U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES ■ Public Health Service
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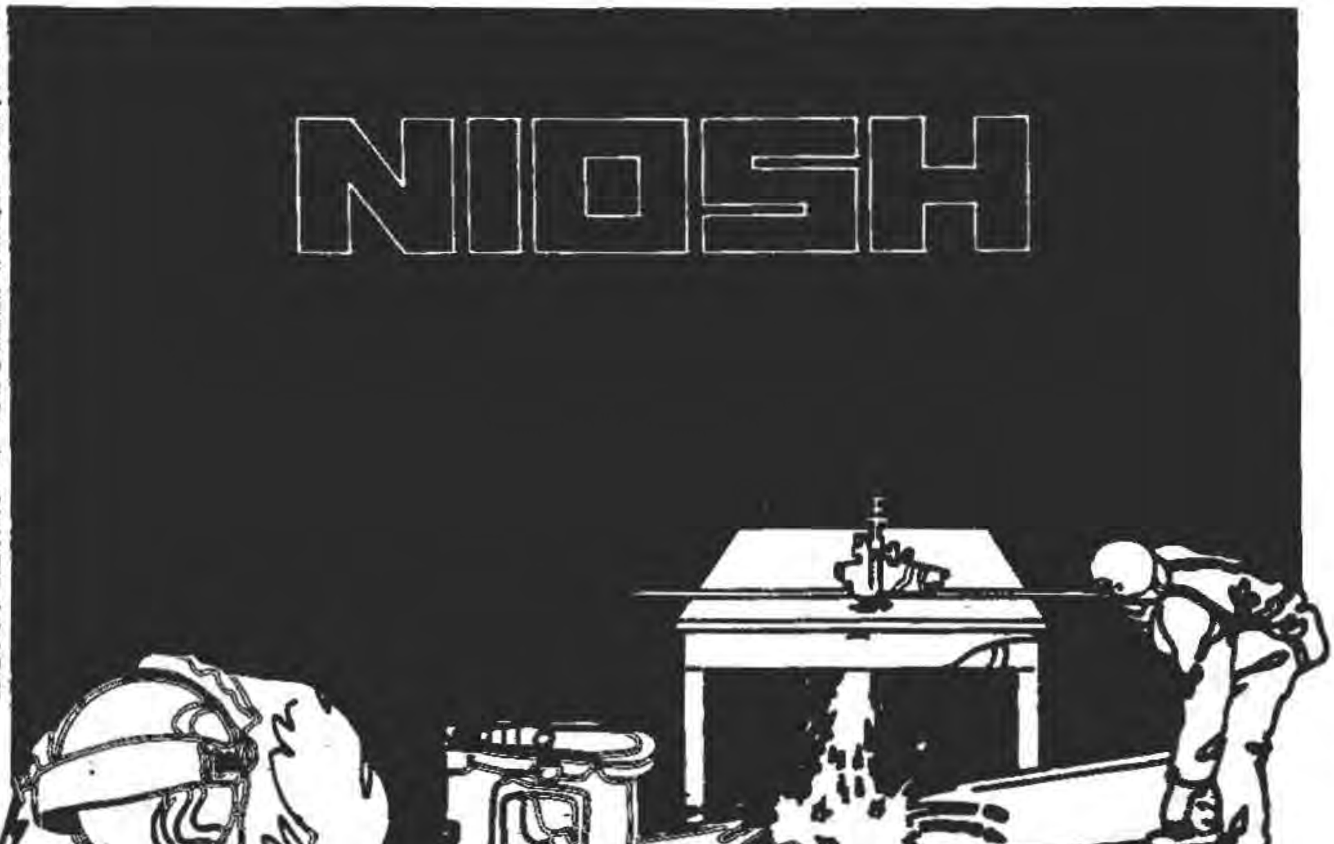

Health Hazard Evaluation Report

HETA 85-111-1770

FEED MATERIALS PRODUCTION CENTER

FERNALD, OHIO

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JANUARY 1987
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NIOSH INVESTIGATORS:
James M. Smith, Ph.D.
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Jerome P. Flesch

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PREFACE

The Hazard Evaluations and Technical Assistance Branch of NIOSH conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

The Hazard Evaluations and Technical Assistance Branch also provides, upon request, medical, nursing, and industrial hygiene technical and consultative assistance (TA) to Federal, state, and local agencies; labor; industry and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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I. SUMMARY

On December 13, 1984, the National Institute for Occupational Safety and Health (NIOSH) was requested by the Director of Health, State of Ohio, on behalf of the facility's workers to assess the potential health effects on workers of uranium releases at the Feed Materials Production Center in Fernald, Ohio. Approximately 270-370 pounds of uranium oxide had reportedly been accidentally released from the dust collectors in Plant 9 between November 16 and December 7, 1984, before operations were shut down.

NIOSH investigators met with constituents which included representatives of NLO, Inc. (which managed the Department of Energy facility), Department of Energy (DOE), the Atomic Trades Labor Council, and the office of Congressman Luken. Meetings were also held with the DOE investigative team, the NLO, Inc. investigative committee, and with workers and management at the Center. In addition, NIOSH investigators conducted an inspection of the health and safety laboratories and toured Plants 1 and 9 at the Center. The NIOSH team, throughout its investigation, obtained the complete cooperation of NLO, Inc., the U.S. Department of Energy, the Atomic Trades Labor Council, and the workers.

To assess the extent of uranium exposure and its potential health effects due to the accidental releases, NIOSH investigators recommended in December, 1984 that all workers from Plant 9 (approximately 100) undergo monitoring for body content of uranium. This testing was carried out by the U.S. Department of Energy (DOE) and NLO using the DOE Mobile Van and the test results of Plant 9 workers indicated that none of the workers had a uranium content in their lungs greater than the DOE maximum permissible limit. Additional testing with permanent, more sensitive monitoring systems was recommended for a subset of workers in order to check the validity of the DOE Mobile Van results.

Results of the comparative monitoring were not entirely in agreement for the systems tested. Argonne National Laboratory reported that one of four workers tested in January, 1985 had an amount of uranium in his lungs 10 times greater than that reported by the DOE Mobile Van. Further definitive testing using a state-of-the-art system at the Battelle Pacific Northwest Laboratory was recommended and subsequently conducted in September, 1985, along with repeat tests at the DOE Mobile Van and at Argonne National Laboratory. These results were

consistent and revealed that the uranium in the lungs of the workers was significantly less than the maximum amount permitted by the DOE.

Based on a review of all the monitoring results, it is concluded that the releases of uranium at the Feed Materials Production Center between November 16 and December 7, 1984, did not result in an excessive uranium body content for the workers. However, it is prudent health practice to maintain exposure to uranium as low as reasonably achievable at all times. A number of deficiencies were found in operations and communication at the Feed Materials Production Center. They are detailed in the report along with specific recommendations for improvement.

KEYWORDS: Uranium, radioactivity, in vivo radiation monitoring, SIC 2819, whole body counting

II. INTRODUCTION

On December 13, 1984, the Director of Health, State of Ohio, asked the National Institute for Occupational Safety and Health (NIOSH) to assess reports of releases of uranium from November 16 to December 7, 1984, and their potential health effects on workers at the U.S. Department of Energy's (DOE's) Feed Materials Production Center, Fernald, Ohio, then operated by NLO, Inc. On December 14, NIOSH contacted NLO/DOE officials to discuss the issue and scheduled a meeting of constituents for December 17.

At this initial meeting, NIOSH investigators made five recommendations for immediate action to NLO, Inc. Among these was that all workers in the Plant where the releases occurred undergo testing using the U.S. Department of Energy's whole body counter, which is a mobile unit and is referred to throughout this report as the DOE Mobile Van. Six additional meetings took place over the following nine months to assess the concerns of workers and management, the extent of the hazard related to the uranium releases, and general radiation safety and health practices at the Feed Materials Production Center (referred to in this report as NLO) related to the company's ability to evaluate the hazard from an accidental uranium release.

It was expected that any adverse health effects on workers would most likely result from uranium incorporated in the body by inhalation. The investigators therefore reviewed the records (acquired by NLO) of urinalyses for uranium in the workers to determine if unusual internal contamination was indicated. They also recommended that the workers in the plant where the releases occurred be monitored for internal contamination by an in vivo assay (i.e., an analysis of the "living body") that can detect radiation from uranium incorporated internally. The urinalysis data did not show evidence of internal uranium contamination. However, the NIOSH investigators considered a more important indicator to be in vivo monitoring of the lungs of potentially exposed workers, using the DOE Mobile Van. A discussion of these results, together with attempts to validate and interpret them, form the main body of this report.

III. BACKGROUND

NLO, Inc. reported that during the period from November 16 to December 7, 1984, approximately 270-370 lbs (120-170 kg) of uranium oxide in the form U_3O_8 ("black oxide") was released from "bag house" operations in Plant 9. During the operations in Plant 9, crucibles containing uranium oxide are burned and vented via a bagging system. Uranium-laden dust, primarily the "black oxide," passes through the system consisting of wool bags 22'2" in length. The heat and steam generated during the operations caused the bags to shrink, losing about 22" in length. One of the bags came loose causing the breach through which the uranium oxide escaped, resulting in a protracted, probably continuous, leak through the stacks at Plant 9. Approximately 130 lbs (60 kg) of primarily black oxide was recovered from the roof of the plant.

In another incident on November 29, two millwrights were exposed to a confined cloud of black oxide while performing an inspection at a Cyclone operation. The amount of uranium oxide dust they may have inhaled was not known.

Beginning December 17, 1984, a series of meetings were held among NIOSH investigators and other interested parties at NLO, Inc. in Fernald, Ohio. At the initial meeting, NIOSH investigators requested permission to talk with workers within the plant and to meet with the Department of Energy investigative team. The NIOSH investigators recommended that all workers normally assigned to Plant 9 undergo in vivo assay for uranium. In addition, the two millwrights who were involved in a specific incident with possible exposure on November 29 were also recommended for in vivo assay. It was also requested that all plant records be made available to the NIOSH investigators. After this meeting, the following took place:

NIOSH meeting with the Department of Energy investigation team - On December 19, 1984, NIOSH investigators were briefed on the purpose and status of the Department of Energy accident investigation team by its members.

NIOSH meeting with NLO investigation team - NIOSH investigators met on December 21, 1984, with the investigation committee appointed by NLO.

NIOSH meeting with representatives of NLO and Department of Energy representatives - On January 8, 1985, NIOSH investigators met with representatives of NLO and DOE to discuss the in vivo monitoring program and to review the results of December, 1984 monitoring of Plant 9 workers.

NIOSH meeting with hourly workers - On January 24, 1985, NIOSH investigators met with approximately 30 workers about their concerns with the recent uranium releases.

NIOSH inspection of Health and Safety Division laboratories - On April 10, 1985, NIOSH investigators visited the Health and Safety Division of NLO for the purpose of evaluating radiation safety practices, particularly with regard to some of the questions raised by the workers at the meetings that had previously taken place.

NIOSH tour of Plants 1 and 9 - On September 12, 1985, a NIOSH investigator met with NLO management to discuss the various uranium processes being used and to make a general tour of Plants 1 and 9.

Summaries of the above meetings appear in Appendix A.

IV. METHODOLOGY

An *in vivo* radiation monitor (often referred to as a whole body counter) is a sensitive radiation detection system used to detect radioactive substances such as uranium that may have accumulated in the body from ingestion, inhalation, or a puncture wound. For workers at NLO, the predominant mode of uranium exposure would be by inhalation and the most likely way to detect uranium incorporated internally would be by monitoring the lungs. An *in vivo* radiation monitor is used for this purpose and consists of three components: (1) a shield to minimize background radiation; (2) detectors that receive radiation emitted by the decay of radioactive substances incorporated in the body; and (3) an analyzer and computer that determine the type and amount of radionuclide (e.g., ^{40}K or ^{137}Cs).

The DOE Mobile Van system uses two 9" sodium iodide (with thallium phosphor) crystals for detection. The typical counting time for the workers was 20 minutes. The minimum detection level (MDL) for the Mobile Van is determined as described below.

At least several hundred people who were not occupationally exposed to uranium have been monitored by the DOE Mobile Van in the past and serve as controls. Although everyone has uranium within them due to its ubiquitous presence in the environment, the instrumentation is not sufficiently sensitive to detect naturally occurring levels of uranium; therefore, the expected result for any individual within this control population is zero. The monitoring results, however, vary considerably about zero, including negative values, due to routine instrument counting fluctuations. These results form an approximate normal distribution and one standard deviation is equivalent to 24.5 micrograms for U-235 and 2.5 mg for U-238.

A level equivalent to two standard deviations above zero is used to express the "sensitivity" or "critical level" of the counting system. The result must be above that level for a decision of "detection." The minimum detection limits (MDL) for the Mobile Van would then be 49 micrograms for U-235 and 5.0 mg for U-238. If the numerical results of the assay are below those limits, then no U-235 or U-238 is detected.

At the Argonne National Laboratory (Argonne, Illinois), the system used for the January, 1985 assay consists of a 10" diameter sodium iodide/cesium iodide crystal (referred to as a "phoswhich" detector) which detects photons in the 10 to 120 keV energy range. (1 keV is one thousand electron volts, a unit of energy.) This system differs from that of the DOE Mobile Van and the Battelle Northwest Laboratory system discussed below, in that radiation in the energy range of 12-24 keV is used for U-235 assay. The Battelle and DOE Mobile Van systems use the 186 keV photopeak for detecting U-235. (The photopeak represents a specific radiation emission characteristic of the radionuclide and thus is used to identify it.)

In addition to the "phoswhich" system, two other counting systems were used at Argonne in the September, 1985 assay. The first consists of a 6" diameter x 8" long sodium iodide crystal to detect higher energy photons. The second detection system is a 11 1/2" diameter by 1/2" thick sodium iodide crystal for detecting intermediate energy photons in the 30 to 300 keV range. Each subject was counted for 40 minutes in each system.

The Battelle Northwest Laboratory in vivo counting system consists of six high purity germanium detectors, each cooled by liquid nitrogen (Palmer and Rieksts, 1984). The total counting time for each subject was 100 minutes except for Case Number 100 which was 67 minutes.

V. EVALUATION CRITERIA

The U.S. Department of Energy (DOE) has established radiation protection standards and requirements for DOE operations and those of its contractors based upon the recommendations of the Environmental Protection Agency and the National Council on Radiation Protection and Measurements (U.S. D.O.E. Regulations 5840.1; Title 10, Code of Federal Regulations, Part 20).

The maximum permissible lung burden for uranium is the amount of uranium which, if present in the lungs, would result in a maximum permissible dose rate to the lungs. This limiting dose rate is currently 15 rems per year (a rem is a unit of radiation dose commonly used in radiation protection). To determine this limiting dose rate in any specific case, one has to take into account the isotopic composition of the uranium and its radiation emmissions spectrum (Helgeson, 1969). The DOE has provided the results of these calculations in tabular form (Table 2).

VI. RESULTS

In December, 1984, NIOSH investigators recommended that all Plant 9 and other potentially exposed workers (e.g., maintenance workers) undergo assay by the DOE whole body counting system (DOE Mobile Van) to determine body content of uranium. This recommendation was immediately carried out and the results indicated that all of the workers had a lung burden for uranium less than the maximum permissible. This implies that, if there were exposures due to recent uranium releases at the Feed Materials Production Center, then no health effects on workers from the releases would be expected. However, NIOSH investigators determined that it would be prudent to have some of the workers assayed with an independent in vivo monitoring system in order to have an indication of the validity of the DOE Mobile Van results.

It was therefore recommended that four NLO workers be sent to Argonne National Laboratory at Argonne, Illinois, for uranium in vivo monitoring. Two of these workers (NIOSH Case Numbers 22 and 26) were among the highest in uranium lung content according to the December, 1984 results. The other two were millwrights (NIOSH Case Numbers 50 and 51) who were involved in the November 29, 1985, incident.

The results of the December, 1984 and January, 1985 assays with the DOE Mobile Van and those for the January, 1985 at Argonne National Laboratory are shown in Table 1. (Note that values above the minimum detection level have an asterisk.)

Comparison of the Initial Results for the DOE Mobile Van and the Argonne Laboratory: The results of the analysis at Argonne National Laboratory were transmitted by letter on February 27, 1985. In all four cases, the values of U-235 were higher by a factor of 2 to 20 over those reported by the Mobile Van in December (see Table 1). Only Case Numbers 22 and 26 had a detectable amount of U-235. For Case Number 22, the amount of U-235 detected was equivalent to a factor of about 2 times the maximum permissible lung burden. All the values for U-238 were below the minimum detection level. The results for the DOE Mobile Van are not expressed with confidence limits in Table 1 since a standard deviation was not provided with the data.

Attempt to Resolve the Discrepancy Between the Argonne Laboratory and Mobile Van Results: On March 19, 1985, NIOSH investigators sent a letter to NLO stating their inability to resolve the discrepancies between the results of the DOE Mobile Van and those of Argonne National Laboratory. It was recommended in this letter that additional in vivo monitoring be conducted by the Battelle Pacific Northwest Laboratory in Richland, Washington. The Battelle system offers significantly better capability because of its lower detection limit for U-235 and much higher spectral resolution which would be helpful in determining whether radionuclides are present that may interfere with the detection of the uranium isotopes. In addition, it was recommended that isotopic analyses for uranium in the excreta (urine and feces) of Case Number 22 be performed by an independent laboratory. This latter recommendation was not carried out to our knowledge.

On March 30, a letter was sent to NIOSH from the Fernald Atomic Trades Labor Council (FATLC). In that letter, the Council questioned the impartiality of Battelle Pacific Northwest Laboratory because it is operated for the U.S. Department of Energy by Battelle Memorial Institute. The Council therefore stated that it was inadvisable to use that facility for the purpose that NIOSH recommended. Five alternative sites for the monitoring were recommended by the FATLC including locations in California, Canada, and Great Britain. The locations in Great Britain were not investigated by NIOSH but the other sites were.

On May 13, NIOSH investigators sent a letter to the FATLC stating that for reasons of both detection sensitivity and resolution the best system to resolve the discrepancy is that of the in vivo monitor at the Battelle Pacific Northwest Laboratory.

In Vivo Assay at the Battelle Pacific Northwest Laboratory: On September 9, 1985, Case Numbers 22 and 26 were sent by NLO, Inc. to Battelle Pacific Northwest Laboratory in Richland, Washington. Accompanying them were representatives of NIOSH, FATLC and NLO, Inc. Case Numbers 50 and 51, who participated in the monitoring at Argonne National Laboratory, chose not to take the trip. Since the representative from the FATLC is also a worker at the Fernald Plant, it was agreed that he would undergo in vivo monitoring (NIOSH Case Number 100). The results are shown in Table 1 (Battelle Laboratory 9/10/85).

Because seven months had elapsed since the previous in vivo monitoring, the assays at the Mobile Van and Argonne were repeated within at most a few days following the one at Battelle. On September 12, the three subjects were tested at the site of the Fernald plant in the DOE Mobile Van using the same protocol as the previous Mobile Van monitoring. These results are shown in Table 1 (DOE Mobile Van 9/12/85).

On September 16 the three subjects, accompanied by NIOSH and NLO representatives, were assayed at the Argonne National Laboratory. The monitoring was performed with three different detection systems, including the system used in January. The advantage of this approach is that the systems could be compared for consistency. The results are shown in Table 1 (Argonne Laboratory 9/16/85).

VII. DISCUSSION

ANALYSIS OF THE IN VIVO MONITORING RESULTS

For the Battelle Laboratory results of September 10, only one of the three subjects had detectable levels of uranium, NIOSH Case Number 22. Although these results and those of Argonne for September 16 are consistent, the DOE Mobile Van data of September 12 did not indicate any U-235 in Case No. 22 above the system's minimum detection level, that is, it did not detect any U-235.

What fraction of the maximum permissible lung burden do the values above for Case No. 22 represent? That can be determined from Table 2, provided by the Department of Energy, which lists the maximum permissible uranium lung burden for U-235 enrichment values from 0.2 to 1.5%. However, one cannot accurately determine the uranium enrichment using the data in Table 1 because of the degree of uncertainty in the values for each isotope. The weight percent of U-235 in the lungs of Case Number 22 according to the Battelle results can be estimated by the ratio of U-235 to U-238 (25 micrograms/4.7 mg) which is 0.5 percent U-235. The same calculation for the Argonne results (41 micrograms/5.7 mg) gives 0.7 percent U-235. If it is assumed that the true weight percent of U-235 in the lungs of Case Number 22 is an intermediate value of 0.6 percent, then from Table 2, 175 micrograms U-235 would be used as the maximum permissible lung burden. The Battelle results would then indicate that Case Number 22 had 14 $\pm$ 7 percent [(25 $\pm$ 12)/175] of the maximum permissible lung burden (MPLB) and the Argonne results would give 23 $\pm$ 5 percent MPLB [(41 $\pm$ 8)/175].

A worst case calculation (in the context of the present discussion) would assume that the exposure for Case Number 22 was entirely to depleted (0.2 percent U-235) uranium. NLO reported this case had been exposed to depleted uranium continually for many years until about March, 1985. From Table 2, the maximum permissible lung burden would be 100 micrograms of U-235. The Battelle results would suggest that Case Number 22 had 25 $\pm$ 12 percent MPLB and the Argonne results 41 $\pm$ 8 percent MPLB. However, if uranium in the lungs of Case Number 22 were entirely 0.2 percent U-235, then the Battelle result of 25 micrograms U-235 would be expected to be associated with 12.5 mg U-238; however, only 4.7 $\pm$ 1.1 mg U-238 was measured. In the Argonne measurement, 41 $\pm$ 8 micrograms U-235 would be associated with 20.5 $\pm$ 4.0 mg U-238; only 5.7 $\pm$ 1.0 mg U-238 was measured.

It is therefore unlikely that the uranium in the lungs of Case Number 22 is depleted, and it is likely close to natural (0.7 percent) uranium. Therefore, it is concluded that the uranium in the lungs of Case Number 22 in September, 1985 was in the range of 14 to 23 percent of the maximum permissible lung burden, as indicated previously in this section.

It is important to note that if any of the three subjects had a depleted (0.2 percent) uranium lung burden corresponding to 100 percent of the maximum permissible, it should have been easily detected by any of the 3 systems. From Table 2, that lung burden would be equivalent to 100 micrograms of U-235 which would be present along with 50 mg of U-238. For either counting system, this quantity of U-235 is approximately a factor of 8 greater than the MDL and for U-238 about a factor of 45 greater. For the DOE Mobile Van, these values would correspond to about a factor of 2 greater than the MDL for U-235 and a factor of 10 for U-238.

It is unfortunate that all four NLO subjects could not have been tested in both January and September. However, Case Numbers 22 and 26 were assayed both times. The results were lower by about a factor of 10 in September for the U-235 isotope. Apparently the U-238 isotope increased by a factor of at least 2 or 3 during this period (U-238 was not detectable in January).

Do the DOE Mobile Van results for September 12 agree with the Argonne Laboratory results of September 16? The results are not inconsistent. The values for U-235 reported by Argonne for Case Numbers 22 and 26, are below the minimum detection levels on the DOE Van System. The values reported by the DOE Van are less than the MDL for that system. The DOE Van did report two counts greater than the MDL for U-238. The value for NIOSH Case Number 22 of 6.22 mg is in agreement with the Argonne report of 5.7 $\pm$ 1.0 mg. The value of 5.21 mg of U-238 found in the one count of Case Number 26 is higher than the Argonne result of 2.4 $\pm$ 0.6 mg, but the second count (2.28 mg U-238) was below the MDL. For Case Number 100, the values reported on all three systems are below the MDL.

When the U-235 results of Argonne are compared with the Mobile Van from the January, 1985 assays, the results are indeed puzzling. As noted previously, for neither system were the results for U-238 greater than the minimum detection levels except for one of the two counts for Case Number 22 which was slightly above the MDL (6.41 mg U-238 with an MDL of 5.0 mg).

The measurements for Case Number 22 on January 21, a lung burden of 480 microgram U-235 with an upper limit of 1.6 mg U-238, would imply a U-235 enrichment of at least 30%. For Case Number 26, the enrichment would have been at least 14% (using 170 microgram U-235 and an upper limit of 1.2 mg U-238). These enrichment values are at least a factor of 10 higher than those for any other measurements with detectable levels shown in Table 1.

NLO reported that the highest enriched uranium to which Case Numbers 22 and 26 could have been exposed is 1.25%. They also noted their authorization to handle up to 19.99% enrichment and that uranium enriched greater than 10% is present on site, although only in small quantities relative to low-enriched and depleted uranium. The Argonne National Laboratory results of January 21, 1985, infer the following:

(1) The DOE Mobile Van <u>in vivo</u> monitoring system is not capable of detecting U-235 in the lungs at levels of several hundred micrograms <u>and</u>

(2) The U-235 in the lungs of Case Numbers 22 and 26 was in a soluble form that cleared the lungs and was excreted by September, 1985. The U-235 levels decreased by at least a factor of 10 in the January to September period.

The NIOSH investigators cannot determine any technical reason for assumption (1) above. Although the DOE Van in vivo system is not as sensitive as the in vivo system at Battelle and Argonne (one would not expect a mobile system to be as sensitive), the system should readily detect U-235 in the lungs at levels of hundreds of micrograms. Furthermore, no source of recent exposures has been identified for Case Numbers 22 and 26 to soluble, highly enriched (> 10%) uranium in support of assumption (2) above. Although the Argonne Laboratory results of January 21, 1985, indicate elevated U-235 lung burdens (at least for Case Number 22), the results of this measurement are insufficient to conclude that the DOE Mobile Van in vivo monitor is not capable of detecting uranium lung burdens greater than the current maximum permissible levels. However, the DOE should undertake a study to compare directly the in vivo monitoring systems used by its Mobile Van and that of Argonne National Laboratory.

REPORTING OF IN VIVO MONITORING RESULTS

A problem noted during this investigation is the way NLO and DOE reported to the worker results of the in vivo monitoring. As stated previously, all monitoring systems have a minimum detection level (MDL). The DOE Mobile Van has an MDL for the uranium isotopes determined by monitoring subjects who have not been occupationally exposed to uranium. These results yield an MDL for U-235 of 49 micrograms and for U-238 5.0 mg; apparently NLO and the DOE do not consider this when they report monitoring results.

Let us take a specific example. On September 12, 1985, two 20 minute assays were performed on NIOSH Case Number 26. For the first count, NLO reported to the subject that he had 16% of the MPLB and for the second count 11%. When the specific results of the monitoring are examined, it is seen that for the first count the amount of U-235 reported was 23.4 micrograms which is below the MDL. The amount of U-238 reported, 5.21 mg, is only slightly above the MDL. However, both of these values were used to determine the uranium enrichment "present" in the lungs. By taking the ratio U-235/U-238 one arrives at a value of 0.45% which gives a MPLB of 146 micrograms U-235 from Table 2. Using the reported value of 23.4 micrograms, it was then calculated that the percentage of MPLB was 16% (23.4/146).

The problem with this calculation is that no U-235 was detected. The value reported is within the expected range (< 1 standard deviation) of values for control subjects without any detectable levels of uranium isotopes. Although the U-238 result was above the MDL, it was not high enough to be quantified with any degree of certainty, i.e., at best one could say that U-238 was detected, but one cannot say from this count how much U-238 was present. The numbers reported were used as if they represented actual detected amounts in order to arrive at a number which is supposed to represent the percentage of MPLB present. But this calculated percentage is meaningless.

The problem is compounded in the case of the second count for which both values for U-235 and U-238 were below their respective MDL. Nevertheless, these values were treated as if they represented amounts of the isotopes present, which they do not, and they were used to calculate a percentage of MPLB present, when no uranium was detected.

The primary problem with this method of reporting is the confusion that it gives to the workers. In meetings that NIOSH investigators had with them, one of the questions that arose several times was why the amount of uranium between *in vivo* assays changed as much as reported. For example, one worker was puzzled that his reported lung burden doubled after he worked a year in a "cleaner" area.

Apparently, NLO and DOE have been too concerned with giving the workers a number, without sufficient concern as to whether the number is meaningful. Clearly the DOE Mobile Van is a screening system, the value of which is to determine whether the workers have lung burdens approaching or greater than permissible levels. Exactly how near maximum permissible levels the system can quantify cannot be readily determined by us. This minimum quantitation level (as opposed to minimum detection level) should be determined by DOE and the workers should be told following monitoring whether uranium was detected and if so whether it is below the minimum level that can be quantified and what that level is. If it is above that level, then further counting is called for to yield a reasonable estimate of the amount present.

The workers at the Fernald plant should have available an *in vivo* assay facility comparable to that of the present Battelle Pacific Northwest Laboratory which represents state-of-the-art. The purpose of this recommendation is to provide a permanent facility on or reasonably near the site so that uranium burdens can be determined in all of the workers as accurately as possible using state-of-the-art technology. By monitoring frequently and accurately the body content of uranium, the management of the Fernald Plant can ascertain: (a) whether any accidental exposures have occurred soon after an incident as well as (b) the effectiveness of any program designed to provide a working environment with uranium exposures as low as reasonably achievable.

CONCLUSIONS

The purpose of this NIOSH investigation was to assess the extent of uranium exposure and the potential health effects on workers of the releases of uranium during November and December, 1984 at the Feed

Materials Production Counter operated by NLO, Inc. The NIOSH team, throughout its investigation, obtained the complete cooperation of NLO, Inc., the U.S. Department of Energy, the Atomic Trades Labor Council, and the workers.

Upon reviewing the data obtained from the Department of Energy Mobile Van used for the in vivo monitoring of workers, it is concluded that if there were any internal uranium contamination of the workers, the levels of contamination were below maximum permissible lung burdens permitted by the U.S. Department of Energy and therefore no adverse health effects would be expected.

It is also concluded that there should be an independent check on the DOE Mobile Van in vivo monitoring system. In the course of carrying this out, an apparent discrepancy was detected. However, this discrepancy was not found to be due to any deficiency in the DOE Mobile Van system. Although this system is capable of detecting uranium lung burdens greater than the maximum permissible, there should be a more accurate detection system available for the in vivo assays. With a more sensitive system permanently in place and used regularly for worker monitoring, the management of the Feed Materials Production Plant at Fernald can ascertain whether any accidental exposures have occurred soon after an incident as well as the effectiveness of any program designed to provide a working environment with uranium exposures as low as practical.

VIII. RECOMMENDATIONS

At the time of this report, the Feed Materials Production Center is under the management of Westinghouse Materials Corporation and no longer NLO, Inc. It is recognized that concerns expressed in this report may have already been addressed by Westinghouse. Nevertheless, in view of the findings of this investigation, the following recommendations are made to ameliorate existing or potential hazards and to provide a better working environment:

1. The Feed Materials Production Center should construct or obtain access to a permanent in vivo assay facility on or near the Plant for monitoring as accurately as possible uranium and other radionuclides to which the worker may be exposed. This facility should be state-of-the-art, and NIOSH recommends that the in vivo assay facility at the Battelle Pacific Northwest Laboratory be used as the model.

2. The entire program of in vivo assays for the workers who have potential exposure to uranium should be revised. Lung counting for uranium isotopes should be performed on all workers semiannually for a period of several years. Following that, the monitoring data should be reviewed to determine whether more or less frequent lung monitoring is required. The extent of other

routine monitoring such as urinalysis or fecal analysis should be determined based on the chemical/physical form of the material processed at the Plant. A formal, rigorous protocol for in vivo monitoring should be developed and implemented with a two-fold purpose: (a) determine and document whether the individual worker's exposure is below regulatory and administrative limits, and (b) determine whether the worker's exposure is kept as low as is practicable.

3. There is a need for better communication between the health physics and industrial hygiene personnel on the one hand, and the workers throughout the Feed Materials Production Center on the other. The workers should understand such matters as how basic radiation survey measurements are performed and how permissible work time is determined. They should feel free to discuss health and safety concerns with members of that Division. Informative presentations and discussions should be held at regular intervals involving the workers and Health and Safety personnel.

4. The Feed Materials Production Center should communicate clearly to their employees the protection afforded them against discrimination for any testimony or proceeding related to matters of safety and health at the Plant. Assurance of such protection is in concert with provisions of the Occupational Safety and Health Act and the Federal Executive Order applicable to federally operated facilities.

5. There is a need for more radiation safety training courses for all workers, including supervisors; consideration should be given to having annual refresher training courses.

6. All measurement and monitoring techniques in the Health and Safety Division should have documented and approved (both by DOE and management) standard operating procedures.

7. The Health and Safety Division should re-evaluate the need for respiratory protection for machinists who machine uranium ingots, with regard to DOE/NRC regulations and good radiation protection practice. Particular attention should be given to the inhalation hazards from "chip fires" that occur during machining.

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XI. DISTRIBUTION AND AVAILABILITY OF REPORT

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1. Feed Materials Production Center
2. Westinghouse Materials Corporation
3. NLO, Inc.
4. Fernald Atomic Trades Labor Council
5. Ohio Department of Health
6. Congressional Representatives
7. OSHA, Region V
8. Others, as requested

For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

APPENDIX A - SUMMARY OF MEETINGS HELD BY NIOSH INVESTIGATORS

This appendix is a summary of the meetings between NIOSH investigators and others involved with the release of uranium from November 16 through December 7, 1984, at the U.S. Department of Energy's Feed Materials Production Center in Fernald, Ohio.

A. INITIAL NIOSH MEETING AT NLO

On December 17, 1984, NIOSH investigators met with representatives of NLO, Inc., the U. S. Department of Energy, the Atomic Trades Labor Council (ATLC), and the Office of Congressman Luken.

According to NLO management, during the period from November 16 to December 7, 1984, approximately 270 pounds (120 kg) of uranium oxide in the form of U_3O_8 was released from "bag house" operations in Plant 9. During the operations in Plant 9, crucibles containing uranium oxide are burned out, generating dust and a high vacuum system pulls the dust through the bagging system. The source of the leak was a bag that had come loose on a stack within Plant 9. NLO management stated that the NIOSH investigators could have complete access to the site for its investigation and to whatever records NIOSH investigators required as long as the Department of Energy (DOE) granted permission.

The ATLC requested assurance that NIOSH would be allowed to investigate the incident completely, including hearing testimony from workers. Also requested was assurance that the the workers giving testimony and cooperating with NIOSH would pose no security violation. The final request was that there be no reprisal to any of the workers from management for cooperating with the NIOSH investigative team. A written statement was requested, stating that the worker shall have complete immunity from the act of cooperating in the investigation.

The Department of Energy (DOE) representative stated that DOE intended to give all records to NIOSH; however, access would have to come through formal channels. DOE could immediately give complete access to the plant to NIOSH. DOE also formed an investigation team which included three outside experts to look at the bag collecting operations in Plant 9.

At the meeting, NIOSH investigators requested permission to talk with workers within the plant and to meet with the Department of Energy investigative team. They further requested that NLO send letters to the workers assuring no reprisal for those who cooperate with the NIOSH investigative team. NIOSH recommended that all workers normally assigned to Plant 9 undergo in vivo assay for uranium. In addition, two millwrights who were involved in a specific incident with possible exposure on November 29 (see below) were also recommended for in vivo assay. NIOSH investigators requested that all plant records be made available.

NLO management stated that the company considers both medical and exposure records as Department of Energy records and that there were three separate investigative teams, one from NLO, one from the parent company, NL, Inc., and one from the U.S. Department of Energy.

On December 18, 1984, a letter was sent by the NIOSH investigators to all members present at the December 17 meeting, giving the following recommendations:

1. A statement should be provided by NLO, Inc. which reiterates the protection afforded to workers against discrimination for any testimony or proceeding related to health and safety matters at the plant. Assurance of such protection is in concert with provisions of the Occupational Safety and Health Act and the Federal Executive Order applicable to federally operated facilities. Further, security requirements should be clarified with the employees with respect to Plant 9 operations, so that workers who wish to come forward to disclose information related to the uranium release may be informed of any potential breach of their security clearances.

2. Workers should be given the opportunity to have private interviews with NIOSH investigators in the course of their evaluation pursuant to NIOSH regulations (42 CFR Part 85) on the conduct of health hazard evaluations. Under these regulations, NIOSH will protect the privacy of workers and protect against potential breeches of security, if applicable, by using NIOSH investigators having appropriate security clearances.

3. NIOSH investigators should be apprised of current ongoing DOE/NLO investigations being conducted at NLO, Inc. related to the uranium release. Based upon these investigations and information/results available, NIOSH will conduct further investigations of the uranium release as it deems necessary to protect the health and safety of NLO, Inc. workers.

4. It recommended that all NLO, Inc. Plant 9 workers and other potentially exposed workers (e.g., maintenance) undergo in vivo testing via the DOE whole body counter as soon as possible to determine body content of uranium.

5. NIOSH awaits final determination by DOE for the access to NLO, Inc. workers' personal exposure and medical records. DOE final determination is expected within 30 days, whereupon, NIOSH investigators will begin working with NLO/DOE to access the data. Review of this data will continue the ongoing health hazard evaluation previously requested (NIOSH Health Evaluation and Technical Assistance request number 83-144) and help NIOSH evaluate the workers concerns, particularly those related to chronic respiratory disease.

B. NIOSH MEETING WITH DEPARTMENT OF ENERGY INVESTIGATIVE TEAM

On December 19, 1984, NIOSH investigators were briefed on the purpose and status of the Department of Energy accident investigation team by its members. The team was appointed on December 10 and arrived at NLO on December 12. They adopted the Management Oversight and Risk Tree (MORT) system, a formal system that is an aid in determining what happened and why. The team came from Oak Ridge, Tenn., and brought the DOE Mobile Van Monitor (under contract to the Martin-Marietta Corp.) which had been in operation since December 19 to perform in vivo assays for uranium in those residents from the surrounding community who volunteered to take part.

Seventeen NLO workers had been interviewed by the team, including maintenance workers, maintenance supervisors, and each layer of management above maintenance supervisors including first line managers. It was emphasized that there was no intention to keep anything from NIOSH or in any way impede NIOSH's investigation.

According to the DOE investigators, the gas drying of operations within Plant 9 are vented through the bagging system. Uranium laden dust, primarily "black oxide" (U_3O_8), passes through a bagging system where it is captured. The bags used are of wool, 22'2" in length. The heat and steam generated during the operations cause the bags to shrink, losing about 22" in length. A bag came loose, causing the breach through which the uranium oxide escaped. The breach resulted in a protracted and probably continuous leak through the stacks at Plant 9. From November 16 to December 7, they estimated that 374 pounds (170 kg) were released. They noted that approximately 132 pounds (60 kg) of primarily black oxide had been recovered from the roof of Plant 9. They also noted that on November 27 there was a fire at a Cyclone operation. Two millwrights performed an inspection at the Cyclone on November 29 that resulted in their exposure to an unknown amount of a confined cloud of black oxide.

C. NIOSH MEETING WITH THE NLO INVESTIGATION COMMITTEE

NIOSH investigators met on December 21, 1984, with the investigation committee appointed by NLO on December 13. Also present at the meeting were representatives of NL, Inc., the parent company. A representative stated that if the NIOSH investigators needed any information from the parent company, they would be happy to comply.

The purpose of the NLO investigative team was to examine, in an unbiased fashion, all the data that had been collected about the release incident. Specifically, they planned to examine the condition of the dust collector in Plant 9 and to determine the magnitude of the release. They stated that a brief review of the history of releases from the stacks at NLO indicated that in the 1960's about 1,000 kg of uranium was released annually, but in 1983 only 115 kg of uranium was released from the 70 stacks in the plant.

Five NLO workers had undergone assay for uranium on the DOE Mobile Van. The results of these assays, without personal identifiers, were reviewed. The results were expressed as percent of maximum permissible lung burden (MPLB) for uranium; that is, the maximum amount of uranium permitted in the lungs of workers as determined by the Department of Energy. The results varied from 3% to 15% with an average of 7%.

At the conclusion of this meeting, NIOSH investigators met with an officer of the ATLC who stated that his primary concern was the safety of the worker and the workplace. He stated that on November 27 there was a fire in the Cyclone operations and on November 29 at 5:50 p.m. two millwrights were exposed to black oxide during an inspection at the site of the fire. On December 13, NLO management phoned to inform him of the incident.

D. NIOSH MEETING WITH NLO AND DOE REPRESENTATIVES

On January 8, 1985, NIOSH investigators met with representatives of NLO and DOE to discuss the DOE in vivo counting system (Mobile Van). To determine U-238 activity, they assume that the U-238 is in equilibrium with Thorium-234, and the gamma ray emission spectrum from the Thorium-234 is used to identify and quantify it. (This is the same procedure used at the Battelle Pacific Northwest Laboratory.)

The results of the uranium assays using the DOE Mobile Van for the workers in Plant 9 were reviewed. All workers had MPLB's less than maximum permissible by the DOE. The results of the urinalyses for uranium were also reviewed and there was no indication of elevated uranium levels. NLO uses fluorometric analysis (a chemical assay) for uranium in urine and the level for which administrative action is taken is 40 micrograms/liter or greater.

The protocol and methodology for assaying for uranium using the Mobile Van was reviewed. This included an inspection of the detection system, with explanations of the various system components.

E. NIOSH MEETING WITH HOURLY WORKERS ON JANUARY 24, 1985

On January 24, 1985, NIOSH investigators met with approximately 30 workers (most of them were millwrights). No management representatives were present. The workers were told by Union Representatives that the union was recommending full participation in the DOE Mobile Van counting.

Several millwrights questioned the policy of maximum allowable time in an area, which seemed to be determined arbitrarily. They believed that radiation safety was being compromised and that the Health and Safety Division personnel were working with management to get jobs done too quickly. Much concern was expressed with regard to the radiation monitoring. Several felt that those who used the survey instruments were not qualified and doubted that these instruments were properly calibrated. One worker expressed the belief that the motto around the company seemed to be "production first, safety second."

A millwright stated that, in one particular instance, 10 hours was the maximum allowable time for a specific job to be performed. Subsequently, the area had been cleaned of its radioactive contamination and the maximum allowable time scheduled later was reduced to 6 hours. Since the room had presumably been decontaminated, he did not understand why the maximum allowable time became significantly shorter. This is illustrative of the kinds of apparent contradictions that confused the workers.

In addition to their concerns about radiation, there were several workers who complained about breathing-air in their respirators when the air was provided from compressors. One worker noted that the air from a compressor was used both for instrumentation and breathing, and that filters in an air line going into an instrument were found to be covered with oil.

Workers also complained about carbon monoxide getting into the air lines. One worker was dismayed that it presumably took one year to get carbon monoxide monitors to tie into the breathing air lines. There was a feeling among some that the lines should be purged following activation of the carbon monoxide alarm because it takes time for the carbon monoxide in the system to dissipate.

A general distrust was expressed, not only of the technicians, but also the supervisors, in the Health and Safety Division. One worker presented the following incident:

> On the 6th or 7th of November, 1985, alarms were set off at about 10:00 p.m. The alarms are mechanical ones activated by differential pressure. Their purpose is to alert personnel to a leak in the "bag assembly" through which the uranium-laden dust passes. The worker told

the foreman that there appeared to be a problem and Health and Safety should be alerted, but the foreman did not do so. Instead, the alarm was silenced and the workers were required to keep working. "Management was aware of the malfunction and they elected to bypass the alarm system."

The workers were asked how many have been monitored by the DOE Mobile Van and how frequently. It was generally agreed that new employees were not monitored and that the maintenance workers were monitored every two years, although there were some exceptions to this.

At the conclusion of this meeting NIOSH investigators met with NLO management to brief them on the general discussion with the workers, expressing in particular the concern that workers had with breathing air from the compressors, although this was not part of the present NIOSH investigation.

F. NIOSH INSPECTION OF HEALTH AND SAFETY DIVISION LABORATORIES

On April 10, 1985, NIOSH investigators visited the Health and Safety Division of NLO for the purpose of evaluating radiation safety practices, particularly with regard to some of the questions raised by the workers at the meetings that had previously taken place involving workers and NIOSH. The observations made during the April 10 inspection are summarized below by topic.

Staff Size: The Division is divided into 2 areas - Industrial Hygiene (IH) and Health Physics (HP). Within the Division there were 13 people: 4 professionals in IH, 2 professionals in HP, and the remaining were technicians shared between the two areas.

Equipment: There were about 20 portable radiation detectors for field use - "pancake" Geiger-Mueller (2-3), Zn scintillator (6-7), and side window Geiger-Mueller (10-11). In addition, there were 4 scintillation alpha counters, 3 gas flow proportional counters, one automatic proportional counter, and other laboratory-oriented system counters.

Maintenance/Calibration of Equipment: Maintenance and calibration was carried out by the Bioassay Division which is independent of the Health and Safety Division. In the past DOE had given this area high marks. All field detectors were maintained by NLO - rarely did anything go to the manufacturer for repair or maintenance. Log books were checked, and appeared reasonable for the last 3 years; written calibration techniques existed and appeared to be followed. Detectors were calibrated with Ra-226 using the $1/R^2$ approach. The technician in charge of the calibration/maintenance program appeared qualified for the electronics area. However, he stated that he had received only 1 hour of on-the-job-training in radiation safety.

One of the portable instruments was labeled "30% High" (this was brought up as a concern by a worker in a previous meeting with NIOSH investigators). It was explained that one of five meter scales on this instrument reads high, and that is the highest scale, which is rarely needed. There was only one such meter and it was used only as a back-up to another calibrated meter when it is returned to the manufacturer.

Contamination ("Swipe") Records: During 1984 a contamination control program was started at NLO using "swipe tests." However, very little data existed in this program.

Technique of Measurements: Standard Operating Procedures (SOPs) have not been written or approved by higher management for use in many of the health physics areas. It is estimated that 40-50% of the needed SOPs exist. However, some were written for the important area of calibration.

Protective Equipment: The issue of respirators was identified as a worker concern in a previous meeting with workers. HP & IH persons told NIOSH investigators that straps on the respirators did become contaminated and in many cases low level contamination becomes embedded in the straps.

Apparently gloves need to be checked for cracks due to use around acidic material; small cracks appear in them after extended use. HP and IH personnel were fully aware of this situation, however, and no control measures were discussed for this problem.

One oil compressor produced oil mist in December, 1984 - at present it is not operating (but no one stated it had been repaired). Carbon monoxide lines are not always purged - the industrial hygienist claimed it may not need to be done due to the low levels.

NIOSH investigators were told that, of 1100 employees last year, the highest penetrating and non-penetrating doses recorded were 1 R and 11 R, respectively.

Work Permit: Upon request, the HP technicians go to the area and record worker exposure. Based upon the exposure, a permissible work time is evaluated. The workers and supervisors are responsible for adherence to that time. If there is a complex work situation, then the highest exposure measured over several sites is used. The NLO administrative control level is 300 mR/week. The HP technician told us that typically a 30 min duration is used. Since different HP technicians might be called into the same area at different times to measure exposure, it is entirely possible to have different permissible time evaluations. Depending on the location of the measurement, time estimates could vary greatly. This is a radiation safety concern that is difficult to explain to workers. The technicians never stop an operation or suggest that the worker has been in an area too long. The technicians do not have any authority, other than to write down non-compliance items and submit them through appropriate channels.

The HP technicians have at least a Bachelor's degree or have attended college for 2 years. They rarely acquire more than on-the-job-training at NLO. Refresher training would be useful in addition to work permit evaluations. The technicians also perform basic HP surveys, certify transportation shipments, prepare NLO badges, and spend approximately 30-40% of their time in the field.

G. NIOSH TOUR OF PLANTS 1 AND 9

On September 12, 1985, a NIOSH investigator met with NLO management to discuss the various uranium processes used and to make a general tour of Plants 1 and 9. It was explained that there are two primary product streams at NLO, one involving depleted uranium, containing 0.2% U-235 (natural uranium is 0.7% U-235). The other product is slightly enriched uranium in which the U-235 isotope is either 0.95% or 1.25% abundant. NLO has handled small amounts of more highly enriched material in Plant 1. It is authorized by the Department of Energy to receive up to 20% enriched uranium, but generally the highest enrichment is 6% and is used in Plant 1, where reactor fuel rod splitting takes place.

On the tour of Plant 1, there were a number of opened fuel rod casings labeled with 3.9% enrichment. No respirator use was posted, but the work in the area appeared to be carried out in hoods. However, one hood that had a visual air flow indicator adjacent to the "safe geometry dissolver" was not marked to indicate whether there was adequate flow present. Clear instructions were posted for working with uranium enriched up to 10%.

In Plant 9, there were a number of uranium ingots stored throughout the plant labeled 0.2% depleted or 1.25% enriched. The area was not posted for respirator use. During the tour, machining was taking place on a uranium ingot and a "chip fire" occurred during the operation. With smoke being generated, no respirators were being worn by the machinists. In talking with workers in other meetings, it was noted that machining fires occur occasionally, especially during the sawing of ingots for sampling or for chemical purity assay .

TABLE 1: *In Vivo* Monitoring Results for ^{235}U and ^{238}U (in parentheses) for 5 NLO Workers. The Values for ^{235}U are expressed in units of micrograms and those for ^{238}U in milligrams.

NIOSH Case #	DOE Mobile Van December, 1984	Argonne Laboratory 1/21/85	DOE Mobile Van 1/22/85	Battelle Laboratory 9/10/85	DOE Mobile Van 9/12/85	Argonne Laboratory 9/16/85
22	55.6*	480 ± 140*	18.8 42.1	25 ± 12*	11.5 12.6	41 ± 8*
	(13.4*)	(< 1.6)	(6.41*) (3.45)	(4.7 ± 1.1*)	(6.22*) (3.32)	(5.7 ± 1.0*)
26	82.8*	170 ± 120*	36.2 31.6	13 ± 11	23.4 27.7	17 ± 8*
	(4.05)	(< 1.2)	(1.59) (3.27)	(0.47 ± 1.0)	(5.21*) (2.28)	(2.4 ± 0.6*)
50	39.9	170 ± 280	4.02 14.6			
	(0.140)	(< 1.8)	(-5.02) (-3.56)	--	--	--
51	9.56	190 ± 240	9.76 13.6			
	(-2.46)	(< 1.6)	(-4.33) (-4.35)	--	--	--
100				12 ± 17	-7.96 -7.61	31 ± 34
	--	--	--	(0.63 ± 1.6)	(1.27) (0.47)	(4.3 ± 4.8)

*Values above the minimum detection level (MDL)

TABLE 2

MAXIMUM PERMISSIBLE URANIUM LUNG BURDENS

FOR VARIOUS U-235 ENRICHMENTS

Enrich. (% U-235)	U-235 (µg)	Enrich. (% U-235)	U-235 (µg)	Enrich. (% U-235)	U-235 (µg)
0.20	100	0.50	156	0.80	212
0.21	102	0.51	158	0.81	214
0.22	104	0.52	160	0.82	216
0.23	105	0.53	162	0.83	218
0.24	107	0.54	163	0.84	220
0.25	109	0.55	165	0.85	222
0.26	111	0.56	167	0.86	224
0.27	113	0.57	169	0.87	226
0.28	115	0.58	171	0.88	227
0.29	116	0.59	173	0.89	229
0.30	118	0.60	175	0.90	231
0.31	120	0.61	176	0.91	233
0.32	122	0.62	178	0.92	235
0.33	124	0.63	180	0.93	237
0.34	126	0.64	182	0.94	239
0.35	128	0.65	184	0.95	240
0.36	129	0.66	186	0.96	242
0.37	132	0.67	188	0.97	244
0.38	133	0.68	190	0.98	246
0.39	135	0.69	192	0.99	248
0.40	137	0.70	193	1.0	250
0.41	139	0.71	195	1.1	252
0.42	141	0.72	197	1.2	254
0.43	143	0.73	199	1.3	255
0.44	145	0.74	201	1.4	257
0.45	146	0.75	202	1.5	260
0.46	148	0.76	205		
0.47	150	0.77	206		
0.48	152	0.78	208		
0.49	154	0.79	210		

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