

iodide). Interference in bed efficiency because of chloride buildup was also cited by Heeb [1994]

At times leading up to their regeneration their efficiencies decreased to less than 50% [Pas and Soldat, 1951]. Their performance was highly variable according to Hanford monthly operating reports and decreased as they aged and even regeneration did not correct this. Warren [1961] stated: .prior to 1957, emissions frequently contained large quantities of iodine . A 1951 report [Shaw,1951] states: it appears that 20% of I-131 passes to points not affected by Ag reactors. In March, 1953, four Ag reactors failed and higher I-131 releases occurred [HW-27580, Mar 3]. Many iodine emissions in the multi-curie range occurred during early 1955 owing to the malfunction of Ag reactors in REDOX and T plants [Michels *et al*,1955]. As a result, new orking limits were established at 1 Ci/d or 10 Ci/wk maximum. However, these were frequently exceeded as it required 99.9+% removal efficiencies and such was considered highly improbable [Browne, 1955]. For example, 1955 emissions at REDOX and T plants consistently were above 10 Ci/d and at one point were as high as 90 Ci/d. Our current estimate of total 1955 releases of 25,300 Ci (Table 4) corresponded to about 85 Ci/d released.

There are many other reports documenting the variable and decreasing reactor removal efficiencies. An release of 44 Ci. in April 2 was ignored by Heeb [1994] who reported negligible emissions during the month; similarly, in Sep 3 when 100.000 Ci in reen metal was inadvertently loaded into the dissolvers [HW-89067].

On the other hand, Raab and Van der Cook [1970] reported that the PUREX back-up silver reactor, which followed an acid-removal scrubber, in treating vessel and room ventilation exhausts, operated at high efficiency for an extended period where there was relatively low acidity and chloride content.

Therefore, in the light of this operating history for Ag reactors, the release estimates of HEDR [Heeb94] which credit the devices with 99+% removal efficiencies are very low and cannot be considered representative of the post-1951 actual operating performance. Backup acid and iodine removal devices were in place in 1959-60, from which records, such estimates were made applicable back to 1951[Warren,1961]. In should also be pointed out that release fractions for the 1950 were based in part on historical stack sample measurements which were proved to be erroneous and subject to analytical errors [Browne,1955].

In consideration of evidence of fluctuating reactor efficiencies from 99% to less than 50%, it is our opinion that more realistic release estimates should be based on a mean efficiency of 95% from May, 1951 to 1960. Herrmann and Herrmann [1996] also considered that removal efficiencies of 95% (i.e. worse than the 1959-60 estimates by a factor of 4) were more realistic for the 1951-57 period. A similar conclusion was reached by Hoffman *et al* [1994].

However, an even greater source of error in HEDR release estimates from 1944 and over the lifetime of the plants was their neglect of other forms of gaseous radioiodine being released.

E.4 Organic Iodides:

It now appears that more than one-half of the I-131 released after filters and Ag beds were installed, was in the form of gaseous organic iodides. The existence of such organic-I was not considered until they were discovered in downwind air [Perkins, 1964] and in stack gases at 30-71%, [Haller & Perkins, 1967]; although Harvey [1962] and McCormack [1962] had suggested that some organic iodine compounds were formed based on instrumental stack monitoring. By their nature, organic iodides, or alkyl iodides such as methyl-I and butyl-I are fairly un-reactive gaseous compounds which are readily emitted from acidic dissolver solutions, are not absorbed by filters, scrubbers or Ag reactors and therefore, not measurable by stack samplers. These compounds were not unknown at the time. Initially it was speculated that the organic form was methyl-I [du Plessis and Sutter, 1969] but later it was shown to be butyl-I by Haller and Perkins [1967] and this was also confirmed by Evans and Jervis [1992].

Napier [2002] speculated that organic iodide was formed by reactive iodine with organic solvents in the Purex process. However, Evans and Jervis [1992] found that, whenever inorganic I-131 was placed in acidic solutions, organic iodide, mainly butyl-I, formed within a few hours and moved to any gas space over the solution. In lab experiments, the organic was not caught in traps that removed I_2 or HI but could only be caught in treated activated charcoal traps. There was no added carbon for the organic-I formation and it readily formed by iodine reactions with carbonaceous impurities in the acidic solutions. These experiments were carried out at 10^{-6} to 10^{-7} molar concentrations, similar to the levels in the Hanford dissolvers. The mechanisms and rates of formation of organic iodide were elucidated in detail by Evans, Mirbod and Jervis [1993]. Further it was found that the rate of formation of organic iodide in acidic solutions was greatly accelerated in the presence of high radiation fields such as existed in the dissolvers [Taghipour and Evans, 2001].

Considering the high acidity and elevated temperatures in the Hanford dissolvers, it is conservatively estimated here that a fraction of 10% of total I-131 was in the form of organic iodide from 1944 and throughout the operating history. Exactly this proportion of organic iodide was measured also in I-131 solutions by Numakura, Saeki and Tachikawa [1973]. That such appreciable levels of other forms of gaseous iodine had been overlooked was pointed out in two previous iodine reports [Jervis95, McNJ99]. Such gaseous organic iodides, *being much less reactive than I_2 and I, passed freely through fiber filters, scrubbers or Ag reactors and were not trapped in stack samplers, hence went undetected.* Marter [1963] stated that lab testing of caustic scrubbers (used for stack sampling) indicated a 92% efficiency to trap I-131. However, when compared with charcoal bed samples taken at the same time, what they had collected was actually only 20% of total iodine in the stack. Since

charcoal was a good collector of all iodine species, this comparison can now be seen to have indicated that about 80% of the I-131 was not elemental but organic iodide.

The presence of this postulated 10% fraction of organic-I in the dissolvers would also constitute about 10% of I-131 in emitted stack gases from 1944-48, 15% from May 8 to Oct 0, 40-60% from Nov 0 to Apr 1 and 65% thereafter. The revised RF given in this present report (shown in column 7, Table 3), reflect these substantial proportions of organic-I.

The existence of such a large proportion of organic-I at Hanford had very serious implications, not only for revised RF values, but also for atmospheric dispersion and deposition, conversions by atmospheric chemistry, and pathways to human exposure and animal uptake. Unlike the reactive (inorganic) iodine and iodide, organic-I would have deposited more slowly at greater distances, would not as readily have been adsorbed on airborne particulate matter, and would have been much more slowly converted to inorganic iodine by sunlight and through atmospheric reactions.

E.5 Computation of RF, Release Factors (1944-1956):

A significant revised correction factor in this report is the RF, release factor (shown in column 7, Table 3)

$$\text{Release Factor, RF} = \text{RF}_{\text{dissolve.}} + \text{RF}_{\text{org-I}} + \text{RF}_{\text{processing}} \text{RF}_{\text{condensate}}$$

where: $\text{RF}_{\text{dissolve.}}$ is fraction released during dissolving, less that removed by scrubbers, [ref. Work, 1946]

$\text{RF}_{\text{org-I}}$ is fraction of iodine released as org-I,

$\text{RF}_{\text{processing}}$ is fraction released in subsequent handling and processing, less that removed by sand beds

$\text{RF}_{\text{condensate}}$ is fraction removed as stack condensate

Assumptions made for these computations:

86% evolved during dissolution and air sparging (inorg + org-I)

10% of iodine was organic (not removed by scrubbers)

(assumed to be the same for B, T, REDOX and PUREX plants)

7.5% evolved after dissolution stage in subsequent processing

3% was collected as stack condensate until 1948

40% removal efficiency of water scrubbers

30% removal efficiency of sand beds

For example, for the period: May 8 to Oct 1:

$$RF = 0.08_6 + (100-40\%)(0.86-0.09) + (100-30\%)(0.07) - 0.03 = 0.57$$

The corresponding RF over the 1944-1956 time period are given in the table below.

Table 1

Revised I-131 Release Factor Estimates: (1944-1956;all plants)

DATE	Estimated RF	HEDR-Heeb RF	Ratio
Startup May 8	0.91 0.1	0.905	1.0
May 8 - Oct 8	0.59 0.08	0.285	2.07
Nov 8 - Oct 0	0.57 0.08	0.25	2.28
Nov 0 - Jan 1	0.20 0.04	0.12	1.67
Feb 1 Apr 1	0.14 0.03	0.05	2.80
After May 1	0.14 0.03	0.0125	11.2

In the appended table (Table 3) are listed the HEDR [Heeb94] release fractions and estimated monthly I-131 releases (in Curies) together with our revised FIFO, ECT, LAG and RF factors which are applied to correct the HEDR underestimates.

There are some inherent uncertainties in our correction factors which, when combined, give overall uncertainties of the corrected I-131 releases in Column 10, Table 3. For the different time periods involved, the combined uncertainties, expressed as mean deviations, and which provide estimates of the range of our corrected release computations, are as follows:

<u>Time Period</u>	<u>Relative Uncertainty</u>
1944 1948	10%
1948 1950	22%
After 1950	22%

Exhibit D

1504 144th Place S. E.
Mill Creek, WA 98012
September 22, 1994

HEDR RECORD
Task <u> </u>
File <u>A7.3</u>
Working Copy <u> </u>

Dr. Melvin W. Carter
4621 Ellisbury Drive S. E.
Atlanta, GA 30338.

Dear Mel:

SUBJECT: Source Term Task Responses (September 9, 1994) to
EPRP Outstanding Issues Cited in June 17, 1994 FAX,
Carter to Shipler

These are my comments on the subject memo. I realize that I have provided exhaustive (more likely, exhausting) detail and probably more than you would want. I have considered this a significant problem and have been somewhat frustrated by its not being corrected. As I have mentioned, my concern has been that technical errors in the particulate releases might tend to undermine the credibility of the I-131 source term. The reconstruction of I-131 source term was an impressive accomplishment, and it warrants high credibility.

Since December, 1993, the EPRP has repeatedly emphasized the point that there is a problem with the releases of radioactive particulates (Ce, Ru, Sr, and Pu) from B and T Plants for the period of 1944 until early 1951; i.e., the releases are in error and require correction. This issue is still unresolved.

The subject memo states that the approach used in PNWD-2222-HEDR involved: (1) establishing generic release factors for the radioactive particles from data available from the operation of the Redox, Purex, B, and T Plants; and (2) adjusting the generic release factors, and consequently the releases, at B and T Plants to account for the removal efficiency which existed at B and T Plants. This

approach is sound, and it was followed in PNWD-2222 in the discussion of the I-131 releases from B and T Plants. But it was not followed in the treatment of the radioactive particulates from B and T Plants.

The error entered the system by ascribing the particulate decontamination achieved at B and T Plants only to the water scrubbers which were installed in the dissolver off-gas lines in May, 1948. Actually, 3 different filtration devices were installed in B and T Plants at different times: (1) water scrubbers to treat the dissolver off-gases (May, 1948); (2) sand filters for the canyon ventilation air (October, 1948); and (3) deep bed, fiberglass filters for the dissolver off-gases (October, 1950 to February, 1951). The water scrubbers were by far the least efficient. Their unsatisfactory performance led to their removal from the plants and replacement with the fiberglass filters (October, 1950 to February, 1951).

All of the separations plants had two major effluent air/gas streams containing radioactive particles--the canyon ventilation air and the dissolver off-gases. The combined cleanup of these two effluent streams determined the overall plant decontamination factor for radioactive particles.

Redox and Purex profited from the B and T Plants' operating experience and had all of their filtration equipment in place at startup. B and T Plants had their various filtration devices installed at different times. Consequently, an accurate picture of the overall removal efficiency for radioactive particles at B and T Plants requires a consideration of the installation time and removal efficiency of the individual filter units. The general picture of the B and T Plant situation is shown in Figure 1. Neglecting this consideration has led to the errors.

This can be illustrated by the PNWD-2222-HEDR information regarding the release of radioactive particulates at B and T Plants during the period of 1944 to May, 1948. In the discussion of Pu-239 release factors for B and T Plants (second paragraph, pg. 4.27), it is stated that "Emission control equipment was assumed to have been about 99 percent efficient, so the early period (prior to May, 1948)

Pu-239 release factor for the T and B Plants was 4.0×10^{-5} . (The release factor for prescrubber operations {1944-1948} was increased two orders of magnitude to account for increased releases because of the absence of off-gas scrubbers.)"

This is not correct. It is contradicted by the Pu-239 release factor estimates presented in Table 4.8, page 4.28 and the overall particulate decontamination which existed at B and T Plants at the time the release data were obtained. The B and T Plant data were obtained during the years 1951 and 1952. At that time, the water scrubbers had been removed from the dissolver off-gas lines at B and T Plants, and the plants were outfitted with a sand filter for the canyon ventilation air and a deep bed fiberglass filter for the dissolver off-gases. Also at that time, a great deal of monitoring data had been obtained, which established that the overall plant efficiency for radioactive particles was 99.8%. If a combined plant average monthly release of 4.0×10^{-7} existed with a decontamination efficiency of 99.8% in place, then the release factor before this equipment existed (prior to May, 1948) was 4.0×10^{-4} vs. the 4.0×10^{-5} (as stated in PNWD-2222), and the releases for this period of time were an order of magnitude greater than the values in PNWD-2222.

The same type of situation exists for the Ce, Ru, and Sr releases from B and T Plants during the period of 1944 to May, 1948. The generic release factors for these radionuclides in particulate form were obtained from Redox and Purex Plants. Redox and Purex had their complete filtration systems in place at startup. These were more efficient than the final system used in B and T Plants (from late 1950 and early 1951 to shutdown). In both Redox and Purex, there were a high efficiency filter for the canyon ventilation air, a high efficiency filter for the dissolver off-gases, and, in addition, the vent pipes from all the process vessels were manifolded and the vent gases were passed through a high efficiency filter. This provided an overall plant decontamination efficiency for radioactive particles of at least 99.9%.

Since the generic release factors for Ce, Ru, and Sr were obtained at Redox and Purex Plants with a decontamination efficiency of 99.9% present, the translation of these factors to B and T Plants for the period of 1944 to May, 1948 (when there was no filtration

equipment at those plants) would require increasing the generic release factors by 3 orders of magnitude (vs. a 2 order of magnitude increase in PNWD-2222). This would increase the releases of these radionuclides by an order of magnitude for this time period as compared to the values in PNWD-2222.

As illustrated in Figure 1, the dissolver off-gas water scrubbers would affect the overall particulate removal efficiency at B and T Plants during two time periods: (1) May, 1948 until October, 1948, wherein they were the only particulate removal device installed in the Plants; and (2) October, 1948 until October, 1950-February, 1951, wherein they remained in the dissolver off-gas lines, and the sand filters were in place to filter the canyon ventilation air.

The EPRP has questioned HEDR's use of a particle removal efficiency of 99% for these water scrubbers. The question has been based upon the following factors:

1. Measurements were made of the particle size distribution of the radioactive aerosol at B and T Plants. The radioactive aerosol was determined to have a mean particle diameter of 0.2 - 0.3 micron. High efficiency removal of sub-micron particles from air/gas streams requires specialized equipment. It would not be expected that the B and T Plant water scrubbers (a column packed with Berl saddles with a water distribution ring at the top) would be capable of achieving an efficiency as high as 99%.
2. Early development studies were conducted with a test scrubber having the same design as the B and T Plant water scrubbers and operated on the plant radioactive aerosol. The tests were conducted with and without steam injection prior to the scrubber. Steam injection did improve the efficiency, but the plant units were never operated using this technique. The test results without steam injection ranged from 53-90%.
3. PNWD-2222 cites HW-67520 as providing information which established the particle removal efficiency of a water scrubber in the Redox Plant at 99%; hence the basis for using this value for the B and T Plant scrubbers. The design of the Redox scrubber is not presented in HW-67520, and the Redox effluent air streams were

efficiency was approximately 93%. Since the generic release factors and a plant filtration efficiency of 99% were used for B and T Plants, the particulate releases in PNWD-2222 are low by a factor of approximately 70.

Following the replacement of the water scrubbers with the silver reactor/fiberglass filter assemblies (10/1950-2/1951), the overall particulate removal efficiency of B and T Plants was in the order of 99.8% (Figure 1). The generic release factors are applicable, and the release values in PNWD-2222 are correct.

The other issues in the reference memo are secondary and relate to earlier comments from the EPRP. These comments were made in the interest of seeking or attempting to assist the clarification of some of the complexities associated with the treatment and/or releases of airborne radionuclides from the separations plants. If any of these are still considered open, they should be closed.

Mel, it has been an interesting and enjoyable project. I have thoroughly enjoyed being a member of the Panel and our working together. I hope our paths cross again.

Best personal regards,



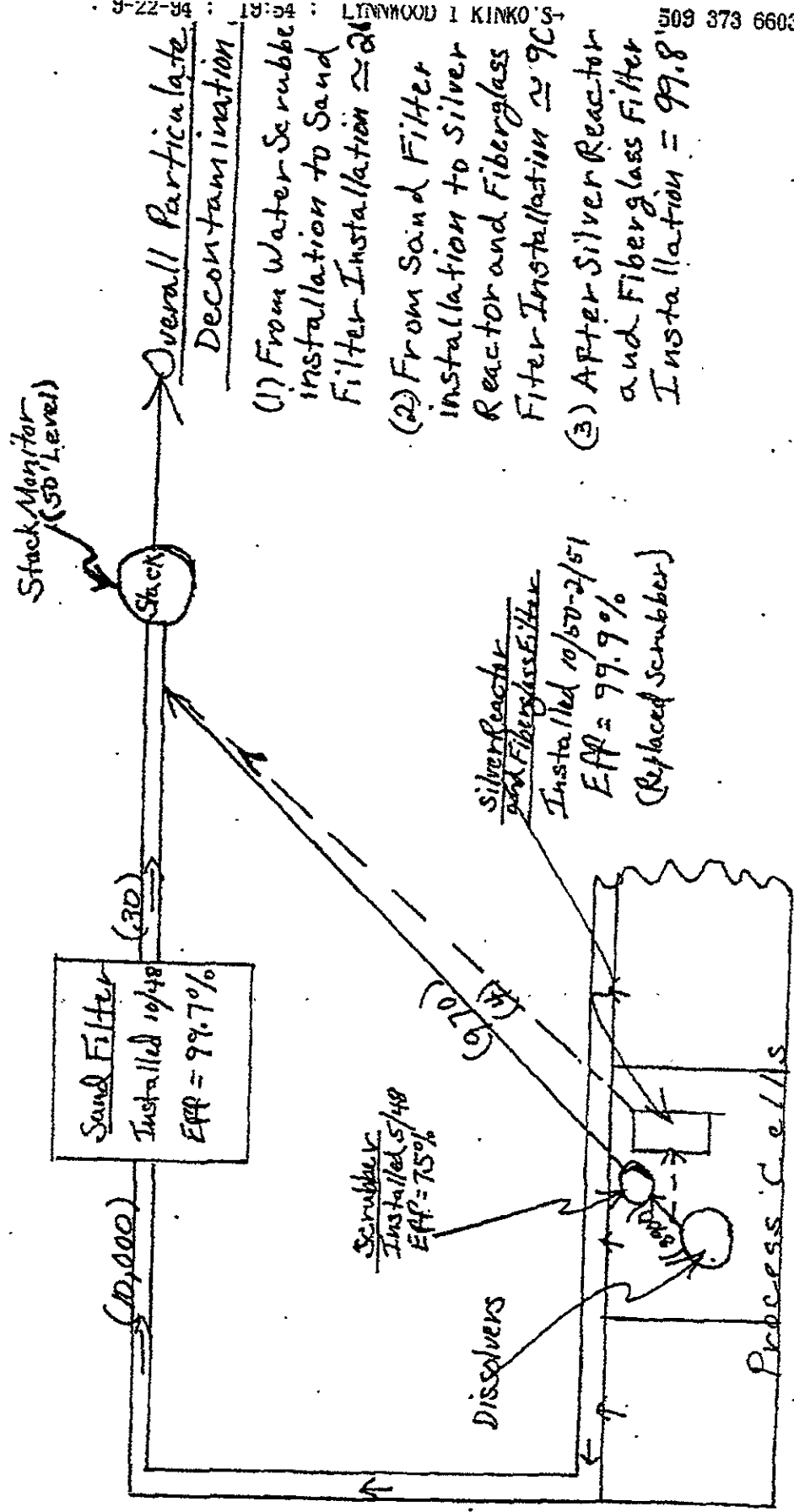
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Exhibit E

Band 7 Plant Ventilation System and Decontamination Equipment

FIGURE 1



Note: Figures in parentheses () are units of radioactive contamination (particulates)

Exhibit F

Route List

1. CN Gross

2. WK MacGraw

3. R.H. B... ..

4.

5. #13178

6. 271T

FILE File 700-N

DATE 8-6-49

SUBJECT Stack Contamination - 200 Ar

To C.N. Gross

FROM J.P. Martel

COPY No. ...

BEFORE READING THIS DOCUMENT, SIGN AND DATE BELOW:

<u>ans 8/10</u>
<u>W.A. ... 8-15-48</u>
<u>Hawley 11-1-48</u>
<u>E. Shaver 1-25-49</u>
<u>John ... 9-15-49</u>
<u>FRB</u>
<u>C.N. ... 12-20-51</u>
<u>CRA 8/24/59</u>
<u>Proch ... 63011</u>
<u>D.T. ... 03902</u>
<u>R.J. Davis 4/9/75</u>

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HDC 611

J. P. Bartel

- 4 -

August 6, 1948

The data indicated that a 2-foot bed of 20-40 mesh sand was capable of giving over 99% collection of suspended active particles at superficial velocities as high as 10 ft./min.. Coarser sands gave this degree of cleanup at velocities on the order of 1 to 2 ft./min. but the collection efficiency dropped off rapidly at higher velocities.

SCRUBBER TESTS

High spot tests were conducted by Technical Division on an 3-inch diameter scrubber packed with 6 feet of 1/2-inch Berl saddles followed by 1 foot of 1/2-inch Berl saddles dry packing and a cyclone entrainment separator. The test procedures and results are discussed in Exhibit B and summarized in Table V.

The data indicated a collection efficiency under 96%, and predominantly under 90%, at superficial velocities up to 1 ft./sec. (equivalent to 250 (lb.)/(hr.)(sq. ft.)) and water rates up to 200 (gal./min.)/(1000 cu.ft./min.) or 3300 (lb.)/(hr.)(sq.ft.), although in one run with steam injection at the rate of 1/4 (lb./hr.)/(cu.ft./min.), a collection efficiency of 96% was obtained. While these tests were far from comprehensive, the results did indicate that this type of scrubber was not capable of very high degrees of particle removal even at relatively low capacity. Future studies will evaluate the performance of fiberglass packing. Other types of scrubbers will also be considered for test.

CONCLUSIONS AND RECOMMENDATIONS

In view of the above analysis and results, it is recommended that the large-scale experimental scrubber program be dropped and that efforts be directed toward a large scale sand filter installation. This recommendation was accepted in a meeting held on July 27, 1948. Estimates and schedules prepared through the joint efforts of Project Engineering, Maintenance, Construction and "S" Division since that time have arrived at December 1, 1948 as an anticipated start-up date for a 48-foot by 110-foot sand filter in 200 West Area.

In Exhibit D is given a detailed discussion of the factors considered in arriving at the full scale design. Exhibit E lists some comments on problems related to that of the particle contamination in 200 Area.

ES

Exhibit G

NOTICE: THIS MATERIAL MAY BE
PROTECTED BY COPYRIGHT LAW
(TITLE 17 U.S. CODE)

Use of Natural Airborne Radioactivity to Evaluate Filters for Alpha Air Sampling

C. L. LINDEKEN

Lawrence Radiation Laboratory, University of California, Livermore, California

Using natural airborne radioactivity as a test aerosol, a method is described which is designed to compare the surface collection efficiency of filters used for alpha air monitoring.

Introduction

A DESIRABLE property of an alpha air-sampling filter is that the collected activity be retained on the filter surface to avoid counting losses due to burial. Most of these filters now in use have been tested with 0.3-micron di-2-ethylhexyl phthalate (DOP) particles (DOP-Smoke Penetration and Air Resistance of Filters, Military Standard 282, Method 102.9.1, May 28, 1956, Government Printing Office, Washington, D. C.). While this test is useful in rating filters for their ability to retain particles of this size, it does not provide adequate information if the filter is to be used for sampling airborne alpha-emitting radioisotopes, because it gives no distinction between surface collection and burial. Depending on the burial depth and the density of the filter, buried alpha emitters may escape detection because of complete energy dissipation within the filter medium. Thus it is seen that in contrast to chemical analysis, where the only requirement for detection is retention, direct alpha counting is only effective for particles collected on or near the filter surface. Accordingly, a test method showing the relative surface collection efficiency of filters would furnish information of considerable value.

In principle, this method should employ an alpha emitter, such as plutonium, generated as an aerosol in the particle size range typical of air-contaminating accidents. However, in addition to the obvious difficulties in selecting a "typical" size, there are many technical problems associated with controlled particle-size generation. In the method described here, use is made of the short-lived natural alpha activity attached to atmospheric dust. This aerosol occurs freely in nature.

Presented at the Twenty-second Annual Meeting of the American Industrial Hygiene Association, Detroit, Michigan, April 1961.

Natural Airborne Radioactivity

Natural airborne radioactivity originates with uranium and thorium found in varying amounts throughout the surface of the earth. In the radioactive decay scheme of each element a gas is produced—radon from uranium and thoron from thorium. These gases diffuse into the atmosphere where they decay into solid daughter products. Decay schemes for each of these gases are shown diagrammatically in Schemes 1 and 2.

These decay products become attached to airborne dust particles. Each of the decay schemes contains alpha emitters. Consequently if atmospheric dust is collected by filtration, the concentration of airborne radon and thoron daughter products can be determined from the collected alpha activity. The concentration of natural airborne radioactivity varies depending on the geographical area. Within a given area the concentration also varies with changes in meteorological conditions. Diurnal variations are well recognized. Burke and Nolan¹ found that natural airborne activity increased with increases in the concentration of condensation nuclei. They found further that, with an increase in the concentration of the larger less mobile ions, there also was an accompanying increase in intermediate and smaller ions. It may be assumed, therefore, that conditions promoting buildup of large dust particles in the atmosphere may also tend to increase the number of small particles.

From a medical and health physics standpoint, there is interest in the degree of lung retention of particles in the range of 0.001 to 0.1 micron.^{2,3} If, as suggested by some of the authorities, these particles are significantly retained in the alveoli, then it is important to know the efficiency of our sampling media for retaining particles in this size range. As the number of atmospheric dust particles in the size

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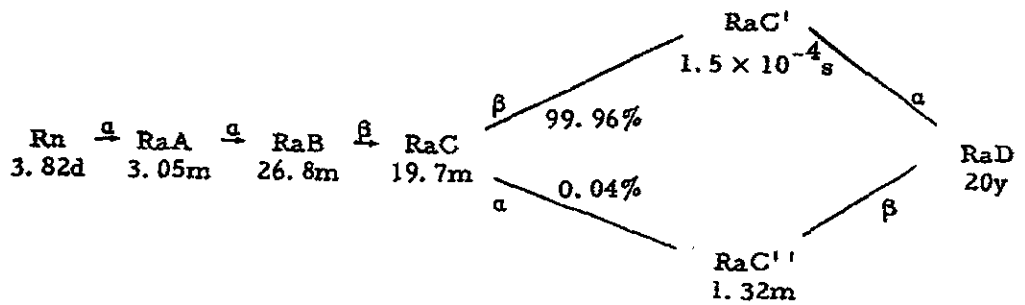
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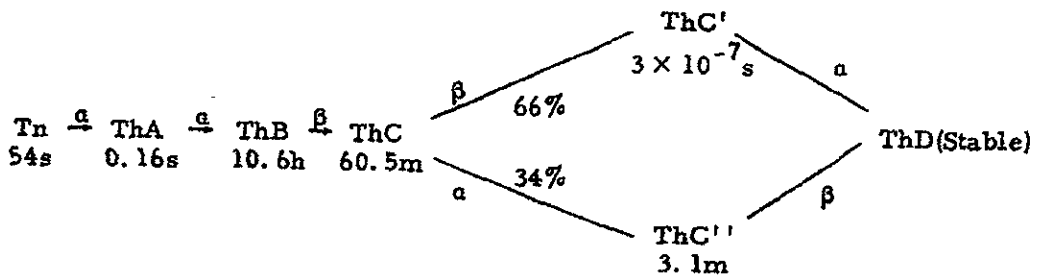
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SCHEME 1. Radon.



SCHEME 2. Thoron.

range of 0.01 micron and less is exceedingly abundant, compared with microscopic sizes, the probability for interaction of decay products with these very small particles is high. Wilkening⁴ has found that the major portion of natural activity is present on particles 0.001 to 0.04 micron in diameter. Accordingly, nature may have supplied us with a test aerosol well suited for testing filters for their efficiency in retaining extremely small particles. Its use has appealed to many workers. Carmichael and Tunnicliffe⁵ employed natural activity to determine burial losses in an asbestos cellulose paper. They used an electrostatic precipitator as a reference collector. Harley⁶ also used natural radon-daughter airborne radioactivity to determine the collection efficiency of aerosol sampling filters, including Whatman 41 and membrane filters. Efficiencies were determined by reference to total activity collected in a static ion chamber. Hasenclever⁷ mixed thoron with a dust aerosol of known particle size to produce a radioactive dust. Concentration of thoron daughter products was determined before and after filtration to calculate retention efficiency.

Apparatus and Test Method

In the present method, three samples of atmospheric dust are collected simultaneously at the same flow rate. The first sampler contains a Millipore AA filter used as a reference collector. The test filter, operated in parallel, is the second

filter. The third sampler, again using Millipore, follows the test filter in series as a backup. This filter collects activity penetrating the test filter. As alpha activity is collected it is detected by ZnS (Ag) fluors coupled to photomultiplier tubes. Integrated counts are recorded by amplifier scalars. A sketch of the equipment is shown in Figure 1.

Although the filters were originally 47 mm in diameter, they are held in position by a retaining ring which reduces the effective diameter to 42 mm. Fluors are prepared by depositing 10 mg/cm² of scintillator on polystyrene plates 2 1/4 inches in diameter by 1/4 inch in thickness. The

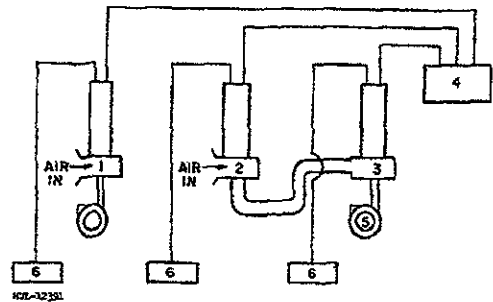


FIGURE 1. Equipment sketch for filter testing: (1) Millipore reference filter collector-detector assembly; (2) test filter collector-detector assembly; (3) Millipore backup filter collector-detector assembly; (4) high-voltage power supply; (5) Gast pumps; (6) amplifier scalars.

scintillator is thermally pressed into the plastic. Distance from fluor surface to filter surface is approximately 0.2 inch. The photomultiplier tube is a 2-in. RCA 6655A coupled to the fluor with Dow Corning QC 2-0057. The photomultiplier tube output is fed through a gain-of-10 pre-amplifier to an amplifier scaler. Figure 2 shows the sample collection-detection assembly.

Sampling periods varied from about 5 minutes to 1 hour, depending on the concentration of airborne activity. As a rule, the sampling time was determined by the time required for the reference filter scaler to collect 1000 to 2000 counts. The instrument background was normally one cpm or less.

By means of bypass valves, flow rates could be selected within the range of 0.5 to 3 cfm. Flow rates were measured at the air inlets using Venturi meters equipped with 0- to 1-in. water Magnehebe gauges. The lower flow limit was established by the accuracy with which the gauge could be read, while the upper limit was determined by the maximum head developed by the Gast 1550 air pump. Venturi meters were calibrated using an 1800-cf/hr dry gas meter. Overall accuracy of the flow measuring system as used was approximately $\pm 5\%$. A pressure tap was installed in the test filter assembly, just after the filter, to measure the pressure drop across the filter at the selected flow rate (3 cfm). Correction was made for the pressure drop across the filter assembly itself with only the filter support in place.

Using Millipore AA, it follows that relative to this filter,

$$\frac{\Sigma \text{ counts on test paper} \times 100}{\Sigma \text{ counts on Millipore reference}}$$

= % of activity collected on test filter surface,

$$\frac{\Sigma \text{ counts on Millipore backup} \times 100}{\Sigma \text{ counts on Millipore reference}}$$

= % of penetration through test filter,

and $100 - [\% \text{ surface collection} + \% \text{ penetration}] = \% \text{ burial losses within filter.}$

The above procedure is similar in principle to the one employed by Carmichael and Tunnicliffe. The difference is that the present method detects activity as it is collected and integrates over the collection period. Using this technique, every detectable (counting efficiency is about 35%) disintegrating event occurring during the sampling period is recorded. If counting began after sampling—as in the Carmichael method—the apparent count rate would be lower due to the short half-life of the activity. Thus, for equal

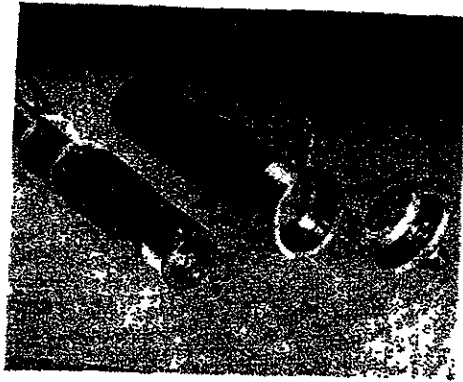


FIGURE 2. Sample collection-detection assembly.

sampling periods, the integration method yields better precision because of improved counting statistics.

Results and Discussion

Table I shows a comparison between several filters used or proposed for use in alpha air sampling. In all cases these measurements were made at 3.0 cfm, equivalent to a face velocity of 200 fpm.

Data shown in Table I represent averages of several measurements obtained under different concentrations of airborne activity. Variations in surface collection were within $\pm 10\%$ with no significant correlation with concentration.

It appears that for alpha air monitoring the

TABLE I
Comparison of Alpha Air-Sampling Papers

Paper	Surface collection %	Penetration %	Burial %	Pressure drop, inches of mercury
Hollingsworth & Vose (HV-70, 4-mil)	80	2	18	3.0
Hollingsworth & Vose (HV-70 gauze backing, 20-mil, material in roll 3 in. wide, for moving-tape air monitor)	70	2	28	2.8
Gelman E glass fiber (25-mil)	89	2	9	1.5
Whatman 41	38	22	40	1.6
Whatman Ap/A Polystyrene (30-mil)	98	2	nil	7.6
Microsaban (Pads of polystyrene sheets; filter was 75 mils thick)	54	3	43	0.8

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ic- a- on %	Bur- ial %	Pres- sure drop, inches of mer- cury
3	18	3.0
2	28	2.8
1	9	1.5
4	40	1.6
5	nil	7.6
6	43	0.8

glass fiber medium (Gelman E) is superior to the popular HV-70, both with respect to surface collection and flow resistance. While the Whatman polystyrene paper has higher surface retention than glass fiber, it has the disadvantages of high flow resistance and being difficult to handle without shredding. Glass fiber is available in a variety of thicknesses; however, the thinner stocks are too fragile to be serviceable for field use. As might be expected, the surface collection efficiencies for the two HV-70 papers (9-mil and 20-mil) show greater burial in the thicker paper. Final choice of filter media must depend on a balance between the factors of surface collection, flow resistance, and ease of handling.

Collection Efficiency of Millipore AA

The Millipore AA paper is used in the test procedure merely to normalize all measurements to a single reference. As such, filters are compared one to another with respect to surface collection, but always relative to Millipore AA. The only requirements of the reference filter then are that it have relatively high surface retentivity for the test aerosol employed, and that it be reproducible in performance.

It is recognized that Millipore AA paper does not collect all the natural activity available from atmospheric dust. In fact, Fitzgerald and Detwiler⁸ found that the optimum size for penetration through Millipore AA was in the size range of 0.01 micron, the same general range in which Wilkening found most of the natural radioactivity. However, since we have found no reference filter significantly superior to the Millipore product in surface collection, we have chosen this filter as a point of reference.

Comparison of Data: Natural Activity Measurements versus DOP

The method just described is designed to determine relative surface collection efficiencies of filter media. It is of interest, however, to compare filter penetration data obtained using this method with the 0.3- μ DOP method. Such a comparison is shown in Table II. DOP data are based on the work of Smith and Suprenant.⁹ The equipment (Figure 1) could not be operated accurately at the lower velocities; accordingly, a closed-shell sample holder using larger sections of filter paper was placed in series with the Millipore backup filter. Otherwise the procedure was the same.

Retention of aerosols by a filter is due to several forces: impaction (inertial separation), interception, electrostatic forces, and diffusion.

La Mer has discussed these factors in some detail.¹⁰ For our present purpose it is sufficient to note that:

- (1) The size of atmospheric dust particles carrying the majority of natural airborne activity is about one-tenth the size of the DOP aerosol.
- (2) Diffusional separation is more effective for small particles and is greater at low velocities, since the slower the aerosol passes through the filter the more time the particle will have for diffusion away from the air streamline.
- (3) Retention by impaction increases with particle size and velocity.

From Table II it is seen that the deviation between the two methods is greatest for filters such as glass fiber, which show high efficiency for retaining 0.3- μ DOP. Penetration of natural activity through this medium appears to be independent of velocity. However, because of the small amount of activity collected on the backup filter, the statistical errors are too large to confirm this observation.

Medium efficiency filters such as HV-70 show good agreement at low velocities. At higher velocities, when separation of 0.3- μ DOP is influenced by the impaction mechanism, the agreement deteriorates.

Whatman 41, which shows relatively low efficiency for retaining either size aerosol, clearly indicates that the penetration of both natural activity and DOP is velocity dependent. Figure 3 shows the penetration-vs-velocity curve for

TABLE II
Comparison of Penetration Measurements,
Natural Airborne Activity vs 0.3- μ DOP.

Filter medium	Velocity, ft/min	Penetration %	
		Natural activity	0.3- μ DOP
Glass fiber	20	2	0.04
	150	—	0.01
	200	2	—
HV-70	20	4	3.5
	150	—	0.1
	200	2	—
Whatman 41	5	—	89
	5.5	29	—
	20	42	77
	50	48	67
	100	—	44
	118	32	—
	150	—	29
	200	22	15

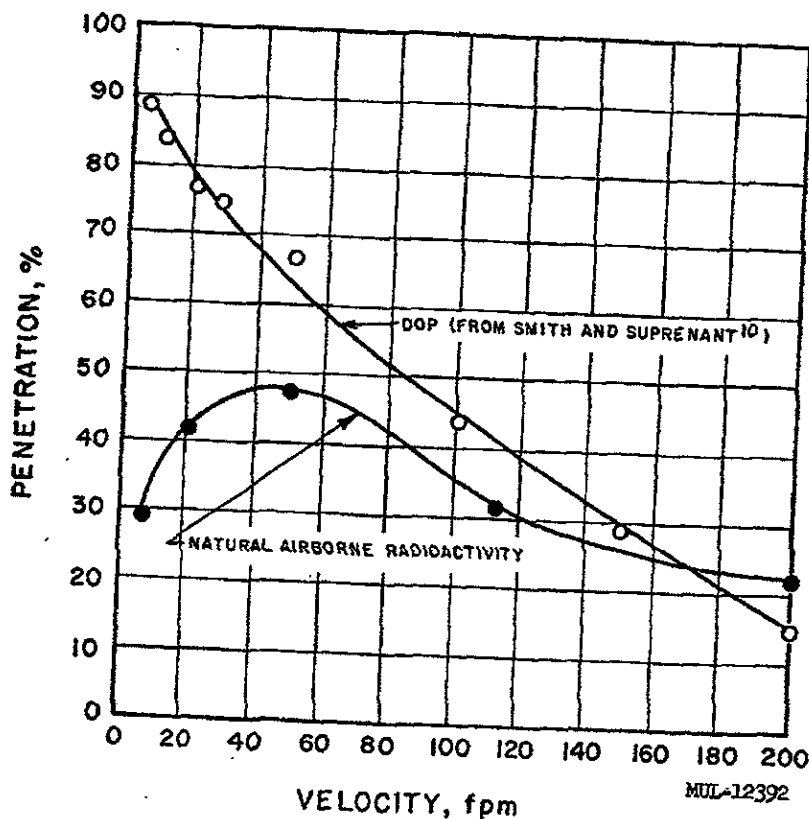


Figure 3. Penetration vs velocity, 0.3- μ DOP and natural airborne radioactivity through Whatman 41 filter paper.

Whatman 41 using natural activity and DOP. Separation of 0.3- μ particles by diffusional forces is not apparent in this medium at the velocities employed by Smith and Suprenant. As the penetration of DOP constantly decreases with increased velocity, this suggests that impaction is the principal factor involved. It appears, however, that diffusional separation has a strong influence on particles of the size carrying natural activity, as evidenced by the maximum in the natural activity curve. Because of their small size, this influence is exerted over a wide velocity range. Impaction is also involved, but becomes predominant at higher velocities than is the case with larger particles.

At low velocities it would appear that Whatman 41 retains small particles better than 0.3- μ particles. At 200 fpm, the penetration data between the two methods are in close agreement. For those who use Whatman 41 for atmospheric sampling, these results suggest an additional argument for higher face velocities. Not only is retention of 0.3- μ particles reasonably good at 200 fpm, but also it appears that very small particles are better retained at this velocity.

Summary

A method has been described using natural airborne radioactivity as a test aerosol, which is designed to compare the surface collection efficiency of filters used in alpha air sampling. Of the filters tested it appears that glass fiber is superior to HV-70. Thin sheet polystyrene filters, although superior to glass in surface collection, have the dual disadvantage of high resistance to flow and handling difficulty due to shredding.

Although the method lacks the accuracy desirable in a reference procedure for penetration measurements, it does provide a screening technique for new filters for which DOP data are lacking.

Data are presented for Whatman 41 paper which show that the retention of particles in the size range associated with natural activity is quite velocity-dependent. A maximum occurs in the penetration-vs-velocity curve showing that both diffusion and impaction separation mechanisms are involved. At low velocity (≈ 5 fpm), Whatman 41 retains natural activity with

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greater efficiency than 0.3- μ DOP particles. At 200 fpm, retentions for both particle-size ranges are in close agreement.

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AIR POLLUTION LIBRARY INDEX

THE BAY AREA AIR POLLUTION CONTROL DISTRICT established its technical library and this specialized index in 1956-57 to serve the District staff and others who have air pollution problems in the Bay Area. More than 8,000 technical reports and other publications on air pollution and its control have been extensively cross-indexed for rapid search and retrieval. This index now consists of 16,850 reference cards. It is the most comprehensive index on this subject and is currently valued at \$50,000.

Complete copies of the index have been purchased by the United States Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, and by the New York State Air Pollution Control Board, Albany, New York. Additional sets are available and are offered to others at prices ranging from \$2,000 to \$2,800 depending on the special features desired. The indexes are kept up-to-date by semi-annual shipments of the additional cards at a charge of about \$250 per year to the subscriber.

Requests for further information are welcome and should be addressed to: BENJAMIN LINSKY, Air Pollution Control Officer, Bay Area Air Pollution Control District, 1480 Mission Street, San Francisco 3, California:

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Exhibit H

Notes of Interview With
Bernard Saueressig on 8/15/96

Mr. Saueressig had a degree in chemical engineering. He went to Hanford on 1951 as radiation engineer and was shift head for radiation engineering that included the 234-5 building (the Z plant) until 1954. In 1957 he went to the Z plant as day radiation monitoring (RM) supervisor for 4 years. In 1961 he went to Purex as an operation shift supervisor responsible for Purex headend operations as well as for tank farm operations and surveillance. In addition, Radiation Monitoring shift personnel reported to him in support of the plant's radiation protection programs. In 1962 he assumed responsibility for the Strontium Semiworks, a solvent extraction process for fission product recovery which included loading of shielded transfer casks with multi curies of strontium and cesium for on and off site shipments. These operations were transferred to B plant some time around 1965 for strontium recovery by solvent extraction and cesium recovery by ion exchange. He continued shift operating responsibilities until Jan. 1974 when he became manager of the radiation monitoring group for the entire 200 area which included the Z plant.

The Z plant ventilation system had record samplers at various locations. There were sampling ports in the ventilation system ductwork, some at points before and after the HEPA filters, and at the stack. These permitted the RM crews to draw off a sample of the ventilation stream through a sample filter. The sample filters used included Acropore AM 3000 and Whatman 40 and also HV-70 types. These filters had pore size ratings from 2-10 microns. We did not try to catch these particles less than two microns. (a Norm P. Nisick who was in radiological engineering would possibly have a more detailed recollection of the makes and types of sample filters used). The filter paper would be taken to the counting room where the alpha disintegrations per minute (dpm) would be counted and converted into activity concentrations (microcuries per unit volume) by means of a graph that related dpm to concentrations. We did not try to *sample the vacuum lines.*

The samples for the 291Z stack, which was the 200 ft. stack for the Z plant, initially would be taken daily. The stack samples were taken from the stack plenum area at the base of the stack. The sampler was a piece of pipe with holes in it through which the stack gas would be drawn by a vacuum pump through the filter at the end of the piping connected to the sampling pipe. The holes in the sampling pipe were sized and spaced in an effort designed to obtain an isokinetic sample (an even distribution of the gasflow up the stack). Around the mid-70's a much improved sampling system was installed at the 50 ft. level. The samples for other sections of the ventilation duct work would also be taken on a regular basis. Whenever they would get an abnormal stack sample the RM crews would then backtrack through the samples for the various upstream locations to determine the

source and cause of the abnormal stack reading. They made a real effort at this work of detection since they were very serious about discovering and correcting any possible sources of stack releases.

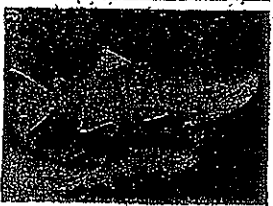
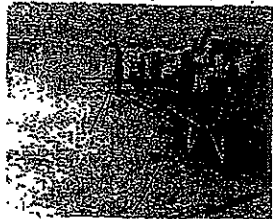
In the 1970's Continuous Air Monitoring (CAM) devices were installed throughout the Z plant rooms occupied by personnel. These devices would sound an alarm and start a light flashing when the air concentration exceeded a predetermined level. A similar device was also installed in the 291Z stack and was set to alarm just above a certain threshold.

Initially the Z plant glovebox ventilation for the 9A and 9B hoods was routed from their glove boxes, which each had a HEPA filter, to one of the E-4 filter rooms (there were two such rooms used alternatively). Both the 9A and 9B started with the forming of an oxalate precipitate which was converted to an oxide by going through a calciner and the oxide was converted to a fluoride via a fluorinator. The 9B hood handled the fluoridation process (and later on the 9A hood handled the making of plutonium oxide for special uses offsite and also for the FFTF). This meant the exhaust from these gloveboxes was filtered through two HEPA filter stages, one at the glove box and one at the E-4 room. However because of the amount of contamination created at these glove boxes, around the late 1950's a separate HEPA filter unit was established on the second floor for these glove boxes and their exhaust was routed past the E-4 rooms, so that these glove boxes continued to have two stages of HEPA filtration, but no longer utilized the E-4 rooms. Then after the 1976 shutdown, before restarting, the system was changed to route from the second stage on the second floor through the E-4 rooms (no longer being bypassed) so thereafter this 9AB process had three stages of HEPA filtration, one at the glovebox, one at the second floor (room 264) and one in one of the E-4 rooms.

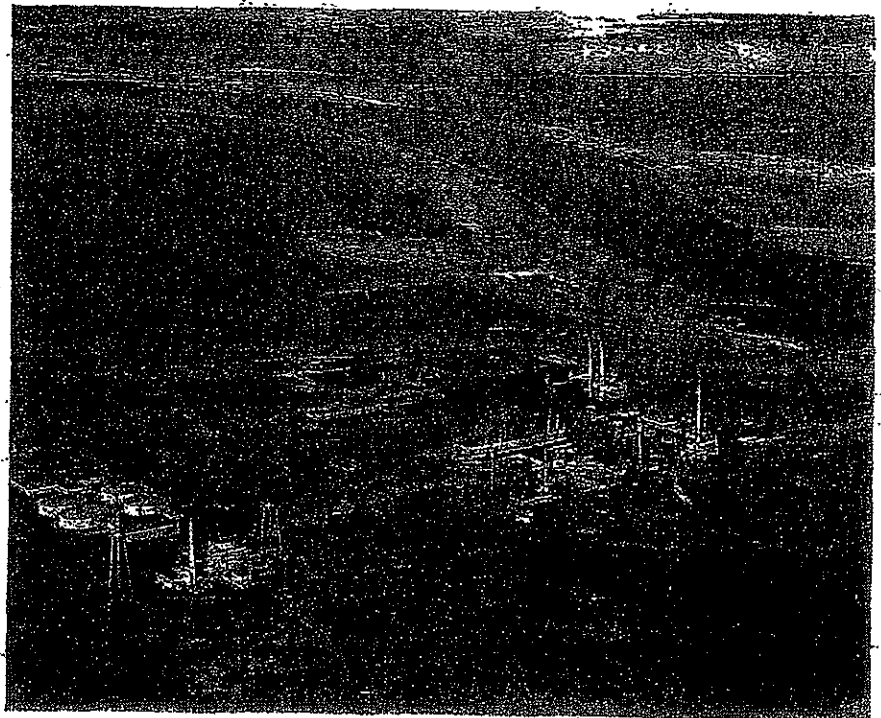
The above two pages of interview notes as corrected or modified in bold type are correct to the best of my recollection.


Bernard Saueressig October 17 1996

Exhibit I



Reconstructing Hanford's Past Releases of Radioactive Materials:



The History of the Technical Steering Panel 1988-1995

November 1996

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- Ensure that the Milk Producer Survey report for the seven counties in which the work was planned clearly indicated how the results are compatible or incompatible with the present dose codes. Ensure that contract reviewers providing oversight of this work have detailed knowledge of the present dose code parameters. Gain detailed comments from reviewers on the experimental protocol and work plans of the contractor before implementing this project.
- Obtain adequate funding to expand the Milk Producer Survey work to include at least 19 counties with a minimum of 200 separate observations.
- Work closely with the states prior to making any future changes in TSP directed work for funding or any other reason. The TSP believed the public must be assured of continued independent oversight.
- Work closely with the states' transition group for the remainder of the TSP directed work. Ensure the transition team reviews task plans for workshops.
- Work with TSP members to provide peer or oversight review on work plans and other contractor work after the TSP sunsets. Have appropriate TSP members review task scopes of work and report findings to the transition team.
- Conduct the remaining dose-related work in an open, publicly accessible, timely and independent way. Ensure that contractor reports are publicly available and written to easy reading standards.
- Conduct a cost/benefit analysis of completing a comprehensive review of Hanford's unclassified documents.
- Request the National Academy of Sciences conduct a complete review of the Project work.

Key Issues Remain to be Resolved

The TSP identified seven priority tasks to be completed before the panel could say that dose reconstruction models and data could be used with confidence in Hanford health-related work. The CDC

plans these tasks to be performed by outside contractors.

The seven key issues are, in order of priority:

1. **Air model concerns.** Many people remain concerned about "disappearance factors"—the inconsistencies between measured and predicted deposition of iodine in the 1940s—and the role weather and topography may have played in the amounts and locations of radioactive iodine deposited.
2. **Feed-to-milk transfer factors.** The major way people were affected by airborne releases was through drinking contaminated milk. The level at which iodine was transferred from feed to milk (the feed-to-milk transfer factor) account for one of the largest sources of uncertainty about doses. If scientists can reduce this uncertainty, results will be significantly more reliable.
3. **Radioactive particles.** In early Hanford separation operations, particles containing radioactive ruthenium and other isotopes built up in smokestacks and were occasionally released. How much these particles contributed to doses has not been calculated. Anecdotal reports and recorded measurements suggest "hot particles" could have traveled some distance and could have contributed radiation doses to some people.
4. **Milk distribution.** The TSP remains skeptical that there is sufficient data about dairy farming practices and milk distribution underlying present dose calculations. This is especially true for areas to the northeast of the Tri-Cities. As milk is so important to dose, further work to reduce uncertainties here is essential.
5. **"Special populations" and others.** Due to location, work and living situations, some people may have experienced doses consistently different from those most people received. Migrant workers, "unbadged workers" and military staff at Hanford, and people living out of the study area to the northeast may all assert, with reason, that the current dose models don't deal with their situations. The TSP has long advocated

Appendix I

Technical Steering Panel Members

Dr. Delbert Barth

University of Nevada, Las Vegas
Specialty: Environmental Pathways
Chair, Quality Assurance and Technical Integration Subcommittee
Chair, Future of TSP Working Group
Member, Environmental Transport Subcommittee
Unclassified Document Review
TSP Member: May 1988 to December 1995

Warren Bishop

State of Washington Representative
Specialty: Public Policy
Coordinator, Native American Working Group
Member, Demography, Communications, Budget/Fiscal and Quality Assurance and Technical
Integration Subcommittees, Future of TSP Working Group
Unclassified Document Review
TSP Member: November 1988 to December 1995

Mary Lou Blazek

State of Oregon Representative
Specialty: Health Physics
TSP Vice Chair, May 1988 to July 1994
TSP Chair, July 1994 to December 1995
Chair, Communications Subcommittee
Member, Source Term Subcommittee, Future of TSP Working Group
Classified and Unclassified Document Review
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Member, Environmental Transport and Demography Subcommittees
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Member, Communications Subcommittee, Future of TSP Working Group
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Member, Environmental Transport and Quality Assurance and Technical Integration
Subcommittees
Unclassified Document Review
TSP Editor
TSP Member: May 1988 to December 1995

Exhibit J

ATMOSPHERIC DISPERSION AND DEPOSITION OF ^{131}I RELEASED FROM THE HANFORD SITE

J. V. Ramsdell, Jr., C. A. Simonen, K. W. Burk, and S. A. Stage*

Abstract—Approximately 2.6×10^4 TBq (700,000 Ci) of ^{131}I were released to the air from reactor fuel processing plants on the Hanford Site in southcentral Washington State from December 1944 through December 1949. The Hanford Environmental Dose Reconstruction Project developed a suite of codes to estimate the doses that might have resulted from these releases. The Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET) computer code is part of this suite. The RATCHET code implements a Lagrangian-trajectory, Gaussian-puff dispersion model that uses hourly meteorological and release rate data to estimate daily time-integrated air concentrations and surface contamination for use in dose estimates. In this model, iodine is treated as a mixture of three species (inorganic gases, organic gases, and particles). Model deposition parameters are functions of the mixture and meteorological conditions. A resistance model is used to calculate dry deposition velocities. Equilibrium between concentrations in the precipitation and the air near the ground is assumed in calculating wet deposition of gases, and irreversible washout of the particles is assumed. RATCHET explicitly treats the uncertainties in model parameters and meteorological conditions. Uncertainties in ^{131}I release rates and partitioning among the nominal species are treated by varying model input. The results of 100 model runs for December 1944 through December 1949 indicate that monthly average air concentrations and deposition have uncertainties ranging from a factor of two near the center of the time-integrated plume to more than an order of magnitude near the edge. These results indicate that ~10% of the ^{131}I released to the atmosphere decayed during transit in the study area, ~56% was deposited within the study area, and the remaining 34% was transported out of the study area while still in the air.

Health Phys. 71(4):568–577; 1996

Key words: ^{131}I ; dose assessment; radioactivity, airborne; emissions, atmospheric

INTRODUCTION

EARLY STUDIES in the Hanford Environmental Dose Reconstruction (HEDR) Project (Ramsdell and Burk 1991a, b) showed that ^{131}I releases from the B and T fuel processing plants at the Hanford Site were of sufficient

magnitude that there was a large area in the vicinity of Hanford where doses could be of concern. As a result, the study area shown in Fig. 1 was selected for atmospheric dispersion and deposition modeling. This rectangular area is centered at $46^{\circ}40'\text{N}$, $118^{\circ}45'\text{W}$ and extends ~500 km from north to south and 400 km from east to west. Geographically, the study area extends from central Oregon to northern Washington and from the crest of the Cascade Mountains to the eastern edge of northern Idaho. The study area is bounded by the major topographic features of the region and is situated with more of the area on the downwind side of the releases, given the prevailing wind direction.

Rattlesnake Mountain is the most notable topographic feature in the immediate vicinity of the Hanford Site. It is a treeless ridge that runs along the southwest boundary of the Hanford Site and has an elevation that exceeds 1,050 m. The southwestern slope of Rattlesnake Mountain is gentle, but the northeast face of Rattlesnake Mountain is extremely steep. The elevation of the Hanford Site in the vicinity of the reactor fuel processing plants is about 225 m. There is a broad valley between Rattlesnake Mountain and the processing plants. To the north and east of the processing plants, the terrain slopes toward the Columbia River. Light nighttime drainage winds may cause plumes to drift either to the west toward Rattlesnake Mountain or to the east toward the Columbia River.

The study area is sufficiently large that systematic variations in meteorological and climatological conditions are found across the area. Wind roses are a graphical means of showing the climatological distribution of wind directions at a location. The wind roses in Fig. 2 show the effects of Rattlesnake Mountain, the channeling of flow by the mountain valleys along the western edge of the study area, and the prevailing southwest winds over most of the Mid-Columbia Basin (see Pasco, LaCrosse, and Harrington in Fig. 2) and the Spokane area (see Fairchild in Fig. 2). Annual precipitation varies from a low of ~16 cm y^{-1} near Hanford to more than 250 cm y^{-1} in the Cascade Mountains on the western edge of the study area. The annual precipitation along the eastern edge of the study area is generally more than 50 cm y^{-1} .

The size of the study area, the variations in meteorological conditions, the length of time being modeled, and the desire to model uncertainty led to the cautions

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rate of evolution of the iodine during fuel processing. According to Heeb (1993), the uncertainty in timing of releases ranges from a few hours to a day or more. As a result, the uncertainty in release rate at a specific time is large. The release rate may range from 0 to several terrabecquerels per hour. In contrast, the uncertainty in total release over long periods, for example months or years, is much smaller. Coefficients of variation of the monthly release estimates are typically 0.1 or lower (Heeb 1994).

For HEDR model runs, the iodine associated with particles was assumed to be uniformly distributed between 5% and 45%, and the I_2 was assumed to constitute 20% to 60% of the gaseous iodine. The remainder of the iodine was assumed to be CH_3I . The range of values for each iodine fraction, based on these assumptions, is shown in Table 3. Note that the sum of the fractions is constrained to be 100% and that the fraction for the particulate component is the only uniformly-distributed fraction. The fractions for I_2 and CH_3I are more likely to be near the center of the ranges than near the ends. The distribution of iodine among the three species was changed from realization to realization but not within a realization.

RESULTS

The footprints for the time-integrated, ^{131}I air concentrations and surface deposition are consistent with the wind roses shown in Fig. 2. Fig. 4 shows a footprint based on the median deposition at each of the nodes from 100 model runs. The highest values near the Hanford Site were found to the east and southeast of the release point, which is consistent with the prevailing winds at the Hanford Meteorology Station. Farther from the Site, the highest values are found to the northeast, which is consistent with the prevailing southwest winds in the Mid-Columbia Basin. The pattern shown in Fig. 4 is somewhat broader than the footprint for a typical model run because the spatial correlations in deposition within a model realization were lost by using median values.

Variability of the total deposition from realization to realization is a function of position within the study area. In the 100 realizations, the ranges of values at nodes in the main part of the footprint are generally less than a factor of four, but the ranges for several nodes at the edge of the footprint exceed an order of magnitude. Table 4 shows statistics for 12 locations; the ranges of values at Yakima, WA, and The Dalles, OR (which are on the upwind edge of the footprint) can be compared with the

Table 3. Ranges of iodine species fractions.

Component	Component fraction	
	Minimum	Maximum
Particles	5%	45%
I_2	11%	57%
CH_3I	22%	76%

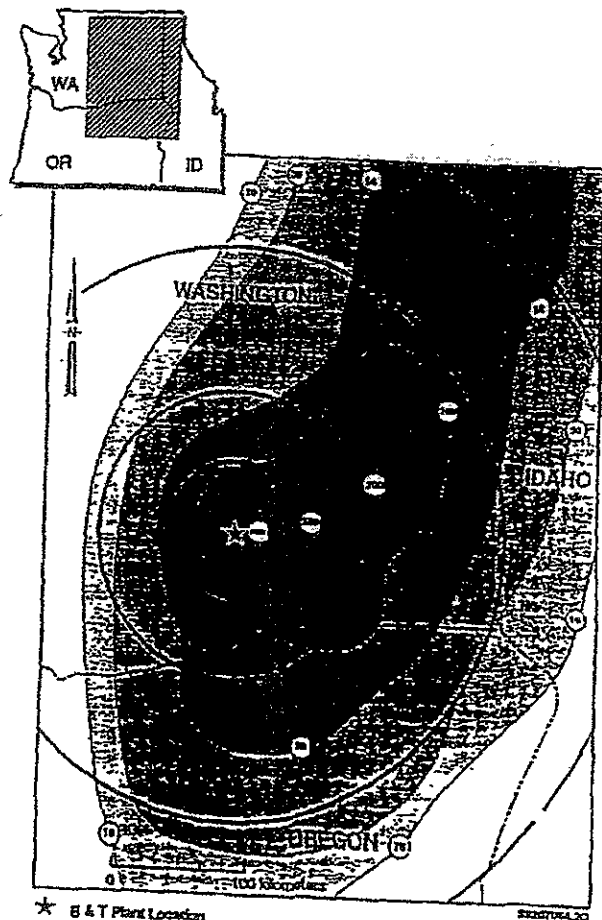


Fig. 4. Median estimates of total ^{131}I deposition (kBq m^{-2}), December 1944 through December 1949.

Table 4. Variation in total ^{131}I deposition in 100 realizations of RATCHET.

Location	Mean (kBq m^{-2})	Standard Deviation (kBq m^{-2})	Maximum (kBq m^{-2})	Minimum (kBq m^{-2})
Bonner's Ferry	31.4	4.1	41.5	21.7
Colfax	57.1	10.5	87.4	33.9
Coulee City	24.9	6.1	48.1	14.6
Lewiston	18.6	2.9	24.3	12.3
Othello	261	59.0	434	174
Pendleton	79.5	12.2	124	54.5
Richland	766	152	1,400	385
Ritzville	194	36.4	309	115
Spokane	80.1	11.6	119	55.5
The Dalles	3.2	1.4	7.2	0.9
Walla Walla	70.5	18.7	160	44.8
Yakima	6.7	2.3	13.2	2.6

ranges at Richland, Ritzville, and Spokane, WA, and Bonner's Ferry, ID (which are in the main portion of the footprint).

The way in which iodine was partitioned among the three species had a significant effect on time-integrated

air concentrations and total deposition at nodes. Of the three species, the organic iodine fraction was most highly correlated with variations in time-integrated air concentrations and total deposition. However, this correlation is a function of position within the study area. Near the Hanford Site the correlation between the organic fraction and time-integrated air concentration is low and positive. As distance increases, the correlation becomes larger. Far downwind from the Hanford Site variations in the organic fraction account for more than 70% of the variability in time-integrated air concentrations. In contrast, the correlation between the organic fraction and total deposition is relatively high and negative near the Hanford Site and decreases as distance increases.

Fig. 5 illustrates these changes in the correlation between organic fraction and time-integrated air concentrations and total deposition by showing the model output for all 100 realizations for Richland and Bonner's Ferry. The changes in correlation between organic fraction and time-integrated air concentrations and total deposition with distance are shown more quantitatively in Table 5. Richland, Spokane, Bonner's Ferry lie near the long-term plume axis at distances of approximately 50 km, 200 km, and 350 km, respectively.

Table 5. Spatial variation of the correlations between the ¹³¹I organic species fraction and time-integrated air concentrations (MBq s m⁻³) and total deposition (kBq m⁻²).

Location	Approximate distance (km)	Time-integrated air concentration		Total deposition	
		r ²	Correlation	r ²	Correlation
Richland	50	0.101	positive	0.465	negative
Spokane	200	0.702	positive	0.268	negative
Bonner's Ferry	350	0.705	positive	0.047	negative
Yakima	60	0.186	positive	0.000	not significant

The changes in correlation are explained physically by considering the effect of deposition on air concentration as distance increases. The effective deposition velocity for iodine is negatively correlated with organic fraction. As a result, when the organic fraction is small, iodine deposition near the source will be large and concentrations far downwind will be low. At the other extreme, when the organic fraction is large, there will be relatively little deposition near the source and concentra-

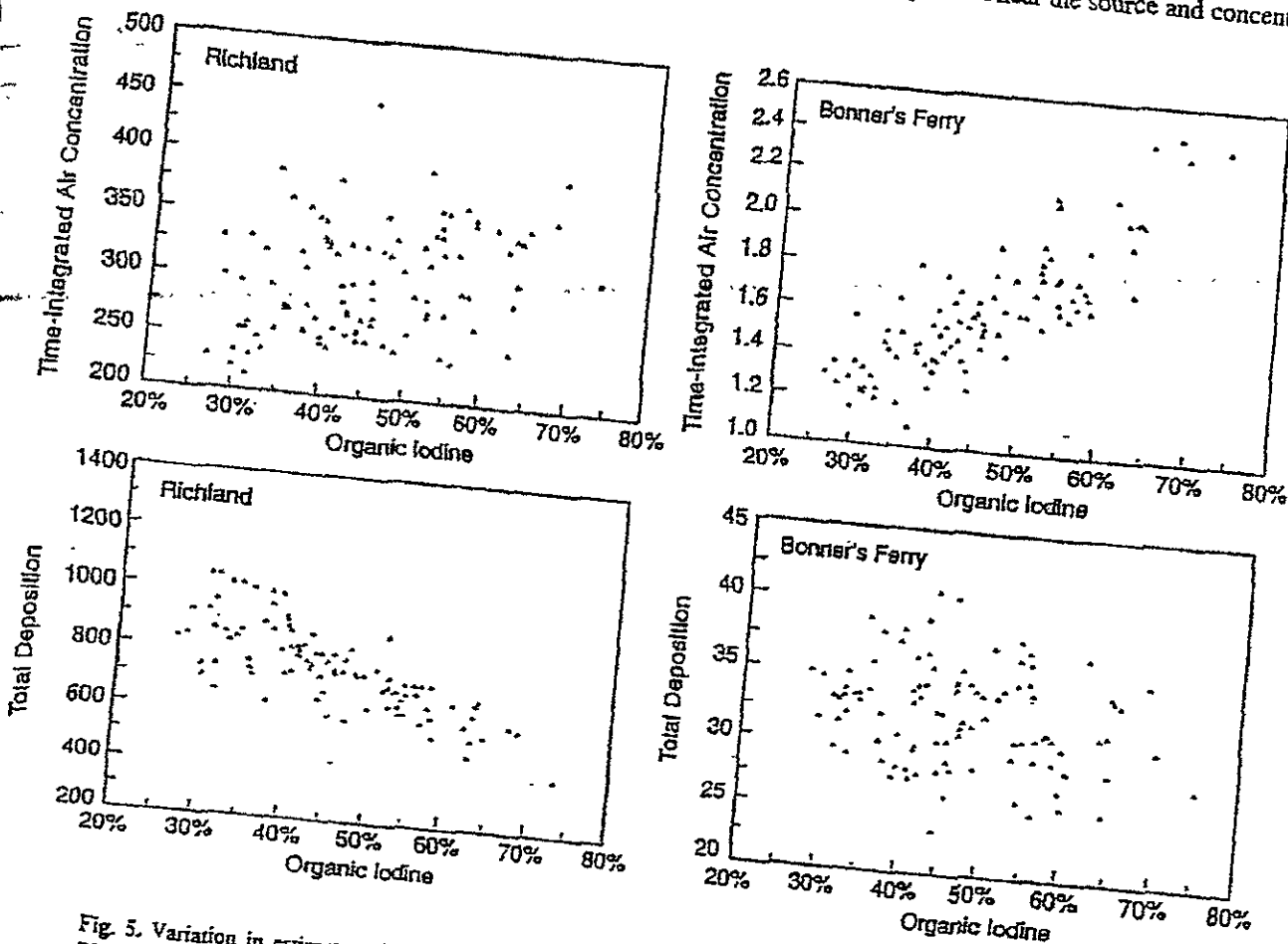


Fig. 5. Variation in estimates of total time-integrated air concentration (MBq s m⁻³) and deposition (kBq m⁻²) at Richland, Washington, and Bonner's Ferry, Idaho, as a function of percent organic iodine (CH₃I).

tions far downwind will be relatively high. However, these higher concentrations do not result in correspondingly high deposition at distance because the effective deposition velocity is low.

Yakima, which is included in Table 5, is slightly farther from the release point than Richland. Thus, the correlation between the organic fraction and time-integrated air concentrations at Yakima is consistent with correlations at other locations. On this basis, the correlation between total deposition at Yakima and the organic fraction might be expected to be similar to the correlation for Richland; however, Table 5 shows that there is no correlation. Although there is no proof, intermittency is suspected to be one of the reasons for the lack of correlation since RATCHET output indicates that released material reached Yakima only a few times each year.

The footprint for median estimates of the maximum surface contamination at any time during the 5-y period is shown in Fig. 6. For most of the study area, the maximum surface contamination is ~10% of the total deposition. This result is consistent with the pattern of monthly releases shown in Fig. 3. While it is highly unlikely that the maximum surface contamination occurred simultaneously over the entire area, it is likely that the maxima for most locations in the main portion of the footprint occurred during the last half of 1945.

Heeb (1994) estimates that $\sim 2.6 \times 10^4$ TBq of ^{131}I were released from Hanford during the first 5 years of operation. The ultimate fate of this iodine was estimated using the mass balance statistics generated by RATCHET (see Table 6). It is estimated that ~56% of the ^{131}I released at Hanford was deposited within the

Table 6. Variability in the fate of ^{131}I in 100 realizations, December 1944 through 1949.

	Total release (TBq)	Deposited in study area (%)	Decayed in study area (%)	Left study area (%)
Mean	2.57×10^4	56.5	9.6	33.9
Standard deviation	1.37×10^3	6.5	0.90	5.4
Maximum	2.93×10^4	71.4	11.6	45.9
Minimum	2.33×10^4	37.3	7.8	23.9

study area, ~10% decayed while in transit in the atmosphere within the study area, and the remaining 34% left the area in the air. The uncertainties in these fractions are relatively small in comparison with the uncertainties in the values at specific nodes or for shorter time periods.

The variability in the organic iodine fraction is a major contributor to the variations in the overall ^{131}I mass balance. Fig. 7 shows the relationship between the fraction of the ^{131}I deposited in the study area and the organic fraction. The variations in the organic fraction account for almost 50% of the variations in the total deposition. Variations in the organic fraction account for similar percentages in the amount of ^{131}I that decayed during atmospheric transport within the study area and the amount that left the area. In contrast to the variation shown in Fig. 7, these last two correlations were positive. Increasing the organic fraction increases the percentage of ^{131}I that decayed in, or departed from, the study area.

CONCLUSIONS

Early HEDR Project studies determined that existing information was sufficient to reconstruct the ^{131}I releases to the atmosphere from early Hanford Site operations and to track the ^{131}I through the environment. Therefore, the HEDR Project developed a suite of computer codes to estimate the radionuclide releases, track them through the environment, and estimate doses. The RATCHET computer code is part of this suite.

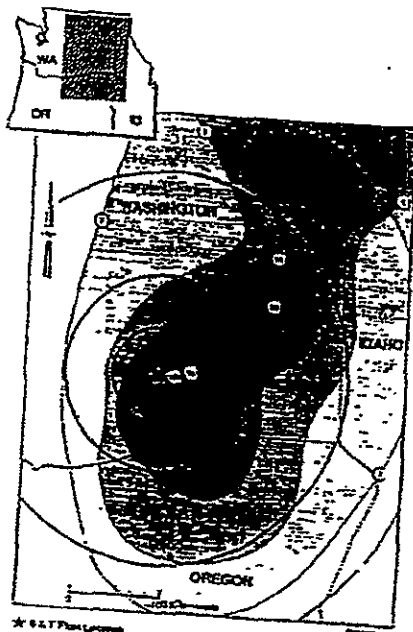


Fig. 6. Median estimates of the maximum surface contamination (kBq m^{-2}), December 1944 through December 1949.

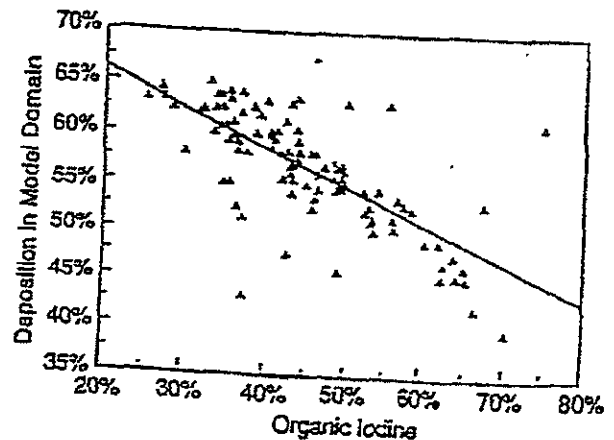


Fig. 7. Variation in percent of ^{131}I deposited as a function of the percent of organic iodine.

Exhibit K

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF WASHINGTON

IN RE HANFORD NUCLEAR MASTER FILE,
RESERVATION LITIGATION No. CY-91-3015-WFN

VIDEOTAPE DEPOSITION OF: JOHN TILL, Ph.D.

Taken on behalf of the Plaintiffs

November 19, 2004

BE IT REMEMBERED THAT, pursuant to the Washington Rules of Civil Procedure, the deposition of John Till, Ph.D., was taken before Barbara Birger, Registered Professional Reporter, Certified Realtime Reporter and Notary Public for the State of Colorado, on November 19, 2004, commencing at the hour of 8:58 a.m., the proceedings being reported at Gibson Dunn & Crutcher, 1801 California Street, Suite 4200, Denver, Colorado.

Page 2

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 10
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 23
 24
 25

Page 3

1 APPEARANCES CONT.
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Page 4

1 WHEREUPON, the following proceedings were taken
 2 pursuant to the Washington Rules of Civil Procedure.
 3 * * * * *
 08:57:33 4 THE VIDEOGRAPHER: We are on the record. This
 08:57:35 5 is a statement for a video deposition. I am the
 08:57:39 6 videographer, and my name is Kafay Kinney. I am here on
 08:57:42 7 behalf of Naegeli Reporting Corporation headquartered at
 08:57:46 8 111 Southwest 5th Avenue, Suite 2020, Portland, Oregon
 08:57:51 9 97204.
 08:57:54 10 This videotape deposition has been noticed by
 08:57:57 11 attorney Thomas Foulds, and is being held on
 08:58:00 12 November 19, 2004, at 8:58 a.m. The location is 1801
 08:58:07 13 California, Suite 4200, in Denver, Colorado.
 08:58:10 14 The case caption -- the case caption is In Re
 08:58:16 15 Hanford Nuclear Reservation Litigation, United States
 08:58:20 16 District Court for the Eastern District of Washington at
 08:58:24 17 Spokane, Case No. CY-91-3015-WFN. The deponent is John
 08:58:32 18 Till.
 08:58:33 19 Would counsel and all present please identify
 08:58:36 20 yourselves and state whom you represent.
 08:58:39 21 MR. FOULDS: I'm Tom Foulds, I represent the
 08:58:43 22 plaintiffs.
 08:58:44 23 MR. HABER: Roy Haber, I represent the
 08:58:46 24 plaintiffs.
 08:58:46 25 MR. RADFORD: And Lee Radford representing the

Page 5

08:58:48 1 defendants.
 08:58:50 2 THE VIDEOGRAPHER: The deposition is being
 08:58:51 3 taken before Barbara Birger, court reporter, who will
 08:58:55 4 now swear in the witness.
 08:58:57 5 JOHN TILL, Ph.D.,
 08:58:57 6 having been first duly sworn to state the whole truth,
 08:58:57 7 testified as follows:
 08:58:57 8 EXAMINATION
 08:59:08 9 BY-MR.FOULDS:
 08:59:10 10 Q. Dr. Till, as you know, my name is Tom Foulds,
 08:59:14 11 and I represent the plaintiffs. This deposition --
 08:59:17 12 perhaps you've had previous depositions -- it's really a
 08:59:23 13 court-mandated procedure, but it's in the very informal
 08:59:27 14 setting. But the witnesses are required to respond to
 08:59:34 15 the best of their knowledge and as truthfully as
 08:59:37 16 possible.
 08:59:38 17 Now if any one of my questions are -- that you
 08:59:44 18 can't quite understand it or you didn't hear it all,
 08:59:47 19 anything of that nature, don't hesitate to ask me to
 08:59:50 20 repeat it or to clarify it for you.
 08:59:54 21 The attorney representing the defendants here,
 08:59:57 22 Mr. Radford, may on some occasion have an objection to
 09:00:01 23 my questions. Once he gets the objection on the record,
 09:00:06 24 then you can go ahead and proceed to answer since all
 09:00:10 25 objections -- the determination of the validity of all

09:17:56 1 The seven key issues are in order of priority:
 09:18:00 2 1. Air model concerns. Many people remain concerned
 09:18:06 3 about, quote, disappearance factors, end of quote,
 09:18:10 4 hyphen, the inconsistencies between measured and
 09:18:14 5 predicted deposition of iodine in the 1940s, hyphen, and
 09:18:18 6 the role weather and topography may have played in the
 09:18:22 7 amounts and locations of radioactive iodine deposited.
 09:18:29 8 Now, Dr. Till, in reading this, would it be
 09:18:33 9 correct to say that as of the time of the release of
 09:18:37 10 Phase II -- of the Phase II HEDR report in 1994, would
 09:18:45 11 it be correct to say that it could not be used, quote,
 09:18:49 12 With confidence in Hanford health-related work, end of
 09:18:54 13 quote?
 09:18:57 14 MR. RADFORD: Objection, form.
 09:19:00 15 A. I would appreciate your repeating that
 09:19:02 16 question.
 09:19:04 17 Q. (BY MR. FOULDS) Sure. Would it be correct to
 09:19:06 18 say that as of the time the Phase II HEDR report was
 09:19:16 19 released in 1994, that it could not be used, quote, With
 09:19:24 20 confidence in Hanford-related work, end of quote?
 09:19:31 21 A. I would say that when the Phase II results
 09:19:38 22 were released, there was additional work that we felt
 09:19:46 23 that should be done. These are not my words that they
 09:19:52 24 could not be used with confidence, of course, but -- and
 09:19:58 25 that following what was done, or following that report

09:20:02 1 in 1994, there were a number of additional issues that
 09:20:11 2 were addressed by CDC and other scientists that would
 09:20:20 3 have raised this level of confidence in the TSP results.
 09:20:29 4 Q. Now the -- do you know what improvements, if
 09:20:53 5 any, have been made in the air modeling since this
 09:21:01 6 final -- since the final Phase II report?
 09:21:06 7 MR. RADFORD: Objection, form, ambiguous.
 09:21:11 8 A. I don't know that the air modeling has been
 09:21:13 9 changed much at all. What I can tell you is that since
 09:21:22 10 that time the air model used in HEDR, which is the
 09:21:28 11 RATCHET model, has undergone a tremendous amount of
 09:21:33 12 scrutiny, review, validation, and so forth. So I would
 09:21:42 13 have to put it in that context that the RATCHET model
 09:21:46 14 has held up very well.
 09:21:52 15 As far as changes are concerned, no, they have
 09:21:55 16 not undergone -- RATCHET has not undergone significant
 09:22:00 17 changes.
 09:22:01 18 Q. (BY MR. FOULDS) Well, the reason I ask is the
 09:22:04 19 list of the key issues that remain to be resolved, the
 09:22:08 20 air model was listed as the number-one concern. Now if
 09:22:24 21 I understand your response correctly, sir, you feel that
 09:22:27 22 subsequent analysis of the RATCHET model indicated that
 09:22:35 23 it was holding up fairly well, to use your -- I'm trying
 09:22:39 24 to use your terminology -- or how would you express it?
 09:22:45 25 In other words, even though this was indicated

09:22:47 1 as the number-one priority to make an improvement on, is
 09:22:53 2 it your testimony that the -- that improvements in the
 09:22:58 3 RATCHET model itself were not needed; is that correct?
 09:23:02 4 Is that correct?
 09:23:03 5 MR. RADFORD: Objection, compound.
 09:23:07 6 MR. FOULDS: I'm sorry, I didn't hear that
 09:23:10 7 last response. Would you read it back.
 09:23:16 8 THE REPORTER: I don't think he gave a
 09:23:17 9 response.
 09:23:18 10 A. I'm going to ask you to repeat your question
 09:23:20 11 again.
 09:23:28 12 Q. (BY MR. FOULDS) Is it your testimony that
 09:23:36 13 despite the indication in the TSP final report that the
 09:23:48 14 air modeling needed some work to remedy disappearance
 09:24:08 15 factors and inconsistencies between measure and
 09:24:12 16 predictions deposition of iodine in the 1940s, is it
 09:24:18 17 your testimony that subsequent studies showed that such
 09:24:22 18 improvement in the RATCHET model was not necessary?
 09:24:26 19 MR. RADFORD: Objection, compound, foundation.
 09:24:29 20 A. As I mentioned, at the end of HEDR we
 09:24:32 21 indicated there were a number of concerns about the air
 09:24:36 22 model that warranted a further look. And these were
 09:24:43 23 looked at subsequent to the HEDR project. And in
 09:24:49 24 addition to this, the model has been reviewed, peer-
 09:24:56 25 reviewed, validated, and as a result has not been

09:25:03 1 changed. And I do not feel that it needs to be changed.
 09:25:45 2 MR. FOULDS: Would you mark this as -- I guess
 09:25:49 3 the next exhibit should be 3.
 09:26:05 4 (Deposition Exhibit-3 was marked.)
 09:26:15 5 Q. (BY MR. FOULDS) Dr. Till, the reporter has
 09:26:17 6 passed you Exhibit 3, which is entitled Technical
 09:26:23 7 Steering Panel Task Report, published December 1995,
 09:26:29 8 Comparison of HEDR Atmospheric Models to Environmental
 09:26:33 9 Data at Other Sites.
 09:26:38 10 And I would direct your attention, sir, to
 09:26:40 11 page 9 in which they are reviewing the Regional
 09:26:57 12 Atmospheric Transfer Code for Hanford Emission Tracing,
 09:27:04 13 we're using the acronym RATCHET. And the number-one
 09:27:12 14 conclusion, "Time Sequence-Vegetation Contamination
 09:27:23 15 Comparisons. Visual evaluation of the HEDRIC model is
 09:27:28 16 that only below about 316 nanocuries of iodine-131 per
 09:27:34 17 kilogram of vegetation does the median prediction of the
 09:27:37 18 model agree within the factor of three within the
 09:27:40 19 measured results. At higher concentrations median model
 09:27:43 20 predictions are within an order of magnitude agreement.
 09:27:46 21 Furthermore, the model underpredicts the resultant
 09:27:49 22 iodine-131 in the great majority of cases."
 09:27:55 23 Now would it be your testimony that further
 09:27:57 24 study of RATCHET indicated that that underprediction and
 09:28:10 25 coming just within an order of magnitude at higher

Exhibit L

1 UNITED STATES DISTRICT COURT
2 EASTERN DISTRICT OF WASHINGTON

3 **UNCERTIFIED ROUGH DRAFT**

4 IN RE HANFORD NUCLEAR MASTER FILE
5 RESERVATION LITIGATION No. CY-91-3015-WFN

6

7 DEPOSITION OF ARTHUR S. ROOD

8 Taken on behalf of the Plaintiff

9 November 5, 2004

10 ---

11

12 BE IT REMEMBERED THAT, pursuant to the Washington
13 Rules of Civil Procedure, the deposition of Arthur
14 S. Rood was taken before Marta M. Rice, CCR No.
15 2050, CSR No. 722, Registered Professional Reporter,
16 and a Notary Public for the State of Idaho, on
17 November 5, 2004, commencing at the hour of 9:20
18 a.m., the proceedings being reported at Moffatt,
19 Thomas, Barrett, Rock & Fields, 420 Memorial Drive,
20 Idaho Falls, Idaho.

21

22

23 **UNCERTIFIED ROUGH DRAFT**

24

25

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1 MR. FOULDS: Okay.
 2 BY MR. FOULDS:
 3 Q. So I understand it's -- it's your -- it's
 4 still your thought that somehow or another there was
 5 a way of establishing or coming up with the hourly
 6 release quantities, other than just taking the
 7 monthly amounts and dividing it by a certain number
 8 of days and hours?
 9 A. (Nodding in the affirmative.
 10 Q. Okay.
 11 THE COURT REPORTER: Is that a yes?
 12 THE WITNESS: Yes. That's a yes.
 13 MR. FOULDS: Now, let me see. Did I get S
 14 out yet? Yeah. I think I did. Just a second. I
 15 had S here some place.
 16 MR. PIERSON: So if that assumption is
 17 incorrect then what? Would it make it less
 18 accurate?
 19 MR. FOULDS: Yeah. Oh, here it is. I was
 20 getting ready to give it to you two gentleman.
 21 Would you mark this as a (sic) exhibit, please.
 22 (Whereupon, Exhibit-13 was marked for
 23 identification.)
 24 BY MR. FOULDS:
 25 Q. Now, Mr. Hanna, I understand that --

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1 MR. RADFORD: Mr. Stewart -- Mr. Rood.
 2 THE WITNESS: Mr. Rood.
 3 MR. FOULDS: I'm sorry. Please forgive
 4 me.
 5 THE WITNESS: You are forgiven.
 6 BY MR. FOULDS:
 7 Q. Mr. Rood, I understand that you read
 8 Doctor Stewart's deposition?
 9 A. Most of it.
 10 Q. Yeah. Okay. Do you recall in the early
 11 part of the deposition that he pointed out to what
 12 he thought was an error in the formulas used by HEDR
 13 to calculate the amount of the -- I'm coming to the
 14 right part here -- the amount of the deposition --
 15 no -- correction -- the amount of the depletion from
 16 the plume. Do you recall that?
 17 A. You're asking whether I recall him
 18 questioning the correctness of equation 2.61? The
 19 analytical integration? If -- if I remember
 20 correctly, that was the equation in question.
 21 Q. Well, this was on pages 225 and 238.
 22 A. Right. Equation 2.61 is on page 238. And
 23 from my understanding of his -- reading his
 24 deposition, he questioned the integration that is
 25 initially introduced in equation 2.60.

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1 MR. FOULDS: I'll read from the paragraph
 2 just above the equation number 2.60. "The mass
 3 removed from each puff is determined by analytical
 4 integration of deposition flux over the area covered
 5 by the puff and computation interval.
 6 "The mass removed from each puff to account for
 7 dry deposition of particles and dry and wet
 8 deposition of gases is computed using," and then he
 9 gives the integral formula.
 10 Then the next sentence underneath the first
 11 formula, 2.60, is, "Substituting the deposition of X
 12 from equation 2.29 for X and performing the
 13 integration, the decrease in material becomes," and
 14 then he's got a -- an algorithm -- or equation, I
 15 guess, to represent the -- the decrease in
 16 material. And he -- there's a number two in front
 17 of the right side of the equation. Now, according
 18 to his testimony, he believes that that last
 19 integration was done in error and he submitted two
 20 different ways to do that equation.
 21 BY MR. FOULDS:
 22 Q. My question to you is, have you reviewed
 23 any of that material?
 24 A. I reviewed the -- his deposition statement
 25 and followed through the mathematics and performed

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1 the integration myself. First, just for the record,
 2 that's not an X, it's a chi (CHECK). Pronounced
 3 chi.
 4 Q. Okay.
 5 A. It's a concentrate. Just for the
 6 record --
 7 Q. Sure.
 8 A. -- so we're talking the same terms. And
 9 when I did the integration I -- I agreed with -- I
 10 came up with what Doctor Stewart came up with.
 11 Q. Okay.
 12 A. Now, I called Van Ramsdell and had him
 13 look into this matter. He returned my call and came
 14 up with this resolution.
 15 RATCHET has a typographical error in
 16 equation 2.61 and an omission in equation 2.61. The
 17 typographical error revolves around the term G of Z.
 18 It should be G prime of Z. G prime of Z is given by
 19 the form similar to what's shown on -- in equation
 20 2.31 on page 2.25 of the RATCHET manual.
 21 Q. Okay.
 22 A. Everybody there?
 23 Q. Yes. I'm ready. Go ahead.
 24 A. Okay. That -- he explained to me that
 25 that two should not be there for G of Z prime.

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1 Okay? So G of Z prime is equal to G of Z without
2 that two.

3 Q. All right. Now --

4 THE VIDEOGRAPHER: You've got about 10
5 minutes left on the tape.

6 THE WITNESS: Okay. Without -- if we
7 define in equation 2.61, replace G of Z with G of Z
8 prime, then the integration is correct and that two
9 should be there.

10 BY MR. FOULDS:

11 Q. Now, can we go back to equation 2.31, and
12 tell me what that represents? And maybe I
13 misunderstood you. I thought this was the one you
14 referred to.

15 A. Oh, okay. 2.31 is the vertical term and
16 it's a component of 2.29, which is what's
17 substituted there. 2.29, if you can see there --

18 Q. Yes.

19 A. -- is -- has chi has a function of the
20 radius R.

21 Q. Um-hmm.

22 A. Actually, R is in terms of a distance.

23 Q. Um-hmm.

24 A. Z, that is the height and time. Okay?
25 Now, you see there it has a term G of Z in there.

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1 See G of Z in equation --

2 Q. Wait. Just a second. Just a second. I'm
3 looking for it. Yeah. GZ?

4 A. Right. G of Z.

5 Q. G -- okay. G of Z?

6 A. Right. G is the function of Z.

7 Q. Yeah.

8 A. Okay. Now, G of Z is given by equation
9 2.31.

10 Q. Okay.

11 A. Okay? So when he substitutes chi, given
12 by equation 2.29, he is also putting G of Z in
13 there.

14 Q. Right. Okay.

15 A. Okay? Now, what Ramsdell did was, define
16 another term called G of Z prime. And G of Z prime
17 is G of Z without that two. So in the language of
18 mathematics we say, he factored the two out.

19 Q. So this last equation 2.61, would be
20 correct without the two. Is that right?

21 A. Equation 2.61 could be written two ways.
22 Could be written as it's stated here without the
23 two, or as stated here with the two, but instead of
24 G of Z, G prime of Z, where G -- G prime of Z is as
25 I have previously defined it.

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1 Q. I'm -- where is G prime of -- no -- G
2 prime of Z found?

3 A. This is what I referred to earlier, that
4 Mr. Ramsdell admitted a mistake in the RATCHET
5 manual. Well, a typographical error and an
6 omission.

7 Q. Um-hmm.

8 A. I'll use those terms.

9 Q. Sure.

10 A. The typographical is that in -- in
11 defining equation 2.61, he should have had G prime
12 of Z.

13 Q. Okay.

14 A. And the omission is, he didn't define what
15 G prime of Z was.

16 Q. Yeah. Right. And there's no definition
17 of -- of G -- G prime of Z, is there?

18 A. Not in the -- the RATCHET manual. That
19 was an omission.

20 Q. Okay.

21 THE VIDEOGRAPHER: You've got about five
22 minutes left on the tape.

23 MR. FOULDS: Sir?

24 THE VIDEOGRAPHER: Five minutes left on
25 the tape.

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1 MR. FOULDS: Okay.

2 BY MR. FOULDS:

3 Q. Well, for somebody like yourself or Doctor
4 Stewart that further wanted to test the accuracy of
5 this thing, where would they go to find what the
6 definition of G prime of Z is? Is there some other
7 source that it may be available?

8 A. That is -- I think, suffice it to say,
9 that the mistake in the -- in -- the -- the
10 typographical mistake or the omission caused much
11 confusion. And you wouldn't go to look at that,
12 you'd just need to define each term and work through
13 the mathematics.

14 I suspect the reason why they went that
15 approach -- and, in fact, I mean, I looked at it and
16 said, well, why did they do that? But there --
17 there was reason for it and because that's the way
18 they worked it in the coding. It's the way they
19 wanted to represent it in the coding.

20 Q. Okay. Okay. Now, have you had a chance
21 to ever review their coding to determine that they
22 did work it out properly?

23 A. Yes. I did review --

24 Q. Okay.

25 A. -- the coding.

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1 Q. Did you -- did you confirm, in your own
 2 mind, that the actual coding does not create the
 3 error as suggested by the printed equation 2.61?
 4 A. I -- I reviewed the coding and looked at
 5 Doctor Stewart's -- where he pointed out the error,
 6 and then went back to the definitions of all the
 7 terms that made up that equation. And so, on the
 8 surface, without looking at the definition of the
 9 terms, one might conclude there was an error. But
 10 after reviewing the definition of the terms, I'm
 11 satisfied that the equation was coded correctly in
 12 RATCHET.
 13 Q. Okay. Oh, well -- well, you would still
 14 need the definition of G of Z prime, wouldn't you,
 15 to make that determination?
 16 A. G of Z prime is defined within the code
 17 and it's defined as Van Ramsdell had explained to
 18 me.
 19 Q. Okay.
 20 A. And I found the definition, it -- it can
 21 be -- if -- if you have a copy of the code I can
 22 point that out.
 23 MR. FOULDS: Okay. Okay. Well, that --
 24 okay.
 25 THE VIDEOGRAPHER: Okay. We're coming

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1 pretty close to the end of the tape.
 2 MR. FOULDS: Yeah. Let's -- let's take a
 3 break and you can change your tape.
 4 THE VIDEOGRAPHER: This marks the end of
 5 tape number two in the deposition of Arthur Rood.
 6 The time is now 3 o'clock. We're off the record.
 7 (Recess.)
 8 THE VIDEOGRAPHER: Back on the record.
 9 Here marks the beginning of tape number three in the
 10 deposition of Arthur Rood.
 11 BY MR. FOULDS:
 12 Q. Mr. Rood, in review of your testimony so
 13 far, isn't it correct that as of the time of this
 14 deposition, you have not reviewed the meteorological
 15 data used by RATCHET to support your opinion that
 16 the data available to RATCHET in the earliest five
 17 years of Hanford operation, was complete enough to
 18 provide adequate accuracy?
 19 MR. RADFORD: Objection. Foundation.
 20 Form.
 21 THE WITNESS: I relied on the work of HEDR
 22 for some of my -- for that opinion. I trusted the
 23 work of HEDR for that. I think there should be some
 24 statement made that we cannot --
 25 MR. FOULDS: Excuse me, sir.

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1 THE WITNESS: There -- there needs to be
 2 some statement made as to there -- we cannot, as
 3 scientists, do everything from the ground up. From
 4 ground zero. We have to rely on work, quality work,
 5 of others. And we establish that quality by the
 6 peer review process and by looking and checking each
 7 one of our -- all our work to -- if -- if we cannot
 8 proceed in that, if everybody has to check
 9 everything from the ground up, then we can throw our
 10 arms up and give up. I mean, we have to build on
 11 what's been done before.
 12 BY MR. FOULDS:
 13 Q. Mr. Rood, isn't it also true that you
 14 never bothered to -- or -- or never -- I shouldn't
 15 use the word bothered, because I'm not trying to be
 16 disparaging.
 17 Isn't it true that you never ran Stewart's
 18 mass balance file, for whatever reason, although it
 19 was identified for you several months ago, along
 20 with the devices on how to run it?
 21 MR. FOULDS: Objection. Asked and
 22 answered. Form. Compound.
 23 THE WITNESS: I looked -- I obtained his
 24 source code to read the file. It's not really
 25 running it, it's reading it. I compiled it on my

Page 141

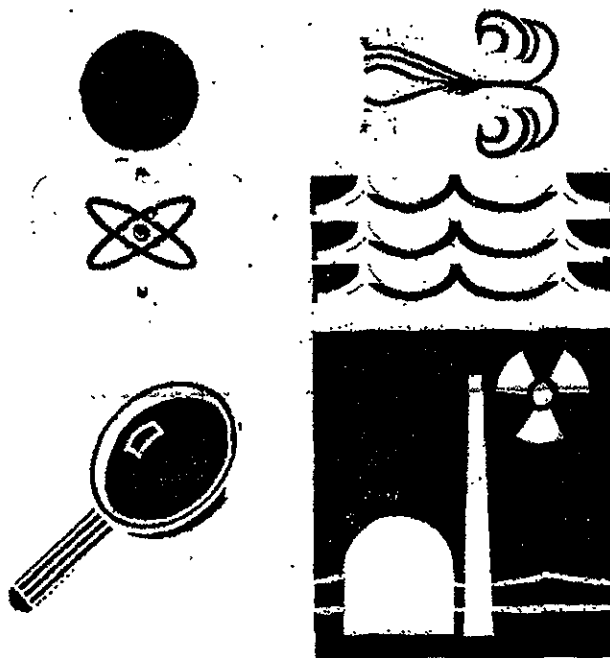
1 machine, and then ascertained that the file was
 2 binary and I couldn't read it directly on my
 3 machine.
 4 At the time, our report was -- had to be put
 5 out and, basically, ran out of time to look at that.
 6 We do have the mechanisms to -- as a team, to look
 7 at that. I just have not got around to doing that.
 8 MR. FOULDS: Okay.
 9 BY MR. FOULDS:
 10 Q. Now, just to summarize and finish up here.
 11 Isn't it also true you never ran a complete mass
 12 balance comparison on RATCHET to test your theory
 13 that summing across the nodes would be the proper,
 14 or a proper, way to check mass balance?
 15 MR. RADFORD: Objection. Foundation.
 16 Asked and answered.
 17 THE WITNESS: To run -- again, I had to
 18 rely on the work -- the previous work done by
 19 Ramsdell -- Ramsdell et al. in terms of their
 20 reviewing the massive amount of data regarding mass
 21 balance.
 22 I was not trying to do a -- the definitive mass
 23 balance comparison of RATCHET or -- or any
 24 definitive mass balance. I'm looking at a -- what
 25 we call a sanity check. And, usually, if the sanity

Exhibit M

Regional Atmospheric Transport Code for Hanford Emission Tracking (RATCHET)

J. V. Ramsdell, Jr.
C. A. Simonen
K. W. Burk

February 1994



Prepared for the Technical Steering Panel
and the Centers for Disease Control and Prevention
under Contract 200-92-0503(CDC)/18620(BNW)

 **Battelle**
Pacific Northwest Laboratories



Pacific Northwest Laboratories
Battelle Boulevard
P.O. Box 999
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Telephone (509) 375-4354

January 18, 1994

Dr. John E. Till, Chairman
Technical Steering Panel
Hanford Environmental Dose
Reconstruction Project
Rt. 2, Box 122
Neeses, SC 29107

Mr. Michael R. Donnelly
Public Health Service
Centers for Disease Control and Prevention
2201 Sixth Avenue, Mail Stop RX-22
Seattle, WA 98121

Dear Dr. Till and Mr. Donnelly:

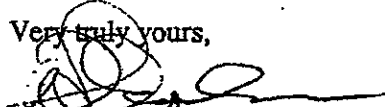
**REGIONAL ATMOSPHERIC TRANSPORT CODE FOR HANFORD EMISSION TRACKING
(RATCHET)**

Enclosed is the final report, *Regional Atmospheric Transport Code For Hanford Emission Tracking (RATCHET)* (PNWD-2224 HEDR). This report describes the atmospheric model and computer code developed for use in calculating daily time-integrated air concentrations and surface contamination. The output from the RATCHET code has been transferred to the Environmental Pathways and Dose Estimates Task for use in dose calculations. This report fulfills Milestone 0402B.

This final RATCHET report is substantially different from the draft RATCHET report (PNL-8003 HEDR) and is, therefore, a replacement for rather than a revision of the draft report. Many of the changes in this final RATCHET report reflect changes that have been made in the RATCHET code and model parameterizations since the draft report was issued. Recent information, including the results of the krypton-85 model evaluation tests and results from the model sensitivity studies, has been added to the report. The source code for RATCHET and the utility codes will be published separately on a diskette rather than as part of the report.

RATCHET has been subjected to an extensive review process. We have incorporated the reviewers' recommendations in the code and in this document. These incorporations are not always in a directly identifiable form because so much of the draft report was either deleted or rewritten. Therefore, the responses to the Technical Steering Panel members' comments are not being issued as part of the report but are enclosed as an attachment to this letter.

Very truly yours,


Dillard B. Shippler, Manager
Hanford Environmental
Dose Reconstruction Project

DBS:prc

Enclosure

cc: MS Power (TSP)
LB

**HEDR
PROJECT RECORD**

**Regional Atmospheric Transport Code for
Hanford Emission Tracking (RATCHET)**

Hanford Environmental Dose Reconstruction Project

January 1994

**This document has been reviewed and
approved by the Technical Steering Panel.**



**J. E. Till, Chair
Technical Steering Panel
Hanford**

January 17, 1994
Date

2.6 Diffusion

Once material is released to the atmosphere, it acts as a passive tracer. Large-scale motions move plumes about, and small-scale atmospheric motions distribute material within plumes. The preceding discussion of transport described how RATCHET accounts for the effects of large-scale motions. This section describes how RATCHET accounts for the effects of the small-scale motions. Section 2.7 describes the deposition of material on surfaces and depletion of the puffs to account for material lost due to deposition and radioactive decay.

2.6.1 Calculation of Time-Integrated Air Concentrations

The second basic assumption in puff models is that a continuous plume can be approximated by a finite number of puffs released in succession. The concentration at a receptor is assumed to be equal to the sum of the concentrations from all of the puffs, that is

$$\chi(x,y,z,t) = \sum_{i=1}^N \chi_i(x,y,z,t) \quad (2.28)$$

where χ = concentration
 x,y,z = position of the receptor in Cartesian coordinates
 t = time of the concentration estimate
 i = puff number
 N = total number of puffs in the model domain.

In practice, computational rules based on puff dimensions have been established to limit the number of terms included in the summation. These rules include assigning a finite radius to each puff and combining puffs that overlap. The rules and RATCHET sensitivity to the rules are discussed in Section 3.2.

In the absence of external influences such as the ground, the concentration distribution in each of the puffs in RATCHET is assumed to be Gaussian. Diffusion in the direction of the wind and cross-wind diffusion are assumed to be equal; that is, horizontal cross sections through puffs are circular. A corollary of this assumption is that concentrations in a horizontal plane decrease as a function of increasing distance from the puff center and are independent of the direction in which the distance is increased. It is, therefore, possible to revise the definition of the coordinate system without changing the relationship in Equation (2.28). The x axis of the coordinate system now may be assumed to point toward the east, with the y axis pointing north and the vertical axis pointing upward.

Because the concentration in puffs is horizontally symmetrical, it is only necessary to know the height of the center of a puff and the distance between the center of a puff and a node to compute the puff's contribution to the concentration at the node. Therefore, the concentration distribution in puffs is defined in terms of the radial distance, r , from the puff center rather than x and y . With these assumptions, the concentration at x,y,z at time t due to puff i is given by

$$x_i(r,z,t) = Q(t)F(r)G(z)/[2\pi]^{3/2}\sigma_r^2\sigma_z \quad (2.29)$$

where

- Q(t) = mass of material (radionuclide) in the puff at time t
- F(r) = exponential function that describes the horizontal concentration distribution
- G(z) = set of terms describing the vertical concentration distribution.
- σ_r = diffusion coefficient that describes the spread of the puff in the horizontal
- σ_z = diffusion coefficient that describes the spread of the puff in the vertical

F(r) is defined by

$$F(r) = \exp[-r^2/(2\sigma_r^2)] \quad (2.30)$$

where $r^2 = (x - x_0)^2 + (y - y_0)^2$, with x,y representing the position of the node and x_0, y_0 representing the horizontal position of the puff center.

The diffusion coefficient σ_r is assumed to be the same as the crosswind diffusion coefficient σ_y used in Gaussian plume models.

Definition of G(z) requires further description of the modeling assumptions. The height of the puff center above ground, which is assumed to be constant, is referred to as the effective release height. If the release is from a stack or elevated vent, the effective release height is the actual stack or vent height plus plume rise.

The ground and the top of the mixing layer are assumed to be totally reflecting surfaces for material within the mixing layer. The top of the mixing layer is not a reflecting surface for material above the mixing layer. Consequently, the top of the mixing layer is similar to a semipermeable membrane.

G(z) describes both the vertical diffusion of material and the effects of the reflection. It is an infinite sum that involves superposition of contributions from virtual sources located below the ground and above the top of the mixing layer. This approach follows from the discussion in Csanady (1973) and is described in detail in Ramsdell et al. (1983). When receptors are at ground level, as they are in RATCHET, G(z) is given by

$$G(z) = 2 \sum_{n=-\infty}^{\infty} \exp\{-0.5(2nH - h_0)^2/\sigma_z^2\} \quad (2.31)$$

where H is the mixing-layer depth and h_0 is the effective release height.

The infinite sum of exponential terms rapidly converges to a limit. Only the terms with $n = -1, 0$, and 1 are used in RATCHET. When the vertical diffusion coefficient becomes sufficiently large ($\sigma_z \approx H$ or $\sigma_z \approx 0.8 h_0$, whichever is larger), material may be assumed to be uniformly distributed in the vertical. In this case, G(z) is given by

RATCHET uses the following expression, which is discussed in Slim (1984), for computing washout of particles by rain:

$$\Lambda = (C E P_r) / (0.35 P_r P_n^{1/4}) \quad (2.55)$$

where Λ = washout coefficient (hr^{-1})
 C = empirical constant assumed to have a value of 0.5
 E = average collision efficiency assumed to be 1.0
 P_r = precipitation rate (mm/hr)
 P_n = normalized precipitation rate ($P_r/1\text{mm/hr}$).

Table 2.2 shows particle washout coefficients for the default rainfall rates in RATCHET.

During periods of snow, the washout coefficient for particles is computed using

$$\Lambda = 0.2 P_r \quad (2.56)$$

Scavenging of gases takes place when the temperature is near freezing. When the temperature falls below -3°C scavenging ceases because of changes in the physical character of the precipitation.

2.7.4 Surface Contamination

Given the dry and wet deposition velocities, the surface contamination that accumulated at any point during a short period is computed as

$$SC1_i(x,y) = d_v x_i(x,y) \Delta t \quad (2.57)$$

where $SC1_i(x,y)$ = mass or activity deposited (Ci/m^2) at x,y from puff i
 d_v = total deposition velocity, $d_{vd} + d_{vw}$ (m/s)
 $x_i(x,y)$ = ground-level concentration (Ci/m^3) in puff i
 Δt = time period (s).

Equation (2.57) simply states that surface contamination in an interval is equal to the product of a transfer coefficient (deposition velocity), the concentration in the air, and the time period.

To this contamination, RATCHET adds the contamination resulting from the washout of particles. This additional contamination is computed using

$$SC2_i(x,y) = \frac{\Lambda Q_i \exp[-0.5(t/\sigma_r)^2] \Delta t}{2\pi \sigma_r^2} \quad (2.58)$$

where $SC2_i(x,y)$ = mass deposited at x,y from puff i by washout of particles
 Λ = washout coefficient (hr^{-1})
 Q_i = mass in puff i
 r = horizontal distance of x,y from the center of the puff
 σ_r = horizontal diffusion coefficient (m)
 Δt = time period (hr).

Equation (2.58) is derived by substituting a washout coefficient for the deposition velocity in Equation (2.58) and then integrating the equation from ground level through the vertical extent of the puff

The total surface contamination at x,y during any period Δt is the sum of the contributions of all puffs:

$$SC(x,y) = \sum_i [SC1_i(x,y) + SC2_i(x,y)] \quad (2.59)$$

2.7.5 Depletion

RATCHET maintains a mass balance. Material deposited on the surface by dry and wet deposition is removed from the material in the puff by decreasing the total mass of the puff. Material is not selectively removed from the bottom of the puff. This approach, which is a variation of the source-depletion model described in Hanna et al. (1982), was used in MESOILT2.

In the atmosphere, deposition results in a mass deficit in the layer of air next to the surface. Source-depletion models instantaneously propagate this deficit through the full vertical extent of the puff. This propagation is unrealistic, particularly in stable atmospheric conditions. Using the resistance analogy to estimate deposition velocities does not deal with this problem explicitly. However, using the resistance analogy results in lower deposition velocities during stable conditions, which reduces the magnitude of the error.

The mass removed from each puff is determined from analytical integration of the deposition flux over the area covered by the puff and computation interval. The mass removed from each puff to account for dry deposition of particles and dry and wet deposition of gases is computed using

$$\Delta Q_d = \Delta t \int_{\theta=0}^{2\pi} \int_{r=0}^{\infty} d_v \chi r dr d\theta \quad (2.60)$$

Substituting the definition of χ from Equation (2.29) for χ and performing the integration, the decrease in material becomes

$$\Delta Q_d = 2d_v QG(z)\Delta t / [2\pi]^{1/2} \sigma_z \quad (2.61)$$

Exhibit N

Petitioner Authorization Form

Use of this form is voluntary. Failure to use this form will not result in the denial of any right or benefit.

Instructions:

If you wish to petition HHS to consider adding a class of employees to the Special Exposure Cohort and you are NOT either a member of that class, a survivor of a member of that class, or a labor organization representing or having represented members of that class, then 42 CFR Part 83, Section 83.7(c) requires that you obtain written authorization. You can obtain such authorization from either an employee who is a member of the class or a survivor of such an employee. You may use this form to obtain such authorization and submit the completed form to NIOSH with the related petition. **Please print legibly.**

For Further Information: If you have questions about these instructions, please call the following NIOSH toll-free phone number and request to speak to someone in the Office of Compensation Analysis and Support about an SEC petition: 1-800-356-4674.

Authorization for Individual or Entity to Petition HHS on Behalf of a Class of Employees for Addition to the Special Exposure Cohort

I, _____
Name of Class Member or Survivor

Street Address of Class Member or Survivor Apt. # P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner Apt. # P.O. Box

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

In providing this authorization, I recognize that the petitioner named above will have all the rights of a petitioner as provided for under 42 CFR Part 83.

Signature of Class Member or Survivor

Date 8/8/05

Name or Social Security Number of First Petitioner: _____

Petitioner Authorization Form

Use of this form is voluntary. Failure to use this form will not result in the denial of any right, benefit,

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If you wish to petition HHS to consider adding a class of employees to the Special Exposure Cohort and you are NOT either a member of that class, a survivor of a member of that class, or a labor organization representing or having represented members of that class, then 42 CFR Part 83, Section 83.7(c) requires that you obtain written authorization. You can obtain such authorization from either an employee who is a member of the class or a survivor of such an employee. You may use this form to obtain such authorization and submit the completed form to NIOSH with the related petition. **Please print legibly.**

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1. _____
Name of Class Member or Survivor

Street Address of Class Member or Survivor Apt. # P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner Apt. # P.O. Box

City, State and Zip Code of Petitioner

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In providing this authorization, I recognize that the petitioner named above will have all the rights under 42 CFR Part 83.

Signature of Class Member or Survivor Date

Name or Social Security Number of First Petitioner: _____

Petitioner Authorization Form

OMB Number: 0920-0639

Expires: 05/31/2007

Page 1 of 2

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Street Address of Class Member or Survivor Apt. # P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner Apt. # P.O. Box

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

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Signature of Class Member or Survivor

Date

Name or Social Security Number of First Petitioner: _____

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Authorization for Individual or Entity to Petition HHS on Behalf of a Class of Employees for Addition to the Special Exposure Cohort

I,

Name of Class Member or Survivor

Street Address of Class Member or Survivor

Apt. #

P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner

Apt. #

P.O. Box

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

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Signature of Class Member or Survivor

Date

9/19/05

Name or Social Security Number of First Petitioner:

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Authorization for Individual or Entity to Petition HHS on Behalf of a Class of Employees for Addition to the Special Exposure Cohort

I, _____
Name of Class Member or Survivor

Street Address of Class Member or Survivor Apt. # P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner Apt. # P.O. Box

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

In providing this authorization, I recognize that the petitioner named above will have all the rights 42 CFR Part 83.

Signature of Class Member or Survivor

Date

Name or Social Security Number of First Petitioner: _____

Special Exposure Cohort Petition
under the Energy Employees Occupational
Illness Compensation Act

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

OMB Number: 0920-0639

Expires: 05/31/2007

Petitioner Authorization Form

Page 1 of 2

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Authorization for Individual or Entity to Petition HHS on Behalf of a Class of Employees for Addition to the Special Exposure Cohort

I, _____
Name of Class Member or Survivor

_____ Apt. # _____ P.O. Box _____
Street Address of Class Member or Survivor

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

_____ Apt. # _____ P.O. Box _____
Address of Petitioner

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

In providing this authorization, I recognize that the petitioner named above will have all the rights of a petitioner as provided for under 42 CFR Part 83.

Signature of Class Member or Survivor

Date

Sept. 16, 2005

Name or Social Security Number of First Petitioner: _____

Special Exposure Cohort Petition
under the Energy Employees Occupational
Illness Compensation Act

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

OMB Number: 0920-0639

Expires: 05/31/2007

Petitioner Authorization Form

Page 1 of 2

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Name of Class Member or Survivor

Street Address of Class Member or Survivor Apt. # P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner Apt. # P.O. Box

City, State and Zip Code of Petitioner

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Signature of Class Member or Survivor

Date

9-20-05

Name or Social Security Number of First Petitioner: _____

Special Exposure Cohort Petition
under the Energy Employees Occupational
Illness Compensation Act

U.S. Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

OMB Number: 0920-0639

Expires: 05/31/2007

Petitioner Authorization Form

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Use of this form is voluntary. Failure to use this form will not result in the denial of any right, benefit,

Instructions:

If you wish to petition HHS to consider adding a class of employees to the Special Exposure Cohort and you are NOT either a member of that class, a survivor of a member of that class, or a labor organization representing or having represented members of that class, then 42 CFR Part 83, Section 83.7(c) requires that you obtain written authorization. You can obtain such authorization from either an employee who is a member of the class or a survivor of such an employee. You may use this form to obtain such authorization and submit the completed form to NIOSH with the related petition. **Please print legibly.**

For Further Information: If you have questions about these instructions, please call the following NIOSH toll-free phone number and request to speak to someone in the **Office of Compensation Analysis and Support** about an SEC petition: **1-800-356-4674.**

Authorization for Individual or Entity to Petition HHS on Behalf of a Class of Employees for Addition to the Special Exposure Cohort

I, _____
Name of Class Member or Survivor

Street address of Class Member or Survivor

Apt. #

P.O. Box

City, State, Zip Code of Class Member or Survivor

do hereby authorize:

Name of Petitioner

Address of Petitioner

Apt. #

P.O. Box

City, State and Zip Code of Petitioner

to petition the Department of Health and Human Services on behalf of a class of employees that includes:

Name of Class Member (employee, not the employee's survivor)

for the addition of the class to the Special Exposure Cohort, under the Energy Employee's Occupational Illness Compensation Program Act (42 U.S.C. §§ 7384-7385).

In providing this authorization, I recognize that the petitioner named above will have all the rights of a petitioner as provided for under 42 CFR Part 83.

Signature of Class Member or Survivor

Date

9-20-05

Name or Social Security Number of First Petitioner: _____