APPENDIX A

NRC/AEC REPORTS & EXCERPTS

(complete files on CDRoM)

NRC NMI License SMB179 Search Results

1974 AEC Reports, "Deplorable" Conditions and Violations

1974 April WBT NRC, Violation of air sampling and finger dose monitoring

1974 NRC Memo of NMI Violations, Civil Penalties

1978 June Foundry Over Exposure Letter

1982 March NMI Report Corrective Action, Foundry Overdoses

1984 May Foundry OverExposure Report to NRC FVV

1996 Shinopolous Vent Fire Report

2006 EPA Report Drums Buried at NMI, Case Study

circa 1993 NMI Site Contamination Assessment

UNITED STATES
ATOMIC ENERGY COMMISSION
DIRECTORATE OF REGULATORY OPERATIONS
REGION 1
631 PARK AVENUE
KING OF PRUSSIA, PENNSYLVANIA 19406

Knapp

FEB 15 1974

Nuclear Metals, Inc.

License No. SNM-65
SMB-179
Inspection No. 70-82/73-05
40-672/73-02

Gentlemen:

This refers to the inspection conducted by [redacted] of this office on [redacted], 1973 and [redacted], 1974 of activities authorized by AEC License Nos. SNM-65 and SMB-179 and to the discussions of our findings held by [redacted] with [redacted] and to subsequent telephone discussions between [redacted] and [redacted] on [redacted], 1974 and between [redacted] on [redacted], 1974.

Areas examined during this inspection are described in the Regulatory Operations Inspection Report which is enclosed with this letter. Within these areas, the inspection consisted of selective examinations of procedures and representative records, interviews with personnel, measurements made by the inspector, and observations by the inspector. In addition, your activities in response to telephone conversations on [redacted] confirmed by our letter to you dated [redacted], 1974, were reviewed.

Our inspector also verified the steps you had taken to correct the violations brought to your attention in our letters dated [redacted], 1973 and [redacted], 1973. We have no further questions regarding Items 1.a, 1.b, 1.c, and 1.e of Enclosure 1 and Items 1.c, 2, 3, and 4 of Enclosure 2 to the [redacted], 1973 letter; and Item 2 of the Enclosure to the [redacted], 1973 letter. With regard to Items 1.b, 1.c, 1.d and 2 of Enclosure 1 to this letter, we note that you had taken steps to correct these violations but your evaluations were inadequate in that they failed to include provisions to cover beta and gamma radiation.

During this inspection, it was found that certain of your activities appeared to be in violation of AEC requirements, and another activity appeared to raise a question concerning the safety of operations. The items and references to the pertinent requirements and to generally accepted guidance are listed in the enclosure to this letter. This letter constitutes a notice sent to you pursuant to the provisions of Section 2.201 of the AEC's "Rules of Practice", Part 2, Title 10, Code of Federal Regulations. Section 2.201 requires you to submit to this office within 20 days of your receipt of this notice, a written statement of explanation in reply, including: (1) steps which have

A169

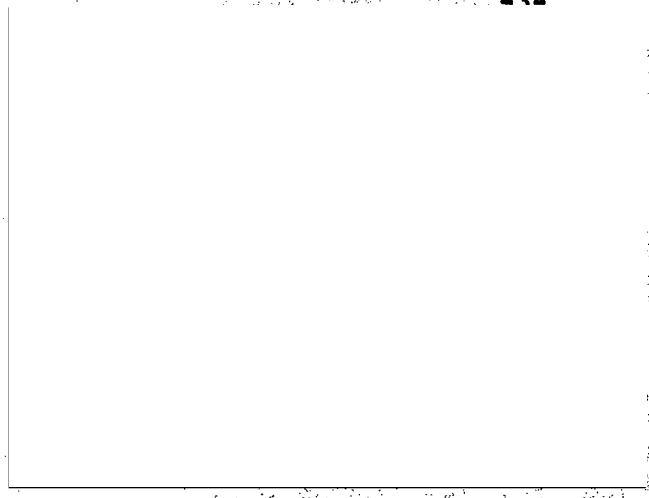
been or will be taken by you to correct the violations, and the results achieved; (2) steps which will be taken to avoid further violations; and (3) the date when full compliance will be achieved. With respect to the question concerning safety of operations, please include in your response your comments concerning this item, a description of any steps that have been or will be taken to correct it, a description of any steps that have been or will be taken to prevent recurrence, and the date all corrective actions or preventive measures were or will be completed.

During the management meeting with you on [redacted] detailed our enforcement policies and expressed our concern about the implementation of your management control systems that permitted these deficiencies to occur. Consequently, in your reply, you should describe in particular these actions taken or planned to improve the effectiveness of your management control systems as you described during the meeting.

In accordance with Section 2.790 of the AEC's "Rules of Practice", Part 2, Title 10, Code of Federal Regulations, a copy of this letter and the enclosed inspection report will be placed in the AEC's Public Document Room. If this report contains any information that you (or your contractor) believe to be proprietary, it is necessary that you make a written application within 20 days to this office to withhold such information from public disclosure. Any such application must include a full statement of the reasons on the basis of which it is claimed that the information is proprietary, and should be prepared so that proprietary information identified in the application is contained in a separate part of the document. If we do not hear from you in this regard within the specified period, the report will be placed in the Public Document Room.

Should you have any questions concerning this inspection, we will be pleased to discuss them with you.

Enclosure:
Description of Violations
RO Inspection Report No. 70-82/73-05 and
40-672/73-02



ENCLOSURE NO. 1

DESCRIPTION OF VIOLATIONS

Nuclear Metals, Incorporated
2229 Main Street
Concord, Massachusetts 01781
Docket No. 40-672

Certain activities under your license appear to be in violation with AEC regulations. The following apparent violations are considered to be of Category II severity.

1. 10 CFR 20.201(b), "Surveys", requires that surveys be conducted as may be necessary to comply with the regulations contained in each section of Part 20. A "survey", as defined in Paragraph 20.201(a), means "an evaluation of the radiation hazards incident to production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive materials present".

   a. Contrary to this requirement, you failed to make such surveys as were necessary to assure compliance with 10 CFR 20.101(a), "Exposure of individuals to radiation in restricted areas", a regulation which, in part, establishes a quarterly limit for dose to the hands. Specifically, you failed to conduct adequate evaluations of the hand exposures to all forms of radiation incurred by your employees through use of gloves contaminated with beta-gamma emitting material and through direct handling of uranium-238.

   b. Contrary to this requirement, you failed to make such surveys as were necessary to assure that employees exposed to airborne uranium-238 and associated alpha, beta and gamma emitting daughters were not exposed to concentrations exceeding those specified in 10 CFR 20.103, "Exposure of individuals to concentrations of radioactive material in restricted areas". Specifically, the surveys you conducted did not measure alpha and beta-gamma concentrations in workers' breathing zones. This is an uncorrected violation.

   c. Contrary to this requirement, you failed to make such surveys as were necessary to assure that effluents released from your stacks did not contain concentrations exceeding those specified in 10 CFR 20, 106, "Concentrations in effluents to unrestricted areas". Specifically, the surveys you conducted did not include analysis for beta-gamma emitting materials resulting from your process. This is an uncorrected violation.

d. Contrary to this requirement, you failed to make such surveys as were necessary to assure compliance with 10 CFR 20.106, "Concentrations in effluents to unrestricted areas", a regulation that in part, limits the yearly average concentration of radioactive material contained in liquids discharged from your plant to the unrestricted areas. Specifically, the surveys which you did conduct of your liquid waste, resulting from the dissolution of copper from uranium-238, prior to its disposal to a bag on your property, did not include measurement of beta-gamma emitting materials which may have been present. This is an uncorrected violation.

2. Condition 8 of the license requires that material possessed and used in accordance with procedures submitted with your license application dated February 26, 1969. Section II of these procedures is entitled "Health and Safety". It specifies, among others, the requirement shown below:

> Environmental water and soil samples will be collected and analyzed annually.

Contrary to this requirement, the environmental water and soil samples collected were not analyzed for the concentration of beta-gamma emitting materials which may have been present. This is an uncorrected violation.

ENCLOSURE NO. 2

DESCRIPTION OF SAFETY ITEM

Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742
Docket No. 40-672

Accepted radiological safety practices dictate that radioactive contamination be controlled to the lowest level practicable. For example, the National Council on Radiation Protection and Measurements in its Report 30 "Safe Handling of Radioactive Materials", clearly advocates this principle.

Contrary to this generally accepted practice, you failed to identify and control contamination and particularly that due to beta and gamma emitting radionuclides associated with your depleted uranium operation. This failure lead to the spread of contamination outside the confines of the immediate work area into office and other non-manufacturing areas. In a few cases, contamination was carried out of the plant on the personal clothing of employees.

Among other things, you failed to routinely survey individuals to determine that they were free of alpha, beta and gamma contamination upon leaving the work area and before undertaking such activities as eating or smoking. This situation was noted on our last inspection.

To assure an acceptable contamination control program, one must:

1. Establish an area of control.

2. Implement procedures (including the use of protective clothing and instruments) for entering, conducting operations, and exiting from the controlled area.

3. Routinely monitor uncontrolled areas at a frequency adequate to detect significant contamination spread.

4. Monitor by appropriate methods and frequency to assure that employee ingestion is not occurring.

FEB 15 1974

[redacted], Facilities Radiation Protection Section, RO:I

INSPECTOR EVALUATION

Nuclear Metals, Inc.
2229 Main Street
Concord, Massachusetts 01742
License Nos. SNM-65 and SMB-179

The licensee's SNM program is being deactivated. It may be reactivated in about seven years. No significant problems were apparent.

An inspection conducted in [redacted] 1973 indicated a beta-gamma contamination problem in association with the depleted uranium program. Apparently, we failed to impress the licensee concerning the problem and it was not brought under control. Consequently, the licensee is again being cited for the whole gamet of survey violations.

I blame the safety office [redacted] primarily for the deplorable situation of this plant. He was made well aware of beta-gamma contamination problems on the previous inspection. Either he ignored it or he didn't get the message. Until about a year ago he was a technician with no knowledge of health physics and he doesn't appear to have improved his knowledge since he was made Safety Officer. [redacted] appears to be quite knowledgeable but was not directly involved in the previous inspection. He is now Manager, Health and Safety and also Manager, Quality Control. I get the impression he doesn't want to be bothered with radiation safety. Both [redacted] were aware that uranium-238 daughter products were concentrated in the impurities resulting from melting the uranium.

It will take more than [redacted] to straighten out this operation. He can't conduct a decent survey. Let's give the licensee a month to straighten things out and then inspect them again to see how well they have done.

[redacted]

U. S. ATOMIC ENERGY COMMISSION

DIRECTORATE OF REGULATORY OPERATIONS

REGION I

RO Inspection Report No.: 70-82/73-05 and 40-672/73-02

Docket No.: 70-82
40-672
SNM-65

Licensee: Nuclear Metals, Incorporated

License No.: SMB-179

2229 Main Street

Priority: 1 and 3

Category: A (1)&E

Location: Concord, Massachusetts

Type of Licensee: Fuel Fabricator and Product Manufacturer

Type of Inspection: Routine, Unannounced

Dates of Inspection: December 27-28, 1973 January 8-9, 1974

Dates of Previous Inspection:

Principal Inspector:

Accompanying Inspectors:

Date

Other Accompanying Personne

Reviewed B

SUMMARY OF FINDINGS

Enforcement Action

A. Violations

1. Failure to evaluate the dose to hands of individuals handling uranium-238 and wearing gloves contaminated with uranium-238 and its daughter products. (Details, Paragraph 12a and b)

B. Continuing Violations

The material presented below is organized in the following order: (1) The violation as contained in the Region I letter dated _____ 1973; (2) The corrective action reported in the licensee's reply dated _____ 1973; and (3) a brief statement of the inspector's findings.

1. "... you failed to make such surveys as were necessary to assure that employees at risk of exposure to airborne uranium-238 were not exposed to concentrations exceeding those specified in 10 CFR 20.103, 'Exposure of individuals to concentrations of radioactive material in restricted areas'. You did make surveys that were intended to achieve this objective but these surveys did not measure the airborne concentrations in the workers' breathing zones."

"Corrective Action Taken

Our method of continuous inplant monitoring as described in our license application has been in effect for several years. Our sampling heads are located from six to eight feet above the floor, and sample air just above the breathing level of personnel. Program of air monitoring will continue, under new schedule/calendar control. Special air samples will be taken during June to provide data for correlation with normal sampling stations. This will be done periodically with portable air samplers."

The inspector examined the corrective action taken and noted that the air sampling performed measured only alpha activity and did not measure workers' breathing zone air. (Details, Paragraph 9)

2. "Filters from stack air monitoring samplers will be collected monthly and analyzed to assure compliance with requirements of 10 CFR 20.106 'Concentrations in effluents to unrestricted areas'.

Contrary to this requirement, your air sample filters were collected and analyzed only once between _____ 1972."

"Corrective Action Taken

Stack air monitoring samples have been taken, analyzed, and recorded each month since 72."

The inspector examined the corrective action taken and noted that the stack samples were taken at the indicated intervals but were counted only for alpha radiation. (Details, Paragraph 10)

3. "You failed to make such surveys as were necessary to assure compliance with 10 CFR 20.106, 'Concentrations in effluents to unrestricted areas', a regulation that limits the yearly average concentration of uranium-238 contained in the liquids discharged from your plant to the unrestricted areas. Specifically, no surveys were made of liquid wastes, resulting from the dissolution of copper from uranium-238, prior to its disposal to a bog on your property."

"Corrective Action Taken

Our inplant plumbing system directs all liquid wastes to our acid house disposal area. Our two-tank system allows the treatment of wastes prior to dumping in the bog at the rear of the disposal facility. Samples of the contained effluent are taken as the waste is treated from an acid to an alkaline condition. This was achieved by adding lime in sufficient amount to accomplish the appropriate PH reading.

Under this method, uranium content in the effluent is precipitated, and remains on the bottom of the holding tank. The tanks are flushed, on reaching the proper PH level, above the level of precipitates.

We will take additional samples for analysis to supplement our normal PH tests.

No dumping can take place without the approval of the Safety Department, after appropriate analyses have been made."

The inspector examined the corrective action taken and noted that the samples were analyzed only for uranium. (Details, Paragraph 16a.)

4. "Environmental water and soil samples will be collected and analyzed annually.

Contrary to this requirement, the only samples collected since November 10, 1970 were collected December 28, 1971 and these samples were not analyzed."

"Corrective Action Taken

Samples taken _71 were analyzed and report submitted by our consultant on 73. Samples taken 73 were analyzed and report submitted by our consultant on 73."

The inspector examined the corrective action taken and noted that samples were evaluated only for uranium. (Details, Paragraph 11)

C. Safety Item

"10 CFR 20.201(b), 'Surveys', requires you to make such surveys as may be necessary for you to comply with all sections of Part 20.

Contrary to this requirement, you failed to survey individuals to determined that they were free of contamination before eating, smoking or leaving the plant."

"Corrective Action Taken

As a matter of company policy for many years, all employees have been given a five minute clean-up period before the lunch break, and before quitting time. This policy remains in effect.

New "NO SMOKING" signs are on order and will be posted appropriately, accompanied by a reaffirmation of company policy on the subject.

We have ordered a new electronic "frisking" device, as specified by our radiation consultant, to suit our needs. The unit is a Model RM-15-Radiation Monitor with Alpha Scintillation Probe Model AC-3B.

This unit will be installed at our employees' entrance in Building B, which is also near the factory first floor washroom. The unit will be available at all times during work hours to allow for self-analysis before coffee breaks, lunch periods, and a final check on the way home for factory and engineering personnel."

The inspector examined the corrective action taken and noted that although the instrument had been obtained, it had not been installed as indicated nor were employees required to use it and no arrangement for beta-gamma surveys had been made. (Details, Paragraph 12a.)

D. Corrected Violations

The following violations contained in the Region I letter dated April 23, 1973 were found corrected.

1. Quarterly meetings and training sessions for fire brigade members; the licensee stated quarterly meetings would be held. The inspector verified the corrective action taken. (Details, Paragraph 3)

2. Periodic health and safety meetings; the licensee stated periodic meetings would be held. The inspector verified the corrective action taken. (Details, Paragraph 4)

3. Operational checks of hoods and sucker hoses; the licensee stated that records of checks would be maintained. The inspector verified the corrective action taken. (Details, Paragraph 5)

4. Periodic direct measurement surveys with gas proportional counters; the licensee stated that periodic measurements would be made. The inspector verified the corrective action taken. (Details, Paragraph 6a.)

5. Records of transfer and disposal; the licensee stated that records of transfer and disposal would be maintained. The inspector verified the corrective action taken. (Details, Paragraph 13b.)

   The following violation contained in the Region I letter dated 1973 was found corrected.

6. Posting of notices to employees; the licensee stated that notices would be posted stating where the regulations and license could be examined. The inspector verified the corrective action taken. (Details, Paragraph 14b.)

Unusual Occurrences

Measurements made by the inspector revealed that significant amounts of undetected beta-gamma contamination existed in the work area. As a result of this finding and management's statement that it could not be guaranteed that employees always changed into uncontaminated personal clothing before leaving the plant, two inspectors revisited the plant and the residences of affected employees on 1974 to further evaluate the extent of contamination spread. (Details, Paragraph 18)

Other Significant Findings

A. Current Findings

The licensee has fulfilled its current contract with Argonne National Laboratory for fabrication of CP-5 reactor fuel elements. The last production run was completed in 1973 and all fuel elements have been shipped. This had been the licensee's sole enriched uranium fuel element fabrication activity, and renewal of the contract is not anticipated for several years.

B. Status of Previously Reported Unresolved Items

Not applicable

Management Interview

At the conclusion of the inspection on 1973, a management meeting was held with the following persons in attendance:

Nuclear Metals

AEC

The following subjects were discussed:

A. The violations found were discussed. Many existed because the licensee failed to identify the existence of beta-gamma emitting radionuclides associated with the foundry operation. Mr. Jerman reiterated the violations to Mr. Tuffin in a phone conversation on 1974.

B. The use of lapel air samplers for determining exposure of individuals to airborne concentrations of radioactive material was discussed.

C. The need to survey for both alpha and beta-gamma emitters was discussed.

At the conclusion of the inspection on 1974, a management meeting was held with the following in attendance:

Nuclear Metals

State of Massachusetts Department of Health

AEC

The following subjects were discussed:

A. Results of residence and auto surveys

B. Whole body counts for foundry employees. agreed that whole body counts would be made on the five foundry employees.

C. The need to establish full contamination control. The inspectors pointed out that they observed actions on the part of employees which raised questions concerning the adequacy of the training they had received. Licensee management agreed further training was needed.

DETAILS

1. Individuals Contacted

2. Scope of Operations

   a. A licensee representative stated that the final fabrication of CP-5 Reactor fuel elements under the current contract with Argonne National Laboratory was completed in 1973. This has been the only enriched uranium fuel fabrication conducted by the licensee. There will be no additional need for fuel of this type for several years. The uranium used in fuel element fabrication was fully enriched metal. It was extruded with aluminum to make tubular elements up to three inches in diameter.

   b. Depleted uranium is melted in induction furnaces and molded into shields for radioactive sources and into penetrators.

3. Fire Brigade Meetings

   The record of fire brigade meetings held was examined. The record shows that meetings were conducted on 1973; 1973 and 1973.

4. Health and Safety Meetings

5. Hood and Sucker Hose Checks

   The record of hood and sucker hose checks made was reviewed. The record showed that checks were made on 1973. The face velocity at all hoods and sucker hoses ranged from 1000 to 4500 lf/m.

6. Direct Reading Surveys

a. Records were examined and showed that 14 locations were routinely surveyed directly with an alpha detection instrument (Eberline Model RM-15). The survey was conducted monthly. Readings up to 360 d/m were recorded. Records of a special survey conducted on [redacted] 973 showed 4500 d/m alpha on the foundry podium floor. A licensee representative stated that no beta-gamma measurements were made.

b. The inspector surveyed the foundry area using a Model E-120 Eberline instrument with a GM end window probe with about 2 mg/cm^2 absorber. Dose rates up to 5 mR/hr at 1 cm were measured on the floor. Hoods showed up to 25 mR/hr. The instrument was calibrated with cobalt-60. Calibration of the same model instrument with a uranium (natural) slab showed that a correction factor of 6 should be applied for measuring dose rates from uranium. (Refer to footnote 4 of table 3 for a discussion of instrument response.)

7. Wipe Surveys

a. Records were examined for the period from [redacted] 1973 and showed that wipes were taken monthly at 14 locations in the plant area. The wipes were counted only for alpha contamination. The maximum wipe showed 28.5 d/m alpha/100cm^2. It was taken on the floor near the large door in the foundry area.

b. The inspector took wipes at ten locations as indicated in Table 1. The wipes were counted on [redacted] 1974 using an Eberline Model SAC-4 for alpha counting and Eberline Model LCS-1 with Eberline Model RD-14 Beta Detector for beta counting. Figure 1 shows the location of the wipes by number.

TABLE 1

INSPECTOR SMEAR SAMPLE RESULTS

(For Locations See Figure 1)

SMEAR NUMBER	LOCATION	d/m alpha	d/m beta-gamma
1	Floor near tower (Foundry)	78	10,105
2	Inside side wall crucible hood (Foundry)	270	11,224
3	Step to tower (Foundry)	78	17,559
4	Floor of tower hood (Foundry)	189	5 mR/hr (1)
5	Inside paint hood, side wall (Foundry)	34	705
6	Floor near hack saw (Foundry)	25	4,256
7	Floor near exit to hall (Main shop area)	6	686
8	Tower counter top (Foundry)	40	5,331
9	Floor near entrance to shipping and receiving area(Main Shop Area)	6	335
10	Floor in hall at reception room	9	148

(1) Footnote 4 of Table 3

8. In-Plant Air Monitoring - Special Nuclear Material

In-plant air sampling records for fuel element fabrication operations were reviewed. The records showed that samples were collected and analyzed monthly from the eight in-plant stations. The maximum concentration shown on the records was noted to have been 8.5×10^{-13} uCi/ml. Results for samples taken after 1973, had not been received from the contractor who supplies the analytical service.

9. In-Plant Air Monitoring - Source Material

The inspector observed that two air sample stations in the foundry area were in the same locations as observed during the inspection conducted in 1973. One was located at the side of the hood canopy (outside of the canopy air flow pattern), on the furnace platform and the other was about 8 feet above the foundry floor, remote from where source material was processed. The air sample records examined showed that samples were collected and analyzed for alpha monthly. The maximum concentration shown on the records was noted to have been 8.0×10^{-13} uCi U-238/ml. The MPCa for insoluble U-238 is 1×10^{-10} uCi/ml. Records also showed that on two occasions a series of three air samples was taken with a portable air sampler in the vicinity of work performed in the foundry area. The first of these was on 1973 when samples were taken at the furnace while lifting the furnace cover, while manipulating the crucible. and "while burning". The second series was on 1973. The maximum sample showed a concentration of 3.0×10^{-12} uCi/ml. A licensee representative stated that the samples were only analyzed for alpha activity, with no analysis for presence of beta or gamma radiation.

10. Surveys of Airborne Effluents

Examination of the stack air sampling records showed that samples had been collected from all stacks monthly since 1973. Analyses showed the maximum concentration to be 9.4×10^{-12} uCi alpha/ml from the E-30 stack during the period from to 1974. The MPCa for soluble uranium-238 is 3×10^{-12} uCi/ml. The average concentration for this stack and each of the other stacks for the twelve month period ending 1973 was less than 3×10^{-12} uCi/ml uranium-235 or uranium-238. Results for samples removed at the end of November, 1973 had not been received from the vendor. A licensee representative stated that the stack air samples were analyzed only for alpha radiation.

11. Environmental Monitoring

Examination of environmental monitoring records showed that water and soil samples collected from wells on the plant property on 1973 and from nearby streams and ponds on 1971 and 1973, were analyzed for uranium content. The maximum concentrations of uranium found in well samples were

0.075 ugms/ml of water and 8.9 ugms/gram of soil. The maximum quantity of uranium found in samples taken from locations off the plant property were 0.020 ugms/ml of water and 8.3 ugms/gram of soil.

12. Personnel Surveys

a. A licensee representative stated that an Eberline Model RM-15 alpha detector had been procured which the company intended to install so that employees could monitor their persons before eating, smoking or leaving the plant. Instructions were given to employees concerning proper use of the instrument. However, the instrument was not installed and there was no requirement that the employees use it. The instrument was used for direct reading surveys in the entire plant area. Records examined showed that on [redacted] 1973 personnel in the foundry area working with U-238 were spot checked for clothing and hand contamination. As much as 1560 and 8400 d/m alpha were found on clothing and gloves, respectively. No hand contamination was found. The shop employees continued to use plant issue shirts, trousers, shoes, socks, and gloves but did not check their persons before eating, smoking or leaving the plant. No beta-gamma surveys of personnel were conducted.

b. The inspector examined the foundry area where uranium-238 is processed. The shoes and clothing of two technicians were checked with an Eberline Model E-120 with an end window GM probe containing about 1.8 mgr/cm^2 end window. Readings up to 5 mR/hr* and 2 mR/hr were found on shoes and clothing, respectively. One technician stated he had used the canvas gloves he was wearing for about five days. The reading on the inside surface of the palm of the right glove (turned inside out) was greater than 50 mR/hr at 2 cm. He produced a pair of leather gloves which he stated he wore for one or two days. The palm of the right glove (turned inside out) showed 30 mR/hr at 2 cm. A licensee representative stated that finger TLD's had been used during June, July and August, 1973. Ten dosimeters were received for use each month. The only positive result was for dosimeter #148 used during June, 1973. It showed 270 mrem. The individual who wore it was not identified. The licensee representative stated that the finger TLD's had not been used by personnel who worked in the foundry area. It was noted by the inspector that uranium-238 shields for which the theoretical surface dose rate is 240 mrads/hr, were directly handled by personnel with and without the use of gloves. The licensee had done no other evaluation of the radiation doses to employee's hands.

*See footnote 4 to table 3

13. Use of Licensed Materials

a. The licensee's records of receipt, inventory and transfer of licensed source material were examined. It was found that source materials had been used for purposes authorized by the license and that quantities possessed had not exceeded the quantities authorized.

b. Examination of the records of transfer of source material showed that the quantity of material transferred was always listed. A licensee representative stated that each customer to whom source material products were transfered had been contacted to determine that the customer was authorized to receive the material. Examinations of this correspondence file showed that each customer to whom source material was transfered was authorized to receive it.

14. Posting and Labeling

a. It was noted that the areas in which depleted uranium shields were stored at which dose rates in excess of 5 mR/hr at 18 inches were measured, were posted with signs bearing the radiation caution symbol and the words "Caution Radiation Area".

b. It was noted that notices were posted both in the lunch room and the shop area which informed personnel a copy of the regulations and a copy of the license could be obtained for examination.

15. Personnel Monitoring

a. The licensee's records of whole body radiation exposure for 1973 through November 30 were examined. The maximum exposure received by any employee as indicated by film badge results was 1170 mrem, whole body exposure and 5970, skin of whole body exposure.

b. A licensee representative stated that film badges were checked for the presence of contamination each time they were collected for exchange of the film packets. No contamination was found. It was observed when examining film badge records that the processor indicated the possibility of contamination on a few badges. In no case was the film not read. The maximum reading reported for film showing the contamination notation was 60 mrem. It was observed that no contamination notation appeared for film used during the month of [redacted] 1973.

16. Liquid Effluent Released to Unrestricted Areas

a. Records showed that the acid used to dissolve the copper sheath from [illegible] ined to a bog on plant property on [illegible] 1973. The 2000 gallons released on [illegible] 1973 showed 0.68 ugms U-238/ml and the 5000 gallons released on August 9, 1973 showed 3.85 ugms U-238/ml. The MPC is 119.2 ugms U-238/ml. A licensee representative stated that the samples of neutrilized acid taken were not analyzed for the concentration of radioactive material other than U-238 such as the beta-gamma emitting uranium daughter products.

b. Soil samples were taken from the bog area. Records examined showed the following results:

TABLE 2

BOG SAMPLE ANALYSIS RESULTS

	ug Uranium/gm Soil	
	1973	1973
Soil from bog depression	1550	38
Soil from edge of bog	440	188
Soil 30' east of bog	325	38
Soil 30' south of bog	138	363

17. Bioassay

Examination of bioassay records revealed that seven employees submitted urine samples on [illegible] 1973 and that eleven employees submitted urine samples on [illegible] 1973 all of which were analyzed. The maximum results determined by the radiometric method and the flourometric method were 81 and 25 dpm alpha/liter, respectively. The previous urine samples were submitted on [illegible] 1972. It appears possible, based on the degree of contamination control exercised by the licensee, that many of the samples submitted were contaminated. This coupled with the inability to determine when an uptake was received, if received, makes it apparent that it would be impossible to establish the degree of internal deposition which occurred in any case.

18. Status on [illegible] 1974

In the Region I letter to the licensee dated [illegible] 1974, understandings regarding immediate actions taken by the licensee were listed. The actions stated in the letter are shown below together with the findings of the inspectors.

a. "You ceased uranium melting and casting operations on [redacted] 1974 and do not intend to restart until the situation has been resolved to your satisfaction and ours."

The inspectors observed that no uranium melting and casting operations were being performed.

b. "You have surveyed the foundry area and undertaken extensive cleanup operations. A restricted area has been established and contamination control procedures have been implemented."

The inspectors observed that the only activities conducted in the foundry area were cleanup operations. A rope boundary had been established for the foundry area with appropriate signs. Shoe covers and lab coats were supplied for assigned employees. A step off procedure had been implemented. A thin end window GM survey meter was provided at the boundary exit point.

c. "You have instructed all involved employees in personnel contamination control methods and performed contamination surveys on them."

1. A licensee representative stated that meetings had been held with involved employees to instruct them in personnel contamination control method and that contamination surveys had been performed on them. A memo in regard to personnel contamination control methods had been issured to employees and was examined by the inspector. The following observations were made by the inspectors in regard to this item.

2. A foreman (employee C listed in Table 3 below) was working in the foundry area when he was informed that the AEC inspectors located in the plant conference room, a non-controlled area, wished to see him. The purpose was to initiate a home survey. His response was to go directly to the Conference Room in the "work clothes" he was wearing at the moment, despite the fact that he knew these clothes were possibly contaminated. He was monitored by an inspector who found up to 3* mR/hr on the soles of his shoes, up to 1 mR/hr on most of the exterior of the waist length jacket he was wearing. The cuffs of the shirt he was wearing protruded from the sleeves of the jacket. The edges of these cuffs measured 0.5 mR/hr.

3. When four employees were requested to open their autos for survey, they proceeded to the plant parking lot in plant issued clothing and shoes, and personal outer clothing. Three sat is their autos awaiting survey because of cold wind.

*See Footnote 4 TO Table 3

4. Members of licensee management witnessed the matters reported in Paragraphs 2 and 3 above. The inspectors pointed out that this behavior on the part of the employees was not in accord with good contamination control practices.

d. "You will undertake all other steps necessary to prevent contamination spread outside the plant confines and to prevent the possible ingestion of radioactive material by personnel"

1. A licensee representative stated that wipes had been taken of the floor inside and outside of each entrance door to the plant building. The wipes showed less than 50 d/m for both alpha and beta-gamma emitters.

2. Surveys of the second floor of the building were conducted by the inspector. Nine wipes taken on tables in the lunch room showed no indication of contamination. A crack in the tile of the floor in the hall just outside the lunch room read 0.3 mR/hr at 1 cm*. Particles which collected on the floor at door jams in the hall read up to 0.5 mR/hr at 3 cm. Three dry mops used exclusively in halls and rooms outside the shop area showed dose rates from 0.3 to 0.8 mR/hr at 2 cm. A licensee representative stated the mops surveyed had been used 1974 after contamination control procedures had been instituted in the foundry area. The licensee stated that the dry mops in question had not been taken into the controlled foundry area. A janitor's shoes were surveyed and showed no indication of contamination.

e. "You will assist in arranging for a survey of the homes of appropriate employees to assure that there has been no significant transfer of contamination."

1. The licensee had arranged for surveys of homes and autos. The inspectors surveyed the residences of five employees whose work assignments were primarily in the foundry area where uranium-238 was processed. The automobiles of four of these employees were also surveyed. The other employee rode to and from work with one of the four employees. The automobile of Employee F which was used frequently by some of the five employees mentioned above during lunch periods was also surveyed. Results of the survey were as follows:

*See Footnote 4 to Table 3

TABLE 3

RESIDENCE AND AUTO SURVEY RESULTS

Employee	Residence Survey[3]	Auto Survey
A	No contamination found	0.25 mR/hr on front floor, drivers side
B[1]	Trousers-0.3[4] mR/hr	No auto to survey
C	Boots - 0.1 mR/hr	0.2 mR/hr on front floor, drivers side
D	2 shirts - 0.2 mR/hr at cuffs Boots - 0.3 mR/hr Jacket - 0.3 mR/hr	0.2 mR/hr on rear right floor
E	Boots - 0.5 mR/hr	0.1 mR/hr on front floor mat
F	No residence survey	1.0 mR/hr on back floor hump 0.5 mR/hr on right rear floor[2]

(1) Residence was in New Hampshire. All other residences were in Massachusetts.
(2) Licensee reported survey of auto showed no contamination.
(3) All clothing listed was personal clothing, not plant issued.
(4) Measurements on clothing and autos were made with radiation passing through the thin end window of a portable G.M. Survey Instrument, (Eberline E120), which is calibrated against cobalt 60 gamma radiation. Contamination measured was independently determined to be predominately beta. The instrument used in this survey has been calibrated with beta radiation from depleted uranium passing through the thin end window and for this case mR/hr readings must be multiplied by a factor of 6 or slightly more to obtain true mrad/hr readings.

2. All contaminated items found in residences were immediately returned to the licensee's plant except the boots of Employee C and one shirt of employee D. A licensee representative stated these articles would be returned to the plant and all articles would be decontaminated at the plant or by an authorized laundry. A licensee representative notified RO:I by phone on January 11, 1974 that all contaminated autos had been decontamined to background level. (<0.1 mR/hr).

19. Subsequent Action by the Licensee

a. On _____ 1974, in a telephone call, the licensee's management representative reported that whole body counts had been done on the five employees for whom home surveys were conducted. He stated that the preliminary report from MIT, based on 20 minute counts, showed no abnormal activity in the individuals counted.

b. He also reported that his radiation consultant had been to the plant twice during the week, that a ventilation consultant had been to the plant once and that extensive phone consultation had been conducted with both of them. He said that decontamination operations were continuing and that as of the time of his telephone call, surveys conducted with his thin window portable GM counter revealed no detectable contamination up to the entrance of the work area.

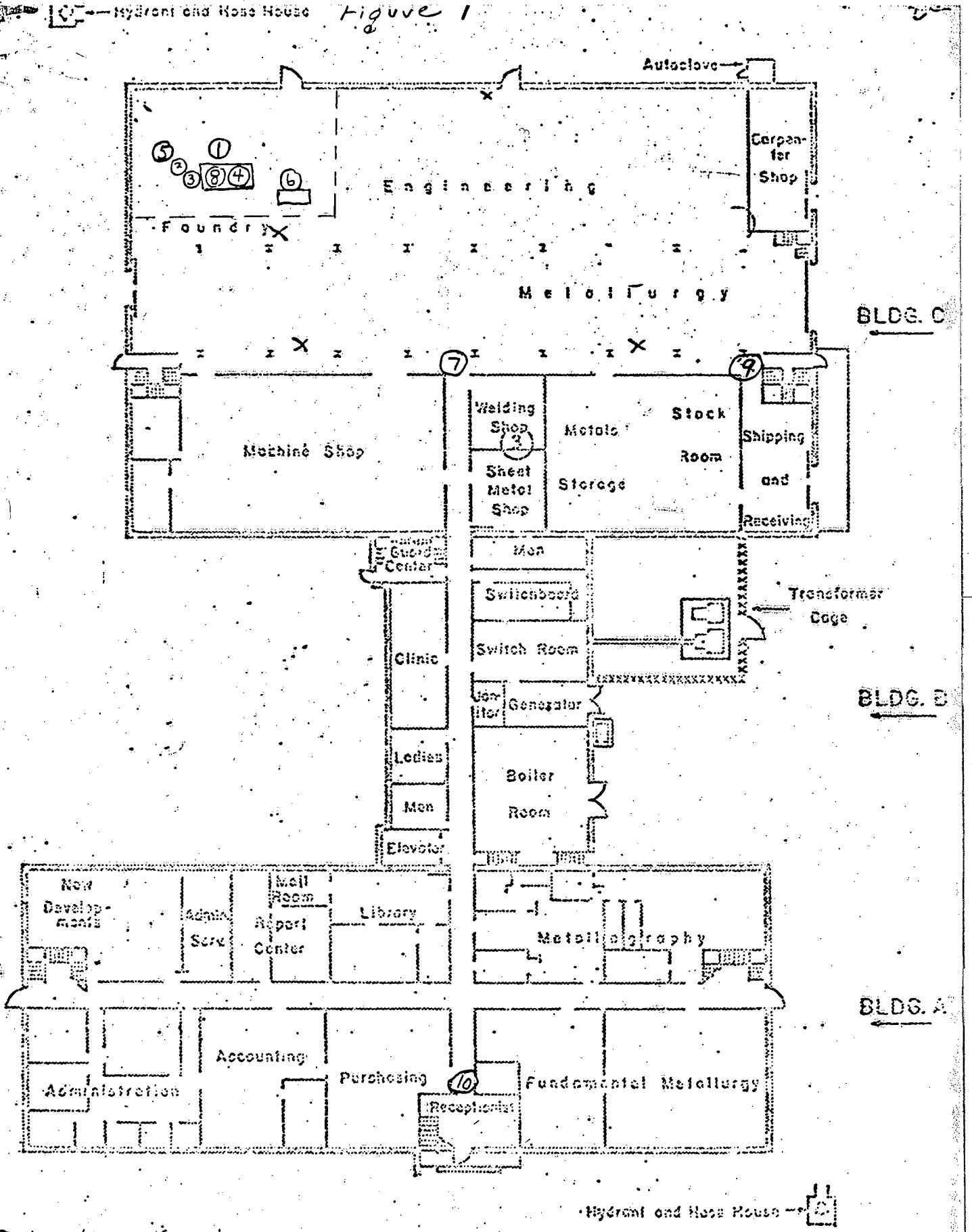
He stated that there was what he referred to as a buffer zone between the entrance to the work area and the platform on which the melting is accomplished. He reported that in this buffer zone, instrument readings never exceeded 0.4mR/hr including a background of 0.2 mR/hr.

c. The management representative then requested approval to begin melting operations again and outlined a plan under which the procedure would be undertaken. He stated that every step of the operation would be monitored in the following manner. Initially, contamination and smear surveys would be made of the work area. During the operation, breathing zone air samples would be taken and upon completion of each step of the operation smear and instrument surveys would be done to determine whether contamination spread was taking place. In the event that it was, decontamination would be undertaken as necessary.

d. He reported that the first melt would be typical of their smallest batch, consisting of a 96 pound charge which produces two of the smallest shields weighing 30 pounds each with the remaining material recaptured as waste. The management representative agreed to notify RO:I in the event of any unusual occurrence during the operations. He stated that rough checks of smears and air samples would be made with a thin end window GM detector as a screening process and that the samples then would be sent immediately to their consultant for processing and stated that he expected results back within a couple of days. If the first melt went well, he then planned to go on to a larger melt using the same steps as previously outlined. In the event this permitted them to fully delineate and control their contamination problems he indicated that they intended to resume normal operations.

e. Based on the information provided in this phone call, RO:I gave its approval to resume melting operations.

Figure 1


Hydrant and Hose House
Autoclave
Engineering
Foundry
Carpenter Shop
Metallurgy
BLDG. C
Machine Shop
Welding Shop
Sheet Metal Shop
Metals Storage
Stock Room
Shipping and Receiving
Guard Center
Men
Switchboard
Switch Room
Transformer Cage
Clinic
Generator
BLDG. B
Ladies
Men
Elevator
Boiler Room
New Development
Admin. Serv.
Mail Room
Report Center
Library
Metallography
BLDG. A
Accounting
Administration
Purchasing
Receptionist
Fundamental Metallurgy
Hydrant and Hose House
Location of wipes
FIRST FLOOR PLAN

UNITED STATES
ATOMIC ENERGY COMMISSION
DIRECTORATE OF REGULATORY OPERATIONS
REGION 1
631 PARK AVENUE
KING OF PRUSSIA, PENNSYLVANIA 19406

1974

Nuclear Metals, Inc.
Attention:

License Nos. SNM-65
SMB-179

2229 Main Street
Concord, Massachusetts 01742

Re: Your Letters Dated 1974 and 1974
In Response to Our Letter Dated 1974

Gentlemen:

Thank you for informing us of the corrective and preventive actions you documented in response to our correspondence. These actions will be examined during our next inspection of your licensed program.

Your cooperation with us is appreciated.

Sincerely,

0189

Form

NUCLEAR METALS, INC.

2229 MAIN STREET
CONCORD, MASSACHUSETTS 01742
TELEPHONE: 617 369-5410

1974

U.S. Atomic Energy Commission
Directorate of Regulatory Operations
Region 1
631 Park Avenue
King of Prussia, Pa. 19406

Attention:

Subject:

References: (1) License Nos. SNM-65, SMB-179
(2) Inspection Nos. 70-82/73-05; 40-672/73-02
(3) Your letter of February 15, 1974

Gentlemen:

This letter constitutes a response to points raised in the ref. (3) letter as required by Sec. 2.201 of the AEC's "Rules of Practice", Part 2, Title 10,CFR.

Item 1. Surveys:

Reference: Enclosure No. 1, Item No. 1, Ref.(3) letter.

(a) Survey of hand exposures:

1. Steps which have been or will be taken:

Results of surveys of hand exposure conducted prior to inspection of 1973 were regrettably not completely available to during his visit, since our was out of plant at that time. While reviewed reports of hand dosage provided by the company evaluating dosimeters, these were not identified as to which individuals had worn the dosimeters. The following paragraphs define our usage of finger dosimeters.

During the month of 1973, 4 gamma finger dosimeters were placed on our employees, 3 on foundry employees and 1 on a machinist, all directly handling uranium. One of the foundry personnel received 50% of the maximum permissible monthly dose to the hand, the other two received 10%, and the machinist received only 1%.

Then in 1973, of our employees wore gamma finger dosimeters, all of these persons were directly handling uranium, though the portion of working hours spent handling uranium was less than for the group surveyed in April. None of these employees exceeded 0.5% of the maximum monthly permissible dose to the hands. (For purposes of clarification, these calculations are based on dividing the maximum permissible quarterly dose to the hands, as defined in 10CFR20.101 by 4.3 to arrive at a monthly limit).

It has been and continues to be our judgment and the judgment of our consultants that the finding of relatively low whole body dosage to our employees relative to penetrating radiation is adequate indication that the likelihood of approach to hand exposure limits was not of concern, particularly in view of the markedly higher limits for hand exposure as compared to whole body exposure. The body badges have consistently shown low exposure; our report for 1973 appended hereto, shows only 1 person out of 38 wearing body badges who exceeded 25% of the maximum permissible dose to the whole body (his dose was 40%), the average of all employees wearing body badges was only 4% of maximum permissible whole body doses. It does not appear axiomatic that a house averaging 4% of permissible whole body dose has failed in adequacy of hand exposure evaluation when penetrating beta-gamma radiation is under evaluation, particularly including hand surveys of one third of its labor force involved with active materials, when both the total labor force and the segment evaluated with hand dosimeters, each contained only 1 individual exceeding 25% of permissible dose. The language of the "Description of Violations" would make it appear that Nuclear Metals failed to make <u>any</u> assessment of radiation hazard. Para. 10CFR20.201(a) defines a survey as "an evaluation of hazards". We submit that such evaluation may include use of engineering judgment, particularly when the data presented above shows rather low levels of radiation exposure.

Nonetheless, Nuclear Metals has since, on a rotating basis, been placing finger dosimeters on some 3 to 4 of its employees monthly and expects to continue to do so until such time as we judge the accumulation of data to show exposure levels sufficiently low to be beyond concern.

2. <u>Steps to avoid further violation</u>:

We are of the opinion we were not in violation of the requirement for hand exposure evaluation, but nonetheless, as defined above, we are using finger dosimeters on a rotating basis.

3. <u>Date of compliance</u>:

We are surveying some 3 to 4 of our uranium-handling employees on a

rotating basis, monthly, since 1974 in addition to the surveys performed in of 1973.

(b) Surveys of breathing zone air:

1. Steps which have been or will be taken:

The location of inplant air samplers has been well documented in prior correspondence. The location of the air sampler adjacent to the foundry furnace used for the bulk of our uranium melting is in the workers' breathing zone. This sampler is 68.5 inches above the platform floor and is at the entrance of the fume hood, i.e., air entering the fume hood passes by the sampler. The noses of foundry workers in this area are 4 to 6 inches below the entrance to the air sampler. We are of the opinion that this sampler performs an effective function in monitoring breathing zone air.

We are of the opinion we are not in violation on this matter as shown by surveys made in 1973, but nonetheless, we have ordered and received a portable (Mine Safety Appliances) battery powered air sampler which we are using to monitor breathing zone air for our workers.

2. Steps to avoid further violation:

The use of the breathing zone air sampler is expected to provide additional evidence of acceptable breathing zone air quality. Such air samples will be evaluated for both alpha and beta-gamma activity.

3. Date of compliance:

Air sampling has been a continuing program at this facility for years. We are now enhancing this program with the portable unit and evaluating for both alpha and beta-gamma activity.

(c) Effluents released from stacks:

1. Steps which have been or will be taken:

All stack air samples are now evaluated for beta-gamma activity in addition to alpha activity. We do not understand this to be an uncorrected violation since we find no reference to beta-gamma measurements in prior Region 1 correspondence.

2. Steps to avoid further violations:

Our responsible for sending filter discs from air samplers

to our consultants for analysis, assures that the shipping papers accompanying filter discs request measurement of both alpha and beta-gamma activity, Returned reports are also checked and logged in for both alpha and beta-gamma activity.

3. Date of compliance:

Effective with the date of this letter, reports now filed include results of monitoring for beta-gamma activity.

(d) Liquid effluents:

1. Steps which have been or will be taken:

Liquid effluents have been resampled and are under analysis for beta-gamma activity. We do not believe this to be an uncorrected violation, since to our knowledge this matter has not previously been called to our attention.

2. Steps to avoid future violations:

Effective with the date of this letter, all future samples of liquid effluents will be evaluated for both alpha and beta-gamma activity.

3. Date of compliance:

Reports of results of analysis of liquid effluents after the date of this letter will report both alpha and beta-gamma measurements.

Item 2. Evironmental Samples:

Reference: Enclosure No. 1, Item No. 2, Ref. (3) letter.

1. Steps which have been or will be taken:

An additional series of soil and water samples are under analysis for beta-gamma activity. We do not believe the lack of evaluation for beta-gamma activity to represent an uncorrected violation, since to our knowledge this matter has not previously been called to our attention.

2. Steps to avoid future violations:

Effective with the date of this letter, all future environmental samples will be evaluated for both alpha and beta-gamma activity.

3. Date of compliance:

Reports of results of analysis of environmental samples dated later than the date of this letter will report both alpha and beta-gamma measurements.

General Note: Alleged Violations relating to Daughter Product Beta-Gamma Activity

The general tenor of a number of the alleged violations discussed above relates to the discovery of beta-gamma radiation attending the depleted uranium, and coming from the daughter products of uranium. The conclusion of Region 1 has been that since beta-gamma activity exists, the licensee is in violation for performing an incomplete survey.

We wish to bring to your attention the point that Nuclear Metals, Inc. is not processing these beta-gamma daughter products as pure materials, separated from the parent uranium, but rather that any occurrence of beta-gamma radiation attends our work with uranium.

The maximum quantity of daughter product in existence at this facility cannot therefore exceed that amount in equilibrium with the parent uranium. We are therefore in the process of examining the relationship between an equilibrium quantity of parent and daughter in both effluent and inplant air and liquids as compared to allowable limits for these daughters as defined in Appendix B of 10CFR20. Preliminary data suggests it may not be possible to exceed Appendix B limits for these daughters when their only existence stems from the parent uranium. We intend further evaluation of this matter with the intent of better defining one of the aspects of the process of performing a survey in order to assure its completeness.

Item 3. Contamination Control Program:

Reference: Enclosure No. 2, Ref. (3) letter.

1. Corrective steps taken or planned:

(a) extensive cleanup of operations
(b) additional surveys
(c) establishment of restricted area
(d) implementation of contamination control procedures
(e) employee instruction in personnel contamination control
(f) use of shoe covers and lab coats
(g) implementation of stepoff procedure
(h) supply of survey meters to employees, including instructions for use
(i) wipe tests both inplant and beyond plant entrances
(j) monitoring of janitors' mops
(k) whole body counting of foundry personnel
(l) extensive utilization of consultants
(m) evaluation of both alpha and beta-gamma activity during surveys
(n) purchase and use of lapel-type breathing zone air sampler
(o) procedural revisions designed to minimize the number of work areas processing uranium
(p) substitution of equipment with surfaces easy to decontaminate for equipment more difficult to decontaminate within work areas processing uranium
(q) extensive use of plastic bagging of uranium objects between processing operations
(r) enhancement of ventilation around certain equipment processing uranium
(s) enhancement of filtration of effluent air
(t) expanded use of dosimeters for hand exposure
(u) establishment of changeroom in restricted area
(v) equipment modification to minimize contamination potential of a given process
(w) procedural modifications to minimize contamination potentials of a given process

2. Steps taken or planned to prevent recurrence:

The items listed above of course also operate in the direction of minimizing the potential for recurrence of spread of contamination beyond work areas processing uranium, but in addition, the magnitude and degree of our attention to control of programs involving uranium merits discussion. Nuclear Metals, Inc. is a company of about 100 employees involved in many phases of specialty metals manufacture. The involvement with uranium constitutes less than 10% of our total business, yet the degree of attention found to be necessary to control uranium operations, including use of our

consultants' time and the time required for performance of purchased services for evaluation functions, exceeds the equivalent of two men working full time. This ratio of more than one fulltime person in control functions per 5% of our total business then greatly exceeds the extent of control effort found to be necessary over the balance of our operations, this balance including control programs to satisfy both the regulations of such agencies as OSHA, EPA and other state, federal and local town agencies, as well as to meet our internal goals for assurance of satisfactory operations.

3. Completion data for action items:

Listed below are each of the action items listed above with projected or actual completion dates:

(a) cleanup: projected completion about 4/30/74, initiated 1/2/74
(b) additional surveys: initiated 1/2/74, and continuing
(c) restricted area establishment: initiated 1/2/74, final permanent barricades projected to be installed about 5/30/74
(d) control procedure implementation: 1/2/74 and continuing under progressive refinement as needed
(e) employee instruction: significant numbers of formal meetings with operating personnel during the period 1/2/74 to 1/18/74, and again in the period 2/25/74 thru 2/28/74. Frequent on-the-spot observations and instructions of personnel in a continuing program initiated 1/2/74. This program is a continuing program
(f) protective clothing: implemented prior to 1/18/74, continuing and under refinement as dictated by experience
(g) stepoff procedure: implemented prior to 1/18/74, continuing under refinement as indicated by experience
(h) survey meter use by operating employees: initiated prior to 1/18/74, continuing
(i) wipe test program expansion: initiated prior to 1/18/74, continuing
(j) monitoring of janitors' mops: initiated prior to 1/18/74, continuing
(k) whole body counting: performed prior to 1/18/74. We do not propose whole body counting as an ongoing program, since it is the opinion of our consultants that a more definitive evaluation of body burden is obtained from periodic urinalyses for uranium, this program continues and reveals satisfactory low values
(l) enhanced utilization of consultants: initiated prior to 1/18/74, continuing. At least one man-day of consultant visitation has occurred weekly since 1/18/74, continuing consultant visitation will of course be on an as-needed basis
(m) evaluation of both alpha and beta-gamma activity: initiated prior to 1/18/74 and continuing

(n) use of lapel-type air sampler: initiated 3/21/74 on receipt of the unit and continuing
(o) minimization of work areas processing uranium: initiated during February 1974 and continuing
(p) enhanced surface decontamination capability: initiated during January 1974 and continuing
(q) plastic bagging of uranium: initiated prior to 1/18/74 and continuing
(r) ventilation enhancement: initiated during January 1974 and continuing with expected completion about 10/30/74
(s) effluent filtration enhancement: initiated during March 1974 and continuing with expected completion about 10/30/74
(t) expanded use of hand dosimeters: initiated during January 1947 and continuing
(u) changeroom establishment: plans formulated during February 1947, equipment relocation to make space available for changeroom progressing as of date of this letter, expected completion of changeroom installation expected about 5/30/74
(v) equipment modification to minimize contamination: minor modifications completed as of 3/29/74; more major equipment modifications now in planning stage, expected completion about 10/30/74
(w) procedural modifications to minimize contamination: a continuing program; several procedure changes implemented prior to 1/18/74 have been shown effective in minimizing contamination, results of surveys are used to direct additional procedural modifications as needed.

Item 4. Management Control Systems:

As defined in our letters of May 15 and June 20, 1973, we have implemented a master time schedule/calendar, established by the Safety Engineer as a working tool and control document for our entire Safety Program. This schedule is reviewed weekly both for compliance to the schedule and to authorize the allocation of resources needed to stay on schedule.

This management control system constitutes a complete listing of all operations which require monitoring, inspection, and documentation of results, as a supplement to all other logs and required documentation. The Safety Engineer is responsible for maintaining the document and assuring that all operations have been carried out and properly documented.

Our Director of Industrial Safety performs weekly reviews and sign-offs relative to completion of assigned tasks; the document is further reviewed at monthly Safety Committee meetings and at monthly Management Review Meetings. The purpose of these reviews are to assure that all action items are completed on a timely basis and to discuss any problems which may have arisen and the effectiveness of corrective action.

This procedure has demonstrated its usefulness as an effective Management Control System and is subject to revision as we find ways to improve its effectiveness.

Since 1/18/74, several actions have been taken to enhance our control over operations. These actions include the following:

a) Doubling of the size of the NMI Safety Committee to include extensive worker representation.

b) The more extensive use of consultants to the NMI Management Group as defined previously.

c) Extensive meetings with the Management Group of the Manufacturing Department to define program requirements and assure implementation.

d) Additional assignment of personnel to assist the Safety Engineer in conduct of his duties.

e) Allocation of additional financial resources, not only to the operating budget of the NMI Safety Program, but also to equipment and plant modifications designed to enhance contamination control.

f) Increased utilization of operating plant personnel to enhance contamination

control, i.e., an increased number of manhours per week of operating plant personnel is now invested in assurance of clean areas and in prevention of personal contamination.

NUCLEAR METALS, INC.

2229 MAIN STREET
CONCORD, MASSACHUSETTS 01742
TELEPHONE: 617 369-5410

April 16, 1974

U.S. Atomic Energy Commission
Directorate of Regulatory Operations
Region 1
631 Park Avenue
King of Prussia, Pa. 19406

Attention:

Subject:

References: (1) License Nos. SNM-65, SMB-179
(2) Inspection Nos. 70-82/73-05; 40-672/73-02
(3) Your letter of February 15, 1974
(4) Our letter of March 27, 1974
(5) Telecon from your Mr. Jerman of April 4, 1974

Gentlemen:

This letter provides information supplemental to the ref.(4) letter regarding: (1) usage of gloves for hand protection, (2) monitoring of hand and glove contamination; and (3) usage of our breathing zone air sampler. This additional information is provided in response to telephone requests made on April 4, 1974 by your

Item 1 and 2: Usage of Gloves; Monitoring Hands and Gloves:

The attached memoranda summarize our policies in this regard, though they were issued primarily for the purpose of consolidating prior instructions to operating personnel. We should like to point out that we are currently operating to glove contamination levels of 5 mr/hr and 1 mr/hr and to hand contamination levels at instrument background on an experimental basis only; as we gain experience these levels are subject to modification. We believe these to be extremely conservative levels in that our hand/finger dosimeters have shown very modest exposure of 18.75 Rems per calendar quarter as defined in 10CFR20.101(a) would appear to permit continuous exposure of the hands to 36 mr/hr, based on a 40-hour work week.

Since none of our personnel are continuously handling uranium nor continuously wearing those gloves reserved for uranium handling, it would appear that trigger points markedly higher than 5 mr/hr would continue to

provide assurance against the likelihood of excessive hand exposure; our continuing program of evaluation of dosimetry data should allow this judgment at some future time.

Item 3: Usage of Breathing Zone Air Sampler:

Our receives daily advices from as to operations to be conducted that day with uranium and beryllium, he then selects on a rotating basis those operations that will be monitored by use of the breathing zone air sampler. It is our desire to make use of the sampler each day that either beryllium or uranium operations occur, but at times this may not always be the case, since the instrument has a long recharging time and has been twice repaired since its receipt.

As we build an experience file of breathing zone data, we expect usage frequency to revert to spot checks of repetitive and well characterized operations and to usage for those operations found by experience to possess some real potential for air contamination.

Should you have any further questions, please do not hesitate to contact the undersigned.

Office Memorandum · NUCLEAR METALS

TO :

DATE: 1974

FROM :

SUBJECT:

This memo serves the purpose of consolidating and definitizing prior memoranda and discussions relative to use of protective gloves by Foundry personnel, and is to be implemented immediately as standard operating procedure.

Category 1. Glove usage when handling uranium, crucibles, molds, and contaminated furnace parts:

(a) A double glove system shall be worn for all Category 1 handling, the inner glove to be rubber to avoid possibility of contamination transfer to the skin of the hands.

(b) The outer glove may be cotton, leather, or a plastic or rubber coated glove as found convenient by operating personnel, though leather is recommended because of its shielding ability (leather reduces the hand dose by half).

(c) The outer glove for Category 1 handling shall be marked with a large yellow U on the back and shall only be used for Category 1 handling. When not in active use, Category 1 gloves shall be placed in plastic bags. It is recommended that such bags be suspended from platform railings to permit easy use of the gloves therein.

(d) After each use in a melt cycle, Category 1 outer gloves shall be monitored for beta-gamma contamination and shall be either cleaned or discarded (at your option) when found to be contaminated in excess of 5 mr/hr when held approx. 2" from the end of the Geiger counter probe.

(e) After each removal of Category 1 outer gloves, the operator shall wash and dry his hands while still wearing the inner rubber gloves, and only then may he remove the rubber gloves. The bare hands shall then be monitored and shall be washed on any finding of contamination in excessof normal instrument background.

Category 2. Glove usage for general foundry handling:

(a) Usage of a single glove is permissible for general foundry handling and may be of any material found convenient by the operator.

(b) No special marking is to be applied to Category 2 gloves.

(c) Category 2 gloves are to be monitored at least once daily and are to be discarded or cleaned (at your option) on finding of contamination in excess of 1 mr/hr, monitored under the same practices as for Category 1 gloves.

(d) On each removal of Category 2 gloves, the operator shall monitor the bare hands and shall wash the hands on any finding of contamination in excess of normal instrument background.

ARG

CC:

Office Memorandum · NUCLEAR METALS

TO :

FROM :

SUBJECT: Radiation Exposure to the hands, use of protective gloves by Machine Shop and Fabrication Dept. Personnel

This memo consolidates and further defines prior memoranda and discussions relative to use of protective gloves by Machine Shop and Fabrication personnel, and is to be implemented immediately as standard operating procedure.

Glove Usage When Handling Uraniam or
Materials Contaminated with Uranium

(a) Gloves must be worn at all times when actually handling bare uranium or materials and equipment known or suspected to be contaminated from contact with uranium.

(b) The type of glove is totally at the option of the operator and may be cotton, leather, rubber, asbestos, or plastic, though leather gloves are recommended since the dose to the hands is reduced to half by the shielding effect of the leather.

(c) It is not the intent of this requirement to encumber or interfere with operation of equipment by requiring wearing of gloves. Operators are encouraged to remove gloves when manipulating the controls of the equipment, For example, when performing lathe machining of U, it is actually desirable to wear the gloves only when loading the uranium piece into the chuck; wearing the gloves when handling the wrench for tightening the chuck or when operating the lathe controls would only transfer the contamination to tools or parts of the lathe that should be kept clean.

(d) When work is interrupted such as at breaks, lunch, at the end of the day, or on conclusion of a given task, the gloves and hands must be monitored with a Geiger counter.

The operator should hold the gloves about 2" from the end of the probe of the Geiger counter and discard or wash the gloves on finding of contamination in excess of 1 mr/hr. Bare hands should be washed, dried, and rechecked on any finding of contamination in excess of normal instrument background.

MEMO TO FILE

MAR 20 1974

MANAGEMENT MEETING - NUCLEAR METALS, INC., CONCORD, MASS.
DOCKET NOS. 70-82 and 40-672
LICENSE NOS. SNM-65 and SMB-179

On February 13, 1974, Paul R. Nelson and Peter Knapp met with Mr. W.B. Tuffin, President, and his staff, A. Gillman, R. Franks, and R. Robie. Also present was S. Levin, consultant for Nuclear Metals.

Mr. Nelson opened the meeting by describing available enforcement tools (enforcement letter, civil penalty, and cease and desist orders) and their purpose. He then described the conditions requiring a civil penalty, namely unsuccessful enforcement through documentation letters and recurring violations. Nelson then described the actions taken before levying a civil penalty. First a strongly worded enforcement letter followed by a meeting with the licensee if the letter failed to achieve compliance. It was explained that the management meeting was for the express purpose of ensuring the licensee was aware that a civil penalty would be levied if the condition was not corrected. Nelson pointed out that these steps had already been taken by Region I including a previous management meeting with them on March 21, 1973, and our recent inspection revealed recurring violations.

Mr. Tuffin was informed that Region I had given serious consideration to leveying a civil penalty but had concluded it would not be appropriate at this time. It was explained we reached this decision because Nuclear Metals had taken action to resolve the violations previously noted but had overlooked the need for beta and gamma measurement. Further, Mr. Nelson stated that in this situation there was a need for Regulatory to have better clarified this need.

Mr. Nelson concluded by stressing the fact that now Nuclear Metals was fully aware of beta-gamma survey requirements and that the imposition of a civil penalty would depend on our findings during our next inspection, which would be conducted in the near future.

Knapp noted that it is Nuclear Metals responsibility at all times to take whatever action is necessary to protect health and safety and meet regulatory requirements.

He then stressed three areas that he particularly wanted to bring to the attention of Nuclear Metals:

a. The need for beta and gamma as well as alpha evaluation. This was a reiteration of material already known to the licensee to assure that the questions was clearly settled in everyone's mind.

A181

b. The question of whether adequate steps were being taken to assure that air samples were representative and that the employee's breathing zone was being monitored.

c. The fact that certain actions of licensee employees, reported in Section 18 of Inspection Report 70-82/73-05 and 40-672/73-02 (specifically the employee and foreman actions of entering uncontrolled areas in contaminated clothing observed by inspectors during the visit of January 7, 19764) showed that even after the licensee had agreed to control contamination spread he had failed to do so. Knapp emphasized that findings of similar actions at subsequent inspections would show clear recurrence of a very significant violation.

Nuclear Metals' President expressed a strong desire to comply with all regulatory requirements, described and demonstrated actions they had taken to correct the problems and said that he looks forward to the next inspection which he felt confident would demonstrate compliance.

Peter J. Knapp, Senior
Facilities Radiation Protection Section

Paul R. Nelson, Chief
Radiological & Environmental
Protection Branch

040-00672

NUCLEAR METALS, INC.

2229 MAIN STREET
CONCORD MASSACHUSETTS 01742
TELEPHONE 617 369-5410

June 30, 1978

U.S. Nuclear Regulatory Commission, Region I
Office of Inspection and Enforcement
631 Park Avenue
King of Prussia, Pa. 19496

Subject: REPORT OF OVEREXPOSURE

Gentlemen:

This is a report of overexposure of the skin of the whole body to beta plus gamma radiation as required by 10CFR20.405(a)(1). This is our first experience of such an apparent overexposure during our 35 years of operations with uranium. We have completed our investigation, we have had the films re-evaluated by the film badge service, and we are filing this report based on confirmation of the film badge data as received by us on May 30, 1978.

1. Extent of Exposure:

To help assure accurate assessment of exposure, we have for some time been assigning two film badges to each foundry worker. Exposures of beta plus gamma recorded for the first quarter of 1978 for the badges worn by two foundry workers are as follows: (1)

Badge No.	Exposure in Rems (Beta plus Gamma) Jan.	Feb.	March	Total
	4.210	1.780	2.550	8.540
	3.770	1.480	2.070	7.320
	4.180	2.020	3.440	9.640
	3.020	1.670	3.500	8.190

The total gamma ray dosage for each individual was below the quarterly permissible dose of 1.25 Rems.

(1) Information required by 10CFR20.405(b) appears on a separate attachment.

Status 4

IX 30

2. Levels of Radiation:

Surveys have been made of the materials involved in all foundry operations with particular attention to post-melt cleanup. The highest radiation levels related to the cleaning of the crucibles. A maximum beta ray dose rate of approximately one Rem per hour was determined by radiation measurements at the operator's location relative to the open end of the crucible (the closest expected approach of the film badge). The associated gamma ray dose rate was approximately 0.020 Rem per hour.

3. Cause of Overexposure:

The source of radiation exposure, principally beta rays, results from the selective deposition of daughter products on crucible surfaces following uranium melting operations. An exposure equivalent to being in close juxtaposition to the crucibles for some eight to ten hours during the calendar quarter could produce the reported exposures.

4. Corrective Action:

We are implementing a number of corrective actions to avoid a recurrence:

A. Reassignment of Personnel: The two individuals were transferred to non-foundry activities pending completion of our evaluation and implementation of corrective action.

B. Early Alert: Our processor of film badges has been directed to telephone us immediately on the finding of any individual badge reading in excess of one third the limits stated in 10CFR20.101(a). This will allow prompt investigation of exposures exceeding the average permissible monthly limit.

C. Shielded Storage: Used crucibles and covers stored within the work area are now placed inside steel containers of sufficient thickness to shield against beta radiation.

D. Shielding during Operations: Wherever possible during the post-melting cleanup cycle, added shielding will be used to reduce the beta ray exposure to the body.

E. Increased Supervisory Attention: The supervisors of foundry employees are placing still greater emphasis on the education of the workers and on efficient work techniques to reduce exposures.

While foundry operations certainly involve exposure to heat and the handling of heavy objects that could place pressure on the badges, our review has discovered no conclusive indication that these factors have influenced the reported exposures.

We are of the opinion the corrective actions defined above will be effective in minimizing the possibility of a recurrence. The exposures to the skin of the whole body for foundry workers during the month of April are indicative of our efforts in this regard -- the average exposure was 0.4 Rems, with a maximum of 0.67 Rems, and during the month of May the average exposure was 0.5 Rems, with a maximum of 1.2 Rems.

Please let us know if any added information is needed.

Very truly yours,

Attachment (Per 10CFR20.405)(b))

CC: Director of Inspection and Enforcement
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

NUCLEAR METALS, INC.

INFORMATION REQUIRED BY 10CFR20.405(b)

Name	SSN	DOB	Badge Nos.
(b)(6)			

NUCLEAR METALS INC.

March 1, 1982

To: Mr. John D. Kinneman
U. S. Nuclear Regulatory Commission
Region I

From: David J. Allard and Frank J. Vumbaco

Subject: Report on 1981 Last Quarter Skin Dose to an NMI Employee

This report is being submitted as per our February 16, 1982 telephone conversation/letter and 10 CFR 20.405. It is a summary of an initial investigation into a Vendor reported skin dose of 8,100 mREM to one of our Melting and Casting Technicians. Even though the investigation to date has been extensive, it will be ongoing into the future. As additional information is obtained, it will be forwarded accordingly.

Appendix I contains a breakdown of doses assigned by R. S. Landauer, Jr. and Company (Vendor), to the individual's film badges throughout the quarter. It should be noted that the badges were assigned to the individual for a two-week period, therefore, latent image fading is no doubt quite negligible. In addition, two reports have notes indicating that respective film badges were contaminated. Our Vendor determines this through direct contamination measurements of the film envelope and manual observations of density patterns/distributions on the processed film (1). If the values reported for the two contaminated badges are omitted, and the remaining values assumed to be valid and averaged over the quarter, one obtains 7,425 mREM for a quarterly skin dose. Reviewing official time sheets and records of specific tasks performed by the subject individual, this latter statement seems quite reasonable. He (individual) had done nothing different during the periods when contaminated badges were reported, than the rest of the quarter.

This problem of contaminated film badges is no doubt a factor that is leading to an overestimate of all Melting/Casting Technician exposures. During the late summer of 1981 our dosimetry reports indicated a number of contaminated film badges for this group of employees. In an effort to rectify this situation, the solution was to begin placing film badges in small plastic bags. The employees attach them daily to their uniform shirt pockets with safety pins positioned at the top of the bag. This managed to eliminate most of the contamination problem. However, some bags still get torn and film badges get contaminated (as seen in the Appendix I data). The last

quarter 1981 film badges of the subject individual were all in plastic bags. A recent survey of plastic bags from the Melting and Casting area indicates one of several problems with the "solution". Figure 1 shows a histogram of levels of contamination on a group of bags after two weeks of use. This is the first problem. To get a handle on the magnitude, six unused film badges were placed in used plastic bags for one week. The bags were selected from the distribution shown in Figure 1. Reports on these films indicate that the bags themselves will cause readings ranging from "minimal" to 480 mREM (beta-gamma) in a one week period. With Melting and Casting operations at present, direct lifting of contaminated graphite crucibles cannot be avoided. Therefore, contamination of protective plastic bags cannot be avoided without operational changes.

The second problem these plastic bags pose is that of the position of film badges when Melting and Casting Technicians are being exposed. As stated in Item 9 of our September 1, 1974 License Renewal under Casting Operations: "localized radiation levels approximating 1 REM/hr (principally beta-rays) may occur within the area in such locations as inside the furnaces, inside vented enclosures, or adjacent to castings or charge stock". This situation has always been known to the employees and our Health Physics Department. Unfortunately, the employee's posture when working on the above stated items, and respective position of his film badge, was not correlated when the use of bags began. Prior to informing the subject individual of his potential overexposure, the writers wanted to observe his work habits without bias. It was noted that whenever the subject individual (or other technicians) worked on any of the above items, they were bending over them. Furthermore, the plastic bags pinned at the top and to their shirt pockets caused the film badge to fall four to six inches away from the trunk of the body and closer to the radiating source. Past practice of clipping the badge to the pocket did not cause such large distance discrepancy, with respect to the dosimeter and the individual(s). The accuracy problem this situation has caused can be inferred from Figure 2. The graphite crucibles depicted are the most significant source of exposure in the Melting and Casting area. This is due to a quantity of uranium-decay products physically separating in the melt and being left in the crucible after the molten metal is poured from the bottom. When Melting and Casting Technicians work on the crucibles (i.e. vacuuming, precoating interior surfaces, loading a metal charge for alloying) they are bending over and reaching into the crucible. It is clear that badge distance discrepancies can cause large errors in dose measurements. Most importantly, it can be seen from Figure 2 that only a small fraction of the skin is being irradiated to the maximum, as indicated by a dosimeter. We estimate that one-seventh (1/7) of the subject individual's skin is receiving maximum exposure.

The above stated situation of film badge positioning has caused, what we feel has been a large unexpected increase in Vendor reported doses to Melting and Casting Technicians. The problem was compounded by

past reporting procedures of the Vendor. It can be seen in Appendix I that actual reports on dosimetry were received on an untimely basis. High values for an exposure period would be called in to Health Physics, but cumulative quarterly totals would not be. Not expecting to have any Melting and Casting Technicians exceed a quarterly skin dose limit, based on past experience, cumulative totals were not done during the last quarter of 1981.

The previous discussion has been focused on events leading to the subject individual receiving a reported 8,100 mREM skin dose for the last quarter of 1981. The remaining body of the report will be a summary of our experiments/evaluation of film badge response to mixed beta/low energy gamma and x-ray fields, appropriate modification of reported doses, a summary of discussions with the subject individual, and corrective actions to date and planned for the future.

After we received the dosimetry report of January 18, 1982 showing a potential overexposure, efforts were undertaken to verify the Vendor's dosimetry. Dr. George Chabot was hired at that time as a consultant to NMI. Discussions with Dr. Chabot led us to setting up a crucible horizontally in a fume hood, and measuring a beta dose rate (at 10.75 inches) with his NBS traceable extrapolation chamber/electrometer. A series of test film badges were then irradiated singularly at that point (with and without backscatter) through a range of values exceeding the highest two-week reported dose to the subject individual. A series of film badges from the same batch were similarly irradiated (through 7 mg/cm^2) with a depleted uranium (DU) metal slab recently calibrated by Dr. Jack Pruitt at NBS. Figure 3 illustrates the results after our Vendor "blindly" processed these films. The crucible irradiations are more appropriate with respect to environmental conditions and standardized conditions (2,3,4,5). The DU slab irradiations were done to monitor any unaccounted film processing changes on the part of our Vendor from batch to batch. That is, any change in the least-squares line of slab irradiations would cause a similar change in the line for the crucible irradiations. The latter is assumed to be a true beta surface dose delivered/observed Vendor reading relation. To see how our Vendor has performed lately, we overlaid tracing paper on Figure 3 and plotted data from a series of slab irradiations performed on January 14, 1982. The trace (Figure 4) was adjusted to line up with the slab irradiation data of February 3, 1982, and an "expectation" absolute relation line was drawn in. As can be seen from Figures 3 and 4 the Vendor beta dose readings have overstated and understated the true surface dose by about the same magnitude in these two cases. For these reasons we believe our Vendor's calibrations provides a quite accurate indication of beta <u>skin surface</u> dose under controlled conditions.

Additional experiments we've performed since January involved irradiation of many of our Vendor's film badges behind pieces of NMI uniform shirts and pants, plastic used to "bag" film badges in the Melting and Casting area, and plastic and glass safety glasses used by

employees. The relative percent change in reported beta doses of the above, and unattenuated badges, is tabulated in Appendix II. These irradiations were done on the DU slab with 7 mg/cm^2 of tissue eqivalent covering. Similar measurements were made with an ionization chamber and a crucible through a uniform shirt and pants. These results are also tabulated in Appendix II and no doubt are more representative of actual conditions. The DU slab appears to have a "harder" beta spectrum.

At this point a brief discourse regarding the subject individual's, Vendor reported, gamma (photon) dose is in order. The source material processed here at NMI is strictly purified depleted uranium, devoid of high enery gamma emitters (i.e. Radium-226 decay products). An examination of the decay products in equilibrium shows little yield of photons above 90 KeV on a weighted specific activity basis (6). Further, most Bremsstrahlung from betas emitted by decay products would be expected to be in the same energy range. A recent investigation by one of the writers, performed over a one year period, indicates that the Vendor's GARDRAY film badge over-responds to photons in this energy region (7). This is no doubt due to the high photoelectric cross-section of silver halide, despite the use of flattening filters in the badge. An appropriate correction to the subject individual's "gamma" dose would involve a straight line function with "m" equal to 1.17 and "b" equal to 33.5 mREM. This problem relating to our Vendor's mixed field accuracy has not yet been directly addressed, with respect to photons. However, the NRC may have an indication of their (Vendor) performance in the University of Michigan Study (2). In addition to the over-response of these film badges to just low energy photons, there are some theoretical problems with mixed field dosimetry using their film badges. In conversations with our Vendor it has been stated that the GARDRAY badge has 375 mg/cm^2 total, of plastic and aluminum, over the region of film where the photon film density measurements are made (8). Examining a beta range (mg/cm^2) versus energy curve indicates that 1100 mg/cm^2 would be required to stop the most energetic betas from Protactinium-234m (6). Betas degraded in energy may cause an additional film darkening behind the 375 mg/cm^2 region that is not proportional on a RAD to RAD basis (9). If this is happening, our Vendor may be further overestimating photon doses. We have not investigated this problem to date.

Considering all of our data we feel some practical modifications of our Vendor's reported cumulative quarterly dose to the subject individual are reasonable and justified. One adjustment will be an increase and the remainder decreases. They are as follows:

For the 900 mREM gamma dose, a decrease by the straight line function in Reference 7;

If, $y = 900$ mREM, $b = 33.5$ mREM, and $m = 1.17$
and, $y = mx + b$
then, $900 = (1.17)x + 33.5$
$x = 741$ mREM (adjusted photon dose)

For the 7,200 mREM beta dose an increase of 0.8% for the unaccounted attenuation of the "anti-contamination" plastic bags, and a decrease of 10% for attenuation of the individual's shirt (badges worn on outside).

Adjusted Beta Dose = 7,200 + 57.6 - 720
Adjusted Beta Dose = 6,538 mREM

Total adjusted Beta-Gamma Dose = 7,279 mREM

The writers feel this is an extremely conservative adjustment of the reported skin dose to this individual. Considerations being given to the following: two reportedly contaminated film badge envelopes, an ever present degree of contamination on the plastic bags during this period of time, and the film badge positioning errors created when these bags were used. We seek the NRC's opinion so we may adjust our legal records.

In order for us to put this exposure into perspective, with respect to biological effects, we performed several calculations on the above adjusted skin surface dose. These calculations were also conservative, in that the adjusted photon dose was not altered further, because of lack of knowledge regarding the appropriate tissue attenuation and backscatter factors. The beta surface dose was adjusted by using the Theory of Loevinger and his semiempirical equations (10,11). It was done for the two dominant decay product beta spectra (i.e. Th-234 with E_{MAX} = 0.193 MeV and Pa-234m with E_{MAX} = 2.29 MeV), being unable to modify the equations for overlapping energy spectra. This results in a dose range with upper and lower limits; the actual dose is somewhere between. The equations used are as follows:

Dose at depth (i.e. to live tissue at 7 mg/cm^2):

$$D_{(x)} = D_o e^{-\nu x}$$

Average Dose to the live skin layer (i.e. between 7 and 150 mg/cm^2):

$$\bar{D}_t = \frac{D_o}{\nu T}\left[e^{-\nu x} - e^{-\nu(x+T)}\right]$$

Where, $\nu_{Tissue} = 18.6\ (E_{MAX} - 0.036)^{-1.37}$, cm^2 g^{-1}

D_o = surface dose
$D_{(x)}$ = dose at depth
$\bar{D}_t$ = average dose to thickness T, below thickness x

The results of these calculations are informative and are summarized below for D_o = 6,538 mREM.

	Beta Dose (mREM)	Beta-Gamma Dose (mREM)
Upper limit dose to tissue at 7 mg/cm^2	6,276	7,017
Lower limit dose to tissue at 7 mg/cm^2	1,242	1,983
Upper limit dose to live skin layer	4,119	4,860
Lower limit dose to live skin layer	33	774

To date, numerous discussions have taken place with Melting and Casting Technicians, Management and the subject individual regarding our surveys and dosimetry in the area. One of the writers has personally observed the subject individual's work habits and has had a discussion lasting several hours regarding his Vendor reported doses. At that time he was reintroduced to the concepts involved with the different types of radiation which he is is exposed to in his workplace. His last quarter 1981 dosimetry was broken down into "skin" and "whole body" doses and presented to him as reported. The biological significance of these doses were reiterated with respect to risk to the various tissues involved. He understands these concepts well. Prior to the mentioning of dosimeter position he expressed a concern over "how the badge hangs into a crucible when I work on it". The individual is right handed and wears the badge on his right shirt pocket. This was verified prior to him (individual) being informed of the possible overexposure. Further, he (individual) personally feels the way badges had been placed may have caused an overestimate of his exposure. He (individual) did not seem anxious about the situation and was very willing to cooperate with any future investigations we propose.

Throughout this report numerous problems relating to dosimetry in this area have been pointed out. Mixed beta-gamma fields are difficult to resolve from a quantitative measurement perspective. However, we have made significant strides in overcoming these difficulties. We have assured ourselves that on the average our beta dosimetry is accurate under specified conditions.

Corrective measures that are in place now, and will be in place soon are as follows:

Presently Being Done

1) Film badges used by employees in the Melting and Casting area are being shipped via Federal Express to our Vendor for development and reading. Our Vendor is processing on an "Emergency Basis". (See attached Purchase Order Change). Results for the exposure period and cumulative totals are promptly called in to NMI's Health Physics Department.

2). "Anti-contamination" plastic bags protecting the film badges are monitored for contamination after each shift and changed, if required.

3). Two safety pins (one at the top and bottom) are now used to pin badges through the employee's shirt. Position on the shirt will remain the same (i.e. if the person is right handed - pinned to the right breast pocket). We feel this is a conservative estimate of the dose to the "skin of the whole body".

4). Whenever employees are working on graphite crucibles they will do so through newly fabricated half-inch Lexan covers (i.e. vacuuming and inverior surface coating). Figure 5 is a photograph of one of these covers. Measurements with an ionization chamber show a reduction of the dose rate from a crucible on the order of 98%.

5). Long rubberized/vinyl coats with hoods have recently been purchased. Employees will be wearing this outer gear and a plastic face shield whenever working with used crucibles or working in the interior of the induction furnaces. Again, measurements indicate a 22% reduction in dose rate using a crucible as a broad beam source. Aluminized-asbestos suits with hoods and plexiglass face shields have been ordered for when employees open furnace heads. If a Melting and Casting Technician were to reach into a hot furnace with a vinyl suit, it would melt to his arm.

6). Senior management meetings, including the VP/Technical Director and Health Physics staff, have been initiated. These meetings are held monthly and review Health Physics aspects of Melting and Casting. ALARA concepts have been introduced and will be reflected in future dosimetry reports.

Proposed Future Corrective Actions

1). Locking metal covers will be placed over crucibles while they are being removed from the Melting and Casting furnaces. This engineering effort was initiated several months ago, prior to the subject individual's "reported" overexposure. Final design has been approved and twenty of these covers are being fabricated.

2). An enclosed automated crucible cleaner/interior surface coater is being designed to eliminate technician contact time with open crucibles. Cost of the design and fabrication of this device is estimated to be close to two hundred thousand dollars. This device has been in the design phase for about a half a year now. It is a difficult engineering problem, but we are pushing the engineering firm working on it for prompt fabrication.

3). Permanent assignment of a full-time Health Physics Technician to assist with ALARA engineering in the area will occur as soon as possible.

4). Aluminum covers as a beta shield for all charge trays are being fabricated and will be utilized as soon as they are available.

SUMMARY

The key points to this report are as follows:

* As per the above discussion, we feel that the total adjusted beta-gamma dose to the subject individual is conservatively placed at 7279 mREM for the final quarter of 1981. Rational as iterated above.

* Management and technical changes, both present and planned, have been undertaken to prevent recurrence.

* The writers request NRC guidance to appropriately modify the subject individual's dosimetry record.

* The writers emphasize the fact that the practice of ALARA will be the driving force behind forthcoming reviews and subsequent changes in our operating procedures.

If any additional information is required, do not hesitate to contact the undersigned individuals.

David J. Allard
Supervisor of Health Physics

Frank J. Vumbaco, Manager
Health and Radiation Safety

DJA/FJV:dg/aj

Appendix I

The Subject Individual's Last Quarter 1981 Dosimetry*

Exposure Period	Gamma (mREM)	Beta (mREM)	Beta-Gamma (mREM)	Date Report Received	Vendor's Comments
10/1 to 10/14	150	810	960	11/23/81	
10/15 to 10/31	190	1930	2120	11/23/81	"contaminated badge"
11/1 to 11/14	250	1310	1560	12/23/81	
11/15 to 11/30	110	920	1030	12/23/81	"contaminated badge"
12/1 to 12/14	100	1220	1320	1/5/82	
12/15 to 12/31	100	1010	1110	1/18/82	
TOTALS:	900	7200	8100	1/18/82	

*As reported by R. S. Landauer, Jr. and Company (Vendor).

Appendix II

DU Metal Slab As Beta Source*

Attenuator	Relative Percent Decrease in Beta Dose
Polyester Shirt	3.1%
Polyester Pants	6.3%
"Anti-contamination" plastic bag	0.8%
Plastic Safety Glass Lens	64.5%
Glass Safety Glass Lens	80.6%

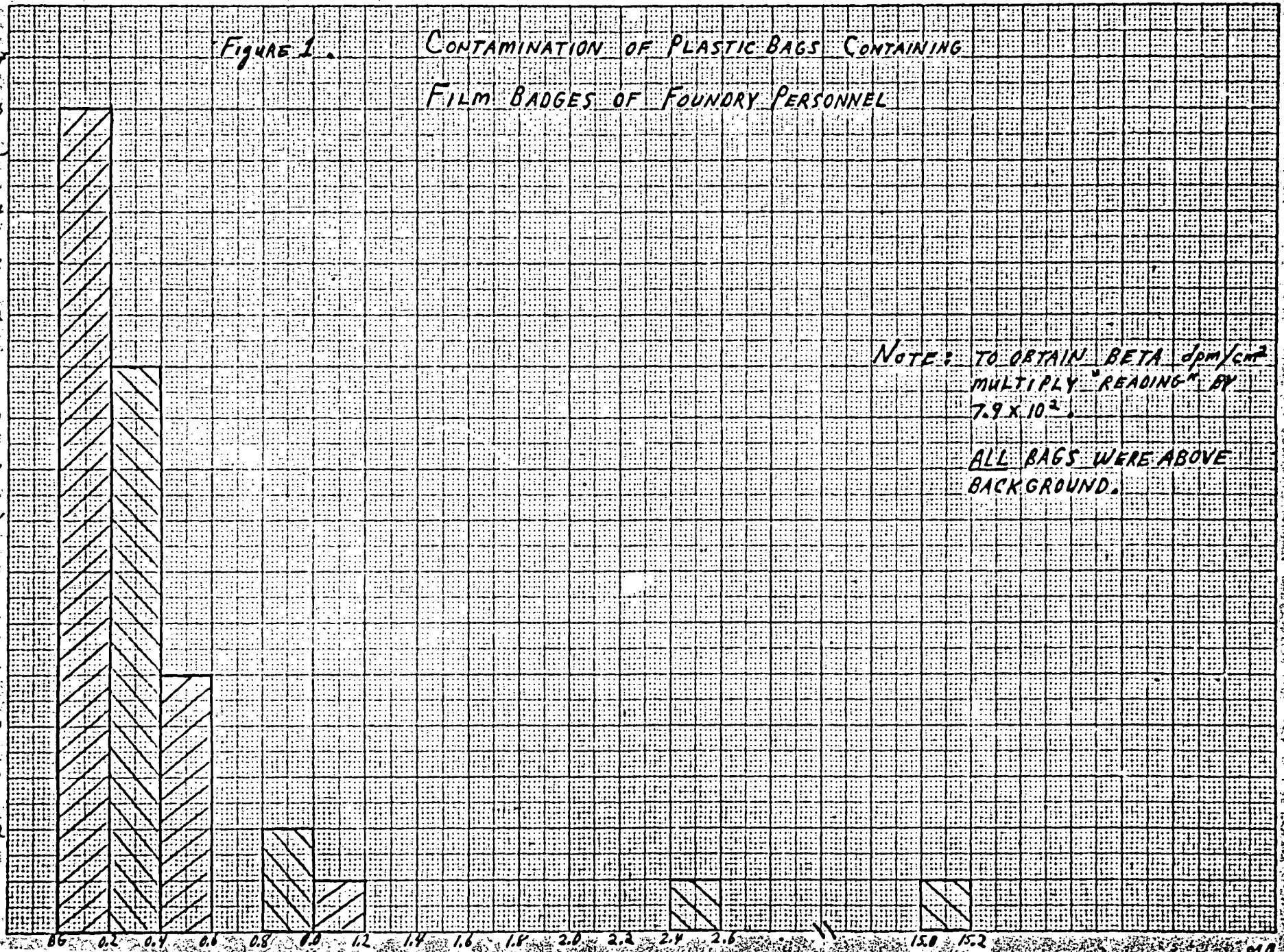
*(Apparent "hard" beta spectrum)

Used Crucible with Oxides as Beta Source*

Attentuator	Releative Percent Decrease in Beta Dose
Polyester Shirt	10%
Polyester Pants	11%

*(Apparent "softer" beta spectrum)

Figure 1. Contamination of Plastic Bags Containing Film Badges of Foundry Personnel



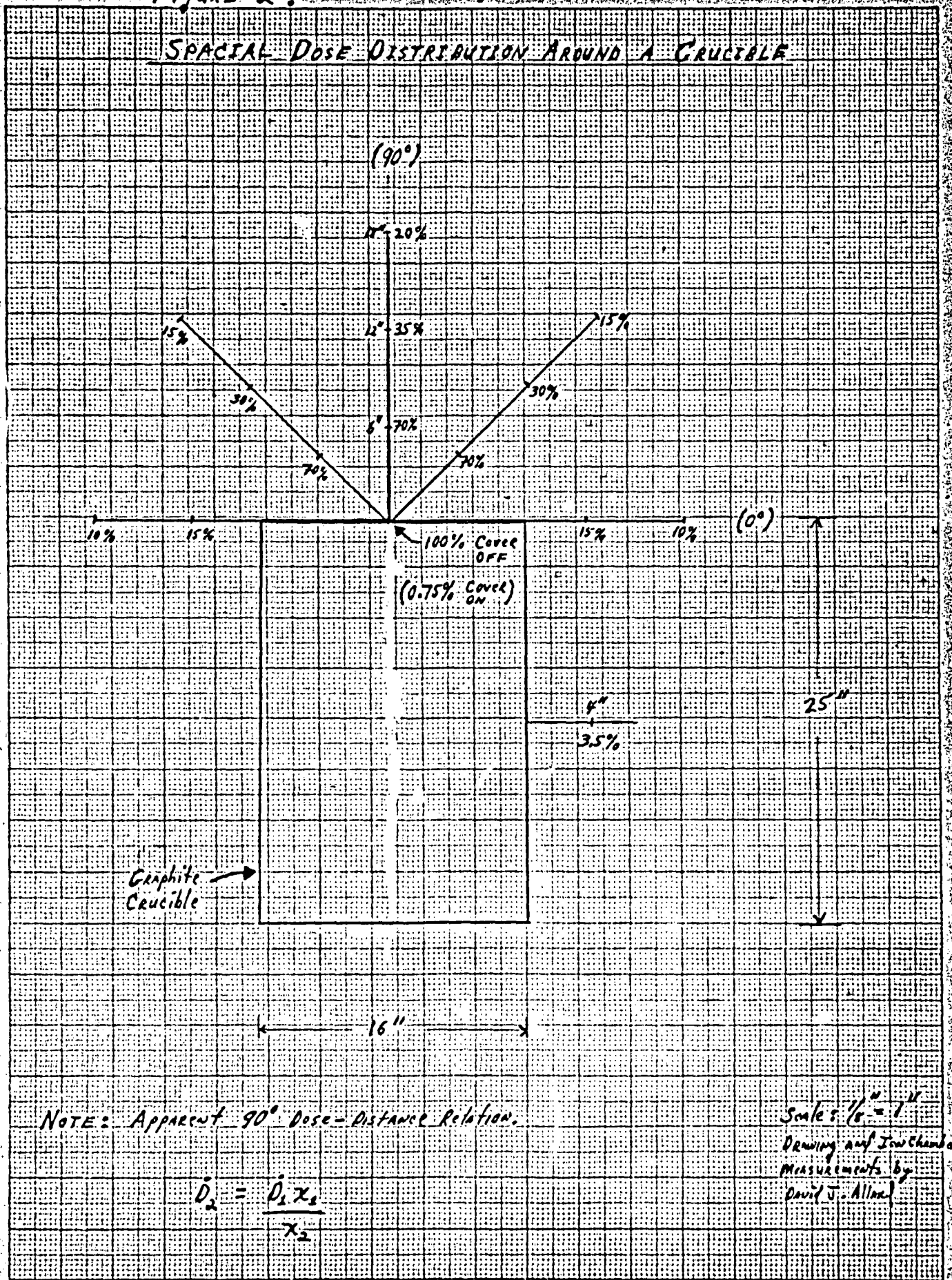
Note: To obtain Beta dpm/cm² multiply "Reading" by 7.9×10^{2}.

All bags were above background.

Attachment Sheet No. 11

FIGURE 2.

SPACIAL DOSE DISTRIBUTION AROUND A CRUCIBLE



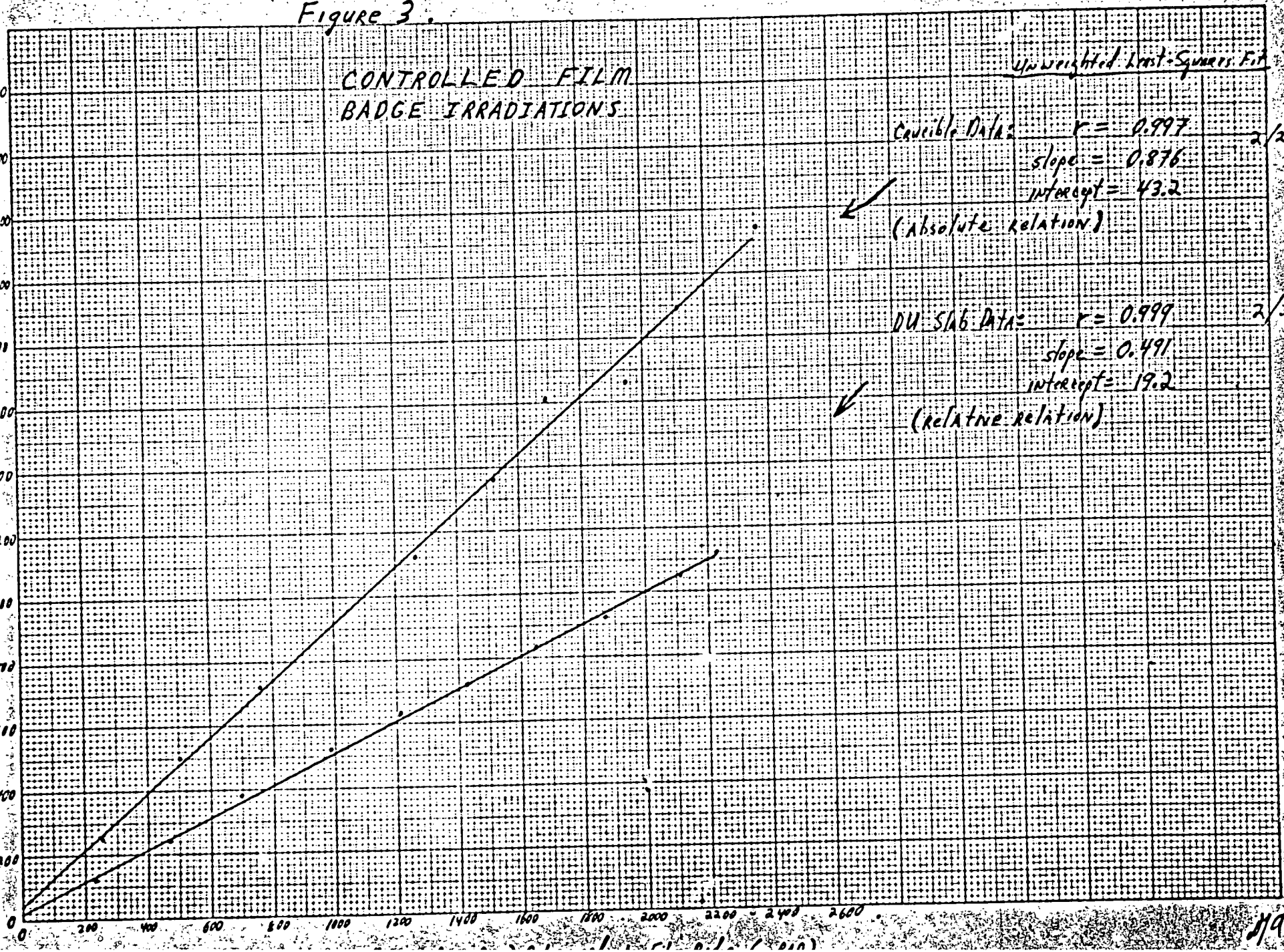
NOTE: Apparent 90° Dose-Distance Relation.

$$\dot{D}_2 = \frac{\dot{D}_1 x_1}{x_2}$$

Scale: 1/8" = 1"

Drawing and Ion Chamber Measurements by David J. Allen

Figure 3.

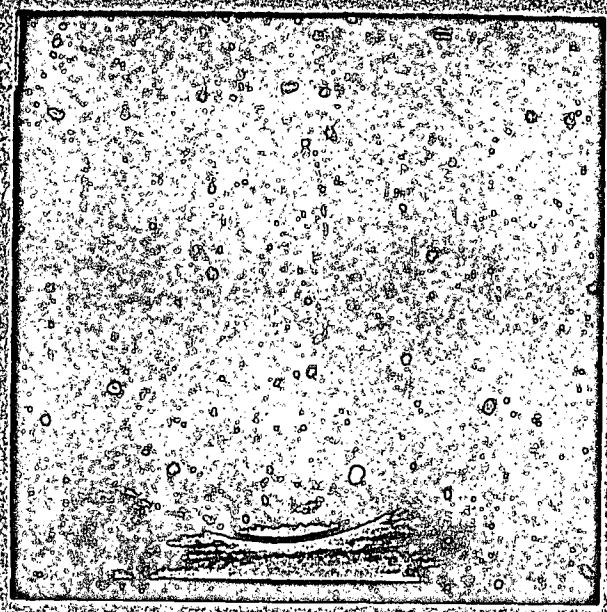


ATTACHMENT SHEET No. 13

Figure 4.

ATTACHMENT SHEET No. 14

Figure 5:



Lexan crucible shield.

References

(1) McDonald, Jeanine; Private Communication. R. S. Landauer, Jr. and Company.

(2) Plato, P. and Hudson G.; "Performance Testing of Personnel Dosimetry Services", NUREG/CR-1064, January 1980.

(3) American National Standards Institute; "Criteria For Film Badge Performance", ANSI N13.7-1972.

(4) U.S. Atomic Energy Commission; "Film Badge Performance Criteria", Regulatory Guide 8.3, February 2, 1973.

(5) American National Standards Institute; "Draft American National Standard Criteria for Testing Personnel Dosimetry Performance", ANSI N13.11, July 1978.

(6) U.S. Department of H.E.W.; "Radiological Health Handbook", Revised January 1970.

(7) Allard, D. J. and Memoli, L.C.; "Quality Assurance on Commercially Supplied Dosimeters", Proceedings of the 1980 Health Physics Society Mid-year Symposium on Medical/Health Physics.

(8) Wheeler, Robert; Private Communication. R. S. Landauer, Jr. and Company.

(9) Tochilin, E. and Golden R.; "Investigations on the Relative β- to γ - Ray Sensitivity of Photographic Emulsions" Health Physics, Vol. 4, pg. 244, April 1961.

(10) Loevinger, Robert; "The Dosimetry of Beta Radiations", Radiology, Volume 62, pg. 74, January 1954.

(11) Loevinger, Robert; "The Dosimetry of Beta Sources in Tissue. The Point Source Function", Radiology, Volume 66, pg. 55, January 1956.

PURCHASE ORDER

STANDING ORDER

NUCLEAR METALS, INC.
2229 Main Street • Concord, MA 01742
Tel. (617) 369-5410 • TWX 710-347-1056

SHIP AND BILL TO

DATE 3-1-82

P.O. NUMBER
NM— 31109
PAGE 1 OF 1
THIS ORDER NUMBER MUST APPEAR ON ALL INVOICES, CORRESPONDENCE, PACKAGES, AND SHIPPING PAPERS.

TO R. S. Landawer Jr. & Co
Glenwood Science Park
Glenwood, Ill 60425

A PACKING LIST MUST ACCOMPANY EACH SHIPMENT. INVOICES MUST BE RENDERED IN TRIPLICATE AND MUST DESCRIBE ITEMS AS SHOWN ON PURCHASE ORDER.

THIS ORDER IS SUBJECT TO THE TERMS AND CONDITIONS ON THE REVERSE SIDE HEREOF AND ANY ATTACHMENT(S) HERETO. ACCEPTANCE OF THE OFFER REPRESENTED BY THIS ORDER IS EXPRESSLY LIMITED TO SUCH TERMS AND CONDITIONS WITHOUT CHANGE OR ADDITION. SIGNING AND RETURNING THE ACKNOWLEDGMENT COPY OF THIS ORDER OR IN ANY EVENT, DELIVERY IN WHOLE OR IN PART OF THE ARTICLES OR SERVICES TO BE FURNISHED HEREUNDER SHALL CONSTITUTE ACCEPTANCE OF THIS ORDER. THIS IS THE ENTIRE CONTRACT AND ANY OTHER TERMS OR CONDITIONS PROPOSED BY SELLER'S ACKNOWLEDGMENT SHALL NOT BE BINDING UPON BUYER.

CONFIRMATION TO	PHONE	MATERIAL RESUMED BY	VENDOR SHIPPING PROMISE	PERMIT NUMBER	RESALE
yes				04-2506781	NOT FOR RESALE

TERMS	SHIP VIA	F.O.B.	☐ PURCHASES OF GOVERNMENT SUPPLIES
net 30	Federal Express	shipping point	CONTRACT NO.

ITEM NO.	QUANTITY	REC'D	B.O.	DATE	DESCRIPTION	ACCOUNT NUMBER	UNIT PRICE	AMOUNT
1	1				Requesting this Purchase Order to be a standing order for all Dosimeters on this Account. Landawer account 38566 Will always be sent via Federal Express for Emergency Processing	8425-852		

REQUESTED BY	APPROVED BY	BUYER	TOTAL
T. Carpenito	T. Carpenito	T. Wright	

Thomas G. Wright
PURCHASING AGENT
NUCLEAR METALS, INC.
Thomas G. Wright

VENDOR COPY

NUCLEAR METALS INC.

Lic. # SMB-179
Docket No. 40-00672

May 24, 1984

United States Nuclear Regulatory Commission
Region I
631 Park Avenue
King of Prussia, PA 19406

Attention: Mr. John D. Kinneman
Nuclear Materials Section

Re: Docket No. 40-00672
License No. SMB-179

Gentlemen:

Under the provisions set forth in 10 CFR 20.405(a), Nuclear Metals, Inc. (NMI) is hereby submitting thirty day written notification pursuant to an exposure of an individual to radiation in excess of the applicable limits as set forth in 10 CFR 20.101. Specifically, an exposure in excess of the 18.75 Rem/quarter limit to the extremities has occurred. Attached please find a description of the occurrence, as well as the evaluation of the actual exposure to the hand of the individual in question.

Should you or your staff have any questions, please feel free to contact me.

Sincerely,

Frank J. Vumbaco

Frank J. Vumbaco, Manager
Health and Radiation Safety

FJV/swk

Attachments

CC: Director of Inspection
and Enforcement
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Mr. Frank R. Archibald, P.E.
Industrial Radiation Control Supervisor
The Commonwealth of Massachusetts
Department of Labor and Industries
Division of Occupational Hygiene
39 Boylston Street
Boston, MA 02116

May 24, 1984

ATTACHMENT I

INDIVIDUAL'S PERSONAL INFORMATION

(b)(6)

Name:
Position
SS No.:
DOB:

May 24, 1984

ATTACHMENT II

EVALUATION OF EXPOSURE

Introduction

As indicated in Attachment I, the individual that received the exposure in excess of regulatory limits is a Health Physics Technician. He is assigned to our Foundry area to perform routine surveys and often, with his high level of motivation and interest, becomes involves in non-routine surveys and investigations.

We have in past correspondence described in detail the operations performed by the Melting and Casting Technicians in this area. Whole body and extremity dosimetry is issued and read-out on a weekly frequency. The subject individual of this report is also on the weekly dosimeter change frequency. All individuals in the facility are subject to administrative quarterly dose limits which are two-thirds that of the NRC limits. The application (i.e., actual values) of administrative limits depends on the dosimeter type and frequency. For instance, with the weekly frequency these administrative dose limits are 64 mRem deep dose whole body, 385 mRem shallow dose whole body, and 961 mRem deep and/or shallow dose extremity.

The above information is discussed because of this individual's integral job function in the area, and the actual events leading to his recent extremity exposure.

Discussion

During the third week (April 16, 1984 - April 22, 1984) of this quarter the Melting and Casting Procedures were changed in the Foundry resulting in an upward trend in extremity exposures for the Melting and Casting Technicians. The change was that of requiring cleaning and zirconia painting of the interior of the crucible extension. This was done in order to improve casting chemistry. Attachment III shows the crucible extension as it would be used in a melt cycle. As can be seen, these extensions are not subject to contact with molten depleted uranium metal. They do, however, pick up unsupported Th-234/Pa-234m daughter product activity, as do other internal components of the furnace. The Foundry Melting and Casting Technicians had, up to this point in time, minimal extremity contact with these extensions. Additionally, we had instituted the decay of extensions, crucibles, break off rod and pour cup by storage for a six week decay period. This latter item was initiated to maintain exposures ALARA.

As stated, once the above procedure was implemented, an increase in the Melting and Casting Technicians' extremity dosimetry values was observed. Based on our weekly dosimetry tracking, several individuals were receiving hand exposures which would have placed them above our quarterly administrative limit before the end of the calendar quarter. This prompted an investigation and evaluation as to the cause and possible solution to the problem. (Note: No other individuals in the area have received exposures anywhere near that described below nor has anyone else been restricted from work in the area.)

Part of the investigation involved a number of surveys of the furnace graphite components before placed in 55 gallon drums for decay. Also, surveys of used graphite components coming back into the area for re-use were performed. The radiological surveys were done by the subject individual and were no doubt the cause of extremity exposure in excess of regulatory limits. Surveys were performed with the individual in the standard safety equipment; that is, an aluminized cape/apron, plastic face shield/safety glasses, leather gloves, company issue uniform, and the required whole body and extremity dosimetry. The survey results indicated beta dose rates on the interior surfaces of the extensions that were quite high. The results are below. Also, it is unclear at this time if the zirconia painting contributed to the plating of Th-234/Pa-234m on these interior surfaces.

Typical Dose Rate Range	60 to 80 RAD/hr	(primarily beta)
Highest Observed Dose Rate	217 RAD/hr	(primarily beta)

The individual's whole body and extremity dosimetry for the second calendar quarter of 1984 is outlined below. All values are in mRem.

Period	Whole Body Deep	Whole Body Shallow	Right Extremity Shallow	Left Extremity Shallow
4/02-4/08/84	Minimal	Minimal	90	70
4/09-4/15/84	Minimal	Minimal	Minimal	Minimal
4/16-4/22/84	Minimal	Minimal	Minimal	Minimal
4/23-4/29/84	Minimal	Minimal	70	70
4/30-5/06/84	Minimal	70	1940	400
5/07-5/13/84	Minimal	60	8780	20,790
5/14-5/16/84	-	-	180	180
TOTALS:	Minimal	130	11,060	21,510

On Wednesday, May 9, 1984, a routine call-in from our dosimetry vendor indicated the individual had, during the previous week, received an exposure of 1940 mRem to his right hand while performing surveys of crucible extensions. At that time, the Dosimetry Health Physicist spoke to the individual and instructed him to stop the surveys. Six extensions were surveyed from April 30, 1984 to May 6, 1984. However, by the time we received the routine call-in, sixteen additional extensions were surveyed during the beginning of the week of May 7, 1984. On Wednesday, May 16, 1984, a call-in was received for the May 7, 1984 - May 13, 1984 exposure period. The individual was immediately pulled from duties in restricted areas on May 16, 1984. The next day his currently dated TLD rings (i.e., May 14, 1984) were sent for processing; results were received on May 21, 1984 for the partial week. He was issued spare TLD rings for the remainder of the week.

In addition to the above dosimetry logistics, the individual was interviewed by the Dosimetry Health Physicist, the Manager of Health and Radiation Safety, and the Vice President, Health/Safety. (His self-disappointment was quite evident at the time.) He was asked to estimate his extremity exposures through calculation, which has resulted in the following shallow dose estimates for the two exposure periods in question:

Period	Estimated Extremity Exposure (mRem)
4/30/84 - 5/06/84	5,560
5/07/84 - 5/13/84	12,330
TOTAL:	17,890

As can be seen, the estimates are well within a factor of 3 and 2 for the two respective periods. The agreement is good, in that, some statistical and systematic errors are to be expected with a TLD readout.

Conclusions

The individual has an appointment to be examined by our Company Physician on Thursday, May 24, 1984. This is routine for anyone who has been pulled from an area for radiological concerns.

The Melting and Casting Procedures have been changed back, such that there will be no cleaning or painting of crucible extensions. Additionally, all new extensions have been modified to allow remote/shielded (aluminum) handling. The extremity dosimetry in the area is being critically evaluated each week in order to maintain exposures within our administrative limits. Meetings with much communication between the Melting and Casting Technicians and the Health Physics Department Staff have increased in frequency. It is being stressed that all those involved use uniform safety procedures so new dose reduction measures will be reflected in the dosimetry.

The Health Physics Technician presently in the area is under instruction to perform routine surveys (ambient, smears and air) only. Any non-routine surveys must be cleared through a member of the Health Physics Staff. Previously, the Staff member would review the survey results in relation to the work to be performed by the production worker. This should prevent re-occurrence of a similar exposure scenario.

Lastly, we are planning to obtain a telescopic survey instrument once we identify one suitable for our radiation fields. Inquiries are currently being made to various Health Physics equipment vendors as to availability.

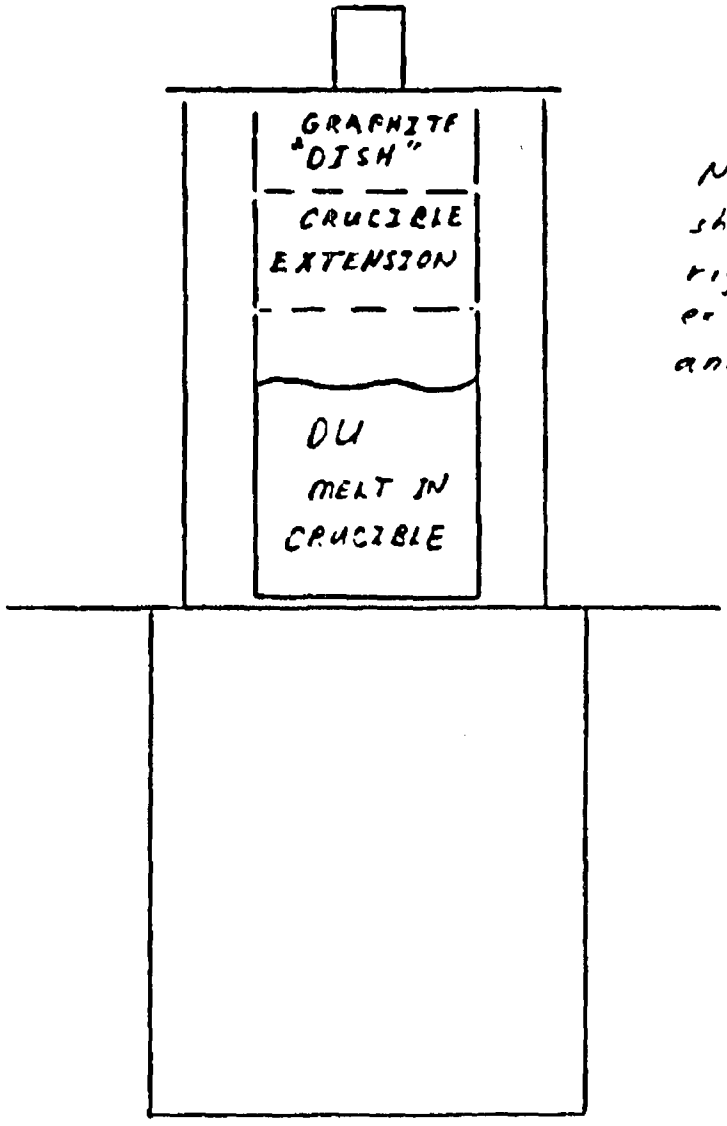
Respectfully submitted,

David J. Allard
Dosimetry Health Physicist

Frank J. Vumbaco, Manager
Health and Radiation Safety

FJV/DJA/swk

FOUNDRY FURNACE



Note: components shown are schematically right cylinder. The extension is graphite and open at both ends.

OFFICE MEMORANDUM

Nuclear Metals, Inc.

To: DISTRIBUTION

Date: February 29, 1996

From: George Shinopulos

Subject: REPORT OF FINDING: SONODYNE VENT FIRE, February 21, 1996

1. EVENTS LEADING UP TO VENT FIRE

The Sonodyne thermocouple system was found to be reading room temperature erroneously (-3°F) on Thursday, February 15, 1996. The Electrical Group (Richall) was called to replace the thermocouple which he did. The problem persisted. Chemical Engineer (Schiller) suggested that the thermocouple lead wire may be defective. It was temporarily bypassed and the room temperature reading read correctly. New permanent lead wire was then installed. For a point of information, the HEPA filters were changed this same day having lasted a normal useful life before reaching the differential pressure limit of 8 inches of water. The Sonodyne was next started for a test run on Tuesday February 20. It was quickly seen that the indicated temperature was going down rather than up. It was shut down and Richall called. He reversed the lead wires at the controller which appeared to correct the problem. The Sonodyne system was then started and run for about 10 minutes to check out its operation. Shut down was accomplished by shutting off the feed water and allowing the high temperature limit to automatically shut down the system. All appeared normal during that 10 minute test. Full normal operation was approved for the next day, February 21, 1996.

2. VENT FIRE

The following is a chronology of the events that took place during the Sonodyne vent fire of February 21, 1996. The sources of the information are the Guard's Log Sheet, Sonodyne Log Sheet for that run, Ed Cantino as the Sonodyne operator, Mark Nelson as Leadman of the area and assisting the Emergency Response Team, Paul Roberts as a responding member of the Emergency Response Team, Larry Hafer who reported the vent fire and a participant in extinguishing the fire, and myself as an observer.

5:35 AM Sonodyne started, good start
5:37 AM Overtemp shutdown at 266°F
5:50 AM Running normal
6:05 AM Running normal with 20% water flow
6:20 AM Running normal with 18% water flow
6:25 AM Running normal with 20% water flow
6:25 to 6:55 AM Temperature fluctuating and dropping to about 250°F, compensating by reducing water flow to 10%
6:50 AM Hafer smelled smoke when entering building
6:58 AM Operator entered Sonodyne room to check fullness of waste drum; no off condition evident
6:59 AM Guards log smell in court yard

A-18

7:00 AM Sonodyne auto shut down upon loss of the exhaust fan operation. Operator logged an indicated temperature of 258°F. Operator could smell smoke then

7:01 - 7:10 AM Nelson went to roof and saw smoke coming from Sonodyne vent exhaust stack. Hafer also went to roof and saw smoke coming from Sonodyne Room exhaust stack. Both reported fire to Cantino. Room supply air was turned off and room exhaust fan shut down about 15 minutes later.

7:07 AM Guard log indicates Nelson requested Emergency Response Team for fire in Sonodyne

7:13 AM Code 2 (fire) for Sonodyne announced shortly after 7:07 but logged in at 7:13.

7:35 AM Building E evacuated

7:42 AM Schlier and Shinopulos arrive and met by Nelson to inform both of the fire

8:00 AM approx.: Emergency Response Team (Cormier, Roberts, Hedin, Alverez, assisted by Nelson) and others assemble at entrance to Building E to develop action plan

8:30 AM approx.; Emergency Response Team members enter Sonodyne room to find smoke, hot Torit hopper. Removed back hatch of Torit and only saw smoke; no flame. High temperature limit on Sonodyne control panel was seen to be reading 21°F.

9:00 - 11:15 AM approx.; Four CO_2 bottles brought to roof and four to Torit collector. Fire was seen then through rear Torit hatch coming out of filter cartridges. Sprayed down fire with water hose and closed hatch. Monitoring thermocouple inserted into Torit through rear hatch. A temperature of about 750°F was indicated. The four CO_2 bottles discharged down duct from roof through flex connection. Temperature of monitoring thermocouple indicated 578°F and was dropping about 1 1/2°F per minute. Four bottles that had been on floor were also brought to roof and discharged down duct. Temperature indicated by thermocouple showed 497°F then crept up to 500°F before resuming drop of about 1°F per minute. When temperature fell to 400°F, prefilter and HEPA filter housing covers were removed for inspection. Cardboard framed prefilters had been completely burned; however, high temperature HEPA filters were found to be substantially in tact and were removed from housing and dropped to floor below. At that time Roberts reported that the fire had restarted as seen through the Torit rear hatch. Said to be more of a glow with a lazy type flame coming out of one cartridge. Nelson then sees smoke coming from HEPA housing filter ports. Cartridges sprayed with water and front access was made to the Torit by removing six cartridge hatch covers. Cartridges were said to be glowing. They were water sprayed and six cartridges were removed to provide room to spray all from the front to completely kill the low intensity filter fire.

12:30 PM Building E re-opened.

3. INVESTIGATORY FINDINGS

Later inspection of the HEPA filters found three of the four to be in good condition with the fourth having suffered some heat damaged which seemed to blind the media rather than opening voids. The media had been pulled away from one side of the frame on the fourth filter. Roberts states he did not see this upon removal of the filter from the housing and believes that it occurred from the drop to the floor. All four filters show mechanical damage obviously from the drop.

As said above, the HEPA filters were in fairly good condition and remained effective throughout the entire fire event. Depending on the exact time the fire started during the 6:25 to 6:55 period of high temperature/erratic temperature control, the vent blowers were on somewhere between 5 and 35 minutes during the fire. Based on the condition of the HEPA filters, the comparatively short period of time that the blowers were on during the fire and, most importantly, that the uranium content measured by the discharge vent sampling filter reported to show no increase, it is concluded that the fire did not cause an increase of uranium to be discharged from the vent to the environment. A'so, the integrity of the 12 gasketed round metal cover plates for the Torit Cartridges was apparently sufficient to keep any dust from entering the closed front compartment of the Torit housing. The Torit cartridges themselves function as a solids separation device and are not part of the containment structure. Therefore, it is concluded that there was no loss in integrity of the containment structure of the Torit filter housing, duct work, HEPA filters and housing nor any other component of the complete Sonodyne Pulse Combustion drier structure. Smoke from the fire however, with a potential for airborne uranium, entered the Sonodyne room either during opening inspection ports for evaluation, during periods of fighting the fire or from down drafts. This was drawn into the interior space of Building E and exhausted through the three HEPA filtered general building and other process vents. Total filtered building vents provide about 38,000 cfm of filtered exhaust air. The removal of the filters during the final periods of the fire fighting process did present another pathway for uranium to enter the work area.

There were no injuries resulting from the fire. Damage or loss to equipment was minor and limited to the Torit cartridge filters, prefilters, HEPA filters (mostly from handling), gaskets and caulking. The estimated cost to repair the damage is $8,000 for materials and 150 man hours of NMI labor.

The root cause of the vent fire was found to have been the purchased thermocouple supplied with reversed wires (polarity). Secondary to the root cause was the reversal of the lead wire polarity at the instrument. It was an incorrect fix of the root cause. In fact, what this did was to introduce a secondary thermocouple that caused the instrument to read an artificially low temperature and the Sonodyne vent system to overheat.

Testing and information was gathered to identify the material that first ignited; the fuel. No oil could be found in the waste water. There was some inconsistent evidence that the dried Sonodyne solids could burn under red heat from a propane flame; much higher than would have been experienced in the Sonodyne at the time of ignition. Visolite powder which is used to check the integrity of the Torit filters did ignite with the propane torch and sustained a flame. This material had been used for a number of years without a problem and again the propane flame was hotter than the Sonodyne overheat condition. The possibility of a hot spark being carried over to the filters from the combustion chamber was discussed. Sparks had been seen some years ago in the primary collector but cleaning procedures where instituted to keep this from happening. The other material investigated was the Torit filter media itself. Both Nelson and Roberts independently observed the media burning during fighting the fire. Mr. Mirvan Wright of the Donalson Company (the cartridge supplier) stated that their experience indicated that the media would have to exceed 600°F, say 650°F, before it would combust. He did say however that they have observed that if carbon and rich diesel fuel are present, the media could ignite as low as 550°F. Although this is at the upper limit to which one could expect the Sonodyne

as 550°F. Although this is at the upper limit to which one could expect the Sonodyne vent gas to have reached, it could have occurred. It can be said with some certainty that the Torit filter media is what started burning and provided the fuel to the fire. In summary, the defective thermocouple caused the Sonodyne vent system to exceed the maximum operating temperature of 285°F and ultimately burn the Torit Filter media.

4. CORRECTIVE ACTION

The following was done to prevent a similar situation from occurring again.

- A properly functioning thermocouple and leadwire were installed with the correct polarity
- An independent over temperature thermocouple, leadwire and controller were installed to limit the maximum temperature excursion should the primary high temperature limit system fail again

The following was done to assist in fighting a Torit fire should one occur again.

- A water deluge system was installed directly into the Torit housing

The following is being evaluated as an additional layer of fire control.

- Installation of a CO_2 system to be actuated automatically before there would be a need to use water.

Distribution: BEZ, FJV, DSS, RTF, MAN, EBA, FGO'K, LEH, MPJ

Facilities/vents/Sonodyne vent fire

TO: Eric Andersen
FROM: David Schlier
Subject: Potential Uranium involved in Vent Fire, 2/21/96

1. Sample: took sample from feed tank bottom, 1/21, attemping to maintain normal (2 gpm) flow.
2. Measured 3 mls sulfuric acid into 50 ml volumetric flask. Added about 40 ml. mixed sample and mixed. Filled to volume with more mixed sample. Mixed well
3. Analyzed using colorimeter at 400 nm.
   1. Aliquoted 20 ml. acidified sample (from 2 above) into 50 ml. volumetric flask.
   2. Added 5 ml. 20% Ammonium Tartrate solution.
   3. Added 15 ml. NH_4OH (conc.)
   5. Added 0.1 ml. H_2O_2, 50%.
   6. Brought to volume, mixed well.
   7. Read on Milton-Roy Spec 20D Colorimeter at 400 nm per instrument instructions.
   8. Reading was 0.144 AU, factor is 10.6 mg U/AU
4. Total solids in sample is approximately 0.33 lb/gallon (from Resorce Recovery Monthly Report).
5. Approximate weight of contaminated solids in Collector: 2 lb/filterx24 filters: 50 lb.
6. Calculations:
   1. Determine U in Sample

$$U = 0.144AU \times 10.6\frac{mgU}{AU}$$

$$U = 1.53mgU$$

   where U is the total amount of Uranium found in the volume analyzed.
   2. Determine sample size.

$$V = (20ml) \bullet \left(\frac{50 - 3ml}{50ml}\right)$$

$$V = 18.8ml$$

   where V is corrected sample volume.
   3. Uranium concentration.

$$[U] = \frac{1.53mgU}{18.8ml} \bullet \frac{1000\frac{ml}{l}}{1000\frac{mg}{g}}$$

$$[U] = 0.0814gU/l$$

   where [U] is the uranium concentration.
   4. Total uranium in Collector

$$W_U = \frac{0.0814gU/l \bullet 3.785l/gal}{0.33lb/gal} \bullet 50lb.$$

$$W_U = 47gU$$

   where W_U is the weight of Uranium in the collector.
7. Conclusion: less than 50 grams U could have been potentially involved in the vent fire on 2/21/96.

REGION I
MSS LICENSEE EVENT REPORT

License No. SMB-179
Docket No. 040-00672
96-23

LICENSEE Nuclear Metals
EVENT DESCRIPTION Fire in liquid radioactive waste process system
EVENT DATE Feb 21, 1996
REPORT DATE 4/22/96
3/25/96

1. REPORTING REQUIREMENT

( ) 10 CFR 20.2201 Theft or Loss
( ) 10 CFR 20.2203 30 Day Report
( ) 10 CFR 30.50 Report
( ) 10 CFR 35.33 Misadministration
( ) License Condition
(X) Other 10 CFR 40.60(c)

2. REGION I RESPONSE

(X) Immediate Site Inspection — Inspector/Date Mulle 2/27-28/96
(X) Special Inspection — Inspector/Date Miller 2/27-28/96
( ) Telephone Inquiry — Inspector/Date
(X) Preliminary Notification
( ) Daily Report
(X) Information Entered on the Region I Log
( ) Review at Next Routine Inspection
( ) Report Referred to

3. REPORT EVALUATION

(X) Description of Event
(X) Levels of RAM Involved
(X) Cause of Event
(X) Corrective Actions
( ) Calculation Adequate
( ) Letter to Licensee Requesting Additional Information

4. SPECIAL INSTRUCTIONS OR COMMENTS

Completed by [signature] Date 5/7/96
Reviewed by [signature] Date 5/8/96

RETURN ORIGINAL TO REGION I

g:\las\mlerform
(Revised 1/6/95)

100066

Depleted Uranium
Technical Brief

United States
Environmental Protection Agency

Office of Air and Radiation
Washington, DC 20460

EPA-402-R-06-011
December 2006

Depleted Uranium
Technical Brief

EPA 402-R-06-011

December 2006

Project Officer
Brian Littleton
U.S. Environmental Protection Agency

Office of Radiation and Indoor Air
Radiation Protection Division

FOREWARD

The Depleted Uranium Technical Brief is designed to convey available information and knowledge about depleted uranium to EPA Remedial Project Managers, On-Scene Coordinators, contractors, and other Agency managers involved with the remediation of sites contaminated with this material. It addresses relative questions regarding the chemical and radiological health concerns involved with depleted uranium in the environment.

This technical brief was developed to address the common misconception that depleted uranium represents only a radiological health hazard. It provides accepted data and references to additional sources for both the radiological and chemical characteristics, health risk as well as references for both the monitoring and measurement and applicable treatment techniques for depleted uranium.

Acknowledgments

This technical bulletin is based, in part, on an engineering bulletin that was prepared by the U.S. Environmental Protection Agency, Office of Radiation and Indoor Air (ORIA), with the assistance of Trinity Engineering Associates, Inc. (TEA) under Contract No.68-D-00-210, and EnDyna, Inc. under Contract No. 06-H-00-1057.

Thanks go to Ron Wilhelm, Madeleine Nawar and Schatzi Fitz-James of ORIA, and Charles Sands, Stuart Walker, Robin Anderson, and Kenneth Lovelace of OSWER for their comments and suggestions and to the following EPA regional staff: R2: Angela Carpenter; R3: Randy Sturgeon; R4: David Dorian; R6: Camille Hueni, Raji Josiam and George Brozowski, R10: Rick Poeton.

TABLE OF CONTENTS

1. PURPOSE

Technical Briefs are designed to convey available information and knowledge about a particular contaminant of interest, such as depleted uranium (DU), to the Environmental Protection Agency (EPA) Remedial Project Managers (RPM), On-Scene Coordinators (OSC), contractors, and other site cleanup managers involved with the remediation of sites contaminated with radioactive material.

This Technical Brief is intended to help the user understand the characteristics, behavior in the environment, and potential human health risks of DU as a contaminant in soils and groundwater. The document also identifies available monitoring and measurement tools and various treatment technologies for remediation of sites contaminated with DU. Supplementary discussions and additional information are provided in the appendices.

This Technical Brief specifically addresses DU in an environmental contamination setting and specifically does not consider airborne DU micro-particulates of the type associated with DU munitions. Further, it considers only contamination scenarios in the United States, though it has used international scientific data, where appropriate, for its technical basis. In these environmental contamination settings, the major risk from DU is toxicological rather than radiological, and chemical toxicity is the major driver for site cleanup.

Further, since most available literature concerning chemical properties of uranium focus on natural uranium, this document will make frequent reference to these studies in full knowledge that the chemical properties addressed for natural uranium are identical to those of DU. Addenda will be issued periodically to update the original Technical Brief, whenever deemed necessary.

2. INTRODUCTION

Depleted uranium (DU) is a byproduct of the process used to enrich natural uranium for use in nuclear reactors and in nuclear weapons. Natural uranium is composed of three isotopes; ^{234}U, ^{235}U, and ^{238}U (see Table 1) [1]. The enrichment process concentrates both the ^{235}U and the ^{234}U isotopes in the product material, resulting in a waste product or byproduct *depleted* in both ^{235}U and ^{234}U. The resultant DU retains a smaller percentage of ^{235}U and ^{234}U, and a slightly greater percentage of ^{238}U (99.8% by mass instead of 99.3%). Because of the shorter half-life of ^{234}U and ^{235}U compared to ^{238}U, the radioactivity associated with DU is approximately 40% less than that of natural uranium.

Table 1: Typical Isotopic Abundances in Natural and Depleted Uranium

Isotope	Abundance (by weight)	
	Natural Uranium	Depleted Uranium
^{234}U	0.0058%	0.001%
^{235}U	0.72%	0.2%
^{238}U	99.28%	99.8%

In the United States, DU is available mainly from the U.S. Department of Energy (DOE) and other government sources. DU occurs in a number of different compounds with different characteristics, which may have a significant impact on the management and disposition of this material.

Because DU metal is 1.7 times more dense than lead, it is valuable for industrial uses. It has been used for civil and military purposes for many years. Detailed information on uranium, its chemical forms, manufacturing/enrichment processes, and uses of DU are further discussed in Appendix 1.

2.1 Characteristics of Uranium and Depleted Uranium

Uranium is a naturally occurring radioactive metal in all rocks and soils in low concentrations (1 to several hundred picocuries per gram (pCi/g)). All three isotopes are radioactive and produce decay products upon radioactive disintegration. After purification (processing) of uranium, the decay products of all of the uranium isotopes will begin to accumulate very slowly, and traces of these decay products can be detected.

Other trace isotopes that have been observed in depleted uranium, and are likely of anthropogenic origin, include plutonium-238 (^{238}Pu), plutonium-239 (^{239}Pu), plutonium-240 (^{240}Pu), americium-241 (^{241}Am), neptunium-237 (^{237}Np) and technetium-99 (^{99}Tc).

Table 2: Radiological Properties of Uranium Isotopes

Isotope	Half-life (years)
^{234}U	2.455×10^5
^{235}U	7.038×10^8
^{238}U	4.468×10^9

Table 2 above lists the half-life of each isotope. Approximately 48.9% of the radioactivity of natural uranium is associated with ^{234}U, 2.2% is associated with ^{235}U, and 48.9% is associated with ^{238}U. All three isotopes behave the same chemically but have different radiological properties. As may be calculated from the tables, the radioactivity of natural uranium is approximately 0.70 μCi/g, whereas the radioactivity of DU is approximately 0.40 μCi/g.

The weight percentages in Table 1 and radioactivity percentages given previously are different because each isotope has a different physical half-life - the shorter half-life makes ^{234}U the most radioactive and the longer half-life makes ^{238}U the least radioactive. Each isotope decays by emitting an alpha particle.

For natural uranium present in soils and rocks, the activities of ^{234}U and ^{238}U are identical; they are said to be in secular equilibrium. In natural waters, however, the ^{234}U can appear to be slightly more soluble and the radioactivity ratio of ^{234}U to ^{238}U varies from 1:1 to more than 20:1. This is believed to be due to the fact that as ^{238}U decays to ^{234}U, it passes through thorium-234 (^{234}Th) (*first decay product*) and then protoactinium-234 (^{234}Pa) (*second decay product*) which are slightly more soluble than the uranium isotopes. The ^{234}U thus appears to move while the ^{238}U remains sparingly soluble. When converting from activity to mass or vice versa, knowledge of the concentration of each the three uranium isotopes is required.

2.2 Health Concerns

A common misconception is that radiation is the primary hazard DU poses to human health. This is not the case under most exposure scenarios. Though irradiation from DU can occur, chemical toxicity is usually the major hazard from soluble forms of uranium, while the radiological hazard dominates inhalation of sparingly soluble forms. Since all forms of uranium possess the same inherent chemical properties, they also display the same behaviors of chemical toxicity, and if internalized, will all lead to adverse health effects similar to those of other heavy metals such as lead and cadmium. The Agency for Toxic Substances and Diseases Registry (ATSDR) Toxicological Profile on uranium [1] summarizes the existing animal and human data on the toxicology of natural uranium.

Natural and depleted uranium differ only in their relative concentrations of uranium isotopes. Depleted uranium is roughly 60% as radioactive as natural uranium because the more radioactive isotopes have been removed. All three naturally occurring uranium isotopes emit alpha particles as their primary radiation. Because alpha particles cannot penetrate the skin, uranium is usually considered an internal radiological hazard rather than an external radiation hazard. Awareness should be maintained regarding the external hazard since DU can contain trace amounts of ^{236}U and other substances (such as plutonium, americium, and technetium); however, the risk posed by these trace contaminants is usually regarded as insignificant.

2.2.1 Exposure Pathways

Uranium occurs widely in the environment, and as a consequence small amounts of natural uranium in air, water, and soil are ingested and inhaled every day. This normal intake results in a natural level of uranium in the body of approximately 90 μg [1]. Excess loading occurs through three exposure pathways – inhalation, ingestion, and dermal contact – though the latter (dermal) is usually considered to be an insignificant exposure scenario.

Inhalation is the most likely route of intake of DU. In the case of sites contaminated with DU, this may occur through resuspension in the atmosphere through wind or dust disturbances due to site operations. Accidental inhalation may also occur as a consequence of fire in a DU storage facility, an aircraft crash, manufacture of armor-piercing weapons, or the decontamination of contaminated objects. [34]

Ingestion can occur in a large section of a community or population if drinking water or food supplies become contaminated with DU. In addition, ingestion of soil by children is considered a potentially significant pathway [34].

Dermal contact is considered a relatively unimportant type of exposure since little of the DU will pass across the skin into the blood. However, DU could enter systemic circulation through open wounds or from embedded fragments of DU [34].

2.2.2 Chemical Risk

When incorporated into the body, the highest concentrations of uranium occur in the kidneys, the most sensitive organ, as well as liver tissue and skeletal structure. The amount of DU subsequently absorbed into the blood and deposited in the kidneys or other organs is dependent upon several factors (e.g., exposure pathway, particle size, solubility) [1]. DU particles and oxides retained in the body have different solubilities. The three uranium oxides of primary concern (UO_2, UO_3, and U_3O_8) are relatively insoluble [35]. Insoluble and sparingly soluble uranium compounds are believed to have little potential to cause renal toxicity but could cause pulmonary toxicity through inhalation exposure [1].

The ingestion exposure pathway currently has a number of established risk levels and standards for chemical toxicity. ATSDR has a "minimal risk" level for intermediate-duration ingestion set at an oral uptake of 2 µg of uranium per kg of body weight per day, though the World Health Organization (WHO) has established a tolerable daily intake (TDI) for uranium of 0.6 µg/kg body weight per day. WHO has a provisional guideline for drinking water quality of 15 µg/L - a value considered to be protective for sub-clinical renal effects reported in epidemiological studies. EPA's Rule on Radionuclides in Drinking Water sets a maximum contaminant level for naturally occurring uranium at 30 µg/L, and its preliminary remediation goal (PRG) for Superfund is 2.22 µg/L for ^{238}U in tap water. The Nuclear Regulatory Commission's occupational annual limit on intake (ALI) for oral ingestion is 14.8 mg.

2.2.3 Radiological Risk

The general population is exposed to uranium primarily through food and water with an average annual intake from all dietary sources being about 350 pCi [31]. On average, approximately 90 µg (micrograms) of uranium exists in the human body from natural intake of water, food, and air. About 66% is found in the skeleton, 16% in the liver, 8% in the kidneys, and 10% in other tissues [32]. In the United States, the typical concentration of uranium in the skeletal structure (wet weight) is about 0.2 pCi/kg [31]. The lungs, kidneys, and bone receive the highest annual doses of radiation from uranium, estimated at 1.1, 0.92, and 0.64 mrem, respectively, for U.S. residents.

As they decay, DU and its decay products emit alpha, beta, and gamma radiation that can result in external and internal exposure to those who handle or encounter DU-contaminated materials. Based on the zero-threshold linear dose response model, any absorbed dose of uranium is assumed to result in an increased risk of cancer. Since uranium tends to concentrate in specific locations in the body, the risk of cancer of the bone, liver, and blood (such as leukemia) may be increased.

Inhaled DU particles that reside in the lungs for long periods of time may damage lung cells and increase the possibility of lung cancer after many years. DU is considered primarily an internal hazard, although there is some external radiation hazard associated with DU since its progeny emit gamma rays.

The amount of uranium in the air is usually very small and effectively insignificant for remedial operations. People who live near federal government facilities that produced or tested nuclear weapons in the past, or facilities that mine or process uranium ore or enrich uranium for reactor fuel, may have increased exposure to uranium. For example, data from the United States and Canada have shown elevated uranium levels in and around milling and processing facilities, and estimated airborne releases of uranium at one DOE facility amounted to 310,000 kg between 1951 and 1988, which produced an estimated offsite inventory of 2,130-6,140 kg of excess uranium in the top 5 cm of soil in the vicinity of the facility [34].

3. URANIUM IN THE ENVIRONMENT

Due to its natural abundance, uranium can be found anywhere in water, in food, and air. Because DU and naturally occurring uranium are chemically the same, knowledge about transformation, transport, fate and effect on natural uranium in the environment is applicable to the study of DU.

3.1 Occurrence

As an environmental contaminant, DU most frequently occurs as the metal, and as a number of solid oxides, which may include those arising from oxidation of the metal, those from hydrolysis of uranium hexafluoride accidentally released to the environment, and those from neutralization of acidic industrial wastes that contain dissolved DU. It can also occur as soluble aqueous species (primarily the uranyl ion) or as a number of insoluble and sparingly soluble species, including mineral forms that have arisen as a result of uranium's complex environmental chemistry.

3.2 Geochemistry

Oxidation-reduction processes play a major role in the occurrence and behavior of uranium in the aqueous environment. The dominant uranium valence states that are stable in the geologic environment are the uranous (U^{4+}), and uranyl (U^{6+}, UO_2^{2+} ion) states; the former is much less soluble [2] while the latter can form many complexes and is regarded as a dominant feature of uranium chemistry. For the metal, the oxidation rate is likely to be controlled by variables such as temperature, metal size and shape, presence or absence of coatings, soil matrix, and presence of water and other contaminants.

3.3 Mobility

Uranium transport generally occurs in oxidizing surface water and groundwater as the uranyl ion, UO_2^{2+}, or as uranyl fluoride or carbonate complexes. UO_2^{2+} and uranyl fluoride complexes dominate in acidic oxidizing acidic waters, whereas the carbonate complexes dominate in near-neutral and alkaline oxidizing waters, respectively. In contrast, the uranous ion, U^{4+}, is essentially insoluble. An important point in considering uranium migration in soils is that when UO_2^{2+} is reduced to U^{4+} by humus, peat, or other organic matter or anaerobic conditions, it is essentially immobilized. It should also be noted that phosphates and sulfides usually precipitate uranium and hence stop migration, a behavior that can be exploited in remedial operations.

Hydroxyl, silicate, organic, and sulfate complexes might also be important, sulfate especially in mining and milling operations that use sulfuric acid as a leaching agent. Maximum sorption of uranyl ions on natural materials (e.g., organic matter; iron, manganese and titanium oxyhydroxides, zeolites, and clays) occurs at a pH of 5.0-8.5. The sorption of uranyl ions by such natural media appears to be reversible. For uranium to be "fixed" and therefore accumulate, it requires reduction to U^{4+} by the substrate or by a mobile phase, such as hydrogen sulfide (H_2S).

3.4 Enhanced Mobility

A further complication in predicting the mobility of DU is the existence of facilitated transport. Facilitated transport is the accelerated movement of contaminants in an aqueous system at a rate greater than would be predicted by either the simple solubility of the contaminant, the formal flow-rate of the aqueous phase, or by the interaction of a contaminant with the solid phases present. Facilitated transport is usually attributed to the contaminant being bound to particles such as colloids, or having enhanced

solubility due to the presence of complexants, ligands, and/or chelators. While the aqueous phase in general may be able to explore a very tortuous path through the geologic media when contaminant attached to a particle that is too large to travel through the smaller pathways, it is effectively restricted to wider cracks and crevices, thus giving it an enhanced mobility. Colloids are typically tiny (spanning the size range from large molecules to small biological entities such as bacteria) particles of mineral and/or organic matter that can remain suspended in the aqueous phase without settling. They may be hydrolysis products of uranium, organic chelates (natural and anthropogenic ligands), or mineral/oxide/humic colloids.

4. FATE AND TRANSPORT OF DEPLETED URANIUM

Environmental contamination by DU can occur in soil, water, biota, and as airborne particles. Although the radiological properties of uranium isotopes differ considerably, their chemical behavior is essentially identical. Hence, knowledge about the transformation, transport, fate, and effect of natural uranium in the environment is applicable to DU.

Under some conditions, such as the reducing conditions characteristic of swamps and wetlands, the stable chemical form of uranium is the +4 state in which it will not readily dissolve in water, and will thus become relatively immobile. Under oxidizing conditions, such as on the surface of the ground or in shallow water, DU oxidizes to a state in which it can dissolve and become mobile in water. Metallic forms will oxidize faster as small particles than as large pieces [37].

Aside from pH, a number of other parameters affect uranium fate and transport. Other parameters that influence movement are the presence (or absence) of organic compounds, redox status, ligand concentrations (i.e., carbonate, fluoride, sulfate, phosphate, and dissolved carbon), aluminum- and iron-oxide mineral concentrations, and uranium concentrations.

Given the long half-life of uranium (see Table 2), decay is not particularly relevant to uranium fate and transport in the environment. The following sections discuss DU fate/transport by medium.

4.1 Fate in Soil

Upon weathering, non-oxidized small particles may be adsorbed to clay minerals and humus. The surfaces of remaining DU fragments in soil exposed to the atmosphere will slowly oxidize to uranium oxides.

Uranium can exist in the +3, +4, +5, and +6 oxidation states. The +4 and +6 states are the most common in the environment. These oxides are only sparingly soluble, but will gradually form hydrated uranium oxides in moist conditions. The hydrated uranium oxides will then slowly dissolve and be transported into the surrounding soil, pore water, and eventually groundwater, although adsorption of uranium to organic compounds in the soil may inhibit the rate of migration. It should be noted that the +6 form (uranyl ion) can be adsorbed on clays and organic compounds and later be “eluted” or displaced by other cations. However, many organic materials reduce the uranyl ions to the +4 forms which are not likely to be eluted, though they might be subsequently reoxidized and made soluble.)

In the case of metallic particles, the oxidation rate depends on fragment size, pH, humidity, soil moisture content, soil chemistry, soil oxygen content, and the presence of other metals in the soil. The system’s pH and dissolved carbonate concentrations are the two most important factors influencing the adsorption behavior of U^{6+} in soil [38].

Iron and manganese oxides, smectite clays, and naturally occurring organic matter can act as somewhat irreversible sinks for uranium present in soils. As a result, sorption onto iron and manganese oxides can be an effective extraction process, although the presence of dissolved carbonate can inhibit this process. Uranium transfer between these bound phases and the dissolved phase is subject to very slow reaction rates [38].

Aqueous pH influences the sorption of U^{6+} to solids. The poorer-adsorbing uranium species are most likely to exist at pH values between 6.5 and 10. Additionally, lowering the pH reduces the number of available exchange sites on variably charged surfaces, such as iron oxides and natural organic matter.

Microbial activity might speed up the corrosion of metallic DU, but it should be noted that the titanium present in DU of military origin (typically 3.5%) would tend to counteract and slow down the process [39]. On the other hand, in soil with high concentrations of organic materials, naturally occurring soil bacteria can reduce soluble U^{6+} to sparingly soluble U^{4+}, thereby limiting uranium mobility as well. Oxygen content, presence of water, size of the metal particles, presence of protective coatings, and the salinity of the water present all impact the rate of microbial action. Although it is known that organic matter is a sink for uranium in soils and sediments, the actual mechanism of the process is still unclear [38].

4.2 Fate in Water

U^{4+} solid phases have relatively low solubilities, so the total concentration of U^{4+} in water is usually low (3-30 mg/L) [38]. In general, aqueous U^{4+} forms precipitates that are sparingly soluble, adsorbs strongly to mineral surfaces, and partitions into organic matter. All of these properties lead to its reduced mobility in water.

Under reducing conditions, U^{4+} is the dominant oxidation state in aqueous solutions. Reducing conditions are found in deep aquifers, marsh areas, and engineered barriers. U^{4+} is not strongly complexed by common inorganic ligands and is present predominantly as the $U(OH)_4$ ion under pH conditions typical of most natural waters. U^{4+} precipitates to form relatively insoluble solids, such as uraninite (UO_2) and coffinite ($USiO_4$) [40].

As previously mentioned, the U^{6+} ions can be removed from solution by sorption on iron hydroxides and organic soil matter. Sorbed uranyl ions can be reduced to U^{4+} by reductants such as hydrogen sulfide (H_2S), methane (CH_4), or ferrous iron (Fe^{2+}). If uranyl ions are sorbed by organic matter, the organic matter may reduce the uranyl ions [40]. Uranyl ions may also be removed from solution by precipitation as U^{6+} solid phases such as schoepite ($\exists$-$UO_3 \bullet 2H_2O$), which is relatively soluble, or by precipitation of the less soluble phases carnotite ($K_2(UO_2)_2(VO_4)_2$) or tyuyamunite ($Ca(UO_2)_2(VO_4)_2$) [40].

Uranyl ions form strong complexes with carbonate ion in solution. These carbonate complexes increase the solubility of uranium solids, facilitate U^{4+} oxidation, and increase uranium mobility by limiting uranium sorption in oxidized waters [40]. Fluoride, phosphate, and sulfate ligands can also significantly complex uranyl ions [40].

At low ionic strengths with low concentrations of U^{6+}, the concentration of dissolved U^{6+} is mostly controlled by cation exchange and adsorption processes. As the ionic strength of a solution increases, other cations (e.g., Ca^{2+}, Mg^{2+}, K^{+}) displace any uranyl ions on soil exchange sites and force them back into solution.

4.3 Fate in Air

Atmospheric releases of DU are almost exclusively in particulate form, as the vapor and gas forms of DU are not commonly encountered. The high density of DU in most particulate forms limits the air transport of DU to relatively small particles. Air releases of DU can occur via emission from stacks, re-suspension from soil, or through emissions of fugitive dust from piles or industrial process areas containing DU.

Source estimates for stack releases are generally derived from stack monitors. The revised wind erosion equation [41] may be used to estimate releases via suspension from soil. Sources of fugitive dust releases to air are often estimated using the EPA AP-42 guidance [42]. Air transport of long-term ($\exists$one year) releases of DU in the form of aerosols or other respirable particle sizes is typically analyzed using codes based on the Gaussian plume model. These models estimate air concentrations as a function of direction and distance from the source, and also will usually provide estimates of ground

concentrations resulting from deposition of the airborne DU. It is reported that most of the DU dust will be deposited within a distance of 100 meters from the source [43].

Following airborne transport, the migration of DU will ultimately become subject to water, soil, and biological transport mechanisms. In general, DU deposited by airborne transport will be present on or near the soil surface and shows minimal uptake by plant roots. DU is not effectively transported through the food chain, as low-level organisms tend to excrete the soluble uranium species quickly.

4.4 Fate in Biota

Some plant material, such as lichens, can serve as an indicator of airborne DU contamination. Lichens consist of fungi and algae living together symbiotically, in a mutually beneficial way. As lichen morphology does not vary with the seasons, their accumulation of pollutants can occur throughout the year, and they usually live for very long periods.

Some lichens growing on the surface of another plant have a high capacity to accumulate uranium. Because they lack roots, lichens do not have access to soil nutrient pools and accumulate substances mainly via trapping atmospheric particulates. Uranium is accumulated in lichen thallus under moist and dry conditions from airborne particles and dust. Even tiny fragments of lichens may contain concentrations that are readily detectable [43].

4.5 Partition Coefficients

Partition coefficient (K_d) is a parameter used when estimating the migration potential of contaminants present in aqueous solutions in contact with surface, subsurface, and suspended solids. K_d is defined as the ratio of the contaminant concentration associated with the solid to the contaminant concentration in the surrounding aqueous solution when the system is at equilibrium. Generic or default partition coefficient values found in literature can result in significant errors when used to predict the absolute impacts of contaminant migration or site-specific remediation options. Partition coefficient values measured at site-specific conditions are essential for site-specific calculations [44].

With respect to uranium movement in the environment, however, the EPA guidance on K_d suggests that the best way to model the concentration of precipitated uranium is through the solubility constants of the different uranium compounds involved, rather than through K_d [44].

As with other uranium properties, uranium K_d values are strongly influenced by pH because of the pH-dependent surface charge properties of soil minerals and the complex aqueous speciation behavior of dissolved U^{6+}. In general, at pH less than 3, the adsorption of uranium by soils and single-mineral phases in carbonate-containing aqueous solutions is low, reaching a maximum in adsorption between pH 5-8, then decreasing at pH values greater than 8 [44]. Table 3 provides minimum and maximum K_d values for uranium as a function of pH and shows the wide variation that occurs in K_d.

4.6 Fate and Transport Modeling

Obviously, the best method for determining the concentration of a contaminant at a location in a contaminated site is by direct, site specific measurement using the appropriate analytical method and protocol. The contaminant concentration is then usually used to determine K_d for further modeling purposes. The use, advantages, and limitations of the K_d approach have been well discussed in the literature [43], and we recommend that whenever possible K_d should be measured. It is important to note that soil scientists and geochemists knowledgeable of sorption processes in natural environments have long known that generic or default partition coefficient values found in the literature can result in significant errors when used to predict the absolute impacts of contaminant migration or site-remediation options. Accordingly, one of the major recommendations is that for site-specific calculations, partition coefficient values measured at site-specific conditions are absolutely essential [43]. However, due to the complexities of both geological media and chemical behavior within this media, the necessary measurements of contaminant concentration may not be possible. For example, at a given point in a geological matrix, a contaminant will be partitioned between the

groundwater and the host geological matrix, and a "true" measurement at that point requires removal of a sample containing both the solid and aqueous phase; this may not always be easy to achieve. If such problems are the case, or if the contaminant has not yet reached exposure points, environmental fate and transport models must be used to predict contaminant concentrations.

Table 3: K_d Values for Uranium as a Function of pH

pH	K_d (mL/g) Minimum	Maximum
3	<1	32
4	0.4	5,000
5	25	160,000
6	100	1,000,000
7	63	630,000
8	0.4	250,000
9	<1	7,900
10	<1	5

Source: [44 - Table 5.15]. (See also reference 43, Table 5.18 and pages 5.79 – 5.81)

While many fate and transport models are available for various media, this type of modeling is an area of active research with much debate on the problems associated with existing models and little consensus on how chemical reactions and reaction parameters should be determined for field applications. The Federal Interagency Steering Committee on Multimedia Environmental Models (ISCMEM) exists to coordinate efforts among agencies that actively use or support the development of coupled hydrologic and geochemical models to simulate the transport of chemical contaminants in the subsurface environment.

Fate and transport modeling is of great importance in radiation risk assessments and conceptual site models required for remediation, and considerable importance is attached to the availability of expertise in their use.

5. SITE SCREENING FOR DEPLETED URANIUM CONTAMINATION

EPA has published several guidance documents on the approach for remediation of sites contaminated with hazardous materials, including radionuclides. Because of the complexity and comprehensiveness of the subject matter, the reader is advised to consult the relevant details in the following documents/websites:

1. "Distribution of OSWER Radionuclide Preliminary Remediation Goals (PRGs) for Superfund Electronic Calculator", February 7, 2002. http://epa.gov/superfund/resources/radiation/pdf/rad.pdf

2. Soil Screening Guidance, User's Guide, 2nd Edition 9355.4-23, 1996. This Guide [3] provides a methodology to calculate risk-based, site-specific soil screening levels (SSL).

3. Soil Screening Guidance for Radionuclides: Technical Background Document, EPA/540-R-95/128, 1996 [4], and Soil Screening Guidance for Radionuclides: User's Guide, EPA/540-R-00-007, 2000 [5].

4. EPA website, http://www.epa.gov/radiation/radionuclides/uranium.htm

5. Inventory of Radiological Methodologies for Sites Contaminated with Radioactive Materials, EPA/402-R-06-007, 2006 (See Table 10, page 42, for analytical methodologies applicable to each radionuclide, and Section 3.2.1 for discussion of water sample preservation and transport issues).

It should be noted that information on the chemical toxicity of uranium is available in the ATSDR Toxicological Profile for Uranium [1]. It should also be noted that since uranium, including DU, is both a chemical and radiological hazard, SSLs for DU should consider both types of hazards. SSLs for uranium should be calculated using both the Soil Screening Guidance for non-carcinogenic chemicals and the Soil Screening Guidance for Radionuclides. Since the SSL is a numerical concentration, it should be based on the most protective health quantity, whether that is kidney toxicity or radiological risk.

6. MEASUREMENT TOOLS AND MONITORING TECHNIQUES

Uranium and DU can be detected by measuring the different types of radiation (i.e., alpha, beta and/or gamma radiation) emitted. Presently, a vast choice of equipment for monitoring such radiation is available. Refer to Table 6, Appendix 2**,** for a description of selected specific measurement tools and monitoring techniques.

Measurements made with field equipment are typically less sensitive than laboratory measurements and may be impaired by environmental characteristics such as natural soil composition. If these field measurements are not, or are only partly, successful, field samples must be collected and analyzed in a laboratory in order to obtain a comprehensive assessment of the contamination.

EPA's Office of Radiation and Indoor Air completed a draft compendium on the Inventory of Radiological Methodologies, focusing on the radionuclides likely to be found in soil and water at contaminated sites. While it is not a complete catalog of analytical methodologies, it is intended to assist project managers to understand the concepts, requirements, practices, and limitations of laboratory analyses unique to radioactive environmental samples. Detailed guidance on recommended radioanalytical practices may be found in current editions of the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP) [6] and the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) [7].

7. REMEDIATION TECHNOLOGIES

Technologies for the remediation of DU contamination may involve one or more of the following processes: excavation and earth moving, physical separation, chemical separation, in-situ stabilization, or a combination of these technologies. Remediation of surface and groundwater contaminated with DU may include conventional pump and treat methods and/or permeable reactive barriers. These technologies are described in the following subsections [8]. However, no technologies exist that are capable of significantly reducing the chemical and radiological toxicity of DU, characteristics also fundamental to natural uranium. Case studies of the remediation efforts of two sites with DU contamination, Nuclear Metals, Inc. in Concord, Massachusetts, and Maxey Flats in Hillsboro, Kentucky, are provided in Appendix 5 and 6. It should be noted that the following descriptions of remediation technologies are brief and serve only as a guide for further investigation and analysis. The evaluation and selection of a remediation technology can be a complex matter; critical issues include the physical and chemical forms of the depleted uranium contaminant, physical and chemical properties of the contaminated media, and the presence of other contaminants. The technologies below broadly cover DU contaminated sites, storage sites, sites associated with UF_6, and address DU-contaminated soil and groundwater. In such remedial situations, consideration must also be given to related media, such as dust with the potential to become airborne as a result of remediation operations. The scope presented here does not include air pollution such as particulates from munitions and projectiles, and in this regard it is worthy to note that EPA is unaware of any National Priority List sites associated with DU contamination arising from projectiles.

7.1 Soil Technologies

Several technologies have been developed for use on DU-contaminated soils [8]. Examples include:

- Excavation, followed by disposal of soils in a low-level waste repository; and
- Excavation of contaminated soil followed by treatment (i.e., physical separation and chemical extraction).

7.1.1 Physical Separation

Remediation of soils contaminated with metallic DU typically begins with physical removal of large fragments, either by hand sorting or by size classification using a screening device [8]. Excavation and physical separation with

screening devices may be used as the principal means of remediation of contaminated soil if the contamination is associated with a particular soil size fraction. Physical separation of contaminated and uncontaminated soils may also be accomplished using magnetic separation technology; or gravimetric separation. Other proprietary devices include the Segmented Gate System (SGS), produced by the Eberline Instrument Corporation, which monitors radiation in soil as the soil moves along conveyor belts and then diverts the contaminated material [8] [9]. After separation of the contaminated and uncontaminated soil fractions, the uncontaminated soils are used as clean fill, and contaminated soils are treated or processed for disposal. The volume reduction of contaminated soil that requires disposal or treatment can result in significant cost savings [10].

7.1.2 Chemical Extraction

Chemical extraction methods (also referred to as soil washing or heap leaching) use water with various chemical additives to dissolve DU from contaminated soils. The chemical additives include oxidants to convert relatively insoluble U^{+4} to the more soluble U^{+4} form, complexing agents such as carbonate that increase uranium solubility, and strong acids or bases [8] [9] [10] [11]. The cleaned soil is then generally used as fill material, and leachate containing the uranium and other contaminants is often treated to remove contaminants in a concentrated form for disposal [8].

7.2 Groundwater Technologies

Technologies for the treatment of DU in groundwater include:

- Treatment of groundwater contamination by conventional pump and treat methods;
- Treatment of groundwater contamination by permeable reactive barriers; and
- Emerging/Pilot Studies treatments.

7.2.1 Pump and Treat

Pump and treat methods remove contaminated groundwater from the aquifer and can be used to contain and manage migration of contaminant plumes. Pump and treat methods involve pumping contaminated water from the ground, treating it, and either injecting it back into the aquifer or discharging it to a suitable surface system.

7.2.2 Permeable Reactive Barriers

Permeable reactive barriers are passive systems consisting of reactive materials placed in the subsurface. As groundwater flows through the system, the reactive materials in the permeable barrier remove and immobilize the contaminants [12] [13] [14]. Reactive materials used to remove uranium from groundwater in these systems typically include different forms of metallic (zero-valent) iron [13], but other materials (e.g., amorphous ferric oxyhydroxide) have also been used to remove uranium from groundwater (www.gjo.doe.gov). A disadvantage of using metallic iron is that the uranium is removed by a precipitation reaction and the precipitate product has a tendency to clog the barrier, thus reducing its long-term effectiveness. In contrast, the use of a material such as apatite, a calcium phosphate mineral, leads not only to the formation of sparingly soluble uranium phosphate minerals but also to adsorption of uranyl carbonate complexes on the apatite surface with little clogging.

Examples of the effective use of permeable reactive barriers to remove uranium from groundwater include installations at Fry Canyon, Utah, and Durango, Colorado (www.gjo.doe.gov). A permeable reactive barrier system has also been used to remove uranium from contaminated groundwater in an area known as the mound site plume at DOE's Rocky Flats Environmental Technology Site (RFETS) in Colorado [15]. It is important to note that the mode of action of permeable barriers leaves the contaminant in place unless the barrier is excavated (usually at great cost), so barrier longevity and long-term performance are important engineering issues.

7.2.3 Commercial Test Studies

Several research and development (emerging) processes have been tested on a pilot scale by Water Remediation Technology, LLC, (WRT)

of Arvada, Colorado, using an adsorptive media Z-92™, for treatment of well waters contaminated with uranium in excess of the maximum contaminant level (MCL). WRT conducted three studies at Brazos Mutual Domestic Water in New Mexico [16]; the Mountain Water & Sanitation District in Conifer, Colorado [17]; and the Fox Run Water Company at Chesdin Manor in Dinwiddie County, Virginia [18]. In each of these studies, municipal water suppliers had wells that contained water with concentrations of uranium in excess of the MCLs. WRT provided pilot scale (approximately one gallon per minute) and larger scale (80 gallons per minute) systems using the Z-92™ media to demonstrate the effectiveness of the treatment process, establish design parameters for the full-scale systems or document the effectiveness of the WRT system, and meet regulatory compliance requirements. In each case, the pilot unit or larger scale system successfully met gross alpha and uranium compliance at all times.

7.3 Technologies for Soil and Water

Several technologies can be used to treat either soil or groundwater. Examples include:

- In-situ stabilization, through the use of amendments, grouting, or capping of contaminated soil; and
- Phytoremediation, in which plants are used to extract contaminants from soil or groundwater.

7.3.1 In-Situ Stabilization/Treatment

In-situ stabilization, treatment, and amendment methods are available for immobilizing uranium contamination in soils and groundwater [10]. The addition of amendments (e.g., apatite or phosphate solutions) stabilizes uranium in soils and groundwater through the formation of relatively insoluble uranium-phosphate solids [10] [19] [20]. Grouting or capping of contaminated soils and sediments may also be used to stabilize uranium contamination in place [10]. As with permeable reactive barriers, stabilization leaves the contamination in place. Precipitation of uranium to the phosphate form leaves uranium highly insoluble and essentially inert chemically. Even ingestion would not result in much uranium retention in the body. Nevertheless, most methods for screening for uranium would show that the uranium was still present, and it may be difficult to be sure that the uranium found by screening is effectively stabilized as the phosphate.)

7.3.2 Phytoremediation

Phytoremediation refers to the utilization of green plants' natural absorption of specific components of their host growing medium; it is an emerging, rather than established, technology for remediation. Uptake of uranium by plants is typically small [21] [22]. However, phytoremediation of uranium using sunflowers (genus *Helianthus)* has been demonstrated with uranium waste at Ashtabula, Ohio, and at a small pond contaminated with uranium near the Chernobyl nuclear power plant site in Pripyat, Ukraine [23]. Phytoremediation using Indian mustard (*Brassica juncea*) of DU contamination at a firing range at the Aberdeen Proving Ground in Maryland has also been demonstrated [24]. Phytoremediation of uranium is accomplished through the process of rhizofiltration in which plant roots sorb, concentrate, and precipitate metal contaminants from surface or groundwater [23]. The concentration of uranium contamination removed from the soil by the plants can reduce the volume of material that otherwise would need be removed for disposal.

A requirement of phytoremediation is that a proper disposal approach must be adopted for the contaminant-bearing plants to prevent cross media transfer of contaminants and subsequent exposure. For inorganic contaminants such as uranium, simply burning the plants will not destroy the contaminant.

7.3.3 Monitored Natural Attenuation

In addition to the remediation technologies described above, the use of monitored natural attenuation (MNA) may be applied as an optional process, which should be evaluated with other applicable remedies (including innovative technologies) for restoring contaminated groundwater, preventing migration

of contaminant plumes, and protecting groundwater and other environmental resources.

MNA refers to the reliance on natural attenuation processes (including a variety of physical, chemical, or biological processes) to achieve site-specific remediation objectives within a reasonable timeframe compared to other more active methods. In order for natural attenuation to be selected as a remedy, determining the existence and demonstrating the stability and irreversibility of these mechanisms is important to show that a MNA remedy is sufficiently protective. Additionally, site-specific determinations will always have to be made to ensure that sorption capacity of the subsurface is sufficient to be fully protective of human health and the environment. [25]

8. EPA STANDARDS APPLICABLE TO DEPLETED URANIUM SITES

When contaminated sites to be released for public use are to be remediated to meet EPA's media specific risk-based standards or criteria, several potential drivers for the remediation need to be considered. Various statutes apply to different aspects of the remediation process. Table 4 lists the major statutes that apply to various media that may come into consideration during remediation. The following sections also provide further details of the drivers. It should be noted that the discussion presented here is not intended to be comprehensive, but is provided as a starting point for further investigation.

Table 4: Main Statutes Applying to Various Media in the Remediation Process.

Media	Statute
Air	CAA
Water	SDWA
Soil	CERCLA, RCRA
Waste	NRC regulations, DOE Orders

8.1 For Soil

Under CERCLA/RCRA, EPA's site cleanup standards limit a person's increased chance of developing cancer to between 1 in 10,000 and 1 in 1,000,000 from residual uranium on the ground [26]. Site-specific factors are weighed in establishing the actual clean up value.

8.2 For Air

Under the CAA, EPA established the amount of uranium in the air as the maximum dose to an individual not to exceed 10 millirems (mrem) per year [27].

8.3 For Water

Pursuant to the SDWA, EPA established an MCL of 30 micrograms per liter (:g/L) for uranium in drinking water [28].

8.4 Storage of Depleted Uranium

DU is not stored widely around the country; the majority of the inventory of DU is stored at United States Enrichment Corporation (USEC) sites or at DOE sites. DU stored by the military is only a fraction of the total. It should be noted that under the Atomic Energy Act (AEA), the storage of depleted uranium hexafluoride (DUF_6) is self-regulated by the DOE. DU is mainly stored in the form of uranium hexafluoride (UF_6), which is a colorless high molecular weight (352) solid, at ambient temperature. It is readily transformed into a gas at atmospheric pressure by raising its temperature above 56.5^{o}C, and into a liquid by increasing the pressure and temperature above 1.5 atmospheres and 64^{o}C. All three phases, solid, liquid and gas, coexist at 64^{o}C

A 2001 joint report by the Organization for Economic Cooperation and Development (OECD) Nuclear Energy Agency and the International Atomic Energy Agency on Management of Depleted Uranium noted that DU arising from the operations of enrichment plants can be safely stored in different forms, including uranium tetrafluoride (UF_4), or uranium oxides (U_3O_8, UO_2, and UO_3) in coated steel containers in external yards, provided that contact with standing water is prevented and that containers are routinely inspected and localized defects leading to corrosion are treated. [29]

8.5 For Disposal

For purposes of disposal, DU is considered a low-level waste (LLW) and its disposal is subject to U.S. Nuclear Regulatory Commission (NRC) regulations and appropriate DOE Orders. Disposal of DU mixed waste having both a radioactive component and a RCRA hazardous waste component must be performed in compliance with NRC LLW requirements and RCRA hazardous waste requirements.

The Executive Summary of the DOE, Oak Ridge National Laboratory's *Assessment of Preferred DU Disposal Forms* published in June 2000 noted that "...the four potential forms of DU (DU metal, DUF_4, DUO_2, and DU_3O_8) in this study should be acceptable for near-surface disposal at sites such as the Nevada Test Site (NTS) and Envirocare." [30]. It further added that, "The DU products are considered to be low-level waste under both DOE orders and NRC regulations." It indicated the preference for disposal at "...the NTS because of its unique geohydrologic and institutional settings." The study also noted that, "Each DU form has a degree of uncertainty regarding DUF_4, DUO_2, and DU_3O_8 acceptability [for disposal at NTS], with the uncertainty decreasing in the following order: DU metal, DUF_4, DUO_2, and DU_3O_8 [30]

EPA has issued guidance entitled "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination" (OSWER No. 9200.4-18, August 22, 1997) which provided clarification for establishing protective cleanup levels for radioactive contamination at CERCLA sites. The guidance reiterated that cleanups of radionuclides are governed by the risk range for all carcinogens established in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) when applicable or relevant and appropriate requirements (ARARs) are not available or are not sufficiently protective. Cleanup should generally achieve a level of risk within the 10^{-4} to 10^{-6} carcinogenic risk range based on the reasonable maximum exposure for an individual. In calculating cleanup levels, one should include exposures from all potential pathways, and through all media (e.g., soil, groundwater, surface water, sediment, air, structures, etc.) To assist with calculating risk, EPA has developed a Superfund radionuclide preliminary remediation goal (PRG) calculator. PRGs for the Superfund programs are risk-based concentrations, derived from standardized equations combining exposure information assumptions with EPA toxicity data. They are considered to be protective for humans, though not always applicable to a particular site and they do not address non-human health endpoints such as ecological impacts. PRGs are used for site "screening" and as initial cleanup goals if applicable. PRGs are not actually cleanup standards and should not be applied as such. Their role in site "screening" is to help identify areas, contaminants, and conditions that do not require further federal attention at a particular site. Additionally, they could be used to establish final cleanup levels for a site after a proper evaluation takes place. In the Superfund program, this evaluation is carried out as part of the nine criteria for remedy selection outlined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Once the nine criteria analysis is completed, the PRG may be retained as is, or modified (based on site-specific information) prior to becoming established as a cleanup standard.

Acronyms

AEA	Atomic Energy Act
ALI	Annual Limits on Intake
ARAR	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Diseases Registry
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
DU	Depleted Uranium
EPA	U.S. Environmental Protection Agency
ISCMEM	Interagency Steering Committee on Multimedia Environmental Models
LLW	Low-Level waste
MARLAP	Multi-Agency Radiological Laboratory Analytical Protocols
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Contaminant Level
MNA	Monitored Natural Attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NRC	Nuclear Regulatory Commission
NTS	Nevada Test Site
OECD	Organization for Economic Cooperation and Development
OSC	On-Scene Coordinators
OSWER	Office of Solid Waste and Emergency Response
PRG	Preliminary Remediation Goal
RCRA	Resource Conservation and Recovery Act
RFETS	Rocky Flats Environmental Technology Site
RPM	Remedial Project Managers
SDWA	Safe Drinking Water Act
SGS	Segmented Gate System
SSL	Soil screening Levels
TDI	Tolerable Daily Intake
USEC	United States Enrichment Corporation
WHO	World Health Organization
WRT	Water Remediation Technology, LLC

Glossary

Alpha particle – A positively charged particle made up of two neutrons and two protons emitted by certain radioactive nuclei. Alpha particles can be stopped by thin layers of light materials, such as a sheet of paper, and pose no direct or external radiation threat; however, they can pose a serious health threat if ingested or inhaled.

Becquerel (Bq) – The international, or SI, unit used to measure radioactivity, equal to one transformation (or disintegration) per second. Often radioactivity is expressed in larger units like: thousands (kBq), or millions (MBq) of Becquerels. One Curie (the traditional activity unit) is equal to 3.7×10^{10} (37 billion) Bq.

Beta particle – An electron or positron emitted by certain radioactive nuclei. Beta particles can be stopped by aluminum. They can pose a serious direct or external radiation threat. They also pose a serious internal radiation threat if inhaled or ingested.

Curie (Ci) – A traditional unit used to measure radioactivity. One Curie equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium-226 is approximately 1 Ci.

Depleted uranium – Uranium containing less than 0.7% uranium-235, the amount found in natural uranium. (See also enriched uranium)

Enriched uranium – Uranium in which the proportion of the isotope uranium-235 has been increased. (See also depleted uranium.)

Gamma rays – High-energy electromagnetic radiation emitted by certain radionuclides when their nuclei transition from a higher to a lower energy state. These rays have high energy and a short wavelength. Gamma rays are very similar to X-rays.

Half-life – The time in which one-half of the atoms of a radioactive isotope disintegrate into another nuclear form. Half-lives vary from billionths of a billionth of a second to billions of years. Also called physical or radiological half-life.

Ion – An atom or molecule that has too many or too few electrons, causing it to have an electrical charge, and therefore, be chemically active.

Isotope – A nuclide of an element having the same number of protons but a different number of neutrons.

Maximum contaminant level (MCL) – The amount of a contaminant that may be present in drinking water under the Safe Drinking Water Act. MCLs are the standards that drinking water treatment systems must meet.

Microcurie (μCi) – One-millionth of a Curie. (3.7×10^{4} disintegrations per second.)

Molecule – A combination of two or more atoms that are chemically bonded. A molecule is the smallest unit of a compound that can exist by itself and retain all of its chemical properties.

Monitoring – The use of sampling and detection equipment to determine the levels of radiation or other toxic materials in land, air, or water.

Millirem (mrem) – One-thousandth of a rem.

Neutron – A small particle possessing no electrical charge typically found within an atom's nucleus. A neutron has about the same mass as a proton.

Nuclide – A general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus, as well as by the amount of energy contained within the atom.

Oxide – A compound formed by the reaction of oxygen with another element. For example, rust - ferrous oxide - is iron that has combined with oxygen.

Picocurie (pCi) – One one-millionth of a microcurie ($3.7x10^{-2}$ disintegrations per second).

Proton – A small particle, typically found within an atom's nucleus, that possesses a positive electrical charge. The number of protons is unique for each chemical element.

Rad – (See Radiation Absorbed Dose)

Radioactive decay – The process in which an unstable (radioactive) nucleus emits radiation and changes to a more stable nucleus. A number of different particles can be emitted by decay. The most typical are alpha, beta and gamma particles.

Radioactivity – The process of undergoing spontaneous transformation of the nucleus, generally with the emission of alpha or beta particles, often accompanied by gamma rays.

Radioisotope – An isotope of an element that has an unstable nucleus. Radioactive isotopes are commonly used in science, industry, and medicine. The nucleus eventually reaches a more stable number of protons and neutrons through one or more radioactive decays. Approximately 3,700 natural and artificial radioisotopes have been identified.

Radionuclide – An unstable form of a nuclide.

Rem – (See Roentgen Equivalent Man)

Roentgen Absorbed Dose (rad) – A basic unit of absorbed radiation dose. It is being replaced by the "gray," which is equivalent to 100 rad. One rad equals the dose delivered to an object by 100 ergs of energy, per gram of material.

Radiation Equivalent Man (rem) – A unit of equivalent dose. Rem relates the absorbed dose in human tissue to the effective biological damage of the radiation. Not all radiation has the same biological effect, even for the same amount of absorbed dose.

Specific activity – The activity of radioisotope per unit mass of a material, either (a) in which the radioisotope occurs, or (b) consisting of only that isotope.

Treatment – A 'treatment' technology means any unit operation or series of unit operations that alters the composition of a hazardous substance, pollutant, or contaminant through chemical, biological, or physical means so as to reduce toxicity, mobility, or volume of the contaminated material being treated. See Appendix 7 for complete definition.

Uranium – A naturally occurring radioactive element whose principal isotopes are uranium-238 and uranium-235. Natural uranium is a hard silvery-white shiny metallic ore that contains a minute amount of uranium-234.

X-rays – High-energy electromagnetic radiation emitted by atoms when electrons fall from a higher energy shell to a lower energy shell. These rays have high energy and a short wave length. X-rays are very similar to gamma rays.

Additional Sources of Information

The following reports, documents, and websites offer additional information about DU:

Argonne National Laboratory. *Depleted Uranium, Human Health Fact Sheet*. October 2001.

Argonne National Laboratory. Depleted UF6 Management Information Network. http://web.ead.anl.gov/uranium/

International Atomic Energy Agency. Depleted Uranium Fact Sheet. International Atomic Energy Agency Information Series, Division of Public Information, 01-01198 / FS Series 3/02/E.

North Atlantic Treaty Organization. NATO Information: Depleted Uranium. http://www.nato.int/du/home.htm

The Royal Society. The Health Hazards of Depleted Uranium in Munitions. Policy Document 7/01. May 2001. Available at http://www.royalsoc.ac.uk/

U.S. Department of Defense. Deployment Health Support. http://www.deploymentlink.osd.mil/

U.S. Department of Energy, Office of Environmental Management, Depleted Uranium Hexafluoride Management Program. *Depleted Uranium Hexafluoride Fact Sheet*. Washington, DC. Fall 2001.

U.S. Department of Energy, Office of Environmental Management and Office of Technology Development. *Depleted Uranium: A DOE Management Challenge*. Washington, DC. October 1995.

U.S. Department of Energy, Office of Nuclear Energy, Science, and Technology. Final Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride. April 1999. http://web.ead.anl.gov/uranium/documents/nepacomp/peis/index.cfm

U.S. Environmental Protection Agency. *EPA Facts About Uranium*. July 2002. http://www.epa.gov/superfund/resources/radiation/pdf/uranium.pdf

U.S. Environmental Protection Agency. Soil Screening Guidance for Radionuclides: Technical Background Document. Office of Radiation and Indoor Air, EPA/540-R-00-006. OSWER Directive 9355.4-16. October 2000. http://www.epa.gov/superfund/resources/radiation/radssg.htm

U.S. Environmental Protection Agency. Soil Screening Guidance: A User's Guide. OSWER 9355.4-16A. October 2000.

U.S. Environmental Protection Agency. Common Radionuclides Found at Superfund Sites. OSWER 9200.1-34. July 2000. http://www.epa.gov/superfund/resources/radiation/pdf/nuclides.pdf

U.S. Environmental Protection Agency. Field Demonstration of Permeable Reactive Barriers to Remove Dissolved Uranium from Groundwater: Fry Canyon, Utah, September 1997 through September 1998 Interim Report. Air and Radiation Emergency Response. EPA 402-C-00-001. November 2001

World Health Organization, Department of Protection of the Human Environment. *Depleted Uranium: Source, Exposure, and Health Effects*. Geneva, April 2001.

Nuclear Energy Agency, Organization for Economic Cooperation and Development; Environmental Remediation of Uranium Production Facilities, A joint report by the OECD-NEA and the International Atomic Energy Agency (IAEA).

National Research Council. Evaluation of Guidelines for Exposure to TENORM. 1999. Pgs. 33, 34, & 76.

Appendix 1: Technical Background on Uranium and Depleted Uranium

Origin and History

After the discovery of fission, it was realized that to produce a practical military weapon, the much rarer isotope of ^{235}U would have to be separated from the much more common ^{238}U isotope. In the United States, massive efforts were undertaken, as part of the Manhattan Project, to produce uranium enriched in ^{235}U.

Enrichment is a process that increases the amount of one isotope relative to another. Regardless of the enrichment method utilized for uranium, large quantities of uranium depleted in ^{235}U, are generated as a waste product. This waste became known as depleted uranium, or DU.

Production of highly enriched uranium (HEU) ended in 1992 due to the decreased needs of U.S. defense programs. In 1993, the United States Enrichment Corporation assumed responsibility for the production of low-enriched uranium (LEU) for commercial nuclear reactor fuel. As a result of past enrichment activities, DOE currently maintains a large inventory of DU, most of it stored in the form of uranium hexafluoride. Smaller quantities of DU are stored in the form of uranium metal, uranium metal alloys, and uranium oxides.

Uses of Depleted Uranium

The most well known use for DU is in the manufacture of armor-piercing projectiles due to its high density and pyrophoric properties. It is also used for other military purposes to reduce the effect of other conventional munitions. Civil applications are also prevalent, including use in counterweights in aircraft, missiles, racing sailboat keels, and as a material used in hospitals for shielding X-rays or gamma radiation from equipment used for radiation therapy. Below are further discussions of some of these applications.

Further Enrichment

DU was once proposed as a feedstock for further uranium enrichment. This application has been postponed indefinitely because of the present low cost of uranium ore. It should be noted that, like the initial enrichment process, any further enrichment of DU would result in small quantities of "enriched" uranium and about the same amount of DU. The DU would contain an even smaller proportion of ^{235}U than the original DU.

Nuclear Reactor Fuel

While DU cannot be used directly in nuclear reactor fuel, it can be used as a fertile material in a breeder reactor to produce plutonium-239 (^{239}Pu). The plutonium, once extracted, can be blended with DU to make mixed oxide (MOX) reactor fuel (typically 6% Pu and 94% DU).

Down-blending Highly Enriched Uranium

DU could be blended with weapons grade highly enriched uranium (HEU) to make commercial reactor fuel. This option is one method to reduce the quantity of HEU, as part of a reduction in the nuclear weapons stockpile.

Munitions

DU metal has been used in conventional military applications, most notably in tank armor and armor-piercing projectiles. Conventional weapons using DU were used in the 1991 and 2003 Gulf Wars and in NATO operations in Kosovo and Bosnia.

Shielding

The high atomic number (Z=92) and high density (19.5 g/cm^3) make DU an excellent potential material for shielding persons or equipment from X-rays and gamma rays.

Counterweights
The high density that, in part, makes uranium such an attractive shielding material also makes it suitable as a small but heavy counterweight in aircraft and other similar applications.

It should be noted that Military Specification MIL-U-70457 stipulates that DU used by the U.S. Department of Defense (DoD) must have a ^{235}U concentration of less than 0.3% by weight. Most DU has a ^{235}U concentration of approximately 0.2% by weight. In addition to ^{234}U, ^{235}U, and ^{238}U, DU may contain trace amounts of ^{236}U. The detection of ^{236}U indicates that part of the depleted uranium originated from reprocessed uranium.

To date, the above uses of DU have consumed only a small portion of the DU in storage. A number of other uses for DU have been proposed, some of which might result in the consumption of a significant amount of the stored DU. Additional proposed uses include the following.

High-Density DU Shielding
DU metal has been used in some shielding applications, but the high cost of converting UF_6 to metal has prevented more widespread use. One proposal being considered is to incorporate DU into concrete for applications in self-shielded storage boxes for radioactive waste and dry spent fuel storage shields for onsite storage of civilian reactor fuel.

Cask Fill Material, Repository Inert Material, or Back Fill Material
Depleted UO_2 has been proposed for use as a fill material in spent fuel nuclear waste containers. The concept is intended to provide additional shielding, reduce the likelihood of criticality accidents, and reduce the long-term release of radionuclides. For similar reasons, DU has also been proposed as a repository inert or backfill material.

Counterweights for Forklift Trucks
Use of DU metal, clad in protective steel shielding, in fork lifts as counterweights would result in the design of forklifts that could lift heavier loads, while at the same time reduce the turning radius of the forklift. This would allow the forklift to work in narrower aisles, increasing the usable warehouse floor space.

Depleted Uranium and its Chemical Forms

DU can exist in any chemical form in which uranium occurs. Since all isotopes of an element undergo the same reactions in nature and have almost identical physical characteristics, natural, enriched and depleted uranium are essentially chemically identical. Each isotope has the same chemical reactions in the environment, and the same biochemical and biological effects on the human body. Any differences exist because of small mass differences between various isotopes.

Chemically, DU is identical to “normal” uranium. Uranium is the heaviest existing natural element and can react with most elements except rare gases. In the air, it forms oxides such as uranium oxide (UO_2) and triuranium octaoxide (U_3O_8). At room temperature, humidity can promote the oxidation of uranium. When uranium is fragmented in chips, powder, and turnings, the metal becomes pyrophoric, spontaneously ignites in air. Uranium is produced in a number of chemical forms, including uranium oxides, uranium hexafluoride, uranium tetrafluoride, and uranium metal. These forms are explained below in greater detail. The physical properties of some of the most important uranium compounds are given in Table 5.

Uranium Oxides

Uranium oxides include U_3O_8, UO_2, and uranium trioxide (UO_3). Both U_3O_8 and UO_2 are solids that are relatively stable over a wide range of environmental conditions, with a low solubility in water. In these forms, the DU is chemically more stable and suitable for long-term storage or disposal. U_3O_8 is the most stable form of uranium and is the form most commonly found in nature. The most common form of U_3O_8 is "yellow cake," a solid produced during mining and milling operations, and named for its characteristic yellow color. UO_2 is a solid ceramic material, and the form of uranium most commonly used in nuclear reactor fuel. At ambient temperatures, UO_2 gradually converts to U_3O_8.

Uranium Hexafluoride

Uranium hexafluoride is the chemical form of uranium used during enrichment. UF_6 can be a solid, liquid, or gas within a reasonable range of temperatures and pressures. Solid UF_6 is a white, dense, crystalline material, resembling rock salt. While UF_6 does not react with oxygen, nitrogen, carbon dioxide, or dry air, it does react with water or water vapor to form corrosive hydrogen fluoride (HF) and uranyl fluoride (UO_2F_2). Because UF_6 reacts with water, including humidity in the air, it is always handled in leak-tight containers or processing units. Although very convenient for processing, UF_6 is not favored as a chemical form for long-term storage or disposal because of its relative instability.

In uranium conversion and enrichment processes, a major hazard is the handling of uranium hexafluoride (UF_6), which is chemically toxic. Uranium in these situations can also react with moisture to release highly toxic hydrofluoric acid.

Uranium Tetrafluoride

Uranium tetrafluoride (UF_4), sometimes called green salt because of its characteristic green color, is a solid composed of agglomerating particles with a texture similar to baking soda. It is nonvolatile, nonhydroscopic, and slightly soluble in water. When exposed to water, UF_4 slowly dissolves and undergoes hydrolysis, forming several possible uranium compounds and hydrogen fluoride (HF). UF_4 is generally an intermediate in the conversion of UF_6 to uranium oxide (UO_2 or U_3O_8) or uranium metal.

Uranium Metal

Uranium metal is among the densest materials known, with a density of 19 grams per cubic centimeter (g/cm^3). The silvery white, malleable, and ductile metal is not as stable as uranium oxide and will undergo surface oxidation. It tarnishes in air, with the oxide film preventing oxidation of the bulk material at room temperature. Uranium metal powder or chips will ignite spontaneously in air at ambient temperature.

Manufacturing/Enrichment Processes

To produce uranium for commercial reactor fuel or military applications, the uranium must first be mined, milled, enriched, and converted to a usable form. Uranium ore contains about 0.1% uranium by weight. This ore is processed at mills using mechanical and chemical measures to separate the uranium from the remainder of the ore. The uranium mills produce "yellow cake," a powder containing mostly U_3O_8.

Since isotopes of the same element have the same chemical properties, enrichment must be accomplished by using processes that are based on the physical differences between isotopes, such as mass. A number of methods have been developed to enrich uranium, including gaseous diffusion, gas centrifuge, and electromagnetic separation. In gaseous diffusion, enrichment is accomplished by first converting the yellow cake (U_3O_8) into uranium hexafluoride (UF_6), a highly corrosive gas. This gas is allowed to pass through a porous barrier, where the lighter ^{235}U molecules are slightly more likely to pass through the barrier than the heavier ^{238}U molecules. Because $^{235}UF_6$ and $^{238}UF_6$ molecular weights are nearly the

same, the gas is only slightly enriched in a single stage. The gas is passed through many stages, until the ^{235}U fraction in the gaseous UF_6 is increased to the required enrichment. In addition to the enriched uranium produced, a large quantity of DU, containing about 0.2% ^{235}U, is also generated as a byproduct.

Some of this DU has been used to manufacture armor-piercing penetrators and armor. Army contractors manufacture penetrators from DU metal at contractor-owned, contractor-operated facilities. The U.S. Nuclear Regulatory Commission (NRC) and Agreement States license these contractors to possess and store DU and to manufacture munitions components from it. A typical license would allow a contractor to receive depleted UF_6, transport it to a manufacturing facility, convert it into UF_4 and/or metal, and sell the DU components to an authorized buyer. Most of the depleted uranium hexafluoride (DUF_6) is stored in cylinders at the gaseous diffusion plants where it was generated.

USEC was created as a government corporation to shift some of the enrichment capacity from military to civilian use. In the early 1990s, USEC was created as a government corporation that became USEC, Inc. when it was privatized in 1998. Today, USEC, Inc. is the world's leading supplier of enriched uranium fuel for commercial nuclear plants. They currently manage enrichment processes out of the Paducah, Kentucky, plant and perform research and laboratory functions out of the Portsmouth, Ohio plant.

DUF_6 can be stored in three forms –liquid, gaseous, or solid. At ambient temperatures and pressures DUF_6 is a solid; therefore, it is not easily released from the storage container. When DUF_6 mixes with the water vapor in the air and the iron of the cylinders, a plug of solid uranium and iron compounds and a small amount of HF gas is created, limiting the amount of material released from a breached cylinder.

Most of DOE's DU inventory contains between 0.1 to 0.4 weight-percent uranium-235, in the form of uranium hexafluoride (UF_6) or uranium tetra-fluoride (UF_4), well below levels necessary to create a nuclear chain reaction. A large stockpile has been contained primarily in the form of UF_6 in metal cylinders stored at DOE's enrichment facilities. DU manufacturing and testing facilities in the United States are provided in Appendix 3, while Appendix 4 contains a listing of sites on the NPL that have or may have DU contamination.

Table 5: Physical Properties of Uranium Compounds

Compound	Melting Point (°C)	Density (g/cm^3)		Solubility in Water at Ambient Temperature
		Crystal Particle	Bulk	
Uranium Hexafluoride (UF_6)	64.1	4.68	4.6	Decomposes to UO_2F_2
Uranium Tetrafluoride (UF_4)	960 ± 5	6.7	2.0-4.5	Very Slightly Soluble
Uranyl Fluoride (UO_2F_2)	Decomposes to U_3O_8 at 300	6.37	~2.6	Soluble
Triuranium Octaoxide (U_3O_8)	Decomposes to UO_2 at 1,300	8.30	1.5-4.0	Sparingly Soluble
Uranium Dioxide (UO_2)	2,878 ± 20	10.96	2.0-5.0	Sparingly Soluble
Uranium Metal (U)	1,132	19.05	19	Sparingly Soluble

Source: http://web.ead.anl.gov/uranium/guide/ucompound/propertiesu/tablephysprop.cfm

Appendix 2: Measurement Tools and Monitoring Techniques

Monitoring uranium in the environment includes both field measurements and analysis of environmental samples in the laboratory. Since there is considerable natural uranium around in all soils and the concentration of natural uranium varies greatly, analyses for uranium alone may not tell anyone if DU is present, and so isotopic analyses are generally needed. This is also important since, although there is little difference between the hazard from natural uranium and that from DU, there could be serious legal issues when a site could be responsible for the DU, but not for the natural uranium. DOE has had cases where the total uranium present could have been either background or from leaks or emissions.

The following sections provide some introductory information on measurement tools and monitoring techniques used for uranium. It should also be noted that EPA has recently published an inventory of radiological methodologies for sites contaminated with radioactive materials (see reference 4 on page 9) and the interested reader is referred to this document for further information.

Field Measurements

Field measurements are typically performed using hand-held survey meters, capable of detecting alpha particles while discriminating against beta particles. These instruments typically provide an estimate of the surface contamination due to all alpha emitting radionuclides present. Alpha scintillation (ZnS) detectors have been commonly used in the past, but large-area gas-flow proportional counters have often been found to be more suitable for remediation efforts where lower detection limits are required [1].

The Measurements Applications and Development Group at Oak Ridge National Laboratory (ORNL) compared the performance of several hand-held detectors commonly used to detect DU in soil [45]. Detectors reviewed included a Field Instrument for Detection of Low Energy Radiation (FIDLER), a 1.25" x 1.5" sodium iodide (NaI) detector, and open and closed window pancake-type detectors. The open-window pancake detector showed the best detection sensitivity, although the NaI detector systems provided more consistent results.

Field measurements using survey meters are best suited for identifying surface contamination. The detection of DU below the surface using hand-held proportional counters, ionization chambers, and GM counters is inhibited by the absorption of alpha and beta particles in the soil. Hand-held gamma ray spectrometers can detect DU below the surface, but the lack of a high-energy, high-yield gamma-ray emission by ^{238}U significantly reduces the effectiveness of this technique for field identification and survey [46].

Laboratory Analysis of Environmental Samples

A number of analytical methods have been developed to quantify uranium in environmental samples. Environmental media that have been analyzed include air filters, swipes, biota, water, and soil [1]. Analytical methods include both chemical methods that usually determine only the total quantity of uranium, and radiological methods that can determine the quantity of individual uranium isotopes. Chemical methods include kinetic phosphorescence analysis, X-ray fluorometry, and mass spectrometry. Among the most common radiological methods are alpha spectrometry, gamma ray spectrometry, delayed neutron counting, and instrumental neutron activation analysis. These methods are briefly described below.

Kinetic Phosphorescence Analysis (KPA)

KPA is a method that uses a laser to excite uranium in an aqueous solution and then measures the emission luminescence intensity over time. The intensity of the luminescence is proportional to the total

quantity of uranium in the sample. The technique provides no information about the relative isotopic abundances of uranium and, therefore, cannot distinguish DU from natural uranium in the sample.

X-Ray Fluorometry (XRF)

XRF is similar to KPA, but uses X-rays to excite secondary X-ray fluorescence in the sample material. The secondary X-rays have wavelengths characteristic of the element that produced them. The X-rays are separated by wavelength by Bragg diffraction in a crystal with the appropriate lattice spacing. The measurement of the intensity of the X-rays at the characteristic wavelength provides quantitative information about trace elements in the sample material, including uranium. XRF does not provide information about the isotopic composition of the uranium in the sample.

Mass Spectrometry (MS)

MS is a technique that separates and analyzes ions based on the ratio of the mass to the charge. Unlike most chemical methods, this method provides quantitative information about both the total quantity of uranium in the sample and the isotopic composition. The two most common MS techniques for quantification of uranium in environmental samples are thermal ionization mass spectrometry (TIMS) and inductively coupled plasma-mass spectrometry (ICP-MS). Until recently, TIMS had been the preferred method for the determination of uranium isotopic ratios in environmental samples because of its superior sensitivity, accuracy, and precision, but ICP-MS has been shown to provide similar accuracy and precision, with higher sample throughput and ease of use [46].

Alpha Spectrometry

Alpha spectrometry is a method that relates the quantity of a given alpha-emitting radionuclide to the number of alpha particles detected. Since radionuclides emit alpha particles at one or more discrete energies, it is possible to relate the area of a peak in the alpha spectrum to the quantity of a radionuclide in the sample. Alpha particles continuously lose energy to the electrons in the medium they are traveling in, and will travel only a short distance before they lose all their energy. For this reason, samples should be kept thin and placed near the detector.

Gamma Spectrometry

Gamma spectrometry involves the detection of gamma rays emitted by radionuclides. Radionuclides typically emit gamma rays at one or more discrete energies. The areas of peaks in the gamma ray spectrum can be related to the quantity of the appropriate radionuclide. Since different isotopes of uranium emit gamma rays of different energies, gamma spectrometry can be used to quantify the relative abundance of uranium isotopes in addition to the total quantity of uranium. Unlike alpha particles, gamma rays can penetrate soil and water, and can be detected some distance from the source.

Instrumental Neutron Activation Analysis (INAA)

INAA involves the irradiation of a sample with neutrons to produce an activation product that decays by emission of gamma rays characteristic of the radionuclide. After irradiation, the sample is counted using a high resolution gamma ray spectrometer. For DU, the radionuclide of interest is ^{238}U, which absorbs a neutron to become ^{239}U. ^{239}U emits gamma radiation when it decays to neptunium-239 (^{239}Np). As mentioned in the previous section, INAA can be used with delayed neutron counting to measure both the isotopic composition and the total quantity of uranium in the sample.

Delayed Neutron Counting (DNC)

DNC is a method for determining the quantity of ^{235}U and other fissile radionuclides in a sample by irradiating the sample with neutrons and counting the delayed neutrons from fission. Delayed neutrons result from a small fraction of fission products that emit neutrons as part of their decay chain. DNC can be used with instrumental neutron activation analysis, described previously, to determine the isotopic composition of uranium, which is necessary to distinguish DU from natural uranium.

Analytical Methods for Air Samples

Air samples are typically collected on some type of air filter and then analyzed by one of the methods described previously, including ICP-MS, alpha spectrometry, or INAA.

In a method used by EPA's National Air and Radiation Environmental Laboratory (NAREL), the air filters are ashed, silica content is volatilized with hydrogen fluoride, uranium is extracted with triisooctylamine, purified by anion exchange chromatography, and co-precipitated with lanthanum as fluoride. The uranium is then collected by filtration and dried. The activities of ^{234}U, ^{235}U, and ^{238}U are measured by alpha spectrometry. This method is used to measure uranium in air as part of the Environmental Radiation Ambient Monitoring System [47].

In another method, described by Singh and Wrenn, air filters are ashed, re-dissolved, and co-precipitated with iron hydroxide and calcium oxalate. The uranium is further purified by solvent extraction and electrodeposition. A detection level of 0.02 dpm/L for ^{238}U in solution was reported using alpha spectrometry [48].

Analytical Methods for Water Samples

EPA's Environmental and Support Laboratory published standardized procedures in 1980 for measurement of radioactivity in drinking water that included uranium analysis by both radiochemical and fluorometric methods [49], and more recently, developed an ICP-MS method.

In the radiochemical method, the uranium is co-precipitated with ferric hydroxide, purified through anion exchange chromatography, and converted to a nitrate salt. The residue is transferred to a stainless steel planchet, dried, and flamed. The gross alpha activity is measured using either a gas flow proportional counter or a scintillation detection system following the chemical separation [49].

For the fluorometric method, uranium is concentrated by co-precipitation with aluminum phosphate, dissolved in diluted nitric acid containing magnesium nitrate as a salting agent, with the co-precipitated uranium extracted into ethyl acetate, and dried. The uranium is dissolved in nitric acid, sodium fluoride flux is added, and the samples fused over a heat source [50].

The ICP-MS method was developed for measuring total uranium in water and waste. The sample preparation is minimal – filtration for dissolved uranium, followed by acid digestion for total recoverable uranium. Recovery is quantitative (near 100%) for a variety of aqueous and solid matrices and detection limits are low, 0.1 :g/L for aqueous samples and 0.05 mg/kg for solid samples [51].

Analytical Methods for Soil Samples

EPA's Office of Radiation and Indoor Air has developed two methods for the radiochemical analysis of uranium in various environmental media including soil: a fusion method and a non-fusion method [47]. In the fusion method, the sample is ashed, the silica volatilized, the sample fused with potassium fluoride and pyrosulphate, a ^{236}U tracer added, and the uranium extracted with triisooctylamine, purified on an anion exchange column, co-precipitated with lanthanum, filtered, and prepared in a planchet. Alpha spectrometry is used to quantify the individual uranium isotopes, and the sample concentration is calculated using the ^{236}U yield.

In the non-fusion method, the sample is ashed, the silica volatilized, a ^{236}U tracer added, and the uranium extracted with triisooctylamine, stripped with nitric acid, co-precipitated with lanthanum, and transferred to a planchet. Further analysis by alpha spectrometry is the same as that for the fusion method.

Table 6: Selected Analytical Methods for Determining Uranium in Environmental Samples
(see Table 6-2 of the Toxicological Profile for Uranium [1] for additional methods and details)

Sample Matrix	Sample Preparation	Analytical Method	Sample Detection Limit	Accuracy
Water	Sample fusion with sodium fluoride (NaF) and lithium fluoride (LiF)	Fluorometry (total uranium)	5 mg/L	117.5% at 6.3 mg/L
Water	Pre-concentration by ion exchange chromatography; purification by ion-exchange and solvent extraction	Neutron Activation Analysis (NAA) (^{235}U and ^{238}U)	No data	No data
Water	Extraction by ion-exchange; dissolution in low oxygen solvent; irradiation	Delayed neutron analysis (total uranium)	0.4 mg/L	No data
Water	Wet-ashed; reaction with complexant	Pulsed-laser phosphorimetry	0.05 ppb	103 (average)
Groundwater	Separation on resin; automated	Flow Injection – Inductively Coupled Plasma – Mass Spectrometry (FI-ICP-MS) (isotope quantification)	0.3 mg/L for ^{238}U	±0.3 ng/L
Groundwater	Separation and concentration on two High Performance Liquid Chromatography (HPLC) columns; complexation with Arsenazo III	Spectrophoto-metry (total uranium)	1-2 mg/L	No data
Soil	Dissolution in HCl-HNO_3 –HF; purification by co-precipitation, solvent extraction and electrodeposition	Alpha Spectrometry (isotope quantification)	0.03 mg/sample	67%
Soil	Soil leached with HCl-$HClO_4$ –HF; purification by ion exchange, and solvent extraction and electrodeposition	Alpha Spectrometry (isotope quantification)	No data	No data
Soil, sediment, and biota	Ashing; fusion with potassium fluoride (KF) and potassium pyrosulfate ($K_2S_2O_7$); purification by extraction with triisooctylamine; anion exchange chromatography and co-precipitation	Alpha Spectrometry	No data	No data
Soil, sediment, and biota	Ashing; extraction into triisooctylamine, strip from triisooctylamine with nitric acid (HNO_3), and coprecipitation with lanthanum.	Gross Alpha Spectrometry or Alpha Spectrometry	No data	No data

Sample Matrix	Sample Preparation	Analytical Method	Sample Detection Limit	Accuracy
Field Survey	None	Scintillation Detector and Count Rate Meter		No data
Air	Air particulate collection on glass fiber filter, digestion in nitric acid (HNO_3)	Inductively Coupled Plasma – Mass Spectrometry (ICP-MS) (total uranium)	0.1 mg/L in final solution	No data
Air	Spiked air particulate dry and wet ashed; dissolution; coprecipitation with iron hydroxide and Ca oxalate, purification by solvent extraction and electrodeposition onto platinum	Alpha Spectrometry	0.02 dpm/L for ^{238}U in solution	No data
Air	Sample collection on cellulose filters; ashing; extraction with triisooctylamine; purification by anion exchange chromatography and co-precipitation	Alpha Spectrometry	0.015 pCi	No data
Air	Collection on cellulose filters	Instrumental Neutron Activation Analysis (INAA)	0.03 mg per filter	No data

Source: Toxicological Report for Uranium [1], Table 6-2

Appendix 3: National Priorities List (NPL) Sites that have or may have DU Contamination

NPL Site	EPA Region	Description
Maxey Flats Nuclear Disposal, Hillsboro, Kentucky (NPL-1986)	Region 4	The Maxey Flats Nuclear Disposal Site is located in eastern Kentucky near Hillsboro in Fleming County and was a disposal facility for low-level radioactive waste. Approximately 533,000 pounds of source material (consisting of uranium and thorium or ores containing them), 2.5 megacuries (MCi) of byproduct materials, and 950 pounds of special nuclear material (i.e., plutonium and enriched uranium) were buried in an area known as the Restricted Area. Radioactive leachate was discovered to be leaching out of this area and into surrounding fractured bedrock, soil, and possibly groundwater. The remediation approach was to capture and evaporate the leachate, producing solid concentrates that were then buried in onsite disposal trenches, which were ultimately capped. Other liquid waste was solidified and buried in another onsite disposal trench, which was also capped.
Malta Rocket Fuel Area, Malta, New York (NPL-1987)	Region 2	This site is located in the towns of Malta and Stillwater, New York, approximately 1 mile south of Saratoga Lake and 2 miles northeast of Round Lake. All or part of the Test Station on the site has been leased and used for a wide range of rocket and weapons testing programs and for space and other research. In 1979, approximately 8 grams of uranium hexafluoride gas were released in a portion of the former GE/Exxon nuclear building. The area was cleaned and the contaminated material was sent to licensed disposal facilities.
Savannah River Site, Aiken, South Carolina (NPL-1989)	Region 4	Savannah River has produced nuclear materials for national defense since 1951. This site is surrounded by woods and ranges from dry hilltops to swampland. The Department of Energy (DOE) reports that a small quantity of DU was released in January 1984 into Upper Three Runs Creek, which eventually flows into the Savannah River. The site remedy has included groundwater pump and treat, capping/solidification of various disposal basins and solid waste disposal sites, removal and treatment and/or disposal of hazardous substances, and shipping process waste to the Waste Isolation Pilot Project in New Mexico.
Rocky Flats Environmental Technology Site, Golden, Colorado (NPL-1989)	Region 8	This former plant manufactured plutonium components for nuclear weapons and shut down operations in 1989 in response to alleged violations of environmental statutes. In 1992, the United States decided not to resume production at this site. During the summer of 1998, DOE excavated 171 drums of uranium and contaminated soil from Trench T-1. Most of this waste was shipped to the Nevada Test Site for disposal.
Oak Ridge Reservation (DOE), Oak Ridge, Tennessee (NPL-1989)	Region 4	Two facilities at this site produced enriched uranium: the Y-12 plant by an electromagnetic process, and the K-25 plant by gaseous diffusion. DU is a byproduct of both of these processes. There has been leakage from this site into the surrounding environment. At the Y-12 plant, the Abandoned Nitric Acid Pipeline was used to carry waste effluent, which included DU.
Iowa Army Ammunition Plant, Des Moines County, Iowa (NPL-1990)	Region 7	The Iowa Army Ammunition Plant site's primary activity has been to load, assemble, and pack a variety of conventional ammunition and fusing systems. In the fall of 2000, chunks of DU were reported at the Firing Site. This has prompted increased focus on the site.

NPL Site	EPA Region	Description
Naval Surface Warfare Center, Dahlgren, Virginia (NPL-1992)	Region 3	NSWC is approximately 4,300 acres and located 40 miles south of Washington, D. C., along the Potomac River. This site conducts research, development, testing, and evaluation of surface ship weaponry. Six sites are related to the former use of munitions, some of which included DU.
Materials Technology Laboratory (U.S. Army), Watertown, Massachusetts (NPL-1994)	Region 1	Located on 48 acres of land on the north bank of the Charles River, this arsenal has been in operation since 1816. In addition to storage, this facility has expanded into weapons development and production. Specifically, DU machining, milling, forging, and casting took place on this site. Radiological contamination present at the site has been remediated and removed. At the time of this writing, the site's remediation focus is on decontaminating the soil.
Gaseous Diffusion Plant (USEC), Paducah, Kentucky (NPL-1994)	Region 4	This site, which is 3 miles south of the Ohio River and 10 miles west of Paducah, KY, performed the first step in the uranium-enrichment process. Separating the uranium by diffusing it through a barrier results in several end products, one of which is DU. Radiological and volatile organic compound (VOC) contamination has been found in on- and offsite wells, and polychlorinated biphenyl (PCBs) in offsite surface water bodies.
Nuclear Metals, Concord, Massachusetts (NPL-2001)	Region 1	The Nuclear Metals, Inc., also known as Starmet Corporation, site is located in Concord, Massachusetts. In 1958, NMI began operating a manufacturing facility that produced DU products, primarily as penetrators for armor piercing ammunition. Soil, sediment, and surface water samples taken historically and recently indicate that the holding basin, sphagnum bog, and cooling recharge pond all have elevated levels of DU.

Appendix 4: Depleted Uranium Manufacturing and Testing Facilities

Facility/Site/Company Name	Location	EPA Region
Sierra Army Weapons Depot	Susanville, California	Region 9
Aerojet Ordinance Company	Downy, California	Region 9
NI Industries	Los Angeles, California	Region 9
Hughes Helicopter	Los Angeles, California	Region 9
Armtec Defense Products	Coachella, California	Region 3
China Lake Naval Weapons Center	China Lake, California	Region 3
Elgin Air Force Base Munition Test Facility	Valpariso, Florida	Region 4
Chamberlain	Waterloo, Iowa	Region 7
Mason & Hangar	Middletown, Iowa	Region 7
Specific Manufacturing Capability, INEEL	Idaho Falls, Idaho	Region 10
U.S. Army Armament Munitions & Chemical Compound	Rock Island, Illinois	Region 5
Olin Corporation	East Alton, Illinois	Region 5
Jefferson Proving Ground, U.S. Army	Madison, Indiana	Region 5
U.S. Army	Fort Riley, Kansas	Region 7
Paducah Gaseous Diffusion Plant, U.S. DOE	Paducah, Kentucky	Region 4
Nuclear Metal, Inc.	Concord, Massachusetts	Region 1
U.S. Army Laboratory Command	Watertown, Massachusetts	Region 1
Chamberlain	New Bedford, Massachusetts	Region 1
U.S. Army Aberdeen Proving Ground	Aberdeen, Maryland	Region 3
General Dynamics	Detroit, Michigan	Region 5
U.S. Army Camp Grayling	Grayling, Michigan	Region 5
Honeywell	Minnetonka, Minnesota	Region 5
Honeywell Corporation	Hopkins, Minnesota	Region 5
U.S. Army Twin Cities Army Ammunition Plant	New Brighton, Minnesota	Region 5
Kisco	St. Louis, Missouri	Region 7
Remington Arms Company Lake City Army Ammunition Plant	Independence, Missouri	Region 7
Target Research, Inc.	Dover, New Jersey	Region 2
Los Alamos National Laboratory	Los Alamos, New Mexico	Region 6
Los Alamos, New Mexico	Albuquerque, New Mexico	Region 6
Kirkland Air Force Base	Albuquerque, New Mexico	Region 6
Terminal Effects Research and Analysis	Socorro, New Mexico	Region 6
Aerojet General Corporation	Lockwood, Nevada	Region 9
U.S. Ecology	Beatty, Nevada	Region 9
U.S. Army Ballistics Research Laboratory, Nevada Test Site	Mercury, Nevada	Region 9
Nellis Air Force Base	Las Vegas, Nevada	Region 9
National Lead Industries	Colonie, New York	Region 2
Watervliet Arsenal	Albany, New York	Region 2
Bulova Systems	Valley Stream, New York	Region 2
Lima Army Tank Plant, General Dynamics	Lima, Ohio	Region 5
Feed Materials Plant, U.S. DOE	Fernald, Ohio	Region 5
Portsmouth Uranium Enrichment Plant, U.S. DOE	Portsmouth, Ohio	Region 5
Ashtabula Extrusion Plant	Ashtabula, Ohio	Region 5
Sequoyah Fuel Corporation	Gore, Oklahoma	Region 6
General Defense	Red Lion, Pennsylvania	Region 3
Carolina Metals	Barnwell, South Carolina	Region 4
Savannah River Site, DOE	Aiken, South Carolina	Region 4
Defense Consolidation Facility	Snelling, South Carolina	Region 4
Aerojet Heavy Metals	Jonesboro, Tennessee	Region 4
Martin Marietta Energy Systems K-25 Site*	Oak Ridge, Tennessee	Region 4
Day and Zimmerman	Texarkana, Texas	Region 6
Pantex Plant, U.S. DOE	Amarillo, Texas	Region 6
General Dynamics	Falls Church, Virginia	Region 3
U.S. Naval Surface Weapons Center	Dahlgren, Virginia	Region 3

Facility/Site/Company Name	Location	EPA Region
Hercules	Radford, Virginia	Region 3
Ethan Allen Firing Range General Electric	Burlington, Vermont	Region 1
Hanford Nuclear Reservation, U.S. DOE	Hanford, Washington	Region 10
U.S. Army Yakima Firing Range	Yakima, Washington	Region 10
Stresau Labs	Spooner, Wisconsin	Region 5

* The Martin Marietta Energy Systems K-25 facility is now known as the East Tennessee Technology Park; it was originally known as the Oak Ridge Gaseous Diffusion Plant.

Appendix 5: Case Study - Nuclear Metals, Inc. (NMI) site, Concord, Massachusetts

Background

The Nuclear Metals, Inc. (NMI) site, also known as the Starmet Corporation site, is located on a 46.4-acre parcel located at 2229 Main Street in Concord, Middlesex County, Massachusetts. The facility includes five interconnected buildings, a paved parking area, a sphagnum bog, a cooling water recharge pond, and a holding basin.

In 1958, NMI began operating a manufacturing facility on previously undeveloped land. Nuclear Metals, Inc. produced DU products, primarily as penetrators for armor piercing ammunition. NMI also manufactured metal powders for medical applications, photocopiers, and specialty metal products Disposal was executed via waste stream discharge. From 1958 to 1985, NMI discharged wastes to an unlined holding basin. Extrusion operations on depleted uranium produced rods with a thin layer of copper coating that was removed in a nitric acid pickling operation during which "small quantities" of copper and uranium were dissolved in the nitric acid. The spent nitric acid solution was collected, neutralized with a lime slurry, and discharged to the unlined, in-ground holding basin along with other wastes. Discharge to the holding basin ceased in 1985 when NMI began using an acid closed-loop recycling process.

NMI was renamed Starmet Corporation in 1997. In March 1997, the company's NRC license to handle source material (including depleted uranium, thorium, and thorium oxide) was transferred to the Massachusetts Department of Public Health, Radiation Control Program. The state collected groundwater samples and detected volatile organic compounds (VOCs) in NMI's supply well, previously used for drinking water. Further analytical results indicated that the groundwater beneath the property was contaminated with radionuclides (i.e., uranium and thorium), and other materials. In addition, a sphagnum bog on the property was also been sampled and has shown evidence of radionuclides. Soil, sediment, and surface water samples taken historically and recently indicated that the holding basin, sphagnum bog, and the cooling water recharge pond all have exhibited elevated levels of depleted uranium.

Cleanup Approach

In 1998, Starmet conducted a voluntary partial cleanup of contaminated soils under the Massachusetts Department of Environmental Protection (MADEP) oversight. The partial cleanup consisted of excavation and transportation off-site of approximately 8,000 cubic yards of soil contaminated with depleted uranium and copper. The cleanup halted in late 1998 when Starmet determined that the cleanup level set by MADEP could not be met without excavation of a significantly greater quantity of material. The site has since been listed on the National Priorities List; further evaluation of remaining contamination at the site will be addressed under EPA authority.

Response Action

A time-critical removal assessment was conducted to determine if buried drums on site contain hazardous material. Two areas containing buried drums and other laboratory equipment were located during the removal assessment: one in a fenced-in area adjacent to the holding basin and cooling water pond, and contains approximately 70 drums; the other, called the "old landfill" contains an unknown number of drums and laboratory equipment. A time-critical removal action was conducted which included: 1) installation of fencing around the "old landfill" area where buried drums are located; 2) re-grading and capping of the "old landfill" area; and 3) installation of a liner in the holding basin to eliminate fugitive dust and reduce the leaching of contaminated soils into the groundwater. Sampling and analysis of soils in the holding basin was conducted in September 2001 to fill data gaps in previous sampling efforts and to determine if data from past sampling efforts performed by Starmet were comparable to EPA data. In June 2002, EPA assumed the groundwater monitoring program previously performed by Starmet. During the

June 2002 sampling event, EPA also sampled sediment and surface water on-site and in the Assabet River. EPA sampled the groundwater monitoring wells again in July 2003 before turning site work over to Potentially Responsible Parties.

Progress and Current Status

Removal of 8,000 cubic yards of soil from the holding basin by Starmet under MADEP oversight has reduced the threat of potential exposure at the site. A time-critical removal action has been conducted to prevent the direct contact threat with the contaminated surface soils located in the "old landfill" area, and to reduce the infiltration of precipitation into the holding basin soils. EPA has installed a fence and warning signs around the perimeter of contaminated soils in the "old landfill" area, has capped the "old landfill" area; and, has installed a liner over the holding basin. In June 2003, EPA also negotiated an agreement with five potentially responsible parties including: U.S. Army, U.S. DOE, Whittaker Corporation, MONY Life Insurance Co., and Textron, Incorporated, for the performance of a Remedial Investigation/Feasibility Study (RI/FS), which includes the performance of an Engineering Evaluation and Cost Analysis (EE/CA). An EE/CA Approval Memorandum was signed on September 27, 2002, which authorizes the performance of an EE/CA in support of a Non Time-Critical Removal Action for the holding basin and buried drum areas. A lien has been recorded on the Starmet property at 2229 Main Street in Concord.

In May 2001, Starmet transported 1,700 drums containing depleted uranium from its South Carolina facility to the site, to facilitate its planned sale of that facility. Starmet also has approximately 2000 drums and other containers of depleted uranium wastes and approximately 100 drums of beryllium wastes stored at the site. Starmet is currently in violation of its MADPH radioactive materials license because it has failed to remove the stored drums of depleted uranium materials from the site and is therefore not allowed to process any radioactive material at the facility under their license. After Starmet indicated that it planned to cease operations or file for bankruptcy, the Commonwealth of Massachusetts obtained a preliminary injunction in state court in January 2002, requiring Starmet to continue to provide site security and necessary utilities. On March 15, 2002, the state court placed Starmet into temporary receivership. On or about March 18, 2002, Starmet abandoned the site property. The temporary receiver provided security and necessary utilities, with the assistance of MADPH, until March 25, 2002. Thereafter, MADPH began providing security at the site. Starmet filed for Chapter 11 bankruptcy protection on April 3, 2002, returned to the site, and continues to operate and provide site security. MADPH currently has funding available to provide security and necessary utilities if needed, through the financial assurance mechanism provided under Starmet’s radioactive materials license. If MADPH’s funding is exhausted and no other funding source is available, resulting in abandonment of the facility, then EPA may be required to address the security and utilities issues.

In April 2004, the state reached an agreement with the Army to remove the more than 3,000 drums of depleted uranium and other materials from within the facility. The state has procured a contractor for performance of the work, and shipments of drums and other material to the Envirocare waste disposal facility in Clive, Utah, began in September 2005. It is expected that the state removal work will be completed in spring 2006. In September 2004, EPA conditionally approved the RI/FS Work Plan submitted by de maximis, inc., the project coordinator for the private PRPs. Field work associated with the remedial investigation began in October 2004. In October 2004, under the supervision of U.S. Environmental Protection Agency, de maximis, inc., started an investigation of the Superfund Site to locate all contaminants and prepare a feasibility study of the Site cleanup. So far over 1300 samples of soil, sediment and water have been collected and analyzed. Since each sample is analyzed for a number of different contaminants, the data base contains over 300,000 records. Soil contamination has been found at several locations on the site. Contamination has also been located in the groundwater. The major contaminant is uranium. Polychlorinated biphenyls (PCBs) and volatile organic compounds are also

present. A number of other chemicals have been detected at lower concentrations. Analysis of data is being conducted to determine the extent of, and the risk from, the contamination.

Under a contract with MADEP, Envirocare Inc. is removing all identifiable radioactive and other waste material from the Starmet Plant. The material shipped so far to Clive, Utah, includes 1,315 drums of uranium tetrafluoride, 1,097 drums of a concrete and uranium mixture (conjoint) and 447 drums of other uranium waste. Approximately 250 drums of uranium tetrafluoride, 200 tons of uranium metal, and other miscellaneous waste remain to be shipped. The material is removed every working day in two or three Landstar Co. tractor trailers. The work was scheduled for completion by March 31, 2006. Removal of the radioactive material is required prior to starting the EPA investigation of the buildings and soil and water beneath them. The funding for the contract was provided by the U.S. Army.

In December 2004, de maximis, inc., under supervision of the EPA, removed from the ground between the Holding Basin and Cooling Water Recharge Pond a number of drums containing some uranium and beryllium waste, production tools and production materials, buried in 1967.

In April 2003 Weston Solutions Inc., under a contract with EPA, removed from the ground in the area of the Old Landfill (south of Bog) drums containing uranium and beryllium, more production tools and materials, then filled, graded and covered the area. Another phase of the plant cleanup, which will include the removal of all contaminated equipment, is anticipated after Starmet leaves the premises.

Further Information

- http://yosemite.epa.gov/r1/npl_pad.nsf/f52fa5c31faf5c885256adc0050b631/7B6349F1A22FFDF385259E5006CA840?OpenDocument
- http://www.crewconcord.org/pages/whats_new.html

Appendix 6: Case Study - Maxey Flats Nuclear Disposal Site, Hillsboro, Kentucky

Background

The Maxey Flats Nuclear Disposal Site is located in eastern Kentucky, near Hillsboro, in Fleming County. The site was a disposal facility for low-level radioactive wastes. The site is located on a spur of Maxey Flats, a ridge 300 feet above the surrounding stream valleys. The area surrounding the site is rural and agricultural. More than 300 people live within a five mile radius of the restricted area; the closest residence is within ¼ mile. More than 120 wells and 25 springs are situated within five miles; however, nearby residents receive household water from a municipal water system.

From 1963 to 1977, the Commonwealth of Kentucky, under authorities granted by the U.S. Government, licensed private operators including the Nuclear Engineering Company (NECO) to dispose of low-level radioactive wastes from military ships and facilities, hospitals, universities, corporations, etc.; an estimated five million cubic feet of material were disposed. Most was solid waste; however, other waste types were disposed and some were highly radioactive. Approximately 533,000 pounds of source material (consisting of uranium and thorium or ores containing them), 2.5 megacuries (MCi) of byproduct materials, and 950 pounds of special nuclear material (plutonium and enriched uranium) were buried in an area known as the Restricted Area.

Between 1973 and 1986 a large evaporator facility was operated on site to handle contaminated liquids. During the operation of the facility, workers capped each disposal trench with a layer of soil after it was filled, but the earth eventually collapsed into the ditches. Water collected in the trenches, leaching radionuclides into the surrounding environment. A restricted area of approximately 40 acres is situated entirely on top of the flats. The fenced and patrolled restricted area encompasses the disposal trenches, "hot wells" (sealed concrete pipes containing plutonium and uranium), waste storage buildings, and an evaporator facility. Including the acquired buffer zone properties, the site occupies 900 acres.

Operations closed in 1973 and by 1985, the U.S. EPA had developed a list of potentially responsible parties (PRPs) from the disposal records toward whom to point financial responsibility. In 1986 Maxey Flats was placed on the National Priorities List, becoming, at 300 acres, one of the largest Superfund sites in the history of the program, and from 1987 to 1991 extensive studies on remediation options were carried out.

Response Action

To assure proper management and closure, the Commonwealth of Kentucky has maintained the site since the time that commercial operations ended. The Remedial Investigation and Feasibility Study was conducted from March, 1987 until September, 1991 under an administrative Order by Consent. The Record of Decision was issued in September, 1991. Meanwhile, between December, 1988 and November, 1989, U.S. EPA Emergency Response solidified 286,000 gallons of tanked leachate because of significant leakage from the metal leachate (radioactively contaminated trench water) tanks. Subsequently, from March, 1991 to September, 1992, U.S. EPA Emergency Response disposed of the solidified leachate blocks in an underground on-site trench and installed 30 acres of temporary above-ground plastic, impermeable liner to prevent infiltration of rain into the waste trenches.

After negotiations lasting from June, 1992 until June, 1995, two Consent Decrees (one for the 50 de maximis parties and one for the 306 de minimis parties) arranged for cost allocation and for the performance of the Remedial Design (RD) and Remedial Action. After the required public comment periods, the U.S. District Court activated the decrees in April 1996; the RD for the first of two major cleanup phases (1. Leachate Removal and Disposal; 2. Building Demolition, On-Site Disposal, and Other Items) began immediately thereafter. Construction of Phase I and Phase II of the reinforced concrete

bunkers (for disposal of solidified radioactive leachate and other contaminated materials) have been completed.

Approximately 900,000 gallons of leachate and have been removed from within the landfill since current dewatering operations began in September, 1998. However, the median total daily volumes of water removed declined from more than 5,050 gallons in 1998 to less than 600 gallons during the 2000 pumping season. Landfill dewatering operations were discontinued during the early fall of 2000. Construction of an interim cap to prevent water infiltration with a perimeter drainage system that includes the groundwater interceptor channel has been completed. To verify the drainage system does not negatively impact erosion rates, erosion monuments have been installed for monitoring the rate of erosion.

The completion of the Initial Remedial Phase was declared in October 2003 by U.S. EPA. Remedial work completed at the Maxey Flats Waste Disposal Site has been under the guidance of the U.S. EPA, Atlanta, Georgia, and in accordance with the Consent Decree signed in 1996. International Technology Corporation and Shaw Environmental Group performed the remedial construction.

Progress and Current Status

A five year review was completed in 2002; other five year reviews are planned for 2007 and 2012, the latter of which, if successful, will render the Commonwealth of Kentucky fully responsible for the site. Corrective steps completed in 2003 have brought most problems at the site under control. The steps include installation of the geomembrane liner, which directs rainwater into a detention basin to be tested for radioactivity before it is released into a nearby creek. Contaminated water was pumped out of the storage trenches, solidified with concrete, and buried on site. Automatic monitoring equipment samples surface water at multiple locations around the site every six hours for testing. A 550-acre "buffer zone" has been added around the perimeter of the site to separate it from the surrounding farms and homes.

No contaminated water has been found outside Maxey Flats' restricted area, with the exception of two springs in the buffer zone where low levels have been detected. If work continues on schedule, a permanent "cap" consisting of multiple layers of liner and soil, with grass sown on the surface, is planned to cover the site sometime around 2012. The total cost of cleanup and monitoring is expected to exceed $60 million. In addition to the depleted uranium contamination, Maxey Flats is also noted for tritium, strontium-90, and radium-226 contamination.

Further Information

- http://www.waste.ky.gov/programs/sf/Maxey+Flats.htm
- http://www.epa.gov/Region4/waste/npl/nplky/maxfltky.htm
- http://nucnews.net/nucnews/2006nn/0604nn/060423nn.txt

Appendix 7: Treatment Defined by NCP

The concept of treatment is discussed in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) under Section 300.5, as follows:

> "Treatment technology" means any unit operation or series of unit operations that alters the composition of a hazardous substance, pollutant, or contaminant through chemical, biological, or physical means so as to reduce toxicity, mobility, or volume of the contaminated materials being treated. Treatment technologies are an alternative to land disposal of hazardous wastes without treatment.

The NCP further states that

> "EPA expects to use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials." (See Section 300.430 (a)(iii)(A))

The preamble to the NCP provides further clarification of treatment:

> "This goal [treatment expectation] reflects CERCLA's preference for achieving protection through the use of treatment technologies that destroy or reduce the inherent hazards posed by wastes and result in remedies that are highly reliable over time. The purpose of treatment in the Superfund program is to significantly reduce the toxicity and/or mobility of the contaminants posing a significant threat (i.e., "contaminants of concern") wherever practicable to reduce the need for long-term management of hazardous material. EPA will seek to reduce hazards (i.e., toxicity and/or mobility) to levels that ensure that contaminated material remaining on-site can be reliably controlled over time through engineering and/or institutional controls.
>
> Further, the Superfund program also uses as a guideline for effective treatment the range of 90 to 99 percent reduction in the concentration or mobility of contaminants of concern (see preamble discussion below on "reduction of toxicity, mobility or volume" under Section 300.430 (e)(9)). Although it is most important that treatment technologies achieve the remediation goals developed specifically for each site (which may be greater or less than the treatment guidelines), EPA believes that, in general, treatment technologies or treatment trains that cannot achieve this level of performance on a consistent basis are not sufficiently effective and generally will not be appropriate. [See 55 FR 8701]

For further information on this definition please contact EPA's Office of Superfund Remediation & Technology Innovation.

References

1. U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Diseases Registry. *Toxicological Profile for Uranium*. September 1999.

2. U.S EPA, Office of Air and Radiation. *Environmental Characteristics of EPA, NRC, and DOE Sites Contaminated with Radioactive Substances*, EPA 402-R-93-005 Washington, DC, March 1993.

3. U.S. EPA, Office of Solid Waste and Emergency Response. *Soil Screening Guidance: User's Guide*, 2nd Edition Publication 9355.4-23. Washington, DC, July 1996.

4. U.S. EPA, Office of Solid Waste and Emergency Response. *Soil Screening Guidance: Technical Background Document*, EPA/540-R-95/128. Washington, DC, May 1996.

5. U.S. EPA, Office of Radiation and Indoor Air & Office of Solid Waste and Emergency Response. *Soil Screening Guidance for Radionuclides: User's Guide*, EPA/540-R-00-007. Publication 9355.4-16A. Washington, DC, October 2000.

6. U.S. EPA, U.S. DoD, U.S. DOE, U.S. DHS, U.S. NRC, U.S. FDS, USGS, and NIST. *Multi-Agency Radiological Laboratory Analytical Protocols Manual* (MARLAP), NUREG-1576, EPA 402-B-04-001A, and NTIS PB2004-105421. Washington, DC, July 2004.

7. U.S. EPA, U.S. DOE, U.S. NRC, and U.S. DoD. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM). NUREG-1575, Rev. 1, EPA 402-R-97-016, Rev. 1, DOE/EH-0624, Rev. 1, Washington, DC, August 2000.

8. Army Environmental Policy Institute (AEPI). 1995. *Health and Environmental Consequences of Depleted Uranium Use in the U.S. Army: Technical Report*. http://www.fas.org/man/dod-101/sys/land/docs/techreport.html, accessed August 29, 2005.

9. Los Alamos National Laboratory (LANL) 2003. High Gradient Magnetic Separation (HGMS). http://www.emtd.lanl.gov/TD/Remediation/HGMS.html, accessed April 8, 2003.

10. National Nuclear Security Administration (NNSA). *Proceedings from the Remediation of Radioactive Surface Soils Workshop*, August 14-15, 2001. U.S. DOE National Nuclear Security Administration, Nevada Operations Office, DOE/NV–798, January 2002.

11. Morris, D.E., P.G. Allen, J.M. Berg, C.J. Chisholm-Brause, S.D. Conradson, R.J. Donahoe, N.J. Hess, J.A. Musgrave, and C.D. Tait. 1996. Speciation of Uranium in Fernald Soils by Molecular Spectroscopic Methods: Characterization of Untreated Soils. Environmental Science and Technology 30:2322-2331.

12. Carpenter, C., S. Morrison, and D. Metzler. "Monticello Permeable Reactive Barrier Project." *Ground Water Currents* Issue No. 36, June 2000, http://www.clu-in.org, accessed April 1, 2003.

13. U.S. EPA. Permeable Reactive Barrier Technologies for Contaminant Remediation. Office of Solid Waste and Emergency Response, EPA/600/R-98/125, September 1998.

14. Feltcorn, E., and R. Breeden. 1997. "Reactive Barriers for Uranium Removal." *Ground Water Currents* Issue 26, December 1997, http://www.clu-in.org, accessed April 1, 2003.

15. U.S. EPA. Office of Solid Waste and Emergency Response, *Iron reactive barrier used at Rocky Flats Site in Ground Water Currents* EPA 542-N-01-005, Issue No. 39, April 2001.

16. Water Remediation Technology, LLC, *Pilot Study Report for Z-92™ Uranium Treatment Process conducted at Brazos Mutual Domestic Water, New Mexico October 21, 2004* http://wrtnet.com/pdf/Brazos.pdf, accessed August 28, 2005.

17. Water Remediation Technology, LLC, *Pilot Study Report for Z-92™ Uranium Treatment Process conducted at the Mountain Water & Sanitation District, Conifer, Colorado November 11, 2004* http://wrtnet.com/pdf/Mtn%20Water.pdf, accessed August 28, 2005

18. Water Remediation Technology, LLC, Pilot Study Report for Z-92™ Uranium Treatment Process conducted at conducted at Chesdin Manor Dinwiddie County, Virginia for the Fox Run Water Company July 5, 2005 http://wrtnet.com/pdf/Fox_Run.pdf, accessed August 28, 2005.

19. Arey, J.S., J.C. Seaman, and P.M. Bertsch. "Immobilization of uranium in contaminated sediments by hydroxyapatite addition." *Environmental Science and Technology* 33:337-342. 1999.

20. Hughes, J.E. "In situ stabilization of uranium contaminated groundwater in low permeability clay using phosphate amendments with prefabricated vertical drains." *Proceedings of the 2001 International Containment & Remediation Technology Conference and Exhibition,* June 2001 Orlando, Florida, http://www.containment.fsu.edu/cd/content/, accessed April 8, 2003.

21. Fetter, S., and F.N. von Hippel. "The hazard posed by depleted uranium munitions." *Science & Global Security* 8:125-161. 1999.

22. Stegnar, P., and L. Benedik. "Depleted uranium in the environment- an issue of concern?" *Archive of Oncology* 9:251-255. 2001.

23. Schnoor, J.L. "Phytoremediation". Ground-Water Remediation Technologies Analysis Center Technology Evaluation. 1997

24. Edenspace. *Case Study: Depleted Uranium Phytoextraction Project Profile: Aberdeen Proving Ground*. http://www.edenspace.com/casestudy-uranium.html, accessed August 29, 2005.

25. U.S. EPA, "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites." OSWER Directive No. 9200.4-17P, April 21, 1999

26. U.S. EPA Website, http://www.epa.gov/radiation/radionuclides/uranium.htm, accessed May 29, 2003.

27. Clean Air Act as amended in 1970, 1977, 1990 (42 USC 7401 et seq.).

28. Safe Drinking Water Act as amended in 1985, 1996 (43 USC s/s 300f et seq.).

29. *Nuclear Energy Agency, Organisation for Economic Cooperation and Development, Management of Depleted Uranium,* A Joint Report by the OECD Nuclear Energy Agency and the International Atomic Agency, 2001.

30. U.S. DOE, Oak Ridge National Laboratory's Assessment of Preferred DU Disposal Forms. June 2000.

31. National Council for Radiation Protection (NCRP). *Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition.* 1987.

32. World Health Organization (WHO) Fact Sheet No. 257, Jan.2003 http://www.who.int/mediacentre/factsheets/fs257/en/index.html, accessed August 29, 2005.

33. National Council for Radiation Protection (NCRP). *Ionizing Radiation Exposure of the Population of the United States.* 1987.

34. World Health Organization, Department of Protection of the Human Environment. *Depleted Uranium: Source, Exposure, and Health Effects*. Geneva, April 2001.

35. Health Physics Society (HPS). *Bioassay Programs for Uranium*. N13.22-1995 McLean, VA, October 1995.

36. U.S. Department of Defense (DoD) Office of the Special Assistant for Gulf War Illnesses (OSAGWI). *Environmental Exposure Report - Depleted Uranium in the Gulf.* http://www.gulflink.osd.mil/du/, accessed on August 29, 2005.

37. U.S. Army Environmental Policy Institute. *Summary Report to Congress - Health and Environmental Consequence of Depleted Uranium Use by the U.S. Army*. June 1994. http://www.fas.org/man/dod-101/sys/land/docs/du.html, accessed August 29, 2005.

38. U.S. EPA, Office of Indoor Air and Radiation, and U.S. DOE, Office of Environmental Restoration. *Understanding Variation in Partition Coefficient, K_d, Values. Volume 2: Review of Geochemistry and Available Kd Values for Cadmium, Cesium, Chromium, Lead, Plutonium, Radium, Strontium, Thorium, (^{3}H) Tritium, and Uranium*, EPA-402-R-99-004B. Washington, DC, August 1999.

39. United Nations Environmental Programme and United Nations Centre for Human Settlements. UNEP/UNCHS Balkans Task Force (BTF): The potential effects on human health and the environment arising from possible use of depleted uranium during the 1999 Kosovo conflict. A preliminary assessment. Geneva, October 1999. Cited in "Report of the World Health Organization Depleted Uranium Mission to Kosovo. Undertaken at the request of the Special Representative of the Secretary-General and Head of the Interim Administration Mission in Kosovo (UNMIK). Draft Text 28th January 2001", http://www.euro.who.int/document/e71919.pdf, accessed August 8, 2006.Langmuir, D. *Aqueous Environmental Geochemistry*. Prentice Hall, Upper Saddle River, New Jersey, 1997.

40. U.S. Department of Agriculture, Agricultural Research Service, Southern Plains Area Cropping Systems Research Laboratory, Wind Erosion and Water Conservation Research Unit. "Revised Wind Erosion Equation" Technical Bulletin Number 1, June 1998.

41. U.S. EPA, *Compilation of Air Pollutant Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources*. Research Triangle Park, North Carolina, January 1995.

42. UNEP Scientific Mission to Kosovo. *Depleted Uranium in Kosovo, Post-Conflict Environmental Assessment*. November 2001.

43. U.S. EPA, Office of Indoor Air and Radiation and U.S. DOE, Office of Environmental Restoration. *Understanding Variation in Partition Coefficient, K_d, Values. Volume 1: The K_d*

Model, Methods of Measurement, and Application of Chemical Reaction Codes. EPA-402-R-99-004A. August 1999.

44. Coleman, Robert and Murray, Michael E. "Detection of Depleted Uranium in Soil Using Portable Hand-Held Instruments." IAEA-SM-359/P-5. Presented & Published at the IAEA Annual Meeting. Washington, DC; November 1999.

45. World Health Organization, Department of Protection of the Human Environment. *Depleted Uranium: Source, Exposure, and Health Effects*. Geneva, April 2001.

46. U.S. EPA Office of Radiation Program. *Radionuclides: Background Information Document for Final Rules. Vol 1*. EPA 520/1-84-022-1. Washington, DC. NTIS PB85-165751.

47. Singh NP, Wrenn ME. 1988. 5th Symposium: Environmental Radiochemical Analysis, Part B, Harwell England, UK, October 1-3, 1986. Sci Total Environ 70:187-204.

48. Krieger HL, Whittaker EL. Prescribed procedures for measurement of radioactivity in drinking water. Govt Rep Announce Ind, Issue 25. NTIS PB80-224744. 1980.

49. U.S. EPA. Environmental Monitoring and Support Laboratory. *Prescribed procedures for measurement of radioactivity in drinking water*. Cincinnati, OH. 1980 EPA-600-4-0-032. 96-111.

50. Long SE, Martin TD. 1991. Method 200.8: determination of trace elements in waters and wastes by inductively coupled plasma - mass spectrometry (revision 4.4), Office of Research and Development, U.S. EPA, Environmental Monitoring Systems Laboratory (Cincinnati, OH), April 1991.

51. U.S. EPA, Office of Radiation and Indoor Air & Office of Solid Waste and Emergency Response. *Common Radionuclides Found at Superfund Sites*, EPA 540-R-00-004. Washington DC, March 2002.

U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
Radiation Protection Division
1200 Pennsylvania Avenue, NW
Washington, DC 20460
EPA 402-R-06-011
December 2006
www.epa.gov/radiation

Analysis of Nuclear Metals Site

by
M. Rose Byrne and Richard Codell
Performance Assessment and Hydrology Branch
Division of Waste Management
Office of Nuclear Materials Safety and Safeguards

Introduction and Statement of Problem

The Nuclear Metals Incorporated (NMI) site is located in Concord MA, near the banks of the Assabet River. This site has been operating since 1958, producing military ordinance from depleted uranium (DU). The production of the DU ordinance produced until recently a waste product sludge rich in DU, nitrate, copper and other contaminants. The waste sludge was disposed of in a holding basin. Dewatering of the sludge and infiltration of meteoric water lead to releases of the contaminants in the local groundwater. Discharge of contaminated sludge ceased in 1985. In 1986, the holding basin was covered by an impermeable membrane to reduce the discharge of contaminants. The staff of the Performance Assessment and Hydrology Branch was asked to evaluate two questions: (1) Should the contaminated sludge in the holding basin be removed in the near future or allowed to stay on-site for 7-8 years; and (2) Will existing levels of contaminants in the groundwater require remediation before the site is released to unrestricted use?

We have analyzed the available data and reached some tentative conclusions about the performance of the sludge holding basin and the possible need for site cleanup to comply with environmental standards for uranium. Our conclusions are based on observation and interpretation by means of visualization and correlation analyses of the available on-site data, and some relatively simple flow models. While we intended originally to apply numerical forecasting models to predict the migration of contaminants in the groundwater at the site, such an effort would require considerably more characterization of the site by the licensee and analyses by the staff. We are reasonably confident that observation of the data and application of simple models support our conclusions to the degree necessary for licensing decisions. We point out needs for further information where we feel it is necessary.

Visualization of Contaminant Plumes

Concentration data collected at approximately 6-month intervals from April 1984 through 1992 were available from up to 82 sampling locations on and near the site, however we used no more than 28 of these locations at any one time in our analyses. These data were analyzed visually using Earthvision (Dynamic Graphics, 1994) software, and have been helpful in showing the progression of the contaminant plumes with time. The somewhat spotty sampling of boreholes and the fact that all of the monitoring wells were not in place at earlier times or were not sampled at every interval may confuse the picture of the plume shape, because the graphical algorithms used to plot the contours do not have the physical "intuition" to deal with missing data. For example, the algorithm does not account for missing data during a sampling period, even though the data from previous sampling periods indicated the presence of contaminant. Furthermore, extrapolation of plume contours outside of the spatial boundaries of the data can lead to erroneous conclusions because the graphical algorithms are not based on

models of physical behavior of transport. For these reasons, the intuition and comprehension of the analyst must be used at all times to interpret the contour drawings, rather than relying solely on the interpretations of the computer.

Since the emplacement of the holding basin cover, concentrations of nitrate and uranium in nearby wells seems to be decreasing overall with time, but there are cyclic increases and decreases within the general trend. There seems to be a gradual dispersal of the nitrate concentration plume away from the site of the holding basin toward the Assabet River.

The uranium plume is clearly more retarded than the nitrate plume. The direction of uranium migration appears to be more westward than the nitrate for reasons that are not clear. The sparse network of wells gives a poor resolution picture of uranium migration. There is an area of elevated uranium concentration near the western boundary of the site visible at later times. The contamination in this region could be the remnants of earlier uranium discharges. This plume could be very large, but there is not yet enough data to draw an accurate picture of it. Part or all of this plume resides in the fractured bedrock, at depths greater than those of the wells near the holding basin. It appears that uranium is migrating in the groundwater, and will eventually contaminate the groundwater beyond the site boundaries to levels above the EPA limits of 20 micrograms per liter. A possible source of error in drawing the plumes might be the concentrations at the locations of the septic tanks. For the purpose of drawing the uranium plumes, these concentrations have been interpreted to be that of the groundwater at the locations of the septic tanks. This may not be the case, because there is evidence that the concentrations in the septic tanks came from unwitting disposal inside the plant, and therefore are not representative of concentrations in the water table migrating outside the plant. It should be noted, however, that the picture for May 1993 near the western boundary depends primarily upon the measurement at GZW-6-3, the most westward bedrock well. Figures 1 through 5 are surface contour plots showing a time-wise progression of the nitrate plume for a few sampling intervals irrespective of sampling depth. Figure 6 through 10 show the progression of the uranium plume. Figure 10 is the uranium concentrations for May 1993 in two dimensions, and also shows the outline of the plant buildings, holding basin, cooling pond and site boundary. Figure 11 is a 3-dimensional perspective plot showing the possible westward migration of the uranium plume in the deeper strata.

Flow Net Model

The code RESSQ (Jandoval, 1984) was used to develop two-dimensional flow nets in the vicinity of the site. The model is steady state and highly simplified, requiring constant, spatially invariant (horizontal and vertical) properties. RESSQ cannot accurately represent the complicated hydrogeology of the glacial lithology overlying fractured rocks at the site. However RESSQ can provide a general picture of circulation at the site if we make the following assumptions: (1) there is good vertical hydraulic communication among the sedimentary layers, (2) there is good vertical communication between the unconsolidated material and the bedrock, and (3) the overall transmissivity of the water-bearing layers is uniform.

These flow nets show the general recirculation among the service water wells SW-1 and SW-2, the cooling pond, and upgradient recharge. This circulation has a major influence on the groundwater hydrology of the site, and affects the

migration of the contaminants presently in the groundwater. The recirculation among the service water wells and the cooling pond was superimposed on a regional groundwater flow in the general direction of the river of either 0.5 or 1.0 feet per day. Groundwater velocities were estimated using Darcy's law from the natural gradient between monitoring wells on the site, hydraulic conductivities from hydraulic tests, and typical porosities of sedimentary materials.

Well SW-1 is a 60 foot deep gravel pack well located in glacial sedimentary material, and provides most of the cooling water needs. The remainder comes from well SW-2, which extends 500 feet into bedrock. The cooling pond is represented as three circular areas in order to approximate the elongated shape. The analysts specified streamlines emanating from up-gradient points to show the direction of circulation and capture by the pumping wells. RESSQ also allows calculation of "isochrone" lines emanating from one or more recharge areas to show the progression of flow away from these areas. Figure 12 shows the circulation for 0.5 ft/day aquifer velocity. The pumpage from SW-1 and SW-2 was 1313 ft^3/hr and 652 ft^3/hr, respectively. The recharge from the cooling pond was the sum of the pumpages, 1865 ft^3/hr, distributed among the three subareas of the cooling pond. Isochrones from the center circular area of the cooling pond are shown in the figures.

The flow net analyses suggest that groundwater following streamlines flowing under the holding basin are drawn into SW-2, at least in the case of the 0.5 ft/day regional groundwater flow rate. If this were the case, then contaminants leaching from the holding basin would reach the cooling pond relatively quickly. Recharge from the cooling pond is largely captured by SW-1, with the remainder traveling to the river. The flow net for the 1.0 ft/day regional groundwater flow is similar, but there would be less of the contaminants drawn into SW-2. There appears to be no recharge from the river to SW-1 in either case. The circulation between the service water wells and the cooling pond is the probable transport mechanism for contaminated groundwater between the holding basin and the cooling pond and all groundwater between them (This model appears to be borne out by correlation analyses reported in the next section). The circulation between SW-1, SW-2 and the cooling pond also serves as an untreated "pump and treat" operation, which at the very least is diluting the uranium concentrations to lower levels than found in SW-2. It does not appear likely that the uranium in the holding basin would have reached well SW-1 directly by natural gradient flow alone because of its high retardation in the soil. The fate of the uranium plume after shutdown of the pumps is uncertain. It is possible that after decommissioning the site, existing groundwater contamination would migrate at higher concentrations than is now the case because the dilution mechanism would be lost.

There is a considerable driving force for the vertical migration of contaminated groundwater. The likely cause of the gradients is the cones of depression from the service water wells, particularly SW-2, which is a deep well screened into the fractured bedrock. The vertical gradients form a potential mechanism for the transport of contaminated water from the holding basin to the bedrock. Retardation of uranium in the bedrock may be less than in the sediments, but the relative migration velocity of the uranium would be controlled by a number of factors such as gradient, porosity and permeability. There appears to be a deeper contamination of uranium to the west of the holding basin, as noted in Figure 11, possibly indicative of an earlier release which has entered the bedrock because of the vertical gradient.

Correlations of Data

Concentrations of nitrate and uranium were correlated at several locations at the site and to other factors such as rainfall. These correlations serve to augment or refute the conceptual models of the site. The results of several of the correlation analyses are presented below:

(1) Correlations among service water wells and cooling pond - The concentrations of nitrate and uranium in service water wells SW-1 and SW-2 were correlated to the cooling pond concentrations. The results of these correlations are presented in Table 1. The "U-combined" and "N-combined" values are weighted concentrations of uranium and nitrate, respectively, based on the approximated mix of water from SW-1 (67%) and SW-2 (33%). The correlations suggest that for uranium, most of the contamination leaving the holding basin enters the cooling pond via SW-2 because little if any uranium has reached SW-1 directly from the holding basin through groundwater. For nitrate, however, the correlation with SW-1 is slightly higher, suggesting that the travel time of nitrate from the cooling pond to the well is relatively short. The correlation between nitrate and the weighted concentration "N-combined" is very high (0.973), greater than for either well alone. For uranium however, the correlation with weighted concentrations is lower than for SW-2 alone. A likely explanation for this decreased correlation is the long travel time for uranium from the cooling pond to SW-1, and the effect of contaminated sediments in the cooling pond releasing to, or removing uranium from solution at times unrelated to the pumping rates. These correlations generally support the flow net analyses.

Table 1 - correlations between wells and cooling pond

Pairs of concentration	Correlation (r^2)
U, SW-1 - cooling pond	0.123
U, SW-2 - cooling pond	0.927
U, Combined - cooling pond	0.425
N, SW-1 - cooling pond	0.905
N, SW-2 - cooling pond	0.944
N, Combined - cooling pond	0.973

(2) Correlations with rainfall - In an attempt to show whether or not infiltration through the holding basin cover could be a factor in the release of contaminants to the groundwater, we correlated concentrations of nitrate and uranium in several of the wells versus rainfall. The rainfall parameter were monthly averages lagged by 7 days, calculated from weather records from Boston. The time period for the correlations was divided into two periods: (1) "pre-cover", prior to May 1987, and (2) "post-cover", May 1987 and beyond. Although the holding basin was actually covered in December 1986, the contaminated sludge was apparently still dewatering for a time, so the first samples of concentration after covering was included in the pre-cover period. Coincidentally, rainfall averages for the December 1986 time period were high, so keeping these values in the post-cover data would have contributed to a positive, but probably

misleading, correlation between release and rainfall.

There were barely enough data to perform correlations for the pre-cover period, but there appeared to be no recognizable correlations between well concentrations and rainfall averages. The results for the post-cover period are given in Table 2. If rainfall was infiltrating the holding basin cover, one would expect to see a positive correlation between rainfall average and concentration. This however does not appear to be the case, because most of the correlations are negative and weak; i.e., higher rainfall leads to lower well concentrations. This result may reflect the dilution of water concentrations in some of the sampling wells because of local infiltration of rain water. We had insufficient time to try other representative averages based on the Boston data (e.g., longer or shorter windows, lags or weights), nor were there any data closer to the site available to us that might have been more representative. The correlations at this time do not permit any conclusions about the relationship between rainfall and uranium concentration, nor about the effectiveness of the holding basin cover.

Table 2 - Concentration/Rainfall Correlations

Well Name	U-Rainfall r^2	N-Rainfall r^2
HB-7	-0.382	-0.28
HB-8	-0.4	-0.22
HB-9	-0.85	-0.295
SW-2	-0.14	-0.24
P-3		+0.03
SW-1		-0.115
ST-1	-0.36	

Conclusions and Need for Further Information

We have reviewed NMI's submissions and concluded that their characterization of the holding basin is adequate. We still have questions however about aspects of the current groundwater contamination away from the holding basin.

We would like to gain access to the most up-to-date sampling data that NMI has. The most recent data available to us is for May 1993, and we suspect that there have been further samples taken from the site. Furthermore, if there are any on-site or nearby meteorological records, especially precipitation, we would like to obtain them to explore further the relationship between rainfall and possible contaminant releases from the holding basin.

We believe that there needs to be more work to characterize the bedrock well contaminations. We would like to see a plan to characterize the uranium concentrations in the area to the west and northwest of well GZW-6-3 to establish whether or not there is a threat of off-site contamination in the future. We believe the uranium is migrating, albeit at a speed slower than the groundwater, and that there is the possibility that concentrations off-site may eventually

exceed the current standards of 20 micro rams per liter.

We are also concerned about the potential for migration of uranium once the pumping of cooling water ceases and the gradients in the region of the plant return to normal. We believe that the pumps may be in effect reducing the groundwater concentrations by dilution and recirculation. We would like to investigate whether cessation of pumping will remove a beneficial, though unintended feature of plant operation. We further would like to ask if cooling water pumping should be replaced by another process such as pump-and-treat or in-situ fixation to comply with environmental standards for unrestricted release of the site.

References

Jandoval, I, C. Doughty, and C.Tsang, Groundwater Transport: Handbook of Mathematical Models, American Geophysical Union, Washington D.C. (1984)

Earthvision, Dynamic Graphics Inc, Alameda CA, 1994

Figure 1 - Nitrate Concentrations, April 1985
(scales are inches from lower left corner, site map)

Figure 2 - Nitrate Concentrations, October 1987
(scales are inches from lower left corner, site map)

Figure 3 - Nitrate Concentrations, April 1989
(scales are inches from lower left corner, site map)

Figure 4 - Nitrate Concentrations, May 1991
(scales are inches from lower left corner, site map)

Figure 5 - Nitrate Concentrations, May 1992
(scales are inches from lower left corner, site map)

Figure 6 - Uranium Concentrations, April 1985
(scales are inches from lower left corner, site map)

Figure 7 - Uranium Concentrations, May 1987
(scales are inches from lower left corner, site map)

Figure 8 - Uranium Concentrations, May 1989
(scales are inches from lower left corner, site map)

Figure 9 - Uranium Concentrations, May 1991
(scales are inches from lower left corner, site map)

Figure 10 - Uranium Concentrations, May 1993
showing site features
(scales are inches from lower left corner, site map)

Figure 11 - 3-Dimensional Perspective Plot of Uranium Concentrations, May 1993

Figure 1 - Nitrate Concentrations, Milligrams/liter, April 1985
(scales are inches from lower left corner, site map)

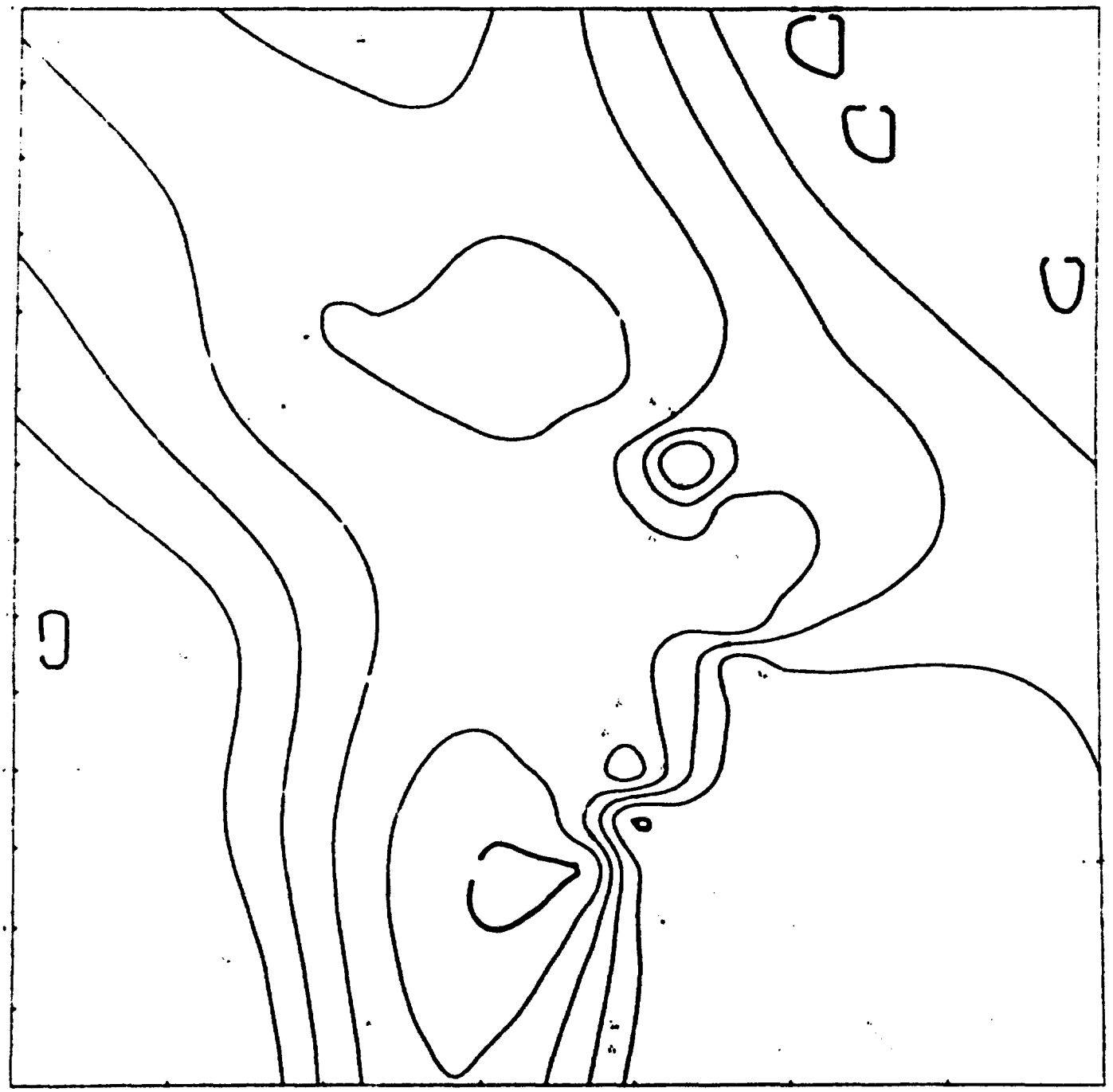


Figure 2 - Nitrate Concentrations, milligrams/liter, October 1987
(scales are inches from lower left corner, site map)

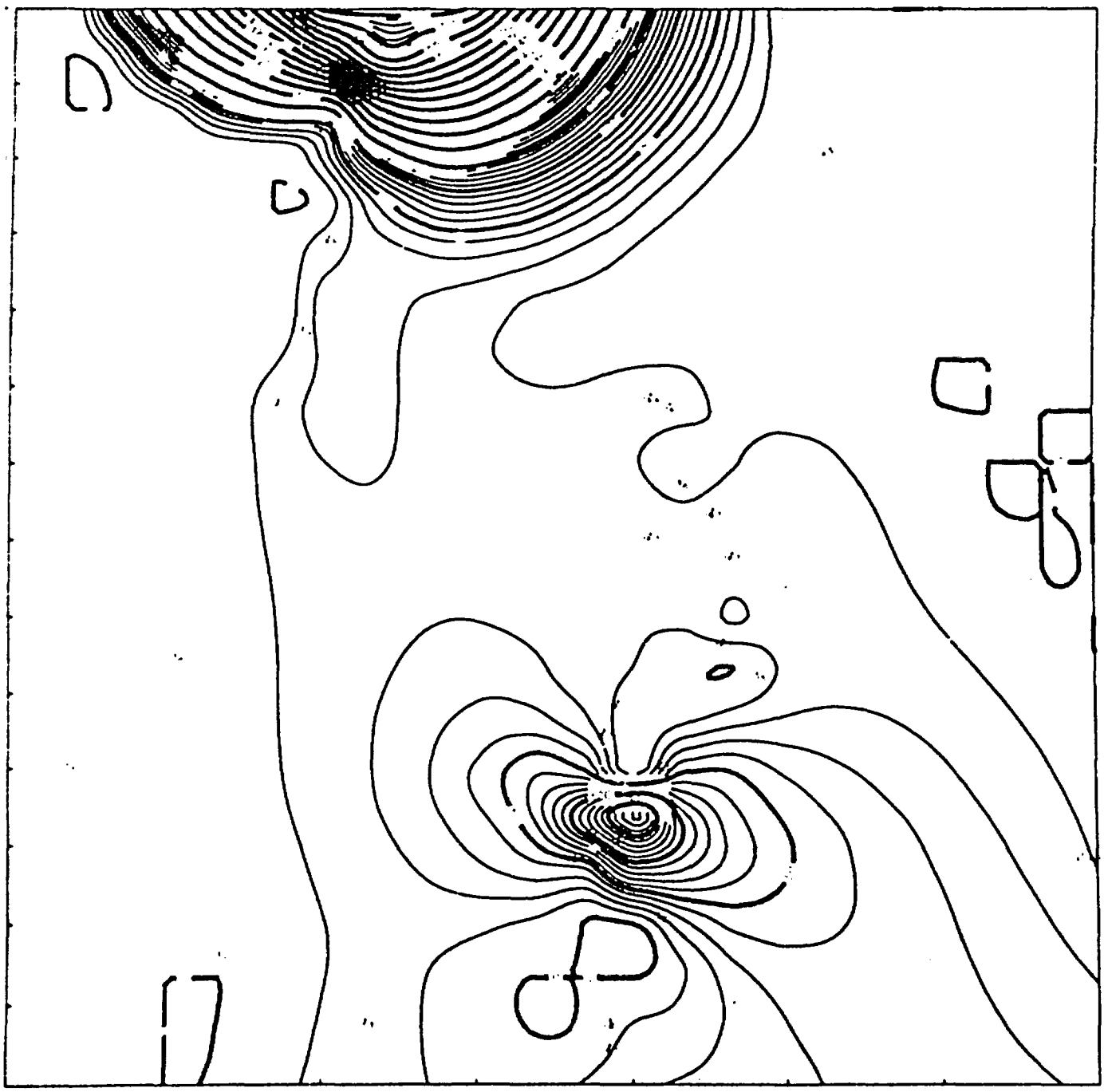


Figure 3 - Nitrate Concentrations, milligrams/liter, April 1989
(scales are inches from lower left corner, site map)

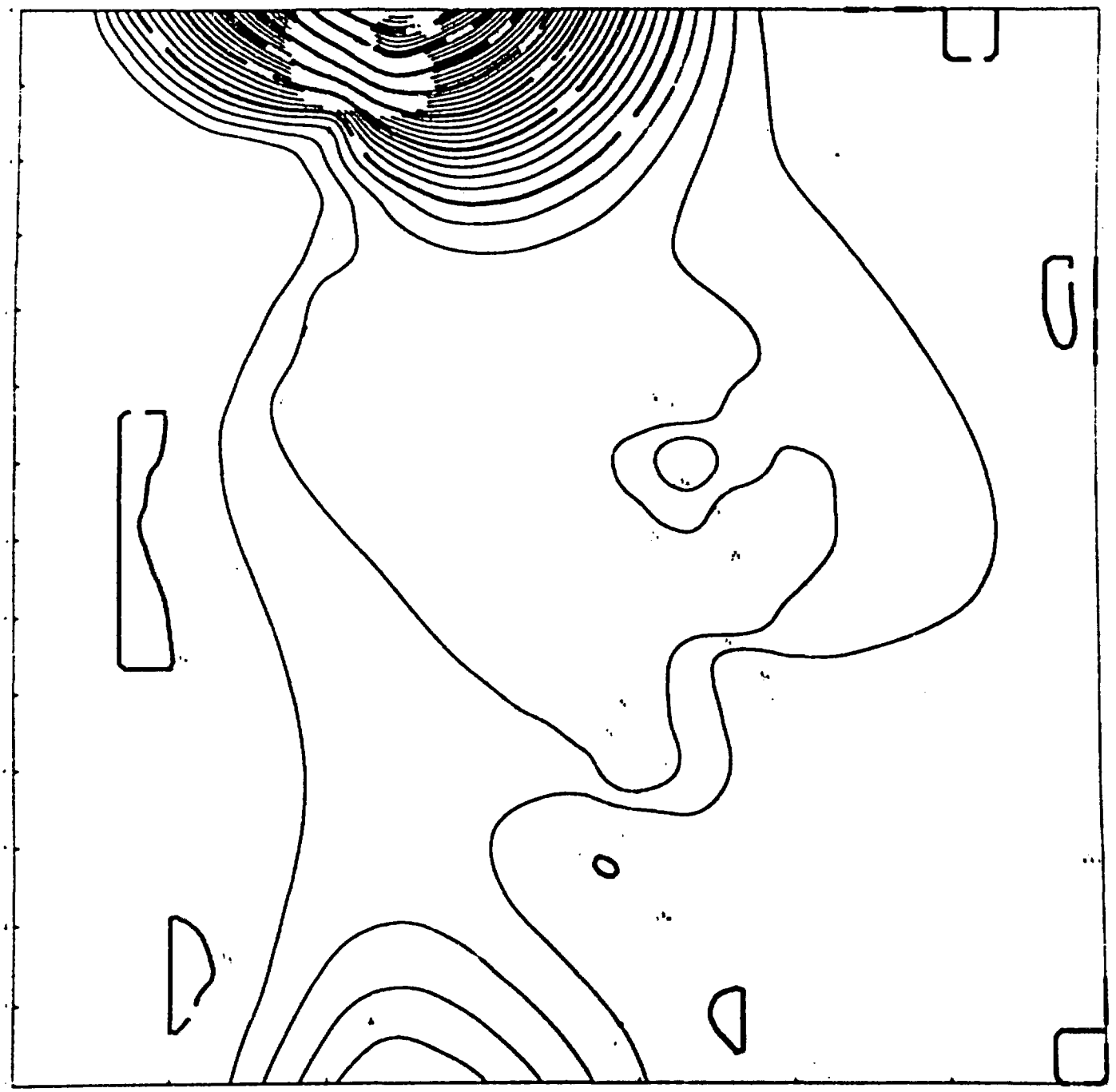


Figure 4 - Nitrate Concentrations, milligrams/liter, May 1991
(scales are inches from lower left corner, site map)

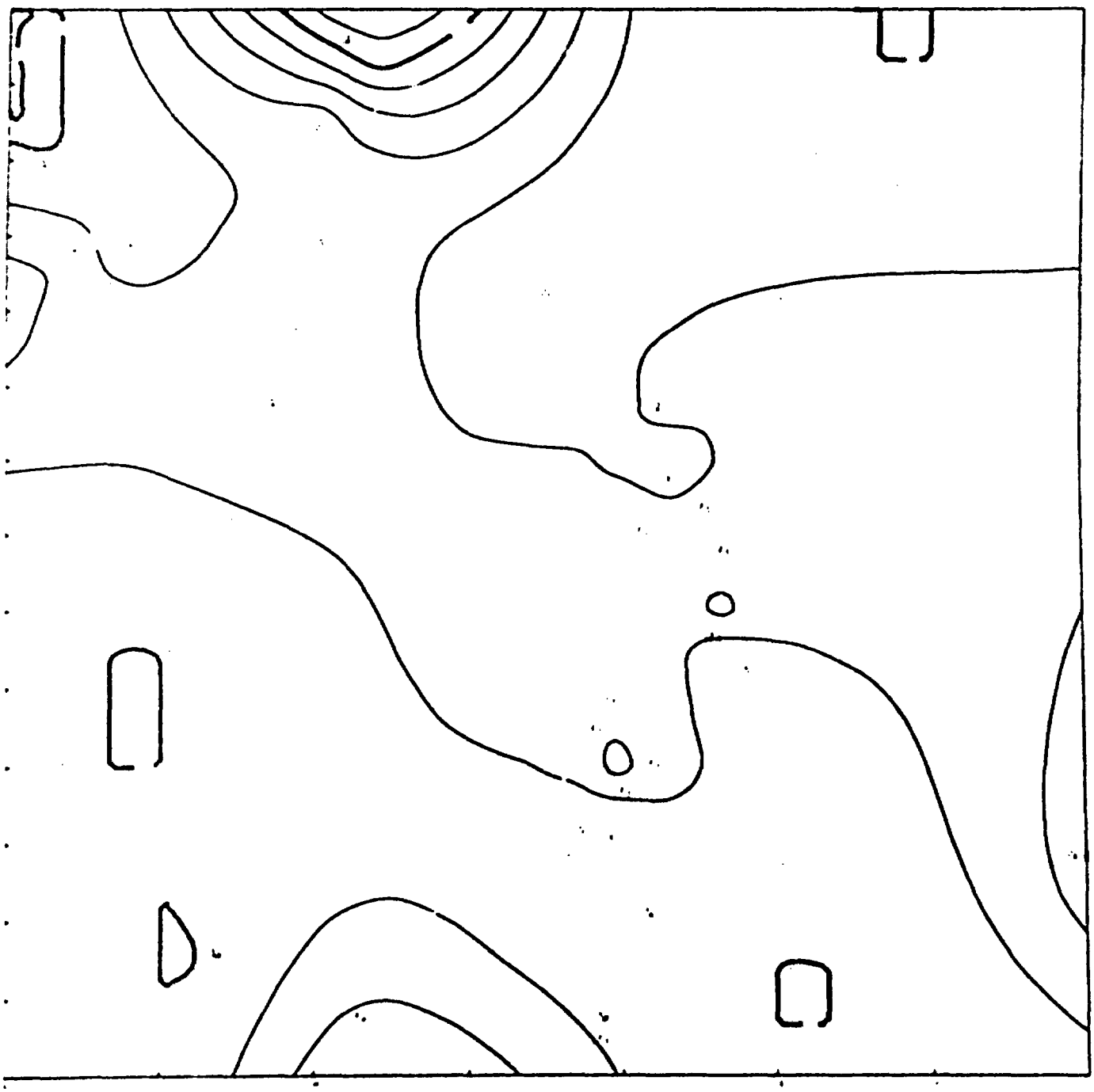


Figure 5 - Nitrate Concentrations, milligrams/liter, May 1992
(scales are inches from lower left corner, site map)

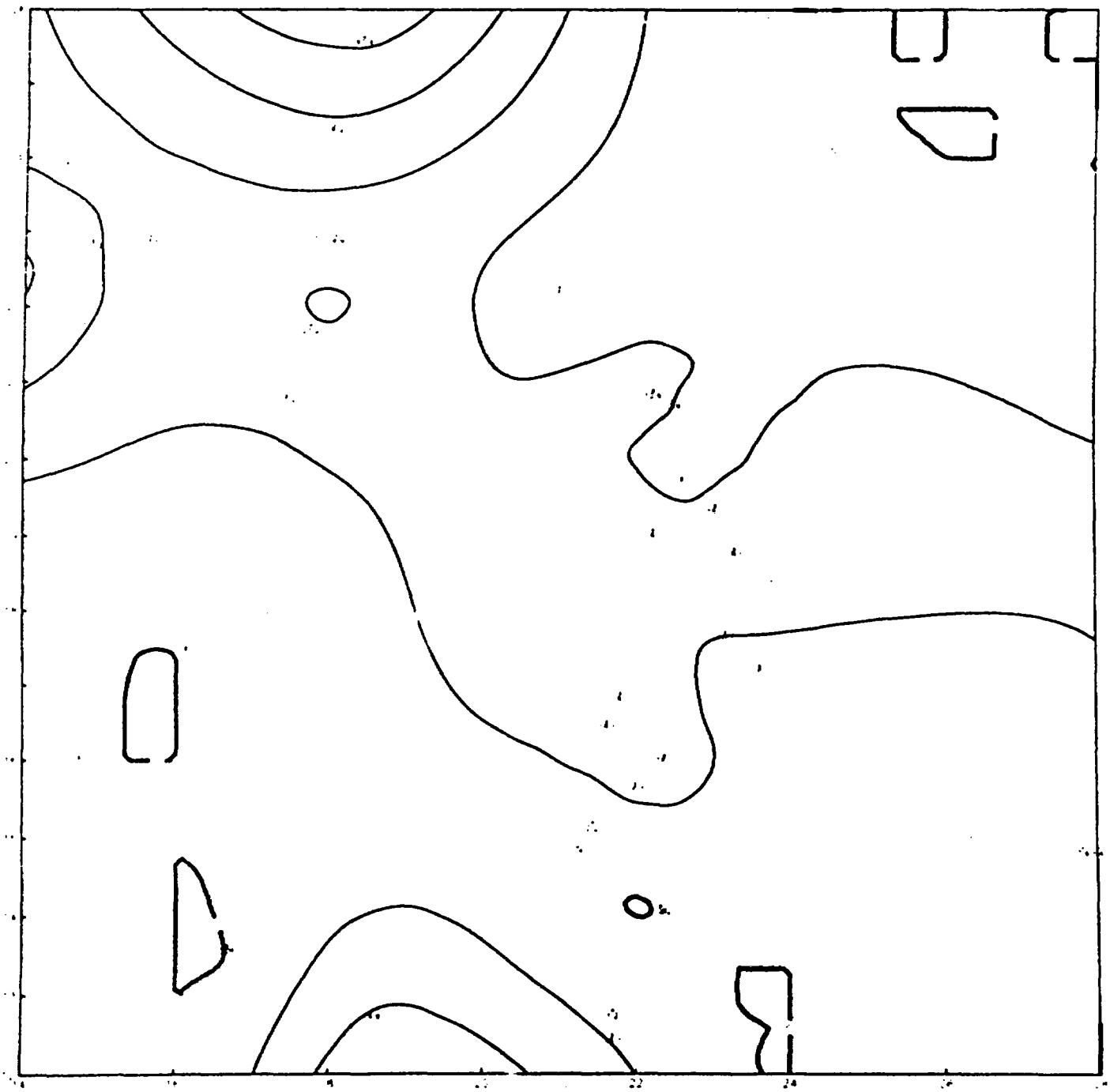


Figure 6 - Uranium Concentrations, micrograms/liter, April 1985
(scales are inches from lower left corner, site map)

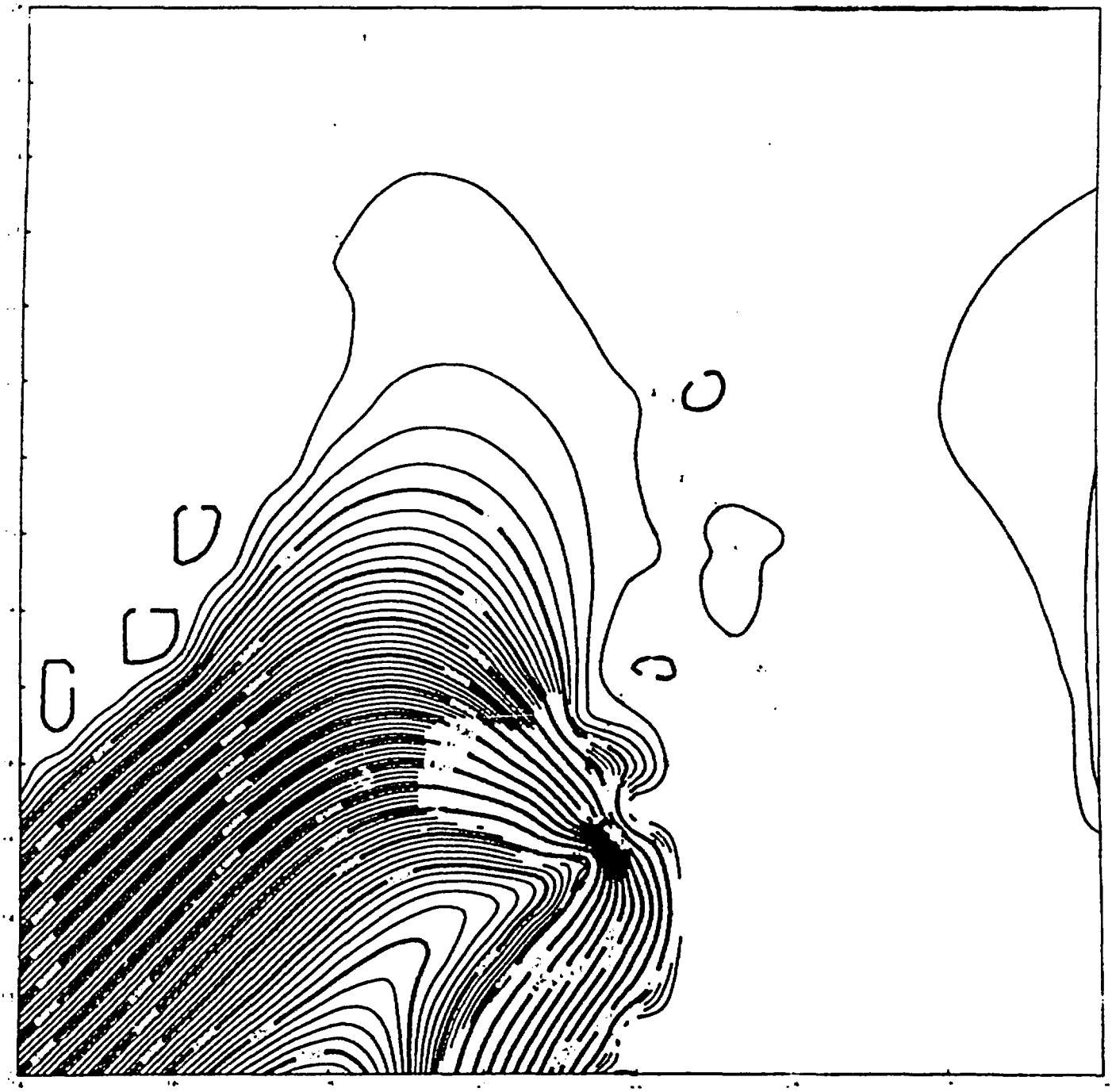


Figure 7 - Uranium Concentrations, micrograms/liter, May 1987
(scales are inches from lower left corner, site map)

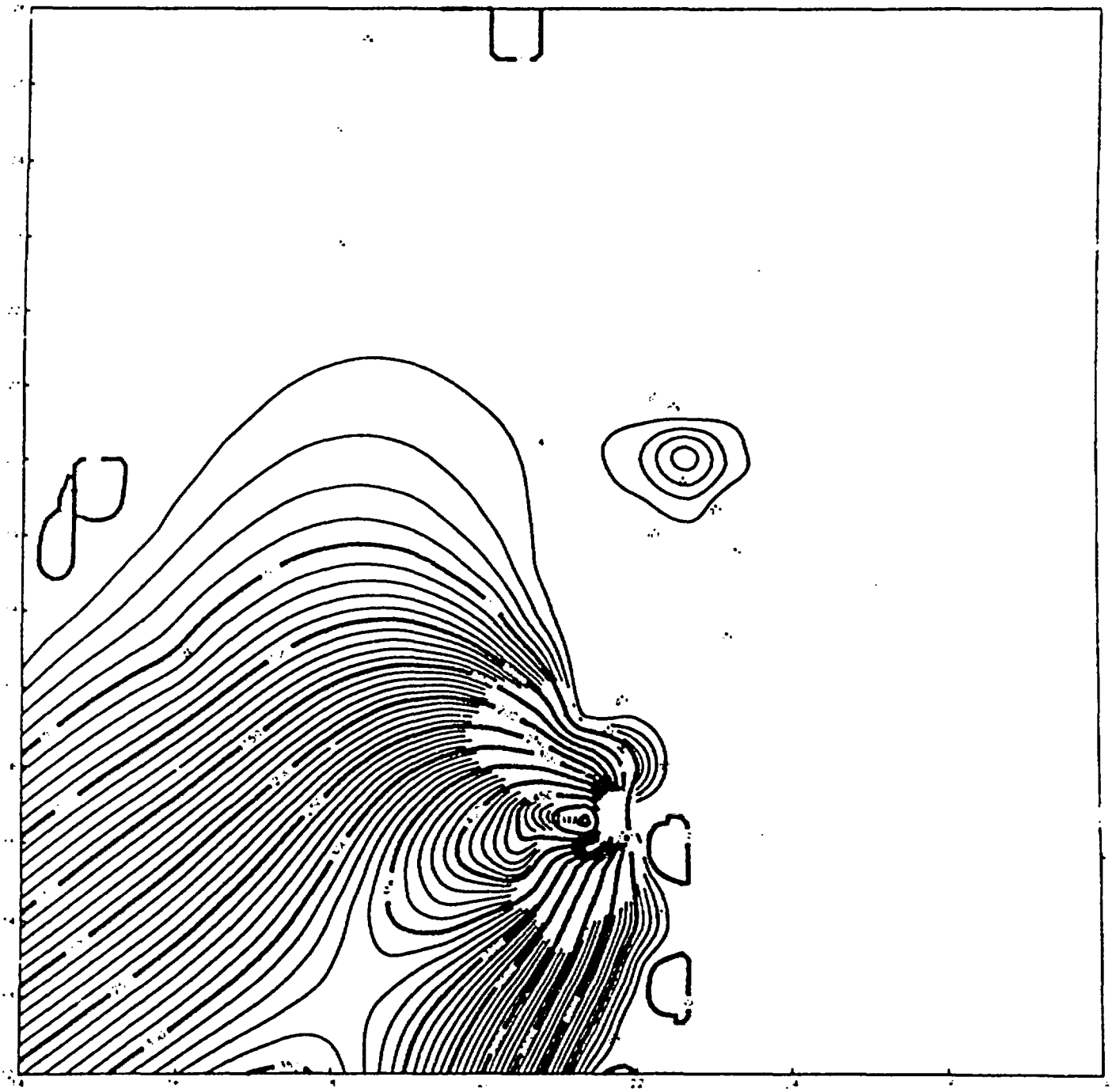


Figure 8 - Uranium Concentrations, micrograms/liter, May 1989
(scales are inches from lower left corner, site map)

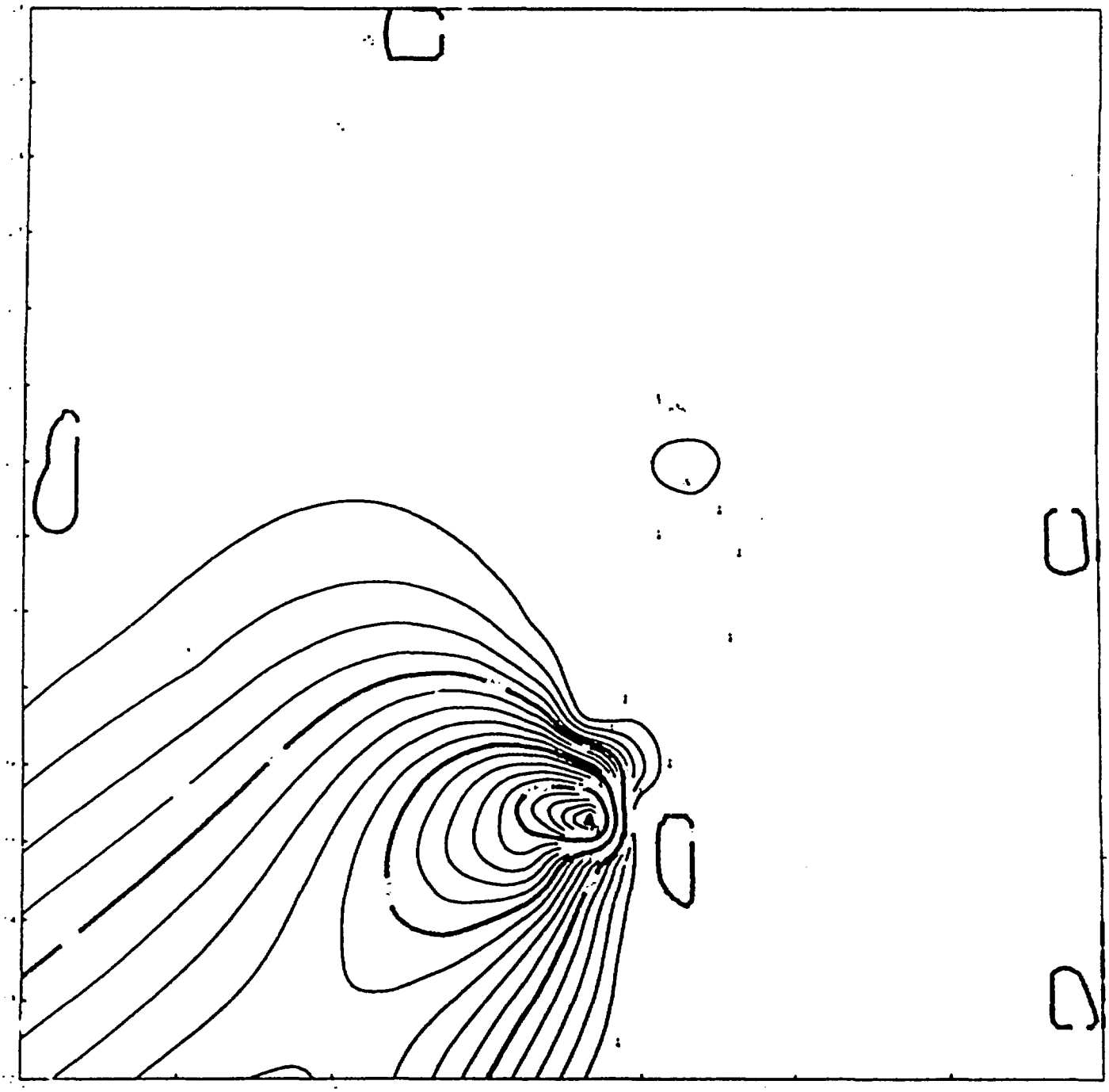


Figure 9 - Uranium Concentrations, micrograms/liter, May 1991
(scales are inches from lower left corner, site map)

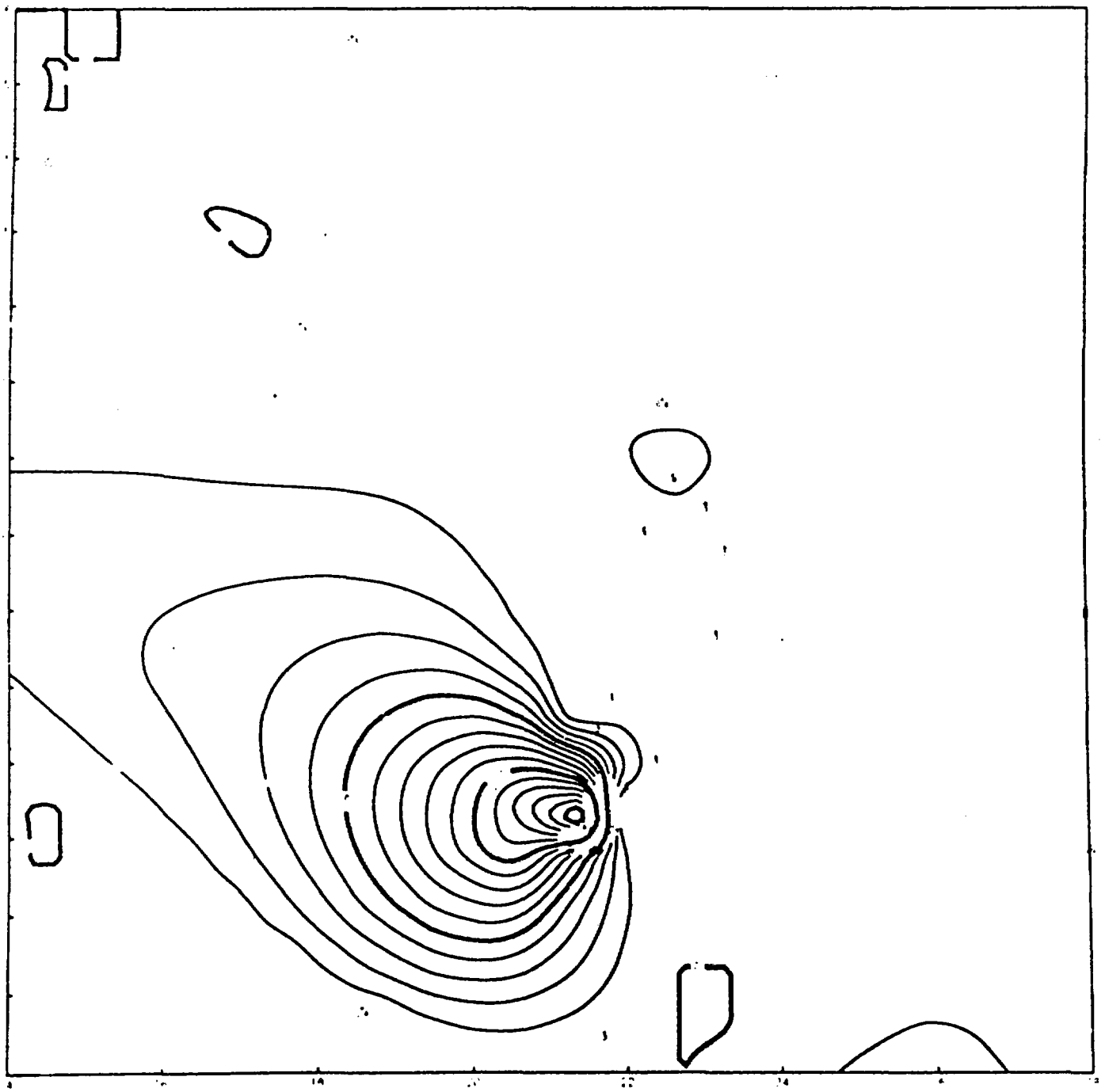


Figure 10 - Uranium Concentrations, micrograms/liter, May 1993
showing site features
(scales are inches from lower left corner, site map)

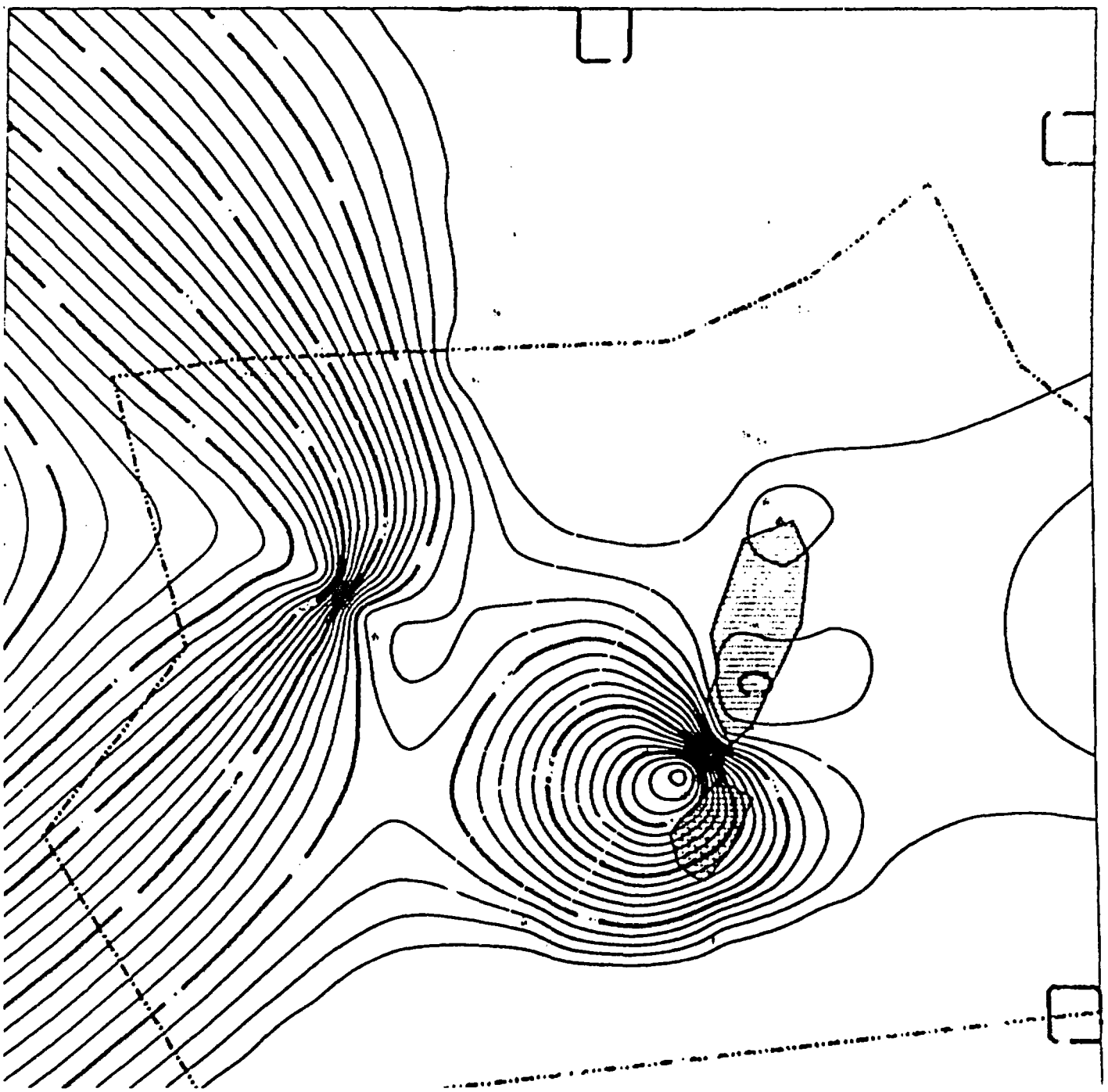


Figure 11 - 3-Dimensional Perspective Plot of Uranium Concentrations, micrograms/liter, May 1993

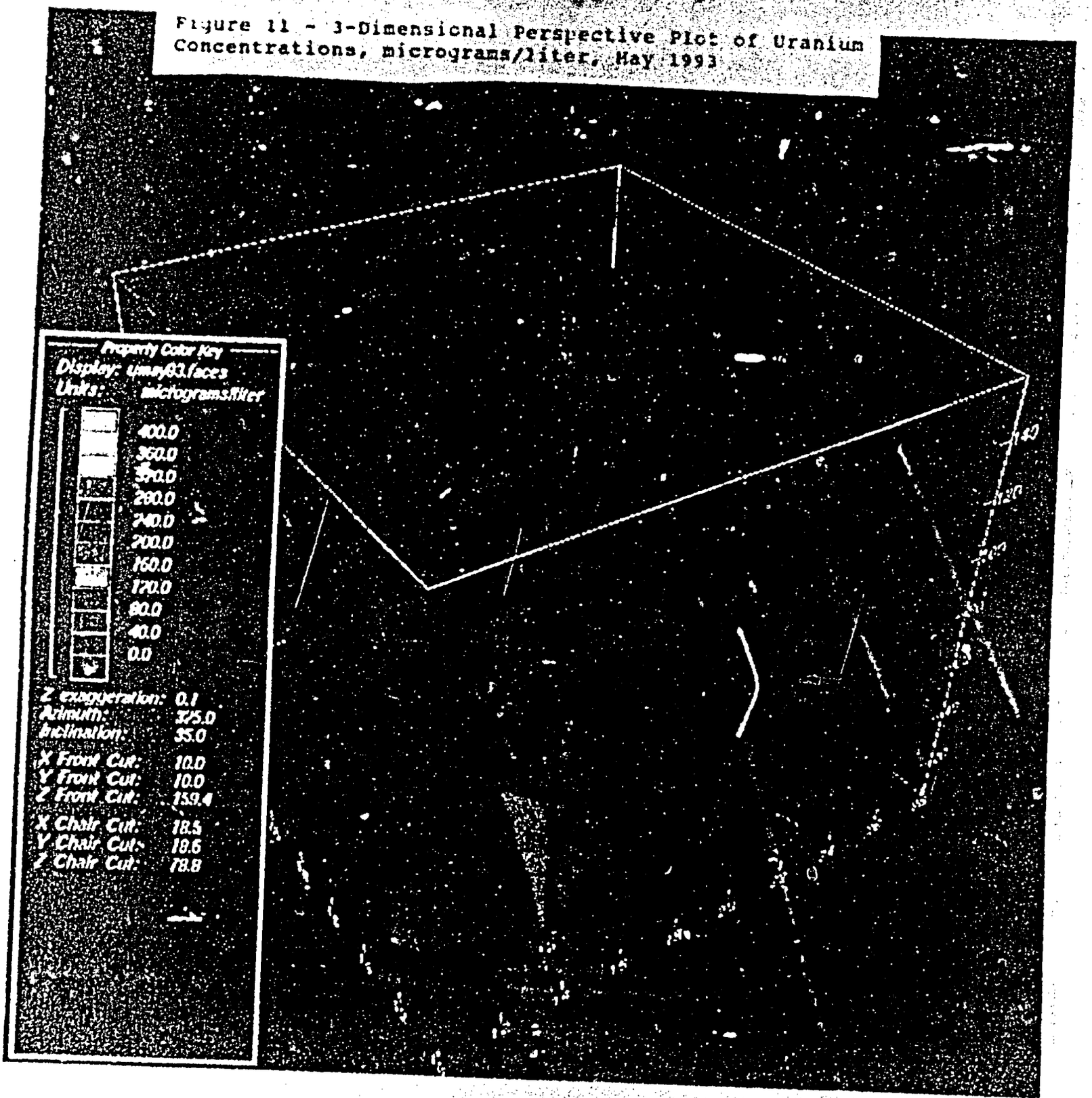
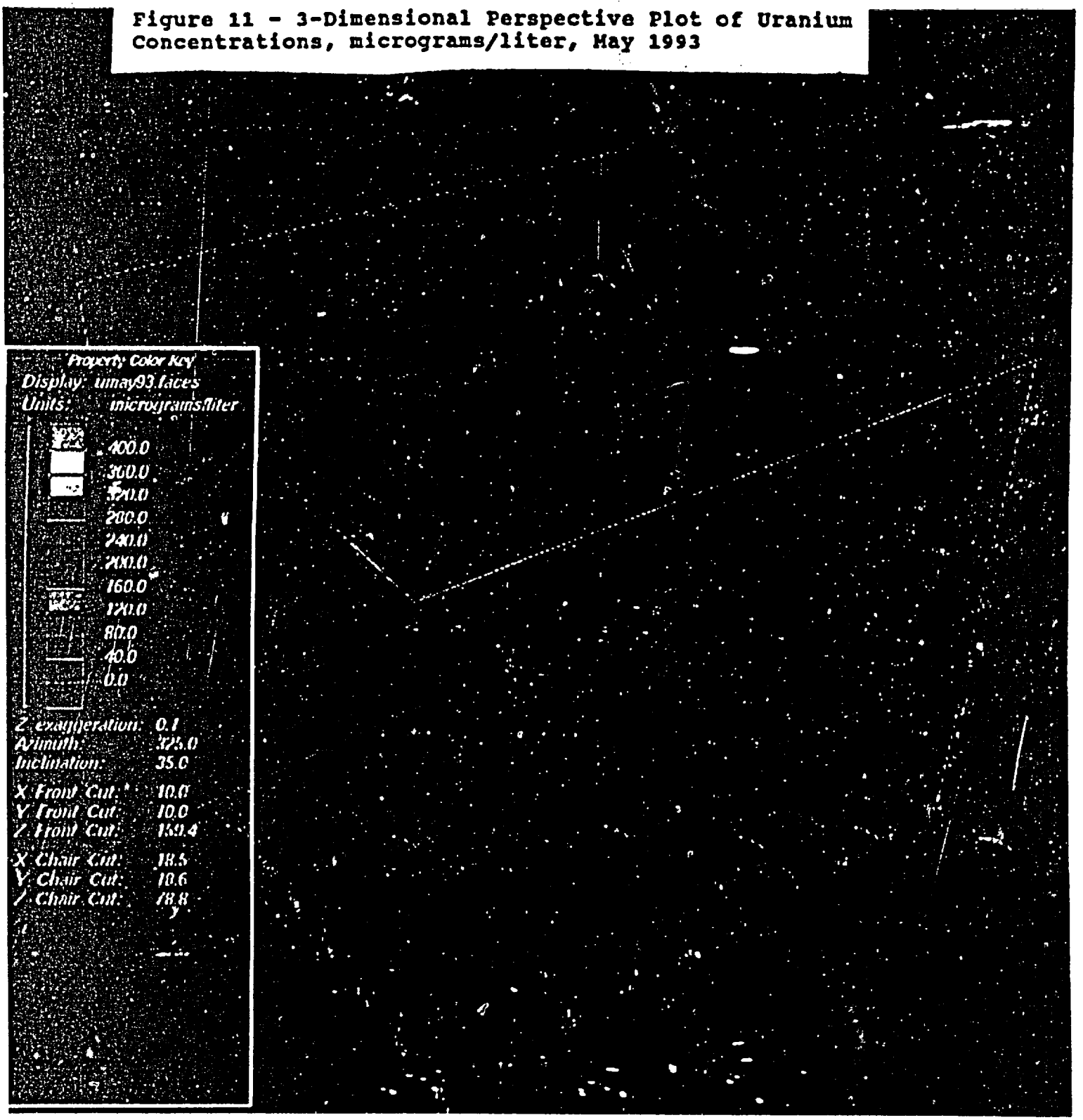


Figure 11 - 3-Dimensional Perspective Plot of Uranium Concentrations, micrograms/liter, May 1993



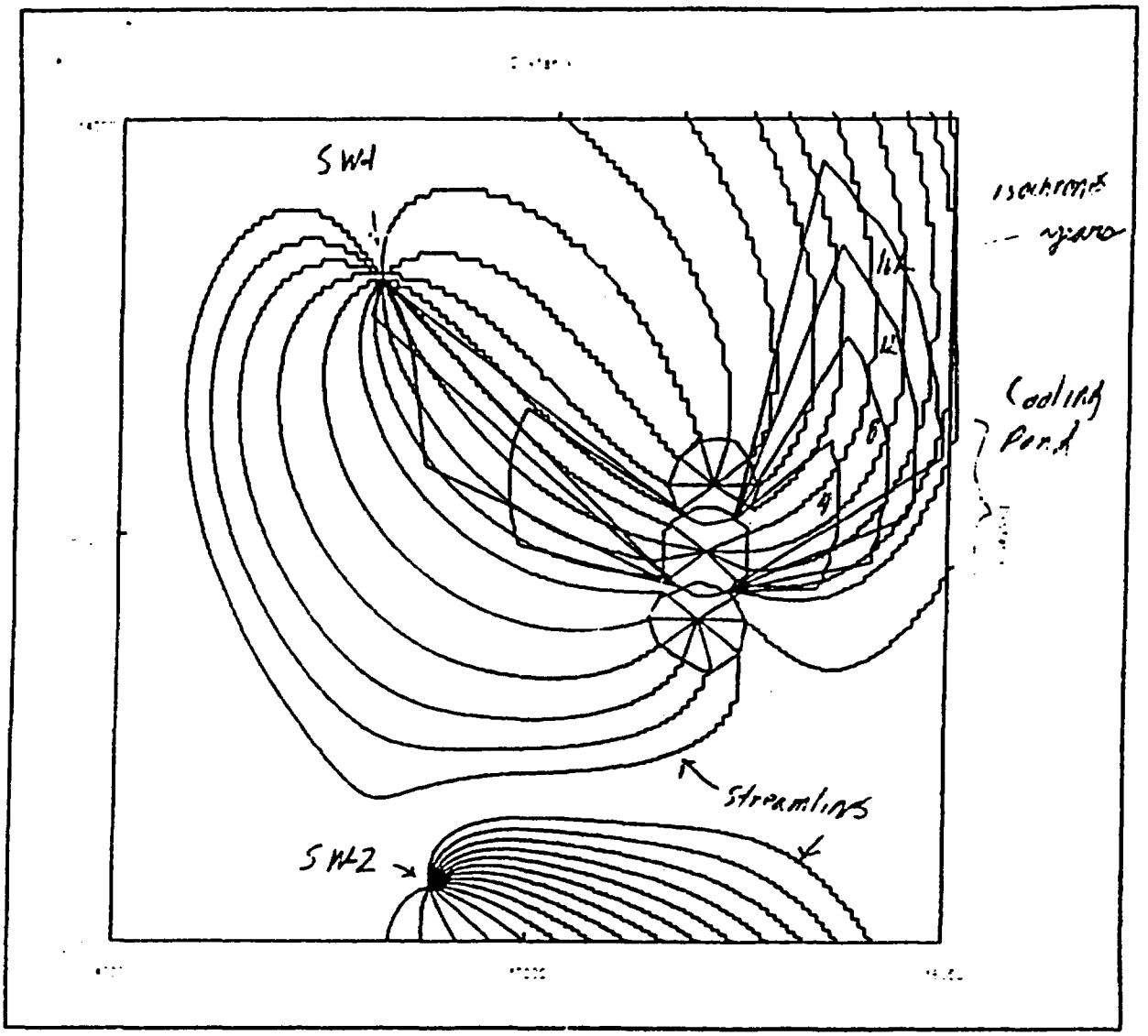


Figure 12, RESSQ analysis of circulation among Service Water Wells, cooling pond, and upgradient recharge

NRC Database Search for Lic# SMB-179

Discusses insp of License SMB-179 on 581020 re use of source matl.Major areas inspected:organization & procedures & procurement & record control.	9103150274	10/20/1958 12:00:00 AM	320 bytes	05/01/2001 02:21:18 AM	
Discusses listed items of noncompliance noted during insps on 581020-21 under Licenses SMB-179 & SNM-65.Insp rept for License SMB-179 encl.	9103150271	02/13/1959 12:00:00 AM	320 bytes	05/01/2001 02:21:13 AM	
Discusses insp of Licenses SMB-179 & SNM-65 on 601103 & 04. Noncompliances noted.	9103150283	07/11/1961 12:00:00 AM	320 bytes	05/01/2001 02:21:32 AM	
Insp Findings & Licensee Ack dtd 620424 of License SMB-179. Insp findings:no noncompliance noted.	8305120234	04/24/1962 12:00:00 AM	320 bytes	05/21/2001 11:41:00 PM	
Notifies that License SMB-179 expires on 690930.Renewal application should be filed within 30 days.Encl certification of status of source matl activities form should be completed for nonrenewal of license.	8305120283	07/25/1969 12:00:00 AM	320 bytes	05/21/2001 11:45:50 PM	
Memo to File from Smith, Back-Up Notes to Form AEC-592, Whittaker Corporation, Nuclear Metals Division.	ML080810179	09/18/1969 12:00:00 AM	520 Kb	03/27/2008 09:03:21 AM	
Responds to 690918 ltr re findings during recent insp of activities authorized under Licenses SNM-65 & SMB-179. Corrective actions:environ samples will be collected in future in compliance w/sampling schedule.	9103150294	10/08/1969 12:00:00 AM	320 bytes	05/01/2001 02:21:47 AM	
Memorandum from R. Kirkman of USAEC to P. Ulf Gummeson of Whittaker Corporation, Regarding Noncompliance.	ML080780596	10/20/1969 12:00:00 AM	825 Kb	04/04/2008 02:36:27 PM	
Advises that response to 690822 application for License SMB-179 has not been received.Info re issuance of license requested.	8305120264	10/22/1969 12:00:00 AM	320 bytes	05/21/2001 11:44:02 PM	
Ltr from R. Smith of USAEC to Whittaker Corporation, Regarding Noncompliance Observed During Inspection and an AEC-591 Form for License SNM-65 and SMB-179.	ML080780599	01/06/1970 12:00:00 AM	601 Kb	04/04/2008 02:36:11 PM	
Source Matl License SMB-179 for Whittaker-Corp,authorizing use of 80,000 lb U metal or alloy & 20,000 lb thorium metal or alloy.	8301110045	03/25/1970 12:00:00 AM	320 bytes	05/16/2001 04:12:16 PM	
USAEC Inspection Findings and Licensee Acknowledgment, License Number SNM-65 and SMB-179.	ML080850148	07/16/1970 12:00:00 AM	118 Kb	04/04/2008 02:36:38 PM	
Discusses insp of Licenses SNM-65 & SMB-179 on 700715-16. No items of noncompliance observed & AEC-591 form issued. Insp rept encl.	9103150303	08/05/1970 12:00:00 AM	320 bytes	05/01/2001 02:22:01 AM	

Ltr from R. Smith of USAEC to H. Crocker of Whittaker Corporation, Regarding Noncompliance.	ML080850149	08/05/1970 12:00:00 AM	514 Kb	04/04/2008 02:36:11 PM	
Insp rept for Licenses SNM-65 & SMB-179 on 700715-16.No items of noncompliance noted & AEC-591 form issued.Major areas inspected:review of health physics records & practices.	9103150306	08/06/1970 12:00:00 AM	320 bytes	05/01/2001 02:22:06 AM	
Memorandum from R. Smith of USAEC to File, Regarding Backup Notes to Form AEC-591.	ML080850276	06/11/1971 12:00:00 AM	562 Kb	04/04/2008 02:36:28 PM	
Ltr from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals, Inc., regarding inspection conducted on March 14 thru 16, 1973.	ML080810052	04/23/1973 12:00:00 AM	312 Kb	04/04/2008 02:36:05 PM	
Daily Reports - Region I, Including Notification, Event and regional Action.	ML080810338	01/07/1974 12:00:00 AM	143 Kb	04/04/2008 02:34:56 PM	
Ltr from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Telephone Discussion Regarding the December 27 and 28.	ML080810365	01/07/1974 12:00:00 AM	81 Kb	04/04/2008 02:36:01 PM	
USAEC, Blue Sheet, Directorate of Regulatory Operations, Notification of an Incident or Occurrence, Regarding Nuclear Metals, Inc. License No. SMB-179.	ML080810496	01/10/1974 12:00:00 AM	176 Kb	04/04/2008 02:36:44 PM	
USAEC Directorate of Regulatory Operations, Region RO Inspection Report No. 07000082-73-005 and 04000672-73-002.	ML080810506	02/05/1974 12:00:00 AM	935 Kb	04/04/2008 02:36:35 PM	
Daily Report - Region I, Regarding Facility Notification, Event and Regional Action.	ML080810508	02/14/1974 12:00:00 AM	35 Kb	04/04/2008 02:21:04 PM	
Ltr from J. O┐ Reilly of USAEC to W. Truffin of Nuclear Metals Inc., Regarding Inspection Conducted on December 27-28, 1973.	ML080850232	02/15/1974 12:00:00 AM	1,493 Kb	04/04/2008 02:21:21 PM	
Memorandum from P. Nelson of USAEC to File, Regarding Nuclear Metals Inc. Meeting on 02/13/74.	ML080850526	03/20/1974 12:00:00 AM	106 Kb	04/04/2008 02:21:29 PM	
Ltr. from W. Kinner of USAEC to H. Crocker of Nuclear Metals Inc., Regarding Draft of Enforcement Letters.	ML080850744	04/11/1974 12:00:00 AM	1,761 Kb	04/04/2008 02:21:27 PM	
Ltr. from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Corrective and Preventive Actions.	ML080850766	04/26/1974 12:00:00 AM	864 Kb	04/04/2008 02:21:25 PM	

Ltr. from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Corrective and Preventive Actions.	ML080850797	04/26/1974 12:00:00 AM	871 Kb	04/04/2008 02:21:26 PM	
Discusses insp of License SMB-179 radiation control program. License classification should be changed from E-3 to B-1. Next insp scheduled during Nov 1974.	8305120303	08/22/1974 12:00:00 AM	320 bytes	05/21/2001 11:47:58 PM	
Ltr from P. Nelson of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Inspection Conducted on May 30 and 31, 1974.	ML080850870	08/22/1974 12:00:00 AM	1,352 Kb	04/04/2008 02:21:23 PM	
Corrected copy of Amend 3 to Nuclear Metals,Inc License SMB-179 authorizing mfg of derbies,castings,extrusions & machined or formed parts.Ltr dtd 750508 added to Section 13.	8301110039	02/16/1977 12:00:00 AM	320 bytes	05/16/2001 04:11:39 PM	
In accordance w/781213 application,Matl/Byproduct License SMB-179 for Nuclear Metals,Inc is amended to limit max amount of depleted uranium possessed to 5.1 million lbs.	7903010447	02/09/1979 12:00:00 AM	320 bytes	05/25/2001 09:18:01 PM	
Requests amend of Matl/Byproduct License SMB-179 authorizing incorporation of two consultant repts extending evaluations of effluent air re degree of conservatism inherent in method of air sampling & dilution of plume.	8001020309	11/05/1979 12:00:00 AM	320 bytes	05/21/2001 09:14:37 PM	
Letter to NRC Div. of Materials Licensing from A.R. Gilman, NMI, subj: License Amendment Application.	ML093070382	11/05/1979 12:00:00 AM	1,624 Kb	11/06/2009 01:47:38 PM	
USAEC Memorandum from J. Delaney, Regarding Nuclear Metals, INC (NMI); Termination of Special Nuclear Material License NO. SNM-65.	ML080850883	02/15/1980 12:00:00 AM	445 Kb	04/04/2008 02:22:04 PM	
Discusses IE insp of License SMB-179 on 800304-05.No noncompliance noted.Major areas inspected:procedures & representative records,interviews w/personnel & measurements & observations made by inspectors.	8005140324	03/27/1980 12:00:00 AM	320 bytes	05/24/2001 10:22:23 AM	
Matl/Byproduct License SMB-179 for Nuclear Metals,Inc is amended per 791105 application.Amend 5 changes Condition 13 re possession & use of licensed matl.	8004170154	03/31/1980 12:00:00 AM	320 bytes	05/24/2001 03:22:39 AM	
Responds to 810527 application for amend of License SMB-179. Amend fee required.	8108040013	06/10/1981 12:00:00 AM	320 bytes	05/25/2001 02:26:37 AM	

Responds to 810527 application for amend of License SMB-179. Amend fee required.	8108040013	06/10/1981 12:00:00 AM	320 bytes	05/25/2001 02:26:37 AM	
Responds to 810527 application for amend to License SMB-179. Ventilation consultant 810413 rept proposing dilution factor of 143 for air effluent releases appears to request increase in effluents.Impact of airborne releases not clarified.	8301110083	11/21/1981 12:00:00 AM	320 bytes	05/16/2001 04:16:31 PM	
Forwards application for renewal of License SMB-179.	8201050171	11/30/1981 12:00:00 AM	320 bytes	05/19/2001 03:21:14 AM	
Ack receipt of application for renewal of License SMB-179. License will not expire until final action taken by NRC.	8305130006	12/28/1981 12:00:00 AM	320 bytes	05/22/2001 12:25:24 AM	
Comments on application for renewal of License SMB-179. Application should provide more specific procedures for frisking personnel & clothing at exits from controlled area.	8305130037	04/01/1982 12:00:00 AM	320 bytes	05/22/2001 12:28:49 AM	
FOIA request for license applications,licenses & insp repts re License SMB-179 & incidents of employee overexposure.	8301110007	11/15/1982 12:00:00 AM	320 bytes	05/16/2001 04:08:13 PM	
Partial response to FOIA request for license applications, licenses & insp repts re License SMB-179 & incidents of employee overexposure.Search for documents continuing. Forwards documents listed on App A.	8301110010	12/15/1982 12:00:00 AM	320 bytes	05/16/2001 04:08:33 PM	
Boeing Company Request Concerning Depleted Uranium Counterweights.	ML103440585	04/14/1983 12:00:00 AM	419 Kb	12/17/2010 11:09:08 AM	
Forwards,for review,info for inclusion into renewal application for License SMB-179 based on request from Region I & documented in 830805 Confirmatory Action Ltr 83-08.	8403050150	01/15/1984 12:00:00 AM	320 bytes	05/16/2001 05:42:24 PM	
IE Info Notice 84-34, "Respirator User Warning:Defective Self-Contained Breathing Apparatus Air Cylinders." Svc list encl.	ML082970362	04/23/1984 12:00:00 AM	42,596 Kb	12/15/2009 11:37:36 AM	
Amend 6 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8510160308	05/23/1984 12:00:00 AM	320 bytes	05/15/2001 12:58:03 PM	
Letter from NMI to Region I, NRC, Subj: Giving Thirty Day Written Notification in Regards to Excessive Radiation Exposure.	ML093070394	05/24/1984 12:00:00 AM	300 Kb	11/06/2009 01:47:21 PM	

Letter from NMI to Region I, NRC, Subj: Giving Thirty Day Written Notification in Regards to Excessive Radiation Exposure.	ML093070394	05/24/1984 12:00:00 AM	300 Kb	11/06/2009 01:47:21 PM	
Discusses insp of Licenses SMB-179 & 20-02217-05 on 840616- 19 & forwards notice of violation.Civil penalty will not be issued.	8410030278	09/14/1984 12:00:00 AM	320 bytes	05/18/2001 10:47:19 AM	
Responds to NRC 840914 ltr re violations noted in insp of Licenses SMB-179 & 20-02217-05 on 840616-19.Corrective actions:purchase order placed to obtain telescopic survey instrument & health physics technicians performed surveys.	8411090209	10/10/1984 12:00:00 AM	320 bytes	05/18/2001 06:00:41 PM	
Amend 7 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8606300390	04/24/1986 12:00:00 AM	320 bytes	05/11/2001 10:03:34 AM	
Forwards Amend 7,renewing License SMB-179.	8606300395	04/24/1986 12:00:00 AM	320 bytes	05/11/2001 10:03:42 AM	
Amend 8 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8804200356	09/17/1987 12:00:00 AM	320 bytes	05/08/2001 02:20:49 PM	
Forwards Amend 8 to License SMB-179.	8804200360	09/17/1987 12:00:00 AM	320 bytes	05/08/2001 02:20:55 PM	
Corrected Amend 8 to License SMB-179 for Nuclear Metals,Inc, amending license in entirety.	8806080174	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:07 PM	
Corrected Amend 8 to License SMB-179 for Nuclear Metals,Inc, amending license in entirety.	8806080174	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:09 PM	
Forwards corrected Amend 8 to License SMB-179 due to address change.	8806080180	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:19 PM	
Voided matls licensing action for License SMB-179 for Nuclear Metals,Inc.Control:109641.	9004240277	06/07/1989 12:00:00 AM	320 bytes	05/04/2001 11:29:31 AM	
Ltr from NMI to NRC, subj: NMI Request to Amend Two Source Material Licenses.	ML100040212	07/26/1990 12:00:00 AM	610 Kb	01/05/2010 03:01:04 PM	
Requests adjudicatory hearing be scheduled in order to express resident concerns on renewal application for license SMB-179.	9110180030	01/24/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:35 AM	

Submits motion & petition to intervene in renewing licenses SMB-179 & SUB-1452.	9110180035	02/14/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:43 AM	
Forwards SJ Lewis ltr requesting hearing on license renewal application for SMB-179.	9110180021	02/21/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:20 AM	
SECY-91-0096, "Updated Report on Site Decommissioning Management Plan".	ML080880218	04/12/1991 12:00:00 AM	192 Kb	03/28/2008 04:38:49 PM	
Ltr from NRC to NMI, re; Financial Assurance for License Nos. SUB-1452 and SMB-179.	ML093640091	06/07/1991 12:00:00 AM	86 Kb	01/05/2010 03:01:15 PM	
FOIA request for documents on adjudicatory hearing held on renewal application for license SMB-179.	9110180013	08/07/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:08 AM	
Matls licensing package for amend 9 to license SMB-179 for Nuclear Metals,Inc.Control:113009.	9210290104	05/13/1992 12:00:00 AM	320 bytes	04/30/2001 10:27:13 AM	
Ltr from NMI to NRC, subj: Draft Letter of Credit.	ML100040213	07/27/1992 12:00:00 AM	579 Kb	01/05/2010 03:00:50 PM	
Informs that NRC in process of reviewing application to License SMB-179 & that,although OL appears to be covered by categorical exclusions in 10CFR51.22 (c)(xiii) & (xv),because of plant size & other factors,NRC to prepare EA covering OL.	9408290397	10/06/1992 12:00:00 AM	320 bytes	05/02/2001 06:20:47 PM	
USNRC Site Decommissioning Management Plan, NUREG-1444, regarding Nuclear Metals, Inc.	ML080860275	10/31/1993 12:00:00 AM	229 Kb	04/04/2008 02:36:46 PM	
Matls licensing package for amend 10 to license SMB-179 for Nuclear Metals,Inc.Control:119160.	9405060198	03/02/1994 12:00:00 AM	320 bytes	04/25/2001 05:32:13 PM	
Ltr from NMI to NRC, Subj: NRC Letter dated 2 March 1994.	ML093640092	04/15/1994 12:00:00 AM	413 Kb	01/05/2010 03:01:06 PM	
Application for renewal of licenses SMB-179 & SUB-1452.	9408260298	06/03/1994 12:00:00 AM	320 bytes	05/02/2001 06:09:54 PM	
Memo from J. Joyner to J. Kinneman, subj: NMI Financial Assurance for Decommissioning Funding Plan.	ML093640093	06/21/1994 12:00:00 AM	866 Kb	01/05/2010 03:01:55 PM	

Ltr from NRC to NMI, Subj: Enforcement Conf.	ML093640094	10/28/1994 12:00:00 AM	92 Kb	01/05/2010 03:01:22 PM	
Ltr to NRC from Peabody & Arnold on Behalf of NMI, re; Request to Keep Confidential Portions of Response to DMI.	ML093640096	11/17/1994 12:00:00 AM	178 Kb	01/05/2010 03:01:45 PM	
Ltr to NRC from Peabody & Arnold on Behalf of NMI, subj: Affidavit of James M. Spiezio.	ML093640097	11/22/1994 12:00:00 AM	122 Kb	01/05/2010 03:01:47 PM	
Ltr from NMI to NRC, subj: Re: NRC/Decommissioning Funding.	ML093640730	01/11/1995 12:00:00 AM	453 Kb	01/05/2010 03:01:08 PM	
Ltr from NRC to NMI, subj: Enforcement Conf on Financial Assurance.	ML093640733	02/24/1995 12:00:00 AM	96 Kb	01/05/2010 03:01:18 PM	
Ltr from NRC to NMI, subj: Enforcement Conf on Financial Assurance.	ML093640735	04/05/1995 12:00:00 AM	138 Kb	01/05/2010 03:01:20 PM	
Ltr from NMI to NRC, re; Withholding of Information from Enforcement Conf Transcript.	ML093640737	04/28/1995 12:00:00 AM	219 Kb	01/05/2010 03:00:44 PM	
Ltr to NMI from NRC, subj: Request for Withholding.	ML093640815	05/23/1995 12:00:00 AM	120 Kb	01/05/2010 03:01:43 PM	
Partially withheld ltr discussing 941208 enforcement conference to discuss adequacy of NMI financial assurance & compliance w/requirements set forth in license condition 15 of licenses SMB-179 & SUB-1452.	9508310378	06/15/1995 12:00:00 AM	320 bytes	04/25/2001 10:05:07 PM	
Ltr. to NMI from NRC, subj: Mtg. on May 12, 1995.	ML093640816	06/15/1995 12:00:00 AM	98 Kb	01/05/2010 03:01:50 PM	
Ltr to NMI from NRC, subj: Request for Withholding.	ML093640817	06/21/1995 12:00:00 AM	101 Kb	01/05/2010 03:01:42 PM	
Ltr from NMI to NRC, subj: Response to Your Letter of 15 June 1995.	ML093640818	06/30/1995 12:00:00 AM	54 Kb	01/05/2010 03:01:13 PM	
Ltr from NMI to NRC, subj: Request for Partial Exemption To D&D Requirements.	ML093640820	08/15/1995 12:00:00 AM	374 Kb	01/05/2010 03:01:11 PM	

Forwards FR notice of receipt of application for renewal of license SMB-179.	9511020184	10/24/1995 12:00:00 AM	320 bytes	04/26/2001 05:36:24 AM	
Forwards questions to receive better understanding of issues surrounding Nuclear Metals,Inc Decommissioning Plan for Holding Basin,US licenses SMB-179 & SUB-1452.	9512120483	11/15/1995 12:00:00 AM	320 bytes	04/26/2001 09:51:48 AM	
US NRC Site Decommissioning Management Plan, NUREG-1444, Supplement 1, regarding Nuclear Metals, Inc.	ML080860308	11/30/1995 12:00:00 AM	145 Kb	04/04/2008 02:36:34 PM	
Ltr from NMI to NRC, re; License Nos. SMB-179, SUB-1452, Decommissioning Estimate.	ML093641126	01/31/1996 12:00:00 AM	606 Kb	01/05/2010 03:00:42 PM	
Preliminary Notification of Event, NMI, re; Fire in Liquid Radioactive Waste Processing System.	ML093000378	02/26/1996 12:00:00 AM	174 Kb	11/06/2009 01:47:52 PM	
Preliminary Notification of Event, NMI, re: Update: Fire in Liquid Radioactive Waste Processing System.	ML093000422	03/01/1996 12:00:00 AM	97 Kb	11/06/2009 01:47:51 PM	
ORNL Sites - Summary; License No. SNM-00065; Docket 070-00082, Licensee Nuclear Metals Inc.	ML080860316	08/13/1996 12:00:00 AM	147 Kb	04/04/2008 02:36:33 PM	
Notification of significant licensee meeting on 960930 w/NMI to discuss decommissioning cost estimate for licenses SMB-179 & SUB-1452.	9609240041	09/13/1996 12:00:00 AM	320 bytes	04/24/2001 12:58:32 AM	
Ltr from NMI to NRC, re; Decommissioning Financial - Assurance.	ML093641128	09/16/1996 12:00:00 AM	56 Kb	01/05/2010 03:00:40 PM	
Responds to NRC 960918 ltr re violations noted in insp of licenses SMB-179 & SUB -1452.Corrective actions:alpha & beta results now being entered into logbook.	9610150115	10/08/1996 12:00:00 AM	320 bytes	04/24/2001 03:16:21 AM	
Memo to D. Cool, NRC from C. Hehl, NRC, subj: Action Plan for Pending Renewal with Non-Compliance...	ML093070379	12/12/1996 12:00:00 AM	1,279 Kb	11/06/2009 01:47:47 PM	
Ltr from NRC to NMI, subj: Financial Assurance.	ML093650239	12/18/1996 12:00:00 AM	102 Kb	01/05/2010 03:01:27 PM	
Responds to 961105 ltr to Chairman re concern for pending request to renew license SMB-179 issued to Nuclear Metals Inc.	9704070074	12/31/1996 12:00:00 AM	320 bytes	04/21/2001 05:48:42 PM	

Ltr from NMI to NRC, subj: Financial Assurance Submittal.	ML093650240	01/17/1997 12:00:00 AM	274 Kb	01/05/2010 03:00:54 PM	
Notice of renewal of source matl licenses SMB-179 & SUB-452 for continued operation of Nuclear Metals,Inc located in Concord,MA.	9702280035	02/20/1997 12:00:00 AM	320 bytes	04/21/2001 03:02:41 AM	
Voided matls licensing action for license SMB-179 for Nuclear Metals,Inc.Control:122277.	9809030425	03/04/1997 12:00:00 AM	320 bytes	04/19/2001 12:47:52 PM	
Voided matls licensing action for license SMB-179 for Nuclear Metals,Inc.Control:117080.With 18 oversize drawings.	9809150264	03/11/1997 12:00:00 AM	320 bytes	04/19/2001 03:45:39 PM	
Discusses FRN,which announced availability of EA & staff FONSI to support renewal of licenses SMB-179 & SUB-1452.W/o encl.	9703280066	03/12/1997 12:00:00 AM	320 bytes	04/21/2001 04:58:57 PM	
Memo to Commissioners TAs from J. Craig, EDO re: Staff Evaluation of Sites Indentified in the USA Today Article Dated 09/06/00.	ML023290540	10/02/2000 12:00:00 AM	906 Kb	12/02/2002 09:06:07 AM	
Memo to Commissioners TAs from J. Craig, EDO re: Final Staff Evaluation of Sites Identified in the USA Today Article Dated 09/06/00.	ML023290541	10/19/2000 12:00:00 AM	877 Kb	12/02/2002 09:06:10 AM	
Aptec-NRC, Inc.; License Termination; dtd 12/14/2000	ML003779484	12/14/2000 12:00:00 AM	311 Kb	03/26/2008 04:29:32 PM	
03/28/01 - Update on Formerly Utilized Sites Remedial Action Program List, (To: Commissioner Assistants; From: J W Craig).	ML030520156	03/28/2001 12:00:00 AM	1,379 Kb	02/27/2003 09:35:49 AM	
FOIA/PA-2008-0068 - Nuclear Metals Inc., Concord, Middlesex County, Massachusetts, license SMB-179, SNM-65, records re: environmental conditions or decommissioning, 1957 to present	ML073460034	12/11/2007 12:00:00 AM	140 Kb	02/28/2008 09:01:24 AM	
SECY-07-0220 - "Weekly Information Report - Week Ending 12/14/07"	ML073541105	12/20/2007 12:00:00 AM	128 Kb	12/26/2007 01:09:26 PM	
Subject: NRC FOIA Report Jan 2005 thru Present.	ML080570402	02/11/2008 12:00:00	3,035 Kb	02/28/2008 09:02:36	

Memo to Commissioners TAs from J. Craig, EDO re: Final Staff Evaluation of Sites Identified in the USA Today Article Dated 09/06/00.	ML023290541	10/19/2000 12:00:00 AM	877 Kb	12/02/2002 09:06:10 AM	
Aptec-NRC, Inc.; License Termination; dtd 12/14/2000	ML003779484	12/14/2000 12:00:00 AM	311 Kb	03/26/2008 04:29:32 PM	
03/28/01 - Update on Formerly Utilized Sites Remedial Action Program List, (To: Commissioner Assistants; From: J W Craig).	ML030520156	03/28/2001 12:00:00 AM	1,379 Kb	02/27/2003 09:35:49 AM	
FOIA/PA-2008-0068 - Nuclear Metals Inc., Concord, Middlesex County, Massachusetts, license SMB-179, SNM-65, records re: environmental conditions or decommissioning, 1957 to present	ML073460034	12/11/2007 12:00:00 AM	140 Kb	02/28/2008 09:01:24 AM	
SECY-07-0220 - "Weekly Information Report - Week Ending 12/14/07"	ML073541105	12/20/2007 12:00:00 AM	128 Kb	12/26/2007 01:09:26 PM	
Subject: NRC FOIA Report Jan 2005 thru Present.	ML080570402	02/11/2008 12:00:00 AM	3,035 Kb	02/28/2008 09:02:36 AM	
FOIA/PA cases received from 02/12/07 to 02/12/08.	ML080590579	02/14/2008 12:00:00 AM	1,465 Kb	03/04/2008 09:51:37 AM	
USAEC Post Inspection Cover Sheet from P. Jerman to P. Knapp Regarding Inspection of Nuclear Metals, Inc.	ML080810510	02/15/2008 12:00:00 AM	1,047 Kb	04/04/2008 02:22:05 PM	
FOIA/PA-2008-0068 - Resp 1 - Partial.	ML080780586	02/15/2008 12:00:00 AM	878 Kb	04/04/2008 02:35:49 PM	
Status of Decommissioning Activities.	ML080930574	03/26/2008 12:00:00 AM	41 Kb	04/03/2008 09:10:06 AM	
FOIA/PA Cases Received from 01/01/04 to 06/20/08.	ML081900087	07/01/2008 12:00:00 AM	4,953 Kb	07/14/2008 09:11:23 AM	
List of FOIA Requests from 10-01-07 to 10-01-08.	ML082980293	10/22/2008 12:00:00 AM	825 Kb	11/03/2008 09:09:17 AM	
FOIA/PA-2009-0225 - Resp 2 - Final.	ML093640088	12/09/2009 12:00:00 AM	187 Kb	01/05/2010 03:00:23 PM	

NRC Database Search for Lic# SMB-179

Discusses insp of License SMB-179 on 581020 re use of source matl.Major areas inspected:organization & procedures & procurement & record control.	9103150274	10/20/1958 12:00:00 AM	320 bytes	05/01/2001 02:21:18 AM		
Discusses listed items of noncompliance noted during insps on 581020-21 under Licenses SMB-179 & SNM-65.Insp rept for License SMB-179 encl.	9103150271	02/13/1959 12:00:00 AM	320 bytes	05/01/2001 02:21:13 AM		
Discusses insp of Licenses SMB-179 & SNM-65 on 601103 & 04. Noncompliances noted.	9103150283	07/11/1961 12:00:00 AM	320 bytes	05/01/2001 02:21:32 AM		
Insp Findings & Licensee Ack dtd 620424 of License SMB-179. Insp findings:no noncompliance noted.	8305120234	04/24/1962 12:00:00 AM	320 bytes	05/21/2001 11:41:00 PM		
Notifies that License SMB-179 expires on 690930.Renewal application should be filed within 30 days.Encl certification of status of source matl activities form should be completed for nonrenewal of license.	8305120283	07/25/1969 12:00:00 AM	320 bytes	05/21/2001 11:45:50 PM		
Memo to File from Smith, Back-Up Notes to Form AEC-592, Whittaker Corporation, Nuclear Metals Division.	ML080810179	09/18/1969 12:00:00 AM	520 Kb	03/27/2008 09:03:21 AM		
Responds to 690918 ltr re findings during recent insp of activities authorized under Licenses SNM-65 & SMB-179. Corrective actions:environ samples will be collected in future in compliance w/sampling schedule.	9103150294	10/08/1969 12:00:00 AM	320 bytes	05/01/2001 02:21:47 AM		
Memorandum from R. Kirkman of USAEC to P. Ulf Gummeson of Whittaker Corporation, Regarding Noncompliance.	ML080780596	10/20/1969 12:00:00 AM	825 Kb	04/04/2008 02:36:27 PM		
Advises that response to 690822 application for License SMB-179 has not been received.Info re issuance of license requested.	8305120264	10/22/1969 12:00:00 AM	320 bytes	05/21/2001 11:44:02 PM		
Ltr from R. Smith of USAEC to Whittaker Corporation, Regarding Noncompliance Observed During Inspection and an AEC-591 Form for License SNM-65 and SMB-179.	ML080780599	01/06/1970 12:00:00 AM	601 Kb	04/04/2008 02:36:11 PM		
Source Matl License SMB-179 for Whittaker-Corp,authorizing use of 80,000 lb U metal or alloy & 20,000 lb thorium metal or alloy.	8301110045	03/25/1970 12:00:00 AM	320 bytes	05/16/2001 04:12:16 PM		
USAEC Inspection Findings and Licensee Acknowledgment, License Number SNM-65 and SMB-179.	ML080850148	07/16/1970 12:00:00 AM	118 Kb	04/04/2008 02:36:38 PM		
Discusses insp of Licenses SNM-65 & SMB-179 on 700715-16. No items of noncompliance observed & AEC-591 form issued. Insp rept encl.	9103150303	08/05/1970 12:00:00 AM	320 bytes	05/01/2001 02:22:01 AM		

Ltr from R. Smith of USAEC to H. Crocker of Whittaker Corporation, Regarding Noncompliance.	ML080850149	08/05/1970 12:00:00 AM	514 Kb	04/04/2008 02:36:11 PM	
Insp rept for Licenses SNM-65 & SMB-179 on 700715-16.No items of noncompliance noted & AEC-591 form issued.Major areas inspected:review of health physics records & practices.	9103150306	08/06/1970 12:00:00 AM	320 bytes	05/01/2001 02:22:06 AM	
Memorandum from R. Smith of USAEC to File, Regarding Backup Notes to Form AEC-591.	ML080850276	06/11/1971 12:00:00 AM	562 Kb	04/04/2008 02:36:28 PM	
Ltr from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals, Inc., regarding inspection conducted on March 14 thru 16, 1973.	ML080810052	04/23/1973 12:00:00 AM	312 Kb	04/04/2008 02:36:05 PM	
Daily Reports - Region I, Including Notification, Event and regional Action.	ML080810338	01/07/1974 12:00:00 AM	143 Kb	04/04/2008 02:34:56 PM	
Ltr from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Telephone Discussion Regarding the December 27 and 28.	ML080810365	01/07/1974 12:00:00 AM	81 Kb	04/04/2008 02:36:01 PM	
USAEC, Blue Sheet, Directorate of Regulatory Operations, Notification of an Incident or Occurrence, Regarding Nuclear Metals, Inc. License No. SMB-179.	ML080810496	01/10/1974 12:00:00 AM	176 Kb	04/04/2008 02:36:44 PM	
USAEC Directorate of Regulatory Operations, Region RO Inspection Report No. 07000082-73-005 and 04000672-73-002.	ML080810506	02/05/1974 12:00:00 AM	935 Kb	04/04/2008 02:36:35 PM	
Daily Report - Region I, Regarding Facility Notification, Event and Regional Action.	ML080810508	02/14/1974 12:00:00 AM	35 Kb	04/04/2008 02:21:04 PM	
Ltr from J. O┐ Reilly of USAEC to W. Truffin of Nuclear Metals Inc., Regarding Inspection Conducted on December 27-28, 1973.	ML080850232	02/15/1974 12:00:00 AM	1,493 Kb	04/04/2008 02:21:21 PM	
Memorandum from P. Nelson of USAEC to File, Regarding Nuclear Metals Inc. Meeting on 02/13/74.	ML080850526	03/20/1974 12:00:00 AM	106 Kb	04/04/2008 02:21:29 PM	
Ltr. from W. Kinner of USAEC to H. Crocker of Nuclear Metals Inc., Regarding Draft of Enforcement Letters.	ML080850744	04/11/1974 12:00:00 AM	1,761 Kb	04/04/2008 02:21:27 PM	
Ltr. from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Corrective and Preventive Actions.	ML080850766	04/26/1974 12:00:00 AM	864 Kb	04/04/2008 02:21:25 PM	

Ltr. from J. O┐ Reilly of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Corrective and Preventive Actions.	ML080850797	04/26/1974 12:00:00 AM	871 Kb	04/04/2008 02:21:26 PM	
Discusses insp of License SMB-179 radiation control program. License classification should be changed from E-3 to B-1. Next insp scheduled during Nov 1974.	8305120303	08/22/1974 12:00:00 AM	320 bytes	05/21/2001 11:47:58 PM	
Ltr from P. Nelson of USAEC to W. Tuffin of Nuclear Metals Inc., Regarding Inspection Conducted on May 30 and 31, 1974.	ML080850870	08/22/1974 12:00:00 AM	1,352 Kb	04/04/2008 02:21:23 PM	
Corrected copy of Amend 3 to Nuclear Metals,Inc License SMB-179 authorizing mfg of derbies,castings,extrusions & machined or formed parts.Ltr dtd 750508 added to Section 13.	8301110039	02/16/1977 12:00:00 AM	320 bytes	05/16/2001 04:11:39 PM	
In accordance w/781213 application,Matl/Byproduct License SMB-179 for Nuclear Metals,Inc is amended to limit max amount of depleted uranium possessed to 5.1 million lbs.	7903010447	02/09/1979 12:00:00 AM	320 bytes	05/25/2001 09:18:01 PM	
Requests amend of Matl/Byproduct License SMB-179 authorizing incorporation of two consultant repts extending evaluations of effluent air re degree of conservatism inherent in method of air sampling & dilution of plume.	8001020309	11/05/1979 12:00:00 AM	320 bytes	05/21/2001 09:14:37 PM	
Letter to NRC Div. of Materials Licensing from A.R. Gilman, NMI, subj: License Amendment Application.	ML093070382	11/05/1979 12:00:00 AM	1,624 Kb	11/06/2009 01:47:38 PM	
USAEC Memorandum from J. Delaney, Regarding Nuclear Metals, INC (NMI); Termination of Special Nuclear Material License NO. SNM-65.	ML080850883	02/15/1980 12:00:00 AM	445 Kb	04/04/2008 02:22:04 PM	
Discusses IE insp of License SMB-179 on 800304-05.No noncompliance noted.Major areas inspected:procedures & representative records,interviews w/personnel & measurements & observations made by inspectors.	8005140324	03/27/1980 12:00:00 AM	320 bytes	05/24/2001 10:22:23 AM	
Matl/Byproduct License SMB-179 for Nuclear Metals,Inc is amended per 791105 application.Amend 5 changes Condition 13 re possession & use of licensed matl.	8004170154	03/31/1980 12:00:00 AM	320 bytes	05/24/2001 03:22:39 AM	
Responds to 810527 application for amend of License SMB-179. Amend fee required.	8108040013	06/10/1981 12:00:00 AM	320 bytes	05/25/2001 02:26:37 AM	

Responds to 810527 application for amend of License SMB-179. Amend fee required.	8108040013	06/10/1981 12:00:00 AM	320 bytes	05/25/2001 02:26:37 AM	
Responds to 810527 application for amend to License SMB-179. Ventilation consultant 810413 rept proposing dilution factor of 143 for air effluent releases appears to request increase in effluents.Impact of airborne releases not clarified.	8301110083	11/21/1981 12:00:00 AM	320 bytes	05/16/2001 04:16:31 PM	
Forwards application for renewal of License SMB-179.	8201050171	11/30/1981 12:00:00 AM	320 bytes	05/19/2001 03:21:14 AM	
Ack receipt of application for renewal of License SMB-179. License will not expire until final action taken by NRC.	8305130006	12/28/1981 12:00:00 AM	320 bytes	05/22/2001 12:25:24 AM	
Comments on application for renewal of License SMB-179. Application should provide more specific procedures for frisking personnel & clothing at exits from controlled area.	8305130037	04/01/1982 12:00:00 AM	320 bytes	05/22/2001 12:28:49 AM	
FOIA request for license applications,licenses & insp repts re License SMB-179 & incidents of employee overexposure.	8301110007	11/15/1982 12:00:00 AM	320 bytes	05/16/2001 04:08:13 PM	
Partial response to FOIA request for license applications, licenses & insp repts re License SMB-179 & incidents of employee overexposure.Search for documents continuing. Forwards documents listed on App A.	8301110010	12/15/1982 12:00:00 AM	320 bytes	05/16/2001 04:08:33 PM	
Boeing Company Request Concerning Depleted Uranium Counterweights.	ML103440585	04/14/1983 12:00:00 AM	419 Kb	12/17/2010 11:09:08 AM	
Forwards,for review,info for inclusion into renewal application for License SMB-179 based on request from Region I & documented in 830805 Confirmatory Action Ltr 83-08.	8403050150	01/15/1984 12:00:00 AM	320 bytes	05/16/2001 05:42:24 PM	
IE Info Notice 84-34, "Respirator User Warning:Defective Self-Contained Breathing Apparatus Air Cylinders." Svc list encl.	ML082970362	04/23/1984 12:00:00 AM	42,596 Kb	12/15/2009 11:37:36 AM	
Amend 6 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8510160308	05/23/1984 12:00:00 AM	320 bytes	05/15/2001 12:58:03 PM	
Letter from NMI to Region I, NRC, Subj: Giving Thirty Day Written Notification in Regards to Excessive Radiation Exposure.	ML093070394	05/24/1984 12:00:00 AM	300 Kb	11/06/2009 01:47:21 PM	

Letter from NMI to Region I, NRC, Subj: Giving Thirty Day Written Notification in Regards to Excessive Radiation Exposure.	ML093070394	05/24/1984 12:00:00 AM	300 Kb	11/06/2009 01:47:21 PM	
Discusses insp of Licenses SMB-179 & 20-02217-05 on 840616- 19 & forwards notice of violation.Civil penalty will not be issued.	8410030278	09/14/1984 12:00:00 AM	320 bytes	05/18/2001 10:47:19 AM	
Responds to NRC 840914 ltr re violations noted in insp of Licenses SMB-179 & 20-02217-05 on 840616-19.Corrective actions:purchase order placed to obtain telescopic survey instrument & health physics technicians performed surveys.	8411090209	10/10/1984 12:00:00 AM	320 bytes	05/18/2001 06:00:41 PM	
Amend 7 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8606300390	04/24/1986 12:00:00 AM	320 bytes	05/11/2001 10:03:34 AM	
Forwards Amend 7,renewing License SMB-179.	8606300395	04/24/1986 12:00:00 AM	320 bytes	05/11/2001 10:03:42 AM	
Amend 8 to License SMB-179 for Nuclear Metals,Inc,amending license in entirety.	8804200356	09/17/1987 12:00:00 AM	320 bytes	05/08/2001 02:20:49 PM	
Forwards Amend 8 to License SMB-179.	8804200360	09/17/1987 12:00:00 AM	320 bytes	05/08/2001 02:20:55 PM	
Corrected Amend 8 to License SMB-179 for Nuclear Metals,Inc, amending license in entirety.	8806080174	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:07 PM	
Corrected Amend 8 to License SMB-179 for Nuclear Metals,Inc, amending license in entirety.	8806080174	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:09 PM	
Forwards corrected Amend 8 to License SMB-179 due to address change.	8806080180	10/01/1987 12:00:00 AM	320 bytes	05/08/2001 08:42:19 PM	
Voided matls licensing action for License SMB-179 for Nuclear Metals,Inc.Control:109641.	9004240277	06/07/1989 12:00:00 AM	320 bytes	05/04/2001 11:29:31 AM	
Ltr from NMI to NRC, subj: NMI Request to Amend Two Source Material Licenses.	ML100040212	07/26/1990 12:00:00 AM	610 Kb	01/05/2010 03:01:04 PM	
Requests adjudicatory hearing be scheduled in order to express resident concerns on renewal application for license SMB-179.	9110180030	01/24/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:35 AM	

Submits motion & petition to intervene in renewing licenses SMB-179 & SUB-1452.	9110180035	02/14/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:43 AM	
Forwards SJ Lewis ltr requesting hearing on license renewal application for SMB-179.	9110180021	02/21/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:20 AM	
SECY-91-0096, "Updated Report on Site Decommissioning Management Plan".	ML080880218	04/12/1991 12:00:00 AM	192 Kb	03/28/2008 04:38:49 PM	
Ltr from NRC to NMI, re; Financial Assurance for License Nos. SUB-1452 and SMB-179.	ML093640091	06/07/1991 12:00:00 AM	86 Kb	01/05/2010 03:01:15 PM	
FOIA request for documents on adjudicatory hearing held on renewal application for license SMB-179.	9110180013	08/07/1991 12:00:00 AM	320 bytes	05/02/2001 06:44:08 AM	
Matls licensing package for amend 9 to license SMB-179 for Nuclear Metals,Inc.Control:113009.	9210290104	05/13/1992 12:00:00 AM	320 bytes	04/30/2001 10:27:13 AM	
Ltr from NMI to NRC, subj: Draft Letter of Credit.	ML100040213	07/27/1992 12:00:00 AM	579 Kb	01/05/2010 03:00:50 PM	
Informs that NRC in process of reviewing application to License SMB-179 & that,although OL appears to be covered by categorical exclusions in 10CFR51.22 (c)(xiii) & (xv),because of plant size & other factors,NRC to prepare EA covering OL.	9408290397	10/06/1992 12:00:00 AM	320 bytes	05/02/2001 06:20:47 PM	
USNRC Site Decommissioning Management Plan, NUREG-1444, regarding Nuclear Metals, Inc.	ML080860275	10/31/1993 12:00:00 AM	229 Kb	04/04/2008 02:36:46 PM	
Matls licensing package for amend 10 to license SMB-179 for Nuclear Metals,Inc.Control:119160.	9405060198	03/02/1994 12:00:00 AM	320 bytes	04/25/2001 05:32:13 PM	
Ltr from NMI to NRC, Subj: NRC Letter dated 2 March 1994.	ML093640092	04/15/1994 12:00:00 AM	413 Kb	01/05/2010 03:01:06 PM	
Application for renewal of licenses SMB-179 & SUB-1452.	9408260298	06/03/1994 12:00:00 AM	320 bytes	05/02/2001 06:09:54 PM	
Memo from J. Joyner to J. Kinneman, subj: NMI Financial Assurance for Decommissioning Funding Plan.	ML093640093	06/21/1994 12:00:00 AM	866 Kb	01/05/2010 03:01:55 PM	

Ltr from NRC to NMI, Subj: Enforcement Conf.	ML093640094	10/28/1994 12:00:00 AM	92 Kb	01/05/2010 03:01:22 PM	
Ltr to NRC from Peabody & Arnold on Behalf of NMI, re; Request to Keep Confidential Portions of Response to DMI.	ML093640096	11/17/1994 12:00:00 AM	178 Kb	01/05/2010 03:01:45 PM	
Ltr to NRC from Peabody & Arnold on Behalf of NMI, subj: Affidavit of James M. Spiezio.	ML093640097	11/22/1994 12:00:00 AM	122 Kb	01/05/2010 03:01:47 PM	
Ltr from NMI to NRC, subj: Re: NRC/Decommissioning Funding.	ML093640730	01/11/1995 12:00:00 AM	453 Kb	01/05/2010 03:01:08 PM	
Ltr from NRC to NMI, subj: Enforcement Conf on Financial Assurance.	ML093640733	02/24/1995 12:00:00 AM	96 Kb	01/05/2010 03:01:18 PM	
Ltr from NRC to NMI, subj: Enforcement Conf on Financial Assurance.	ML093640735	04/05/1995 12:00:00 AM	138 Kb	01/05/2010 03:01:20 PM	
Ltr from NMI to NRC, re; Withholding of Information from Enforcement Conf Transcript.	ML093640737	04/28/1995 12:00:00 AM	219 Kb	01/05/2010 03:00:44 PM	
Ltr to NMI from NRC, subj: Request for Withholding.	ML093640815	05/23/1995 12:00:00 AM	120 Kb	01/05/2010 03:01:43 PM	
Partially withheld ltr discussing 941208 enforcement conference to discuss adequacy of NMI financial assurance & compliance w/requirements set forth in license condition 15 of licenses SMB-179 & SUB-1452.	9508310378	06/15/1995 12:00:00 AM	320 bytes	04/25/2001 10:05:07 PM	
Ltr. to NMI from NRC, subj: Mtg. on May 12, 1995.	ML093640816	06/15/1995 12:00:00 AM	98 Kb	01/05/2010 03:01:50 PM	
Ltr to NMI from NRC, subj: Request for Withholding.	ML093640817	06/21/1995 12:00:00 AM	101 Kb	01/05/2010 03:01:42 PM	
Ltr from NMI to NRC, subj: Response to Your Letter of 15 June 1995.	ML093640818	06/30/1995 12:00:00 AM	54 Kb	01/05/2010 03:01:13 PM	
Ltr from NMI to NRC, subj: Request for Partial Exemption To D&D Requirements.	ML093640820	08/15/1995 12:00:00 AM	374 Kb	01/05/2010 03:01:11 PM	

Forwards FR notice of receipt of application for renewal of license SMB-179.	9511020184	10/24/1995 12:00:00 AM	320 bytes	04/26/2001 05:36:24 AM	
Forwards questions to receive better understanding of issues surrounding Nuclear Metals,Inc Decommissioning Plan for Holding Basin,US licenses SMB-179 & SUB-1452.	9512120483	11/15/1995 12:00:00 AM	320 bytes	04/26/2001 09:51:48 AM	
US NRC Site Decommissioning Management Plan, NUREG-1444, Supplement 1, regarding Nuclear Metals, Inc.	ML080860308	11/30/1995 12:00:00 AM	145 Kb	04/04/2008 02:36:34 PM	
Ltr from NMI to NRC, re; License Nos. SMB-179, SUB-1452, Decommissioning Estimate.	ML093641126	01/31/1996 12:00:00 AM	606 Kb	01/05/2010 03:00:42 PM	
Preliminary Notification of Event, NMI, re; Fire in Liquid Radioactive Waste Processing System.	ML093000378	02/26/1996 12:00:00 AM	174 Kb	11/06/2009 01:47:52 PM	
Preliminary Notification of Event, NMI, re: Update: Fire in Liquid Radioactive Waste Processing System.	ML093000422	03/01/1996 12:00:00 AM	97 Kb	11/06/2009 01:47:51 PM	
ORNL Sites - Summary; License No. SNM-00065; Docket 070-00082, Licensee Nuclear Metals Inc.	ML080860316	08/13/1996 12:00:00 AM	147 Kb	04/04/2008 02:36:33 PM	
Notification of significant licensee meeting on 960930 w/NMI to discuss decommissioning cost estimate for licenses SMB-179 & SUB-1452.	9609240041	09/13/1996 12:00:00 AM	320 bytes	04/24/2001 12:58:32 AM	
Ltr from NMI to NRC, re; Decommissioning Financial - Assurance.	ML093641128	09/16/1996 12:00:00 AM	56 Kb	01/05/2010 03:00:40 PM	
Responds to NRC 960918 ltr re violations noted in insp of licenses SMB-179 & SUB -1452.Corrective actions:alpha & beta results now being entered into logbook.	9610150115	10/08/1996 12:00:00 AM	320 bytes	04/24/2001 03:16:21 AM	
Memo to D. Cool, NRC from C. Hehl, NRC, subj: Action Plan for Pending Renewal with Non-Compliance...	ML093070379	12/12/1996 12:00:00 AM	1,279 Kb	11/06/2009 01:47:47 PM	
Ltr from NRC to NMI, subj: Financial Assurance.	ML093650239	12/18/1996 12:00:00 AM	102 Kb	01/05/2010 03:01:27 PM	
Responds to 961105 ltr to Chairman re concern for pending request to renew license SMB-179 issued to Nuclear Metals Inc.	9704070074	12/31/1996 12:00:00 AM	320 bytes	04/21/2001 05:48:42 PM	

Ltr from NMI to NRC, subj: Financial Assurance Submittal.	ML093650240	01/17/1997 12:00:00 AM	274 Kb	01/05/2010 03:00:54 PM	
Notice of renewal of source matl licenses SMB-179 & SUB-452 for continued operation of Nuclear Metals,Inc located in Concord,MA.	9702280035	02/20/1997 12:00:00 AM	320 bytes	04/21/2001 03:02:41 AM	
Voided matls licensing action for license SMB-179 for Nuclear Metals,Inc.Control:122277.	9809030425	03/04/1997 12:00:00 AM	320 bytes	04/19/2001 12:47:52 PM	
Voided matls licensing action for license SMB-179 for Nuclear Metals,Inc.Control:117080.With 18 oversize drawings.	9809150264	03/11/1997 12:00:00 AM	320 bytes	04/19/2001 03:45:39 PM	
Discusses FRN,which announced availability of EA & staff FONSI to support renewal of licenses SMB-179 & SUB-1452.W/o encl.	9703280066	03/12/1997 12:00:00 AM	320 bytes	04/21/2001 04:58:57 PM	
Memo to Commissioners TAs from J. Craig, EDO re: Staff Evaluation of Sites Indentified in the USA Today Article Dated 09/06/00.	ML023290540	10/02/2000 12:00:00 AM	906 Kb	12/02/2002 09:06:07 AM	
Memo to Commissioners TAs from J. Craig, EDO re: Final Staff Evaluation of Sites Identified in the USA Today Article Dated 09/06/00.	ML023290541	10/19/2000 12:00:00 AM	877 Kb	12/02/2002 09:06:10 AM	
Aptec-NRC, Inc.; License Termination; dtd 12/14/2000	ML003779484	12/14/2000 12:00:00 AM	311 Kb	03/26/2008 04:29:32 PM	
03/28/01 - Update on Formerly Utilized Sites Remedial Action Program List, (To: Commissioner Assistants; From: J W Craig).	ML030520156	03/28/2001 12:00:00 AM	1,379 Kb	02/27/2003 09:35:49 AM	
FOIA/PA-2008-0068 - Nuclear Metals Inc., Concord, Middlesex County, Massachusetts, license SMB-179, SNM-65, records re: environmental conditions or decommissioning, 1957 to present	ML073460034	12/11/2007 12:00:00 AM	140 Kb	02/28/2008 09:01:24 AM	
SECY-07-0220 - "Weekly Information Report - Week Ending 12/14/07"	ML073541105	12/20/2007 12:00:00 AM	128 Kb	12/26/2007 01:09:26 PM	
Subject: NRC FOIA Report Jan 2005 thru Present.	ML080570402	02/11/2008 12:00:00	3,035 Kb	02/28/2008 09:02:36	

Memo to Commissioners TAs from J. Craig, EDO re: Final Staff Evaluation of Sites Identified in the USA Today Article Dated 09/06/00.	ML023290541	10/19/2000 12:00:00 AM	877 Kb	12/02/2002 09:06:10 AM	
Aptec-NRC, Inc.; License Termination; dtd 12/14/2000	ML003779484	12/14/2000 12:00:00 AM	311 Kb	03/26/2008 04:29:32 PM	
03/28/01 - Update on Formerly Utilized Sites Remedial Action Program List, (To: Commissioner Assistants; From: J W Craig).	ML030520156	03/28/2001 12:00:00 AM	1,379 Kb	02/27/2003 09:35:49 AM	
FOIA/PA-2008-0068 - Nuclear Metals Inc., Concord, Middlesex County, Massachusetts, license SMB-179, SNM-65, records re: environmental conditions or decommissioning, 1957 to present	ML073460034	12/11/2007 12:00:00 AM	140 Kb	02/28/2008 09:01:24 AM	
SECY-07-0220 - "Weekly Information Report - Week Ending 12/14/07"	ML073541105	12/20/2007 12:00:00 AM	128 Kb	12/26/2007 01:09:26 PM	
Subject: NRC FOIA Report Jan 2005 thru Present.	ML080570402	02/11/2008 12:00:00 AM	3,035 Kb	02/28/2008 09:02:36 AM	
FOIA/PA cases received from 02/12/07 to 02/12/08.	ML080590579	02/14/2008 12:00:00 AM	1,465 Kb	03/04/2008 09:51:37 AM	
USAEC Post Inspection Cover Sheet from P. Jerman to P. Knapp Regarding Inspection of Nuclear Metals, Inc.	ML080810510	02/15/2008 12:00:00 AM	1,047 Kb	04/04/2008 02:22:05 PM	
FOIA/PA-2008-0068 - Resp 1 - Partial.	ML080780586	02/15/2008 12:00:00 AM	878 Kb	04/04/2008 02:35:49 PM	
Status of Decommissioning Activities.	ML080930574	03/26/2008 12:00:00 AM	41 Kb	04/03/2008 09:10:06 AM	
FOIA/PA Cases Received from 01/01/04 to 06/20/08.	ML081900087	07/01/2008 12:00:00 AM	4,953 Kb	07/14/2008 09:11:23 AM	
List of FOIA Requests from 10-01-07 to 10-01-08.	ML082980293	10/22/2008 12:00:00 AM	825 Kb	11/03/2008 09:09:17 AM	
FOIA/PA-2009-0225 - Resp 2 - Final.	ML093640088	12/09/2009 12:00:00 AM	187 Kb	01/05/2010 03:00:23 PM	