.50	336.50	331.00	<BKG
2"	104.36	108.61	106.49	56.50	66.50	61.50	<BKG
4"	42.54	36.03	39.29	30.50	30.50	30.50	<BKG
6"	15.38	14.18	14.78	10.10	10.90	10.50	<BKG
9"	9.58	9.69	9.64	6.50	6.90	6.70	<BKG
12"	4.24	4.41	4.32	2.50	2.50	2.50	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 5
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

300 GRAM DU FRAGMENT (COMPLETE ROUND), WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3'
0"	1081.66	1319.96	1200.81	464.50	470.50	467.50	6.25
2"	277.30	302.76	290.03	146.50	166.50	156.50	5.25
4"	113.04	119.64	116.34	76.50	76.50	76.50	<BKG
6"	52.82	56.61	54.72	26.50	31.50	29.00	<BKG
9"	17.33	18.51	17.92	11.50	11.50	11.50	<BKG
12"	9.34	9.21	9.28	6.50	6.00	6.25	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 6
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

1 GRAM DU FRAGMENT, RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	1.12	1.46	1.29	0.75	1.75	1.25	<BKG
2"	0.89	1.02	0.96	<BKG	<BKG	<BKG	<BKG
4"	0.31	1.07	0.69	<BKG	<BKG	<BKG	<BKG
6"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
9"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
12"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 7
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

50 GRAM DU FRAGMENT, RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	187.72	204.97	196.35	191.25	191.25	191.25	<BKG
2"	65.65	69.25	67.45	25.25	25.25	25.25	<BKG
4"	23.01	23.51	23.26	11.25	11.25	11.25	<BKG
6"	10.48	11.23	10.86	6.25	5.75	6.00	<BKG
9"	3.44	3.77	3.61	2.25	2.25	2.25	<BKG
12"	1.42	1.79	1.61	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 8
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

101 GRAM DU FRAGMENT, RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	312.07	331.17	321.62	116.25	101.25	108.75	<BKG
2"	84.00	93.28	88.64	81.25	81.25	81.25	<BKG
4"	37.76	41.87	39.82	27.25	27.25	27.25	<BKG
6"	19.69	20.27	19.98	15.25	15.25	15.25	<BKG
9"	8.01	8.36	8.19	7.25	7.25	7.25	<BKG
12"	3.13	3.78	3.46	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 9
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

300 GRAM DU FRAGMENT (COMPLETE ROUND), RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	1520.87	1078.07	1299.47	271.25	266.25	268.75	<BKG
2"	247.97	218.47	233.22	116.25	119.25	117.75	<BKG
4"	84.45	84.51	84.48	46.25	51.25	48.75	<BKG
6"	48.05	50.20	49.13	26.25	31.25	28.75	<BKG
9"	22.78	24.08	23.43	13.25	14.25	13.75	<BKG
12"	8.77	9.55	9.16	5.25	5.25	5.25	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 10
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

ALPHA BAG, WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3'
0"	375.41	384.76	380.09	186.50	191.50	189.00	11.25
2"	146.03	155.39	150.71	106.50	111.50	109.00	11.00
4"	61.95	68.01	64.98	46.50	44.50	45.50	10.00
6"	33.08	37.38	35.23	24.50	25.50	25.00	9.00
9"	11.67	13.12	12.40	10.50	10.50	10.50	<BKG
12"	9.05	9.81	9.43	12.00	11.00	11.50	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 11
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

BETA BAG, WHITE SAND

SOIL DEPTH	FIDLER #1 Bkg 3.34 kCPM	FIDLER# 2 Bkg 3.34 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 3.5 uR/hr	MICRO-R #2 Bkg 3.5 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3'
0"	11.44	11.70	11.57	8.00	8.50	8.25	<BKG
2"	5.15	5.54	5.35	5.50	5.00	5.25	<BKG
4"	4.30	4.68	4.49	5.50	5.00	5.25	<BKG
6"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
9"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
12"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 12
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

ALPHA BAG, RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	362.47	371.37	366.92	189.25	186.25	187.75	3.50
2"	129.50	172.95	151.23	91.25	101.25	96.25	3.10
4"	73.57	78.59	76.08	46.25	41.25	43.75	<BKG
6"	32.69	34.93	33.81	19.25	19.25	19.25	<BKG
9"	7.74	9.16	8.45	5.25	5.25	5.25	<BKG
12"	4.52	5.11	4.82	3.25	3.25	3.25	<BKG

<BKG = LESS THAN BACKGROUND

TABLE 13
SUMMARY OF DU TEST
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

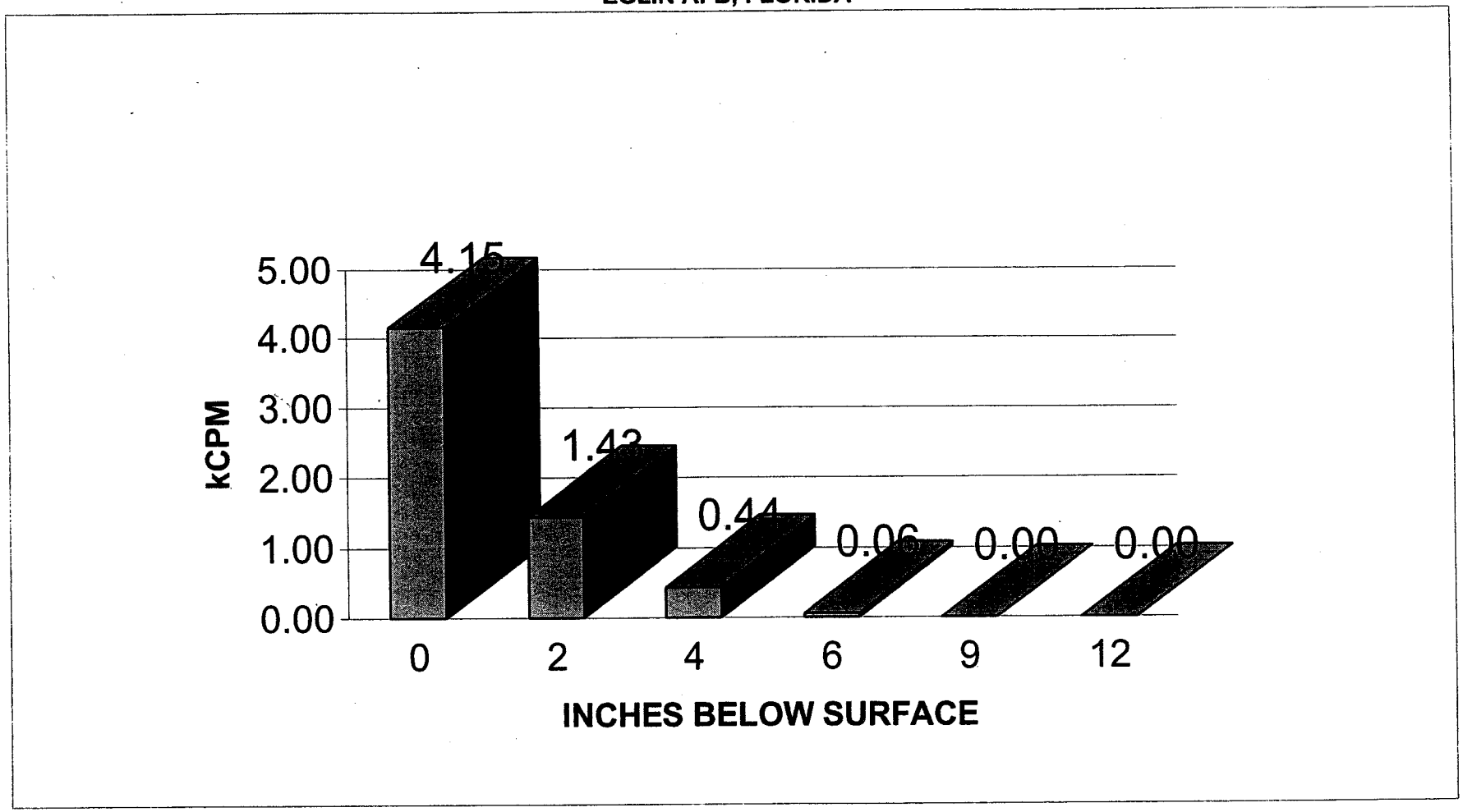
BETA BAG, RED CLAY

SOIL DEPTH	FIDLER #1 Bkg 7.63 kCPM	FIDLER #2 Bkg 7.63 kCPM	FIDLER AVERAGE	MICRO-R #1 Bkg 8.75 uR/hr	MICRO-R #2 Bkg 8.75 uR/hr	MICRO-R AVERAGE	MICRO-R AVERAGE 3' ABOVE DRUM Bkg 10.5 uR/hr
0"	7.98	7.64	7.81	2.25	2.25	2.25	<BKG
2"	1.92	2.23	2.08	1.25	0.75	1.00	<BKG
4"	0.64	0.99	0.82	0.25	1.25	0.75	<BKG
6"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
9"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG
12"	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG	<BKG

<BKG = LESS THAN BACKGROUND

FIGURES

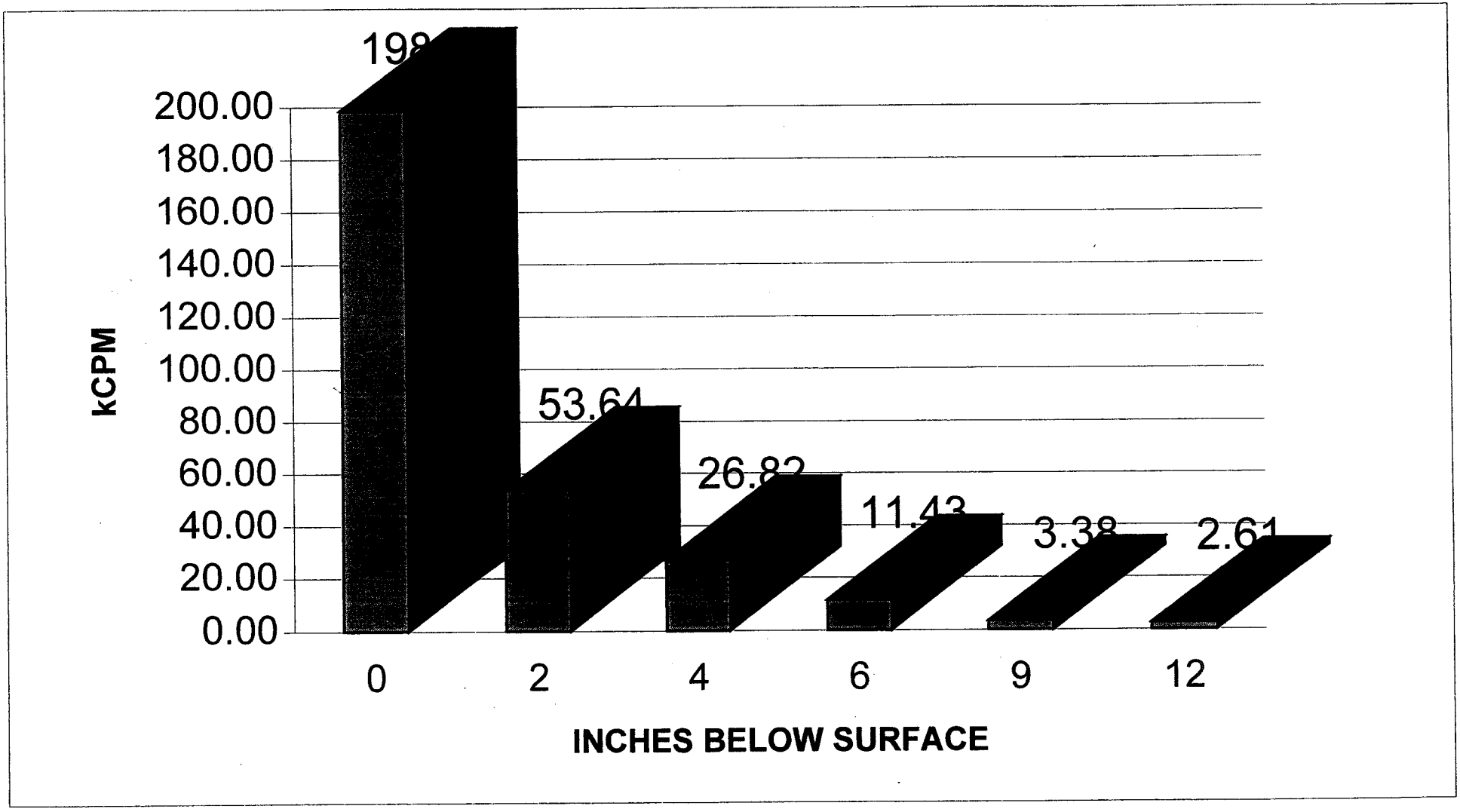
FIGURE 1
FIDLER DU TEST RESULTS
1 GRAM DU FLAKE, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (Bkg 3.50 uR/hr)
0" = 3.50
2" = 0.44

FIDLER BACKGROUND = 3.34 kCPM

FIGURE 2
FIDLER DU TEST RESULTS
50 GRAM DU FRAGMENT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

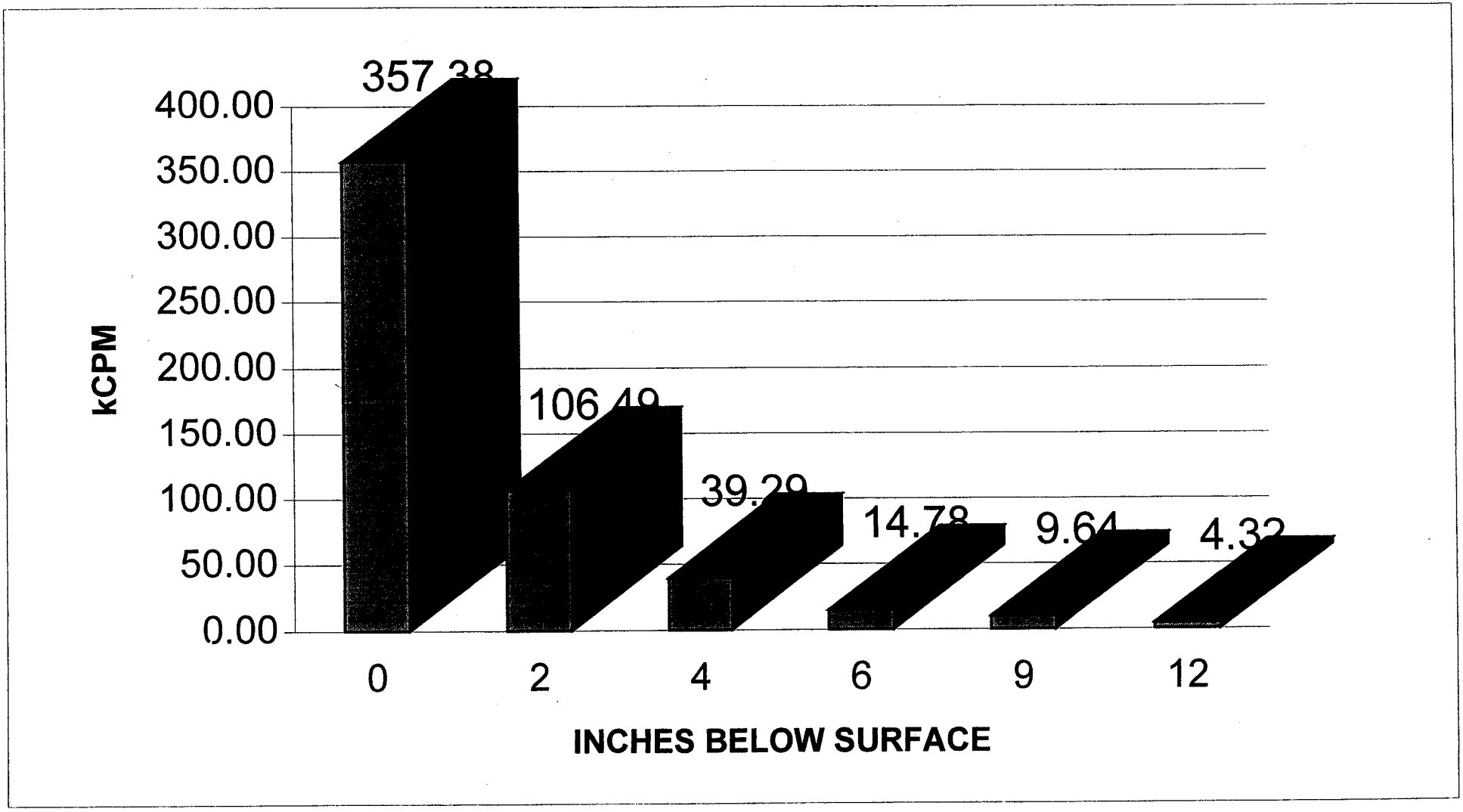


AVERAGE MICRO-R READINGS (Bkg 3.50 ur/hr)

0" = 193.50	6" = 6.80
2" = 34.90	9" = 1.90
4" = 15.35	12" = 1.50

FIDLER BACKGROUND 3.34 kCPM

FIGURE 3
FIDLER DU TEST RESULTS
101 GRAM DU FRAGMENT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

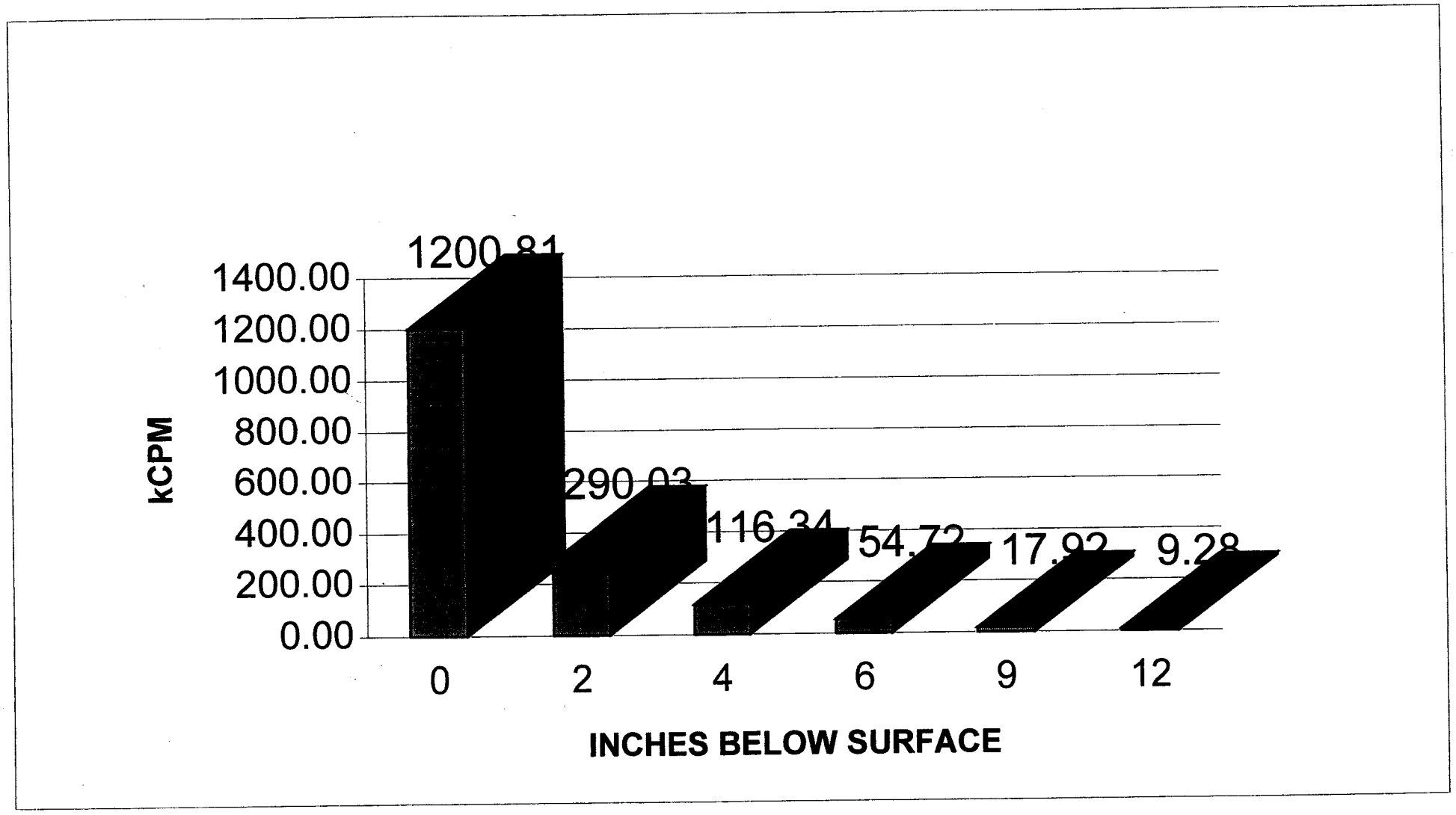


AVERAGE MICRO-R READINGS (BKG 3.50 ur/HR)
0" = 331.00 6" = 10.50
2" = 61.50 9" = 6.70
4" = 30.50 12" = 2.50

FIDLER BACKGROUND 3.34 kCPM

FIGURE 4

FIDLER DU TEST RESULTS
300 GRAM FRAGMENT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

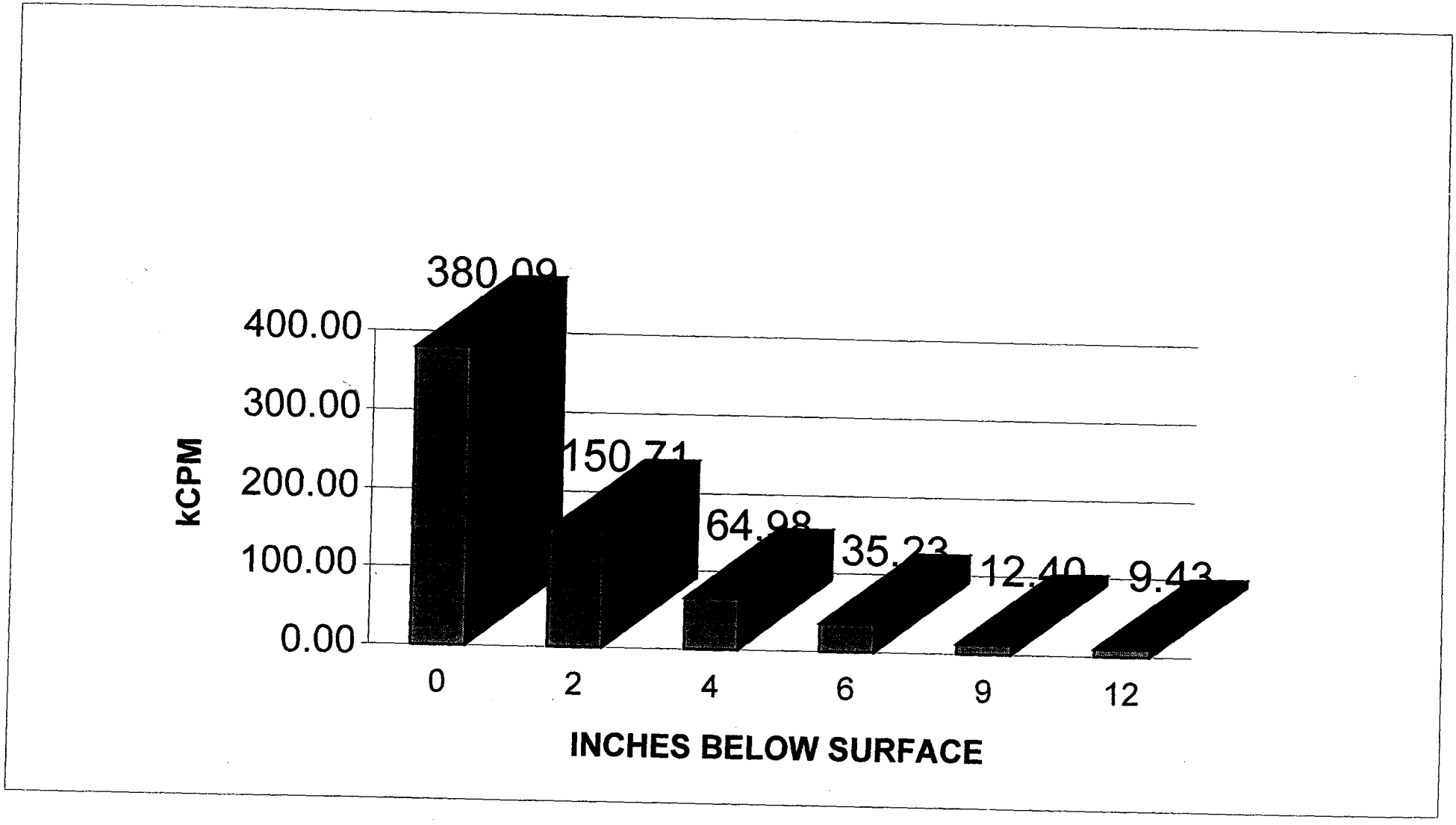


AVERAGE MICRO-R READINGS (BKG 3.5 uR/hr)

0" = 467.50	6" = 29.00
2" = 156.50	9" = 11.50
4" = 76.50	12" = 6.25

FIDLER BACKGROUND 3.34 kCPM

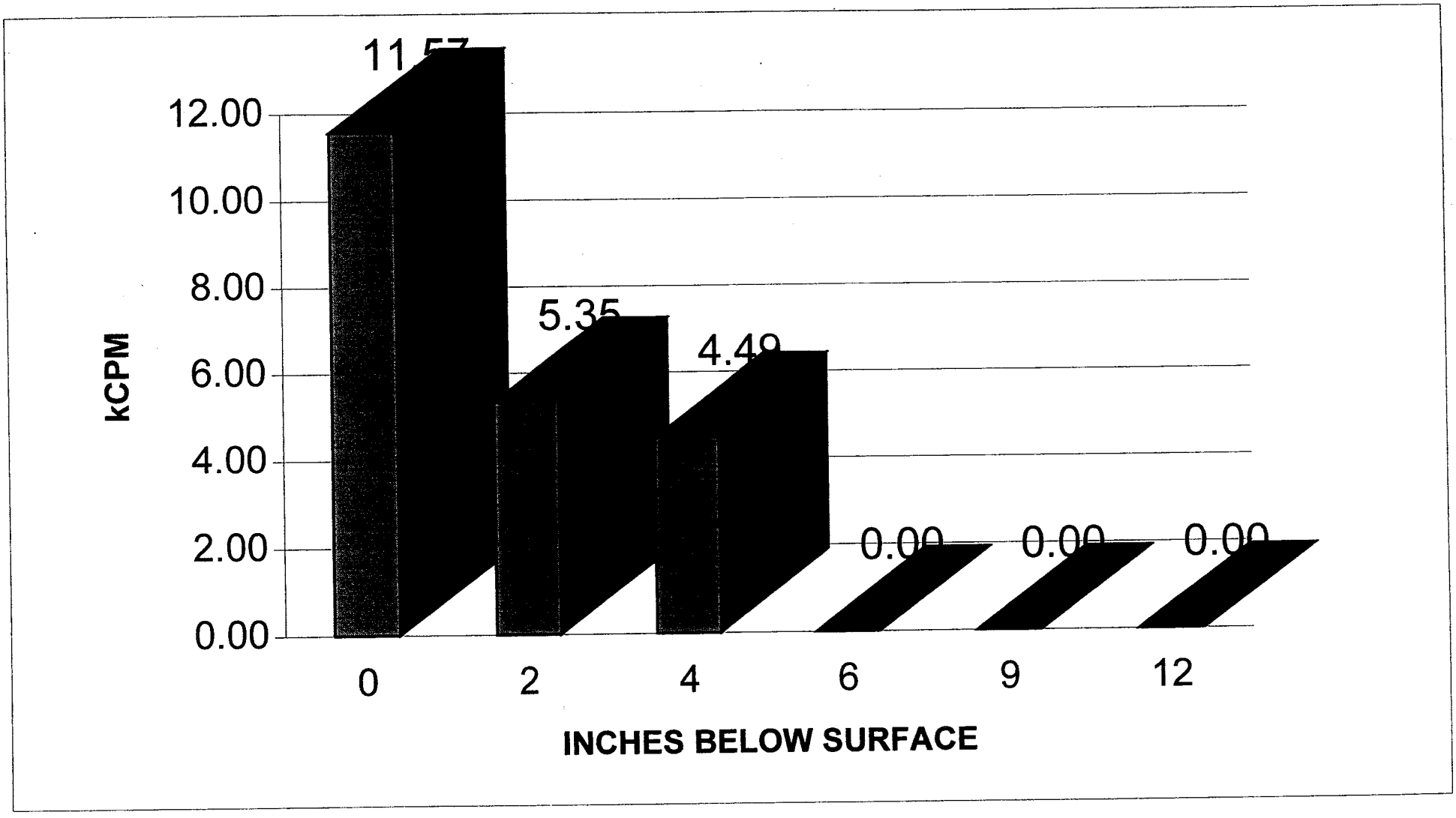
FIGURE 5
FIDLER DU TEST RESULTS
ALPHA BAG, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (BKG 3.50 uR/hr)
0" = 189.0 6" = 25.0
2" = 190.0 9" = 10.5
4" = 45.5 12" = 11.50

FIDLER BACKGROUND 3.34 kCPM

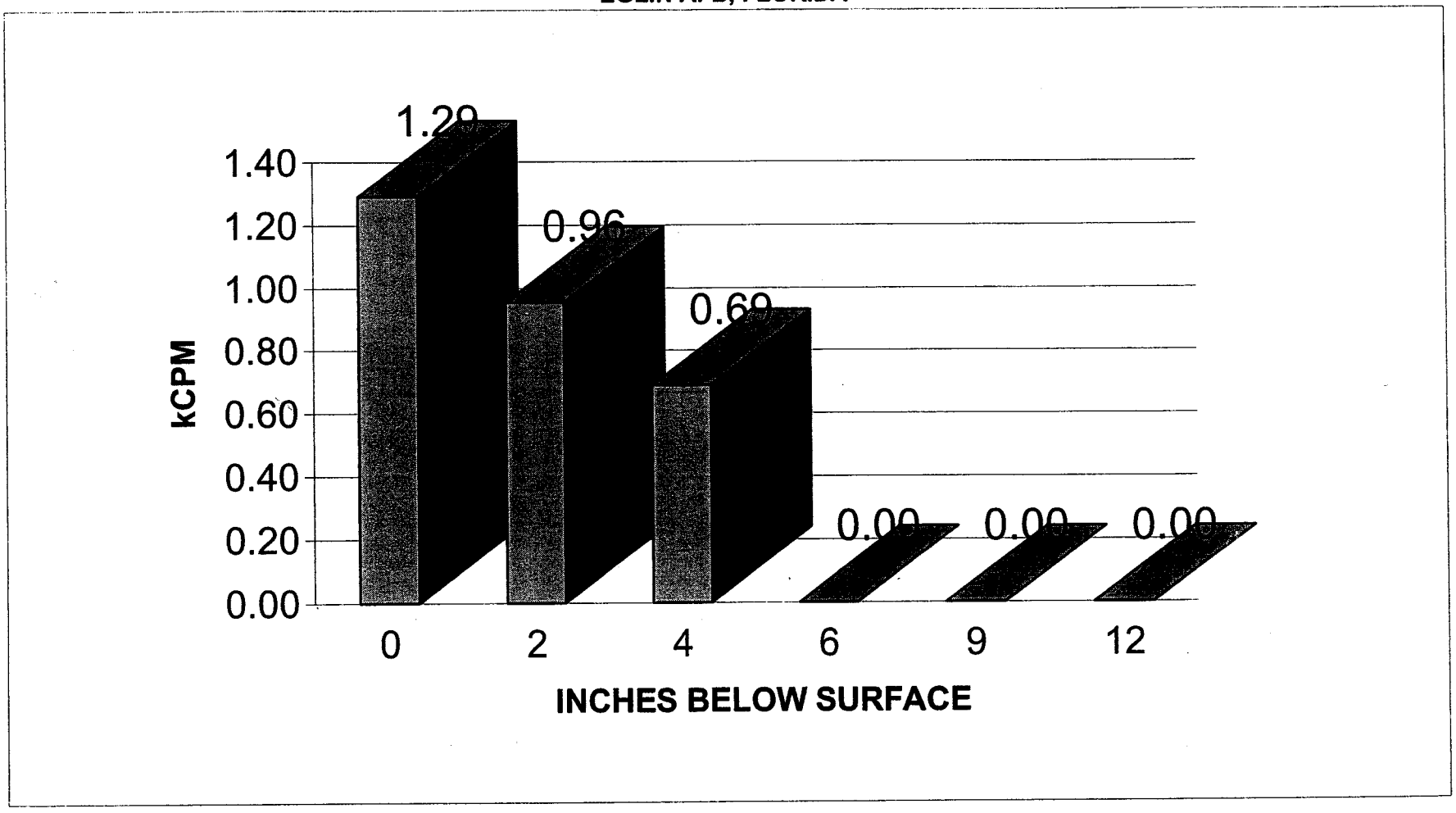
FIGURE 6
FIDLER DU TEST RESULTS
BETA BAG, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (BKG 3.5 uR/hr)
0" = 8.25
2" = 5.25
4" = 5.25

FIDLER BACKGROUND 3.34 kCPM

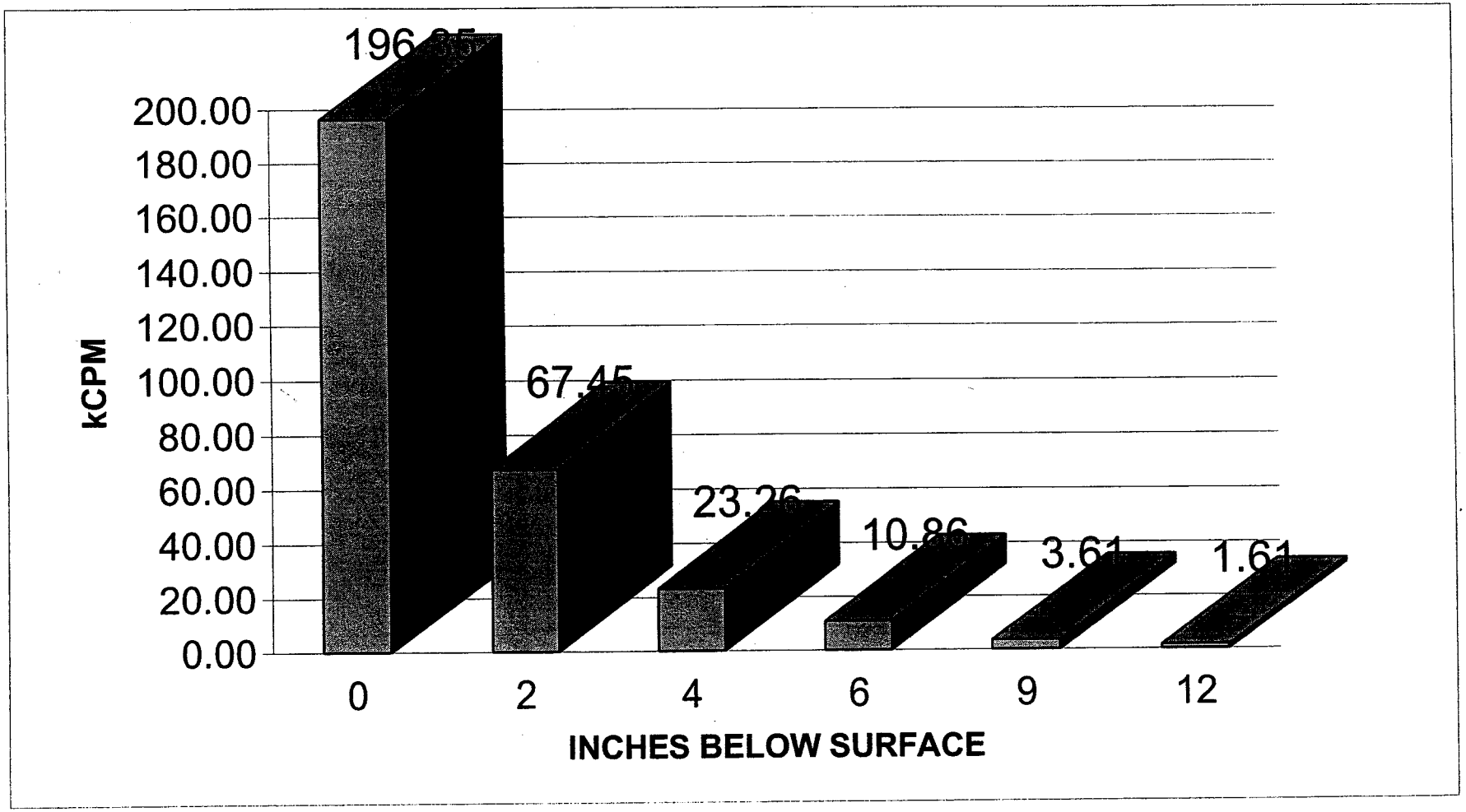
FIGURE 7
FIDLER DU TEST RESULTS
1 GRAM DU FLAKE, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (Bkg 8.75 uR/hr)
0" = 1.25

FIDLER BACKGROUND = 7.63 kCPM

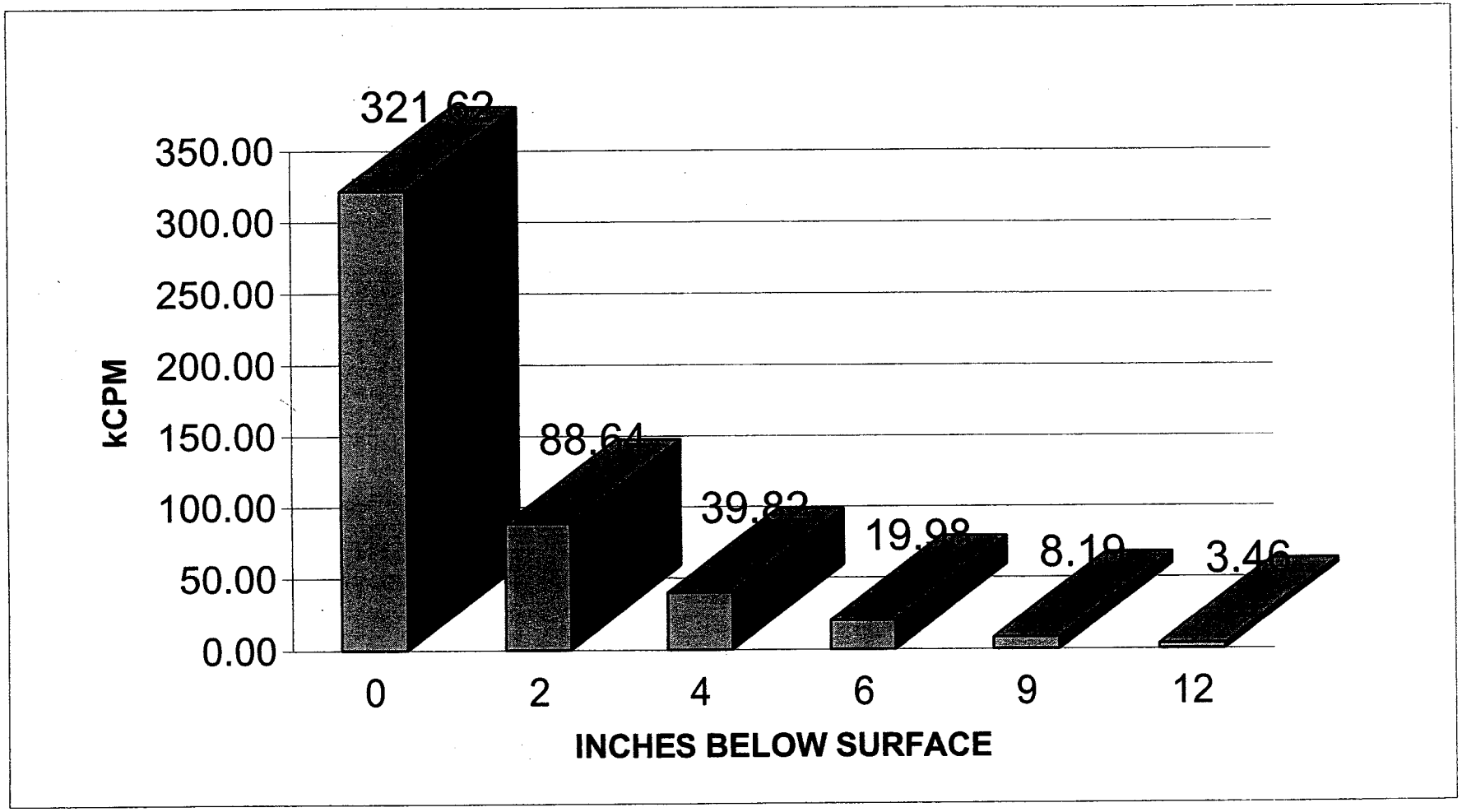
FIGURE 8
FIDLER DU TEST RESULTS
50 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (Bkg 8.75 uR/hr)
0" = 191.25 6" = 6.00
2" = 25.25 9" = 2.25
4" = 11.25

FIDLER BACKGROUND 7.63 kCPM

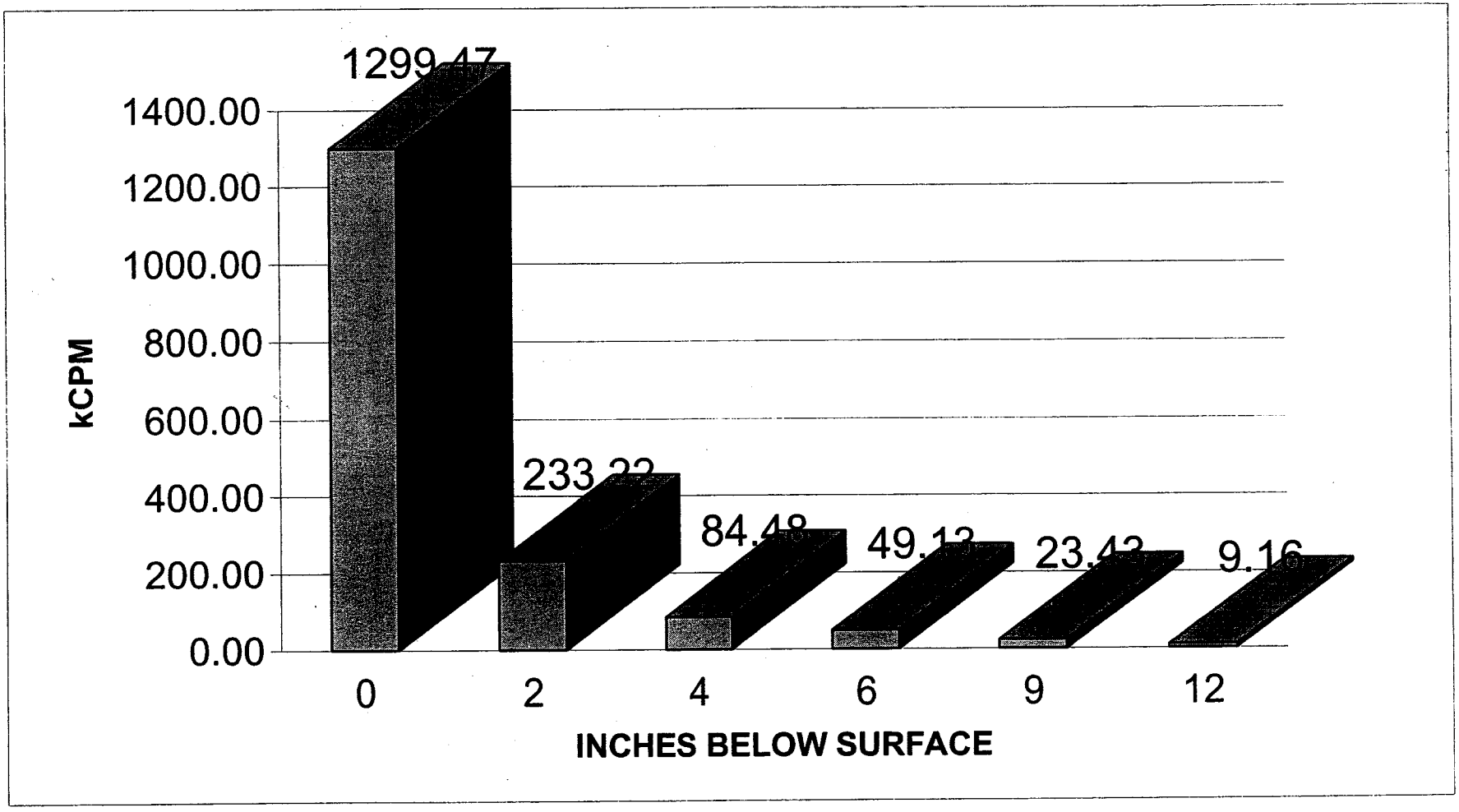
FIGURE 9
FIDLER DU TEST RESULTS
101 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS(BKG 8.75 uR/HR)
0" = 108.75 6" = 15.25
2" = 81.25 9" = 7.75
4" = 27.25

FIDLER BACKGROUND 7.63 kCPM

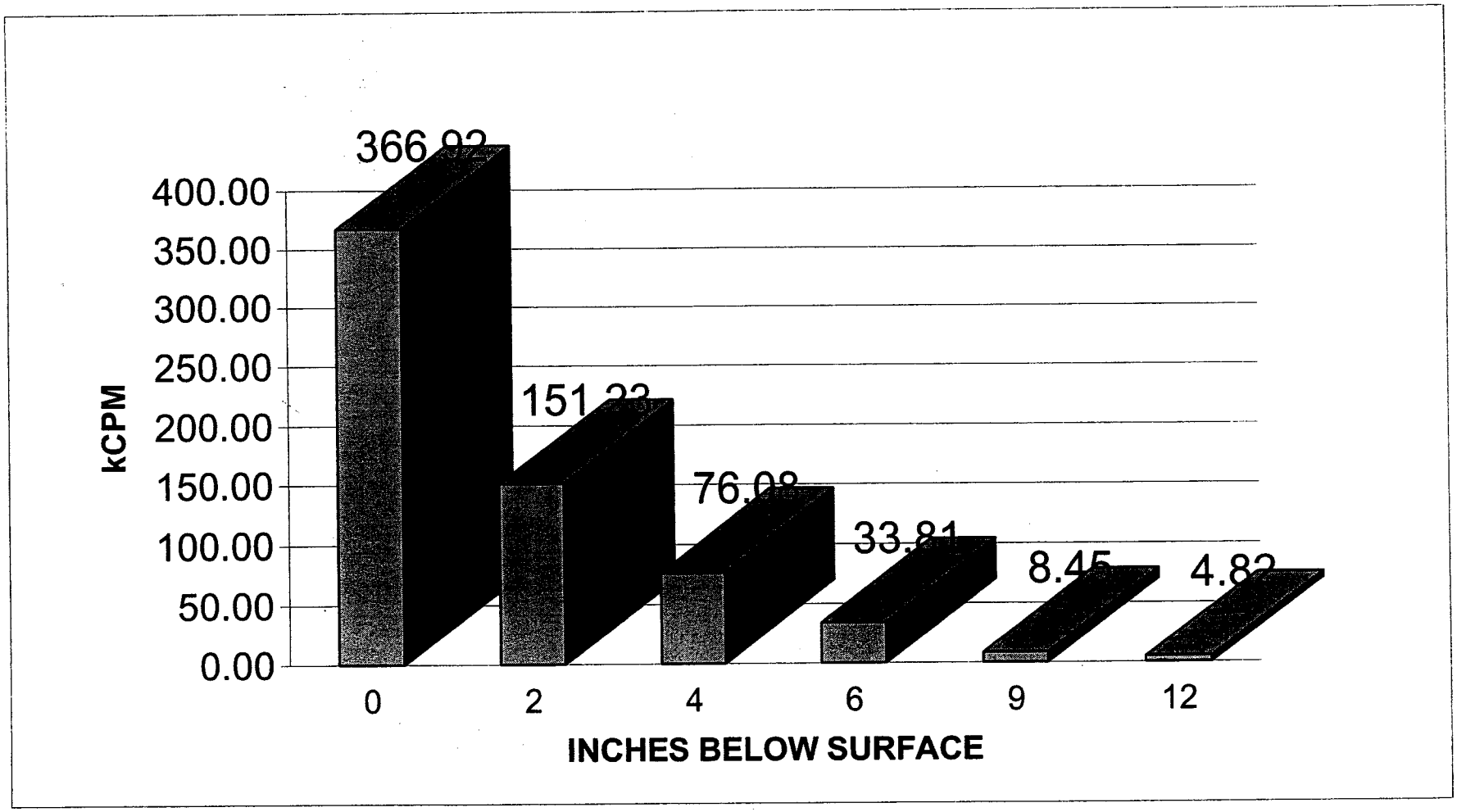
FIGURE 10
FIDLER DU TEST RESULTS
300 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (BKG 8.75 uR/hr)
0" = 268.75 6" = 28.75
2" = 117.75 9" = 13.75
4" = 48.75 12" = 5.25

FIDLER BACKGROUND 7.63 kCPM

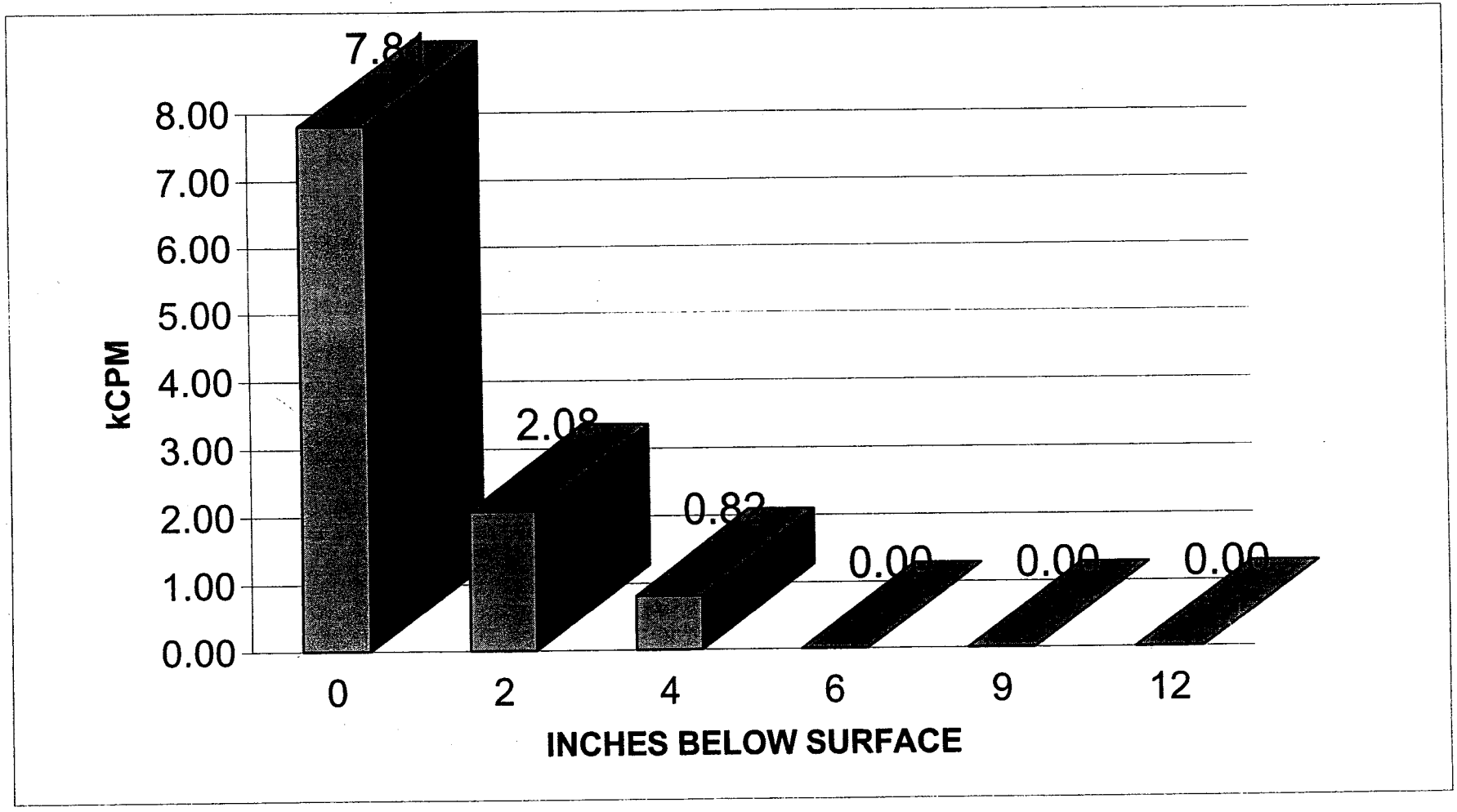
FIGURE 11
FIDLER DU TEST RESULTS
ALPHA BAG, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (BKG 8.75 uR/hr)
0" = 187.75 6" = 19.25
2" = 96.25 9" = 5.25
4" = 43.75 12" = 3.25

FIDLER BACKGROUND 7.63 kCPM

FIGURE 12
FIDLER DU TEST RESULTS
BETA BAG, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA



AVERAGE MICRO-R READINGS (BKG 8.75 uR/hr)
0" = 2.25
2" = 1.00
4" = 0.75

FIDLER BACKGROUND 7.63 kCPM

FIGURE 13
FIDLER RESPONSE
1 GRAM DU FRAGMENT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

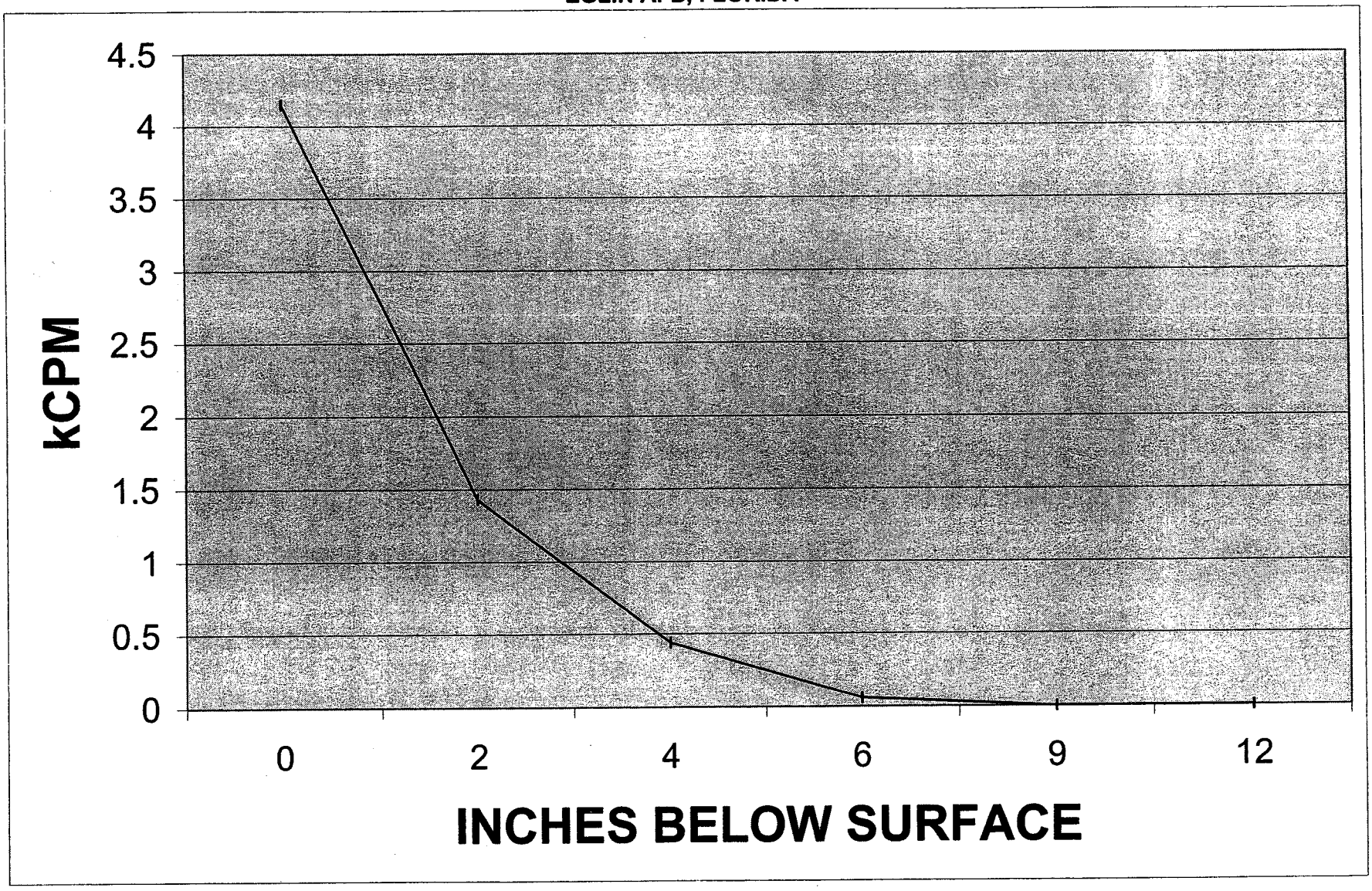


FIGURE 14
FIDLER RESPONSE
50 GRAM DU FRAGMENT, WHITE SAND
EGLIN AFB, FLORIDA

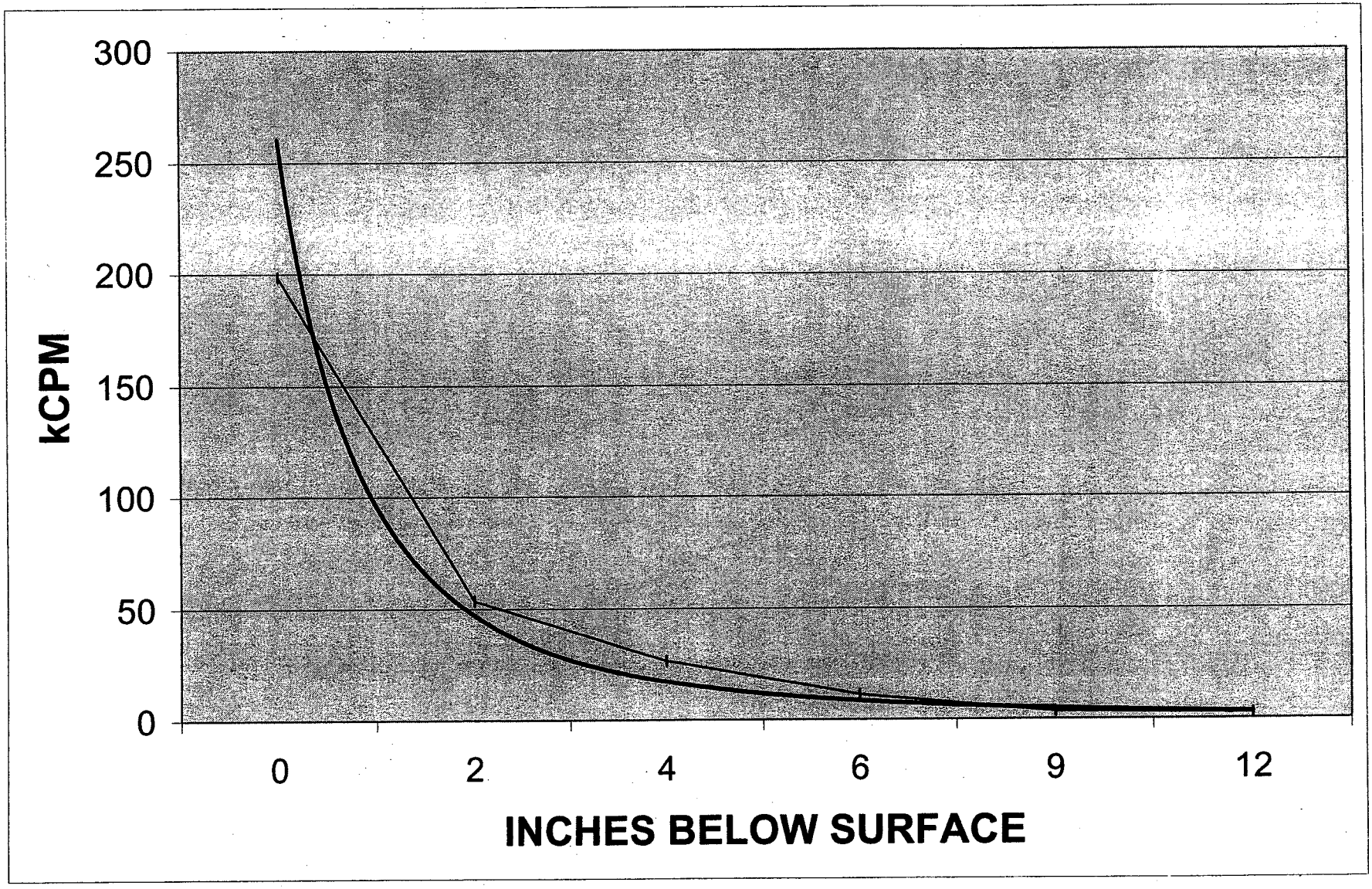


FIGURE 15
FIDLER RESPONSE
101 GRAM DU FRAGMENT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

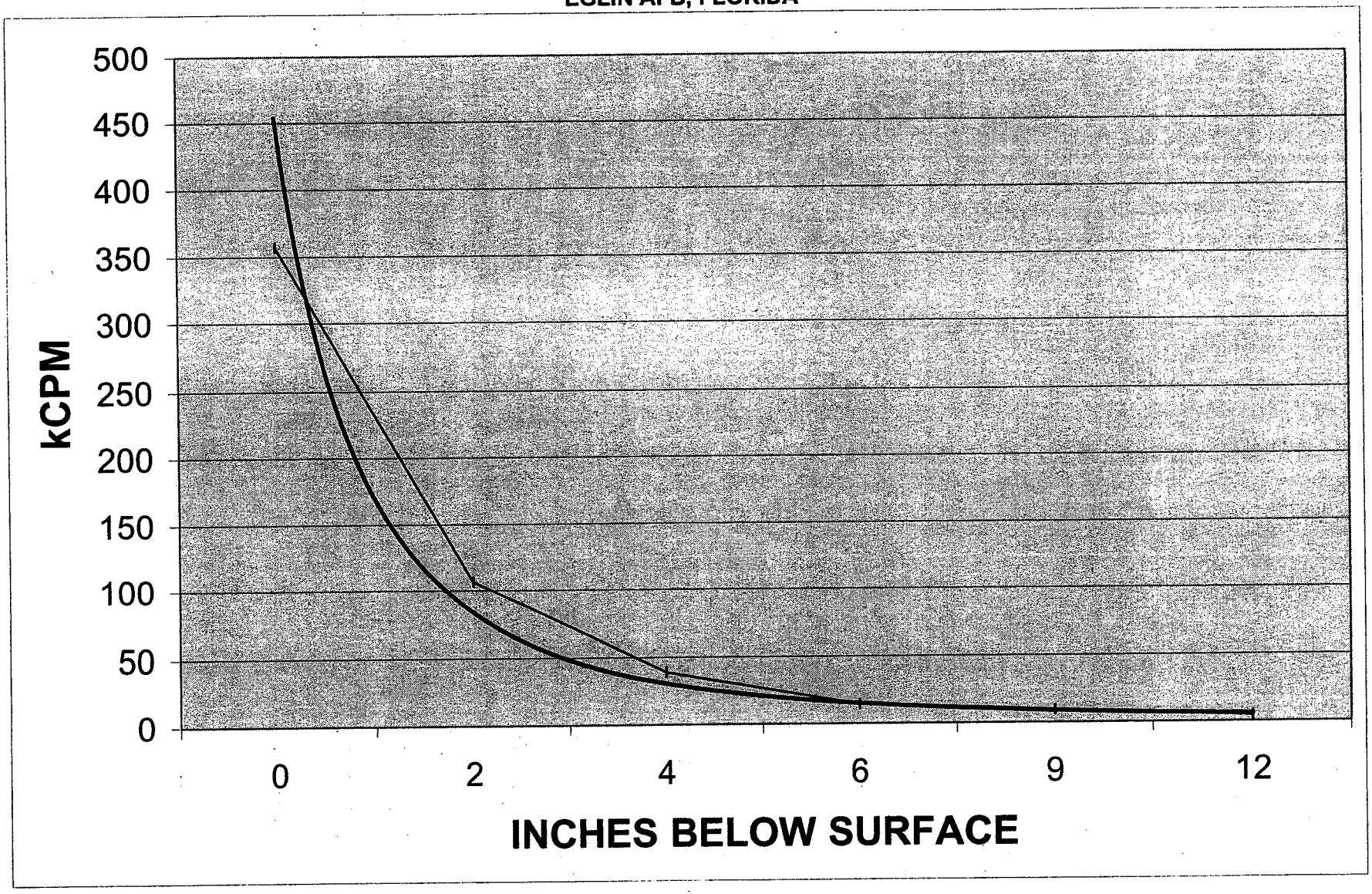


FIGURE 16
FIDLER RESPONSE
300 GRAM DU FRAGEMNT, WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

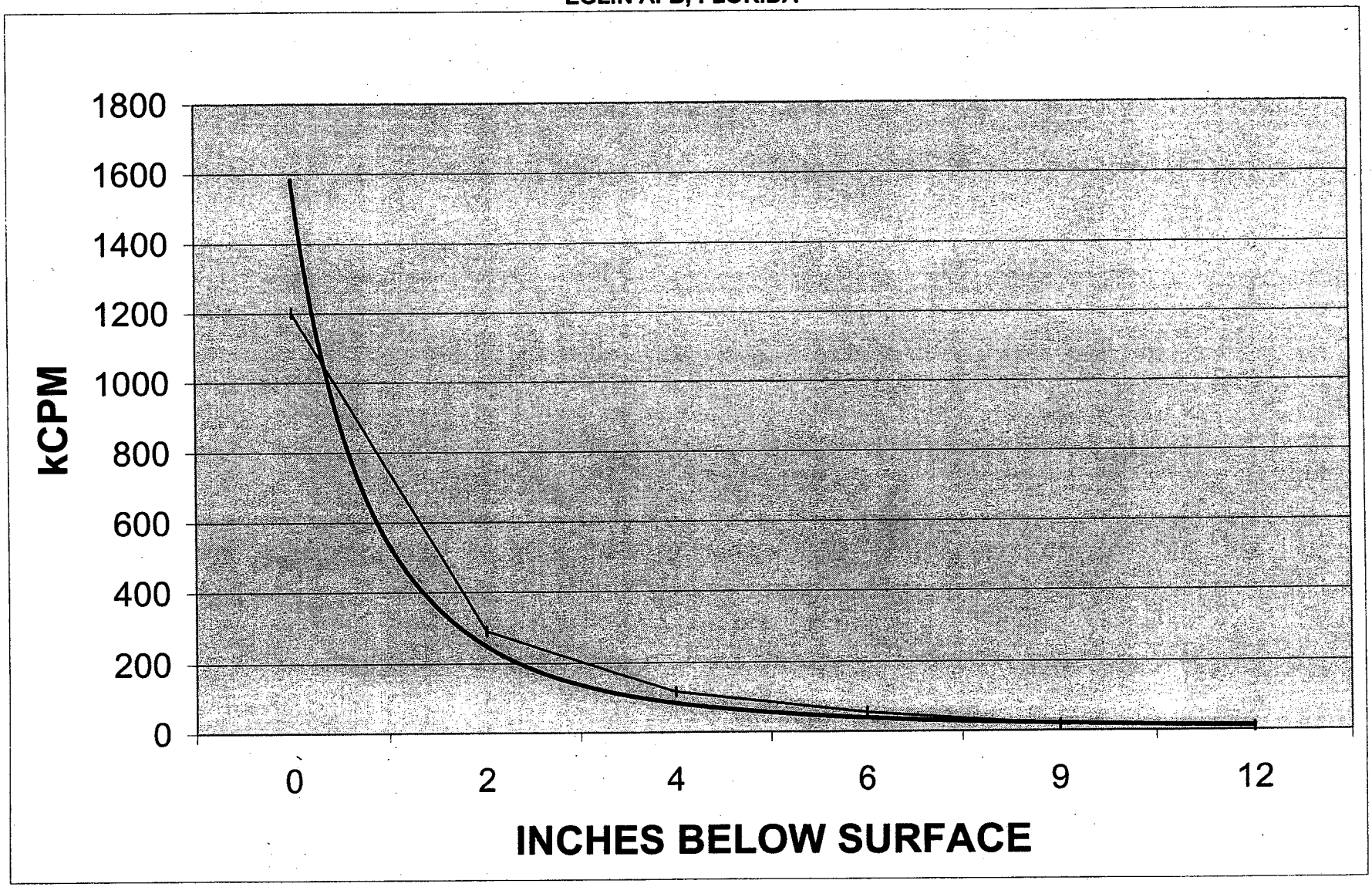


FIGURE 17
FIDLER RESPONSE
1 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

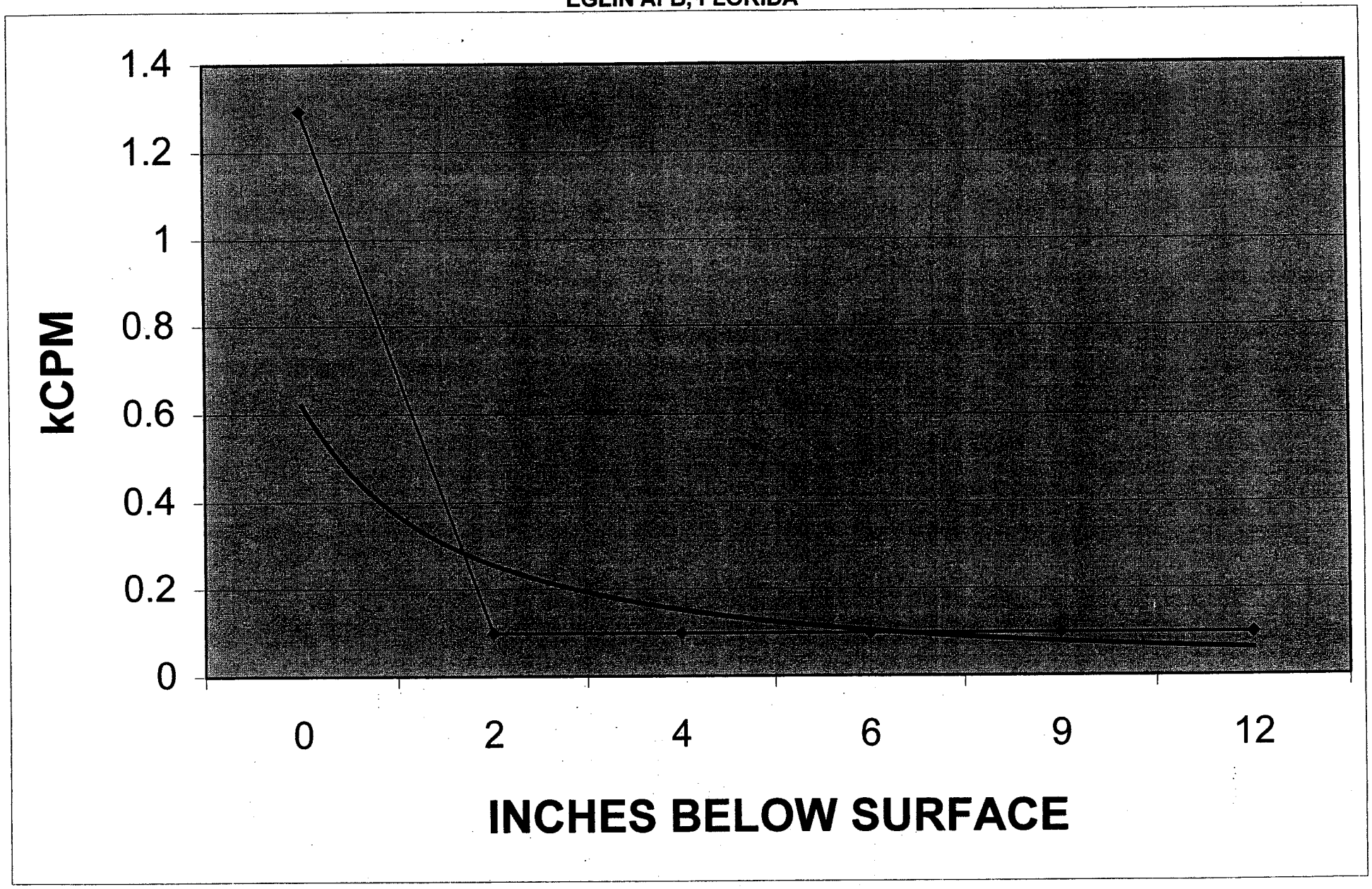


FIGURE 18
FIDLER RESPONSE
50 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATION
EGLIN AFB, FLORIDA

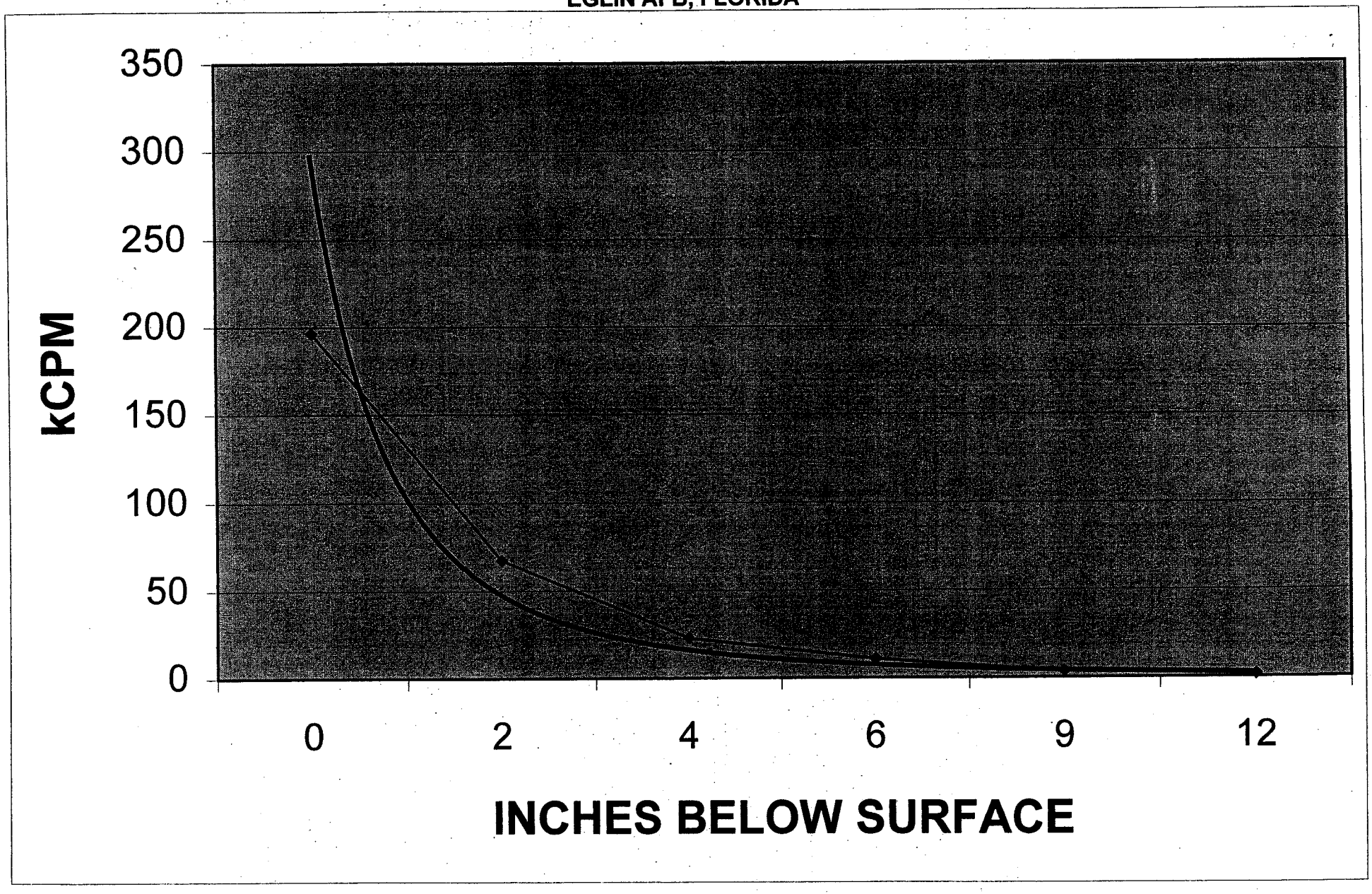


FIGURE 19
FIDLER RESPONSE
101 GRAM DU FRAGMENT,RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

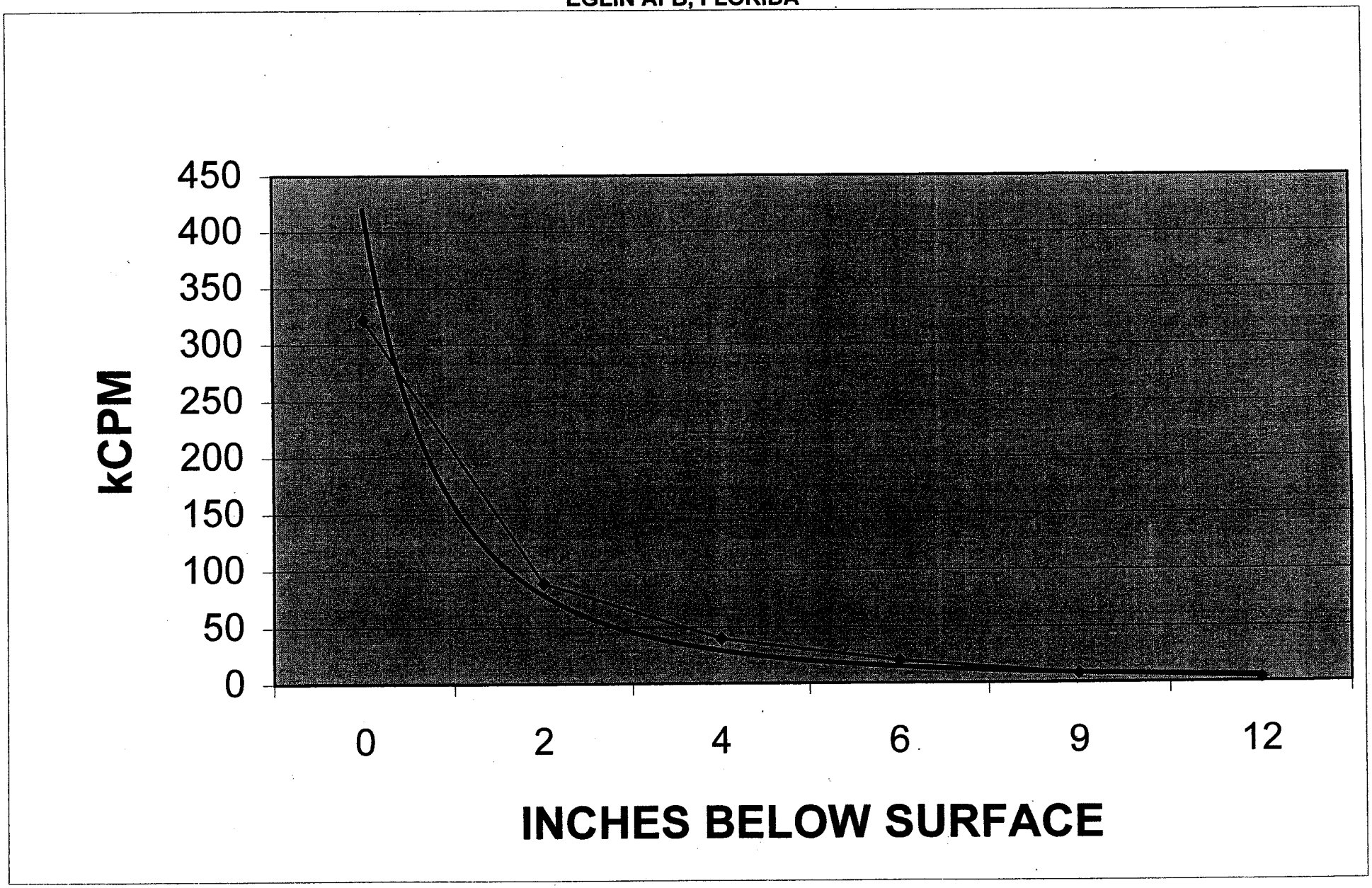


FIGURE 20
FIDLER RESPONSE
300 GRAM DU FRAGMENT, RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

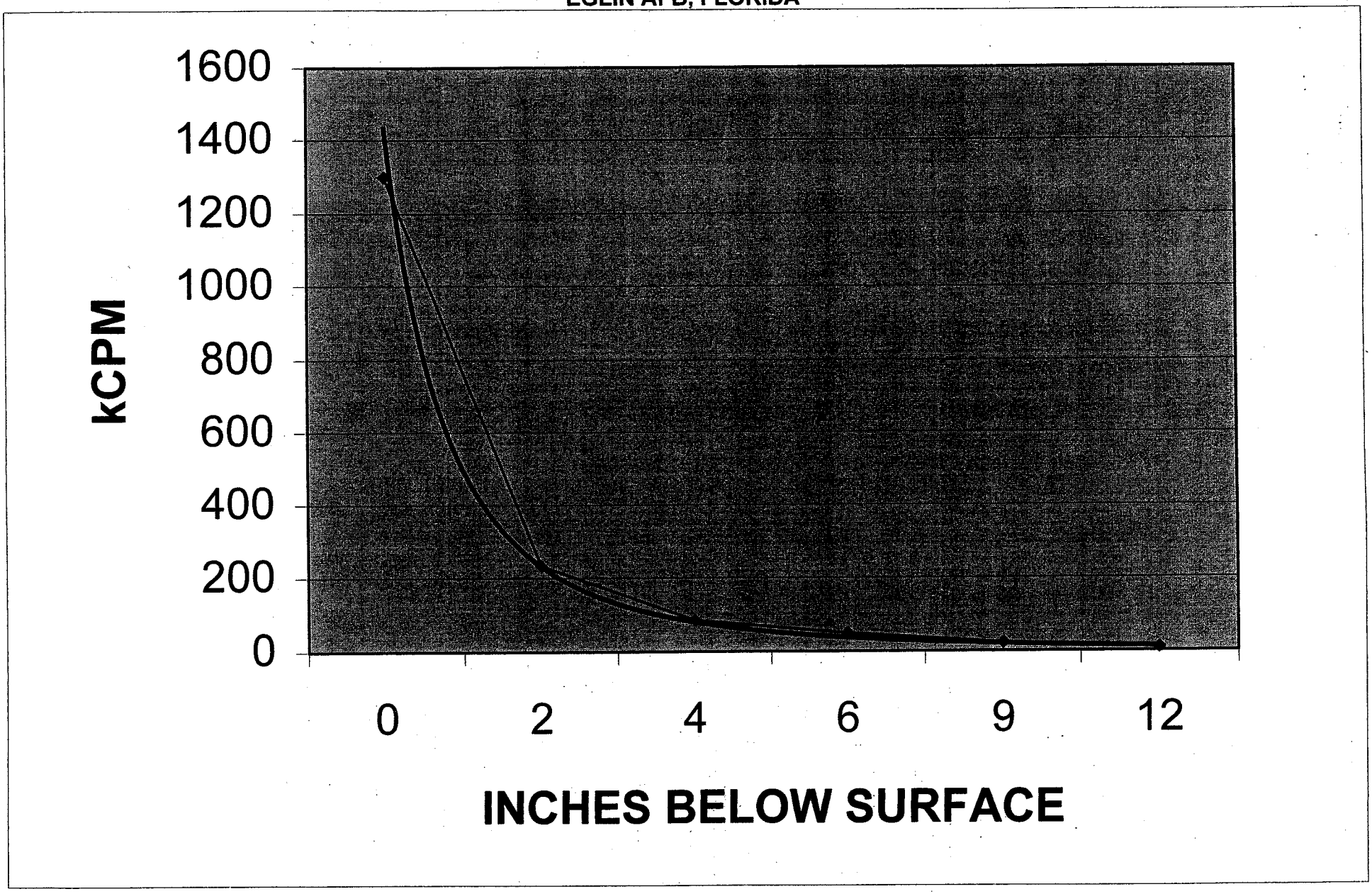


FIGURE 21
FIDLER EFFICIENCY - WHITE SAND
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

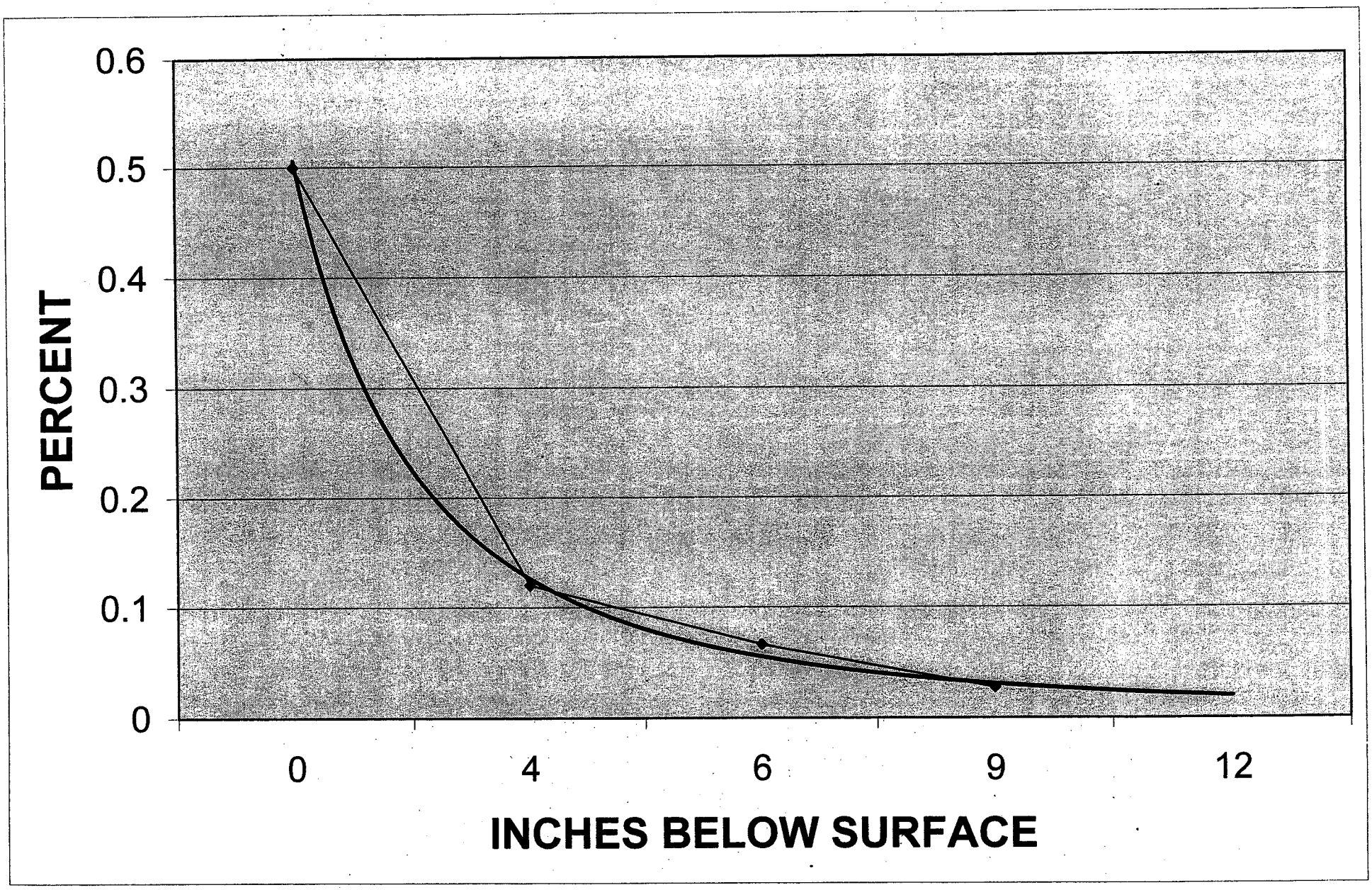


FIGURE 22
FIDLER EFFICIENCY - RED CLAY
LLRM INVESTIGATIONS
EGLIN AFB, FLORIDA

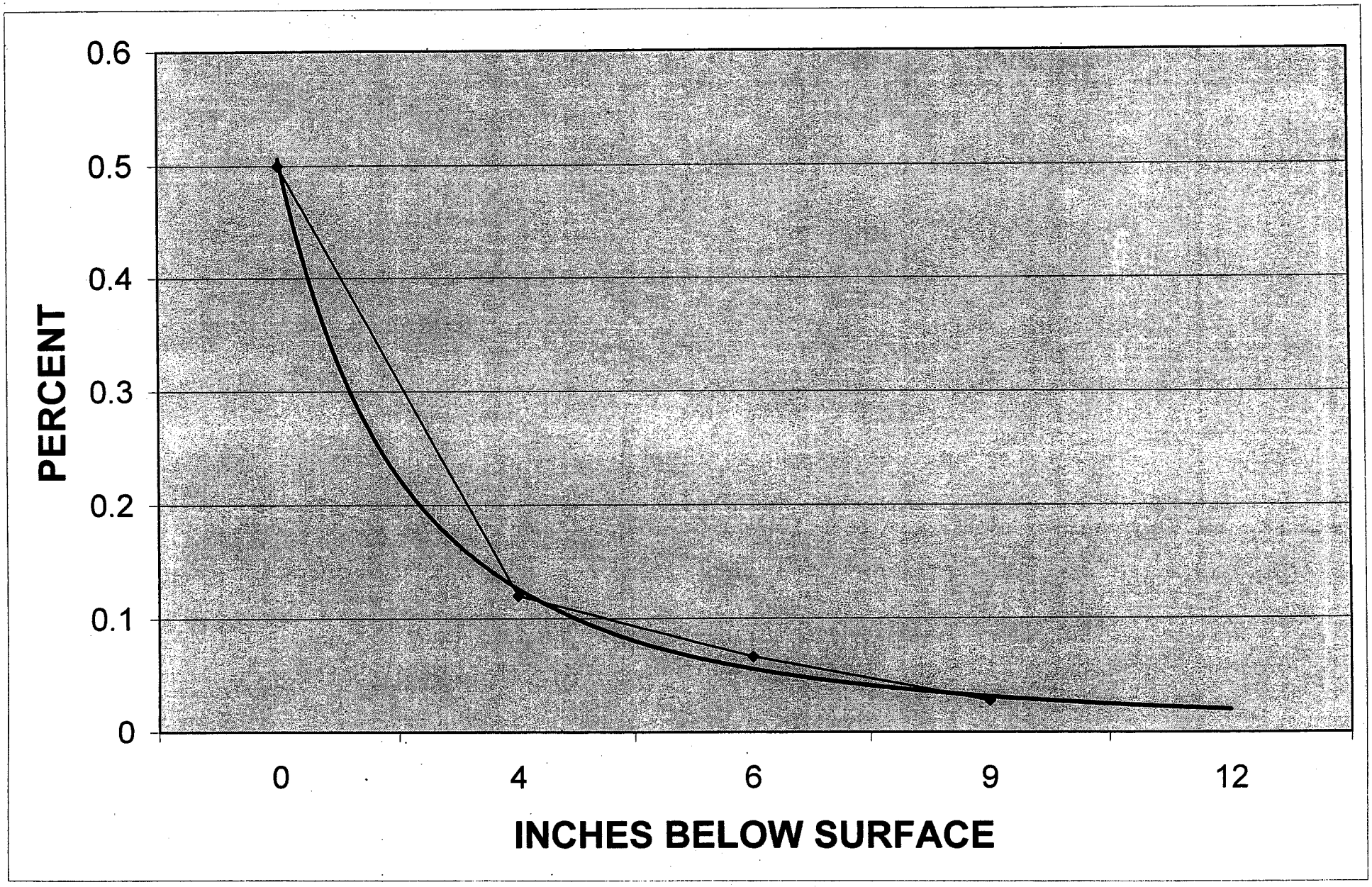


FIGURE 23

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY1-6.MS5
Run Date: January 20, 2000
Run Time: 1:00:05 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 1 gram DU
Description: WHITE SAND Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.1 cm	0.0 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	13.273 cm³	Uranium	18.75
Shield 1	15.24 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	3.5814e-011	1.3251e+000	2.6982e-006	9.9835e-002
Bi-214	3.7195e-011	1.3762e+000	2.8023e-006	1.0368e-001
Pa-234	1.1520e-010	4.2624e+000	8.6791e-006	3.2113e-001
Pa-234m	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002
Pb-210	3.5815e-011	1.3252e+000	2.6983e-006	9.9837e-002
Pb-214	3.7195e-011	1.3762e+000	2.8023e-006	1.0368e-001
Po-210	3.5791e-011	1.3243e+000	2.6965e-006	9.9770e-002
Po-214	3.7187e-011	1.3759e+000	2.8017e-006	1.0366e-001
Po-218	3.7203e-011	1.3765e+000	2.8028e-006	1.0370e-001
Ra-226	3.7203e-011	1.3765e+000	2.8029e-006	1.0371e-001
Rn-222	3.7203e-011	1.3765e+000	2.8028e-006	1.0370e-001
Th-230	1.3745e-010	5.0857e+000	1.0356e-005	3.8316e-001
Th-234	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002
U-234	1.0366e-008	3.8356e+002	7.8100e-004	2.8897e+001
U-238	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY1-6.MS5
Run Date: January 20, 2000
Run Time: 1:00:05 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	5.217e-03	2.019e-15	6.843e-15	8.932e-18	3.026e-17
0.05	5.215e-01	4.304e-11	2.271e-10	1.147e-13	6.049e-13
0.06	1.043e+02	1.240e-07	9.241e-07	2.463e-10	1.836e-09
0.08	4.104e+00	7.123e-08	7.749e-07	1.127e-10	1.226e-09
0.1	1.637e+02	1.176e-05	1.490e-04	1.799e-08	2.280e-07
0.15	1.347e+00	2.055e-07	2.794e-06	3.385e-10	4.601e-09
0.2	1.047e+00	5.469e-07	6.150e-06	9.653e-10	1.085e-08
0.3	5.936e-01	1.177e-06	8.712e-06	2.233e-09	1.653e-08
0.4	7.884e-01	3.253e-06	1.805e-05	6.338e-09	3.518e-08
0.5	4.133e-01	2.802e-06	1.265e-05	5.500e-09	2.483e-08
0.6	2.252e+00	2.223e-05	8.603e-05	4.338e-08	1.679e-07
0.8	8.974e+00	1.545e-04	4.805e-04	2.939e-07	9.139e-07
1.0	2.871e+01	7.438e-04	1.987e-03	1.371e-06	3.663e-06
1.5	8.585e-01	4.474e-05	9.426e-05	7.528e-08	1.586e-07
2.0	4.453e-01	3.670e-05	6.801e-05	5.676e-08	1.052e-07
TOTALS:	3.180e+02	1.022e-03	2.915e-03	1.874e-06	5.332e-06

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	5.217e-03	1.384e-16	4.671e-16	6.122e-19	2.066e-18
0.05	5.215e-01	2.775e-12	1.455e-11	7.393e-15	3.877e-14
0.06	1.043e+02	7.781e-09	5.755e-08	1.546e-11	1.143e-10
0.08	4.104e+00	4.369e-09	4.709e-08	6.914e-12	7.452e-11
0.1	1.637e+02	7.140e-07	8.944e-06	1.092e-09	1.368e-08
0.15	1.347e+00	1.239e-08	1.664e-07	2.040e-11	2.741e-10
0.2	1.047e+00	3.274e-08	3.630e-07	5.779e-11	6.408e-10
0.3	5.936e-01	6.978e-08	5.093e-07	1.324e-10	9.662e-10
0.4	7.884e-01	1.918e-07	1.051e-06	3.738e-10	2.048e-09
0.5	4.133e-01	1.647e-07	7.352e-07	3.233e-10	1.443e-09
0.6	2.252e+00	1.304e-06	4.993e-06	2.545e-09	9.746e-09
0.8	8.974e+00	9.035e-06	2.784e-05	1.719e-08	5.296e-08
1.0	2.871e+01	4.341e-05	1.150e-04	8.001e-08	2.120e-07
1.5	8.585e-01	2.603e-06	5.447e-06	4.379e-09	9.165e-09
2.0	4.453e-01	2.131e-06	3.927e-06	3.296e-09	6.072e-09
TOTALS:	3.180e+02	5.968e-05	1.691e-04	1.094e-07	3.092e-07

DOS File: CY1-6.MS5
Run Date: January 20, 2000
Run Time: 1:00:05 PM
Duration: 00:00:04

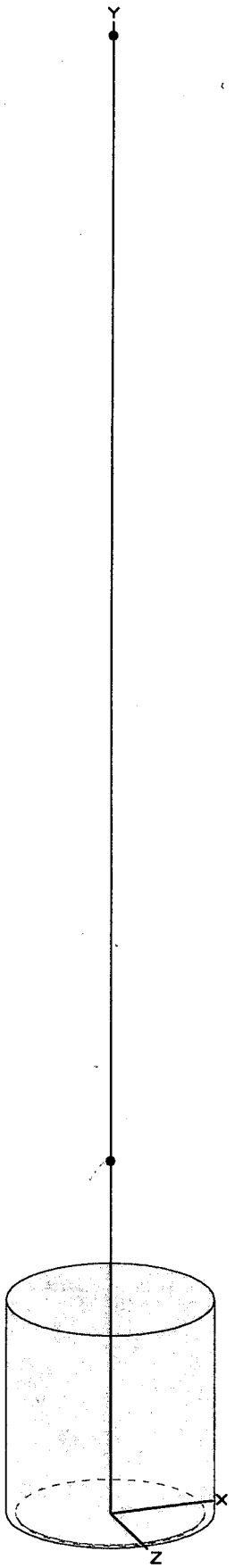


FIGURE 24

Page : 1
DOS File: CY1-12.MS5
Run Date: January 20, 2000
Run Time: 12:54:49 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 1 gram DU
Description: White Sand Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.1 cm	0.0 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in
# 2	0 cm	121.92 cm	0 cm
	0.0 in	4 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	13.273 cm³	Uranium	18.75
Shield 1	30.48 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	3.5814e-011	1.3251e+000	2.6982e-006	9.9835e-002
Bi-214	3.7195e-011	1.3762e+000	2.8023e-006	1.0368e-001
Pa-234	1.1520e-010	4.2624e+000	8.6791e-006	3.2113e-001
Pa-234m	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002
Pb-210	3.5815e-011	1.3252e+000	2.6983e-006	9.9837e-002
Pb-214	3.7195e-011	1.3762e+000	2.8023e-006	1.0368e-001
Po-210	3.5791e-011	1.3243e+000	2.6965e-006	9.9770e-002
Po-214	3.7187e-011	1.3759e+000	2.8017e-006	1.0366e-001
Po-218	3.7203e-011	1.3765e+000	2.8028e-006	1.0370e-001
Ra-226	3.7203e-011	1.3765e+000	2.8029e-006	1.0371e-001
Rn-222	3.7203e-011	1.3765e+000	2.8028e-006	1.0370e-001
Th-230	1.3745e-010	5.0857e+000	1.0356e-005	3.8316e-001
Th-234	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002
U-234	1.0366e-008	3.8356e+002	7.8100e-004	2.8897e+001
U-238	7.2000e-008	2.6640e+003	5.4245e-003	2.0070e+002

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY1-12.MS5
Run Date: January 20, 2000
Run Time: 12:54:49 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,40.48,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	5.217e-03	2.919e-21	1.263e-20	1.291e-23	5.586e-23
0.05	5.215e-01	5.441e-15	4.184e-14	1.449e-17	1.115e-16
0.06	1.043e+02	1.123e-10	1.362e-09	2.230e-13	2.706e-12
0.08	4.104e+00	3.232e-10	6.579e-09	5.115e-13	1.041e-11
0.1	1.637e+02	1.018e-07	2.701e-06	1.557e-10	4.132e-09
0.15	1.347e+00	3.473e-09	1.075e-07	5.720e-12	1.770e-10
0.2	1.047e+00	1.281e-08	3.406e-07	2.260e-11	6.012e-10
0.3	5.936e-01	4.086e-08	7.186e-07	7.751e-11	1.363e-09
0.4	7.884e-01	1.463e-07	1.856e-06	2.851e-10	3.617e-09
0.5	4.133e-01	1.525e-07	1.500e-06	2.994e-10	2.943e-09
0.6	2.252e+00	1.405e-06	1.128e-05	2.742e-09	2.201e-08
0.8	8.974e+00	1.221e-05	7.262e-05	2.323e-08	1.381e-07
1.0	2.871e+01	6.917e-05	3.310e-04	1.275e-07	6.102e-07
1.5	8.585e-01	5.440e-06	1.834e-05	9.152e-09	3.086e-08
2.0	4.453e-01	5.244e-06	1.448e-05	8.110e-09	2.239e-08
TOTALS:	3.180e+02	9.393e-05	4.550e-04	1.716e-07	8.364e-07

Results - Dose Point # 2 - (0,121.92,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	5.217e-03	3.663e-22	1.583e-21	1.620e-24	7.000e-24
0.05	5.215e-01	6.527e-16	5.007e-15	1.739e-18	1.334e-17
0.06	1.043e+02	1.320e-11	1.597e-10	2.622e-14	3.172e-13
0.08	4.104e+00	3.739e-11	7.581e-10	5.918e-14	1.200e-12
0.1	1.637e+02	1.169e-08	3.088e-07	1.789e-11	4.725e-10
0.15	1.347e+00	3.970e-10	1.222e-08	6.537e-13	2.012e-11
0.2	1.047e+00	1.458e-09	3.856e-08	2.574e-12	6.806e-11
0.3	5.936e-01	4.630e-09	8.097e-08	8.783e-12	1.536e-10
0.4	7.884e-01	1.653e-08	2.087e-07	3.221e-11	4.066e-10
0.5	4.133e-01	1.721e-08	1.683e-07	3.378e-11	3.305e-10
0.6	2.252e+00	1.583e-07	1.265e-06	3.089e-10	2.469e-09
0.8	8.974e+00	1.373e-06	8.134e-06	2.612e-09	1.547e-08
1.0	2.871e+01	7.770e-06	3.705e-05	1.432e-08	6.829e-08
1.5	8.585e-01	6.098e-07	2.050e-06	1.026e-09	3.450e-09
2.0	4.453e-01	5.872e-07	1.617e-06	9.080e-10	2.501e-09
TOTALS:	3.180e+02	1.055e-05	5.093e-05	1.927e-08	9.363e-08

DOS File: CY1-12.MS5
Run Date: January 20, 2000
Run Time: 12:54:49 PM
Duration: 00:00:04

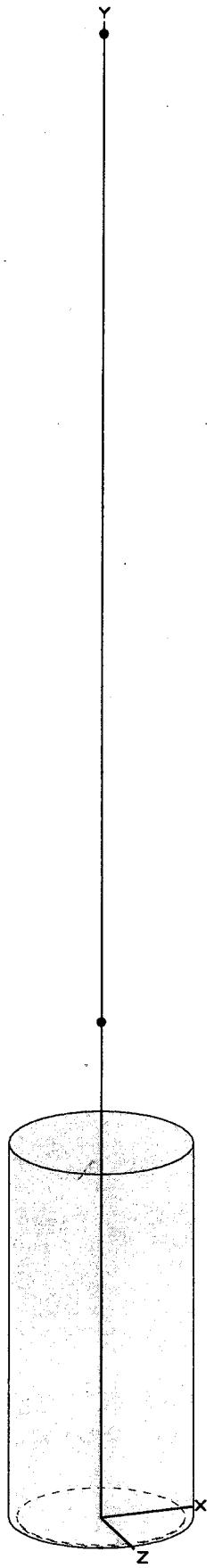


FIGURE 25

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY50-6.MS5
Run Date: January 20, 2000
Run Time: 1:10:03 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 50gram DU
Description: White Sand Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	15.24 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	2.7146e-011	1.0044e+000	4.0903e-007	1.5134e-002
Bi-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Pa-234	2.8800e-008	1.0656e+003	4.3396e-004	1.6056e+001
Pa-234m	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
Pb-210	2.7148e-011	1.0045e+000	4.0906e-007	1.5135e-002
Pb-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Po-210	2.7102e-011	1.0028e+000	4.0837e-007	1.5110e-002
Po-214	2.9753e-011	1.1009e+000	4.4832e-007	1.6588e-002
Po-218	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Ra-226	2.9767e-011	1.1014e+000	4.4852e-007	1.6595e-002
Rn-222	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Th-230	2.2873e-010	8.4631e+000	3.4465e-006	1.2752e-001
Th-234	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
U-234	5.0952e-008	1.8852e+003	7.6774e-004	2.8406e+001
U-238	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY50-6.MS5
Run Date: January 20, 2000
Run Time: 1:10:03 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	1.034e-13	3.505e-13	4.573e-16	1.550e-15
0.05	2.277e+00	3.861e-11	2.038e-10	1.028e-13	5.428e-13
0.06	2.607e+04	6.373e-06	4.750e-05	1.266e-08	9.436e-08
0.08	9.470e+02	3.392e-06	3.704e-05	5.367e-09	5.861e-08
0.1	4.088e+04	6.282e-04	8.253e-03	9.610e-07	1.263e-05
0.15	3.360e+02	1.065e-05	1.476e-04	1.753e-08	2.431e-07
0.2	2.249e+02	2.675e-05	3.372e-04	4.721e-08	5.951e-07
0.3	7.762e+01	5.181e-05	4.976e-04	9.828e-08	9.439e-07
0.4	6.585e+01	1.268e-04	9.108e-04	2.471e-07	1.775e-06
0.5	9.719e+01	3.745e-04	2.107e-03	7.352e-07	4.136e-06
0.6	3.976e+02	2.512e-03	1.171e-02	4.902e-06	2.285e-05
0.8	2.211e+03	2.767e-02	9.906e-02	5.264e-05	1.884e-04
1.0	7.069e+03	1.422e-01	4.258e-01	2.621e-04	7.848e-04
1.5	1.493e+02	6.479e-03	1.486e-02	1.090e-05	2.501e-05
2.0	1.953e+01	1.370e-03	2.735e-03	2.119e-06	4.229e-06
TOTALS:	7.855e+04	1.814e-01	5.665e-01	3.348e-04	1.046e-03

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	6.968e-15	2.352e-14	3.082e-17	1.040e-16
0.05	2.277e+00	2.442e-12	1.281e-11	6.506e-15	3.412e-14
0.06	2.607e+04	3.919e-07	2.899e-06	7.785e-10	5.757e-09
0.08	9.470e+02	2.038e-07	2.205e-06	3.225e-10	3.489e-09
0.1	4.088e+04	3.741e-05	4.864e-04	5.724e-08	7.441e-07
0.15	3.360e+02	6.286e-07	8.616e-06	1.035e-09	1.419e-08
0.2	2.249e+02	1.573e-06	1.961e-05	2.776e-09	3.461e-08
0.3	7.762e+01	3.037e-06	2.889e-05	5.760e-09	5.481e-08
0.4	6.585e+01	7.426e-06	5.285e-05	1.447e-08	1.030e-07
0.5	9.719e+01	2.190e-05	1.221e-04	4.299e-08	2.397e-07
0.6	3.976e+02	1.467e-04	6.778e-04	2.863e-07	1.323e-06
0.8	2.211e+03	1.613e-03	5.727e-03	3.067e-06	1.089e-05
1.0	7.069e+03	8.271e-03	2.459e-02	1.525e-05	4.533e-05
1.5	1.493e+02	3.758e-04	8.570e-04	6.323e-07	1.442e-06
2.0	1.953e+01	7.934e-05	1.576e-04	1.227e-07	2.436e-07
TOTALS:	7.855e+04	1.056e-02	3.274e-02	1.948e-05	6.043e-05

DOS File: CY50-6.MS5
Run Date: January 20, 2000
Run Time: 1:10:03 PM
Duration: 00:00:04

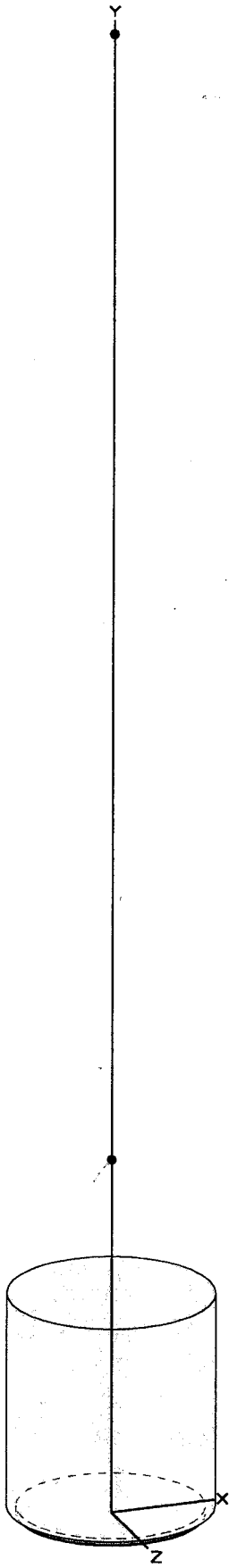


FIGURE 26

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY50-12.MS5
Run Date: January 20, 2000
Run Time: 1:09:09 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 50gram DU
Description: White Sand Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in
# 2	0 cm	121.92 cm	0 cm
	0.0 in	4 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	30.48 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	2.7146e-011	1.0044e+000	4.0903e-007	1.5134e-002
Bi-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Pa-234	2.8800e-008	1.0656e+003	4.3396e-004	1.6056e+001
Pa-234m	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
Pb-210	2.7148e-011	1.0045e+000	4.0906e-007	1.5135e-002
Pb-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Po-210	2.7102e-011	1.0028e+000	4.0837e-007	1.5110e-002
Po-214	2.9753e-011	1.1009e+000	4.4832e-007	1.6588e-002
Po-218	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Ra-226	2.9767e-011	1.1014e+000	4.4852e-007	1.6595e-002
Rn-222	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Th-230	2.2873e-010	8.4631e+000	3.4465e-006	1.2752e-001
Th-234	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
U-234	5.0952e-008	1.8852e+003	7.6774e-004	2.8406e+001
U-238	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY50-12.MS5
Run Date: January 20, 2000
Run Time: 1:09:09 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,40.48,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	1.483e-19	6.416e-19	6.557e-22	2.838e-21
0.05	2.277e+00	4.837e-15	3.720e-14	1.288e-17	9.909e-17
0.06	2.607e+04	5.715e-09	6.936e-08	1.135e-11	1.378e-10
0.08	9.470e+02	1.524e-08	3.110e-07	2.412e-11	4.921e-10
0.1	4.088e+04	5.388e-06	1.464e-04	8.243e-09	2.240e-07
0.15	3.360e+02	1.782e-07	5.584e-06	2.934e-10	9.195e-09
0.2	2.249e+02	6.215e-07	1.784e-05	1.097e-09	3.149e-08
0.3	7.762e+01	1.793e-06	3.764e-05	3.401e-09	7.141e-08
0.4	6.585e+01	5.711e-06	8.646e-05	1.113e-08	1.685e-07
0.5	9.719e+01	2.047e-05	2.339e-04	4.017e-08	4.591e-07
0.6	3.976e+02	1.595e-04	1.459e-03	3.114e-07	2.847e-06
0.8	2.211e+03	2.202e-03	1.447e-02	4.188e-06	2.752e-05
1.0	7.069e+03	1.332e-02	6.922e-02	2.455e-05	1.276e-04
1.5	1.493e+02	7.941e-04	2.848e-03	1.336e-06	4.792e-06
2.0	1.953e+01	1.974e-04	5.757e-04	3.052e-07	8.902e-07
TOTALS:	7.855e+04	1.671e-02	8.910e-02	3.076e-05	1.646e-04

Results - Dose Point # 2 - (0,121.92,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	1.842e-20	7.960e-20	8.147e-23	3.520e-22
0.05	2.277e+00	5.739e-16	4.402e-15	1.529e-18	1.173e-17
0.06	2.607e+04	6.644e-10	8.037e-09	1.320e-12	1.596e-11
0.08	9.470e+02	1.743e-09	3.541e-08	2.758e-12	5.604e-11
0.1	4.088e+04	6.121e-07	1.656e-05	9.365e-10	2.534e-08
0.15	3.360e+02	2.012e-08	6.275e-07	3.313e-11	1.033e-09
0.2	2.249e+02	7.001e-08	2.000e-06	1.236e-10	3.529e-09
0.3	7.762e+01	2.013e-07	4.205e-06	3.819e-10	7.976e-09
0.4	6.585e+01	6.394e-07	9.628e-06	1.246e-09	1.876e-08
0.5	9.719e+01	2.286e-06	2.599e-05	4.487e-09	5.102e-08
0.6	3.976e+02	1.779e-05	1.619e-04	3.472e-08	3.159e-07
0.8	2.211e+03	2.449e-04	1.602e-03	4.658e-07	3.047e-06
1.0	7.069e+03	1.479e-03	7.657e-03	2.727e-06	1.411e-05
1.5	1.493e+02	8.798e-05	3.145e-04	1.480e-07	5.292e-07
2.0	1.953e+01	2.184e-05	6.352e-05	3.377e-08	9.823e-08
TOTALS:	7.855e+04	1.856e-03	9.858e-03	3.416e-06	1.821e-05

DOS File: CY50-12.MS5
Run Date: January 20, 2000
Run Time: 1:09:09 PM
Duration: 00:00:04

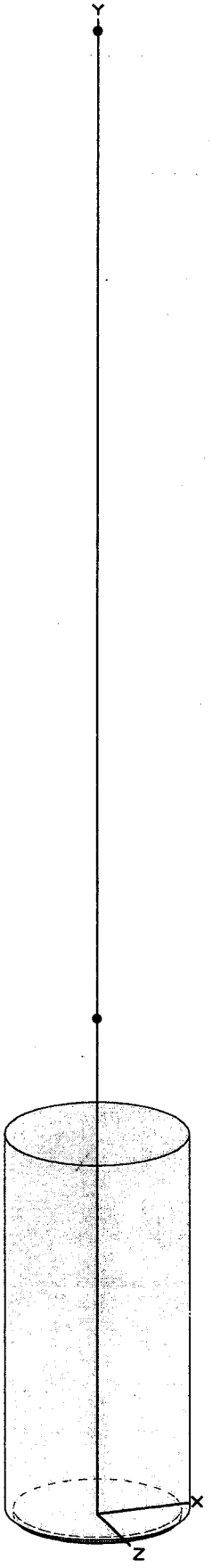


FIGURE 27

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY30-6.MS5
Run Date: January 20, 2000
Run Time: 1:02:35 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 300gram DU
Description: White Sand Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	15.24 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	1.6693e-009	6.1765e+001	2.5153e-005	9.3067e-001
Bi-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Pa-234	1.7280e-007	6.3936e+003	2.6037e-003	9.6338e+001
Pa-234m	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
Pb-210	1.6694e-009	6.1766e+001	2.5154e-005	9.3069e-001
Pb-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Po-210	1.6682e-009	6.1723e+001	2.5136e-005	9.3004e-001
Po-214	1.7353e-009	6.4207e+001	2.6148e-005	9.6747e-001
Po-218	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Ra-226	1.7361e-009	6.4235e+001	2.6159e-005	9.6788e-001
Rn-222	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Th-230	6.5998e-009	2.4419e+002	9.9445e-005	3.6795e+000
Th-234	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
U-234	6.6126e-007	2.4467e+004	9.9638e-003	3.6866e+002
U-238	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY30-6.MS5
Run Date: January 20, 2000
Run Time: 1:02:35 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	6.204e-13	2.103e-12	2.744e-15	9.301e-15
0.05	3.208e+01	5.439e-10	2.870e-09	1.449e-12	7.646e-12
0.06	1.564e+05	3.824e-05	2.850e-04	7.595e-08	5.661e-07
0.08	5.695e+03	2.040e-05	2.227e-04	3.228e-08	3.525e-07
0.1	2.453e+05	3.769e-03	4.952e-02	5.766e-06	7.576e-05
0.15	2.016e+03	6.389e-05	8.857e-04	1.052e-07	1.458e-06
0.2	1.356e+03	1.612e-04	2.032e-03	2.846e-07	3.587e-06
0.3	4.776e+02	3.188e-04	3.062e-03	6.047e-07	5.808e-06
0.4	4.172e+02	8.035e-04	5.770e-03	1.566e-06	1.124e-05
0.5	5.842e+02	2.251e-03	1.266e-02	4.419e-06	2.486e-05
0.6	2.413e+03	1.524e-02	7.105e-02	2.976e-05	1.387e-04
0.8	1.327e+04	1.661e-01	5.946e-01	3.159e-04	1.131e-03
1.0	4.243e+04	8.534e-01	2.556e+00	1.573e-03	4.711e-03
1.5	9.070e+02	3.935e-02	9.027e-02	6.621e-05	1.519e-04
2.0	1.326e+02	9.303e-03	1.857e-02	1.439e-05	2.871e-05
TOTALS:	4.715e+05	1.091e+00	3.405e+00	2.012e-03	6.285e-03

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	4.181e-14	1.411e-13	1.849e-16	6.240e-16
0.05	3.208e+01	3.440e-11	1.804e-10	9.165e-14	4.806e-13
0.06	1.564e+05	2.352e-06	1.739e-05	4.671e-09	3.454e-08
0.08	5.695e+03	1.226e-06	1.326e-05	1.940e-09	2.098e-08
0.1	2.453e+05	2.245e-04	2.918e-03	3.434e-07	4.465e-06
0.15	2.016e+03	3.772e-06	5.170e-05	6.211e-09	8.513e-08
0.2	1.356e+03	9.482e-06	1.182e-04	1.674e-08	2.086e-07
0.3	4.776e+02	1.868e-05	1.778e-04	3.544e-08	3.373e-07
0.4	4.172e+02	4.704e-05	3.348e-04	9.165e-08	6.523e-07
0.5	5.842e+02	1.316e-04	7.340e-04	2.584e-07	1.441e-06
0.6	2.413e+03	8.903e-04	4.114e-03	1.738e-06	8.031e-06
0.8	1.327e+04	9.679e-03	3.438e-02	1.841e-05	6.539e-05
1.0	4.243e+04	4.965e-02	1.476e-01	9.151e-05	2.721e-04
1.5	9.070e+02	2.283e-03	5.205e-03	3.840e-06	8.758e-06
2.0	1.326e+02	5.386e-04	1.070e-03	8.330e-07	1.654e-06
TOTALS:	4.715e+05	6.348e-02	1.968e-01	1.171e-04	3.632e-04

DOS File: CY30-6.MS5
Run Date: January 20, 2000
Run Time: 1:02:35 PM
Duration: 00:00:04

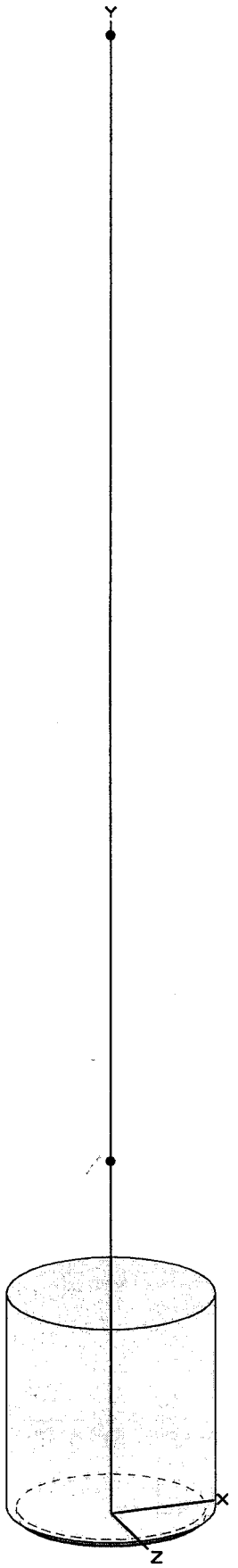


FIGURE 28

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY300-12.MS5
Run Date: January 20, 2000
Run Time: 1:05:23 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 300gram DU
Description: White Sand Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in
# 2	0 cm	121.92 cm	0 cm
	0.0 in	4 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	30.48 cm	White Sand	1.5
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	1.6693e-009	6.1765e+001	2.5153e-005	9.3067e-001
Bi-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Pa-234	1.7280e-007	6.3936e+003	2.6037e-003	9.6338e+001
Pa-234m	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
Pb-210	1.6694e-009	6.1766e+001	2.5154e-005	9.3069e-001
Pb-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Po-210	1.6682e-009	6.1723e+001	2.5136e-005	9.3004e-001
Po-214	1.7353e-009	6.4207e+001	2.6148e-005	9.6747e-001
Po-218	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Ra-226	1.7361e-009	6.4235e+001	2.6159e-005	9.6788e-001
Rn-222	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Th-230	6.5998e-009	2.4419e+002	9.9445e-005	3.6795e+000
Th-234	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
U-234	6.6126e-007	2.4467e+004	9.9638e-003	3.6866e+002
U-238	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY300-12.MS5
Run Date: January 20, 2000
Run Time: 1:05:23 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,40.48,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	8.895e-19	3.850e-18	3.934e-21	1.703e-20
0.05	3.208e+01	6.813e-14	5.240e-13	1.815e-16	1.396e-15
0.06	1.564e+05	3.429e-08	4.162e-07	6.811e-11	8.266e-10
0.08	5.695e+03	9.167e-08	1.870e-06	1.451e-10	2.959e-09
0.1	2.453e+05	3.233e-05	8.786e-04	4.946e-08	1.344e-06
0.15	2.016e+03	1.069e-06	3.351e-05	1.761e-09	5.518e-08
0.2	1.356e+03	3.746e-06	1.076e-04	6.612e-09	1.898e-07
0.3	4.776e+02	1.103e-05	2.316e-04	2.093e-08	4.394e-07
0.4	4.172e+02	3.618e-05	5.477e-04	7.049e-08	1.067e-06
0.5	5.842e+02	1.230e-04	1.406e-03	2.415e-07	2.759e-06
0.6	2.413e+03	9.684e-04	8.854e-03	1.890e-06	1.728e-05
0.8	1.327e+04	1.321e-02	8.683e-02	2.514e-05	1.652e-04
1.0	4.243e+04	7.995e-02	4.155e-01	1.474e-04	7.659e-04
1.5	9.070e+02	4.823e-03	1.730e-02	8.114e-06	2.910e-05
2.0	1.326e+02	1.340e-03	3.908e-03	2.072e-06	6.044e-06
TOTALS:	4.715e+05	1.005e-01	5.356e-01	1.850e-04	9.893e-04

Results - Dose Point # 2 - (0,121.92,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	1.105e-19	4.776e-19	4.888e-22	2.112e-21
0.05	3.208e+01	8.084e-15	6.201e-14	2.154e-17	1.652e-16
0.06	1.564e+05	3.986e-09	4.822e-08	7.918e-12	9.578e-11
0.08	5.695e+03	1.048e-08	2.130e-07	1.659e-11	3.370e-10
0.1	2.453e+05	3.673e-06	9.937e-05	5.619e-09	1.520e-07
0.15	2.016e+03	1.207e-07	3.765e-06	1.988e-10	6.200e-09
0.2	1.356e+03	4.220e-07	1.205e-05	7.447e-10	2.127e-08
0.3	4.776e+02	1.239e-06	2.587e-05	2.350e-09	4.908e-08
0.4	4.172e+02	4.050e-06	6.099e-05	7.892e-09	1.188e-07
0.5	5.842e+02	1.374e-05	1.562e-04	2.697e-08	3.066e-07
0.6	2.413e+03	1.080e-04	9.824e-04	2.108e-07	1.918e-06
0.8	1.327e+04	1.470e-03	9.617e-03	2.796e-06	1.829e-05
1.0	4.243e+04	8.879e-03	4.596e-02	1.637e-05	8.472e-05
1.5	9.070e+02	5.343e-04	1.910e-03	8.990e-07	3.214e-06
2.0	1.326e+02	1.483e-04	4.313e-04	2.293e-07	6.669e-07
TOTALS:	4.715e+05	1.116e-02	5.926e-02	2.055e-05	1.095e-04

DOS File: CY300-12.MS5
Run Date: January 20, 2000
Run Time: 1:05:23 PM
Duration: 00:00:04

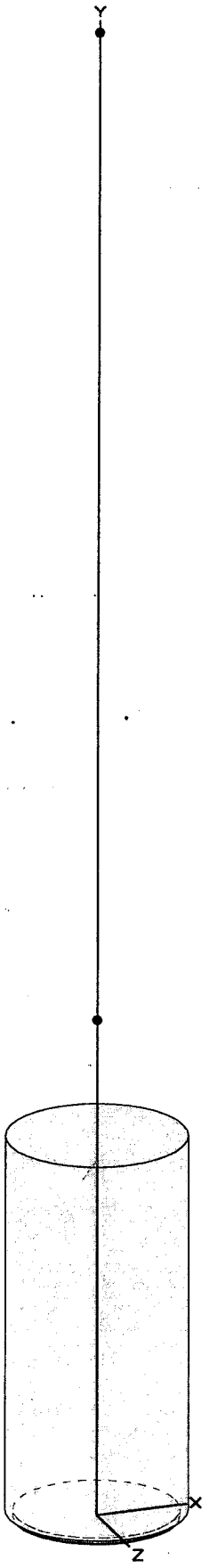


FIGURE 29

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY1R-6.MS5
Run Date: January 20, 2000
Run Time: 1:01:10 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 1 gram DU
Description: RED CLAY Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.1 cm	0.0 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	13.273 cm³	Uranium	18.75
Shield 1	15.24 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	8.8311e-011	3.2675e+000	6.6533e-006	2.4617e-001
Bi-214	9.0306e-011	3.3413e+000	6.8036e-006	2.5173e-001
Pa-234	5.7600e-010	2.1312e+001	4.3396e-005	1.6056e+000
Pa-234m	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003
Pb-210	8.8312e-011	3.2676e+000	6.6534e-006	2.4618e-001
Pb-214	9.0306e-011	3.3413e+000	6.8036e-006	2.5173e-001
Po-210	8.8277e-011	3.2663e+000	6.6508e-006	2.4608e-001
Po-214	9.0287e-011	3.3406e+000	6.8022e-006	2.5168e-001
Po-218	9.0324e-011	3.3420e+000	6.8050e-006	2.5178e-001
Ra-226	9.0325e-011	3.3420e+000	6.8051e-006	2.5179e-001
Rn-222	9.0324e-011	3.3420e+000	6.8050e-006	2.5178e-001
Th-230	2.3356e-010	8.6418e+000	1.7596e-005	6.5107e-001
Th-234	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003
U-234	1.1356e-008	4.2017e+002	8.5556e-004	3.1656e+001
U-238	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY1R-6.MS5
Run Date: January 20, 2000
Run Time: 1:01:10 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	2.609e-02	1.437e-16	5.381e-16	6.354e-19	2.380e-18
0.05	6.651e-01	3.557e-12	2.186e-11	9.476e-15	5.824e-14
0.06	5.214e+02	7.837e-08	7.086e-07	1.557e-10	1.407e-09
0.08	1.971e+01	7.472e-08	1.038e-06	1.182e-10	1.643e-09
0.1	8.178e+02	1.599e-05	2.699e-04	2.446e-08	4.130e-07
0.15	6.725e+00	3.504e-07	6.533e-06	5.770e-10	1.076e-08
0.2	4.855e+00	9.680e-07	1.516e-05	1.708e-09	2.675e-08
0.3	2.237e+00	1.938e-06	2.007e-05	3.677e-09	3.808e-08
0.4	2.587e+00	5.096e-06	3.892e-05	9.929e-09	7.583e-08
0.5	2.003e+00	6.919e-06	4.216e-05	1.358e-08	8.275e-08
0.6	9.552e+00	5.054e-05	2.590e-04	9.865e-08	5.055e-07
0.8	4.454e+01	4.435e-04	1.766e-03	8.436e-07	3.358e-06
1.0	1.424e+02	2.256e-03	7.513e-03	4.158e-06	1.385e-05
1.5	3.619e+00	1.263e-04	3.182e-04	2.125e-07	5.353e-07
2.0	1.279e+00	7.458e-05	1.609e-04	1.153e-07	2.487e-07
TOTALS:	1.579e+03	2.982e-03	1.041e-02	5.482e-06	1.915e-05

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	2.609e-02	1.044e-17	3.895e-17	4.619e-20	1.723e-19
0.05	6.651e-01	2.385e-13	1.456e-12	6.353e-16	3.878e-15
0.06	5.214e+02	5.066e-09	4.541e-08	1.006e-11	9.020e-11
0.08	1.971e+01	4.687e-09	6.440e-08	7.417e-12	1.019e-10
0.1	8.178e+02	9.895e-07	1.648e-05	1.514e-09	2.522e-08
0.15	6.725e+00	2.146e-08	3.943e-07	3.534e-11	6.494e-10
0.2	4.855e+00	5.878e-08	9.053e-07	1.037e-10	1.598e-09
0.3	2.237e+00	1.163e-07	1.185e-06	2.207e-10	2.248e-09
0.4	2.587e+00	3.039e-07	2.286e-06	5.920e-10	4.453e-09
0.5	2.003e+00	4.109e-07	2.468e-06	8.065e-10	4.845e-09
0.6	9.552e+00	2.992e-06	1.513e-05	5.841e-09	2.954e-08
0.8	4.454e+01	2.615e-05	1.029e-04	4.974e-08	1.958e-07
1.0	1.424e+02	1.326e-04	4.372e-04	2.445e-07	8.059e-07
1.5	3.619e+00	7.391e-06	1.847e-05	1.243e-08	3.107e-08
2.0	1.279e+00	4.353e-06	9.323e-06	6.732e-09	1.442e-08
TOTALS:	1.579e+03	1.754e-04	6.069e-04	3.225e-07	1.116e-06

DOS File: CY1R-6.MS5
Run Date: January 20, 2000
Run Time: 1:01:10 PM
Duration: 00:00:04

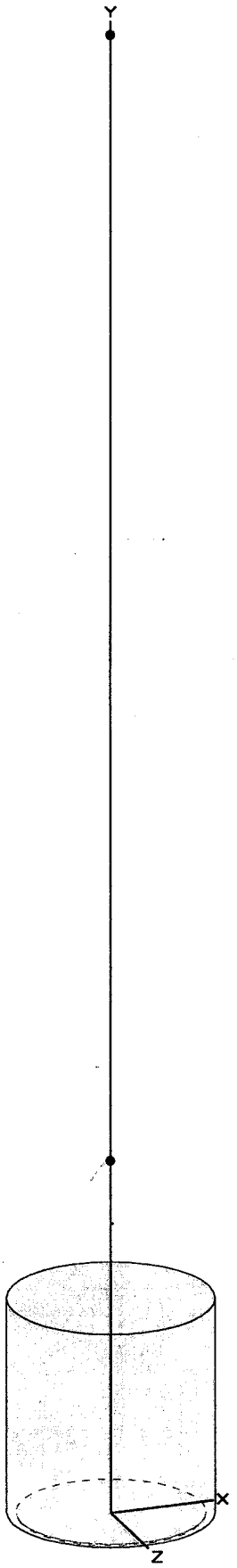
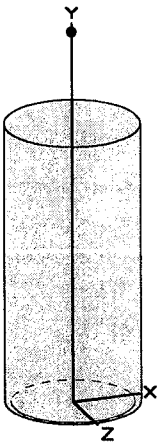


FIGURE 30

Page : 1
DOS File: CY1R-12.MS5
Run Date: January 14, 2000
Run Time: 9:33:49 AM
Duration: 00:00:03

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 1 gram DU
Description: RED CLAY Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields



Source Dimensions

Height	0.1 cm	0.0 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	13.273 cm³	Uranium	18.75
Shield 1	30.48 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	8.8311e-011	3.2675e+000	6.6533e-006	2.4617e-001
Bi-214	9.0306e-011	3.3413e+000	6.8036e-006	2.5173e-001
Pa-234	5.7600e-010	2.1312e+001	4.3396e-005	1.6056e+000
Pa-234m	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003
Pb-210	8.8312e-011	3.2676e+000	6.6534e-006	2.4618e-001
Pb-214	9.0306e-011	3.3413e+000	6.8036e-006	2.5173e-001
Po-210	8.8277e-011	3.2663e+000	6.6508e-006	2.4608e-001
Po-214	9.0287e-011	3.3406e+000	6.8022e-006	2.5168e-001
Po-218	9.0324e-011	3.3420e+000	6.8050e-006	2.5178e-001
Ra-226	9.0325e-011	3.3420e+000	6.8051e-006	2.5179e-001
Rn-222	9.0324e-011	3.3420e+000	6.8050e-006	2.5178e-001
Th-230	2.3356e-010	8.6418e+000	1.7596e-005	6.5107e-001
Th-234	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003
U-234	1.1356e-008	4.2017e+002	8.5556e-004	3.1656e+001
U-238	3.6000e-007	1.3320e+004	2.7122e-002	1.0035e+003

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

Results

DOS File: CY1R-12.MS5
Run Date: January 14, 2000
Run Time: 9:33:49 AM
Duration: 00:00:03

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	2.609e-02	3.185e-24	1.526e-23	1.409e-26	6.748e-26
0.05	6.651e-01	3.063e-17	2.805e-16	8.161e-20	7.473e-19
0.06	5.214e+02	9.318e-12	1.428e-10	1.851e-14	2.837e-13
0.08	1.971e+01	7.623e-11	2.111e-09	1.206e-13	3.340e-12
0.1	8.178e+02	3.859e-08	1.490e-06	5.903e-11	2.279e-09
0.15	6.725e+00	2.064e-09	9.747e-08	3.398e-12	1.605e-10
0.2	4.855e+00	8.815e-09	3.657e-07	1.556e-11	6.455e-10
0.3	2.237e+00	2.987e-08	8.167e-07	5.666e-11	1.549e-09
0.4	2.587e+00	1.110e-07	2.139e-06	2.162e-10	4.168e-09
0.5	2.003e+00	1.944e-07	2.833e-06	3.816e-10	5.560e-09
0.6	9.552e+00	1.733e-06	2.022e-05	3.383e-09	3.947e-08
0.8	4.454e+01	2.049e-05	1.701e-04	3.898e-08	3.236e-07
1.0	1.424e+02	1.295e-04	8.387e-04	2.387e-07	1.546e-06
1.5	3.619e+00	1.036e-05	4.475e-05	1.743e-08	7.528e-08
2.0	1.279e+00	7.590e-06	2.596e-05	1.174e-08	4.014e-08
TOTALS:	1.579e+03	1.701e-04	1.107e-03	3.110e-07	2.039e-06

Page : 3
DOS File: CY1R-12.MS5
Run Date: January 14, 2000
Run Time: 9:33:49 AM
Duration: 00:00:03

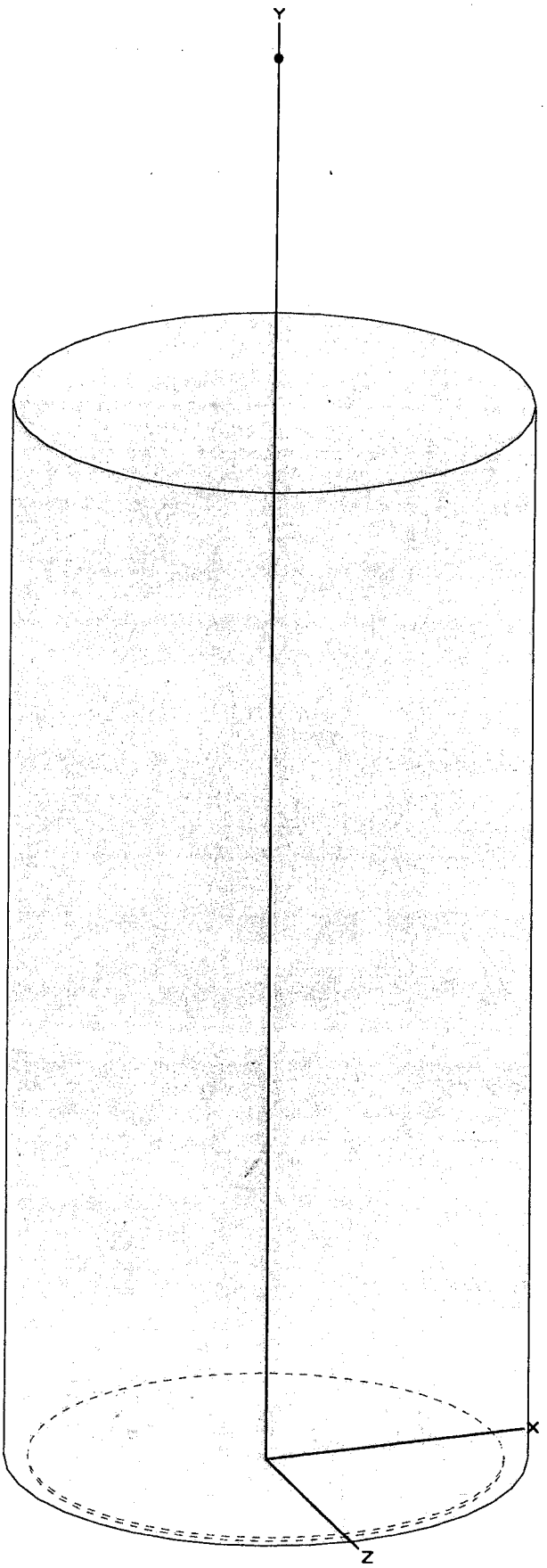


FIGURE 31

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY50R-6.MS5
Run Date: January 20, 2000
Run Time: 1:13:15 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 50gram DU
Description: RED CLAY Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	15.24 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	µCi/cm³	Bq/cm³
Bi-210	2.7146e-011	1.0044e+000	4.0903e-007	1.5134e-002
Bi-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Pa-234	2.8800e-008	1.0656e+003	4.3396e-004	1.6056e+001
Pa-234m	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
Pb-210	2.7148e-011	1.0045e+000	4.0906e-007	1.5135e-002
Pb-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Po-210	2.7102e-011	1.0028e+000	4.0837e-007	1.5110e-002
Po-214	2.9753e-011	1.1009e+000	4.4832e-007	1.6588e-002
Po-218	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Ra-226	2.9767e-011	1.1014e+000	4.4852e-007	1.6595e-002
Rn-222	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Th-230	2.2873e-010	8.4631e+000	3.4465e-006	1.2752e-001
Th-234	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
U-234	5.0952e-008	1.8852e+003	7.6774e-004	2.8406e+001
U-238	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY50R-6.MS5
Run Date: January 20, 2000
Run Time: 1:13:15 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	1.469e-15	5.502e-15	6.495e-18	2.434e-17
0.05	2.277e+00	2.499e-12	1.536e-11	6.657e-15	4.093e-14
0.06	2.607e+04	8.048e-07	7.279e-06	1.599e-09	1.446e-08
0.08	9.470e+02	7.405e-07	1.032e-05	1.172e-09	1.634e-08
0.1	4.088e+04	1.708e-04	2.973e-03	2.614e-07	4.549e-06
0.15	3.360e+02	3.634e-06	6.889e-05	5.985e-09	1.134e-07
0.2	2.249e+02	1.021e-05	1.761e-04	1.802e-08	3.108e-07
0.3	7.762e+01	2.263e-05	2.925e-04	4.292e-08	5.548e-07
0.4	6.585e+01	6.053e-05	5.767e-04	1.179e-07	1.124e-06
0.5	9.719e+01	1.908e-04	1.406e-03	3.745e-07	2.759e-06
0.6	3.976e+02	1.346e-03	8.100e-03	2.627e-06	1.581e-05
0.8	2.211e+03	1.600e-02	7.209e-02	3.044e-05	1.371e-04
1.0	7.069e+03	8.691e-02	3.202e-01	1.602e-04	5.902e-04
1.5	1.493e+02	4.339e-03	1.178e-02	7.300e-06	1.981e-05
2.0	1.953e+01	9.693e-04	2.231e-03	1.499e-06	3.450e-06
TOTALS:	7.855e+04	1.100e-01	4.199e-01	2.029e-04	7.758e-04

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	1.051e-16	3.922e-16	4.650e-19	1.734e-18
0.05	2.277e+00	1.646e-13	1.005e-12	4.384e-16	2.676e-15
0.06	2.607e+04	5.104e-08	4.575e-07	1.014e-10	9.088e-10
0.08	9.470e+02	4.553e-08	6.277e-07	7.206e-11	9.933e-10
0.1	4.088e+04	1.038e-05	1.783e-04	1.588e-08	2.728e-07
0.15	3.360e+02	2.181e-07	4.076e-06	3.592e-10	6.713e-09
0.2	2.249e+02	6.092e-07	1.036e-05	1.075e-09	1.829e-08
0.3	7.762e+01	1.343e-06	1.715e-05	2.548e-09	3.252e-08
0.4	6.585e+01	3.584e-06	3.375e-05	6.983e-09	6.576e-08
0.5	9.719e+01	1.127e-05	8.209e-05	2.212e-08	1.611e-07
0.6	3.976e+02	7.936e-05	4.723e-04	1.549e-07	9.219e-07
0.8	2.211e+03	9.404e-04	4.193e-03	1.789e-06	7.975e-06
1.0	7.069e+03	5.094e-03	1.859e-02	9.389e-06	3.427e-05
1.5	1.493e+02	2.532e-04	6.821e-04	4.260e-07	1.148e-06
2.0	1.953e+01	5.642e-05	1.290e-04	8.725e-08	1.995e-07
TOTALS:	7.855e+04	6.451e-03	2.440e-02	1.190e-05	4.508e-05

DOS File: CY50R-6.MS5
Run Date: January 20, 2000
Run Time: 1:13:15 PM
Duration: 00:00:04

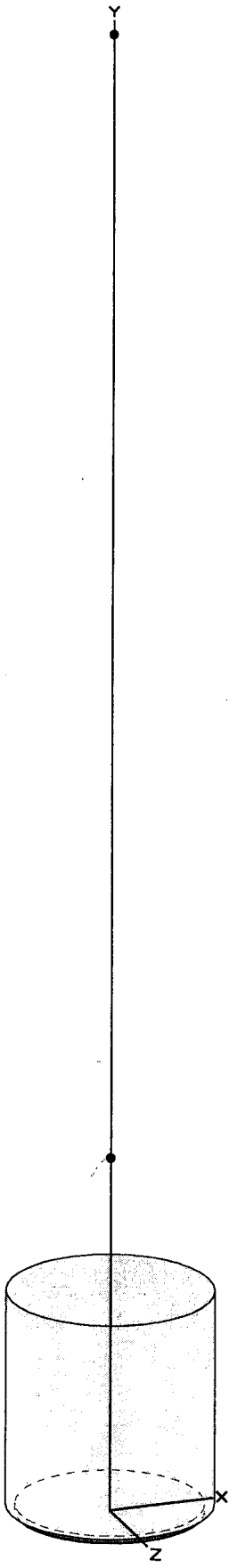


FIGURE 32

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY50R-12.MS5
Run Date: January 20, 2000
Run Time: 2:48:28 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 50gram DU
Description: RED CLAY Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in
# 2	0 cm	121.92 cm	0 cm
	0.0 in	4 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	30.48 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	2.7146e-011	1.0044e+000	4.0903e-007	1.5134e-002
Bi-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Pa-234	2.8800e-008	1.0656e+003	4.3396e-004	1.6056e+001
Pa-234m	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
Pb-210	2.7148e-011	1.0045e+000	4.0906e-007	1.5135e-002
Pb-214	2.9760e-011	1.1011e+000	4.4841e-007	1.6591e-002
Po-210	2.7102e-011	1.0028e+000	4.0837e-007	1.5110e-002
Po-214	2.9753e-011	1.1009e+000	4.4832e-007	1.6588e-002
Po-218	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Ra-226	2.9767e-011	1.1014e+000	4.4852e-007	1.6595e-002
Rn-222	2.9766e-011	1.1013e+000	4.4850e-007	1.6595e-002
Th-230	2.2873e-010	8.4631e+000	3.4465e-006	1.2752e-001
Th-234	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004
U-234	5.0952e-008	1.8852e+003	7.6774e-004	2.8406e+001
U-238	1.8000e-005	6.6600e+005	2.7122e-001	1.0035e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY50R-12.MS5
Run Date: January 20, 2000
Run Time: 2:48:28 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,40.48,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	3.232e-23	1.549e-22	1.430e-25	6.849e-25
0.05	2.277e+00	2.134e-17	1.954e-16	5.685e-20	5.206e-19
0.06	2.607e+04	9.483e-11	1.454e-09	1.884e-13	2.887e-12
0.08	9.470e+02	7.485e-10	2.076e-08	1.184e-12	3.286e-11
0.1	4.088e+04	4.088e-07	1.609e-05	6.254e-10	2.461e-08
0.15	3.360e+02	2.120e-08	1.012e-06	3.491e-11	1.666e-09
0.2	2.249e+02	9.225e-08	4.077e-06	1.628e-10	7.196e-09
0.3	7.762e+01	3.477e-07	1.101e-05	6.595e-10	2.089e-08
0.4	6.585e+01	1.320e-06	2.950e-05	2.571e-09	5.748e-08
0.5	9.719e+01	5.380e-06	8.910e-05	1.056e-08	1.749e-07
0.6	3.976e+02	4.639e-05	6.025e-04	9.055e-08	1.176e-06
0.8	2.211e+03	7.443e-04	6.720e-03	1.416e-06	1.278e-05
1.0	7.069e+03	5.025e-03	3.487e-02	9.262e-06	6.427e-05
1.5	1.493e+02	3.588e-04	1.633e-03	6.037e-07	2.747e-06
2.0	1.953e+01	9.944e-05	3.564e-04	1.538e-07	5.511e-07
TOTALS:	7.855e+04	6.281e-03	4.433e-02	1.154e-05	8.182e-05

Results - Dose Point # 2 - (0,121.92,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	1.304e+00	4.203e-24	2.011e-23	1.859e-26	8.892e-26
0.05	2.277e+00	2.609e-18	2.382e-17	6.950e-21	6.346e-20
0.06	2.607e+04	1.128e-11	1.723e-10	2.240e-14	3.421e-13
0.08	9.470e+02	8.704e-11	2.403e-09	1.377e-13	3.803e-12
0.1	4.088e+04	4.713e-08	1.844e-06	7.210e-11	2.821e-09
0.15	3.360e+02	2.423e-09	1.149e-07	3.991e-12	1.893e-10
0.2	2.249e+02	1.050e-08	4.612e-07	1.854e-11	8.140e-10
0.3	7.762e+01	3.940e-08	1.240e-06	7.474e-11	2.352e-09
0.4	6.585e+01	1.490e-07	3.309e-06	2.903e-10	6.447e-09
0.5	9.719e+01	6.056e-07	9.966e-06	1.189e-09	1.956e-08
0.6	3.976e+02	5.209e-06	6.726e-05	1.017e-08	1.313e-07
0.8	2.211e+03	8.331e-05	7.481e-04	1.585e-07	1.423e-06
1.0	7.069e+03	5.612e-04	3.875e-03	1.034e-06	7.144e-06
1.5	1.493e+02	3.994e-05	1.810e-04	6.719e-08	3.045e-07
2.0	1.953e+01	1.105e-05	3.945e-05	1.708e-08	6.100e-08
TOTALS:	7.855e+04	7.015e-04	4.928e-03	1.289e-06	9.096e-06

DOS File: CY50R-12.MS5
Run Date: January 20, 2000
Run Time: 2:48:28 PM
Duration: 00:00:04

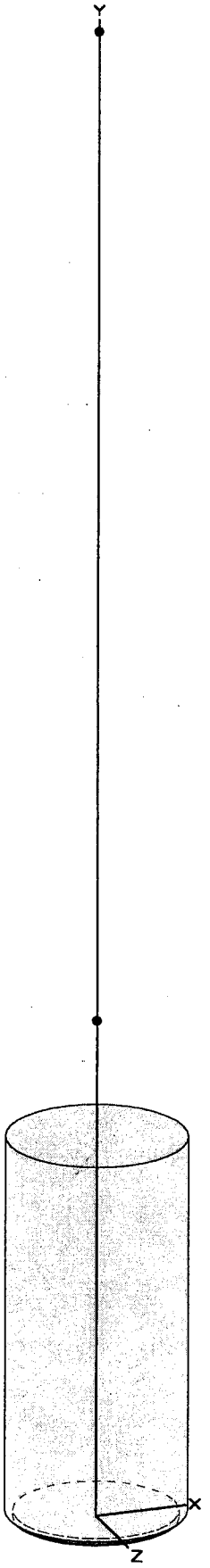


FIGURE 33

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY30R-6.MS5
Run Date: January 20, 2000
Run Time: 1:07:27 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 300gram DU
Description: RED CLAY Cylinder 6", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	25.24 cm	0 cm
	0.0 in	9.9 in	0.0 in
# 2	0 cm	106.68 cm	0 cm
	0.0 in	3 ft 6.0 in	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	15.24 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	1.6693e-009	6.1765e+001	2.5153e-005	9.3067e-001
Bi-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Pa-234	1.7280e-007	6.3936e+003	2.6037e-003	9.6338e+001
Pa-234m	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
Pb-210	1.6694e-009	6.1766e+001	2.5154e-005	9.3069e-001
Pb-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Po-210	1.6682e-009	6.1723e+001	2.5136e-005	9.3004e-001
Po-214	1.7353e-009	6.4207e+001	2.6148e-005	9.6747e-001
Po-218	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Ra-226	1.7361e-009	6.4235e+001	2.6159e-005	9.6788e-001
Rn-222	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Th-230	6.5998e-009	2.4419e+002	9.9445e-005	3.6795e+000
Th-234	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
U-234	6.6126e-007	2.4467e+004	9.9638e-003	3.6866e+002
U-238	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY30R-6.MS5
Run Date: January 20, 2000
Run Time: 1:07:27 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,25.24,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	8.812e-15	3.301e-14	3.897e-17	1.460e-16
0.05	3.208e+01	3.520e-11	2.164e-10	9.378e-14	5.765e-13
0.06	1.564e+05	4.829e-06	4.367e-05	9.591e-09	8.674e-08
0.08	5.695e+03	4.453e-06	6.208e-05	7.047e-09	9.824e-08
0.1	2.453e+05	1.025e-03	1.784e-02	1.568e-06	2.729e-05
0.15	2.016e+03	2.181e-05	4.134e-04	3.591e-08	6.807e-07
0.2	1.356e+03	6.153e-05	1.061e-03	1.086e-07	1.873e-06
0.3	4.776e+02	1.392e-04	1.800e-03	2.641e-07	3.413e-06
0.4	4.172e+02	3.834e-04	3.654e-03	7.471e-07	7.119e-06
0.5	5.842e+02	1.147e-03	8.449e-03	2.251e-06	1.658e-05
0.6	2.413e+03	8.170e-03	4.917e-02	1.595e-05	9.597e-05
0.8	1.327e+04	9.606e-02	4.327e-01	1.827e-04	8.230e-04
1.0	4.243e+04	5.217e-01	1.922e+00	9.616e-04	3.543e-03
1.5	9.070e+02	2.635e-02	7.152e-02	4.433e-05	1.203e-04
2.0	1.326e+02	6.581e-03	1.515e-02	1.018e-05	2.342e-05
TOTALS:	4.715e+05	6.616e-01	2.524e+00	1.220e-03	4.663e-03

Results - Dose Point # 2 - (0,106.68,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	6.308e-16	2.353e-15	2.790e-18	1.041e-17
0.05	3.208e+01	2.318e-12	1.415e-11	6.176e-15	3.770e-14
0.06	1.564e+05	3.063e-07	2.745e-06	6.083e-10	5.453e-09
0.08	5.695e+03	2.738e-07	3.775e-06	4.334e-10	5.973e-09
0.1	2.453e+05	6.227e-05	1.070e-03	9.526e-08	1.637e-06
0.15	2.016e+03	1.309e-06	2.446e-05	2.155e-09	4.028e-08
0.2	1.356e+03	3.672e-06	6.245e-05	6.481e-09	1.102e-07
0.3	4.776e+02	8.265e-06	1.055e-04	1.568e-08	2.001e-07
0.4	4.172e+02	2.270e-05	2.138e-04	4.423e-08	4.166e-07
0.5	5.842e+02	6.774e-05	4.934e-04	1.330e-07	9.685e-07
0.6	2.413e+03	4.817e-04	2.867e-03	9.402e-07	5.596e-06
0.8	1.327e+04	5.645e-03	2.517e-02	1.074e-05	4.787e-05
1.0	4.243e+04	3.058e-02	1.116e-01	5.636e-05	2.057e-04
1.5	9.070e+02	1.538e-03	4.143e-03	2.587e-06	6.970e-06
2.0	1.326e+02	3.830e-04	8.759e-04	5.923e-07	1.355e-06
TOTALS:	4.715e+05	3.879e-02	1.466e-01	7.151e-05	2.709e-04

DOS File: CY30R-6.MS5
Run Date: January 20, 2000
Run Time: 1:07:27 PM
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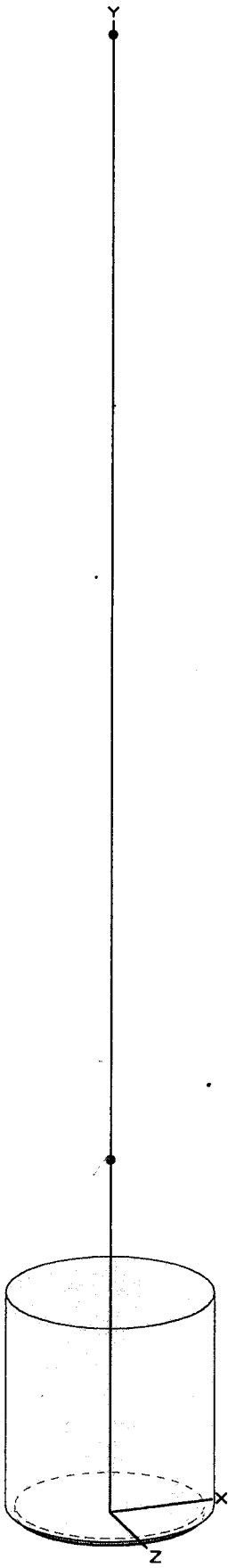

FIGURE 34

MicroShield v5.05 (5.05-00020)
Earth Tech, Inc.

Page : 1
DOS File: CY30R-12.MS5
Run Date: January 20, 2000
Run Time: 1:06:24 PM
Duration: 00:00:04

File Ref: _____
Date: _____
By: _____
Checked: _____

Case Title: 300gram DU
Description: RED CLAY Cylinder 12", dose 10cm
Geometry: 8 - Cylinder Volume - End Shields

Source Dimensions

Height	0.5 cm	0.2 in
Radius	6.5 cm	2.6 in

Dose Points

	X	Y	Z
# 1	0 cm	40.48 cm	0 cm
	0.0 in	1 ft 3.9 in	0.0 in
# 2	0 cm	121.92 cm	0 cm
	0.0 in	4 ft	0.0 in

Shields

Shield Name	Dimension	Material	Density
Source	66.366 cm³	Uranium	18.75
Shield 1	30.48 cm	Red Clay Dense	2
Air Gap		Air	0.00122

Source Input
Grouping Method : Standard Indices
Number of Groups : 25
Lower Energy Cutoff : 0.015
Photons < 0.015 : Excluded
Library : Grove

Nuclide	curies	becquerels	μCi/cm³	Bq/cm³
Bi-210	1.6693e-009	6.1765e+001	2.5153e-005	9.3067e-001
Bi-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Pa-234	1.7280e-007	6.3936e+003	2.6037e-003	9.6338e+001
Pa-234m	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
Pb-210	1.6694e-009	6.1766e+001	2.5154e-005	9.3069e-001
Pb-214	1.7357e-009	6.4221e+001	2.6153e-005	9.6767e-001
Po-210	1.6682e-009	6.1723e+001	2.5136e-005	9.3004e-001
Po-214	1.7353e-009	6.4207e+001	2.6148e-005	9.6747e-001
Po-218	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Ra-226	1.7361e-009	6.4235e+001	2.6159e-005	9.6788e-001
Rn-222	1.7360e-009	6.4233e+001	2.6158e-005	9.6786e-001
Th-230	6.5998e-009	2.4419e+002	9.9445e-005	3.6795e+000
Th-234	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004
U-234	6.6126e-007	2.4467e+004	9.9638e-003	3.6866e+002
U-238	1.0800e-004	3.9960e+006	1.6273e+000	6.0211e+004

Buildup
The material reference is : Shield 1

Integration Parameters

Radial	20
Circumferential	10
Y Direction (axial)	10

DOS File: CY30R-12.MS5
Run Date: January 20, 2000
Run Time: 1:06:24 PM
Duration: 00:00:04

Results - Dose Point # 1 - (0,40.48,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	1.939e-22	9.292e-22	8.577e-25	4.109e-24
0.05	3.208e+01	3.006e-16	2.753e-15	8.008e-19	7.333e-18
0.06	1.564e+05	5.690e-10	8.722e-09	1.130e-12	1.733e-11
0.08	5.695e+03	4.501e-09	1.249e-07	7.123e-12	1.976e-10
0.1	2.453e+05	2.453e-06	9.653e-05	3.753e-09	1.477e-07
0.15	2.016e+03	1.272e-07	6.072e-06	2.095e-10	9.999e-09
0.2	1.356e+03	5.560e-07	2.457e-05	9.814e-10	4.337e-08
0.3	4.776e+02	2.139e-06	6.775e-05	4.058e-09	1.285e-07
0.4	4.172e+02	8.360e-06	1.869e-04	1.629e-08	3.641e-07
0.5	5.842e+02	3.234e-05	5.356e-04	6.348e-08	1.051e-06
0.6	2.413e+03	2.816e-04	3.657e-03	5.496e-07	7.138e-06
0.8	1.327e+04	4.468e-03	4.033e-02	8.498e-06	7.672e-05
1.0	4.243e+04	3.016e-02	2.093e-01	5.560e-05	3.858e-04
1.5	9.070e+02	2.179e-03	9.915e-03	3.667e-06	1.668e-05
2.0	1.326e+02	6.751e-04	2.420e-03	1.044e-06	3.742e-06
TOTALS:	4.715e+05	3.781e-02	2.666e-01	6.944e-05	4.918e-04

Results - Dose Point # 2 - (0,121.92,0) cm

Energy MeV	Activity photons/sec	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.04	7.826e+00	2.522e-23	1.206e-22	1.115e-25	5.335e-25
0.05	3.208e+01	3.675e-17	3.356e-16	9.791e-20	8.939e-19
0.06	1.564e+05	6.768e-11	1.034e-09	1.344e-13	2.053e-12
0.08	5.695e+03	5.235e-10	1.445e-08	8.284e-13	2.287e-11
0.1	2.453e+05	2.828e-07	1.107e-05	4.326e-10	1.693e-08
0.15	2.016e+03	1.454e-08	6.897e-07	2.395e-11	1.136e-09
0.2	1.356e+03	6.331e-08	2.780e-06	1.117e-10	4.906e-09
0.3	4.776e+02	2.424e-07	7.628e-06	4.599e-10	1.447e-08
0.4	4.172e+02	9.437e-07	2.096e-05	1.839e-09	4.084e-08
0.5	5.842e+02	3.640e-06	5.990e-05	7.144e-09	1.176e-07
0.6	2.413e+03	3.162e-05	4.083e-04	6.172e-08	7.969e-07
0.8	1.327e+04	5.001e-04	4.491e-03	9.511e-07	8.542e-06
1.0	4.243e+04	3.368e-03	2.326e-02	6.209e-06	4.288e-05
1.5	9.070e+02	2.426e-04	1.099e-03	4.081e-07	1.849e-06
2.0	1.326e+02	7.500e-05	2.678e-04	1.160e-07	4.142e-07
TOTALS:	4.715e+05	4.223e-03	2.963e-02	7.756e-06	5.468e-05

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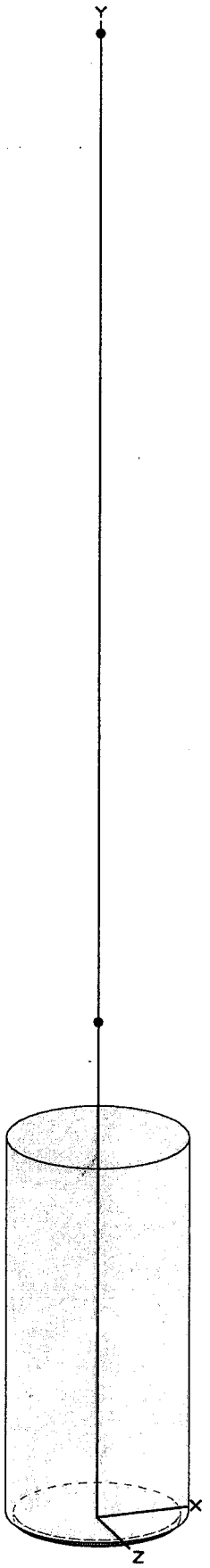
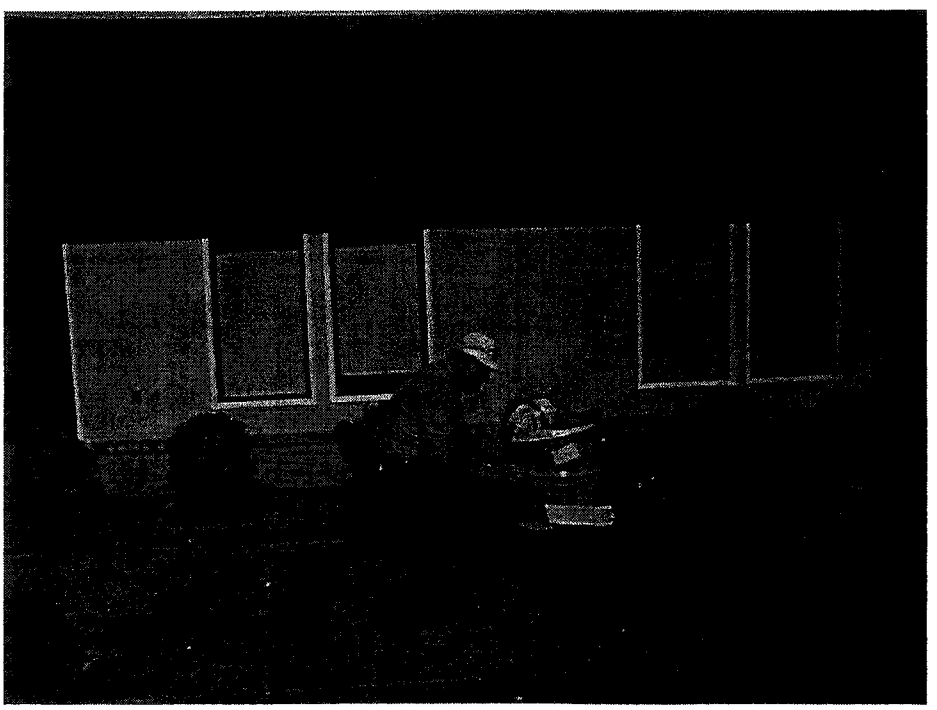


PHOTOGRAPHS

PHOTOGRAPH 1
DU TEST QUALITY CONTROL

PHOTOGRAH 2
DU TEST APPROVAL



PHOTOGRAPH 3
FIDLER MEASUREMENTS

PHOTOGRAPH 4
MEAURING SOIL DEPTH