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UCRL-TR-221217

2005 Annual Health Physics Report for HEU Transparency Program

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May 8, 2006

This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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During the 2005 calendar year, LLNL provided health physics support for the Highly Enriched Uranium Transparency Program (HEU-TP) in external and internal radiation protection and technical expertise into matters related to BDMS radioactive sources and Russian radiation safety regulatory compliance. For the calendar year 2005, there were 161 person-trips that required dose monitoring of the U.S. monitors. Of the 161 person-trips, 149 person-trips were SMVs and 12 person-trips were Transparency Monitoring Office (TMO) trips. Additionally, there were 11 monitoring visits by TMO monitors to facilities other than UEIE and 3 to UEIE itself. There were two monitoring visits (source changes) that were back to back with 16 monitors. Each of these concurring visits were treated as single person-trips for dosimetry purposes. Counted individually, there were 191 individual person-visits in 2005. The LLNL Safety Laboratories' Division provided the dosimetry services for the HEU-TP monitors.

External Dosimetry

LLNL provided 1004 TLD dosimeters in 2005 for monitoring for potential external dose: 344 personal dosimeters, 480 control dosimeters and 180 spares to UEIE and TMC in Moscow. Approximately 590 of the dosimeters supplied were returned and were not read. This number includes the unused spare dosimeters from UEIE and Moscow and both the personal and control arbitration TLDs left in Russia until a post trip dose letter is provided. The current agreements require only one set of two U.S. TLDs for each monitor visiting any of the Russian plants. An additional 77 dosimeters were used for an ongoing study of the impact of the airport x-ray security screening on the TLD recorded dose.

In 2005, all HEU-TP monitors went on assignments in Russia with a complete set of personal and control dosimeters. In order to avoid a failure of a trip mission due to lost dosimeters at customs, a pool of 60 spare dosimeters is maintained at TMC in Moscow, in addition to the 30 spare TLDs at the TMO. The spare dosimeters are exchanged semi-annually. Customs letters for both the U.S. and Russian customs were included in the dosimeters packages for each trip to facilitate customs inspections if needed. LLNL retrieved all 2005 arbitration dosimeters from the monitored Russian nuclear facilities with the exception of the arbitration TLDs for the last trips. These arbitration TLDs will be retrieved by the first trips in 2006.

In 2005 LLNL provided DOE's HEU-TP management with post trip dose reports after each trip. All HEU monitors received zero doses from external radiation exposure in 2005. Based on our studies of the x-ray exposure during flight and during luggage screening at airports, the reliable lower limit of external dose (TLD) determination was set to 20 mrem in the first quarter of 2005. Evaluation of the new limit according to the DOE Standard for Performance Testing of Personnel Dosimetry Systems DOE/EH-0027 is provided in Appendix A, reporoducedfrom the 2004 Annual Health Physics Report.

External dose investigations
For any dosimeter reading above 10 mrem, the arbitration TLD was analyzed together with the reported dose from the Russian TLD (if provided to the US team) in order to get assurance that the monitor has/ has not received occupational dose from the HEU assignment in Russia. There were six external dose investigations of measured individual doses by the TLDs (MPA – 2; UEIE – 1; ECP – 0; SChE – 3). These results in question were very close to the investigation limit (10 mrem) and there is indication that they were caused by radiation type or levels very unlikely to be encountered in the visited facilities or caused by issues associated with the control TLDs. Furthermore, the information about the activities, area visited and time spent by the monitors did not support the likelihood of significant occupational exposures. The investigations in all cases determined that the TLD readings were not associated with occupational exposure; rather they were likely caused by multiple exposures at airport luggage x-ray screenings and statistical fluctuations. The accumulated personal dose history, the arbitration TLDs, and the radiological data from the plants were very helpful for resolving the exposure investigations.

Exposures from screening luggage at airports
LLNL conducted studies of the effect of airport security x-ray screening of the checked-in and hand-carried luggage. The tests indicate that checked-in luggage on international and domestic flights is exposed, on average, to 20-80 mrem (and in some cases on non-HEU foreign travel, to over 200 mrem). There is evidence that not all airports (domestic and international) have installed or use new x-ray units with increased exposure levels. The average dose data from the x-ray screening of checked-in luggage from trips to Ekaterinburg, Seversk, Tomsk, Washington D.C., and New York (JFK) was provided in last year's Annual Health Physics report, Appendix B. On the other hand, the hand-carried luggage on international and domestic flights is exposed on average to 1-8 mrem. A detailed discussion on the impact of these exposures was provided to HEU management in a November 11, 2003 memo. To minimize the effects of airport x-ray screening on the evaluated personal doses, our procedures require that the TLDs be transported in a hand-carried luggage.

No other external dose and radiation safety concerns were raised during the 2005 calendar year.

Internal Dosimetry

A total of 173 bioassay samples were submitted in 2005: 156 post-trip (for uranium) and 17 baseline samples (for uranium and plutonium). There are 5 outstanding bioassay samples yet to be submitted. All HEU-TP monitors who participated in assignments in Russian uranium processing facilities have provided baseline bioassay samples. All analyzed bioassay samples from 2005 calendar year showed results that were below or at the normal background level. Currently there are 17 bioassay samples that are in the process of being analyzed. No other internal dose and corresponding radiation safety concerns were raised during 2005 year. The internal dose is assigned based on the bioassay result (content of uranium compounds in urine), appropriate biokinetic models, chemical and physical form of uranium compounds and other pertinent information. The minimum detectable internal dose (MDD) from uranium bioassays depends on several factors, two of which are the chemical and physical form of the uranium compound and the time elapsed between a potential uranium intake and the time the bioassay sample was provided. Appendix B provides values of MDD for various uranium compounds and times of providing the bioassay sample. The information underscores the importance of providing a bioassay sample as soon as possible and of adhering to the safety precautions.

In 2005, LLNL provided DOE's HEU-TP management with quarterly internal dose reports (bioassay reports) containing information on the internal dose, the baseline bioassays, the procedure compliance and the status of bioassay samples received, analyzed and in process of being analyzed. The established bioassay procedure requires each monitor to provide a post trip bioassay sample within 3 days of arrival in the USA. For 2005 calendar year, 92% of the samples were in compliance with this requirement, with the average time interval between the arrival of the monitors in the USA and the providing of the post trip bioassay sample being 1.42 days. Only 6 monitors have provided bioassay sample more than 10 days after their return to the U.S.A. Appendix C of this report has a chart providing information on the bioassay sample compliance for 2005 calendar year.

HEU health physics information database

LLNL maintains a confidential database for the HEU radiation protection data. The database contains historical external and internal dose information for every HEU-TIP monitor, as well as specific information for each trip, TLDs supplied, returned or left in Russia, baseline bioassays, and monitor's data. The health physics database is essential for generating the post trip and the annual dose reports. The HEU health physics database was modified in 2005 to meet DOE requirements for handling of confidential information. Further changes that need to be incorporated include the tracking of the quarterly bioassay reports and the annual reports to DOE and to individual monitors. In order to comply with the provisions of the Privacy Act of 1984, we have obtained and filed signed Radiation Exposure Release forms for all HEU-TP monitors that had assignments in the calendar 2005. This information is also kept in the health physics database and is updated as new monitors are added to the active monitors list. The individual annual occupational dose information for each monitor for 2005, detailing the total dose as well as the external and internal doses from each monitoring assignment, was mailed to each monitor in the first quarter of 2006.

2005 Radiological data from the Russian plants

The 2005 radiological data, received from the Russian uranium processing plants under the HEU agreement, do not indicate that there are radiological concerns for the U.S. monitors working in Russia who follow the work and personnel protection guidelines. Plant's radiological data include gamma exposure rates, airborne and removable surface contamination levels in the areas visited by the U.S. monitors. These data supplement the information from the U.S. dosimeters and the bioassay sample analysis. In 2005 agreements have been reached or confirmed with plant's radiation safety management to provide the radiological data in more useful form to us. From radiation safety point of view specific radiological data should be available for each time interval (hour) the U.S. monitors are in a radiological environment. Since such detailed data are not likely to be provided by the plants, an acceptable compromise is to have data averaged over one day or less desirable averaged over the 5 working days of a SMV. As per these verbal agreements, next year (2006) the U.S. teams are expected to receive plant's radiological data as follows:

- MPA – Data for each monitoring day will be provided at the end of the current SMV. Each day data will be on a separate sheet. There is no change in the data form from the previous year.
- ECP - Data for each monitoring day will be provided at the next SMV. The agreement was reached during the source change in March 2005. Prior to that SMV the data used to be provided averaged for a calendar quarter.
- SChE - Data will be provided averaged over the five SMV days at the end of the current SMV. No change is anticipated in the data format from 2005 year.
- UEIE - *for SMVs assignments*

  Averaged over the five SMV days data will be provided during the next SMV or to the TMO monitors. The data need to be requested in writing each time. This agreement was achieved during the source change in December 2005. Up until now the data were provided irregularly (in intervals from two to six months) and averaged over various periods (from 2 to 6 months).

  for TMO assignments

  Data will be provided averaged over one month upon a written request. This agreement was achieved during the source change in December 2005. Prior to December 2005, one set of data were provided for SMV and TMO monitors averaged over irregular periods varying from 2 to 6 months.

The graphs in Appendix D (Appendix D is a separate C/FIG-MOD document) provide the gamma exposure levels, airborne and surface contamination in the monitoring points for each of the plants in 2005. The guiding action levels are provided at the left of the graphs. Some surface contamination values for the Siberian Chemical Enterprise (SChE) conversion plant exceed the “low dose level” (no U.S. concern level) which provides further emphasis to the requirement that monitors use personal protective equipment (lab coats, gloves, etc.) and avoid touching Russian equipment. Detailed plant radiological data along with the action levels and the recommended precautions were included in the dosimetry package for each SMV and TMO trip in 2005.

Health physics support of the BDMS activities

During CY 2005 LLNL provided support in the dose rate measurements around the Blend Down Monitoring Systems (BDMSs) for Russian regulatory compliance and in the development of procedures for the californium sources relative measurements. LLNL also provided neutron dosimetry support to the Ural Electrochemical Integrated Plant (UEIE), Russian Federal Nuclear Center - Institute of Technical Physics (VNIITF, C-70) and ElectroChemical Plant, Zelenogorsk (ECP).

Neutron and gamma dose rate measurements for regulatory compliance
The quality of the dose rate measurements for regulatory compliance was significantly improved at all sites in 2005. A consistent dose rate measurement methodology was used in all Russian plants. This methodology improves the accuracy and allows a better comparison of measurement results from different years and different sources. The improved quality and accuracy of the measurement results provide additional confidence in the source characteristics and their proper installation and manipulation. During the UEIE and ECP source replacement visits, detailed dose rate measurements were performed and the measurement results were included in the radiation safety reports. The radiation safety reports indicate that during and after source installation and source replacement the individual doses, as well as the gamma and neutron dose rates around the BDMS, did not exceed the Russian radiation safety limits. We now apply more relaxed radiation dose rate regulatory limits based on lower occupancy levels of the BDMS premises at all three plants. The relaxed limits will allow the use of stronger sources that can improve the accuracy of the mass flow measurement and can increase the time between source changes resulting in substantial savings to the HEU-TP.

Relative Cf source measurements
LLNL assisted in developing procedures for the californium sources relative measurements at the blend point locations and coordinated the procedures with the VNIITF staff. LLNL assisted in the analysis of the raw data from these measurements and concluded that they are consistent with the data from the old (removed) californium sources, the “reference” californium sources and the source passports data. The relative measurements between the old (removed), ”reference”, and the currently installed californium sources at all plants provide assurance that the BDMS neutron sources are not a cause of any anomalies in the mass flow data. The source measurements data provide also seamless continuation of quality mass flow data after the californium sources are replaced in two years.

TV monitoring system and neutron detection equipment
We are now using technology that allows monitoring of the process of californium source change and source relative measurements. The U.S. supplied neutron detection system (NDS) allows a substantial reduction of overall and per source measurement time. LLNL supplied TV monitoring system allows U.S. monitors and plant personnel to avoid unnecessary exposure while remotely observing source change and relative source measurement operations. Both systems were shipped to VNIITF and were successfully used during source replacement at ECP and UEIE and during BDMS installation at SChE.

BDMS sources specifications
In 2005 LLNL provided assistance for developing the Co-57 source specifications for the BDMS sources at UEIE and ECP. The source specifications were developed in a manner to maximize the output and the reliability of the BDMS measurements, and in the same time to comply with the Russian Federation radiation safety regulatory limits. The specifics of the dose rate measurement instrumentation and treatment of measurement errors were taken into account in the development of the source specifications.

Bubble dosimeters
During CY 2005 LLNL shipped 180 bubble dosimeters with high sensitivity (~ 20-30 bubbles per mrem) to ECP, UEIE and SChE to support the BDMS sources changes (60 dosimeters per campaign). Prior to shipment of the bubble dosimeters to Russia, LLNL tested their calibration with Cf-252 source (manufacturer calibrates them with Am-Be source) and, if needed, excluded or exchanged any dosimeters out of tolerance. The bubble dosimeters are used to measure the personal neutron doses for the involved plant, VNIITF and U.S. personnel, as well as, for area monitoring around BDMS. The bubble dosimeter information is valuable for the U.S. monitors and the Russian personnel as an immediate indication in case of a significant exposure or radiation leakage from the BDMS shielding. Due to uncontrolled by us delays in getting the dosimeters in time to the plants we maintained a back-up supply of bubble dosimeters at Pragma office in Ekaterinburg. Shipping the bubble dosimeters from Pragma to any of the BDMS sites can be done on a short notice and takes one to two days for the dosimeters to arrive at the final destination. Since the bubble dosimeters have relatively short warranty, the back-up supply at Pragma usually consists of dosimeters delayed from the previous shipment and redirected to Pragma.

Information on DARTS
The BDMS sources and bubble dosimeter information on DARTS was updated and expanded in the last year. The available data on DARTS in the BDMS directory include two folders – BDMS Sources and Bubble Dosimeters for the use of the HEU community. The BDMS Sources folder contains subfolders for:

- All current and past Cf-252, Co-57 an Am-241 passports for UEIE, ECP and SChE BDMS sources
- Co-57, Am-241 and Cf-252 source specifications for current and upcoming source changes/installation

- All radiation safety reports for the source change activities in English and the Russian originals for UEIE, ECP and SChE
- Tables (in Excel spreadsheet format) of the detailed dose rate (gamma+neutron) measurements at UEIE, ECP and SChE
- Tables (in Excel spreadsheet format) of the relative californium source measurements of the new, old, and the reference sources with any pertinent information for source changes and installations at the three plants
- Tables of the Cf-252, Co-57 and Am-241 source positions at UEIE, ECP and SChE

Bubble dosimeters' folder on DARTS contains:

- Test results from Doza (in Russian)
- Bubble dosimeter Accreditation certificate - original in Russian and the English translation
- Accreditation testing report and description - in Russian and in English

Reporting

In 2005 LLNL provided the following reports related to the health physics issues of the HEU-TP activities:

- Post trip dose reports to the DOE's HEU-TP management after each trip
- Quarterly bioassay (internal dosimetry) reports to the DOE's HEU-TP management
- 2004 Annual health physics report to the DOE's HEU-TP management
- 2004 Annual Occupational Dose reports to each monitor that had a trip to Russia
- 2004 Annual Occupational Dose reports to the POC for all monitors in his area
- U.S.-Russian radiation safety report for regulatory compliance after the ECP BDMS source replacement (UEIE report was brought by the first SMV team in 2006)
- BDMS health physics issues were reported as part of the consensus trip report for the ECP source change trip
- Reports on various health physics topics requested by the HEU-TP management

In 2005, the HEU-TP activities in Russia were conducted in a radiologically safe manner for the HEU-TP monitors in accordance with the expectations of the HEU-TP staff, NNSA and DOE. The HEU–TP now has ten years of successful experience in developing and providing health and safety support in meeting its technical objectives.

Appendix A

Evaluation of the Lower Level of Detection (LLD) for the HEU-TP TLDs

To assess the impact of the airport x-ray screening of the luggage the readings of 15 TLDs carried in the carry-on luggage and the readings of 12 TLDs carried in the checked-in luggage were evaluated. The test TLDs were carried to all Russian plants under the HEU Program, however, they were not used for personnel monitoring (i.e. they were not exposed to any radiation but airport x-ray screening and in-flight background radiation). DOE Methodology for calculating the LLD is provided in the DOE Standard for Performance Testing of Personnel Dosimetry Systems DOE/EH-0027. The formula for Low Level of Detection (LLD) is

$$LLD = 2(k\sigma_0 + alter^2 H_B)/(1 - alter^2)$$

where

alter	= k*S/(1+B)
k	= 1.75 – single-sided 95% confidence level value with 5% false positive and negative values
S	= standard deviation of readings of DOELAP test TLDs dosimeters
B	= bias of DOELAP test TLD readings
σ_0	= absolute standard deviation of the background dosimeters readings
Hb	= average background dosimeter readings

The bias and standard deviation of DOELAP (DOE Laboratory Accreditation Program) readings were taken from DOELAP tests conducted previously in the lab with pre-exposed TLDs sent for evaluation by DOELAP. Since the x-ray energy of the airport screening machines is not known and it may vary from airport (or manufacturer) to airport (manufacturer), the bias and the standard deviation were taken for two energies: standard DOELAP x-ray and Cs source energies. The more conservative of the two values was adopted for the LLD.

Calculation of the LLD for checked-in TLDs

Using the data from the TLDs transported in checked-in luggage in the airport x-ray exposure study yields

LLD for whole body deep dose is evaluated to be 35 mrem
LLD for the shallow (skin) dose is evaluated to be 45 mrem

Calculation of the LLD for carry-on TLDs

Using the data from the TLDs transported in carry-on luggage in the airport x-ray exposure study yields

LLD for whole body deep dose is evaluated to be 20 mrem
LLD for the shallow (skin) dose is evaluated to be 18 mrem

Appendix B

Minimum Detectable Dose (MDD) from Uranium Bioassays

The Minimum Detectable Dose (MDD) is the lowest value of committed effective dose equivalent (CEDE, a dose a person will receive for 50 years following a single intake) that would be expected to be reliably detected based on a single bioassay result. The bioassay samples undergo radiochemical preparation followed by state-of-the-art ICP (inductively coupled plasma) mass spectrometry analysis by LLNL bioassay lab. The results are reported as a concentration of uranium by mass in the urine. Several key assumptions are used by the internal dose dosimetrist in the determination of any potential internal dose:

- Average natural background is about 0.01 micrograms of U-238 per liter (based on LLNL and PNNL studies)
- Reference Man excretion rate = 1.4 liters per day (standard assumption)
- Breathing particle size distribution = 5 microns AMAD (standard assumption)
- Use of the new ICRP-66 lung model, and the new ICRP-67/68 etc, biokinetic models for uranium (ICRP = International Council on Radiation Protection)
- Different solubility classes are assumed for the main Uranium compounds encountered in the HEU-TP
  - UF_6 (uranium hexafluoride) would be very soluble (Type F) material
  - Oxides of uranium (e.g., U_3O_8) are assumed to be moderately soluble (Type M) material
  - Metal fumes or powder and high-fired oxides of uranium (perhaps $U0_2$) are assumed to be very insoluble (Type S) material.

Three of the most critical factors influencing the minimum detectable dose (MMD) are the physical and chemical form (solubility) of U compounds, the time between potential U intake and providing the bioassay sample, and uranium enrichment with U-235 and U-234. Although all U isotopes have approximately the same detection level by mass, their minimum detectable dose differs significantly. Higher enriched uranium compounds have higher MDD since U-235 and especially U-234 have much higher specific activities then U-238. The relationship between MMD and these three factors is provided in the table below and the graphs on the next pages.

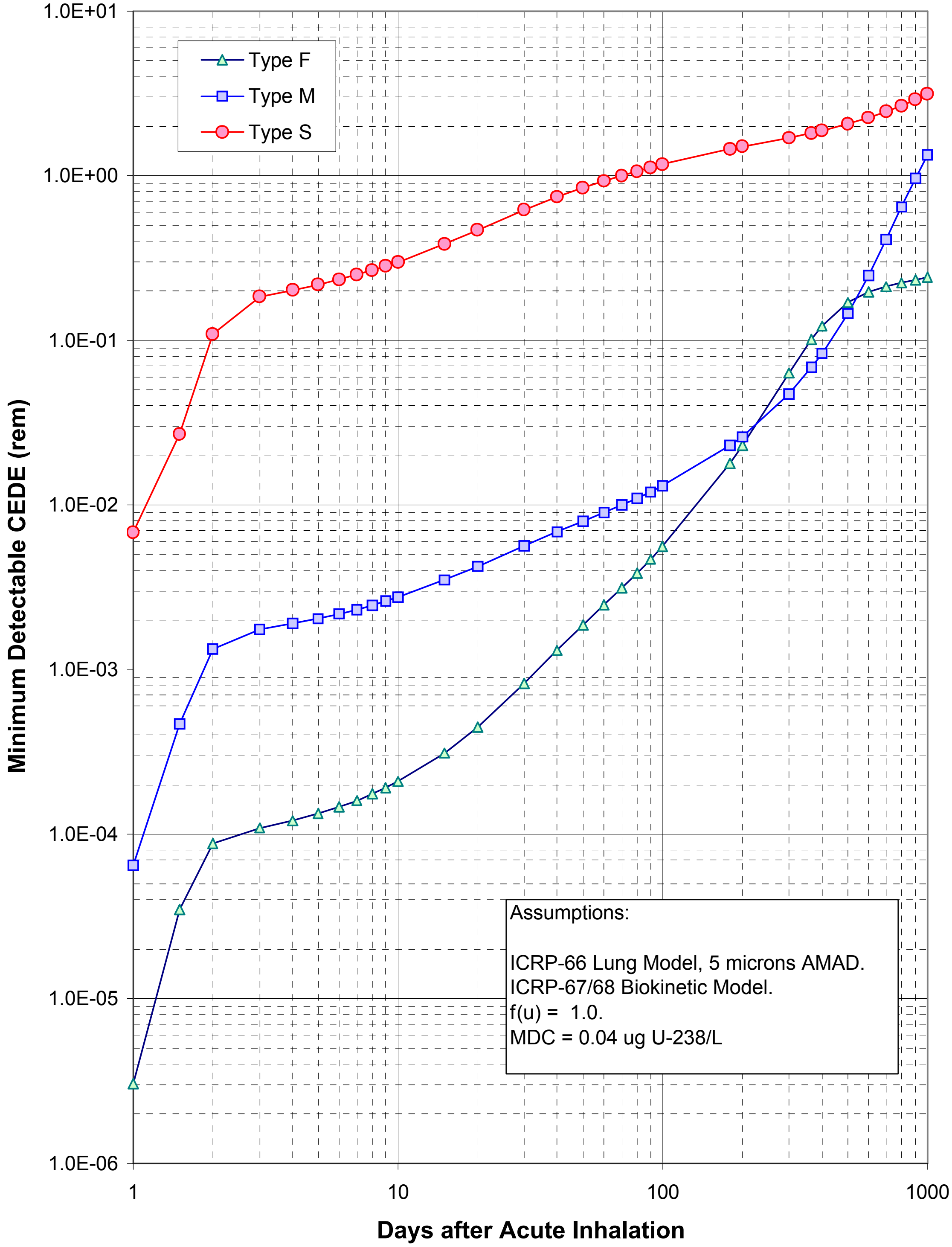
Appendix B

Material	UF_6			U_3O_8			U metal		
Solubility	F	F	F	M	M	M	S	S	S
Enrichment U-235 mass %	**DU**	**5%**	**90%**	**DU**	**5%**	**90%**	**DU**	**5%**	**90%**
Days after intake	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**	**MDD (rem)**
3	1.49E-5	1.09E-4	3.04E-2	2.21E-4	1.75E-3	4.92E-1	2.42E-2	1.81E-1	5.71E+1
7	2.19E-5	1.61E-4	4.47E-2	2.92E-4	2.31E-3	6.50E-1	3.28E-2	2.50E-1	7.01E+1
10	2.85E-5	2.09E-4	5.81E-2	3.47E-4	2.74E-3	7.72E-1	3.92E-2	3.00E-1	8.39E+1
20	6.11E-5	4.49E-4	1.25E-1	5.35E-4	4.23E-3	1.19E+0	6.15E-2	4.70E-1	1.31E+2
30	1.12E-4	8.25E-4	2.29E-1	7.10E-4	5.62E-3	1.58E+0	8.15E-2	6.22E-1	1.74E+2

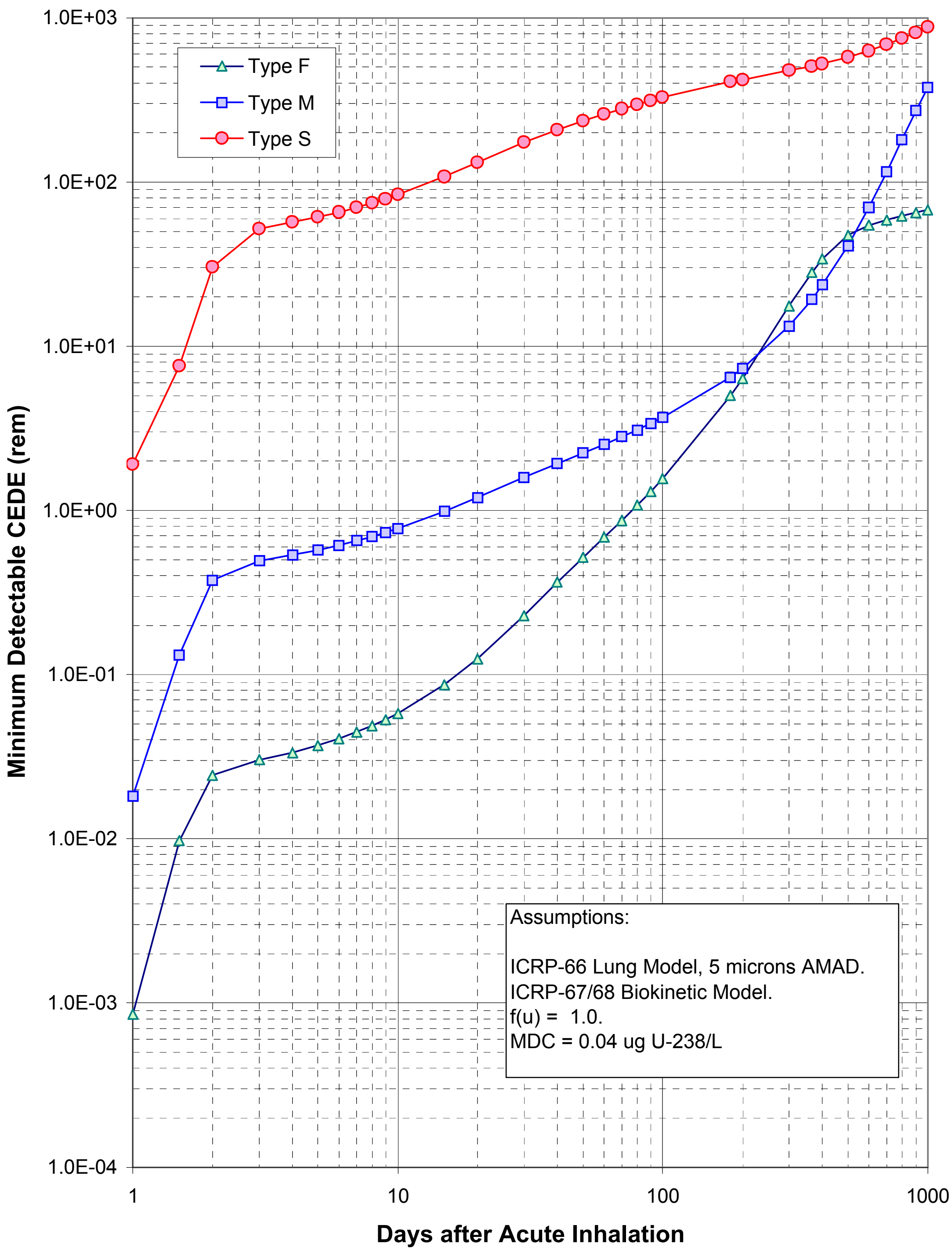
Note that MDDs in the table do not consider any chemical toxicity - only the 50-year committed effective dose equivalent (CEDE) received from inhalation.

One can see that urine bioassay alone is generally quite adequate for depleted U and natural U. Dose monitoring sensitivity decreases rapidly as the enrichment increases, and as the solubility goes from Type F to Type S. Dose sensitivity for highly enriched, highly insoluble uranium is very poor. In these cases the bioassay results are supplemented with workplace radiological monitoring data such as airborne uranium concentration and surface contamination. The relationship between MMD and U solubility and time after a potential intake (inhalation) is provided in graphical form for HEU (90% enrichment) and LEU (5% enrichment) on the next pages.

Appendix B
Minimum Detectable Dose (CEDE) - 5% LEU
Using ICP-MS Spot Urine Sampling for U-238

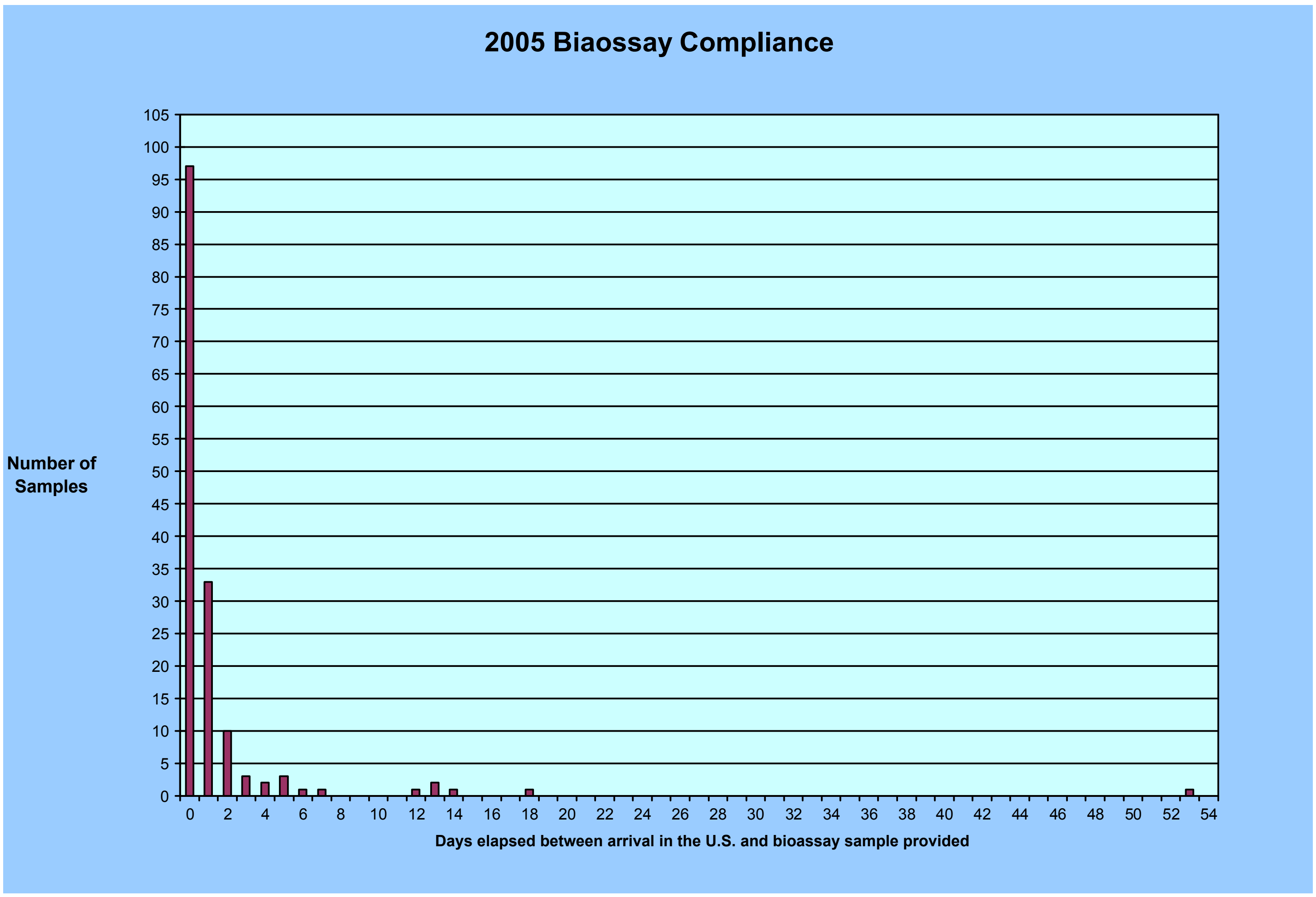


Appendix B
Minimum Detectable Dose (CEDE) - 90% HEU
Using ICP-MS Spot Urine Sampling for U-238



Appendix C

2005 Timely Bioassay Sample Compliance



Appendix D

Appendix E is a separate document that is marked C/FIG-MOD