EXTRACTED VERSION

REPORT OF PROJECT 1-M-54 ON THIRTY SERVICE MEN EXPOSED TO RESIDUAL RADIATION AT OPERATION CASTLE

5 July 1954

The Surgeon General
Department of the Army
Main Navy Building
Washington, D.C.

NOTICE

This is an extract of REPORT OF PROJECT 1-M-54 ON THIRTY SERVICE MEN EXPOSED TO RESIDUAL RADIATION AT OPERATION CASTLE, which contains information subject to the Privacy Act.

Extract version prepared for:

Director

DEFENSE NUCLEAR AGENCY

Washington, D. C. 20305

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FOREWORD

This report has had material removed in order to make the information available on an open publication basis to any interested parties. This effort has been accomplished specifically to support the Department of Defense Nuclear Test Personnel Review (NTPR) Program. The objective is to facilitate studies of the low levels of radiation received by some individuals during the atmospheric nuclear test program by making as much information as possible available to all interested parties.

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5 July 1954

SUBJECT: Report of Project 1-~~4~~-54 on Thirty Service Men Exposed to Residual Radiation at Operation Castle

TO: The Surgeon General
Department of the Army
Main Navy Building
Washington 25, D. C.

FROM: Director, Project 1-~~4~~-54

Following the 1 March detonation at Bikini Atoll, the Commanding General of the Armed Forces Special Weapons Project visited the Proving Ground with some of his staff. Lt. Colonel G. M. McDonnel, MC, USA was on this staff as a medical advisor. At that time the thirty service men (24 Air Force, 3 Army, and 3 Navy) who had been exposed to debris from the 1 March detonation were under the care of Project 4.1 (Commander E. P. Cronkite, MC, USN) on Kwajalein Island. Discussions of how to return the thirty service men to duty took place on Kwajalein between Dr. Cronkite, Dr. Bugher, Dr. Bond, Dr. Conard, Colonel Maupin, Lt. Colonel Browning, Lt. Colonel McDonnel, and the other physicians present. It was agreed that the thirty service men should be admitted somewhere on patient status and studied further before going back to regular duty. Eventually, after consideration of several alternatives, it was decided to return the thirty men to Tripler Army Hospital at Honolulu where the Tripler facilities and

professional staff could be utilized.

In a letter (MEDDD-SO 471.6 OTSG No. 127148) dated 23 April, The Surgeon General of the Department of the Army directed that a special team be assembled "to conduct a detailed medical evaluation of certain members of the Armed Forces furnished for that purpose by the Commanding General of Joint Task Force 7." In accordance with that directive, a team of fourteen people was assembled at Walter Reed Army Medical Center in Washington, D.C. The work was designated at Project 1-M-54 and the personnel of the Project are described in Appendix VIII.

The team departed Washington on 23 April and arrived at Tripler Army Hospital in Honolulu on 24 April. An advanced party consisting of the four physicians proceeded immediately to Kwajalein Atoll arriving there on 27 April. Dr. Cronkite, Dr. Bond, Dr. Bugher and Colonel Mangin were present and, although they were already extremely busy, they took time to orient the members of Project 1-M-54 and bring them up to date. Meanwhile preparations were being made at Tripler Army Hospital to receive the thirty patients.

The advance party returned to Tripler on 28 April and on 29 April, the thirty service men were received and admitted as patients. It is difficult to do justice in words to the magnificent cooperation of Colonel Hartford and the Tripler Army Hospital staff. All needs and requests of Project 1-M-54 were given the highest priority and were filled with astonishing speed.

The clinical observations on the thirty patients were completed by 15 May and the patients were discharged to duty on 17 May.

Shortly after the arrival of these thirty patients at Tripler a short press release was made by Joint Task Force 7 describing the situation. The local Hawaiian press took no interest in the matter beyond printing the release. The fact that the work could be done in a calm and quiet atmosphere and with the best of clinical facilities was of great assistance.

The first members of Project 1-M-54 to return to the Mainland departed Honolulu on 9 May and the last member left on 28 May.

CLINICAL OBSERVATIONS

Each of the thirty patients was seen in consultation by the following departments at Tripler Army Hospital:

1. Medicine (Colonel Hughes)
2. Dermatology (Lt. Colonel Olsen)
3. Surgery
4. Ophthalmology (Colonel Lowrey)
5. Neuropsychiatry
6. Dentistry

Special emphasis was placed upon examination of the lens of the eyes so as to establish a firm base-line to aid in the evaluation of any cataracts that may appear in the future. No lens abnormalities of any kind were found. One patient was found to have multiple, superficial, whitish, stromal opacities in the lower half of each cornea. These were possibly, but not necessarily, due to dust which the patient reported getting into his eyes on the day of the accidental exposure.

Ten patients in all were found to have skin lesions attributable to contact with radioactive debris. The most striking findings were in the four Negroes in the group, all of whom showed the brownish bands across the fingernails that are seen in Fig. 1. None of the other 26 men had any such lesions, but the finding was common in the 240 dark-skinned Marshallese

natives studied by Cronkite who were exposed at the same time. The present position of these bands indicate that at the time of the exposure the damaged cells were in the nail root.

In two of the four Negroes the soles of both feet showed hyperpigmented brownish spots as seen in Fig. 2.

Fig. 3 and Fig. 4 are examples of the hypopigmented spots found over the shoulders, chest, back, and cubital or popliteal fossae of nine patients. The dermatologist had no difficulty in demonstrating Malassezia furfur in the lesions and the skin closely resembled that seen in tinea versicolor. It was decided that the decision as to the nature of these lesions should depend upon the observations made earlier by the members of Project 4.1, Operation Castle.

All clinical observations were recorded and placed in the individual's hospital chart. Also attached to each chart is a copy of the record of clinical observations made during the period 12 March to 28 April by Project 4.1. These copies were kindly furnished by Dr. Cronkite.

All other clinical findings were irrelevant to the 1 March accident. The hematological studies were likewise negative. The latter are reported in detail in Appendix VII.

Investigation of Internally Deposited Radioactive Materials

A series of tests aimed at detecting any internally deposited radioactive materials was made and all patients were included. For medico-legal reasons it is necessary that all measurements made on the patients be reported herein. This makes it necessary to include a great deal of negative

data which does not merit discussion and which is tedious. In what follows, therefore, each sub-project is mentioned briefly and the details of each investigation are relegated to an appendix. By making liberal use of appendices, it is hoped to maintain some measure of continuity.

Fig. 1

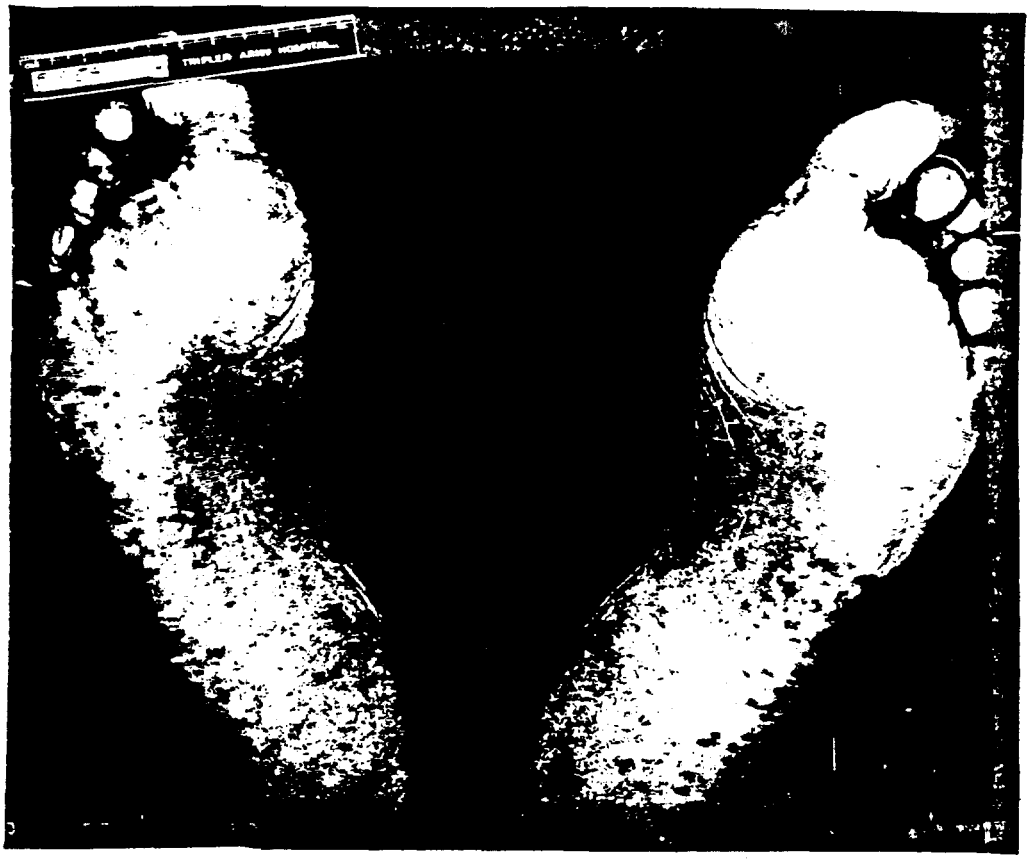

Fig. 2

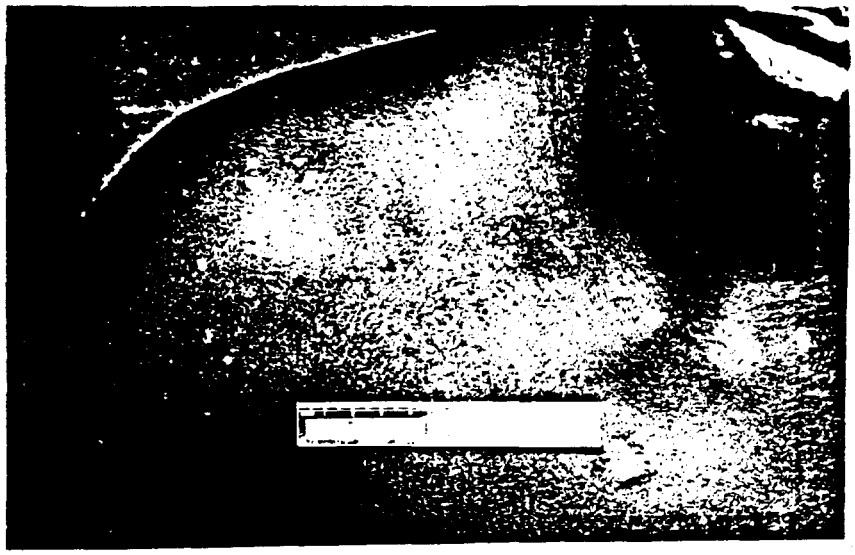

Fig. 3

Assay of Urine for Radioactive Iodine

A method was developed and applied for extracting the iodine from a urine sample and depositing same on one planchet for counting. Some 24-hour samples gave counts as high as twice background. Subsequently pooled samples of six liters of urine gave counts 12 times background. The results are reported in Appendix I.

All samples were followed with repeated counts until 24 May and an eight-day half life was found identifying the isotope as I^{131}

The quantities of I^{131} found in the urine indicate a body burden of about 10% of the maximum permissible amount.

In Vivo External Surveys

A clinical scintillation counter, Fig. 1, Appendix II, was employed to survey seven points on each patient (thyroid, thigh, T-4, sacrum, sternum, both knees). Some slight evidence of internally deposited gamma emitters was found but the total body burdens indicated were well below the official maximum permissible amounts. The method and results are presented in Appendix II.

Assay of Feces

The morning stools of eleven patients were analyzed for radioactive Ba and Sr by a method in which the chemical processing of the samples was simple enough to be accomplished with the facilities at hand.

All samples gave counts above background, the highest counts being about twice background. The indicated body burdens of radioactive Ba and Sr were of the order of 1% to 10% of the maximum permissible amounts. The data are given in Appendix III.

8 Page 7 Deleted.

Analyses of Urine Samples for Radioactive Materials Other Than Iodine

Concentrated urine samples, potassium free, failed to show significant amounts of radioactivity. A more laborious effort to analyze for radioactive Sr and Ba in urine samples also yielded negative results. The results of these tests are given in Appendix IV.

Radioactivity of Expired Air

Exhaled air was examined for radioactivity by introducing the air directly into an ion chamber and measuring the resulting current with a vibrating reed electrometer. No radioactivity was detected and the precision of the method was such as to set an upper limit of 70 uc on the body burden of C^{14}. This is to be compared with the maximum permissible body burden of 250 uc.

In a subsequent series of measurements an improved technique was employed using the same apparatus but in this case each patient exhaled 1000 times through a 6 Molar NaOH solution to trap the CO_2. The CO_2 collected in this fashion was then re-converted to a gas and measured as before. Again no radioactivity was found and in this case the precision of the method was such as to set an upper limit of 2 uc on the body burden of C^{14}.

These data and the details of the method are given in Appendix V.

Autoradiographic Studies

Urine samples from patients and controls were reduced to dryness and applied to Eastman Blue Brand X-ray film for about 200 hours. No significant evidence of darkening due to radioactivity was found.

A similar attempt to detect individual alpha tracks on NTB film revealed only those tracks normally found in all urine. Appendix VI reports these measurements.

Hematological Studies

These included a complete blood count, hemoglobin, hematocrit, platelet count, and cell morphology. All cell counts and observations were made and recorded personally by the Hematologist (Capt. O'Brien). No technicians were employed for this work.

The hematological studies were uniformly negative with respect to radiation effects and are reported in detail in Appendix VII, as well as in each patient's hospital record.

Personnel Assigned to Project 1-[illegible]54 and Their Participation

The necessary personnel for this Project could be assembled and supported only because numerous individuals and organizations cooperated to the fullest extent. Appendix VIII is an account of these efforts.

Discussion

In the absence of any large amount of internally deposited radioactive materials it is unlikely that the future health of any of these individuals will be influenced significantly. Each of them does have a slightly increased chance of eventually showing one or more of the diseases known to be late sequelae of radiation exposure. These include leukemia, osteogenic sarcoma and bronchiogenic carcinoma. The natural incidence of these diseases is such as to make a slight increase imperceptible in a group as small as thirty individuals.

Insofar as they are beta burns, the skin lesions present a problem that cannot be evaluated at present and, as with the diseases noted above, only time can tell whether or not there will be serious sequelae. In some experimental animals under some conditions, beta burns can be expected to result in skin carcinoma in about 25% of the cases.

During the period of clinical observation we had no difficulty in establishing pleasant doctor-patient relationships with these thirty men. They came to us from an isolated forward post where life is something of a hardship for everyone. The pleasant surroundings at Tripler were a welcome change. A liberal pass policy was instituted, but there were no incidents in town and no one over-stayed a pass. This harmony was a result of the superb efforts of the Tripler permanent staff.

Upon discharge all thirty men were in a cheerful mood and it appeared that, in their minds, the incident was past history.

From the military-medical point of view it is important to note that we have, in this group of men (and in the Marshallese natives), an example of external residual radiation as opposed to internal. The dose of external gamma received by these individuals was not insignificant. The estimates run as high as 20% or 25% of a lethal dose. At the same time, the internal hazard was relatively small. This verifies the conclusions drawn from animal experiments done at Operation Jangle in Nevada.

The beta burns are, of course, classified as an additional external hazard and are not included in the 20 to 25% estimate noted above.

When mixed fission products are deposited internally, the short half life materials (e.g. I^{131}) begin to eliminate themselves rapidly. Beginning about

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a year after exposure the principal internal hazard is radioactive strontium, the other competitors having been eliminated by physical decay or by excretion. In the long range view, therefore, it is the 25-year strontium fixed in bone that poses the main problem. A finding of radioactive iodine in the urine may or may not indicate a full complement of the other fission products, depending on whether or not there has been physical fractionation of the fission product mixture during the movements of the cloud. It is therefore important that we understand how the kinetics of cloud diffusion influence the internal and external hazards. For example, it is possible that the gaseous fission products such as Iodine and Xenon are much more widely dispersed than the metallic oxides. Also it is conceivable that at greater distances, and later times, the situation is reversed with the internal hazard becoming dominant.

With the exception of the gaseous fission products, the radioactivity in a bomb cloud is bound to discrete particles. The external and inhalation hazard is, therefore, one of multiple point sources and in order to evaluate such a hazard it is necessary to know in detail the strength of the particles, how they move, and how they lie upon various surfaces of interest. At the present time our knowledge of these items, particularly the last, is inadequate for prediction purposes.

In the case of the thirty service men at Tripler, an attempt was made to detect alpha emitters in the urine. A scintillation crystal with a discriminator circuit was used. This apparatus, which failed to show any positive findings, was capable of detecting the levels of urine alpha activity associated with a maximum permissible body burden. In order to pursue this matter of alpha further, a 24-hour urine sample was collected

from each man and the samples shipped to the Health Physics Department (H. M. Parker) of the Hanford Plant of the U.S. A.E.C. This effort was made possible through the cooperation of Dr. John Gofman, Division of Biology and Medicine, U.S. A.E.C. The results obtained from these samples are not yet available.

APPENDIX I

Assay of Radioactive Iodine in Urine

Work was begun on this Project upon arrival of the group at Tripler Army Hospital. However, several modifications of the method had to be developed and it was not until 5 May that the first seven samples were counted. The most active of these individual 24-hour samples (See Table 1, Appendix I) was some five times background and consequently the method became of paramount interest immediately because with respect to internal deposition this was the only unequivocal demonstration of a positive finding obtained up to that time. The comparative ease with which Iodine was found in the urine does not indicate a body burden of Iodine high relative to the other elements, but is rather a reflection of the high excretion rate of Iodine and an efficient method for Iodine extraction from urine. In view of what is known about the excretion rate of Iodine, the results of Table 1, Appendix I indicate a body burden of Iodine to the extent of about 10% of tolerance.

In order to obtain more active iodine samples, a 24-hour urine sample was obtained from each of the patients and all thirty samples were pooled. From this pool it was possible to get the iodine from six liters of urine all on one planchet for counting. This sample counted 12 times background. A parallel run using 6 liters of Tripler Army Hospital tap-water yielded a planchet which counted background only.

All of the iodine samples were transported back to Walter Reed Army Hospital and counted during the period 12 to 24 May. All samples decayed with an eight-day half life, the test decay curves being obtained from those samples that were the most active initially.

Method of Extraction of Iodine From Urine [a]

A. Preparation of 24-hour urine sample.

1. Acidify urine by the addition of H_2SO_4, using 20 ml of $6NH_2SO_4$/liter of urine.

2. Filter whole sample through a Buchner filter prepared as follows:
   (a) A filter sandwich made with two circles separated by a loosely packed layer of asbestos.

B. Add K I; 1 ml of a solution containing 20 mg/ml as carrier.

C. Save urine until filter mat is prepared as follows.

D. Preparation of Gooch filter.

1. 70 mm D medium sintered glass filter is placed in suction apparatus arranged with valve permitting instantaneous return to atmospheric pressure.

2. 50 ml of a suspension of Gooch Asbestos contining 1 gm of asbestos/100 ml H_2O is placed in the filter and dried by suction.

3. Preparation of filter mat[b] containing colloidal silver chloride.

   (a) 250 ml of asbestos suspension as in D-2 above. Separated into two 125 ml portions, which will be used together for a single filter mat.

   (b) Acidify each portion in D-3a by adding 2.5 ml $6NH_2SO_4$ to each portion.

   (c) Add 1.3 ml of a solution of $AgNO_3$ containing 0.1 gm per ml to each portion.

   (d) Add slowly with constant stirring 11 ml of a 0.1N solution of HCl to each portion.

   (e) Carefully add the 250 ml asbestos in 4 portions suspension to the filter as in D-2, extract by suction enough fluid to leave a <u>thick slurry</u> prior to the addition of each aliquot and after the last addition.

   (f) Carefully cover the slurry with a layer of sea sand about 5 mm in thickness making certain that the glass to asbestos margin is well covered to prevent channeling.

   (g) Finally cover the sand with a filter paper to prevent disturbing the asbestos layer.

(h) Wash with 150 ml of 0.1 NH_2SO_4 removing with suction again, being careful not to permit the mat to become dry.

(i) Each filter so prepared should be used for not more than 2 liters _ 500 ml of urine.

E. Filtration of urine should proceed not faster than about 1 liter/ten minutes.

F. Oxidation of I^- to IO_3^- and extraction.

1. After removing last addition of urine wash mat with 200 ml of 0.1 NH_2SO_4, discard filtrate.

2. IO_3^- extraction is accomplished by adding 50 ml 0.1NH_2SO_4 to which is added 3 ml of "Clorox" (sodium hypochlorite). Allow this solution to stand on the filter mat for 5 - 10 minutes then slowly suction off the filtrate into a collecting vessel. At this time[c] the filter bed may be allowed to dry after washing with an additional 25 ml of 0.1 NH_2SO_4.

3. Heat filtrate gently for 10 minutes on a hot plate to drive off Cl_2.

G. Precipitation of AgI.

1. Add 5 ml of a 10% solution (10 gms/100 ml) of sodium bisulfite.

2. Add 1 ml of $AgNO_3$ (0.1 gm/ml) slowly with constant stirring.

3. Filter in demountable Buchner funnels and mount the precipitate on a planchet for counting.

[a] Modified from the procedure described by H. D. Purves, Nature 169:111-112, 1952.

[b] The filter bed must never be allowed to dry or pack since this produces channels through the asbestos and interferes with proper exchange of Cl^- and I^- during urine filtration.

[c] At this time the filter mat may be sucked dry of its content and discarded.

Table 1 - Appendix I

I^{131} IN URINE SAMPLES

G-M Counter, 1.7 mgm/cm^2 window

Sample No.	Name	CPM	Net Counts/min	Activity/24-hour urine
Background		26.0 ± 0.7	—	—
73		151.3 ± 4.1	125.3 ± 4.1	568.0 x 10^{-6} mc I
74		27.3 ± 0.7	1.3 ± 1.0	—
76		89 ± 2.4	63. ± 2.5	288.0
77		140.9 ± 3.9	114.9 ± 4.0	520.0
78		35.5 ± 1.0	9.5 ± 1.2	42.9
54		43.7 ± 1.2	17.7 ±	82.0
55		36.9 ± 1.0	9.9 ±	45.0
63x10^{-6} mc I^{131}		40. ± 1.1	14.0 ± 1.3	

APPENDIX II

In Vivo External Surveys

Prior to leaving Washington, D.C., word was received at Walter Reed Army Medical Center from the Los Alamos Laboratories (Dr. [illegible] C. Anderson) to the effect that urine samples from the thirty service men had been found to contain radioactive iodine. This led naturally to the idea of looking for thyroid iodine uptake in the thirty men, employing the apparatus used routinely for this purpose in the Radioisotope Clinic at Walter Reed Army Medical Center.

The first exploratory measurements made at Tripler on the thirty patients showed no particular concentration of activity in the thyroid but there were indications of a slight amount of gamma activity over various points on the body. Consequently, a systematic survey of all thirty patients was made in the manner shown in Fig. 1, Appendix II. Seven anatomical points were surveyed on each patient. The points chosen were:

1. The thyroid gland (cricoid cartilage).
2. Thigh, 4 inches above the knee.
3. The sternum, mid-way between the xiphoid process and the sternal notch.
4. The fourth thoracic vertebra (See Fig. 1, Appendix II).
5. The sacrum.
6. Lateral aspect of the right knee.
7. Lateral aspect of the left knee.

During the actual surveys the distance from the counter to the skin was 15 cm.

For each patient one five-minute count was made over each of the seven points noted above. In addition, one five-minute background run was made

before and after surveying the seven points. The background for each individual was taken as the mean of these two readings. On different days the mean background varied from 165 to 208 counts per minute. For any one patient the mean difference between the two background counts was 9.1 cpm and the greatest difference noted was 29 cpm. The results obtained on the patients are given in detail in Table 1 of Appendix II in terms of counts per minute above background. The highest counts noted are of the order of 15% above background and many counts are actually below background. No conclusions can therefore be drawn from the raw data.

Table 2 of Appendix II summarizes the data of Table 1 together with the standard error of the determination. Table 2 shows that the thirty left knees averaged 11 $\pm$ 2.0 counts per minutes above background. In this case the standard error of $\pm$ 2.0 implies that if the whole procedure (counting thirty left knees) were repeated, the probability is .67 that the new result would be between 9 and 13. On this basis it appears possible that all points except the sternum and thoracic vertebra contain some activity.

The DS-1 counters were calibrated with a 50 ml flask containing 10^{-2} uc of I^{131} in 50 ml of water. The flask was mounted in a water neck phantom and placed at 15 cm from the counter. With this calibration, counts per minute may be converted to I^{131} equivalent as shown in Row 2 of Table 2, Appendix II.

Insofar as these data do actually represent internally deposited materials, the following may be said:

1. The elements responsible are gamma emitters and from the curves of Hunter and Ballou (1) Zr, Nb, Ce, and Pr appear to be the most

likely candidates. The bremsstrahlung from Sr and Y will be negligible (2).

2. I^{131} gamma rays could not be responsible for these readings since the thyroid counts are not high relative to other points on the body.

3. Taking the worst case (the right knee) and noting that in surveying this point the counter "sees" about 2% of the total volume of the body, the total body burden indicated would be $\frac{0.015}{.02}$ = 0.7 uc of I^{131} equivalent. This is to be compared with the following maximum permissible body burdens of some relevant fission products.

Nb - 90. uc

Ce^{144} & Pr^{144} - 5. uc

Pr^{144} - 29.

Fig. 1, Appendix II
In Vivo External Survey Over the Interclavicular Point
(Fourth Thoracic Vertebra)

References:

(1) Hunter, F.F. and Kellou, M.B., "Simultaneous Slow Neutron Fission of U^{235} Atoms. I Individual and Total Rates of Decay of the Fission Products." UCRPDL ADC-65, April 1949.

(2) Spiers, F. W. and Burch, P.R.J., "Measurement of the Normal Radioactivity of the Body" in Biological Hazards of Atomic Energy, edited by A. Haddow, Clarendon Press, 1952.

APPENDIX II

IN VIVO MATERNAL SURVEYS
WITH DB-1 SCINTILLATION COUNTER

Given as counts per minute above background
Negative numbers indicate counts less than background

Patient	Thyroid	Thigh	Sternum	Inter-Clavicular	Sacrum	Right Knee	Left Knee
	-10	25	4	-4	21	29	34
	-9	-10	-15	-5	-4	-5	13
	-3	7	3	-7	-3	10	15
	-2	8	2	-5	0	6	2
	1	-4	22	11	1	9	13
	1	-1	11	15	37	15	11
	3	22	8	8	25	13	2
	3	7	7	6	7	42	5
	3	1	3	-1	9	17	32
	6	9	-17	-5	-10	-3	-10
	7	8	-5	-5	4	1	3
	10	1	0	-1	5	15	6
	10	3	-3	4	14	11	12
	10	30	12	11	5	25	17
	10	13	-5	-10	0	2	-1
	12	20	14	4	9	7	13
	12	25	4	6	-3	4	-2
	12	18	2	-4	-3	25	27
	14	13	11	-3	22	17	20
	14	14	10	6	32	21	14
	15	16	-4	-5	-2	8	2
	15	-2	-4	-5	-4	20	23
	16	16	12	15	16	31	28
	16	17	0	2	0	10	2
	17	15	-19	-6	-5	16	0
	21	32	-4	-12	1	32	15
	22	26	-2	4	11	1	9
	29	29	9	1	22	9	22
	36	26	11	7	11	4	12
	37	32	10	8	1	7	27

"Original listing was in alphabetical sequence. The order of the patients was scrambled to protect the privacy of the individuals. The data remain intact."

Table 2 - Appendix II

SUMMARY OF IN VIVO SURVEY DATA

	Thyroid	Thigh	Sternum	4th Thoracic	Sacrum	Right Knee	Left Knee
Counts per minute above background	11 ± 2.3	14 ± 2.5	3 ± 1.7	3 ± 1.4	8 ±2.5	13 ± 2.4	11 ±2.0
µUi equivalent in microcuries	0.016	0.019	0.0077	0.0067	0.014	0.016	0.014

Counts per minute are given as net CPM above background plus or minus the standard error where the standard error is:

$$\text{S. E.} = \sqrt{\frac{(\bar{x} - x)^2}{n\,(n-1)}}$$

and

$\bar{x}$ = the mean of thirty measurements
x = one measurement
n = 30 (thirty patients)

APPENDIX III

Assay of Feces

A major portion of the morning stools of eleven patients were assayed.

The samples were dried in a platinum dish at 100 - 130° C for 12 - 16 hours in an oven and transferred to a muffle furnace and heated at 600° C for 8 - 12 hours. The closed muffle door limited the supply of oxygen to the samples and prevented violent burning with loss of ash. Twenty to forty ml of 4 N HCl were added to each crucible and heated for 10 - 20 minutes under an infra-red lamp. This hastened the solution and evaporated some of the excess acid. The solution and a small amount of insoluble ash were washed into a small beaker and made up to 50 - 60 ml. The residue appeared to consist of some sand and silicic acid.

The above mixture was divided into three portions.

(a) The insoluble residue (discarded).

(b) Sulfate insoluble portion as brought down with carrier consisting of 25 mg of Ba and 25 mg of Sr.

(c) The dried filtrate from the $BaSO_4$ - $SrSO_4$ precipitation.

(b) A solution of $Ba(NO_3)_2$ and $Sr(NO_3)$ containing 25 mg each of Ba and Sr was added to the filtrate from (a). H_2SO_4 was added to insure complete precipitation. The solution was digested at 60 - 70° C for 2 hours and filtered in the two-piece Buchner funnel. The precipitate was air dried, secured with a thin coat of plastic and counted for beta-gamma activity with a thin window G-M tube. The results are attached as Table 1 of Appendix III.

(c) Two of the filtrates from (b) were neutralized with NaOH and the PH adjusted to between 4 and 5 with acetic acid. The sodium Cobaltinitrite

added to remove potassium (if any) was destroyed as indicated by change in color on standing. No precipitate was produced. No further attempt was made to remove any possible potassium. All samples (including two mentioned above) were reduced to dryness on a hot plate and a portion assayed using a Nuclear of Chicago well counter (gamma only). Counts equal to or greater than background were found. See Table 2, Appendix III.

The results of Table 1, Appendix III, suggest but do not prove the presence of internally deposited radioactive Ba and Sr. Considering the known excretion rates the total body burdens indicated for these two elements are of the order of 1% to 10% of the maximum permissible amount.

Table 1 - Appendix III

ASSAY OF FECES FOR RADIOACTIVE BA AND SR

Precipitate on Planchet
G-M Tube Counter - Tracerlab - 1.7 mgm/cm^2 window

Sample Number	Name	Time (min)	Counts	Total Counts	CPM	Net Cts.	Activity in 10^{-6}uc of I^{131} equivalent
120		30	18x64 + 6	1157	38.5 ± 1.1	15.4 ± 1.3	40.5
121		30	22x64 + 12	1356	45.2 ± 1.2	22.1 ± 1.4	69.5
122		30	15x64 + 1	961	32 ± 1.0	8.9 ± 1.1	28.0
123		30	15x64 + 61	1021	34.1 ± 1.1	11.0 ± 1.3	35.0
124		30	16x64 + 10	1034	34.5 ± 1.1	11.4 ± 1.3	36.8
125		30	18x64 + 15	1167	38.9 ± 1.1	15.8 ± 1.3	49.7
127		30	14x64 + 40	936	31.2 ± 1.0	8.1 ± 1.2	25.5
128		30	15x64 + 0	960	32.0 ± 1.0	8.9 ± 1.2	28.0
129		30	12x64 + 47	815	27.1 ± 0.9	4.0 ± 1.1	12.7
130		30	13x64 + 0	832	27.7 ± 0.9	4.6 ± 1.1	14.5
131		30	16x64 + 30	990	33.0 ± 1.0	9.9 ± 1.2	31.5
Background		30	10x64 + 64	704	23.1 ± 0.8	—	
$0.3x10^{-6}$uc I^{131} (calibration source)		30	30x64 + 11	1891	32 ± 1.2	20.0 ± 1.2	

Table 2 - Appendix III

WET ASHED FECES - FINAL FILTRATE

Sample Number	Name	Time	Total Counts	CPM	Net Counts	Sample Ratio	G M Corrected	Activity/Total Sample ^{131}I Equiv.
123.		15	7351	489 ± 5.7	79 ± 7.6	6/5	95 ± 9	0.7×10^{-4} uc
124.		15	6668	445 ± 5.4	35 ± 7.3	9/5	60 ± 13	0.6 "
125.		15	6956	462 ± 5.4	52 ± 7.2	10/5	104 ± 15	0.8 "
127.		15	6541	436 ± 5.3	26 ± 7.2	5/5	26 ± 7	0.2 "
128.		15	6703	447 ± 5.4	37 ± 7.3	5/5	37 ± 7	0.3 "
129.		15	6855	457 ± 5.4	47 ± 7.5	5/5	47 ± 7	0.3 "
130.		15	6538	436 ± 5.3	26 ± 7.2	5/5	26 ± 7	0.2 "
131.		15	8468	564 ± 5.8	54 ± 7.3	5/5	54 ± 7	0.5 "
122.		15	6709	441 ± 5.4	31 ± 7.2	5/5	37 ± 7	0.3 "
Background				410 ± 8	28 ± 7.2			

APPENDIX IV

Analyses of Urine Samples for Radioactive Materials Other Than Iodine

The first systematic attempt to find activity in urine was done on urine samples from which the naturally radioactive K^{40} had been removed by the cobaltinitrite method. One ml of 1 M HNO_3 and 2 ml of 20% sodium cobaltinitrite were added to a 100 cc aliquot from a 24-hour urine sample. This was allowed to stand for 2 hours at room temperature and the potassium removed as a precipitant. In order to reduce the chances of loss of iodine, the filtrate was made basic (pH - 9) with NH_4OH. The solution was then concentrated to a volume of about 7 - 11 cc (each measured) on a hot plate. Five ml of the slurry was placed in a test tube for assay in gamma well counter; one ml was dried onto a planchet for beta plus gamma assay.

The results obtained with the gamma well counter are given in Table 1, Appendix IV. In the column called "Urine Ratio" in this table, the denominator of each ratio denotes the actual volume, in cc, to which the 100 ml sample was reduced by heating.

Table 2 of Appendix IV gives the results of counting for Beta plus Gamma using a thin window G-M counter.

No significant amount of radioactivity was detected by this simple concentration method and therefore a wet ashing procedure was adopted.

Processing of Wet Ashed Urine Samples

Various aliquots (never less than one-half) of the 24-hour sample were assayed.

From 300 to 400 cc of urine and 25 to 100 cc of concentrated HNO_3 were placed on a hot plate and slowly reduced in volume. Additional urine

and acid were added until entire aliquot was reduced to dryness. A few cc of concentrated HNO_3 were added and the sample again brought to dryness. This was repeated three or four times until the residue was a yellowish white. This was suspended in 100 ml of warm water.

The aliquot was divided into three parts for assay.

(a) The water (dilute HNO_3) insoluble residue

(b) The insoluble sulfates as brought down with Ba and Sr carrier and H_2SO_4.

(c) The filtrate from (b) after the removal of K with sodium cobaltinitrite.

(a) The insoluble residue was removed by filtration through filter paper. The samples were filtered in a special two-piece Buchner-type funnel containing a 1" disc of paper which could be removed and mounted on a planchet for counting.

(b) A solution of $Ba(NO_3)_2$ and $Sr(NO_3)$ containing 25 mg each of Ba and Sr was added to the filtrate from (a). H_2SO_4 was added to insure complete precipitation. The solution was digested at 60 - 70° C for 2 hours and filtered in the two-piece Buchner funnel. The precipitate was air dried, secured with a thin coat of plastic and counted for beta - gamma activity with a thin window G-M tube.

(c) Before the filtrate from (b) could be concentrated and assayed for gamma it was necessary to remove the potassium. The solution was neutralized with NaOH until a permanent faint cloudiness was produced (pH 6). The solution was cleared with one ml of concentrated acetic acid. The potassium was then removed stepwise with small additions of sodium cobaltinitrite. This was added slowly to a warm solution (60 - 70° C) and the solution allowed

) stand two hours before filtering. These additions were continued until) more precipitate was produced. The solution was then evaporated to dry- ess and a portion assayed on the well" scintillation counter.

The data obtained from (a) and (b), above, are given in Table 3 and et from (c) is given in Table 4 of Appendix IV. The findings do not dicate any significant quantities of activity in the urine samples.

Table 1 - Appendix IV

CONCENTRATED URINE SAMPLES - GAMMA ONLY

Well Counter - 5 cc urine, potassium free, concentrated 10:1

Background Average	30 Min.	11000 cts.	(350 ± 19) cpm
2.5x10⁻⁵uc Ir¹⁹²	10 Min.	36400 cts.	(3300 ± 190) cpm

Sample Number	Name	Net counts/min.	Urine Ratio	CPM corrected for urine ratio
11		5	100/6.7	7
12		13	100/8.3	21
13		5	100/7.3	7
14		10	100/7.3	15
15		5	100/8.3	7
17		4	100/8.4	6
18		12	100/8.9	21
21		9	100/10	18
22		3	100/7.7	5
23		11	100/8.3	20
24		11	100/8.8	20
25		10	100/9.2	18
26		3	100/9.1	6
27		5	100/9.2	9
28		16	100/8.8	25
29		14	100/8	17
30		15	100/8.2	21
31		1	100/8.7	2
32		20	100/8	24
33		5	100/7.8	8
34				
35		14	100/11	21
36		15	100/7.3	22
37		5	100/8.4	8
38		7	100/8	8

Table 2 - Appendix IV

CONCENTRATED URINE SAMPLES - BETA PLUS GAMMA

Geiger Counter - 1.7 mgm/cm^2 window

Sample Number	Name	10x126 cts. in min.	CPM $\pm\sqrt{N}$		Net counts from sample		Urine Ratio	CPM corrected for urine ratio for 10 cc fresh urine	Activity per 1000 cc fresh urine in 10^{-6}uc of I^{131} equiv.
11		40.79	31.8	± 0.9	4.8	± 1.1	100/8.7	3.3	1.5
12		44.77	28.8	± 0.8	4.8	± 1.0	100/8.3	1.7	0.8
13		42.22	30.8	± 1.0	3.8	± 1.3	100/7.3	2.6	1.3
14		41.17	31	± 0.9	4.8	± 1.1	100/7.3	3.3	1.5
15		45.26	29.5	± 0.8	3.0	± 1.0	100/8.5	2.0	0.9
16		47.58	26.9	± 0.7	0.4	± 1.0	100/8.8	0.2	0.1
17		41.92	30.5	± 1.0	4.0	± 1.2	100/8.4	3.3	1.5
18		39.95	32	± 0.9	5.5	± 1.1	100/8.9	5.0	2.2
20		42.17	30.3	± 0.8	3.8	± 1	100/9.1	3.5	1.5
21		43.01	29.7	± 0.8	3.2	± 1	100/10	3.2	1.4
22		45.81	27.1	± 0.8	1.6	± 1	100/7.7	1.2	0.6
23		41.86	30.5	± 0.9	4.0	± 1.1	100/8.3	3.3	1.5
24		39.82	29.5	± 0.8	5.0	± 1	100/8.8	5.0	2.2
25		44.92	28.4	± 0.8	1.9	± 1.1	100/9.2	1.7	0.8
26		46.38	27.6	± 0.8	1.1	± 1.1	100/9.1	1.0	0.5
27		43.80	29.2	± 0.9	2.7	± 1	100/9.2	2.5	1.1
28		40.80	31.6	± 0.9	5.1	± 1	100/8.8	5.5	1.6
29		43.31	29.5	± 0.8	3	± 1.1	100/8	1.8	0.8
30		42.68	30	± 0.8	3.8	± 1.1	100/8.2	3.0	1.3
31		43.11	29.6	± 0.8	3.1	± 1.1	100/8.7	2.1	0.9
32		42.42	30.1	± 0.8	3.6	± 1.1	100/8	2.2	1.0
33		43.09	29.7	± 0.8	3.2	± 1.1	100/7.8	2.5	1.1
34		42.30	30.2	± 0.8	3.7	± 1.1	100/8.2	3.0	1.4
35		41.69	30.7	± 0.8	4.2	± 1.1	100/11	4.6	2.1
36		42.25	30.3	± 1.0	3.8	± 1.0	100/7.8	2.7	1.2
37		43.30	29.4	± 1.0	2.9	± 1.0	100/8.4	2.5	1.1
38		42.19	30.8	± 1.0	3.8	± 1.0	100/8	3.0	1.0
	Background	50.00	26.0	± 0.7					
	$3x10^{-6}$uc I-131	31.90	13.6	± 1.2					

Table 3 - Appendix IV

WET ASHED URINE SAMPLES - BETA PLUS GAMMA

Background 26.4 C.P.M

a - Insoluble Residue
b - Ba plus Sr

Sample No.	Name	Net Counts	Sample No.	Name	Net Counts
44	a	0.6 ± 1.0	57	a	—
	b	11.6 ± 1.3		b	3.8 ± 1.0
45	a	5.6 ± 1.2	58	a	—
	b	10.3 ± 1.2		b	4.0 ± 1.1
46	a	0.8 ± 1.0	59	a	0.6 ± 1.1
	b	7.3 ± 1.2		b	5.7 ± 1.1
47	a	0.9 ± 1.0	60	a	0.6 ± 1.0
	b	2.5 ± 1.0			
48	a	5.9 ± 1.2	61	a	1.1 ± 1.0
	b	0.2 ± 1.1			
49	a	0.8 ± 1.1	62	a	2.7 ± 1.1
	b	4.1 ± 1.2		b	8.7 ± 1.2
50	a	4.1 ± 1.2	63	a	3.0 ± 1.1
	b	4.4 ± 1.2		b	3.3 ± 1.2
51	a	—	64	a	4.5 ± 1.2
	b	4.0 ± 1.1		b	4.6 ± 1.2
52	a	0.8 ± 1.0	65	a	—
	b	3.0 ± 1.1		b	7.0 ± 1.2
53	a	11.3 ± 1.3	66	a	4.4 ± 1.1
	b	5.2 ± 1.1		b	6.1 ± 1.3
		—			
		—			

Table 8 - Appendix IV (Continued)

Sample No.	Name	Net Counts	Sample No.	Name	Net Counts
67	a	5.6 ± 1.2	109	a	4.1 ± 1.2
	b	1.4 ± 1.2		b	5.8 ± 1.3
68	a	2.8 ± 1.1	110	a	2.0 ± 1.1
	b	6.3 ± 1.3		b	4.0 ± 1.2
69	a	1.1 ± 1.1	111	a	1.9 ± 1.2
	b	3.3 ± 1.2		b	5.1 ± 1.2
70	a	0.9 ± 1.1	114	a	—
	b	5.0 ± 1.2		b	6.3 ± 1.2
71	a	2.4 ± 1.1	115	a	1.2 ± 1.1
	b	7.6 ± 1.3		b	4.9 ± 1.2
72	a	6.2 ± 1.2	116	a	—
	b	5.5 ± 1.2		b	4.9 ± 1.2
78	a	2.3 ± 1.2	120	b	10.5 ± 1.3
	b	7.1 ± 1.1	121	b	18.1 ± 1.4
79	a	21 ± 1.2			
	b	5.2 ± 1.3	122	b	7.0 ± 1.1
80	a	2.7 ± 1.2	123	b	7.7 ± 1.2
	b	5.2 ± 1.2			
108	a	0.6 ± 1.2			
	b	9.7 ± 1.3			

Table 4 - Appendix IV

WET ASHED URINE (FINAL FILTRATE)

Well Counter for Gamma Only

Sample Number	Name	Time (min.)	C'M	Net Counts	Sample Ratio	C'M Corrected
Background		15	419 ± 5.5			
		15	402 ± 5.2			
		15	422 ± 5.5			
		15	410 ± 5.2			
45		15	409 ± 5.2	—	5/5	—
48		15	464 ± 5.5	54 ± 7.4	25/5	270 ± 35
49		15	437 ± 5.5	27 ± 7.5	6/5	35 ± 9
51		15	417 ± 5.2	—	5/5	—
56		15	460 ± 5.5	50 ± 7.4	5/5	50 ± 12
57		15	456 ± 5.5	46 ± 7.2	20/5	184 ± 26
58		15	438 ± 5.5	28 ± 7.2	5/5	40/± 11
61		15	411 ± 5.2	—	5/5	—
63		15	416 ± 5.2	—	5/5	—
64		15	430 ± 5.5	—	10/5	—
65		15	417 ± 5.2	—	5/5	—
66		15	417 ± 5.2	—	17/5	—
67		15	417 ± 5.2	—	5/5	—
68		15	418 ± 5.5	—	7/5	—
69		15	418 ± 5.5	—	6/5	—
70		15	409 ± 5.2	—	6/5	—
71		15	413 ± 5.2	—	6/5	—
72		15	414 ± 5.2	—	9/5	—
78		15	432 ± 5.5	22 ± 7.2	7/5	51 ± 10
79		15	426 ± 5.2	16 ± 7.2	7/5	21 ± 10
80		15	417 ± 5.1	—	7/5	-
108		15	414 ± 5.5	—	11/5	
109		15	409 ± 5.2	—	11/5	
110		15	423 ± 5.5	—	6/5	
111		15	416 ± 5.2	—	7/5	
114		15	417 ± 5.2	—	5/5	
116		15	428 ± 5.5	16 ± 7.2	5/5	16 ± 7.2

APPENDIX V

Radioactivity of Expired Air

Examination of the breath of the thirty patients for radioactivity was carried out by ionisation chamber technique. The chamber used is one constructed at the National Institutes of Health for tracer studies of the rate of production of labelled carbon dioxide after the administration to animals of substances labelled with C^{14}. This chamber has a capacity of 5 millimoles of carbon dioxide and an efficiency of about 80% for the detection of radiation from C^{14}. It is of dual construction, with a dummy side connected in electrical opposition to the measuring side to minimise background drift.

The potential measurements were made with an Applied Physics Corporation's Model 30 vibrating reed electrometer, which was used without a head resistor as a null (rate of drift) indicator. This chamber-electrometer combination has a drift rate of 1 volt/min. after subtraction of alpha background, when filled with 3.4×10^{-2} uc of C^{14} dioxide. Since the chamber has a capacity of 5 millimoles of CO_2, this is equivalent to a specific activity of 7×10^{-3} uc/mM.

Measurements were made by taking a series of five-minute observations of drift rate. Initially, ten observations were used for a total observation time of fifty minutes; later on, as it became apparent that no significant levels of radioactivity were being encountered, the number of observations was reduced to five since time was pressing. During the observations the panel meter of the electrometer was watched continuously for the detection of alpha events. These were subtracted out manually by compensation with the zero adjustor potentiometer.

Two series of breath measurements were made. In the first, referred to as "total breath" measurements, the subject blew up a rubber balloon to a volume of about five liters and the balloon was connected to the gas inlet of the measuring chamber via a drying tube filled with calcium chloride and provided with a cotton plug to prevent dust from the dessicant being blown into the chamber. The balloon was allowed to discharge its contents through the chamber thereby flushing it with about fifty volumes of sample. The chamber was then closed off, and after a half hour's wait for transients to subside the observations were begun.

The purpose of the measurements on total breath was to look for radioactivity from all possible volatile sources. In particular, it was thought at first that there might be some Xe^{131} present from decay of I^{131}. However, when an estimate of maximum total body burden of I^{131} became available from Geiger counts on urinary iodide it became obvious that the xenon level in the breath could not be sufficient to detect. For this reason, and because of the time-consuming character of ionization chamber measurements, assays of total breath were not made on every individual but only on a sample group.

The data are presented in Table I, Appendix V. It is obvious that none of the values are significant. A rough estimate of the maximum body burden established by these measurements can be made as follows:

V - volume of tidal air, is taken as 10 liters/min.

v - volume of ionization chamber, is 100 ml.

T - biological half life of the isotopes, is given a nominal value of 30 days. (Carbon-14 is not being considered here. It is dealt with seperately.).

S - sensitivity of instrument is 3.4×10^{-2} $\frac{\mu g \text{ of } C^{14}}{\text{mv/min of drift}}$.

M - the number of minutes in 1 day.

H - the number of hours in 1 day.

E - the body burden.

Now if the value for be taken literally, the highest observed reading is 0.3 mv/min above background. There, assuming first order elimination kinetics 0.3 3VMH/v = 0.69 B/T and the maximum body burden is 70 ue C^{14} equivalent.

The necessity for expressing the body burden in C^{14} equivalent stems from the fact that the chamber was calibrated with C^{14}. Estimation of the body burden in terms of roentgens is impossible without knowledge of the radiation characteristics of isotopes presumed to be responsible. Guesses in this direction would be unduly questionable.

The ionization chamber will contain only a small aliquot of the total air passing through the lungs per minute and enhanced sensitivity can be obtained by concentration of the radioactive content. Although attempts to concentrate trace amounts of materials such as Xenon and perhaps others of unknown identity did not appear feasible, this was done with the carbon dioxide in a second series of measurements. Each subject passed 1000 exhalations through 100 ml of a 6M solution of sodium hydroxide. The solution was transferred to a suction flask to the side arm of which was attached a three way stopcock. A rubber balloon was connected to one arm of the stopcock via a ground joint and a vacuum pump was connected to the other arm. A rubber stopper carrying a stopcock was fitted into the neck of the flask and to the upper end of the stopcock was attached a 100 ml syringe filled with 50% sulfuric acid. After evacuation of the air in the system, the

sulfuric acid was forced into the flask and the carbon dioxide was collected in the balloon. The balloon was then twisted at the neck to prevent escape of gas, and the ground joint disconnected from the stopcock. The joint was connected to a drying tube and thence to the ionization chamber. The balloon was then allowed to discharge its contents through the ionization chamber via calcium chloride and a cotton filter plug. With a few exceptions a gas sample of at least one liter was obtained which was sufficient for flushing the chamber satisfactorily.

The data are presented in Table 2, Appendix V. All values are significantly higher than the background drift of the chamber when filled with air. However, there is no significant difference between the experimental group and the controls or between these and tank carbon dioxide. The explanation for the artifact is thought to lie in the fact that during these measurements, the measuring chamber is filled with pure carbon dioxide while the reference chamber is filled with air. Under these circumstances the ionization produced by cosmic ray background will not be equal in the two sides since carbon dioxide, with its greater electronic density, will produce a higher ion yield. Rough calculation indicates that the expected order of magnitude of this effect is in accord with that observed. It will be noted that the drift rate observed when the chamber was filled with carbon dioxide generated from solid sodium carbonate is still higher than that of the other carbon dioxide samples. Presumably the extra activity is due to a trace of radon which has accumulated from natural radioactive contaminants during storage of the sodium carbonate.

The value of 1.4 mv/min obtained for which is somewhat higher than the others is taken for estimation of maximum body burden of C^{14}.

Assuming background to be zero for the sake of conservatism and using the symbols introduced above with T = 180 days (Bureau of Standards pamphlet 52). v = 5 millimoles and taking V, the hourly carbon dioxide output as 40 millimoles, we have

1.4 SVH/v = 0.69 B/T and the maximum body burden of C^{14} is 2 uc.

Table 1* - Appendix V

IONIZATION CHAMBER MEASUREMENTS IN DOG BREATH

Subject	Drift Rate mv/min	Std. Dev.
Background	- 0.1	0.1
	- .1	.2
	.0	.1
control)	.0	.1
(control)	≠ .1	.1
	- .2	.4
	≠ .2	.1
(control)	≠ .1	.1
	≠ .1	.1
	≠ .2	.2
	- .1	.2
Background	- .1	.1

*Each Value is the result of ten five minute observations.

Table 2 - Appendix V

ASSAY OF RESPIRATORY CARBON DIOXIDE

Subject	Drift Rate mm/min	Std. Deviation
Background (air)	≠ 0.1	0.2
	≠ .1	.2
(control)	≠ .4	.1
	≠ .4	.1
	≠ .4	.1
	≠ .4	.1
	≠ .4	.2
	≠ .4	.2
	≠ .4	.2
	≠ .5	.1
	≠ .5	.1
	≠ .5	.1
(control)	≠ .5	.2
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
	≠ .6	.1
(control)	≠ .6	.2
	≠ .6	.1
	≠ .7	.1
	≠ .7	.1
(control)	≠ .7	.2
	≠ .7	.2
Blank CO_2 from stock sodium carbonate	≠ .8	.1
Blank CO_2 from tank of compressed gas	≠ 1.4	.2
Background at end of series (air)	- 1.6	.2

"Original listing was in alphabetical sequence. The order of the patients was scrambled to protect the privacy of the individuals. The data remain intact."

APPENDIX VI

Autoradiographic Studies

Beta Autoradiography on Urinary Solids. A 24-hour urine sample from each individual was ashed with nitric acid. An aliquot of the residue sufficient for the preparation of samples for alpha autoradiography was removed and set aside. The remainder was dissolved in water and divided into two equal portions. From one of these potassium was removed by the cobaltinitrite method. After filtration to remove the potassium cobaltinitrite 5 ml of concentrated hydrochloric acid was added and the solution was evaporated to dryness. To the other portion was added 5 ml of concentrated hydrochloric acid and the solution was evaporated to dryness. The purpose of the hydrochloric acid treatment was to destroy nitrates and thereby minimize deliquescence of the solid residues. Thus two sets of samples of urinary solids were obtained; one representing the total inorganic excretion and the other representing total excretion except for potassium.

From these residues specimens were prepared for autoradiography by packing the solid into stainless steel cups 1 inch in diameter and 8 mm deep. The cups were filled not quite to the rim and the samples were moistened with 0.5 ml of 0.2 N sodium hydroxide to neutralize traces of free acid. The samples were then dried at 110° C. In this way a completed solid sample about 5 mm thick was obtained, which may be considered infinitely thick for beta radiation and the air path from the surface of the sample to the upper rim of the cup was about 3 mm. The samples were arranged in two sets and a sheet of Eastman Blue Brand radiographic x-ray film was placed over each. The exposures were carried out in light-tight boxes in a refrigerator at 5° C. Exposure time for the samples with potassium

removed was 198 hours; for the samples with potassium present it was 213 hours. The films were developed at room temperature for five minutes with Eastman Fast x-ray developer.

The samples with potassium present all gave a barely visible spot on the film and all the spots, including the controls appeared to the eye to be about equally dense. An attempt was made to measure the optical densities with an Ansco densitometer, Model 12, Type 2, with a sensitivity of 0.01 density unit. No reading was registered by the instrument. Similarly, a calibration film which had received x 3 x 10^5 particles/ cm^2 from a C^{14} source also failed to give a reading, although the spot appeared to the eye somewhat denser than that from any of the urinary specimens.

The samples from which potassium was removed gave no spots or an exceedingly faint spot, with a few exceptions when the spot was somewhat darker. It is concluded qualitatively therefore that most of the activity responsible for the images is due to natural K^{40}. Incomplete removal of potassium probably accounts for most of the darkening seen in the "potassium free" samples.

A crude attempt to attach some sort of a number to the autoradiographic data can be made as follows:

Assume that the densities of the spots are all equal to that of the C^{14} calibration spot. Then E, the exposure is x 3 x 10^5 disintegrations/cm^2. Assuming also:

T, the infinite thickness is 0.3 cm

D, the sample density is 2000 mg/cm^3

L, the self absorption loss, is 0.75

G, the geometry, is 0.5 (half the particles go downward)

M, the exposure time is 1.3×10^4 minutes

then S, the specific activity is given by $S = E/(1-L)$ GTDM

and the maximum specific activity is roughly 0.3 dpm/mg, including K^{40} activity.

Alpha Autoradiography on Urinary Solids. The aliquot of ashed urinary solids was dissolved in water and re-evaporated on a hot plate with a little concentrated hydrochloric acid to destroy nitrates. The residue was pulverized and moistened with a very small amount of water. In this condition it could be smeared on cardboard with a spatula. Pieces of cardboard were cut to 4 x 5 inches and in each were drawn twelve 1-inch circles. About 300 mg of sample was smeared uniformly over each circular area to give a preparation infinitely thick for alphas. The samples were mounted in groups of twelve from ten patients and two controls and over each group was placed a 4 x 5 inch Eastman NTB plate with the emulsion in contact with the samples. The plates were exposed in light-tight boxes in a refrigerator at 5° C for periods of about 12 days.

Since it was feared there might be chemical fogging in the direct-contact plates a second set was also prepared with the samples placed in copper planchets an inch in diameter and 3 mm deep. About 200 mg of sample was placed in each planchet, moistened with 0.5 ml of 0.2M sodium hydroxide and dried in an over at 110°. This produced a compacted specimen infinitely thick for alphas whose surface was about 2 mm below the upper rim of the cup. The samples were arranged in groups of twelve from ten patients and two controls and a 4 x 5 NTB plate was placed over each group with the emulsion side down. The plates were exposed in light-tight boxes in a refrigerator at 5° for periods of about 12 days, and were then developed for 15 minutes in Kodak Fast x-ray developer and fixed 40 minutes.

Microscope counts at 430 x were made of ten fields taken at random from each sample area. The results are presented in Table 3.

Since ten fields include a total area of only 0.34 mm^2, it is obvious that these data have no quantitative significance because of the small number of fields counted. The figures are presented merely as a numerical method of describing the appearance of the films. It was not considered worth while to count the plates more exhaustively since these preliminary counts failed to reveal evidence of significant alpha activity. As a rough attempt to ascribe some sort of level of significance to the counts one might take the value of 20 for on Plate 2 as a maximum ignoring film background. Then M, the exposure time, is 20,000 minutes, A, the sample area is 0.34 mm^2 and S, the sample activity is given by S = 20 x 100/AM and the maximum sample activity is 0.02 particles per minute/square centimeter at the surface of an infinitely thick sample. This is the level of activity to be expected from alpha emitters naturally present in urine and in the emulsion itself.

Table 1 - Appendix VI

MICROSCOPE COUNTS OF ALPHA PLATES

	Plate 1	Plate 2	Plate 3	Plate 4	Plate 5	Plate 6	Plate 7
Background	6	10	8	2	10	2	1
	13			3		2	
	15				8		
	10					6	
	9			5		3	
	7			1		0	
	7				2		
	8			5		4	
(control)	4	6		0			
	4			3, 2		5	
	3			2		10	
	0			1, 6		12	
	0			1, 10		4	
		20				3	
		15			7		
		12			0		
		8					
		3					4
		8			7		
		6			9		
(control)		8		3			3
		4			9		
		2			5		
			17				8
(control)			10			2	
			9				0
			8				3
			6		0		
(control)			4				3
			3				
			2				0
(control)			0				3
			0				0
			0				6
			0				12
(control)					4		1
(control)					0	0	
					0		

1. Each number is the total of alphas found in ten fields taken at random at 430X. Field area is 0.034 mm^2. Sample area is 4900 mm^2.
2. Film background obtained by counting ten fields at random outside sample areas.
3. Plate 1 no contact, exposure time 323 hr.
   Plate 2 no contact, exposure time 333 hr.
   Plate 3 no contact, exposure time 289 hr.
   Plate 4 direct contact, exposure time 277 hr.
   Plate 5 direct contact, exposure time 287 hr.
   Plate 6 direct contact, exposure time 285 hr.
   Plate 7 direct contact, exposure time 289 hr.

"Original listing was in alphabetical sequence. The order of the patients was scrambled to protect the privacy of the individuals. The data remain intact."

APPENDIX VII

Hematological Studies

A complete blood count (excluding a red count) was done on each of the men during their first week of hospitalization. This included a white count and platelet count (done with two pipettes and using two sides of the chamber), a hemoglobin (cyanmethemoglobin method on Coleman Jr. Spectrophotometer) and hematocrit using the Wintrobe tube. Blood smears were made on all the men and stained with Leishman-Giemsa stain. A differential of 100 cells was made on each of the slides. Nine volumes of blood were drawn into 1 volume of 0.1 M sodium oxalate. The bloods were quickly centrifuged, the plasma removed and frozen in a mixture of dry ice and alcohol. These plasmas were returned to Washington for prothrombin and factor V content.

RESULTS: All results are included in this appendix in tabular form and are also reported in the usual manner in each patient's individual record.

None of the men showed a consistent abnormality. White counts and platelet counts were done 2-3 times and the results compared favorably. The platelet counts are somewhat below the mean for the population as a whole, but the difference is not statistically significant.

Two of the men showed morphologic abnormalities in their platelets. Many giant and bizarre forms were seen. The white count showed variation within the normal range or only slightly below. The white count seemed to be affected in a normal fashion by external stimuli. In one man, going on pass resulted in a leukocytosis of about 15,000; this was a transient phenomenon and disappeared within 1-2 days.

None of the differentials was abnormal other than a minor leucocytosis. All of the hemoglobins and hematocrits were in the upper range of normal. One man worthy of mention had an hematocrit of 55% and a hemoglobin of 18.5 Gms %. There is no evident reason for a secondary polycythemia and in the absence of leucocytosis and thrombocythemia, it is hard to diagnose polycythemia vera. This should be followed in the years to come.

CONCLUSIONS: No positive findings related to radiation.

HEMATOLOGY

Patient	May	WBC	Neutrophils	Lymphocytes	Monocytes	Eosinophils	Basophils	Hemoglobin	Platelets X 10^{-3}	Hematocrit	Smudge	Morphology
	4	8700	70	17	8	5	0	14.8	205	46.5	1	Some toxic granules in segs. Neg. sickle Test
	10	6000							186			
	4	9700	70	17	8	4	0	16.8	266	48.5	4	O.K.
	10	9800							209			
	4	8400	67	25	8	3	0	16.0	207	49.5		O.K.
	10	10,600							222			
	8	9200	64	27	2	2	1	15.2	254	47.0	4	Some toxic gran. in segs.
	10	9200							195			
	4	6700	62	32	1	3	0	16.2	211	48.5	2	
	10	6000							208			
	4	7000	61	30	3	4	1	15.3	220	45.0	2	O.K.
	10	6200							206			
	4	9500	57	36	3	1	0	16.5	270	47.5	3	O.K.
	10	5800							267			
	8	6700	56	35	6	1	1	15.0	265	45.0	1	O.K.
	10	7500							252			
	8	9000	54	33	10	3	0	16.4	253	47.5	4	O.K.
	10	5600							222			
	4	6800	49	36	8	3	2	14.3	247	48.5	4	O.K.
	10	4900							198			
	8	9200	45	43	5	8	0	16.0	271	47.5	1	Some large platelets
	10	5200							234			

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Table 1 - Appendix VII (Cont'd)

Patient	May	WBC	Neutrophils	Lymphocytes	Monocytes	Eosinophils	Basophils	Hemoglobin	Platelets X 10^{-3}	Hematocrit	Smudge	Morphology
	6	7500	79	11	4	1	2	16.5	210	46.5	5	O.K.Neutrophilia
	10	6000							198			
	6	9300	76	20	2	0	0	16.8	328	49.0	2	O.K.
	10	15,200							307			
	6	6200	73	18	6	3	0	16.2	228	48.0	2	O.K.
	10	5600							201			
	4	7900	71	18	4	5	0	16.1	226	48.5	2	Few reaction Lymphs Type I
	10	7900							215			
	6	6400	70	23	9	3	0	16.7	327	48.5	0	O.K.
	10	5900							256			
	5	5700	67	18	12	2	1	16.3	260	48.0	. .	O.K.
	10	8200							199			
	5	7300	65	27	7	0	0	18.6	237	55.0	1	O.K.
	10	7800							225			
	6	10,200	60	31	6	2	0	18.7	227	46.5	1	O.K.
	10	6200							240			
	6	9700	56	37	6	1	0	16.0	262	46.0		O.K.
	10	11,900							262			
	5	6500	50	45	1	3	0	16.7	192	49.0	1	Few reaction lymphs
	10	4700							208			
	5	5800	47	46	5	0	0	14.7	232	41.5	2	Few giant and bizarre platelets
	10	5100							247			

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Table 1 - Appendix VII (Cont'd)

Patient	May	WBC	Neutro-phils	Lympho-cytes	Mono-cytes	Eosino-phils	Baso-phils	Hemo-globin	Plate-lets X 10^{-3}	Hemato-crit	Smudge	Morpho-logy
	6	5400	68	26	5	1	0	16.7	331	46.5		Some toxic
	10	6700							255			gran. in
	5	7800	67	25	3	5	1	16.0	196	48.2	1	O.K.
	10	7000							213			
	5	8200	68	20	6	1	1	17.0	271	43.5	2	O.K.
	10	6400							177			
	5	6100	64	26	1	7	0	15.8	213	42.5	2	O.K.
	10	9800							240			
	5	8500	64	25	7	2	0	16.6	231	43.2	2	Rare stip-
	10	8800							231			pled RBC
												some tox.
												gran. in
												seg.
	6	7600	59	37	2	1	0	15.2	289	46.0	2	O.K.
	10	8200							227			
	6	6100	59	29	6	4	0	16.7	199	47.0	2	O.K.
	10	7100							227			
	6	6200	45	51	2	2	0	17.2	218	55.5	2	Normal
	10	7900							218			lympho-
												cytes

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Chemical Procedures - C. R. Maxwell, Smith
Counting of Samples - Krebs
In vivo survey - Holland, Landgraf
Radioautographs - Reid
Radioactivity of Exhaled Air - Reid
Hematology - O'Brien
Clinical Consultations and Responsibility for Patient Care - Hansen, Storer
Instrument Maintenance - Murphy
Supply and Administration - Holland

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