RADIATION SAFETY MANUAL

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Chapter 1: Regulation

1.1 Radiation-Producing Devices

The use of radiation-producing devices is regulated by the State of Indiana. The State Department of Health is responsible for the promulgation and enforcement of rules concerning the inspection of machine-produced radiation such as diagnostic and therapeutic X-ray machines, analytical X-ray units, electron microscopes, and particle accelerators. Regulations can be found in the Title 410 Part 5 of the Indiana Administrative Code.

1.2 Radioactive Materials

The possession and use of radioactive materials is governed mainly by federal regulations. The Nuclear Regulatory Commission (NRC) under Title 10 of the Code of Federal Regulations (CFR) regulates the use of byproduct material, source and special nuclear material, and reactor operations. This type of license differs from a specific license in that Purdue University is granted the authority and responsibility to set specific conditions of use within the institution. However, these conditions must be compatible with state and federal regulations, representations made to the NRC, and specific license conditions. The broad scope license number is 13-02812-04 and is scheduled for renewal on a periodic basis.

Purdue University also possesses three additional NRC licenses. These regulate the use of source material (uranium), special nuclear material (enriched uranium), and research reactor operations.

During application for these licenses, procedures and operating conditions are specified to the NRC as part of the license. Any significant changes to these conditions require written approval prior to the initiation of any work. Examples of changes that would require an NRC amendment are: acquisition of radioactive material exceeding currently licensed activity limits, use of radioactive materials in the environment (field studies), use of radioactive material at off-campus locations, and the use of radioactive materials in humans. If new research involves novel applications or work listed above, please allow four to six months for the amendment approval process.

1.3 Radiation Safety Committee

The use of radioactive materials and radiation-producing devices is regulated at Purdue University by the Radiation Safety Committee (RSC). The RSC is composed of faculty and staff

who by their knowledge and experience are qualified to make judgments in the area of radiation safety in accordance with Executive Memorandum B-14 (August 1, 2001).

The policies and procedures established by the RSC are carried out by the Director of the Department of Radiological and Environmental Management (REM) through the Radiation Safety Officer (RSO). The RSO is responsible for day to day operations and reports to the RSC at regular intervals (quarterly).

Chapter 2: Authorization for Use of Ionizing Radiations Sources

All new uses of radioactive material or radiation-producing devices and major changes in existing authorizations must be approved by the Radiation Safety Committee (RSC). Preliminary project review is conducted by REM. Upon recommendation of the RSO, the RSC may grant interim approval of the project. Final approval is granted at quarterly meetings of the RSC.

2.1 Application Procedures

In order to receive authorization for use of radioactive material or radiation-producing devices, the principal investigator must complete a Form A-1. All forms can be obtained using the Radiological and Environmental Management website. The application must contain the following information:

- Principal investigator information.
- All personnel requesting approval to use radioactive material or radiation-producing devices must be listed. Each individual (including principal investigator) must also submit a Form A-4 signed by the principal investigator and must complete the required radiation safety training.
- All proposed use areas for radioactive materials or radiation-producing devices must be listed. This includes "common" areas that may be shared with other investigators such as counting rooms. Complete a Form A1-S for each area requested.
- Each isotope and compound requested must be listed with appropriate experimental, order, and storage limits. Each radiation-producing device must be listed.
- A complete description of the experimental protocol and procedures must be submitted for evaluation by the Radiation Safety Committee. A reprint of a journal article will suffice in most cases. Failure to provide complete information may delay consideration and approval of the application.
- Indicate precautions and practices to be implemented to assure contamination control and security of radioactive material. For use of high-energy beta emitters and gamma emitters, a survey meter with an end window G-M probe will be required. (Submit Form SM-1 and have initial calibration of meter performed by REM). Sign the application.

The addition of new personnel or use areas to an existing project requires the submission of a Form A-4 or Form A1-S, respectively. The addition of new isotopes or procedures requires the submission of a Form A-1.

Chapter 3: Training Requirements

Current regulations require that individuals using sources of ionizing radiation, including the principal investigator, have appropriate training prior to the initiation of any work. Basic training in the areas of radiation safety and emergency procedures is provided by REM.

Training in policies and procedures at Purdue University is also covered in this initial training session. Training in specialized procedures or techniques must be provided by the principal investigator or his designee. No work is allowed to begin unless the individual has received all the appropriate training. Continuing education (retraining) is also required at appropriate intervals in order to maintain authorization to work with radioactive materials.

The principal investigator must demonstrate that he or she has the appropriate training and experience with the types and quantities of radionuclides requested. When, in the judgment of the Radiation Safety Committee, an applicant does not have the requisite training and experience to act as the principal investigator, the applicant may be required to work under the supervision of an approved investigator until this experience is obtained.

3.1 Training Sessions

Please contact REM to ensure you get the appropriate training for your needs. The following types of Radiation Safety Training sessions are offered:

- Unsealed radioisotopes with the potential for contamination (i.e. ^{3}H, ^{32}P, ^{35}S, etc.)
- Sealed sources with no potential for contamination (i.e. ^{60}Co, ^{137}Cs, etc.)
- Analytical X-ray use
- Diagnostic X-ray use (PUSH and School of Veterinary Medicine)
- Gamma irradiator use
- Nuclear gauge use and DOT requirements
- Particle accelerator
- Declared Pregnant Worker
- Electron Capture Detector (ECD)

Chapter 4: Responsibilities of the Principal Investigator

The principal investigator (the individual to whom the authorization for use of radioactive materials or radiation-producing devices has been issued) is responsible for all activities conducted under the scope of that authorization. These responsibilities include ensuring that:

1. All individuals are authorized, appropriately trained, and receive proper supervision for work with radioactive materials or radiation-producing devices.
2. All activities are conducted within the scope of the authorization and any representations made to the Radiation Safety Committee or its designee.
3. All rules, regulations, and procedures for the safe use of radioactive material and radiation-producing devices are followed.
4. Accurate records regarding the amounts, types, and locations of radioactive materials and radiation-producing devices are maintained.
5. Radiological and Environmental Management has approved any changes in use or location of radioactive material or radiation-producing devices prior to implementation of such changes.
6. Ensure that documented lab surveys are performed at the required frequency
    A. Monthly - if material is used at all
    B. Weekly - if greater than 1 mCi is used
    C. Daily - if greater than 5 mCi is used

NOTE: Surveys should be performed after each use of radioactive material where there is a potential for contamination, however, there is no requirement for documentation of those surveys.

Chapter 5: Procurement of Radioactive Material

Purdue University is required to control the acquisition of radioactive material and maintain an accurate inventory. Therefore, all materials must be approved by and ordered with appropriate REM approval. The principal investigator should determine that he or she is authorized to use the amounts and isotopes prior to the initiation of an order.

5.1 Ordering Radioactive Material

To request an order, a complete Form R-1 (Radioactive Material Requisition) must be submitted electronically by attachment to the requisition request. Make sure all account numbers, authorization numbers, and specifications for the material are complete. Indicate the date desired and any other special information. Incomplete requests may delay processing the order.

REM verifies the amount requested with the order and storage limits for which the user is authorized. If satisfactory, REM will approve the order. For additional ordering details, please visit the Radioactive Materials Purchasing page on the REM website.

5.2 Receipt of Radioactive Material

All radioactive materials received at Purdue University must be delivered to REM unless prior arrangements have been made with REM staff. Materials received will be processed to check for proper isotope and form, exposure rate, and any gross contamination. Inner vials are not surveyed for contamination; therefore, these containers should be handled as if they were contaminated.

After processing, the material is delivered to the laboratory. Upon receipt, the user is responsible for maintaining accurate inventory records for all radioactive material possessed.

Chapter 6: Transfer of Radioactive Material

The transfer of radioactive material to another project or licensee (other than properly disposed waste) must be approved by REM prior to transfer of the material. Transport of radioactive or hazardous material must be in compliance with all DOT regulations. Contact REM for information on transportation regulations.

6.1 On-Campus Transfer

Transfer of radioactive material to another user will usually be approved if the receiving individual has authorization to possess that type and amount of radioactive material. A memo or a Form R-1 stating the persons, isotope, form, and amount involved in the transfer must be submitted when the transfer takes place.

6.2 Off-Campus Transfer

Current regulations allow the transfer of radioactive material to holders of current licenses with the Nuclear Regulatory Commission or an agreement state. Prior to transfer, Purdue must have written verification that the facility holds a valid license to possess radioactive material. REM will ship material upon request to ensure that proper packaging and labeling requirements are met.

Any transfer to Purdue University from a non-vendor source (gift, joint research) will be handled in the same manner as that from a vendor source. The material must be shipped to REM, and the user will be notified upon receipt.

Chapter 7: Radioactive Waste Handling

REM is responsible for collection, management, and disposal of all radioactive waste at Purdue University. The disposal of radioactive material via the sanitary sewer or regular trash receptacles is prohibited. Posters outlining waste handling procedures are placed in laboratories on campus. Some general points to follow are outlined below:

- Radioactive waste (both solid and liquid) must be segregated according to half-life. Short half-life material (less than 30 days) such as ^{32}P must be separate from ^{3}H, ^{14}C, and ^{35}S.
- Solid waste (other than short half-life) must be separated according to its combustibility. Paper, cardboard and plastics are incinerated while metal and glass are compacted and shipped for disposal. Sharp items such as needles, razor blades, and Pasteur pipettes must be placed in a box or a "sharps" container to prevent injury during subsequent handling of the waste. Lead containers must be segregated from other solid waste.
- Liquid organic waste and aqueous waste must be collected separately. Scintillation media in vials should be placed in the original carton or packed to prevent leakage of the liquid in transport.
- Radioactive animal carcasses, viscera, or other biological materials subject to putrefaction must be placed in a plastic bag and frozen prior to pick up.
- If possible, the mixing of hazardous chemicals and radioactive materials should be avoided. So called "mixed waste" which contains radioactivity and a component which exhibits corrosivity, reactivity, toxicity, etc. can have significant handling and disposal problems. If these materials must be mixed together, contact REM for assistance in developing procedures to minimize the generation of this type of waste.
- All radioactive waste must be properly labeled with authorization number, isotope(s), amount(s) and the date sealed. Under no circumstances will waste be picked up if the label is not complete. For assistance concerning unique situations, contact REM. All containers (i.e. bags, carboys, etc.) are supplied by REM.

See the Radioactive Waste webpage for more information. Completed Radioactive Waste Pickup Requests forms may be submitted by any of the following means:

- Electronic submission
- Fax to (765) 494-7403
- Campus mail to REM, HAMP

Waste pickup requests submitted before 5:00 pm on Monday will be picked up on Tuesday.

Chapter 8: Personnel Exposure and Monitoring

The personnel monitoring program at Purdue University is designed to keep exposures to ionizing radiation "As Low As Reasonably Achievable" (ALARA). To this end, all personnel with the potential for receiving significant exposure from X-ray, gamma, high-energy beta, and neutron radiation are required to wear appropriate dosimeters. Dosimeters are provided at no cost to the individual. The individual, however, is responsible for prompt return of the dosimeters at the end of each wear date, even if the dosimeter was not worn during that period.

8.1 Occupational Exposure Limits

The current exposure limits in an occupational setting have been established for two reasons. The first is to prevent acute effects (i.e. erythema, epilation, etc.) and the second is to reduce late effects such as cancer and genetic damage to very low levels. The limits for occupational exposure from nuclear reactor operations, radioactive material and devices containing radioactive material can be found in Title 10, Part 20 of the Code of Federal Regulations (10 CFR 20). The limits for occupational exposure from radiation producing devices can be found in Title 410 Part 5 Rule 4 of the Indiana Administrative Code (410 IAC 5-4). Table 1 and Table 2 provide summaries of the respective limits.

Table 1 – Occupational Exposure Limits from 10 CFR 20

Area Exposed	rem*/year
Total Effective Dose Equivalent (Whole Body)	5.0
Committed Dose Equivalent to any Organ	50.0
Eye Dose Equivalent	15.0
Shallow Dose Equivalent (Skin) or Extremity	50.0

Table 2 – Occupational Exposure Limits from 410 IAC 5-4

Area Exposed	rem*/quarter
Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1.25
Hands and forearms; feet and ankles	18.75
Skin of whole body	7.50

***1 rem = 1000 millirem**

Limits for internal exposure to radionuclides through air and water are addressed by the annual limit on intake (ALI) values in Appendix B of 10 CFR 20.

8.2 Exposure Limits for Pregnant Workers

The increased sensitivity of rapidly-dividing cells makes the human embryo and fetus more susceptible to injury from exposure to ionizing radiation. For this reason, the National Council on Radiation Protection and Measurements (NCRP) recommends and NRC regulations require that exposure to the worker (fetus) during the gestation period not exceed 500 millirem (one-tenth of the occupational limit). A declared pregnant woman means a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception. If a declaration is made, it must be given to the Radiation Safety Officer (RSO) in writing. Once the declaration is made, her occupational dose limit will be lowered to 500 millirem, and she will receive a fetal dosimeter. Regulatory Guide 8.13, published by the Nuclear Regulatory Commission, outlines health risk estimates associated with radiation exposure and means to reduce risks. This guide is distributed at the time of the declaration.

8.3 Non-occupational Exposure

The limit for whole-body exposure to the general public and workers not approved to use sources of ionizing radiation is 100 millirem (one-fiftieth of the occupational limit). The Purdue University Radiation Safety Committee has reduced this dose limit to 25 millirem. This exposure is in addition to that received by an average individual from naturally occurring background radiation (approximately 200 millirem/year) and medical exposures (100 millirem/year).

8.4 Personnel Radiation Dosimetry

External exposure to gamma, X-ray, high-energy beta, and neutron radiation is monitored by devices called dosimeters. At Purdue University, film, optically stimulated luminescence (OSL) and thermoluminescent dosimeters (TLDs) are used to measure whole-body exposure. Ring dosimeters are used to measure exposure to the extremities. Wrist dosimeters are issued instead of ring dosimeters when it is necessary to monitor extremity exposure from thermal and fast neutron radiation. To provide accurate estimates of radiation exposure, the dosimeter must be worn properly when working with radioactive materials or radiation-producing devices. A whole-body dosimeter should be worn on the collar, pocket, or belt area. If a lead apron is worn and only one whole-body dosimeter is provided, the dosimeter should be worn outside the apron. If lead apron is worn and two whole-body dosimeters are provided, one dosimeter should be worn on the collar, and the other should be worn under the lead apron. The ring dosimeter should be worn with the sensitive area (label) on the palm side of the hand. Fetal dosimeters should be worn on the abdominal area.

Only individuals using certain radioisotopes and amounts are provided with dosimetry. If a whole-body and/or ring dosimeter is required it will be provided to you at the time of your initial work. The guidelines for issuing dosimetry are as follows:

- Low-energy beta emitters (e.g. ^{3}H, ^{14}C, ^{35}S, ^{45}Ca)
    - No dosimetry required
- High-energy beta emitters (e.g. ^{32}P, ^{90}Sr)
    - Ring dosimeters issued for 1 mCi or greater
    - Whole-body dosimeter issued for 5 mCi or greater
- Low-energy gamma emitters (e.g. ^{51}Cr, ^{57}Co, ^{125}I)
    - Ring dosimeter issued for 1 mCi or greater
    - Whole-body dosimeters issued for 5 mCi or greater
- High-energy gamma emitters (e.g. ^{22}Na, ^{60}Co, ^{137}Cs, ^{131}I)
    - Ring dosimeter issued for 0.1 mCi or greater
    - Whole-body dosimeter issued for 1 mCi or greater
- Neutron emitters (e.g. neutron generators, ^{252}Cf)
    - Extremity dosimeter issued for 10 mCi
    - Whole-body dosimeter issued for any use

8.5 Bioassay

Bioassays are performed to assess the amount of radioactive material that has been taken into the body through inhalation, ingestion, or absorption through the skin. The bioassay is commonly performed by taking a sample of a body fluid such as urine. The amount of radioactivity in the sample is determined and the resulting internal dose to the individual calculated. Thyroid bioassays can be performed using an external probe. The amount of radioactivity in the thyroid is assessed and the resulting internal dose calculated.

In general, urinalyses are performed only when large amounts of volatile radioisotopes are used or when there is a suspected significant uptake of radioactive material. Thyroid bioassays, however, are performed routinely on individuals performing radioiodinations and using radioiodines on a regular basis. This program is designed for early identification of significant uptakes of radioiodines as part of Purdue University's ALARA program.

8.6 Personnel Exposure Records

Radiation exposure records for personnel are maintained by REM. These records are available to the individual upon written request.

The goal of ALARA is to keep radiation exposures as low as possible. Therefore, REM sends a Form F-1 to an individual receiving greater than 100 millirem to the whole body or extremities during any wear period. The Form F-1 must be completed and returned to REM to acknowledge the exposure, provide an explanation for the exposure, and describe how they will reduce future exposures. Although exposures at approximately 100 millirem are not excessive, awareness of these exposures is important.

Chapter 9: Laboratory Safety

Although the potential hazards of working with radioactive materials may be significant, proper facilities and the observance of laboratory safety rules can keep risks to a minimum.

9.1 Facilities

In general, a properly designed chemical laboratory will be adequate to serve the needs of radioisotope users. Specific research may require the use of specially designed facilities to minimize the hazards associated with that particular research. Procedures that differ significantly from those approved in the past must be approved by the Radiation Safety Committee.

As a minimum, radioisotope laboratories should have the following properties:

- Smooth, non-porous floors and walls that can easily be cleaned in the event of spills or contamination.
- Smooth non-porous lab benches that can easily be decontaminated. Porous surfaces must be covered with absorbent paper or work done in an appropriate spill tray.
- When required, laboratory fume hoods and ventilation systems must be of the appropriate design and construction for the hazard.
- The facility should be easily isolated from general personnel access areas such as hallways and office areas. The areas should have locks or some means to prevent access and unauthorized use of radioactive materials when personnel are not in attendance.
- Appropriate shielding and/or interlocks to prevent personnel access must be used when radiation levels would present undue hazards to personnel or the general public. (Note that exposure rates greater than 5 mR/hr. require posting as a "radiation area" and levels in unrestricted areas cannot exceed 2 mR/hr.).

9.2 Procedures and Rules for the Safe Use of Radioactive Material

- Eating, drinking, food preparation, food storage, and application of cosmetics are not permitted in laboratories where significant amounts of unsealed radioactive materials are stored or used. Consumption of beverages may be permitted in Type C labs during periods of time when the user is not actually handling or using radioactive materials. The storage or preparation of food or beverages, the consumption of food, and the application of cosmetics is not permitted in a Type C laboratory. The consumption of food and beverages and the application of cosmetics may be permitted in a Type D

laboratory when the user is not actually handling or using radioactive materials. Storage of food and beverages is not permitted in the same storage location (i.e. refrigerator, cabinet, etc.) as the radioactive materials.

Most radioisotope laboratories are also chemical laboratories subject to the Purdue Chemical Hygiene Plan. Under those guidelines, drinking, eating, and the application of cosmetics is forbidden in areas where hazardous chemicals are in use.

- The use of food containers for handling or storing radioactive materials is not permitted. Any other containers used must be clearly marked as containing radioactive material.
- The pipetting of radioactive solutions by mouth is strictly prohibited.
- A trial run without radioactive material must be conducted for all new procedures. Radioactive material may be used only after the safety of the procedures has been assured.
- Any work performed with volatile material (such as sodium iodide) or operations that have a potential for personnel exposure or contamination must be performed in an appropriate hood or glove box. New procedures involving these types of materials must be approved by the Radiation Safety Committee prior to initiation.
- Protective equipment such as gloves and lab coats must be used for all manipulations of unsealed sources. In addition, eye protection must be worn when working with materials that could be hazardous to the eyes. Eye protection is also required when handling greater than 10 millicuries of high-energy beta emitters such as P-32 (i.e. ^{32}P).
- Protective equipment must not be worn outside the laboratory unless it has been monitored and found to be free of contamination. Gloves, while providing protection to the user, can spread contamination if worn outside the laboratory.
- All work surfaces must be covered with absorbent paper that is changed on a regular basis. Work with large volumes of material and/or material with high spill possibility must be done in an appropriate spill tray.
- A radiation survey should be performed by the radionuclide user at the end of each procedure involving radioactive materials. The survey may be conducted with a portable survey instrument or wipes as appropriate. All items found to be contaminated should be placed in a suitable area or disposed of as radioactive waste. Any radioactive contamination found must not be allowed to remain in any area for an extended period of time. Radiological contamination can be removed from non-porous surfaces by using common household cleaners. If contamination is found outside the immediate use area, REM should be notified immediately.
- Radioactive material use, survey, and inventory records must be maintained at all times by the principal investigator.

- Any equipment that is used in experiments involving radioactive material must have the proper ‘Caution Radioactive Material’ label affixed. This label may only be removed after REM staff have certified that it is free of radiological contamination.

9.3 Inspections and Postings

Radioisotope laboratories are classified and inspected according to their relative hazard. This classification takes into account the radioisotope, amount used and stored, chemical form, and types of procedures performed in the laboratory. The classification scheme and inspection frequency is listed below in Table 3.

Table 3 – Laboratory Inspection Scheduled (by Hazard)

Lab Class	Schedule
Class A (High)	Weekly
Class B (Moderate)	Monthly
Class C (Low)	Quarterly
Class D (Very Low)	Yearly

The purpose of the inspections and laboratory audits conducted by REM is to verify that activities at Purdue University are conducted within the scope of the NRC license and applicable state and federal regulations and conditions approved by the Radiation Safety Committee. These inspections do not take the place of routine surveys conducted by laboratory personnel or waive the requirement to maintain records.

All laboratory areas must be posted with a "Caution-Radioactive Materials" label. These labels are posted by REM once an area is approved for radioactive material use. After an area is no longer needed and radioactive materials are removed, the room will be decommissioned and the label removed by REM.

Chapter 10: Emergency Procedures

Emergencies resulting from accidents in radioisotope laboratories may occur even though all laboratory rules are obeyed. Because of numerous complicating factors, set rules of emergency procedure cannot be made to cover all possible situations. In any situation, the primary concern is protection of personnel from physical and radiation hazards. The secondary concern is confinement of any contamination to the immediate area.

10.1 Minor Accidents/Spills

Accidents involving small quantities of radioactive material in non-volatile form confined to a small area can usually be regarded as minor.

1. Notify all other persons in the room at once.
2. Exclude persons not directly involved in the dealing with the spill.
3. Confine the spill immediately.
    A. Liquids: Drop absorbent paper or material on spill.
    B. Solids: Dampen thoroughly using small quantities of water, taking care not to spread contamination. Use water unless it would generate an air contaminant. Oil should then be used.
4. Notify the laboratory supervisor and Radiological and Environmental Management at (765) 494-6371.

10.2 Major Accidents/Spills

Accidents occurring outside a hood involving volatile material or accidents involving large (millicurie) amounts should be considered major. Discovery of any widespread contamination should also be considered major.

1. Notify all persons in the room and take steps to evacuate the area.
2. Rinse off skin by flushing with water and remove contaminated clothing if applicable.
3. Secure the room and prohibit entry to the contaminated area.
4. Immediately notify the laboratory supervisor and Radiological and Environmental Management at (765) 494-6371. During off hours or if REM cannot be reached contact the University Police at (765) 494-8221.
5. Assemble those persons involved near the laboratory entrance and wait for assistance.

10.3 Fire and Fire-Related Emergencies

If you discover a fire or fire-related emergency such as abnormal heating of material, hazardous gas leaks, hazardous material or flammable liquid spill, smoke, or odor of burning, immediately follow these procedures:

1. Activate the building fire alarm system (fire pull station). If not available or operational, verbally notify persons in the building.
2. Notify the Fire Department at 911.
3. Isolate the area and evacuate the building:
    A. Shut down equipment in the immediate area, if possible.
    B. Close doors to isolate the area.
    C. Use a portable fire extinguisher to control a small fire or assist in evacuation if possible.
4. Provide the fire/police teams with the details of the problem upon their arrival. Special information you know may be helpful in mitigation of consequences due to radioactive materials.
5. Notify Radiological and Environmental Management at (765) 494-6371.

10.4 Injury

All employees and students must notify their immediate supervisor or instructor, and REM of all injuries related to exposure to radioactive materials. Individuals on the West Lafayette campus should report to the Regional Occupational Care Center (ROCC) on Creasy Lane in Lafayette if medical attention is required. A First report of Injury report must also be submitted.

In the case of a serious injury:

1. Administer any life-saving procedures without regard for contamination.
2. Do not move a seriously injured person unless he or she is in further danger.
3. Telephone the University Police for ambulance assistance at 911.
4. Notify Radiological and Environmental Management at (765) 494-6371.

Chapter 11: References

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