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THE UNIVERSITY OF ROCHESTER

U. S. Atomic Energy Commission M-1954

Contract W-7401-eng-49 R II-186

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Division: Radiology and Biophysics Division Head: William F. Bale

MONTHLY PROGRESS REPORT FOR FEBRUARY 1947

February 1947

Part II -- Contents

Instrumentation ..... John B. Hursh

Tracer Chemistry ..... Robert M. Fink

Radiation Physiology ..... Thomas R. Noonan

Radiation Chemistry ..... Kurt Salomon

Spectroscopy ..... Luville T. Steadman

Radiation Mechanics ..... Francis W. Bishop

Metabolism ..... Samuel H. Bassett

DEPARTMENT OF ENERGY DECLASSIFICATION REVIEW
SINGLE REVIEW AUTHORIZED BY: DOE/HQ/OD Appt 11/1/96
REVIEWER (ADD):
NAME:
DATE: 8/20/96
DETERMINATION (CIRCLE NUMBER(S))
1. CLASSIFICATION RETAINED
2. CLASSIFICATION CHANGED TO:
3. CONTAINS NO DOE CLASSIFIED INFO
4. COORDINATE WITH:
5. CLASSIFICATION CANCELLED
6. CLASSIFIED INFO BRACKETED
7. OTHER (SPECIFY):

8005325

Submitted by: Andrew H. Dowdy, M.D.
Director

Report received: 3/20/4
Issued: MAR 31 1947

Classification Cancelled
~~Or Changed~~ To
By Authority Of Div. of Classification
By J K Hartsock/Ch Date 5/10/74

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3. Instrumentation

Section Head -- John B. Hurah

1.1 High Voltage D.C. Voltmeter

This instrument was designed and built by Robert Wyverberg and has been referred to in a previous report. The circuit employed is of the plate detection type using an inverted triode with a zero balancing adjustment in the grid circuit. The entire circuit is isolated from the 115 volt line and from ground so that both positive and negative voltages can be measured. The voltage range is from 0 to 2500 volts D.C. with a linear scale from 400 volts to 2500 volts. The input impedance is of the order of 3×10^{11} ohms. A circuit drawing and calibration curve are appended to this report.

1.2 Geiger-Mueller Tube Mount for Liquid Samples

The Geiger-Mueller tube lead shielded mount used in this laboratory has been specially modified to permit easy handling of liquid samples. Drawings of this modification will be submitted in a future report.

1.3

Work is in progress on

1. A portable ionization chamber

2. Radon absorbtion on charcoal as a method for concentrating radon from breath samples.

1.4 Services and Analyses

1. Radioactivity measuring instruments used by this division have been maintained in operating condition.

2. 27 air samples were analysed for radon content.

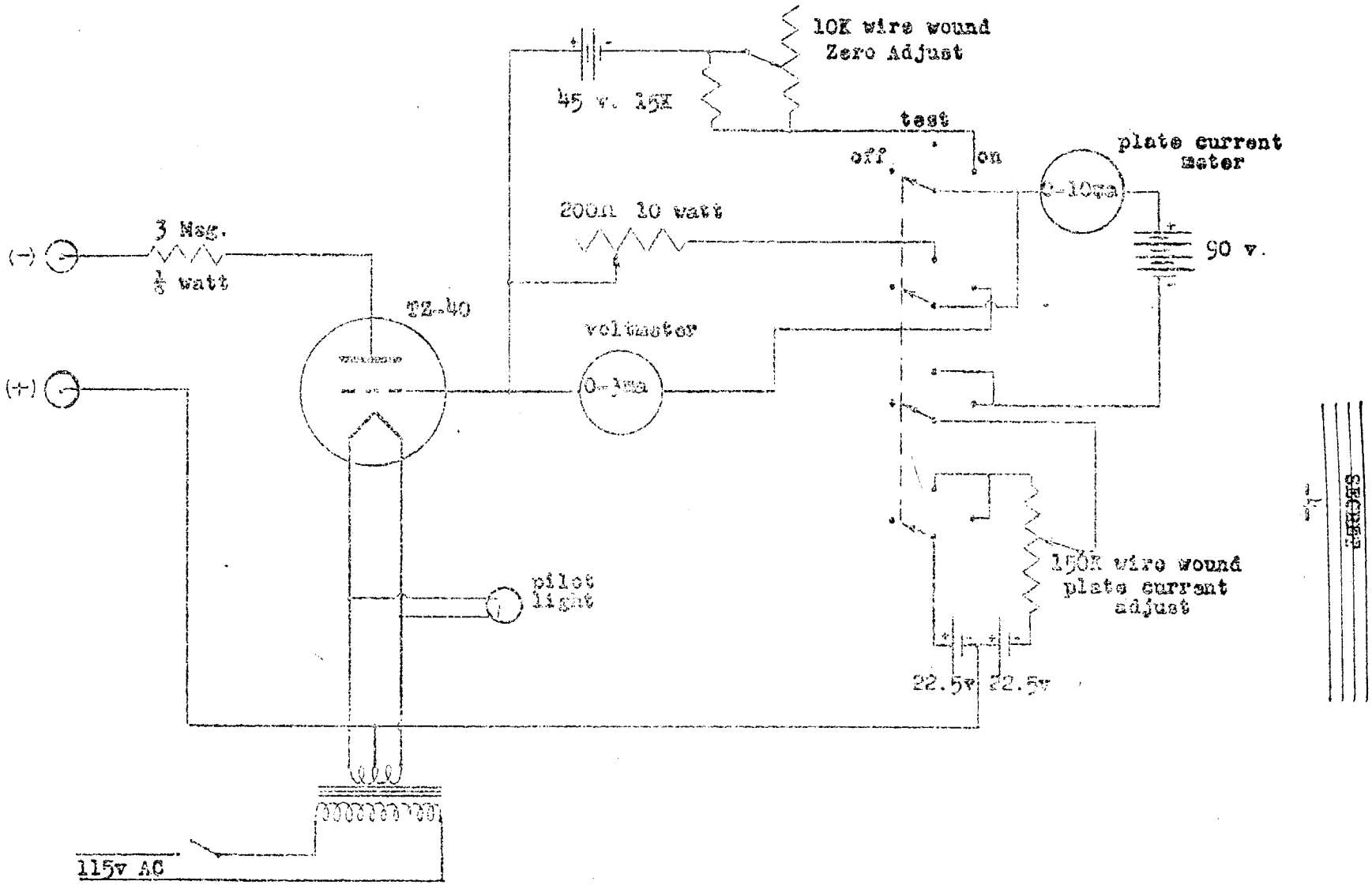

Fig. 1
HIGH VOLTAGE D.C. VOLTMETER

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2. Tracer Chemistry

Section Head — Robert M. Fink

2.1 Intravenous Administration of Polonium Chloride in Dogs (in collaboration with Radiation Physiology Section)

Three dogs, nos. 335, 336, and 337, weighing 9.8, 6.1, and 6.0 kg. respectively, were injected intravenously with freshly neutralized polonium chloride in isotonic saline at a dosage level of 15 microcuries per kilogram. The urinary and fecal excretion data are shown in Table 1 and Figures 3 to 8 as the percentage of the injected dose excreted per day (calculated as if the polonium used had an infinite half-life).

Table 1

Daily Excretion of Polonium (as % of Dose)

Dog No.	Urinary 335	Urinary 336	Urinary 337	Fecal 335	Fecal 336	Fecal 337
Days after Injection						
1	0.157	0.141	0.161	0.72	0.85	0.93
2	0.120	0.086	0.175	0.90	0.68	0.74
3	0.132	0.065	0.094	0.83	1.21	1.62
4	0.109	0.059	0.146	0.77	0.71	1.29
5	0.086	0.053	0.121	1.06	0.14	0.65
6 & 7 (av.)	0.133	0.104	0.112	0.97	0.29	1.56
8	0.155	0.132	0.146	2.05	0.88	1.42
9	0.141	0.131	0.182	1.67	1.20	2.00
10	0.130	0.073	0.216	1.37	1.21	2.01
11	0.197	0.141		1.31	1.87	

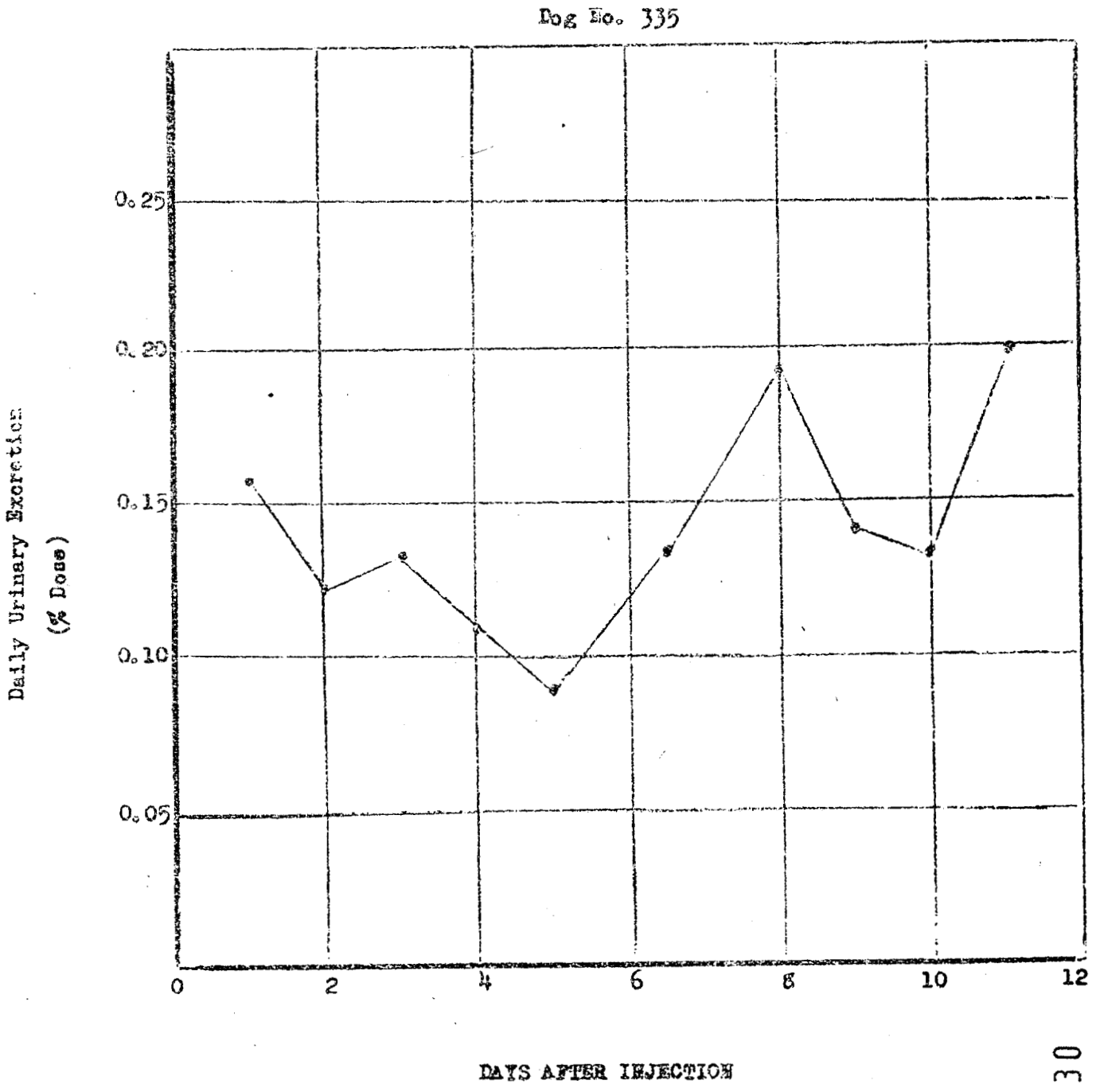

Fig. 3

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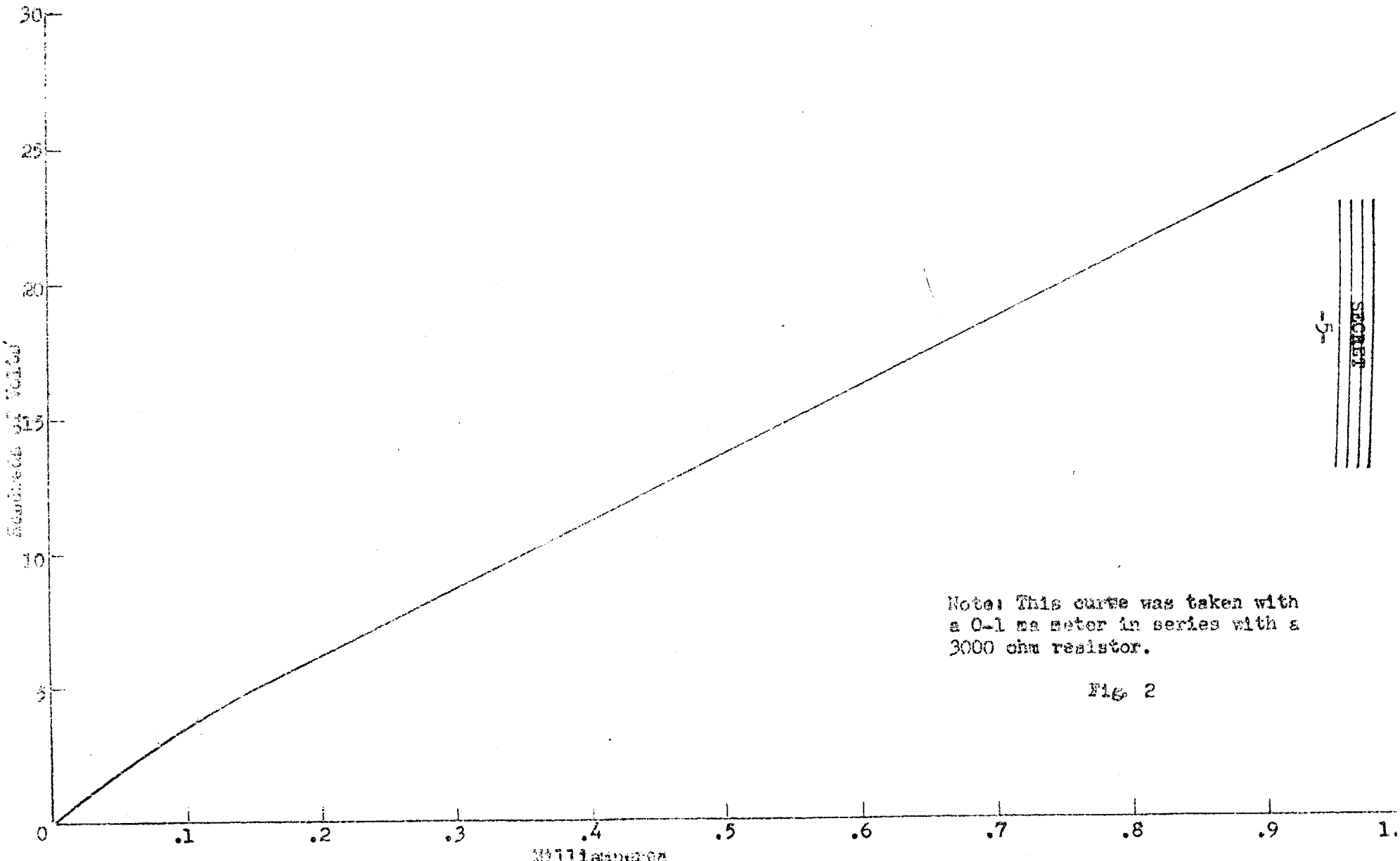
CALIBRATION CURVE
HIGH VOLTAGE D.C. VOLTMETER



Note: This curve was taken with a 0-1 ma meter in series with a 3000 ohm resistor.

Fig 2

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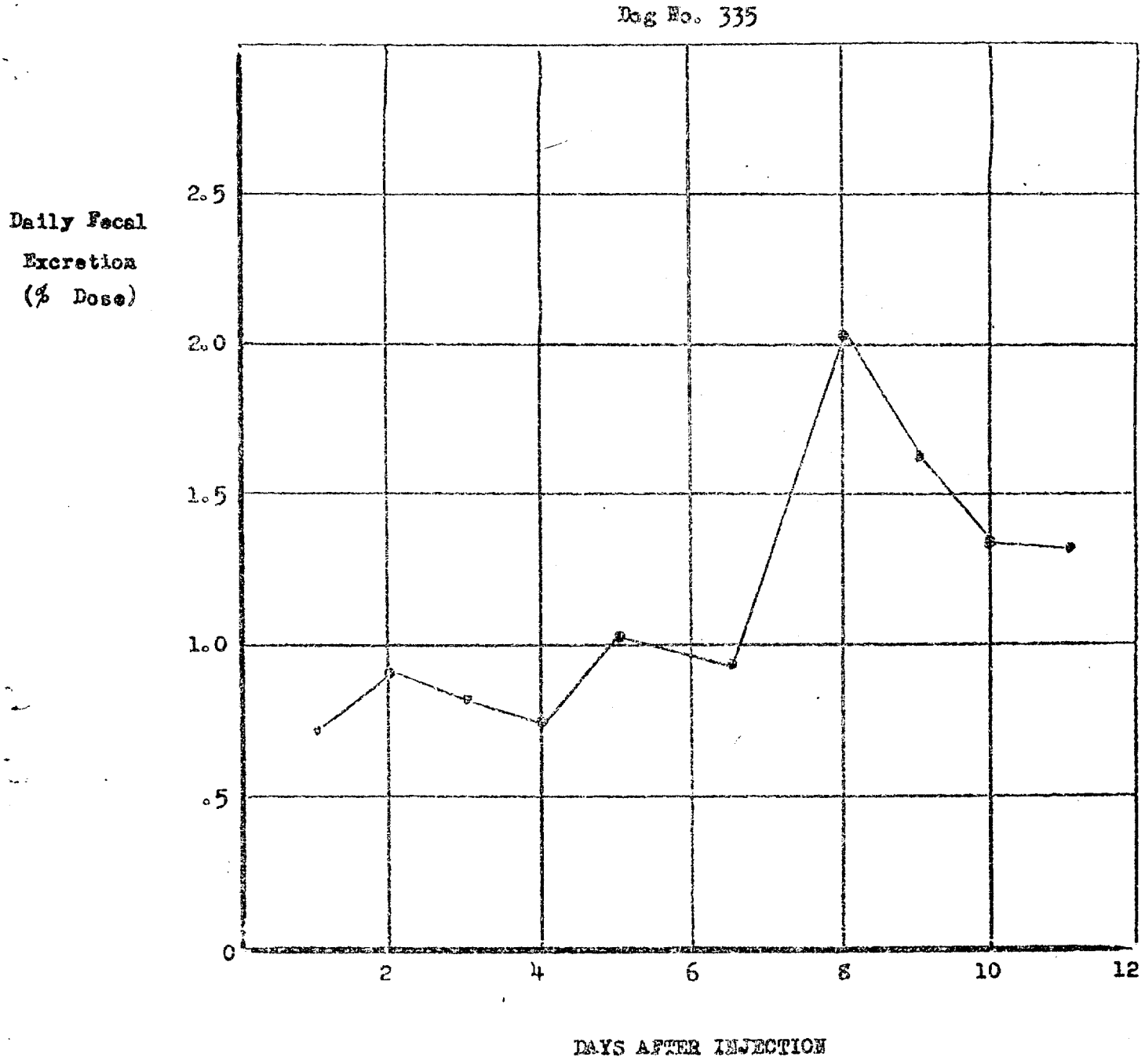
Dog No. 335
Daily Fecal Excretion (% Dose)
2.5
2.0
1.5
1.0
.5
0
2
4
6
8
10
12
DAYS AFTER INJECTION

Fig. 4

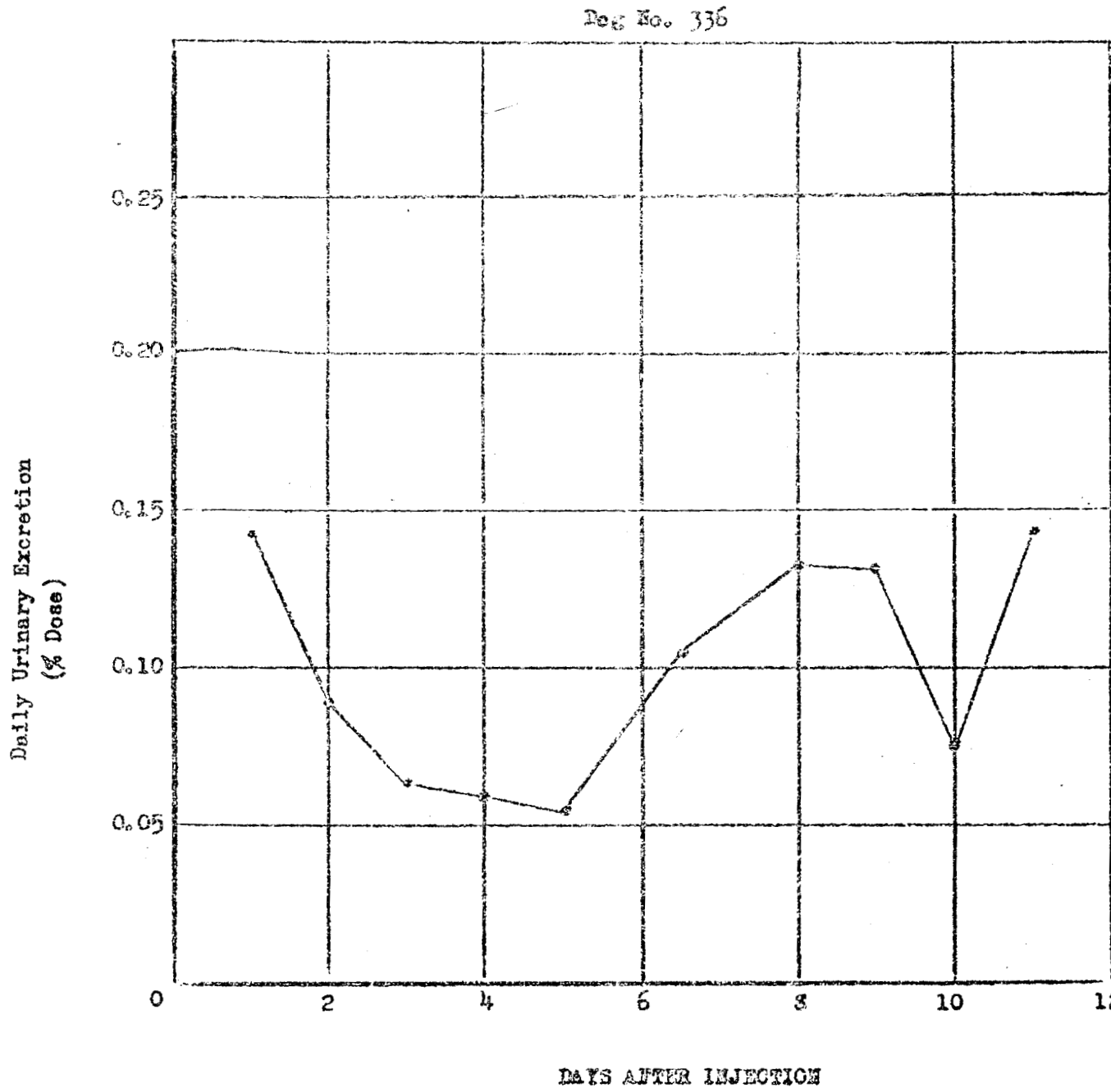
Dog No. 336
0.25
0.20
0.15
0.10
0.05
0
2
4
6
8
10
12
Daily Urinary Excretion
(% Dose)
DAYS AFTER INJECTION

Fig. 5

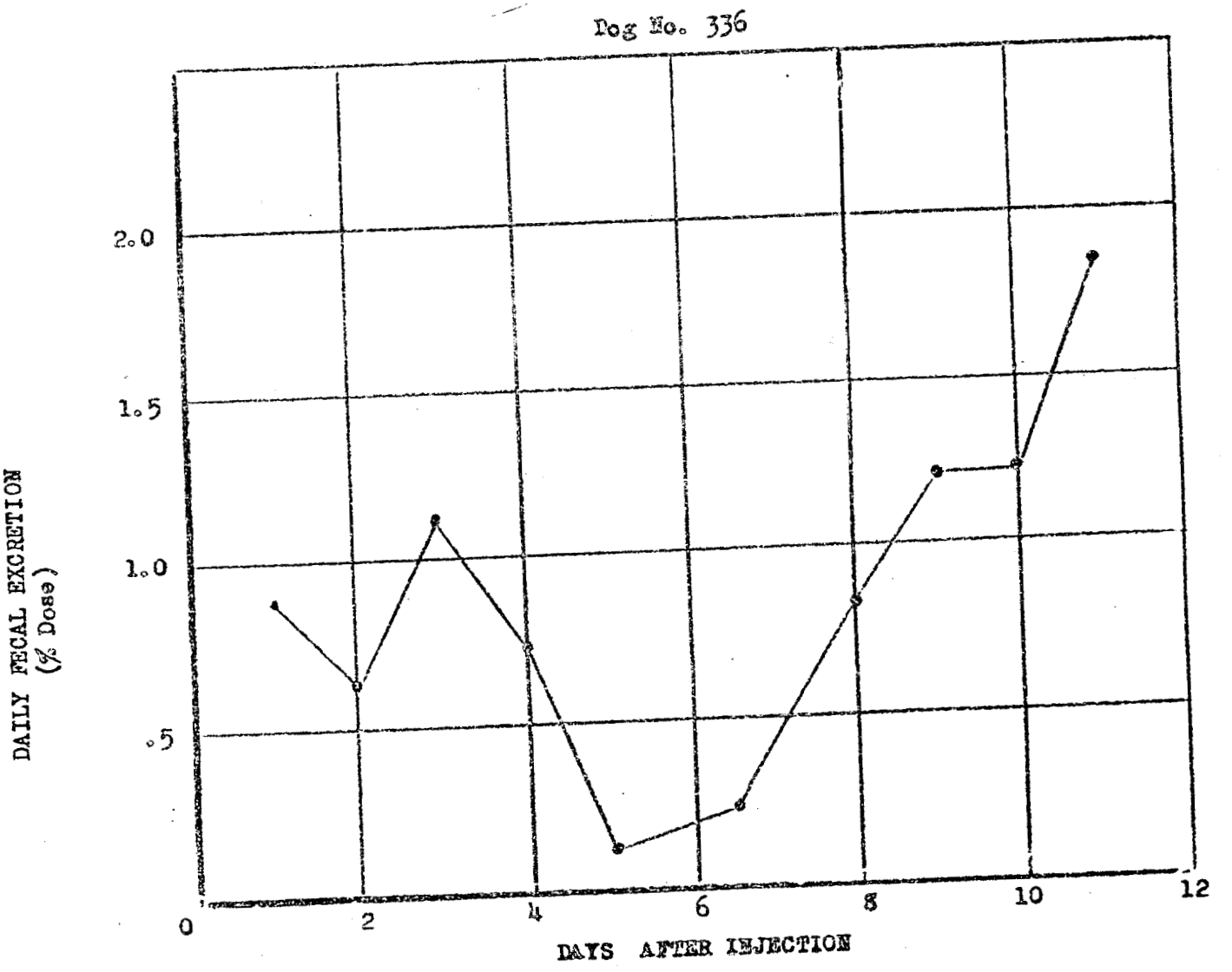
Dog No. 336
2.0
1.5
1.0
.5
0
2
4
6
8
10
12
DAILY FECAL EXCRETION
(% Dose)
DAYS AFTER INJECTION

Fig. 6

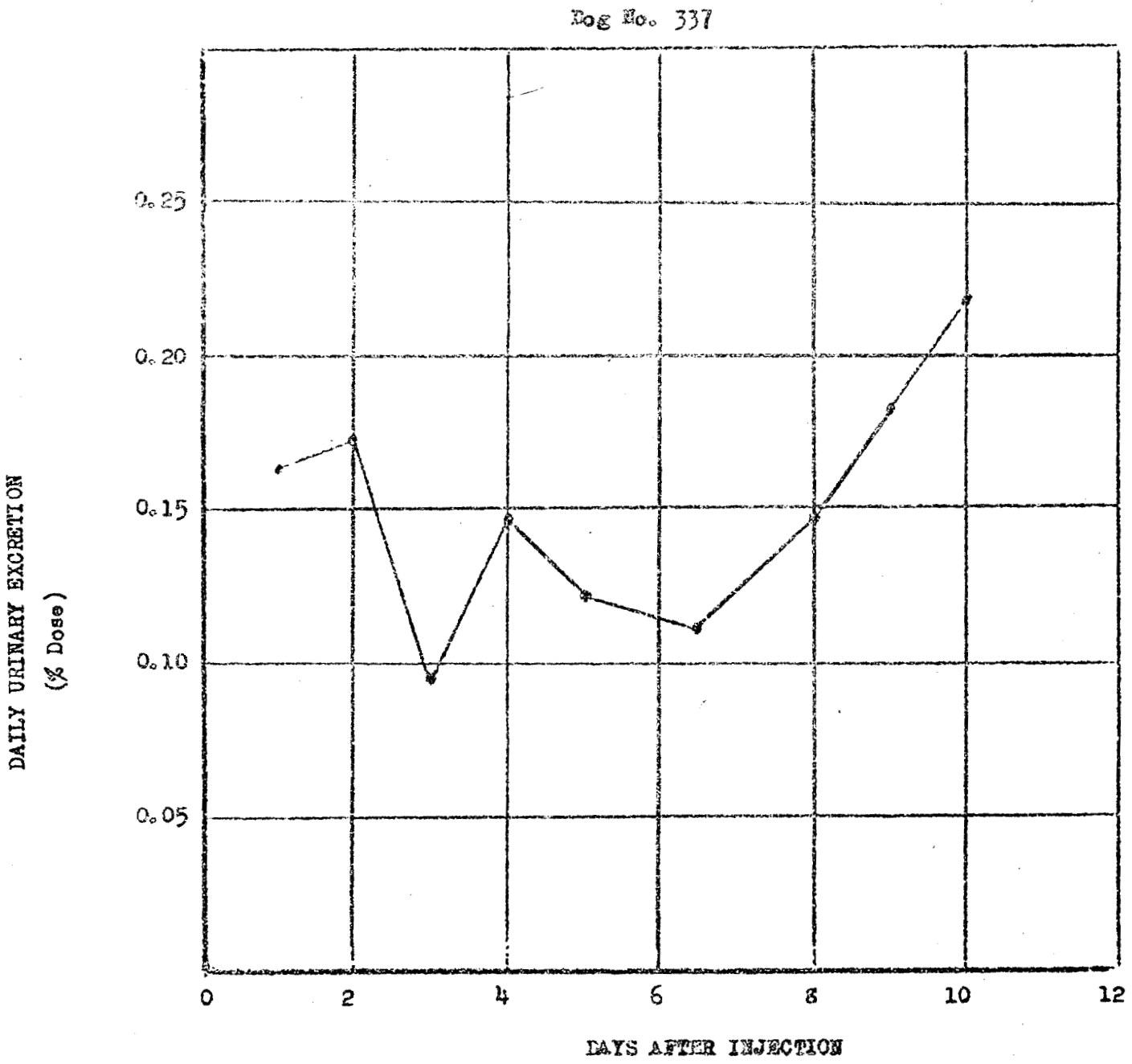
Dog No. 337
0.25
0.20
0.15
0.10
0.05
DAILY URINARY EXCRETION
(% Dose)
0
2
4
6
8
10
12
DAYS AFTER INJECTION

Fig. 7

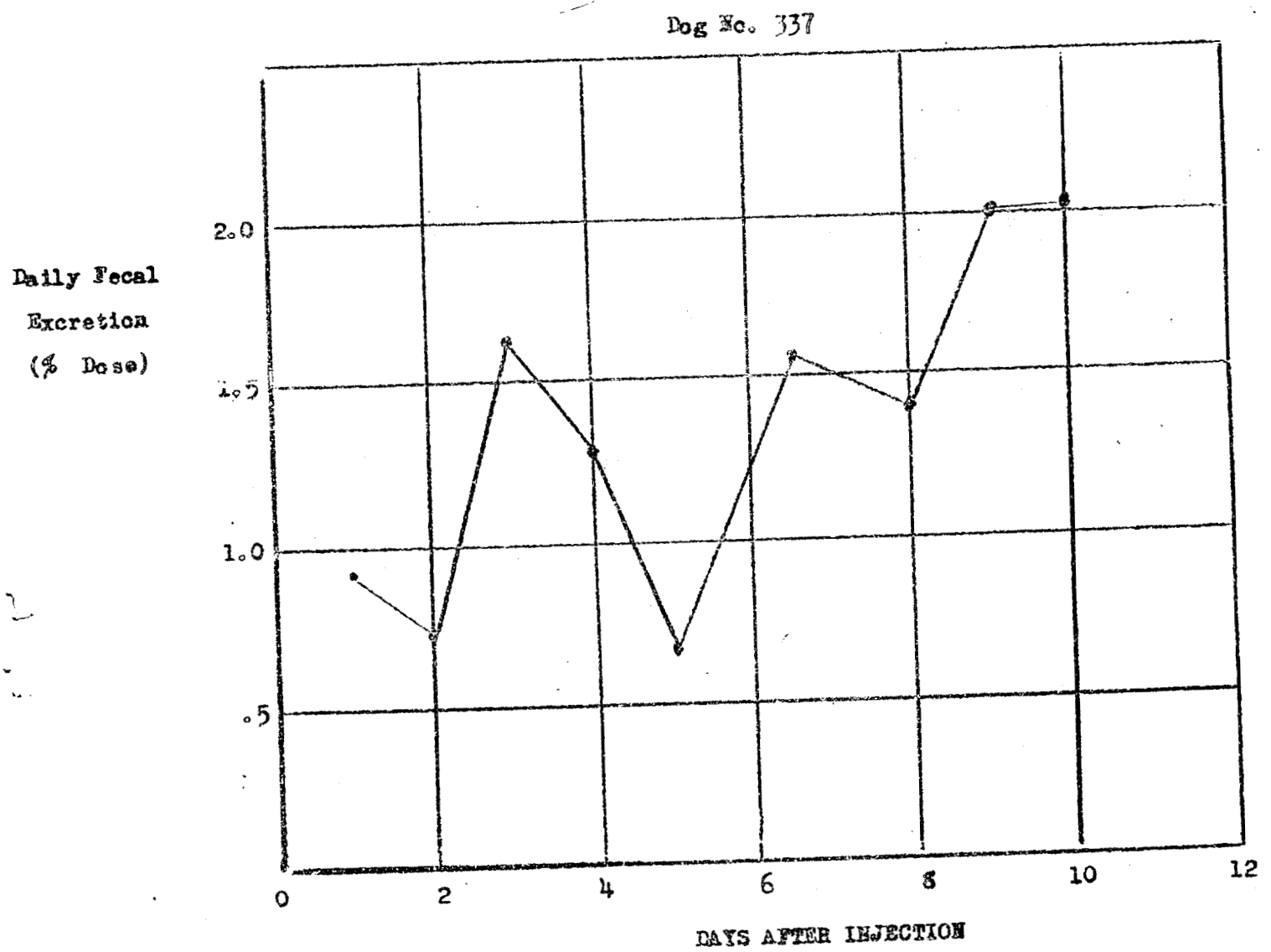

Fig. 8

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3. Radiation Physiology

Section Head -- Thomas R. Hoonan

3.1 Effects of Very High Dose, Single Exposure to X-Irradiation

Some preliminary studies have been made on the effect of exposures to 40,000 r (whole body irradiation) on the cellular elements of the blood of rats. The results will be reported at a later date.

3.2 Effects of Chronic X-Irradiation upon the Susceptibility to Acute Exposure

The experiment reported in detail in the monthly report for January 1947 is being repeated with slight modifications in order to confirm, if possible, the results reported.

3.3 Relationship Between Body Weight and Survival Time After Acute Irradiation

Miss Mildred Taylor has continued experiments designed to investigate the effect of body weight upon survival time. Previously reported experimental results indicated that body weight had no effect upon survival time of rats after 30,000 r (single dose, 65-70 r/min) but that heavier rats had longer survival after 800 r (single dose, 65-70 r/min). Studies have been made after acute exposures to 2000, 5000, 10,000, and 18,000 r. (Intensity of irradiation: 65-72 r/min, 250 KV, H.V.L. = 0.4 mm. Cu). The results are presented in Table I.

From these data, it would seem that the relationships between body weight, dose, and survival time are very complex. Certain general trends, however, can be distinguished. First, at all dosage levels except 10,000 r, the survival time seems to be essentially the same for the weight groups 50-60, 90-110, and 125-140 grams. Groups D & E, however, have longer survival times at all dosage levels. Since these groups are composed of fully mature animals while groups A, B, and C are made up of growing animals, the results are not surprizing.

In the group of animals exposed to 10,000 r, the survival time seems to vary directly as the weight. This is similar to the findings after 800 r (reported in monthly report for December 1946).

The relationships between survival time and dosages, however, are unexpected. In group A (50-60 gram rats), the longest survival time is found among the animals receiving 5000 r, but there seems to be relatively little variation with dosage. In all of the other groups, the longest survival time is found after doses of 10,000 r and the order of survival times is 18,000 r (shortest) 2,000 r, 5000 r, and 10,000 r. This paradoxical result may be due to chance. Previous experiments, however, seem to confirm the unexpected finding that longer survival times are found after exposures to 10,000 r than after exposures to 2000 r. Reference is made to the January 1947 monthly report, page 9, Table II. Groups 100 RHD showed longer survival times than groups 20 RHD. In another experiment, not previously reported, a group of rats which had survived both chronic and acute exposure to X-irradiation, were divided into three groups and exposed to 2000, 5000, and 10,000 r. The survival times were 87.0, 89.8, and

Table 1

Group	Sex (N) Weight (Approximate)	Survival Times			
		2000 r	5000 r	10,000 r	18,000 r
A	M & F 12 50-60	70.53 ± 6.70	76.69 ± 6.30	72.73 ± 8.51	69.54 (± 14.21)
B	M & F 12 90-110	74.82 ± 2.96	75.77 ± 3.84	86.29 ± 7.35	68.30 (± 8.46)
C	M & F 12 125-140	73.79 ± 5.67	77.89 ± 5.11	91.02 ± 7.23	69.46 ± 8.55
D	F 6 190-205	86.13 ± 3.13	90.62 ± 4.52	93.73 ± 7.26	82.68 ± 10.38
E	M 6 280-325	78.23 ± 6.11	83.87 ± 5.62	97.98 ± 8.85	59.38 ± 9.56

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100.0 hours respectively. The data on survival times of rats have been tested statistically by the Student "t" test, and P values of less than .01 were found in all cases where otherwise comparable groups of adult rats receiving 10,000 r were compared to groups receiving 2000 r.

Experiments with hamsters have been on a much smaller scale, but the data support those secured from rats. The mean survival times (in hours) for groups of four hamsters irradiated with 4000, 10,000, and 20,000 r were 115.6, 137.0, and 93.1 respectively (monthly report for November 1946).

The fact that rats which have received 10,000 r of whole body irradiation seem to survive longer than those which received only 2000 r is not easily explained. The formation during whole body roentgen irradiation of a toxic substance (or substances) which can be destroyed by higher doses of irradiation might be a possible mechanism.

3.4 Radioautographic Technique

Experiments indicate that sensitivity of photographic films to beta radiation can probably be increased without great loss in resolving power through the use of phosphor films containing grains of one micron diameter adjacent to the photographic emulsion.

3.5 Coordinated Research Program

Personnel from this section are cooperating with members of the Radiation Chemistry and Tracer Chemistry sections in experimental work to be described in detail by Dr. Kurt Salomon and Dr. Robert M. Fink.

4. Radiation Chemistry

Section Head -- Kurt Salomon

4.1 Experiments on Bone Formation

A. Hyperossification of the long bones in pigeons is correlated with ovarian activity. More specifically, it has been postulated that the hyperossification phenomenon is coincident with the maturation of the ovarian follicle; the increased plasma calcium levels have been correlated with the development of the ova.

Preliminary evidence (plasma calcium determinations and autopsy of female pigeons irradiated with 3000 r and 5000 r respectively) revealed:

1. Extreme ossification of the long bones.

2. Shriveled remnants of ovaries, oviducts, and eggs. (Final evidence for the destruction of the ovarian follicle must be secured).

3. Normal plasma calcium levels.

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The parallelisms and differences of our findings after irradiation and those reported in the literature are obvious. Because of the physiological and biochemical interest of these observations, experiments on bone formation after x-ray treatment will be continued with pigeons as the experimental animals.

B. It has been shown by this writer in collaboration with E. W. Gabrio, E. Reinhard, and E. Silberberg, in a paper which is now in press in the Archives of Pathology, that there exists a relationship between bone marrow activity and the response of osseous tissue to estradiol benzoate. Since bone marrow is more sensitive to x-ray than bone tissue, it was hoped that by heavily damaging bone marrow cells with x-rays, further insight could be gained in the mechanism of ossification as provoked by estradiol benzoate.

One leg of each of six pigeons was subjected to x-ray irradiation, the remainder of each pigeon being shielded from irradiation. Three dosage levels were employed, viz., 300 r, 600 r, and 1200 r, with two pigeons at each level as follows:

Dosage (r)	Pigeon No.	Imposed Survival Time After Irradiation
300	3SPR1	48 hours
300	3SPR2	7 days
600	6SPR1	48 hours
600	6SPR2	7 days
1200	12SPR1	48 hours
1200	12SPR2	7 days

All of the pigeons were sacrificed. The irradiated femur and its marrow were examined histologically and compared with the non-irradiated femur of each animal.

Pathological examinations were performed by Mr. George W. Casarett. He reported that "...bone sections were normal in every case. The bone marrow cells appeared normal in all six pigeons, both in the irradiated and control femora. However, certain differences in the degree of cellularity were noted in pigeons at the 600 r and 1200 r dosage levels... In the two pigeons at 600 r and in one pigeon at 1200 r (12SPR1) there appeared to be slightly less cellularity of bone marrow in the irradiated femora than in the non-irradiated femora. Considering the smallness of the difference, the possible variations within the pigeons, and the technical factors involved, this observation is of doubtful significance.

"In 12SPR2 (1200 r), sacrificed after seven days, this difference in bone marrow cellularity was moderately more marked, suggesting that x-ray irradiation may have been effective in decreasing the number of bone marrow cells in the irradiated femur. In view of the paucity of pigeons examined at this dosage level and at this time interval, however, this minor change must still be regarded as of questionable significance."

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Since pigeons used in earlier experiments were able to survive radiations of 3000 r and even of 5000 r, it is planned to continue the above-mentioned experiments with higher x-ray dosages.

4.2 Experiments with Radioactive Calcium

The reproducability of counting Ca^{45} layers (which were produced by following the method developed in this laboratory) has been tested and found to be satisfactory.

5. Spectroscopy

Section Head -- Luville T. Steadman

5.1 The Spectrochemical Determination of Beryllium

The first report by the author of a feasible spectrochemical method for measuring beryllium was presented in the November 1945 report M-1928. Since then experience with the analysis of this element has led to a few changes in the reported procedure as follows:

(a) The arcking time has been regularly increased from two to three minutes to more completely burn up the beryllium in refractory samples.

(b) An additional internal standard is being employed other than platinum so that samples which have been ashed in platinum, and which may be contaminated with this metal, may be analyzed. This standard is cobalt. Two micrograms are used and the line 2388.9 Å is measured.

(c) The calibration curve has been extended to 10 micrograms Be to make possible the analysis of beryllium in the high grade ore beryl. The beryllium content is 5% or less. The assay is being done on the ore with no initial chemical separations or treatment other than grinding the sample to a fine powder. The powder is diluted 100 times by dry mixing with sodium carbonate. Ten mg. of the mix containing 0.1 mg. of ore and thus about 5 micrograms Be are used in the arc. The calibration curve is established from known amounts of beryllium added to 10 mg amounts of Na_2CO_3 in solution and heated to 600°C. The beryllium lines at 2494.5 Å are read after being photographed with a screen mesh filter of transmission about 0.1. This procedure is being compared with other methods whereby the ore is first dissolved or fused to bring it into solution.

(d) The data on beryllium in bone ash, presented in the table in the November report, were obtained by adding the beryllium in solution to the carbon electrode, drying and then adding the bone ash dry to the crater of the electrode. Thus the beryllium was not originally in the bone ash. Ordinarily, in spectrographic work this distinction is not very important. It so, however, happens that with the beryllium determination the sensitivity of the beryllium lines is very much poorer when the beryllium is incorporated in the bone ash in the same manner as it is when coming from a dry ashed animal skeleton. The high sensitivity may be obtained nevertheless by the expedient of adding 1:1 HNO_3 to the sample in the electrode or by first dissolving the sample in 1:1 HNO_3 and adding it as a solution to the electrode.

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5.2 Infra-red Spectroscopy

The infra-red spectra from 1 to 9 microns have been obtained for normal rabbit plasma and also for the fractions of the same plasma prepared by the usual simple procedure of preferential solubility in salt solutions of ammonium sulfate. The fractions tested are fibrinogen, albumin, euglobulin, pseudoglobulin, and the remaining solution. The following amino acids have also been studied thus far: glycine, alanine, leucine, methionine, cystine, tryptophane, tyrosine, histidine, arginine, lysine, aspartic acid, and glutamic acid.

The above samples were air dried from a water or weak salt solution on mica and represent amounts of the order of 10 mg. dry crystalline material.

All these materials show characteristic absorption curves. The curve for serum is readily seen qualitatively to be a mixture of the albumin and the globulins. At the present, however, serum is best studied by making a fractionation because the curves of the individual components have some things in common.

The absorption spectra curves of the proteins show indications of being made up of the absorption bands characteristic of the component amino acids but the curves for the latter are fairly complex so that it is not easy to make a quantitative analysis of a protein curve into its components or vice versa to construct a probable protein curve out of all the curves of its component amino acids.

It is noted that the absorption curves of both proteins and amino acids in the infra-red are much more complex than in the ultraviolet. The infra-red spectra are therefore much more specific in identifying these materials than ultraviolet spectra.

6. Radiation Mechanics

Section Head -- Francis W. Bishop

6.1 Electron Microscope

The arrangements in Room 112 are being altered to provide for the installation of an R.C.A. type E.M.U. electron microscope, delivery of which is expected the last part of March.

Some modifications of the electrostatic electron lenses have been completed by the shop and are being tried out on the small emission type electron microscope.

The large electron microscope is in the process of calibration of magnification following its reassembly after its overhaul. A considerable number of electron micrographs were made of different materials used in the dust program studies.

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7. Metabolism

Section Head -- Samuel H. Bassett

7.1 Metabolism of Uranium in Human Subjects

Report prepared by: Albert Frenkel (Section on Tracer Chemistry) and Samuel H. Bassett (Section on Metabolism).

Work done by: Albert Frenkel, Dorraine Leake, Helen Van Alstine and Nat Cedars.

Purpose of Experiment

(a) Continuation of the attempt to find the dose of +6 uranium which will produce minimal injury to the human kidney when administered intravenously.

(b) To ascertain to what extent an acute acidosis affects the rate of excretion of uranium by the human kidney.

Previous studies have lead us to believe that a human subject with reasonably adequate renal function should tolerate a dose of uranium of at least 70 micrograms per kilogram of body weight. In the present experiment it was decided to have the subject serve as his own control for part (b). The first dose of approximately 71 micrograms per kilogram (as metal) was given with the individual in a normal state. After a suitable interval to allow for excretion of this dose (or until the daily urinary rate of excretion was reduced to the order of five to ten micrograms per day) the patient was given large doses of ammonium chloride to produce an acidosis as judged by decrease in the CO_2 content of the venous serum. While the subject was acidotic, the second dose of uranium was given but in smaller amounts than the first dose. It was felt that this was a safer procedure since the possible effects of the acidosis could not be anticipated.

The case report and analytical results follow:

1. Subject #6, white, male, aged 61 years was admitted to the Rochester Municipal Hospital for the fifth time on the 14th of October, 1946. Some of his previous diagnosis were arterioscelerosis general; hypertension secondary, heart disease arteriosclerotic and hypertensive class IIa; alcoholism chronic; spontaneous pneumothorax; pneumonia right upper lobe, pneumococcus Type II; tuberculosis pulmonary. The last diagnosis was probably based on insufficient evidence for after three months observation in a tuberculosis sanatorium, he was discharged with a diagnosis of chronic pulmonary fibrosis secondary to his previous Type II pneumonia. The present admission was for symptoms suggesting a gastric lesion. This was confirmed by x-ray and gastroscopy and was thought to be a benign gastric ulcer. He improved promptly on medical treatment and the ulcer appeared to heal. Further pulmonary studies including concentration of sputa, bronchoscopy and x-ray failed to reveal evidence of active pulmonary tuberculosis. As he had no home, he willingly agreed to enter the Metabolic Unit for special studies. The transfer was effected on January 3, 19[illegible]

Examination: Temperature, 37.8 C, Pulse, 80, Respiration, 18, Blood Pressure, 150/84, Height, 163 cm., Weight, 55.1 Kg. Elderly, rather pale, short, gray haired man, alert, cooperative, does not appear ill. Positive findings: Palpable shotty lymph

nodes in right supraclavicular fossa, both axillae and both inguinal regions; complete upper edentia, carious lower teeth; slight marginal atrophy of lingual papillae; deviation of trachea to the right; lungs reveal hyper-resonant percussion note except over the right upper lobe where the note is somewhat dull; heart not well outlined but had regular rhythm and soft apical systolic murmur; diastasis of the abdominal secti muscles above umbilicus; prostate gland about twice normal size.

Laboratory data:

Blood: Hb. 13.8 gm./100 ml.

RBC 4.62 million/cu. mm.

WBC 8,300

Differential Count:

Neutrophiles 75, Lymphocytes 22, Monocytes 3

Urine:

Specific Gravity 1.024, Albumin 0, Sugar 0.

Acetone 0. Microscopic 2-3, W.B.C. per high power field

Stool:

Negative guaiac reaction for blood on admission to metabolism.

X-ray of Lungs:

Resolving pneumonic process in right upper lobe with residual fibrosis.

X-ray of Stomach:

Decrease in size of the ulcer on the lesser curvature.

Renal Function: 1/9/47 (Condition normal)

Renal plasma flow	432 ml./min.	(Normal 697 ± 130)
Glomerular Filtration Rate	99 ml./min.	(" 131 ± 22)
Maximum Tubular Excretory Capacity	95 mg./min.	(" 77.5 ± 12.9)
Filtration Fraction	0.205	(" 0.19 ± 0.02)

Blood Chemistry 1/6/47

NPN 30 mg. %	Globulin 2.3 gm. %
Total Serum Protein 6.5 gm. %	Chloride 98 m. eq./liter
Albumin 4.2 gm. %	CO_2 64 vols. %

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Experiment 1. Condition Normal

Uranium in the amount of 3910 micrograms was injected intravenously at 10:25 A.M. on 1/10/47. As in previous instances uranyl acetate was used, enriched with U_{234} and having a total activity of 0.03 microcuries. The uranyl salt was dissolved in 7 ml. of sodium acetate buffer isotonic with blood plasma. Body weight was 55 kilograms and th dose therefore 70.9 micrograms uranium/kilogram of body weight.

In Table 1 the uranium analyses for urine are given as determined by the plating and alpha counting method. Improved procedures have made it possible to follow uranium excretion for a longer period of time. Due to the varying composition of urin particularly in respect to phosphate, the ether extraction method is likely to give low values at low concentrations of uranium in a rather unpredictable manner unless th concentration of phosphate and of other interfering ions is known. We have therefore abandoned the ether extraction method for urine and are simple wet ashing a volume of urine in which the amount of calcium is not so large that it will interfere with the formation of a thin metal deposit on the foil on which the uranium is being electroplated. This method of analysis is simpler and is giving more consistant results.

All physiological tests for renal and particularly tubular damage were again negative.

In addition to determinations of urinary catalase, protein, and amino acid/creati ratio the previously mentioned tests of renal clearance were repeated on the 16th of January. This was at a time when on the basis of animal work one might expect renal damage to be present.

Renal plasma flow	499 ml./min.
Glomerular filtration rate	93 ml./min.
Maximum tubular excretory capacity	83 mg./min.
Filtration fraction	0.185

The reductions in glomerular filtration and maximum tubular excretory capacity are not considered significant.

Experiment #2

On January 22, about 90 percent of the first dose of uranium had been excreted in the urine and acidification of the patient was begun. He received 8 gm. of ammonium chloride daily for three days and 12 gm. daily on the 4th and 5th days. By January 27, the CO_2 content of serum was 32 vols. %, chloride 116 m. eq./liter, NPN 60 mg. %. The second dose of uranium was injected on this day and the dose of ammoniu chloride reduced to 4 gm. daily and discontinued entirely on February 1.

Blood Chemistry	Jan. 27	Jan. 28	Jan. 31	Feb. 4
CO_2 Content Serum Vols. %	32	36	48	70
Chloride in eg./liter	116	112	108	104
Non-protein nitrogen	60	50	41	---

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The dose of uranyl-acetate administered the second time was somwehat lower than the first dose, corresponding to 3170 µg. or 56.5 µg of uranium per kilogram body weight of the patient (weight of patient on 1/27/47 56.5 kilograms). A blood sample was withdrawn in a period of 15 to 17 minutes after the administration of uranyl-acetate. From the analysis of this sample 17.5% of the uranium was still in the blood assuming that complete mixing had taken place.

In Table 4 the values for the uranium analyses are given as determined by the usual method. No significant amount of uranium could be detected in the feces. Also all physiological tests were again negative.

From the analytical data it is apparent that the immediate excretion of uranium during the first day was slowed down due to the acidification. However, after 13 days the percentage of uranium was approximately the same as under "normal" conditions. In the following report data will be presented for the rate of excretion of uranium after thirteen days.

In contrast to the first or normal condition, under acidification the excretion of uranium continues for a longer period of time although at a rather low level. See Figure 1. This is in agreement with the data of Dr. William Neumann who has shown that in rats acidification increases the amount of uranium deposited in the kidney. Re-solution of uranium deposited originally in the bone drops to a very low level while uranium conbined with kidney proteins continues to be dissolved and excreted in the urine.

Summary

1. No evidence of injury to renal function was encountered when 71 micrograms of uranium (as uranly-acetate)/1/6 of body weight was injected intravenously into a human subject.

2. A smaller dose of uranium, 57 micrograms per kilogram, was also without injurious effect during a period of acute acidosis induced by the ingestion of large amounts of ammonium chloride.

3. The initial rate at which uranium was excreted in the urine was appreciably slower during the period of acidosis, but the percentage of the total dose excreted in 13 days was nearly the same (about 90%) for the two experiments.

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Table 1

Excretion of Uranium by Patient No. 6

Date	Hour	Time After Injection hr.	Time After Injection min.	Uranium in Specimen µg.	Uranium in Specimen in % of Dose	Cumulative Excretion in % of Dose	% of Dose Excreted per ml. of Urine
10/47	10:25 a.m.		25	46.75	1.19	1.19	.027
	12:30 p.m.	2	30	855.0	21.81	23.00	.096
	3:25 p.m.	5	25	672.0	17.20	40.20	.089
	5:45 p.m.	7	45	600.0	15.32	55.52	.0715
	7:45 p.m.	9	45	301.0	7.70	63.22	.050
	10:05 p.m.	12	05	222.0	5.68	68.90	.029
11/47	12:40 a.m.	14	40	144.9	3.70	72.60	.0145
	3:55 a.m.	17	55	101.7	2.60	75.20	.0072
	7:05 a.m.	21	05	60.6	1.55	76.75	.0072
	8:00 a.m.	22	00	34.3	.86	77.61	.0093
12/47	8:00 a.m.	46	00	204.7	5.24	82.85	.0033
13/47	8:00 a.m.	70	00	70.9	1.81	84.66	.0009
14/47	8:00 a.m.	94	00	70.9	1.81	86.47	.001
/15/47	8:00 a.m.	118	00	38.9	1.00	87.47	.00045
/16/47	8:00 a.m.	142	00	29.5	.75	88.22	.00045
/17/47	8:00 a.m.	166	00	16.5	.42	88.64	.00025
/18/47	8:00 a.m.	190	00 less than	18.1	.46	89.10	.0003

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Table 1 (continued)

Date	Hour	Time after Injection hr.	Uranium in Specimen µg.	Uranium in Specimen in % of Dose	Cumulative Excretion in % of Dose	% of Dose Excreted per ml. of Urine
1/19/47	8:00 a.m.	214	17.1	.44	89.54	.00025
1/20/47	8:00 a.m.	238	16.9	.44	89.98	.00025
1/21/47	8:00 a.m.	262	17.9	.46	90.44	.00025
1/22/47	8:00 a.m.	286	16.4	.41	90.85	.00025
1/23/47	8:00 a.m.	310	10.6	.27	91.12	.00015
1/24/47	8:00 a.m.	334	less than 6.5	less than .17	less than	.00008

Excretion during first 22 hours	3038.25 µg.	77.61%
Excretion during following 5 days	414.9 "	10.61"
Excretion during seven days following the first six days	113.5 "	2.90"
Total excretion:	3566.65 µg.	91.12%

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Table 2

Ratio of urinary amino acid nitrogen to urinary creatinine.

(analyzed by H. Berke and M. Cresmon.)

Date	Amino acid N. / Creatinine	Urinary pH.
1/4/47 - 1/5/47	.16	6.02
1/5 - 1/6	.15	5.75
1/6 - 1/7	.15	5.61
1/7 - 1/8	.13	5.34
1/8 - 1/9	.13	5.22
1/9 - 1/10	.13	5.52
Uranium administered 10 a.m. 1/10/47		
1/10 - 1/11	.04	5.67
1/11 - 1/12	.14	5.44
1/12 - 1/13	.14	5.34
1/13 - 1/14	.15	5.31
1/14 - 1/15	.14	5.35
1/15 - 1/16	.14	5.87
1/16 - 1/17	.12	5.54
1/17 - 1/18	.15	5.36
1/18 - 1/19	.17	5.32
1/19 - 1/20	.28	5.28
1/20 - 1/21	.16	5.41
1/21 - 1/22	.12	5.44

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Table 3

Urinary Catalase and protein

Date		Catalase (mm. of H_2O)	mg. Albumin/5 ml. urine
1/4/47	10:30 a.m.	5.5	0
1/6/47	"	8	0
1/7/47	"	10.5	0
1/8/47	2 p.m.	7.5	0
1/9/47	10:30 a.m.	16	0
1/10/47	9:40 a.m.	9.5	0
Uranium administered 10 a.m. 1/10/47			
1/11/47	10:30 a.m.	8	0
1/12/47	9:30 a.m.	8.5	0
1/13/47	10:30 a.m.	11	0
1/14/47	"	10.5	0
1/15/47	9:45 a.m.	12.5	trace (less than 5 mg.)
1/16/47	8:00 a.m.	12.5	" " " " "
1/17/47	10:30 a.m.	11	0
1/18/47	"	8	0
1/19/47	"	11	0
1/22/47	"	12	0

Table 4 (Continued)

Date	Hour	Time After Injection hr. ×	Uranium in Specimen µg.	Uranium in Specimen in % of Dose	Cumulative Excretion in % of Dose ×	% of Dose Excreted per ml. of Urine	Urinary pH.
2/5/47	8:00 a.m.	210	40.0	1.26	86.09	.0007	5.91
2/6/47	"	234	27.8	.88	86.97	.0007	----
2/7/47	"	258	27.6	.87	87.84	.00065	6.84
2/8/47	"	282	25.8	.81	88.65	.0004	6.75
2/9/47	"	306	31.1	.98	89.63	.00055	7.14
2/10/47	"	330	14.4	.45	90.08	.00035	6.83
2/11/47	"	354	16.2	.51	90.59	.0004	7.01

Excretion during first 17 hours:	1817.8 µg.	57.33 %
Excretion during following 5 days:	770.9 "	24.31 %
Excretion during seven days following the first six days:	253.4 "	7.99 %
Excretion in next two days:	30.6 "	.96 %
Uranium in blood sample of January 1, 1947:	2.7	.08
Total uranium recovered	2875.4 µg	90.67 %

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Table ~~4~~ 21

Subject 6

Excretion of Uranium by Patient No. 6 Following Acidification

Date	Hour	Time After Injection hr.	Time After Injection min.	Uranium in Specimen µg.	Uranium in Specimen in % of Dose	Cumulative Excretion in % of Dose	% of Dose Excreted per ml. of Urine	Urinary pH.
1/27/47	3:00 p.m.	1		315.7	9.95	9.95	.0506	5.04
	4:10 p.m.	2	10	229.5	7.24	17.19	.060	5.13
	5:30 p.m.	3	30	235.7	7.43	24.62	.056	5.19
	7:30 p.m.	5	30	327.0	10.32	34.94	.051	5.28
	9:00 p.m.	7	00	159.5	5.03	39.97	.032	5.22
	10:35	8	35	147.9	4.66	44.63	.034	5.32
	12:35	10	35	119.5	3.77	48.40	.024	5.33
1/28/47	2:50 a.m.	12	50	143.8	4.54	52.94	.014	5.21
	4:50 a.m.	14	50	75.5	2.38	55.32	.010	5.06
	7:05 a.m.	17	05	63.7	2.01	57.33	.011	5.00
1/29/47	8:00 a.m.	42	00	363.7	11.15	68.48	.0057	5.25
1/30/47	"	66		158.3	4.99	73.47	.0025	5.38
1/31/47	"	90		115.3	3.64	77.11	.0017	5.38
2/1/47	"	114		75.7	3.39	79.50	.00094	5.43
2/2/47	"	138		67.9	2.14	81.64	.0011	5.38
2/3/47	"	162		49.0	1.55	83.19	.0008	5.34
2/4/47	"	186		52.1	1.64	84.83	.0007	5.30

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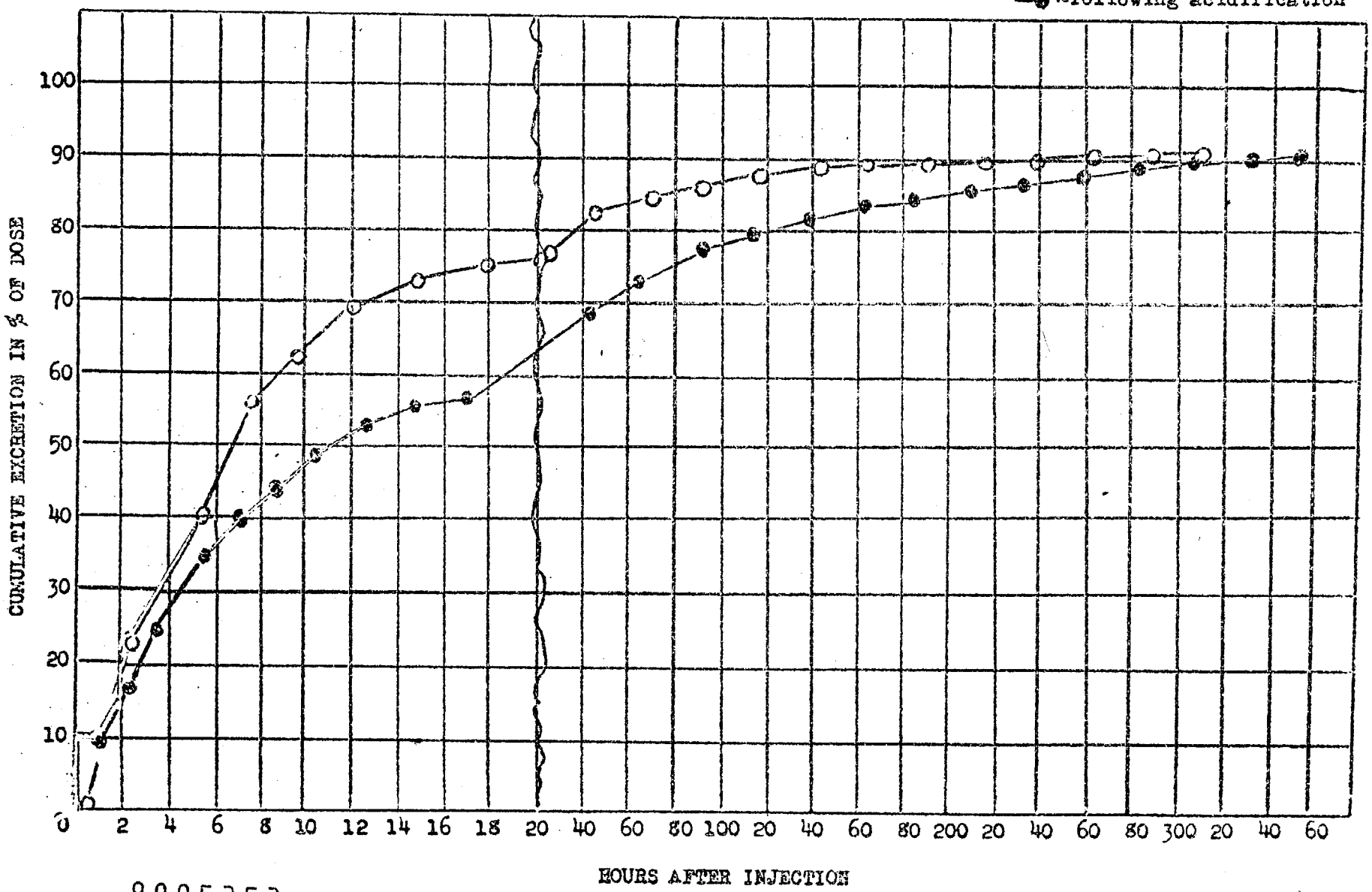
Figure 1. Excretion of Uranium by Subject #6



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