SAFETY LIGHT CORPORATION
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8 May 1990

U.S. Nuclear Regulatory Commission
Region I
475 Allendale Rd.
King of Prussia, PA 19406

ATTN: Mr. Francis M. Costello, Sr. Health Physicist.

RE: USNRC License No. 37-00030-08.

Dear Sir:

Further to information provided during the March 19-20, 1990 inspection, we submit herewith additional data relative to (a) average HTO concentration of air exhausted from our Solid Waste Building, (b) estimated HTO concentration at the nearest restricted area fence locations, and (c) estimated maximum dose at these fence locations.

All records of measurements and calculations used are on file here and are, of course, available for inspection at any time.

Please contact us if any items require clarification.

Yours sincerely,
SAFETY LIGHT CORPORATION

Norman G Fritz

Norman G. Fritz
Radiation Safety Officer

SUMMARY OF DATA FOR AIR EXHAUSTED FROM SOLID WASTE BUILDING (1)

PERIOD	Average HTO Concentration of Exhaust Air (μCi HTO/mL Air)	Est. Ave. HTO Conc. at Nearest Restricted Area Fence Location(2)(3) (μCi HTO/mL Air)	Corresponding Est. Max. Dose at Nearest Restricted Area Fence Locations (3)(4) (mrem)
Year 1989	0.8×10^{-6}	1.1×10^{-9}	0.3*
1st Quarter 1990	0.3×10^{-6}	4.0×10^{-10}	0.02*

(1) Bldg. is exhausted normally 8 hours/day, 5 days/week only.

(2) Nearest locations are: South 33.5 m and East 39.2 m.

(3) In accordance with Fig. 1, NUREG-1140, it was assumed that, for atmospheric stability Class F, wind speed 1 m/sec., a non-buoyant ground-level release, at 0 - 100 m downwind from release point:

Atmospheric dispersion factor $(x/Q) = 3.3 \times 10^{-3}$ sec/m^3

(4) Per Page 11, NUREG-1140, it was assumed that:

Dose (rem) = (DCF)(B)(X/Q)(Q)

where: DCF = Dose Converstion Factor = $1/2 \times 10^{-4}$ rem/inhaled μCi.
B = Breathing Rate = 2.66×10^{-4} m^3/sec.
$x/Q = 3.3 \times 10^{-3}$ sec/m^3
Q = μCi released for period
= 10.2 Ci for 1989 & 0.94 Ci for 1st Quarter of 1990.

*NOTE: Assumption was also made that the wind was in the fence location direction only 25% of the time.

SLC 4/30/90

RADIOLOGICAL INVESTIGATION OF THE GROUNDS AND GROUND WATER
U.S. RADIUM CORPORATION
BLOOMSBURG, PENNSYLVANIA

By

Radiation Management Corporation
3356 Commercial Avenue
Northbrook, Illinois
April 23, 1979

This report presents a summary of work conducted December, 1978 through April, 1979, in accordance with U.S. Radium Purchase Order Number 120401

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One copy to be supplied under separate cover

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PREFACE

The purpose of this study was to provide information on the radiological composition, extent of on-site contamination, and possible off-site releases which could have resulted from prior waste disposal practices at the U.S. Radium manufacturing facility in Bloomsburg, Pennsylvania.

This report summarizes findings made pursuant to RMC Proposed Course of Action outlines dated December 18, 1978 and January 26, 1979. Initial investigation work commenced January 3, 1979.

RMC personnel contributing to the project were Frazier Bronson, C.H.P., Project Manager, Scott Murray, H.P., Mark Roberts, H.P., and David Groff.

The services of Meiser and Earl, hydrogeologists, provided ground water mevement information and soil sample borings for analyses. Information contained in their investigation report of April 4, 1979 is utilized, in part, in this report.

Qualitative and quantitative analyses of selected soil and water samples were performed by RMC Analytical Labs in Philadelphia, Pennsylvania.

SECTION 1

INTRODUCTION

1.0 INTRODUCTION

This study considered contaminated grounds and potential releases to the ground water relative to suspected leakage of two on-site low level waste disposal silos constructed during the mid 1950's and sealed during the 1960's. Each is approximately fifteen feet deep and 190 feet from the Susquehanna River's edge.

Prior to RMC involvement, three sampling wells were constructed in October, 1978, below the burial pits on a line perpendicular to the Susquehanna River. Soil and water samples from these wells provided initial contamination levels and indicated the need for further sampling. Additional borings were selected in late January, 1979, to provide movement information through the lower site plateau, with three remote locations placed to indicate background levels in soil. A total of eighteen permanent monitoring wells were drilled to provide pertinent information summarized in this report and to provide a means for future ground water sampling.

TOTAL BORE HOLES AS AT 7/1/80 = 23

SECTION 2

SUMMARY

2.0 SUMMARY

Major soil and ground water contaminants were identified as Cs-137, Ra-226, and Sr-90. Highest subsurface concentrations of these nuclides was 836 pCi/gm for soil and 110 pCi/ml* in ground water, both of which were Sr-90 from Well #1. Areas of surface and near-surface contamination (primarily Cs-137) were detected on the lower plateau, with a maximum of 750 pCi/gm. Other areas of similar concentrations (~~≠~~ within a factor of 10) were detected, but not analyzed.

Contaminated ground water flow to the river is the most probable mode for off-site releases. Projected values of these releases, based on five months' water samples from wells 1, 2, and 3, indicate that ground water concentrations flowing into the river are projected to be below the Nuclear Regulatory Commission's allowable concentrations for unrestricted areas (10CFR 20, Appendix B). One additional sampling well should be considered to confirm and document these concentrations. River water samples, both for this project and 1974-1978 samples from nearby reactor environmental monitoring projects, show no detectable releases to the Susquehanna River which may be attributed to U.S. Radium operations.

General conclusions of this report are as follows:

1. Present conditions of the U.S. Radium site at Bloomsburg do not represent a significant public health hazard with regard to radiation or radioactivity releases. In addition, there has been no significant impact to the environment and surrounding communities associated with conditions identified in the course of our investigation.

* MPC of SOLUBLE Sr^{90} FOR UNRESTRICTED AREAS = 0.3 pCi/ml (= 3×10^{-7} µCi/ml)

2. Substantial corrective measures, such as the physical removal of all on-site contaminated soil and waste materials for relocation at a radioactive burial site, are not appropriate or justified at this time. Further considerations may be required if a change in ownership of the property is anticipated.

3. These statements, however, do not preclude the need for continued monitoring of the situation or actions recommended in section 7.2, or those which may be deemed necessary by regulatory agencies.

SECTION 3

LITERATURE SEARCH

3.0 LITERATURE SEARCH SUMMARY

Introduction

A study of available articles was undertaken to gather information useful to develop sound recommendations involving Sr-90 migration, preliminary measurements, and environmental monitoring for this project. A preliminary indication from the licensee was that Sr-90 was expected to be the major soil contaminant.

Information sources researched included Health Physics, Nulcear Science Abstracts, IAEA & ICRP publications, a keyword computer search by the Department of Energy Technical Information Center, and the Environmental Information Center at Argonne National Labs. Six topic areas were identified:

	Topic	No. of Articles
I.	Sample collection and preparation	3
II.	Rapid methods to measure Sr-90 in environmental samples	5
III.	Migration characteristics and factors affecting movement of Sr-90 in soil	5
IV.	Strontium metabolism in the environment and its uptake in plants	3
V.	Alternatives and contaminated soil methods and procedures	5

Conclusion

1. A rapid method to detect Sr-90 contamination in soil by direct gamma measurement could be developed. By gamma counting bremsstrahlung radiations on sodium iodide spectroscopic counting equipment, large numbers of soil samples could be easily counted. This will eliminate the need for elaborate sample preparation and minimize costs by submitting only selected samples for further laboratory analysis.

2. Strontium migration in the environment is controlled by the extent to which Sr++ can replace Ca++ in calcium bearing materials, such as limestones. It is readily taken up by plants where it can enter man's food chain (plant, milk, man). It will react and behave in the environment as calcium; therefore, a higher available calcium content ($CaCO_3$) in soils will produce a faster migration rate.

3. Strontium movement in soil can be controlled or slowed by producing an underground chemical barrier which will increase the absorptive characteristics of the contaminated soil. A dilute acid is first injected underground to etch the silica sand, followed by a water soluable salt with a high absorption capacity for strontium ions. Retention properties of the barrier are reported to increase by a factor of 20 over that of untreated soil.

DISCUSSION OF SELECTED ARTICLES

1. In an article published in Health Physics (Vol. 14, 1968), Dudley and Haim describe monitoring bremsstrahlung photons produced from the beta decay of Sr-90. Their method involved a NaI crystal and multichannel analyzer to sum the counts over the energy range of 0.05 to 1.0 Mev, which includes the total bremsstrahlung production region. Like beta decay, the energy spectrum of bremsstrahlung photons is continuous from zero energy to βmax; therefore, no true "peak" will be recognized. To avoid interference caused by other isotopes appearing in this region, an optimum band of 0.06 to 0.15 Mev was selected. It was thus determined to be feasible to use a similar technique to monitor for Sr-90 contained in

soil samples. For accurate comparisons, each sample would be unformly dried and a predetermined size and weight would be counted on the gamma spectroscopy equipment available on site for a rapid, preliminary screening method.

When compared to background soil samples, those showing abnormally high counts in a selected (Sr-90 bremsstrahlung) energy region would be recomme for further analysis. In addition, this method provides a gamma spectrum of each sample to supplement the identification of other gamma emitting contaminants which may be present.

2. Strontium is a member of group IIA of the periodic table which includes the alkaline earths such as beryllium, magnesium, calcium, and radium. Isotopes of these are considered hazardous to man because of bone seeking characteristics and long rentention times in the body. Sr-90, for example, has a relatively high hazard to man index and relatively long half-life (T½-28.8y). The maximum permissable concentration to unrestricted waters for soluable Sr-90 permitted by the NRC is $3x10^{-7}$ uCi/ml* (0.3pCi/ml).

Strontium will readily form ions having a charge of +2 and will produce ionic bonds with non-metallic elements including oxygen, which encourages water migration through an ion exchange process.

The distribution of strontium in soil is controlled by the extent Sr++ can replace Ca++ in calcium bearing materials such as limestones. The principal carriers of strontium in igneous rocks are plagioclase feldspar and apatite. Natural concentrations of stable strontium in rocks vary

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*Title 10 CFR 20, Appendix B. This is more restrictive by a factor of 100 than other beta-gamma emitters such as Cs-137.

from 10 to 500ppm with the highest concentrations found in basalt and limestone. Background levels of Sr-90 in soil (mostly due to weapons testing) typically range from 0.1 to 0.5 pCi/gm. Subsurface migration rates will be largely dependant upon groundwater flow velocities in the aquifer and the retention capacity of the type of soil.

Ivanov and Shagalova (1972) in a paper on strontium metabolism in the environment describe factors affecting strontium uptake by plants, such as pH of the soil, calcium content and saturation degree with $CaCO_3$.

Their conclusions were that a greater concentration of calcium in soils will produce a faster uptake of available strontium in plants; while a high pH appears to have an opposite effect. A high pH value (basic) tends to decrease the radiostrontium content in plants. This is due, in part, by the presence of phosphates which increase the absorptive characteristics of soils and reduces the number of free ions available for uptake.

Other papers reported similar findings. The extent of accumulation and concentration in plants is largely dependent upon: 1) concentrations in the soil and the extent available as ions, 2) metabolic requirements of the organism, and 3) physiochemical factors in the soil.

3. The adsoption of strontium from solution by a given soil is a function of several factors:

   1) Mineral composition of the soil,
   2) Isotope concentration in the solution,
   3) pH of the system,
   4) Other cations present competing for binding sites, and
   5) Total salt concentrations.

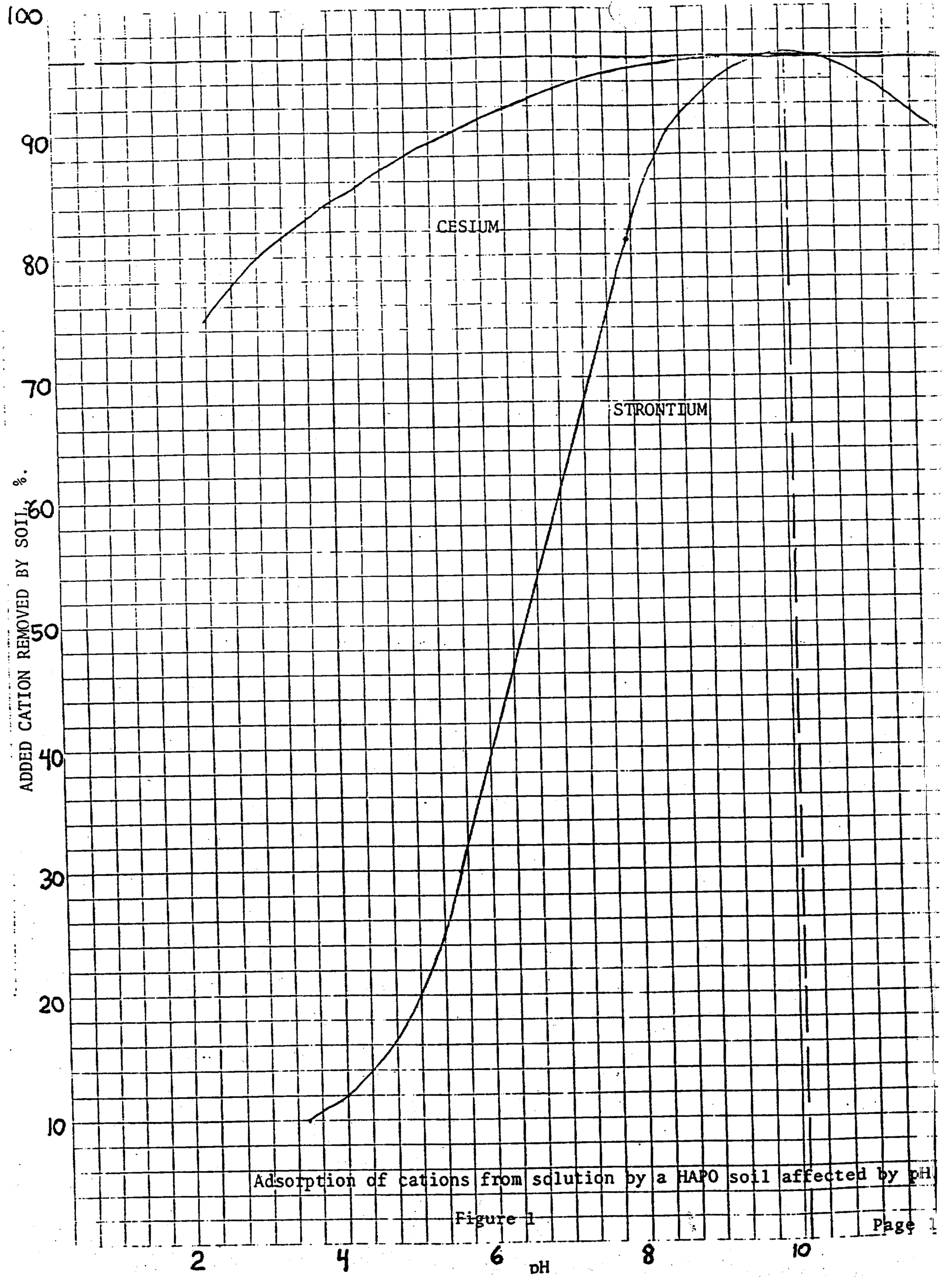
Total strontium removal varies markedly with pH as illustrated in Figure 1. Highest retention by soil is obtained with a pH of ten.

The rate of migration can be considerably influenced by introducing a highly sorptive material into the soil and thus delaying the contamination of ground water. Straub (1964) reports that the addition if PO_4^{3-} in the presence of 3.3M $NaNO_3$ increases the absorptive characteristics of clay soil

In another paper on installation of chemical barriers in aquifers, Baetsle and Souffriau (1967) describe injecting chemical reagents which react with the soil to form an absorptive barrier to underground migrations.

It involves treating the quartz sand with 10% hydrofluoric acid (HF) which etches and preapres the area for injection of an absorptive salt specific for strontium. Of the various salts investigated, $K_2H_2Sb_2O_7$ showed the best results at a concentration of 0.05M.

Three injection wells about one meter apart were placed on the down-gradient side to a depth where the chemical barrier was to be installed (6M). The first chemical was 1320 gallons of 10% HF prepared from 365 pounds of commercially available 70% HF. The solution was slowly injected under pressure with an acid resistant pump and allowed to etch the sand for 48 hours. Next, 1475 gallons of a 0.05M $K_2H2Sb_2O_7$ salt (potassium pyroantimonate) solution was introduced using the same method. The chemical barrier was reported to have increased the retention properties of the soil by a factor of 20. The total volume of soil treated was abo 320 ft.^{3}. At current costs for materials this process would cost approx $10,000. Labor costs are expected to be comparable.



Adsorption of cations from solution by a HAPO soil affected by pH

Figure 1

SECTION 4

RADIONUCLIDE MONITORING AND SAMPLING - METHODS, PROCEDURES AND RESULTS

4.0 RADIONUCLIDE MONITORING AND SAMPLING - METHODS, PROCEDURES AND RESULTS

4.1 Soil samples were collected throughout the drilling process from all eighteen test borings. Each was prepared and counted on-site using the available U.S. Radium NaI gamma spectrometer and supplemented by RMC's field monitoring kit. In this manner, the large number of soil samples anticipated (200) could be quickly screened with reduced costs and recommendations made for further quantitative analysis only on selected samples.

Soil samples were gathered at two feet intervals from most borings and retained in plastic bags marked with the well number, depth and date of the sample. Each sample was thinly spread on absorbent paper to air dry overnight. The samples taken from below the water table were usually water saturated so that a heat lamp was used to speed the drying process. Large stones were removed and clods broken up as much as possible.

When completely dry, all samples were sifted through a course (3/16") screen and the rocks discarded. Fines were weighed (250 gms net) into 3" aluminum sample cans and canned with a master sealer to preserve each sample.

Fines from each sample were also placed in ¼" deep counting planchets producing an infinitely thick sample (11 gms) for on-site gross alpha and beta counting.

A Packard 400 channel analyzer and 3" x 3" NaI crystal was utilized by modifying the detector shield to accommodate aluminum sample cans and provide background shielding. Analyzer settings were adjusted to produce

10 Kev/channel, and each sample was counted for 10 minutes. Counts per channel were totaled according to preselected regions of interest, then posted on counting data sheets. At the completion of each count, an X-Y plotter was used to record a gamma spectrum of each sample for further reference. Selected spectra are contained in Appendix A.

Due to limited data reduction capabilities on the analyzer, and lack of calibrated soil standards, quantitative analytical results were not obtained. However, sample to sample comparisons were made and specific isotopic information was inferred from the selected regions of interest. A soil contamination profile showing gamma counts vs. depth was prepared for each well; selected profiles are in Appendix B.

Soil planchets were gross alpha and beta counted to help confirm gamma isotopic identification. Beta counting was performed on all samples usin a windowless gas flow (Ar-Me) proportional counter. Samples were beta counted for one minute each with the total counts per minute recorded on the counting data sheet. Gross alpha counting was performed only on selected samples where the presence of Ra-226 was suspected but could not be confirmed from the gamma spectra. A two inch diameter alpha scintilla and scaler was used with counts taken for 10 minutes. This information also recorded on the counting data sheet for each sample counted.

A total of eleven soil samples were submitted to RMC analytical labs in Philadelphia for quantitative analysis of Sr-90 by chemical separation and/or high resolution GeLi gamma spectroscopic analysis. Results of th analyses are shown in Table 4-1.

Table 4-1

QUANTITATIVE LAB ANALYSIS OF SELECTED SOIL SAMPLES

Bore-Sample #	Depth(ft) To - From	Chemical Separation Sr-90 (pCi/gm)	GeLi γ Spectroscopy(pCi/gm) Ra-226	Cs-137
1- 4	6- 8	26.4 ± 2.6	58	12
1- 9	16-18	836. ± 83.	<MDL*	<MDL
2- 6	10-12	264. ± 26.	<MDL	<MDL
3- 1	0- 2	5.1 ± 0.5	1.1	0.84
3- 5	8-10	3.3 ± 0.3	1.0	1.30
3-10	18-20	83.4 ± 8.3	< MDL	<MDL
3-11	20-22	<.2	< MDL	<MDL
4- 8	14-16	233. ± 23.	< MDL	<MDL
5- 2	2-4	58.5 ± 5.9	17	250
5- 7	12-14	38.3 ± 3.8	59	25
6- 7	12-14	1.8 ± 0.2	7.3	2.4

*MDL - Minimum Detectable Level (Approx. 1 pCi/gm)

Ten river silt samples were collected from five locations along the river's edge between the property lines. Distances into the river sampled were from three to twenty feet. All were dried and NaI counted on-site, similar to the procedure described above for boring samples. Only one sample showed detectable levels above background, (Cs-137). Since the river was abnormal high at the time of measurement, it is speculated that this is simply an extension of the surface contamination found on the lower plateaus, rather than river sedimentation.

4.2 Ground water samples from borings were collected using two methods: drawing liquid into an evacuated container through ½" tygon tubing and by lowering a rigid "dip tube" designed for this purpose into the water table.

Samples were drawn from wells 1, 2 and 3 about monthly starting October 18, 1978. Initial samples were sent to RMC Analytical Labs in Philadelphia for drying, gross alpha and beta counting, and analysis for Sr-90. Subsequent samples from these wells were also submitted for quantitative analysis to compare month to month fluctuations. The concentrations of ground water from wells 1, 2, and 3 are shown in Table 4-2. This data is graphically shown as Figure 2, which shows an apparent dilution effect of the ground water concentration as it moves towards the river.

Ten additional samples wells were completed and sampled by Meiser & Earl on February 21, 1979. Half gallon water samples were collected using a "dip tube" bailer and allowed to stand overnight so suspended solids could

Table 4-2

GROUNDWATER CONCENTRATION (pCi/ml)

Well No.	I		II		III	
Date	Sr-90	Gross β	Sr-90	Gross β	Sr-90	Gross β
10/18/78	32	(49)	16	(15)	3.5	(5.8)
12/18/78	72	(67)	33	(22)	6.3	(5.6)
1/18/79	110	(83)	22.2	(36.5)	3.2	(5.2)
2/23/79	-	(70.6)	-	(28.7)	-	(4)
3/15/79	-	(57)	-	(9)	-	(4.4)

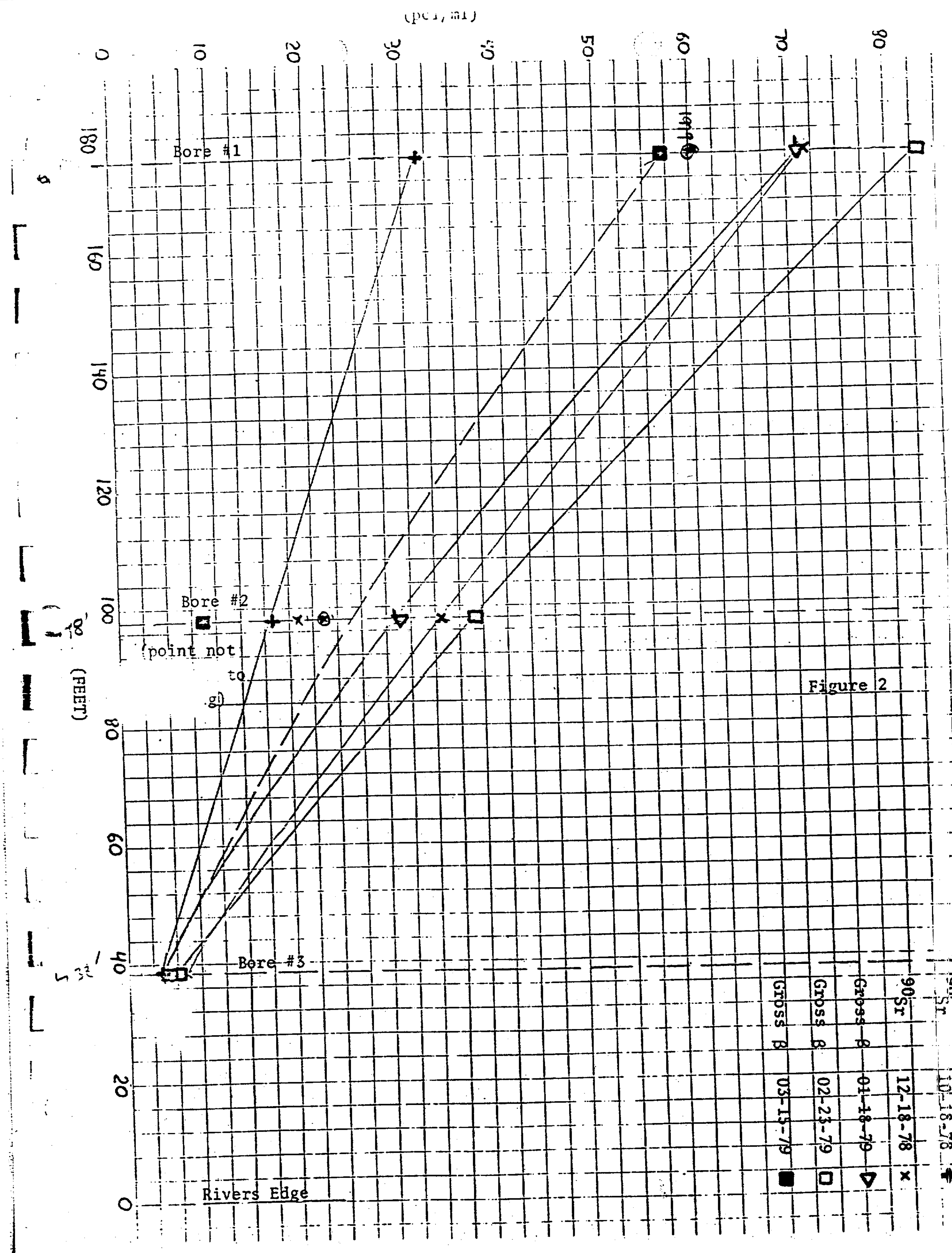


Figure 2

(pci/ml)
0
10
20
30
40
50
60
70
80
(FEET)
180
160
140
120
100
80
60
40
20
0
Bore #1
Bore #2
(point not to
g)
Bore #3
Rivers Edge
10-18-78 Sr
12-18-78 90Sr ×
01-18-79 Gross β ▽
02-23-79 Gross β □
03-15-79 Gross β ■

settle out. A 50 ml aliquot was slowly evaporated in an aluminum counting planchet using a hot plate. Dried samples were counted for one minute (beta) and ten minutes (alpha) using the equipment mentioned previously. These results provided rapid sample to sample comparisons and a basis to determine the need for further quantitative analysis.

Water from all wells (19) was collected on March 14, 1979. One gallon samples were submitted to Philadelphia for gross alpha and beta analysis and a second 50 ml sample was dried and counted on-site as above. These results are shown in Table 4-3.

In addition to these specially drilled well samples, water was collected and analyzed from the Susquehanna River between the property lines, main building feed lines, and old process well near the pits, and the Susquehanna River at the Mifflin Bridge to document the absence of detectable off site releases. All samples were at or near minimum detectable levels (MDL) as shown in Table 4-4.

Other accessable on-site surface water measured included samples from the east and west lagoons, water from a small surface run off stream at three locations, and five back hoe water samples which were obtained when pits 1, 2, 4, 6 and 7 were dug below the water table. Results of these samples are also shown in Table 4-4.

4.3 Surface gamma measurements were taken throughout an area bounded by the abandoned canal fence, the river, and the property lines, to document the extent of detectable surface and near surface contamination.

Table 4-3

GROUND WATER SAMPLES COLLECTED MARCH 14, 1979

1/50

	Field Determinations (50 ml Dried Sample)		Philadelphia Counting Analytical Results(pCi/ml	
Sample No.	Gross α (net cpm) [1]	Gross β (net cpm)[1]	Gross α	Gross
Bore 1	.45	2459	<MDL[2]	57.
2	.55	456	<MDL	8.9
3	<MDL	350	<MDL	4.4
4	.55	29 ?	X 1.4	X 2.4
5	<MDL	<MDL	X 0.67	X 0.83
6	<MDL	<MDL	X 0.96	X 1.1
7	1.2	<MDL	X 0.71	X 0.42
8	.55	<MDL	X 0.18	X 0.15
9	1.0	2	0.005[3]	0.05
10	<MDL	<MDL	X 0.242	X 0.19
11	<MDL	<MDL	0.004[3]	0.04
12	<MDL	57 ?	<MDL	X 0.6
13	.85	<MDL	<MDL	0.04
14	<MDL	<MDL	0.006[3]	0.008
15	<MDL	<MDL	0.005[3]	0.012
16	<MDL	<MDL	0.008[3]	0.016
17[3]	<MDL	<MDL	0.001[3]	0.009
18	2.9	62 ?	X 0.345	X 0.45
19	6.8	76 ?	X 1.23	X 2.
East Lagoon Water	<MDL	<MDL	0.002[3]	0.016[2]
West Lagoon Water	<MDL	<MDL	-	-

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[1] Units are counts per minute per 50ml. No self absorption correction applied. Samples were not filtered and are, therefore, not exact duplicates.

[2] Approximately 0.001 pCi/ml

[3] Old process well sample

Table 4-4

MISCELLANEOUS WATER SAMPLES

Sample	Collection Date	Gross α (pCi/ml)	Gross β (pCi/ml)	Sr-90 (pCi/l)	Where Analyzed
Susquehanna River Sample #1	12/19/79	≤1.6x10^{-3}	2.3x10^{-2}	<9.12	Phila.
Sample #2	12/19/79	<1.1x10^{-3}	1.1x10^{-2}	<8.68	Phila.
Sample #3	12/19/79	<1.1x10^{-3}	1.7x10^{-2}	<8.24	Phila.
Main Building Water	12/19/79	<7.9x10^{-4}	9.7x10^{-3}	<5.8	Phila.
On-Site Process Well Water	1/24/79	2.5x10^{-3}	1.2x10^{-2}	-	Phila.
River Water At Mifflin Bridge	2/2/79	<9.4x10^{-4}	4.4x10^{-3}	-	Phila.
Run Off #1	3/15/79	.1	<0.2(MDL)	-	US Radiu
#2	3/15/79	.12	<0.2	-	US Radiu
#3	3/15/79	.8	<0.2	-	US Radiu
Back Hole #1	3/15/79	<.06	5.8	-	US Radiu
#2	3/15/79	<.06	0.29	-	US Radiu
#4	3/15/79	<.06	0.28	-	US Radiu
#6	3/15/79	<.06	1.6	-	US Radiu
#7	3/15/79	<.06	3.4	-	US Radiu

Using a hand held 2" x 2" NaI crystal and a portable ratemeter, levels were measured in counts per minute (cpm) at contact with the soil and recorded on a site map (Figure 3) as multiples of background. Typical background readings were 1,000 to 1,500 cpm. From this information, a rough sketch of contaminated areas was constructed of areas greater than twice background. In some locations, several "hot spots" were reading 25 times background at contact, as shown.

In five higher reading areas, marked A through E on Figure 3, levels were measured at 6" and 12" below the surface by digging a 2 foot diameter hole. Location "B" was chosen in an area off-site on neighboring property. Three soil samples were collected at each location and counted in the same fashion as mentioned in Section 4.1 to identify the radionuclide(s) present. The major surface contaminants were Ra-226 and Cs-137. Gamma spectra of these samples are shown in Appendix A. Three samples, location "A" at 6", "C" at surface and "E" at 12", were submitted for GeLi gamma spectroscopic analysis. These results are shown in Table 4-5. The highest soil concentration was 750 pCi/gm of Cs-137 at "A".

To better define surface and near-surface contamination, seven back-hoe trenches were constructed in the lower plateau at various locations as shown (Figure 3). Gamma readings were taken along the exposed wall into the trenc and are summarized in Table 4-5. Highest readings were found in Back Hoe #1 which was dug into the abandoned canal. There was evidence of contaminated trash, building rubble and other debris at a depth of 6 feet.

Selected spectra of back-hoe soil samples are contained in Appendix A.

Table 4-5

Special Samples	GeLi Spectroscopy (pCi/gm)	
	Ra-226	Cs-137
A - 6"	< MDL	750
C - Surface	64	550
E - 12"	480	250

Back Hoe Pit Observations

Back Hoe #1

Located about 50 ft. south of Lacquer Storage Building.

Surface reading was 40,000 cpm. Four foot depths showed same levels. At 6 feet, trash, boards, trees, and other debris were uncovered indicating that waste may have been used as fill material in the old canal. Readings increased to greater than 60,000 cpm (full scale) below 6'. A water sample was taken.

Back Hoe #2

Located below any contaminated areas about 100 feet directly below pit #1 (towards river).

No readings were observed above background. Water sample taken.

Back Hoe #3

Located directly south of the waste building five feet from the abandoned canal fence. Should have been located into the old canal. ?

No readings above background to a depth of 7 feet. No trash or debris to indicate other than earth fill. Water did not accumulate in pit before back filling.

Table 4-5, Con't.

Back Hoe #4

Location was selected in a contaminated area by well #18 about 20 feet from the S.E. corner property line.

Surface readings were 10 times background (10,000 cpm).

Levels dropped considerably to 2,000 cpm at three feet, and to background at 6 feet, indicating surface contamination only.

Back Hoe #5

Located directly south of Evaporator House, five feet below the abandoned canal fence.

Readings were twice background at the surface only. There was no debris or water down to 6 feet.

Back Hoe #6

In a contaminated area near well #19.

Highest readings (3 times background) were at 3 feet.

Appeared to be gravel and sand fill down to 6 feet, then black clay. Readings dropped to background below 6 feet.

Back Hoe #7

Located slightly north of Pit #1.

As the trench was being dug towards #1, a rock wall was encountered, apparently that of the abandoned canal.

Readings north of the wall (towards Lacquer Storage) were background. Readings south of the wall (towards the river) increased to well above 60,000 cpm.

A soil and water sample was taken.

FIGURE 3

CONTAMINATED AREAS AND LOCATIONS - SITE MAP

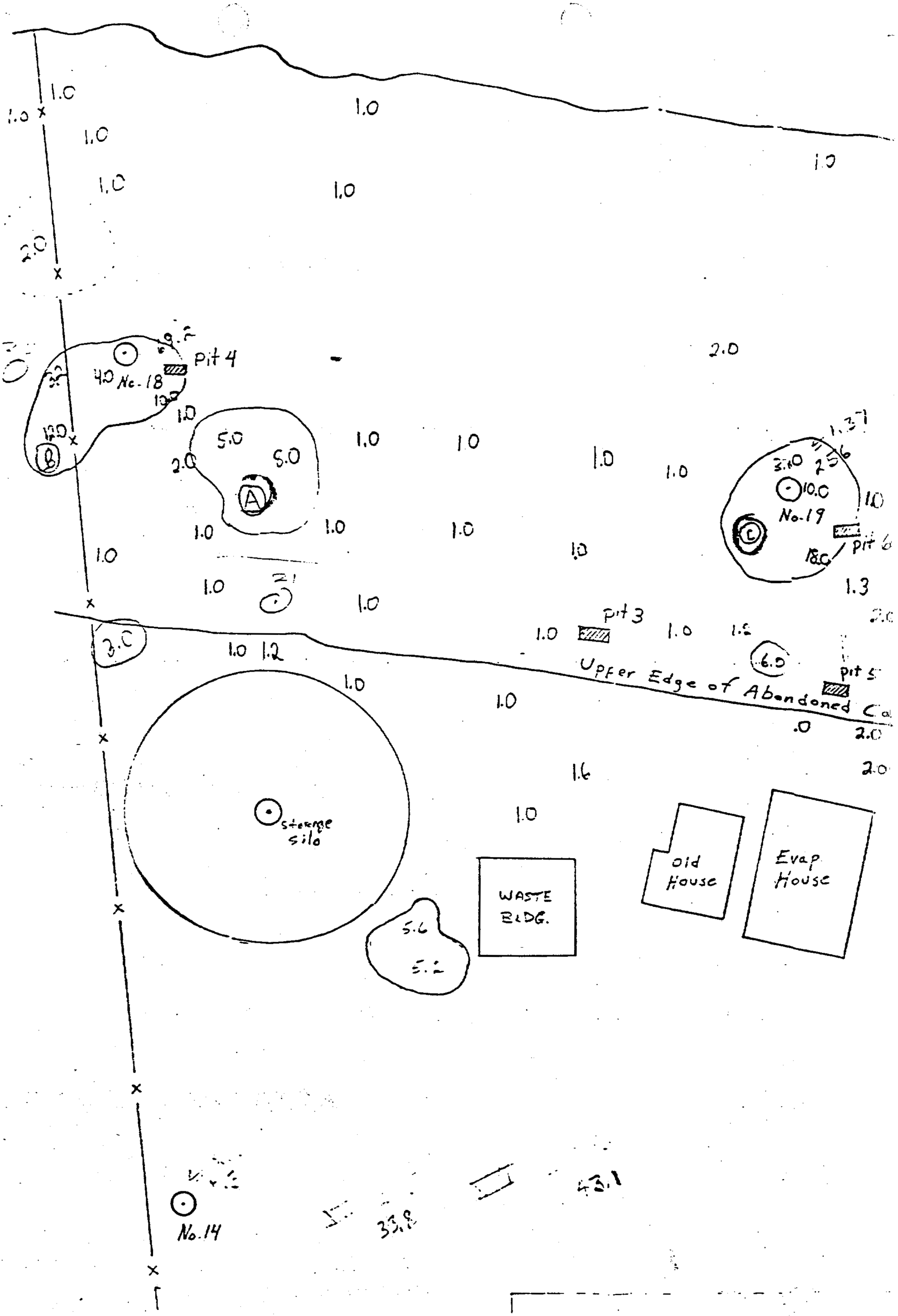
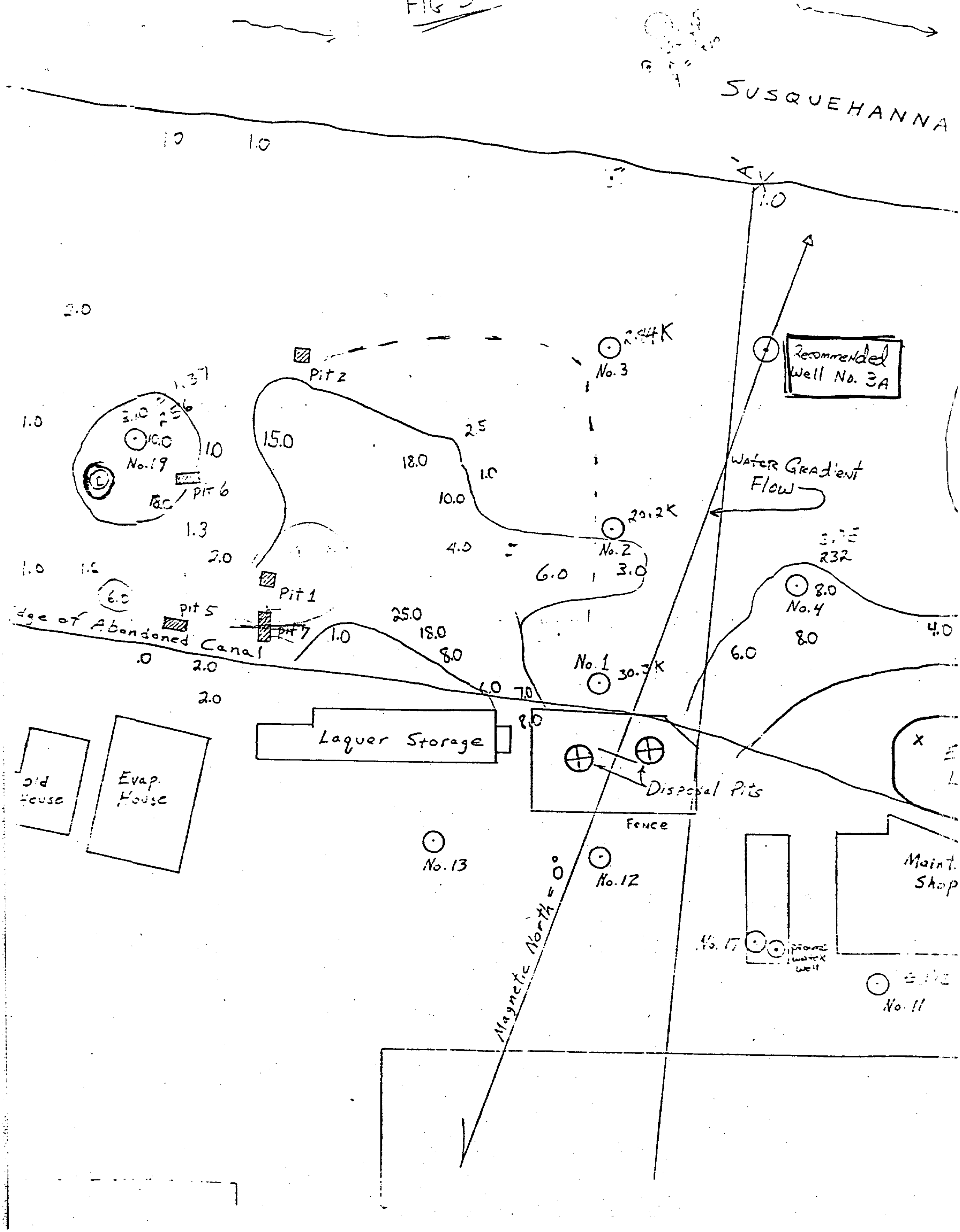
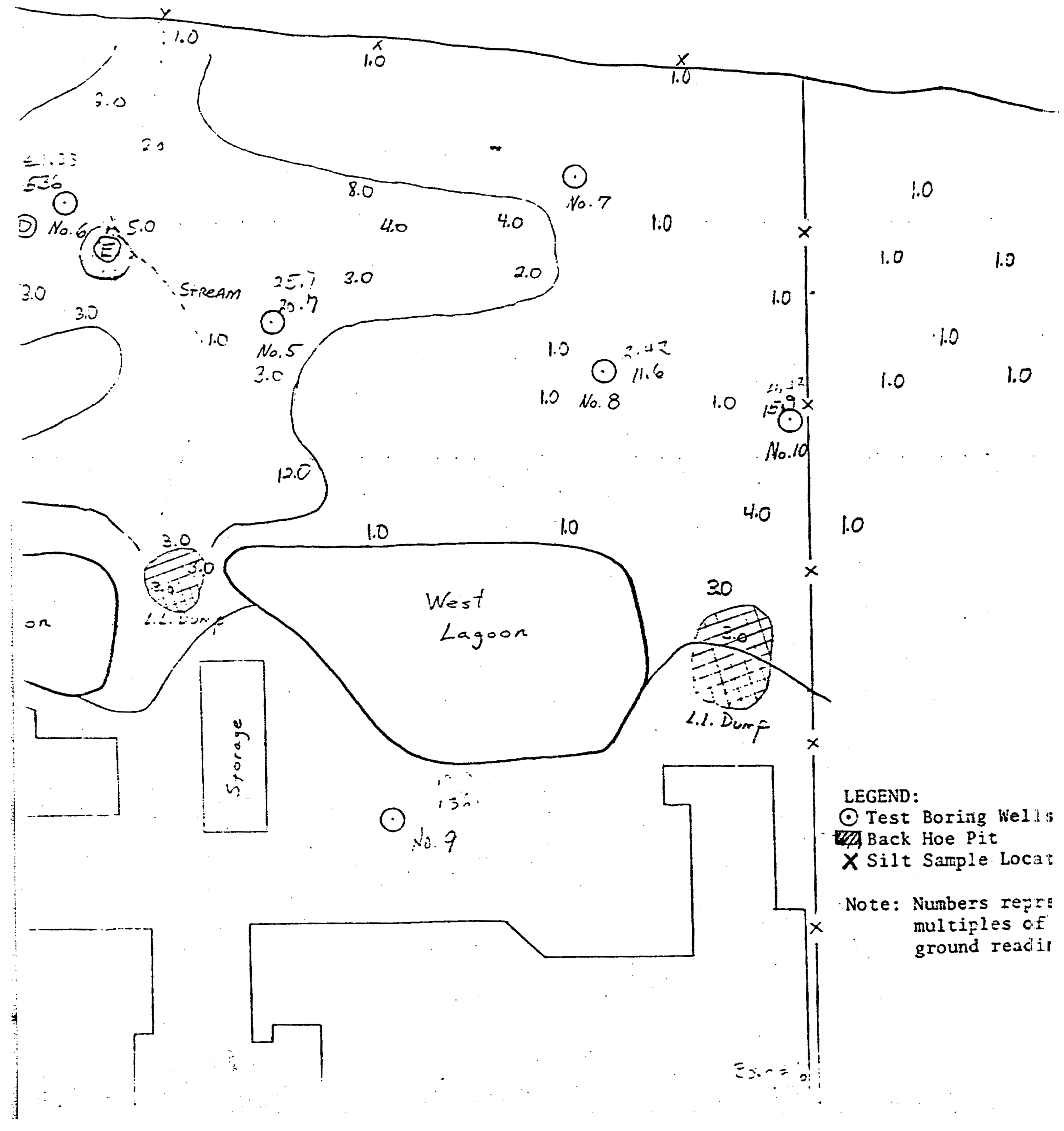

1.0
1.0
1.0
1.0
1.0
1.0
1.0
2.0
2.0
9.2
Pit 4
4.0
No.18
10.0
3.2
12.0
B
1.0
5.0
5.0
2.0
A
1.0
1.0
1.0
1.0
1.0
1.0
1.37
2.5
6
3.0
2
10.0
No.19
1.0
C
Pit 6
18.0
1.0
1.0
1.0
1.0
1.0
1.0
1.0
1.3
21
1.0
3.0
1.0
1.2
Pit 3
1.0
1.0
1.6
6.0
Pit 5
Upper Edge of Abandoned Ca
1.0
1.0
.0
2.0
1.6
2.0
1.0
storage silo
WASTE BLDG.
Old House
Evap House
5.6
5.2
No.14
33.8
43.1

FIG 3


SUSQUEHANNA
A
1.0
1.0
1.0
2.0
Pit 2
No. 3
2.54K
Recommended Well No. 3A
1.37
3.10
10.0
No. 19
1.0
1.0
15.0
18.0
2.5
1.0
10.0
Pit 6
18.0
1.3
2.0
Water Gradient Flow
20.2K
No. 2
4.0
6.0
3.0
232
No. 4
8.0
8.0
4.0
1.0
1.6
6.0
Pit 1
Pit 5
Pit 7
Edge of Abandoned Canal
25.0
18.0
1.0
8.0
6.0
.0
2.0
2.0
No. 1
30.3K
6.0
7.0
8.0
Laquer Storage
Old House
Evap. House
Disposal Pits
Fence
No. 13
No. 12
Magnetic North = 0°
Maint. Shop
No. 17
Process water well
No. 11

R-226	30
Sr-90	300
Cs-137	20,000
H-3	3,000,000



SECTION 5

INTERPRETATION OF DATA

5.0 Interpretation of Data

5.1 Soil sample analysis indicates that Sr-90, Cs-137 and Ra-226 are the primary contaminants. This was initially determined by high count rates in selected regions of interest and reviewing the corresponding contamination profiles (Appendix B).

Gamma spectra provided more information to confirm the presence of these isotopes. Sr-90 was indicated by the presence of low energy bremsstrahlung photons in Bore 1-7 and 1-8, Appendix A. Ra-226 was indicated by four "medi energy peaks (180, 240, 290, and 350 Kev) as shown in Bore 4-1, 5-1 and others. The presence of Cs-137 best was indicated by the presence of a 662 Kev photon as shown in the spectrum of point "A" at the surface. Relative amounts of each isotope or the absence of a single nuclide can be seen by making spectrum to spectrum comparisons. Quantitative analysis was recommended when a combination of isotopes could not be identified or a concentration level was useful.

Subsurface soil concentrations are highest in wells 1, 2, 3, 4, and 5, ranging from background to 836 pCi/gm of Sr-90 in well 1-9 (18 ft). Well number 5 showed the highest concentrations of Ra-226 and Cs-137 with 59 and 750 pCi/gm respectively. These amounts represent fairly high levels in soil, although unless it is leached into ground water no great hazard exists. The licensee can maintain adequate control over on-site contaminated soil. Contamination levels may have to be re-evaluated if a sale of the property is planned.

Other wells (6, 8, 10, 11, 12, 18, and 19) showed measurable amounts of ground contamination, but within a factor of 10 to that of normal background concentrations (1-5pCi/gm).

5.2 As stated earlier, ground water flow into the river is the most probable mode for release to an unrestricted area (river).

Samples from wells 1, 2, and 3 have been suprisingly consistent over a six month period, considering the varying conditions and ground water flows dur the same time. In addition, all tend to be consistent enough to suggest a near linear dilution effect (Figure 2) as the activity moves towards the river. In reality, the curves should be more exponential than suggeste However, either method shows a projected release concentration of less than maximum permissable (0.3 pCi/ml) for Sr-90. Other radionuclides which may be present in ground water would also be below the maximum permissable at the river's edge. Two high gross alpha readings shown in Table 4-3 from wells #4 and 19 are not confirmed by additional results. These levels in water are reported as 1.4 pCi/ml and 1.23 pCi/ml. A radium determinatio of these water samples appears warranted.

Assuming a total water flow of 320 gallons/day through a one foot "window" as the hydrologist suggests, no more than 160 mCi of Sr-90 could be released to the river in a single year. This is less than the one curie limit set by the NRC for discharges to a sewer system. It assumes a worst possible case of continuously releasing at the MPC (0.3 pCi/ml for Sr-90) along the entire river's edge between the property lines (approximately 1200 feet). Information from wells 7, 8, and 18 and from back-hoe pit #2 do not indicate signigicant gross beta levels, so the actual "width" of discharge is probbaly less than 100 feet.

However, to confirm and document these releases, one additional sampling well should be constructed along the expected maximum concentration line shown by the hydrgeologist, somewhere between wells 3 and 6. In this manner, concentrations of releases moving through this point could be accurately compared to the MPC's on a routine basis. *

Other environmental water sampled indicates that potential releases cannot be distinguished from the natural background concentrations already present. This is due in part to the small releases expected and the huge river dilution of 3300 gal/min. (??)

5.3 The extent and pattern of surface or near surface ground contamination do not appear to be related to the below ground waste storage silos. Major contaminants are Cs-137 and Ra-226 and usually appear in the first three feet of soil. The large contaminated area below the east lagoon tends to suggest surface run off from the lagoons or from surface dumps during flooding rather than leaching from the silos.

Exposures to individuals in these areas are estimated to be insignificant. Sodium iodide probe readings cannot be directly converted to mR/hr exposure rates; however, HASL-300 lists a conversion factor of 0.38 uR/hr/pCi/g of Cs-137, assuming a typical surface level distribution in soil. The maximum 750 pCi/g sample would cause an exposure rate of 0.3 mR/hr. Continuous exposure (40 hrs/wk) in this location would produce a calculated dose of 1.2mR/40hrs. or about 1% of the occupational exposure limit.

As shown on Figure 3, there was one surface area of soil contaminated with Cs-137 which was off-site. The exposure rate in this area does not exceed NRC unrestricted limits, and expected resultant exposures should have been slight. This area of soil should be removed, however, as soon as possible as recommended.

SECTION 6

LICENSE REVIEW - PUBLIC DOCUMENT ROOM

6.0 License Review Summary

U.S. Radium File

NRC Public Document Room, Silver Springs, Maryland

The purpose of this task was to gather and document information which may be contained as a part of the public record relative to prior facility operations. Under the Freedom of Information Act, RMC had arranged to view and copy selected licenses, applications, inspection reports, internal memoranda, waste disposal records, material transfer reports and distributions, submitted to the Nuclear Regulatory Commission.

On March 16, 1979, the complete U.S. Radium file had been assembled, except for information designated as proprietary. It consisted of all retained correspondence and submittals made to the NRC/AEC since about 1954. Prior to that, users of material were required to obtain specific authorizations to possess, use and transfer active material; and those records are not retained and have been destroyed.

A large portion of the forty to fifty file folders made available contained product literature information required by the NRC for distributions under general distribution license provisions. The broad scope manufacturing license of U.S. Radium under which some 14 various isotopes were possessed (including Sr-90, Tl-204, Cs-137, Co-60, Kr-85 and Po-210) was the 37-30-02 license applied for on June 6, 1956 and issued on June 20, 1956 under the new licensing program.

We were reviewing early files to supplement incomplete information on activities relative to on-site burials of material made in two disposal silos, supposedly during the 1950's.

Waste disposal procedures were mentioned several times in various early correspondence between the Commission and U.S. Radium:

> In an early inspection report dated 11/7/55, NRC inspector Robert Barker, referred to waste disposal as "being made in two old silos which have been buried in the ground, some 15 feet in diameter. They have concrete floors and manholes in the top for introducting contaminated solids. These cost about $150 three years prior to filling the first one. The top of the full one was covered with concrete. This, they think, is (sic) permanent type of disposal system. The other is only partially filled".

Seven months later, in an application letter dated June 6, 1956, at the request of the AEC for more information on waste disposal procedures, C.C. Carroll, General Manager of the Bloomsburg Division, replies:

> "All dry wastes are encased in glass bottles or metal cans and enclosed in a secondary metal container.... These wastes are shipped, upon approval of Mr. J. H. Gillette, to ORNL for disposal. For disposal of low level contaminated equipment, a locked concrete burial site has been constructed on the premises."

Finally, in a file memo dated December 18, 1957, about discussions of a recent inspection of the Bloomsburg facility by New York operations on October 2, 1957, J.W. Hitch of the AEC writes:

> "Permissible levels of radiation in unrestricted areas at the waste disposal silo is (sic) being surrounded by a 6 ft. fence which

Mr. Dooley states will be effective in controlling entry into this area".

These three mentions are the only references about the on-site waste disposal practices contained in the public record files. It indicates that the NRC was aware of U.S. Radium's intent to bury contaminated waste on site as a "permanent type of disposal", as one inspector referred to it. Since there was no evidence that the intent or manner of these disposals was defined or that the AEC/NRC objected to the process due to existing regulations, the licensee has apparently not violated any license conditions by burying these materials on site.

Subsequent inspection reports contained no information about the disposals, probably due to the fact that on-site burials ceased when the second silo was filled.

In addition to these findings, there was considerable correspondence beginning about 1967 questioning the boundaries of the plant restricted areas. In a letter to the AEC of April 24, 1969, O.L. Olson stated that "the total plant site will be used as a restricted area for the purposes of calculating atmospheric dispersion". However, the AEC, in correspondence dated September 10, 1973, and again on April 20, 1976, apparently questioned the validity of the total plant site as a restricted area and requested additional information.

Again, on April 28, 1977, Jack Bell of the NRC stated "....if the total plant site is used as a restricted area..., as you have stated it is, you must control access... If you do not control access to this area, it may not be considered a restricted area for any purpose".

This clarification, defining to the Commission the boundaries of the restricted area is crucial in determining where release limits to an unrestricted area apply and will have to be defined with the NRC as per our recommended actions in Section 7.0.

SECTION 7

CONCLUSIONS AND RECOMMENDATIONS

7.0 Conclusions and Recommendations

7.1 General conclusions are as follows:

1) It is our opinion that there is no immediate risk to the public health and safety from the conditions encountered at the Bloomsburg facility.

2) Sub-surface water contamination was detected in the water table below the lower plateau. Sr-90 analyses of the well water samples surrounding the disposal silos indicate that a) the silos are the source of Sr-90, and b) release concentrations are projected to be below those allowable by the NRC. This is assuming that the river's edge is the south property boundary, is located as shown in Figure 3, and the lower plateau is designated as a restricted area. Recent gross alpha and gross beta counts of wells 18, 19, 4, 6, 5, 7, 8, 10, and 12 show detectable activity, in excess of that in the three background wells (14, 15, and 16). These results are not supported by preliminary field analyses, collected on February 23, 1979, and may represent sample cross-contamination, or varying concentrations with time. These results should be confirmed by re-sampling and re-count, followed by specific quantitative and qualitative analyses.

3) Soil contamination appears to have three origins: a) The subsurface area south of the disposal pits (Sr-90) appears to have leaked from the pits; b) buried debris in the abandon canal as indicated by back-hoe trenches, and c) non-uniform surface or near-surface contamination in random areas throughout the lower plateau from either surface deposition or runoff/overflow from the lagoons.

These concentrations represent a slight hazard due to the low exposure rate and leaching rate. Off-site contamination (mostly Cs-137) is detected across the southeast property line. This also represents a slight hazard.

4) Removal of on-site contaminated soil or the relocation of the waste disposal sites do not appear to be warranted or justified at this time. Continued monitoring is necessary.

7.2 Recommendations

[illegible] my recommendations to M. [illegible] Ralph & Larry on 6-04-79

OK 1) Clearly indicate to the NRC that the area below the abandoned canal fence to the river is a restricted area. Control access to this area by posting "keep out," "no trespassing," and "restricted area" signs along both property lines. Physical barriers, i.e. a fence, may be necessary.

No Alternately, remove the contaminated soil to the restricted area.

OK 2) Remove contaminated soil from the off-site neighboring property and relocate in the restricted area. Monitor to insure removal is complete.

3) Drill one additional monitoring well (3A) along the maximum expected ground water table flow between the pits. The hydrogeologist indicates this to be slightly west of Bore #3. This will confirm that projected concentrations based on samples from wells 1, 2, 3, and 3A represent maximum concentrations being released. If the projection of the concentration is in excess of limits, three options would be available:

   No 1) Excavate and relocate contaminated materials and soil now located on-site to an authorized burial site.

   No 2) Design and implement techniques to contain or slow the migration of the contaminated ground water, such as a grout curtain, injection of a chemical barrier, or pH adjustment.

N

3) Apply for a license condition to allow the release of effluents greater than MPC as per 10 CFR 20.106 or obtain approval for alternate disposal methods provided for in 10 CFR 20.302.

4) Design and implement an ongoing monitoring program to document the status and changes in the current situation. Routine water samples should be taken monthly from wells 1, 2, 3, and 3A for gross alpha and gross beta, with quarterly composites analyzed for Sr-90. These values can be used to project the release concentration at the river's edge. Water from all the wells should be sampled quarterly and analyzed by gross alpha and gross beta counting of the soluble fraction. Selected samples should be isotopically analyzed as indicated by the gross alpha/beta results.

Environmental samples such as river water (quarterly, gross alpha/beta) vegetation (seasonally, gamma spec.), squirrels (annually, gamma spec.), and fish (semi-annually, Sr-90 bone, gamma spec. flesh) should be collected to document the absence of environmental releases.

5) Consideration should be given to flooding conditions of the Susquehanna River. It is difficult to determine the rate of discharge to the environment as the river floods over contaminated areas of the lower plateau. This may have contributed to the widespread surface contamination locations. A properly constructed dike along the south and east property line could prevent water from flooding over the contaminated areas and

reduce the chance for contamination spread. Alternately, the contaminated areas of the lower plateau could be removed and placed in a protective area (i.e. west lagoon) for later disposal.

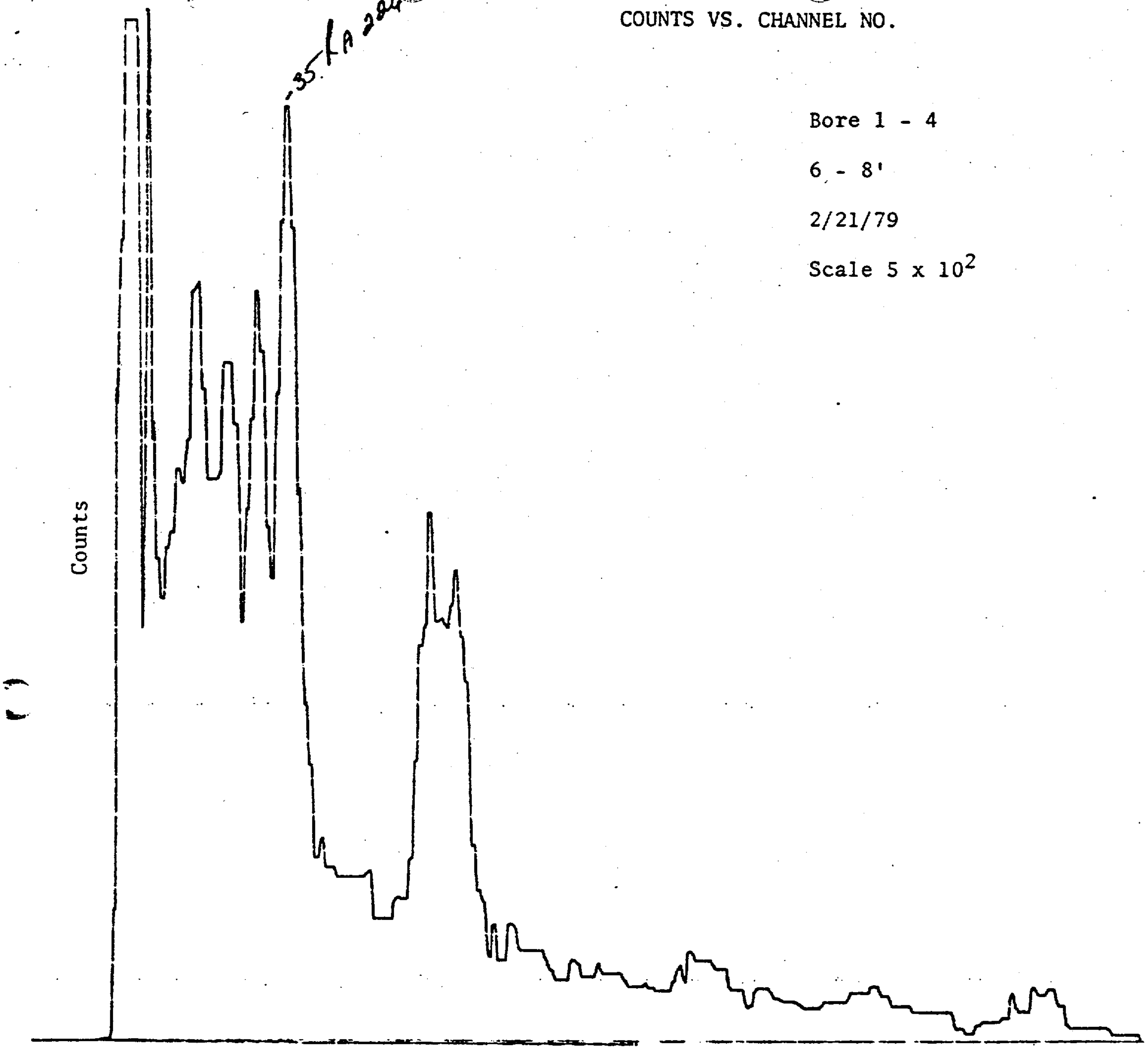
Final disposal techniques before resale or license termination may involve additional measures to be considered. The scope of these will also be influenced by the regulatory agencies involved and future intended use of the property.

APPENDIX A

SELECTED GAMMA SPECTRA OF SOIL SAMPLES

GAMMA SPECTRUM OF SOIL SAMPLES

COUNTS VS. CHANNEL NO.



Bore 1 - 4

6 - 8'

2/21/79

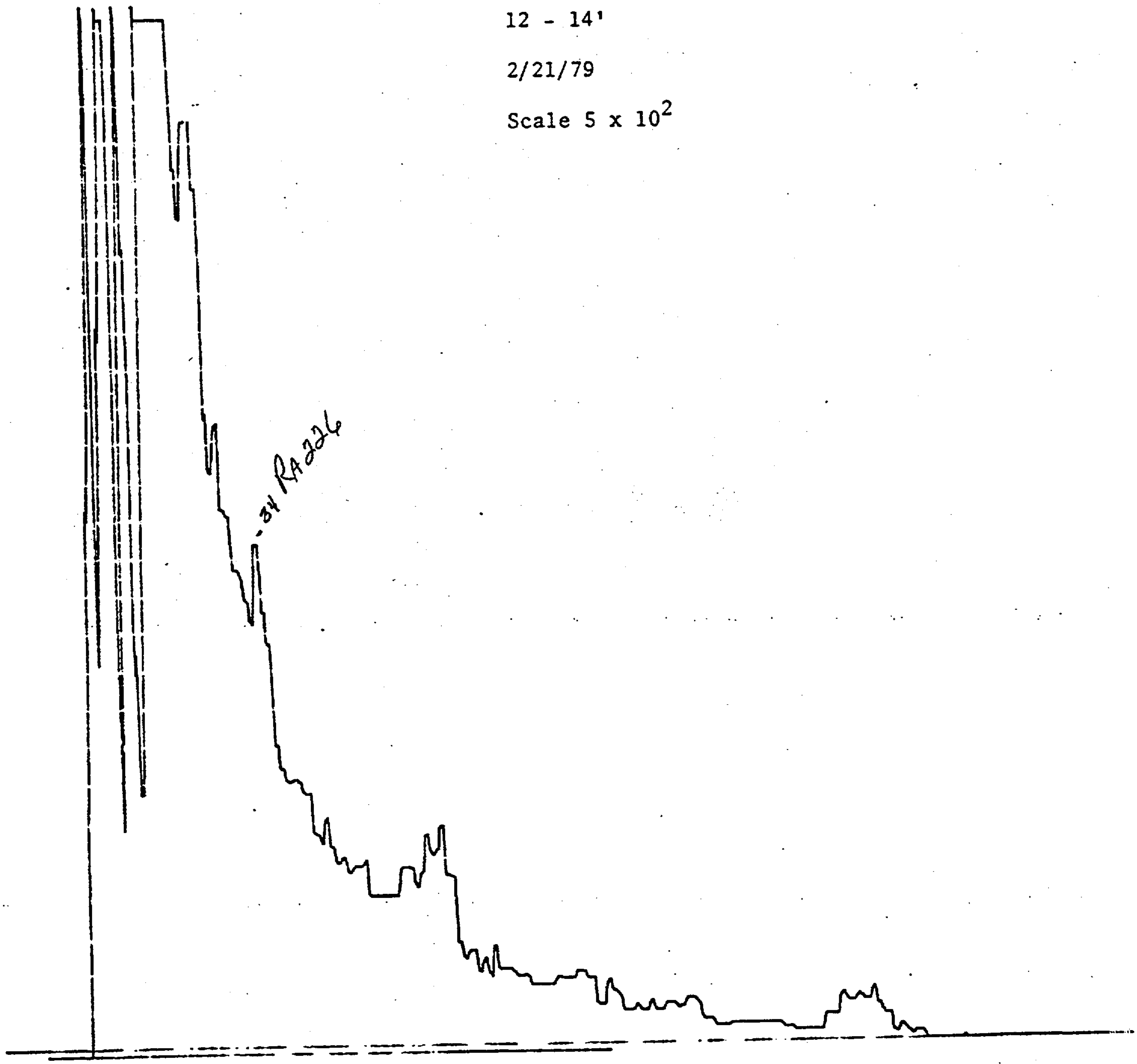
Scale 5 x 10^2

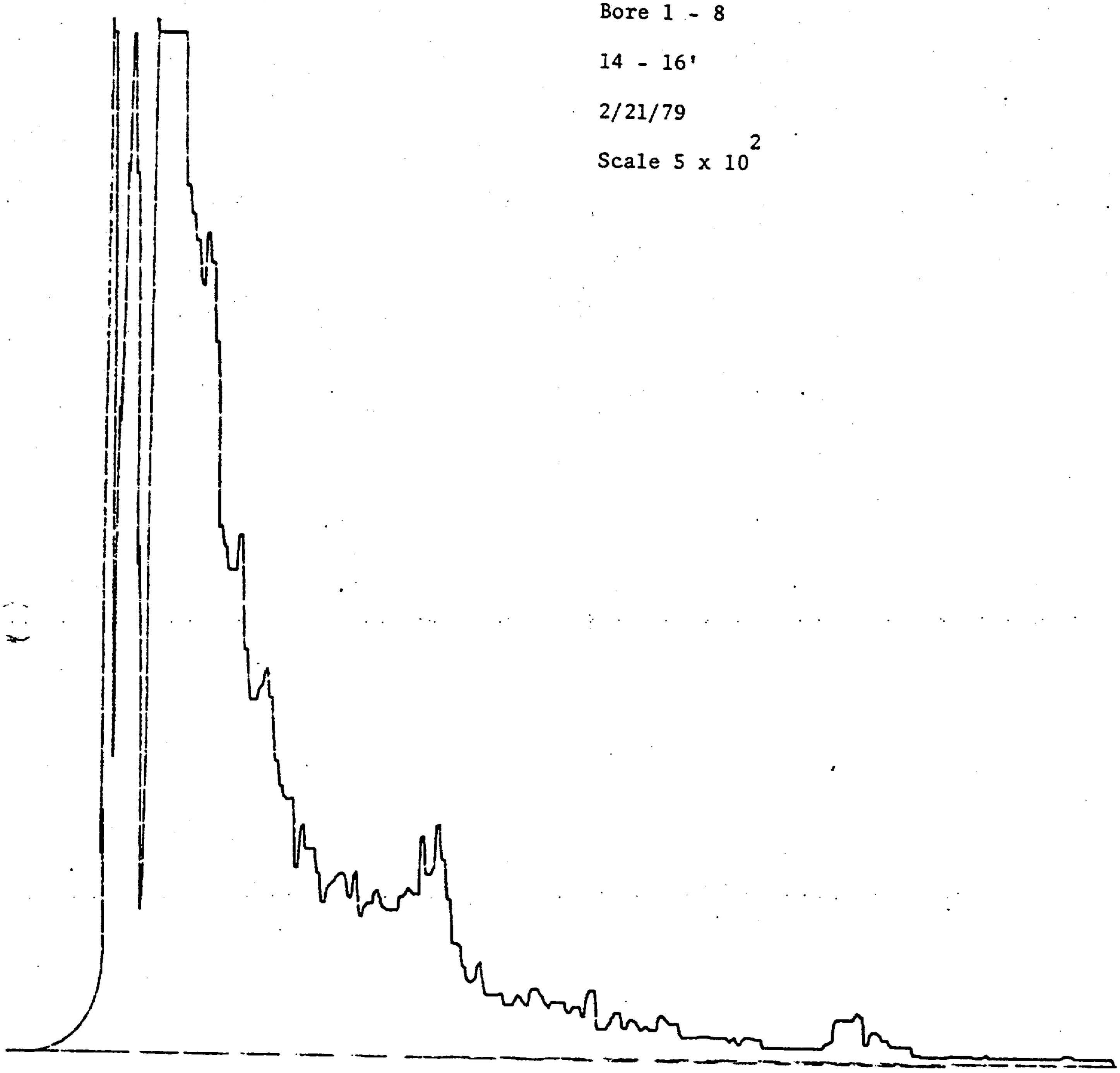
Bore 1 - 7

12 - 14'

2/21/79

Scale 5 x 10^2





Bore 1 - 8

14 - 16'

2/21/79

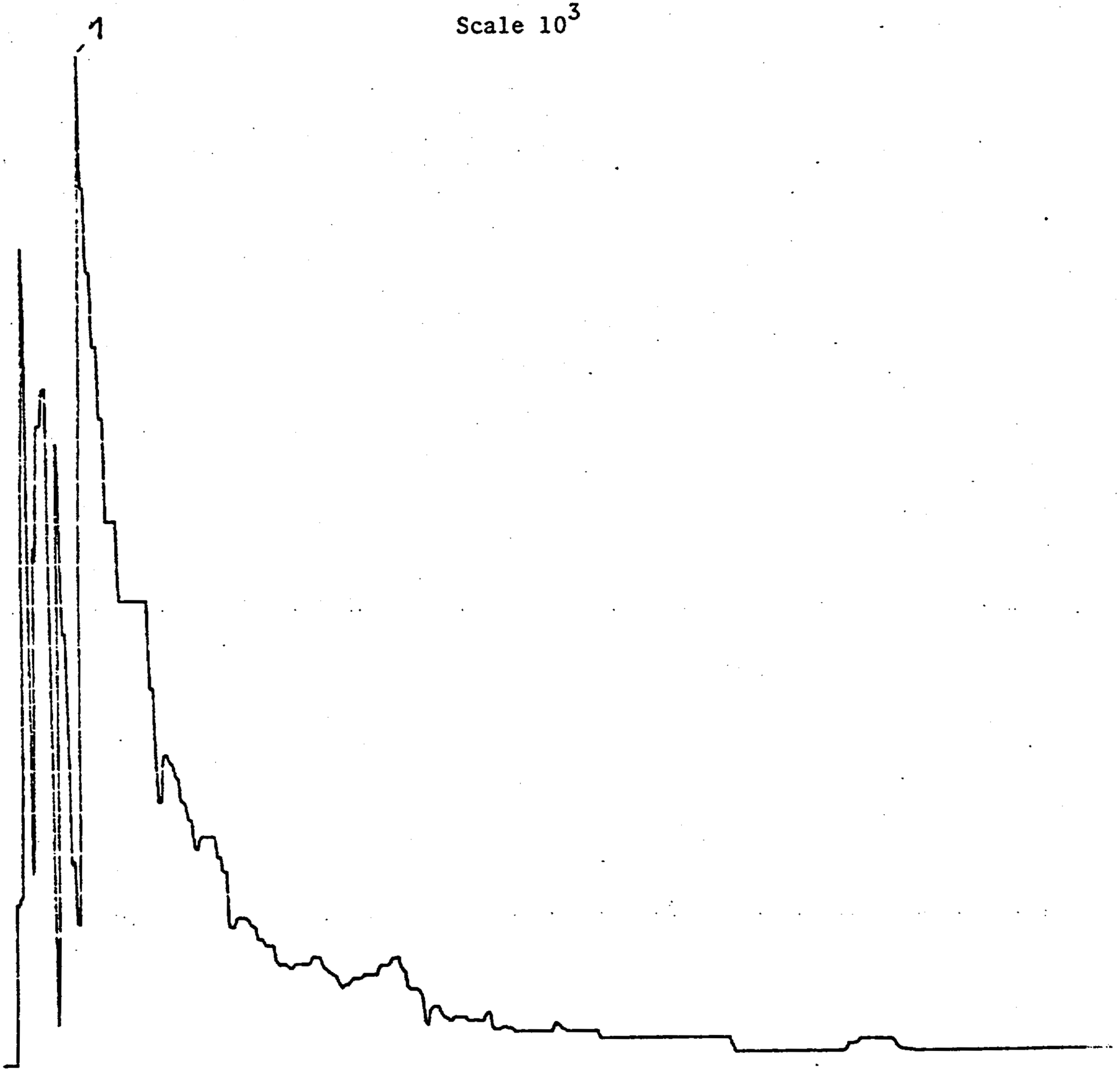
Scale 5 x 10^2

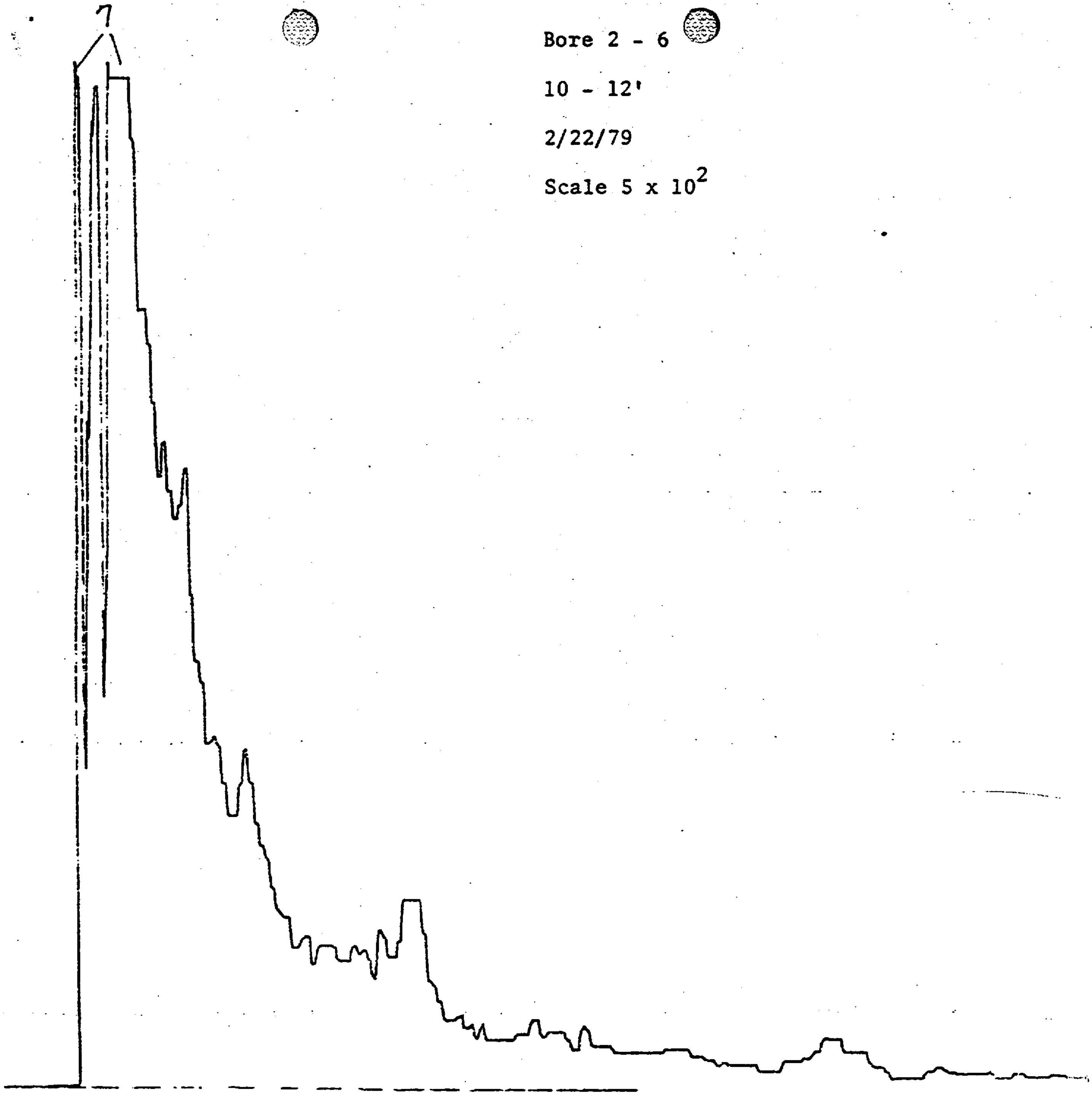
Bore 1 - 9

16 - 18'

2/21/79

Scale 10^3





Bore 2 - 6

10 - 12'

2/22/79

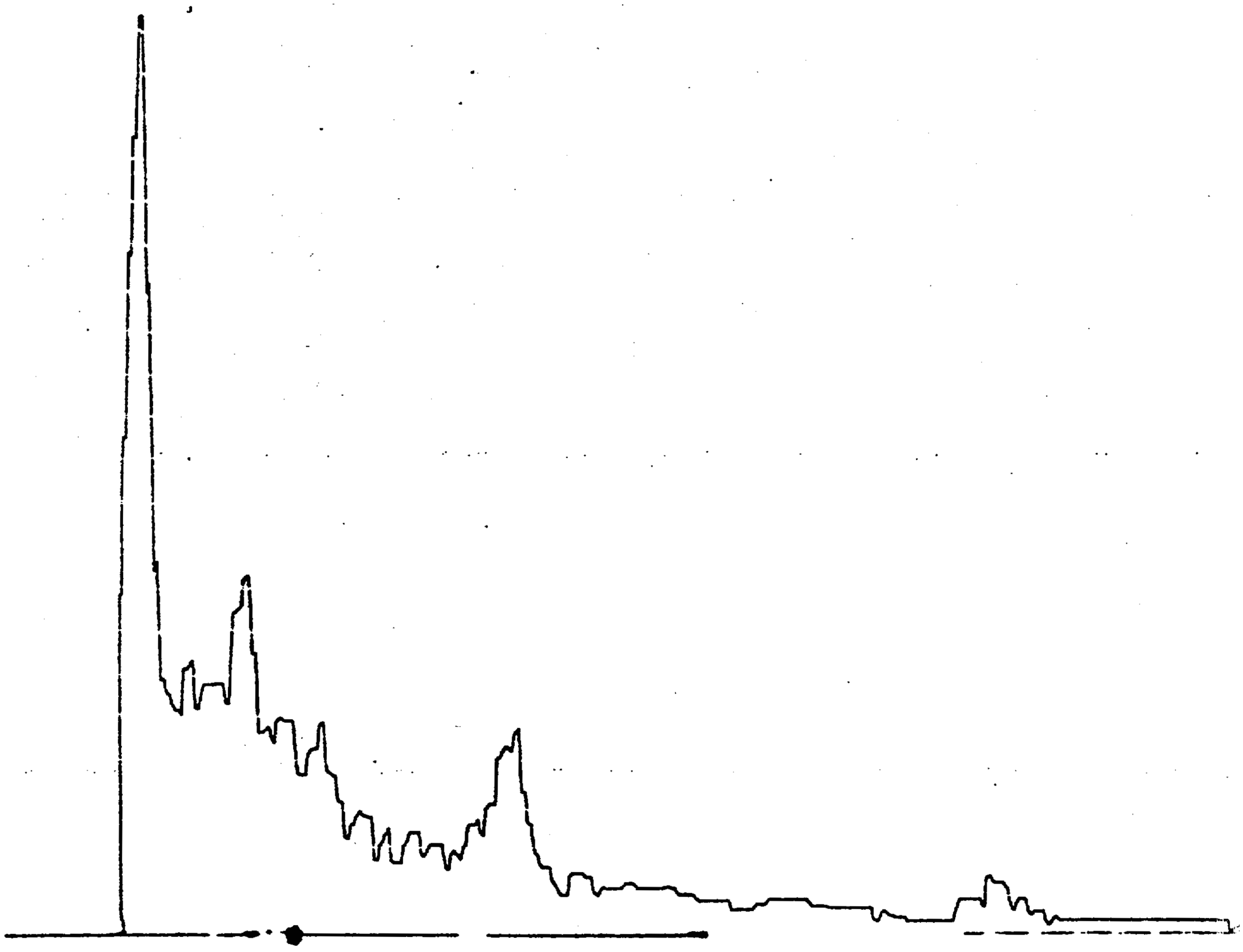
Scale 5 x 10^2

Bore 3 - 5

8 - 10'

2/22/79

Scale 5 x 10^2

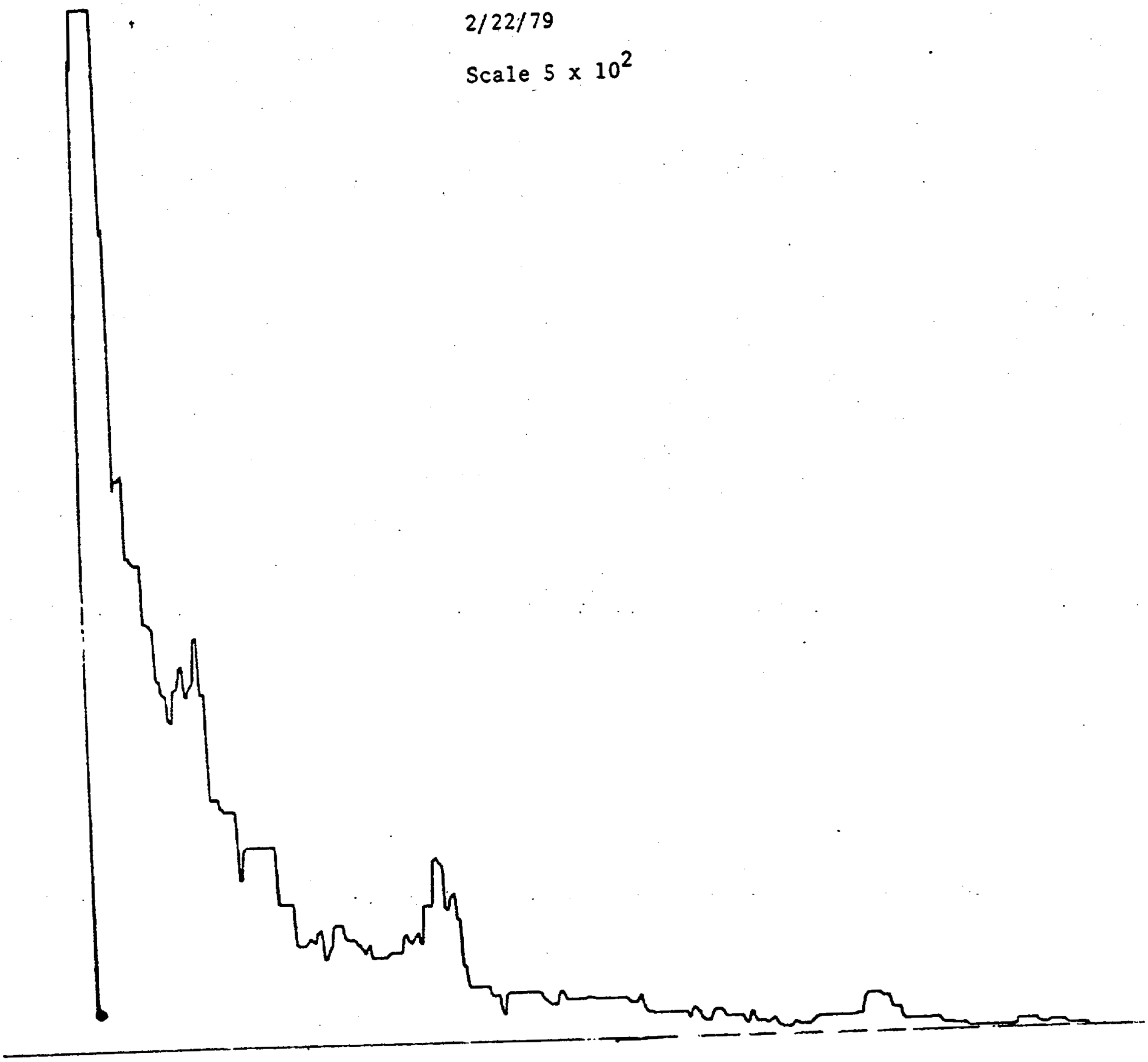


Bore 3 - 10

18 - 19'

2/22/79

Scale 5 x 10^2

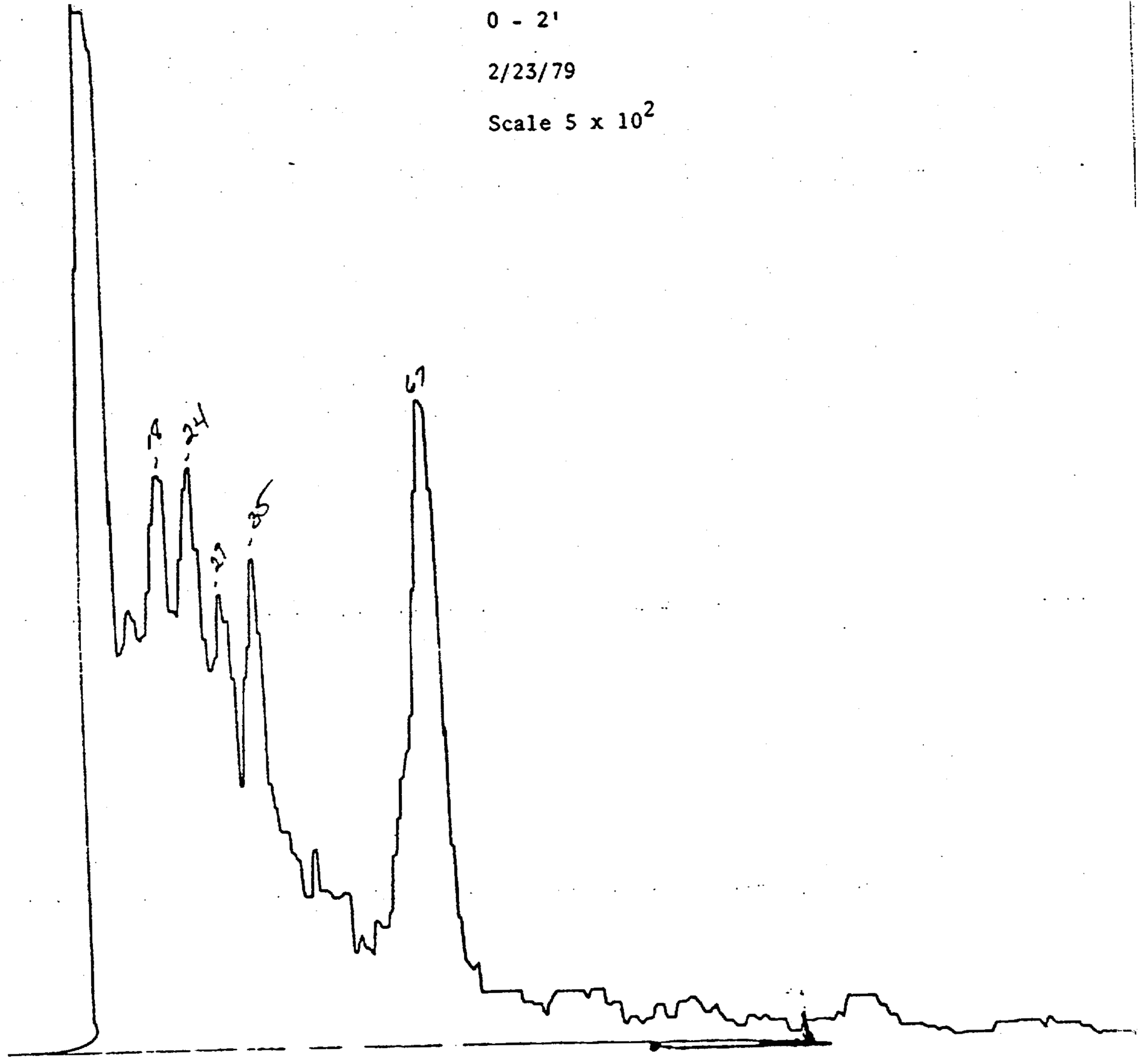


Bore 4 - 1

0 - 2'

2/23/79

Scale 5 x 10^2

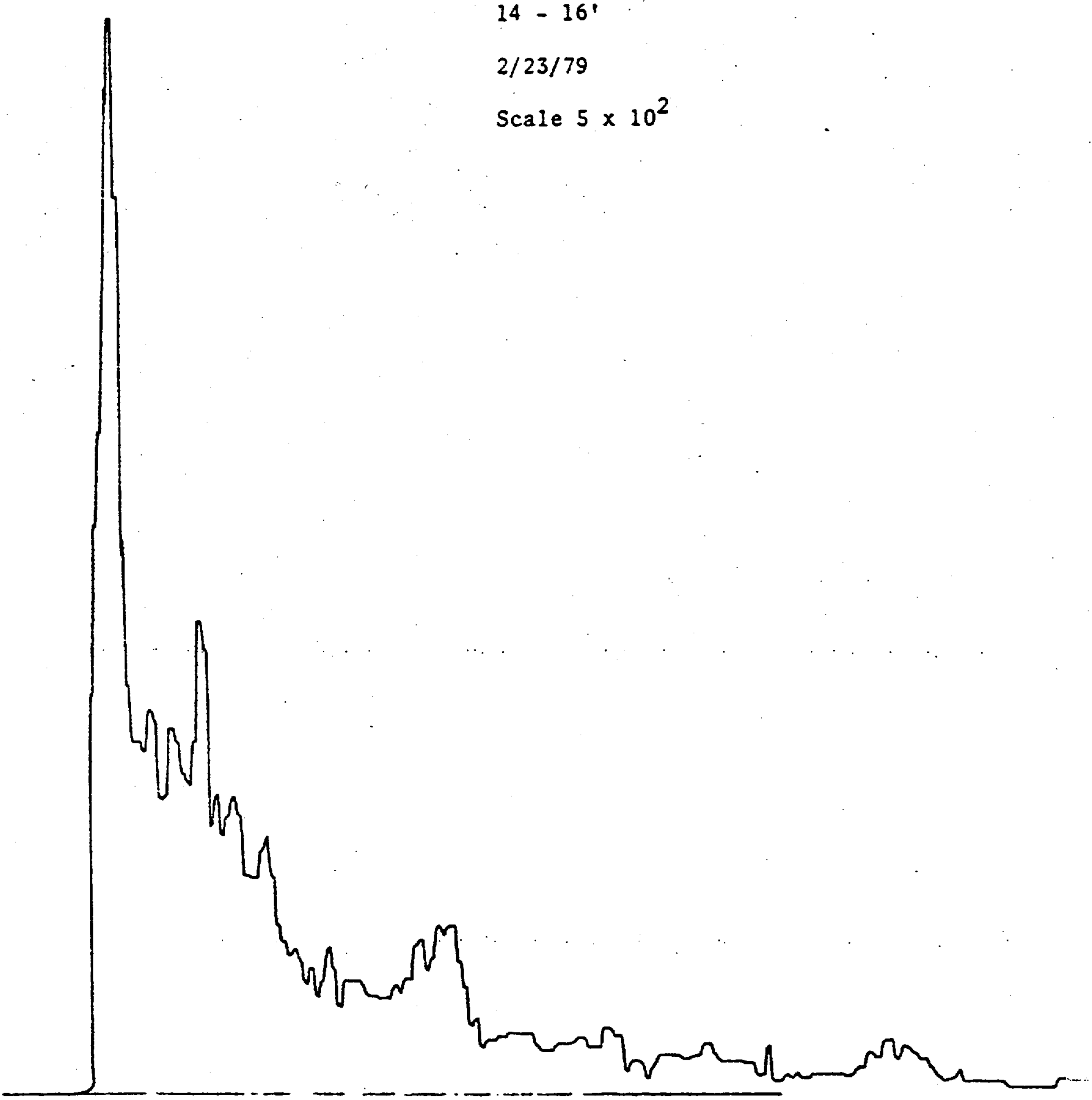


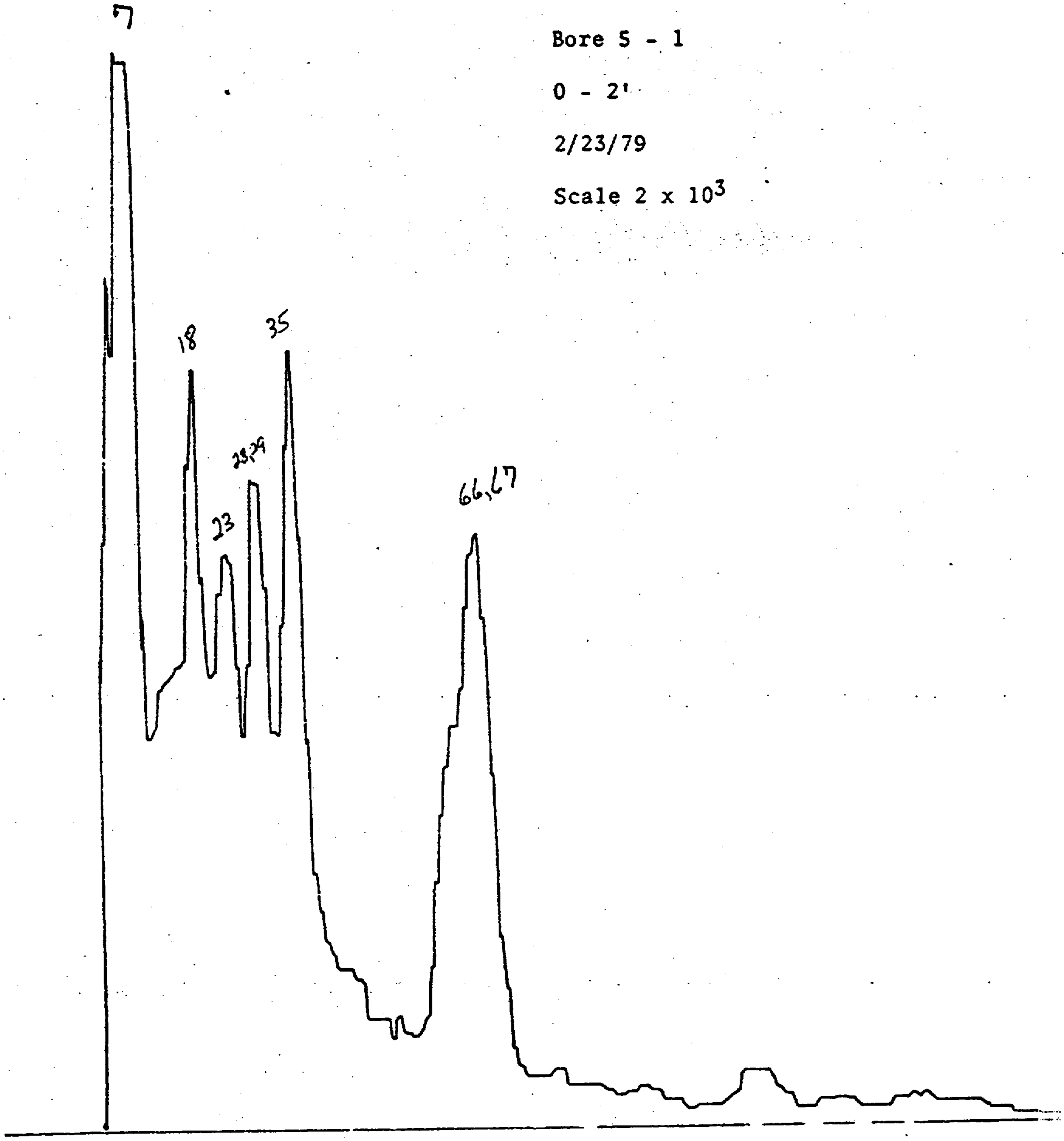
Bore 4 - 8

14 - 16'

2/23/79

Scale 5 x 10^2





Bore 5 - 1

0 - 2'

2/23/79

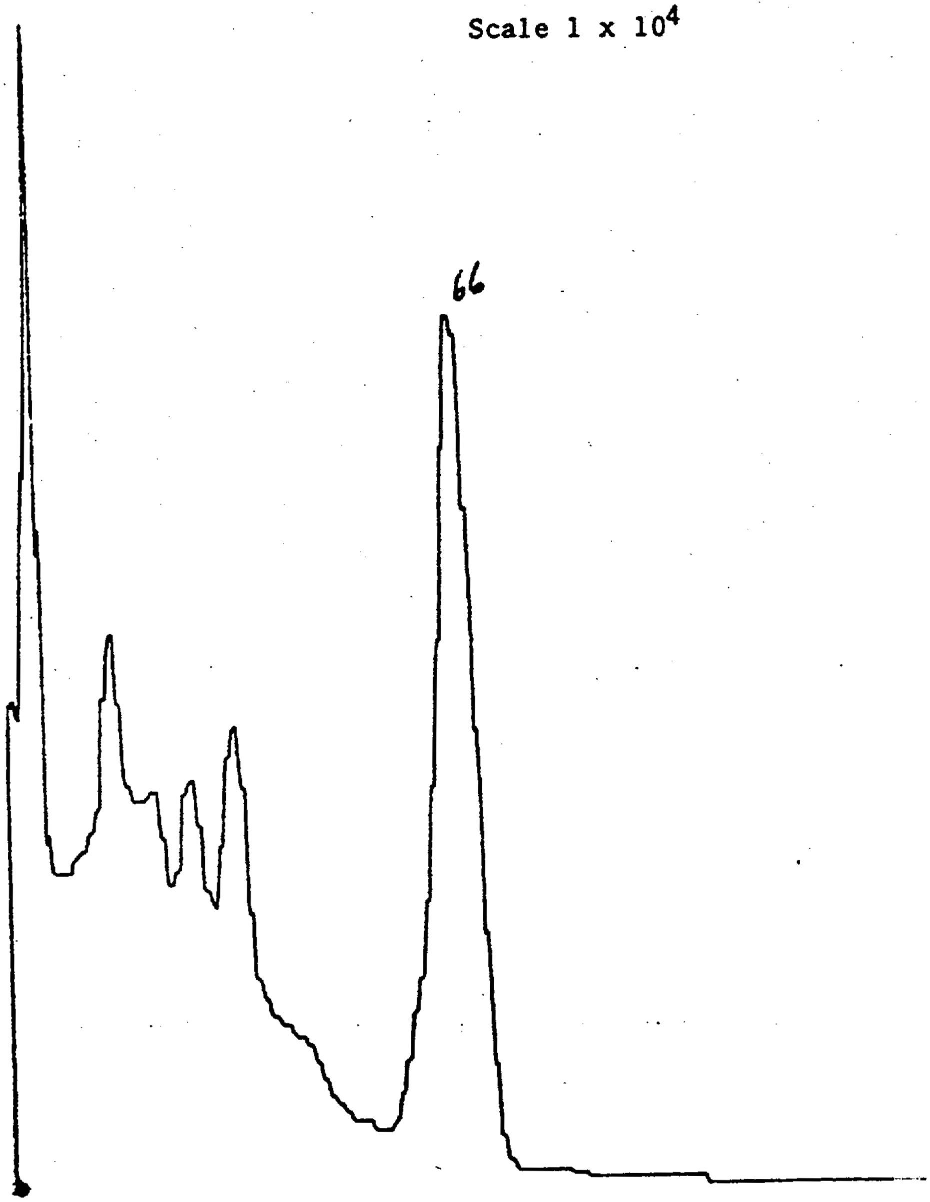
Scale 2 x 10^3

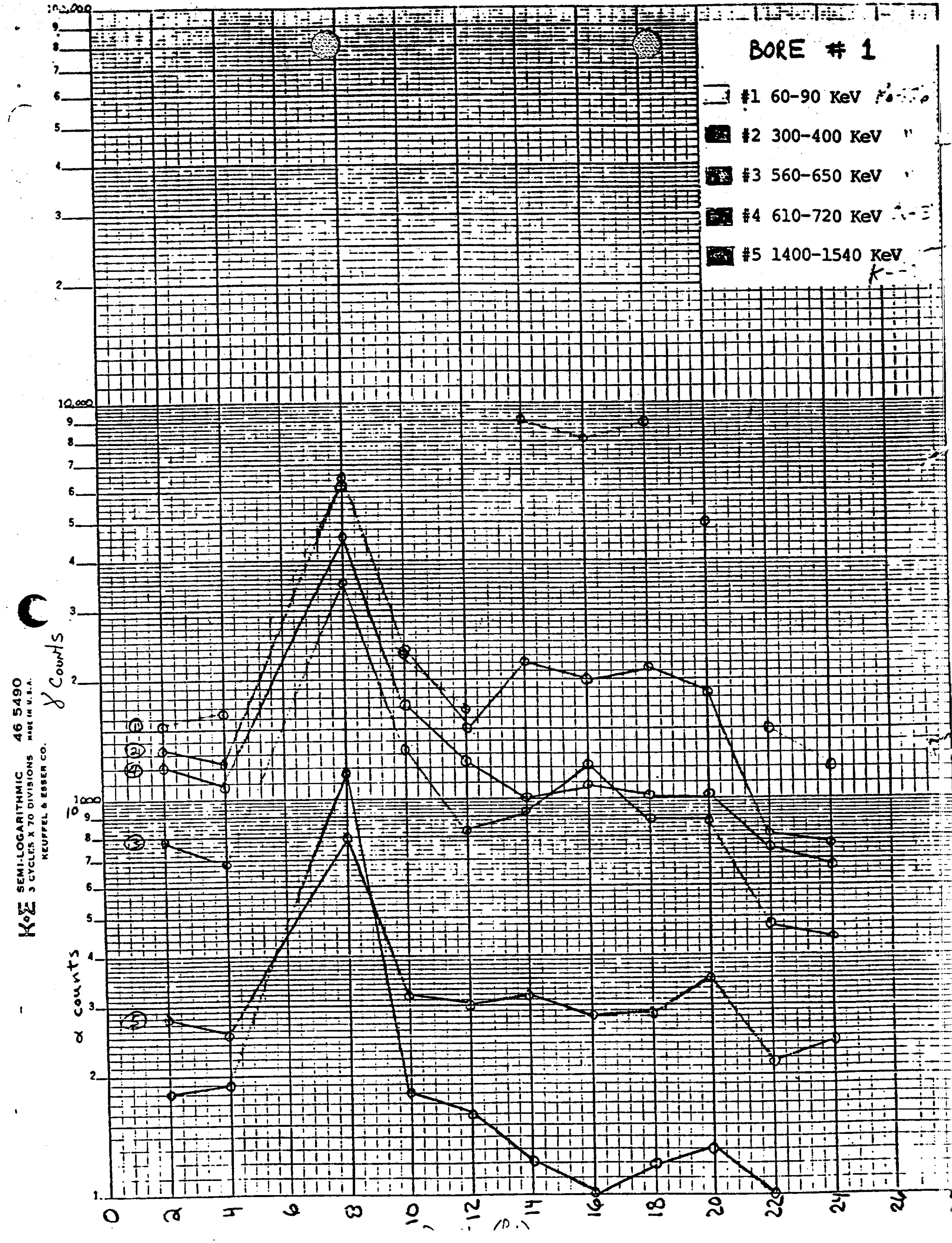
Bore 5 - 2

2 - 4'

2/23/79

Scale 1 x 10^4



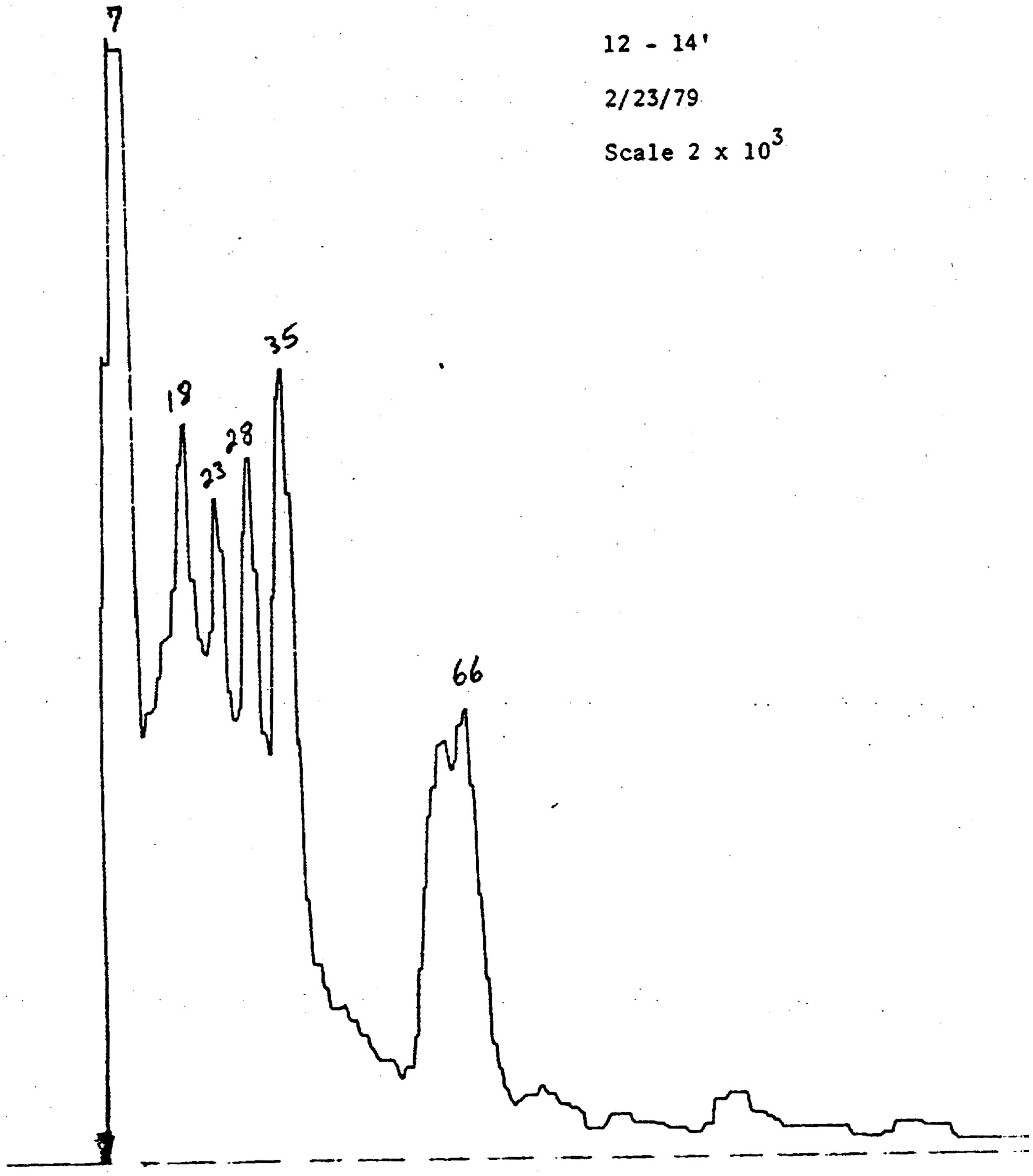

BORE # 1
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
K
γ counts
α counts
10,000
9
8
7
6
5
4
3
2
1000
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
K&E SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

Bore S - 7

12 - 14'

2/23/79

Scale 2 x 10^3

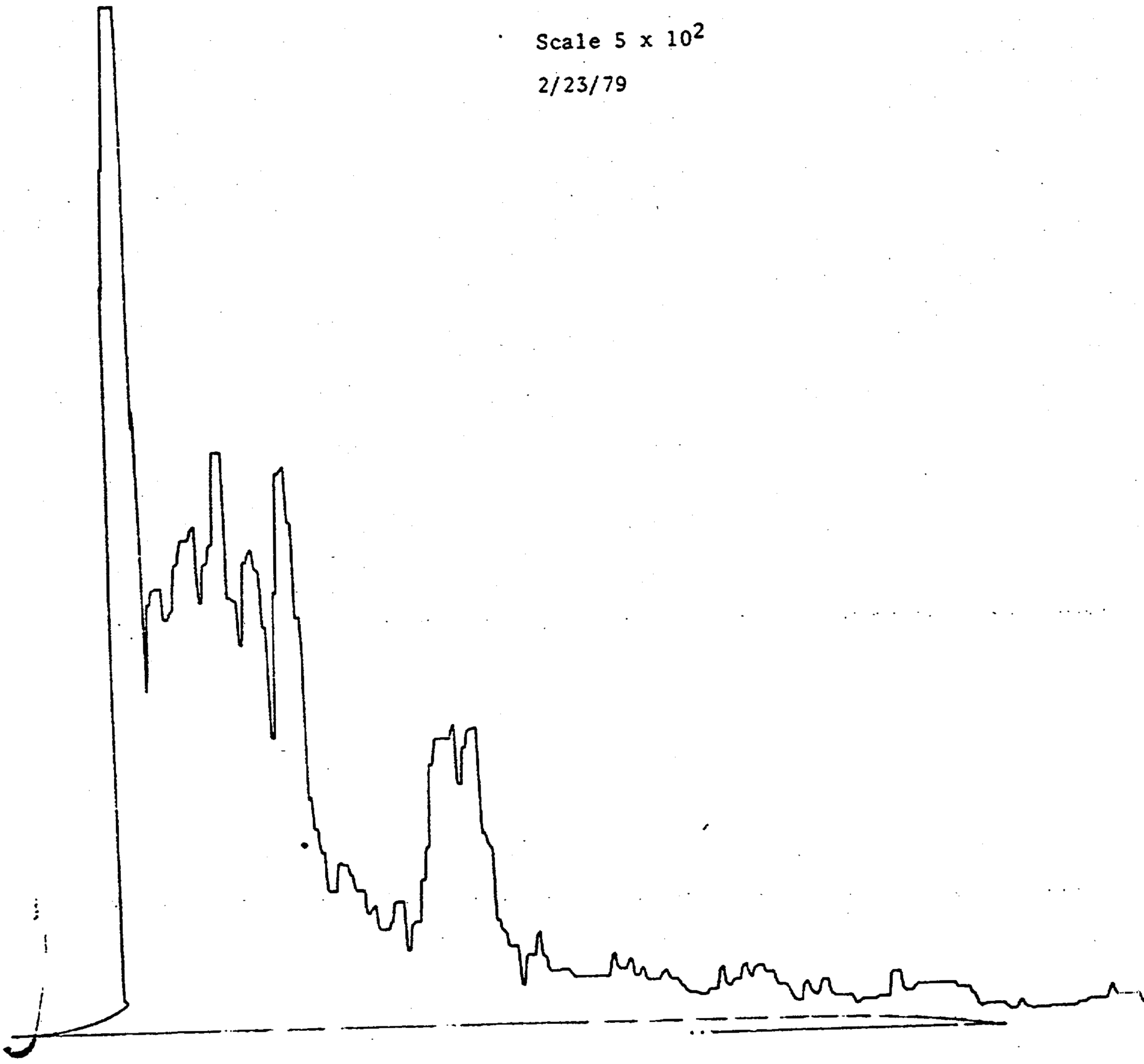


Bore 6 -7

12 - 14'

Scale 5 x 10^2

2/23/79



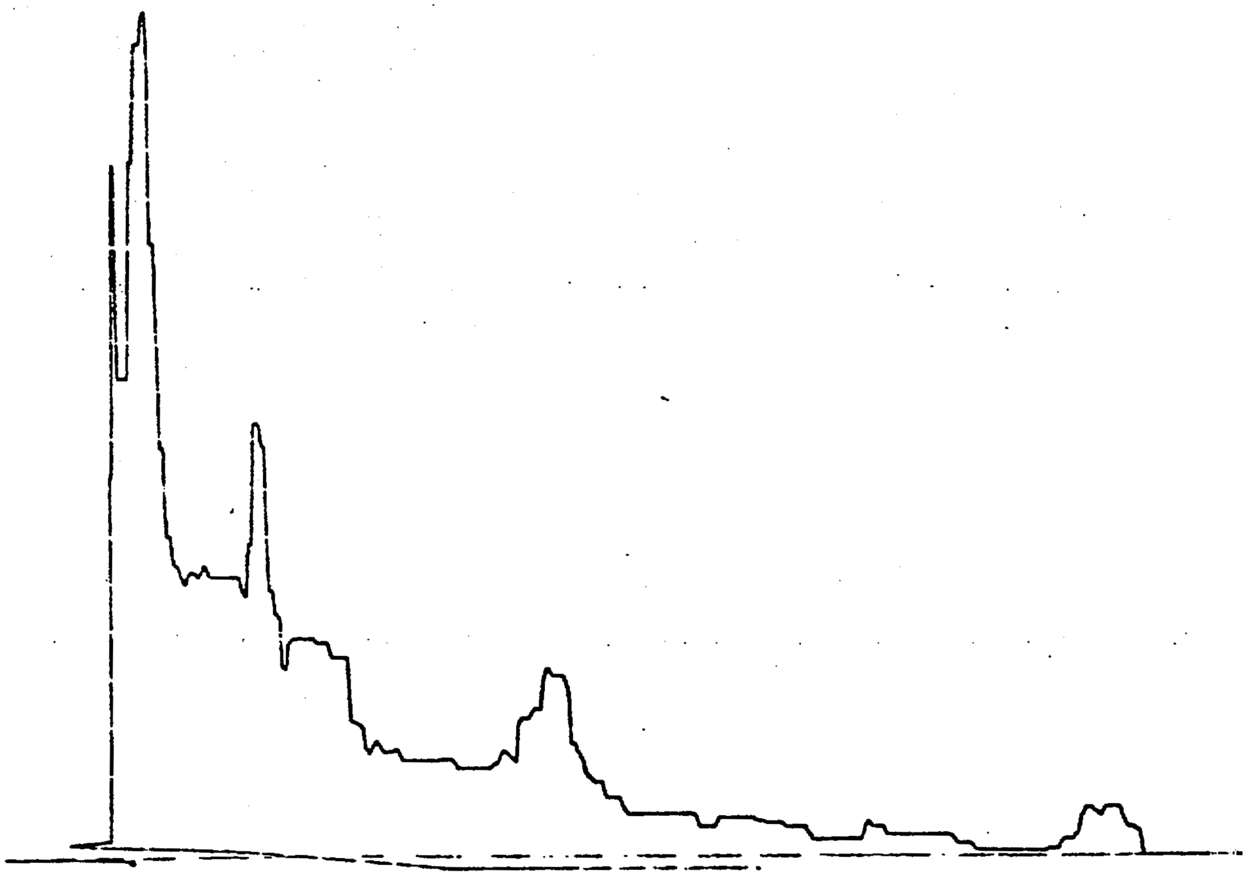
Bore 15-S

20 - 25'

2/21/79

5×10^2 Scale

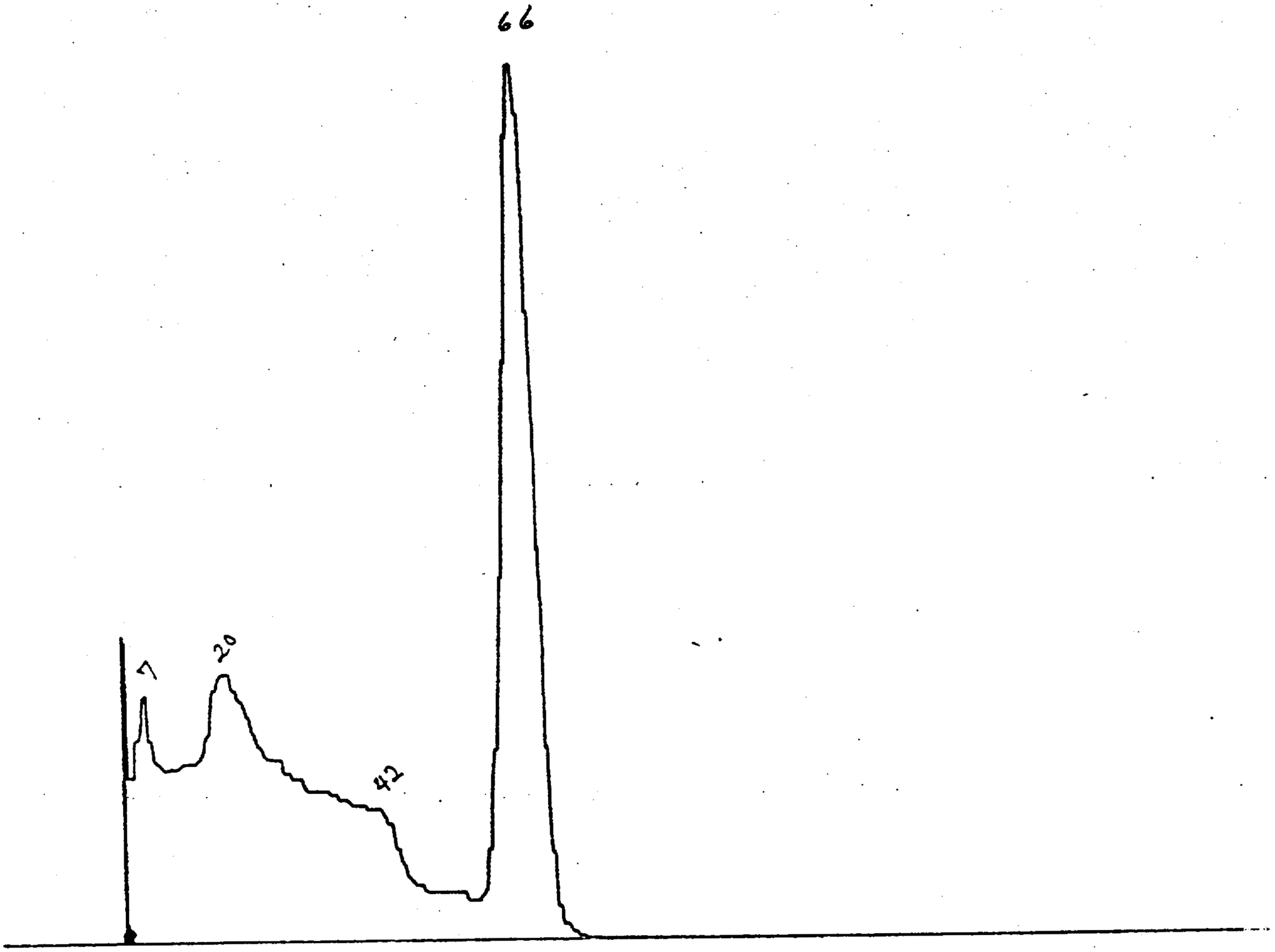
Typical Background Levels in Soil

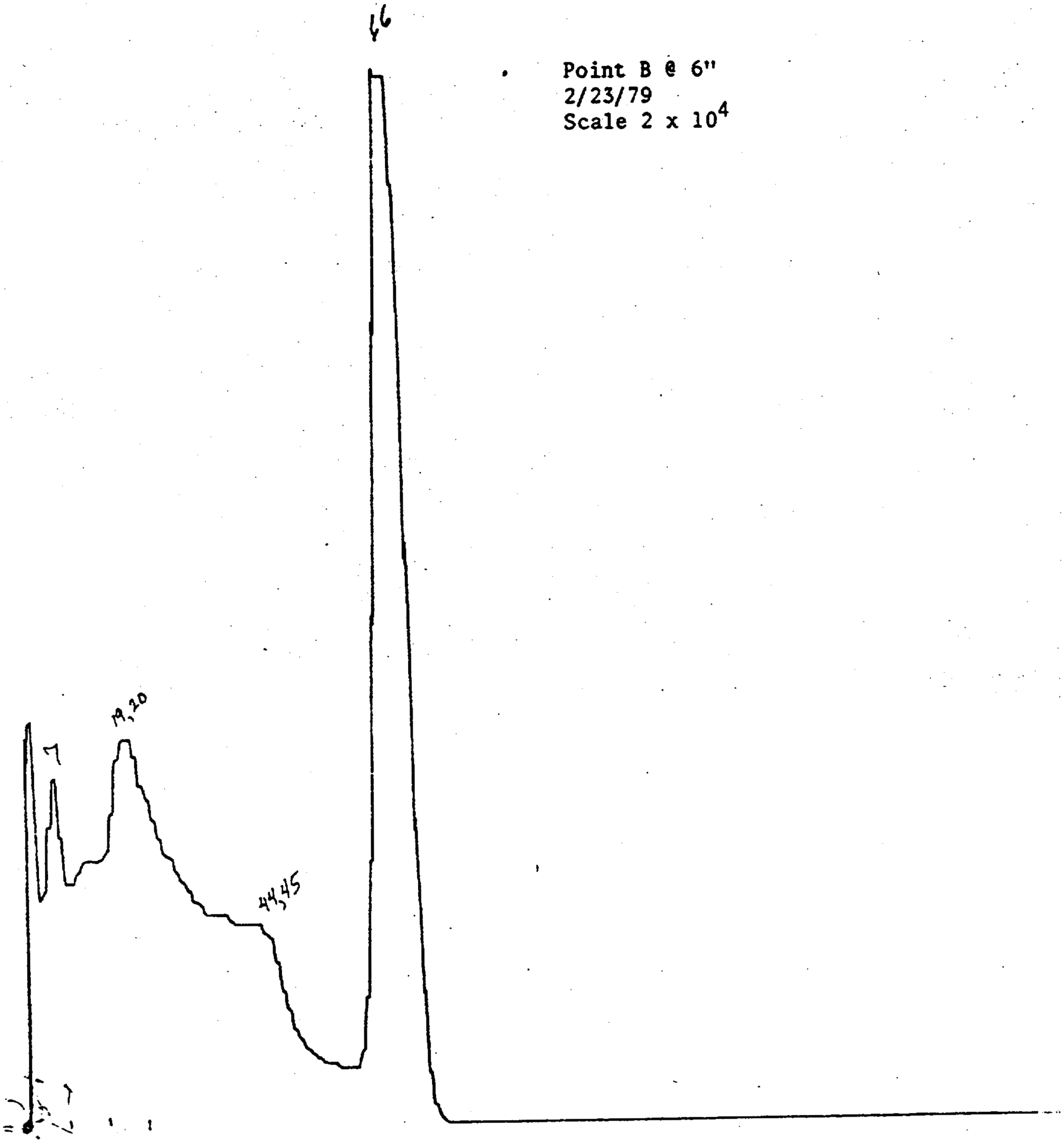


Point "A" @ 6"

2/23/79

Scale 2 x 10^4

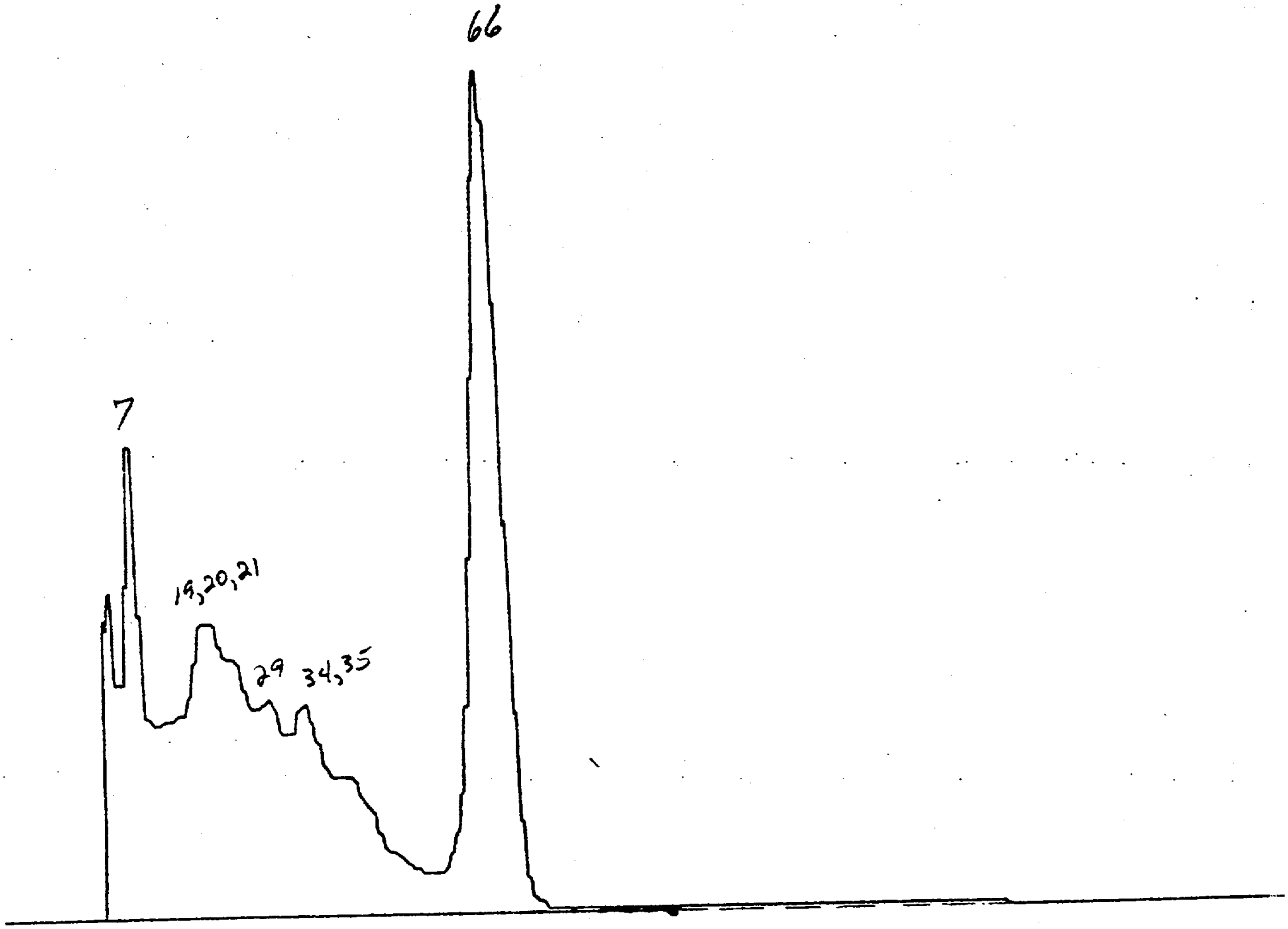




Point B @ 6"
2/23/79
Scale 2 x 10^4

Print
~~Bore~~ C
Subsurface
2/26/79

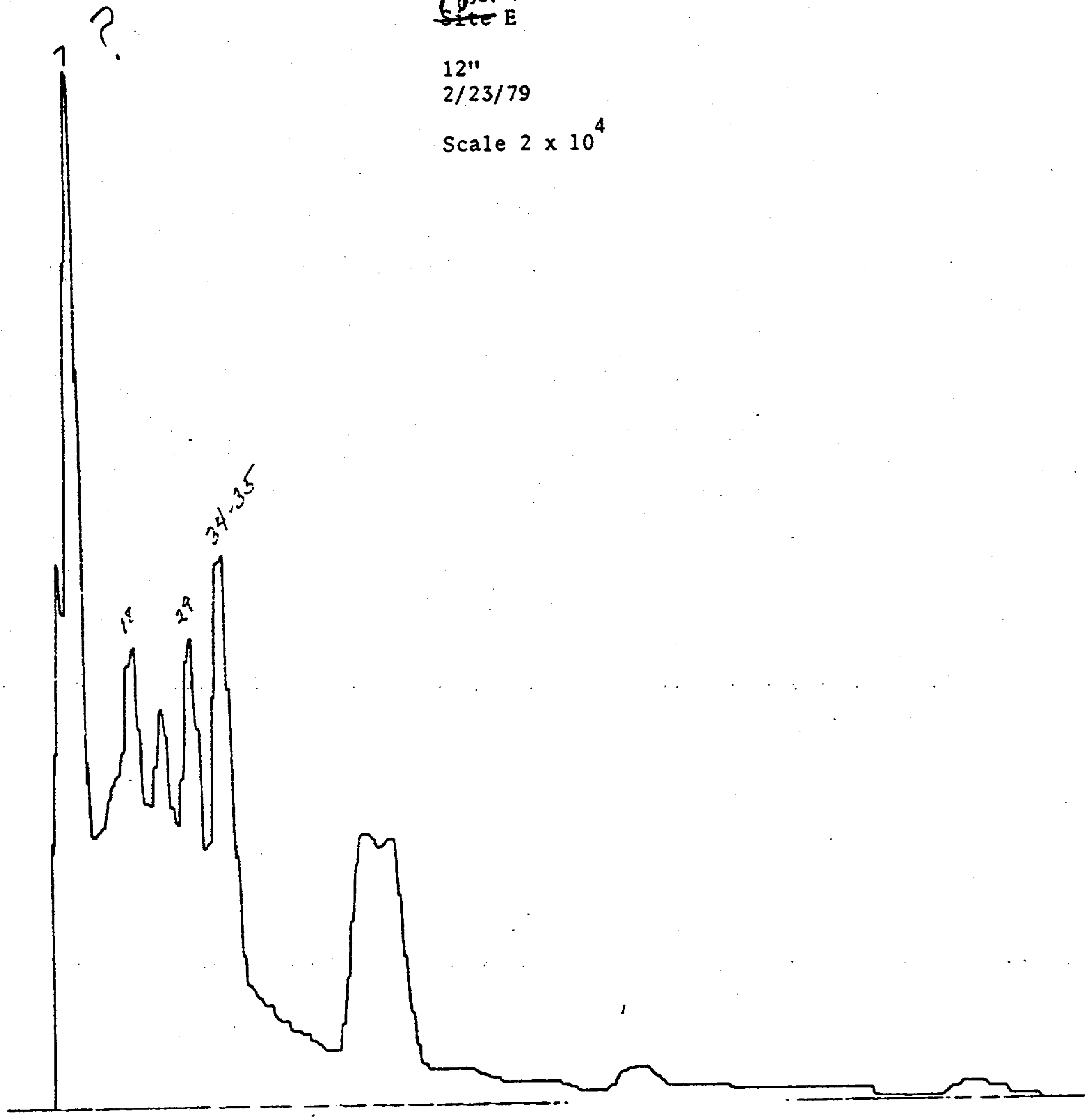
Scale 2 x 10^4



Point ~~Site~~ E

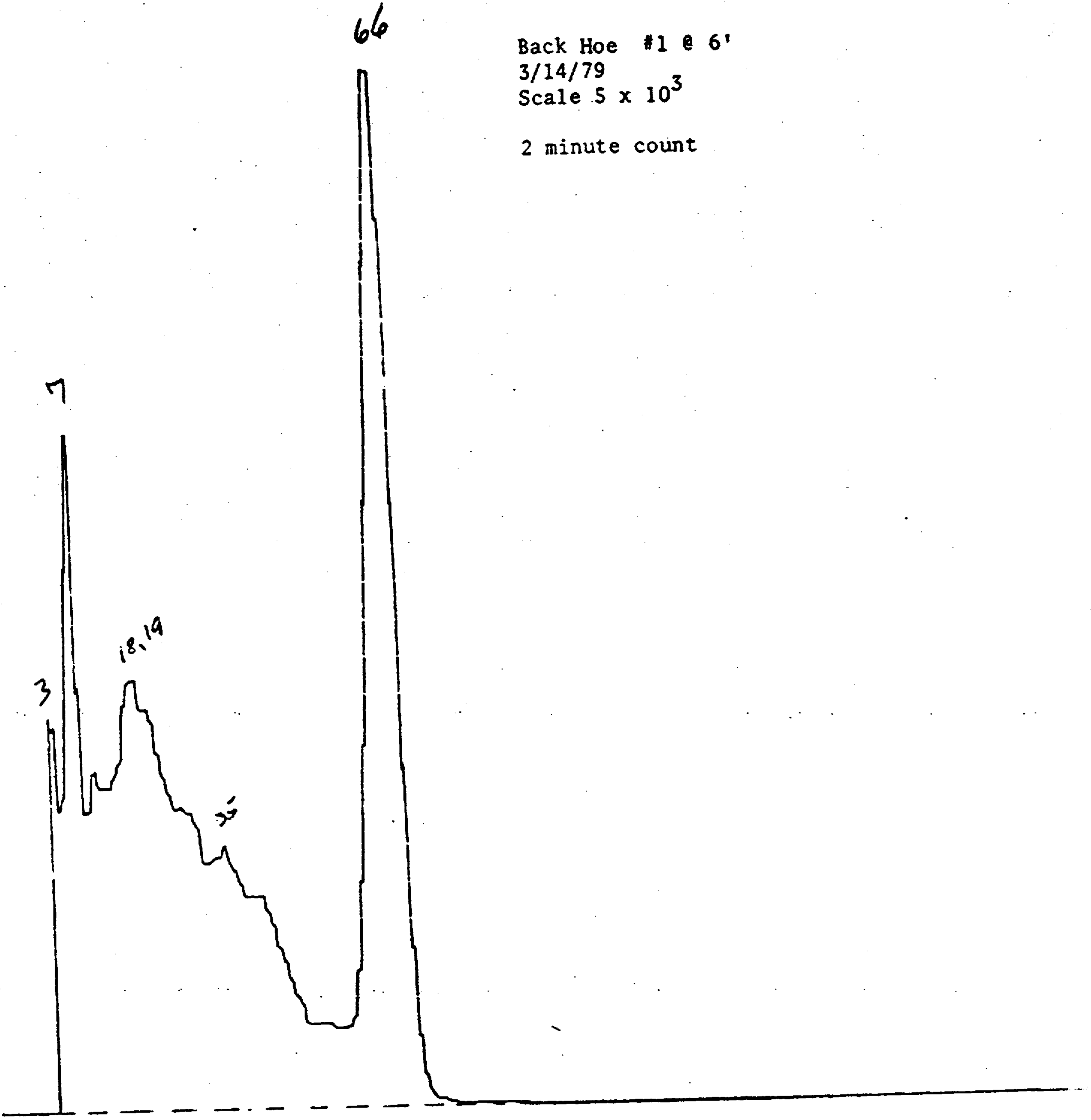
12"
2/23/79

Scale 2 x 10^4



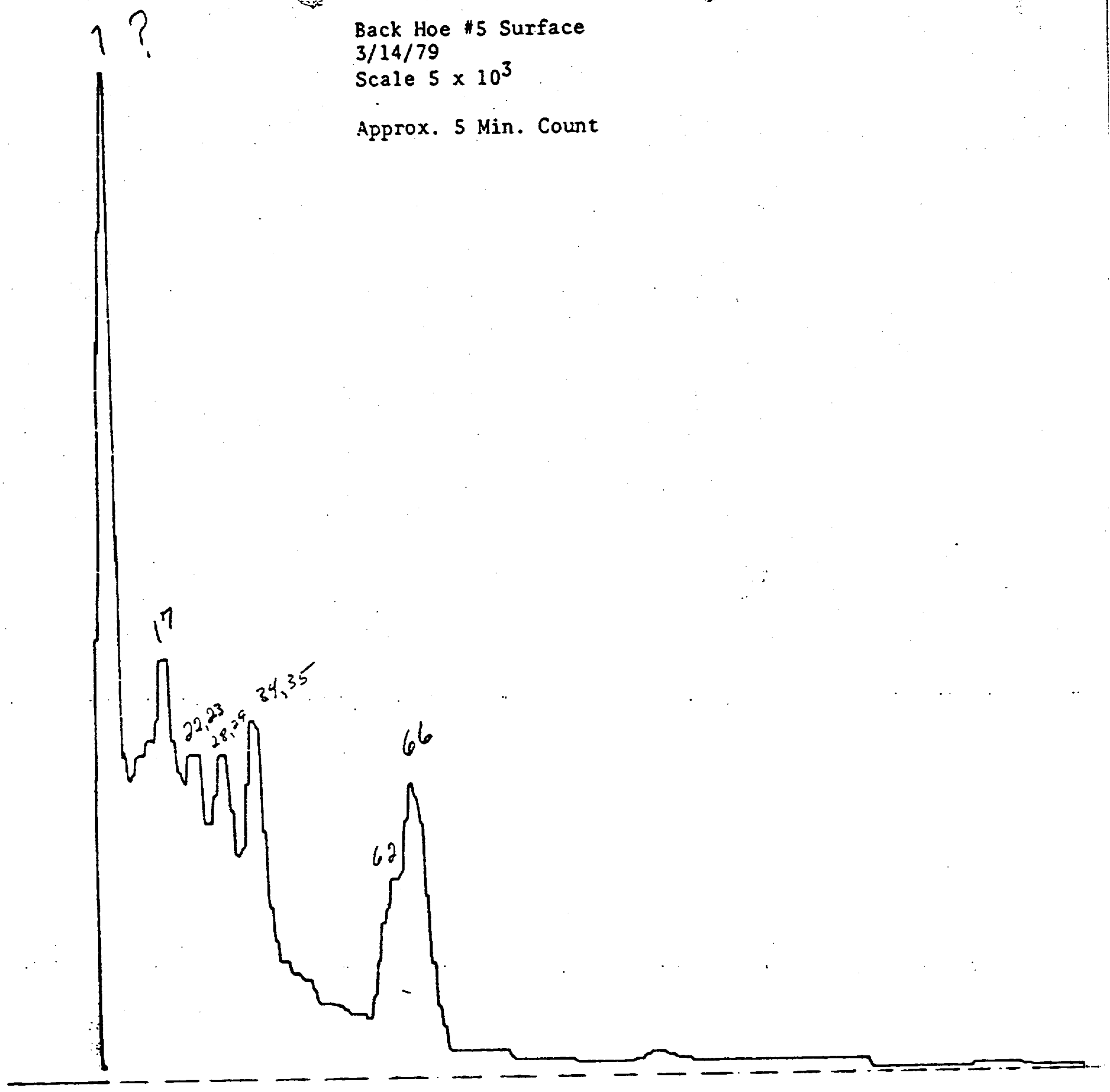
Back Hoe #1 @ 6'
3/14/79
Scale 5 x 10^3

2 minute count



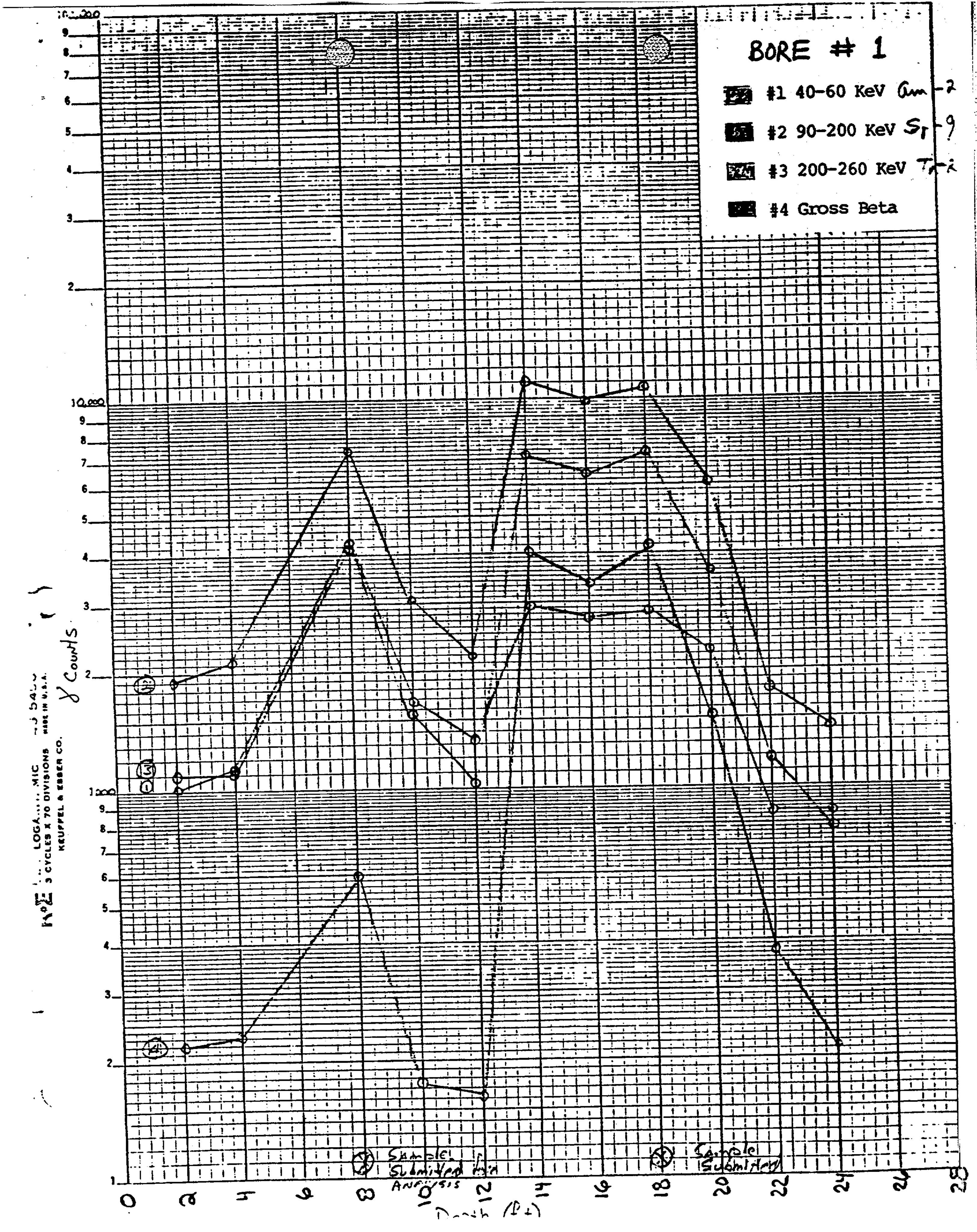
Back Hoe #5 Surface
3/14/79
Scale 5 x 10^3

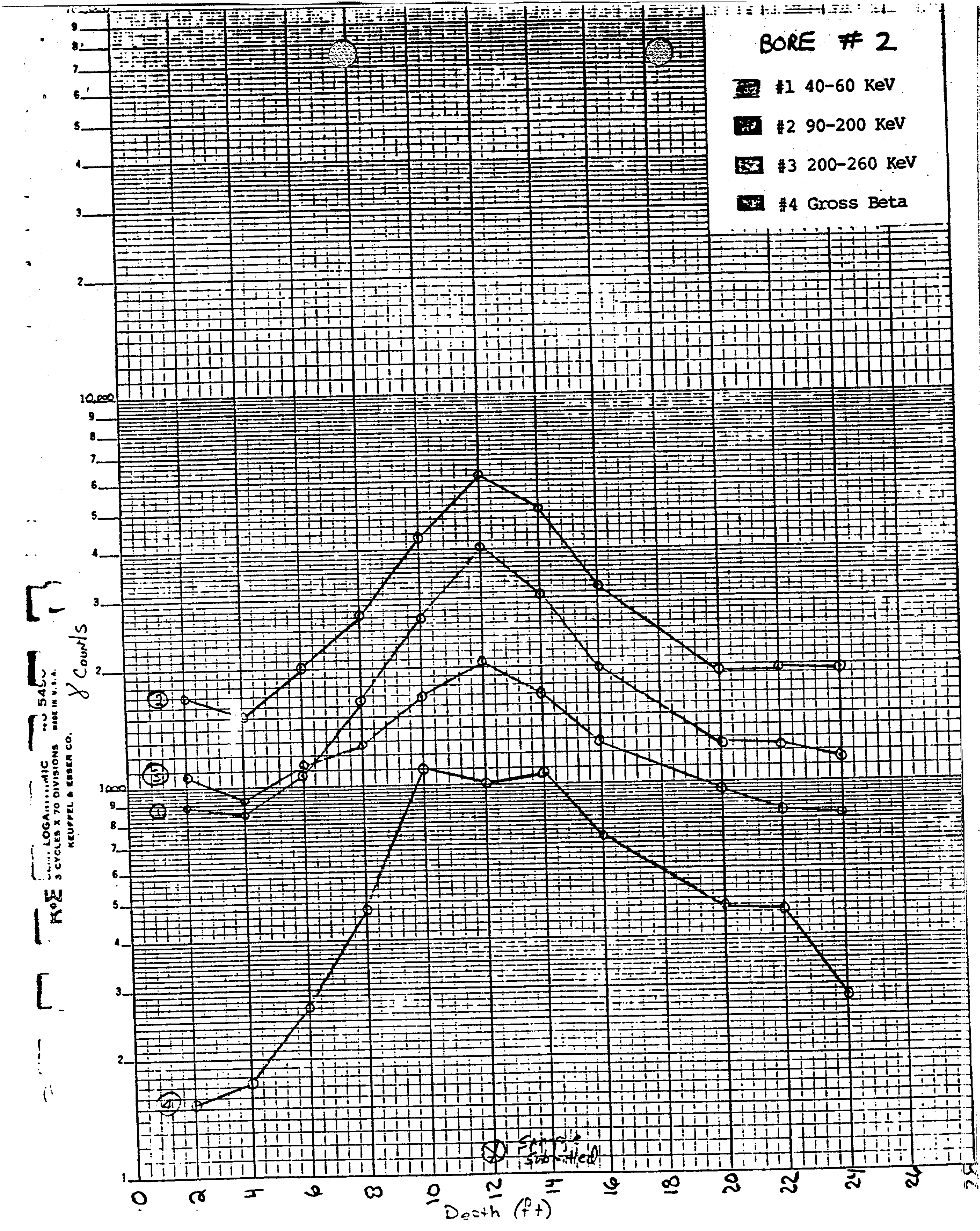
Approx. 5 Min. Count

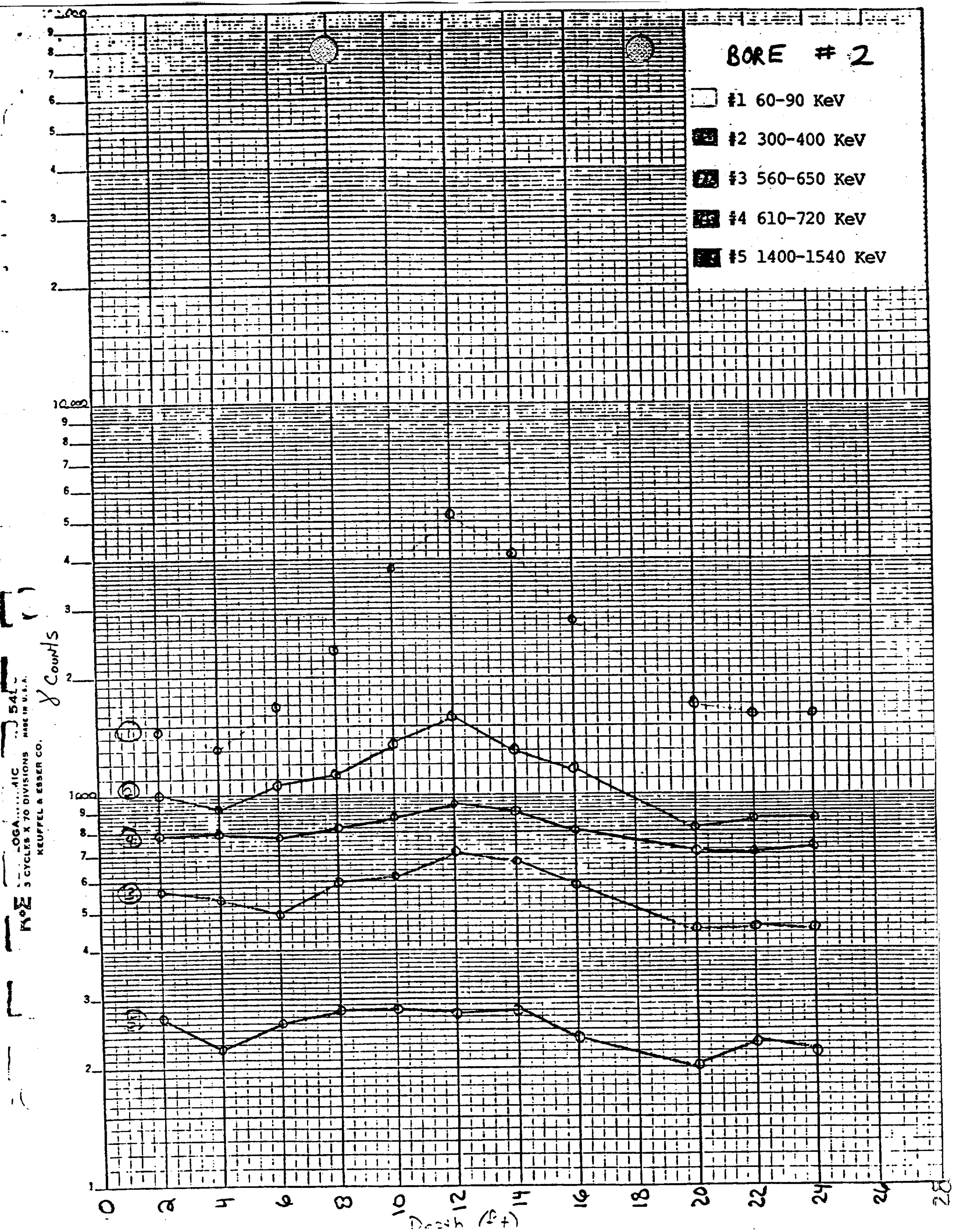


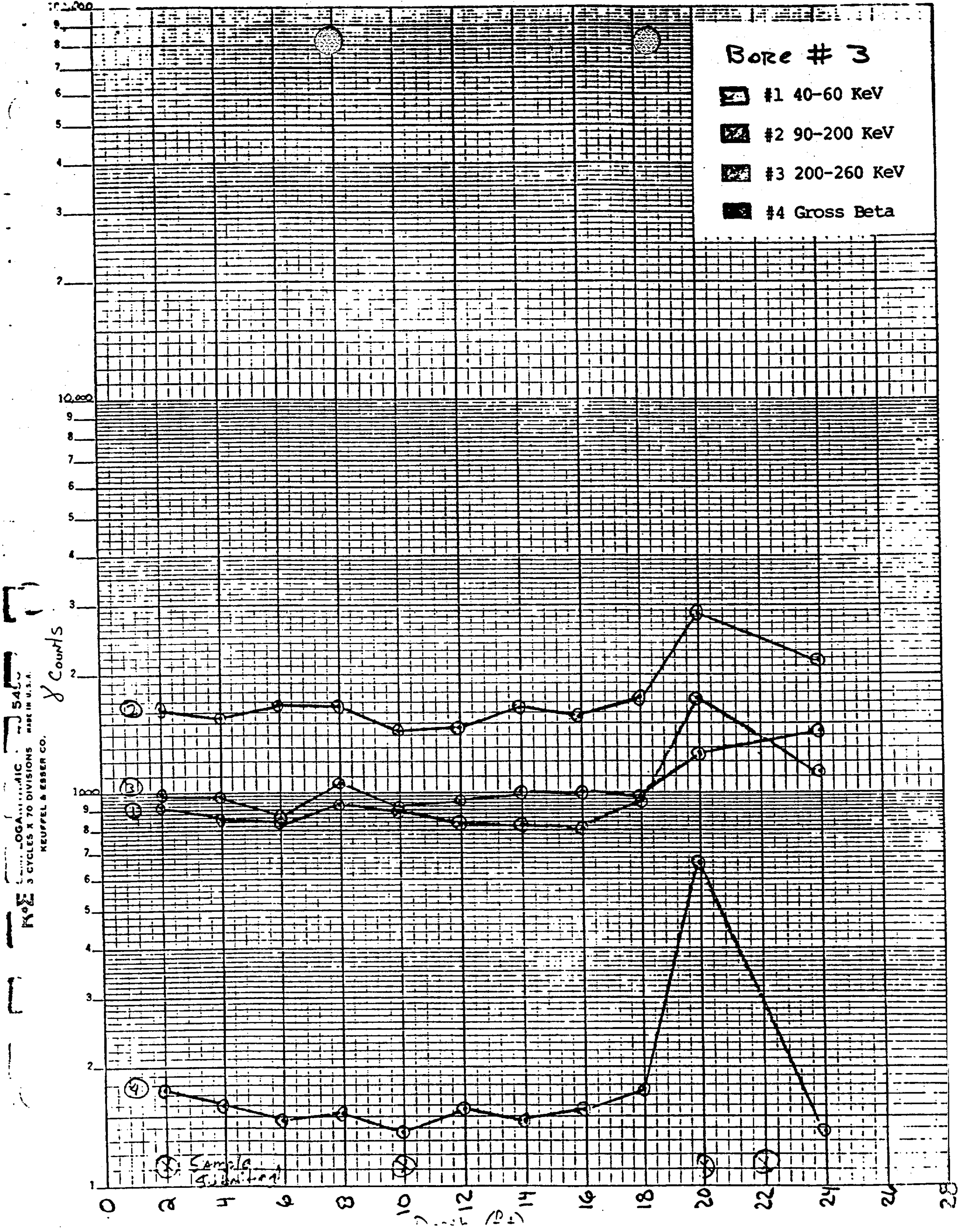
APPENDIX B

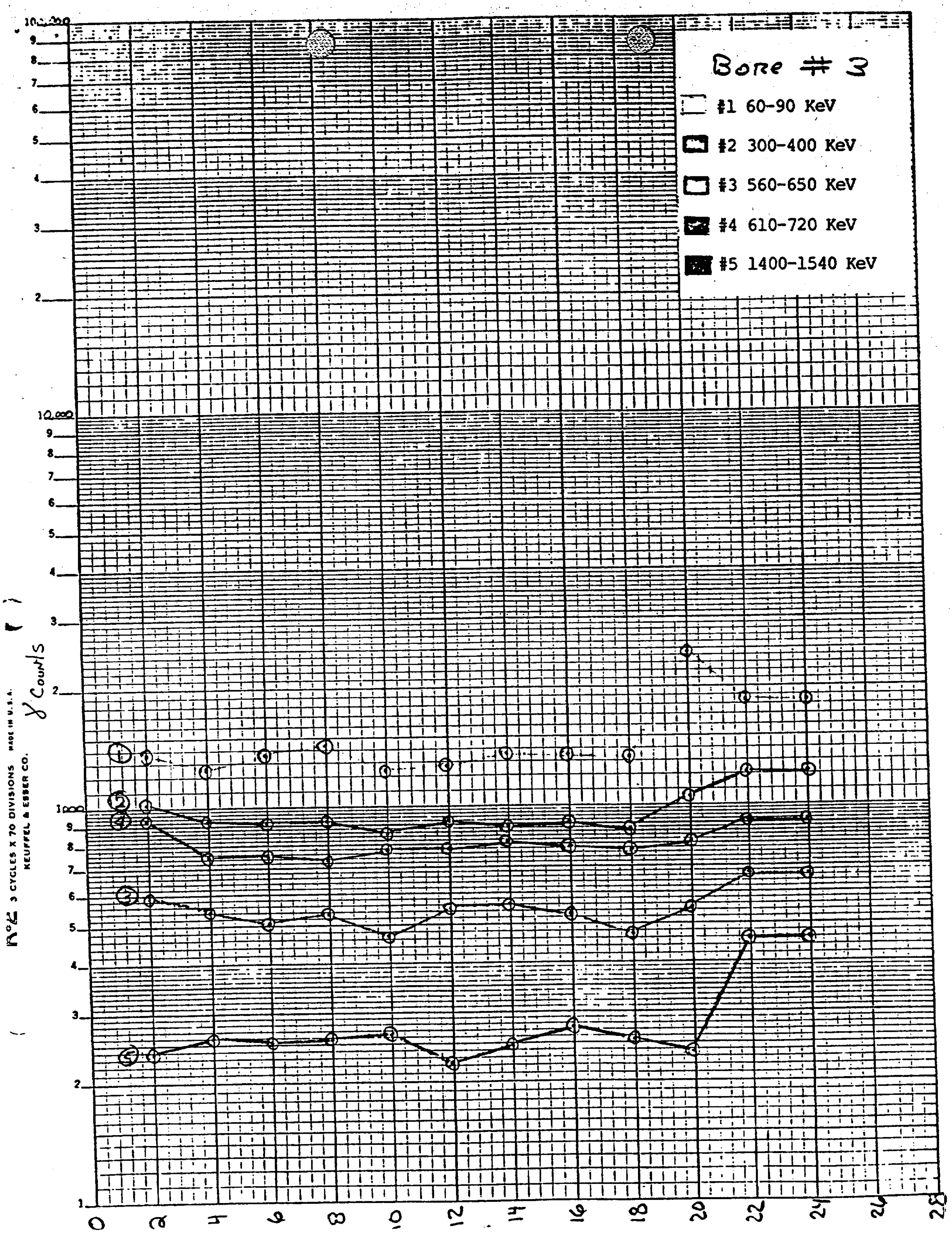
SELECTED SOIL CONTAMINATION PROFILES

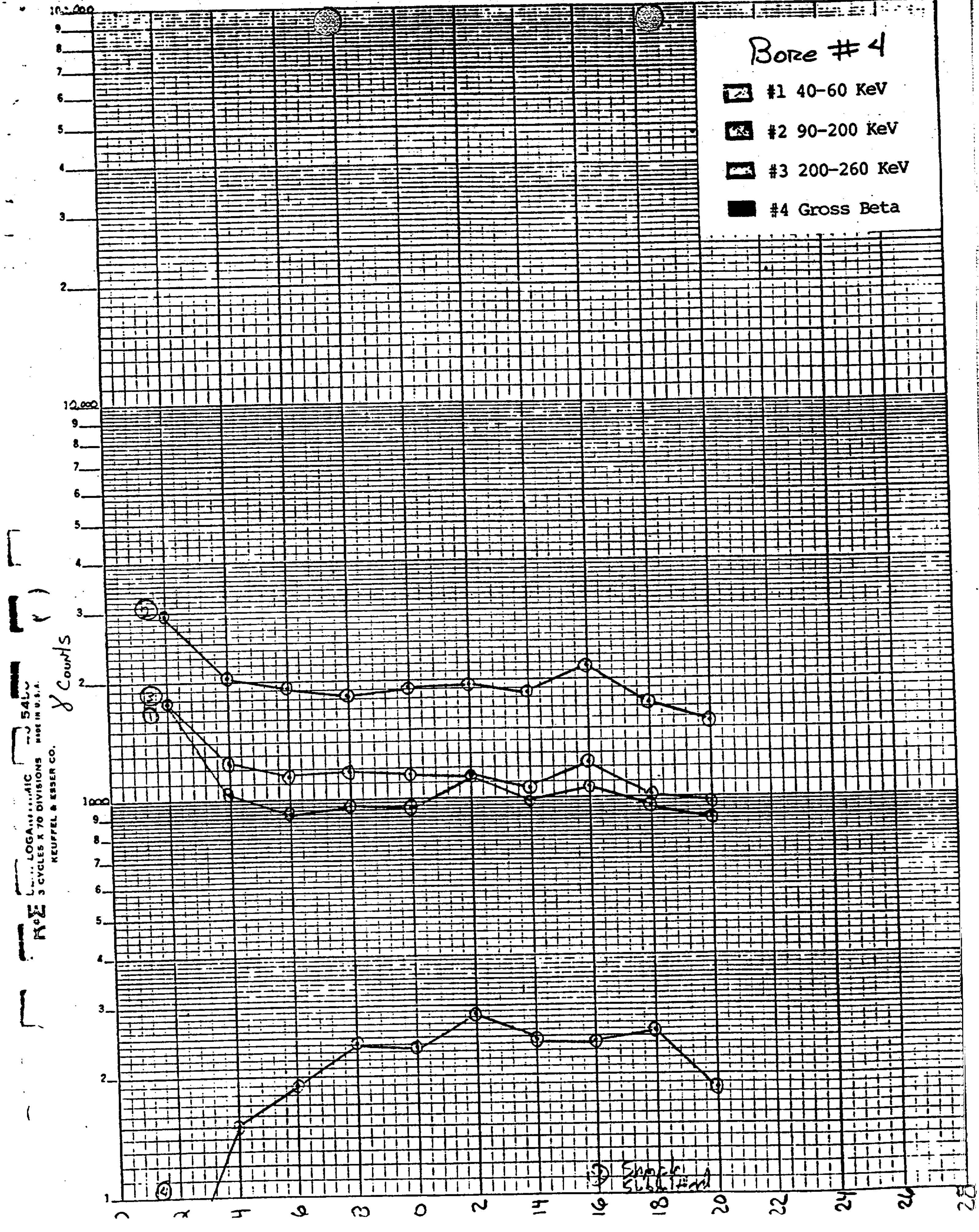

BORE # 1
▨ #1 40-60 KeV Am-2
■ #2 90-200 KeV Sr-9
▨ #3 200-260 KeV Tr-i
■ #4 Gross Beta
γ Counts
②
③
①
④
10,000
1000
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Depth (ft)
Sample Submitted for ANALYSIS
Sample Submitted
K+E LOGA....MIC 3 CYCLES X 70 DIVISIONS MADE IN U.S.A. KEUFFEL & ESSER CO.

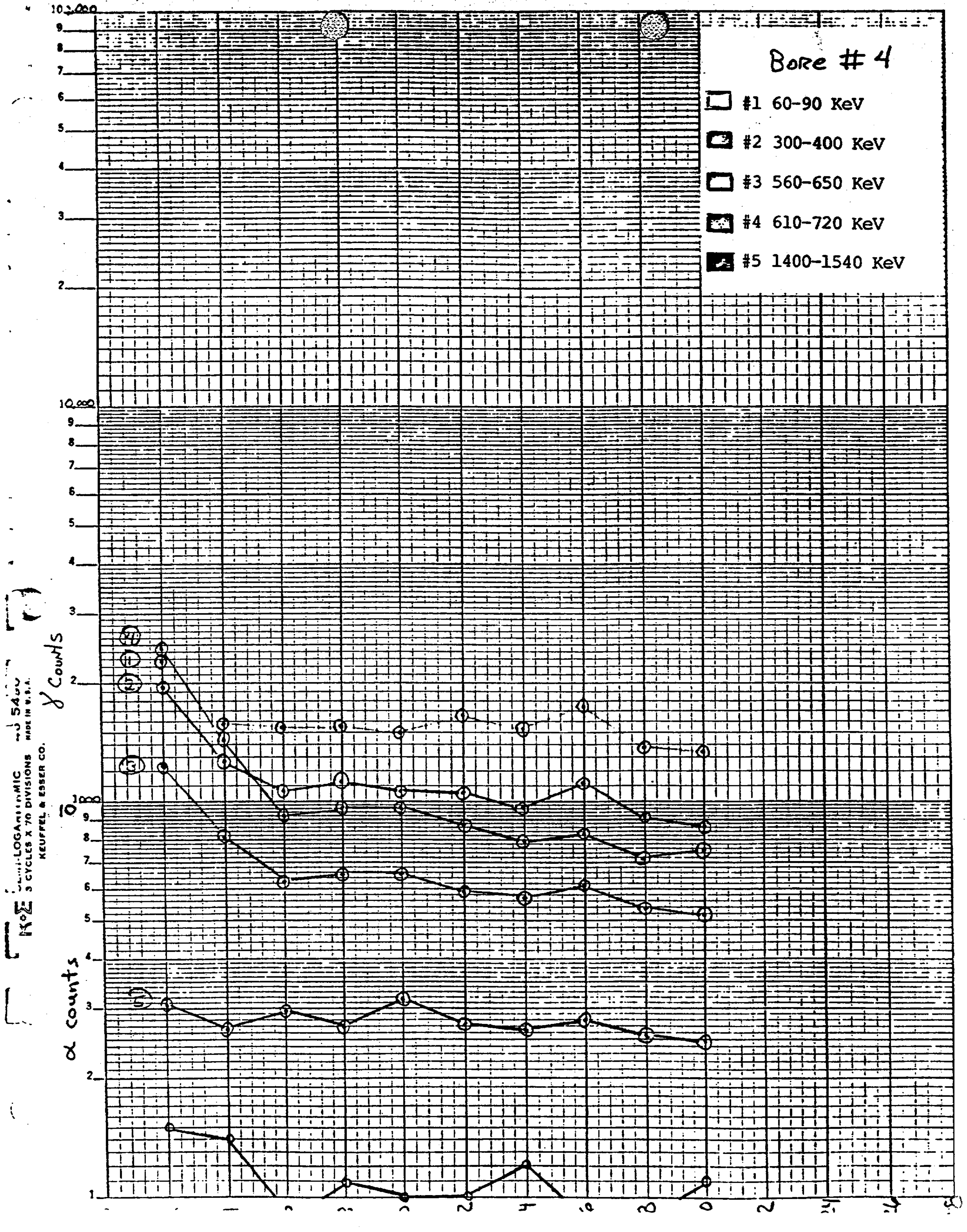

BORE #2
#1 40-60 KeV
#2 90-200 KeV
#3 200-260 KeV
#4 Gross Beta
10,000
1000
9
8
7
6
5
4
3
2
1
γ Counts
②
③
①
④
Sample Submitted
0
2
4
6
8
10
12
14
16
18
20
22
24
26
Depth (ft)
K&E
LOGARITHMIC
3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
MADE IN U.S.A.

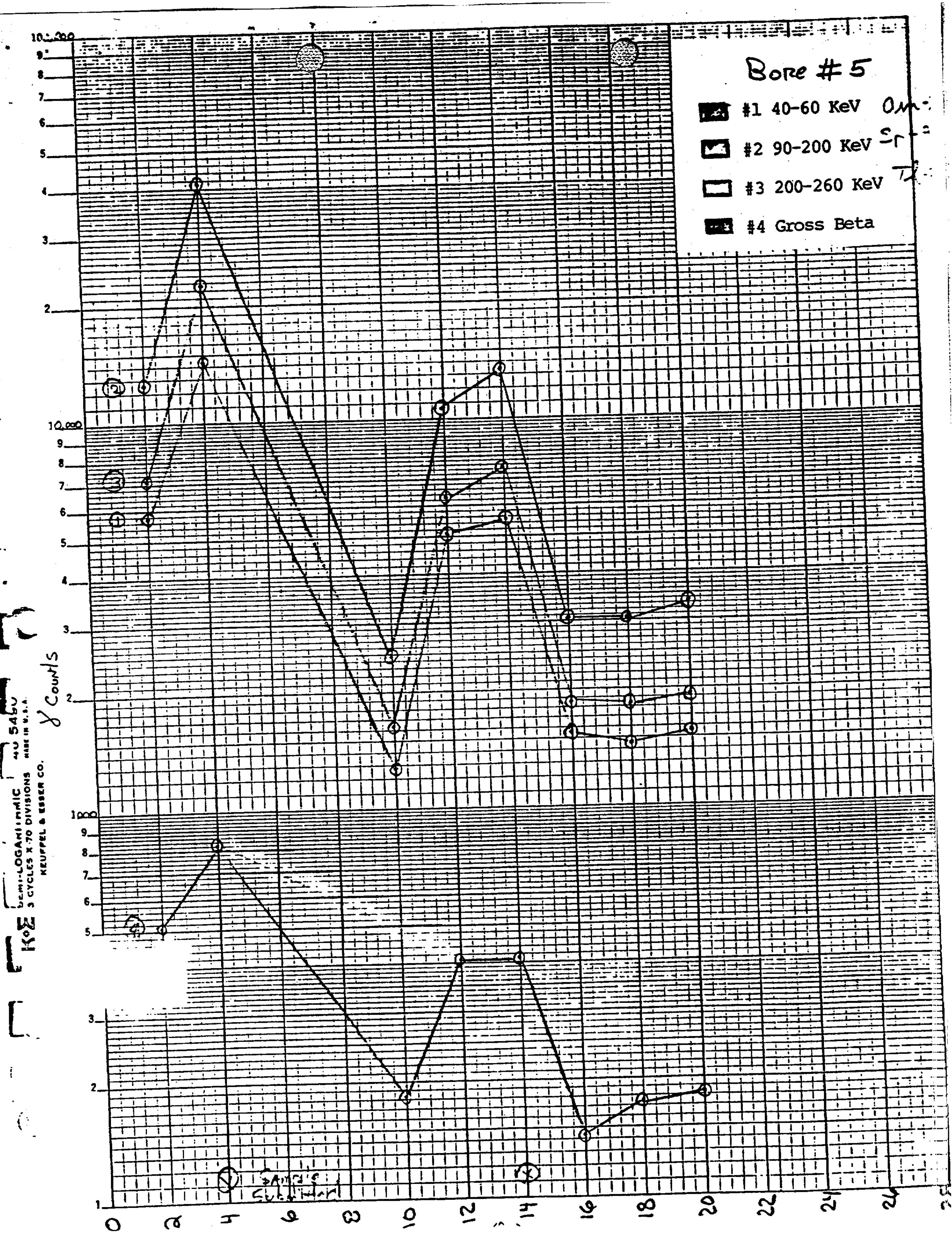

BORE # 2
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
γ Counts
10,000
1000
①
②
③
④
⑤
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Depth (ft)
K+E LOGARITHMIC 3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

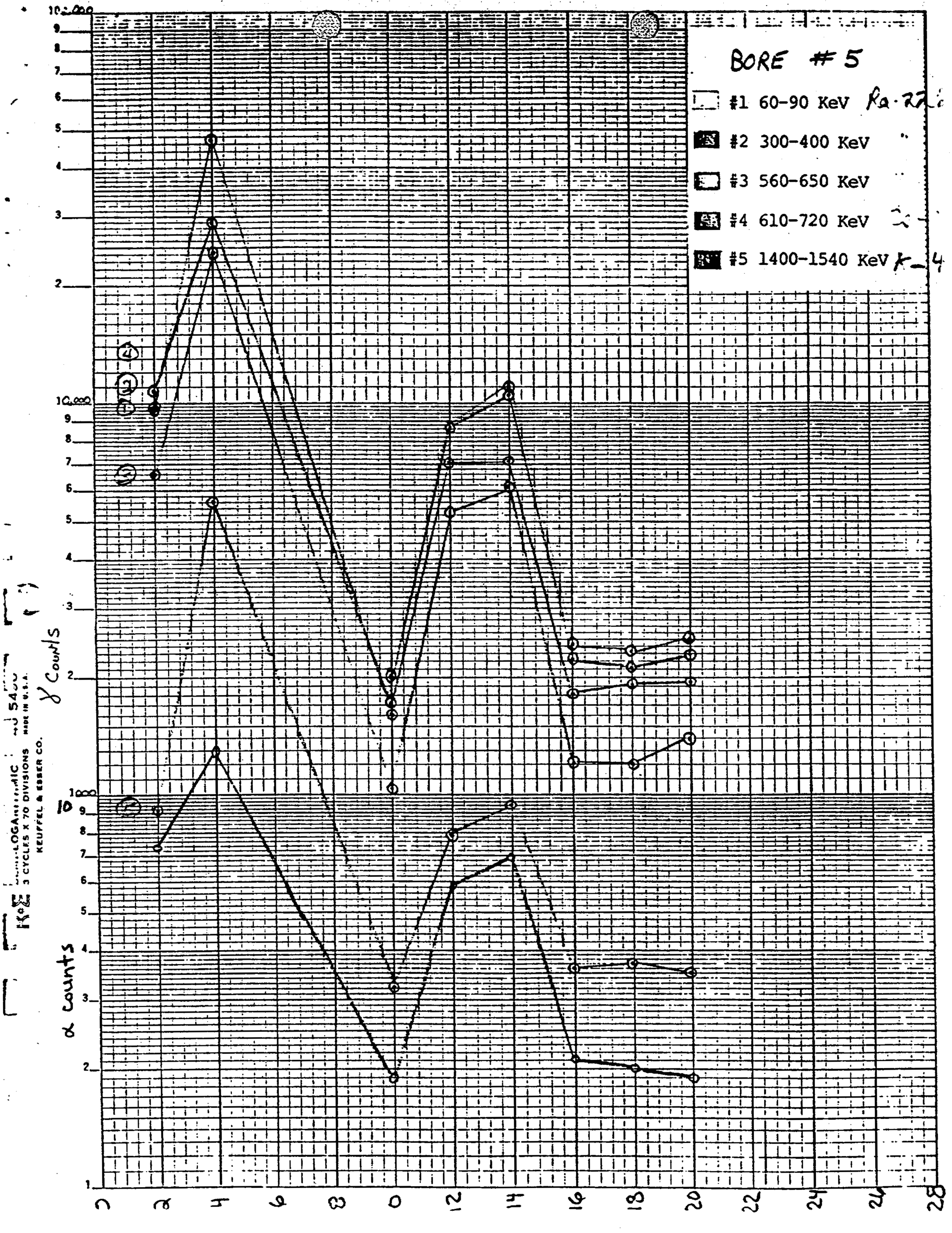

Bore # 3
▨ #1 40-60 KeV
▨ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts
100,000
10,000
1000
9
8
7
6
5
4
3
2
1
①
②
③
④
ⓧ Sample Submitted
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
Depth (ft)
K&E LOGARITHMIC
3 CYCLES X 70 DIVISIONS
MADE IN U.S.A.
KEUFFEL & ESSER CO.
54

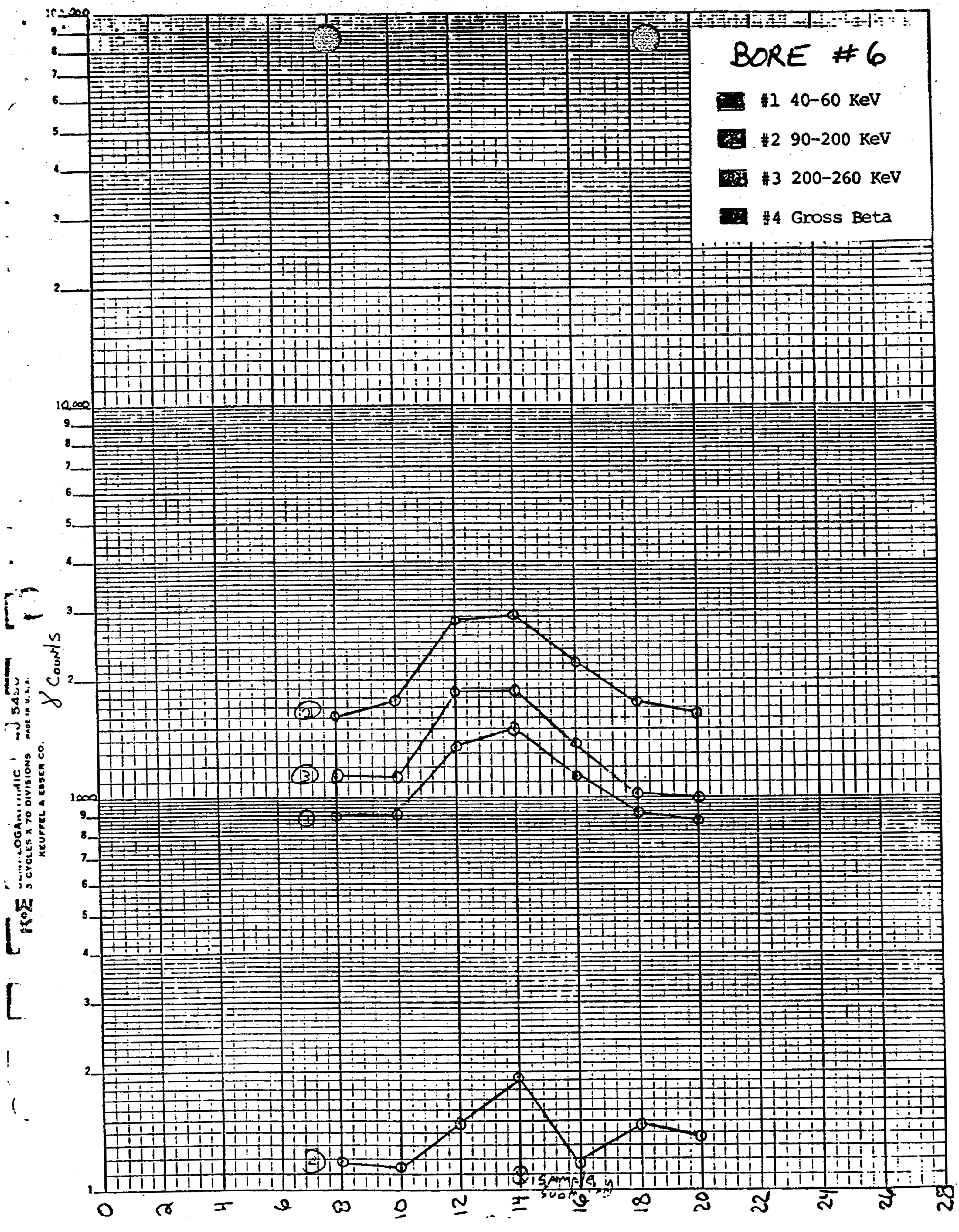

Bore # 3
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
γ Counts
100,000
10,000
1000
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
①
②
③
④
⑤
NO 46 3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

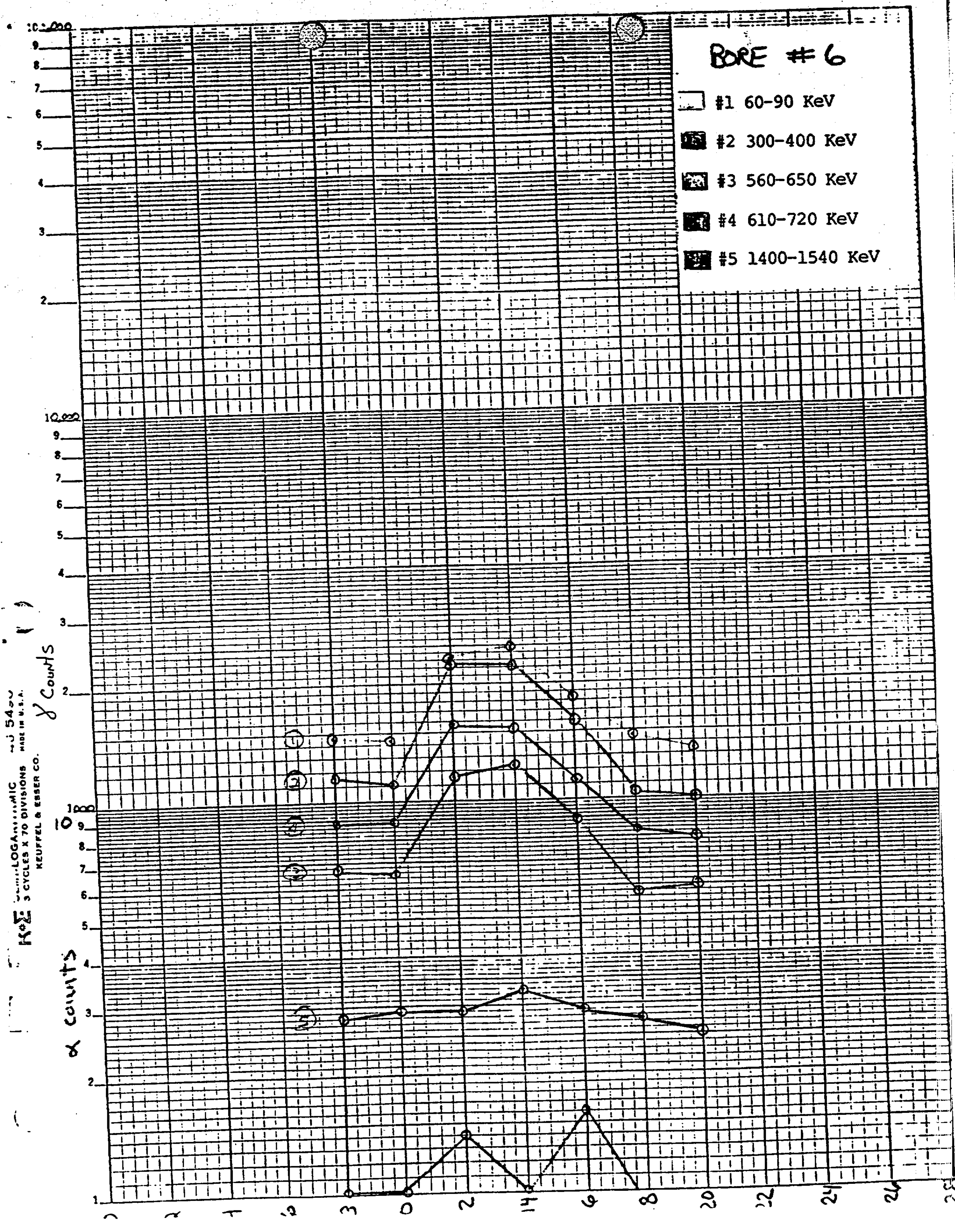
Bore #4
▨ #1 40-60 KeV
▨ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts
10,000
9
8
7
6
5
4
3
2
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
1
③
①
②
④
③ Shack Subtracted
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
K+E 54..
LOGA...MIC 3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

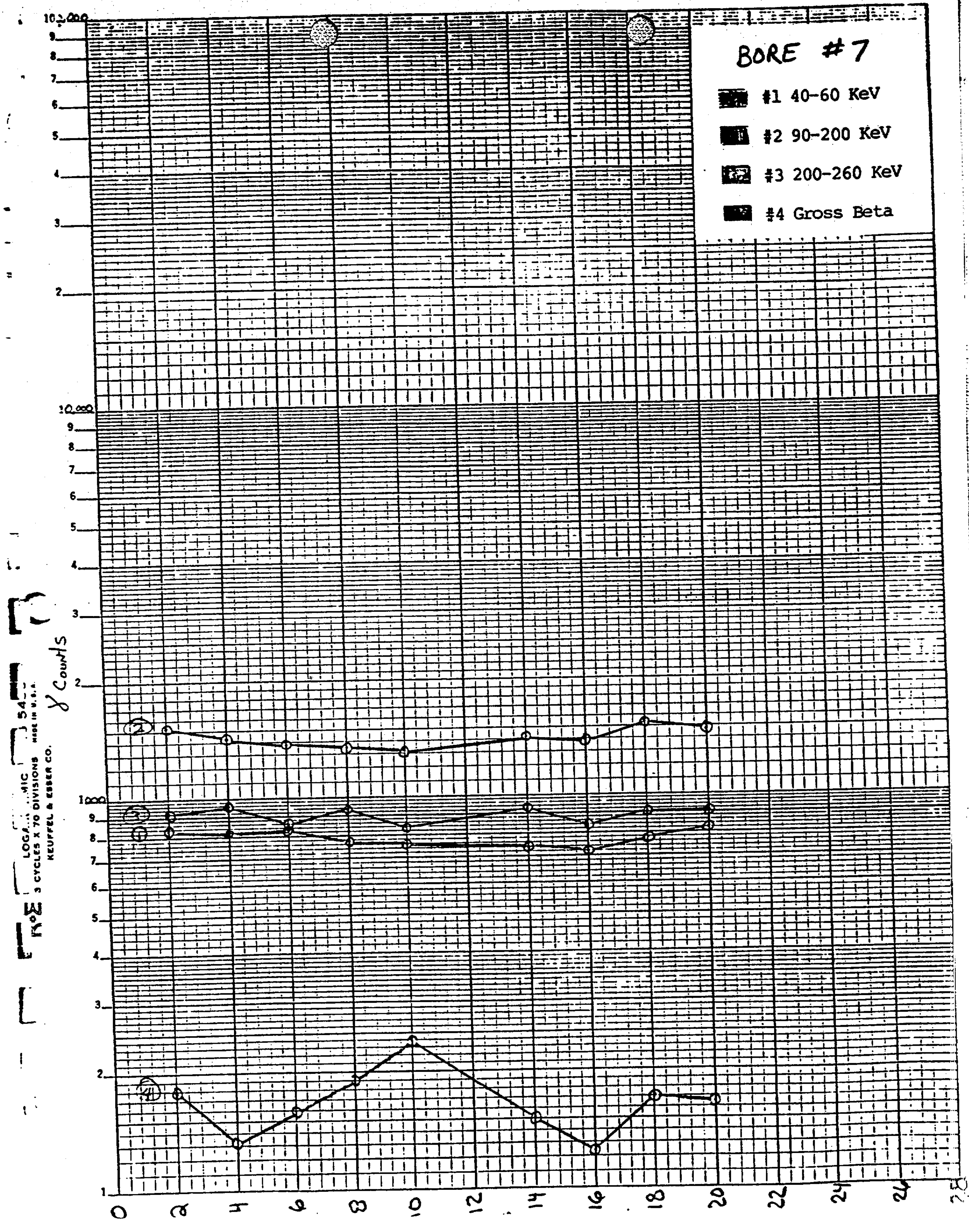

Bore # 4
▭ #1 60-90 KeV
▣ #2 300-400 KeV
▭ #3 560-650 KeV
▨ #4 610-720 KeV
■ #5 1400-1540 KeV
γ Counts
α counts
④
②
①
③
⑤
10,000
1000
10
9
8
7
6
5
4
3
2
1
K+E SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

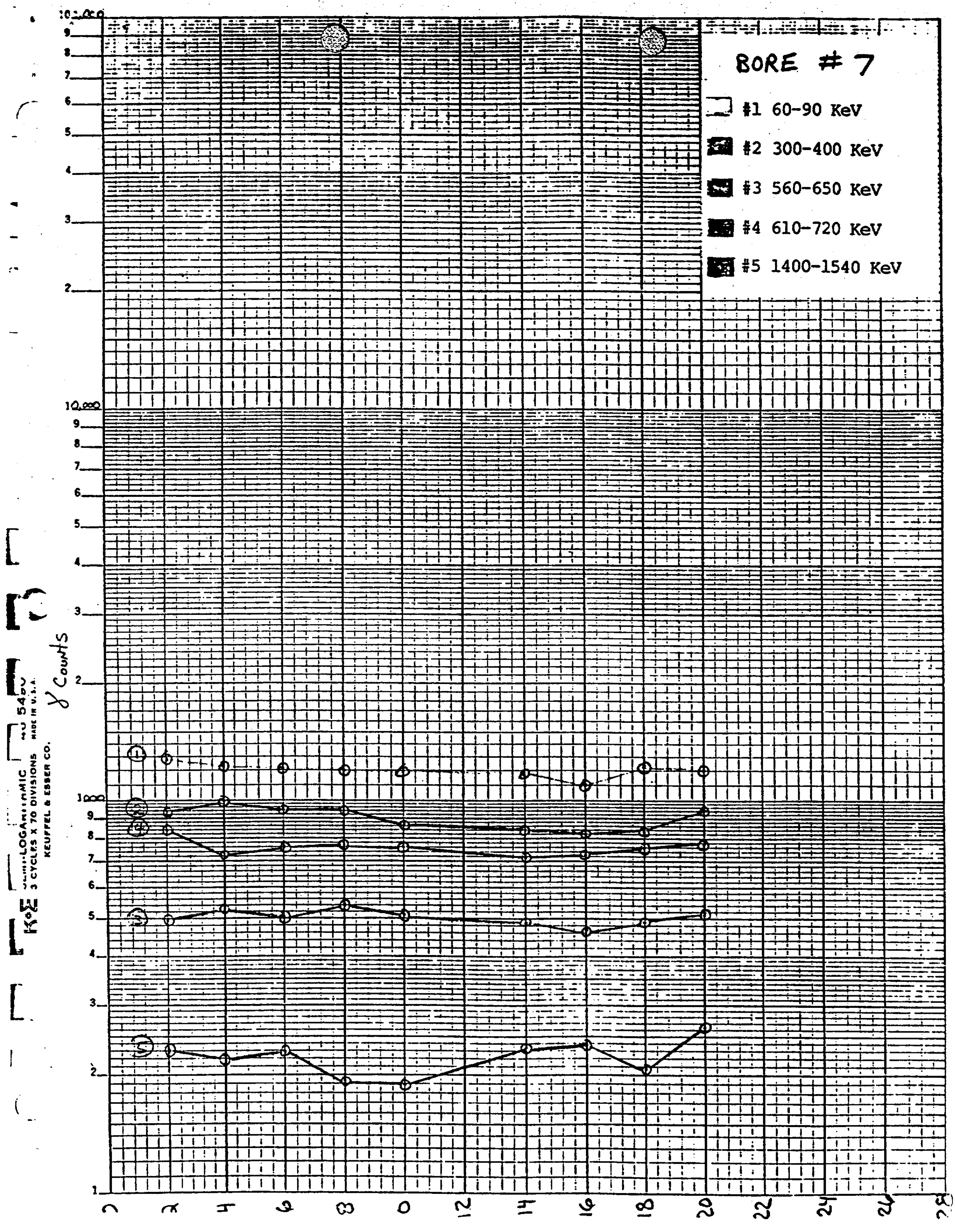

Bore #5
#1 40-60 KeV
#2 90-200 KeV
#3 200-260 KeV
#4 Gross Beta
Om
Sr
Tc
γ Counts
10,000
10,000
1000
9
8
7
6
5
4
3
2
1
①
②
③
④
Sand's Surface
0
2
4
6
8
10
12
14
16
18
20
22
24
26
K+E SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

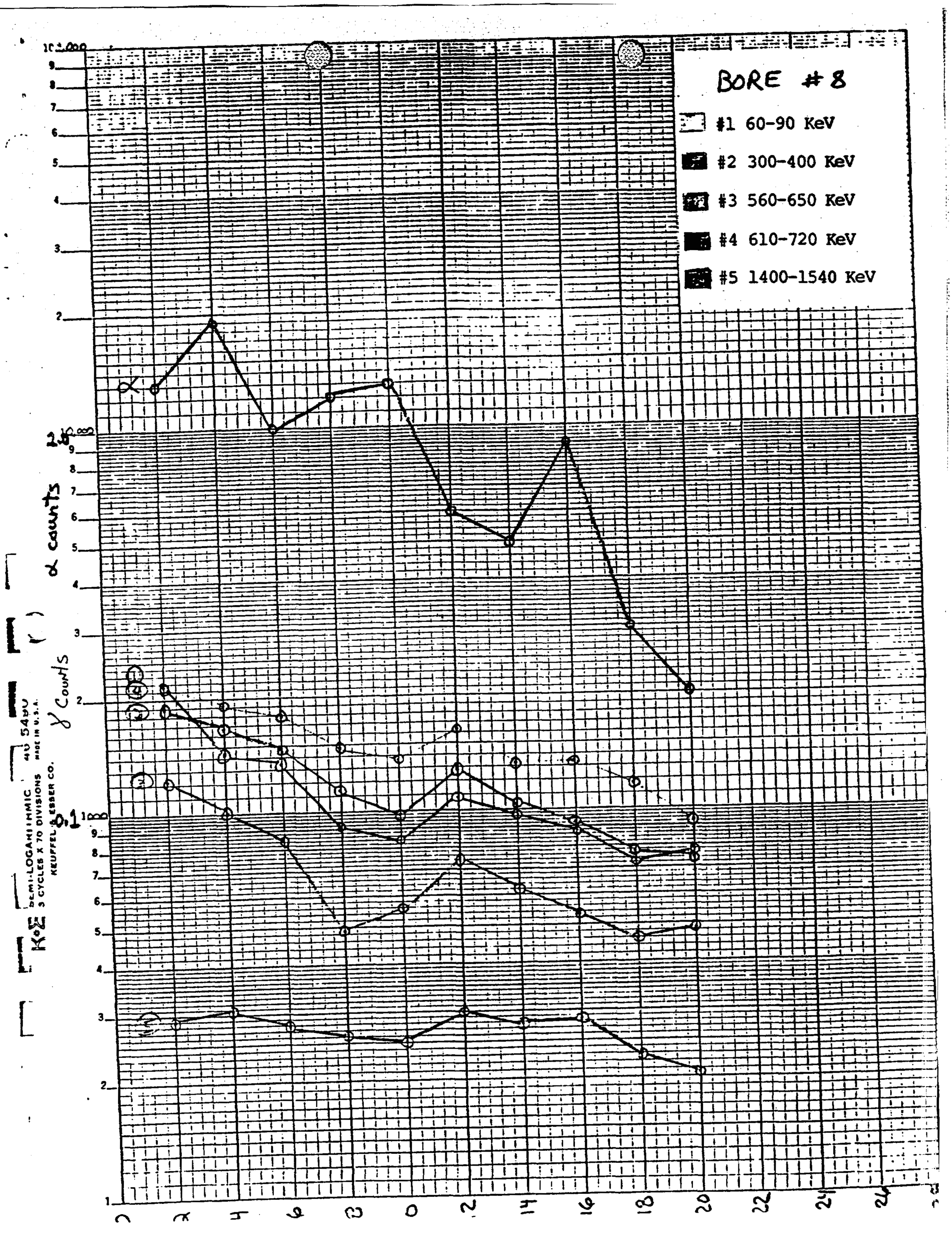

BORE #5
▭ #1 60-90 KeV Ra-22
▨ #2 300-400 KeV "
▭ #3 560-650 KeV "
▨ #4 610-720 KeV
▨ #5 1400-1540 KeV K-4
γ Counts
α counts
10,000
10,000
1000
10
9
8
7
6
5
4
3
2
1
④
③
①
②
②
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. 5400 MADE IN U.S.A.

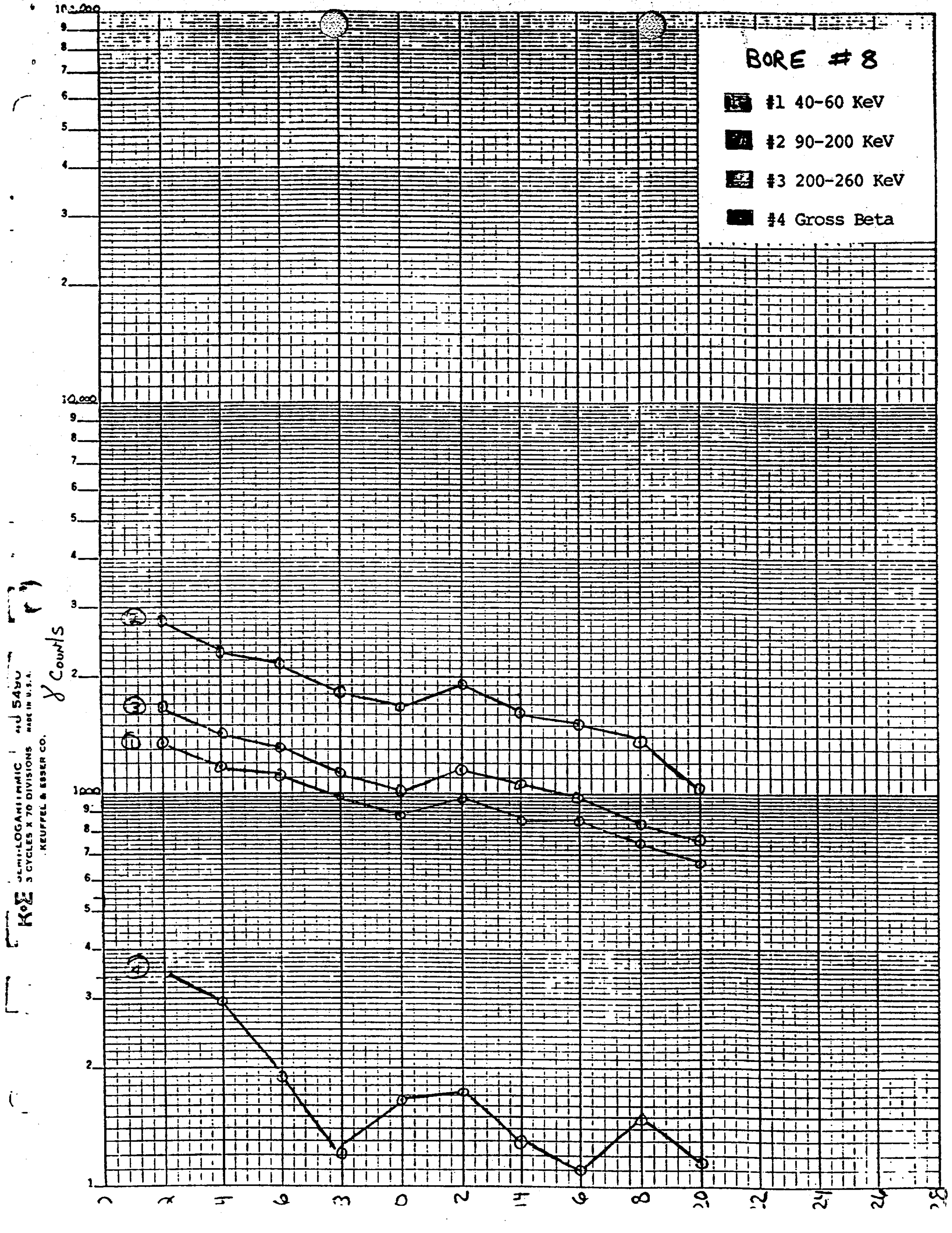

BORE #6
■ #1 40-60 KeV
▨ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts
②
③
①
④
④ Sample in
500m
100,000
9
8
7
6
5
4
3
2
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
24
28
K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

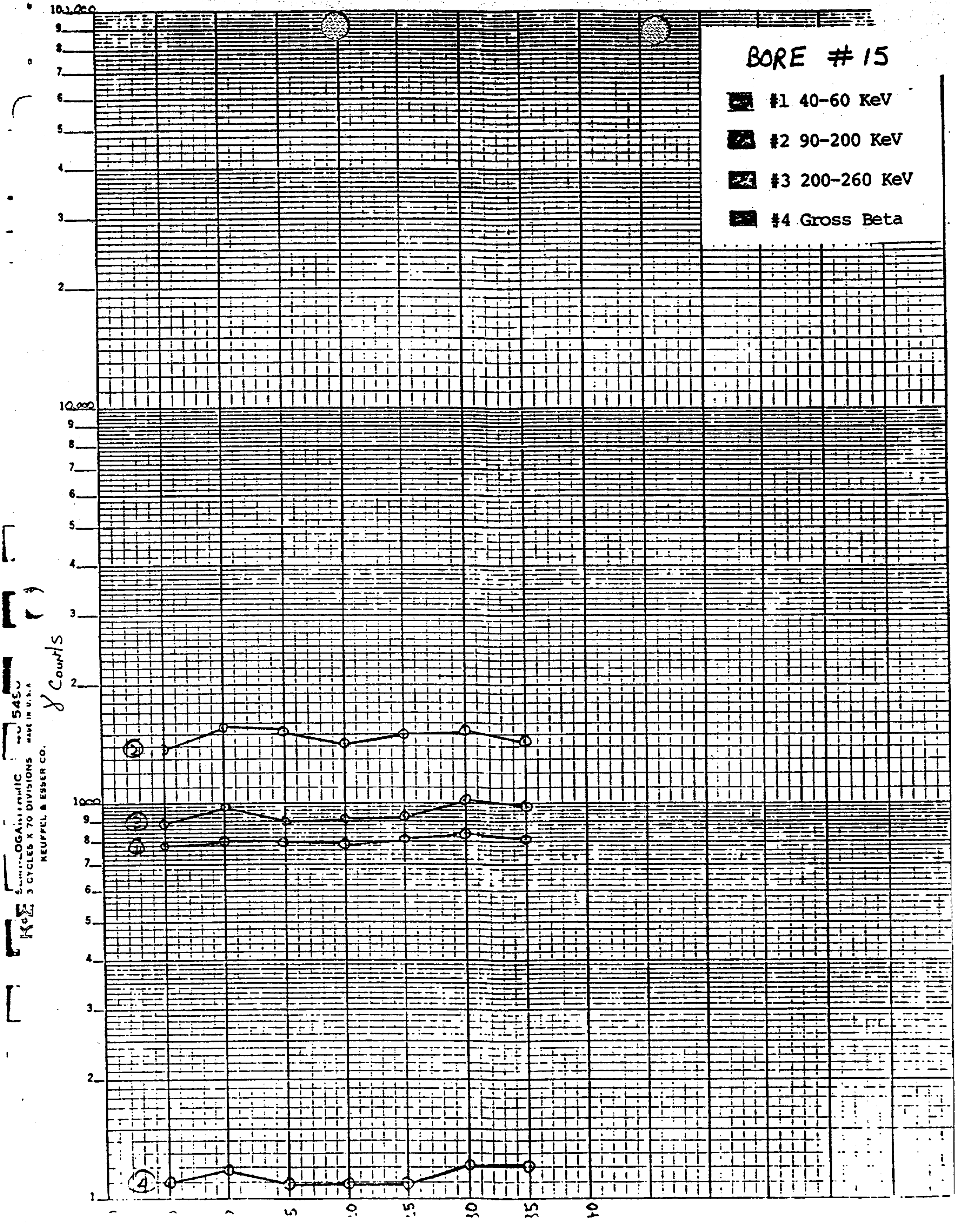

BORE #6
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
10,000
10,000
1000
γ Counts
α counts
①
②
③
④
⑤
K+E SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.
2
14
6
8
20
22
24
26

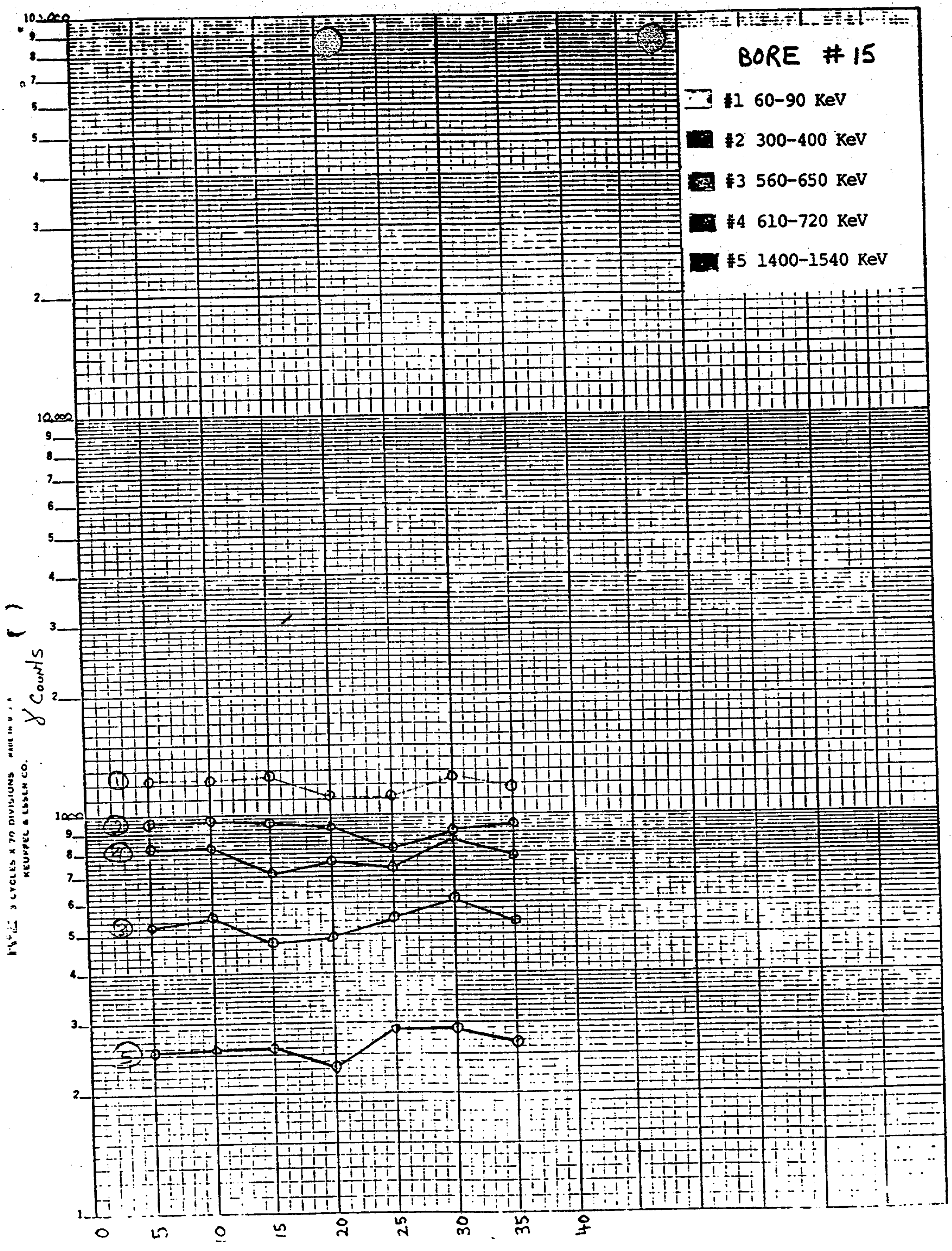

BORE #7
▩ #1 40-60 KeV
■ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts
10,000
10,000
1000
1
①
②
③
④
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
LOGARITHMIC 3 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.
354
MADE IN U.S.A.

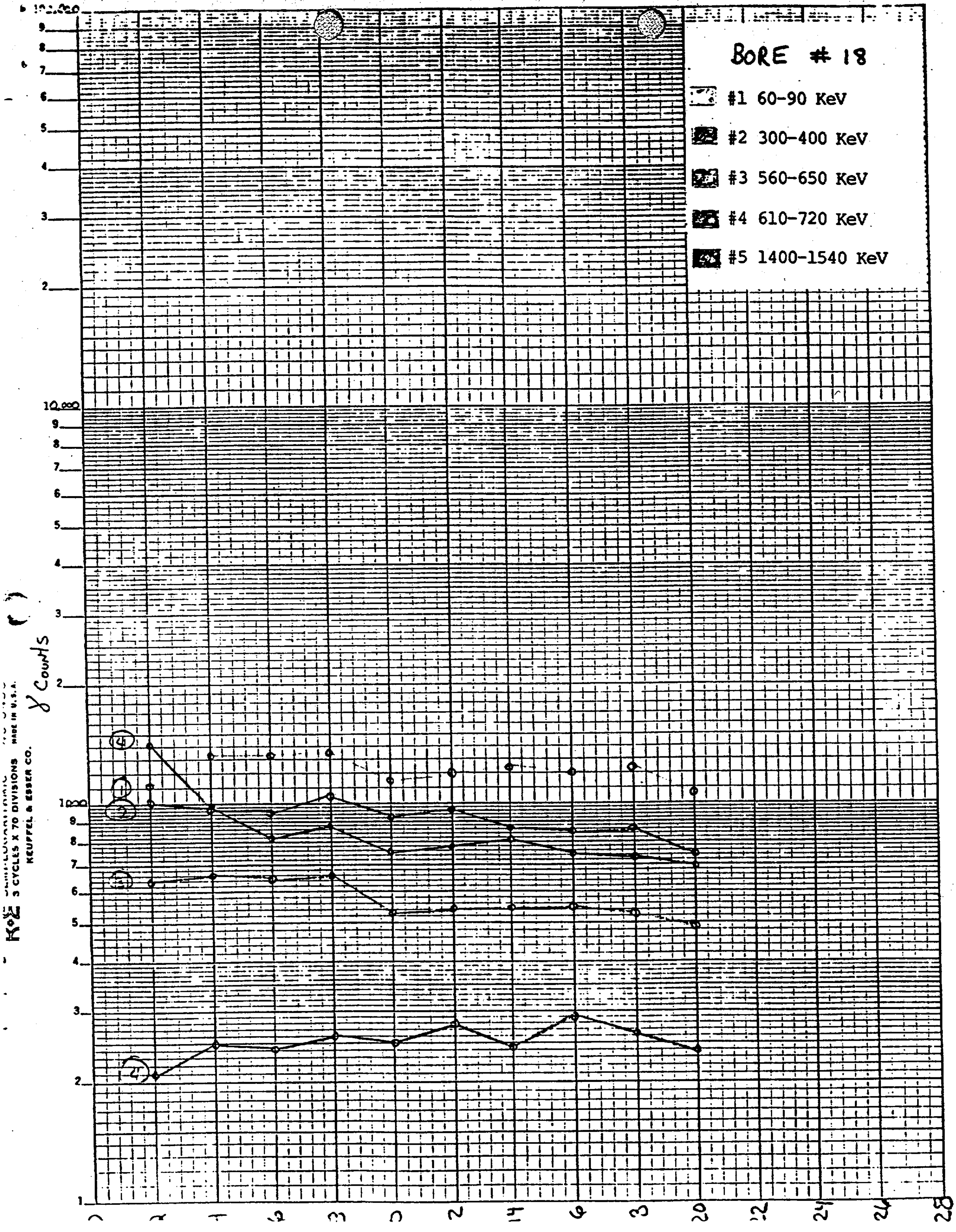

BORE #7
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
γ Counts
100,000
10,000
1000
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
①
②
③
④
⑤
K&E LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.

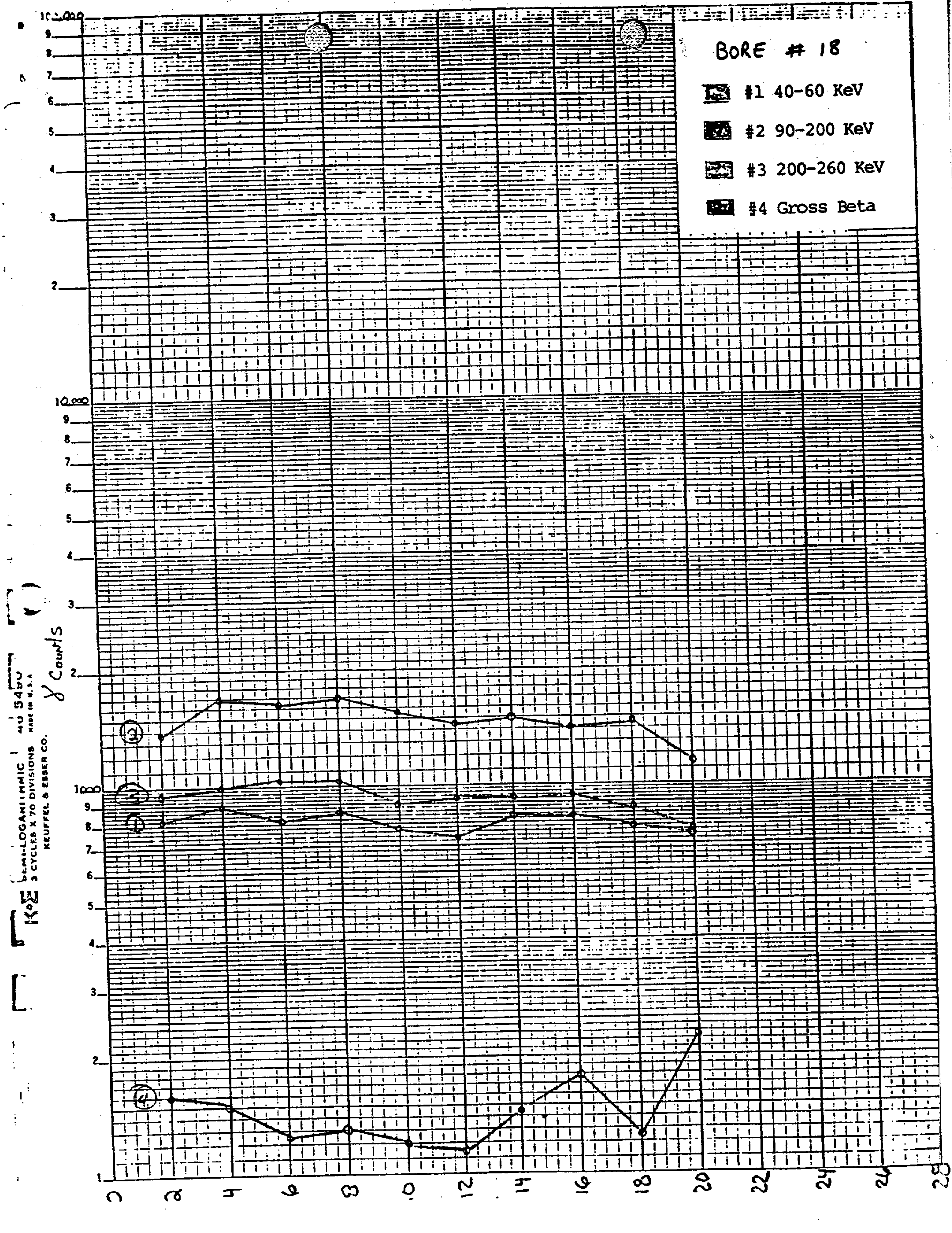

BORE #8
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
α counts
γ counts
α
10,000
1.0
0.1
1000
1
2
3
4
5
6
7
8
9
2
4
6
8
10
12
14
16
18
20
22
24
26
K+E SEMI-LOGARITHMIC 3 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. 46 5490 MADE IN U.S.A.


BORE #8
▨ #1 40-60 KeV
■ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts/s
①
②
③
④
10,000
1000
1
2
3
4
5
6
7
8
9
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
K&E SEMI-LOGARITHMIC 46 5490 3 CYCLES X 70 DIVISIONS MADE IN U.S.A. KEUFFEL & ESSER CO.

BORE #15
#1 40-60 KeV
#2 90-200 KeV
#3 200-260 KeV
#4 Gross Beta
γ Counts
100,000
10,000
1000
9
8
7
6
5
4
3
2
1
②
③
①
④
25
30
35
40
SEMI-LOGARITHMIC
46 5450
3 CYCLES X 70 DIVISIONS
MADE IN U.S.A.
KEUFFEL & ESSER CO.


BORE #15
▭ #1 60-90 KeV
■ #2 300-400 KeV
▨ #3 560-650 KeV
■ #4 610-720 KeV
■ #5 1400-1540 KeV
γ Counts
10,000
10,000
1000
9
8
7
6
5
4
3
2
1
①
②
④
③
⑤
0
5
10
15
20
25
30
35
40
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


BORE # 18
▨ #1 60-90 KeV
▨ #2 300-400 KeV
▨ #3 560-650 KeV
▨ #4 610-720 KeV
■ #5 1400-1540 KeV
γ Counts
100,000
9
8
7
6
5
4
3
2
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
4
1
2
3
5
K&E SEMI-LOGARITHMIC
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


BORE # 18
▨ #1 40-60 KeV
▨ #2 90-200 KeV
▨ #3 200-260 KeV
▨ #4 Gross Beta
10,000
9
8
7
6
5
4
3
2
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
1
γ Counts
①
②
③
④
0
2
4
6
8
10
12
14
16
18
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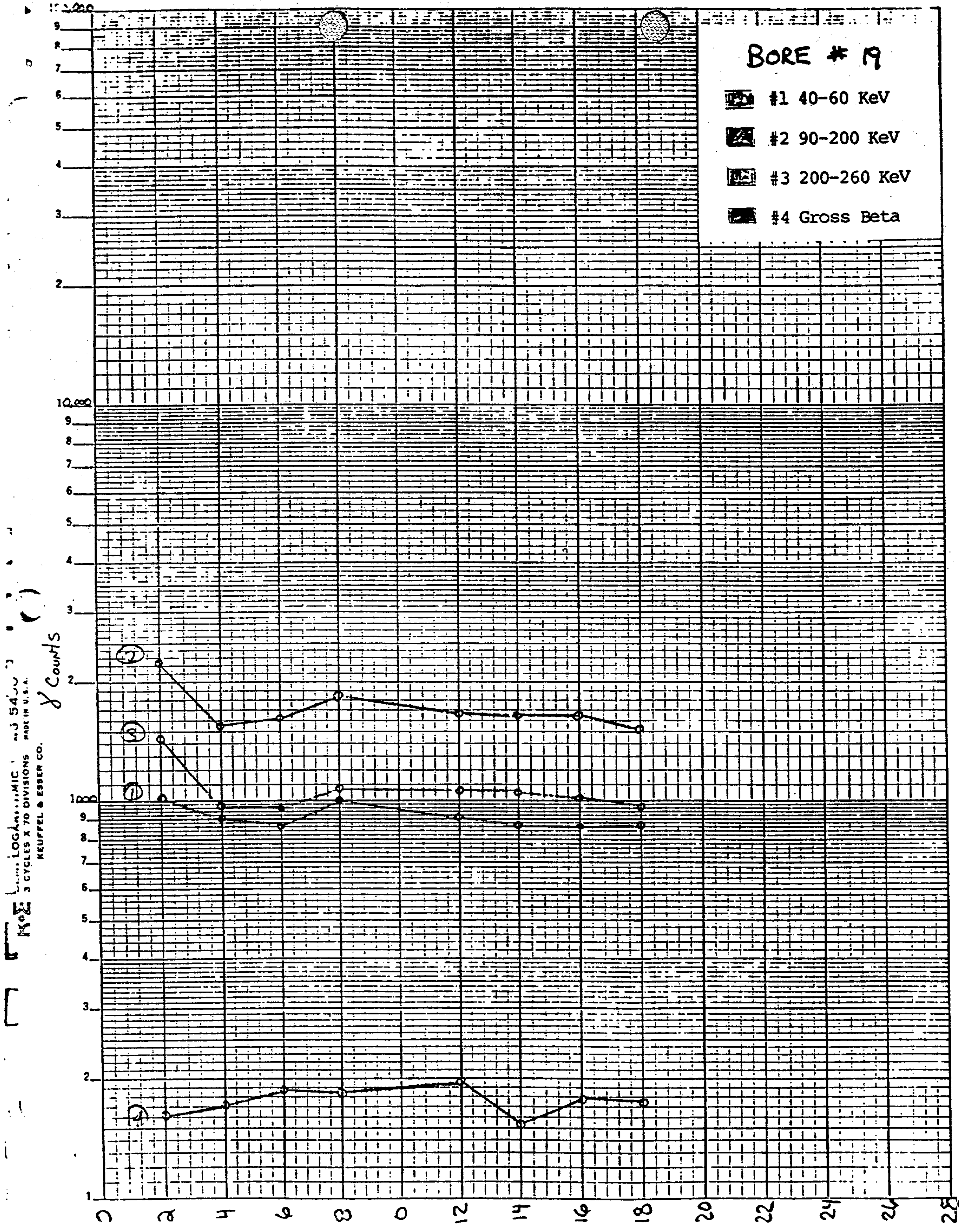
28
K&E SEMI-LOGARITHMIC 46 5490
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


BORE # 19
▨ #1 40-60 KeV
▨ #2 90-200 KeV
▨ #3 200-260 KeV
■ #4 Gross Beta
γ Counts
①
②
③
④
10,000
1000
9
8
7
6
5
4
3
2
1
0
2
4
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8
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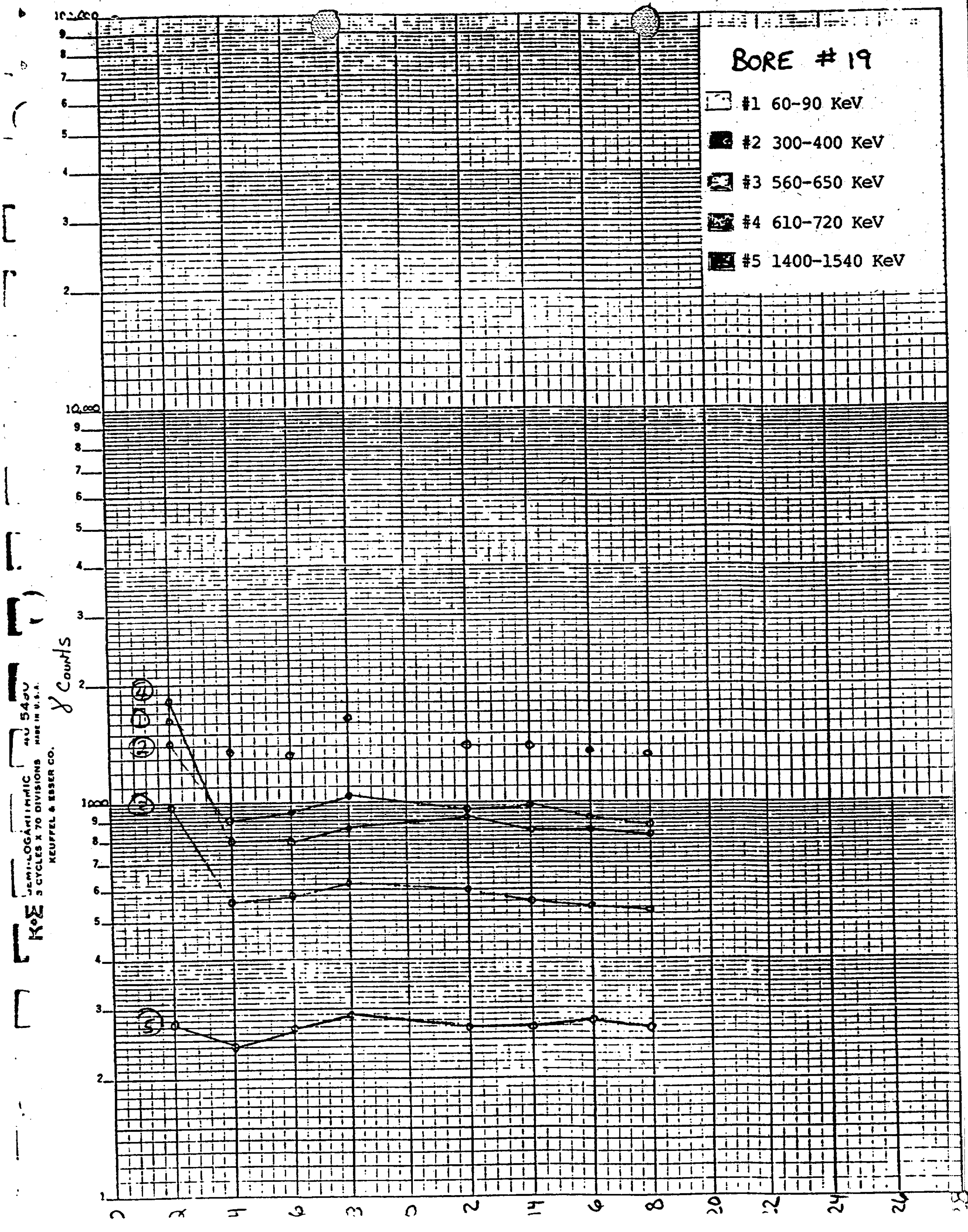
K&E LOGARITHMIC 3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.


BORE # 19
#1 60-90 KeV
#2 300-400 KeV
#3 560-650 KeV
#4 610-720 KeV
#5 1400-1540 KeV
γ Counts
10,000
9
8
7
6
5
4
3
2
10,000
9
8
7
6
5
4
3
2
1000
9
8
7
6
5
4
3
2
1
④
①
③
②
⑤
0
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K&E SEMI-LOGARITHMIC 46 5493
3 CYCLES X 70 DIVISIONS MADE IN U.S.A.
KEUFFEL & ESSER CO.