707599

Health Physics Pergamon Press 1969. Vol. 17, pp. 781–791. Printed in Northern Ireland

REPOSITORY Oak Ridge Energy Sys.
COLLECTION
BOX No.
FOLDER

URANIUM CASES SHOWING LONG CHEST BURDEN RETENTION—AN UPDATING

C. M. WEST and L. M. SCOTT
Y-12 Plant, Union Carbide Corporation, Nuclear Division, Oak Ridge, Tennessee 37830

(*Received* 27 *February* 1969; *in revised form* 5 *May* 1969)

Abstract—Routine uranium *in vivo*, urine and fecal measurements have been continued on four employees previously reported as having unusually long retention of uranium chest burdens. Data have been obtained for a period of 3½ yr since that report. The data including this period are compared to those previously obtained, and the cases are reassessed on the basis of these additional data.

It was found that the half-life of uranium in the chest, as measured by *in vivo* monitoring of these employees, is not statistically different from that previously reported. The urine to fecal elimination rate ratio on these employees averaged about 1, indicating fecal excretion to be an important mode of lung clearance.

Efforts to better determine the nature and causes of these exposures by the selection of the most likely exposure material(s) and conduction of animal inhalation experiments are outlined. These efforts have not been successful in establishing a complete understanding of the reason(s) for the unusual retention patterns exhibited by these persons.

INTRODUCTION

Background

OAK RIDGE Y-12 plant employees who have an exposure potential to either uranium and/or thorium have been routinely monitored by *in vivo* gamma spectrometry since 1961. Of the thousands monitored, 5 exposure cases detected in 1962 and 1963 showed chest burdens of enriched uranium which exhibited unexpectedly slow decreases after the persons were assigned to non-uranium activities. These persons had indicated biological half-lives of uranium in the chest of from 380 to 1470 days.

Scope and purpose

Since the initial reporting of these cases by WEST and SCOTT,[1] additional *in vivo*, urianalysis, and fecal data have been obtained over a period of up to 3½ yr on four of the five cases.

The purpose of this report is to (1) summarize the extended data, (2) compare the data obtained for the total period of monitoring with those previously reported, and (3) briefly describe the continuing efforts made to determine the reason for these unusual retention patterns.

DATA

These persons have been scheduled to give urine samples weekly and fecal samples monthly. *In vivo* counts were also scheduled monthly. The total amounts of data obtained and periods covered are shown in Table 1, showing that the shortest period of coverage was 1660 days—almost 5 yr—and that there are as many as 300 measurements on some individuals.

Table 1. *Period and number of measurements*

Case	Period (days)	Number of measurements		
		In vivo	Urine	Fecal
Y-1	1660	39	112	17
Y-2	2130	62	178	67
Y-4	2000	55	206	56
Y-5	1730	47	139	43

Tables 2 through 5 give the individual *in vivo* measurements and the monthly averages of urine and fecal results obtained since the initial period. Data from the initial period were tabulated in the previous report[1] in the same format used in these tables. Table 6 gives a quick resume of the levels encountered

1024046

A-00005
Human Subjects Project

Table 2. Case Y-1

In vivo		Month	Urine		Feces	
Date	pCi		No. of samples	Avg. (pCi/day)	No. of samples	Avg. (pCi/day)
11-18-64	17,500					
1-12-65	11,251	1-65	3	0.1		
		2-65	2	3.3		
3-2-65	16,636	3-65	2	22.3		
4-5-65	10,432					
5-27-65	4500					
6-24-65	0	6-65	3	6.6		
7-20-65	10,704	7-65	3	9.1		
8-23-65	9272	8-65	1	0.1		
		9-65	1	0.1	1	0.1
10-14-65	7774	10-65			1	2.4
12-14-65	6954	12-65			1	7.3
		1-66			1	0.1
2-25-66	5863					
		4-66	2	3.8	1	0.1
5-19-66	5045	5-66	1	8.6	1	6.8
6-24-66	5795					

in the *in vivo* measurements. As a point of reference, 17,000 pico curies (pCi) have been calculated to be the Maximum Permissible Lung Burden. Note that the levels run from about three times the MPLB to one-third the MPLB. Table 7 shows similar data on the urine and fecal levels Traditionally Y-12 has used 32 pCi/day as a urine level action point. Note that all urine levels fall below this action point. It is noted the fecal levels are generally lower than urine values and always below the urine action point.

INTERPRETATION AND COMPARISON

Data treatment

The data were reviewed by plotting the results of *in vivo* measurements and the monthly averages for urine and fecal samples on semi-log coordinates. Straight lines appear to give good fits, indicating that single exponential expressions would adequately represent the data. On the basis of this observation, computer programming was used to determine the least squares fit. Figure 1 illustrates the technique graphically, showing a plot of the *in vivo* data from case Y-2 and a line representing the computer determined curve.

In vivo

Figure 1 also shows the least squares line determined from data at the time of the previous report as it compares with that for the total period. There is little difference in the slopes and intercepts. Included in the computer program was a determination of the statistical confidence limit associated with the slope of the lines. This slope information was used to calculate half-lives and the statistical confidence associated with these half-lives. Figure 2 shows the half-lives computed for the *in vivo* measurements and their confidence limits. It was assumed that the half-life had changed from the initial estimate if the confidence limit did not cross the half-life value calculated for the initial period. The half-lives for the initial report are included for comparison. The figure illustrates some tendency toward longer half-lives but also shows that there is little statistical difference in the half-lives determined for these employees for the two periods.

Urinalyses

Figure 3 shows the half-lives calculated from the monthly average urinalysis data for the

1024047

Table 3. *Case* Y-2

In vivo		Month	Urine		Feces	
Date	pCi		No. of samples	Avg. (pCi/day)	No. of samples	Avg. (pCi/day)
1-25-65	23,900	1-65	3	17.2		
		2-65	3	14.8		
3-10-65	23,630	3-65	2	11.5		
4-21-65	19,669	4-65	2	2.7	1	5.2
5-19-65	21,965	5-65	3	14.4	2	9.4
6-11-65	18,049	6-65	2	4.9	1	3.7
		7-65	2	37.0	1	0.1
8-5-65	20,300	8-65	2	4.3	1	3.9
9-24-65	24,574	9-65	3	7.2	1	0.1
		10-65	3	10.7	1	11.7
		11-65	3	7.1	1	6.1
12-23-65	14,358	12-65	2	7.9		
		1-66	2	5.4	1	64.4
2-23 66	13,413	2-66	2	11.7		
		3-66	1	0.1	1	30.9
		4-66	2	5.2	1	1.7
5-6-66	11,432	5-66	3	3.9	1	8.9
6-22-66	16,384	6-66	2	0.1		
7-28-66	13,638	7-66	2	5.9	1	16.1
8-23-66	14,043	8-66	2	3.6		
9-26-66	13,908	9-66	3	4.5		
10-12-66	16,249	10-66	5	5.9	1	0.1
11-18-66	15,708	11-66	3	9.3		
		12-66	5	4.8		
1-5-67	14,223	1-67	4	0.1	1	14.4
2-1-67	10,172	2-67	3	4.6	1	3.9
		3-67	4	5.0	1	2.2
4-3-67	15,934	4-67	3	12.5	1	10.3
5-5-67	11,432	5-67	3	1.0	1	3.0
		6-67	1	0.1	1	14.4
7-7-67	7787					
		8-67	3	11.7	1	1.1
9-18-67	14,628	9-67	2	0.1	1	3.9
10-11-67	12,423	10-67	4	0.1		
11-10-67	8732	11-67	3	0.1	1	20.4
12-6-67	12,108	12-67	3	5.7	1	4.8
1-12-68	12,153	1-68	3	2.3	1	2.4
2-8-68	8912	2-68	3	3.0	1	13.8
3-7-68	15,979	3-68	3	6.4	1	4.2
4-4-68	17,869	4-68	3	11.2	1	7.6
5-17-68	15,889	5-68	2	0.1		
		6-68	3	3.1	1	0.1

1024048

Table 4. Case Y-4

In vivo		Month	Urine		Feces	
Date	pCi		No. of samples	Avg. (pCi/day)	No. of samples	Avg. (pCi/day)
		1-65	4	15.8		
		2-65	2	5.6		
3-4-65	15,477	3-65	5	0.1		
4-1-65	17,931	4-65	5	1.0		
5-7-65	18,068	5-65	3	30.0		
6-7-65	18,545	6-65	4	6.1	1	2.6
7-8-65	17,931	7-65	2	26.1	1	0.6
8-17-65	20,658	8-65			1	0.9
9-23-65	13,909	9-65	2	0.1	1	0.1
10-25-65	13,909	10-65	3	0.1		
		11-65	1	2.3	1	1.7
12-8-65	16,709	12-65	3	8.0		
		1-66	3	9.8	1	11.8
2-23-66	11,866	2-66	1	0.1	1	7.3
3-23-66	12,140	3-66	4	21.8		
		4-66	4	2.5	1	0.1
5-6-66	10,912	5-66	4	17.1	1	14.4
6-14-66	19,912	6-66	3	0.1		
7-18-66	14,186	7-66	3	6.0	1	3.2
8-23-66	11,458	8-66	4	11.3	1	0.4
		9-66	5	5.0	1	1.0
11-13-66	11,594	10-66	5	14.9	1	0.3
11-9-66	8048	11-66	2	5.8	1	1.4
		12-66	4	13.0	1	1.4
1-3-67	13,367	1-67	3	5.3		
2-1-67	12,071	2-67	3	0.1	1	0.1
3-16-67	8048	3-67	5	1.5	1	13.5
		4-67	2	7.9	1	0.1
5-5-67	9002	5-67	2	0.1	1	0.1
6-8-67	12,890	6-67	6	7.3	1	0.1
		7-67	2	0.1	1	0.1
8-15-67	14,322	8-67	4	5.0	1	2.0
9-8-67	9548	9-67	3	5.7	1	4.8
10-4-67	11,458	10-67	4	10.4	1	1.2
11-6-67	11,578	11-67	2	0.1		
12-4-67	8184	12-67	2	23.2	1	0.1
1-8-68	9071	1-68	3	11.4	1	0.9
2-1-68	8389	2-68	3	9.1		
3-4-68	13,572	3-68	3	25.8	1	24.0
4-2-68	12,617	4-68	2	13.0		
		5-68	2	9.7		
		6-68	2	8.3		

1024049

Table 5. *Case* Y-5

In vivo		Month	Urine		Feces	
Date	pCi		No. of samples	Avg. (pCi/day)	No. of samples	Avg. (pCi/day)
2-15-65	18,700	2-65	1	0.1	1	1.3
3-4-65	16,232	3-65	5	0.1		
4-1-65	17,800	4-65	3	10.5		
5-7-65	15,413	5-65	2	36.2	1	8.2
6-7-65	22,301	6-65	4	14.2	1	10.2
7-9-65	21,074	7-65	3	21.9	1	5.5
8-17-65	14,595	8-65	1	3.1	1	6.4
9-23-65	17,255	9-65	4	0.1	1	10.9
10-25-65	16,914	10-65	4	3.8	1	1.3
		11-65	3	4.5	1	14.2
12-8-65	17,255	12-65	3	0.5		
		1-66	3	11.8		
2-23-66	13,299	2-66	3	4.9		
3-22-66	12,003	3-66	5	12.9	1	8.0
		4-66	4	5.9	1	1.2
5-6-66	10,230	5-66	3	0.1	1	8.6
6-14-66	14,663	6-66	3	1.0	1	10.5
		7-66	3	10.2	1	6.6
		8-66	2	3.2		
9-14-66	15,345	9-66	5	0.1		
		10-66	5	19.6	1	7.2
11-9-66	13,572	11-66	3	9.6		
		12-66	4	11.5		
1-3-67	11,526	1-67	3	1.5	1	0.1
2-1-67	9480	2-67	3	12.7	1	0.2
3-29-67	10,571	3-67	2	10.1		
		4-67	3	8.6	1	9.4
5-5-67	10,093	5-67	5	1.5	1	4.4
6-29-67	13,367	6-67	3	9.9	1	28.6
		7-67	1	3.1		
8-15-67	11,867	8-67	4	6.5	1	0.1
9-8-67	7775	9-67	4	1.0		
10-4-67	8320	10-67	3	12.1		
11-6-67	11,185	11-67	3	0.1	1	8.4
12-4-67	17,186	12-67	1	8.5		
1-8-68	11,253	1-68	3	0.1	1	0.1
		2-68	2	16.9		
3-1-68	16,095	3-68	1	7.2		
4-2-68	15,209	4-68	2	22.7		
5-1-68	13,231	5-68	1	6.3		
		6-68	2	16.2	1	3.3

two periods. There is a tendency toward longer half-lives, with three of the four cases showing longer half-lives for the total peroid. Although it is not shown in this figure, the calculated confidence limits show that only in the case of Y-5 which has an indicated positive slope is the half-life for the total period statistically different from that of the initial period.

Feces

Figure 4 shows the half-lives derived from the fecal data for the two periods. The fecal

1024050

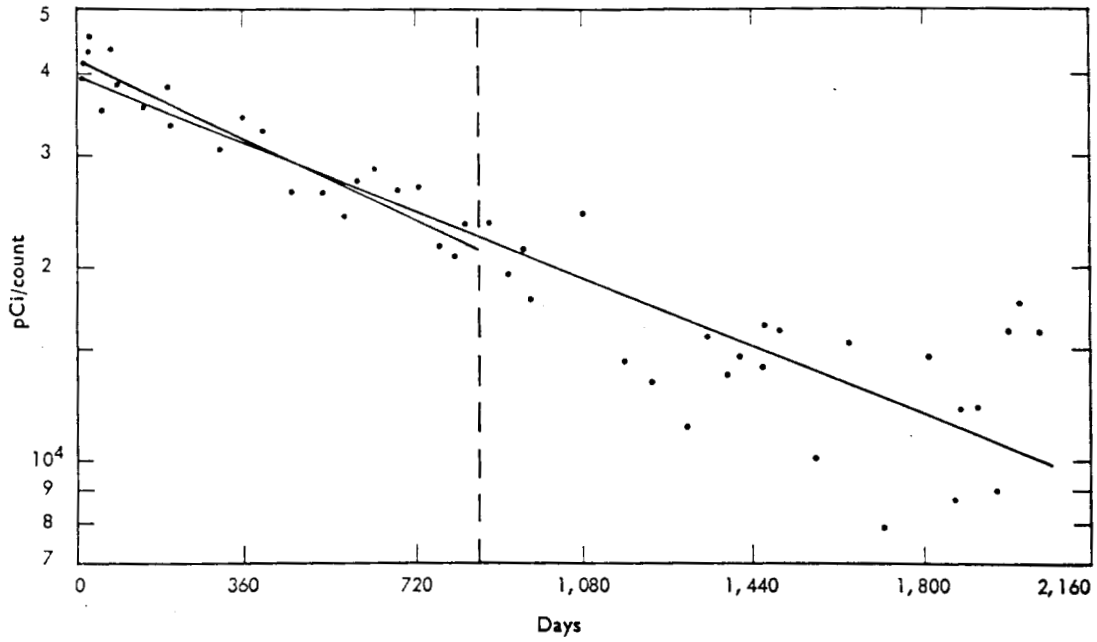

FIG. 1. *In vivo* measurements, case Y-2.

Table 6. *Levels of in vivo measurements* pCi

Case	Initial	End of first report period	End of present report period
Y-1	45,000	13,000	6000
Y-2	41,000	21,000	10,000
Y-4	22,000	16,000	10,000
Y-5	21,000	19,000	11,000

Table 7. *Levels of urine and fecal measurements* (pCi/day)

	Case	Initial	End of first report period	End of present report period
Urine	Y-1	30	4	1
	Y-2	28	7	1
	Y-4	5	4	3
	Y-5	3	3	4
Fecal	Y-1	8	4	∠1
	Y-2	14	7	2
	Y-4	8	3	∠1
	Y-5	20	8	∠1

data obtained were so variable that there is no statistically significant difference in any of the half-lives shown by the cases between periods. This is true even, in the case of Y-4, where there is apparently a much shorter half-life.

Fecal to urine ratio

The total amount of uranium excreted by urine and feces was estimated by integrating the functions obtained from the least squares fit. Figure 5 shows the ratio of the amount excreted by feces to that excreted by urine. The ratio obtained at the time of the previous report is included for comparison. It is of interest that the ratios have decreased in *all* cases. However, the elimination by feces for this period is still a large enough fraction of the total that it must be considered a significant mode of chest clearance for uranium.

Ratio between drop in chest measurement and total excreted

The ratio of the drop in the *in vivo* chest measurements to that excreted by the urine

1024051

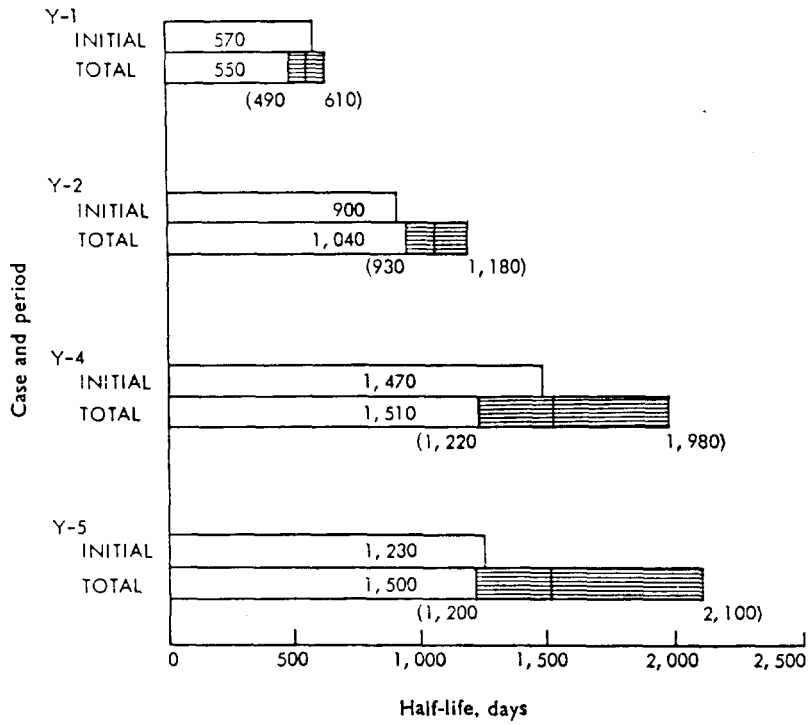

FIG. 2. Half-lives as derived from *in vivo* data for two periods.*

* Periods: Initial—From the time of the first elevated *in vivo* measurement to early 1965.
Total—From the time of the first elevated *in vivo* measurement to July, 1968 (as available),
Numbers in parenthesis are the lower and upper statistical confidence limit on the "total" half-life.

and feces is shown in Fig. 6. Included for comparison are like ratios from the previous report. With the exception of case Y-1, these ratios are as near or nearer to unity than those previously reported. In case Y-1 it is believed that the high drop in chest measurement to excreted ratio as well as the low fecal to urine excretion ratio shown in Fig. 5 is associated with a low fecal elimination estimation. Only 17 fecal samples were obtained from this person in the 55-month period during which she was monitored. These samples were bunched and covered only two periods of nine months and eight months with a lapse of 26 months between. As shown in Table 1, data from other cases, are much more complete.

STUDIES TO BETTER DEFINE PROBLEM

Selection and characterization of possible exposure materials

In the period since the last report, further efforts have been made to better delineate the reason for the long retention periods in these persons. One of these has been reported by STECKEL and WEST.[2] In this effort 22 different process materials were selected as suspect exposure materials on the basis of detailed work and exposure histories of the employees involved. These materials were subjected to extensive chemical and physical tests to determine which of them would most likely result in high biological insolubility. These tests consisted

1024052

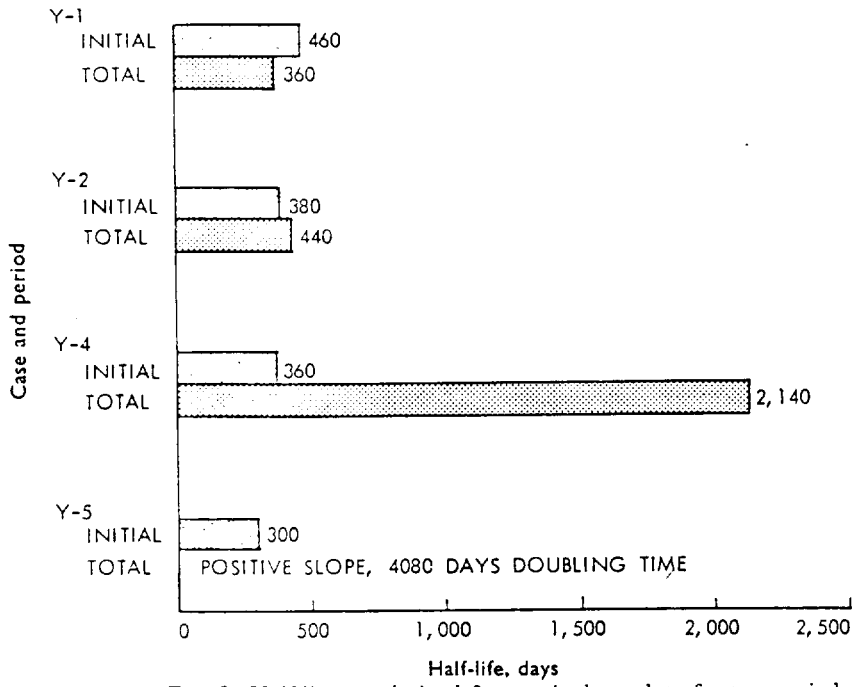

FIG. 3. Half-lives as derived from urinalyses data for two periods.*

* Periods: Initial—From the time of the first elevated *in vivo* measurement to early 1965.
Total—From the time of the first elevated *in vivo* measurement to July, 1968 (as available).

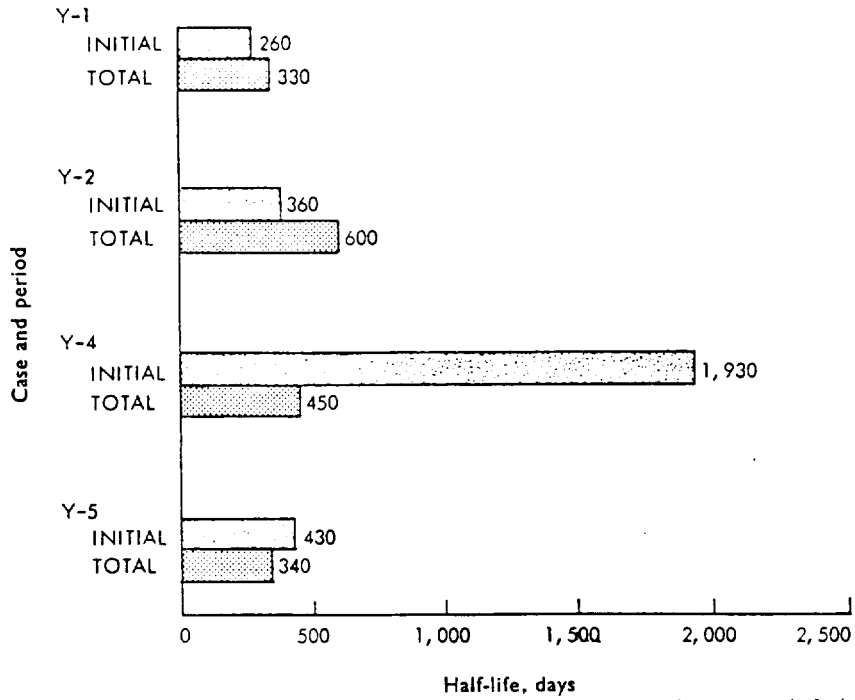

FIG. 4. Half-lives as derived from fecal data for two periods.*

* Periods: Initial—From the time of the first elevated *in vivo* measurement to early 1965.
Total—From the time of the first elevated *in vivo* measurement to July, 1968.

1024053

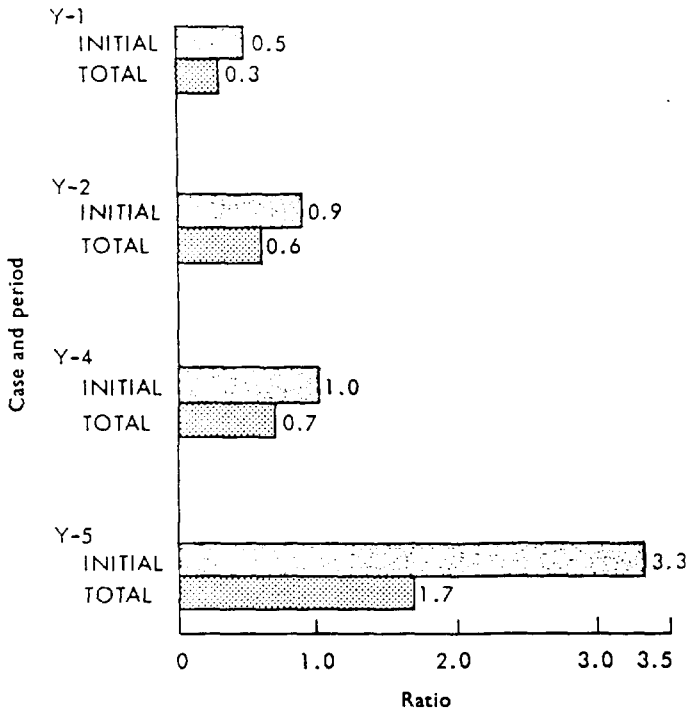

FIG. 5. Ratio of fecal excretion* to urine excretion for two periods.†

* Fecal excretion (pCi)/urine excretion (pCi).

† Periods: Initial—From the time of the first elevated *in vivo* measurement to early 1965

Total—From the time of the first elevated *in vivo* measurement to July, 1968 (as available).

of a check for solubility in a simulated lung fluid as well as characterization as to uranium content, chemical composition, particle size and contaminants. Twelve of these compounds, all containing uranium oxide, appeared to have the characteristics necessary to make them possible exposure materials. These oxides differed in solubility by factors of up to 50, with indicated half dissolving times in simulated lung fluids of from 500 to 26,000 days. Further experimentation and evaluations of the data led to the conclusion that the solubility of uranium oxides decreased with increasing particle size and temperatures of formation; facts accounting for the variability of the solubility of oxide samples.

The information obtained from the various tests led to the selection of three process combustion oxides containing U_3O_8 as the most likely exposure material.

Animal experimentation

Previous animal experiments using oxides of uranium indicated a lung or chest half-life of approximately 120 days,[3–6] thus introducing an apparent contradiction between animal data information and the experience with these Y-12 employees. However, further comparisons indicated that the selected likely exposure materials have a larger particle size, higher heats in their thermal histories, and greater concentration of contaminants than did the oxides used in animal studies.

Because of these differences it was decided that it would be helpful if animal data were obtained using the most insoluble of these materials. Consequently, an animal experiment using dogs was arranged through the AEC and is presently being conducted by Dr. W. J. BAIR[7] at the Battelle Northwest Laboratory.

1024054

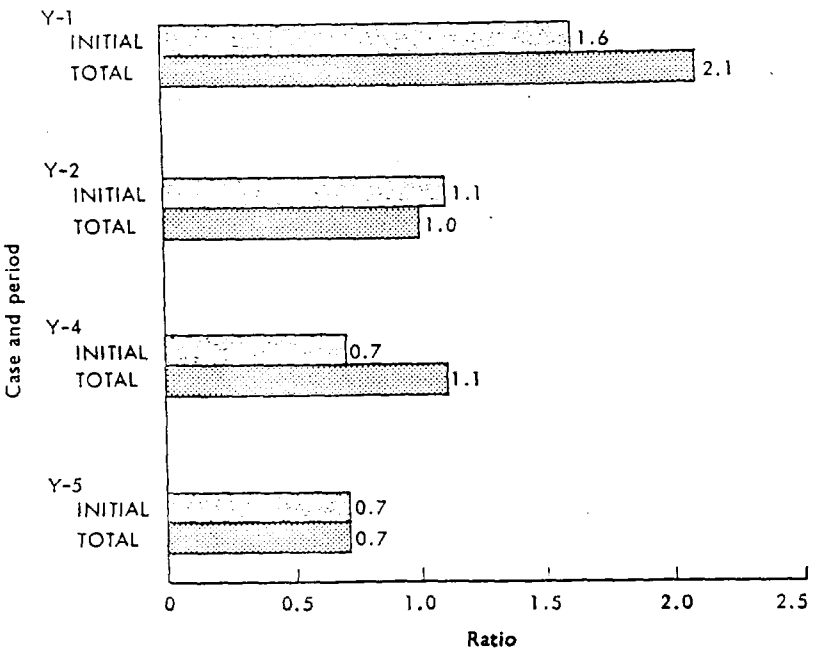

FIG. 6. Ratio of drop in chest measurement to total excreted* for two periods.†

* Drop in chest measurement (pCi)/sum of integral of urine and fecal functions (pCi).

† Periods: Initial—From the time of the first elevated *in vivo* measurement to early 1965.
Total—From the time of the first elevated *in vivo* measurement to July, 1968.

Respiratory test facility

In early 1964 a respirator test facility was installed in Y-12 and a routine program instigated to check respirator fit on individuals whose job assignments require some wearing of respiratory protective devices. These tests revealed that women in general (and these four employees specifically) were difficult to fit with respirators. It has not been possible, however, to establish any direct relationship between respirator fit and the nature and magnitude of these exposures.

SUMMARY

Four employees who showed a long chest retention of enriched uranium have been sampled for periods of up to three and one-half years since their data were last reported. Additional data do show some indication of longer biological half-life, but these indications are not statistically significant on an individual basis at this time. Fecal excretion continues to be a significant mode of elimination although the ratio of fecal to urine excretion showed a decrease since the prior reporting. Material balance in general showed better agreement than at the last reporting. Although efforts to delineate the cause and nature of the problem of long chest half-lives have brought out some interesting facts, they have not established the reason(s) for the unusual retention patterns exhibited by these persons.

CONCLUSIONS

The conclusions reached after this review of the data are basically the same as those reached in the first report, i.e.:

1. A very small percentage of Y-12 employees were exposed to uranium of a form which continues to show a long half-life in their chest.

1024055

2. Fecal excretion is a significant mode of elimination in such cases.
3. Relatively high chest burden coupled with low excretion rates makes it difficult, if not impossible, to evaluate such cases with excretion data.

REFERENCES

1. C. M. West and L. M. Scott, A comparison of uranium cases showing long chest burden retentions. *Health Phys.* **11,** 1545 (1966).
2. L. M. Steckel and C. M. West, *Characterization of Y-12 uranium process materials correlated with in vivo experience*, Y-1544-A, Union Carbide Corp., Nuclear Div., Y-12 Plant (1966).
3. C. Voegtlin and H. C. Hodge, *The Pharmacology and Toxicology of Uranium Compounds*, National Nuclear Energy Series, Division VI, Vol. 1, Part III, p. 1370, and Part IV, p. 2128. McGraw-Hill, New York (1953).
4. H. C. Hodge and R. G. Thomas, *Proc. 2nd United Nations Int. Conf. Peaceful Uses of Atomic Energy*, Vol. 23, p. 739 (1958).
5. B. R. Fish, *Inhaled Particles and Vapors*, p. 151. Pergamon Press, London (1961).
6. P. E. Morrow, F. R. Gibb, and L. Johnson, Clearance of insoluble dust from the lower respiratory tract. *Health Phys.* **10,** 543 (1964).
7. W. J. Bair, personal communication.

1024056