Radioactive Materials Manual

Scope and Applicability

Procedures and information in this manual apply to all personnel working at or visiting ASU who procure, utilize and/or dispose of radioactive material.

Radioactive material covered includes all sealed and unsealed sources. Sealed sources of radioactive material contained within machinery such as liquid scintillation counters, gas chromatographs, and static eliminators are within the scope of this manual.

Radiation producing equipment not containing radioactive material, such as x-ray equipment, electron microscopes, lasers, and radio-frequency generators, is not covered. Procedures and information regarding the safe use of lasers or radiation producing equipment including x-ray equipment, electron microscopes and radio-frequency generators may be found in the "Laser Manual" and "Radiation Producing Equipment Manual" respectively.

ASU procures and uses radioactive material under a license issued by the Arizona Radiation Regulatory Agency (ARRA). The license requires that ASU personnel use ARRA approved procedures for acquisition, control, and disposal of all radioactive material. In order to ensure compliance with the ARRA license granted to ASU it is mandatory that personnel follow these procedures.

CHAPTER I - RADIATION SAFETY ORGANIZATION AT ASU

1.1. Arizona Radiation Regulatory Agency

Arizona State University (ASU) procures and uses radioactive material under Arizona Radiation Regulatory Agency (ARRA) License #7-37. The license requires that ASU personnel use ARRA approved procedures for the acquisition, control, and disposal of all radioactive material. These procedures include those applicable to all institutions using radioactive material as contained in the "State of Arizona Radiation Regulatory Agency Rules and Regulations", and other conditions specified in the license granted to the university. These procedures are designed to protect individuals in the university community from unnecessary exposure to ionizing radiation.

ASU is subject to inspection by ARRA. If ARRA finds that ASU is not in compliance with license conditions, it may issue fines, or in the case of serious infractions, suspend or revoke the license.

ARRA rules and regulations, the ARRA License issued to ASU, and supporting documentation are on file in the Office of Radiation Safety for review by ASU personnel.

1.2 Radiation Safety Committee

ASU governs the use of radioactive materials through the Radiation Safety Committee (RSC). This committee is a group of professionals appointed by the president of ASU to establish policy and procedures for the use of radioactive material and to oversee all aspects of radiation safety. The committee meets at least quarterly to review the University's
radiation safety program, and to review requests for permission to use radioactive material. The RSC has the authority to approve the use of radioactive material at ASU, or to deny its use in procedures deemed unsafe or by personnel deemed unqualified.

### 1.3 Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible for implementing the radiation safety program as directed by the RSC. The RSO is assisted by the staff of the Office of Radiation Safety (ORS). The RSO and ORS staff receive and in-process radioactive material, manage the radiation dosimetry program, collect and process radioactive waste, conduct radiation safety training, perform radiation safety surveys, and assist in the management of incidents involving radioactive material. The RSO is available as a consultant on safety aspects of radioactive material use, and for information on experimental design.

The RSO has the authority to suspend or prevent the use of radioactive material by individuals, and/or seize radioactive material when in their opinion work is being conducted in a hazardous manner, or in a manner that constitutes violation of ARRA rules and regulations or conditions of the ARRA License issued to ASU. These actions of the RSO are reviewed by the RSC.

### 1.4 ASU Sub-licensees

All possession, use, and disposal of radioactive material at ASU must be conducted under the auspices of a sub-license issued by the RSC or the RSO. Sub-licenses are issued to professionals at ASU who have applied for, and received permission to use radioactive material in a specified research or education program. Sub-licensees are responsible for all work conducted under their sub-license. Their responsibilities include:

- Ensuring that the conditions of their sub-license, as well as ASU and ARRA approved procedures, are followed when procuring, using, and disposing of radioactive material;
- Training and supervising users handling radioactive materials under their sub-license;
- Ensuring that their sub-license is current with respect to quantities of radioactive material used, procedures being used, and location of use.

Procedures for sub-license application are contained in Chapter II of this manual.

### 1.5 Approved Users

Approved Users are personnel who have been designated in writing by the ORS as individuals who may use radioactive material without direct supervision. Approved Users must use radioactive material under a sub-license, or sub-licenses, specified in writing by the RSC. The sub-licensee maintains overall responsibility for use of radioactive material by Approved Users.

### 1.6 Visitors

Sub-licensees are responsible to see that visitors to spaces containing radioactive material are not exposed to radiation from the material. Visitors who plan to participate in work
involving the use of radioactive material must contact the RSO for appropriate briefings and dosimetry devices.

1.7 Minors

Minors, or persons under the age of 18, are not allowed in ASU spaces containing radioactive material unless permission is obtained from the RSO. Children of University employees must not be allowed in these spaces.

Personnel under the age of 18 who desire to work with radioactive material must receive written permission to do so by the RSO.

CHAPTER II - OBTAINING PERMISSION TO USE RADIOACTIVE MATERIAL AT ASU

2.1 Sub-licenses for Use of Radioactive Material

All radioactive material at ASU is procured and used in accordance with provisions of a sub-license issued by the Radiation Safety Committee or the Radiation Safety Officer. In general, sub-licenses will be issued only to full time faculty or staff of ASU. Temporary or adjunct faculty members are to use radioactive material as an RSC Approved User under a sub-license held by a full time faculty or staff member. Temporary and adjunct faculty are individuals as defined in the "ASU Faculty Handbook" and include "post doctoral" personnel and instructors.

2.1.1 Application for New Sub-licenses

Applications for new sub-licenses are made by submitting "ASU Radioactive Materials Sub-license Application Forms" to the RSO. Forms and instructions for their completion are available online. The RSO has the authority to give temporary approval to sub-licensees for use and storage of radioactive material equal to or less than quantities listed in Table 2-1. The RSC reviews these sub-licenses at the meeting following approval by the RSO. The RSC may modify or revoke temporary sub-licenses issued by the RSO when, in their opinion, the training and experience of the users is inadequate, or the procedures are unsafe. For nuclides not listed in Table 2-1, the limits are ten times the exempt activities listed in the Arizona Administrative Code 12-1, Article 3 Schedule B.

2.1.2 Sub-license Conditions

Radioactive material sub-licenses are to be specific with respect to the following:

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Activity (uCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{195}$Au</td>
<td>100</td>
</tr>
<tr>
<td>$^{14}$C</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{45}$Ca</td>
<td>100</td>
</tr>
<tr>
<td>$^{109}$Cd</td>
<td>100</td>
</tr>
<tr>
<td>Nuclide</td>
<td>Maximum Activity</td>
</tr>
<tr>
<td>---------</td>
<td>-----------------</td>
</tr>
<tr>
<td>$^{14}$Ce</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{57}$Co</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{60}$Co</td>
<td>10</td>
</tr>
<tr>
<td>$^{51}$Cr</td>
<td>10,000</td>
</tr>
<tr>
<td>$^{59}$Fe</td>
<td>100</td>
</tr>
<tr>
<td>$^{3}$H</td>
<td>10,000</td>
</tr>
<tr>
<td>$^{205}$Hg</td>
<td>100</td>
</tr>
<tr>
<td>$^{125}$I</td>
<td>10</td>
</tr>
<tr>
<td>$^{11}$In</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{22}$Na</td>
<td>100</td>
</tr>
<tr>
<td>$^{24}$Na</td>
<td>100</td>
</tr>
<tr>
<td>$^{32}$P</td>
<td>100</td>
</tr>
<tr>
<td>$^{86}$Rb</td>
<td>100</td>
</tr>
<tr>
<td>$^{103}$R</td>
<td>100</td>
</tr>
<tr>
<td>$^{35}$S</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{48}$Sc</td>
<td>100</td>
</tr>
<tr>
<td>$^{113}$Sn</td>
<td>100</td>
</tr>
<tr>
<td>$^{85}$Sr</td>
<td>100</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>10</td>
</tr>
</tbody>
</table>

Table 2-1 Maximum activities of radionuclides which may be given temporary approval for use by the RSO.

a. Nuclides to be used, including:
   1. chemical/physical form,
   2. maximum quantity of each nuclide stored in the laboratory,
   3. maximum quantity of each nuclide stored in a single container,
   4. maximum quantity of each nuclide used in each experimental procedure;

b. Experimental procedures for each nuclide;

c. Locations(s) in which radioactive material is stored and used.

Other conditions for use of radioactive material may be imposed by the RSC at the time the sub-license is issued, or anytime thereafter.

### 2.1.3 Amendment of Sub-licenses

Sub-licenses must be amended prior to changes in procedures or other conditions listed in paragraph 2.1.2. Amendments are requested as follows:

a. Request for changes in radionuclides used under an existing sub-license are made by way of a memorandum to the RSO. Use of the "ASU Radioactive
Materials Sub-license Application Form* is optional. Information about presently licensed material is not required.

b. Requests for changes in the use of currently licensed nuclides are made by way of a memorandum to the RSO. These changes include:
   1. activity limits for currently licensed nuclides,
   2. chemical/physical form of currently licensed nuclides,
   3. procedures for use of currently licensed nuclides,
   4. location of use of currently licensed nuclides.

The RSO has the authority to give temporary approval to amendments for nuclides to be used and stored in quantities equal to or less than those listed in Table 2-1. The RSC reviews these amendments at the meeting following approval by the RSO. The RSC may modify or revoke amendments approved by the RSO when the committee feels the training and experience of users is inadequate, or the new procedures are unsafe.

2.1.4 Responsibilities of Sub-license Holders

In addition to responsibilities listed in paragraph 1.4, sub-licensees must:

a. Request amendments prior to implementation of new procedures or other changes which would violate conditions of the sub-license;

b. Ensure that users of radioactive material are properly trained and supervised;

c. Comply with regulations of ARRA, and with the conditions of their radioactive materials sub-license.

d. Notify the RSO prior to all extended absences from campus.

2.1.5 Responsibilities of Approved Users

Unsupervised use of radioactive materials by Approved Users must be conducted as directed by the sub-licensee under whose sub-license work is being conducted. Approved Users may not use radioactive material unsupervised, or supervise the use of radioactive material under sub-licenses other than those specified by the RSC. Approved Users must know and observe conditions of the sub-license under which they are working, and know the procedures for the use of radioactive material as stated in these regulations and the regulations of ARRA.

2.2 Training Required of Personnel Handling Radioactive Material

All personnel working with radioactive material at ASU must receive periodic training on radiation safety and ASU procedures for use of radioactive material.

2.2.1 Radiation Safety Training

All personnel, regardless of previous training and experience, must attend radiation safety training under the direction of the RSO before beginning work with radioactive material. Please call the ORS office at 965-6140 or send an email to register for this training. The training will last from one to two hours, and will include a test that must be passed with an 80 percent. Information will include the following:
a. Types and amounts of radiation and/or radioactive materials to which workers could be exposed while working at ASU;
b. Health effects of exposure to low doses of ionizing radiation;
c. Precautions and procedures to minimize exposure to ionizing radiation;
d. Applicable provisions of ARRA rules and regulations, and the rules and regulations established by ASU as specified in this manual;
e. Responsibilities of personnel using radioactive material;
f. Response in the event of spills and emergencies;
g. Rights of workers to have access to radiation exposure records.

2.2.2 Annual Radiation Safety Training

All personnel working with radioactive material must attend annual refresher training presented under the direction of the RSO. All sub-licensees are notified in advance of the time and place for these training sessions. Topics covered during these classes include those covered at the briefing, and others selected by the RSO. These classes are approximately one hour in length.

2.2.3 Training and Experience Required for Sub-licensees

Personnel granted sub-licensees will be required, as a minimum, to have 16 hours of formal radiation safety training. Personnel using large quantities of radioactive material or using unusual or hazardous procedures may be required to have additional training or experience relating to the particular procedures involved. Training obtained at locations other than ASU may meet these training requirements. The RSC may waive some or all of the training requirements on presentation of evidence of appropriate experience in the use of radioactive material. HOWEVER, PERSONNEL MUST DOCUMENT AT LEAST 6 MONTHS OF ROUTINE EXPERIENCE WITH THE PROCEDURES INVOLVED.

CHAPTER III - PERSONNEL DOSIMETRY AND REGULATORY LIMITS

3.1 Monitoring Radiation Doses from External Sources

3.1.1 TLD Badges

TLD badges are used at ASU to monitor personnel for exposure of the body to penetrating ionizing radiation such as gamma and x-rays, and exposure of the skin to less penetrating radiation such as beta particles. For most individuals results of the TLD badge readings are also used as estimates for the exposure of the lens of the eye. TLD badges must be worn by personnel working with most sources of ionizing radiation. TLD badges may not be required for individuals handling the following radioactive materials, however:

a. $^3$H, $^{14}$C and/or $^{35}$S
b. Micro-curie quantities of material in check sources,
c. Micro-curie quantities of materials in radio-immuno assay kits,
d. Material contained in gas chromatographs or other equipment as a sealed source.
TLD badges must be worn on the trunk of the body at or above the waist. Dosimetry devices must not be taken home or left in laboratory areas where they may be exposed to radiation from radioactive material. The TLD badge is sensitive to heat and humidity. False positive readings may result when badges are left in hot cars, near hot windows, or other sources of heat.

### 3.1.2 Extremity Dosimetry

Ring dosimetry devices are used at ASU to monitor for radiation exposure to the hands and are issued to personnel handling millicurie quantities of $^{32}\text{P}$ or other "hard" beta emitters, and to personnel handling large gamma-emitting sources. Ring badges must be worn under gloves with the sensitive portion of the ring toward the source.

### 3.1.3 Dosimeter Exchange

The TLD badges and the rings are exchanged on a quarterly basis. ORS personnel hand carry replacement TLDs and rings to department offices during the last few days of the quarter. Old TLDs and rings must be hand carried to the ORS. Campus mail must not be used. This policy has been established to avoid exposure of TLDs to sources of radiation, heat, and humidity during transit.

TLD badges should be returned to the ORS during the first 5 working days of the new quarter.

### 3.1.4 Lost or Damaged Dosimeters

Periodically, dosimetry devices are lost or damaged. This should be reported to ORS staff immediately so that replacement dosimeters can be issued. Lost or damaged dosimeters will cost $10 per badge to replace.

### 3.2 Monitoring for Exposure from Internal Radioactive Materials

#### 3.2.1 Thyroid Bioassay

All personnel handling more than 100 uCi of $^{125}\text{I}$ or $^{131}\text{I}$ during a calendar month must have a thyroid scan within 6 – 72 hours of use. Thyroid scans are obtained at the ORS on a walk-in basis.

#### 3.2.2 Urine Bioassay and Whole Body Counts

Individuals handling in excess of 10 mCi of $^{3}\text{H}$ in any given month must submit a urine sample for analysis to the Radiation Safety Officer within 6 – 72 hours of use. Personnel handling large unsealed sources of radioactive material other than $^{3}\text{H}$ may be required to submit urine samples or submit to a whole body count.

ORS staff will notify individuals requiring bioassays as needed.

### 3.3 Regulatory Dose Limits

#### 3.3.1 Limits for Radiation Workers
ARRA has imposed limits on the dose of ionizing radiation which may be received by individuals working with sources of ionizing radiation. These limits are shown in Table 3-1.

<table>
<thead>
<tr>
<th>Annual Limit, which is the more limiting of:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Total Effective Dose Equivalent</td>
<td>5 rem (0.05 Sv)</td>
</tr>
<tr>
<td>b. Sum of the deep dose equivalent and committed dose equivalent to any organ or tissue other than the lens of the eye</td>
<td>50 rem (0.5 Sv)</td>
</tr>
<tr>
<td>Eye Dose Equivalent</td>
<td>15 rem (0.15 Sv)</td>
</tr>
<tr>
<td>Shallow Dose Equivalent to the skin or to each of the extremities</td>
<td>50 rem (0.5 Sv)</td>
</tr>
</tbody>
</table>

**Table 3-1 Regulatory Dose Limits**

### 3.3.2 Limits to the Embryo/Fetus of Declared Pregnant Workers

Due to concerns about prenatal radiation exposure (Appendix B) ARRA regulations provide separate limits for the embryo/fetus of Declared Pregnant Workers. **The limit is 0.5 rem dose equivalent to the fetus during pregnancy.**

*This limit applies only for workers who have formally declared pregnancy in writing.* Declaration of pregnancy should be sent to the Radiation Safety Officer and include the estimated date of conception.

Individuals concerned about radiation and pregnancy should feel free to speak to the Radiation Safety Officer.

### 3.3.3 Limits for Members of the Public

The regulatory limit for members of the public is 0.1 rem total effective dose equivalent per year. This limit applies to all individuals who are not trained to work with sources of ionizing radiation. At ASU this includes most faculty, staff, and students.

### 3.4 ALARA

In view of uncertainties that exist concerning the health effects of exposure to low doses of radiation (see Appendix A), it is prudent to keep doses to personnel "as low as is reasonably achievable" (ALARA). Each user of radioactive material at ASU has the responsibility to incorporate shielding and protective devices, and to take any other steps required to keep doses ALARA.

### 3.4.1 Investigational Levels
In order to maintain doses ALARA, investigational dose levels have been established at ASU. These dose levels are shown in Table 3-2. The limits are evaluated on a quarterly basis.

Personnel exposures equal to or greater than Investigational Level I, will be reviewed by the RSO, who will report the results to the RSC at their next regularly scheduled meeting. The RSC may require corrective actions on the part of the RSO or sub-licensee.

Personnel exposures equal to or exceeding Investigational Level II will be investigated in a timely manner by the RSO who will take immediate action if warranted. A report of the investigation, actions taken, and a copy of the individual's radiation dosimetry history will be presented to the RSC at their regularly scheduled meeting following completion of the investigation. The RSC may impose restrictions on the user, and/or additional conditions on the sub-license under which the exposed individual was working, as warranted.

Investigational limits exceeding those listed in Table 3-2 may be established by the RSC for a worker or group of workers when the higher investigational levels are consistent with good ALARA practice for the work being conducted by the individual or group.

<table>
<thead>
<tr>
<th>Limit</th>
<th>Level (rem/quarter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Effective Dose Equivalent</td>
<td>Level II Level II</td>
</tr>
<tr>
<td>Eye Dose Equivalent</td>
<td>0.065 0.200</td>
</tr>
<tr>
<td>Shallow Dose Equivalent to the Skin or to each of the Extremities</td>
<td>0.180 0.600</td>
</tr>
<tr>
<td></td>
<td>0.625 2.000</td>
</tr>
</tbody>
</table>

Table 3-2 Investigational Dose Levels

3.5 Reports to Workers on Radiation Dosimetry

The ORS keeps careful records on results of radiation dosimetry and bioassay for personnel on the ASU dosimetry program. These records are available for review by these personnel.

3.5.1 Review of Records in the ORS

Personnel issued dosimeter devices are welcome to review dosimetry results on file in the ORS. This review should be arranged with the RSO. The RSO requires positive identification of individuals seeking access to dosimetry since these records are covered by state and federal privacy laws.

3.5.2 Annual Dosimetry Report

During the spring of each year, a report on dosimetry results for the previous calendar year is sent to each individual issued dosimeters at ASU. A summary of individual dosimetry results are also sent to the sub-licensee responsible for supervising the work requiring dosimetry.
3.5.3 Notification of Results Exceeding Investigation Limits

Personnel will be notified quickly of results which exceed Investigation Levels listed in Table 3-4. Personnel are not notified quarterly of routine dosimetry results which do not exceed the Investigation Levels.

3.6 Radiation Dosimetry Units

The following paragraphs explain the dosimetry units used in this chapter.

3.6.1 Absorbed Dose

The amount of energy absorbed by irradiated tissue is an important variable in the assessment of radiation risk and damage. The absorbed dose is defined as the energy absorbed per unit mass of tissue. The traditional unit for absorbed dose is the rad.

\[ 1 \text{ rad} = 100 \text{ erg / gram} \]

The rad is being replaced by a new unit based on the International System of Units (SI). The new unit is the gray.

\[ 1 \text{ gray} = 1 \text{ joule / kg} \]

Spending a little time with the units will reveal that

\[ 1 \text{ gray} = 100 \text{ rad} \]

The SI units have not found widespread use in radiation protection in this country. It is the system of units which is used internationally, however, and will eventually replace the older units here.

3.6.2 Dose Equivalent

Alpha, beta, gamma/x-radiation, and neutrons differ in the tissue damage produced for a given absorbed dose. Special units of dose equivalent are used to adjust the absorbed dose for this difference. The traditional unit of dose equivalent is the rem.

\[ 1 \text{ rem} = 1 \text{ rad} \times Q \]

Q is called the quality factor and is assigned to radiation based on the relative risk for a given dose. Currently a quality factor of 1 is used for photons, electrons, and positrons. A quality factor of from 2.3 to 10 is used for neutrons, depending on their energy, and a quality factor of 20 is used for alpha particles. The SI unit for dose equivalent is the sievert.

\[ 1 \text{ sievert} = 1 \text{ gray} \times Q \]

<table>
<thead>
<tr>
<th>RADIATIONS TYPE</th>
<th>Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>x and gamma-rays</td>
<td>1</td>
</tr>
</tbody>
</table>
beta particles | 1
---|---
alpha particles | 20
neutrons | 2.3 to 10

**Table 3-3 Radiation Quality Factors**

### 3.6.3 Exposure

The energy absorbed by irradiated tissue is rarely measured directly. Most radiation detection instrumentation used in radiation protection measures the number of ion pairs produced in a volume of gas. The traditional unit used to measure ionization in air is the roentgen:

\[ 1 \text{ roentgen} = 2.58 \times 10^{-4} \text{ coulombs / kg air} \]

The roentgen is defined only for x-rays and gamma rays. It is not used for beta, alpha, or neutron radiation.

Exposure of 1 roentgen of radiation results in an absorbed dose to tissue of 0.97 rad. For purposes of radiation protection and dosimetry, it is usually assumed that the roentgen, rad, and rem are numerically equivalent for gamma-rays and x-rays.

### 3.6.4 Effective Dose Equivalent

The various organs and tissues in the body differ in their sensitivity to radiation. For instance, the bone marrow and other blood forming tissues of the body are much more sensitive to radiation than the skin of the body. In order to quantify the risk from radiation exposure when the body is not irradiated uniformly (different doses are delivered to different organs or tissues of the body) a unit called the effective dose equivalent has been developed. The effective dose equivalent is given the symbol H and is defined as:

\[ H = \sum D_i W_i \]

where \( D_i \) is the dose equivalent received by the ith tissue or organ, and \( W_i \) is a weighting factor which is assigned to the ith tissue or organ depending on its sensitivity to radiation. Weighting factors currently in use are listed in the accompanying table. The units of the effective dose equivalent are the rem and the sievert depending on which is used for the individual tissue or organ dose equivalent.

<table>
<thead>
<tr>
<th>TISSUE</th>
<th>WEIGHTING FACTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gonads</td>
<td>0.25</td>
</tr>
<tr>
<td>Breast</td>
<td>0.15</td>
</tr>
<tr>
<td>Red Bone Marrow</td>
<td>0.12</td>
</tr>
<tr>
<td>Lung</td>
<td>0.12</td>
</tr>
<tr>
<td>Thyroid</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Table 3-4 Effective Dose Equivalent Weighting Factors

<table>
<thead>
<tr>
<th>Bone Surfaces</th>
<th>0.03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remainder</td>
<td>0.30</td>
</tr>
<tr>
<td>Whole Body</td>
<td>1.00</td>
</tr>
</tbody>
</table>

The 0.30 for remainder results from 0.06 for each of 5 remaining organs, excluding the skin and the lens of the eye, that receive the highest doses.

3.6.5 Committed Effective Dose Equivalent

When radioactive materials are inhaled, ingested, or otherwise internalized, they may be retained in some tissues for a long period of time. In some cases a fraction of the material may remain in the body for years. The committed dose equivalent is the dose equivalent that will be received by tissues or organs from an intake of radioactive material during the 50 year period following the intake. The committed effective dose equivalent is the effective dose equivalent that will be received from an intake of radioactive material by an individual during the 50 year period following the intake.

3.6.6 Deep Dose Equivalent

The deep dose equivalent is the dose equivalent at a tissue depth of 1 cm.

3.6.7 Shallow Dose Equivalent

The shallow dose equivalent is the dose equivalent at a tissue depth of 0.0007 cm averaged over an area of 1 square centimeter.

3.6.8 Eye Dose Equivalent

The eye dose equivalent is the dose equivalent to the lens of the eye.

3.6.9 Total Effective Dose Equivalent

The total effective dose equivalent is the sum of the committed effective dose equivalent for all intakes of radioactive material and the deep dose equivalent to the whole body resulting from exposure to external sources of radiation.

CHAPTER IV - LABORATORY PROCEDURES FOR USE OF RADIOACTIVE MATERIAL

4.1 Posting of Laboratories and Space for Use of Radioactive Material

All work with radioactive material must be conducted in spaces approved by the RSO under the direction of the RSC. Entries to these spaces are posted by the RSO with signs containing the yellow and magenta radiation warning symbol. The warnings on the signs will vary according to the following conditions:
a. Spaces approved for radionuclide use but not containing significant radiation fields are labeled with signs containing the words

| CAUTION (or "DANGER") | RADIOACTIVE MATERIAL |

b. Spaces in which the radiation field could lead to personnel receiving a whole body dose of 5 millirem in any hour or 100 millirem in any 5 consecutive days are posted with signs containing the words

| CAUTION RADIATION AREA |

c. Spaces in which the radiation fields could lead to personnel receiving a whole body dose of 100 millirem in any hour, are posted with signs containing the words

| CAUTION (or "DANGER") | HIGH RADIATION AREA |

Additional signs and warnings may be posted for contaminated spaces or other purposes. All instructions on or with signs containing radiation warnings should be strictly obeyed.

Radioactive material may be taken into unposted spaces for educational purposes only under provisions of a sub-license granted by the RSO or RSC. This radioactive material must be attended at all times by the sub-licensee or a user for whom the sub-licensee is responsible.

4.2 Labeling and Storage of Radionuclides

4.2.1 Labeling

Regulations require that any containers with radioactive material in excess of the limits specified in Table 4-1 be labeled with the nuclide, activity, date, and name of user. Limits for nuclides not specified are contained in Arizona Administrative Code 12-1, Article 4 Appendix C. Containers with lesser amounts of radioactive material should be labeled when practical. Racks or boxes containing a number of samples with small amounts of radioactive material may be labeled in lieu of a label on each vial.

<table>
<thead>
<tr>
<th>NUCLIDE</th>
<th>ACTIVITY (uCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{14}$C</td>
<td>1,000</td>
</tr>
<tr>
<td>$^{45}$Ca</td>
<td>100</td>
</tr>
<tr>
<td>$^{57}$Co</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 4-1 Labeling

\[
\begin{array}{|c|c|}
\hline
\text{Nuclide} & \text{Activity} \\
\hline
\text{\textsuperscript{60}Co} & 1 \\
\text{\textsuperscript{51}Cr} & 1,000 \\
\text{\textsuperscript{59}Fe} & 10 \\
\text{\textsuperscript{3}H} & 1,000 \\
\text{\textsuperscript{125}I} & 1 \\
\text{\textsuperscript{22}Na} & 10 \\
\text{\textsuperscript{32}P} & 10 \\
\text{\textsuperscript{35}S} & 100 \\
\hline
\end{array}
\]

4.2.2 Storage

All radioactive material must be stored so that radiation fields are less than those specified for a "Radiation Area" in sub-chapter 4.1, unless specific approval is obtained from the RSO. Radioactive sources must be secured against unauthorized removal at all times. This means that one of the following conditions must be met:

a. Material is attended by a responsible person authorized to work with radioactive material;
b. Material is contained in a locked container;
c. The room in which the material is stored is locked.

4.3 Contamination Control

4.3.1 General Rules for Contamination Control

a. The area within the laboratory where unsealed sources of radioactive material are used must be covered with absorbent material surrounded with yellow tape or tape with the standard radiation caution symbol. If possible, work should be conducted in a tray lined with absorbent paper and in a chemical or radionuclide fume hood.
b. Disposable gloves and lab coats must be worn at all times when handling unsealed sources of radioactive materials. Lab coats must not be taken from the lab to lunch rooms.
c. All radioactive waste must be placed in marked containers which have been approved by the ORS.
d. Never pipette solutions by mouth.
e. Use the smallest quantity of radioactivity compatible with the objective of the experiment.
f. Label containers of radioactive material clearly indicating nuclide, total activity, and date.
g. Do not eat, drink, smoke, chew gum, or apply cosmetics in spaces where unsealed sources of radioactive material are used.
h. Do not store food, drink, or personal items with radioactive material.
i. Know how to react in case of a spill or personal contamination.

j. Wear assigned dosimetry devices as required.

k. Work carefully, and regularly monitor the work area to avoid accidental contamination.

4.3.2 User Surveys for Surface Contamination

After procedures using unsealed sources of radioactive material are complete, or at the end of each day during which radioactive materials are used, the work areas must be surveyed for surface contamination.

The extent of the survey depends on the type of procedures being conducted and the amount of radioactive material.

Use of activities equal to or less than those in paragraph 4.2.1 requires a check for contamination in the immediate work area, and on the hands and feet of those handling the material.

Complicated procedures, and those involving quantities of radioactive material in excess of those listed in paragraph 4.2.1 require more extensive surveys; including checks on surfaces such as the floor, table tops, phones, doorknobs, feet, hands, and other areas where there is a potential for the spread of radioactive material.

Surveys must be documented. The individual conducting the survey must initial or sign a document indicating that the survey was conducted, and whether contamination was or was not found. The documentation may be through use of the source utilization logs, or other log provided by the user.

4.3.3 Survey Procedures (See RAM Survey)

Surveys for some nuclides may be made using a laboratory survey instrument. Surveys for other nuclides, such as H-3, require wiping surfaces with filter papers. Removable activity on the filter papers can be counted using liquid scintillation. Specific procedures for some nuclides in use at ASU are:

l. \(^{3}\text{H}\): Wipe surfaces with filter paper and count by liquid scintillation for five minutes. If the count rate is more than 15 cpm above background, the surfaces should be decontaminated.

m. \(^{14}\text{C} / \^{35}\text{S} / \^{45}\text{Ca} / \^{125}\text{I}\): G.M. counters with thin windows (1.2-2 mg/cm\(^2\)) may be used for detecting areas of gross contamination. However, the efficiency of thin window G.M. detectors for these nuclides is such that contamination in excess of allowable limits may not be detected. A final check must be conducted using filter paper wipes as outlined for \(^{3}\text{H}\).

n. \(^{32}\text{P}\) and other "hard beta emitters": These nuclides are adequately detected with laboratory survey meters. The probe should be placed within a couple of millimeters of the surface, and moved very slowly. Surfaces with readings of more than 50 cpm above background should be decontaminated.

o. Laboratory survey techniques for other nuclides may be obtained from the RSO.

4.3.4 Contaminated Surfaces and Equipment
Instruments and glassware which are repeatedly used with radioactive materials may be stored in their contaminated condition if they are bagged, marked with the radiation warning symbol, and placed in a closed container such as a drawer or cupboard which also shows the radiation warning symbol.

Interior surfaces of some equipment, such as centrifuges, may contain low level contamination if the equipment is properly marked and closed so that contaminated surfaces are not exposed to the room. Measurable contamination must not be allowed to remain on equipment and laboratory surfaces other than those listed above. Exceptions to this policy must be approved by the RSO.

**4.3.5 Laboratory Surveys by Radiation Protection Personnel**

Personnel from the ORS enter laboratories and spaces designated for use of radioactive materials periodically to conduct surveys. Personnel conducting surveys make measurements of surface contamination and radiation levels. They also examine laboratory records and observe laboratory conditions for compliance of the sub-licensee and users of radioactive material with ARRA and ASU rules and regulations for use of radioactive material. Most spaces in which radioactive material is used are surveyed by ORS personnel once each month. Laboratories using radioactive material on an infrequent basis will be surveyed by ORS personnel annually.

**4.3.6 Sealed Source Leak Checks**

Sealed sources containing more than 100 uCi of beta or photon-emitting material or more than 10 uCi of alpha-emitting material are wipe tested for leakage once every 6 months by ORS personnel. Sub-licensees are contacted for access to sources as needed. Should leakage in excess of 0.005 uCi be discovered on these sources, they are removed from use and repaired or disposed of by the RSO.

**4.4 Protection from External Exposure**

**4.4.1 \(^3\)H, \(^{14}\)C, and \(^{35}\)S**

External exposure to radiation emitted by these low-energy beta emitters is not a problem unless they are present as contamination on the surface of the skin. Beta particles from these nuclides travel less than 25 cm (10 inches) in air and less than 0.3 mm (0.1 inch) in tissue. Most radiation is absorbed by containers, solutions, air, clothing, and the dead layer of skin. The beta particle from tritium does not have sufficient energy to penetrate the dead layer of cells protecting the skin.

**4.4.2 Limiting Time of Exposure**

The external dose received is a function of the time spent working in the proximity of radioactive materials. Plan procedures in advance and examine ways of doing the job which will speed the procedure and/or limit the amount of time that exposure to radiation is necessary. Equipment which eliminates the need for direct handling of radioactive material is desirable.
Practice procedures using non-radioactive materials. These dry runs will increase worker's ability to conduct experiments quickly and carefully.

### 4.4.3 Maximizing Distance from Sources

For sources of radiation which are small in physical size, the intensity of the radiation field is inversely proportional to the square of the distance from the source. The importance of the so called "inverse square law" lies in the quadratic relationship between exposure rate and distance. By doubling the distance between a worker and the source, the exposure rate is decreased by a factor of four. Distance should be maximized by using remote handling instruments, such as tongs for handling vials of radioactive material, and by staying away from the source whenever possible.

### 4.4.4 Shielding Beta Particles

Shielding pure beta emitters is simplified by the lack of the more penetrating radiations. Beta particles have a finite range in shielding materials beyond which they cannot penetrate. The best shielding for $^{32}\text{P}$ is plastic, lucite, glass, and aluminum. Use of lead or other high atomic number shielding materials may create penetrating bremsstrahlung radiations. Lucite and plexiglass are easily worked materials for constructing beta shields. One fourth inch of these plastics will protect users working with millicurie quantities of $^{32}\text{P}$. Beta shields in various configurations can be obtained commercially. Information on sources of these shield materials is available in the ORS.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Radiations Emitted</th>
<th>Range of $\beta$ Particle in Air</th>
<th>$^1$Dose Rate to Skin from 1 uCi/cm$^2$ Skin Contamination (rad/hr)</th>
<th>$^2$Annual Limit on Intake (mCi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{3}\text{H}$</td>
<td>$18.6$ keV $\beta$</td>
<td>$0.5$ cm</td>
<td>0.0</td>
<td>80</td>
</tr>
<tr>
<td>$^{14}\text{C}$</td>
<td>$156.5$ keV $\beta$</td>
<td>$0.2$ m</td>
<td>1.2</td>
<td>2</td>
</tr>
<tr>
<td>$^{32}\text{P}$</td>
<td>$1.7$ MeV $\beta$</td>
<td>$6.2$ m</td>
<td>8.9</td>
<td>0.6</td>
</tr>
<tr>
<td>$^{35}\text{S}$</td>
<td>$166.7$ keV $\beta$</td>
<td>$0.24$ m</td>
<td>1.3</td>
<td>2</td>
</tr>
<tr>
<td>$^{36}\text{Cl}$</td>
<td>$709.3$ keV $\beta$</td>
<td>$1.9$ m</td>
<td>7.2</td>
<td>0.2</td>
</tr>
<tr>
<td>$^{45}\text{Ca}$</td>
<td>$256.7$ keV $\beta$</td>
<td>$0.46$ m</td>
<td>3.3</td>
<td>0.8</td>
</tr>
<tr>
<td>$^{59}\text{Fe}$</td>
<td>$465.6$ keV $\beta$</td>
<td>$1.1$ m</td>
<td>4.7</td>
<td>0.3</td>
</tr>
</tbody>
</table>
1.1 MeV g | - | -
1.3 MeV g | - | -

<table>
<thead>
<tr>
<th>125I</th>
<th>35 keV electrons</th>
<th>1.5 cm</th>
<th>2x10^-3</th>
<th>0.04</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 keV x-rays</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>35 keV g</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1 Dose rate estimated for basal skin cells

2 Amount of ingested or inhaled radioactive material resulting in a 5 rem effective dose equivalent. The number listed is the smallest of the inhalation and ingestion ALI.

Table 4-2 Characteristics of Nuclides in Common Use at ASU

4.4.5 Shielding of Gamma and X-Rays

Lead or other high atomic number materials are most efficient for shielding gamma and x-rays. The thickness required depends on the energy of the photon and the activity of the source. One quarter inch of lead will reduce radiation from 125I by a factor of 100. Over two inches of lead is required for a comparable reduction in radiation from Co-60, however.

Radioactive materials should be stored in shielding such that the dose rate to people in the laboratory is less than 2 mrem/hr. Lead shielded storage pigs, lead sheet and lead bricks are commercially available for shielding photons. The RSO should be consulted when designing or evaluating shielding.

4.5 Internal Contamination

All radioactive materials will expose tissues of the body if inhaled, ingested, injected or otherwise introduced into the body. (See Table 4.2). Prevention of internalization of material is through contamination control including clean work habits and frequent user surveys.

4.6 Skin Contamination

When nuclides are present on the surface of the skin, relatively large doses may be delivered in a short period of time. (See Table 4.2). Wear gloves at all times during use of radioactive material. If contaminated, the skin should be washed immediately. In all cases of skin contamination, ORS staff should be notified immediately.
CHAPTER V - SOURCE PROCUREMENT AND ACCOUNTABILITY

5.1 Ordering Radioactive Material

The Advantage System is used for purchasing radioactive material at ASU. Purchasing Department personnel obtain approval for these purchases either on-line, or through written approval on hard copies of the requisition. To process orders for radioactive material:

a. Complete information using Advantage - use object code 7320 10 for radioactive material;
b. Specify, in the appropriate space, that delivery is to be made to the ORS;
c. Describe the item(s) in terms of the nuclide, the chemical/physical form of the nuclide, and the activity in uCi or mCi.

5.1.1 Procurement Other than by Purchase Order

Radioactive material in any quantity must not be obtained for use at ASU without approval of the ORS. Before arrangements are made with organizations or individuals to obtain radioactive material, the organization or person from which the material is obtained must have certification from the ORS that ASU is licensed to receive it. The ORS is responsible to see that DOT and NRC regulations are adhered to with respect to transport and receipt of the source.

5.1.2 Receipt of Radioactive Material

All radioactive material shipped to ASU facilities is sent to the ORS. Upon receipt of radioactive material, ORS staff survey material for radiation levels and surface contamination.

The responsible user is notified of its arrival. Radioactive material is delivered to users by ORS staff.

5.2 Transfer of Radioactive Material to Other Users at ASU

Transfer of radioactive material between sub-licensees at ASU must be approved by the RSO prior to transfer of the material.

5.3 Radioactive Material Accountability

5.3.1 Source Control Number

Each vial or source containing radioactive material is given a Source Control Number (SCN) at the time it arrives at ASU. The SCN assists users in tracking down information on orders and keeping track of material in each laboratory.

A “Source Utilization Log” is issued to users for each vial of consumable radioactive material when it is delivered by ORS personnel. The log is updated by the user when radioactive material is disposed of as waste. The log remains in the possession of the user until all of the radioactive material in the vial has been disposed of, at which time the log is returned to the ORS. These records must be maintained in the
laboratory to assist in keeping track of radioactive material in work areas, and be available for review by ORS personnel and/or state inspectors and auditors. All entries should be as accurate as possible, but may be conservative estimates when exact quantities are not known. Logs may be corrected for radioactive decay at the discretion of the sub-licensee.

5.3.2 Quarterly Radioactive Source Inventory

At the end of each calendar quarter, a computer printout with a list of radionuclide sources in the possession of the user is sent to each sub-licensee. Sources are identified by source number, radionuclide, and chemical/physical form.

A physical check must be conducted by the sub-licensee for all radioactive material. Sources in possession of the user which are not listed on the printout, or sources listed which are not in the possession of the user, must be brought to the attention of the RSO. The activity of sources on hand should be checked and corrected if there are changes due to disposal or decay.

CHAPTER VI - SHIPMENT AND TRANSPORT OF RADIOACTIVE MATERIAL

6.1 Shipment and Transport of Radioactive Material to Off-Campus Locations

Radioactive material must not be taken off of ASU property without prior notification and approval of the RSO. The RSO will direct packaging and transportation of the material. This restriction includes movement of:

a. Small amounts of radioactivity in samples or culture media;
b. Sealed check sources or sources contained in equipment such as liquid scintillation counters and chromatographs;
c. Radioactive material between the main campus and other ASU owned facilities such as the Animal Care Facility or the Community Services Building.

6.2 Transportation of Radioactive Material Between Buildings on the ASU Campus

Radioactive material moved between buildings of the main campus must be packaged to prevent spillage of liquid or powdered material. The material should be in closed containers with tight fitting lids. These containers should be properly labeled (See paragraph 4.2.1). Glass containers should be surrounded by enough absorbent material to prevent loss of material in the event of breakage. Material should be shielded such that the exposure rate 1 meter from the package surface is less than 10 mR/hr. Packages with exposure rates in excess of 10 mR/hr at the package surface should be transported using a cart and not carried by hand.

6.3 Transportation of Radioactive Material in Hallways of Buildings

Radioactive material carried or transported into hallways should be in closed containers with tight fitting lids. Exceptions to this policy must be approved by the RSO.
CHAPTER VII - DISPOSAL OF RADIOACTIVE WASTE

7.1 Solid Radioactive Waste

Office of Radiation Safety personnel place solid waste containers in each posted laboratory. The container is marked with the words "Radioactive Waste" or "Radioactive Material" prominently displayed on the side and lid of the container. Solid radioactive waste, including damp paper, and solid containers with residual moisture on the surfaces, may be placed in these containers. Test tubes and vials containing pourable quantities of radioactive liquid must be emptied before placing them in solid waste containers.

7.2 Liquid Radioactive Waste

Polyethylene cubitainers are available for disposal of liquid radioactive waste. These containers should be placed in an outer container such as a plastic dish pan marked with a radioactive warning label with the words "Radioactive Material" or " Radioactive Waste".

Care must be taken when disposing of radioactive liquid not to contaminate the side of the containers. Users must not dispose of radioactive waste in sinks.

7.3 Scintillation Vials

Liquid scintillation vials should not be disposed of as either solid or liquid radioactive waste. Liquid scintillation vials should be segregated into two groups:

1. Vials containing only $^3$H or $^{14}$C in scintillation fluid.
2. Vials containing any other isotopes in scintillation fluid.

Vials may be packaged for disposal in the original cardboard racks supplied by the vial manufacturer or placed into containers supplied by the Office of Radiation Safety. Do not place any liquid filled vials into solid radioactive waste containers. Do not dispose of scintillation fluid in sinks.

7.4 Animal Carcasses

All animal carcasses and tissue samples containing radioactive material are bagged in strong plastic bags and securely fastened. A radioactive carcass tag indicating the date of disposal, responsible investigator, nuclide, and its activity must be attached to the bag. The carcasses are then placed in a laboratory freezer until removed by Radiation Safety Personnel.

7.5 Waste Documentation

Current records should be kept by users on the nuclides and activity of the waste in all solid, liquid, and scintillation waste containers. Before ORS personnel pick up waste, a waste documentation tag must be attached to the container which gives nuclides, and their activities, responsible sub-licensee and effective date of the information on the card.
7.6 **Mixed Radioactive and Hazardous Wastes**

Occasionally radioactive wastes will contain hazardous wastes as defined by the ASU Office of Hazardous Materials Management. This includes xylene and toluene based liquid scintillation fluids. The presence of hazardous wastes in addition to radioactive nuclides, must be noted on the waste documentation card.

Users anticipating the generation of these mixed wastes should bring these plans to the attention of the RSO as soon as possible.

7.7 **Waste Pickup from Laboratories**

Radioactive waste is picked up and taken to the campus processing facility by ORS personnel. Contact the ORS for removal of any radioactive waste. Campus-wide pick-up of radioactive waste is usually performed on a weekly basis but extra containers are usually available at the ORS office anytime during daytime office hours.

**CHAPTER VIII - RADIOACTIVE MATERIAL WITH ANIMALS**

8.1 **General Procedures**

Special care must be taken when using radioactive material with laboratory animals to ensure that all conditions of the sub-license under which work is conducted are followed.

Secretions from animals administered radioactive material should be considered to be radioactive. Precautions should be taken to prevent contamination of facility surfaces and personnel handling the animals.

Animals to which radioactive material has been administered must be attended at all times during experimental procedures. These animals must be housed in the ASU Laboratory Animal Care Facilities (LACF) unless specific approval for alternative housing has been obtained from the RSC.

8.2 **Housing of Animals in Laboratory Animal Care Facilities**

The Office of Radiation Safety and the Laboratory Animal Care Facilities must be notified prior to administration of radioactive material to animals which are to be housed in the LACF.

All cages containing animals to which radioactive material has been administered must be labeled with radioactive warning tape. Labels will contain the name of the responsible investigator, the nuclide administered, the activity administered, and the date of administration.

Excretions and bedding from animals administered radioactive material will be considered radioactive and disposed of as radioactive waste.

Laboratory Animal Care Facilities personnel handling animals administered radioactive material, collecting waste, or cleaning cages must receive training in subjects listed in
Paragraph 2.2.1 and in specific techniques for handling animals containing radioactive material.

CHAPTER IX - HEALTH PHYSICS EMERGENCY PROCEDURES

Health physics emergencies in laboratories utilizing radioactive material will usually be limited to minor spills. The potential does exist, however for emergencies involving the creation of significant radiation hazards. These incidents may be complicated by injuries to personnel.

In all emergency situations the primary concern must always be the protection of personnel from radiation and non-radiation hazards. The secondary concern is to confine contamination. Medical assistance should not be withheld or delayed because of contamination of personnel by radioactive material.

9.1 Minor Spills Involving No Radiation Hazard to Personnel

1. Notify all other persons in the room at once.
2. Confine the spill immediately, but make no attempt to clean up the spill.
   a. For liquid spills, don protective gloves and place absorbent paper on the spill.
   b. For dry spills, don protective gloves and place lightly moistened absorbent paper on the spill, taking care not to spread contamination.
3. If the spill is on the skin, flush thoroughly with water. If the spill is on the clothing, discard outer clothing at once.
4. Notify the ORS immediately.

ORS 8 to 5 Mon.-Fri. (480) 965-6140
DPS Nights/Weekends (480) 965-3456
Fire Department (Do not dial 8) 911

5. Permit no one to resume work in the area or leave the premises without approval of the RSO or his/her designated representative.

9.2 Accidents Involving Radioactive Dusts, Mists, Fumes, Organic Vapors and Gases

1. Notify all personnel to vacate the room immediately.
2. Hold breath, close all windows and escape valves, and switch off circulating air.
3. Vacate the room.
4. Notify the ORS at once.
5. Ascertain that all doors giving access to the room are closed and locked. If necessary, post guards to prevent accidental opening of doors.
6. Do not re-enter the room or permit anyone to leave the premises until the approval of the RSO or his/her designated representative is obtained.

9.3 Injuries to Personnel Involving Radiation Hazards

1. Wash minor wounds immediately under running water.
2. Report all radiation accidents (wound, over-exposure, ingestion, inhalation) to the ORS immediately.
3. Call a physician as needed.
4. Do not permit personnel involved in a radiation injury incident to return to work or leave the premises without the approval of the RSO or the physician.

9.4 Fires

1. Use normal fire emergency procedures for control of the fire and evacuation of the personnel.
2. Notify the ORS immediately.

Appendix A - Instruction Concerning Risks From Occupational Radiation Exposure

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Appendix B - Instruction Concerning Prenatal Radiation Exposure

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Appendix C - ARRA Form 6: Notice to Employees

PDF Version

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