8005140051

EA 278

April 14,1980

Director,
Three Mile Island Support
NRR
Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Enclosed is a copy of a study for your consideration in making a decision on venting of Kr-85 from TMI-2.

Its findings are sufficient to make a prudent individual say, "Halt!" The probability of damage to fatty soluble tissue and bone marrow from Kr-85 doses present too great a threat to the local population. Total doses of radiation already received are unknown and may well be beyond tolerable cell limits.

Even if venting is done over a 5 day period, there is the risk of, again unknown, amounts of Krypton lingering in the environment for the 10-year half-life of the gas.

The people of this area have to look ahead to accidental and expected releases of radioactivity for the duration of Clean-Up, 6 -10 years.

It is your responsibility to prevent as much radioactivity from escaping as possible, and insisting on the use of alternate methods to remove all remaining radioactive elements from the island and transporting them to waste disposal areas.

If this job cannot be handled safely, then this technology is beyond your control and regulation. You should be the first voices pleading for a nuclear moratorium.

It is time to get back to the laboratories and start at the beginning. Perhaps fusion will prove feasible, but the nuclear systems developed over the last 30 years are not measuring up to humane standards. Government allowable limits of radiation dosage are shortening lives and causing genetic defects.

Is this to be the leading social commentary remembered about the 20th "Technologically Superior" Century? If so, then God help us all!

Sincerely,

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17022

717-367-2405

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KINETICS OF INHALED KRYPTON IN MAN*

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Abstract—The total body retention of ^{79}Kr and its clearance following a 10-min rebreathing period were measured *in vivo* in order to refine the dosimetry calculations. Radioactivity in the chest region and in the recirculating krypton–air mixture were measured continuously during rebreathing of the gas mixture and in the first 5 min of the gas washout period using a gamma camera and shielded NaI detector, respectively. Subjects were then counted in the Brookhaven whole-body counter at varying time intervals for up to 55 hr. The retention data of krypton for 16 subjects (12 males, 4 females) were resolved into a five-component exponential curve. The average half-times were 21.5 ± 5.7 sec, 4.74 ± 2.0 min, 0.33 ± 0.11 hr, 2.41 ± 0.95 hr, and 7.0 ± 1.7 hr. The half-time of the long-term component correlated highly with the percentage of total body fat. Internal dose calculations were performed using the MIRD techniques and were compared with previous estimations.

INTRODUCTION

THE PROJECTED growth of the nuclear power industry necessitates an assessment of potential environmental pollutions. One such pollutant, krypton-85, produced by nuclear reactors and nuclear fuel processing, constitutes a potential radiation risk for an exposed population. The radiation dose results not only from external radiation following exposure but also from internal radiation from inhalation of the gas. Evaluation of the degree of internal radiation hazard requires knowledge of the parameters of ^{85}Kr metabolism in human beings. Data on the rate of saturation and desaturation of the body tissues are required for this estimation.

At present, only limited data are available on the behavior of Kr within the human body. Values of the solubility coefficient of inert gases in different biological tissues have been obtained from *in vitro* studies (Kit72a; Kit72b; Ye63; Ye65). Measurements in the total tissue, as well as its major constituents (water, lipid and protein), have been used to calculate the saturation level of the gas. *In vivo* studies using guinea pig and rat models (Ki72; Ki73a; Ki73b; Ki75a; Ki75b) have been extrapolated to man. There are few *in vivo* studies of Kr in man (To49; Tu75). Krypton has been used mainly as an inert tracer for determination of physiological parameters (Ho64; Le63; Hy66; Ad73).

The object of this *in vivo* study was to characterize the metabolism of inhaled Kr. For this purpose, measurements were made of the distribution and clearance of Kr following inhalation of ^{79}Kr by normal subjects. The data were analyzed with a computer program and related to body composition and respiratory parameters of the individual subjects. Internal radiation dose estimations for the short-term exposures used were performed by the method of MIRD (MIRD75).

MATERIALS AND METHOD

(1) *Subjects*

Total body retention (TBR) of radiokrypton was studied in 16 adult subjects (12 males, 4 females) with no known respiratory disorders. Institutional review committee approval was obtained for this research project in accordance with rules set by DHEW. Informed consent was obtained from each subject after a thorough discussion of the procedures and associated risks. Kryp-

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ton-79 was chosen for its short half-life ($t_{1/2}$ = 34.6 hr) and positron decay properties.

The general physical characteristics (age, weight, height, sex) and values for total body potassium (TBK), lean body mass (LBM), and percentage of body fat of the subjects are presented in Table 1. Total body potassium was derived from the measurement of the naturally occurring ^{40}K in the body (Co70). Lean body mass was estimated from TBK since the LBM/TBK ratio is relatively constant for this age span (TA60). Percentage of fat was defined as follows:

$$\%\ \text{body fat} = [(BW - LBM)/BW] \times 100,$$

where body weight (BW) and lean body mass (LBM) are in kg units.

Table 1. Physical characteristics of the normal subjects

Subject	Age (yr)	Ht (cm)	Wt (kg)	TBK (g)	LBM (kg)	% body fat
1	30	171.9	67.7	135.5	52.6	22.3
2	61	181.4	78.2	149.5	58.1	25.7
3	45	180.8	74.6	142.4	55.3	25.8
4	45	164.3	71.8	133.2	52.1	27.5
5	49	174.0	77.3	138.3	53.7	30.5
6	47	172.2	75.0	132.9	51.6	31.2
7	58	180.3	84.1	141.0	54.7	35.0
8	47	177.3	92.7	153.4	59.5	35.8
9	43	176.8	73.2	129.4	46.3	36.7
10 (F)	45	163.7	54.1	77.9	33.7	37.7
11	39	175.1	93.2	148.7	57.7	38.1
12 (F)	54	[illegible]	58.2	86.5	35.2	39.5
13 (F)	56	167.8	70.4	91.7	39.7	43.7
14	36	169.3	106.4	141.5	54.9	48.4
15	52	170.3	106.4	140.4	54.5	48.8
16 (F)	52	157.5	90.0	99.8	43.2	52.0

TBK = total body potassium
LBM = lean body mass
% body fat = 100 [body wt (kg) − LBM (kg)]/body wt (kg).

(2) *Rebreathing and initial washout phase*

Prior to each run, spirometry was perfor med to determine total lung capacity an functional residual capacity (FRC). The sub ject's average lung volume was determine from the sum of FRC plus half the tid volume (V_t). The initial amount of ^{79}Kr in troduced into the spirometer-lung volum was adjusted so that the average Kr concen tration in the lungs was relatively constan for all the subjects. Tidal volumes of ^{79}Kr–a mixture were rebreathed for 10 min in closed spirometer system (Fig. 1). A constan volume was maintained by absorption of CO in soda lime and the automatic replenishmen of O_2 during the rebreathing phase. The con centration of ^{79}Kr in the recycled gas mixtur was monitored continuously at the mout piece using a shielded NaI detector and in th chest region with an Ohio-Nuclear Model 11 wide-field gamma camera. A calibrated sampl volume of the gas mixture was obtained jus prior to the start of gas washout from which th ^{79}Kr concentration and total lung activity wer obtained.

The subjects were then switched from th closed spirometer system to breathing roo air. During the initial 5-min interval (washou phase), the ^{79}Kr activity in the exhaled air an

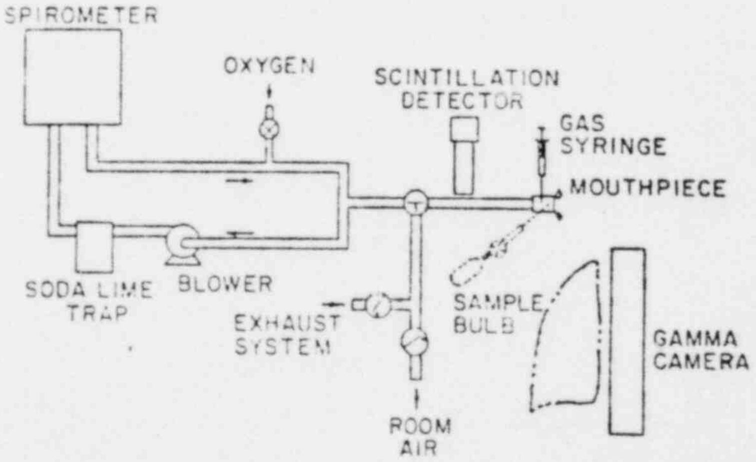

FIG. 1. A schematic representation of the experimental apparatus used for rebreathing the ^{79}Kr–air mixture.

chest region were again monitored continuously. Estimates of the initial clearance rates of ^{79}Kr were derived from these data.

(3) *Whole-body counting*

The Brookhaven whole-body counter, which has been described elsewhere (Co69), has an invariant response to both radionuclide distribution and body size. Counting for the TBR of ^{79}Kr started at 8–9 min after the start of the washout phase and continued for as long as 55 hr. The subjects were counted at varying time intervals usually for 12–16 times in the first 8 hr, three times on the second day (24–32 hr), and when sufficient activity remained, twice on the third day (48–55 hr).

Since ^{79}Kr is a positron emitter, the coincidence circuitry of the Brookhaven counter (Ch74) was used to enhance the body localization of the isotope. Due to the NaI detector configuration of the whole-body counter, the spatial localization is defined by 85 regions (17 × 5 array). The sum of the values in each row of crystals provides a profile distribution as a function of height (Ch74), while the coincidence count rate at a single crystal position gives the retention value for that localized region of the body. Each subject was counted in the coincidence mode at approx 1, 6 and 24 hr after the start of gas washout. Two subjects (14 and 16) were given higher doses of ^{79}Kr to allow counting up to 55 hr.

RESULTS

The rebreathing and washout phases for a typical run (subject 6) are shown in Fig. 2. During the rebreathing period, the activity in the recirculating gas decreased slightly, indicating a gradual uptake by the body tissues. This uptake is also shown as a slow monotonic increase in chest activity, viewed by the gamma camera. The start of gas washout is clearly indicated, as is the clearance for both the exhaled air and the chest region. The retention data were resolved into a two-component exponential model by means of using a computer program (BE62). For this run, the half-times from the start of washout were 28.1 sec and 1.74 min, while the corresponding values in the exhaled air were 21.8 sec and 2.32 min, respectively. Data on the ^{79}Kr activity in the chest region were curve fitted for 10 of the subjects (Table 2). The mean half-times were 21.5 ± 5.7 sec and 4.74 ± 2.05 min, respectively.

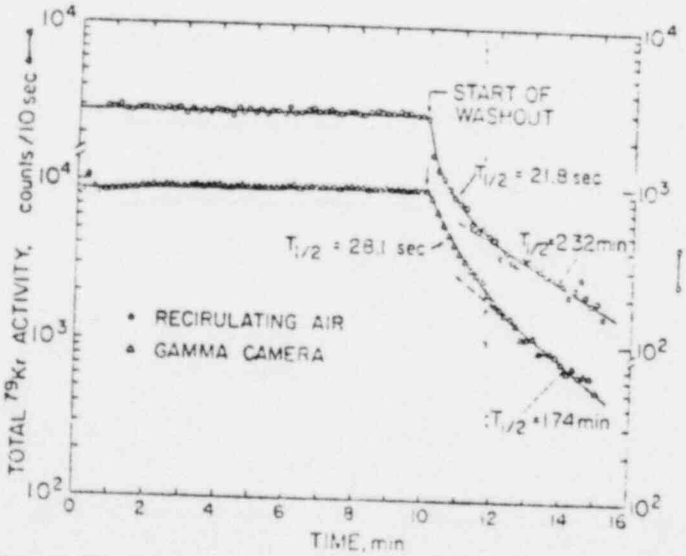

FIG. 2. Variation of ^{79}Kr activity in subject 6 with time for a typical run during the rebreathing and initial 5-min washout phases, measured with the gamma camera.

*Table 2. Rapid half-times during initial 5-min washout phase**

Subject	Half-times for component A (sec)	B (min)
2	22.6	5.83
3	29.6	4.10
4	23.7	4.53
6	28.1	1.74
8	15.5	5.45
9	27.1	2.44
12	20.7	4.93
13	19.4	3.36
14	14.1	8.74
16	14.2	6.05
mean	21.5	4.74
S.D.	±5.7	±2.05

*Measured with the gamma camera.

*Table 3. Results of exponential analysis of ^{79}Kr retention data**

Subject	Half-times (hr) for component C	D	E	% total body activity for component at $t = 0$§ C	D	E
1	0.32	2.81	5.50	81.3	15.2	3.5
2	0.13	1.10	4.20	45.1	41.3	13.6
3	0.35	2.81	6.14	74.3	20.6	5.1
4	0.35	2.17	6.30	69.2	29.1	1.7
5	—†	0.96	5.37	—†	81.3	18.7
6	0.13	3.85	5.63	58.1	29.8	12.2
7	0.42	2.01	5.41	64.7	23.1	12.2
8	0.44	2.69	6.79	64.5	25.8	9.8
9	0.38	1.44	6.13	59.5	28.3	12.2
10 (F)	0.29	2.92	7.40	61.0	34.1	4.8
11	0.35	2.90	8.01	61.1	32.7	6.2
12 (F)	0.21	1.98	7.32	42.1	45.9	12.0
13 (F)	0.43	4.30	9.53	63.1	29.0	7.8
15	0.46	3.40	9.62	57.8	30.0	12.2
Mean	0.33	2.41	6.67 (6.99)‡	61.7	29.6	9.4
±S.D.	0.11	0.95	1.57 (1.72)‡	10.5	8.1	4.7

*Based on whole-body counter data only.

†Insufficient data points in first 2 hr to permit accurate three-component fit.

‡Includes values for long-term component for subject 14 (8.9 hr) and subject 16 (9.6 hr).

§Start of Kr washout.

Whole-body retention data were similarly resolved into a sum of exponentials. A typical clearance curve (subject 11) and its resolution into three components is shown in Fig. 3. The results of the exponential curve fitting for each subject are listed in Table 3. The intercept values for each component are expressed as a percentage of the calculated value to the start of gas washout ($t = 0$). The 100% TBR (Table 4) value was based only on the whole-body counter data and did not include the rapid clearance shown in the gamma camera data. Up to five components were tested in fitting the whole-body counter data. The retention curves were described most precisely by a three-component model, with mean half-times of 0.33 ± 0.11, 2.41 ± 0.95 and 6.67 ± 1.6 hr, respectively. The associated values of the uptake by each component at the start of gas washout were 61.7, 29.6 and 9.4% of the TBR value.

The coincidence counting data were used to determine the spatial distribution at approx 1, 6 and 24 hr after the start of washout. A typical profile distribution is shown in Fig. 4. As the total activity decreased, the relative distribution shifted from the chest region to the lower abdomen and upper legs—regions of high fat content. Subjects 14 and 16 were given higher concentrations of ^{79}Kr during the

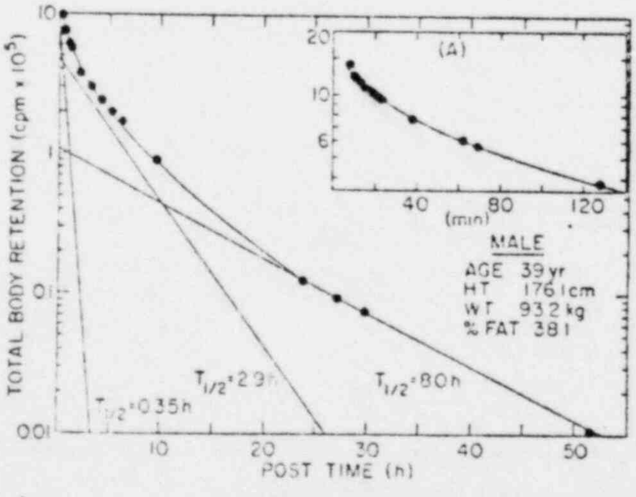

FIG. 3. Typical clearance curve measured with the whole-body counter and the three-component computer fit (subject 11). The inset shows the data in the first 2 hr.

Table 4. ^{79}*Kr activity in the lungs, total body and long-term retention component*

Subject	FRC (l)	V_T (l)	Average lung volume (FRC + 1/2 V_T) (l)	Total ^{79}Kr activity (μCi) Lungs	TBR*	Component *E*
1	3.7	0.9	4.2	266.6	56.13	1.98
2	4.5	1.6	5.3	170.9	39.95	5.45
3	5.2	0.9	5.7	281.8	49.03	2.50
4	3.2	0.6	3.5	333.9	77.25	1.31
5	2.6	0.8	3.0	193.4	53.70	10.06
6	6.0	0.6	6.3	445.3	66.56	8.09
7	4.5	0.7	4.9	470.4	126.6	15.46
8	4.0	1.3	4.7	341.4	99.40	9.70
9	4.6	0.5	4.8	217.0	35.33	4.30
10(F)	3.3	0.4	3.5	304.9	53.8[illegible]	2.59
11	2.0	0.7	2.9	265.9	78.[illegible]	4.81
12(F)	3.2	0.7	3.6	137.6	[illegible]	2.92
13(F)	3.6	0.4	3.8	229.5	[illegible]	2.91
14	2.1	0.8	2.5	990.9†	–	75.49†
15	3.0	1.0	3.5	288.6	[illegible]	9.44
16(F)	1.7	0.7	2.1	1250.8†	–	25.42†
Mean				281.9	[illegible]	5.82
±S.D.				±95.1	± [illegible]	±4.12

*TBR = total body retention (based on whole-body counter data only)
†Value omitted from calculation of mean value.

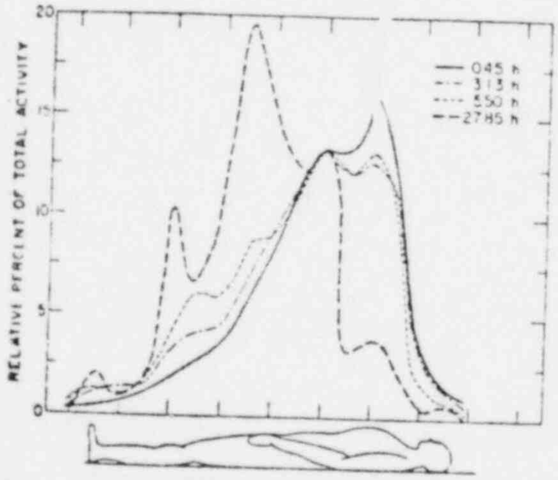

FIG. 4. A typical profile distribution of ^{79}Kr in man, based on the coincidence counting mode of the whole-body counter.

rebreathing phase so that the retention distribution could be followed for up to 55 hr. The half-times for the slowest component were 8.9 hr for subject 14 and 9.6 hr for subject 16. Estimation of the more rapid components in these two subjects was not possible because of the high initial activity of ^{79}Kr.

DISCUSSION

The rate at which a tissue releases or stores an inert gas is determined by the blood–tissue partition coefficient and the rate of blood perfusion to the tissue (Ke51). The Fick principle describes the basic process in which the retention in a single tissue, $R(t)$, at time t is

$$R(t) = R(0)\,e^{-kt},$$

where $R(0)$ = retention in the tissue at $t = 0$, k = rate constant, t = time.

Since the body is composed of tissues of varying compositions with widely differing perfusion rates and partition coefficients, the TBR at time t becomes the sum of the retentions for the different tissue components:

$$\mathrm{TBR}(t) = \Sigma R_i(t) = \Sigma R_i(0)\,e^{-k_i t}.$$

The results of this study indicated that the human body has at least five similarly perfused compartments for krypton gas. The associated values of $T_{1/2}$ range from 14 sec to 9.6 hr and are in good agreement with the values obtained by other investigators (Ho64; To49; Tu75). Holzman *et al.* (Ho64) reported an average half-time of 17.8 ± 8.2 min for 65 determinations in 28 subjects. In that study a NaI detector was placed directly over the injection site following the injection of ^{85}Kr into forearm muscle. Tobias and co-workers (To49) reported three components of ^{85}Kr uptake in the hand (nine subjects) during a 2-hr rebreathing period. The average half-times were 4.3 min, 33 min and 188 min. In the same study, analysis of data on seven subjects yielded average values of 55 and 400 min for the knee. Turkin and Moskalev (Tu75) reported three components for six male subjects following inhalation exposures in a 3.1-m^3 chamber from 30 min to 40 hr. The mean half-times were 30 sec, 7.9 min and 2.7 hr assigned to the lungs, muscle and fatty tissues, respectively. Release of ^{85}Kr from the body was determined with a single crystal counter repositioned over different regions of the body for up to 16 hr following inhalation. They also found that the rate of ^{85}Kr uptake was much faster for a small, lean subject than for a heavy, fat one. Saturation times varied from 3 to 9 hr.

In the present study, the mean half-times for the five components were in general agreement with those found by other investigators for the different tissues of the body (Table 5). The fastest component (*A*) ($T_{1/2} = 21.5 \pm 5.7$ sec) probably represents clearance of ^{79}Kr from the circulating blood, in particular from blood plasma (Tu75). The second component (*B*) would appear to be representative of hemoglobin in that its half-time ($T_{1/2} = 4.74 \pm 2.05$ min) is similar to that determined for xenon (Sc76). Desaturation of ^{85}Kr following absorption through the skin (Ad73) gave a clearance half-time of 4.5 min. The third component (*C*) is most likely related to the clearance of Kr from muscle. The mean value in the present study (19.8 ± 6.6 min) is in good agreement with the value of 17.8 ± 8.2 min obtained by intramuscular injection of ^{85}Kr (He64).

The two components with the slowest clearance (*D* and *E*) should be related to body fat compartments. The component (*D*) with a mean half-time of ~2.4 hr (2.41 ± 0.95 hr) would indicate a substantial fat compartment not located in adipose tissue, or else a nonuniformity in the perfusion rate for adipose tissue (Le67). The half-time for the slowest component (*E*) correlated significantly with the percentage of total body fat ($r = 0.89$). The linear relationship is

$$T_{1/2} = 0.172(\%\ \text{fat}) + 0.75,$$

where $T_{1/2}$ is in hr; the standard error of the estimate is 0.80 (Fig. 5). The long-term retention of Kr in adipose tissue is confirmed by the data from the whole-body counter, when operated in the positron mode. The Kr distribution at ~1 hr indicated significant concentrations in the chest area, i.e. lungs and heart. At ~24 hr, the lung concentration had decreased, whereas significant Kr concentrations were retained in the lower abdomen and upper thighs.

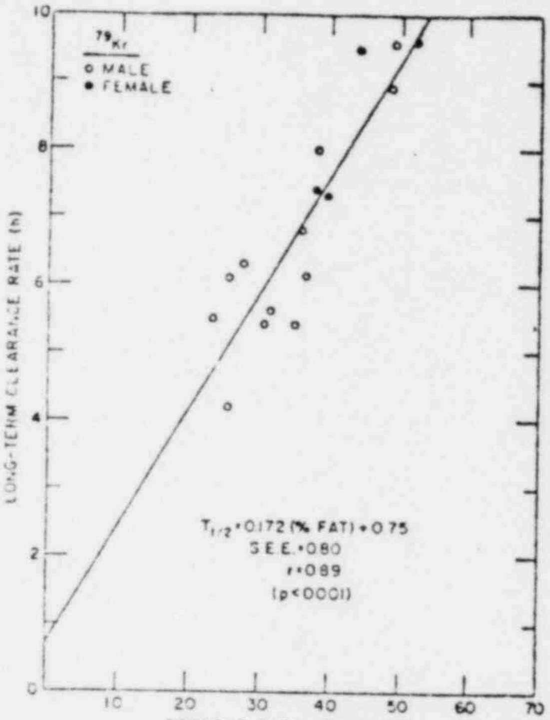

FIG. 5. The relationship between the clearance rate for the long-term component and the per cent total body fat.

Table 5. Comparison of half-times with data in the literature

Body compartment	Present study Mean	(range)	Literature Mean	Reference
Blood plasma	21.5 sec	(14.1–29.6)	30 sec	Tobias *et al.*
Hemoglobin	4.7 min	(1.7–8.9)	3 min	Schoenborn
Muscle	19.8 min	(7.8–27.6)	17.8 min	Holzman *et al.*
Fat*	2.41 hr	(0.9–4.3)	2.7 hr	Turkin *et al.*
Fat†	6.99 hr	(4.2–9.6)	6.7 hr	Tobias *et al.*

*Non-adipose fat or non-uniformity in the perfusion rates.
†Adipose tissue.

Equilibrium for all the body tissues was not attained during the short exposure time of this study. Thus, the absolute amount of Kr retained in the body was variable, ranging from 24.2 to 127 μCi (Table 4). This was dependent on (1) the Kr concentration in the air mixture, (2) duration of exposure to the Kr–air mixture, and (3) the total body fat content. The first two factors were kept relatively constant in this study. The total Kr activity in the lungs varied between 137.6 and 470.4 μCi, with an average value of 281.9 ± 95.1 μCi. The resulting average concentration in the subjects' lungs was 68.18 ± 21.32 μCi/l. The exposure time was kept constant at 10 min. The significant reduction in total body activity (based on the whole-body counter data) as compared with that in the lungs (gamma camera data) verified the very rapid clearance from the lungs and circulating blood during the initial 5 min of washout.

Calculation of radiation dose from inhaled Kr

The radiation dose from Kr is dependent on the type and length of exposure. Consideration must be given to both the external and inhalation contributions to the total dose. Estimations of the dose to man from atmospheric ^{85}Kr have been made (Di72; Wh72; NCRP75). These calculations assumed a semi-infinite cloud of Kr gas and considered only long-term exposures. Under these conditions, one can assume equilibrium between the various body tissues and the concentration of Kr in the air. The internal dose rate from inhalation would be

$$D = 2.56\bar{E}_\beta C\lambda/\rho \text{ (mrad/hr)},$$

where C is the Kr concentration in air (μCi/cm^3), λ the tissue–air partition coefficient, ρ the density of the tissue (g/cm^3), and $\bar{E}_\beta$ the average energy of the beta particle (MeV) (Hi56). When compared with the dose from the accompanying external irradiation, the whole-body dose from inhalation is negligible (NCRP75).

In short-term exposures, whether administered for medical purposes or occurring as a result of an accident, equilibrium is not achieved between the Kr in the air and in various body tissues. Use of the data presented in this study will allow for a more accurate determination of the inhalation dose. The dose to different tissues was estimated with the MIRD methodology (MIRD75). The calculations were based on whole-body retention data from this study and the "S" values for ^{85}Kr from MIRD pamphlet 11. The dose to any tissue, t, would be

$$D_t = 1.44\tau_t CfS,$$

where τ_t is the average half-life, C the Kr activity in the lungs (μCi), f the fraction of activity in the tissue relative to the air activity, and S the source–target value for ^{85}Kr (rad/μCi-hr). Calculation of the dose for the lungs, body fat and remaining tissues for two different exposure levels are presented in Table 6. The concentrations of ^{85}Kr in air (0.25 and 0.0012 μCi/cm^3) would be representative of medical and accidental exposures, respectively. For comparison, the values of (Wh72) are included in Table 6. The increased dose to fat and other tissues (including gonads) in the present calculations are due, in part, to the longer retention of Kr in fat. When the accidental exposure includes an external irradiation of the body, the dose from the inhaled ^{85}Kr gas increases the whole-body dose by about 1%.

Table 6. Internal radiation dose for short-term exposures to ^{85}Kr

	Medical exposure* (mrad)	Accidental exposure† (mrad)
Lungs	6.2	0.030(0.012‡)
Fat tissue	1.9	[illegible](0.005‡)
Remaining tissue	0.6	0.001(0.0008‡)

*1 mCi ^{85}Kr in lungs (0.25 μCi/

†1 μCi/g air (0.0012 μCi/cm^3).

‡Values of Whitton (Wh72)

CONCLUSIONS

The clearance of ^{79}Kr from the body would indicate five components ranging in half-times from 14 sec to 9.6 hr. The slowest components correlated highly with percentage of body fat, varying between 4.2 and 9.6 hr. The long-term retention was localized to regions of high fat content as determined by the coincidence mode of the whole-body counter. The estimated dose based on the retention data of this study would indicate increased doses to body fat and gonads as compared with those of previous investigators. These increased doses are due to the longer retention of krypton in fat.

The model of standard man used in the MIRD calculations assumes a uniform distribution of fat throughout the body. This approximation is adequate for dose estimations for most radionuclides, but may need refinement when the isotope concentrates in the fat compartments. As was demonstrated in this study, the long-term distribution of ^{79}Kr is not uniformly distributed throughout the body, but localized to the upper thighs and lower abdomen—regions of high fat content. The corresponding dose to the ovaries, which would be completely surrounded by the abdominal adipose tissue layer, would be higher than those calculated in this study. Refinement of the MIRD model to include a more realistic approximation of the body fat distribution may be warranted in the case of radiogases known to concentrate in the adipose tissues.

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OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

January 30, 1980

not coded

OFFICE OF THE DIRECTOR

Department of Energy
Oak Ridge Operations
Attention: Mr. Joseph A. Lenhard
Assistant Manager for Energy Research and Development
Post Office Box E
Oak Ridge, Tennessee 37830

Gentlemen:

Krypton Gas Proposal

Reference is made to your letter dated January 7, 1980, on this subject. As you requested, we have completed a preliminary estimate of the costs and time required to develop, design, construct, and test out a reliable and licensable fluorocarbon system for removing Kr from the gas in the TMI-2 containment vessel.

The system for which we have made the estimate has a nominal 475 standard m^3/hr capacity and a single-pass removal efficiency exceeding 90%. Under these conditions, the desired reduction of ^{85}Kr to permit access to the reactor building can be achieved in less than 60 days. The unit would be housed in four refrigeration-type trailers which, together with a control trailer, could be transported over the road. It was assumed, for convenience in estimating, that system construction and most special fabrication would be done in one of the "N-stamp" approved DOE shops, i.e., ORNL or Y-12. Most engineering and testing were also assumed to be done by UCC-ND in-house. This should not be taken as a recommendation that UCC-ND do the work, because with other commitments already in hand, it seems unlikely that this would be either feasible or the best way to proceed. No further development work would be needed.

Under conditions where a "crash program" could be assured, including rather blanket approval to sole-source purchased hardware, the minimum time to construct the mobile unit would be two years after authorization to proceed. A more normal schedule for such a system would be four years. Both numbers exclude any time required for the licensing process itself. We realize that this lead time of two years is not consistent with the schedule that GPU plans to follow in the recovery of TMI-2, but we think the availability of a mobile gas cleanup device for possible future emergencies warrants construction of this unit.

Our interpretation of your request that the system be "licensable" is that we would have to assure that nothing would be incorporated during the design, fabrication, and testing program which would preclude obtaining a system license. Accordingly, we assumed that all reactor-oriented codes and standards (such as both Sections III and VIII of the ASME code) would have to be followed.

With the constraint that the unit be licensable, we estimate that the cost would be in the range of $15 to $20 million (unescalated). This high cost is basically due to high materials costs associated with such requirements as maintaining traceability on components back to mill certifications. Another example is the scrubber column, which has a nominal 0.6 meter diameter. According to Section III of the code, longitudinal welds are not allowed in vessels of this diameter, so that a special extrusion or casting will have to be obtained. All in all, materials costs are increased by about a factor of six with the "licensable" criterion. If this were not a requirement, then the system cost could perhaps be reduced to something on the order of $10 to $15 million, which is closer to a rough estimate we made previously.* We do not believe that waiving this requirement would reduce the schedule substantially (six months, maximum).

The fluorocarbon process is well-developed and represents very little technical risk. In addition, the system is highly tolerant of impurities and disturbances, has a low operating Kr holdup, and is safe.

Please understand that this estimate was made in only a few days. This makes the second such "crash basis" estimate that we have been requested to make for a mobile Kr removal unit within the last few months. While we have done our best to furnish responsible estimates under the circumstances, we would like to have more time. We do not believe that such preliminary estimates should weigh heavily on important decisions. We urge that at least the first phase of our previous proposal* be approved as soon as possible so that we can provide DOE with a more definitive and more meaningful estimate of project cost and timing. This phase would cost $500,000 and would take about nine months.

We would be pleased to discuss this with you further.

Sincerely,

Herman Postma

Herman Postma
Director

HP:JRM:lmm

cc: W. D. Burch
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*Preliminary Proposal - Emergency Reactor Off-Gas Decontamination System, Union Carbide Corporation, Nuclear Division, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, Tennessee, June 22, 1979 (K/ET-244)