702703

IDO-12047
AEC Research and Development Report
Biology and Medicine
Health and Safety
TID-4500 (47th Ed.)
Issued: February 1966

NRTS

REPOSITORY INEL USDOE-IDO
COLLECTION Public Reading Room
BOX No. DOE/HRE-ID-002
FOLDER Human Radiation Experiment Documents (Idaho) DOE/HRE-ID-xxxy

CONTROLLED ENVIRONMENTAL RADIOIODINE TESTS AT THE NATIONAL REACTOR TESTING STATION 1965 PROGRESS REPORT

C. A. Hawley, Jr.
EDITOR

AUTHORS

D. R. Adams
D. F. Bunch
W. P. Gammill
C. A. Hawley, Jr.
E. H. Markee
M. W. Tiernan

Idaho Operations Office
U. S. ATOMIC ENERGY COMMISSION

0023497

ACKNOWLEDGMENTS

Special thanks are again extended to Drs. James Boyd and Ervin Smith and the staff of Montana State College for their aid in the procurement and management of the dairy cattle. In addition to the work of those listed as authors, essential portions of the experiments were performed by the following persons:

	Division	Branch
G. J. Ball	Health & Safety Division	Health Physics Branch
J. Echo		
J. Detmer		
J. R. Horan		Director
L. Howard		Analytical Chemistry Branch
Dr. N. F. Islitzer	U. S. Weather Bureau	Meteorologist in Charge
J. Keller	Farm Manager	
R. McBride	Health & Safety Division	Health Physics Branch
B. Mortensen		
D. Newcomb		
L. J. O'Neill		
Conrad Willis		Analytical Chemistry Branch

0023498

SUMMARY

The CERT project consists of a series of planned releases of radioiodine over different vegetation and during various meteorological conditions, with the prime objective being to measure the relationships involved in the passage of radioiodine through the air-vegetation-cow-milk-human chain. This report deals with the results of the first five tests in the series, which started in the spring of 1963 and is continuing.

Each test was conducted under measured meteorological conditions and over prepared sampling and grazing courses. Two tests were made over open-range type vegetation, two over irrigated pastures, and one over snow-covered ground. Two tests were conducted under lapse conditions, two under inversion conditions, and one under neutral conditions. In each case, known quantities of elemental $^{131}I_2$ were released. Relationships determined include: (a) air-grass ratios (deposition velocities) which ranged from 0.1 to 1.0 cm/sec; (b) effective half-life of ^{131}I on grass of 3.5 days and 5.5 days; (c) the time of peak activity in milk is at two days following a release; (d) milk-grass ratio (Ci/l:Ci/g) is 130; (e) total ^{131}I secreted in milk by cows to that ingested by cows is about 9.5 percent; (f) adult human thyroid uptake fraction (ingestion) was 0.19; (g) adult human thyroid uptake fraction (inhalation) was 0.30; and (h) based on a breathing rate of 20 m^3/24 hours, the ratio between infinity mills ingestion dose and infinity inhalation dose for a single release was calculated to be an average of about 130.

Data, descriptions of methods, and calculations are reported. Discussions of resuspension factors and particle sizes and behavior are also included.

0023499

CONTENTS

ACKNOWLEDGMENTS ii

SUMMARY iii

I. INTRODUCTION 1

II. SUMMARY OF PROGRESS TO DATE 2

1. CERT I 2

1.1 General Information 2
1.2 Data Summary 2

2. CERT II 3

2.1 General Information 3
2.2 Meteorological Conditions 3

3. CERT III 5

4. CERT IV AND V 6

5. DATA SUMMARY 7

III. DESCRIPTION OF EXPERIMENTAL METHODS AND CONDITIONS . . . 8

1. SAMPLING GRID AND TERRAIN 8

2. IODINE RELEASE MECHANISM 12

3. METEOROLOGICAL ASPECTS 13

4. MILK STUDIES 16

5. GRASS STUDIES 23

6. HUMAN THYROID DOSE STUDIES 31

6.1 Ingestion Studies 31
6.2 Inhalation Studies 31
6.3 Ingestion to Inhalation Dose Ratios 32

7. PARTICLE SIZE MEASUREMENTS 36

8. RESUSPENSION OF IODINE FROM PASTURE 39

8.1 Results 39

9. PROJECTED WORK 40

IV. REFERENCES 41

0023500

FIGURES

1. View of pasture area used during CERT I 8
2. Sampling grid -- pasture 9
3. Sampling grid -- long distance 10
4. Inversion test grid 11
5. Sampling equipment -- CERT II 12
6. Relative crosswind integrated concentration 14
7. Variation of carbon plate V_g with distance 15
8. Iodine-131 activity in cows' milk -- CERT II 19
9. Effective half-life in milk -- CERT II 20
10. Total accumulated ingested and recovered activity -- CERT I and II . . 22
11. Initial deposition -- CERT II 24
12. Grass half-life data 28
13. Deposition of I-131 on grass -- CERT V 30
14. Iodine-131 concentration in milk -- CERT I 34
15. Iodine-131 concentration in milk -- CERT II 35
16. Distribution of activity by particle size -- CERT II 38
17. Redeposition of iodine on grass -- CERT II 40

TABLES

I. Summary of Deposition Data 3
II. Meteorological Conditions During CERT Releases 13
III. Median Deposition Velocities 15
IV. Milk Production Per Day, in Liters -- CERT II 17
V. μCi/l of I-131 Activity in Milk -- CERT II 17
VI. Total Consumption by Cows 21
VII. Average Grass Activity -- CERT II 25

0023501

VIII. Activity of Pasture Samples in pCi/g, Wet Weight -- CERT II 26

IX. Activity of Pasture Samples in pCi/g, Dry Weight -- CERT II 27

X. CERT II Inhalation Thyroid Data 32

0023502

1. CONTROLLED ENVIRONMENTAL RADIOIODINE TESTS AT THE NATIONAL REACTOR TESTING STATION

I. INTRODUCTION

The Controlled Environmental Radioiodine Tests (CERT) which are being conducted at the National Reactor Testing Station (NRTS) in Idaho consist of a series of planned atmospheric releases of radioiodine under varying conditions of meteorology, vegetation type, chemical form, and distance. The project began in the spring of 1963, when a preliminary experiment was conducted to ascertain if the general experimental design was adequate. A major test in the series was conducted in September of 1964, and a minor one in December of 1964. Two tests under inversion conditions were accomplished; a preliminary in May of 1965, and a follow-up test in June of 1965.

The primary objective of the project is to determine the quantitative behavior of radioiodine as it passes through the air-vegetation-cow-milk-human chain. To this end, measurements have included deposition velocities (air-ground ratios), milk-to-grass-activity ratios, half-times of radioiodine in milk and on grass, portable instrument readings relative to contamination levels, and human thyroid uptake fractions. The passage of radioiodine through a segment of the biosphere will be influenced by many factors. The CERT project is intended to define these factors as they apply to the NRTS and its environs, and to reveal which of these factors is the most significant. The resulting data can be of operational use at the NRTS in the development and review of reactor siting criteria, safety analysis report preparation, and in emergency planning and response. Since much of the investigation is of a rather basic nature, the USAEC's Division of Biology and Medicine has contributed support funds to the project.

The purpose of this report is to acquaint the reader with the development of the project, the data obtained thus far, a description of the experimental methods used, a comparison of the data with published information, and a discussion and interpretation of results. Since many readers will not be interested in experimental details or technical discussions, a summary of progress has been included in this report as Section II.

0023503

II. SUMMARY OF PROGRESS TO DATE

As was stated in the introductory paragraph, five tests have been accomplished. Each of the five is discussed below. The first, or preliminary, experiment is designated as CERT I; the second, a major release over irrigated pasture, is designated as CERT II; and the third, a minor test over snow-covered ground, is designated as CERT III. The two inversion tests are identified as CERT IV and CERT V.

1. CERT I

1.1 General Information

The preliminary experiment was conducted during May and June of 1963. The area chosen for this experiment was near the southern boundary of the NRTS in an area which had been planted to Crested Wheatgrass for the purpose of noxious weed control. Two pasture areas were established in this area, one for control purposes and one to be contaminated. No irrigation of the pastures was employed. Five iodine generators were oriented along a 150-meter line to simulate a short line source and assure lateral distribution of the radioiodine. The source line was 50 meters upwind from the "hot" pasture. A sampling grid based on pretest meteorological studies extended 300 meters downwind, with one additional arc at about 1000 meters. The release of approximately one curie of iodine-131 was accomplished on May 27, 1963. Six cows were procured through arrangement with Montana State College, Bozeman, Montana, and were acclimated for two weeks prior to placing them on the contaminated pasture May 28, 1963. Seven human volunteers consumed 500-ml portions of the resulting contaminated milk over an 18-day period. Human thyroid activities were measured periodically over a 39-day period. Full details of the experiment have been published in IDO-12035 [1].

1.2 Data Summary

About one curie of iodine-131 was released in the form of molecular, elemental I_2 gas under moderately unstable conditions and a wind speed of about 7 meters/sec.

Deposition velocities averaged 0.6 cm/sec.

Effective half-life on grass was 3.5 days.

Ratio of milk (pCi/l) to grass (pCi/g) was 240 [a].

Peak activity occurred in milk after 2 days.

Effective half-life in milk (after removal from the hot pasture) was 1 day.

Human thyroid uptake factor averaged 0.19.

2. CERT II

2.1 General Information

During the summer of 1963, construction began on the Experimental Dairy Farm which is located about seven miles northeast of the Chemical Processing Plant. The area was chosen because of the availability of the land, the existence of an adequate well, safety considerations, and relative accessibility. Twenty-seven acres of land were leveled, diked, and fenced. A dairy barn, pumphouse, sprinkler system, and corral were constructed. Construction problems resulted in the pasture grass being seeded too late for adequate fall growth; hence, the area was replanted in the spring of 1964. Growth of the grass was deemed to be adequate for test purposes in September of 1964, when CERT II was conducted. The experimental design was almost identical with that used during CERT I.

2.2 Meteorological Conditions

Approximately the same quantity of the same chemical form of iodine-131 was released under generally the same meteorological conditions which existed during the CERT I release. The wind speed was somewhat greater, being about 9 meters/sec. The deposition velocities (V_g) on various media for both tests are summarized in Table I.

The deposition velocities are generally higher for CERT II except on soil. It is interesting to note that if the

TABLE I

SUMMARY OF DEPOSITION DATA

Deposition Medium	V_g or Deposition Velocity (cm/sec)	
	Test I	Test II
Grass	0.61	0.98
Soil	0.84	0.38
Carbon	0.57	0.73
Sticky Paper	0.14	0.41

[a] The method used to calculate milk-to-grass ratios was changed after CERT II. The new method is explained in Section 2.2.

grass V_g's are divided by their particular average grass densities, 153 and 246 g/m^2 in CERT I and II, respectively, the deposition is practically the same during both tests. This shows the strong influence of grass density on the calculation of deposition velocities. The soil contamination indicates the same influence which manifests itself in an inverse relationship with grass density. The deposition velocities on carbon plates and sticky paper which were used as standard deposition media were significantly higher for CERT II. This suggests that the meteorological factors were different enough between the two tests to influence deposition rates. However, at present,no definite relationships to the friction velocity and the mean wind speed have been found.

2.21 Grass Half-Life. In the first test no specific area was used to measure the half-life on the grass. The daily samples which were taken to measure activity consumed by the cows were used to develop a half-life figure. This turned out to be 3 to 4 days whereas in the second case a plot was established which showed the half-life to be between 5 and 6 days. The latter value agrees well with the literature. The method used during CERT I was used as a check during CERT II. With this system, the half-life number came out to be 4 to 5 days. The reasons for these disagreements have not been determined and are discussed in Section III.

2.22 Milk Activities. In both tests the cows reached peak milk activity in about 2 days. During CERT I, activity levels in the milk produced by the high and the low cow were within a factor of two. In CERT II, the difference in activity levels between the high and the low cow was consistently about a factor of five. Possible reasons for this are discussed in Section III.

During CERT II, all six cows were placed under controlled grazing on the hot pasture for two weeks. Following this period, three cows were removed to the corrals and fed stored feed. The other three were allowed to graze the entire pasture without control. After five more days, all cows were placed on cold pasture. As can be seen in Section III of this report, milk activity decreased with a half-life of about 1 day for the first few days. The decay scheme then became a good deal more complex and varied widely between individual cows.

2.23 Milk-to-Grass Ratio. One of the objectives of the CERT project is to determine the relationship between the iodine concentration on the grass and in the milk. The most reasonable way to define this is by using the ratio of peak activity in the milk (pCi/l) to activity on the grass (pCi/g) at the time grazing was started. On CERT I, the average initial activity was 788 ± 153 pCi/g on the back

section of the pasture. There was a one-day delay before the cows were allowed to graze on the hot pasture. At this time, based on the observed 3-1/2 day effective half-life, the average activity would have been about 663 ± 232 pCi/g. The mean peak activity in the milk, which was observed two days later, was 89,000 ± 19,000 pCi/l. The resulting ratio of milk-to-grass activity is 130 ± 40. During CERT II, mean activity on the grass at the time grazing commenced was 532 ± 146 pCi/g. The mean peak activity in the milk was 71,000 ± 33,000 pCi/l, which again was observed two days later. The resulting ratio was 130 ± 70. In view of the uncertainty involved, it is fortuitous that the ratios compare so closely. Nevertheless, it would seem that a reasonably accurate prediction of mean peak activity for a small dairy herd could be obtained by use of a ratio of 130.

2.24 Human Thyroid Uptake Data. In the first test, one cow was selected to furnish milk for human volunteer consumption. The data from the counting of the human thyroids after ingesting the milk showed the uptake fraction to be 0.19 ± 0.04. In the second test, inhalation thyroid dose measurements were made on three people who were on the test grid during the time of cloud passage. The infinity thyroid dose measurements were 15, 7.7, and 6.1 mrad, and yielded inhalation uptake fractions of 0.46, 0.24, and 0.19. Based upon the ingestion-thyroid uptake factor of 0.19 observed during CERT I, a breathing rate of 10 m^3/8 hours, and upon the ICRP recommended value of 0.23 for the inhalation uptake fraction, the dose expected from ingestion of one liter of milk per day from the second test is roughly a factor of 75 greater than the inhalation dose. To obtain this ratio, it was necessary to correct for the nonuniformity of the pasture contamination and to assume that the test continued for several weeks. A similar treatment of CERT I data yielded an ingestion-to-inhalation-dose ratio of 120. A detailed description of these analyses is presented in Section II-1 of this report.

3. CERT III

The third release, a scaled-down version of the first two, was executed over the snow-covered pasture in December of 1964. The meteorological conditions were much more stable due to low cloudiness and the snow cover. The primary purpose of this test was to determine, through the use of various collection media (carbon plates, sand plates, sticky paper), the influence of the

more stable conditions on deposition and dispersion rates. Deposition velocity on the snow was found to be about 0.2 cm/sec, which is in fair agreement with other investigations [2]. However, the collection media showed an increase in deposition velocity, rather than the expected decrease, which indicated that the collection media themselves may be affected by temperature and humidity conditions.

4. CERT IV AND V

CERT IV involved the release in June of 1965 of 10 mCi of radioiodine through a CCl_4 extraction and subsequent evaporation. During the test, unstable wind conditions and uncertainties about the form of released iodine made some results undependable so only selected results are reported. A subsequent release (CERT V) of 100 mCi of element I-131 was made under early morning inversion conditions over open-range grass. No cows were employed during this test. The average deposition velocity on grass out to 1000 meters from the single ground-level release point was 0.1 cm/sec, or about 15 and 10 percent of those measured during CERT I and CERT II, respectively.

5. DATA SUMMARY

The following tabulation summarizes data accumulated to date:

Type of Data	CERT I	CERT II	CERT III[a]	CERT IV[a]	CERT V[a]
Time of Year	Late May	September	December	June	June
Temperature (°C)	22.3	16.8	-1.9	-1.8	9.9
Relative Humidity (%)	21.0	32.0	71.0	99.0	74.0
Wind Speed At 4m (m/s)	7.1	9.3	6.0	3.1	3.7
Stability Parameter (R_i)	-0.13	-0.10	-0.04	+0.54	+0.10
General Meteorological Condition	Lapse	Lapse	Neutral	Stable-Inversion	Stable-Inversion
Pasture Type	Open-Range	Irrigated	Snow-Cover	Open-Range	Open-Range
Average Grass Density Fresh (g/m^2)	153.0	246.0	--	--	127.0
Grass Condition	Green-Growing	Green-Growing	No Grass-Snow Cover	Green-Damp	Green-Damp
Deposition Velocity $\left(\frac{Ci/m^2}{Ci\text{-}sec/m^3}\right)$	0.58 (grass)	0.98 (grass)	0.22 (snow)	--	0.11 (grass)
Eff $T_{\frac{1}{2}}$ On Grass (Days)	3.5	5.5	--	--	--
Time Till Peak Activity In Milk (Days)	2.0	2.0	--	--	--
Eff $T_{\frac{1}{2}}$ In Milk (Days)	1 (until 5 days)	Changing See Page 20	--	--	--
Milk-Grass Ratio (pCi/l/pCi/g)	130.0	130.0	--	--	--
Percent Of Total Ingested By Cows To Total Excreted In Milk	9.3	9.7	--	--	--
Human Thyroid Uptake Fraction (Ingestion)	0.19	--	--	--	--
Human Thyroid Uptake Fraction (Inhalation)	Average	0.30	--	--	--
Calculated Ratio-Ingestion/Inhalation Dose	110.0	150.0 (Based on $20m^3/24$ hrs breathing rate. See page 33)	--	--	--

[a] Cows not involved in these tests.

0023509

III. DESCRIPTION OF EXPERIMENTAL METHODS AND CONDITIONS

1. SAMPLING GRID AND TERRAIN

CERT I was conducted over somewhat rolling open range terrain, as shown in Figure 1, and the CERT II and III tests over flat terrain which included an irrigated field of mixed pasture grasses. CERT IV and CERT V employed the same general terrain and grass cover as CERT I.

Fig. 1 View of pasture area used during CERT I.

As shown in Figures 2 and 3, the same general grid design was used for the CERT II as was used for CERT I, the major difference being that the iodine generators were placed an additional 50 meters upwind to avoid heavy concentrations of radioiodine on the upwind edge of the pasture. The CERT IV and V grid design is shown in Figure 4.

Air sampling instruments used were Staplex High Volume air samplers equipped with MSA 2133 paper prefilters and a 5-cm-thick activated charcoal filter. Deposition collection media used were 25 x 25 cm plots of sticky paper, sticky paper covered with sand, and sticky paper covered with activated charcoal.

0023510

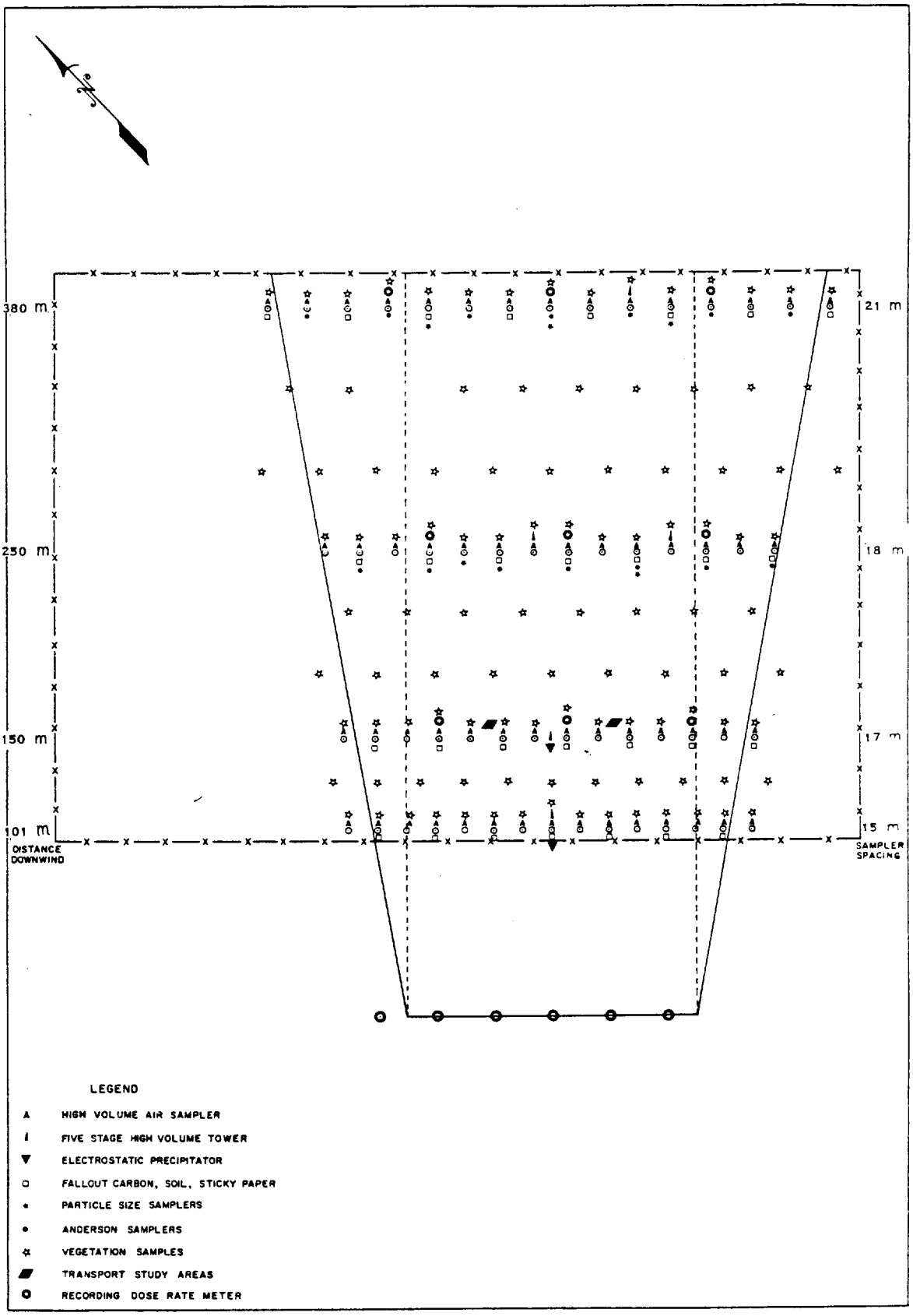


Fig. 2 Sampling grid -- pasture.

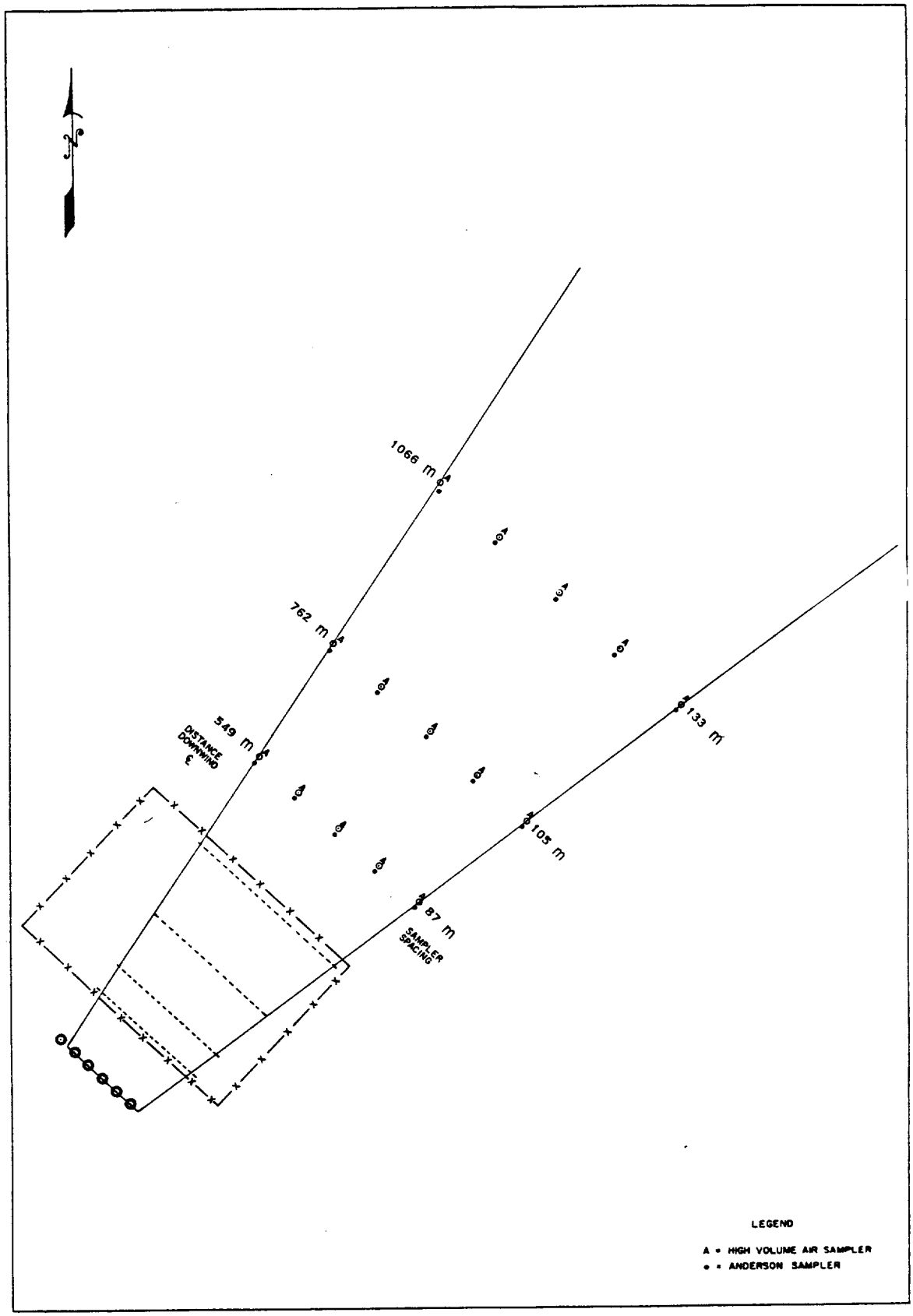


Fig. 3 Sampling grid -- long distance.

0023512

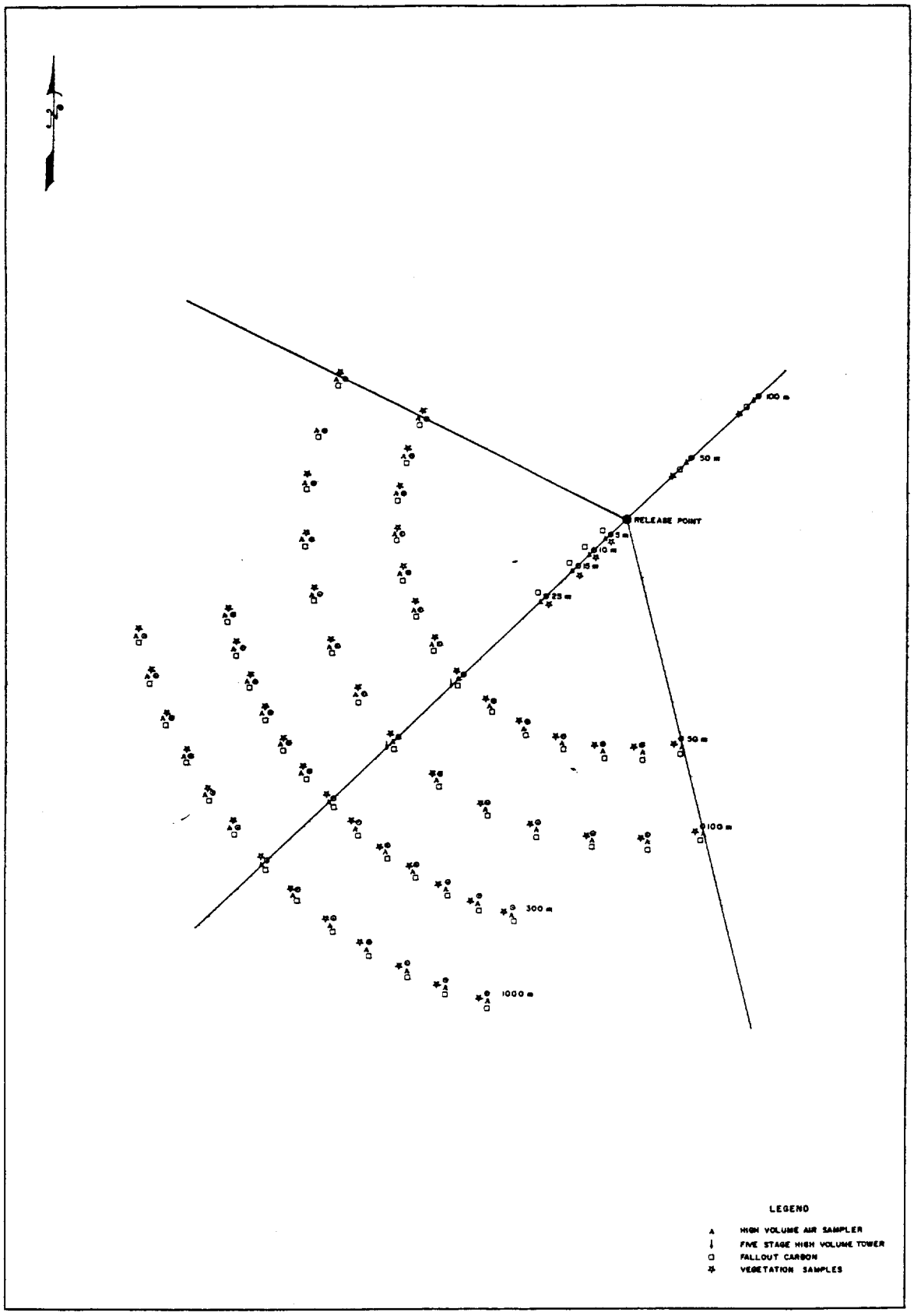


Fig. 4 Inversion test grid.

The sand was deleted during CERT II. Anderson particle size samplers were used at selected locations. A typical sampling station (excluding the Anderson sampler) is shown in Figure 5.

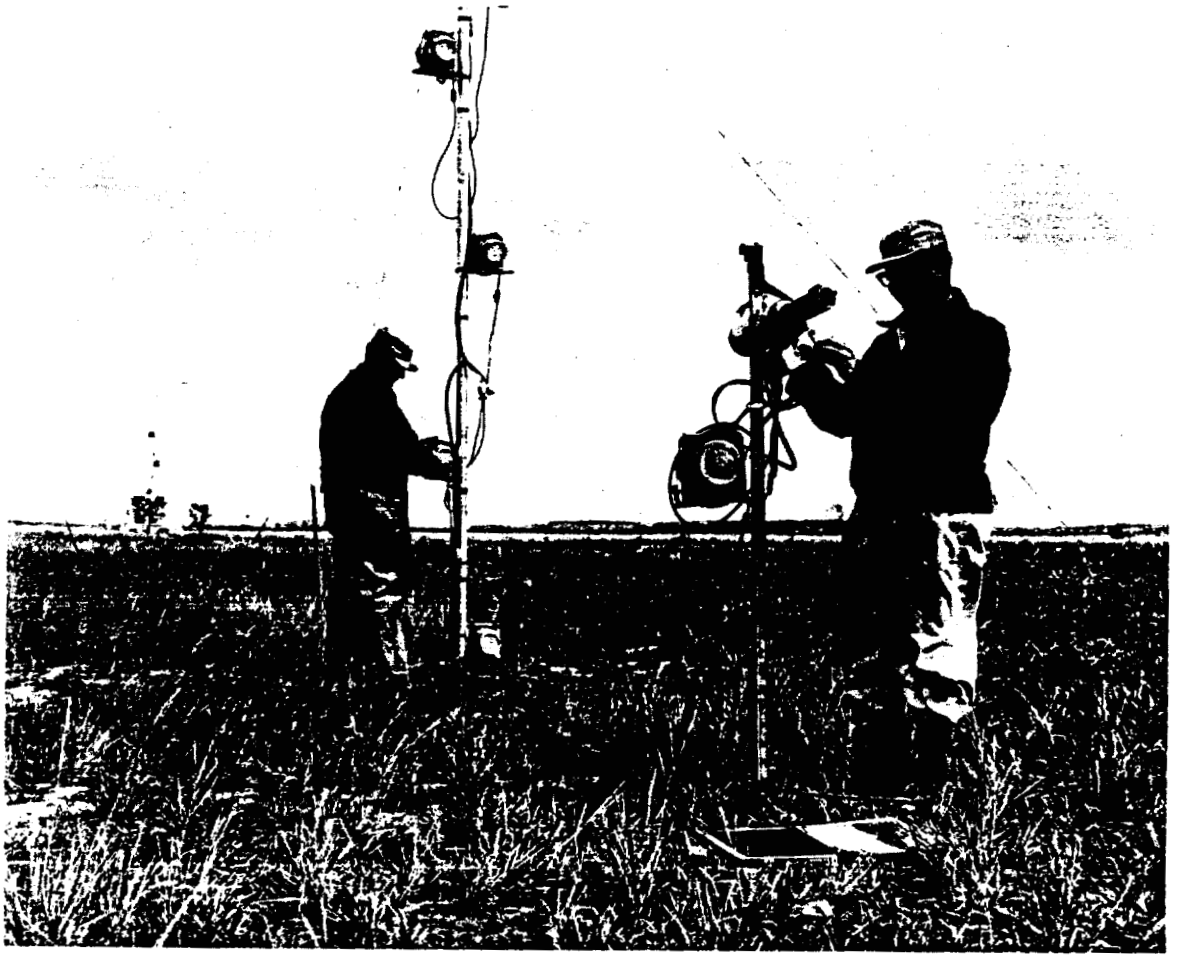


Fig. 5 Sampling equipment -- CERT II.

2. IODINE RELEASE MECHANISM

The same method of releasing the radioiodine was employed in four of the five tests reported herein. A detailed description of the method can be found in IDO-12035.

During CERT I, General Electric personnel from Hanford utilized the iodine release to check some experimental samplers. After returning to Hanford, they independently checked the release system employed and reported that "The generation technique was tested in the laboratory and found to produce elemental iodine gas which was not collected by membrane filters....." [3].

0023514

3. METEOROLOGICAL ASPECTS

Measurements of wind speed and temperature profiles and vertical and horizontal turbulence statistics were made during each release from 1 to at least 16 meters above the surface. A summary of the temperature, wind, and stability for each release is given in Table II. The Richardson number, Ri, shows the wide variation of atmospheric stability encompassed by the releases.

TABLE II

METEOROLOGICAL CONDITIONS DURING CERT RELEASES

Meteorological Parameter	CERT I	CERT II	CERT III	CERT IV	CERT V
Temperature at 1m (°C)	22.3	16.8	-1.9	-1.8	9.9
Relative Humidity (percent)	21.0	32.0	71.0	99.0	74.0
Wind Speed at 4m(m/s)	7.1	9.3	6.0	3.1	3.7
R_i(4-16m) (Stability Parameter)	-0.13	-0.10	-0.04	+0.54	+0.10

The relative crosswind integrated concentrations, shown in Figure 6, also indicate the stability of the atmosphere. The crosswind integrated concentration at a given distance downwind is inversely related to stability. The first two releases were conducted during unstable conditions in the afternoon. CERT III was conducted in near neutral conditions with low cloudiness and snow cover. The last two CERT's were conducted during stable conditions at sunrise.

Table III summarizes the median deposition velocities on the various media for all of the releases. The deposition velocities were calculated by dividing the total activity deposited on the medium per unit area by the total integrated concentrations from the high volume air samplers at the 1-meter level. Median values were used to minimize the effect of skewed distributions. The grass deposition velocity during CERT IV was omitted because background problems existed. The deposition on grass was also calculated on a mass basis to minimize the effects of grass density changes on the deposition per unit area. An empirical study of the relationship between grass density and deposition velocity using data

0023515

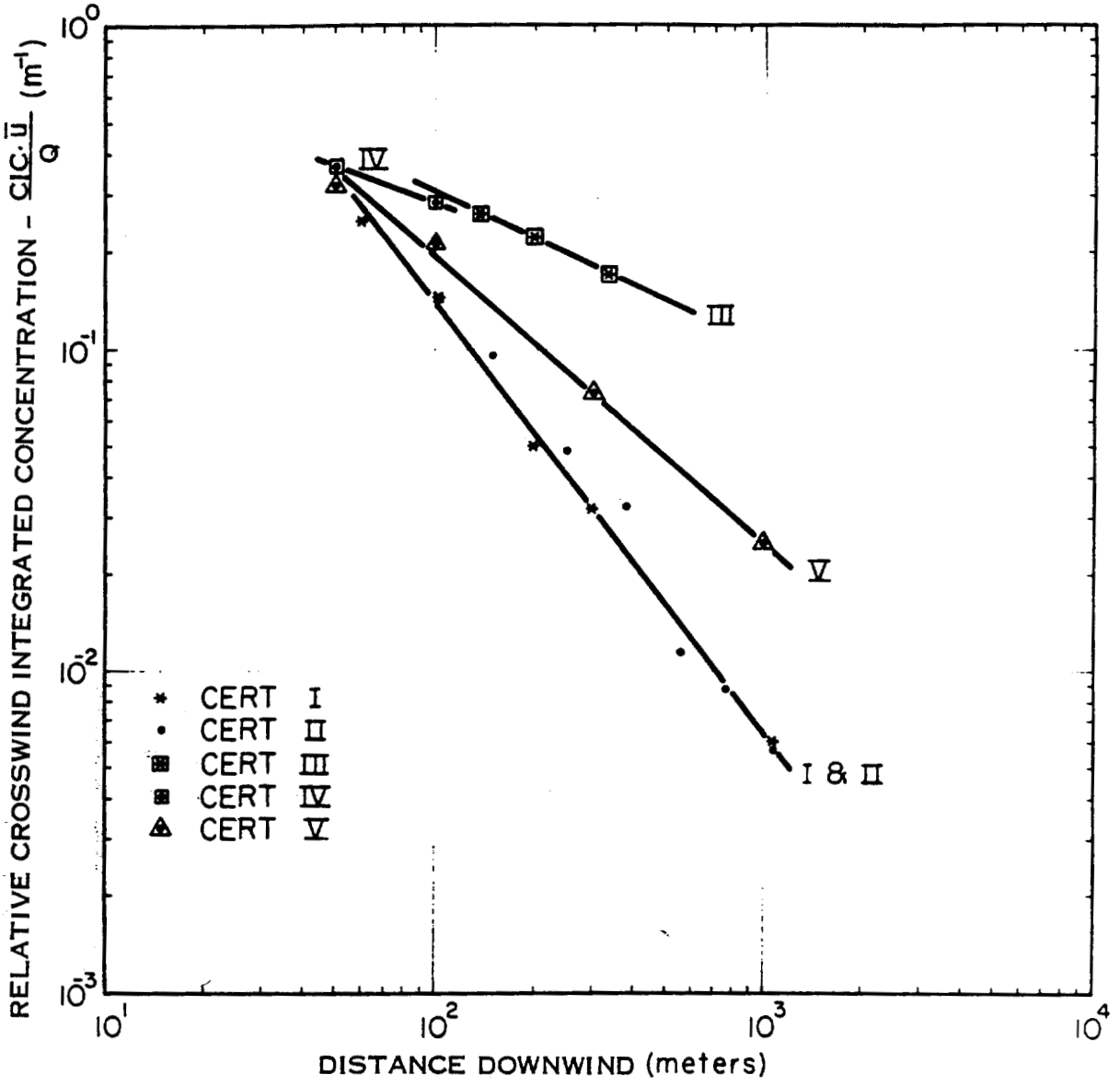


Fig. 6 Relative crosswind integrated concentration.

from the CERT II release, in which the grass density varied widely, showed that about half of the variability in deposition velocity on grass could be explained by density variations.

Figure 7 shows the variation of deposition velocities on carbon plates with distance downwind. From this figure there seem to be no systematic variations with distance. However, plots of grass deposition (pCi/g), which were measured at nine distances downwind in the first two tests, indicate a systematic departure from a power law relationship for CERT I and II. This implies a systematic change of deposition velocity with distance because the integrated concentrations seem to obey a power law relationship.

0023516

TABLE III

MEDIAN DEPOSITION VELOCITIES (RATIOS)

Deposition Medium	CERT I	CERT II	CERT III	CERT IV	CERT V
Grass (cm/sec)	0.58	0.98	-	-	0.11
Grass + Soil (cm/sec)	1.38	1.33	-	-	-
Grass-mass Basis ($cm^3/g/sec$)	38.0	44.0	-	-	10.0
Snow (cm/sec)	-	-	0.22	-	-
Carbon Plates (cm/sec)	0.56	0.73	(0.83)	0.10	0.37
Sticky Paper (cm/sec)	0.14	0.41	0.50	-	-
Sand (cm/sec)	0.19	-	-	-	-

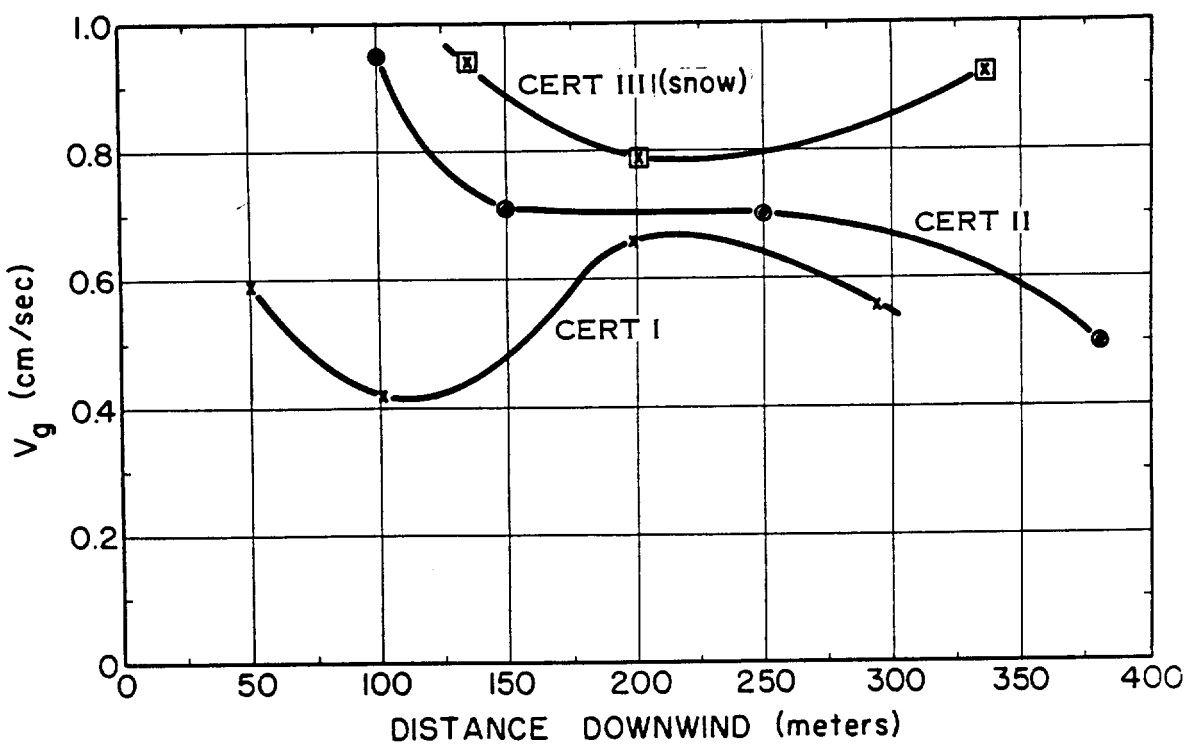


Fig. 7 Variation of carbon plate V_g with distance.

0023517

The median deposition velocities are proportional to the wind speed and are, therefore, in general accordance with theory. The only exceptions are the carbon and sticky paper deposition velocities for CERT III. During this test, some snow had been deposited on the plates and therefore the data are not considered to be reliable. The deposition velocity of 0.22 cm/sec on snow seems to be in agreement with the findings of other investigators.

4. MILK STUDIES

The general methods of collection, handling, and counting milk samples have not changed appreciably from those reported in IDO-12035. Table IV shows the average daily milk production and Table V shows the average daily iodine-131 concentration in milk for CERT II. All iodine-131 values are corrected for decay to time of milking. The cows were placed on the contaminated pasture at 1100 hrs on September 3, 1964.

Figure 8 illustrates several important points. It shows (a) the immediate rise in the iodine-131 content in the milk the day the cows went on contaminated pasture; (b) that the peak activity was reached on September 5 (on second full day of grazing); and (c) a decline of iodine-131 activity in milk for a period of 12 days, which was probably due to ever-decreasing ingested activity. The rise in iodine activity in milk on September 14 is a result of the cows accidentally leaving the controlled pasture and grazing for a time on more highly contaminated pasture. The graph also demonstrates the I-131 concentrations in milk after removal of cows from contaminated pasture. The three observations made on the effective half-life of I-131 in milk after the cows were removed from the contaminated pasture are in good agreement with values reported in IDO-12035 and with findings of Kahn [4] and Lengemann [5]. During the first two or three days, the observed half-life of iodine in milk was approximately one day with the half-life increasing to as much as three days on the fifth day (Figure 9).

A comparison of total ingested activity with the total activity accumulated in the milk (Table VI, Figure 10) shows that about 10 percent of the ingested iodine is recovered in the milk of the dairy cow (9.3 percent recovery during

TABLE IV

MILK PRODUCTION PER DAY, IN LITERS -- CERT II

	9/3/64	9/4/64	9/5/64	9/6/64	9/7/64	9/8/64	9/9/64	9/10/64
High	12.8	16.6	14.8	15.6	14.6	15.1	15.5	15.6
Average	11.6	13.4	12.9	13.2	12.9	12.8	12.9	13.2
Low	10.6	10.7	11.8	11.1	11.6	10.6	11.5	11.1

	9/11/64	9/12/64	9/13/64	9/14/64	9/15/64	9/16/64	9/17/64	9/18/64
High	14.0	14.6	15.6	14.4	15.4	14.0	14.2	13.5
Average	12.4	12.7	12.0	12.4	12.1	12.0	11.5	11.2
Low	9.9	9.8	8.4	8.5	8.5	8.8	7.5	8.9

	9/19/64	9/20/64	9/21/64	9/22/64	9/23/64	9/24/64	9/25/64	9/26/64
High	13.0	12.1	12.5	13.5	12.5	12.5	13.5	13.2
Average	10.9	10.7	11.2	10.9	10.7	10.6	10.8	11.0
Low	8.1	8.0	9.2	8.7	8.4	7.8	8.0	8.0

	9/27/64	9/28/64
High	13.6	12.2
Average	11.1	10.0
Low	8.1	7.2

TABLE V

μCi/l OF I-131 ACTIVITY IN MILK -- CERT II

	9/3/64 (p.m.)	9/4/64 (a.m.)	9/4/64 (p.m.)	9/5/64 (a.m.)	9/5/64 (p.m.)	9/6/64 (a.m.)	9/6/64 (p.m.)
High	0.068	0.104	0.130	0.138	0.131	0.104	0.146
Average	0.043	0.054	0.066	0.071	0.066	0.057	0.068
Low	0.021	0.021	0.034	0.024	0.024	0.022	0.023

Daily Average

	9/4/64	9/5/64	9/6/64
High	0.117	0.134	0.125
Average	0.060	0.068	0.063
Low	0.027	0.024	0.022

	9/7/64 (a.m.)	9/7/64 (p.m.)	9/8/64 (a.m.)	9/8/64 (p.m.)	9/9/64 (a.m.)	9/9/64 (p.m.)	9/10/64 (a.m.)	9/10/64 (p.m.)
High	0.117	0.125	0.107	0.114	0.083	0.091	0.091	0.094
Average	0.057	0.060	0.052	0.055	0.044	0.045	0.042	0.042
Low	0.015	0.019	0.018	0.019	0.014	0.014	0.013	0.013

TABLE V (Cont.)

μCi/l OF I-131 ACTIVITY IN MILK -- CERT II

Daily Average

	9/7/64	9/8/64	9/9/64	9/10/64
High	0.121	0.110	0.087	0.092
Average	0.058	0.053	0.044	0.042
Low	0.017	0.018	0.014	0.013

	9/11/64 (a.m.)	9/11/64 (p.m.)	9/12/64 (a.m.)	9/12/64 (p.m.)	9/13/64 (a.m.)	9/13/64 (p.m.)	9/14/64 (a.m.)	9/14/64 (p.m.)
High	0.078	0.086	0.069	0.072	0.066	0.070	0.081	0.084
Average	0.035	0.037	0.033	0.034	0.031	0.032	0.039	0.037
Low	0.009	0.010	0.009	0.011	0.010	0.011	0.013	0.014

Daily Average

	9/11/64	9/12/64	9/13/64	9/14/64
High	0.082	0.070	0.068	0.082
Average	0.037	0.033	0.031	0.038
Low	0.011	0.010	0.010	0.013

	9/15/64 (a.m.)	9/15/64 (p.m.)	9/16/64 (a.m.)	9/16/64 (p.m.)	9/17/64 (a.m.)	9/17/64 (p.m.)	9/18/64 (a.m.)	9/18/64 (p.m.)
High	0.066	0.067	0.056	0.054	0.049	0.043	0.028	0.021
Average	0.031	0.034	0.028	0.027	0.028	0.026	0.015	0.011
Low	0.012	0.011	0.009	0.010	0.008	0.007	0.005	0.004

Daily Average

	9/15/64	9/16/64	9/17/64	9/18/64
High	0.066	0.055	0.046	0.024
Average	0.032	0.027	0.025	0.012
Low	0.011	0.009	0.007	0.004

	9/19/64 (a.m.)	9/19/64 (p.m.)	9/20/64 (a.m.)	9/20/64 (p.m.)	9/21/64 (a.m.)	9/21/64 (p.m.)
High	0.012	0.009	0.006	0.005	0.003	0.003
Average	0.006	0.005	0.003	0.003	0.002	0.002
Low	0.002	0.002	0.001	0.001	0.001	0.001

Daily Average

	9/19/64	9/20/64	9/21/64
High	0.010	0.005	0.003
Average	0.005	0.003	0.002
Low	0.002	0.001	0.001

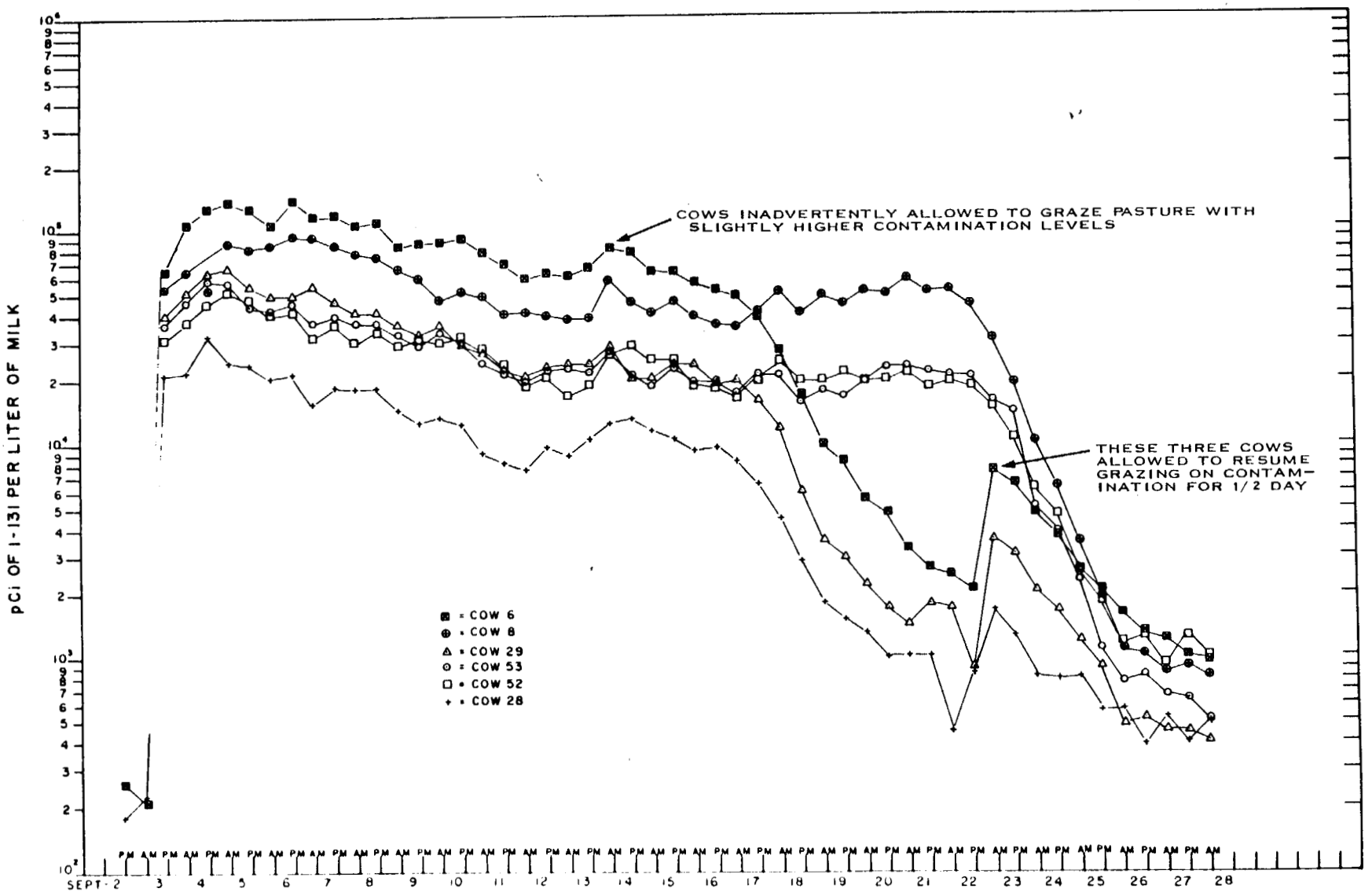


Fig. 8 Iodine-131 activity in cows' milk -- CERT II.

0023521

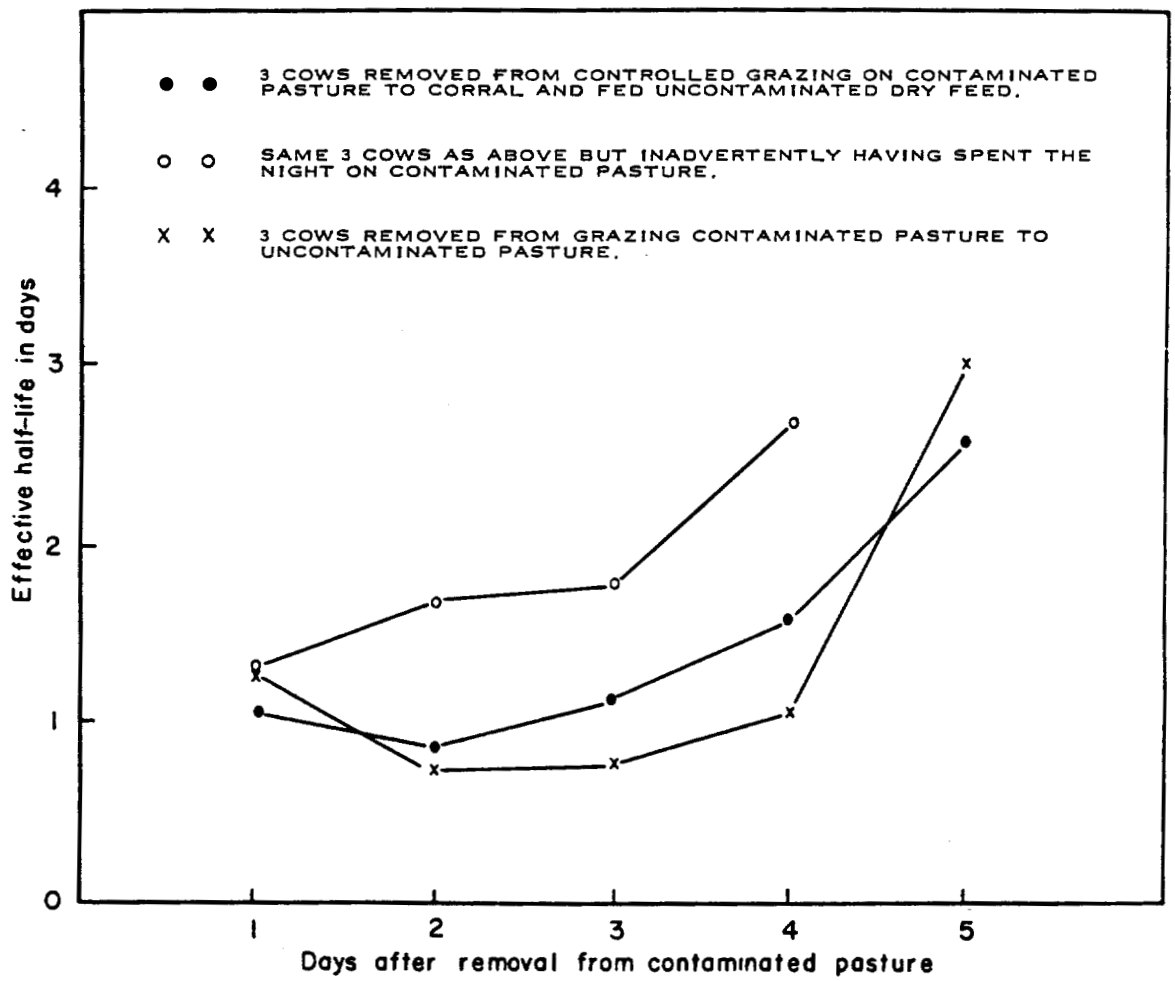


Fig. 9 Effective half-life in milk -- CERT II.

CERT I and 9.7 percent recovery during CERT II). This is a particularly interesting close comparison since it has been postulated by Lengemann et al [5] and Glascock [6] that iodine recovery in the milk may vary with stage of lactation, time of year, and level of milk production. In this instance, all three of these factors were quite different during CERT I and CERT II, and yet the results from these two tests were quite close. This was probably due to a "balancing out" of the involved factors.

The CERT II data, with respect to clean-out time of the milk, milk-grass ratios, and percent recovery of ingested activity, are in very good agreement with those found during CERT I.

TABLE VI

TOTAL CONSUMPTION BY COWS

Wet Weight Basis -- CERT I

Date	pCi of I-131/g of Vegetation	kg of Vegetation Consumed/Cow/Day	pCi($x10^6$) of I-131 Consumed/Cow/Day	Total pCi($x10^6$) Consumed by All Cows
5/28/64	770	36	27.7	166.2
5/29/64	416	36	14.9	89.4
5/30/64	237 (est)	36	8.5	51.0
5/31/64	145	36	5.2	31.2
6/1/64	180	36	6.4	38.4
6/2/64	124	36	4.4	26.4
6/3/64	81	36	2.9	17.4
6/4/64	63	36	2.2	13.2
6/5/64	78	36	2.8	16.8
6/6/64	112	36	4.0	24.0
6/7/64	93	36	3.3	19.8
6/8/64	86	36	3.9	18.0
6/9/64	38	36	1.3	7.8
6/10/64	54	36	1.9	11.4
6/11/64	24	36	0.8	5.1

Dry Weight Basis -- CERT II

Date	pCi($x10^5$) kg of Vegetation	kg of Vegetation Consumed/Cow/Day	pCi($x10^6$) of I-131 Consumed/Cow/Day	Total pCi($x10^6$) Consumed by All Cows
9/3/64	14.5	7.4	10.73	64.38
9/4/64	16.8	6.8	11.42	68.52
9/5/64	11.6	8.3	9.62	57.72
9/6/64	9.0	9.2	8.2	49.20
9/7/64	6.6	8.5	5.61	33.66
9/8/64	4.7	9.9	4.65	27.90
9/10/64	4.8	9.5	4.56	27.36
9/11/64	4.5	9.0	4.05	24.30
9/12/64	3.5	9.2	3.42	20.52
9/13/64	3.9	8.7	3.39	20.34
9/14/64	3.7	8.6	3.18	19.08
9/15/64	3.5	8.5	2.97	17.82
9/16/64	3.1	8.5	2.63	15.78

0023524

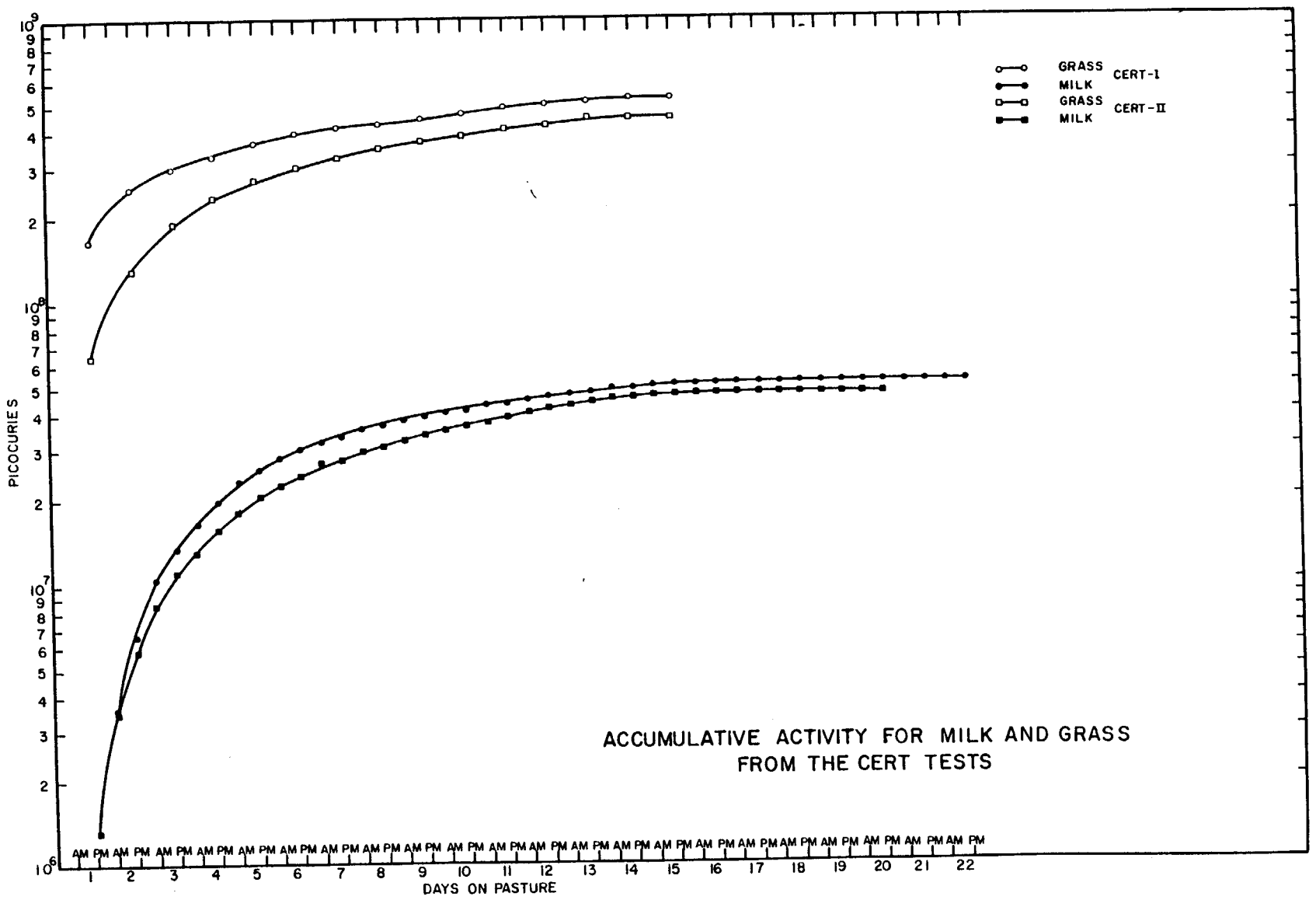


Fig. 10 Total accumulated ingested and recovered activity -- CERT I and II.

5. GRASS STUDIES

The following provides a comparison of initial deposition and daily pasture activity for the CERT I and CERT II, with suggested explanations for the differences which occurred.

Immediately following each release, grass samples were collected from nine arcs which intersected the grid. Samples collected on Arc I were gathered at 22.8-m intervals along the arc, and samples collected on Arcs II through V were gathered at 30.5-m intervals along the arcs. Samples collected on Arcs A through D were gathered at the base of each air sampling station. Over 100 grass samples were collected to ascertain the uniformity of the initial deposition of iodine-131 on the pasture (Figure 11).

Each grass sample consisted of several "grab" samples, ie, several handfuls of grass clipped about one inch above the ground and placed in a plastic bag. The sample was weighed and put in a one-quart ice cream container for counting. All grass samples were counted in a 12.7- x 12.7-cm thallium-activated sodium iodide well crystal coupled to a conventional pulse scaler. Background activity in count/min/g were subtracted from each sample before applying the proper efficiency and conversion factor for reporting the results in picocuries per gram of grass.

The pasture was divided into strips for grazing and each strip was sampled daily to determine the activity on the grass. Twenty samples were collected each day. The grass samples were collected the morning the pasture was used, with exceptions, before the cows were released to graze. The exceptions were Saturday, September 12, and Sunday, September 13. The samples from these pastures were collected and counted on Friday, September 9. Decay factors were applied to the September 11 counting results to arrive at the pasture activity for these two days.

A daily grass sample consisted of a square meter of grass pulled by hand, rather than cut, from the ground which left a stubble about one inch high. Each sample was prepared and counted as previously described. The grass was pulled for removal because this method of collection closely approximated the way the cows were observed to graze the grass, where as the clipping method did not because it was too "clean". Since the grass samples were used not only to determine the activity of the grass but to measure forage and consumption, this sampling technique was adequate.

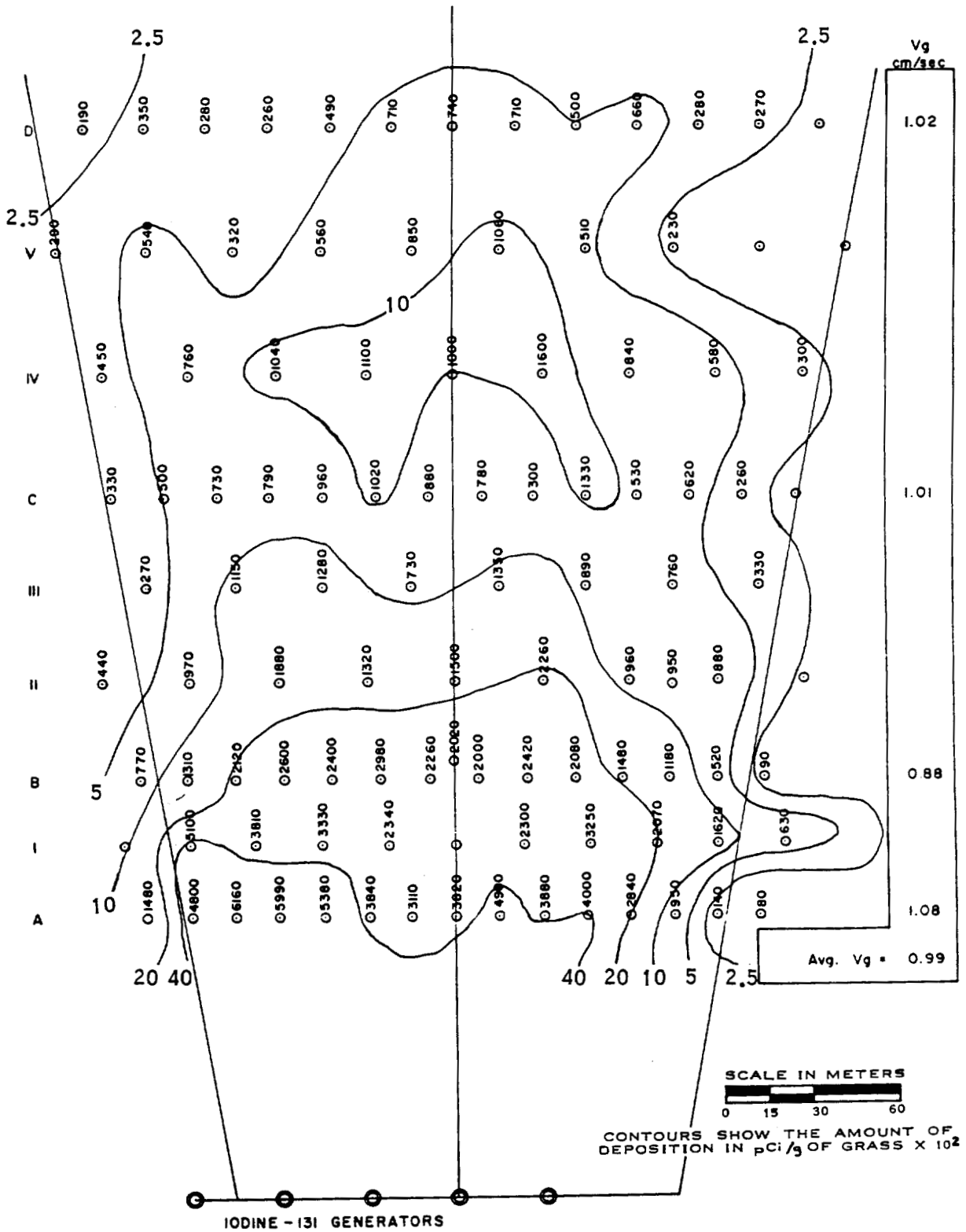


Fig. 11 Initial deposition -- CERT II.

In addition to wet weight activity measurements, dry weight activity was measured. After the wet samples were counted, they were placed in a drying oven at 85°C for about 18 hours. This was sufficient to thoroughly dry the samples. For recounting, the dried samples were returned to the same plastic bags from which they were originally taken. Background counts for dry material were subtracted before the counts were converted to picocuries of iodine-131 per gram of dry grass. The average percent weight loss of fresh grass was approximately 71.

Table VII presents the average activity per gram of grass, wet weight and dry weight, for each day's pasture. Tables VIII and IX present the data from which these averages were derived. The values in Table VII represent activity for about midday.

A comparison of the activity of wet and dry grass samples indicates that, even after adjustment for decay, there was a loss of iodine-131 from the dried grass samples. The dried samples consistently counted lower than the wet samples by an average of eight percent.

In order to determine a half-life on the grass, ten samples consisting of the grass included in one-half square meter, were collected for several days. These samples were collected from a part of the pasture immediately downwind of Arc A and to the left of the centerline where the grass density and iodine-131 deposition were relatively uniform. Since the samples were gathered from the same general area day after day, on an area basis any iodine loss from the pasture, other than that which can be attributed to physical decay, should have been apparent. The average of the ten samples collected each day was convered to picocuries for a data point to plot. The data points and fitted line are presented in Figure 12. The results indicate a 5.5 ± 0.75 day half-life (95 percent confidence interval on the 5.5 day value) on the grass.

TABLE VII

AVERAGE GRASS ACTIVITY -- CERT II

	pCi/g Grass, Wet, 95% Confidence Interval for Mean	pCi/g Grass, Dry, 95% Confidence Interval for Mean
9/3/64	530 ± 80	1450 ± 210
9/4/64	370 ± 40	1680 ± 240
9/5/64	360 ± 60	1160 ± 180
9/6/64	300 ± 40	900 ± 130
9/7/64	200 ± 50	660 ± 150
9/8/64	190 ± 30	470 ± 50
9/9/64	170 ± 30	480 ± 70
9/10/64	160 ± 30	450 ± 60
9/11/64	140 ± 20	350 ± 40
9/12/64	120 ± 20	390 ± 50[a]
9/13/64	120 ± 20	370 ± 60[a]
9/14/64	110 ± 20	350 ± 50
9/15/65	110 ± 20	310 ± 50
9/16/64	100 ± 10	270 ± 50

[a] Estimated. Cows inadvertently grazed slightly higher areas of contamination.

0023527

TABLE VIII

ACTIVITY OF PASTURE SAMPLES IN pCi/g, WET WEIGHT -- CERT II

Sample Number	9/3/64	9/4/64	9/5/64	9/6/64	9/7/64	9/8/64	9/9/64	9/10/64	9/11/64	9/12/64[a]	9/13/64[a]	9/14/64	9/15/64	9/16/64
1	510	190	170	180	180	140	50	100	120	100	120	80	90	90
2	730	300	210	210	190	250	150	110	110	150	150	125	80	90
3	400	370	280	200	190	150	120	110	120	90	90	80	60	90
4	490	390	310	300	130	140	160	110	100	100	110	80	80	70
5	610	300	240	190	60	120	140	100	90	80	70	60	60	70
6	760	350	380	260	160	170	190	130	120	100	130	120	100	80
7	630	360	400	310	200	190	190	130	80	100	130	120	100	120
8	610	290	360	250	80	140	150	130	120	130	110	140	90	120
9	510	300	310	300	190	160	140	140	160	145	130	80	110	140
10	470	450	420	340	260	210	290	220	200	160	170	130	120	150
11	850	420	400	310	280	210	160	170	150	120	230	100	90	90
12	950	450	450	310	110	240	190	150	120	180	160	140	130	120
13	500	580	580	510	390	250	250	150	210	180	230	140	120	100
14	350	410	380	290	110	260	190	280	110	220	210	200	250	100
15	360	440	410	330	290	200	220	210	130	110	160	110	110	80
16	300	520	610	520	320	260	320	230	300	180	220	140	150	110
17	380	420	530	350	440	290	200	230	100	170	90	70	110	80
18	410	310	290	260	240	170	140	130	140	140	120	100	110	90
19	330	360	190	240	50	140	50	90	90	110	100	120	70	80
20	480	250	250	250	70	100	40	170	120	90	90	70	110	80
	10,630	7460	7170	5910	3940	3790	3340	3090	2690	2655	2820	2205	2120	1950
	$\bar{x}$ = 531 σ = 179	$\bar{x}$ = 373 σ = 93	$\bar{x}$ = 358 σ = 130	$\bar{x}$ = 295 σ = 90	$\bar{x}$ = 197 σ = 109	$\bar{x}$ = 190 σ = 55	$\bar{x}$ = 167 σ = 73	$\bar{x}$ = 155 σ = 53	$\bar{x}$ = 135 σ = 51	$\bar{x}$ = 133 σ = 39	$\bar{x}$ = 141 σ = 49	$\bar{x}$ = 110 σ = 34	$\bar{x}$ = 107 σ = 41	$\bar{x}$ = 97 σ = 23

[a] Calculated on 9/11 and decayed.

0023528

TABLE IX

ACTIVITY OF PASTURE SAMPLES IN pCi/g, DRY WEIGHT -- CERT II

Sample Number	9/3/64	9/4/64	9/5/64	9/6/64	9/7/64	9/8/64	9/9/64	9/10/64	9/11/64	9/14/64	9/15/64	9/16/64
1	1080	660	550	570	510	370	140	250	240	190	270	250
2	1580	1090	590	600	600	410	380	230	230	310	260	250
3	1040	1140	710	650	640	340	310	260	210	200	210	190
4	1330	1410	840	580	470	300	390	220	200	200	250	200
5	1620	950	750	540	240	310	360	190	210	190	200	270
6	1540	1210	1100	720	460	310	480	260	260	330	290	230
7	1500	1560	1130	960	630	340	540	290	240	300	280	290
8	1820	1220	1120	730	250	430	460	320	310	330	300	270
9	1330	1940	970	960	680	380	360	300	310	200	300	250
10	1240	1870	1190	1060	800	390	530	410	340	340	330	370
11	2040	1880	1370	740	820	460	450	340	300	310	260	260
12	2380	2210	1570	1070	480	570	540	350	290	380	370	320
13	1490	2360	1390	1100	1060	530	660	330	350	380	300	250
14	800	1330	1310	850	240	510	460	570	290	530	590	240
15	930	1890	1220	860	830	420	570	360	280	310	340	260
16	980	2290	1850	1490	1010	450	690	410	500	400	310	270
17	950	1970	1450	1050	1180	470	550	460	230	220	270	210
18	1030	1100	840	770	770	330	400	300	270	260	310	230
19	990	1300	570	460	140	340	300	220	170	340	160	220
20	980	1400	700	860	160	220	160	250	210	180	170	170
	26,650	30,780	21,220	16,620	11,970	7880	8730	6320	5440	5900	5770	5000
	$\bar{x}$ = 1330 σ = 415	$\bar{x}$ = 1539 σ = 481	$\bar{x}$ = 1061 σ = 365	$\bar{x}$ = 831 σ = 248	$\bar{x}$ = 599 σ = 303	$\bar{x}$ = 394 σ = 87	$\bar{x}$ = 440 σ = 144	$\bar{x}$ = 316 σ = 93	$\bar{x}$ = 272 σ = 72	$\bar{x}$ = 295 σ = 91	$\bar{x}$ = 289 σ = 89	$\bar{x}$ = 250 σ = 45

0023529

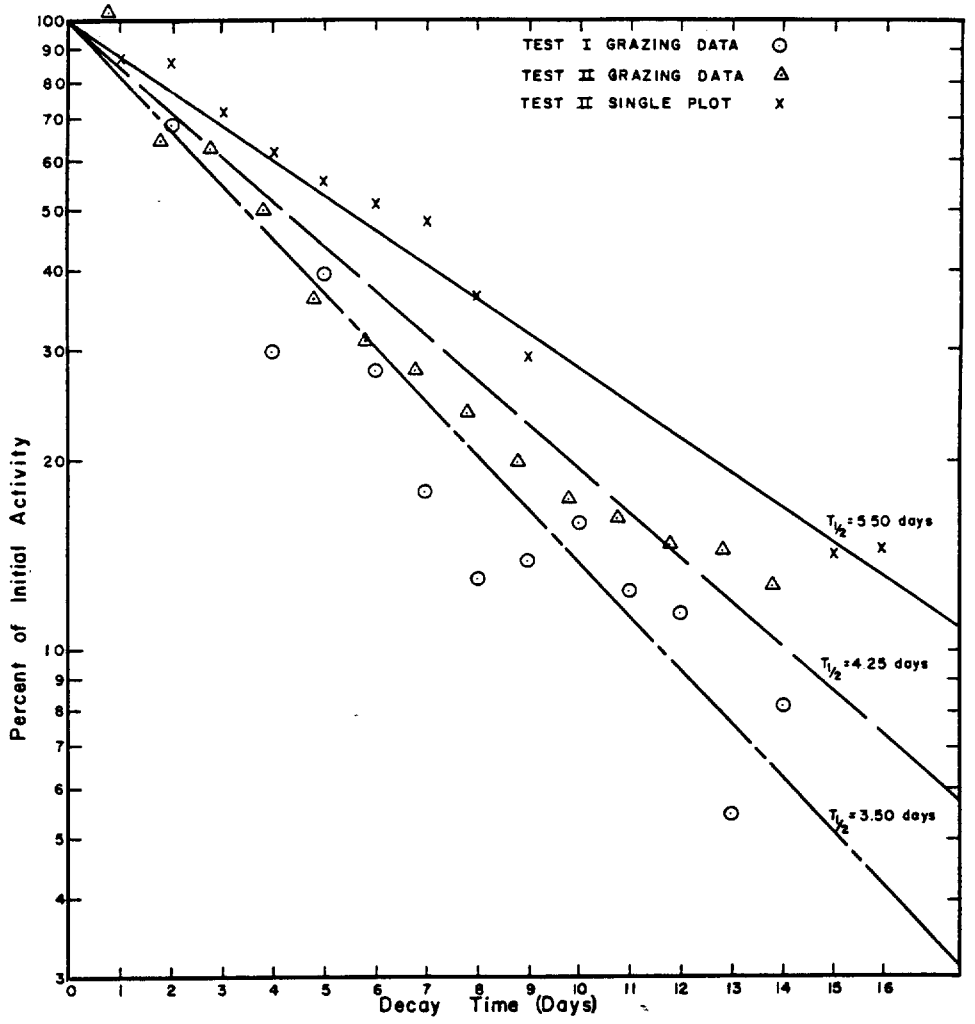


Fig. 12 Grass half-life data.

If the distance of the iodine generators from the edge of the grid is taken into consideration (CERT I -- 50 meters; CERT II -- 100 meters), the activity of iodine on the grass in count/min/g, on Arc B, CERT I, should be approximately equivalent to the activity on Arc A, CERT II, because the two tests were run under similar meteorological conditions and the amount and release rate of iodine were the same.

A comparison of the initial deposition data between CERT I and CERT II, considering the adjusted juxtaposition of the arcs, indicates that the activity is approximately the same for all arcs except two. Arcs A and I of the second test differ from their equivalent arcs in the first test, in this case Arcs B and II, by less than a factor of two; the activity being higher for the second test. Since the daily pasture strips were constructed on the downwind part of the pasture, ie, near Arc D, the activity on the grass where the cows were grazed was approximately equivalent at the beginning of each test. Thus, it would

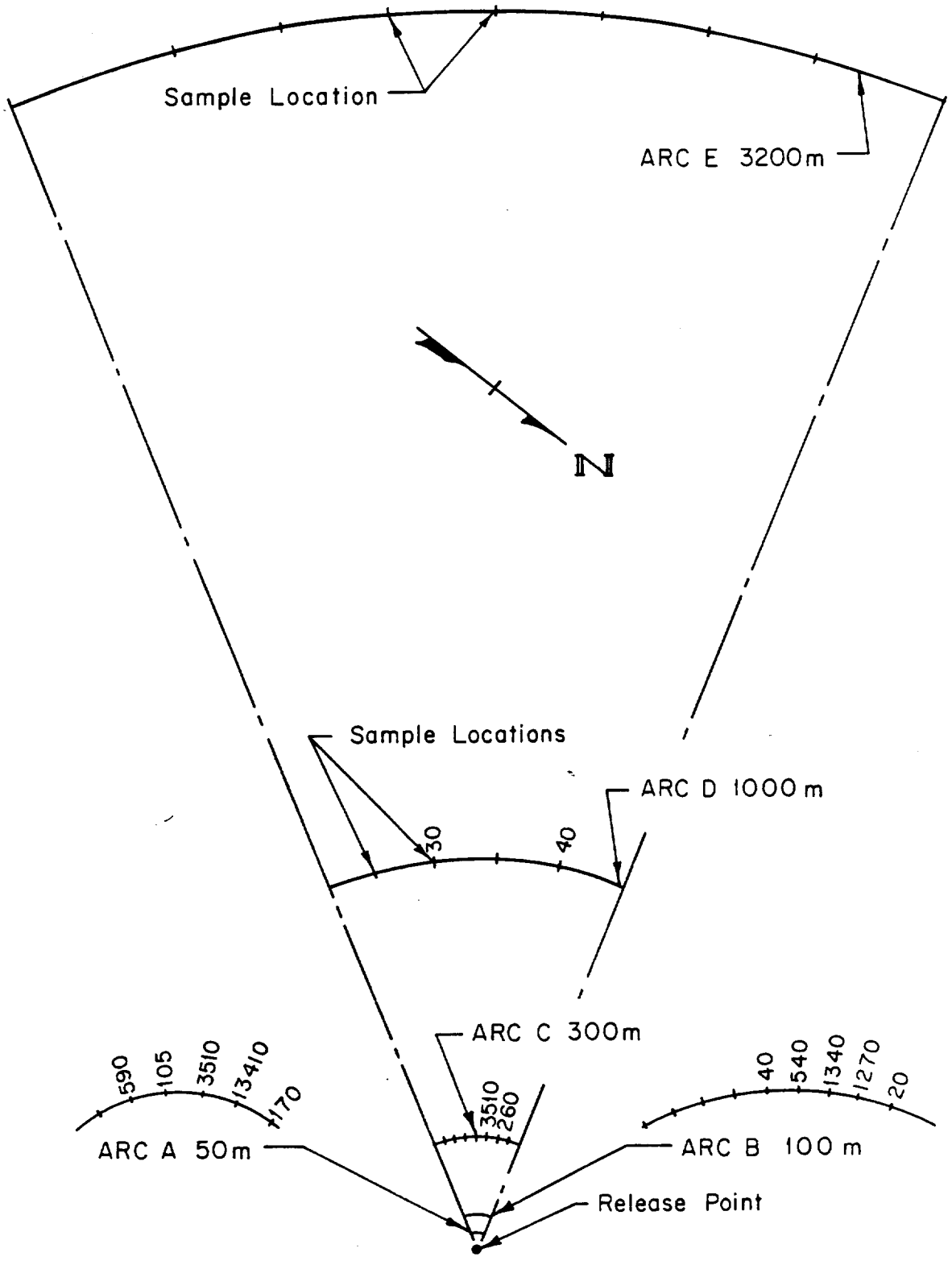
be expected that the activity on each day's pasture would be about the same for each test. A comparison of the daily pasture activity for the two tests indicates, however, that the activity on the CERT II pastures averaged about 80 percent higher than the activity on the CERT I pastures. This suggests that the effective half-life of iodine on the grass was shorter for CERT I than it was for the CERT II. The grass half-life measurements for the two tests indicate that this was indeed the case. The calculated half-life on grass for CERT I is 3 to 4 days. Grass growth, which was a consideration during CERT I but negligible during CERT II, was taken into consideration in this calculation. The calculated (using daily grazing strip data below) half-life on grass for CERT II is 4 to 5 days, and a measured half-life is 5 to 6 days. The measured half-life resulted from sequential sampling of an area set aside expressly for half-life determinations.

If this difference in half-life is taken into consideration, the daily pasture activity becomes roughly equivalent for the two tests. Moisture content of the grass, which could effect the results when reported as count/min/g, was about the same for grass of each test; 66 percent for CERT I and 71 percent for CERT II.

As of now, there is no satisfactory or proven explanation as to why there was a different grass half-life between the first and second tests. There are, however, two factors which might have influenced the results; time of year and rain. The first CERT test was conducted in late May and early June; the second test was conducted in early September. Since time of year probably influences the metabolic processes of the grass, and if the metabolic processes somehow influence the rate of iodine loss from the plant, then time of year may influence the half-life on the grass.

During the first CERT test, rainfall was recorded on 12 out of the 15 days the test was in progress. No precipitation occurred during the second CERT test. Preliminary tests in the laboratory indicate that iodine is not readily removed by washing with water; thus it seems the iodine would not be removed from the grass by rainfall. Yet the fact remains that the half-life on grass was considerably different between the CERT I and CERT II. Thompson [7] has suggested that the difference may well be attributed to grass growth.

Grass samples were collected for the CERT IV and CERT V tests. The results of this sampling were used to calculate deposition velocities for elemental iodine-131 under inversion conditions. The CERT IV release was a pilot study and these data are omitted. The results of the CERT V release, as net pCi/g of grass, are presented in Figure 13.



Sample Taken Of $1m^2$, 4" Stubble – Avg. Density = 134 g/m^2 – Avg Cover 14%
Numbers Shown Are Net Activity pCi/g Of Grass.

Fig. 13 Deposition of I-131 on grass -- CERT V.

0023532

6. HUMAN THYROID DOSE STUDIES

6.1 Ingestion Studies

During CERT I, one cow was selected to furnish milk for consumption by seven human volunteers. The measurements of thyroid uptake of radioiodine by means of *in vivo* thyroid counting techniques indicated the following uptake fractions.

Volunteer No.	Uptake Fraction
1	0.18
2	0.12
3	0.20
4	0.30
5	0.17
6	0.16
7	0.18
	Avg. 0.19

The relatively higher uptake fraction of volunteer No. 4 was possibly attributable to a lower than normal intake of stable iodine since he was using non-iodized table salt. Conversely, the lower uptake fraction of volunteer No. 2 may have been attributable to his daily intake of Kelp extract tablets containing 0.2 mg of stable iodine. The mean uptake fraction was 0.19 ± 0.04, which agrees very well with findings reported by Bernard [8], Eisenbud [9], and Los Alamos investigations [10], and is significantly lower than the value of 0.30 recommended by the International Committee on Radiation Protection (ICRP).

6.2 Inhalation Studies

Following the CERT II iodine release, inhalation dose measurements were made on three persons who were located near the midpoint of Arc D. The mean integrated radioiodine concentration in the atmosphere at that point was 14.6 ± 1.5 μCi-sec/m^3. Table X presents the quantities of iodine-131 present in the thyroid of each individual at various times after the exposure, the thyroid dose calculated for each person (assuming a 20 g thyroid), and the calculated individual thyroid uptake fraction. A standard breathing rate of 10 m^3 per eight working hours was used in the latter calculation. The uptake fractions for individuals Nos. 2 and 3 agree as well as could reasonably be expected with the ICRP recommended value of 0.23. Individual No. 1, with a mean inhalation uptake fraction of 0.47, was the same individual who exhibited the highest uptake fraction during the CERT I ingestion studies.

TABLE X

CERT II INHALATION THYROID DATA

Individual Number	Activity Measurements: Date	Time	Activity (pCi)	Dose (Mrad)	Uptake Fraction
1	9/2/64	1530	2960 ± 890	15.0	0.46
1	9/3/64	1025	2330 ± 700		
1	9/4/64	1240	1920 ± 575		
1	9/8/64	1320	1330 ± 400		
1	9/11/64	1540	1020 ± 305		
1	9/22/64	1400	325 ± 100[a]		
2	9/2/64	1550	2160 ± 650	7.7	0.24
2	9/3/64	1005	1180 ± 355		
2	9/4/64	1310	960 ± 290		
2	9/8/64	1505	630 ± 190		
2	9/11/64	1510	480 ± 145		
2	9/16/64	1330	370 ± 110[a]		
3	9/2/64	1543	1810 ± 540	6.1	0.19
3	9/3/64	1045	1030 ± 310		
3	9/4/64	1533	700 ± 210		
3	9/8/64	1355	550 ± 165		
3	9/11/64	1525	410 ± 125		
3	9/16/64	1245	260 ± 80[a]		
3	9/22/64	1530	110 ± 35[a]		

[a] Thirty minutes net counting time. All others, ten minutes net counting time.

6.3 Ingestion to Inhalation Dose Ratios

The use of an ingestion-to-inhalation-dose ratio in the evaluation of potential or planned atmospheric releases of radioiodine is a practice which is gaining acceptance. The use of this ratio eliminates the need for a separate ingestion dose calculation in the preparation of reactor safety analysis reports. The treatment of this subject in the CERT I report considered only the milk ingested during he first 14 days of the test and made no correction for the short effective half-life of iodine on the grass. It was generally agreed that this treatment resulted in a value which would be too low under normal conditions with an effective iodine half-life of five days on the grass. Since the CERT I report was published, a more realistic evaluation of this ratio has been completed. Basically, this was done in the following manner. The daily concentrations of

radioiodine observed in the milk were multiplied by a factor which corrected for the nonuniformity of the pasture contamination level in the downwind direction. These correction factors were obtained by normalizing the pasture contamination level to the contamination level of the first grazing strip. Semi-log plots of the corrected and observed concentrations are presented in Figure 14. The effective half-life of the iodine in milk on the corrected curve is approximately three days. This provides substantiative evidence for the 3.5 day half-life observed on grass since the two should be about equal. The corrected curve was then extrapolated back one day to account for the one-day delay before grazing was started on the contaminated pasture. It was then calculated that a person drinking one liter of milk per day from a single contaminating event such as this would ingest a total of about 0.6 μCi of iodine-131. Based upon an uptake fraction of 0.19, this would result in 625 mrad for an adult with a 20-g thyroid. The inhalation dose calculated for an adult exposed to the average integrated concentration along the center of Arc D was 12.4 mrad. The ingestion to inhalation dose ratio for this contaminating event would be about 60, based on a breathing rate of 10 m^3 per 8 hours. Still, this was not considered a reasonable ratio due to the fact that a majority of the investigators have reported values for the effective half-life on grass of about five days.

To arrive at a more reasonable value for this ratio, a five-day half-life on grass was assumed. It was further assumed that the difference in half-life would have a minor effect on the peak iodine concentration in the milk. A plot of this postulated situation is also presented in Figure 14. This treatment yielded the following results:

Breathing rate	10 m^3/8 hrs	20 m^3/24 hrs
Inhalation dose	12.4 mrad	8.3 mrad
Total iodine ingested	0.85 μCi	0.85 μCi
Ingestion dose	920 mrad	920 mrad
Ingestion-to-inhalation-dose ratio	75	110

The CERT II data were treated in a similar manner and are presented in Figure 15. The major difference between these two treatments was that the corrected daily milk concentrations fitted a 5-day effective half-life reasonably well, so that it was not necessary to postulate a more reasonable situation. This treatment yielded the following results, again based upon the assumption previously described:

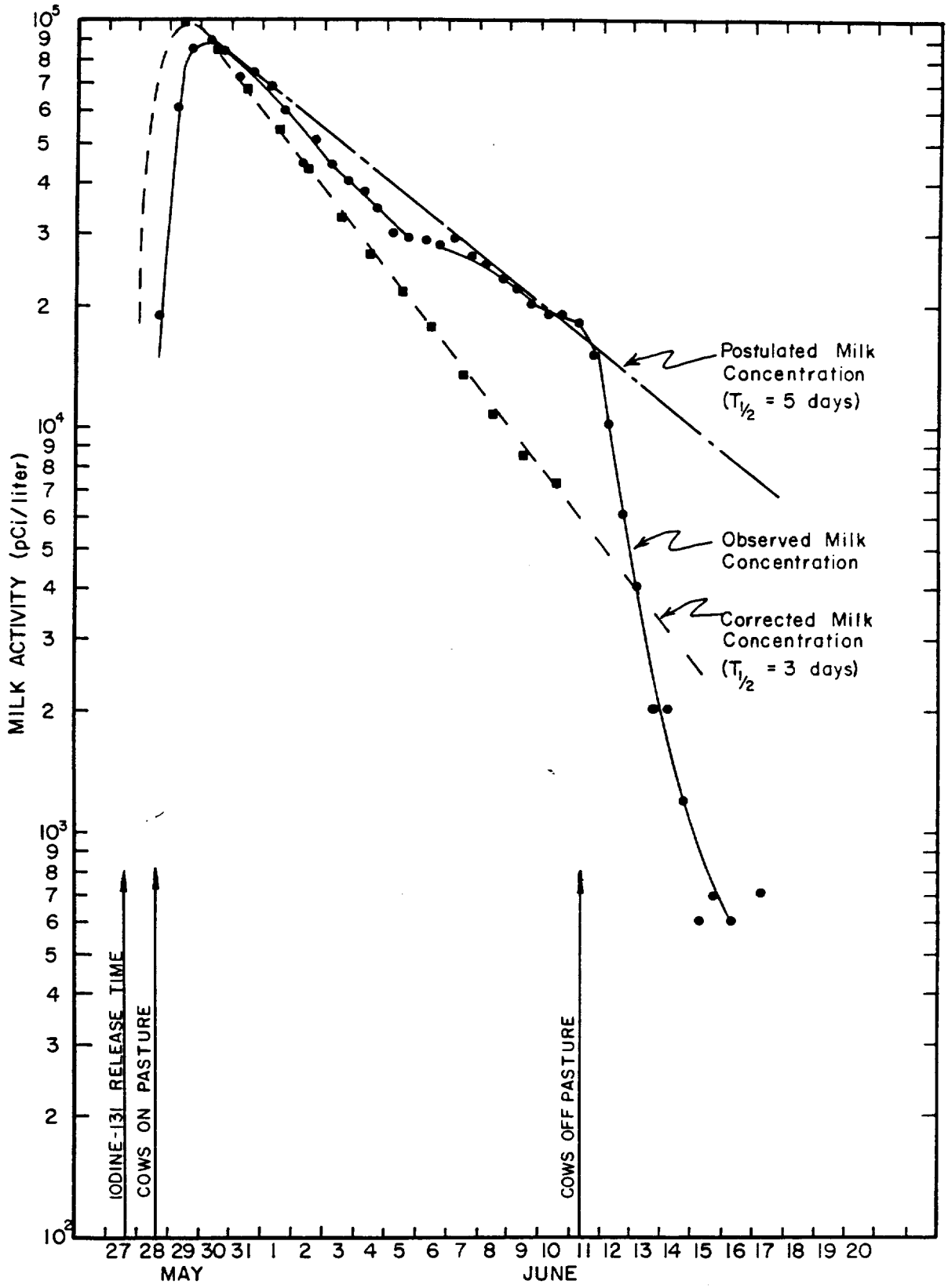


Fig. 14 Iodine-131 concentration in milk -- CERT I.

0023537

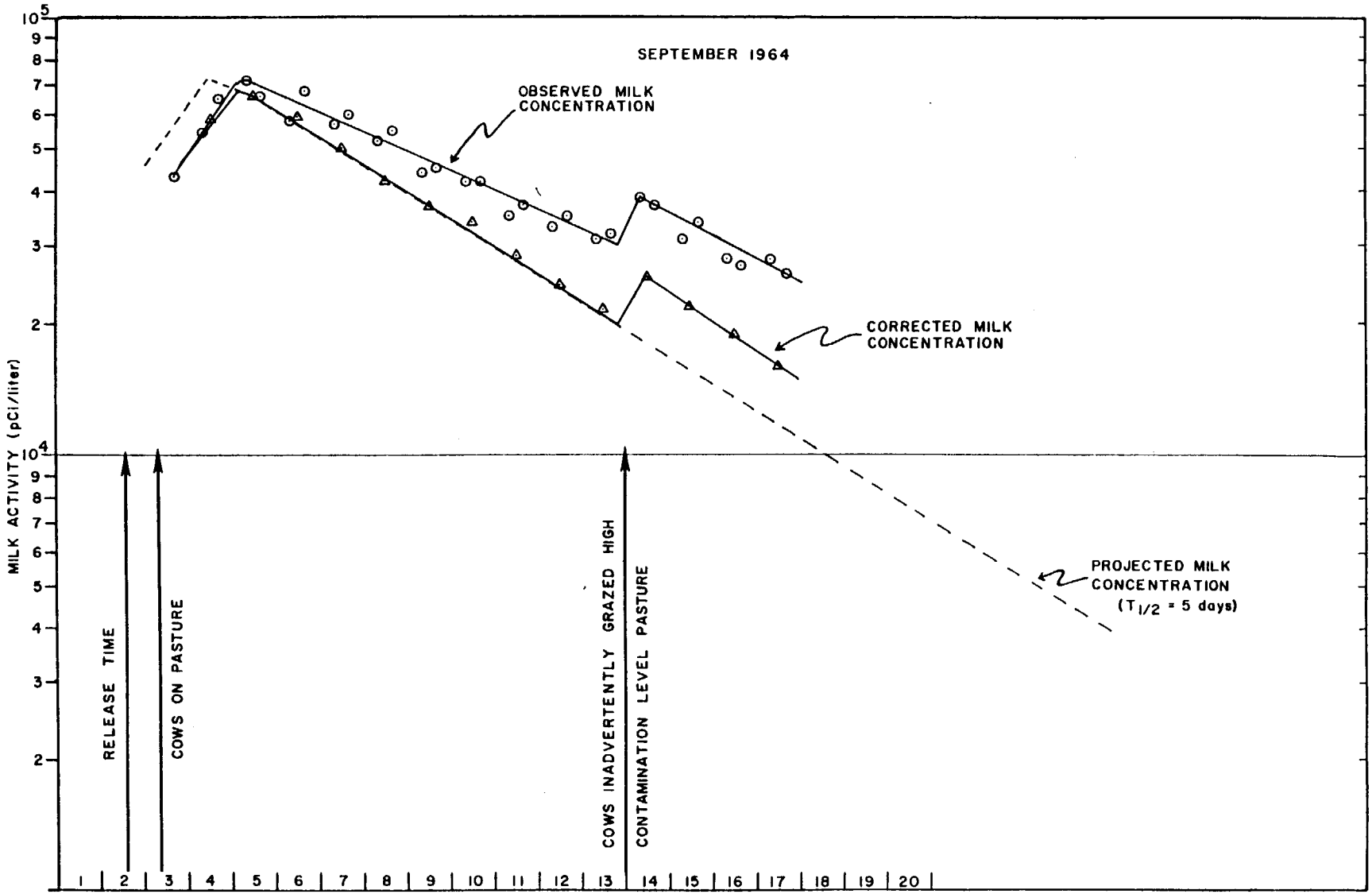


Fig. 15 Iodine-131 concentration in milk -- CERT II.

Breathing rate	10 m^3/8 hrs	20 m^3/24 hrs
Inhalation dose	7 mrad	4.7 mrad
Total iodine ingested	0.635 μCi	0.635 μCi
Ingestion dose	690 mrad	690 mrad
Ingestion-to-inhalation-dose ratio	100	150

In using the ingestion-to-inhalation-dose ratio, it should be remembered that children generally constitute the critical segment of the exposed population because of their smaller thyroid. For a given intake, the dose to the thyroid of a one year old child (thyroid weight of two grams) is about ten times that of an adult. Therefore, it appears that a reasonable ratio of a child's ingestion dose to an adult's inhalation dose would be about 1300 for a release occurring under unstable atmospheric conditions. Based on CERT V data, it would appear that this ratio may be a factor of six lower under stable atmospheric conditions. The reason for comparing this with the adult inhalation dose is that no standard breathing rate for a child has been established. It is normally assumed, however, that a child's lower air intake offsets the larger dose expected because of the smaller thyroid.

7. PARTICLE SIZE MEASUREMENTS

An important adjunct to the CERT project is knowledge of the apparent physical and chemical properties of iodine as a function of time. More specifically, some idea of the "aging" process of iodine in the atmosphere is necessary in order to more fully understand the processes by which the radioactive material is deposited or inhaled.

To this end, estimates of the apparent particle size with which I-131 was associated were made. This essentially involved two measurements:

(1) Prefilter Efficiencies. The high-efficiency prefilters used in high-volume air samplers collect essentially all particles greater than one micron in diameter (MMD). These filters collect lesser fractions of small particles. A comparison of prefilters to carbon (backup) trap activity then provides a rough estimate of apparent particle size.

(2) Activity Found on Various Stages of Anderson Samplers. The samplers segment the particles into eight groups. Comparison of the activity on the various stages gives a measure of the distribution of activity by size ranges.

Information obtained thus far indicates a rapid transformation in apparent particle size. The process by which iodine was released to the atmosphere has been shown [11] to evolve primarily the gaseous product (effective MMD $\approx$ 2 Å). The field measurements, on the other hand, show a much broader spectrum of sizes. Typical results from the Anderson samplers are shown in Figure 16. This figure indicates that the activity distribution by size corresponds closely to the normal distribution, by size, of particles in the atmosphere.

Other treatments of the Anderson data, together with the prefilter to carbon trap ratios from the High Volume air samplers, indicate an effective "splitting" of components. The iodine in the atmosphere, as detected by the sampling procedures, is separated into a gaseous component and a particle-attached component. Research [11] has demonstrated that the absorption of radionuclides onto aerosols (dust particles) does occur and may be either reversible or irreversible. To describe this process, an equation was derived [a], based upon gas kinetic collision theory, which is similar to those reported by Lassen [12] and Chamberlain [13]. This is essentially a description of the rate at which a nuclide attaches to aerosols. Its value is directly proportional to aerosol concentrations in the atmosphere. Attempts to correlate this model with test data indicate that it will adequately predict the behavior of released iodine in the atmosphere for short distances. Comparison of deposition studies by Chamberlain [14], with the observed distribution of activity by size, leads to a predicted deposition velocity of iodine on grass of about 0.9 cm/sec. This compares quite favorably with the observed V_g.

The important thing to note is that field measurements of iodine behavior must attempt to correlate theoretical studies with observed data so that a reliable methodology may be developed. In the case of particle studies it is clear that the gross behavior of iodine in the atmosphere is strongly dependent upon micro-scale events determined by the chemical and physical properties of the released material and the interacting species.

---

[a] The equation was derived using data from CERT as well as data from destructive tests at the NRTS. Full details will be published as a separate report.

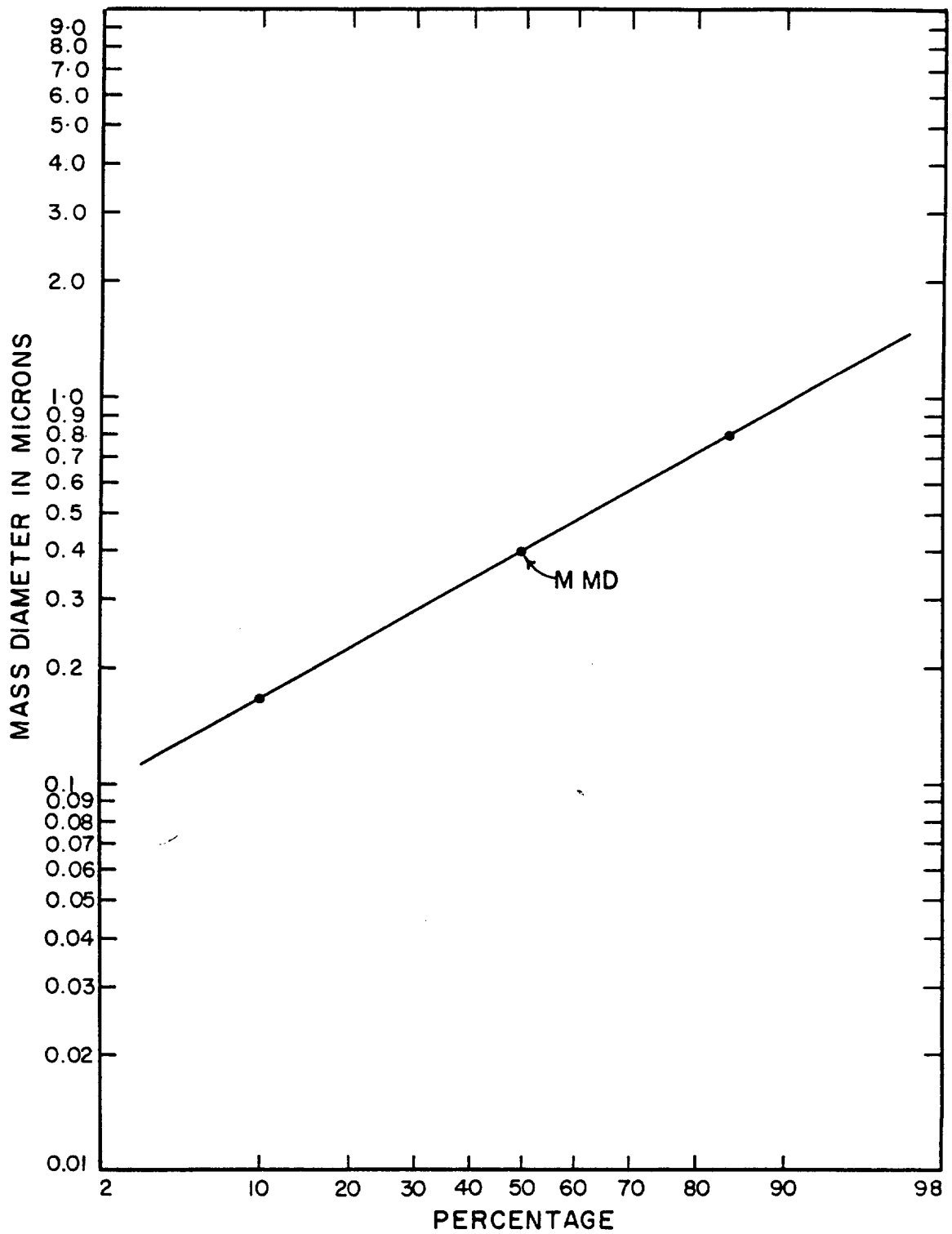


Fig. 16 Distribution of activity by particle size -- CERT II.

0023540

8. RESUSPENSION OF IODINE FROM PASTURE

A potential hazard may arise from resuspension of iodine into the atmosphere followed by entry into the human body by inhalation. The process seems to be extremely complicated. The airborne concentration will depend upon the two rate processes of resuspension and redeposition and, as such, would be expected to decrease markedly with height, except possibly for the submicron particles. A rather thorough study of this problem has been given by Stewart [15].

Two studies were undertaken in order to evaluate the problem of resuspension.

(1) Air Sampling. Low volume air samples were taken at selected areas on the grid. These samples were taken over a 24-hour period at 3 heights: 0.2, 0.5, and 2.0 meters. This provided an estimate of the post-test I-131 concentrations in air.

(2) Vegetation. Two controlled areas delineated near the center of the grid were covered during the release. The covers were removed immediately afterwards. These provided an estimate of redeposition.

The end result desired was the determination of K, where:

$$K\ (m^{-1}) = \frac{\text{Airborne Concentration (units/m}^3)}{\text{Contamination Level (units/m}^2)}$$

8.1 Results

Figure 17 shows the rate of buildup on the two controlled areas of vegetation (the left curve for the one uncovered immediately after the test and the right for one uncovered four hours later). It can be seen that most of the activity on the clean pasture was deposited within the first day after the release. At no time did the activity on the clean area exceed 10 percent of that on the contaminated area.

Air measurements did not show a significant decrease in activity with height. The activity levels recorded were fairly low so that a statistical trend is not evident.

Evaluation of deposition and resuspension data indicate a mean K value of about $2 \times 10^{-6}\ m^{-1}$. This agrees very well with the value suggested by Stewart [15] ($10^{-6}\ m^{-1}$).

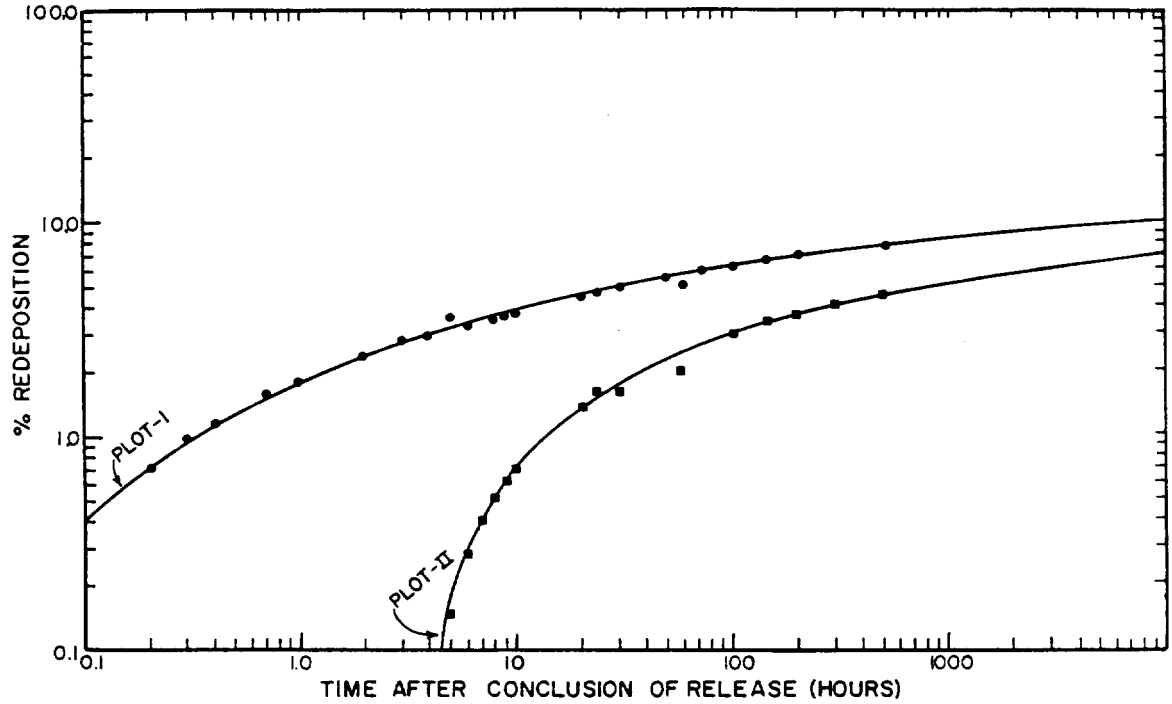


Fig. 17 Redeposition of iodine on grass -- CERT II.

One interesting bit of information was gained from comparative decay studies of the covered and uncovered areas. The measured half-life was 5.5 days on the initially contaminated and 4.2 days on the initially "clean" areas. This indicates that care should be taken in measurements of half-lives. If activity is not uniformly distributed on a pasture, the effective half-life of I-131 on grass could very well be overestimated due to the redeposition factor.

It would appear then that resuspension will not pose an appreciable hazard unless the levels of contamination are fairly high.

9. PROJECTED WORK

As indicated earlier, the work so far has largely been aimed at identifying the major parameters and the extent of their variability. As an aid in planning future tests, a laboratory experiment program for CERT has been initiated (CERTLE). This program, through many small releases into an enclosed chamber, will allow more definitive estimates of parameter variability to be established. The desired result of both the field and laboratory works is to derive a set of empirical equations or factors which will allow estimation of the potential radioiodine hazard as well as a measure of the possible deviation from this estimate. Progress in this work will be reported as other test data become available.

IV. REFERENCES

1. C. A. Hawley, Jr., et al, Controlled Environmental Radioiodine Tests at the National Reactor Testing Station, IDO-12035 (1964).

2. P. J. Barry, Some Recent Experiments on Transfer of Radioactive Tracers From Air to Natural Surfaces, CRL-86 (1964).

3. C. C. Gamertsfelder and J. K. Green (Editors) Hanford Radiological Sciences Research and Development Annual Report for 1963, HW-81746.

4. B. Kahm et al, "Radioiodine in Milk of Cows Consuming Stored Feed and of Cows on Pasture", Science, 138 (1962) pp 1334-1335.

5. F. W. Lengemann and E. W. Swanson, "Secretion of Iodine in Milk of Dairy Cows Using Daily Oral Doses of Iodine-131", J. Dairy Sci., 40 (1957) pp 216-224.

6. R. F. Glascock, "The Secretion of a Single Tracer Dose of Labeled Iodine in the Milk of the Lactating Cow", J. Dairy Research, 21 (1954) pp 318-322.

7. S. E. Thompson, "Effective Half-life of Fallout Radionuclides on Plants with Special Emphasis on Iodine-131", UCRL-12388, January 1965.

8. S. R. Bernard et al, "Human Thyroid Uptake and Body Elimination of I-131 for the Case of Single and Continual Ingestion of Bound Iodine in Resin-Treated Milk", Health Physics, 9 (1963) pp 1307-1323.

9. M. Eisenbud et al, "Estimation of the Distribution of Thyroid Doses in a Population Exposed to I-131 From Weapons Tests", Health Physics, 9 (1963) pp 1281-1289.

10. United States Atomic Energy Commission (Division of Plans and Reports), Fundamental Nuclear Energy Research, Washington, D. C. : U. S. Government Printing Office, 1964.

11. D. K. Craig, An Investigation of the Interactions That Occur Between Radionuclides and Aerosols in the Respirable Size Range, UR-636 (1963).

12. L. Lassen, "The Attachment of Natural Radioactivity to Aerosols", Geofis. pura e appl., 50 (1961) pp 281-285. (In English.)

13. A. C. Chamberlain et al, "Behaviour of Iodine Vapour in Air", Discussions Faraday Soc., No. 30 (1960) p 162.

14. A. C. Chamberlain, Transport of Particles Across Boundary Layers, AERE-M-1122 (1962).

15. K. Stewart, The Resuspension of Particulate Matter from Surfaces, International Symposium on Surface Contamination, June 1964.