APPENDIX H

PERSONNEL MONITORING

I. PERSONNEL MONITORING PROGRAM FOR OCCUPATIONAL DOSE

This Appendix provides information that may be used to develop and implement, or revise, or amend a personnel monitoring program to correctly the measure radiation dose to occupationally-exposed workers. Further, it contains specific information relating to an external occupational dose program and cites references for developing an internal occupational dose program. Applicants may use this information to establish an occupational dose program to meet the requirements of RH-1302 and other requirements of Section 3 of the Rules and Regulations for Control of Sources of Ionizing Radiation. This information includes guidance as well as discussion of regulatory requirements that are to be reflected in the elements of personnel monitoring program.

"Dosimetry" is a broad term commonly applied to the use of monitoring devices, bioassay, and other methods to measure or otherwise quantify radiation doses to individuals. The licensee must control occupational doses and provide individuals with monitoring devices in accordance with the requirements of RH-1302. Paragraph RH-1200 provides the occupational dose limits for adults and RH-1302 states, in part, that adults likely to receive in one year a dose in excess of 10 percent of those dose limits must be provided with dosimetry.

Definitions of relevant terms such as Total Effective Dose Equivalent (TEDE), deep-dose equivalent (DDE), and committed effective dose equivalent (CEDE) can be found in RH-1100, "Definitions". In addition, if monitoring is required pursuant to RH-1302, each licensee shall maintain records of doses received (RH-1509) and individuals must be informed on at least an annual basis of their doses (see RH-2804).

If an individual is likely to receive more than 10% of the annual dose limits, the Department requires the licensee to monitor the dose, to maintain records of the dose, and, on at least an annual basis, to inform the worker of the dose.

The As Low As Reasonably Achievable (ALARA) Program

The Rules and Regulations, Paragraph RH-1004 states that

> "…each licensee or registrant shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities" and, "the licensee or registrant shall use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA)".

Additionally, RH-1004 requires that licensees periodically review the content of the radiation protection program and its implementation.

EXTERNAL DOSE

Radiation Dose Limits

It is necessary to assess radiation doses to workers to demonstrate compliance with regulatory limits on radiation dose and to help demonstrate that doses are maintained at ALARA levels. Providing for the safe use of radioactive materials and radiation is a management responsibility. It is imperative that management recognize the importance of radiation monitoring in the overall requirements for radiation protection.

There are three dose limits included in RH-1200 that apply to external exposure:

- Deep dose to the whole body 5 rem or (0.05 Sv),
- Shallow dose to the skin or extremities 50 rem or (0.5 Sv), and
- Dose to the lens of the eye 15 rem or (0.15 Sv).

According to the definitions in RH-1100, the deep dose equivalent (DDE) to the whole body is considered to be at a tissue depth of 1 cm (1000 mg/cm^2), shallow dose equivalent to the skin or extremities at 0.007 cm (7 mg/cm^2), and eye dose equivalent at 0.3 cm (300 mg/cm^2). In evaluating the eye dose equivalent, it is acceptable to take credit for the shielding provided by protective lenses.

Paragraph RH-1302 requires the use of individual monitoring devices for the following:

- Adults likely to receive, in one year, from sources external to the body, a dose in excess of 10 percent of the occupational dose limits in RH-1200. Monitoring devices are accordingly required for adults with an annual dose in excess of
    - 0.5 rem (0.005 Sv) DDE
    - 1.5 rem (0.015 Sv) eye dose equivalent
    - 5 rem (0.05 Sv) shallow dose equivalent to the skin
    - 5 rem (0.05 Sv) shallow dose equivalent to any extremity.
- Minors who are likely to receive an annual dose in excess of
    - 0.1 rem (1.0 mSv) DDE
    - 0.15 rem (1.5 mSv) eye dose equivalent
    - 0.5 rem (5 mSv) shallow dose equivalent to the skin
    - 0.5 rem (5 mSv) shallow dose equivalent to any extremity.

- Declared pregnant women likely to receive an annual dose in excess of 0.1 rem (1.0 mSv) DDE during the entire pregnancy.
- Individuals entering a high or a very high radiation area.

To demonstrate that monitoring of occupational exposure is not necessary for a group of radiation workers, it must be documented that doses will not exceed 10% of the applicable limits. In this case, the Department does not require licensees to monitor radiation doses for this class of worker.

The following methods may be used to demonstrate that doses are expected to be within 10% of regulatory limits:

- Prior Experience: Review of radiation dose histories for workers in a specific work area show that they are not likely to receive a dose in excess of 10% of the limits;
- Area Surveys: Demonstrate through the conduct of appropriate radiation surveys (e.g., using a survey meter or area thermoluminescent dosimeters (TLDs)) in the work area, combined with estimates of occupancy rates and calculations, that doses to workers are not likely to exceed 10% of the limits (personnel exposures associated with reasonable "accident" scenarios must also be evaluated);
- The licensee performs a reasonable calculation based upon source strength, distance, shielding, and time spent in the work area, that shows that workers are not likely to receive a dose in excess of 10% of the limits.

Radiation Dose Monitoring

External dose is determined by using individual radiation monitoring devices, such as **Film Badges, Optically Stimulated Luminescence Dosimeters (OSLD), and Thermoluminescent Dosimeters (TLDs)**. These devices must be evaluated by a processor that is National Voluntary Laboratory Accreditation Program (NVLAP)-approved, as required by RH-1301.

If external dose monitoring is necessary, the applicant must describe the type of personnel dosimetry, specifically, film badges, OSLs, or TLDs, that personnel will use. If occupational workers handle radioactive material, the licensee must evaluate the need to provide extremity radiation monitors, which are required if workers are likely to receive a dose in excess of 5 rem (0.05 Sv) shallow dose equivalent (SDE), in addition to whole-body badges.

- Applicants must ensure that the personnel dosimetry program contains provisions that personnel monitoring devices be worn so that the part of the body likely to receive the greatest dose will be monitored. The device for monitoring the whole body dose, eye dose, skin dose, or extremity dose shall be placed near the location expected to receive the highest dose during the year (RH-1201.c). When the whole

body is exposed fairly uniformly, the individual monitoring device is typically worn on the front of the upper torso.

- If the radiation dose is highly non-uniform, causing a specific part of the whole body (head, trunk, arms above the elbow, or legs above the knees) to receive a substantially higher dose than the rest of the whole body, the individual monitoring device shall be placed near that part of the whole body expected to receive the highest dose. For example, if the dose rate to the head is expected to be higher than the dose rate to the trunk of the body, a monitoring device shall be located on or close to the head.

- If, after the dose is received, the licensee somehow learns that the maximum dose to a part of the whole body, eye, skin, or extremity was substantially higher than the dose measured by the individual monitoring device, an evaluation shall be conducted to estimate the actual maximum dose.

Because evaluation of dose is an important part of the radiation protection program, it is critical that users return dosimeters on time. Licensees should be vigorous in their effort to recover any missing dosimeters. Delays in processing a dosimeter can result in the loss of the stored information.

Some licensees use self-reading dosimeters in lieu of processed dosimetry. This is acceptable if the regulatory requirements are met. See American National Standards Institute (ANSI) N322, "Inspection and Test Specifications for Direct and Indirect Reading Quartz Fiber Pocket Dosimeters", for more information. If pocket dosimeters are used to monitor personnel exposures, applicants should state the useful range of the dosimeters, along with the procedures and frequency for their calibration.

When evaluating external dose from xenon gas, the licensee may take credit for the reduction of dose resulting from the use of xenon traps. Additionally, periodic checks of the trap effluent may be used to ensure proper operation of the xenon trap. Licensees may vent xenon gas directly to the atmosphere as long as the effluent concentration is within Rules and Regulations, Section 3 limits and is specifically addressed in the Operating Procedures.

When evaluating dose from aerosols, licensees may take credit for the reduction of dose resulting from the use of aerosol traps. Licensees may vent aerosols directly to the atmosphere as long as the effluent concentration is within Rules and Regulations, Section 3 limits and is specifically addressed in the Operating Procedures.

Declared Pregnancy and Dose to Embryo/Fetus

The Rules and Regulations, Paragraph RH-1207 states that the licensee shall ensure that the dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, does not exceed 0.5 rem (5 mSv). The licensee shall make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman. If the pregnancy is declared in writing and includes the worker's estimated date of conception, the dose equivalent to an embryo/fetus shall be taken as the sum of:

- The deep dose equivalent to the declared pregnant woman; and
- The dose equivalent to the embryo/fetus from radionuclides in the embryo/fetus and radionuclides in the declared pregnant woman.

NOTE: The following references are provided:

- Methods for calculating the radiation dose to the embryo/fetus can be found in Regulatory Guide 8.36, "Radiation Dose To the Embryo/Fetus".
- NUREG/CR-5631, PNL-7445, Rev. 2, "Contribution of Maternal Radionuclide Burdens to Prenatal Radiation Doses" (1996).

Records of External Radiation Dose Monitoring

In order to demonstrate compliance with occupational dose limits of RH-1200, the Rules and Regulations include specific requirements for documenting, maintaining, and retaining the results of personnel radiation dose monitoring. The requirements are summarized in Section III of this Appendix.

INTERNAL DOSE

Radioactive Material Licensees are required to monitor occupational intake of radioactive material and assess the resulting dose if it appears likely that personnel will receive greater than 10% of the **annual limit on intake (ALI)** from intakes in 1 year (RH-1302). Section 3 of the Rules and Regulations provides terms and definitions for radionuclide intakes by means of inhalation and ingestion, i.e., **derived air concentration (DAC)** and **ALI**.

It may be necessary to assess the intake of radioactivity for occupationally exposed individuals in accordance with RH-1203 and RH-1302. If internal dose assessment is necessary, the Applicant shall measure the following:

- Concentrations of radioactive material in air in work areas; or
- Quantities of radionuclides in the body; or
- Quantities of radionuclides excreted from the body; or
- Combinations of these measurements.

The Applicant must describe in the Operating Procedures the criteria used to determine the type of bioassay and the frequencies at which bioassay (both *in vivo* and *in vitro*) will be performed to evaluate intakes. The criteria also must describe how tables of investigational levels are derived, including the methodology used by the evaluated internal dose assessments, i.e., the empirical models used to interpret the raw bioassay data. The bioassay procedures should provide for baseline, routine, emergency, and follow-up bioassays. If a commercial bioassay service will be used, the applicant must ensure that the service is licensed by the Department, the NRC, or an Agreement State, or provide another alternative for the Department to review.

The DAC for each class of radionuclide is the concentration of airborne radioactivity in μCi/ml that, if an occupational worker were to be continuously exposed to for 2,000 hours (1 year), would result in either a CEDE of 5 rem (0.05 Sv) to the whole body or a committed dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue, with no consideration for the contribution of external dose. The ALI and DAC for each radionuclide in a specific chemical form are listed in RH-2792, Appendix G.

For each class of each radionuclide, there are two ALIs, one for ingestion and one for inhalation. The ALI is the quantity of radioactive material that, if taken into the body of an adult worker by the corresponding route, would result in a committed effective dose equivalent of 5 rem (0.05 Sv) or a committed dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue, again, with no consideration for the contribution of external dose.

The total effective dose equivalent concept makes it possible to combine both the internal and external doses in assessing the overall risk to the health of an individual. The RH-2792 ALI and DAC numbers reflect the doses to all principal organs that are irradiated. The ALI and DAC were derived by multiplying a unit intake by the appropriate organ weighting factors (W_T), for the organs specifically targeted by the radionuclide compound, and then summing the organ-weighted doses to obtain a whole body risk-weighted “effective dose”. In accordance with RH-2792, Appendix G, when an ALI is defined by the stochastic dose limit, this value alone is given. When the ALI is determined by the non-stochastic dose limit to an organ, the organ or tissue to which the limit applies is shown, and the ALI for the stochastic limit is shown in parentheses.

The types and quantities of radioactive material used at most medical facilities do not provide a reasonable possibility for an internal intake by workers. However, uses such as preparing radioiodine capsules from liquid solutions, and opening and dispensing radioiodine from vials containing milliCurie quantities require particular caution. To

monitor internal exposures from such operations, a routine bioassay program to periodically monitor workers should be established.

If a licensee determines that a program for performing thyroid uptake bioassay measurements is necessary, a program should be established. The program should include:

- Adequate equipment to perform bioassay measurements,
- Procedures for calibrating the equipment, including factors necessary to convert counts per minute into microCuries or Becquerel units,
- Technical problems commonly associated with performing thyroid bioassays (e.g., statistical accuracy, attenuation by neck tissue),
- Interval between bioassays,
- Action levels, and
- Actions to be taken at those levels.

For guidance on developing bioassay programs and determination of internal occupational dose and summation of occupational dose that is acceptable to the Department, refer to the following NRC technical documents:

- Regulatory Guide 8.9, Revision 1, "Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program" dated July 1993,
- Regulatory Guide 8.34, "Monitoring Criteria and Methods to Calculate Occupational Radiation Doses, dated July 1992, and
- NUREG-1400, "Air Sampling in the Workplace," dated September 1993.

Records of Internal Radiation Dose Monitoring

Records of measurement data, calculations of intakes, and methods for calculating dose must be maintained as required by RH-1509. In order to demonstrate compliance with occupational dose limits of RH-1200, the Rules and Regulations include specific requirements for documenting, maintaining, and retaining the results of personnel radiation dose monitoring. The requirements are summarized in Section III of this Appendix.

SUMMATION OF EXTERNAL AND INTERNAL DOSES

If the licensee is required to monitor both the external and internal doses under RH-1302, the licensee is required to demonstrate compliance with the occupational dose limits of RH-1200 by summing the external and internal doses.

III. PERSONNEL MONITORING RECORDS REQUIREMENTS

Records of Prior Occupational Dose

Prior to assigning a personnel monitoring device to a worker the worker's occupational radiation dose received during the current year will be determined. In addition, every reasonable effort must be made to obtain the individual's records indicating the individual's cumulative occupational radiation dose. If a worker is unable to provide the information, records from their previous employer will be obtained. Prior occupational dose records shall include all of the information required by the Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-2826, "Cumulative Occupational Exposure History", Department Form Z, or an equivalent form.

Records of Individual Monitoring Results

Records of doses received by each monitored worker will be maintained as long as the institution's radioactive material license remains in effect. Dosimetry records will be kept in accordance with the Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-2804, "Notifications and Reports to Individuals" on Department Form Y, Paragraph RH-2825, or an equivalent form, and will contain all of the information required by Paragraph RH-2804. These records shall be updated annually.

Annual Reports to Monitored Individuals

Each worker assigned a personnel monitoring badge will receive a written annual dose report describing the past year's monitoring results, as required by the Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-2804, "Notifications and Reports to Individuals". Records documenting that the reports have been furnished to monitored workers will be maintained for at least 3 years.

Termination Reports to Monitored Individuals

Within 30 days of termination of employment, or within 30 days after the individual's exposure has been determined, whichever is later, each monitored worker will receive a written report summarizing the individual's occupational radiation dose, as required by Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-2804, "Notifications and Reports to Individuals". Records documenting that the reports have been furnished to monitored workers will be maintained for at least 3 years.

Records for Declared Pregnancies

The fetal dose will be closely monitored so as not to exceed 500 millirem. Recordkeeping requirements specified in the Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-1207, "Dose to an Embryo/Fetus" and RH-1500.f.5., "Records of Individual Monitoring Results", will be met.

Occupational Dose Limits for Minors

Minors will not exceed an annual occupational dose of 500 millirem. Recordkeeping requirements specified in Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-1206, "Occupational Dose Limits for Minors" and Paragraph RH-2804, "Notifications and Reports to Individuals", will be met.

Worker Overexposure Reports

When a report of an individual's exposure is sent to the Arkansas Department of Health as required by Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-1505, "Notifications and Reports to Individuals", the exposed individual will also be notified no later than when the report is sent out.

Appendix H
Form H

PERSONNEL MONITORING PROGRAM

Describe the proposed personnel radiation dose monitoring program by marking the appropriate boxes or providing the requested information. Submit the completed Form with the Application

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EXTERNAL DOSE MONITORING

1. Personnel Monitoring Device to be Used:
□ **Film** □ **OSLD** □ **TLD**

2. Radiation Detected:
□ **Beta** □ **Gamma**

3. Type Monitoring:
□ **Whole Body** □ **Extremity**

4. Frequency of exchange:
□ **Monthly** □ **Bi-Monthly** □ **Quarterly**

5. Supplier of Personnel Monitoring Service:_____
Arkansas Vendor Registration Number:_____

6. □ **External Dose Monitoring NOT Required.**
Explain:_____

INTERNAL DOSE MONITORING

1. Type of Internal Dose Monitoring to be Performed:
_____
_____
_____

2. Supplier of Internal Dose Monitoring Service:_____
Arkansas Vendor Registration Number:_____

3. □ **Internal Dose Monitoring NOT Required.**
Explain:_____