DOE/EP-0001

Investigation of the Radiological Safety Concerns and Medical History of the Late Joseph T. Harding, Former Employee of the Paducah Gaseous Diffusion Plant

MASTER

A Report from the
Acting Assistant Secretary for Environmental
Protection, Safety, and Emergency Preparedness
to the
Secretary, U.S. Department of Energy

March 1981

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Preface

On October 29, 1979, Mr. Joseph T. Harding met with several officials of the Department of Energy (DOE) to bring to their attention working conditions at the Paducah Gaseous Diffusion Plant which he believed had damaged his health and that of other workers. After listening to his concerns, the DOE officials invited Mr. Harding to return in the near future to explain more fully his experiences and his criticisms of the safety practices of the plant.

Mr Harding returned to DOE on November 28 and 29, 1979, and met with representatives of the Offices of Consumer Affairs, General Counsel, and Environment. He described in some detail the safety and health practices used by the Union Carbide Corporation--which, since 1951, has operated the Paducah Gaseous Diffusion Plant (PGDP) under contract to DOE--that had in his view endangered the health of plant employees. Mr. Harding had been employed at the plant between October 15, 1952 and February 26, 1971. He stated that safety procedures and regulations had sometimes been ignored in order to meet production deadlines. The unsafe radiological conditions Mr. Harding cited as occurring at the PGDP included:

- o the continuous presence of uranium hexafluoride in the air at levels that reduced visibility;
- o the presence of direct radiation levels from the product and waste cylinders;
- o poor respirator protection of workers;
- o lack of proper safety procedures, e.g., opportunity for eating in contaminated areas;
- o lack of adequate training
- o lack of safety awareness or safety enforcement by supervisors;
- o lack of exposure information to employees; and
- o lack of radiological protection overview.

Mr. Harding provided copies of his radiation exposure records and documents related to the termination of his employment by Union Carbide. He reviewed a number of physical disabilities which he felt had been caused by his excessive exposure to radiation. These included:

- o Stomach problems resulting in surgical removal of the majority of his stomach, but with no cancer or ulcer found;

- o Recurring lung problems related to a perforated lining;
- o Numerous skin sores that had begun on his legs and spread over his body;
- o A problem with uncontrolled growth of cartilage from his hand and foot joints; and
- o A problem with his central nervous system.

The Department officials suggested to Mr. Harding that DOE would undertake an investigation of his charges. He in turn expressed a willingness to cooperate fully in such an investigation. He subsequently provided the names of other PGDP employees who had worked at the plant during the years of his employment and who he believed could corroborate his descriptions of work conditions. Mr. Harding continued to suffer from his several debilitating illnesses and died on March 1, 1980.

Following some preliminary information gathering, the Office of Environment began a comprehensive investigation in February 1980. Ruth Clusen, then Assistant Secretary for Environment, charged Eward J. Vallario, Assistant Chief, Occupational Safety Branch, Operational and Environmental Safety Division, and Henry R. Wolfe, M.D., Human Health and Assessment Division, with the task of evaluating the adequacy of the radiological safety practices at the PGDP between 1952 and 1971 and the possible relationship between Mr. Harding's medical conditions and radiation he may have been exposed to. Ms. Carol Jolly, Special Assistant to the Assistant Secretary for Environment, served as the management coordinator during the course of the investigation.

In the course of preparing the medical analysis for the report, Mr. Harding's medical records were sought from the physicians who had treated him. When repeated requests to some doctors--whom the investigators had been told had treated Mr. Harding over a substantial period of time--produced no response, efforts were made to obtain the records from Mrs. Harding. In May, 1980, she directed us to her attorney--Mr. Robert Hager of the Christic Institute, Washington, D.C.--as her representative in providing the requested information.

Mr. Hager, in a series of letters over the following four months, informed the Assistant Secretary for Environment that the medical records in his possession could be made available to the Department only if a "qualified independent medical opinion would also be reflected as an integral part of the report." This independent opinion would be based on a review of the medical records in Mr. Hager's possession and of those used by the Department in conducting its medical analysis. In Mr. Hager's view this addition was necessary so that the report would "fully reflect and give equal prominence to expert opinion representing the full spectrum of medical knowledge concerning the nature and etiology of Joe Harding's health problems."

Because of the Department's interest in assuring that its report be as thorough and comprehensive as possible and not be subject to criticism because possibly critical medical information had been omitted, the conditions proposed by Mr. Hager were agreed to. Further arrangements with Mr. Hager delayed the actual exchange of records until October 1, 1980.

When the investigators reviewed the documents Mr. Hager provided, they discovered that none of the records specifically sought were included. Indeed, the records given to the Department contained no information not previously available to the investigators.

Nonetheless, the independent opinion submitted by Mr. Hager on December 11, 1980, and the biography of its author are included herein as Appendix A. Appendix A also contains the comments of the DOE investigators on the points raised in this opinion. Because the investigating team included both a health physicist and a medical doctor and because information from both disciplines is relevant to the observations submitted, two sets of comments are presented.

The following report reflects the findings on radiological safety and medical analysis relative to the concerns expressed by Mr. Harding.

I. EXECUTIVE SUMMARY

A. Introduction

Between October 15, 1952, and February 26, 1971, Mr. Joseph T. Harding was employed as a cascade operator at the Paducah Gaseous Diffusion Plant, a uranium enrichment facility operated under contract for the Department of Energy by the Union Carbide Corporation. Mr. Harding believed that the radiological safety conditions at the Plant were hazardous to the health and safety of its workers and that he had sustained numerous physical disabilities as a result of his exposure to excessive radiation.

After Mr. Harding had brought his concerns to the attention of Department of Energy officials, the Assistant Secretary for Environment assigned two members of her staff to undertake an investigation of these charges. The investigation included a site inspection of the Paducah Gaseous Diffusion Plant (PGDP), discussions with plant officials and a review of pertinent plant records dating from the early 1950's. To better evaluate conditions in plant operations during the 1950's, the investigators also performed a mock-up test to determine uranium and hydrofluoric acid concentrations in the air. Seventeen current or former employees whose names had been suggested by Mr. Harding as individuals who could corroborate his descriptions were interviewed to discuss their perceptions of working conditions and plant safety. To assess the scope and quality of the safety oversight program conducted by the Oak Ridge Operations Office, discussions were held and records were reviewed at that office. Medical records were obtained and evaluated from both the plant physician and private physicians and hospitals with whom Mr. Harding had consulted. This report presents the findings of both the work place radiation safety analysis and the analysis of Mr. Harding's medical history.

B. Work Place Radiological Safety Analysis

Based on the methods used during this investigation, no evidence has been found which would support the allegation that the PGDP conducted a radiologically unsafe operation during the period 1952-1971. In summary:

- The company's records for external and internal radiation exposure received by Mr. Harding reveal levels substantially below the recommended limits of exposure prescribed by national and international authorities. The total external exposure received for the period 1955-1971 for beta and gamma was 5.7 rems. Similarly, for the same period, the reference organ dose for any given year was less than 1 rem.

- A review of both the dosimetry units and urinalysis methodology applicable to the period in question indicates that the methodology was consistent with "state of art" at the time.

- o A mock up test was conducted to determine the potential for a small puff release* of uranium hexafluoride during routine disconnection of the flexible tubing (the pigtail) connecting the product cylinder and the process stream and availability of this "puff" for inhalation and ingestion. The mock up test results were negligible, i.e., substantially below the concentration limits for airborne uranium.

- o The presence of thick dust in the air which Mr. Harding stated occurred routinely in the product and tails withdrawal buildings is not consistent with the mode of operation. The thick dust could only occur when there was a major release. The airborne dust was of short duration due to settling. Interview statements (and plant records) indicate that a limited number of such releases have occurred. Small "puffs" of uranyl fluoride and hydrogen fluoride, the hydrolysis products of UF_6, occurred routinely when the pigtail was disconnected from the cylinder. However, this material was immediately "captured" by high velocity ventilation hoods located directly over the disconnect.

- o Direct radiation levels at the heel of the cylinders ranged from 10-500 millirems per hour (mR/hr), at contact. Considering the handling or transfer time required to move the cylinders, the resultant exposure was substantially below the recommended limits for exposure.

- o The type of respirators available for use were satisfactory. However, the absence of a respirator fit program did cause a weakness in the respirator use program.

- o The air sampling program in the relevant buildings during the period in question was inadequate.

- o The training program as well as general safety awareness was adequate; enforcement of safety procedures was questionable.

- o The Atomic Energy commission did not have a formal inspection program until 1961, at which time the Oak Ridge Operations Office (OR) conducted its first appraisal of PGDP. The AEC did not maintain at that time an adequate, in-depth appraisal program that would reveal potential technical deficiencies in the radiological safety program.

C. Medical Aspects

Mr. Harding's medical history prior to his employment at PGDP shed scant light on his future medical problems. During and after his employment he did suffer from a number of progressive conditions. Mr. Harding was hospitalized for several weeks early in 1980 and was discovered to have a widespread abdominal cancer. He died at home on March 1, 1980. No autopsy was done.

*As used in this report, a "small puff" is a release of uranium hexafluoride of less than 300 milligrams.

An analysis of available records obtained from his physicians and hospitals led to the conclusion that Mr. Harding's illnesses were not likely to have been caused by occupational radiation exposure. This determination is reinforced by the workplace analysis conclusion that insofar as radiation was concerned, the PGDP was not unsafe.

The five physical disabilities which Mr. Harding alleged were from excessive radiation exposure are discussed:

1) Stomach

Despite denial by Mr. Harding, the records clearly document a gastric ulcer which necessitated removal of most of his stomach. Many of his clinical difficulties thereafter were the result of this surgery. Even the malignancy which killed him probably arose in the stump of the remaining stomach. Factors such as exposure to cigarette tobacco smokes, nitrites and hydrocarbons in diet, cadmium and nickel carbonyl in welding or genetic predisposition were more likely than his occupational radiation exposure to have caused Mr. Harding's ulcer, malignancy and other stomach problems.

2) Lungs

Mr. Harding developed small-airway disease characteristic of long-term heavy smokers. His pulmonary function tests did not fit the pattern of most lungs injured by chronic radiation. His smoking and repeated bouts of pneumonia were far more likely to have brought on his chronic pulmonary disease.

3) Skin

Analyses of biopsied skin lesions did not conform to the pathologic picture of radiation dermatitis. Mr. Harding suffered with skin problems from 1953 until his death, but they were highly unlikely to have been caused by exposure to radiation.

4) Cartilage

Evaluation of radiation induced cartilaginous disorders is difficult because not much is known. Although the medical records are skimpy, Mr. Harding's problems did not fit the picture that is known. It is conceivable that the problem was small joint enlargement. Such a clinical picture was more likely to have been related to his chronic pulmonary and/or gastric disease than to radiation exposure.

5) Tremor

This occurred in his last year. Rather than being due to radiation, it would more likely have been related to the anemias secondary to his stomach removal or to the malignancy.

II. SCOPE OF INVESTIGATION

II. SCOPE OF INVESTIGATION

The investigation evaluated practices, procedures and operations at the PGDP during the period 1951-1971; no effort was made nor should be made to extrapolate from the findings and conclusions to current practices and operations. The investigation was restricted to work place conditions relative to Buildings C310, C315, and C335 which comprise a very small part of the total PGDP operations. The anlaysis and conclusions are specific to the referenced buildings and not to the total plant site or operations.

Investigation Chronology and Methodology

A. Work Place Analysis:

- The Paducah Plant was visited on March 6 and 7, 1980. A site inspection was conducted of Buildings C310, C315 and C335--areas where Joe Harding had worked; extensive discussions were held with plant operations personnel and the Health Physics Department in an effort to reconstruct conditions at these locations during the tenure of Mr. Harding's employment. This was followed by reviews of procedures and practices in place at that time.

- Interviews were held with 17 workers (4 retired) named by Joe Harding as potential sources for useful information on safety conditions during the 1950's. These interviews were taped with the approval of the participants.

- The Oak Ridge Operations Office which maintains contractual and safety overview responsibilities over the PGDP was visited to review pertinent safety documentation.

- On April 2 and 3, 1980, a mock up test was conducted in Buildings C310 and C315 to determine uranium and hydrogen fluoride (HF) concentrations in air during the performance of procedures duplicating those used in the 1950's.

- Ventilation flow rates were assessed and compared with original plant drawings. To avoid any uncertainties regarding changes in the product transfer system, 20 milligram (mg) uranium hexafluoride (UF_6) samples were obtained, experimentally verified and used as the source for the test. Lapel, low volume and high volume air samplers were appropriately located for the test runs. Dr. Melvin First of Harvard University provided independent approval of the sampling protocol. All sample counting was performed under the supervision of Mr. Roger Shaw, Battelle Northwest Laboratory, utilizing plant counting equipment. All filter samples were subsequently taken to Battelle Laboratory for further counting and verification.

- On April 10 another count of all samples was obtained utilizing Battelle Laboratory equipment.

- On April 15-16 the interview recordings were analyzed.

- Technical information was obtained as appropriate by consultation and search of literature.

B. Medical

- Materials (tapes and papers) submitted by Mr. Harding were used to compile a list of the physicians and hospitals he had consulted between 1953 and 1979. Medical information was requested and received from some of these physicians and institutions. (Appendices G, H, and I). As described in the Preface, additional records were obtained through Mrs. Harding's attorney. Some personal habit history was obtained from Mrs. Martha Alls, daughter of Mr. Harding.

- Technical information was obtained by consultation and search of the literature.

- There are gaps in the information reviewed because some physicians and one hospital could not or would not respond to the request for information. (See Appendix I for the list of those to whom requests were made.) For example, only one physician (of the 18 asked) was even partially responsive to the question about x-ray equipment used. Eight physicians did not respond at all. However, the relevant records of three of these individuals appeared in hospital records or the occupational medical records from the PGDP. Records of three others were probably not necessary for the medical analysis.* The successor to one of the physicians contacted stated that his predecessor had never seen Mr. Harding.

  For about six months preceding Mr. Harding's death, Dr. W. Jennings seemed to be accumulating medical records and advising Mr. Harding. The DOE investigator believed that if anyone had evidence supporting Mr. Harding's medical charges, it would be Dr. Jennings. However, despite acknowledgement of the receipt of the authorized request and several promises to provide the requested records, Dr. Jennings did not send any information.

  Two additional physicians whose records and knowledge might have been important are deceased. Dr. R. Reeves, a General Practitioner, kept most of his information in his head rather than on records according to his successor, Dr. M. Kleckner, a Gastroenterologist, probably knew the most about Mr. Harding's stomach problems. His records could not be traced.

  The medical investigator never met Mr. Harding. He did not have an appropriate opportunity to discuss Mr. Harding's medical history with the Harding family as his only meeting with them occurred very soon after Mr. Harding's death.

*Dr. D. Boucher, Otolaryngologist, was apparently seen only once. Drs. F. Simon and L. Reese were Dermatologists; Mr. Harding's skin problems were well documented from five other sources.

III. WORK PLACE RADIOLOGICAL SAFETY ANALYSIS

III. WORK PLACE RADIOLOGICAL SAFETY ANALYSIS

A. Plant and Work Place Description:

1) General

The Paducah Gaseous Diffusion Plant is located in McCracken County, Kentucky, approximately four miles south of the Ohio River and 20 miles east of the confluence of the Ohio and Mississippi Rivers. The Plant, which is owned by the U.S. Department of Energy and operated under contract by Union Carbide Corporation, is part of a three-stage uranium enrichment process.

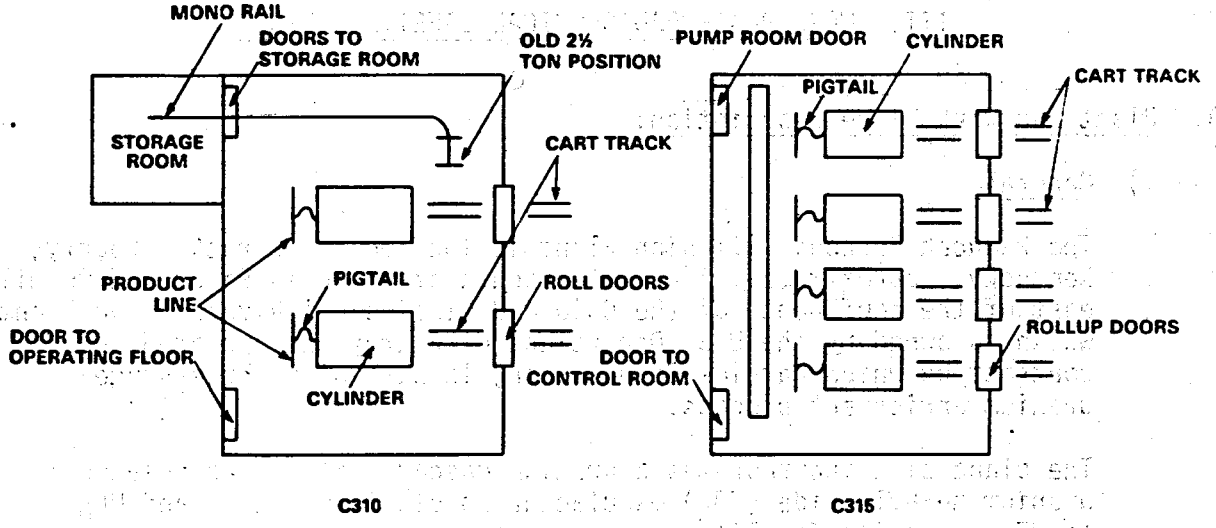
The plant site incorporates a uranium cascade with an associated uranium hexafluoride (UF_6) manufacturing plant, a metals and UF_6 to UF_4 reduction facility, with decontamination and other support facilities. Figure 1 provides the plant layout at Paducah.

The buildings in which Mr. Harding worked are designated as C310, C315 and C335. The buildings of particular interest in the context of this report are C310 and C315, the product withdrawal and tails withdrawal buildings respectively. The C335 building, referred to as the Process Building, houses part of the process gas diffusion equipment. Contamination rarely occurred in this building because the system operated under negative pressure and as a consequence, equipment seal failures would cause "in leakage" to the system rather than release of uranium to the room air. However, some contamination did occasionally occur when equipment was being repaired or replaced. This contamination was attributed to material trapped in the equipment which was subsequently released when the equipment was taken off line. Mr. Harding's job function in this building was control operator; the control room was quite removed from the process equipment area.

2) Building Layout C310 - C315

The C310 Product Withdrawal Building is approximately 53' x 30' in size and contains two roll-up doors, one employee access door, and double doors to the storage room. This building is equipped to handle two 10 to 14 ton cylinders at any given time.

The C315 Tails Withdrawal Building is approximately 53' x 30' in size and contains four cart tracks and product equipment to accommodate four 10 to 14 ton cylinders. Four roll-up doors are located in the east wall to permit the entry and exit of the cylinders (note drawing). The west wall contains doors to the pump room and control room. Thus, there are six penetrations (doors) affecting air current flow in the building.



3) Process - Buildings C310 - C315

The operation in Buildings C310 and C315 are quite similar. The liquefaction is accomplished by the compression of UF_6 flowing to the building from the enrichment operation at a pressure at which the UF_6 gas can be conveniently liquefied. After condensing, the liquid is allowed to flow into the cylinders. The product, UF_6 in C310, and depleted UF_6 in C315, is drained as a liquid into the multi-ton cylinders through a copper tube referred to as a pigtail (note drawing, above). When the cylinder is filled to its capacity, the cylinder and drain valves are closed and the pigtail is evacuated and purged. The pigtail is then disconnected at the cylinder valve. Figure 2 shows a cylinder mounted on the track cart and connected to a pigtail. Figure 3 provides a view of the typical work place.1/

4) Ventilation - Buildings C310 - C315

The C310 Building began operation in early 1953. The ventilation as originally installed provided 900 cubic feet per minute (CFM) exhaust across four registers near the floor of the east wall. The ventilation was modified three months later to accommodate local exhaust hood positions over the pigtails. Two of the old 2-1/2 ton positions have small hoods with flexible ducts which are not in use but still remain as part of the exhaust system. The present ventilation flows are approximately 20% greater than the flow rates experienced after the modifications were originally completed. While the initial ventilation modification (early 50's) resulted in less exhaust than the original design, the changed design and position of the hood close over the cylinder connection point resulted in much more efficient control of

1/ Note: All Figures in the report are derived from photographs taken in March and April 1980.

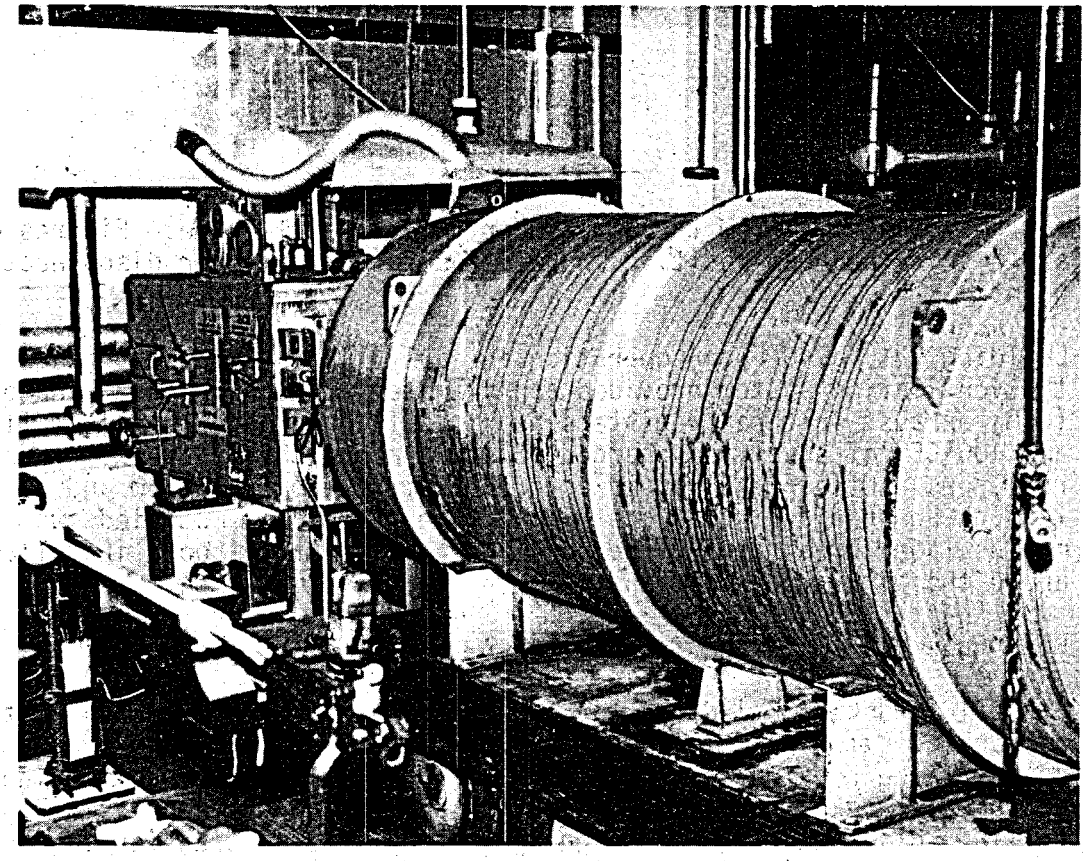


Figure 2 UF_6 Cylinder Mounted On Cart

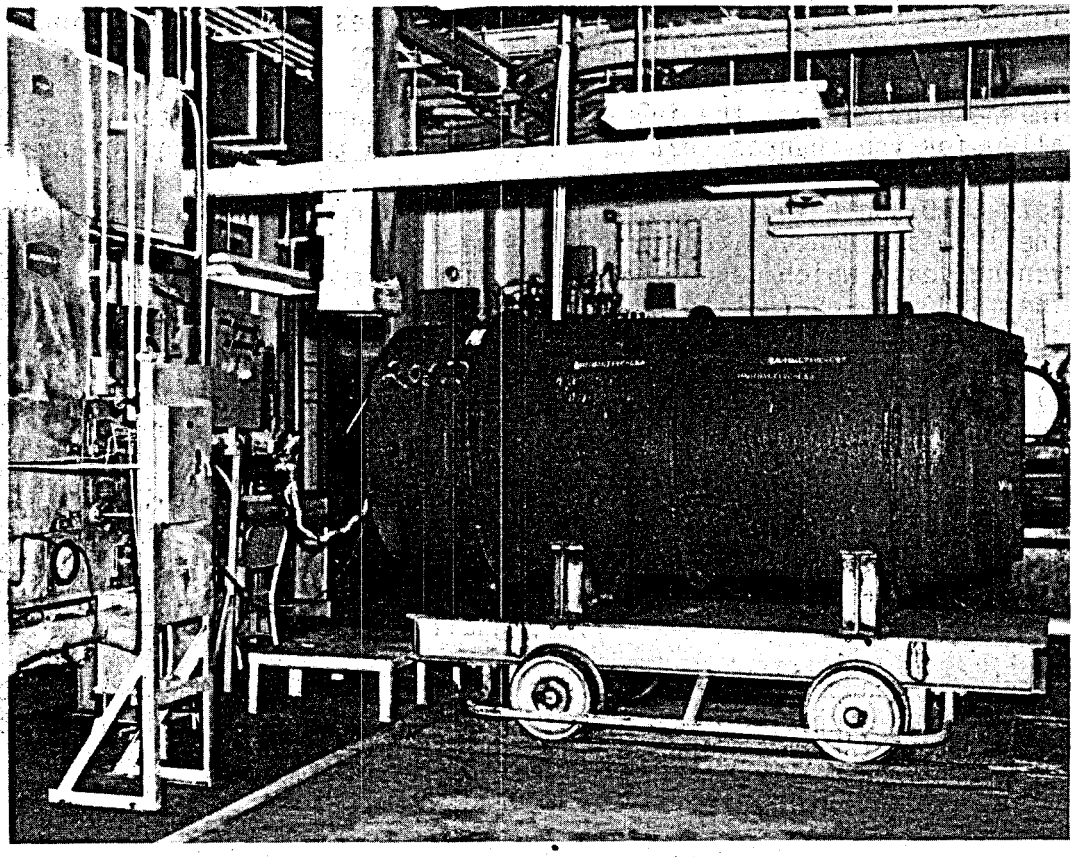


Figure 3 Work Place Cart, Track, Cylinder and Pigtail Connection

the residual puff from the pigtail or valve seat leakage. Figures 4 and 5 show the hood position in relation to the cylinder disconnect point.

Building C315 also began operation in early 1953. At that time, the ventilation system provided approximately 800 cubic feet/minute (CFM) exhaust in three registers near the floor along the west wall and 400 CFM of supply discharged about 9' above the floor from four registers. Other make up air entered from the control room and through an opening in the east wall. The system was modified two months later by extending the local exhaust ducts to hoods installed above the pigtail connections.

5) Work Function

The C310 and C315 Buildings were normally manned by 1-3 persons with a crane operator on call should cylinder transfer involving crane movements be required. The workers were responsible for completing equipment checks, logging equipment data, preparing cylinders for filling, disconnecting and weighing full cylinders, transferring cylinders, and maintaining cylinder records. Mr. Harding performed all of the above functions during his work in these buildings.

6) Building and Equipment Condition

To obtain a better perspective on the analyses of work conditions during Mr. Harding's employment and to assure that the analyses were not prejudiced by improvements since the time Mr. Harding worked in these buildings, the investigators were careful to determine and allow for the changes that have been made to the buildings in question.

Both C310 and C315 are basically the same structurally as they were in the 1950's. However, equipment changes have been made over the intervening years which make it difficult to determine safety conditions in the 1950's by evaluating the practices used today. The most significant changes include:

a) Changes to the purging system to enhance efficiency; this minimizes the "puff" during the disconnect procedure.

b) The installation of an "interlock" system to prevent the withdrawal of the cylinder before the pigtail has been disconnected. In the early fifties before the interlock system was installed, at least three major releases resulted from cylinders being withdrawn while still connected to the pigtail.

In part, because of the difficulties these changes cause in evaluating Mr. Harding's charges, a test was conducted in an effort to reconstruct earlier working conditions. This test is fully described on pages 30 - 35.

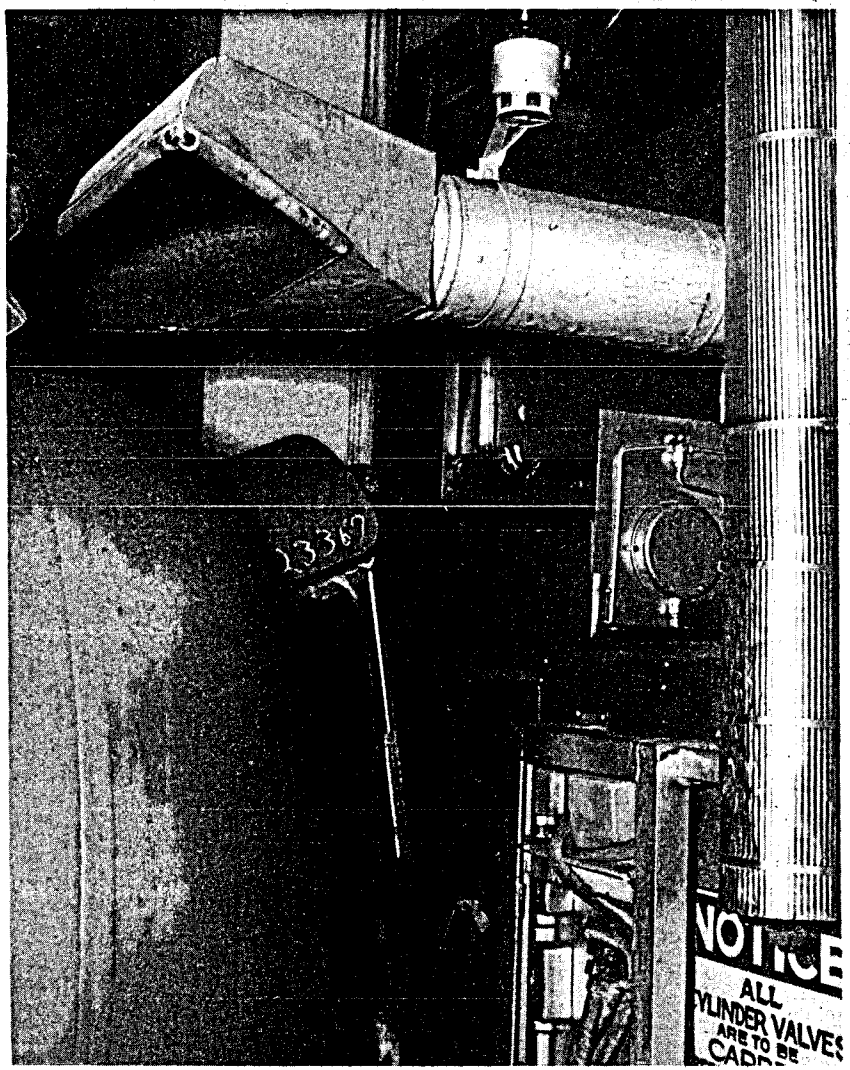


Figure 4 Hood Relative To Pigtail Connection

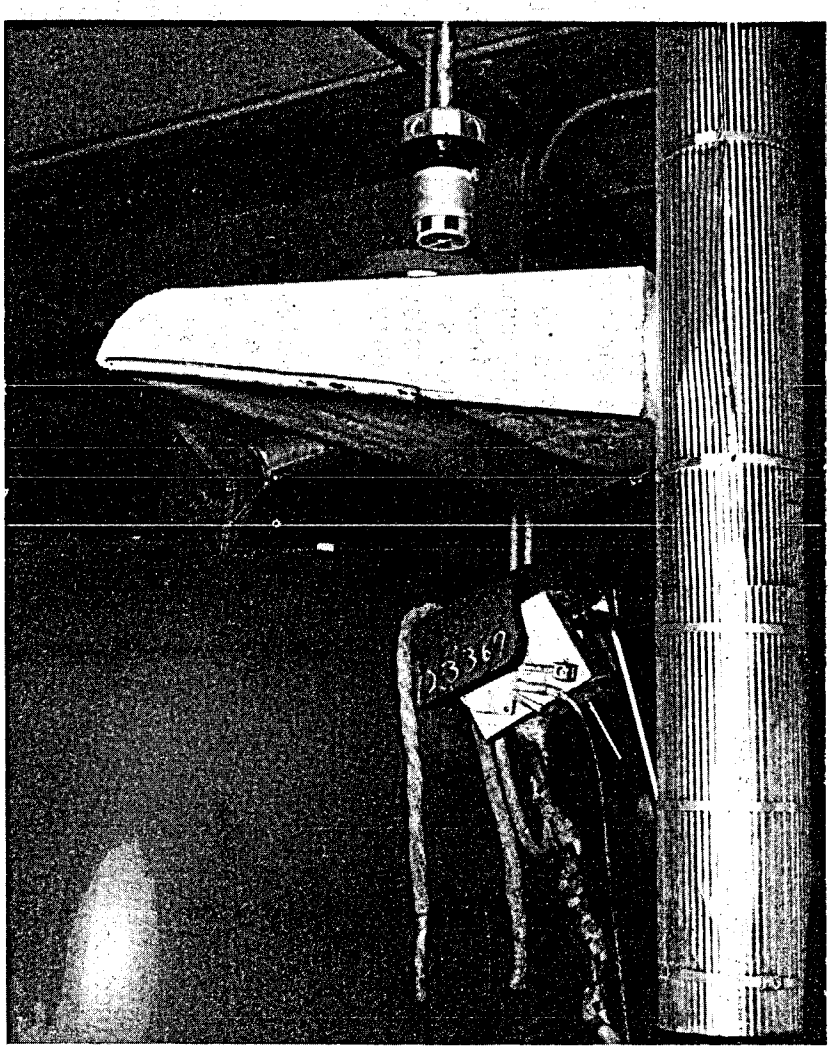


Figure 5 Hood Relative To Pigtail Connection

B. Worker Interviews:

Mr. Harding volunteered the names of 26 workers who had been employed at the PGDP during the period 1951-1970. He suggested that these individuals be interviewed to determine their views on plant working conditions.

Efforts were made to reach all of these individuals during the investigation team's visit to Paducah; however, some of those suggested could not be located in Paducah or its vicinity and others declined to be interviewed. Seventeen of the suggested individuals were contacted and agreed to be interviewed. Of the seventeen, thirteen current employees were interviewed in the PGDP administration conference room; four individuals have retired and were interviewed at their homes.

While it is possible that some current or former employees may have felt constrained from being totally frank by the nature of the interview and its subject, efforts were made to encourage candor by interviewees. Attendance was limited to the person interviewed, the three members of the DOE Headquarters investigation team and two members of the Oak Ridge Operations Office staff. Confidentiality was promised to the interviewees; permission was obtained to tape the interviews with the understanding that the names of individuals would not be revealed under any circumstances. While they were informed of the basis for the interview - i.e., Mr. Joseph Harding's allegations and the Department's investigation - they were not asked to comment directly on Mr. Harding's specific concerns. Rather, each person interviewed was asked for his own views on the radiological safety conditions during the period 1951-1971. It was emphasized that the interview was focused on safety conditions during this period in the past and not on current plant practices.

To minimize subjectiveness in the subsequent analysis of the taped interviews, four DOE staff members jointly summarized the views of each worker. All those involved were conscious of the necessity to avoid discussing or retaining written records of the interviews which might compromise the anonymity of the interviewees.

The staff participating in the summary analysis were:

Carol Jolly - Special Assistant to the ASEV
Eric West - Consumer Impact Specialist, Office of Consumer Affairs
Ferman Stubblefield - Manager, Hazardous Materials Programs, Operational and Environmental Safety Division
Edward Vallario - Assistant Chief/Manager, Health Physics Programs, Operational and Environmental Safety Division

To further assure the privacy of those interviewed, the workers are coded and the summaries do not follow the order of the actual interviews.

1) Summary of Interviews

Worker A

Started work in the Cascade Area (Buildings C310 and C315) in 1952.

While he generally felt that safety was adequate, he expressed reservations about his ability to form a sound judgement on this matter. Small releases resulting from the disconnect of the pigtail from the cylinder occurred every 2-3 days at C315. There were three large releases during the total time he was there. Employees were instructed on how to respond in the event of a leak. Safety equipment was available for their use. Protection coveralls and safety shoes were used in place of personal clothing. His general impression was that the safety program was adequate.

Worker B

Started work in Cascade operations in late 1953 primarily in Buildings 337, 333, with occasional job tasks in Buildings C310 and C315. There were step-by-step operational procedures for the extraction of UF_6 from cylinders. Large releases were estimated to occur about 3 times per year; this was attributed in large measure to equipment failure. Small leaks only occurred when operators did not adhere to proper disconnect procedures, i.e., purge of the system: In the event a leak did occur, they wore coveralls, rubber gloves, respirators, and shoe covers - all were subsequently decontaminated. Regarding urinalysis, he knew nothing about the procedure except that workers were monitored. Respirator use was required in changing cylinders. However, use of safety equipment was not enforced, primarily due to insufficent health physics staff for this purpose.

There was training in safety. Responsibility for measuring radiation was delegated to the worker. However, he felt he was not capable in this area and this may have been a weak spot in the plant's safety system. General impression: "Things are a lot better today than in the 50's."

Worker C

Started work in 1951 and worked closely with Harding during the latter's entire service. He agreed that conditions described by Harding were possible--for example, "blue haze" and dust on the floor could have occurred--however, this was not a continuing or ongoing condition but rather the exception. Safety procedures and equipment were always available--workers were told what to watch for. He noted that there were no ongoing job hazard analyses conducted. There was no enforcement of safety procedures or equipment usage--this was left to the judgement of the worker.

Initially, he and Harding had six months' training - mostly operational. However, there was little said about the hazards or dangers of the work. He noted that there were acid fumes in C340 which he found irritating.

Worker D

Started in 1952 as a maintenance mechanic and continued in this capacity for over ten years. Helped start up C310 and C315. Responsibilities

involved changing of seals in compressors as well as the cut-out of convertors from lines in the Cascade Buildings and C310 and C315. They were aware of hazards and were instructed to use respirators. Observed on occasion that some did not adhere to the respirator procedure. Supervisors did enforce safety procedures and there were safety refresher courses. Health Physics staff did not monitor regularly but were available upon request. Urinalysis data and personnel monitoring were available to the worker upon request. He recalls some instances where workers were given sample bottles to obtain additional urine samples.

Worker E

Started in late 1952 and is still employed at PGDP. Hired as Cascade operator and worked for a short time in C310 and C315. Did receive radiation safety training. Workers were made aware of dangers. Small leaks did occur in C310 and C315 when the pigtail was disconnected. Respirators were required and he had his own assigned respirator; maintenance of the respirator was left to the worker. All kinds of safety equipment were available to the workers. The general safety program was "pretty adequate." He worked with Joe Harding for a short time.

Worker F

Started work in early 1952 as a Cascade operator. He worked in Building C310 and C315 and indicated that safety procedures and working conditions in these buildings have changed very little over the years. He recalled hardly any incidents of leaks, small or large. There were a few unpreventable accidents. His impression was that Union Carbide Corporation (UCC) took adequate steps to clean up and decontaminate after the accidents. Safety procedures and dangers associated with tasks were known and stressed. Safety equipment and clothing was provided. Nevertheless, the use of respirators and other equipment was voluntary. Such things as showers after work were stressed but not required. Urinalysis was regular. In response to a question concerning his exposure he indicated that he did not know what his exposure was. He noted that the UCC took every precaution to make the place safe.

Worker G

This worker started at Paducah in late 1952 as a maintenance mechanic. He worked in C310 and C315 and recalls receiving radiation safety instruction. The standard procedure in the event of an inadvertent release was to leave the area. He had mixed feelings about safety, but did note that they operated by Special Work Permit. He felt that UCC tried to do an adequate job under the conditions. He made the comment that Building 310 was the worst building they had for safety. He did not feel he could comment on the frequency of accidents.

Worker H

Worked at PGDP in the early 1950's. He observed minor releases due to equipment failure. Work seemed safer in early days than at present because it was a new program and greater caution was exercised. Respirators were worn routinely and not left up to the workers' judgement but directed by the supervisor. Workers "had to follow prescribed procedures even if they did not want to."

Worker I

This worker began employement at PGDP in late 1952. He worked as a Cascade operator for over 20 years. Initial training did include radiation protection which stressed use of equipment. Procedures were in place and included Special Work Permits which specified radiation protection requirements for the task. Most supervisors enforced safety procedures but there were some deviations on the part of the workers. In his opinion, safety practices were not as good in the early days as today largely because equipment and personnel were less available. Workers were trained in the selection and use of respirator equipment. Most employees showered before leaving the plant site as recommended by UCC. Workers were not asked to do a job that was considered unsafe. The frequency of leaks was low but they did sometimes occur when changing cylinders. He recalls 6 fairly sizable releases in total. He recalls one incident where he observed HF droplets on his helmet coming from the exhaust stack and another case where he sustained an acid burn from HF.

Worker J

This employee started working at UCC in late 1952. He had over 25 years of continuous service. He received operations and radiation safety training. Procedures were available and used. Supervisors required operators to use safety equipment which included the wearing of respirators. He felt that safety has improved since the 1950's and 1960's. For example, the present "air pack" mask is better than the old army assault mask which had a tendency to fog and limit vision. Safety was adequately stressed throughout his work experience. He did not recall any requests to perform assignments that were unsafe. There were a few small releases that occurred when cylinders were changed. A couple of major releases were experienced and dust would settle on the floor. This was immediately cleaned up. The work environment did not routinely contain dust. Air samplers (filters) were changed every shift, placed in a filter box and picked up by the laboratory for analysis. The worker was unaware of the results of the analyses.

Worker K

Started work in early 1952. Performed the function of Cascade operator for over 15 years and then moved into a supervisory position. Small releases were seen "on occasion." "However, not every day or every

week." Radiation safety training was adequate; workers were instructed in safety through a continuous safety instruction program. Safety was one of the first words he heard and it has always been stressed by UCC. Workers were aware of hazards through the great emphasis on safety. Supervisors were responsible for assuring that workers were informed on safety. The main difference between the program in the 1950's and today is increased documentation requirements now leading to greater attention to areas of safety. Overall, noncompliance with safety procedures was rare. Respirator equipment was available and used. Workers were encouraged to shower and change shoes before leaving the plant site.

Worker L

Worked for a short time in the early 50's but grew increasingly concerned about the potential cancer causing nature of the material they were working with. Experienced 2-3 releases of sufficient magnitude to make visibility in the room difficult. Workers cleaned the area after stopping the leak. He had 6-8 weeks of training. Supervisors were safety conscious and concerned about safety. There was some training in the use of respirators but he was advised that the respirators were only slightly effective. Respirator use was not enforced. The company provided clothes at all times and he always showered after work. He noted small releases or puffs each time the cylinder was changed. There was no monitoring while the cylinder was being changed. No one put pressure on them to do the job rapidly.

Worker M

Started in early 1951 as a supervisor in Building C310. He received some radiation safety training in the course of operations training. They were not extensively trained in use of instruments but did not have much occasion to use the instruments--generally monitoring was done by the health physics staff. Reports based on sampling were provided to area supervisors and next level supervision. The workers were informed of the safety hazards. Supervisors insured that procedures were complied with. During startup of the plant there were more frequent UF_6 releases. During the period 1950-1960 the frequency of minor releases averaged one/week. During routine operations, workers generally complied with safety procedures. Some, on occasion, did not comply. Overall, safety was good during the period 1950-1960. However, today's program by comparison, demonstrates improved safety equipment, better maintenance, and fewer small releases.

Worker N

Started work in early 50's. Observed 2-3 releases per day and massive releases in Building 410. Most commonly released was the hazardous material hydrofluoric acid which he experienced and which resulted in throat irritation. Operators did their own monitoring. In one case he was concerned about his exposure after

working on a specific activity for 4 hours; he was subsequently advised that he should not have been exposed for more than 10 minutes. He was never advised of his exposure level. Felt hazard was "down played"--workers were not advised of dangers. There were many HF releases and respirator equipment was ineffective in protecting the worker against HF. Buildings and site trucks were etched by HF. He noted that UF_6 releases were large enough to require shovels to dispose of the material. Large releases were vented outside the facility. At first the company did not provide clothing until the union negotiated the matter. Emphasis was placed on getting the job done rather than on safety. Also concerned about asbestos hazard although he was advised there was no hazard. Believes that the company falsified safety records.

Worker O

Started in the fire department in 1952 with principal assignment to respond to emergencies. He did not observe any evidence of hazards and felt that generally it was a safe place to work.

Worker P

This worker started with UCC in mid 1951 in the power department. He received both operations and radiation safety training and felt that training was adequate. Safety procedures and use of safety equipment was required and enforced by first line supervision. In the 1960's he worked in Buildings C310, C315 and C333. Small releases occurred about once per month in the form of a puff of smoke from the disconnected pigtail. He worked on the emergency response squad and was aware of safety procedures. All members of the squad had respirators. Most of the emergency response actions related to small open fires and rarely involved radiological contamination. He was generally impressed with the safety programs of the 50's; in some respects, individual initiative was better then. However, safety conscientiousness and enforcement varied from shift to shift. When compared to today, safety emphasis was not as strong.

Worker Q

Started in 1952. As a power plant operator, he worked in most plant buildings including C310 and C315. He was impressed with plant safety practices and felt the employees received good safety training. Although he was not directly involved, he did see several releases.

2) Summary of Findings

The following summary findings are based on a cross-cut analysis of the comments and statements of the workers interviewed.

- Eleven out of seventeen felt that general radiological safety was satisfactory. Two were marginal about safety conditions and three felt that general safety conditions were inadequate.

- o Twelve commented that small observable puffs did occur when the pigtail was disconnected. (See page 2 for a definition of a "small puff.") Of these twelve, six also noted that large releases occurred with frequency ranging from 3-6 releases in total. One additional worker commented about occasional large releases.

- o Thirteen workers noted that radiological safety training was stressed by UCC.

- o Radiological safety procedures did exist according to twelve workers; six workers felt that the use of such procedures was voluntary.

- o Generally, the use of respirators was stressed but their routine use was voluntary and left to the discretion of the worker.

- o Nine workers noted that there was a good degree of safety awareness at PGDP.

- o Three commented on the unavailability of the health physics staff.

In general, approximately three-fourths of the workers interviewed felt that safety conditions between 1950-1971 were satisfactory. Based on the statements of the workers, all of the elements of a radiological safety program were in place, i.e., availability of equipment, procedures, and training. However, the enforcement protocol with respect to safety procedures was deficient.

C. Analysis of Procedures and Practices:

1) Operational Characteristics

An analysis of relevant operations and potential "release rates," reveals that two types of situations released UF_6 to the air:

i) A puff of UF_6 was experienced during the normal disconnect process, i.e., disconnecting the pigtail from the cylinder following the purge procedure. The puff occurred in those cases where the pigtail had been inadequately purged, and

ii) A large release occurred when the pigtail line broke loose from the cylinder, for example when the cylinder was moved before the pigtail was disconnected. Such releases occurred on at least three occasions during the 1950's and 1960's.

Characteristically, when UF_6 is exposed to the atmosphere, it reacts with water vapor to form uranyl fluoride fume and hydrogen fluoride. The reaction is expressed as:

$$UF_6 \text{ (gas)} + 2H_2O \text{ (gas)} \rightarrow UO_2F_2 \text{ (solid fume)} + 4HF \text{ (gas)}$$

If a leak were to result in a UF_6 gas concentration of 1 part per million (ppm), there would be 4 ppm of HF produced from the reaction. One ppm UF_6 is equivalent to 10 milligrams per cubic meter or 50 times the concentration guide for uranium while the 4 ppm HF is only slightly higher than the Threshold Limit Value (TLV) for HF (i.e., 3 ppm).

Thus, worker protection from uranium was felt to be the overriding consideration; to assure comfort as well as protection for the small puff case, half-face dust respirators were specified and required. It appears, however, that use of such respirators was generally left to the discretion of the workers. In the case of large releases, full face respirators equipped with canisters were readily available and required.

2) Policy, Procedures and Standards for Operation

In general, the Paducah Gaseous Diffusion Plant radiological safety program during the 1950's was based on the need to comply with limits for radiation exposure recommended by the National Council on Radiation Protection and Measurements (NCRP). These limits were:

a. Penetrating Radiation

Gamma and X-ray	Total body	300 millirem (mr)/week
	Hands and feet	1,500 mr/week
	Eyes	300 mr/week
Beta	Total body	600 millirem (mr)/week
	Hands and feet	1,500 mr/week
	Eyes	300 mr/week
Neutrons		300 mr/week

PGDP Procedures #41 dated September 2, 1954, required that following an accidental exposure greater than the above limits, action was required to assure that a minimum exposure was maintained until the individual's average weekly exposure was well below the average permissible exposure.

b. Airborne Concentration

The maximum allowable air concentration for uranium was 0.07 mg/m^3, or for normal uranium 100 disintegrations/minute/cubic meter ($d/m/m^3$). Procedures required that operations make every reasonable effort to maintain airborne concentrations to 1/10 the maximum allowable concentration. These limits were not plant derived but were obtained from the National Council on Radiation Protection and Measurements (NCRP) recommendations as reflected in the National Bureau of Standards (NBS) Handbook #52, March 20, 1953.

c. Surface Contamination

PGDP established limits for contamination control specific to hands, body, skin, personal clothing, personal shoes, contamination clothing, respirators, and surfaces. The limits are specified in terms of counts/minute. (Note Appendix B, Procedure #41.) The contamination control limits specification are complete in scope but have two deficiencies:

1. Limits were specified in counts/minute (c/m) which is a direct instrument reading. A more meaningful quantity specification would have been disintegrations per minute (d/m) which is a source corrected value more closely quantifying the contamination level.

2. The limits should have been expressed in activity/unit area, e.g., d/m/100 cm^2.

d. Urinalysis

The exposure status of any worker was evaluated when it was determined that the worker exceeded the investigational levels of 90 micrograms (0.06 mg/l) per day excretion rate as determined by a single sample analysis, or 50 micrograms (0.034 mg/l) per day as determined from the average of all urinalysis results within a calendar quarter. A series of recall samples indicating an excretion rate less than 20 micrograms per day from exposure to relatively soluble uranium compounds was considered as indicative of an insignificant body burden. This was determined to be less than 10% of the maximum permissible dose (MPD) rate to the bone and kidney. A similar series of recall samples indicating an excretion rate less than 12 micrograms per day from exposure primarily to relatively insoluble compounds of uranium was considered as indicative of an insignificant lung burden. This was determined to be less than 20% of the MPD rate. The analytical procedure for the determination of uranium in urine is contained in PGDP-IH-7 dated September 9, 1957. (Note Appendix C.) The procedure is consistent with state-of-art methods. The action levels were derived based on permissible dose to the critical organ for uranium (bone) as recommended by the NCRP in NBS Report #52 dated 1953 superseded by NBS Report #69 dated 1959.

e. Radiation Safety Program

Policy - Procedure PGDP #31 dated April 7, 1952, was also reviewed. This procedure clearly delineated the radiation safety program responsibilities of the worker, supervisor, Health Physics Department, etc. The responsibilities of the

Health Physics Department were defined as follows:

1. To survey working conditions from the standpoint of industrial hygiene and radiation hazards and to keep management informed of such conditions.

2. To make recommendations to supervisors for the correction or prevention of hazardous conditions related to industrial hygiene and health physics.

3. To assist supervisors in establishing departmental health physics programs and to evaluate such programs periodically.

4. To assist supervisors in training personnel to protect themselves from hazards due to radiation.

5. To maintain records of personnel exposure to radiation and radioactive or toxic materials.

6. To assist line supervisors in interpreting and applying established criticality standards and to act as liaison in actions involving criticality safety considerations.

Records indicate that Union Carbide did have procedures in place for a radiation safety program and that responsibilities under this program were well defined. However, it is questionable whether the Health Physics Department was able to maintain an effective overview of each building because of its limited staffing; the entire Health Physics staff was comprised of 4 to 5 health physicists responsible for covering the total plant site. Due to these staffing constraints, it is questionable whether they were able to give appropriate technical attention to special problem areas.

f. Air Sampling Program

Intra-company correspondence dated November 11, 1952, (E. G. Brown to H. S. Gardner, M.D. - note Appendix D) set forth the schedule for air sampling. The frequency rate for sampling in Buildings C310 and C315 was estimated to be eight samples per month. The sampling system in C310 and C315 used at that time as well as today is depicted in Figure 6.

Only one sampling unit was located in a room of 50' x 30'. The sample size is 5 cm in diameter and the unit maintains a flow rate of 0.5 CFM. Generally, air sampling coverage during the 50's and 60's was inadequate. This finding confirms a similar finding set forth in a study committee report dated April 16, 1957, by Dr. Tom Ely et al to S. Sapirie, Manager, Oak Ridge Office, wherein the committee concluded that Paducah was placing undue emphasis on

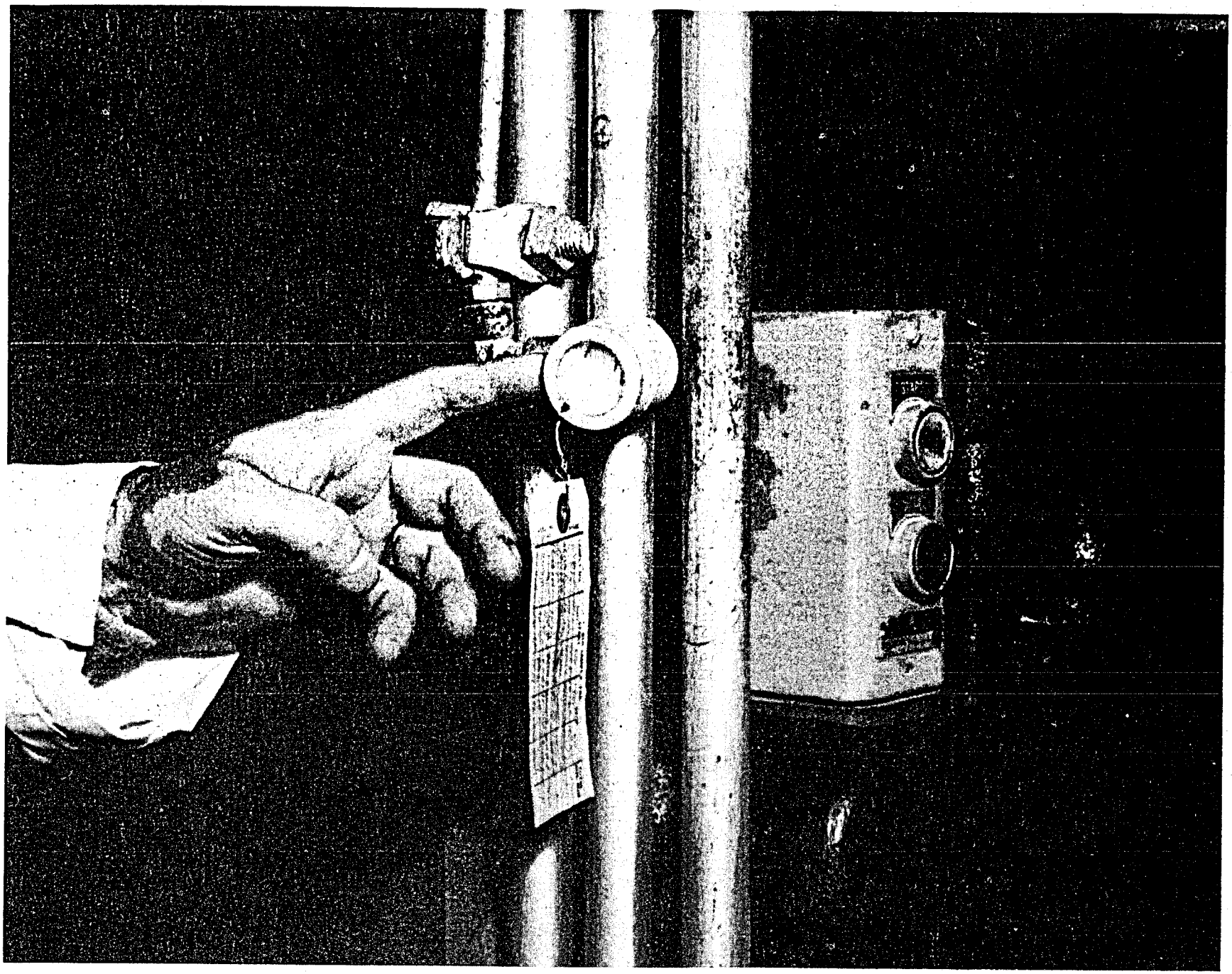


Figure 6 — Constant Room Air Sampler

bioassay to an extent that minimized the importance and value of air sampling. Since routine urinalysis at Buildings C310 and C315 was on a monthly basis, there should have been a more extensive daily air sampling and analysis program in order to provide a daily assurance that air concentrations were within acceptable limits.

g. Exposure Control

External exposures were estimated by film badge monitoring. Prior to 1961, only those employees whose exposure potential was greater than 25% of the radiation protection standard were monitored. Mr. Harding and the other operators in C310 and C315 were monitored during the last half of 1955 and early part of 1956 on a trial basis to determine if monitoring of the withdrawal area operators was also justified. The exposure results were below 25% of the exposure guide. However, this study should have been done at the start of operations since the determination of need for operator monitoring was dependent on its results.

As noted previously, the radiation standards for external exposure were:

1. Skin dose - 10 rem per quarter and no more than 30 rem per year;

2. Whole body - 3 rem per quarter with total employment dose not to exceed 5 rem times number of years beyond age 18.

Radiation exposure records were maintained by UCC as a matter of routine for each plant employee. Copies of all of Mr. Harding's exposure records provided to him by the company were given to the DOE investigators when Mr. Harding visited the Department in November 1979 and appear here as Appendix E. The investigators have no reason to question the authenticity of these records.

According to these records, Mr. Harding's exposure at no time exceeded any of the guide figures. The exposure was low; and total gamma exposure for thirteen years of film badge monitoring did not exceed that permitted for one year (4.94 total rems compared to the allowable 5 rems/year). The total skin exposure for the thirteen years was much lower than the quarterly guide figure (5.70 total rems compared to 10 rems allowed per quarter year). It should also be noted that there is no first quarter 1968 entry due to Mr. Harding's absence from the plant following surgery.

Results of his internal exposure monitoring show rather insignificant levels. The record shows he was involved in two uranium releases. The follow-up urine samples taken at those times indicate there was no significant body retention of uranium. Appendix E includes a summary and detailed record of his urinalysis results.

h. Atomic Energy Commission (AEC) Safety Overview of PGDP

Health and safety requirements were incorporated into the original contract for the operation of the plant. The AEC radiological safety inspection or appraisal program which was intended to assure compliance with policy codes and standards as set forth in the contract requirements was not formally initiated until 1961. While the Oak Ridge Operations Office (ORO) did have two health physicists on the staff in 1952, they were principally concerned with budget and programs (particularly for Oak Ridge National Laboratory). The radiological safety program for contractor facilities was primarily "problem oriented."

On December 15, 1961, the Oak Ridge Office did look into the details of the air sampling program at Building C310 and C315 and recommended the installation of instrumentation to detect UF_6 leakage in the event of a rupture. However, the details of the total health physics practices at these buildings in particular were reviewed only in part.

The AEC Division of Operational and Environmental Safety during the conduct of its appraisals of ORO did not discover this deficiency in the ORO program. Thus, the deficiency prevailed both at the field and Headquarters level.

D. Findings and Conclusions

Allegation #1 is stated as a direct quote from Mr. Harding's statement as reported in The Progressive* and as stated at his November 1979 meeting with Department of Energy representatives. A detailed discussion is presented for this particular allegation since Mr. Harding's other concerns are dependent on the contention that radioactivity was present on a routine basis in large amounts. Allegations #2-#8 represent additional concerns expressed by Mr. Harding at the DOE meeting.

Allegation #1

"There's really no way you can run a plant like that without having releases all the time. At the end of a day you could look back behind you and see your tracks in the uranium dust that had settled that day. You could look up at the lights and see a blue haze between you and the light. And we ate our lunch in all this, everyday, eight hours a day."

Discussion:

Normally, as noted in Section III C (1), the design and corresponding operational characteristics of Buildings C310 and C315 did not result in many large releases of radioactivity that would have caused high exposure of the workers. As a first look into this question, the

*Progressive, January 1980

principal investigator reviewed appropriate records and determined that reasonably good bioassay and survey procedures were in place to assess exposure. Urinalysis was performed immediately after an accidental release and worker exposure information was inferred from the urinalysis data.

However, past survey records were not sufficient to evaluate exposures from the routine small "puffs" which occurred during the disconnection of the pigtail from the UF_6 cylinder. Moreover, there was reasonable doubt that low level exposure that potentially might have resulted from the routine disconnecting operation performed during the month would be detected from a monthly urinalysis program. This doubt arises from the high solubility of the UO_2F_2 and short biological residence time.

Therefore, the investigator conducted a mock-up test in Buildings C310 and C315 to duplicate operating conditions in the early 50's. To assure an independent assessment of the sampling procedures, Dr. Melvin First of Harvard University was retained to assess, modify as appropriate, and approve the test protocol. The services of Mr. Roger Shaw and Mr. John Glissmeyer, sampling specialists from Battelle Northwest Laboratory, were obtained to perform the actual sampling and sample counting. Specialized air sampling equipment was transported from Battelle Laboratory to conduct the tests.

a. Objectives and Methodology

Basically, the objective of the tests was to determine the effectiveness of the ventilation and the potential availability of uranium and hydrofluoric acid concentrations in the air for worker exposure.

The primary objective of the sampling was to obtain strong indicative evidence of the airborne uranium with a minimal effort to obtain data on hydrogen fluoride which may be generated when uranium hexafluoride comes in contact with the moisture in the air.

a(1). Work Areas Sampled

The work areas in which sampling was to be conducted were the two large rooms in which transfers of UF_6 are routinely conducted (see discussion on pages). In these rooms, workers connect and disconnect transfer lines between the process stream and the shipping containers for both the depleted and enriched product from the diffusion process. The room in which the product is handled is designated as the Product Withdrawal Room, Building C310, and the room where the tails (depleted UF_6) are transferred is designated as the Tails Withdrawal Room, Building C315.

In both rooms a localized ventilation hood arrangement is provided at the most crucial location--that of the disconnect region where a small amount of UF is released during each disconnection. The

rooms are large and subject to transient air currents as doors are opened and closed. Completely adequate sampling would have required a long-term sampling protocol which would have allowed all the variables to occur over an extended period of climatic and operational conditions.

Mr. Vallario, Dr. First and Mr. Glissmeyer agreed that three types of samplers would be used--a lapel sampler, a high-volume sampler, and a breathing zone sampler. It was decided that a lapel sampler would be worn by the individual making normal disconnects in each of the buildings, C310 and C315, during the entire shift. The readings from the units would indicate the maximum exposure the operator would experience if he performed his disconnect function without a respirator.

The high-volume samplers would also be on for an entire shift. Since they would be located at various positions within the withdrawal area, they would represent average general room air concentrations over an eight-hour period. The test runs were conducted under varying room air flow conditions. This variability was achieved by conducting the test with access doors in open and closed positions.

The placement of samplers, the duration of the sampling run, and the incorporation into the test of some of the variable features, such as opening doors during some parts of the runs, was intended to produce some of the variables that would have resulted from a long-term sampling protocol.

a(2). Sampling Strategy

a(2)A. Routine Operations Sampling

Three different kinds of air samples were taken during the routine operations performed by assigned shift workers.

- Personal air samplers. A lapel sampler was worn by the operator who performed the product and tails transfer operations. The lapel sampler was worn throughout the entire working shift over a period of five to eight hours. The operator was instructed to remove or turn off the lapel sampler when it became necessary for him to enter areas of potential airborne contamination that had not existed in the 1950s. An accurate log of the running time of the lapel samplers was maintained.

- Room air samples. High volume room air samplers were placed at strategic locations chosen to be as representative as possible of areas which may be occupied routinely. Three or four samplers were operated for 6-7 hours during the shift. Three samplers were in Room C310 and four in Room C315, as shown in Figures 7 and 8.

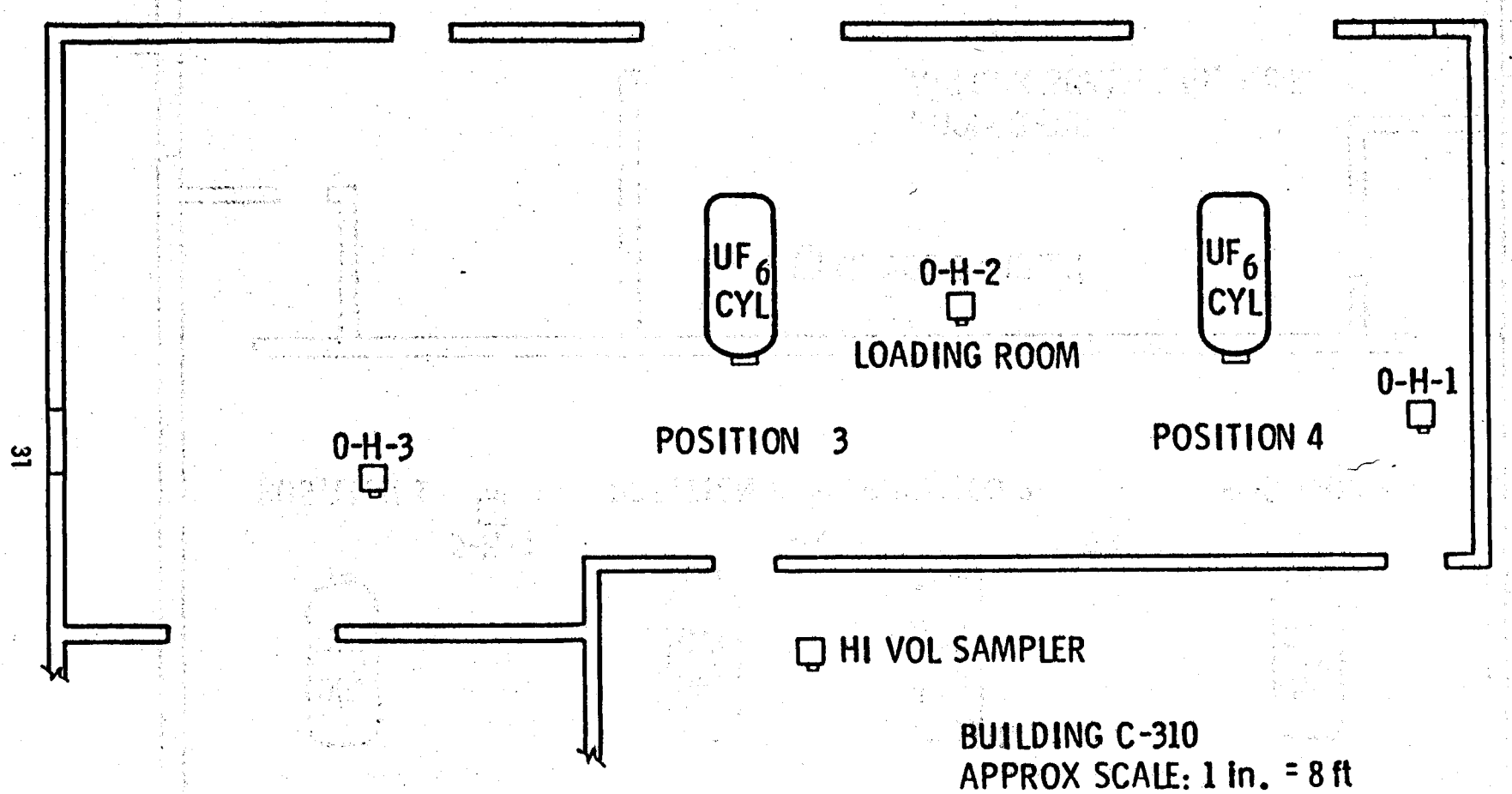


Figure 7. Location of High Volume Samplers in Room 310

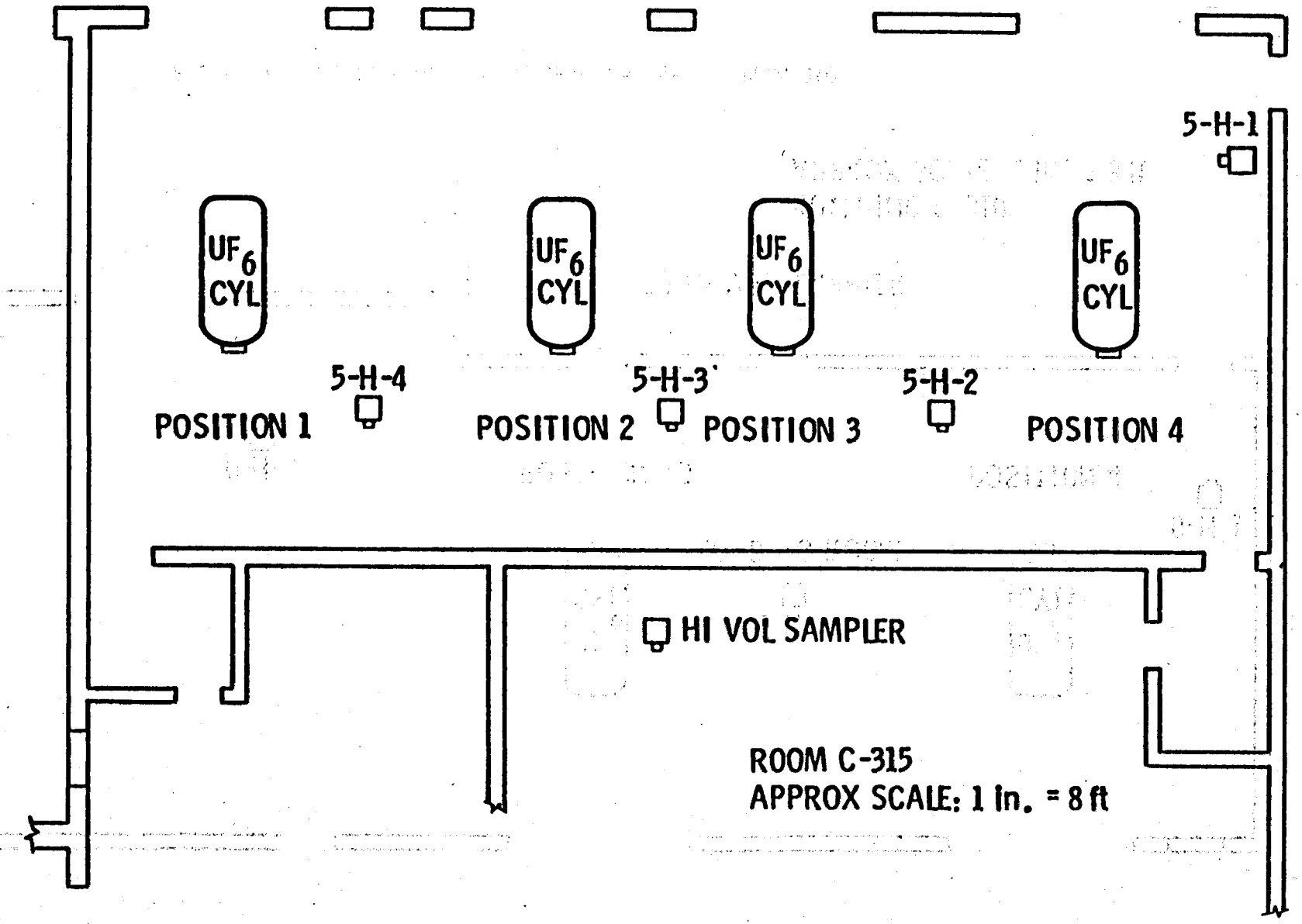


Figure 8. Location of High Volume Samplers in Room 315

Breathing zone samples. The breathing zone of the operator was sampled while he was in the process of making the disconnect. As indicated above, the immediate breathing zone of the operator is ventilated by a hood arrangement at each loading cylinder station.

Experiments were conducted with smoke tubes to determine particle capture velocity. Small puffs of smoke released at various areas around the pigtail valve and the breathing zone of the worker were sucked into the exhaust duct. There were some cases in the 315 Building, cylinder positions 2 and 3, where a puff of smoke generated at waist level of a worker resulted in some drift out into the room as well as into the exhaust. This was particularly the case when the smoke tests were conducted with the four roll-up doors of the room open since there was a breeze that day. The breeze tended to create a cross current in the back part of the rooms where the transfer lines to the cylinders were located. Generally, the breathing zone samplers were located between the hood and the valve connecting the cylinder and the pigtail, although not directly in the stream of air being drawn into the hood. These breathing zone samplers were operated for up to 30 minutes after the pigtail was disconnected from the cylinder. This breathing zone sampling was performed two to four times in each of the two transfer rooms.

a(2)B. Controlled UF_6 Release Sampling

In addition to sampling during routine disconnect operations, sampling experiments were also performed during controlled deliberate releases of UF_6 from a small sample tube. The sample tube contained about 20 mg of UF_6. These releases were performed in a manner to simulate a puff release while the cylinder was in position for a UF_6 transfer. The UF_6 puff was released immediately adjacent to the pigtail valve connection at the cylinder. These experiments were repeated three times in both of the 310 and 315 buildings. The general room air samplers were operated as they were during a routine disconnect. A third breathing zone sampler was placed in another location adjacent to the ventilation hood near where the operator's head would be. During one or two cases of the experimental controlled releases of UF_6, following the five-minute breathing zone sample, the sample filters were immediately changed and replaced with new ones and the sampling continued for several minutes.

a(2)C. Sampling for HF

Although the predominant focus of the sampling was for uranium in airborne compounds, some samples were taken for HF.

a(3). Counting Procedures

Following the sampling run, the high volume filters were carefully transferred to plastic containers and transported to the Union Carbide counting room for counting on alpha particle counters. The filters were left in covered holders until removed for counting. Filters were then returned to the holder for further handling. PNL personnel witnessed all counting performed by the Union Carbide employees, and reviewed and calculated results according to Union Carbide efficiency determinations of the counting equipment and correction factors for counting the specific filter used. All samples were held for at least six hours to reduce alpha particle contribution to the count from natural radioactive materials which were also collected on the filters. This is conservative since six hours decay is sufficient to assure that all natural alpha emitters had decayed to insignificance (compared to the true count from uranium). All air samples were counted for five minutes twice in consecutive counts.

After counting, the samples were sealed and transported to Richland, Washington, where they were placed in a vault until they were once again removed for counting at Battelle Laboratory.

Appendix F explains in detail the methods used to acquire samples and perform subsequent radiometric steps to determine airborne concentrations of uranium.

All samples were counted twice for reliability while on site, and verified by additional counting at Battelle. Statistical errors were not determined. However, comparison between the site counting and Battelle verification counting showed that no gross differences existed.

b. Results

The concentration limit for airborne uranium as applied by Union Carbide Corporation was 200 $d/m/m^3$. A review of the data obtained from the mock-up test shows that all samples counted were more than a factor of 10 lower (20 $d/m/m^3$) than the concentration limit.

The results of the general room sampling showed a radioactivity range from normal background to slightly above background. The lapel samplers and breathing zone samplers showed radioactivity concentrations less than 10% of the concentration guide.

Results of the hydrofluoric acid measurements are shown in Appendix F, Table 4. The concentration was below the lower limit of sensitivity. Sample volumes were small, and the HF levels indicated by these samples must be regarded as non-detectable. More samples of larger volume would have been needed to obtain a more accurate estimate of HF concentrations. However, since the levels were so low, for the purposes of mock-up testing enhanced accuracy did not appear warranted.

c. Conclusion

Based on interviews with seventeen workers, an analysis of past survey records and a review of the characteristics of the equipment in buildings C310 and C315, large releases of UF_6 did not occur as a matter of routine; rather, the UF_6, although visible, could be categorized as a minor "puff" resulting when the pigtail was disconnected from the cylinder. A limited number of major releases of short duration of the type described by Mr. Harding as routine occurred during the period of Harding's employment. The UF_6 normally released in small quantities during the disconnect procedure was captured by a high velocity hood located directly above the pigtail. The results of the mock-up test performed to assess the effectiveness of the hood revealed that the radioactivity released during the disconnect procedure was captured by the hood ventilation system and general airborne radioactivity concentrations were less than 10% of the occupational concentration guidelines. Thus, in the routine work environment, Mr. Harding and the workers were not exposed to high levels of UF_6 or its hydrolysis products.

Allegation #2

He was subjected to high direct radioactive levels from the "heel" of the product and waste cylinder.

Discussion

In one phase of the operation, UF_6 is cold-condensed, liquefied and drained into a 10 ton cylinder. The filled cylinder is then moved into a vaporizer where the UF_6 is reliquefied and vaporized. During the storage of UF_6 in the cylinder there is a build-up of Thorium-234 (Th^{234}) and Proactinium-234 (Pa^{234}) in the UF_6. Since the Th^{234} and Pa^{234} do not vaporize with the UF_6, they tend to collect at the bottom of the cylinder. The maximum equilibrium content is approximately 2 curies each of Th^{234} and Pa^{234}. The gamma radiation attributed to these nuclides at the bottom of the cylinder ranged from 50 mr/hr to a maximum 900 mr/hr (1). Calculated and measured dose rates at 3 feet from the cylinder showed a substantial reduction to a level of 5-15 mr/hr. Since the cylinders rest horizontally on a crib it is not possible to come in contact with the bottom (side) where the "heel" is concentrated. The amount of radiation contribution to the general work location ranged from 15 mr/hr to some small fraction of 1 mr/hr. The instrument readings Mr. Harding was required to take of the cylinder prior to shipment required only a few minutes. Thus, the resultant exposure was only a small fraction of the permissible occupational exposure guidelines (i.e., 300 mrem/wk).

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(1) R. Baker - Symposium on Occupational Health Experience and Practices in the Uranium Industry - HASL 58 - October 15, 1958

Conclusion

Considering the low contact dose rate from the heel of the cylinder, the low general ambient radiation level (at 3 feet) and the nature of the operation (time required to do the job), Mr. Harding's radiation exposure as corroborated by film dosimetry was found to be only a small fraction of the permissible occupational guidelines.

Allegation #3

There was poor respirator protection for the worker.

Discussion

There were approximately ten different respirators available for use at the Paducah Gaseous Diffusion Plant and workers were systematically trained in the use of the respirators. The elements of the general health physics training which included respirator training was reflected in the UCC Health Physics Training Manual KY 292--March 30, 1958. Procedures were established for the proper use of respirators and were specified in Special Plant Procedures (SPP) #29, "Protection Equipment."

Of the ten respirators types, three were selected specifically for C310 and C315 use on the basis of the type and form of the radioactivity encountered at these buildings. The respirators in use were:

1) The MSA Comfo which used the Bureau of Mines 2133 approved filter for dust and fumes. The UCC conducted a filter testing program in early 1950 which showed the MSA Comfo filter to be 98% efficient for sub micronparticle size UO_2F_2 fumes. The filter had enough surface area to absorb some of the HF gas. The filter was not designed for HF and at best its efficiency was 50% for HF. However, as previously noted, the TLV value for uranium was considered the limiting factor and the dust respirator was not intended for large release use but rather for the routine disconnect operation. The MSA Comfo was replaced in the mid 1950's by the MSA Dust Foe Ultra Filter Respirator using a type H filter which showed an efficiency of 99.98% efficiency for UO_2F_2 fumes.

2) The Army Assult Mask M9 (Full Face) with an M-11 canister which provided full protection for dust, gas and fumes. This unit was to be worn in a situation involving a large release with the limitation that it would not be used in oxygen deficient atmospheres.

3) The self contained MSA Chemox Mask which was used principally for reentry into heavy concentration areas and areas of O_2 deficiency.

Conclusion

The respiratory program contained most of the basic elements of sound respirator practices, i.e., (1) availability of respirators, (2) training,

and (3) procedures. A respirator fit program was lacking. However, workers were instructed to "cup the filter" with their hands and test the respirator for leakage.

Allegation #4

Lack of proper safety procedures, e.g., opportunity for eating in contaminated areas.

Discussion

Standard Practice Procedure (SPP) #31 dated April 7, 1952, "Plant Safety Program" and SPP #41 dated September 2, 1954, "Radiation Control" (Note Appendix B) provided the basic framework for the PGDP radiation safety program. In addition, numerous specific work practice type procedures were also issued.

Conclusion

The above procedures do indicate that UCC did not operate in a casual manner. Responsibilities were well defined. Standard Work Practice procedures were prepared and issued. A system of Special Work Permit (SWP) was instituted for operations involving potential exposures. Safety precautions had to be defined before approval to begin the job was given. Eating in contaminated areas was not permitted. However, while procedures did exist, it is questionable whether the health physics department was effective in maintaining an overview on a periodic basis of each building because of limited staffing. The health physics department was comprised of 4 or 5 health physicists covering the total plant site and their ability to give attention to special problem areas is also questionable.

Allegation #5

There was a lack of adequate training.

Discussion

All new hires at PGDP received several weeks of operations and radiological safety training as a prerequisite to job assignments. The scope of the radiological safety training consisted of:

1) Theory
2) History
3) Sources and Characteristics of Radiation Found at PGDP
4) Units of Measurement
5) Methods of Detecting and Measuring Radiation
6) Radiation Survey Instruments
7) Air Sampling
8) Respirator Protection
9) Hazards Control
10) Personnel Exposure Monitoring

11) Instrument Application
12) Plant Limits
13) Effects of Radiation
14) Biological Factors

The technical details for each category above is contained in PGDP Report #KY-292 - Health Physics Manual, March 30, 1958.

Conclusion

The scope of the radiological safety training was adequate. This conclusion is based on the statements received from the interviews, as well as a review of historical procedure records and training manuals.

Allegation #6

There was a lack of safety awareness or safety enforcement by supervisors.

Discussion

Radiological safety procedures were in fact established and supervisors were required to implement the procedures. According to the majority of the workers interviewed, considerable reliance was left to the individual worker to follow the procedures. There was no internal audit system to assure that safety procedures were properly enforced.

The implementation of radiological safety procedures and health physics training programs as previously discussed are indicators of good safety awareness on the part of management and supervision. However, based on the information derived from the interviews, the enforcement of safety requirements by supervisors was not considered adequate.

Allegation #7

There was a lack of exposure information available to employees.

Discussion

Standard Practice Procedure #41 required, in part, that:

41.2(d) It is the responsibility of the Medical Department to determine if any clinical evidence of exposure exists and to report such evidence to the division superintendent concerned.

41.5(4) When a personnel dosimeter (film badge, pocket chamber or other similar device) indicates an employee has received more than the plant acceptable limit of penetrating radiation, the employee's supervisor restricts the employee to work involving no significant exposure until this and subsequent dosimeter results average less than the plant acceptable limits.

It follows that where an individual has exceeded his plant limit for radiation exposure his supervisor is required to immediately inform him of the exposure as well as adjust his work assignments accordingly to minimize further exposure.

Conclusion

Routine exposures were obtainable by any worker upon written request. Workers were automatically notified if exposures exceeded the plant limit.

Allegation #8

There was a general lack of radiological protection overview.

Discussion

PGDP did not have an internal radiological safety audit program. The government overview of UCC in the area of radiological safety did not begin until 1961. At that time the Atomic Energy Commission (AEC) Oak Ridge Operations Office initiated a formal radiological safety appraisal program of the PGDP operations. In reviewing the appraisal records for the period 1961-1971, it is evident that the overview program was not conducted in sufficient technical depth to be considered a proper performance assessment tool in the context of the type of concerns expressed by Mr. Harding. The AEC Headquarters Operational Safety Division maintained an overview of the Oak Ridge Operations Office. Similarly, their appraisal activity failed to reveal the deficiency in the Oak Ridge Operations Overview Program.

Conclusion

Generally the overview function of PGDP by the Oak Ridge Operations Office and AEC Headquarters lacked technical depth in that detailed work place analyses were not conducted; rather, the total PGDP was appraised in a general sense.

IV. MEDICAL ASPECTS

IV. MEDICAL ASPECTS

In the course of arriving at a diagnostic opinion, the medical investigator utilized experience gained in three decades of practicing Internal Medicine which had trained him to evaluate multiple factors in disease causation. Trying to be objective, the findings about workplace safety--and their relevance to Mr. Harding's likely exposure -- were put aside in arriving at diagnostic conclusions.

A. General History

Mr. Joseph T. Harding was born May 28, 1921, in Tennessee. Not very much is known about Mr. Harding's history prior to his employment at the PGDP. His father died at a rather early age of esophageal cancer. One of Mr. Harding's two daughters died as a relatively young adult from a cause not known to the investigator. His surgical history prior to working at the PDGP showed two operations: a tonsillectomy in 1939 and repair of a right inguinal (groin) hernia with testicle removal in 1951. Habit history revealed that he was a long-term heavy cigarette smoker (2-3 packs per day). As a young man he probably had a high hydrocarbon intake (from eating a lot of country ham); as an adult his diet was apparently high in nitrites (from eating bacon daily). Mr. Harding was trained and worked as a cascade operator during his employment at PGDP (October 26, 1971). In 1953 Mr. Harding suffered an occupational injury to his right knee; later problems with this knee led to surgery in 1968 and were related to his termination from the plant in 1971.

B. Chronology of Mr. Harding's Medical History

Much of the following was abstracted from a document submitted to the Department of Energy by Mr. Harding, entitled "Doctors and Hospitals who have Treated Me from 1952 until 1979." (Appendix J)

1953 - Work injury to right knee; skin was treated by PGDP physician.

1954 - 1963 - Skin lesions were treated by PGDP physicians.

1954 - 1961 - Because of abdominal pain which began in 1954, he was eventually diagnosed in 1959 by a Gastroenterologist as having a prepyloric ulcer on the lesser curvature. Because he had intractable pain and functional obstruction, he underwent a sub-total gastrectomy in 1961.

1963 - Odd-looking areas were found in PGDP chest x-ray done as part of a periodic examination.

1964 - Hemoglobin was found low and checked monthly; had unsuccessful treatment by Paducah Dermatologist for one year.

1965 - Biopsy of two lesions of lower lip; pathological results were said to be vague. Skin lesions were examined by a St. Louis Dermatologist.

1966-1968 - Skin lesions and low hemoglobin were treated by a Paducah Generalist.

1967 - A Nashville Dermatologist biopsied the skin lesions, but treatment was not successful.

1968 - A Louisville Dermatologist and a Memphis Dermatologist tried to cure the skin lesions. Had first case of pneumonia.

1969 - He had another unsuccessful skin examination by a different St. Louis Dermatologist; another bout of pneumonia occurred.

1970 - He had pneumonia twice.

1974 - Pneumonia. (In total, Mr. Harding said, he had pneumonia 11 times.)

1975 - He was seen by a Paducah Podiatrist for a joint area abnormality; pneumonia.

1976 - Pneumonia.

1977 - A Paducah Surgeon saw him because of joint area abnormalities.

1978 - Pneumonia.

1979 - He was examined and treated by both a Surgeon and Internist in a Paducah hospital for abdominal pain and weakness. He was seen by a Paducah Neurosurgeon because of a body tremor; a former Paducah Neurologist saw him for the same tremor.

1980 - He was admitted to Memphis hospital with multiple complaints and was discharged with four major diagnoses including advanced abdominal cancer.

1980 - Mr. Harding died at home March 1, 1980. No autopsy was done.

C. Radiation Exposures

These have been divided into occupational and medical diagnostic exposures. As far as is known, the only occupational radiation exposure occurred at PGDP. Appendix E is a copy of Mr. Harding's radiation exposure records. In summary, the external exposures totalled 5.70 rems of which .76 were beta (skin) leaving a whole body or penetrating dose of 4.94 gamma rems. Internal exposures were calculated by measuring the milligrams of uranium per liter of urine. Four of the eighteen

plus years of employment show no records because work occurred in places without apparent exposure. In each of the other years, the number of analyses ranged from one to eighteen. Every year measured showed an organ dose range of less than one rem.

Because of his medical problems, Mr. Harding was subjected to more than the average amount of diagnostic radiation. Since X-rays can be harmful, an estimate of the total bone marrow dose has been made. Arbitrarily, X-rays made after 1978 were not included on the assumption that an effect would take at least two years to develop. A total exposure of about 3.5 rems was reached. The specific data are shown in Appendix K.

Thus, Mr. Harding was exposed to an estimated total of 9.2 rems from occupational and medical sources from 1953 to 1978. Current standards allow up to 3 rem per quarter or 5 rem per year. These standards are in the Code of Federal Regulations, Title X (Energy), Part 20 (Standards for Protection Against Radiation). Even if the yearly standard were reduced to 0.5 rem, Mr. Harding's total occupational radiation exposure (5.7 rem) over an 18-year period would still be "acceptable."

D. Analysis

1. Stomach

Uranium taken orally in quantities much larger than those probably involved in this case does not cause gastric problems.[1] The kidney is a target organ and will function abnormally before the stomach does,[1] especially when exposed to "soluble" uranium, the product involved in the cascade process. There is no evidence of kidney abnormalities in the 1950's or 1960's. Mr. Harding had abdominal pain in 1954. By 1959 he was under the care of a Gastroenterologist. Mr. Harding did have an ulcer although he later denied that this had been the medical diagnosis. Western Baptist Hospital (Paducah) records show that he had a subtotal gastrectomy in 1961, for developing functional obstruction and intractability from an ulcer. X-rays demonstrate a prepyloric ulcer on the lesser curvature of the stomach. This ulcer was confirmed in the Surgeon's operative note and the Pathologist's report. There is no evidence that this ulcer was due to excessive occupational radiation exposure.

Other etiologic factors do exist.[2] People who ingest hydrocarbons and/or nitrites have a higher incidence of gastric cancer than those who do not. According to his daughter, Mr. Harding in his early years frequently ate country ham, a source of hydrocarbons,

1 Appendix L - Reference 2.
2 Appendix L - Reference 5-13.

and later in life, daily ate bacon, most brands of which contain nitrites. Smokers -- Mr. Harding was said to have smoked 2-3 packages of cigarettes daily -- have a higher incidence of ulcers. Mr. Harding operated an air conditioning and heating installation business and the welding involved could have exposed him to cadmium and/or nickel carbonyl fumes. Cadmium has been implicated as a gastric cancer and pulmonary disease causative agent; nickel carbonyl, too, may be related to gastric cancer.

A genetic predisposition may also have existed. Mr. Harding's father died from cancer of the esophagus, an area adjacent to the origin of his own cancer.

All of this discussion is intended to show that it is not possible to definitively isolate the cause of the ulcer. Almost certainly, however, it was not the result of radiation since there is very little cause and effect relationship between radiation exposure and gastric ulcer.

The after effects of subtotal gastrectomy can be terrible, and Mr. Harding sadly experienced many of them. He could not gain weight. He had a "dumping" syndrome with varying kinds and intensity of symptoms such as flushing, dizziness, weakness, pain, headache, and even vasomotor collapse (shock or fainting resulting from the disturbance to nerves controlling the size of blood vessels). He had a chronic anemia often found post-gastrectomy and may have had a "pernicious" anemia. Pernicious anemia patients often suffer neurologic complications such as those discussed in Section 5 below. Post-gastrectomy hormonal imbalances affecting bones are now known to occur.[2] These may be related to the cartilage condition manifested by Mr. Harding as discussed in Section 4 below.

In recent years there have been numerous papers detailing the consequences suffered by gastrectomized patients.[3] There is a high incidence of gastric cancer or cancer of the gastric stump in persons with pernicious anemia and in persons with higher than average gastric-juice nitrite levels. Smokers convert more nitrites to nitrosamines in the stomach and thereby have more cancer.[2]

Although the Methodist Hospital Pathologist's record on Mr. Harding lists his cancer as origin unknown, the Oncologist gave the opinion based on his evaluation of the clinical as well as pathological findings that the cancer was gastric in origin. This case fits the picture of an individual who developed a gastric ulcer, had to have most of his stomach removed when the ulcer did not improve, and unfortunately, suffered until death from the related effects of the surgery.

2 Op. Cit.
3 Appendix L - Reference 3.

2. Lungs

As early as 1956, Mr. Harding's chest X-ray showed lesions suggesting Bleb emphysema, "little holes," in the right upper lung. This occurred just over 3 years after he started working at PGDP -- probably not long enough to be caused by radiation. A far more likely causative factor would have been Mr. Harding's smoking. He had been and continued smoking heavily for years. His pulmonary function tests showed the small-airway disease characteristic of heavy smokers. As years went by his lungs deteriorated and became more susceptible to infection. Eventually he had a bout of pneumonia, and another, and another -- each one leaving his lungs a little weaker. On the basis of comparing the effects of the estimated occupational radiation exposure with the effects of heavy cigarette smoking, it is not logical to assign causation to radiation.

In the cascade process, exposure is from water soluble uranium which is absorbed and either excreted via kidneys or stored in bone. Thus, the small quantities of water soluble uranium involved in this case were not likely to have affected the lungs. The clinical pathologic picture presented by Mr. Harding cannot be attributed to uranium radiation as a primary cause.

In 1954, Mr. Harding was exposed to vapors of hydrofluoric acid (HF), an extremely corrosive substance. If HF gets deep into the lungs, it causes disability for weeks or months, if the individual survives. Disability correlates with dose received. In this case Mr. Harding went back to work after being checked at the PGDP occupational clinic. There is little likelihood, therefore, that his exposure to HF caused his pulmonary condition.

It should be mentioned that during the welding needed for air conditioning and heating installations, Mr. Harding could have been exposed to fumes from cadmium or nickel carbonyl. Evaluation of the significance of this exposure has not been possible.

Looking at the entire picture of Mr. Harding's pulmonary disease, the likelihood is high that the most significant causative factor was cigarette smoke.

3. Skin

Records available indicate that this problem began in 1953. Initially, it was described as a folliculitis, an inflammatory reaction around the hair roots, on his lower legs. Later this condition spread upwards. Mr. Harding was seen by many Dermatologists; at least two biopsies were done -- both showing non-specific inflammatory reactions. No Dermatologist documented the diagnosis to be radiation dermatitis. The skin lesions did not fit the description of radiation dermatitis found in the references consulted.

4. Cartilage

In 1975 Mr. Harding first noted "fingernails and toe nails growing out of joints in fingers, wrists, and elbows, and joints in toes, ankles and knees." Unfortunately, none of the available records do more than mention Mr. Harding's complaint. In the six or seven physical examinations where the history referred to them, the lesions were not described. The cartilage-radiation relationship is difficult to address because so little is known about it. The possibility of cartilaginous overgrowth due to radiation does exist. But the dose or level triggering such a response is not known, nor is the period of latency known. Conceivably, Mr. Harding was describing enlargement of joints, hypertrophy, and/or softening of bone, osteomalacia. The former is often associated with chronic pulmonary disease; the latter (as discussed in Section 1 above) is now recognized as a hormonal imbalance from gastrectomy. Little is known about the relationship of other toxic agents and the condition described by Mr. Harding. There are some cartilaginous diseases which are familiar and occur mainly in middle-aged males, but there is no evidence pointing in this direction. Mr. Harding probably suffered from bone involvement secondary to either his lung or stomach condition.

5. Tremor

Knowledge about the amount, kind, and latency of radiation which would produce tremors like Mr. Harding's is not available. The likelihood that mature, therefore less radiosensitive, nerve cells would show delayed injury from the amount of radiation involved in this case is very small. Two more likely possibilities are that the tremor was a complication of the pernicious anemia syndrome or that it was a consequence of Mr. Harding's malignancy. Because he received treatment for the anemia, he was less likely to derive his tremor from it. The malignancy concept, especially in view of the timing, is more likely. Persons with advanced cancer will frequently have tremors and neurological changes, the pathogenesis of which has not yet been worked out. Moreover, there may be spread of cancer to the central nervous system.

E. Conclusion

The medical evidence points away from Mr. Harding's disabilities being radiation induced. Admittedly, this evidence is not absolutely clear cut. From a scientific viewpoint there were two possible opportunities to clarify the issue: autopsy and radioactive uranium quantification. Regrettably, but understandably in the confusion at

the time of a death at home, an autopsy was not performed. However, it is possible that more definitive information could result from a quantification of the radioactive uranium in Mr. Harding's body. This kind of total body counting is feasible. Assaying tissues obtained via biopsy during his stay at Methodist Hospital* would probably show little or no radioactivity because soluble uranium desposition occurs mainly in kidney and bone, and insoluble uranium occurs in lung. Furthermore, total remains would probably be needed to accurately calculate the total radioactivity. Should total body counting be done, other toxic agents such as cadmium and nickel could and should be assayed.

* Dr. W. Jennings told the investigator in a telephone conversation that biopsied tissues taken from Mr. Harding while he was at Methodist Hospital could be obtained.

APPENDICES

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RJW

APPENDIX A

December 6, 1980

Mr. Robert Hagar Esq.
Christic Institute
1324 North Capitol N.W.
Washington, D.C. 20002

Dear Mr. Hagar:

Thank you for sending me the materials concerning the case of Mr. Joe Harding. I apologize for my late reply but I have been on many out of town trips lately and your material has just worked its way to the top of my stack.

After reviewing the records you furnished me concerning the case of Joe Harding a deceased former worker at the Paducah, Ky. enrichment facility operated by the Union Carbide Corporation, I must comment that basic information about Mr. Harding's exposure history is very conspicuous in its absence. The kinds of data provided by the DOE and Union Carbide, particularly those dealing with Mr. Harding's urine samples are suggestive of a very high body burden. However, there are large gaps in Mr. Harding's exposure history, especially periods when Mr. Harding claimed to be the most heavily exposed. Either an inadequate search was made by the DOE of Mr. Harding's records or Union Carbide has failed to make appropriate measurements and maintain proper records on Mr. Harding's entire work history. However on the basis of information you have provided me, I would like to make the following observations:

(1) Mr. Harding suffered from cancer of the abdomen which is what one might expect from the ingestion of insoluable uranium particles. The kinds of exposure described by Mr. Harding suggests that these particles were quite large as to be visible. After chronic inhalation of uranium particles, it is quite possible that the expelling of these particles from the lung by their collection in mucous and subsequent ingestion of this uranium laden mucous could have provided a considerable dose to Mr. Hardings lower G.I. tract.

(2) Mr. Harding's extensive skin leisons are what one might expect from exposure to beta particles. The immersion dose from uranium hexafloride in its various stages of enrichment can give off a considerable beta dose to the skin. As my research and the work of others at Oak Ridge has shown, immesrion doses by beta particles under circumstances described by Mr. Harding can be as high as 265 mr/hr.

(3)Mr. Harding had extensive damage to his respitory tract which is strongly suggestive of chronic exposure to uranium dust. Although much attention has been given to the damage potential of alpha particles, it should be noted that beta as well as alpha particles in uranium dust are capable of damage to the nasal, pharyngeal, tracheal, bronchial regions of the body. Damage to these regions were observed for Mr. Harding.

(4) On one occasion Mr. Harding had a very high urine count of .4 milligrams per litre. This measurement indicates a body burden 10 times above maximum permissible concentrations. I find it remarkable that the following day Mr. Harding's urine count dropped dramatically. The kidney retains and concentrates uranium particles over periods of days and does not pass out such heavy concentrations within a 24 hour period. Either the second sample taken of Mr. Harding's urine was mistakenly analyzed or it was falsified.

It is my opinion that Mr. Harding's cancer, skin leisons, and respitory damage were major contributors to his death. Insofar as his radiation exposure was the cause of these diseases, one would assume that to be the case.

Sincerely,

Karl Z. Morgan

Karl Z. Morgan

Neeley Professor
School of Nuclear Engineering
Georgia Institute of Technology

KARL ZIEGLER MORGAN

American Health Physicist

Born Enochsville, N.C., September 27, 1907

EDUCATION

B.S., University of North Carolina, 1929
M.S., University of North Carolina, 1930
Ph.D., Duke, 1934

EMPLOYMENT

Westinghouse Electric, 1930-31

Chairman of Physics Department, and Cooperative Research Program, Duke, Lenoir Rhyne College, 1934-43

Member Research Staff, Metall Lab., Health Physics Division, University of Chicago, 1943

Director Health Physics Division, Oak Ridge National Lab., 1943-72

Professor of Nuclear Energy, School of Nuclear Engineering, Georgia Institute of Technology, 1972-

MEMBERSHIP

National Council on Radiation Protection, Chairman, Internal Dose Committee

International Commission on Radiological Protection, Chairman, Internal Dose Committee

Advisory Committee on Reactor Safeguards (Subcomt. NRC) 1975

Advisory Committee, Bureau of Radiological Health, 1975-78

Transportation of Radioactive Materials Comt. to Jt. Comt. of Congress, 1974-

SOCIETIES

American Medical Association
American Association for the Advancement of Science
American Board of Health Physicists
American Association for Physicists in Biology and Medicine
American Industrial Hygiene Association
American Institute of Biological Sciences
American Public Health Association
American Nuclear Society
Health Physics Society

SOCIETIES CONTINUED

International Society of Radiology
American College of Radiology
Medical Research Council
Society of Nuclear Medicine
National Safety Council
Radiation Research Society
International Radiation Protection Association, Chairman & President
Radology Society of North America
Royal Society of Medicine

AWARDS

First Gold Medal, Work Radiation Protection, Royal Academy of Science, Sweden, 1962

First Distinguished Award, Health Physics Society, 1968

Distinguished Achievement Award Health Physics Society, 1973

RESEARCH & WRITINGS ON

Health physics; radiation protection; internal dose from radionuclides; low level exposure of man to ionizing radiation; non-ionizing radiation effect on man; problems of instrumentation, air contamination and internal dose; neutron dosimetry cataract studies.

MAJOR PUBLICATIONS

Health Physics (editor) 1959-

Hanford Symposium on the Biology of the Transuranic Elements (editor in chief) 1962

Energy and the Environment (editor) 1976

Principles of Radiation Protection: a textbook of health physics (coauthor) 1967

This information was taken from:

American Men and Women of Science Vol. 5, 14th ed., Bowker, 1979);
World Who's Who in Science (Marquis 1968);

Biographical listings also appear in:

Leaders in American Science (7th ed. Cook 1967);
Who's Who in Atoms (6th ed. Hodgson 1977).

Response to Dr. Karl Z. Morgan's Letter

By: Edward J. Vallario
Assistant Chief/Manager
Health Physics Program
Operational and Environmental Safety Division
Office of Environment

On December 11, 1980, Mr. Robert Hager, Esquire, the attorney representing the estate of the late Joseph Harding, transmitted to Ruth Clusen, Assistant Secretary for Environment, comments on the causation of Mr. Harding's illnesses. These comments were prepared by Dr. Karl Z. Morgan, a professor at the School of Nuclear Engineering, Georgia Institute of Technology. My comments deal with all of Dr. Morgan's observations since his conclusions are based in large measure on health physics premises.

Dr. Morgan's General Comments

Dr. Morgan states that Mr. Harding's urine samples are suggestive of a very high body burden. I find his statement perplexing. Mr. Harding's reported urinalysis results for the years 1953-1971 show a yearly organ dose of less than 1 rem. Most of Mr. Harding's samples contained uranium concentrations equal to those concentrations found in unexposed people in preemployment physicals. Very few urine samples exceeded 10 micrograms U/liter. This corresponds to an excretion rate of 12 micrograms/day and may be contrasted with the calculated excretion rate from the maximum permissible body burden (MPBB) of 700 micrograms/day (kidney) and 200 micrograms/day (bone).[1] On this basis, Mr. Harding's reported urinalysis excretion rate shows that his body burden was very low.

Dr. Morgan also notes in his general comments that "there were large gaps in Mr. Harding's exposure history." Our investigation disclosed that the gaps in exposure history relate to those periods of time that Mr. Harding did not work in radiation areas. Under Union Carbide policy, routine dosimetry and urinalysis were not required for non radiation work (see Chapter III, page 38). I find this a reasonable practice.

> Dr. Morgan's Observation (1): Dr. Morgan's statement that Mr. Harding ingested insoluble uranium is in error. For the most part, there were only two sources of radiation in Buildings C310 and C315, i.e., material contained in the product cylinders (uranium hexafluoride or UF_6) and small puff releases*occurring during the disconnection of the pigtail connector from the cylinders. Only rarely - as a result of an accident - were there large releases of UF_6.

*See page 2 of text for definition of "small puff release."

In normal operations, the UF_6 in liquid form was fed from the cascade or process system to a multi-ton cylinder. The procedure started in the process system where the UF_6 was initially heated and converted to a gas. The insoluble products of uranium 238, i.e., Thorium 234 and proactinium 234 do not form gaseous compounds during this conversion; rather, these products attach to the surfaces of the process system and, therefore, could not be released to the worker's environment. The gas, essentially free of insoluble products, was then put through a condensor, converted to a liquid and fed to the cylinder. When the transfer was completed and the valves secured, the transfer pigtail was purged and any entrained UF_6 was passed back into the lower pressure part of the process system for recovery. Since the temperature of the liquid was approximately 160° F, any small residual UF_6 in the pigtail remaining after the purge procedure would have vaporized immediatly.

When the pigtail was disconnected, the vaporized UF_6 was released to the atmosphere and reacted with water to form uranyl fluoride fume (UO_2F_2) and hydrogen fluoride. The UO_2F_2 is a highly soluble fume. Thus, the released puff (which was captured by the hood ventilation system) was in the soluble form of UO_2F_2 and not insoluble uranium.

The availability of insoluble uranium from the cylinders also is highly questionable. Insoluble uranium products were contained in the cylinders as a result of past usage. However, the pressure in the cylinders at room temperature was below atmospheric pressure(2); therefore, any leakage of a cylinder would result in air leakage into the cylinder, making the probability of a release of insoluble uranium essentially zero.

In the event of accidental large releases, the UF_6 discharged was transformed to the soluble UO_2F_2 by the same process that occurred with small puff releases. As described above, all insoluble uranium products remained in the process system and could not and did not represent the source term indicated by Dr. Morgan.

Dr. Morgan's Observation (2): As noted in (1) above, there were no insoluble uranium products (beta particle emitters) released to the room to which Mr. Harding's skin might have been exposed.

Dr. Morgan's Observation (3): As noted in (1) above, the uranium source in Mr. Harding's environment was UO_2F_2 which is highly soluble. Although this compound passes through the lung, its biological residence time is too short to result in the damage suggested by Dr. Morgan.

Dr. Morgan's Observation (4): All available studies to date - both human and animal - are reasonably in agreement on the rapid excretion characteristics of UO_2F_2. Animal studies(2) show that approximately 80% of the absorbed dose is excreted in urine during the first 20 hours.

Studies conducted by Bernard and Struxness[4] show that excretion rates 2 hours after exposure may be from 2% to 10% of the inhaled dose. The International Commission on Radiological Protection (ICRP) excretion model predicts 80% urinary elimination the first day.

Dr. Morgan's concerns regarding the dramatic decrease in the urine count after 24 hours are not consistent with these findings regarding radiological residence time of UO_2F_2. Thus, there is no basis for his conclusion that mistaken analysis or falsification were responsible for the change in counts. Furthermore, our investigation showed no evidence of falsification or other mishandling of records.

I am not in accord with the basis for Dr. Morgan's general conclusion. The sources of exposure he describes are not characteristic of the plant equipment or operations in Buildings C310 and C315. The radiological characteristics of the available source term cannot, in my view, have been the cause of Mr. Harding's illnesses.

References

(1) Health Physics Journal, Volume III, 1960, K. Z. Morgan, Report of ICRP Committee II - Permissible Dose for Internal Radiation (1959) with Bibliography for Biological, Mathematical and Physical Data.

(2) Conference on Occupational Health Experience with Uranium ERDA/93 - April 1975.

(3) Acute Effects of Inhalation Exposure to Uranium Hexafluoride and patterns of Deposition NUREG/CR 1045 - July 1979.

(4) A Study of the Distribution and Excretion of Uranium in Man - S. R. Bernard and E. G. Struxness ORNO-2304 - June 1957.

Response to Dr. Karl Z. Morgan's Letter

By: Henry R. Wolfe, M.D.
Human Health and Assessments Division
Office of Health and Environmental Research
Office of Environment

Karl Z. Morgan, Ph.D., in a December 6, 1980 letter to Mr. Robert Hager, Esquire, made four observations on the causation of Mr. Harding's illnesses. I comment from a medical standpoint on the first three observations and on the opinion expressed in the final two sentences of the letter.

Dr. Morgan's Observation (1): This was the diagnosis on the discharge note and front page of the chart from the Methodist Hospital. Closer perusal of the chart's contents reveals that the Pathologist reported the presence of acid-staining and mucin containing cells in the biopsied specimens. These cells characteristically originate in the stomach, not the lower G.I. tract. The Oncologist's diagnosis, taking into consideration the pathology report and the clinical course, stated that the cancer was most likely adenocarcinoma of the stomach. Differentiating between cancer of the stomach and cancer of the lower intestine is important because cancer of the stomach is more likely to be related to causes other than radiation.

Nowhere does Dr. Morgan consider any etiologies other than occupational radiation exposure. In Mr. Harding's case, other exposure possibilities were tobacco, nitrites, hydrocarbons, cadmium, nickel carbonyl and even radiation from medical diagnostic x-rays. Additionally, there may have been a genetic predisposition; for example, his father had died of cancer of the esophagus.

Dr. Morgan's Observation (2): The statement that these lesions are what one might expect from exposure to beta particles is not borne out by the facts in this case. To make a case for beta particle exposure, Dr. Morgan discusses immersion dose from uranium hexafluoride. There is no evidence that Mr. Harding ever had an "immersion" exposure.

Again the histopathology on two separate biospy occasions was not characteristic of radiation lesions. In the early years there was a non-specific heaping up of skin and inflammatory reaction around hair roots, called "folliculitis." Radiated skin in its chronic or delayed stages characteristically shows a flattening, thinning and even shininess called "atrophy." The late skin stages of both inflammatory reaction and radiation are probably indistinguishable, but the early records are consistent with folliculitis and not effects from radiation.

Once again no other causative possibilities have been considered by Dr. Morgan. For example, chemicals might have caused the folliculitis which was mistreated, resulting in a localized loss of resistance that could have led to the progressive skin lesions.

Dr. Morgan's Observation (3): Dr. Morgan states the damage is strongly suggestive of chronic uranium dust exposure. The fact that Mr. Harding had been a long time 2-3 pack a day cigarette smoker is ignored. Again, no other possibilities are considered.

One can compare pulmonary function tests in lungs damaged by radiation with tests in lungs damaged by tobacco smoke. In the late stages they may be indistinguishable; however, in earlier stages there is a difference. Radiation causes a "fibrosis" or scarring of the tissues in the lung around the air sacs. Pulmonary testing of radiation damaged lungs shows an alveolar-capillary block, which means that the oxygen is prevented from getting into the blood stream and the carbon dioxide accumulating in the blood cannot get out through the lungs. Tobacco smoke damaged lungs show mid and small airway disease characterized on testing by a decrease in the volume of air going in and out. Mr. Harding's pulmonary tests fit the smoker's pattern.

Finally, on a medical basis, I take issue with Dr. Morgan's opinion. A differential diagnosis should consider all possible etiologies. Dr. Morgan has apparently only considered one. In my opinion, Mr. Harding's illnesses were induced by several causes, and he could have presented the same clinical picture without any occupational radiation exposure. My clinical judgement is that radiation exposure was not likely to have caused Mr. Harding's illnesses.

STANDARD PRACTICE PROCEDURE
CARBIDE AND CARBON CHEMICALS COMPANY
A Division of Union Carbide and Carbon Corporation
Paducah, Kentucky

APPENDIX B
Number: 31
Date: April 7, 195[illegible]
Revised:

Subject: PLANT SAFETY PROGRAM

31.1 POLICY: It is the policy of this plant to establish and maintain an effectiv safety program to assist line supervision in carrying out its responsibility for safeguarding all employees and plant property.

31.2 REFERENCES: Paducah Plant standard practice procedures and bulletins in effe and other codes and standards referred to in Section #31.5 (Regulations), and listed in Appendix "B", will apply.

31.3 SAFETY COMMITTEE ORGANIZATION: Four types of safety committees will be established to assist in developing a well-rounded and effective accident prevention program in the Paducah Plant; namely, (1) The Central Safety Committe consisting of members of the Superintendents' Committee, (2) the Safety and Emergency Planning Committee, consisting of appointed representatives from each division in the plant, (3) the Division Committees, and (4) the Departmental Safety Sub-Committees.

31.4 RESPONSIBILITIES:

a. The Central Safety Committee is responsibile for administering the over-al Safety Program for the Paducah Plant.

b. The Safety and Emergency Planning Committee will formulate, review, and make recommendations regarding safety policies and procedures to the Superintendents' Committee.

c. The responsibilities of each division are:

1. To appoint a Division Safety Committee which is set up on a permanent basis and will consist of the Division Superintendent, Department Head and other representatives as desired from staff, service and control groups directly engaged in accident prevention activities.

2. To establish one or more Safety Sub-Committees for each department.

3. To direct and assist the Departmental Sub-Committees in maintaining an adequate safety program.

4. To keep and analyze a monthly record and accident report file on all injuries which occur within the division, and a monthly divisional frequency and severity chart. (The Safety Department will furnish the chart and the information to keep this record current).

5. To keep the Safety Department informed of its activity and report any other functions related to the over-all safety program of the division.

WCP-292

d. The responsibilities of each department are:

1. To appoint members of the departmental sub-committees.

2. To keep a record of departmental accidents.

3. To cooperate with other departments in establishing and coordinating precautionary measures affecting inter-related functions.

e. The responsibilities of Departmental Sub-Committees are:

1. To investigate all serious or potentially serious accidents to determine causes, and to recommend corrective action.

2. To schedule safety meetings each month for all employees in the department or group which they represent. (Minutes of these meetings will be forwarded to the Safety Department).

f. The responsibilities of each supervisor are:

1. To insure the safety of his employees and protection of plant property.

2. To see that proper equipment, machines, tools, etc., are provided, and properly used and maintained in accordance with approved methods.

3. To see that the standards of housekeeping are satisfactory.

4. To see that all necessary protective clothing and equipment including linemen's equipment are properly used, maintained, and tested on schedule.

5. To make the proper placement of employees as to job knowledge, and in accordance with Medical Department restrictions.

6. To see that all employees are properly trained in all phases of their job, with proper emphasis on safety, and to follow-up on this training.

7. To send injured employees promptly to the Medical Department, investigate accidents, and make written reports in detail. (Form #WCP-103)

8. To study, classify, and make recommendations on departmental accidents.

9. To cooperate with other supervisors and safety committees and to utiliz the staff, service, and control groups which are set up to assist in accident prevention. (See Appendix "A")

g. The responsibilities of the Safety Department are:

1. To keep management informed of the over-all accident prevention

performance of the entire plant.

2. To render staff assistance to Supervision on safety matters as follo

(a) Keep in touch with new developments and supply advice on all phases of safety problems.

(b) Initiate, compile, and propose safety rules and regulations.

(c) Cooperate with Supervision in developing and maintaining safety consciousness through publicity, demonstrations, and general safety instruction. Material of general interest may be furnis supervisory committees for plant-wide dissemination, and informa tion, specific to particular types of work made available upon request from the group or safety committee concerned.

(d) Interpret for Supervision - laws, regulations, rules, and standards regarding safety.

(e) Compile accident statistics.

(f) Investigate safety suggestions made by employees through line supervision.

(g) Review work orders from the standpoint of accident prevention.

(h) Act as a liaison between all accident prevention groups to see that the Safety Program is uniform throughout the plant.

(i) Develop standards and specifications for the procurement of protective equipment items.

3. To serve as a control check on safety matters by;

(a) Conducting sufficient spot checks and inspections to evaluate the effectiveness of the Plant Safety Program.

(b) Investigating and reporting on accidents.

(c) Checking on safety features of new designs and alterations to plant facilities.

4. To assist the Fire Prevention and Control Department in the solution of technical problems in connection with fire prevention.

b. The responsibilities of the Medical Department are:

1. To assure by pre-employment physical examination that each employee

is assigned to work for which he is physically adapted.

2. To check employees who have been absent from work due to occupationa (or non-occupational) illness or injury before returning them to wor

3. To make certain by physical examination that employees carrying medi cal restrictions are physically suited for new assignments before transfers are made.

4. To render medical assistance in the initial stages for those employe receiving occupational injuries or illnesses, and for recalling such cases that need additional treatment, except in lost time cases when the employee will be under the care of his own physician.

5. To make periodic physical examinations of all employees.

6. To request outside medical assistance and equipment, when needed.

i. Responsibilities of the Health Physics and Hygiene Department are:

1. To survey working conditions from the standpoint of industrial hygie and radiation hazards and to keep management informed (through the Medical Director) of such conditions.

2. To make recommendations to supervision for the correction or prevention of hazardous conditions related to industrial hygiene and health physics.

3. To assist supervision in establishing departmental health physics programs and to evaluate such programs periodically.

4. To assist supervision in training personnel to protect themselves from hazards due to radiation.

5. To maintain records of personnel exposure to radiation and radioactive or toxic materials.

6. To assist line supervision in interpreting and applying established critical mass standards and to act as a liaison in critical mass considerations with special hazards representatives of the Oak Ridge plants.

j. The responsibilities of the Fire Prevention and Control Department are:

1. Formulate and administer fire protection program for the plant.

2. Conduct year around fire prevention educational program.

3. Provide fire protection engineering services.

4. Review work orders, engineering drawings, and specifications which pertain to, involve, or affect fire protection.

5. Conduct periodic fire protection surveys of plant buildings, installations, and operations.

6. Inspect and test all fixed fire protection installations and request maintenance service or repairs as needed.

7. Inspect, test, and maintain all first aid fire fighting equipment for entire plant.

8. Inspect, test, and maintain all fire department apparatus and equipment (with exception of mechancial maintenance).

9. Respond to emergency calls from C&CCC occupied areas and render all possible assistance to the Plant Shift Superintendent in the control of the emergency.

10. Provide ambulance service for entire plant.

11. Investigate all fires and submit reports through proper channels.

k. Responsibilities of the Engineering Division are:

1. To incorporate safety features into all designs of new installations and alterations, as prescribed by plant and industry-wide standards, codes, and procedures which apply (See Appendix "B"); also, to review with the Safety Department any deviations from these standards which are deemed necessary.

2. To cooperate with the Safety Department in setting up ample precautionary measures for emergency work involving risks to personnel.

l. The responsibilities of the Inspection Department (Engineering Division) are:

1. To test and inspect all fixed and mobile pressure vessels and crane and hoisting equipment (including elevators), and those controls and regulating devices which are considered an integral part of this equipment, such as pressure regulators, pressure relief devices interlocks, cable slings, etc: also to submit inspection reports to line supervision in accordance with established procedure.

m. The General Maintenance Division Vehicle Inspection Service is responsibl for the periodic inspection of all heavy and light automotive equipment. (Exception: This does not include the hoisting section of motor or crawler cranes, nor portable air compressors. These will be inspected by the Inspection Department).

n. Responsibilities of the Electrical and Instrument Maintenance Division inspection groups are:

1. To provide a scheduled test and inspection service on all linemen's protective equipment (rubber gloves, hot sticks, rubber blankets, etc.) used within the plant, and to maintain a numbering system on all such items.

2. To provide the Stores Department inspection service on portable electric tools issued through the tool cribs, according to a set schedule.

3. To provide a field inspection service on all other portable and fixed items of electrical equipment, according to common, safe electrical practice.

o. Responsibilities of the Training and Procedure Department are:

1. To provide safety orientation training for all new employees.

2. To conduct First Aid Training Courses.

3. To prepare material for and conduct certain Specialized Safety Training meetings.

4. To assist Safety Department in preparing material for safety meetings

p. The Chemical Operations Protective Equipment Servicing Unit is responsibl for cleaning, testing, and repairing used, dirty, and contaminated items referred to it by the Materials Department.

q. The Plant Shift Superintendents are responsible for:

1. Assuming direct charge of combatting any plant emergency which threatens plant employees or property (or continuity of operations).

2. Calling for and utilizing the assistance of any groups or individuals within the plant who are qualified and authorized to assist in carrying out the above.

31.5 REGULATIONS:

For details pertaining to specific aspects of and protective regulations

involved in the safety program, refer to the procedures, bulletins, standards, and codes shown in Appendix "B" following. Wherever any difference exists between plant-issued procedures or standards and national codes or standards, plant-issued items will govern.

31.6 APPENDIX A:

Staff, Service, and Control Groups Performing Accident Prevention Functions

(1) Safety Department

(2) Medical Department

(3) Health Physics and Hygiene Department

(4) Fire Prevention and Control Department

(5) Engineering Division

(6) Mechanical Inspection Department (Eng. Div.)

(7) General Maintenance Division Vehicle Inspection Service

(8) Electrical and Instrument Maintenance Division Inspection Groups

(9) Training and Procedure Department

(10) Chemical Operations Protective Equipment Servicing Unit

(11) Plant Shift Superintendents

31.7 APPENDIX B:

Safety Procedures, Bulletins, Standards, and Codes Applicable to the Paducah Plant

a. GENERAL:

American Safety Standards (American Standards Association)

National Fire Code (National Fire Protection Association)

Uniform Building Code - 1949 Edition (Pacific Coast Building Officials Conference)

Manufacturing Chemists' Association Manual Sheets

Manufacturing Chemists' Association Chemical Data Sheets

Boiler Construction Code (American Society of Mechanical Engineers)

Building Codes and other Building Criteria (AEC Bulletin GM-Con-3)

Public Health Service Drinking Water Standards (U.S. Public Health Service)

Manual of Recommended Water Sanitation Practice (U. S. Public Health Service)

Ordinance and Code Regulating Eating and Drinking Establishments (U. S. Public Health Service)

Regulations for Transportation of Explosives and Other Dangerous Articles (Interstate Commerce Commission)

Motor Carrier Safety Regulations (Interstate Commerce Commission)

Manual on Uniform Traffic Control Devices for Streets and Highways (Public Roads Administration)

Traffic Engineers Handbook (Institute of Traffic Engineering)

Motor Vehicle Inspection Manual (American Association of Casualty and Surety Companies) (Chapter 6)

List of Inspected Appliances, Equipment, and Materials (Underwriters' Laboratories)

Safe Handling of Radioactive Isotopes (Handbook #42, National Bureau of Standards)

b. Company Issued

SPP #D-1-9 - "Absence for Occupational Disability"

SPP # 23 - "Electrical Work Permits"

SPP # 24 - "Stop Tags"

SPP # 25 - "Hazardous Work Permit" (Except Electrical)

SPP # 26 - "Gas Cylinder Identification, Handling and Use"

SPP # 27 - "Inspection of Pressure Vessels"

SPP # 28 - "Inspection and Maintenance of Hoisting Equipment"

SPP # 29 - "Eye Protection Equipment"

SPP # 31 - "Plant Safety Program"

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SPP #44 - "Material Release Reporting"

SPP #45 - "Protective Clothing"

SPP #50 - "Use of Government Owned Vehicles"

PLANT BULLETIN AR #3 - "Protective Clothing and Equipment"

PLANT BULLETIN AR #5 - "Carbon Tetrachloride"

PLANT BULLETIN AR #6 - "Injury Prevention Report"

PLANT BULLETIN AR #16- "Accident Reporting" (Dated 8-12-52)

ENGINEERING STANDARDS

ENGINEERING SPECIFICATIONS

MATERIAL SPECIFICATIONS

Approved: R. D. [signature]

RCP-393-A

Subject: RADIATION CONTROL

41.1 POLICY: It is the policy of the Paducah Plant to protect its personnel from the potential hazards inherent in the handling of radioactive materials.

41.2 RESPONSIBILITIES:

a. It is the responsibility of line supervision to maintain radiation and contamination levels as low as is practical and to maintain personnel exposures within acceptable plant limits; to maintain a health monitoring program such as the use of film badges where required, air contamination measurements and scheduling of periodical physical examinations; to formulate and administer all rules and regulations pertaining to radiation hazards for each area or major operation; to determine the extent and intensity of radiation and radioactivity contamination; to keep the Medical Department informed of all personnel working in locations, or engage in operations, where some degree of accidental exposure to radiation hazards is possible.

b. It is the responsibility of the Health Physics and Hygiene Department to provide an exposure monitoring service to determine the effectiveness of the health physics program; inspect plant locations and operations for exposure hazards; audit and maintain records of all radiation exposure and contamination data taken in the plant; supply advice and information as requested on radiation or uranium toxicity health hazards; recommend plant guides for controlling employee exposure to acceptable limits.

c. It is the responsibility of the Medical Department to recommend to the Division Superintendent concerned action including removal from exposure when uranium excretion rates indicate acceptable plant limits of uranium accumulation are being exceeded or when clinical evidence indicates such action.

41.3 DEFINITIONS:

a. Acceptable plant limits as used in this procedure defines:

1. The upper limit to the quantity of penetrating radiation to which plant personnel may be exposed for the entire length of a specified period.

2. The upper limit for permissible levels of radioactive contamination of air in locations where plant personnel spend the major part of a work day,

OR

An accumulation of uranium resulting in persistent excretion of uranium in excess of a set daily rate as determined by a series of industrial and recall urinalyses.

41.4 REGULATIONS:

a. Except in case of emergency, as specified by the Plant Emergency Director, personnel will not be required to work where personnel exposure will exceed maximum permissible dose (MPD) limits for external or internal exposure. (R)

b. Notification of Exposure - An employee is notified whenever his recorded valid exposure exceeds the MPD. An employee's occupational radiation exposure record shall be made available to him at his request. (N)

41.5 PROCEDURE:

a. Conditions causing plant acceptable limits to be exceeded will be corrected as soon as is practical and where immediate correction is impractical, the conditions will be identified and adequate personnel protection will be provided.

b. Where there is significant probability of contamination of personal clothing which may subsequently result in inhalation of radioactive material in excess of acceptable plant limits due to contamination levels or operations in progress, or when beta emitter contamination of clothing may add significantly to the skin dose, contamination clothing is issued according to Standard Practice Procedure No. 45. (R)

c. The Health Physics and Hygiene Department will notify the supervisor at the time a film badge is first issued an employee as to whether such employee has had any previous history of exposure to radiation. (N)

d. When exposure records indicate that a person has received during the quarter either 1.6 rem (1.6 rad of gamma or X-ray) whole body exposure or 3.2 rem to the skin (3.2 rad of beta plus gamma or X-ray), the Health Physics Department notifies the employee's supervisor. When exposure records further indicate that a person has received during the quarter either 2.4 rem (2.4 rad of gamma or X-ray) whole body exposure or 4.8 rem to the skin (4.8 rad of beta plus gamma or X-ray), the Health Physics Department notifies the employee's supervisor who restricts the employee to work in which the exposure is so reduced that the total exposure for the quarter will not exceed 3 rem whole body exposure or 6 rem to the skin. (R)

e. Cases of personnel exposure in excess of maximum permissible dose are investigated jointly by line supervision and the Health Physics and Hygiene Department. A report is submitted to the AEC for determination of the acceptability of evaluation technique prior to notifying the employee of the exposure. The employee is notified by the Health Physics and Hygiene Department through line supervision of valid exposures exceeding quarterly or yearly maximum permissible dose limits. (R)

f. The Health Physics and Hygiene Department compiles the total exposure of each exposed employee for each quarter and calendar year to date, lists the personnel by division and transmits a copy of the list to the department head. In addition, should an employee exceed either 5 rad of gamma (whole body) or 10 rad beta plus gamma (skin dose) in one year, the total exposure record since beginning of employment is transmitted with the current record. The employee's exposure record through the preceding quarter shall be made available to him at his request to his supervisor. (R)

g. When a series of urinalyses indicates an employee has accumulated uranium in excess of the acceptable plant limit, the employee's supervisor restricts the employee from working where exposure to uranium in air is probable until another series of urinalyses indicates the man's accumulation of uranium to be less than one-half of the acceptable plant limit or the results of 24-hour urine specimens indicate the accumulation to be below the acceptable plant limit. (R)

Approved: R. J. [signature]

APPENDIX TO SPP NO. 41

PLANT RADIATION AND CONTAMINATION LIMITS AND INDICES

All plant limits and indices are based on principles and standards established by the National Committee on Radiation Protection and Measurements as published by the Bureau of Standards. The values for the allowable body burden of uranium and plutonium are taken directly from the National Bureau of Standards Handbook 52; the values for maximum permissible dose (MPD) for penetrating radiation are from National Bureau of Standards Handbook 59 and the April 15, 1958, Addendum to this handbook. These limits are basic limits applied directly to the individual whereas the other indices shown in the procedure are measures of the environment. (R)

ACCEPTABLE PLANT LIMITS*

MPD for Penetrating Radiation

Whole Body (X-ray, Gamma)	3 rad/13 weeks 12 rad/year (Maximum) 5 rad/year (Average)	(R)
Skin (Whole Body) beta plus gamma or X-ray	6 rad/13 weeks 24 rad/year (Maximum) 10 rad/year (Average)	(R)
Extremities	25 rad/quarter 75 rad/year	(R)

*Limits for disposal of scrap and used equipment may be found in SPP D-2-5. Limits for shipping radioactive material may be found in SPP-47. The use of radiation tags and signs is detailed in SPP-15. (N)

It should be noted that the above maximum permissible dose (MPD) limits are established such that no bodily injury to a person at any time during his lifetime is expected as a result of this dose of ionizing radiation. The shortest period for which a limit is set is one quarter year and any part of the MPD may be received at any time during this 13-week period. However, the dose should be distributed in time as uniformly as possible and in any case the dose should not be greater than 3 rems (γ) in any 13 consecutive weeks. Records will be kept and audited on exposures at such intervals that supervision will be informed as to the employees' exposure status and this limit not be exceeded. This does not mean that these amounts are the largest that may be received in a 13-week period or a year without injury. (R)

Air-Borne Contamination

The maximum allowable concentration (MAC) for uranium in air is 0.07 mg/M^3 or for normal uranium, 110 dpm/M^3. This does not mean that exposure to concentrations exceeding this limit for brief periods will cause injury nor does this mean that urinary uranium may not be detected following exposure to concentrations less than this level. All reasonable effort should be made through confinement of radioactive material, ventilation, and good housekeeping to maintain the air-borne concentration of the general atmosphere of a building or workroom as low as practical. The allowable air-borne beta concentration is 44,000 dpm/M^3. The absence of significant quantities of Strontium 90 permits the adoption of this limit based on Ux_1 and Ux_2. (R)

Internal Accumulation

NBS Handbook 52 (MCRP Recommendation on Internal Dose) gives a maximum permissible body burden of 0.02 microcuries of soluble uranium and 0.009 microcuries of insoluble uranium. Constants and formulae published in this handbook were used to obtain a maximum excretion rate from stored uranium of 50 micrograms/day. The control point for removal from exposure to prevent accumulation of body burdens in excess of the above is an excretion rate of 12 micrograms/day. The temporary restriction may be lifted when the excretion rate falls to below 6 micrograms/day as indicated by spot samples or below 12 micrograms/day as indicated by 24-hour specimens. (R)

Contamination Indices

The following contamination indices have been established to minimize the possibilities of exposures in excess of the plant's acceptable limits due to environmental conditions. Since the amount of exposure may very widely among individuals because of personal habits, adherence to contamination indices does not guarantee that no exposures exceeding the plant acceptable limits will be experienced. However, such exposure should be rare, and the chances of any individual's exposure or body burden exceeding the maximum permissible doses are considered remote.

Alpha Contamination

1. Personal Clothing — 4000 c/m (as measured by available instruments)
2. Personal Shoes — 4000 c/m (as measured by available instruments - No limit on bottom of sole)
3. Contamination Clothing - Contamination clothing having an alpha count in excess of 4000 c/m/100 cm^2 should be changed prior to working in an area not requiring respiratory protection.
4. Surfaces - Good housekeeping practices should be followed to prevent the possibilities of significant air-borne contamination due to accumulated uranium materials.

Beta Gamma Contamination

The following indices are levels below which contamination is considered insignificant as a factor in determining an employee's total dose.

	Instrument Reading at Contact	
1. Surfaces	0.75 mrad/hr	(R)
2. Issued Clothing	0.75 mrad/hr	
3. Personal Clothing and Shoes	0.25 mrad/hr	
4. Gloves	3.0 mrad/hr	
5. Issued Shoes		
a. Inside	3.0 mrad/hr	(2610A)
b. Outside	10 mrad/hr	(soles or uppers)

The following indices are levels at which cleaning of personal effects are required: (N)

1. Personal Clothing	0.75 mrad/hr
2. Personal Shoes	3.0 mrad/hr

Any replacement of personal clothing must be made under the provisions of SPP D-5-1.

LABORATORY DIVISION
TECHNICAL PROCEDURES
UNION CARBIDE NUCLEAR COMPANY
A DIVISION OF UNION CARBIDE AND CARBON CORPORATION
PADUCAH, KENTUCKY

Subject: DETERMINATION OF URANIUM IN URINE

A. METHOD

Hexavalent uranium salts in a matrix of fused sodium fluoride give a characteristic yellow-green fluorescence under ultra-violet light. The intensity of fluorescence is a function of the concentration of uranium in the matrix. The fluorescence is measured with a fluorophotometer.

B. APPARATUS AND REAGENTS

1. Reagent grade sodium fluoride of a lot selected for low residual fluorescence.
2. Concentrated hydrochloric acid.
3. Concentrated sulfuric acid.
4. Concentrated nitric acid.
5. ORNL, Q-1165 Fluorimeter.
6. 0.2 ml platinum dishes to be used with the fluorimeter.
7. Multiple fusion device for preparing melts.
8. Several aluminum trays for handling dishes.
9. Pellet maker.
10. Pipets, 0.200 ml.
11. Heat lamps.
12. Forcepts for handling dishes.

C. PROCEDURE

1. Acidify sample by adding about 1 ml concentrated HCl to the usual 100-200 ml sample. For small samples only a few drops HCl are required. Shake sample well and allow to stand at least 5 minutes before aliquoting.
2. Arrange dishes on sample tray and pipet duplicate 0.200 ml aliquots of each sample into platinum dishes.
3. Evaporate to dryness under heat lamps.
4. Place 0.25 g fusion mixture in each dish using the pellet maker. The pellet should be compact and not break up in the dish.
5. Place dishes on the fusion device for fusion. With timer set for 80 second period, proper burner temperature will completely liquify first fusion in 40-45 seconds and the second fusion will be liquid

Approved by: _____

Subject: DETERMINATION OF URANIUM IN URINE

in 35-40 seconds. The annealing flame should allow the sample to just begin to be opaque in 12 to 15 seconds. Too high an annealing flame will result in imperfectly formed phosphors. The dishes should be allowed to cool one full period after leaving the annealing burner before being removed from the fusion device.

6. Allow melts to cool at least 10 minutes and measure fluorescence with the fluorimeter.

7. The fluorimeter is allowed at least a 30 minute warm up before using. During this time the coarse sensitivity is in the "EV off" position and the fine sensitivity is in the zero adjust position. Switch to coarse X1 scale and adjust volt meter zero set. Switch to fine No. 10 scale and with a clean empty dish under the counter, zero the dark current adjustment. Place the reference standard under counter after first switching fine sensitivity up scale to a position which will not allow the pointer to go off scale or "peg" when the reference standard is in place. "Pegging" the volt meter can seriously injure the instrument and must be avoided. With the standard in place set volt meter at preassigned value by means of the appropriate adjustment control in the top left side of the case. Recheck dark current zero and then recheck standard setting until both are found to be in correct adjustment.

8. Place samples in sample wheel and record scale reading for each dish using appropriate sensitivity scale.

9. Average the scale readings of all blank dishes to obtain an average blank.

10. To calculate mg U/liter sample:

    mg U/l = (Sample reading - blank reading) x Machine Factor

11. Remove melt from dishes by inverting and dropping lightly onto the table top. Clean dishes by heating 10 minutes in hot concentrated sulfuric acid, followed by boiling 30 min. in concentrated nitric acid. Rinse thoroughly with distilled water and dry under heat lamps. Make a fusion in each dish and reject as not blank those with a scale reading greater than 2.5. Tap flux from blank dishes onto a piece of clean paper. Avoid contacting the dishes with fingers, etc. and keep under plastic cover until ready for use. Plastic covers are used to reduce airborne contamination and must be in place over samples and blank dishes whenever possible.

D. CALIBRATION

1. The instrument is recalibrated periodically by fusing ten aliquots each from several solutions of known uranium content. The average scale readings are plotted against the concentration in mg U/l.

$$\text{Machine Factor} = \frac{\text{mg U/liter}}{\text{Scale reading}}$$

 Approved by: J. F. Thompson

INTER-COMPANY CORRESPONDENCE

(INSERT NAME) COMPANY CARBIDE AND CARBON CHEMICALS COMPANY LOCATION Post Office Box 748 PADUCAH, KY.

TO LOCATION: H. C. Gardner, M. D. Medical Director

DATE: November 11, 1952

ANSWERING LETTER DATE:

ATTENTION

COPY TO: R. C. Baker
B. E. McDougal
File

SUBJECT: Transmittal of Estimated Schedules for Industrial Hygiene Samples.

Dear Dr. Gardner:

Transmitted herewith are copies of the estimated industrial hygiene schedules for air, mud and water, and urine samples. These schedules are intended to cover all sampling done on a routine basis, and may later be revised as conditions demand.

Very truly yours,

E. G. Brown
Health Physics & Hygiene Dept.

EGBrown/bm

Estimated Schedule for Air Samples

	Location	Contaminant	Avg. No. of Samples per Wk.
Semi-weekly:			
	Feed Plant (C-410)	U	26
	Feed Plant (C-410)	F_2, HF	17
	Micro-Pulverizer (C-400)	U, HF	9
Weekly:			
	HF Neutralizer (behind C-410)	HF	4
	Cleaning areas of Cleaning Building (C-400)	U, HCl, CO Trichlor.	8
	Vaporizing area (C-410)	U, HF	4
	Surge & Waste (C-315)	U, F	8
	Purge & Product (C-310)	U, F	8
	Pump Shop (C-720)	Hg	4
	Training Loop (C-400)	U, F_2, HF, Cl F_3	4
	Stores (C-720)	CO	4
	Garage (C-720)	CO	4
Semi-monthly:			
	Retubing area (C-720)	CaF_2, Ni	2
	Sampling section, lab. (C-720)	U	4
Every other month:			
	Labs	Hg	As required
As required:			
		C Cl_4	
		Zn O	
		Cd	
		$Cl F_3$	

Estimated Schedule for Mud and Water Samples

One water (and one mud, unless otherwise indicated below) will be collected at each sampling point each month.

Big Bayou Creek

1. Halfway between drainage ditch and railroad bridge southeast of water treatment plant. (Distance between bridge and water treatment plant about three-fourths mile.) (Background or blank for samples).

2. At mouth of ditch from holding pond (C-404).

3. At point where creek leaves government property.

4. Bridge near Rossington's store (on Ogden Landing Road).

5. About two miles northeast of Rossington's store, turn right on the first road that leaves Ogden Landing Road after passing Rossington's store. Follow road approximately two miles to the place where the creek runs closest to the road. (Water sample only).

Little Bayou Creek

6. About one-half mile east of the Surge and Waste Building (C-315).

7. Below the bridge on Ogden Landing Road about three-fourths mile northwest of Crabanville.

8. Below the concrete bridge about one mile east of the northern corner of the magazine area.

If positive results (U, F, Beta) are found, samples may be taken at additional points. If negative results exist, some sampling points may be omitted in the future.

Estimated Schedule for Urine Samples

Location	Freq.	No.	U Avg./Mo.	F Avg./Mo.	Hg Avg./Mo.
Feed Plant Operators (C-410)	1 mo.	35	35	35	
Feed Plant Maintenance	1 mo.	45	45	45	
Process Maintenance	3 mo.	50	17	17	
Cleaning Building (C-400)	1 mo.	50	50	50	20
Purge & Product (C-310)	3 mo.	15	5	5	
Surge & Waste (C-315)	3 mo.	15	5	5	
Laboratory (Sampling & Uranium Analysis)	3 mo.	19	8	8	8
Instrument Maintenance	6 mo.	50	8	8	8
Vacuum Pump Shop	6 mo.	20	3	3	3
Other	6 mo.	50	8	8	8
Totals		399	234	234	47

		Avg./Mo.	
Industrial Health Rechecks	about	225	
Recalls	about	45	
Material Releases	about	30	
Total	about	300	F. & U urinalyses
Total	about	50	Hg urinalyses

UNION CARBIDE CORPORATION, NUCLEAR DIVISION

PADUCAH, KENTUCKY

RADIATION EXPOSURE RECORD

Name & Payroll Number JOE T. HARDING - 1812 Social Security No. 408-26-6072

Period of Employment 10/15/52 - 2/26/71

External Radiation Exposure

The exposures to external radiation listed by calendar year are the sums of the interpretations of personnel monitoring film as occupational radiation exposure. The gamma readings are assumed to represent the dose to the whole body and the beta plus gamma readings are assumed to represent the dose to the skin of the whole body. An RBE of 1 is used.

Monitoring Period	γ rems	β+γ rems	Monitoring Period	γ rems	β+γ rems
1955	00.18	00.77	1966	01.47	01.47
1956	00.00	00.00	1967	00.49	00.49
1961	00.09	00.09	1968	00.00	00.00
1962	00.04	00.11	1969	00.00	00.00
1963	00.47	00.47	1970	00.04	00.05
1964	00.81	00.87	1971	00.00	00.00
1965	01.35	01.38			
		TOTAL		04.94	05.70

Internal Radiation Exposure

The dose to body organs as estimated from bio-essay procedures (primarily urinalyses for uranium) is as follows:

Monitoring Period	Urinalyses: Number of Urine Samples	Urinalyses: mg U/liter (Range)	Organ Dose Range (rem)	Remarks
1953	10	0-0.01	< 1	
1954	11	0-0.40	< 1	The maximum of 0.40 mg U/liter was from a brief exposure in a UF_6 fume release. A urine sample on the following day was 0.01 mg U/liter. The maximum excluding the release sample was 0.03 mg U/liter.
1955	10	0-0.04	< 1	
1956	7	0-0.01	< 1	
1957	6	0-0.015	< 1	
1958	12	0.003-0.008	< 1	
1959	18	0.000-0.303	< 1	The maximum of 0.303 mg U/liter was from a brief exposure in a UF_6 fume release. This sample and one other (0.257 mg U/liter) on same day gave indicated excretion rates of 124 and 148 µg U/day, respectively. Two days later a urine specimen was 0.004 mg U/liter and 4 µg U/day. The maximum excluding the release samples was 0.042 mg U/liter.
1960	5	0.001-0.012	< 1	
1961	1	0.001	< 1	
1962	None			
1963	7	0.001-0.036	< 1	
1964	10	0.001-0.010	< 1	
1965	3	0.003-0.012	< 1	
1966	5	0.003-0.011	< 1	
1967	None			
1968	None			
1969	2	0.006-0.013	< 1	
1970	None			
1971	1	0.005	< 1	

B. E. MacDougal
Safety & Environmental [illegible]

March 13, 1972
RFM:reh

Radiation Protection Guides:

External

Type of Exposure	Period	Dose (rem)
(a) Whole Body (Gamma)	Accumulated Dose	5 X Number of Years Beyond Age 18
	13 Weeks	3
(b) Skin of Whole Body (Beta + Gamma)	Year	~~30~~ 15
	13 Weeks	~~10~~ 5

*Internal

Type of Exposure	Period	Dose (rem)
Body Organs	Year	15
	13 Weeks	5

*Dose is determined from stored uranium as indicated by urinary uranium excretion rates and by whole body counting.

APPENDIX F

Sampling Counting Procedures

and

Results of Mock Up Test

Sampling Counting Procedures and Results of Mock Up Test

1. General

The air sampling and sample analysis program was conducted to measure air concentrations of UO_2F_2 and HF, the hydrolysis products of UF_6, at several locations in the transfer room of Building C310 and of Building C315. The program contained a number of subparts that differed in the sampling instruments employed, the analytical techniques used, and objectives. Briefly, they were: (1) Three high volume (≅ 20 cfm) air samplers with cellulose paper filters were operated simultaneously while located about 5 feet above the floor in the approximate centers of equal areas of each room to collect airborne UO_2F_2. Analysis was by radioactivity counting. The purpose was to measure 8-hour average concentrations of general room air; (2) Three low volume (≅ 1 cfm) air samplers were placed on either side and over the operator's work station, approximately at breathing level, to measure short period (15-minute) peak concentrations of UO_2F_2 in air during and immediately following the disconnect operation.

2. Sampling Rationale

For several of the sampling periods, a personal sampler (sometimes referred to as a lapel sampler) was substituted for one of the low volume samplers while awaiting the arrival of additional low volume sampling pumps. The personal samplers operate at a sampling rate of approximately 1.1 lpm instead of 1 cfm. For all low volume sampling, a cellulose acetate membrane (millipore AA) was used for UO_2F_2 collection. Analysis was by

radioactivity counting; (3) Three low volume air samplers, located as described in (2), above, were used to evaluate short period (5-min.) concentrations of UO_2F_2 in air at the disconnect operator's station during and following the planned release of 20 mg of UF_6. Additionally, this same array of samplers was used to measure 15-min. background concentrations of UO_2F_2 for comparison purposes to correct the 5-min. release measurements.

The purpose of these experiments was to verify the validity of sampling and analytical procedures by measuring airborne concentrations during the release of a known amount of UF_6 in a simulated disconnect. Analysis of the sample filters was by radioactivity counting; (4) Personal samplers were used to measure the 8-hr. exposure of disconnect operators to airborne uranium. As a general rule, each operator who participated in this program performed only one or two disconnects during the entire shift and the disconnect procedures occupied only a small fraction of each operator's work period. The remaining duties were said to be without significant uranium exposure.

The objectives of personal sampling were to measure average operator 8-hr. exposures to uranium by methods recommended and approved by NIOSH and OSHA and to provide a firm basis for evaluating the health significance of whatever short period concentrations might be found during 15-min. disconnect low volume air sampling.

Samples of UO_2F_2 were collected on Millipore AA membrane filters at a rate of approximately 1.5 lpm and analysed by radioactivity counting; (5) Fritted glass bubbles were used to sample for gaseous hydrogen fluoride. They were located in the same positions as was described for the breathing zone low volume samplers. Sampling rate was about 1.5 lpm and sampling period was 30-min. Analysis was by specific ion electrode for fluoride ion. The sampling and analytical methods utilized conformed closely with those recommended by NIOSH for measuring HF in air. Slight deviations from the NIOSH analytical method were made in recognition of the absence of interferences at Paducah that might be encountered in other industrial atmospheres. These slight methodological deviations did not adversely affect the accuracy or sensitivity of the analysis in any way. As hydrogen fluoride is one of the hydrolysis products of UF_6 in air (UO_2F_2 is the other), the objective of HF sampling was to measure exposure to uranium by an entirely independent method to assist in evaluating the reliability and accuracy of the results obtained by UO_2F_2 sampling and analysis.

To prevent the bubbler results from being affected by the presence of fluoride ion derived from UO_2F_2, the other hydrolysis product, the bubbler air intake was preceded by a Millipore AA filter to remove any solid fluoride that might be present in the air. Two disconnect operations were sampled; each with two breathing zone samplers.

The sampling and analytical program was carried out under Dr. Melvin First's supervision exactly as he had recommended with two exceptions: (1) cellulose filter papers were used for high volume sampling instead of the all-glass HEPA filter papers recommended by Dr. First, because of the analytical counting procedures have been standardized for cellulose filters but not for glass paper filters. The choice of all-glass HEPA filter paper was made because it is known to be the highest efficiency filter commercially available. The particle collection efficiency of the cellulose filter papers that were used is somewhat less when the clean filter paper is first placed in service, but as it picks up dust from the air it rapidly increases its efficiency to a value close to that of the all-glass HEPA filter. Therefore, over an 8-hr. sampling period, the difference in total particle collection between cellulose and HEPA filter papers is, at worst, only a few percent. Therefore, Dr. First agreed with the substitution. The advantages in time saving and man power conversation associated with using the standard cellulose paper sampling routine were judged to be far more important than a possible loss of a few percent in measurement accuracy, and the use of cellulose filter papers for high volume sampling was, therefore, approved; (2) It was intended that all operators wearing personal sampling devices would be under constant surveillance throughout the shift by one or another member of the sampling team, but manpower resources proved insufficient and for some parts of each shift, operators were absent from the

transfer room and not under immediate supervision. There is no reason to believe the samplers were adversely affected by anything the operators might have done when not under observation and, in any event, it will be possible to verify the results of personal sampling with a synthetic 8-hr. average exposure reconstructed from the results of high volume and low volume sampling with a proper time allocation applied to the results from each.

The total sampling period extended was from midnight April 1/2 to noon April 3. It covered all three shifts and both transfer rooms (C310 and C315).

3. Source Verification Test

To eliminate the possibility of any change in the pigtail purging system i.e., higher purge efficiency in contrast to the 1950's, a source extraction and release method was used. Several 20 mg UF_6 samples were obtained to be released at the exact disconnect point (note Figure 9) The preparation of the source material was examined and a source verification test applied to the samples to assure that the U tube indeed contained 20 mg of UF_6.

a. Preparation of Source Material for Controlled UF_6 Releases

At room temperature (73 F, 22.8 C) UF_6 has a vapor pressure of 97mm. A source of pure UF_6 is attached to a vacuum manifold and the connecting lines are evacuated and warmed with a propane

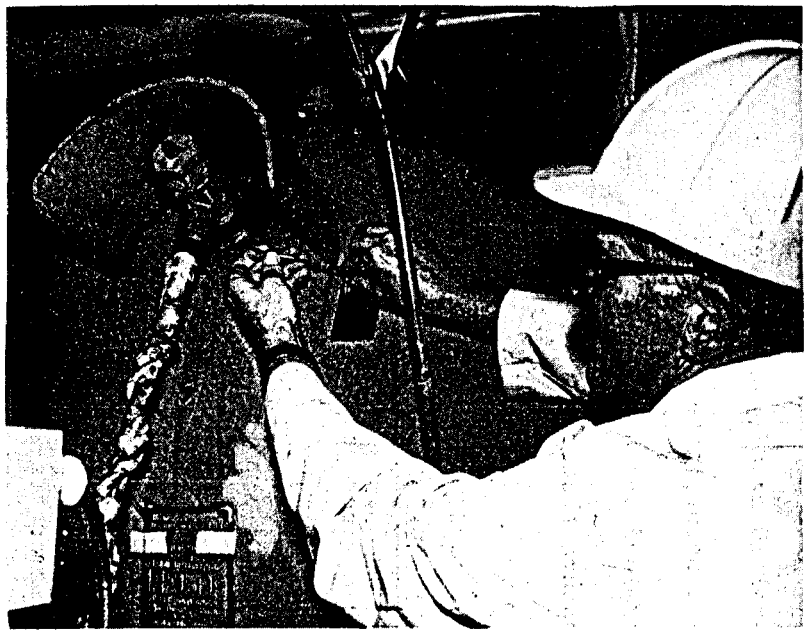

Figure 9 Disconnect Point

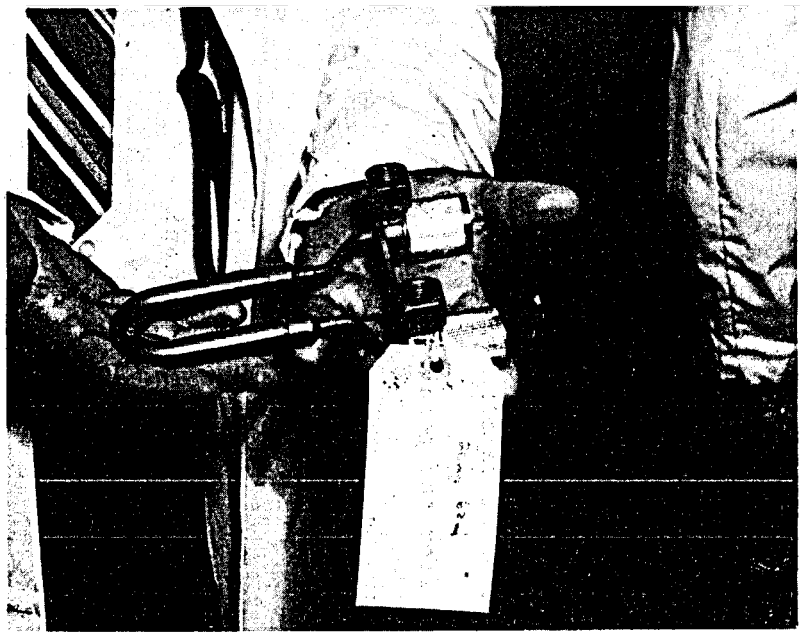

Figure 10 U Tube Containing UF_6 Source

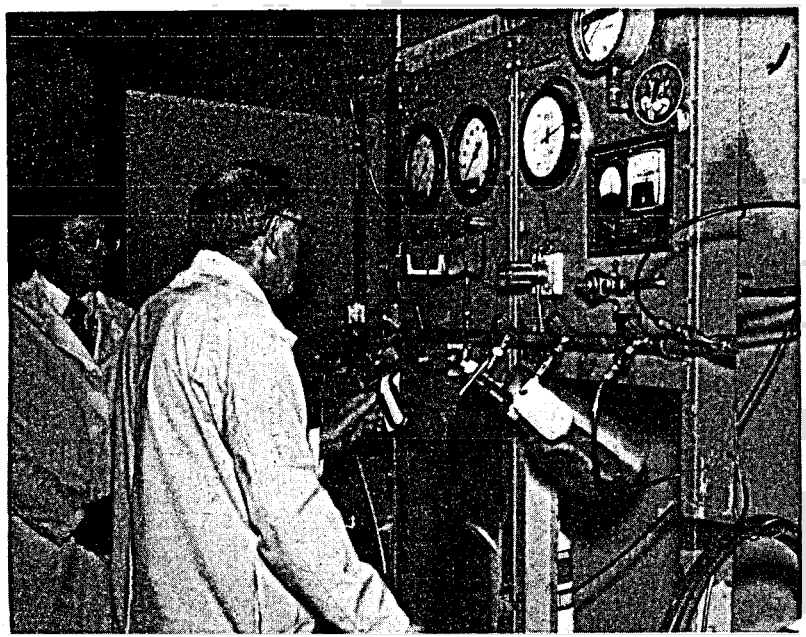

Figure 11 Equipment Panel "Loading" UF_6 Source

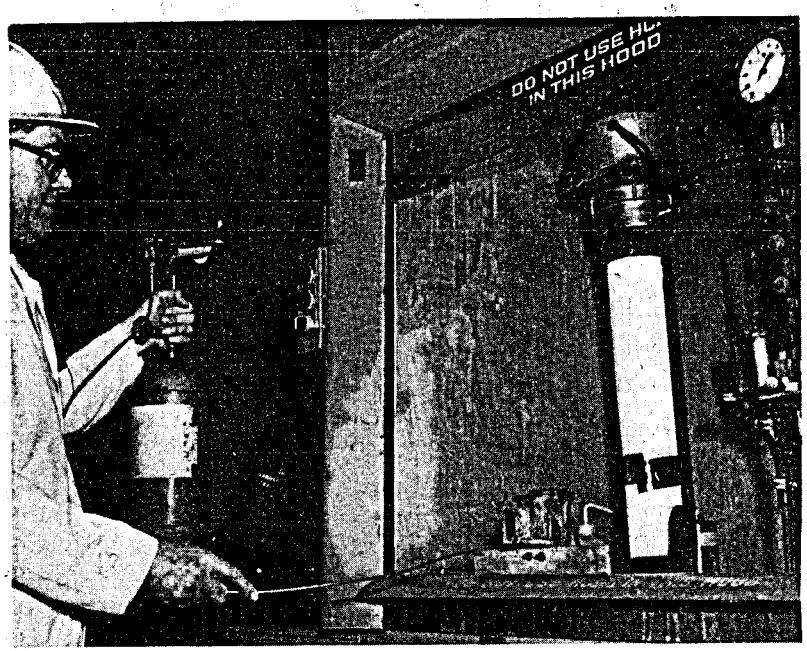

Figure 12 Verification Test Equipment

torch to pump away moisture. The full vapor pressure of the container of UF_6 is observed using a calibrated pneumatic manometer with a range 0-100 torr.

Copper sample tubes in a U configuration fitted with Hoke HAP bellows valves were used to contain the UF_6 (Note Figure 10). These tubes are normally used to sample process streams for U isotopic analysis. The tubes were acid cleaned, dried and passivated with 300 mm F prior to use. The internal volume of the tubes was measured by filling with water from a graduated burette with both bellows assemblies removed. The average volume was found to be 17 cc $\pm$ 0.5 cc.

UF_6 was charged into the tubes from a container of pure UF whose vapor pressure was checked just prior to use to assure that air in leakage or UF buildup had not occurred. A last minute decision was made to discharge 20 milligrams UF_6 for all controlled releases. The sample tube was attached to a vacuum manifold, evacuated and warmed with propane torch to facilitate pump-down. The tubes were charged with UF_6, re-evacuated and then charged to 70 torr (Note Figure 11) and slowly brought down to 62 torr pressure. Contained UF_6 is calculated as follows;

$$\frac{17}{22,400} \times \frac{273}{295.8} \times \frac{62}{760} \times 352 \times 1000 = 20.1 \text{ milligrams}$$

Releases were accomplished by pressuring the UF_6 tube with dry air (20 ppm moisture) from a 5 liter metal sample bulb and slowly

opening the tube valves to allow UF_6 to flow out through a 1/8" od metal tube coupled to the U tube with a Dalton coupling. On contact with atmospheric moisture UF_6 reacts rapidly $UF_6 + 2H_2O_2 = UO_2F_2 + 4HF$. UO_2F_2 is particulate and collectible on filter media. All releases were made within 1 hour of filling to minimize UF losses in the tubes.

Assays involved were:

C315: Normal UF_6 1014 dpm/milligram
C310: Paducah Product UF_6 1528 dpm/milligram

Note that activities are per milligram UF_6.

b. Verification Test Method and Results

For each test, four U tubes were filled with UF_6 and one from this group selected at random for verification. The controlled source verification release experiments were performed to confirm that quantitative release of UF_6 did occur and to permit a verification that the radiometric methods used would account for the released amount within reasonable limits. The UF_6 was released from the tube held below a cardboard "chimney" at the top of which was an operating high-volume sampler with a four-inch filter. In concept, this arrangement should have trapped all the UO_2F_2 and would have been indicative of the amount released if all UF_6 had been converted to particulate forms. Figures 12 and 13 are photographs of this arrangement.

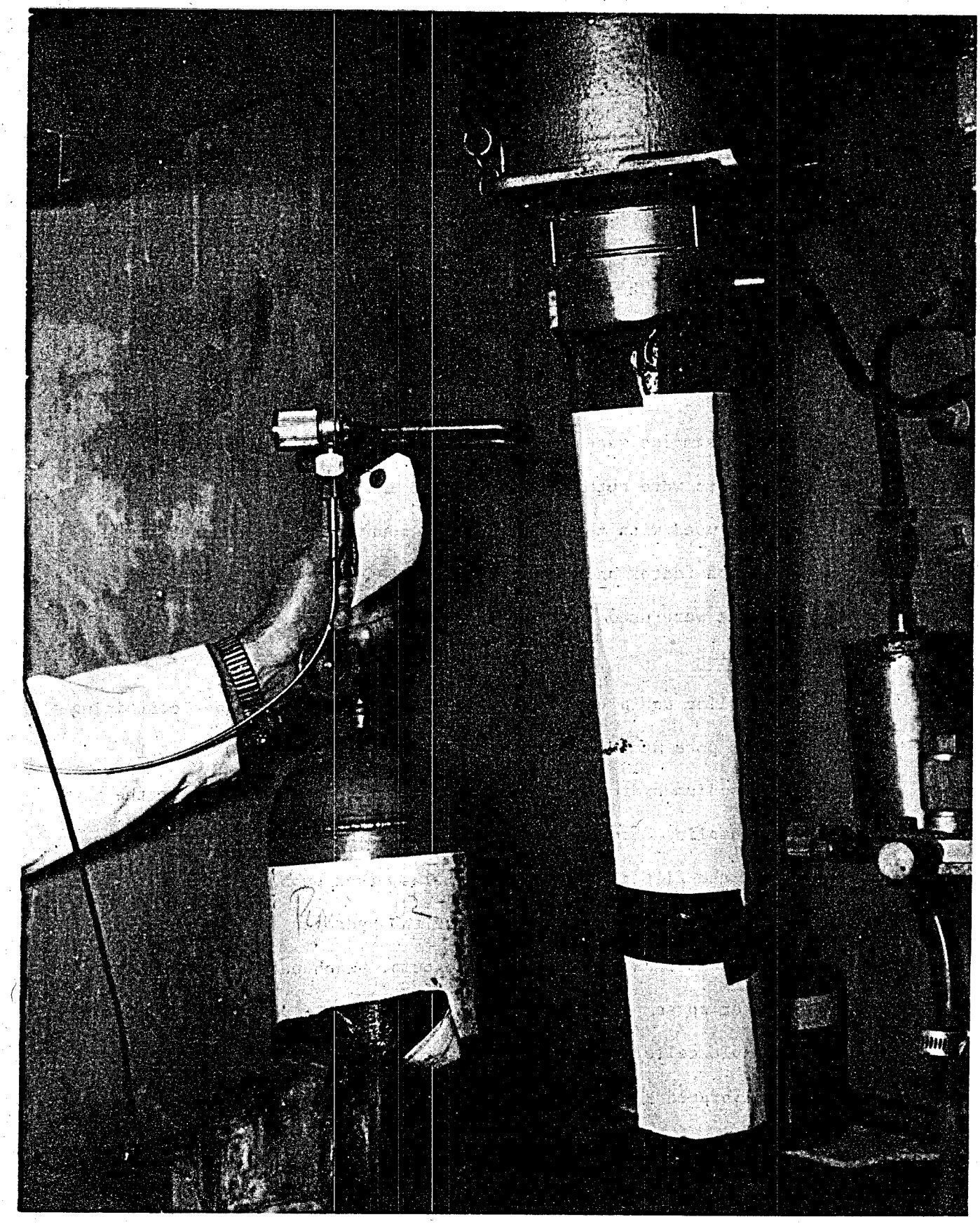

Figure 13 – UF_6 Release Tube and Chimney and Sampler for Collecting UF_6 in Verification Experiment

Results of the verification test, in which 20 mg of UF_6 was released at the base of a short chimney sealed to a high volume sampler at the upper end, are shown in Table 3. Eight sectors cut from the four-inch sample filter were individually counted on the Union Carbide parallel plate counter (Temetec) with a 50% geometry. The self absorption factor for Whatman 41 paper for high counting rates was applied in calculating the alpha particle activity.

The same samples were also counted on PNL scintillation counters. The sectors were cut in two to permit them to be nested in the planchet used with the scintillation counters. The Union Carbide absorption factor and the stated efficiency of 2.55 disintegrations per count were used in determining the activity.

4. HF Sampling

The sampling equipment consisted of a 37 mm filter holder containing a 0.8 um pore membrane filter, a bubbler containing 10 ml, 0.1 normal sodium hydroxide, and the sample vacuum pump used for the lapel sampling discussed earlier. The sampled air was first drawn through the filter to remove particles, then bubbled through the sodium hydroxide solution to remove the hydrogen and fluoride ions and then was exhausted through the pump. Each pump had a built-in flowmeter so sample flow rate could be visually monitored throughout the sample collection. The flow rate through each sampling assembly was calibrated before use with a calibrated rotameter. The flow

Figure 14 — Typical Breathing Zone Sampler Locations

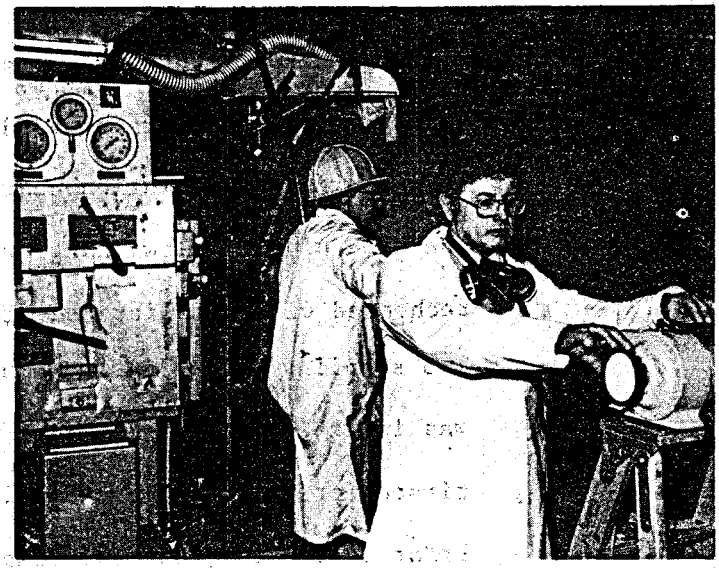

Figure 15 — Hi Volume Sampler Location

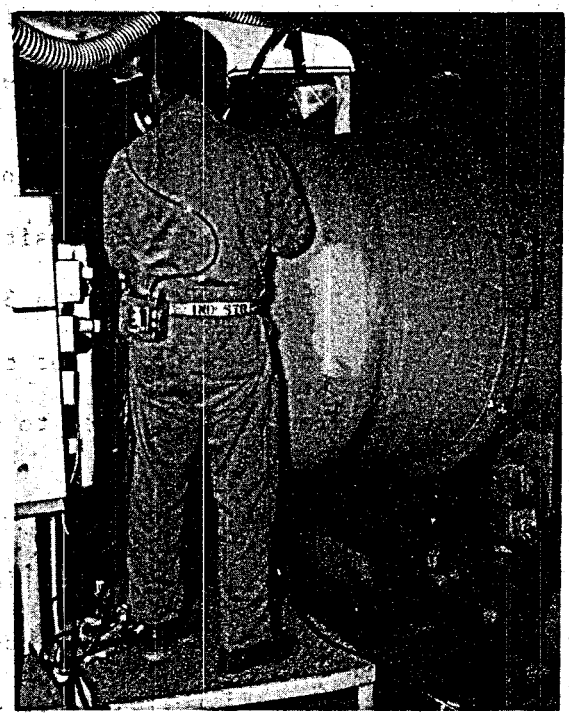

Figure 16 — Worker Equipped with Lapel Sampler

rate was constant during all sampling runs except run 1. In this case, the flow rate was decreased because the bubbling sodium hydroxide solution nearly overflowed the bubbler vessel. The time of this flow change was noted and the flow was rechecked with a calibrated flowmeter after the run.
Two sampling assemblies were used for each run. Each run was initiated just prior to a pigtail disconnect and continued for several minutes following the disconnect.
Prior to the run, the two sampling assemblies were situated on opposite sides of the vent hood at about the elevation of the operator's head and at essentially the same location as the breathing zone sampling heads shown in Figure 14. Both sampling assemblies were operated simultaneously.

Two runs were completed in the 315 Building (run 1 at cylinder position #3 and run 2 at cylinder position #2). Run 3 was begun at cylinder position #4 in the 310 Building but was aborted because the disconnect did not take place. The samples from this last run were analyzed to determine the background air concentration of HF.

The sample analysis was performed by Union Carbide personnel under the constant supervision of the Battelle counting specialist. The analytical method followed was essentially as prescribed by the NIOSH method S176. Each sample was diluted to a known volume (25 ml), the solution slightly acidified, and then stabilized with a buffer solution.

The pH was checked to insure hydroxyl ion was absent so as to not interfere with the analysis. The fluoride ion electrode was used for the analysis.

5. Sampling Equipment

a. Room Air Samplers. The room air samplers (Figure 15) were Radeco high volume samplers with a four-inch disc of Whatman 41 paper. Four of these were operated in Building 315 and three were operated in Building 310. Prior to the series of sampling experiments, each sampler was calibrated with a Whatman 41 filter in place on the filter support head. The flow standard was a calibrated venturi furnished by the Radeco Company. These samplers were initially set to operate in the 16 to 20 ft /min range. Usually as sampling progressed, the flow would drop and needed frequent adjustment to maintain the flow as originally set. However, the adjustment could no longer be maintained after four or five hours. The flow near the end of the run was recorded. The total sample was calculated taking into account an average flow, which assumes a linear decrease in flow over the period of decreasing flow.

b. Breathing Zone Samplers. The breathing zone sampler was Millipore Corporation's three-piece cassette which holds a 37 mm diameter 0.8 micrometer pore size membrane filter and a porous backing pad. The filter holder was of the open face type. On the vacuum side of the filter holder was inserted a flexible tubing adapter which housed a critical orifice. The sampling head was connected to a sampling pump by a length of Tygon tubing. The sampling pump had a vacuum gage and when the appropriate vacuum was obtained in the sampling line, the flow through the filters remained constant (in as much as the filter did not load up excessively). Loading of dust did not appear to be a problem during any of the breathing zone sampling. Initially four breathing zone samplers were used, two in each building. The sampler was positioned in the breathing zone near the pigtail valve (Figure 14). The flow through the sampler was calibrated in the laboratory using a rotameter upstream of the filter inlet. Recalibrations were performed using a PNL standardized rotameter following the entire testing program with three filter holders to determine if there might be significant differences in flow caused by nonuniformities in the filter media. This proved not to be the case. The filters were uniform and the flow was not greatly dependent on individual filter differences.

c. Personal (Lapel) Samplers. The lapel samplers (Figure 16) consisted of a 37 mm open-face plastic cassette. The 0.8 micrometer pore size membrane filter with the same filter backing used on the breathing zone samplers. The sampling pump was an MSA personal sampling pump furnished by the Harvard Air Cleaning Laboratory. The flow through these samplers was calibrated using a calibrated rotameter furnished by Harvard. Again, a filter holder was placed between the rotameter and the pump and an adapter was fixed to the front part of the filter holder to make it into an inline filter holder.

d. Hydrofluoric Acid (HF) Fume Sampler. (Sampling equipment was adequately described previously.)

6. Counting

The Counting equipment used at Union Carbide consisted of Nuclear Measurements Corporation proportional gas (P-10) flow counters. The counters are identified as PCC-11T/DS-2 combination and PCC-51. These are two-pi counters, with a nominal geometry of approximately 50%. The chamber used for the four-inch filters was the PCC-51; the chamber used for the 37 mm filters was PCC-11T. Each filter was placed on a clean planchet for counting and the chamber was purged for 100 seconds before the count. Standardized sources

were used to determine the efficiency of the counter. A factor was also applied to account for the self absorption of the Whatman 41 paper. The self-absorption factor had been determined by Union Carbide by counting uranium-containing samples of various activities, then determining the actual amount of uranium present through digestion of the filters and recounting the extracted uranium as a nearly weightless source.

PNL alpha counters are General Electric Model 9747109G scintillation counters. The four counters have nearly identical efficiencies but each has a slightly different background, ranging from about 0.2 to 0.4 c/m. The counting efficiency determined with standardized sources is 2.55 disintegrations per count. The Union Carbide self-absorption correction for Whatman 41 filter media was applied to the high volume filters counted on the scintillation counters.

7. Results

   a. Radioactivity Determinations. The results required from the measurements is the activity (alpha particles emitted per minute) in each meter of air sampled.

from the measurements is the activity (alpha particles emitted per minute) in each meter of air sampled. The activity can be converted readily to milligrams of uranium per m^3 using the nominal dpm/mg alpha decay rate of uranium. The depleted (tails) uranium has a nominal alpha disintegration rate of 900 dpm/mg and the enriched product has an alpha disintegration rate of 2200 dpm/mg uranium (Union Carbide conversion factors). The sample counting rate was corrected for the background count, the necessary efficiency and self absorption factors applied to yield the activity in the sample. The total volume of air sampled was calculated from the flow rate with a linear correction made for the decreasing flow rate during the period when the flow could no longer be maintained by adjustment. (This was needed only for the high-volume samplers using Whatman 41 paper.) The results of the analyses and calculations are shown in Table 1 (12 pages) for the Union Carbide measurements.

Similar data for the PNL determinations for the same filters are shown in Table 2 (4 pages), but without repeating the common data relating to sample type, duration of sampling, average flow, and volume sampled.

TABLE 1

AIR SAMPLING AND COUNTING DATA

BUILDING: C310

SHIFT: Graveyard 4-2-80

Location & Condition	Sample Number	Type Sample	Sample Duration (min)	Average Flow (cfm)	Volume Sampled (m3)	Gross cpm	Net cpm	Net dpm	dpm/M
O H 1	H-1	HVOL (high volume)	410	17.4	202	75.2 70.4 $\bar{x}$=72.8	36	324	1.6
O H 2	H-2	HVOL	410	17.4	202	61.2 50.4 48 $\bar{x}$=53.2	61	231	1.6
O H 3	H-3	HVOL	410	17.4	202	61 63 $\bar{x}$=62	72	274	1.4
O B 1 (pump #2)	B-1	BZ (breathing zone)	45	0.49	0.6	1.1 0.7 $\bar{x}$=0.9	0.3	1	1.7
O B 2 (pump #3)	B-2	BZ	38	0.47	0.5	1.1 0.7 $\bar{x}$=0.9	0.3	1	2.0
O L 1	L-1	Lapel	449	0.067	0.85	0.85 0.9	0.29	0.87	

NOTE: Purge @ 0047, Disconnect @ 0051, Door Open 0055, Door Closed 0110, Open 0113, Closed 0118. Cylinder No. 2043
Cylinder Position #3
H-1 counted @ 0210 on 4/3/80, Minimum Decay Time to 0705 on 4/2/80 = 19 hrs 5 min

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315
SHIFT: Graveyard 4-2-80

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
5 H 1	H-4	HVOL	327	17.9	166	31,32 x=31.5	35	132	0.8
5 H 2	H-5	HVOL	327	17.9	166	29.6,21.4	28	134	0.8
5 H 3	H-6	HVOL	327	17.9	166	14.0,20.4	18	105	0.6
5 H 4	H-7	HVOL	324	17.9	164	12.6,14.0	13	78	0.5
5 L Harvard #16	L-2	Lapel	74	0.067	0.14	0.5 0.7	0	0	N.D.
5 B 1 (pump #1)	B-3	BZ	32	0.45	0.43	0.8 0.5	0.06	0.18	0.4
5 B 2 (pump #4)	B-4	BZ	32	0.48	0.13	0.8 1.0	0.35	1.0	7.7

NOTE: Pigtail open ended directly beneath 5 B 2 due to loose plug. Disconnect at 0012, Cylinder Position #2
Vent reading 1123 fpm opening approximately 6.5"x22"
UC routine air sample pulled at 0645

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Day Shift 4-2-80

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
5 H 1 (pump S/N HV-1)	H-8	HVOL	307	18.0	156	13.0,12.4	12	74	0.5
5 H 2 (pump S/N 771)	H-9	HVOL	307	18.0	156.	12.0,13.0	12	74	0.5
5 H 3 (pump S/N 1000)	H-10	HVOL	309	18.0	158	12.2,10.0	11	64	0.4
5 H 4 (pump S/N 1001)	H-11	HVOL	309	18.0	158	9.4,6.8	7	56	0.4
NOTE: Sampler positions same as C315 Graveyard, 4-2-80 for above									
5 B 1 (pump #1)	B-7	BZ	31	0.45	0.43	0.6 0.8	0.05	0.15	0.3
5 B 2 (Harvard Lapel pump #9)	B-6	BZ	31	0.067	0.06	0.6 0.6	0	--	N.D.

NOTE: Disconnect at 1111 hrs, reconnect complete at 1124 hrs

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Day Shift 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
5 B 3 (pump #4)	B-5	BZ	31	0.47	0.41	0.6 0.4	--	--	N.D.
5 L 1 Harvard pump #12 (Worn by employee)	L-3	Lapel	273	0.067	0.52	1.9 1.4	1.2	3.6	6.9
5 L 2 Harvard pump #14 Worn for following UF_6 planned releases	L-4	Lapel	273	0.067	0.52	0.9 1.0	0.41	1.23	2.4
NOTE: Later assigned to Employee, C310 swing, 4-2-80									
The following were planned releases (estimated 20 mg) Lines were purged 4-times with subsequent 4-5 minute waiting period									
Release #1 (Background samples)									
5 B 1 (pump #6)	B-10	BZ	5	0.45	0.07	0.7 0.8	0.16	0.48	6.9
5 B 2 (pump #4)	B-9	BZ	5	0.47	0.07	0.5 0.8	0.06	0.18	2.6

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Day Shift 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
5 B 3 (pump #1)	B-8	BZ	5	0.45	0.07	0.4 0.8	0	--	N.D.
Release @ 1141 hrs (doors closed for B-11)									
5 B 3 (pump #1)	B-11	BZ	55	0.45	0.74	0.5 0.4	0	--	N.D.
Release #2 @ 1317 hrs doors open									
5 B 1 (pump #6)	B-12	BZ	5	0.45	0.63	0.5 0.4	0	--	N.D.
5 B 2 (pump #4)	B-13	BZ	5	0.45	0.63	0.5 0.4	0	--	N.D.
5 B 3 (pump #1)	B-14	BZ	5	0.45	0.63	0.5 0.5	0	--	N.D.

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Day Shift 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
Release #3 @ 1325 doors opened									
5 B 1 (pump #6)	B-15	BZ	8	0.45	0.11	0.4 0.3	0	--	N.D.
5 B 2 (pump #4)	B-16	BZ	8	0.47	0.11	0.4 0.4	0	--	N.D.
5 B 3 (pump #1)	B-17	BZ	8	0.45	0.11	0.5 0.3	0	--	N.D.
B-15,B-16-17 changed at 1330 hrs									
5 B 1 (pump #6)	B-19	BZ	12	0.45	0.16	0.5 0.3	0	--	N.D.
5 B 2 (pump #4)	B-18	BZ	12	0.47	0.17	0.1 0.9	0	--	N.D.
5 B 3 (pump #1)	B-20	BZ	12	0.45	0.16	0.5 0.5	0	--	N.D.

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Swing Shift 4-2-80

Location & Condition	Sample Number	Type Sample	Sample Duration (min)	Average Flow (cfm)	Volume Sampled (m3)	Gross CPM	Net CPM	Net DPM	DPM/M
5 H 1 (pump S/N HV-1)	H-15	HVOL	420	17.2	205	27,26.6	30	172	0.8
5 H 2 (pump S/N 771)	H-16	HVOL	419	17.2	204	22,26.6	27	154	0.8
5 H 3 (pump S/N 1000)	H-17	HVOL	419	17.2	204	21.4,21.0	23	133	0.7
5 H 4 (pump S/N 1001)	H-21	HVOL	420	17.2	205	17.8,18.6	19	112	0.5

NOTE: Sample positions same as C315 Graveyard and Day Shift 4-2-80 for above. Doors Open.

Disconnect for station #1 @ 1901 hrs. Note that filter paper on HVOL sample H-21 was replaced before start

Disconnect #1									
5 B 1 (pump #6)	B-25	BZ	34	0.45	0.46	0.6 0.9	0.17	0.51	1.1
5 B 2 (pump #4)	B-22	BZ	34	0.47	0.48	0.1 0.3	0	--	N.D.

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C315

SHIFT: Swing 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
5 B 3 (pump #1)	B-24	BZ	34	0.45	0.46	0.2 0.4	0	--	N.D.
Disconnect for station #2 @ 2228 hrs, doors open									
Disconnect #2									
5 B 1 (pump #6)	B-26	BZ	32	0.45	0.43	0.5 0.6	0	--	N.D.
5 B 2 (pump #4)	B-60	BZ	32	0.47	0.45	0.3 0.7	0	--	N.D.
5 B 3 (pump #1)	B-61	BZ	32	0.45	0.43	0.4 0.4	0	--	N.D.
5 L 1 (pump 563) WA Weston	L-8	Lapel	383	0.057	0.06	0.6 0.4	0	--	N.D.

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C310

SHIFT: Swing 4-2-80

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
O H 1 (pump S/N 772)	H-12	HVOL	445	17.0	214	38.2,38.4	43	165	0.8
O H 2 (pump S/N 2000)	H-13	HVOL	443	17.0	213	40.8,37.8	45	169	0.8
O H 3 (pump S/N 770)	H-14	HVOL	442	17.0	213	35.4,40.4	42	161	0.8
Disconnect for position #4 @ 1657 hrs									
O B 1	B-30	BZ	9	0.48	0.13	0.3 0.1	0	--	N.D.
O B 2	B-27	BZ	9	0.48	0.13	1.4 1.1	0.7	2.1	16.1
O B 3	B-31	BZ	9	0.48	0.13	0.3 0.3	0	--	N.D.

NOTE: 1658 hrs, power lost on south HVOL (H-12) and south BZ, on at 1703 (5 minute loss counting time)

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C310

SHIFT: Swing 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
0 L 1 Worn by operator	L-4	Lapel	420	0.067	0.8	0.9 1.0	0.41	1.23	1.5
NOTE: Also worn by employee on C315 Swing									
Release #1 @ 1741 hrs									
0 B 1	B-32	BZ	14	0.48	0.19	0.3 0.5	0	--	N.D.
0 B 2	B-33	BZ	14	0.48	0.19	0.3 0.3	0	--	N.D.
0 B 3	B-34	BZ	14	0.48	0.19	0.4 0.1	0	--	N.D.
0 L 2 Worn by employee performing planned releases	L-6	Lapel	60	0.07	0.12	0.5 0.5	0	--	N.D.
0 B 1	B-36	BZ	14	0.48	0.19	0.8 0.6	0.12	0.36	1.9
0 B 2	B-37	BZ	14	0.48	0.19	0.7 0.4	0	--	N.D.

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C310

SHIFT: Swing 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
0 B 3	B-35	BZ	14	0.48	0.19	0.4 1.0	0.11	0.33	1.7
Release #2 @ 1803 hrs, doors open									
0 B 1	B-38	BZ	6	0.48	0.09	0.8 0.1	0	--	N.D.
0 B 2	B-39	BZ	6	0.48	0.09	0.3 0.6	0	--	N.D.
0 B 3	B-40	BZ	6	0.48	0.09	0.7 0.6	0.053	0.16	1.8
Release #3 @ 1812 hrs									
0 L 1	L-7	Lapel	9	0.48	0.13	0.3 0.6	0	--	N.D.
0 L 2	L-5	Lapel	9	0.48	0.13	0.7 0.8	0.17	0.51	3.9

TABLE 1 (CONTINUED)

AIR SAMPLING AND COUNTING DATA

BUILDING: C310

SHIFT: Swing 4-2-80 (cont'd)

LOCATION & CONDITION	SAMPLE NUMBER	TYPE SAMPLE	SAMPLE DURATION (MIN)	AVERAGE FLOW (CFM)	VOLUME SAMPLED (M3)	GROSS CPM	NET CPM	NET DPM	DPM/M
O B 1	B-41	BZ	9	0.48	0.12	0.4 0.8	0	--	N.D.
Background No release or disconnect									
O B 1	F-1	BZ	16	0.48	0.23	0.2 0.5	0	--	N.D.
O B 2	F-2	BZ	16	0.48	0.23	0.3 0.4	0	--	N.D.
O B 3	F-3	BZ	16	0.48	0.23	0.6 0.3	0	--	N.D.
Disconnect #2 @ 2100 hrs, position #3									

TABLE 2

SUMMARY OF DATA FROM PNL COUNTING OF AIR SAMPLES

(Data are entered in the same sequence as used for the Union Carbide counting results. See Table 1 for additional description of the sample flow rate and total volume sampled.)

SAMPLE NO.	COUNTER USED	DURATION OF COUNT, min.	GROSS CPM	CPM CORRECTED FOR BG.	DPM SAMPLE	DPM PER M^3
H-1*	1	100	4.48	4.16	262	1.3
H-2*	2		5.04	4.86	307	1.5
H-3*	3		6.57	6.19	391	1.9
B-1	4		0.36	0.18	0.46	0.77
B-2	1		0.66	0.44	1.12	2.24
L-1	3		0.86	0.48	1.22	1.43
	4 (recount)		0.87	0.69	1.76	2.07
H-4*	1		1.95	1.63	103	0.62
H-5*	2		1.50	1.32	83	0.50
H-6*	3		1.87	1.49	94	0.57
H-7*	4		2.27	2.08	131	0.80
L-2	1		0.35	0.03	0.08	0.36
B-3	2		0.34	0.16	0.41	0.95
B-4	3		0.64	0.26	0.66	5.0
H-8*	1		0.62	0.30	19	0.12
H-9*	2		0.67	0.49	31	0.20
H-10*	3		0.83	0.45	28	0.18
H-11*	4		0.64	0.46	29	0.18

(All samples were counted for 100 minutes)

* An aliquot of 0.157 of filter was counted.

TABLE 2 (CONTINUED)

SUMMARY OF DATA FROM PNL COUNTING OF AIR SAMPLES

SAMPLE NO.	COUNTER USED	DURATION OF COUNT, MIN.	GROSS CPM	CPM CORRECTED FOR BG.	DPM SAMPLE	DPM PER M^3
B-7	1	100	0.29	(0.03)	--	N.D.
B-6	4		0.28	0.10	0.26	0.63
B-5	3		0.40	0.02	0.05	0.12
L-3	2		1.14	0.96	2.45	4.7
L-4			0.42	0.24	0.61	1.2
B-10	4		0.24	0.06	0.15	2.1
B-9	3		0.39	0.01	0.03	0.43
B-8	2		0.24	0.06	0.15	2.1
B-11	1	(All samples counted for 100 minutes)	0.31	(0.01)	--	N.D.
B-12	2		0.14	(0.04)	--	N.D.
B-13	3		0.45	(0.06)	--	N.D.
B-14	4		0.12	(0.06)	--	N.D.
B-15	1		0.44	0.12	0.31	2.8
B-16	2		0.26	0.8	2.04	18.5
B-17	3		0.51	0.13	0.33	3.0
B-19	1		0.35	0.03	0.08	0.5
B-18	4		0.14	(0.04)	--	N.D.
B-20	2		0.19	(0.01)	--	N.D.
H-15*			1.39	1.08	68	0.33
H-16*			0.96	0.78	49	0.24
H-17*			0.79	0.41	26	0.13
H-21*			0.64	0.46	29	0.14

* An aliquot of 0.157 of filter was counted.

N.D. Not detectable.

TABLE 2 (CONTINUED)

SUMMARY OF DATA FROM PNL COUNTING OF AIR SAMPLES

SAMPLE NO.	COUNTER USED	DURATION OF COUNT, MIN.	GROSS CPM	CPM CORRECTED FOR BG.	DPM SAMPLE	DPM PER M^3
B-25		100	0.36	(0.02)	--	N.D.
B-22			0.40	0.08	0.20	0.42
B-24			0.32	0.14	0.36	0.78
B-26			0.20	0.02	0.05	0.12
B-60			0.18	(0.14)	--	N.D.
B-61			0.25	0.07	0.18	0.19
L-8			0.13	(0.05)	--	N.D.
H-12*			9.11	8.79	555	2.59
H-13*			9.63	9.45	596	2.80
H-14*			9.55	9.17	579	2.72
B-30	3		0.30	0.08	0.20	1.53
B-27	2		0.54	0.36	0.92	7.08
B-31	4		0.17	(0.01)	--	N.D.
L-4			0.42	0.24	0.61	1.17
B-32	1		0.33	0.01	0.03	0.16
B-33	2		0.35	0.17	0.43	2.26
B-34	3		0.30	0.03	--	N.D.
L-6	4		0.17	(0.01)	--	N.D.
B-36	1		0.47	0.15	0.38	2.00
B-37	2		0.29	0.11	0.28	1.47
B-35	4		0.37	0.19	0.48	2.52
B-38	3		0.28	(0.10)	--	N.D.
B-39	4		0.21	0.03	0.08	0.33
B-40	1		0.35	0.03	0.08	0.33

(All samples counted for 100 minutes)

*An aliquot of 0.157 of filter was counted.

N.D. Not detectable.

TABLE 2 (CONTINUED)

SUMMARY OF DATA FROM PNL COUNTING OF AIR SAMPLES

SAMPLE NO.	COUNTER USED	DURATION OF COUNT, MIN.	GROSS CPM	CPM CORRECTED FOR BG.	DPM SAMPLE	DPM PER M^3
L-7	1	100 (All samples counted for 100 minutes)	0.39	0.07	0.18	1.38
L-5	3		0.44	0.06	0.15	1.15
B-41	2		0.35	0.17	0.43	3.58
F-1	1		0.32	0.0	--	N.D.
F-2	2		0.14	(0.04)	--	N.D.
F-3	3		0.33	(0.05)	--	N.D.

TABLE 3

Verification Test Data

Release No.	Net CPM (Union Carbide Counting)	DPM	Net CPM (PNL Counting)	DPM
I (C-310)	6125	19,600		
II (C-315 #1)	6968	22,298		
III (C-315 #2)	4006	12,819		

NOTE: Twenty mg UF_6 product will contain 13.4 mg uranium with an alpha activity of 2200 dpm/mg (Union Carbide data) or 29,480 dpm. Twenty mg of UF tails will contain 13.4 mg uranium with an alpha activity of 900 dpm/mg (Union Carbide data) or 12,060 dmp.

The results verified that a large fraction, if not all, of the UF_6 was released and accounted for by the filter on the high volume sampler.

TABLE 4

HYDROFLUORIC ACID (HF) SAMPLING, APRIL 3, 1980

Location	Sample	liters/min.	Time On	Time Off	Elapsed Time, At	Volume, liters	ugF	calculated fluorine concent. ng/l	concentration at lower limit of sensitivity, ug/l
315 Bldg. cylinder position #3	1A	1.29	10:15	10:45	30	39	0.5	0.01	0.03
	1B	1.5	10:15	10:45	30	45	0.4	0.009	0.02
315 Bldg. cylinder position #2	2A	1.34	10:46	10:55	9	12.06	44	0.4	0.009	0.02
	--	1.24	10:55	11:21	26	32.24			
	2B	1.38	10:46	11:21	35	48	0.4	0.008	0.02
310 Bldg. cylinder position #4*	3A	1.2	11:30	11:47	17	20	0.06	0.03	0.05
	3B	1.5	11:30	11:39	16	24	0.09	0.04	0.04
			11:40	11:47					

* no disconnect occurred.

APPENDEX G

AUTHORIZATION FOR MEDICAL AND/OR HOSPITAL INFORMATION

RE: Joe T. Harding
214 Old Orchard Road
Paducah, Kentucky
All medical records.

This is to authorize any physician, hospital, medical attendant or others to furnish Henry R. Wolfe, M.D., USDOE, or any representative of his any and all information or opinions, which he may request regarding the physical condition and treatment of Joe T. Harding and to allow him to see, copy or photograph any x-rays or recores pertaining to HIS physical condition or treatment. I hereby waive any privilege I have to said information to Dr. Wolfe. A copy of this authorization shall be as binding as the original.

Clara M. Harding
To be named administratrix
Estate of Joe Harding
March 3-7-80

Witnesses:
Carol Jolly
Martha Allen

APPENDIX H
INFORMATION REQUEST

Department of Energy
Washington, D.C. 20545

Dear

An investigation of a complaint of occupational radiation induced illness has been requested by the Department of Energy. Accordingly, I would appreciate copies of information as mentioned in the enclosed authorization. In addition, in order to assess health effects from other sources would you kindly, wherever possible, provide the following information:

1. Your recall of Mr. Harding's food and drink patterns, e.g., Did he have any special likes or dislikes?

   (Referring to food temperature, spiciness, specialities. Was he a fast or slow eater? To what extent did he use alcohol? Anthing else relevant.)

2. Your recall of any toxic exposures he may have had outside of his employment at Union Carbide.

3. Your recall of Mr. Harding's smoking habits, e.g.,

   (How much did he smoke? Did he inhale and to what extent? Did he smoke cigarettes down to the end? Did he use filter tips? Anything else relevant.)

4. Your recall of his family medical history, e.g.,

   (What kind of malignancy did his father have? Was there any other family history of malignancy? Was there any other family history of G-I, pulmonary, dermatological, osseous, cardio-vascular, neurologic system involvement?)

5. Your estimate of radiation exposures from diagnostic X-rays made under your care. If this exposure information cannot be provided, please identify the X-ray equipment used, as well as the number and size of films and views in each X-ray procedure.

Because I have been requested to make this assessment within a brief period of time, I respectfully ask for a prompt reply. As a former busy clinician, I am aware of this added burden to you. Also, I realize you may not be able to respond to some of the above questions. Your best and most rapid response will be greatly appreciated.

Sincerely,

Henry R. Wolfe, M.D.
Human Health and Assessments Division
Office of Health and Environmental
Research, Office of Environment

Enclosure

APPENDIX I

PHYSICIAN AND HOSPITAL LIST

Response to Request for Records (Y=yes, N=no)	Name	Reason for Visit(s)	Year
Y - pathology report	M. W. Fowler, M.D.	Gastrectomy	1961
Y - denied radiation as cause	N. A. Parrott, M.D.	Skin lesions	1964
N - but not important	D. L. Boucher, M.D.	Hoarseness - non occ.	1966 (1 visit)
Y - Lourdes and Western Baptist	T. T. Myer, M.D.	Chronic and acute lung disease	1966 - 1974
Y - biopsy report	R. N. Buchanan, M.D.	Skin lesions	1967
N - possibly deceased	F. A. Simon, M.D.	Skin lesions	1968
Y	R. B. Miller, M.D.	Right knee surgery	1968
N	L. T. Reese, M.D.	Skin lesions	1969
Y - took over from Reeves	W. J. Petway, M.D.	Chronic lung disease	1970 - 1971
Y - examined in connection with compensation claim	S. L. French, M.D.	Right knee, elbow	1971, 1978
N - but record with Union Carbide	E. W. Rosenberg, M.D.	Skin lesions	1972
Y - no mention of "mutations"	R. E. Stivers, D.P.M.	Foot problems	1973 - 1975
N - according to Myre - never saw	W. O. Montgomery, M.D.	"Mutated fingernails"	1977
Y - but have on Lourdes record	W. H. Hosbach, M.D.	Pernicious anemia, emphysema	1979
N - Lourdes record	W. E. Jackson, M.D.	Pernicious anemia, emphysema	1979
N - despite repeated requests	W. Jennings, M.D.	Tremors	1979
Y - Methodist record	R. Lawson, M.D.	Abdominal cancer	1980
N - but have on Methodist record	S. King, M.D.	Abdominal cancer	1980

Hospitals

Western Baptist	Paducah, Kentucky
Lourdes	Paducah, Kentucky
Methodist	Nashville, Tennessee

MDs Known Deceased

M. S. Kleckner, M.D.	Gastroenterologist
L. T. Byars, M.D.	Dermatologist
R. L. Reeves, M.D.	General Practitioner

APPENDIX J - Mr. Harding's Chronology

Doctors + Hospitals who have treated me from 1952 until 1979

1953 - May - UCNC Dr. Gardner examined, X-Rayed and treated my injured knee when I fell off the Oak Ridge Truck - 15 ft to concrete - Co. fault accident - and started treating my ankles and legs up to my knees for skin sores, used Lassars Paste and Whitfield's full strength ointment.

1954 to 1962 - UCNC Drs. Ward and Moss - treated the skin sores on my legs up to my hips and lanced 2 infected sores. one under the arch of my right foot and one on my chest.

1959 - Dr Martin L. Klockner - Stomach Specialist - Diagnostician - Paducah, Ky. - Complete G.I. X-Rays, etc.

1960 - Dr. Martin L. Klockner again - Complete G.I. exam could not find any ulcers or trouble - said I probably had irritable stomach and X Rays again. He told me to find good Surgeon.

1961 - April - Western Baptist Hospital, Paducah, Ky - Dr. Merle Fowler - removed 95% of my stomach and the Duodenum and some of small intestine. (off from 6 to 8 weeks 3 months)

1963 to 1971 - Dr Richard Rucker - UCNC Plant Doctor kept me on several types of penicillin and Antibiotics for my skin sores, Checked blood hemoglobin each month, and made chest X-Rays monthly or each 2 or 3 months after finding odd looking areas in my lungs in 1963 and especially after I had Pneumonia the first time in Oct, 1968.

964 - Dr. Norman Parrott - Dermatologist - Paducah, Ky, treated my skin for 1 yr. Prescriptions, ointments, shots + infra Red or ultra-violet lights. No improvement.

965 - (Doesn't want to be named) Surgeon, Paducah, Ky, removed two sores from my lower lip. Got biopsy or pathology reports. Not conclusive. Vague.

965 - Dr Louis J. Eyrs - Dermatologist + Skin Surgeon, St. Louis, Mo. (Now Deceased) Examined my life and skin. Said my trouble was radiation damage. Would

not give me a written statement of his diagnosis.

1966 - Dr. Robert L. Reeves - General Medicine, Paducah Ky. (Now Deceased) Treated my skin problem and low hemoglobin problem, prescribed penicillin + vitamins.

1966 - (Doesn't want to be named) Surgeon, Paducah, Ky. removed another sore from my lower lip. Biopsy report - inconclusive + vague.

1967 - Dr. Buchanan - Dermatologist - with Vanderbilt Hospital, Nashville, Tenn. Examined + treated my skin, Biopsy report - inconclusive + vague. Prescribed penicillin.

1968 - March - Dr. Frank A. Simon - Allergy Specialist. Louisville, Ky. Treated my skin for 1 year. No improvement.

1968 - April - Dr Robert Miller - Bone Surgeon - Western Baptist Hospital, Paducah, Ky. - My knee surgery. Removed bad Cartilage from knee injured in fall from truck in May 1953. Co fault accident. (off from work 5 months)

1968 - August - Dr E. William Rosenberg - Head of Dermatology Dept. U.T. Medical Center, Memphis, Tenn. Examined and treated my skin problem. Gave me two prescriptions. No improvement.

1968 - Dr. Robert L. Reeves - General Medicine, Paducah, Ky. (Now Deceased) - Prescribed vitamins + Iron for my low hemoglobin and penicillin for my skin sores.

1968 - October - Western Baptist Hospital, Paducah Ky. Dr Ted J. Myre - Lung specialist + surgeon and Dr. Robert L. Reeves - General Medicine - Treated me for Pneumonia. X-Rays, Lung scan and looked in lungs. No cancer, but unusual condition of tiny pits or holes in my lungs. (off from work 2 months)

1969 - Barnes Hospital, St Louis, Mo, - Dr. L. J. Reese, Head of Dermatology Dept. - Complete Examination for a week. (I used a week of my vacation) He said I had radiation damage, but he would not give me a written statement of his diagnosis. - I had pneumonia again in Nov. 1969

1970 - Feb + March - Dr Ted J. Myre - Lung Specialist and Dr Willard Retway - General Medicine - Pneumonia again, X Rays at Dr, Myres office.

1972 - Dr Robert L. Reeves - General Medicine, Paducah, Ky, Treated me for Pneumonia again. X-Rays at Dr Myres office. Didn't miss any work this time

1974 - Jan. Lourdes Hospital, Paducah, Ky. - Dr Ted. J. Myre - Pneumonia again - X Rays, lung scan + looked in lungs. No Cancer, just more of the unusual tiny pits or holes in lungs.

1975 - Dr Rupert Stivers - Foot Surgeon, Paducah, Ky. Examined Fingernails + Toe Nails growing out of joints in fingers, wrists + elbows, and joints in toes, ankles + knees. He said nothing could be done for them, - I had pneumonia again in Sept. 1975

1976 - Dr Willard Retway - General Medicine, Paducah, Ky. Treated me for Pneumonia again.

1977 - Dr W. O. Montgomery - General Surgeon, Paducah, Ky. Examined my mutated fingernails + toe-nails growing out of joints in my fingers, wrists + elbows and joints in my toes, ankles + knees. He said nothing could be done for them.

1978-Oct Pneumonia again

1979 - Jan - Lourdes Hospital, Paducah, Ky, Dr William Hasback - General Surgeon and Dr William Jackson - General Medicine - Complete Physical Check-up. Prescribed more B-12 shots, Iron and Folic Acid.

4.

1979 - Feb. - Dr James A. Metcalf - Neurologist + Neuro-Surgeon - Examined me to determine cause of my body shaking. Not caused by any normal disease or ailment that causes body shaking, but caused by some kind of damage to brain cells and Central nervous system. Dr. Metcalf is in Paducah, Ky,

1979 - June - Dr William Jennings - Neurologist + Neuro-Surgeon, Paducah Ky. - Examined me to determine cause of my body shaking. Not caused by any normal disease or ailment that causes body shaking, but caused by some kind of damage to brain cells and Central Nervous system. Dr. Jennings has moved away from Paducah, Ky, now, to Western State Hospital, Bolivar, Tennessee.

1979 - Nov. 8 to present time - Dec. 8 - Pneumonia again.

APPENDIX K

Estimated Bone Marrow Dose (in MRAD)*

Union Carbide

No.	X-ray Examination	Estimated Dose Each	Total	Grand Total
1	cervical spine	50	50	
4	hand (and thumbs)	2	8	
3	knee and foot	2	6	
27	chest	40	1080	
1	lumbar spine	1	200	
				1344

Private Practice

2	full mouth dental	20	40	
2	shoulder	2	4	
3	knee	2	6	
25	chest	40	1000	
3	upper G-I	300	900	
1	gall bladder	100	100	
				2050
				3394

This is a crude estimate and could be off by one or two rem. More likely there were more private chest and dental films taken. Translating X-rays into rem, the estimate may be considered 3.5 rem.

* From consultation with Bureau of Radiologic Health and Table 6, p. 15 of DHEW Publication (FDA) 74-8007(1973).

APPENDIX L

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