3.0 Overview of RATCHET

The U.S. DOE directed Battelle Memorial Institute to conduct the Hanford Environmental Reconstruction (HEDR) project. The purpose of the HEDR project is to estimate the radiation dose that individuals were exposed to as a result of emissions since 1944 from the Hanford site.

The HEDR project produced a series of codes to estimate the generation of radionuclides to individual exposure. The computer code of interest in this report is the atmospheric transport model (RATCHET).

RATCHET is a Lagrangian-trajectory Gaussian puff model that computes radionuclide air concentrations and deposition rates. It is capable of predicting long-range (i.e., downwind distances bigger then 100 km) pollutant transport. However, a few limitations preclude RATCHET from being used for such task. Some of these limitations include:

- It presently does not account for vertical wind shear.
- It cannot compute partial puff penetration above the mixing height.
- It is a flat terrain model.

Figure 3.1 presents the terrain features of Hanford site's surrounding area. Figure 3.2 is a plan view of the modeled domain. It is clear that complex terrain features are present and should be considered. The inability to handle complex terrain features, including wind distribution and transport of pollutants over and around hills, plume impacting, and channeling effects in valleys, renders the reviewed version of RATCHET inappropriate to model the site. Therefore, I cannot recommend this model, as it stands in the reports, to reconstruct the source-term object of this litigation.

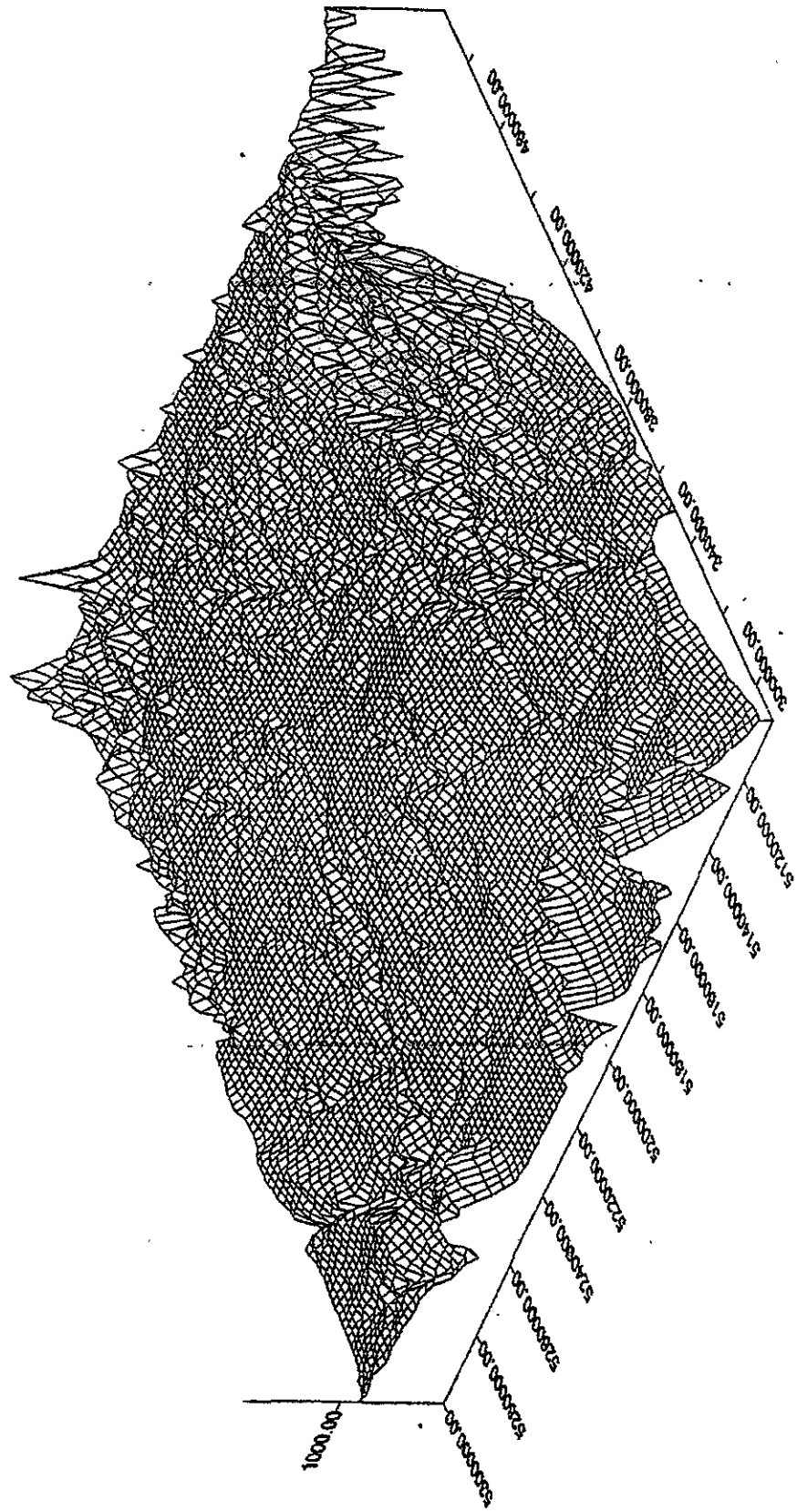

Figure 3.1 – Terrain Elevation over modeled domain (meters)

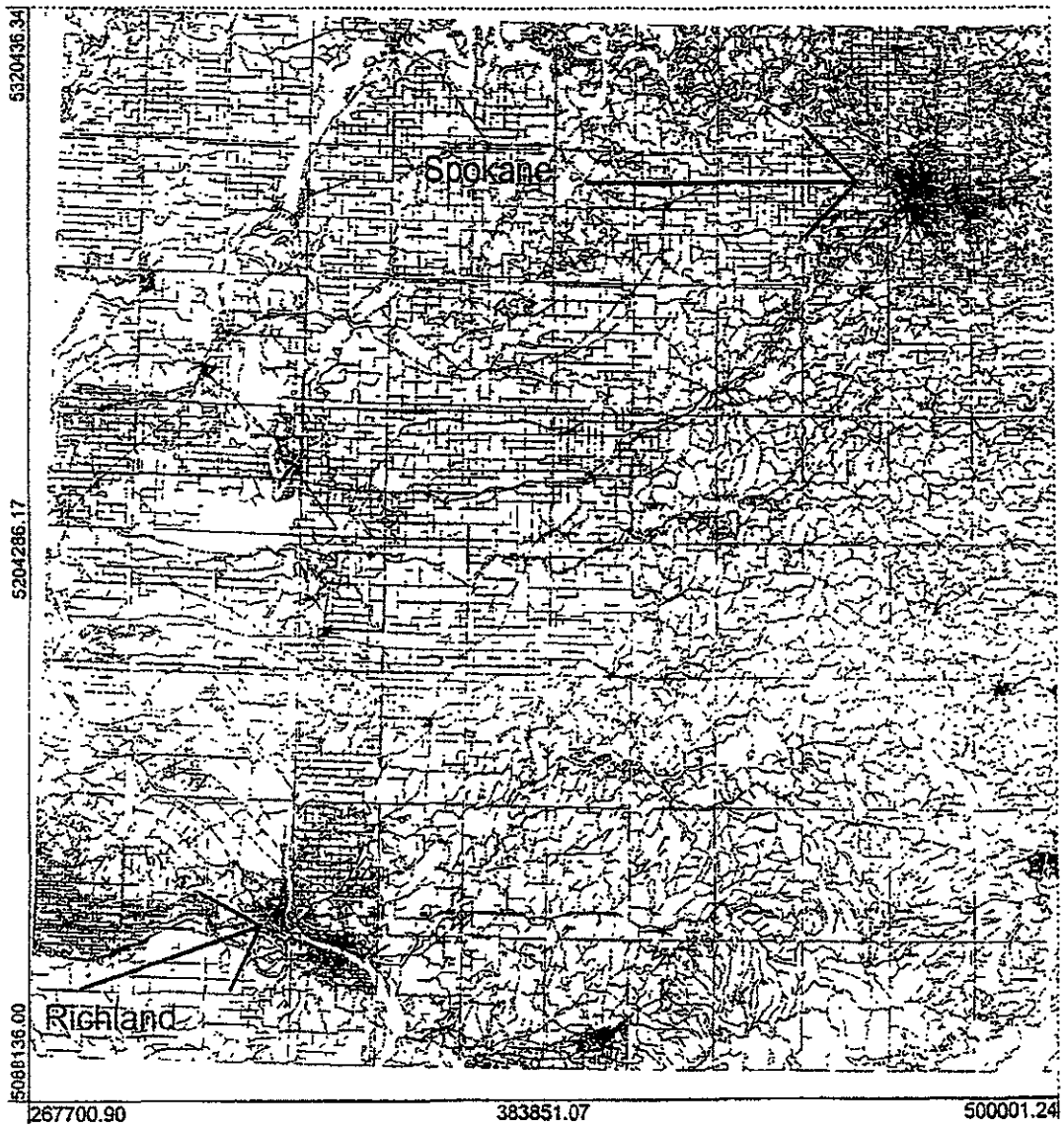

Figure 3.2 – Plane view of modeled domain - UTM Coordinates in meters

4.0 RATCHET Validation Reports

4.1 Validation Procedure

My review of various reports, including Denham (1993), Mart (1993), and Napier (1994) from Battelle's Pacific Northwest Laboratories indicates that RATCHET has not been properly validated. The HEDR computer codes were processed in tandem in order to validate the codes at the same time as the source term reconstruction was being attempted.

Some of Napier's (1994) report assessments, implying validation, are scientifically, unacceptable:

- *"Data are not available to support such an ambitious validation program"* (page 1.3)
- *"It has been possible to infer a validation for earlier information from a validated later step"* (page 1.5). Such a validate procedure should not be used to validate previous steps. Confounding makes evaluation of error compensation among the various modules impossible to establish.
- Table 1.2, in page 1.7, indicates that all validations for RATCHET were executed in an indirect way.
- *"The content of iodine-131 in the fuel, however, was never measured directly so that direct validation is not possible"*. This indicates that the HEDR model responsible for the reactor simulation still has to be thoroughly validated.
- *"January and December factor of 10 under-prediction at all locations."* (page 3-11)
- In page 5.11 it is clear that the lab was contaminated and therefore the background radiation was already high. This is a reason for low measured values.
- The percentile ranges presented in Figures 3.1 to 3.2, in Napier (1994), are very misleading. Note that the y-axis is in logarithmic scale. This procedure hides the significant differences between the model and the measured values. Therefore, Table 4.1 – Application of the measurement score to the results for April 13, 1946, would only change slightly in case all the vegetation data is adjusted by a factor of 10. Additionally, there are no bounds for over-predictions (score 1) or under-predictions (score 6).

4.2 Air Dispersion Model

A defensible work in this area requires a validated and accepted model for long-range transport over complex terrain, with deposition and chemical transformation algorithms. Some of these models have been tested across North America. The main experiments are the Cross-Appalachian Tracer Experiment (CAPTEX) and the Across North America Experiment (ANATEX).

A careful model validation requires model stratification, where several selected model regimes are studied and compared to analytical or field results. This stratification should be based on predominant physics that the model must account for, and this stratification must be easy to verify. The recommended steps to validate both RITM and RATCHET would be:

- Near surface, non-buoyant, rural area, flat terrain, non-depositing, and SO2 emission. Concentrations should be computed from 50m to 1000m. (Barad, 1958).
- Elevated buoyant release (187 m), flat terrain, non-depositing, and SF6 emission. Concentrations should computed for a distance extending from 500m to 50000 m. (Liu and Moore, 1984).
- Elevated buoyant release (100 m), flat terrain, depositing particles (10 microns), and emissions of particulate. Deposition should be computed over a range of 100m to 10000m downwind distances. (Thé, to be published).

Only after an air dispersion model has been tested under controlled conditions, such as the described above, should one attempt to calibrate the model for the Hanford site.

4.3 Terrain Elevations

It is clear from Figure 1 that the local terrain is not flat. A simple facility permit air dispersion model would have been rejected if flat terrain was assumed. In Napier (1994) it was clear that the validation went ahead even when *"Rattlesnake mountain shields that cell from Hanford emissions"*.

The Columbia River Valley and other topographical features will modify air concentration and deposition fluxes. This happens in ways that cannot be estimated by flat terrain models such as RATCHET.

At least two U.S. EPA Lagrangian Gaussian puff models, for long range transport, exist. These codes, MESOPUFF and CALPUFF, have been adequately validated, are well documented, reviewed, available with source code, and free of charge.

4.4 Local Meteorology

Stewart (1996) points out that the wind field is a potentially significant source of error in the RATCHET model. Dr. Stewart also describes that directional bias is commonly as large as 20-45. As an example, an error of 20 degrees, 100 km downwind, can shift the plume by approximately 34 km.

CALPUFF, a long-range transport model from the U.S. EPA, can use an array of meteorological stations to better represent the advection and dispersion process, caused by wind fields, surface roughness, and thermal induced turbulence.

4.5 Wet-to-dry Weight Conversions

The HEDR Validation, as published in Napier (1994), failed to convert wet weight to dry weight. In Napier (1997), it is stated that:

1. *"When adjustment is made for the dry-to-wet correction that was omitted, the HEDR results for this region for 1946 seem to be uniformly low by about a factor of about 3".*

2. *"In the fall and winter months, sagebrush is relatively dry and the impact will be small."*

3. *"If the measurements were overestimated by a factor of three, the observations would again line up on the predictions."*

In Napier (1998), the author states that:

1. *"The errors discovered in the published HEDR validation involve the omission of the wet-to-dry conversion factor for sagebrush in the modeling."*

2. *"Sage brush is acclimated for the annual precipitation pattern, in which nearly half of the annual rainfall occurs in the winter months."*

4.6 Equipment Calibration

Calibration of the Geiger counter equipment is very important in this analysis. First one needs to know the minimum detection level. After that, one should remove all modeling values that are equal or lower than the detection level.

In Appendix B, Table B-1, in Napier (1994), all over predictions (score 1) happen when the median observation is 0.0 μCi/kg.

According to Napier (1994):

1. *"The lower limit of detection was relatively high. One count per minute above background on the detector was equivalent to 2.8E-08 Ci/kg of Iodine-131 (Mark et al. 1993)."*

2. *"The bias introduced by the contaminated laboratory was evaluated to determine the influence on the measurement rank score by the magnitude of the predicted result. In other words, were the small predicted values towards the southern portion of the domain treated as under predictions by the ranking?"*

3. *"The values less than 10 Ci/kg (1nCi/kg), which are predicted for the region southwest of the Hanford Site, where the effects of the laboratory contamination ore most evident. Discounting this portion of the data for which measurements reported were likely in error, ..."*

It is evident that the Geiger counter was calibrated within the Hanford site. Therefore, measured values were low by any standard, and were of an amount difficult to assess.

4.7 Gamma Ray Spectroscopy Correction

In 1957 the vegetation radiation measurement technique was changed from wet chemistry to gamma ray spectrometry. (PNWD-2235). According to Duncan (1994):

*"Early use of gamma ray spectroscopy techniques for vegetation analysis indicated that the wet chemistry techniques being used for I-131 determinations yielded results that were low by a **factor of three**. As a result, all positive I-131 vegetation results for the first and second quarters of 1957 were multiplied by three, giving increased quarterly averages when compare to previous results (HW-51009, HW-52803). Late comparisons of I-131 measurements obtained from gamma spectroscopy method averaged a factor of 1.6 times those obtained with the wet chemistry technique (HW-54841)."*

4.8 Recommendations for the Hanford Air Dispersion Model Validation

Major radiation accidents have always presented unique modeling challenges because of uncertainties related to the source term. An acceptable approach is to use a validated model to calibrate modeled source emissions against field measured results. The resulting postulated emissions are then used to describe the evolution of radiation accidents. Since spatial distributions of concentrations are sensitive to source term changes over long-range, a well tested model and validation criteria must be agreed upon by all parties.

The transport of radionuclides is dependent on the atmospheric motions. A minimum set of physical representation that any model should have to be considered for mesoscale atmospheric transport is described below:

- Spatial variations of:
  - Albedo
  - Surface heat capacity
  - Surface emissivity
  - Surface evaporation rate
  - Surface roughness
- Cloud cover – variable over the mesoscale domain
- Wind speed and direction
- Topography – including terrain features such hills and valleys.

The measured results of radiation from the Hanford site, in the 1940s, consisted of collecting leaves and measuring their radiation levels. The laboratories and the calibration equipment were most times already contaminated and the background values were high. Soil contamination and the various pathways to account for the radiation present on the leaves were not carried out. Additionally, Pacific Northwest Labs employed correction factors in an attempt to improve the quality of radiation measurements performed around the Hanford site in the 1940s. These measurements were used in the validation studies of RATCHET. In a recent document (Napier, 1997) it is clear that the correction factors were understated by a factor of 2.5 times!

Therefore, it is recommended that the serious Hanford site incidents in the 1940s not be used to calibrate the air dispersion model. I recommend that the krypton-85 release measurements for the model concentration estimates and the 1963 PUREX accident for the deposition rate, be used for the final model validations.

5.0 Data Processing and Analysis of Results

5.1 Data availability

The following documents were made available to me by Tom Foulds and Associated Counsel:

From June 17, 1997 to March 26, 1998

Duncan, J., P., "Overview of Vegetation Monitoring Data, 1952-1983", PNWD-2235, Battelle - Pacific Northwest Laboratories, 1994.

Hanna, S., R., "Uncertainties in Air Quality Simulation Model Predictions", Boundary Layer Meteorology, 62, 3-20, 1993.

Jarvis, R. E., "Evaluation of Radiochemical Aspects of HEDR", Report to Tom H. Foulds and Associated Counsel, 1995.

Mart, E. L, D. H. Denham and M. E. Thiede. 1993. "Conversion and Correction Factors for Historical Measurements of Iodine-131 in the Hanford-Area Vegetation, 1945-1947", PNWD-2133 HEDR, Battelle, Pacific Northwest Laboratories, Richland, Washington.

Miley, T.B., Eslinger, P.W., Nichols, W.E., Lessor K.S., Ouderkirk, S.J., "User Instructions for the DESCATES Environmental Accumulation Code", PNWD-2251 HEDR, Battelle – Pacific Northwest Laboratories, May 1994.

Napier, B., Ikenberry, T., "Comparison of Calculated Vegetation Concentrations with Mesurements in 1946", Presentation slides, CDC Technical Workshop, Session III, August 14, 1997.

Napier, B., Letter to Dr. Charles Miller, January 12, 1998.

Napier, B., Letter to Mr. Joe Wayman, April, 1997.

Napier, B., Simpson, J., Eslinger, P., Ramsdell, J., Thiede, M., Walters, W., "Validation of the HEDR Models – Hanford Environmental Dose Reconstruction Project", Battelle – Pacific Northwest Laboratories, 1994.

Stewart, D., "Air Dispersion Modeling Issues Related to the Hanford Radiation Litigation", prepared for Tom Foulds and Associated Counsel for the Hanford Radiation Litigation, March, 1996.

January 6, 1999

A tape that was supposed to contain data for Sagebrush Concentration arrived with CIDER data.

February 18, 1999

Denham, D.H., Dirkes, R.L., Hauf, R.W., Poston, T.M., Thiede, M.E., Woodruff, R.K., "Phase 1 Summaries of Radionuclide Concentration Data for Vegetation, River Water, Drinking Water, and Fish", PNWD – 2145 HEDR, Battelle – Pacific Northwest Laboratories, June 1993.

Hanf, R.W., Duncan, J.P., Thiede, M.E., "Iodine – 131 in Vegetation Collected Near the Hanford Site: Concentration and Count Data for 1948-1951", PNWD-2177 HEDR, Battelle – Pacific Northwest Laboratories, September 1993.

Ms. Karen L. Hoewing, General Counsel, Battelle Pacific Northwest Laboratories, provided a copy of the Hanford Environmental Dose Reconstruction (HEDR) project DESCARTES, output file of the I-131 vegetation concentration of Sagebrush for all nodes for all months of the years 1949 through 1951. This copy was delivered via Federal Express February 11, 1999.

5.2 Data Pre-processing

Tape provided by Battelle was received January 6, 1999. It was supposed to contain vegetation radiation estimates from HEDR codes. This media was an 8mm DAT tape, which contained hundreds of files without description. After a complete analysis of its content, it was possible to verify that the requested data was not present.

On February 11, 1999 the required data was received on a CD-ROM. The large file on that CD was separated into smaller files, each containing a complete year of median values from the 100 stochastic HEDR realization runs.

The final documents, received February 18, 1999, contained vegetation measurement values. These documents, namely Denham (1993) and Hanf (1993) were in paper form and had to be digitized. The office of Tom Foulds and Associated Counsel took note of Cell members in both documents referred to above.

Model Data was then combined with digitized measurement data, in Excel 97 spreadsheets. The data was organized by row, and each row ordered by date and cell number.

5.3 Data Processing

During this review problems were encountered. Some of the problems were related to the measured values, some with the validation of the HEDR codes. These are described above in the section titled "4.0 RATCHET Validation Reports".

5.3.1 Initial Tests

Tests were conducted to evaluate Napier's (1998) statement that increasing the foliage radiation measurement results by a factor of 3 *"would only impact the comparison slightly"*. The results of the tests indicate that the validation "1.5 Data Quality Objectives" in Napier (1994) is false:

"The model validation activities address the DQOs of most of the technical tasks on the HEDR Project. Comparisons of predicted versus monitored historical data must be made, and the

general objective is that the overall bias (ratio of prediction to measurement) of the results be less than a factor of 3. The activities described in this report show that this objective is met"

A sample test indicated that stratifying the results into six segments was not appropriate. Since the difference between the measured and modeled results spans over orders of magnitude, a range limit must be imposed. Figure 5.1 is a histogram of the difference of "measured – modeled" values, by day and cell for the Green run experiment. In figure 5.2 the measured results were multiplied by a factor of 4.8. It is evident that both histograms change only slightly.

To remedy this inappropriate representation of data, the histograms from Figure 5.1 and Figure 5.2 were recreated. From Figure 5.3 and 5.4 one can now identify a significant change in the distribution of differences. Note that a shift to the right of the plot indicates an undeniable bias of underprediction from the HEDR codes.

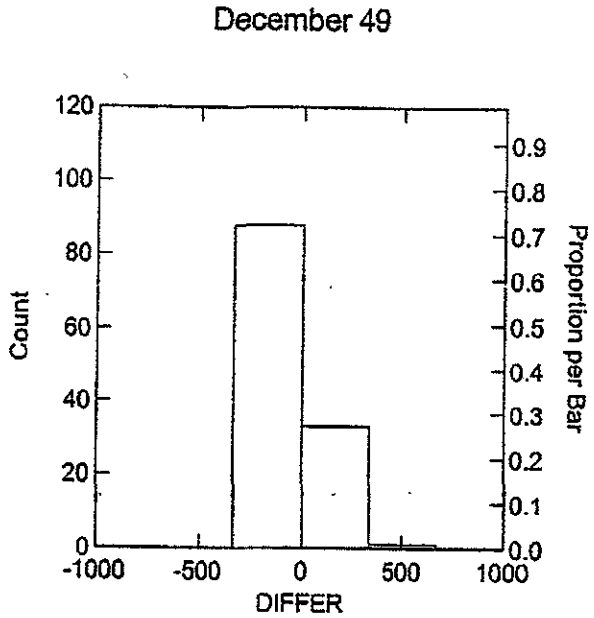

Figure 5.1 – Large range, small stratification (observed – modeled)

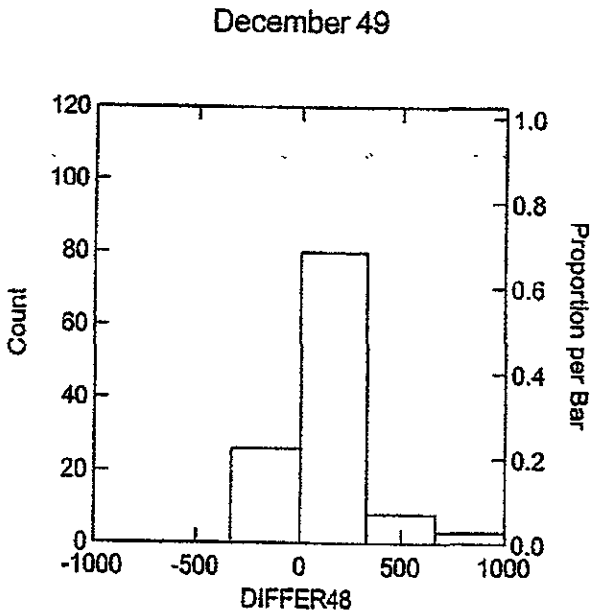

*Figure 5.2 – Large range, small stratification (observed*4.8 – modeled)*

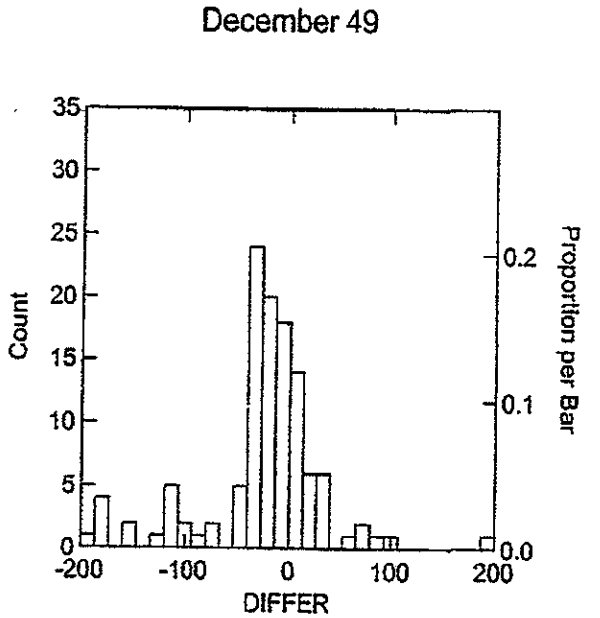

Figure 5.3 – Smaller range, smaller stratification (observed – modeled)

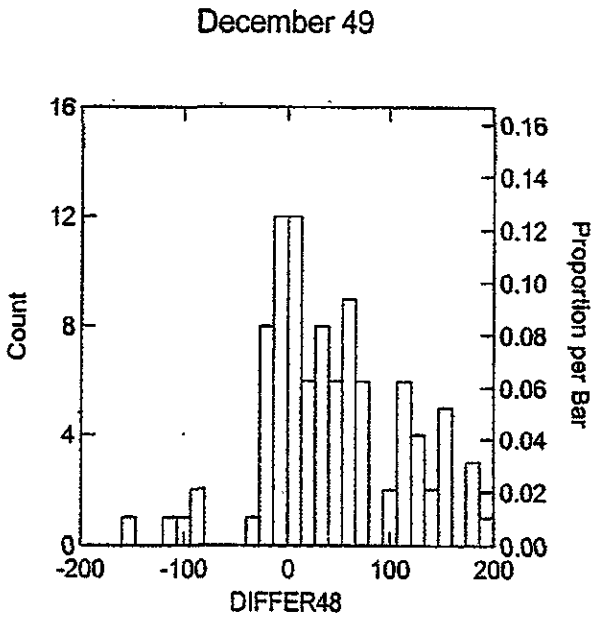

Figure 5.4 – Smaller range, smaller discretization (observed*4.8 – modeled)

5.3.2 HEDR Codes Correction Factor

In air dispersion modeling one can, in most instances, correct results by using a correction factor. There are a number of conditions to be satisfied in order to obtain an acceptable correction. The RATCHET code violates some important requirements:

1. The particle size cannot change.
2. Calibration of flat terrain models to match complex terrain is unacceptable.

However, if RATCHET will still remains as credible evidence in court, a simple mathematical exercise can produce a "Correction Factor" to reduce the average error. The technique involves multiplying all the model values, in each cell, by a factor that will bring the average difference (measurement – modeled) as close to zero as possible.

Two simple cases were tried. For the December 1949 data the correction factor was found to be 12. For the March and April months in 1951 the correction factor was found to be 12.8. Figure 5.5 shows the difference histogram without the correction factor. Figure 5.6 presents the histogram with the 12.8 correction factor.

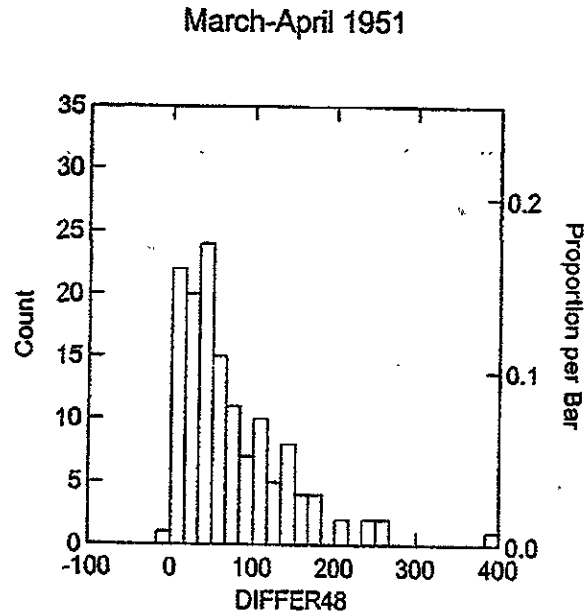

*Figure 5.5 – Corrected 1951 data (observed*4.8 – modeled)*

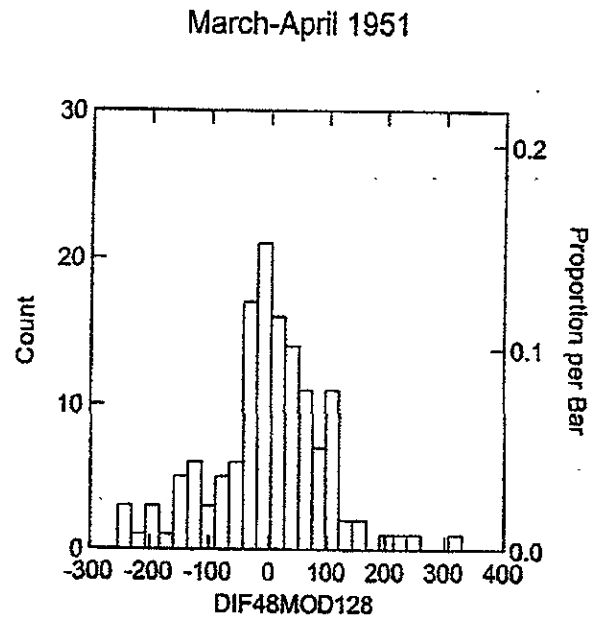

Figure 5.6 – Corrected 1951 data: observed and correction factor applied to modeled values

6.0 Conclusions

The HEDR model validation requires serious modifications. Various models were not validated individually. Such procedure would verify each code adequacy and accuracy. Running the codes together to validate the set is not acceptable, since error confounding would be difficult to trace.

My professional experience indicates that RATCHET, the HEDR Air dispersion model, is not appropriate for the site. Validated U.S. EPA lagrangian puff models for complex terrain are available, with documentation and source codes, free of charge. Such codes would have greater acceptance from the scientific community. RACHET is in my opinion a very weak link in the HEDR codes.

It is clear from the documentation available for this comparison that:

- Almost all vegetation collected was composed of sagebrush leaves.
- According to the DESCARTES model, the biomass rate of change over time ($dB/dt = 0$) for sagebrush is zero. This numerically restricts the internal bio-accumulation of iodine-131 in the plant.
- A letter from a member of the HEDR group [Napier, 1997] confirms that the December 1949 (the Green Run experiment) measurements were under-corrected by a factor of 2.5.
- RATCHET would not be accepted as a dispersion model, according to existing U.S. EPA Guidelines on Air quality models.
- If one must use a correction factor to multiply HEDR results, this number should be between 12 and 12.8.
- This is an ongoing project. Correction factors will scale proportional to the source term.

Prof. Jesse L. Thé, Ph.D., P.Eng.

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Napier, B., Letter to Mr. Joe Wayman, April, 1997.

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Exhibit 7

Exh. 7

EXHIBIT 4 Napier 2/18/04

Paper

A RE-EVALUATION OF THE ^{131}I ATMOSPHERIC RELEASES FROM THE HANFORD SITE

B. A. Napier*

Abstract—The atmospheric release of ^{131}I from the Hanford site for the 1950's and 1960's, focused on the period of releases after the year 1950, has been re-evaluated using processing plant stack monitoring data to address a series of questions and concerns that have arisen related to the source term. Historical stack monitoring data have been used to re-assess the releases by creating either a release factor to use with the calculated plant throughput or using the stack monitoring results as the basic estimate, and the results have been verified using historical atmospheric monitoring data from a location several kilometers distant. Uncertainties in all of the historical data have been addressed in the re-assessment. Compared to the original estimate between 1950 and 1971 of 2.46 ± 0.71 PBq, the stack monitoring results show a release of ^{131}I to the atmosphere of 1.55 ± 0.23 PBq. The concurrent atmospheric monitoring results imply a release of 1.75 ± 0.11 PBq over the same period, but this result is inflated by inclusion of global fallout. The total effective dose estimated to a full-time, nearby adult resident from ^{131}I using the Heeb source term from 1950 through 1972 is 0.73 mSv; using the source term based on stack monitoring data in the Hanford Environmental Dose Reconstruction project models, it is 0.51 mSv. Health Phys. 83(2):204–226; 2002

Key words: radioactivity, airborne; Monte Carlo; dose assessment; ^{131}I

INTRODUCTION

The Hanford Site was built in southeastern Washington State during World War II to provide plutonium for the United States nuclear weapons program. Irradiated uranium produced in the production reactors at Hanford was processed in chemical separations plants to obtain weapons-grade plutonium. Four chemical separations plants (T, B, REDOX, and PUREX) operated at various times with differing processes on the Hanford Site from 1944 through 1972. The locations of these facilities are shown in Fig. 1. In each of the chemical separations plants, the aluminum cladding covering the irradiated uranium slugs was dissolved in sodium hydroxide solution, and then the bare uranium metal was dissolved in concentrated nitric acid solution. A number of radionuclides, including ^{131}I, were released to the atmosphere during these dissolution processes.

The first comprehensive evaluation of the releases of ^{131}I to the atmosphere from these operations was published by Heeb (Heeb 1994; Heeb et al. 1996). Heeb's results formed the basis for individual radiation dose calculations performed by the Hanford Environmental Dose Reconstruction Project (HEDR) (Farris et al. 1994, 1996) and the dosimetry for the Hanford Thyroid Disease Study (HTDS) (FHCRC 1999). In a review of the thyroid study, the National Academy of Sciences (NAS 2000) summarized a series of questions and concerns, primarily attributed to Hoffman et al. (1999), which have arisen related to the source term developed by Heeb (1994). These concerns are focused on the period of releases after the year 1949. This paper provides an independent approach to estimating the atmospheric releases of ^{131}I from Hanford based on historical stack measurements, with a separate verification based on atmospheric monitoring data from a location several kilometers distant. This differs from the approach of Heeb (1994), which was based on estimation of processing plant throughput and release factors.

This paper re-evaluates the source term using historical stack and atmospheric monitoring data. The historical stack data are used either to generate a monthly release factor or as the direct basis of the estimate. The approach taken in this paper includes explicit consideration of the various sources of uncertainty in the available data. Probability distributions are provided for all uncertain parameters used in the calculations. Estimates of the range of possible releases are made using stochastic (Monte Carlo) calculations appropriate for the conditions corresponding to each month of operation between 1950 and 1971. All stochastic computations were made using Excel (Microsoft, Redmond, WA) spreadsheets equipped with the Crystal Ball add-in (Decisioneering 1995).

The HEDR source term

Early in the evolution of the HEDR Project, it was determined that the radionuclide releases to the atmosphere in the early years of the Hanford Site had not been

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0017-9078/02/0

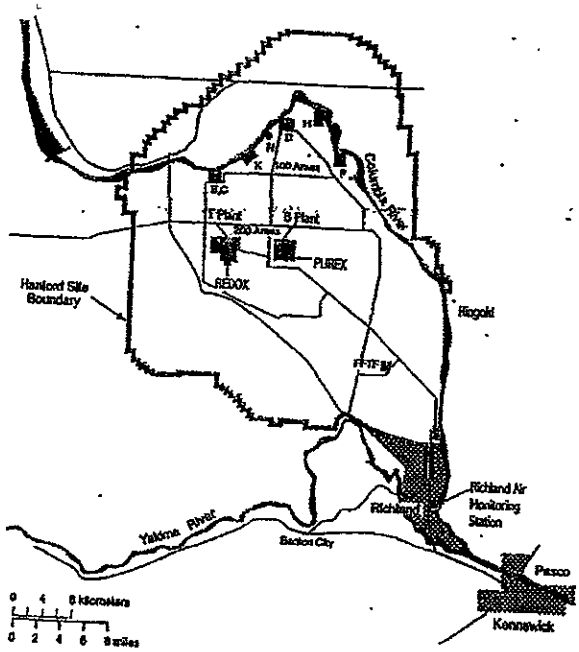

Fig. 1. Map of the Hanford Site indicating locations of the T and B Plants, REDOX, and PUREX, as well as the atmospheric monitoring station in downtown Richland, Washington.

monitored on a routine basis (e.g., Patterson 1948). Therefore, a modeling approach to reconstruct the releases was necessary. The details of the models that were developed are provided by Heeb (Heeb 1994; Heeb et al. 1996). In brief, the first problem was to calculate the amount of ^{131}I that was created in each batch of irradiated fuel. This required a calculation that took into account the varying neutron flux throughout the reactor core, the isotopic cross sections for the unique neutron spectrum of the Hanford reactors, and the length of the fuel irradiation period. Once those calculations were in place, much of the subsequent source-term calculations involved keeping track of the time and place that the fuel was processed. A model of reactor and processing plant operations, based on detailed daily records in the period 1944 through 1949, and on less detailed monthly records thereafter, was developed. The other important variable in the source term derivation was the release factor, which Heeb (1994) defined as "... the ratio of the radionuclide activity released to the radionuclide activity processed." The source term calculation was a matter of keeping track of the ^{131}I that went into a fuel processing plant and then applying a release factor to predict the amount that was released to the atmosphere. The calculations were complex, and uncertainties in the various portions of the model were propagated using Monte Carlo analyses. This model, once established, was used to estimate the releases from the entire period of Hanford operations from 1944 through 1972, when the last processing plant closed, until the mid-1980's.

The primary concerns raised about the Heeb model for the atmospheric releases have involved the estimates of the release factor. Heeb evaluated the release factors for each type of emission-control equipment installed. A time line of the various emission controls in place in the several facilities is presented as Fig. 2. The release fraction in the early years was very high, because there was little filtration equipment installed on the process off-gas lines. The dissolving steps were responsible for most of the releases of iodine and large amounts of nitric acid and nitrogen oxides through the dissolver off-gas line. Gases and vapors were also collected from the rest of the chemical processing plant, including room air, and routed to the same 60-m stack through which the dissolver off-gases were released. According to Heeb's assessment, a fraction of about 0.86 (a normal distribution with a standard deviation of about 0.03) of the iodine was released to the off-gas line, another 0.075 (a uniform distribution between 0.05 and 0.10) was released from the rest of the plant, and about 0.03 condensed and ran back down the inside of the stack. Thus, the early release factor was 0.905.

As time and the wartime urgency passed and as the operators became more aware of the magnitude of the ^{131}I releases, processes were modified and filters added to greatly reduce the releases. In May 1948, water scrubbers were installed in the T and B Plant off-gas line, which removed about 75% (between 71 and 79%) of the iodine from this pathway. Sand filters were installed on the ventilation system that handled the off-gases from the

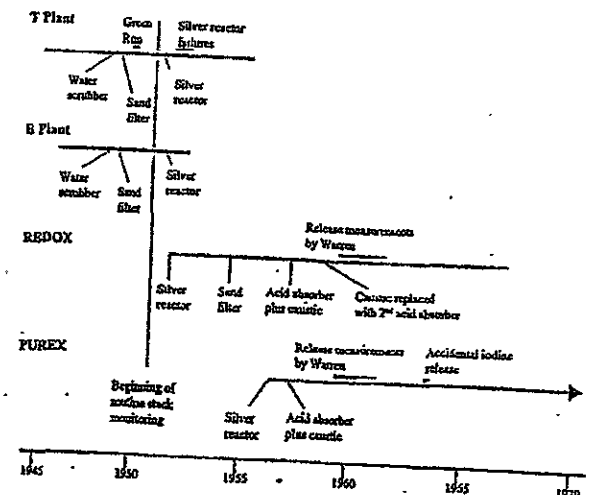

Fig. 2. Time line of operations of Hanford's T, B, REDOX, and PUREX processing plants, illustrating changes in emission controls (below the time lines) and significant events (above the time lines).

remainder of the process during October through December 1948; these filters removed about 47% (between 27 and 68%) of the iodine from this pathway.

Although this emission control equipment reduced the release factor to about 0.25, it was insufficient to solve the iodine emission problem. This problem was eventually solved through the development and installation of the so-called silver reactors. These were stainless steel vessels containing silver-nitrate-coated, unglazed ceramic saddles retained in two beds between grates and wire screens. These silver reactors replaced the water scrubbers in T and B Plants; the first was installed in B Plant in October 1950, and all the dissolvers (there were 3 in each processing plant) were so equipped by January 1951. The silver reactors in the dissolver off-gas stream worked extremely well when conditions were kept optimally. Iodine removal efficiencies of over 99.9% were observed. However, if the temperature was too low, moisture collected and the acid destroyed the silver reactor. If the temperature was too high, the silver nitrate melted and ran off of the ceramic saddles. Provisions were made for both steam and electric heating of the dissolver gases entering the silver reactors, but problems did occur. In addition, chemical impurities could accumulate in the silver reactors, rendering them less efficient. Replacing or "regenerating" the silver reactors by spraying the ceramic saddles with fresh silver nitrate solution could remedy this (e.g., Clark 1954). The primary concerns about Heeb's release factors revolve around the assumptions made regarding the efficiencies of the silver reactors and the frequencies of their failures.

Heeb used a series of measurements of the overall release factor made by Warren (1961) at the REDOX and PUREX plants in 1959–1960 as the basis for releases from T, B, REDOX, and PUREX operating with silver reactors, after a period of operational break-in in 1951. Heeb used summaries of stack release measurements made by Paas and Soldat (1951) for the first months of 1951. Heeb applied release factors based on Warren's 1959–1960 REDOX measurements to the entire period of REDOX operations and to the latter period of B and T Plant operations.

When Warren's measurements are used to generate a stochastic release factor, the result is a lognormal distribution of release factor with a median of 0.0125, geometric mean of 0.0124, geometric standard deviation of 4.12, and mean of 0.0339. In Heeb's summary report (Heeb 1994), the monthly releases are presented as the means, but for some of the values Hoffman et al. (1999) discovered that Heeb inadvertently used the median release factor. The HEDR source term, corrected for this error (Napier 1999), is presented as the second column in Table 1.

Problems with the HEDR source term model

Various observations and suggestions have been made concerning Heeb's approach to the atmospheric source term after about 1950. The error of using median rather than mean release factors was corrected by Napier (1999). One observation is that the Paas and Soldat (1951) data were taken at T Plant and may not well represent simultaneous operations at B Plant, where the silver reactors may have behaved differently. Other observations center on Heeb's use of the REDOX and PUREX release factors from 1959–1960 for other times and other facilities. The intent of using the release factors for earlier releases in these plants, and applying the REDOX release factor to the T and B Plants, was stated by Heeb to be that they represented a long-term set of data. However, the release factors are not quite appropriate for reasons such as the following:

- The T and B Plants use the bismuth-phosphate process, whereas the REDOX process involves organic solvents. Thus, the REDOX Plant may well have had differing characteristics of release of the ^{131}I that remains after the dissolution step;
- The REDOX and PUREX Plants had additional nitric acid recovery systems in place that were found to trap "... most of the radio-iodine escaping from the silver reactors" (Warren 1961). These acid absorbers were installed in both plants in late 1957, and were not present at startup (1952 for REDOX, 1956 for PUREX). Such acid-recovery systems were never installed in the B and T Plants; and
- The REDOX Plant had a sand filter installed on the building and process vessel ventilation. This was installed in August 1954, after about 2.5 y of prior operation.

In addition, it has been noted that even though the 1959–1960 data were used to establish the release factors, the Heeb model results are not consistent with the 1959–1960 REDOX emissions.

Although various arguments can be made that Heeb's results are adequate, a separate approach may be more desirable. Stack emissions monitoring was resumed at Hanford in 1950, and became routine in 1951. It is possible to use the stack data directly, either to develop directly applicable release factors or as the actual release estimate.

HANFORD STACK MONITORING DATA

B and T Plants before 1950

Stack gas monitoring systems were originally installed in the B and T Plant stacks during construction. However, the devices were primitive and inaccurate.

Table 1. Monthly atmospheric releases of ^{131}I from Hanford estimated using three methods.

Month/Year	Mean of Heeb's original estimate (TBq/month)	Mean of estimate based on stack monitoring (TBq/month)	Stack monitoring coefficient of variation	Primary reference for stack estimate	Mean of estimate based on air monitoring (TBq/month)	Primary reference for atmospheric monitoring data
1/1/50	3.4	2.3	0.45	Soldat 1950a,b	1.5	GE 1950a
2/1/50	3.0	2.0	0.49	Soldat 1950a,b	0.3	GE 1950a
3/1/50	4.4	3.0	0.43	Soldat 1950a,b	5.2	GE 1950a
4/1/50	3.9	2.5	0.43	Soldat 1950a,b	1.5	GE 1950b
5/1/50	4.6	2.9	0.39	Soldat 1950a,b	0.6	GE 1950b
6/1/50	3.7	2.3	0.44	Soldat 1950a,b	4.0	GE 1950b
7/1/50	8.9	6.1	0.43	Soldat 1950a,b	2.8	GE 1950c
8/1/50	57.0	37.5	0.43	Soldat 1950a,b	13.2	GE 1950c
9/1/50	48.0	29.7	0.38	Soldat 1950a,b	7.5	GE 1950c
10/1/50	31.6	20.7	0.47	Soldat 1950a,b	76.1	GE 1950d
11/1/50	19.9	12.6	0.54	Soldat 1950a,b	7.8	GE 1950d
12/1/50	35.3	21.7	0.45	Soldat 1950a,b	3.7	GE 1950d
1/1/51	2.8	3.7	0.43	Soldat 1951a	10.2	GE 1951a
2/1/51	3.2	11.4	0.50	Soldat 1951c	11.5	GE 1951a
3/1/51	12.8	22.8	0.48	Soldat 1951b	5.4	GE 1951a
4/1/51	88.4	86.1	0.48	Soldat 1951d	32.2	GE 1951b
5/1/51	360.4	298.7	0.41	Soldat 1951e	130.6	GE 1951b
6/1/51	244.9	360.7	0.42	Soldat 1951f	325.7	GE 1951b
7/1/51	150.6	82.5	0.76	Soldat 1951g	212.6	GE 1951b
8/1/51	92.5	55.0	0.36	Soldat 1951i	152.4	GE 1951b
9/1/51	65.3	168.1	0.53	Soldat 1951h	115.8	GE 1951b
10/1/51	90.7	18.9	0.13	Soldat 1951j,m	26.0	GE 1951d
11/1/51	97.7	5.0	0.13	Soldat 1951k,m	11.9	GE 1951d
12/1/51	61.8	3.7	0.14	Soldat 1951L,m	1.6	GE 1951d
1/1/52	109.5	3.1	0.16	Soldat 1952a	3.1	GE 1952a
2/1/52	76.0	1.9	0.14	Soldat 1952b	14.3	GE 1952a
3/1/52	92.9	3.6	0.15	GE 1952c	4.0	GE 1952a
4/1/52	84.7	10.6	0.13	Soldat 1952d	2.9	GE 1952b
5/1/52	57.0	8.8	0.13	Soldat 1952d	5.9	GE 1952b
6/1/52	22.6	4.0	0.16	Soldat 1952c	11.4	GE 1952b
7/1/52	11.0	1.1	0.11	Soldat 1952e	4.7	GE 1952c
8/1/52	21.8	4.4	0.12	Soldat 1952g	3.4	GE 1952c
9/1/52	12.4	5.6	0.13	Soldat 1952f	2.6	GE 1952c
10/1/52	4.1	2.0	0.16	Soldat 1952h	2.4	GE 1952d
11/1/52	8.6	1.0	0.13	Soldat 1952i	2.0	GE 1952d
12/1/52	12.0	2.8	0.11	Soldat 1952j	1.6	GE 1952d
1/1/53	8.1	4.9	0.15	GE 1953f	1.6	GE 1953a
2/1/53	2.1	1.5	0.14	GE 1953g	1.4	GE 1953a
3/1/53	5.1	1.2	0.17	Keene 1953a	2.0	GE 1953a
4/1/53	16.5	4.6	0.17	Keene 1953b	2.9	GE 1953b
5/1/53	13.2	1.9	0.12	Keene 1953c	3.0	GE 1953b
6/1/53	17.9	1.2	0.13	Keene 1953d	11.4	GE 1953b
7/1/53	38.9	5.7	0.15	Keene 1953e	4.7	GE 1953c
8/1/53	15.8	0.9	0.13	Keene 1953f	3.4	GE 1953c
9/1/53	11.2	2.4	0.15	Keene 1953g	28.3	GE 1953c
10/1/53	25.7	4.7	0.13	Keene 1953h	7.1	GE 1953d
11/1/53	7.2	1.4	0.20	Keene 1953i	2.0	GE 1953d
12/1/53	13.6	1.1	0.15	Keene 1953j	1.6	GE 1953d
1/1/54	19.6	1.5	0.14	Keene 1954a	1.6	GE 1954a
2/1/54	4.5	0.3	0.13	Keene 1954b	1.4	GE 1954a
3/1/54	6.5	5.1	0.17	Keene 1954c	11.9	GE 1954a
4/1/54	4.8	2.7	0.17	Donelson 1954	2.9	GE 1954b
5/1/54	11.4	1.4	0.11	Keene 1954d	3.0	GE 1954b
6/1/54	6.7	0.8	0.13	Keene 1954e	5.7	GE 1954b
7/1/54	2.8	0.4	0.13	Keene 1954f	4.7	GE 1954c
8/1/54	3.7	2.0	0.12	Keene 1954g	3.4	GE 1954c
9/1/54	6.9	3.2	0.12	Keene 1954h	2.6	GE 1954c
10/1/54	9.9	1.5	0.15	Keene 1954i	2.4	GE 1954d
11/1/54	2.1	2.9	0.12	Keene 1954j	6.0	GE 1954d
12/1/54	3.9	1.9	0.14	Keene 1955a	1.6	GE 1954d
1/1/55	2.5	4.3	0.15	Keene 1955b	1.6	GE 1955a
2/1/55	9.5	4.8	0.13	Keene 1955c	1.4	GE 1955a
3/1/55	21.5	24.4	0.14	Keene 1955d	4.0	GE 1955a
4/1/55	3.5	3.7	0.13	Keene 1955e	8.8	GE 1955b
5/1/55	3.0	2.8	0.13	Keene 1955f	3.0	GE 1955b
6/1/55	4.0	1.8	0.15	Keene 1955g	5.7	GE 1955b
7/1/55	3.5	3.8	0.17	Keene 1955h	4.7	GE 1955c
8/1/55	2.0	1.4	0.12	Keene 1955i	3.4	GE 1955c
9/1/55	7.8	3.6	0.14	Keene 1955j	2.6	GE 1955c

Table 1. Continued.

Month/Year	Mean of Heeb's original estimate (TBq/month)	Mean of estimate based on stack monitoring (TBq/month)	Stack monitoring coefficient of variation	Primary reference for stack estimate	Mean of estimate based on air monitoring (TBq/month)	Primary reference for atmospheric monitoring data
10/1/55	6.9	2.3	0.13	Keene 1955k	2.4	GE 1955d
11/1/55	0.3	1.0	0.15	Keene 1955L	2.0	GE 1955d
12/1/55	2.8	0.5	0.15	GE 1956e	1.6	GE 1955d
1/1/56	0.6	0.2	0.14	GE 1956f	1.6	GE 1956a
2/1/56	1.6	0.8	0.12	GE 1956g	1.4	GE 1956a
3/1/56	0.4	0.7	0.16	GE 1956h	2.0	GE 1956a
4/1/56	0.3	2.7	0.15	GE 1956i	5.9	GE 1956b
5/1/56	2.3	1.3	0.16	GE 1956j	3.0	GE 1956b
6/1/56	2.1	5.0	0.16	GE 1956k	5.7	GE 1956b
7/1/56	0.2	0.3	0.15	GE 1956L	4.7	GE 1956c
8/1/56	0.1	0.2	0.17	GE 1956m	3.4	GE 1956c
9/1/56	0.2	0.8	0.16	GE 1956n	2.6	GE 1956c
10/1/56	0.1	0.3	0.16	GE 1956o	2.4	GE 1956d
11/1/56	0.5	2.2	0.18	GE 1956p	2.0	GE 1956d
12/1/56	1.8	5.4	0.16	GE 1957e	1.6	GE 1956d
1/1/57	0.4	1.7	0.16	GE 1957f	1.6	GE 1957a
2/1/57	0.6	2.7	0.15	GE 1957g	1.4	GE 1957a
3/1/57	0.3	1.7	0.18	GE 1957h	2.0	GE 1957a
4/1/57	1.0	1.8	0.20	GE 1957i	2.9	GE 1957b
5/1/57	0.8	0.9	0.16	GE 1957j	3.0	GE 1957b
6/1/57	0.5	0.6	0.17	GE 1957k	40.0	GE 1957b
7/1/57	1.2	2.7	0.17	GE 1957L	4.7	GE 1957c
8/1/57	1.7	1.6	0.19	GE 1957m	3.4	GE 1957c
9/1/57	2.1	0.8	0.16	GE 1957n	2.6	GE 1957c
10/1/57	2.7	0.6	0.16	GE 1957o	9.5	GE 1957d
11/1/57	4.3	1.9	0.18	GE 1957p	2.0	GE 1957d
12/1/57	7.9	1.5	0.16	GE 1958a	4.7	GE 1957d
1/1/58	3.1	1.2	0.16	GE 1958b	3.7	GE 1959L
2/1/58	14.7	2.3	0.16	GE 1958c	3.4	GE 1959L
3/1/58	9.2	5.9	0.16	GE 1958d	4.8	GE 1959L
4/1/58	7.2	2.0	0.16	GE 1958e	7.0	GE 1959L
5/1/58	12.6	1.6	0.16	GE 1958f	7.1	GE 1959L
6/1/58	4.1	1.0	0.16	GE 1958g	13.7	GE 1959L
7/1/58	4.1	0.7	0.16	GE 1958h	11.3	GE 1959L
8/1/58	2.7	1.0	0.16	GE 1958i	8.1	GE 1959L
9/1/58	3.2	2.5	0.16	GE 1958j	6.2	GE 1959L
10/1/58	0.7	1.3	0.16	GE 1958k	5.7	GE 1959L
11/1/58	1.4	2.6	0.16	GE 1958L	4.8	GE 1959L
12/1/58	1.1	0.4	0.16	GE 1959a	3.7	GE 1960m
1/1/59	0.9	0.7	0.16	GE 1959b	5.2	GE 1960m
2/1/59	0.5	1.0	0.16	GE 1959c	2.2	GE 1960m
3/1/59	0.7	0.7	0.16	GE 1959d	1.2	GE 1960m
4/1/59	0.5	1.5	0.16	GE 1959e	1.9	GE 1960m
5/1/59	0.7	1.8	0.16	GE 1959f	0.9	GE 1960m
6/1/59	1.3	1.3	0.16	GE 1959g	0.9	GE 1960m
7/1/59	0.4	0.7	0.16	GE 1959g	3.5	GE 1960m
8/1/59	1.2	1.1	0.16	GE 1959h	1.4	GE 1960m
9/1/59	1.8	1.0	0.16	GE 1959i	0.7	GE 1960m
10/1/59	0.9	1.2	0.16	GE 1959j	1.3	GE 1960m
11/1/59	0.7	1.5	0.16	GE 1959k	1.6	GE 1960m
12/1/59	1.0	1.7	0.16	GE 1960a	0.9	GE 1960m
1/1/60	3.5	1.8	0.16	GE 1960b	2.2	GE 1961m
2/1/60	1.0	1.0	0.16	GE 1960c	0.5	GE 1961m
3/1/60	0.2	0.3	0.16	GE 1960d	0.4	GE 1961m
4/1/60	0.4	1.1	0.16	GE 1960e	2.7	GE 1961m
5/1/60	0.5	1.0	0.16	GE 1960f	0.3	GE 1961m
6/1/60	0.1	0.8	0.16	GE 1960g	0.9	GE 1961m
7/1/60	0.6	4.2	0.16	GE 1960h	0.7	GE 1961m
8/1/60	2.5	2.6	0.16	GE 1960i	0.9	GE 1961m
9/1/60	0.2	2.7	0.16	GE 1960j	1.3	GE 1961m
10/1/60	0.0	0.3	0.16	GE 1960k	0.7	GE 1961m
11/1/60	0.5	1.2	0.16	GE 1960L	0.2	GE 1961m
12/1/60	1.4	2.0	0.16	GE 1961a	0.4	GE 1961m
1/1/61	0.4	1.2	0.16	GE 1961b	0.5	GE 1962m
2/1/61	0.5	0.7	0.16	GE 1961c	0.2	GE 1962m
3/1/61	0.5	1.2	0.16	GE 1961d	0.3	GE 1962m
4/1/61	0.1	1.0	0.16	GE 1961e	0.4	GE 1962m
5/1/61	0.3	1.2	0.16	GE 1961f	0.1	GE 1962m
6/1/61	0.5	1.4	0.16	GE 1961g	0.8	GE 1962m
7/1/61	0.2	1.0	0.16	GE 1961h	0.4	GE 1962m

Table 1. Continued.

Month/Year	Mean of Heeb's original estimate (TBq/month)	Mean of estimate based on stack monitoring (TBq/month)	Stack monitoring coefficient of variation	Primary reference for stack estimate	Mean of estimate based on air monitoring (TBq/month)	Primary reference for atmospheric monitoring data
8/1/61	0.6	1.6	0.16	GE 1961i	0.5	GE 1962m
9/1/61	0.4	1.2	0.16	GE 1961j	0.2	GE 1962m
10/1/61	0.5	1.2	0.16	GE 1961k	1.7	GE 1962m
11/1/61	0.7	1.0	0.16	GE 1961L	0.9	GE 1962m
12/1/61	0 0	0.4	0.16	GE 1962a	0.6	GE 1962m
1/1/62	0.6	0.5	0.16	GE 1962b	0.6	GE 1963m
2/1/62	0.4	0.4	0.16	GE 1962c	0.5	GE 1963m
3/1/62	0.1	0.3	0.16	GE 1962d	0.2	GE 1963m
4/1/62	2×10^{-3}	2.3	0.16	GE 1962e	1.2	GE 1963m
5/1/62	1×10^{-2}	0.1	0.16	GE 1962f	0.2	GE 1963m
6/1/62	2×10^{-2}	0.1	0.16	GE 1962g	1.2	GE 1963m
7/1/62	7×10^{-2}	0.4	0.16	GE 1962h	0.7	GE 1963m
8/1/62	4×10^{-2}	0.4	0.16	GE 1962i	1.1	GE 1963m
9/1/62	0.3	1.2	0.16	GE 1962j	4.2	GE 1963m
10/1/62	2×10^{-2}	0.2	0.16	GE 1962k	0.6	GE 1963m
11/1/62	2×10^{-2}	0.2	0.16	GE 1962L	1.0	GE 1963m
12/1/62	0.2	0.5	0.16	GE 1963a	1.1	GE 1963m
1/1/63	2×10^{-4}	0.2	0.16	GE 1963b	0.4	GE 1964m
2/1/63	1×10^{-2}	0.1	0.16	GE 1963c	0.1	GE 1964m
3/1/63	5×10^{-2}	0.2	0.16	GE 1963d	0.3	GE 1964m
4/1/63	6×10^{-2}	0.3	0.16	GE 1963e	0.3	GE 1964m
5/1/63	5×10^{-2}	0.2	0.16	GE 1963f	0.2	GE 1964m
6/1/63	0.1	0.8	0.16	GE 1963g	1.5	GE 1964m
7/1/63	9×10^{-5}	0.3	0.16	GE 1963h	0.3	GE 1964m
8/1/63	1×10^{-2}	0.2	0.16	GE 1963i	0.2	GE 1964m
9/1/63	3.0	3.7	0.16	GE 1963j	2.2	GE 1964m
10/1/63	1×10^{-2}	0.3	0.16	GE 1963k	0.5	GE 1964m
11/1/63	7×10^{-3}	0.3	0.16	GE 1963L	0.1	GE 1964m
12/1/63	2×10^{-2}	0.6	0.16	GE 1964a	0.2	GE 1964m
1/1/64	1×10^{-2}	0 1	0.16	GE 1964b	0.3	PNL 1965
2/1/64	4×10^{-3}	0.1	0.16	GE 1964c	0.1	PNL 1965
3/1/64	3×10^{-2}	0.3	0.16	GE 1964d	0.4	PNL 1965
4/1/64	3×10^{-3}	0.2	0.16	GE 1964e	0.6	PNL 1965
5/1/64	6×10^{-2}	0 4	0.16	GE 1964f	0.7	PNL 1965
6/1/64	5×10^{-2}	0.5	0.16	GE 1964g	0.5	PNL 1965
7/1/64	2×10^{-2}	0.2	0.16	GE 1964h	0.0	PNL 1965
8/1/64	0.1	0.4	0.16	GE 1964i	0.8	PNL 1965
9/1/64	2×10^{-4}	0.4	0.16	GE 1964j	0.3	PNL 1965
10/1/64	0.1	0.6	0.16	GE 1964k	0.6	PNL 1965
11/1/64	9×10^{-2}	0.6	0.16	GE 1964L	0.4	PNL 1965
12/1/64	7×10^{-3}	0.1	0.16	GE 1965a	0.0	PNL 1965
1/1/65	6×10^{-3}	0.0	0.16	GE 1965b	0.0	PNL 1966
2/1/65	6×10^{-3}	0.1	0.16	GE 1965c	0.1	PNL 1966
3/1/65	2×10^{-2}	0.4	0.16	GE 1965d	0.2	PNL 1966
4/1/65	3×10^{-2}	0.6	0.16	GE 1965e	0.6	PNL 1966
5/1/65	0.2	0.7	0.16	GE 1965f	0.3	PNL 1966
6/1/65	6×10^{-3}	0.5	0.16	GE 1965g	2.9	PNL 1966
7/1/65	4×10^{-2}	0.2	0.16	GE 1965h	1.4	PNL 1966
8/1/65	3×10^{-2}	0 0	0.16	GE 1965i	0 3	PNL 1966
9/1/65	8×10^{-3}	0.1	0.16	GE 1965j	0.3	PNL 1966
10/1/65	5×10^{-2}	0.6	0.16	GE 1965k	0.6	PNL 1966
11/1/65	4×10^{-3}	0.1	0.16	GE 1965L	0.5	PNL 1966
12/1/65	6×10^{-2}	0.2	0.16	GE 1966	0.2	PNL 1966
1/1/66	0.1	0.5	0.16	ISOCHEM 1966a	0.1	PNL 1967
2/1/66	8×10^{-4}	0.2	0.16	ISOCHEM 1966b	1.4	PNL 1967
3/1/66	2×10^{-2}	0.3	0.16	ISOCHEM 1966c	0.0	PNL 1967
4/1/66	7×10^{-2}	0.5	0.16	ISOCHEM 1966d	0.1	PNL 1967
5/1/66	4×10^{-3}	2×10^{-3}	0.16	ISOCHEM 1966e	0.3	PNL 1967
6/1/66	0.3	6×10^{-3}	0.16	ISOCHEM 1966f	0.6	PNL 1967
7/1/66	7×10^{-2}	1×10^{-2}	0.16	ISOCHEM 1966g	0.9	PNL 1967
8/1/66	9×10^{-3}	9×10^{-4}	0.16	ISOCHEM 1966h	0.2	PNL 1967
9/1/66	2×10^{-3}	1×10^{-2}	0.16	ISOCHEM 1966i	0.0	PNL 1967
10/1/66	2×10^{-2}	0.6	0.16	ISOCHEM 1966j	0.0	PNL 1967
11/1/66	8×10^{-6}	0.2	0.16	ISOCHEM 1966k	0.2	PNL 1967
12/1/66	9×10^{-14}	2×10^{-2}	0.16	ISOCHEM 1967a	0.0	PNL 1967
1/1/67	1×10^{-2}	0.5	0.16	ISOCHEM 1967b	0.2	PNL 1969
2/1/67	6×10^{-3}	0.2	0.16	ISOCHEM 1967c	0.1	PNL 1969
3/1/67	2×10^{-2}	9×10^{-2}	0.16	ISOCHEM 1967d	0.1	PNL 1969
4/1/67	1×10^{-11}	8×10^{-2}	0.16	ISOCHEM 1967e	0.6	PNL 1969
5/1/67	2×10^{-2}	0.2	0.16	ISOCHEM 1967f	0.0	PNL 1969

Table 1. Continued.

Month/Year	Mean of Heeb's original estimate (TBq/month)	Mean of estimate based on stack monitoring (TBq/month)	Stack monitoring coefficient of variation	Primary reference for stack estimate	Mean of estimate based on air monitoring (TBq/month)	Primary reference for atmospheric monitoring data
6/1/67	1×10^{-5}	5×10^{-2}	0.16	ISOCHEM 1967g	2.0	PNL 1969
7/1/67	7×10^{-6}	2×10^{-2}	0.16	ISOCHEM 1967h	1.4	PNL 1969
8/1/67	9×10^{-4}	9×10^{-2}	0.16	ISOCHEM 1967i	0.8	PNL 1969
9/1/67	3×10^{-4}	8×10^{-2}	0.16	PNL 1968	0.1	PNL 1969
10/1/67	2×10^{-5}	6×10^{-2}	0.16	PNL 1968	0.2	PNL 1969
11/1/67	3×10^{-4}	3×10^{-2}	0.16	PNL 1968	0.1	PNL 1969
12/1/67	1×10^{-5}	5×10^{-2}	0.16	PNL 1968	0.1	PNL 1969
1/1/68	3×10^{-7}	3×10^{-3}	0.16	ARHCO 1969	0.2	PNL 1970a
2/1/68	2×10^{-8}	1×10^{-3}	0.16	ARHCO 1969	0.3	PNL 1970a
3/1/68	7×10^{-5}	3×10^{-2}	0.16	ARHCO 1969	0.7	PNL 1970a
4/1/68	4×10^{-4}	0.1	0.16	ARHCO 1969	0.3	PNL 1970a
5/1/68	8×10^{-5}	2×10^{-2}	0.16	ARHCO 1969	0.6	PNL 1970a
6/1/68	5×10^{-5}	1×10^{-2}	0.16	ARHCO 1969	0.0	PNL 1970a
7/1/68	4×10^{-7}	2×10^{-2}	0.16	ARHCO 1969	0.5	PNL 1970a
8/1/68	2×10^{-4}	6×10^{-2}	0.16	ARHCO 1969	0.0	PNL 1970a
9/1/68	3×10^{-5}	8×10^{-3}	0.16	ARHCO 1969	0.1	PNL 1970a
10/1/68	2×10^{-4}	3×10^{-2}	0.16	ARHCO 1969	0.5	PNL 1970a
11/1/68	1×10^{-9}	1×10^{-2}	0.16	ARHCO 1969	0.1	PNL 1970a
12/1/68	8×10^{-7}	4×10^{-3}	0.16	ARHCO 1969	0.1	PNL 1970a
1/1/69	1×10^{-6}	1×10^{-2}	0.16	ARHCO 1970	0.0	PNL 1970b
2/1/69	2×10^{-8}	1×10^{-3}	0.16	ARHCO 1970	0.0	PNL 1970b
3/1/69	3×10^{-6}	9×10^{-4}	0.16	ARHCO 1970	0.0	PNL 1970b
4/1/69	4×10^{-8}	2×10^{-3}	0.16	ARHCO 1970	0.0	PNL 1970b
5/1/69	8×10^{-11}	1×10^{-2}	0.16	ARHCO 1970	0.0	PNL 1970b
6/1/69	1×10^{-5}	5×10^{-2}	0.16	ARHCO 1970	0.0	PNL 1970b
7/1/69	2×10^{-5}	1×10^{-3}	0.16	ARHCO 1970	0.7	PNL 1970b
8/1/69	1×10^{-6}	1×10^{-3}	0.16	ARHCO 1970	0.0	PNL 1970b
9/1/69	2×10^{-5}	7×10^{-4}	0.16	ARHCO 1970	0.1	PNL 1970b
10/1/69	6×10^{-6}	2×10^{-3}	0.16	ARHCO 1970	0.1	PNL 1970b
11/1/69	7×10^{-8}	5×10^{-3}	0.16	ARHCO 1970	0.1	PNL 1970b
12/1/69	2×10^{-10}	1×10^{-3}	0.16	ARHCO 1970	0.1	PNL 1970b
1/1/70	5×10^{-5}	2×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
2/1/70	4×10^{-21}	1×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
3/1/70	6×10^{-8}	6×10^{-4}	0.16	ARHCO 1971	0.1	PNL 1973
4/1/70	3×10^{-9}	8×10^{-4}	0.16	ARHCO 1971	0.0	PNL 1973
5/1/70	9×10^{-9}	3×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
6/1/70	0	5×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
7/1/70	0	1×10^{-3}	0.16	ARHCO 1971	1.3	PNL 1973
8/1/70	0	2×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
9/1/70	0	8×10^{-4}	0.16	ARHCO 1971	2.3	PNL 1973
10/1/70	0	1×10^{-3}	0.16	ARHCO 1971	2.2	PNL 1973
11/1/70	0	1×10^{-3}	0.16	ARHCO 1971	1.0	PNL 1973
12/1/70	0	8×10^{-3}	0.16	ARHCO 1971	0.0	PNL 1973
1/1/71	0	5×10^{-4}	0.16	ARHCO 1972	0.0	PNL 1972
2/1/71	0	6×10^{-4}	0.16	ARHCO 1972	0.0	PNL 1972
3/1/71	1×10^{-14}	6×10^{-4}	0.16	ARHCO 1972	0.0	PNL 1972
4/1/71	8×10^{-14}	8×10^{-4}	0.16	ARHCO 1972	4.8	PNL 1972
5/1/71	3×10^{-10}	7×10^{-4}	0.16	ARHCO 1972	1.8	PNL 1972
6/1/71	3×10^{-6}	1×10^{-3}	0.16	ARHCO 1972	4.9	PNL 1972
7/1/71	9×10^{-21}	8×10^{-4}	0.16	ARHCO 1972	0	PNL 1972
8/1/71	7×10^{-19}	1×10^{-3}	0.16	ARHCO 1972	0	PNL 1972
9/1/71	9×10^{-17}	6×10^{-4}	0.16	ARHCO 1972	0	PNL 1972
10/1/71	0	8×10^{-4}	0.16	ARHCO 1972	0	PNL 1972
11/1/71	0	1×10^{-3}	0.16	ARHCO 1972	0	PNL 1972
12/1/71	0	1×10^{-3}	0.16	ARHCO 1972	0	PNL 1972

They were intended as a system for occasional spot checks, rather than routine monitoring, and were only infrequently used. The original system consisted of a stack gas sampling line originating at the 15-m (50-foot) elevation of the stacks. The sample was bubbled through a sodium carbonate solution and the radioactivity of the solution was measured with an ionization chamber in the middle of a coil of tubing containing the sodium carbonate solution. The chamber current (amperes) was then converted to quantity of iodine. Knowledge of the stack-gas flow and sample line flow allowed inference of the amount of iodine going up the stack (Heeb 1994). In January and February 1945, the initial stack monitoring equipment in the 202-T Building was found to be

cross-contaminated and not working properly. Independent test samples run in February showed that the existing calibration factor for this equipment was "low by a factor of 500," and it was adjusted in March. Although new tests revealed correlations within a factor of three, the equipment was not considered reliable, and its use was abandoned on a routine basis in June 1945 (DuPont 1946).

B and T Plants, 1950

Repeated monitoring of the stack gases was resumed at T Plant on 30 August 1950. The monthly reports of J.K. Soldat (1950a, b) indicate that a total of 12 measurements were made in August through September 1950 from the 15-m (50-foot) level of the T Plant stack. An additional 17 measurements were made in October and 7 in December (Soldat 1950c, d; 1951a). These measurements were made prior to the installation of the silver reactors, while the water scrubbers were in operation. Most of the measurements were intentionally made during dissolver operation, and sampling continued for as long as fuel was being dissolved. The apparatus included an air pump (an air-flow-rate recorder was added after the second sample was taken), a filter, and a caustic scrubber. The iodine captured on the filter and in the scrubber solution was correlated with the flow rates of the sampler and stack to obtain the amount released. Tests indicated that most of the activity was accumulated in the scrubber solution, and that what was on the filter media was predominantly ^{131}I as well. It is noted that "work on the stack gas problem will be continued so that as much data as possible will be available before the silver reactors are installed" (Soldat 1950a).

These measurements, in themselves, are insufficient for estimating releases because not all fuel dissolvings are represented, and additional releases would have been expected during periods between dissolvings from the balance of the plant. However, the measurements do give an idea of the release fraction from the bismuth-phosphate process plants prior to the installation of the silver reactors. In raw form, the measurements indicate a mean daily release factor of about 0.14 for the period, standard deviation 0.11, geometric mean 0.085, and geometric standard deviation of about 2. This may be compared to Heeb's central value of 0.25. Note that the uncertainty of the monthly values will be less than the variability of the daily values because of averaging.

A number of factors must be considered when deriving a release fraction from this data. The apparatus used would not capture iodine in an organic chemical form. The sampling line had variability in the flow rates. There is a possibility that iodine would "plate out" on the walls of the sampling pipe. The radiochemical analyses of the filter and caustic solution had some variability. Because the measurements tended to be for a period associated with the dissolving operations, there may be an additional amount of iodine that was released later from the balance of the operations, after the sampler had been turned off. Conversely, there may also have been iodine released from the rest of the plant during the dissolving that was attributed to the dissolver. Each of these areas of uncertainty can be addressed using historical documents.

A number of studies have shown that a portion of the ^{131}I sampled was not collected by the sampler. Schwendiman (1954) observed that the samplers provided a satisfactory approximation of the iodine release, "... since a large fraction of the iodine is present as gaseous iodine," which indicates that only a small fraction was not recovered. Later measurements in the REDOX and PUREX stacks "... indicate that a small fraction of the ^{131}I may be present in a form other than elemental iodine" (McCormack 1962). A correction factor to account for under-collecting organic iodine, with a triangular distribution of minimum 1.0, most likely value 1.1, maximum of 1.2 has been assigned. Uncertainty factors for stack measurements are summarized in Table 2.

Schwendiman (1954) reports that the gas flow rates in the sampling system were recorded and maintained within 20% of the nominal flow rate. Therefore, an uncertainty factor with a triangular distribution of minimum 0.8, most likely value of 1.0, maximum 1.2 has been assigned. See Table 2.

A detailed analysis of the potential for iodine to be trapped in the sampling line was performed by McCormack (1962). McCormack's analyses were made in pairs

Table 2. Uncertainty factors in ^{131}I measurements (all are dimensionless multipliers).

Factor	Distribution type	Minimum	Central value	Maximum
Correction for organic ^{131}I fraction				
B&T Plants	Triangular	1.0	1.1	1.2
REDOX	Triangular	1.0	1.1	1.2
PUREX	Triangular	1.1	1.3	1.5
Air sampler	Uniform	0.4		0.6
Sampling gas flow rate	Triangular	0.8	1.0	1.2
Sampling line losses	Uniform	1.0		1.1
Analytical variability				
B&T plants	Triangular	0.8	1.0	1.2
REDOX & PUREX	Triangular	0.85	1.0	1.15
Air sampler	Triangular	0.8	1.0	1.2
Collection completeness	Triangular	0.92	1.0	1.075
Sampler availability				
B&T plants	Uniform	1.0		1.2
REDOX & PUREX	Uniform	1.0		1.1
Air sampler	Triangular	0.75	1.0	1.25
Reporting period	Uniform	0.8		1.2

of sampling lines of different lengths at REDOX and PUREX. He found about a 10 to 12% difference between the lines, but the higher transmission came through the longer lines. His conclusion was that "In view of the small differences in the iodine concentrations in the gas samples for the rather different pairs of sampling systems, it is concluded that retention of gaseous ^{131}I in the sampling piping is of minor importance." A small correction factor with a uniform distribution between 1.0 and 1.1 has been assigned. See Table 2.

Schwendiman (1954) reports that "Analytical methods and counting corrections for ^{131}I can be expected to give curie values within ±10–15% of the true concentration in the scrubber solution." However, in the same discussion, Schwendiman also discusses the increase in uncertainty caused by the occasional presence of ruthenium isotopes. Therefore, a triangular uncertainty distribution with minimum 0.8, most likely value of 1.0, and maximum of 1.2 has been assigned. See Table 2.

The measurements made by Soldat during this period mostly aligned with periods of dissolver operation. However, some of them were made when no dissolving was occurring, and others may have been made soon after a prior dissolving. Heeb (1994) determined that about 5 to 10% (average 7.5) of the iodine in a dissolver batch could have been evolved from the balance of the plant some time after the dissolving operation ceased. Thus, some of Soldat's measurements may have included iodine from earlier dissolving operations and missed some from the current dissolving. This complicates the assignment of the amount of iodine in the process to the individual measurements. Therefore, a correction factor with a triangular distribution of minimum 0.92, most likely 1.0, and maximum 1.075 was assigned. See Table 2.

On the basis of the measurements made at T Plant from August through December 1950 and the uncertainty factors discussed above, a release factor for the year 1950 for B and T Plant was estimated. Monte Carlo calculations were performed, resulting in a release factor with a mean and median of 0.16, standard deviation of 0.031, and a 5- to 95-percentile range of 0.11 to 0.23. Although it overlaps Heeb's result, this is slightly lower than Heeb's assignment of 0.25, with a 5- to 95-percentile range of 0.21 to 0.29.

The monthly releases from B and T Plants can be estimated using this release factor and the iodine throughput in these facilities produced by Heeb's reactor and processing plant accounting model. The uncertainties included in Heeb's model involving the iodine introduced into the dissolver for number of tons dissolved, reactor power peaking, degree of iodine saturation, length of time since discharge from reactor, and uncertainties in spectrum-averaged cross section (Heeb 1994) are also considered. The revised mean estimates, column 3 of Table 1, are compared with Heeb's (1994) original estimates [as corrected by Napier (1999)], column 2 of Table 1. The coefficient of variation (the standard deviation divided by the mean) is also provided as a measure of the uncertainty in the monthly values.

T Plant, January–September 1951

The releases in the year 1951 require particular attention. Once the silver reactors were installed, Soldat's initial reports prepared in January and February 1951 placed their efficiency rate for ^{131}I removal at 99.9%. Although they were not positioned to entrap the small portion (5 to 10%) of ^{131}I that escaped from the plutonium-bearing solutions in the plants after the dissolving phase, silver reactor performance was so encouraging overall that the decay time between irradiation and dissolving (called metal cooling times at Hanford) were dropped from 80 to 90 d to 67 d in mid February. Decay periods were lowered further in March, and then decreased to an average of only 48 d in April. During these months, the average emission level for ^{131}I hovered between 2 to 5% of that which was evolved in the dissolver cells. In late April, however, a "material change in the efficiency of the silver reactor" was reported. By mid May, with cooling times ranging between 44 to 55 days, the fraction of evolved ^{131}I that was released to the atmosphere greatly increased; in one dissolving, 34% was reported to be released (Soldat 1951e). Additionally, with the greater throughput of irradiated metal, more ^{131}I was being generated than ever before. At T-Plant, a summer production test was planned to determine whether ^{131}I evolution could be suppressed by the addition of mercury to the metal dissolving solution. However, by late July, the silver reactor filters were reported to be "easily saturated" and "failing." The filters in T-Plant were replaced when they overheated, and again showed good results. However, in view of the overall performance record of the silver reactor filters, metal cooling periods were again lengthened (Gerber 1999).

Soldat continued monitoring in T Plant, taking between 5 and 15 stack gas samples per month (Soldat 1951a–i). The data he gathered form the basis for the report by Paas and Soldat (1951), which was used by Heeb (1994) to estimate the monthly release factors for T and B Plants in the first half of 1951. The Paas and Soldat (1951) data were taken at T Plant and do not well represent simultaneous operations at B Plant because the overheating of the T Plant silver reactors caused them to fail, while those in B Plant continued to operate. [This was verified by Soldat (personal communication) on the

basis of air sample measurements made in the Hanford 200 East and 200 West areas in 1951.] Thus, release factors can be derived monthly for T Plant, and a separate approach is required for B Plant.

The monthly T Plant release factors can be derived in a manner parallel to those described above for all of 1950, because more individual measurements are available. The mean of Soldat's monthly individual measurements and the mean monthly release factor derived using the uncertainty adjustments described above are compared in Table 3 to the values derived by Heeb from Paas and Soldat (1951). The monthly release factors are described by a lognormal distribution; the standard deviations are also provided in Table 3. It can be seen that Heeb's estimates are similar to those derived here. An exception is for the month of July; the values reported in Paas and Soldat (1951) only consider the first 3 wk of the month [i.e., through Soldat's July monthly report (Soldat 1951f)]. Soldat's August monthly report includes additional July measurements (Soldat 1951g), which indicate that the releases dropped dramatically following the replacement of the failed silver reactors. Heeb's values of 0.0339 for August and September are the generic values based on the 1959 through 1960 REDOX measurements discussed above; it can also be seen that the actual releases in August 1951 were somewhat lower than this estimate.

In July 1951, a new stack gas monitoring system was installed at T Plant (Soldat 1951g). The basic process was the same as used previously by Soldat, but the equipment was made of stainless steel instead of glass. This equipment was essentially the same as that later used at B Plant, REDOX, and PUREX. It remained basically unchanged through the early 1970's (Schwendiman 1954; McCormack 1962). The equipment allowed essentially continuous monitoring to be performed.

Table 3. Monthly release fractions derived for T Plant.

Month in 1951	Heeb's estimate	Revised	
		Release fraction	Std. deviation
January	0.01	0.0076	0.0029
February	0.01	0.0214	0.0060
March	0.02	0.0172	0.0085
April	0.05	0.0504	0.0167
May	0.132	0.167	0.0375
June	0.125	0.235	0.0532
July	0.12	0.074	0.0458
August	0.0339	0.0014	0.0009
September	0.0339	0.088	0.0024

B Plant, January–September 1951

Measurements were not begun in the B Plant stack until September 1951, but the silver reactors were operational beginning in January 1951. Thus, no measurements are directly applicable. Heeb's use of the same release factor as for T Plant is not justifiable because the silver reactors did not fail. Therefore, a different approach is required. The simplest approach is to parallel the approach Heeb used for T and B Plants in the late 1940's, with an adaptation for use of the silver reactor instead of the water scrubber. The silver reactor only was installed in the dissolver off-gas line, so the fractional release from the other building ventilation through the sand filter would have been unaffected. When they were properly maintained, the silver reactors worked extremely well; Smith (1955) suggests that a reasonable long-term average efficiency is 99.5%. This may be assumed to vary between 99 and 99.9% (Blasewitz and Judson 1951). Using the values and uncertain ranges discussed above of fraction volatilized in the dissolver, released in the remainder of the plant, and passing through the sand filter with this range of efficiency of silver reactor, a release factor of 0.044 (5 to 95 percentile range 0.029 to 0.059) is obtained. Fortuitously, this distribution is close to that used by Heeb (0.0339) for other periods of B, T, and REDOX operation. It is used here for the unmonitored portion of B Plant operations with the silver reactors.

Soldat made the first measurements in the B Plant stack in September 1951. They corresponded with a partial failure of the silver reactor in cell 45-L-B. Both silver reactors were regenerated during September, and the releases were reduced. Because of this known upset, a release factor analogous to those used for 1950 was developed for September 1951 for T Plant. Using the same uncertainty corrections, a lognormal distribution with a mean of 0.177 and a standard deviation of 0.072 was prepared.

T and B Plants, October 1951—Shutdown

Beginning with his October 1951 monthly report, Soldat (1951g) stopped reporting the results of the individual stack monitoring runs. At this time, his measurements were obviously considered to be routine. His monthly reports provided only weekly and monthly summaries of quantity of ^{131}I released to the atmosphere. He retained the responsibility for the monitoring through late 1952 and continued reporting the releases from each facility in his monthly reports through December 1952. The B Plant ceased fuel-processing operations after June of 1952. T Plant continued processing fuel until January 1956. For nearly this entire period, the Hanford Site monthly reports are corroborated (and enhanced) by a

report series authored by Keene (Keene 1951 through 1955L), generally titled *Separations Section Radiation Monitoring Monthly Report*. This series is the outgrowth and continuation of Soldat's reporting series. For almost every month, this series reports B and T Plant releases, and later REDOX releases, or provides sufficient information to deduce them.

While the monitored releases may be used to estimate the source term, the uncertainties in the monitored releases are similar to those described above for B and T Plant in the year 1950 for organic iodine, gas flow rate variability, plate-out in sampling lines, and variability in radiochemical analysis. For monthly analyses, there is an additional uncertainty added by monitoring system reliability; the equipment may not have been functioning 100% of the time. A correction factor with a uniform distribution between 1.0 and 1.2 has been assigned to account for this possibility on the assumption that the equipment could have not functioned up to 20% of the time. In addition, the amount of material reported to be released in the monthly reports was for a reporting month, not a calendar month. Usually, the amount included the releases of the last few days of the preceding month and excluded the last few days of the current month. This lag was caused by the length of time required to collect, transport, process, and report the iodine in the caustic solution from the sampler. A month-to-month adjustment of up to 6 d (measurements were reported weekly) could occur. To account for this, a multiplier with a uniform distribution ranging from 0.8 to 1.2 has been introduced. See Table 2. With these multipliers, a stochastic uncertainty factor with mean/median of 1.25 and 95 percentile range of from 0.7 to 2.2 results. This has been applied independently to B Plant and T Plant reported releases. The estimated releases of ^{131}I are reported in Table 1.

REDOX, January 1952 through January 1956

The sampling system installed in the REDOX stack was essentially identical to that in B and T Plants [although the first few measurements were made with temporary equipment (Soldat 1952a)]. The releases reported by Soldat, Keene, and the Site monthly reports are generally consistent. The uncertainties assigned to the reported values are similar to those described above for T and B Plants, with some exceptions. Because the equipment was newer and installed expressly for monitoring the stack, the down time correction ranges from 1 to 1.1 (up to 3 days/month unavailable). Also, because the process had been standardized, the variability in chemical analyses is assumed to be somewhat less, with a triangular distribution ranging from 0.85 to 1.15 (based on Schwendiman 1954). See Table 2. With these multipliers, a stochastic uncertainty factor with mean/median of 1.2 and 95 percentile range of from 0.75 to 2.0 results. The combined monthly releases of ^{131}I from B, T, and REDOX for this period are reported in Table 1.

PUREX and REDOX, January 1956—Shutdown

The PUREX Plant used a countercurrent solvent extraction process with less hazardous materials than those used in REDOX. The stack monitoring system was basically the same as installed on the other plants. Haller and Perkins (1967) measured the ratio of organic to inorganic ^{131}I in the stack gases; they found that the ratios varied from 0.12 to 1.47 over a 20-d period. This corresponds to organic fractions between 11 and 60%. Most of the results indicated organic iodine fractions of less than 25%; the average is 30%. It is likely that the largest releases, during dissolving operations, corresponded to the lowest organic fraction, although Haller and Perkins do not report the absolute amounts released for any of the sampling periods. On the basis of these measurements, a multiplicative correction to the monitored releases with a triangular distribution, minimum 1.1, mode 1.3, and maximum 1.5 has been applied to all PUREX measurements. See Table 2. Using the same additional uncertainty factors as applied at REDOX, this higher organic multiplier gives an overall uncertainty multiplier for PUREX with mean/median of 1.4 and 95 percentile range from 0.8 to 2.35.

The monitoring report series by Keene ends in late 1955, and the ability to resolve the separate contributors to the total ^{131}I stack releases is lost from the Hanford Site monthly reports after July of 1956. Therefore, because the PUREX uncertainty is larger than that for REDOX, the PUREX uncertainty range has been applied to all subsequent months.

The REDOX Plant ceased dissolving operations in November 1966, and PUREX closed in early 1972. A brief PUREX run of aged N Reactor fuel occurred in the mid-1980's, but the ^{131}I releases from that campaign were negligible because the fuel was many years old.

The coefficient of variation for the releases 1956 through 1957 was directly calculated from stochastic calculations for each month. Because all of the uncertainty factors remain unchanged, the coefficient of variation should be constant. The value assigned for the remaining months, 0.16, is the average of this period. The monthly releases and coefficients of variation from 1956 through 1971 are included in Table 1.

For all months of Hanford reprocessing operations between January 1950 through initial shutdown in 1972, the releases estimated by Heeb are compared with those derived from the stack monitoring data in Table 1. The

same results annualized are presented in Fig. 3. From Fig. 3, it is apparent that Heeb's modeled release fractions tended to overestimate the releases in the period from 1952 through 1954. For this period, Heeb was using a release fraction for the REDOX facility that was based on Warren's (1961) reports of REDOX operations in 1959–1960. For this period, it was acknowledged that the REDOX silver reactors "... were not up to design specifications nor to previously demonstrated values" (Warren 1961). From the stack monitoring data, it is apparent that use of the release fractions based on the degraded performance was overly conservative, and the releases were actually lower than Heeb's estimates. However, it is also apparent from Fig. 3 that Heeb's estimates for the 1960's were underestimates. The releases in the 1960's were primarily from the PUREX plant. The silver reactors worked so well in the PUREX plant that most of the releases resulted from malfunctions and process upsets; this type of release is not included in the Heeb model. Fortunately, the releases in the 1960's were very low in comparison to the earlier years, and even a relatively large fractional increase in the source term is small in the absolute sense.

VERIFICATION WITH ATMOSPHERIC MONITORING DATA

A method of checking the reasonableness of the total release estimates is to compare environmental concentrations predicted using them with the actual measurements made in the environment in 1950's and 1960's. From 1948 through 1957 (GE 1948 through GE 1957d), the Hanford Site quarterly environmental monitoring summaries report monthly average concentrations of ^{131}I in air at several locations throughout the Hanford vicinity. After 1958, the weekly or monthly values were reported in the Hanford Site annual monitoring reports. A common monitoring location is downtown Richland, Washington—the city immediately adjacent to the southeast corner of the Site. A monitoring station was set up near the Atomic Energy Commission (AEC) headquarters. The location of the station is shown on Fig. 1. Integrated samples were taken weekly at this location throughout the period of separations processing.

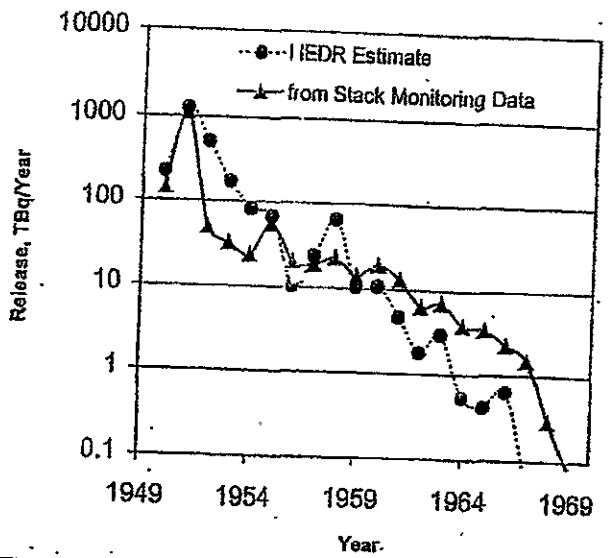

Fig. 3. Comparison of releases of ^{131}I from Hanford as calculated by Heeb (and corrected by Napier 1999) and estimated from stack monitoring data.

The sampling device consisted of an air pump connected to a flow meter, a filter, and a container of caustic solution. Generally, the beta radioactivity captured in the caustic scrubber solution was reported as ^{131}I. This basic system remained essentially unchanged until the 1970's (GE 1950a; Corley 1971).

Just as there are uncertainties in the amount of ^{131}I emitted from the stacks, there is uncertainty in the amount of ^{131}I reported to be in the atmosphere. Iodine exists in three general forms in the atmosphere: as organic (slightly reactive) gases, as inorganic (reactive) gases, and attached to aerosol particles. The monitoring system only collected the gaseous fraction of the iodine from the air in the scrubber solution. The fractions of organic, elemental, and particulate iodine in the air samples are likely to be different than those emitted from the stacks. In measurements made at Hanford, Ludwick (1964) found that in the time it took primarily elemental iodine emitted from the stacks to travel 3,200 m, about two-thirds of the iodine had changed form. Approximately one-third was in organic species, and another third was associated with particulate material. The partitioning of iodine in Ludwick's experiments is consistent with the results of other measurements of iodine at the Hanford Site (Ludwick 1967; Perkins 1963, 1964), with the partitioning of iodine in the plume following the Chernobyl reactor accident (Aoyama et al. 1986; Bondietti and Brantley 1986; Cambray et al. 1987; Mueck 1988), and with the partitioning of natural iodine in the atmosphere (Voilleque 1979). On the basis of these references, a uniform distribution of the reactive gas iodine fraction between 0.4 and 0.6 is assumed here.

Other sampling uncertainties also exist. The flow rate of the sampler may have varied; this is assumed to parallel the stack sampler with a variability of 20% of the nominal flow rate. Therefore, an uncertainty factor with a triangular distribution of minimum 0.8, most likely value of 1.0, maximum 1.2 has been assigned. Using Schwendiman's (1954) report that "Analytical methods and counting corrections for ^{131}I can be expected to give

curie values within ±10–15 percent of the true concentration in the scrubber solution," a triangular uncertainty distribution with minimum 0.8, most likely value of 1.0, and maximum of 1.2 has been assigned to this term. For monthly analyses, there is an additional uncertainty added by monitoring system reliability; the equipment may not have been functioning 100% of the time. If the sampler was not functioning, it could have missed periods of high or low concentration. A correction factor with a triangular uncertainty distribution with minimum 0.75, most likely value of 1.0, and maximum of 1.25 has been assigned to this term to account for this possibility. In addition, the period of time reported to be monitored in the monthly reports was for a reporting month, not a calendar month. Usually, the amount included the measurements of the last few days of the preceding month and excluded the last few days of the current month. This lag was caused by the length of time required to collect, transport, process, and report the iodine in the caustic solution from the sampler. A month-to-month adjustment of up to 6 d (measurements were reported weekly) could occur. To account for this, a multiplier with a uniform distribution ranging from 0.8 to 1.2 has been introduced. See Table 2 for a summary of these distributions.

Considering all the potential areas of uncertainty, a monthly correction multiplier may be estimated with a mean/median of 2.0 and a 5–95 percentile range of 1.05 to 4.0. This has been applied to all the reported air measurements.

In order to compare the atmospheric monitoring results with the stack release estimates, the dilution and dispersion in the atmosphere must be considered. The dispersion model RATCHET (Ramsdell et al. 1994) was used for the HEDR dose calculations, and 5 years' worth of monthly calculations are available. An atmospheric dispersion factor for each of the 12 months of the year was derived using the HEDR results, averaging the annual variabilities and variations in release rate. The resulting dispersion factors for releases from the Hanford separations areas transported to the central Richland monitoring location are presented in Table 4. Dividing the adjusted, measured air concentrations by these values provides an approximation of the release required to result in that air concentration. The central values of the resulting required releases are compared to the adjusted stack monitoring measurements in Table 1, column 6. The same results, annualized, are presented graphically in Fig. 4. Note that uncertainties in the dispersion measurement are not reflected in the Fig. 4 results. The atmospheric monitoring data appear to indicate higher releases in 1953 and 1957 through 1958; however, these were periods of high fallout from above-ground nuclear testing. Beyond about 1968, the releases were too small to be detectable at the Richland air monitoring station. For neither source is the predicted environmental concentration dramatically different from the available historical evidence.

Table 4. Monthly average atmospheric dispersion factors (s m^{-3}) for Hanford 200 area releases transported to Richland.

Month	Dispersion factor
January	1.3×10^{-8}
February	1.3×10^{-8}
March	1.0×10^{-8}
April	6.6×10^{-9}
May	6.7×10^{-9}
June	3.4×10^{-9}
July	4.2×10^{-9}
August	5.8×10^{-9}
September	7.5×10^{-9}
October	8.4×10^{-9}
November	9.6×10^{-9}
December	1.3×10^{-8}

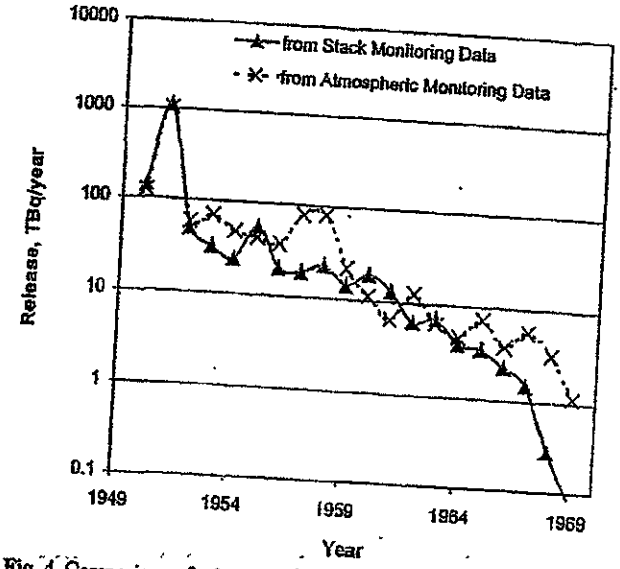

Fig. 4. Comparison of releases of ^{131}I from Hanford estimated from stack monitoring data and back-calculated from atmospheric monitoring data.

It is apparent that the two sets of results are very similar. Within the uncertainties of the two sets of measurements, the results are essentially equivalent. This is demonstrated in Fig. 5, which replicates the information of Fig. 4 but includes the uncertainties in both sets of estimates. In this figure, the distributions of annual release estimates made using the stack data and the environmental monitoring data are compared pair-wise; the stack monitoring results are presented as the first member of each pair and the atmospheric results as the second. Including the uncertainties, it appears that the atmospheric monitoring data would indicate larger releases than reported in 1953, 1956, 1957, 1958, and

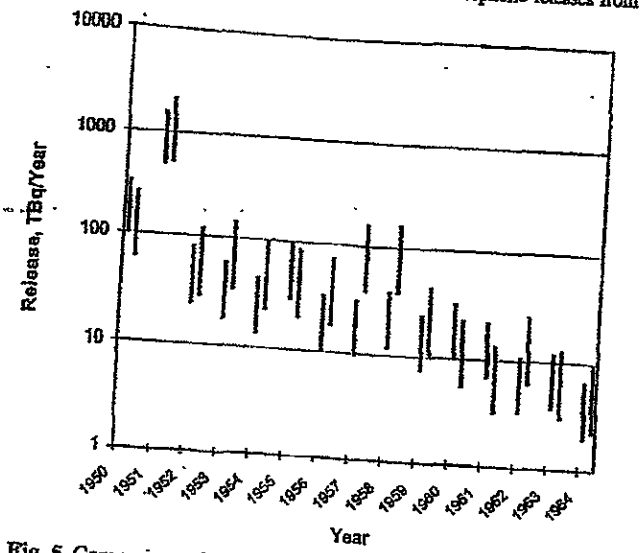

Fig. 5. Comparison of releases of ^{131}I from Hanford estimated from stack monitoring data with those back-calculated from atmospheric monitoring data, including uncertainties. Data are plotted pair-wise, with stack monitoring data first, atmospheric monitoring data second.

1962. However, these were years of high global fallout from atmospheric weapons testing. The records from each of these periods indicates that the atmospheric monitoring stations detected simultaneous increases in all locations throughout the monitoring area, and specifically attribute the higher readings to fallout (GE 1953b, c; 1956c; 1957c, d; 1959L; 1963m).

In no case is there evidence that the stack monitoring data greatly underestimate the release of ^{131}I from the Hanford Site. For the periods with little fallout, the correspondence is very strong, supporting the stack monitoring data. In particular, the atmospheric monitoring data indicate that for the period 1951 through 1954, the stack monitoring data provide a better estimate of the releases than the corrected estimates of Heeb (Napier 1999). This is the period noted above in which Heeb was extrapolating the REDOX release fraction back to the T and B Plants, which was not appropriate.

DISCUSSION

The comments made about the HEDR source term by the National Academy of Sciences are essentially correct. Analysis of the historical stack monitoring data and atmospheric monitoring data indicate that the HEDR estimates were too high in the early 1950's and too low in the 1960's. However, the largest emissions from the Hanford Site occurred in the period of 1945 through 1947, a total of 25.3 PBq (683,000 Ci). The difference in the total ^{131}I emissions from all processing operations indicated here is from Heeb's original estimate of 28.2 PBq to 27.3 PBq using the estimates based on stack monitoring, a decrease of only 3%.

The Hanford Environmental Dose Reconstruction Project used Heeb's source term to prepare radiation dose estimates for reference individuals. Annual doses to an adult at Ringold, the off-site location of highest dose, are presented in Farris et al. (1994, 1996). These calculations have been redone, using the updated source terms developed for this paper. Plots of these doses calculated with the Heeb source term and with the stack monitoring estimates look essentially like Fig. 3. The total effective dose to a full-time, adult Ringold resident from ^{131}I using the Heeb source term (as corrected by Napier 1999) from 1950 through 1972 is 0.73 mSv; using the source term based on stack monitoring data in the HEDR models, it is 0.51 mSv. There are minor temporal differences, for Heeb's source term for the period 1950 through 1953 the dose is 0.65 mSv and for the stack monitoring source term it is 0.45; the dose for the period 1954 through 1957 is 0.05 mSv using the original source term and 0.03 mSv using the stack monitoring source term; the dose for the period 1957 through 1972 is 0.02 mSv using the original source term and 0.03 mSv using the stack monitoring source term. These dose differences follow the source term differences, with minor modifications resulting from crop growing season considerations.

The researchers of the Hanford Thyroid Disease Study (HTDS) have been provided with the source term derived from the stack monitoring data and the HEDR environmental database has been regenerated. Because the results of the HTDS analyses are not projected to be completed until mid-2002, it is premature to speculate what impact the revisions may have on the epidemiological results.

CONCLUSION

This paper provides an independent approach to estimating the atmospheric releases of ^{131}I from Hanford based on historical stack measurements, with a separate verification based on atmospheric monitoring data from a location several kilometers distant. The atmospheric release of ^{131}I from the Hanford site for the 1950's and 1960's has been re-evaluated using processing plant stack monitoring data. The results are broadly compatible with previous estimates (Heeb 1994; Anderson 1974) in terms of overall magnitude and time trends but are based on a detailed review of all available historical data on emissions and measurement technology. The results have been compared with additional historical data derived from regional atmospheric monitoring programs. The original estimates (Heeb 1994; Napier 1999) were a

release of 2.46 ± 0.71 PBq of ^{131}I between 1950 and 1972. The stack monitoring results show a release of ^{131}I to the atmosphere between 1950 and 1972 of 1.55 ± 0.23 PBq (41,900 ± 6,300 Ci). The concurrent atmospheric monitoring results imply an ^{131}I release of 1.75 ± 0.11 PBq (47,200 ± 2,900 Ci) over the same period, but this result is inflated by inclusion of global fallout. For the key period of 1950 thorugh 1957 (the period of highest releases after those of the mid-1940's, and a period included in ongoing epidemiological studies), the stochastic stack monitoring results indicate an ^{131}I release of 1.46 ± 0.23 PBq (39,400 ± 6,300 Ci), supported by atmospheric monitoring results of 1.56 ± 0.11 PBq (42,100 ± 2,900 Ci), compared to the original estimate of 2.37 ± 0.69 PBq (66,800 ± 19,200 Ci).

The detailed evaluation of the releases from the various separations facilities indicates that several of the simplifying assumptions made by Heeb (1994) were inappropriate. When these assumptions are replaced with the actual measured releases, the estimate of the overall magnitude of the releases is decreased in the period 1951 through 1954, and increased in the period 1961 through 1971. The early decrease is by a factor from 3 to 10, and the later increase is by a factor of from 3 to 1,000. However, because the releases in the earlier period are much larger than the releases in the later period, the overall result is that the source term decreases from Heeb's estimate. The primary reason for the decrease is that the release fraction applied by Heeb (1994) to B and T Plants was derived from data taken at the REDOX facility in 1959 through 1960, and the operation of the cleanup systems at REDOX during that period was not as good as earlier operations had achieved. The later increases result because the primary causes of the release, malfunctions and process upsets, were not included in the Heeb model.

Acknowledgments—Special thanks are due to Joseph K. Soldat for providing the original copies of his Hanford monthly reports for the years 1950 through 1952, which detailed the resumption of the stack monitoring systems and individual sampling results. Lynn Anspaugh provided the impetus to re-evaluate the releases using the stack data. Terri Traub and Janice Partlree guided the author to the appropriate hundreds of boxes of documents in the DOE Reading Room, Richland, Washington.

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GE. Radioactive contamination in the environs of the Hanford Works for the period July, August, September, 1950. Richland, WA: General Electric Company; HW-20700; 1950c.

GE. Radioactive contamination in the environs of the Hanford Works for the period October, November, December, 1950. Richland, WA: General Electric Company; HW-21566; 1950d.

GE. Radioactive contamination in the environs of the Hanford Works for the period January, February, March, 1951.

Exhibit 8

Work to be inc. in 0502C EXH. 8

Battelle
Pacific Northwest Laboratories

Project Number _____

Internal Distribution

File/LB
Janna Shaw

13 pages
5 hours
2 hours
in. edit
post edit

Date June 17, 1993

To Dill Shipler

From Sandra Cannon

Subject Hanford's Air Monitoring Program from 1945-1955

Overview

Eva Mart wrote a summary, dated February 10, 1988, of the air monitoring equipment that was used from 1945-1955 at Hanford. It addresses ionization chambers and air sampling devices (filter units, caustic scrubbers, hand pumps). In the conclusions for each piece of equipment, Eva explains why the data measured would not be valid. On a few, she concedes that perhaps the air data from that particular monitor could be used to QA some other data. According to Mike Thiede, this is an important document because it shows why we dropped the air data and concentrated on the vegetation instead.

The document is brief, well organized, and fairly well written. It has no page numbers for the direct quotations, however. It would have to be QA'd.

Recommendation

I envision the summary environmental monitoring report (Milestone 0502C) to include a discussion of why we stopped work on the air data and concentrated on vegetation. Eva's report would be the perfect backup material to include in that summary as an appendix. That means for this report I am recommending the full-blown treatment because that is what we will be doing for the 0502C summary report.

8/2/93

Mike would encorporate concept into this report into 0502C

4014213

Battelle
Pacific Northwest Laboratories

Project Number _____

Internal Distribution
DH Denham
LB

Date February 10, 1988

To File

From EI Mart EIM

Subject Hanford's Air Monitoring Program From 1945 To 1955 - A Compilation of Notes

The air monitoring program at Hanford developed and changed from 1945 to 1955 as experience led to improved techniques. The air monitoring program contained two basic types of monitors: ionization chambers and air samplers. The air samplers consisted of filter devices or caustic scrubbers. This memo discusses the basic types of monitors considering interpretation of ^{131}I levels from the data.

IONIZATION CHAMBERS

Environmental ionization chambers were used from the start and continued past 1955. They consisted of detachable chambers and integrons. The detachable chambers included "W", "S", and "C" types (as they designated them) and were made at Hanford (Health Instrument Section 1946). The chambers were located on specified outdoor stands, and later some were added to 614 Buildings. The first integrons were installed in March 1945 (Health Instrument Group 1945). They were always located in the Environmental Monitoring Shacks (614 Buildings).

The ionization chambers did not specifically monitor ^{131}I. Moreover, the detachable chambers measured general radiation levels coming from the air and ground. Indeed, the ground may have even been the major dose contributor, as indicated by the following:

> The Health Instrument Group report (1945) states that at each location the readings on these chambers were due to ground contamination, not from atmospheric radiation.
>
> The first quarter 1946 report (Healy 1946b) states that the close correlation between the decrease in readings over certain time periods and the half life of ^{131}I indicate that a large portion of the reading on those chambers comes from ground contamination and not from atmospheric radiation.

Also, the integron units had considerable problems, especially at first. They did not calibrate properly according to reports by Botsford (1945) and the Health Instrument Group (1945), although a new amplifier design may have corrected this problem early (Botsford 1945). They were reported (Health Instrument Group 1945) to be unreliable, often showing readings not due to radiation.

4014214

Conclusions:

Data from the integrons and detachable chambers cannot be reliably used to assess airborne radioiodine levels, because they did not exclusively monitor iodine, the ground may have been the major source, and the integrons had considerable problems.

AIR SAMPLING DEVICES

The air sampling devices consisted of filter units (including standard, dual, Constant Iodine {CI} Units, and particulate), caustic scrubbers (including portable ones), little suckers, and hand pumps (Healy 1945, Healy and Gamertsfelder 1946, Singlevich and Paas 1949, and Paas and Singlevich 1951a).

A. Filter Units

A.1 Standard Filter Units

The first mention of filter units (in the literature reviewed) occurred in a weekly Environs report for the week ending 2/6/46 (Health Instrument Group 1945). One filter unit was located offsite (in Richland). More filter units were added with time. In February 1950, 15 filter units were in place, 3 of which were offsite in Richland, Kennewick and Pasco (Paas and Singlevich 1950c). In December 1951, 20 units were in place, 6 of which were offsite in North Richland, Richland, Kennewick, Pasco, Benton City and Riverland (Paas 1952a). In December 1955, 18 units were in place, 4 of which were offsite in the 1100 Area, Pasco, Benton City and Riverland (Andersen and Soldat 1956a).

Air was filtered through CWS #6 filter paper (1-1/2 inch asbestos disks, (Healy et al. 1951) at a rate of 2 to 2.5 cfm (Paas 1954a,b). The filters collected air for periods of 1 day to 1 week (Paas and Singlevich 1950c, Paas 1952c) for a total volume approaching 20,000 cubic feet (Paas and Singlevich 1950c). No mention is made of how accurately the cfm (and, thus, volume of sampled air) was known. The only discussion on air flow is made regarding particulate filters (in 6/51) which drew from 2 to 10 cfm. The following statement was made (Paas and Singlevich 1951b):

> "The volume of sampled air was accurately summed by placing running time meters in series with the motor and using the total operating time along with the pre-calibrated flow rate."

Whether this was done with the regular air filters is not stated. The filters were not counted until the radon and thoron daughters had decayed several days (Paas and Singlevich 1950e). Until 1947, the filters were apparently counted directly. In 1948, the filters were analyzed for total beta activity by a nitric acid extraction (Healy 1948b). The filters were counted by the standard, 1-inch diameter, thin mica window GM detector, which was in a lead pig (Healy 1947, 1948b; Paas and Singlevich 1951b). The filter

was counted on the first shelf about 1/8-inch below the counter. It was placed on a card and covered with cellophane (Healy 1948b). The results were corrected for decay (Turner 1947; Singlevich 1948b), back scatter from the counting plate, absorption in the counter window, and geometry; but, not for self absorption or self scatter (Healy 1948b).

Until June 1948, all of the activity was assumed to be from ^{131}I (Singlevich 1948b, Healy 1948a). This was supported by earlier studies. Early in 1946, they had determined that asbestos paper absorbed 70% of ^{131}I (Healy 1946a). However, in June 1948, an investigation indicated that the filters were only 3 - 4% efficient for ^{131}I. Thus, they stated that (Healy 1948a):

> "The activity listed for the air filters should be regarded as chiefly the long lived activities discharged from the stack."

This finding of low efficiency was later contradicted by decay curve studies in March 1949 which indicated that an appreciable amount of iodine was collected on the air filters (Singlevich 1949d). Data from 6 to 8 filters indicated that 80 to 95% of the activity was from ^{131}I. Experimentation followed. By 8/50 they had determined that, indeed, only 5 to 10% of ^{131}I was retained by the filter (Paas and Singlevich 1950d).

A few mentions are made of how the filter data correlated with other data (from scrubbers or vegetation). In one case the filter activity (for 3 areas) indicated greater activity than from the vegetation data (Turner 1947). A couple mentions are made of the filter activity and scrubber activity agreeing well (Paas and Singlevich 1950a; 1951a,b).

Conclusions:

Data from filters cannot be reliably used to indicate airborne ^{131}I levels since they had a low iodine collection efficiency.

However, correlations of filter activity with vegetation and scrubber activity for the same time periods could potentially serve a QA function. Such correlations could also potentially provide a better "overall" picture. Ratios of scrubber results to filter results could potentially be used to estimate earlier ^{131}I contributions from the filter data, or ^{131}I contributions at locations where scrubbers were not found.

A.2 Dual Filter Units

Data from dual filter units is first provided for the first quarter of 1951 (Paas and Singlevich 1951b). The dual monitors were not described, nor the analyses done. They were, however, operated at several locations for the purposes of studying the rate of buildup and decay of beta emitters. Thus, they provided a supplemental means of evaluating the activity seen on the standard filters (Paas 1954a). The dual monitors were operated past

December 1955 (Andersen and Soldat 1956a). A couple of the units were located in Richland (Paas 1954a; Andersen and Soldat 1956a).

Conclusions:

Not enough information is provided about the operation and analysis of the dual filter units. They are not specific to ^{131}I, and only two units were located offsite. Thus, they are not of much use in assessing public doses from ^{131}I.

A.3 Constant Iodine Monitoring Units

The first constant iodine (CI) monitor was installed onsite (in the 3746 Building) in July 1945 (Healy 1945). In December of 1945, two additional CI units were installed: in the 614 Building SE of the B-Plant stack and in Benton City (Health Instrument Section 1946a). However, the monitor in Benton City was not yet giving satisfactory service in December, 1945. By May 1, 1946 another CI unit had been placed in the 300 Area (with further expansion contemplated) (Health Instrument Section 1946). In March of 1947, five CI units were in operation (Gamertsfelder 1947a). In April of 1950, six CI units were in place (Singlevich 1950a). Sometime, between April and September, 1950 data from CI units were not reported any longer (Singlevich 1950a,b).

The CI units consisted of a GM tube enclosed by a probe. The GM counted contamination on a special filter paper fastened to the grid portion of the probe. Air was drawn through the filter paper and any iodine present (was assumed) deposited. The reading was shown on a counting rate meter and was also recorded on a Leeds & Northrup Micromax (Health Instrument Section 1946).

A collection efficiency of from 20 to 50% was assumed. The geometry was assumed to be from 1.2 to 15% (Healy 1945, 1946a).

Conclusions:

Data from the CI units cannot be reliably used to assess past airborne ^{131}I levels, because the efficiency of the CI Unit filters for ^{131}I is questionable and the filters did not specifically collect ^{131}I.

A.4 Particulate Filters

Apparently, at first, the standard air filters were radioautographed to detect hot particle; and later, actual particulate filters were established. At first, the particles were measured to monitor particles being discharged from Hanford. Later, the particles were monitored to detect fallout. This became the main method for identifying airborne fallout. Particles were discussed extensively in the atmospheric monitoring sections when fallout was

found (for example, see Paas 1952a,b). Also, special particle collection units were located at far off locations.

Conclusions:

Data from particulate filters may be useful in assessing general fallout contributions. However, the particulate data would not directly provide information on the iodine contribution. The ^{131}I contribution from fallout depended on the transit time from detonation to Hanford. This depended on the particular wind and precipitation patterns. Thus, the percent of iodine in Hanford fallout may not have been constant.

B. Caustic Scrubbers

Caustic scrubbers were connected in series to a few of the standard air filter to a Motoair pump. Thus, the filters trapped particulates, some iodine, and other fission products before the air passed through the scrubber (Paas and Singlevich 1950c; Singlevich and Paas 1949). The scrubber solution consisted of 50%, 0.1 normal sodium hydroxide and 50%, 0.1 normal sodium carbonate; sodium iodide was also added as the carrier (Singlevich and Paas 1949). Air was sampled from 1 to 7 days at a flow rate of from 2 to 2.5 cfm (Paas 1952c, 1954b). The ^{131}I was extracted from scrubber solution according to the standard procedures by Healy et al. (1951). The scrubber had a detection limit of about 1×10^{-13} μCi/ml (Andersen and Soldat 1956b).

In February, 1949, they were making efforts to install scrubbers on all the air filter devices (Singlevich 1949b). Iodine-131 results from caustic scrubbers for five locations are first included in an April through June 1949 quarterly report (Paas and Singlevich 1950b). Five locations are given two of which are offsite (in Benton City and Richland). By July 1950, nine scrubbers were in place, three of which were offsite in Benton City, Richland and the 3000 Area. During the last quarter of 1951, three more units were added (Paas 1952a). The offsite scrubbers were located at Richland, North Richland, Benton City, Pasco and Kennewick. During the first quarter of 1953, the Kennewick unit was removed (Paas 1953). During the first quarter of 1955, the North Richland unit was moved to the 1100 Area 614 Building (Radiation Measurements Unit 1955). Thus from the first quarter of 1953 to the end of 1955, four scrubbers were located offsite.

Preliminary investigations indicated scrubber efficiencies of 90% (Singlevich 1950b). And, the average yield was established at about 70% (Healy et al. 1955). Early work indicated that the scrubber solution contained 20 to 50% of the total activity (Singlevich 1949c). The scrubber results were corrected for geometry, yield efficiency, and volume as per Healy et al (1951), Wolf (1951), and Paas (1952b). [The Appendix in HW-22682 (Wolf 1951) provides information on calculating the activity density from beta emitters in scrubber samples. The Appendix was effective 8/25/51. Healy et al. (1950) provides general information on calibrations of the GM counter and

correction factors (dated 7/50).] Prior to 1950, little information is available on correction factors used for scrubber samples.

Some documents mention that the scrubber and filter results agreed well (Paas and Singlevich 1950a, 1951a, 1951b). Other documents also note that scrubber and vegetation results agreed well (Paas and Singlevich 1950c; Paas 1952c).

Portable scrubbers were used to track the plume. In one case, several were installed to specifically monitor the discharge from the December 1949 "green run" (Paas and Singlevich 1950a)

Conclusions:

The few offsite scrubber locations (from 1945 to 1955) make the usefulness of scrubber data in assessing iodine doses questionable. However, a comparison of scrubber and vegetation data may serve a QA function. Also, as mentioned earlier, correlations of filter and scrubber data may provide some indications of airborne ^{131}I levels at sights where scrubbers were not found.

Several questions remain on the accuracy of the scrubber data. Questions (that need answering to better evaluate scrubber data) and uncertainties are in the attached appendix.

C. Hand Pumps

Hand pumps (with thiosulfate solution) were developed in August 1945 (Healy 1945). The first mention of a hand pump measurement is in the Environs Report for the second half of September 1946 (Healy and Gamertsfelder 1946).

The hand pumps contained glass absorption columns using sodium thiosulfate solution (10 cc of a 1% solution) as the absorbing medium. These columns contained glass wool packing to insure close contact between the solution and air. Air was pulled through the column with a three liter hand pump. The solution was then evaporated by fastening a capillary directly to the column and allowing the solution to drop on a 1 inch watch glass. The watch glass was counted by a mica window counter. They estimated that it was possible to detect 7 x 10(-15) Ci/cc of iodine (Cantril and Healy 1945) with 3 liters of air, or 7 x 10(-16) Ci/cc with 30 liters of air assuming 100% absorption in the thiosulfate (Healy 1945).

Apparently, the hand-pump samples were taken to track plume concentrations. Mention of sample collection is in reference to plume looping. In the last half of May 1947, warmer weather and more looping of stack gases caused a renewal of the hand pump sample collection (where 15 samples were taken) (Gamertsfelder 1947b).

Conclusions:

Because hand-pump samples were mainly (if not exclusively) used to measure plume levels in the environment and the location of measurements is usually not provided, the data is not useful for assessing public doses from ^{131}I.

D. Little Suckers

Little suckers were mostly used to collect air samples within buildings (Health Instrument Section 1946a). Only in September 1945 is mention made of offsite "Little Sucker" samples.

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APPENDIX

POTENTIAL ERRORS AND UNCERTAINTY IN 1949 - 1950'S MEASUREMENTS OF AIRBORNE IODINE-131 LEVELS VIA CAUSTIC SCRUBBERS

TABLE 1. Potential Measurement Errors

Error	Discussion
SCRUBBER OPERATION	AIR FLOW: This would probably cause a bias so that the results would indicate lower ^{131}I levels. We need to know how and when air flow was measured; how air flow was included in the calculation of ^{131}I levels; and how deviations from assumed air flow was compensated for. No references on air flow for the scrubbers exist except that air was drawn at a rate of 2.0 cfm (Paas and Singlevich 1950b) to 2.5 cfm (Paas 1951) for a total volume of 20,000 cubic feet (Paas and Singlevich 1950b). Air flow could also introduce an uncertainty if the air flow was within a range (i.e., 2.0 to 2.5 cfm) (Paas 1951). FILTER REMOVAL: The asbestos filter (through which air was drawn before flowing through the scrubber) would have removed around 3 - 4% (Healy 1948) or 5 - 10% (Paas and Singlevich 1950a) of the total atmospheric ^{131}I. Whether this removal was taken into account needs to be determined. PLATEOUT: Potential plateout in the unremovable lines between the filter and the scrubber could have caused a negative bias.

TABLE 1. Potential Measurement Errors (cont)

Error	Discussion
IODINE-131 ANALYSIS (cont)	IODINE-131 ASSUMPTION: The assumption that all the beta activity in the caustic scrubbers was ^{131}I may cause a bias so that the results would indicate higher ^{131}I levels. How specific the caustic solution was for iodine needs to be determined. YIELD: In 1951 they had established that the scrubber had an average yield of about 70% (Healy et al. 1951). In 1949, the yield was estimated to be 20 to 50% (Singlevich 1949). Whether (or when) yield was taken into account in the calculation of atmospheric ^{131}I levels needs to be determined.

TABLE 2. Potential Measurement Uncertainty

Uncertainty	Discussion
COUNTING	CALIBRATION STANDARDS: Prior to 1950, knowledge was poor of the actual activity of "spike" standards by which instruments were calibrated. Healy et al. (1950) stated that: "Measurements have either been relative or with large uncertainty in the final value with poor cross-checks between various laboratories." Poor knowledge of the standard's activity would cause considerable uncertainty in the absolute activity of any samples measured by the instruments calibrated by that standard. The indication is that indeed the measurements (prior to 1950) were more relative than absolute. However, more information is needed on the source of the standard and how its activity was determined. Moreover, the accuracy of the correction factors used (besides decay) depends on the "spike" sample.

TABLE 1. Potential Measurement Errors (cont)

Error	Discussion
COUNTING (cont)	SAMPLE PREPARATION: Inconsistency in sample preparation would lead to some uncertainty in the final value. This is probably a minor source of uncertainty. The procedure for sample preparation is given by Healy et al. (1951) in HW-20136, pg. 4.15-1.

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Healy, J. W., R. C. Thorburn and Z. E. Carey. 1951. H. I. Control Laboratory Routine Chemical Procedures. HW-20136, General Electric Company, Richland, Washington.

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March 15, 2006

Office of Compensation Analysis and Support
National Institute for Occupational Safety and Health

SEC Petition
4676 Columbia Parkway, MS-C-47
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Supplements to: SEC 00050,
Response to NIOSH letter of March 2nd, 2006 Special Exposure Cohort

Petitioner: Authorized Representative for Claimants on Record with Original Petition

See Point F.2 below explaining why NIOSH and ORAUT are incorrect in believing that CEDR has stored examples of records of personal monitoring records of Hanford Dupont workers.

In addition to CEDR's Data File Set HFC78A01 of the *Hanford Cohort Study, 1989 and the Hanford Cohort Study, 1993, Data File Set HFI89A01*, where both studies specified that Pacific Northwest Laboratories (PNL) was the source of their external and internal dosimetry data, and knowing that PNL has gone on record as **not** being able to obtain any DuPont Hanford worker dosimetry, there is **yet another** study in CEDR's database that makes the same point.

See PNL-8449, ***"Description of Process Used to Create 1992 Hanford Mortality Study Database,"*** E. S. Gilbert, 1992.

"These records belonged to employees who left Hanford with Du Pont when General Electric replaced Du Pont as the major contractor. Because Du Pont had taken exposure records of these persons with them, a decision was made that these dose records were the responsibility of Du Pont rather than the Hanford Radiological Records program." See footnote on pg. 2.2.

In other words, the **Du Pont Hanford worker dose records are not a part of the Hanford Radiological Records program.** This would appear to be the definitive word on the subject.

Accordingly, in regard to point F.2, The extensive documentary evidence continues to confirm there are no individual dosimetry or bio-assay records available for Du Pont workers at Hanford, and Petitioner would respectfully **again** suggest that CEDR and ORAUT make that point clear in their reports.

To understand the impact of the documents and expert reports that Petitioner is submitting have upon **"the limitations of existing DOE or AWE records in radiation exposures at"** Hanford, a review of the errors or deficiencies in the steps or stages of the underlying basis of ORAUT's dose reconstruction demonstrate the **limitations** of existing records.

Supplement of Klementiev's Qualifications

In regard to these errors, Petitioner had attached the expert report of A. A. Klementiev in his Response of questions raised in the phone conference with NIOSH and ORAUT representatives. To supplement his report please **see attached Klementiev's CV** of his enormous academic training in physics, mathematics and in the mathematical modeling of complex systems, and publications.

Supplement to Studies demonstrating invalidity of Napier's reliance upon atmospheric air monitoring.

HEDR' chief author, Napier, made a critique of Heeb's work which supported some of the same points made by Petitioner's experts and the EPRP. But Napier depended also upon the atmospheric air monitoring

data for validation of his use of questionable stack release data despite three separate previous studies finding such data to be unreliable and inadequate for any use.

In addition to Exh. #8: Memo from Sandra Cannon to Dill Shipler: *Hanford's Air Monitoring Program from 1945-1955*, June 17, 1993, and following Memo: *Hanford's Air Monitoring Program from 1945 To 1955 - A Compilation of Notes*, E. I. Mart, February 10, 1988, there **is also:**

Exh. #9: PNWD-2226, Thiede, 1994.
"Therefore the historical air monitoring data were not used by the HEDR project because the data were **not satisfactory in quality or number for dose calculation or validation of models."** Pg. 4.1.

Exh. #10: PNWD-2234, R. W. Hanf, 1994.
"The result was that air monitoring data are insufficient for use in the HEDR project." Pg. 1.

In other words, not only are Heeb's release fractions inaccurate, but Napier's effort to correct HEDR is also deficient. HEDR cannot be used with any scientific plausibility as a source for release fractions, or releases, for any time period.

Yours truly,

Petitioner

PNL-8449
UC-605

Description of the Process Used to Create 1992 Hanford Mortality Study Database

E. S. Gilbert
J. A. Buchanan
N. A. Holter

December 1992

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

PNL-8449

Health Issues

1. Data on OHH_OP (This meant that according to HEHF records in 1988, the worker had been employed in operations work prior to 1979.) A total of 44,407 workers qualified by meeting this criterion.

2. OHH79 data on MST79 (This meant that according to HEHF records in 1979 the worker had been employed in operations work prior to 1979.) An additional 104 workers, who had not qualified under criterion 1, met criterion 2. It is noted that there were 3 workers with OHH79 data on MST79 where data on more recent OHH88 files indicated that initial employment was after 1978; these 3 workers were not considered to be eligible for the study population.

3. Current records (other than OHH_OP) at HEHF indicating the worker was a part of the operations worker cohort. To ascertain this, staff at HEHF searched for records of workers who were on MST79, but not on OHH_OP. Many of these workers had only dosimetry data, and had not previously had data on the OHH79 file. These searches were primarily conducted in 1989.

   An additional 36 workers, who had not qualified under criteria 1 or 2, qualified under criterion 3. Thus, a total of 44,547 workers met at least one of the three criteria.

Because it is known that the OHH files sometimes erroneously included workers who reported for initial physical examinations, but never actually started work, it was also required that <u>in addition</u> workers meet <u>at least one</u> of the three criteria listed below. The first two criteria involve use of dosimetry records from both ORE and MST79. The use of MST79 was necessary, because the ORE system no longer includes the records of over 10,000 early workers, for whom external dosimetry data were available in 1979 when MST79 was created.[1]

A. Workers had to have at least one year of onsite operations dosimetry on the ORE file prior to 1979. 26,375 workers qualified by meeting this criterion. Dosimetry data for these workers were taken from ORE.

B. Workers had to have dosimetry data on MST79. An additional 10,305 workers, who did not meet criterion A, qualified under criterion B. For these workers, dosimetry data were taken from MST79. In some cases, workers had dosimetry on MST79, had a Social Security number match with ORE but no onsite operations dosimetry on ORE (offsite or construction

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[1]These records belonged to employees who left Hanford with DuPont when General Electric replaced DuPont as the major contractor. Because DuPont had taken exposure records of these persons with them, a decision was made that these dose records were the responsibility of DuPont rather than the Hanford Radiological Records program.

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OBJECTIVE N/A

EDUCATION Mathematical Epidemiology (Ph.D.), Institute of Cybernetics, Kiev, Ukraine, 1991.
Applied Mathematics in Automation and Remote Control (Ph.D.), Moscow Institute for Physics and Technology, Dolgoproudniy, Russia, 1971.
Electrical Engineering (M.S.), Moscow Institute for Physics and Technology, Dolgoproudniy, Russia, 1966.

AWARDS Malcolm L. Peterson Award (1994, Washington Physicians for Social Responsibility).
Best Diploma Research Award (1966, Moscow Institute for Physics and Technology, Dolgoproudniy, Russia,).

PROFESSIONAL EXPERIENCE **Tacoma-Pierce County Health Department,** Tacoma, WA. Epidemiologist II (Dec.1996- Present). Computer modeling for Public Health related projects:
Establishing Health Intervention Priorities;
Designing databases, such as "*Mother and Child Health*", "*Domestic Violence*";
Conducting projects on epidemiology.

CDC/WHO, Training Course *Evidence-Based Noncommunicable Diseases Prevention, Moscow,* Russia. Instructor, (Apr.2003). Taught course "*Introduction to the Behavioral Risk Factor Surveillance System*".
Chelyabinsk-McGill Project in Population Child Health, Chelyabinsk, Russia. Instructor, (Jan.2000 - Feb.2000). Taught courses *Biostatistics* and *Epidemiology.*

Tacoma Community College, Tacoma, WA. Instructor (Jan.1996-Dec.1996). Teaching course *Business Data Processing,* Lab assisting for the course *Programming Visual Basic.*

Tom H. Foulds and Associated Counsel: Hanford Litigation Office, Seattle, WA. Consultant, Expert witness (1994 - Present).
· Developed computer model for estimation of radioactive Iodine-131 releases into the atmosphere from Hanford Site in 1944 - 1948;
· Estimated of Pu-239 releases into the atmosphere from Hanford Site;
· Developed computer model for prevalence estimation of degenerative type diseases.

NeuRobotics, Inc., Puyallup, WA. Senior Research Scientist (1992-1994).
· Provided professional analysis for airborne radionuclide releases including estimates for population health impacts;
· Constructed and supplemented GIS representations of radionuclide contamination for Eastern Washington;
· Served as scientific and technical translator for Russian scientific articles, research papers, and texts;
· Established NeuRobotics support groups in Moscow, Kiev, and Vladivostok and facilitated communication with these groups via E-mail.

Institute of Control Sciences (Russian Academy of Sciences), Moscow, Russia.

Engineer, Senior Research Scientist, Leading Research Scientist (1966-1971, 1973-1975, 1978-1992).
Developed mathematical and computer models for the epidemiological studies (1972 - 1992).
· Developed software for prevalence estimation for different types of cancer;
· Developed computer programs for public health assessment for the populations residing in the areas contaminated due to Chernobyl accident;
· Developed computer programs for evaluating the effectiveness for health program interventions;
· Developed computer models which are used in the Russian Health Ministry Computing Research Centers for population survival analysis;
· Developed mathematical models for the estimation of sexually transmitted diseases prevalence;
· Developed various computer models for health resources allocation.

International Institute for Applied Systems Analysis / Bio-Medical Project, Vienna, Austria. Research Scholar (1975 - 1978).
· Developed a new approach to prevalence estimation for degenerative type diseases based on the use of mortality data;
· Developed the computer model for estimating health resources requirements.

Moscow City Council Research Computing Center, Moscow, Russia. Head, Laboratory for Systems Analysis (1971 - 1973).
· Provided technical support for the Moscow city planning committee.

TEACHING EXPERIENCE

Courses taught :
· *Business Data Processing,* Tacoma Community College (1996 - Present);
· *Programming-Visual Basic* (Lab assisting), Tacoma Community College (1996 - Present);
· *Computer Modeling in Health Field,* Moscow Institute of Physics and Technology (1984 - 1992);
· *Systems Modeling,* Moscow Power Institute, (1981-1982);
· *Automation and Remote Control,* Moscow Institute for Automation and Computer Technology, (1980 - 1981).
· *Biostatistics* and *Epidemiology*, Chelyabinsk-McGill Project in Population Child Health, Chelyabinsk, Russia, (2000).

CONSULTING

Consulted the regional Health Ministry Computer Centers in the former USSR on applications of mathematical modeling for epidemiological studies (Stavropol, Moscow, Novosibirsk, Tbilishi).

COMPUTER SKILLS

Languages: *FORTRAN, Pascal, C, Extend, Visual Basic;*
Software: Variety of MS DOS and Windows software - *MS Office, GIS (IDRISI), SPSS, STATA, SAS, Crystal Ball*, etc.

PUBLICATIONS

2 monographs and over 50 articles and papers in Russian and English on mathematical modeling in public health related fields

Klementiev A.A.

A.A.Klementiev: List of main publications

1. A.A.Klementiev
Optimal process with random termination. N.Y. Consultants Bureau. Automation and remote control. 6, 1970.
2. A.A.Klementiev, A.I.Yashin
On the problems of estimation and control in health system. In: Control problems in technology, economy and biology. M., Nauka, 1974, (RUSSIAN).
3. A.M.Petrovsky, A.A.Klementiev, A.I.Yashin
On the use of the method of control with incomplete data in certain public health management problems. Proc. VIth Congr. IFAC. Boston, Cambridge. 1975.
4. A.A.Klementiev
Mathematical approach to developing a simulation model of health care system. Laxenburg, Austria, 1976, 28p. IIASA; RM-76-65.
5. A.A.Klementiev
A computer method for projecting a population age-sex structure. Laxenburg, Austria, 1976, 26p. IIASA; RM-76-36.
6. A.M.Petrovsky, A.A.Klementiev, A.I.Yashin
Use of the control theory methods for the solving of the health management problems. In: Biologic aspects of the control theory. M. Institute for Control Sci., 1976, (Russian)
7. A.A.Klementiev
On the estimation of morbidity. Laxenburg, Austria, 1977, 19p. IIASA; RM-77-43.
8. P.Fleissner, A.A.Klementiev
Health care system models: a review. Laxenburg, Austria, 1977, 76p. IIASA; RM-77-49.
9. K.Atsumi, A.Fujimasa, S.Kaihara, A.Klementiev
An approach to building a universal health care model: morbidity model for degenerative diseases. Laxenburg, Austria, 1978, 28p. IIASA; RM-77-06.
10. A.A.Klementiev
Health care modelling: morbidity estimation for degenerative diseases. Proc. of Intern. Symp. "Simulation-77". Zurich, Acta press, 1977.
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Welcome to MIPT Home Page

I have great pleasure in presenting Russia's most famous science and technology educational establishment -- the Moscow Institute of Physics and Technology from which I graduated in 1952 and of which I am now the rector.

The MIPT is the first Russian University of Physics and Technology and was founded in 1951 from the physics and technology department of Moscow State University by the Nobel Prize winners P.L.Kapitza, N.N.Semenov, L.D.Landau et al. Our 1,000 staff members are working diligently with 5,000 students and postgraduates to train the best researchers in solid state physics, chemistry, biology, high energy physics, space research, computer science etc.

The majority of the staff work here part-time, being well-known scientists of the following research centers cooperating with MIPT:

- *P.N.Lebedev* Physical Institute of the Russian Academy of Sciences
- *P.L.Kapitza* Institute for Physical Problems of the Russian Academy of Sciences
- *General Physics Institute of the Russian Academy of Sciences*
- *L.D.Landau* Institute of Theoretical Physics of the Russian Academy of Sciences
- Russian Research Center "*Kurchatov Institute*"
- *N.N.Semenov* Institute of Chemical Physics of the Russian Academy of Sciences
- Institute of Physics and Technology of the Russian Academy of Sciences
- High Energy Institute
- General Aerohydrodynamic Institute

During the first 3 years students receive a fundamental university training in physics and mathematics after which they continue their education for another 3 years specialising in research at the Institutes mentioned above and some others. They carry out their research together with the best scientists, and the best students continue their research work as postgraduates for their Ph.D.

For over 40 years about 17,000 researchers and 7,000 Ph.D's. have graduated from the MIPT and some of them are now very well known, such as:

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- prof. *S.T.Belyaev* (Russian Research Center "Kurchatov Institute", Moscow)
- prof. *O.M.Belotserkovsky* (Institute of Computer Aided Design, Moscow)
- prof. *L.M.Barkov* (Institute of Nuclear Research, Moscow)
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- prof. *L.P.Gor'kov* (L.D.Landau Institute of Theoretical Physics, Moscow)
- prof. *Yu.V.Gulyaev* (Institute of Radiotechnics and Electronics, Moscow)
- prof. *Yu.A.Ryzhov* (Russian Ambassdor, Paris)
- prof. *V.I.Ryzhii* (Institute of Physics and Technology, Moscow)

МОСКОВСКИЙ ОРДЕНА ТРУДОВОГО КРАСНОГО ЗНАМЕНИ
ФИЗИКО-ТЕХНИЧЕСКИЙ ИНСТИТУТ
141700, Долгопрудный, Москов. обл.
Тел. 408-42-54

от_____

№_____

Выписка из учебного плана выпускника МФТИ 1966 года
Клементьева Александра Александровича

наименование курсов	часы
Математический анализ	380
Аналитическая геометрия	132
Дифференциальные уравнения	132
Вычислительная математика	99
Теория функций комплексных переменных	85
Уравнения математической физики	149
Теоретическая механика	132
Общая физика	760
Теоретическая физика	149
Общая химия	102
Иностранный язык	520
Основы инженерного проектирования	34
Основы программирования	66
Введение в экологию	32
Безопасность жизнедеятельности	36
Естественно-научные курсы по выбору	58
Общеинженерная подготовка	34
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Электронные приборы	134
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Импульсные и цифровые приборы	66
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Основы обработки сигналов	66
Основы теории автоматического управления	66
Теория управления в социально-экономических системах	66
Теория стохастических систем	98
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Охрана труда	16
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141700 Dolgoprudniy, Moscow region **Phone 408-42-54**

Excerpt from the curriculum of Klementiev Alexander Alexandrovich, graduated from M.I.Ph.T. in 1966

Course title	Hours Total
Calculus	380
Analytical geometry	132
Differential equations	132
Computational mathematics	99
Functions of a complex variable	85
Equations of mathematical physics	149
Theoretical mechanics	132
General physics	760
Theoretical physics	149
General chemistry	102
Foreign language	520
Basics of draughting	34
Basics of computer programming	66
Introduction to ecology	32
Life safety	36
Natural science course	58
General engineering	34
Electrical circuits	132
Electronic devices	134
Telecommunications theory and devices	326
Pulse and digital devices	66
Lab for telecommunications devices	224
Signal processing	66
Basics of automatic control theory	66
Control theory in social-economic systems	66
Theory of stochastic systems	98
Optimal control in dynamic systems	99
Computers and principles of computer programming	99
Stochastic processes in control systems	54
Simulation in control systems	51
Occupational safety	16
Master's thesis work	3,028

Dean (signature)

The International Institute for Applied Systems Analysis (IIASA)

Membership: IIASA is supported by National Member Organizations (NMO's) in 17 countries: the United States, Russia, Japan, Canada, Austria, Bulgaria, the Czech Republic, Finland, Germany, Hungary, Khazakstan, the Netherlands, Norway, Poland, Slovakia, Sweden, and Ukraine. NMO's are non-governmental scientific organizations. The American NMO is the American Academy of Arts and Sciences. The Russian NMO is the Russian Academy of Sciences.

Location: The Institute is located in Laxenburg, Austria, outside Vienna, in a former Hapsburg summer palace provided by the Austrian government for a token annual rent payment.

Staff: Of a total staff of 220 people, IIASA has approximately 100 full-time senior research scholars. The staff is recruited primarily from NMO countries. There are no quotas. The Director has full authority for all hiring and, if need be, firing. Scientists are on fixed-term contracts from a few months to several years. The in-house research staff is supplemented by an active network of 1,700 alumni and extensive additional collaboration with individuals and organizations throughout the world. The Institute also conducts a summer combined work and study program for a select group of sixty young international scientists. The program's objective is to expose particularly promising young researchres early in their careers to IIASA's international, interdisciplinary setting and research approaches.

Research Agenda: The Institute conducts policy research centered on the theme of global change. Projects address environmental issues (e.g., agricultural impacts of possible climatic changes), technological issues (e.g., the diffusion of increasingly efficient energy technologies), and economic issues (e.g., transitions to market economies in the former Soviet Union and Eastern Europe). The research agenda emphasizes connections between regional policies and global considerations.

History: In 1966 President Johnson proposed to the Soviets an institution to build a bridge between East and West through joint research on common problems. After six years of negotiation IIASA was founded in 1972 with 12 original members. For two decades it maintained a broad research portfolio bringing researchers from East and West together for joint studies of environmental, management, and policy issues. The end of the Cold War in 1989 defined a new era for IIASA. In 1990, members negotiated a new Strategic Plan focused on environmental, technological, and economic issues of global change. In 1994, ministers from NMO-country governments, meeting for the first time since IIASA's founding, reviewed, endorsed, and pledged their support for the Institute's new direction.

Finance and Governance: IIASA's annual budget is about $13 million. 80% of the budget comes from core contributions by NMO's. Contracts and grants from government ministries, private foundations, and industry make up the balance. NMO's contribute according to a three-tier schedule, with Americans and Russians contributing the most. Payments are in Austrian schillings. The CEO of the Institute is the Director, currently Gordon J. MacDonald of the United States. There is a

Example: Usually required skills

International Institute for Applied Systems Analysis (IIASA)

Schlossplatz 1, A-2361 Laxenburg, Austria + Phone: +43-2236-807

POSITION ANNOUNCEMENT

Senior Research Scholar

Environmentally Compatible Energy Strategies Project (ECS)

The Environmentally Compatible Energy Strategies (ECS) Project at the International Institute for Applied Systems Analysis (IIASA) is one of the leading research groups worldwide in the analysis of long-term interactions between energy, development, and the environment. IIASA is an interdisciplinary, non-governmental, independent international research organization, located in Laxenburg, Austria.

Current ECS research focuses on:

1. Contributions to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) on long-term emissions scenarios (ECS project members served as convening and lead authors in the Second Assessment Report of the IPCC and will continue this function during the preparation of the Third Assessment Report).
2. Integrated assessment modeling of energy and environmental interactions with focus on climate change and regional acidification (research activities in this domain are mostly externally sponsored).
3. Methodological and model development for endogenizing technological change.

All research activities involve the development and use of formal modeling techniques of different mathematical (simulation, optimization) as well as disciplinary (macroeconomic, engineering, ecological) orientation. Research activities are supported through extensive networking activities (coordination of international research networks, organization of workshops, participation in international research consortia for contracted research) and documented in an extensive publication record both in peer-reviewed academic journals and reports to external sponsors.

In order to enhance the project's human resources, we are seeking candidates for the position of:

Senior Research Scholar

Tasks

Assumes responsibility for the advancement of the ECS set of mathematical analysis tools. Works independently on all aspects of model development, model application, result interpretaion, and report preparation for externally funded research contracts.

Profile

typical requirements

Ph.D. in mathematics, energy-economics, operations research, environmental sciences or similar discipline. Demonstrated accomplishments in the field of mathematical modeling. Modeling-related programming and computer skills (PC and UNIX environment). Good peer-reviewed publication record. Ability to work independently in an interdisciplinary and international team. At least ten years of experience in the relevant research areas.

Appointment Terms

The successful candidate will be offered a one-year, fixed-term contract, beginning as soon as possible. The salary is competitive and commensurate with experience. It is exempt from taxation in Austria, but subject to the principle of income aggregation. The appointment includes moving and settlement allowances. An exceptionally beautiful working environment with a true international and interdisciplinary institute are added rewards for those seeking association with a highly motivated and productive research team.

Applications

To apply send a cover letter, resume, plus names, addresses, telephone and fax numbers of three work-related references, as well as copies of two recent publications/papers (articles, research papers, model documentation, proposals, minutes of meetings, etc.) to:

Walter Foith, Personnel Administrator
International Institute for Applied Systems Analysis (IIASA)
Schlossplatz 1, A-2361 Laxenburg, Austria
Fax: (+43) 2236-713-13
E-mail: foithw@iiasa.ac.at

Review of applications will begin immediately.

For further information about the post, please contact:

Dr. Nebojsa Nakicenovic
Project Leader
Environmentally Compatible Energy Strategies Project
Tel: (+43) 2236-807-411
E-mail: naki@iiasa.ac.at

For general information about our institute, please visit our IIASA web site or go right to the ECS homepage.

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Last update: 12/27/96

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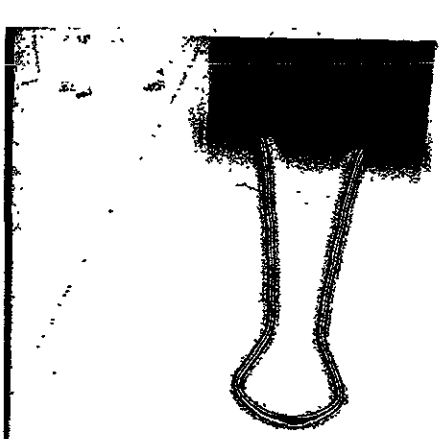
Exhibit 9



PNWD-2226 HEDR
UC-000
DRAFT

A Guide to Environmental Monitoring Data, 1945-1972

Hanford Environmental Dose Reconstruction Project

M. E. Thiede
D. J. Bates
E. I. Mart
R. W. Hanf

March 1994

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

Battelle,
Pacific Northwest Laboratories
Richland, Washington 99352

4.0 Overview of Previously Published Data

Radioactive emissions from the Hanford activities were released to three general pathways: the air pathway, the Columbia River pathway, and the ground-water pathway. Historical data for the air pathway are described in previously published HEDR documents listed in Sections 4.1 and 4.2. Previously reported information concerning the Columbia River pathway is in Section 4.3. Environmental data on the ground-water pathway are addressed in Section 4.4.

4.1 Air Measurements

Historical documents concerning air monitoring data for 1945 through 1957 were searched for, inventoried (Huesties 1992, 1993), and reviewed (Hanf and Thiede 1994). Historical sampling devices are described in Hanf and Thiede (1994), along with a brief statement about the problems associated with using historical air monitoring data collected with each device.

In general, historical measurements of air contamination cannot be used because the historical air sampling devices did not provide accurate measurements. The air sampling devices were difficult to maintain and calibrate, did not exclusively monitor the radionuclide found to be the major contributor of dose, iodine-131 (Napier 1992), and were used in only a few offsite locations. Therefore, the historical air monitoring data were not used by the HEDR Project because the data were not satisfactory in quality or number for dose calculations or validation of models.

4.2 Vegetation Measurements

Historical data (1945-1947) of iodine-131 (as total beta activity in 1-gram pellets) in vegetation are summarized in Denham et al. (1993a). Reconstructed conversion and correction factors for these pellets to correct the 1945-1947 vegetation data to today's best estimates of iodine-131 activity are described in Mart et al. (1993). Uncertainty and sensitivity of the conversion and correction factors for the 1945-1947 vegetation data are discussed in Gilbert et al. (1994). Historical vegetation data (1948-1951) are summarized in Hanf et al. (1993), and the conversion and correction factors for best estimates of activity for the 1948-1951 vegetation data are described in Denham et al. (1993b). A year-by-year overview (1952-1983) of historical documents available concerning vegetation and foods sampled near Hanford is in Duncan (1994). Databases of historical vegetation data have not been compiled beyond 1951 for the HEDR Project. Hanford's Surface Environmental Surveillance Project has compiled environmental media (including vegetation and foods) after 1971.[a]

4.3 River Measurements

(a) Unpublished report (project no. SESP-PDMS-001), *Project and Data Management System (PDMS) Users Guide Surface Environmental Surveillance Project*, by L. E. Bisping, 1990. Unpublished report (project no. SESP-PDMS-002), *Project and Data Management System (PDMS) Database Steward's Handbook*, by L. E. Bisping, 1990.

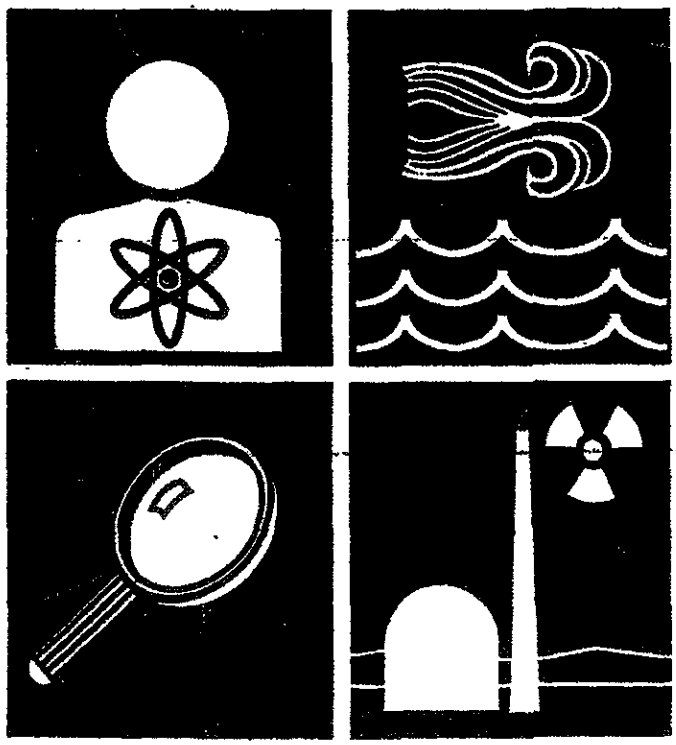
Exhibit 10

PNWD-2234 HEDR
UC-000

Environmental Radiological Monitoring of Air, Rain, and Snow on and near the Hanford Site, 1945 – 1957

R. W. Hanf
M. E. Thiede

March 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

PNWD-2234 HEDR

Introduction

To support the Hanford Environmental Dose Reconstruction (HEDR) Project's objective of estimating the radiation dose that individuals could have received as a result of emissions from the Hanford Site, HEDR Project staff developed a database of historical environmental measurements. The data from these measurements are made available to the applicable HEDR tasks and the public.

Environmental sampling for radiological contaminants has been conducted at and around the Hanford Site since operations began in the mid-1940s. This report provides information on the measurement of ambient environmental radiation levels in the air and on the collection of air, rain, and snow samples for radiological analysis from 1945 through 1957. The information in this document was compiled to assess the type and amount of data collected during these years. No databases of historical air, rain, and snow concentration and/or measurement data have been created. During the 1940s and early 1950s, the equipment and techniques used for collecting radiological samples and monitoring radiation levels were often inaccurate. This was due to the newness of the nuclear industry and the haste with which the industry (including the facilities and monitoring equipment at the Hanford Site) was developed. The result was that the air monitoring data are insufficient for use in the HEDR Project. Because access to these data may be of interest to the public, however, an overview of the available air monitoring data for 1945-1957 is being published.

Data Quality Objectives

The information in this report has been compiled without analysis. The original purpose was to provide an overview of the data available. Because it was determined that the air monitoring data would not be used in the HEDR Project, no data quality objectives were established nor were the data submitted to a rigorous data quality review. The information presented in this report should only be used as a guide to the original documents. The original documents need to be consulted directly prior to use of any of the data presented in this report.

General Information

For the most part, the data are reported here in the units provided in the original documents. No attempt was made to quantitatively convert the data to currently used units. Radiation exposure was reported in units of milliroentgen (mr) and milliroentgen-equivalent-physical (mrep) through the third quarter of 1953. The roentgen (abbreviated r for old or R for new) is a unit for defining exposure in the air to x- or gamma radiation (ionizing