

120.594: continued

(2) The licensee shall submit a written report to the Agency within 30 days after discovery of the unauthorized departure. The written report must include:

- (a) The licensee's name;
- (b) The date and time of the unauthorized departure;
- (c) The projected date and time when release would have occurred;
- (d) The general location address of the patient's or human research subject's home or anticipated destination following departure;
- (e) The radionuclide, chemical and physical form and calculated activity at time of release;
- (f) The apparent reason(s) for the departure prior to authorized release; and,
- (g) A description of any changes in the licensee's patient release criteria or patient instructions that are designed to avoid a recurrence of such an event.

(E) Notification of Deceased Patients or Human Research Subjects Containing Radioactive Material.

(1) The licensee shall notify the Agency by telephone immediately upon discovery that a patient or human research subject containing radioactive material has died, and it is possible that any individual could receive exposures in excess of 105 CMR 120.221 as a result of the deceased's body.

(2) The licensee shall submit a written report to the Agency within 30 days after discovery that the patient or human research subject referenced in 105 CMR 120.594(E)(1) has died.

The written report must include:

- (a) The licensee's name;
- (b) The date of death;
- (c) The radionuclide, chemical and physical form and calculated activity at time of death; and
- (d) The names (or titles) and address(es) of known individuals who might have received exposures exceeding five mSv (500 mrem).

120.600: RADIATION SAFETY REQUIREMENTS FOR ANALYTICAL X-RAY EQUIPMENT

120.601: Purpose and Scope

105 CMR 120.600 provides special requirements for analytical x-ray equipment. The requirements of 105 CMR 120.600 are in addition to, and not in substitution for, applicable requirements in other Sections of 105 CMR 120.000.

120.602: Definitions

As used in 105 CMR 120.600, the following definitions apply:

Analytical X-ray Equipment means equipment used for x-ray diffraction or fluorescence analysis.

Analytical X-ray System means a group of components utilizing x or gamma rays to determine the elemental composition or to examine the microstructure of materials.

Fail-safe Characteristics mean a design feature which causes beam port shutters to close, or otherwise prevents emergence of the primary beam, upon the failure of a safety or warning device.

Local Components mean part of an analytical x-ray system and include areas that are struck by x-rays such as radiation source housings, port and shutter assemblies, collimators, sample holders, cameras, goniometers, detectors, and shielding, but do not include power supplies, transformers, amplifiers, readout devices, and control panels.

Normal Operating Procedures mean step-by-step instructions necessary to accomplish the analysis. These procedures shall include sample insertion and manipulation, equipment alignment, routine maintenance by the registrant (or licensee), and data recording procedures, which are related to radiation safety.

120.602: continued

Open-beam Configuration means an analytical x-ray system in which an individual could accidentally place some part of his body in the primary beam path during normal operation.

Primary Beam means radiation which passes through an aperture of the source housing by a direct path from the x-ray tube or a radioactive source located in the radiation source housing.

120.603: Equipment Requirements

(A) Safety Device. A device which prevents the entry of any portion of an individual's body into the primary x-ray beam path or which causes the beam to be shut off upon entry into its path shall be provided on all open-beam configurations. A registrant [or licensee] may apply to the Agency for an exemption from the requirement of a safety device. Such application shall include:

- (1) A description of the various safety devices that have been evaluated;
- (2) The reason each of these devices cannot be used; and,
- (3) A description of the alternative methods that will be employed to minimize the possibility of an accidental exposure, including procedures to assure that operators and others in the area will be informed of the absence of safety devices.

(B) Warning Devices.

- (1) Open-beam configurations shall be provided with a readily discernible indication of:
 - (a) X-ray tube "on-off" status located near the radiation source housing, if the primary beam is controlled in this manner; and/or,
 - (b) Shutter "open-closed" status located near each port on the radiation source housing, if the primary beam is controlled in this manner.
- (2) Warning devices shall be labeled so that their purpose is easily identified. On equipment installed after the effective date of 105 CMR 120.600, warning devices shall have fail-safe characteristics.

(C) Ports. Unused ports on radiation source housings shall be secured in the closed position in a manner which will prevent casual opening.

(D) Labeling. All analytical x-ray equipment shall be labeled with a readily discernible sign or signs bearing the radiation symbol and the words:

- (1) "CAUTION - HIGH INTENSITY X-RAY BEAM", or words having a similar intent, on the x-ray source housing; and,
- (2) "CAUTION RADIATION - THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED", or words having a similar intent, near any switch that energizes an x-ray tube if the radiation source is an x-ray tube; or,
- (3) "CAUTION - RADIOACTIVE MATERIAL", or words having a similar intent, on the source housing in accordance with 105 CMR 120.237 and 120.238 if the radiation source is a radionuclide.

(E) Shutters. On open-beam configurations installed after the effective date of 105 CMR 120.600, each port on the radiation source housing shall be equipped with a shutter that cannot be opened unless a collimator or a coupling has been connected to the port.

(F) Warning Lights.

- (1) An easily visible warning light labeled with the words "X-RAY ON", or words having a similar intent, shall be located:
 - (a) Near any switch that energizes an x-ray tube and shall be illuminated only when the tube is energized; or,
 - (b) In the case of a radioactive source, near any switch that opens a housing shutter and shall be illuminated only when the shutter is open.
- (2) On equipment installed after the effective date of 105 CMR 120.600, warning lights shall have fail-safe characteristics.

(G) Radiation Source Housing. Each radiation source housing shall be subject to the following requirements:

120.603: continued

(1) Each x-ray tube housing shall be equipped with an interlock that shuts off the tube if it is removed from the radiation source housing or if the housing is disassembled.

(2) Each radioactive source housing or port cover or each x-ray tube housing shall be so constructed that, with all shutters closed, the radiation measured at a distance of five centimeters from its surface is not capable of producing a dose in excess of 2.5 millirems (0.025 mSv) in one hour. For systems utilizing x-ray tubes, this limit shall be met at any specified tube rating.

(H) Generator Cabinet. Each x-ray generator shall be supplied with a protective cabinet which limits leakage radiation measured at a distance of five centimeters from its surface such that it is not capable of producing a dose in excess of 0.25 millirem (2.5 μ Sv) in one hour.

120.604: Area Requirements

(A) Radiation Levels. The local components of an analytical x-ray system shall be located and arranged and shall include sufficient shielding or access control such that no radiation levels exist in any area surrounding the local component group which could result in a dose to an individual present therein in excess of the dose limits given in 105 CMR 120.221. For systems utilizing x-ray tubes, these levels shall be met at any specified tube rating.

(B) Surveys.

(1) Radiation surveys, as required by 105 CMR 120.222, of all analytical x-ray systems sufficient to show compliance with 105 CMR 120.604(A) shall be performed:

- (a) Upon installation of the equipment, and at least once every 12 months thereafter;
- (b) Following any change in the initial arrangement, number, or type of local components in the system;
- (c) Following any maintenance requiring the disassembly or removal of a local component in the system;
- (d) During the performance of maintenance and alignment procedures if the procedures require the presence of a primary x-ray beam when any local component in the system is disassembled or removed;
- (e) Any time a visual inspection of the local components in the system reveals an abnormal condition; and,
- (f) Whenever personnel monitoring devices show a significant increase over the previous monitoring period or the readings are approaching the limits specified in 105 CMR 120.211.

(2) Radiation survey measurements shall not be required if a registrant [or licensee] can demonstrate compliance with 105 CMR 120.604(A) to the satisfaction of the Agency.

(C) Posting. Each area or room containing analytical x-ray equipment shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words "CAUTION - X-RAY EQUIPMENT" or words having a similar intent in accordance with 105 CMR 120.238.

120.605: Operating Requirements

(A) Procedures. Normal operating procedures shall be written and available to all analytical x-ray equipment workers. No individual shall be permitted to operate analytical x-ray equipment in any manner other than that specified in the procedures unless such individual has obtained written approval of the radiation safety officer.

(B) Bypassing. No individual shall bypass a safety device or interlock unless such individual has obtained the approval of the radiation safety officer. Such approval shall be for a specified period of time. When a safety device or interlock has been bypassed, a readily discernible sign bearing the words "SAFETY DEVICE NOT WORKING", or words having a similar intent, shall be placed on the radiation source housing.

(C) Repair or Modification of X-ray Tube Systems. Except as specified in 105 CMR 120.605(B), no operation involving removal of covers, shielding materials or tube housings or modifications to shutters, collimators, or beam stops shall be performed without ascertaining that the tube is off and will remain off until safe conditions have been restored. The main switch, rather than interlocks, shall be used for routine shutdown in preparation for repairs.

120.605: continued

(D) Radioactive Source Replacement, Testing, or Repair. Radioactive source housings shall be opened for source replacement, leak testing, or other maintenance or repair procedures only by individuals authorized to specifically conduct such procedures under a license issued by the U.S. Nuclear Regulatory Commission, an Agreement State, or a Licensing State.

120.606: Personnel Requirements

(A) Instruction. No individual shall be permitted to operate or maintain analytical x-ray equipment unless such individual has received instruction in and demonstrated competence as to:

- (1) Identification of radiation hazards associated with the use of the equipment;
- (2) Significance of the various radiation warning, safety devices, and interlocks incorporated into the equipment, or the reasons they have not been installed on certain pieces of equipment and the extra precautions required in such cases;
- (3) Proper operating procedures for the equipment;
- (4) Recognition of symptoms of an acute localized exposure; and,
- (5) Proper procedures for reporting an actual or suspected exposure.

(B) Personnel Monitoring.

- (1) Finger or wrist dosimetric devices shall be provided to and shall be used by:
 - (a) Analytical x-ray equipment workers using systems having an open-beam configuration and not equipped with a safety device; and,
 - (b) Personnel maintaining analytical x-ray equipment if the maintenance procedures require the presence of a primary x-ray beam when any local component in the analytical x-ray system is disassembled or removed.
- (2) Reported dose values shall not be used for the purpose of determining compliance with 105 CMR 120.200 unless evaluated by a qualified expert.

120.620: LICENSING AND RADIATION SAFETY REQUIREMENTS FOR IRRADIATORS120.621: Purpose and Scope

(A) 105 CMR 120.620 contains requirements for the issuance of a license authorizing the use of sealed sources containing radioactive materials in irradiators used to irradiate objects or materials using gamma radiation. 105 CMR 120.620 also contains radiation safety requirements for operating irradiators. The requirements of 105 CMR 120.620 are in addition to other requirements of 105 CMR 120.000. In particular, the provisions of 105 CMR 120.001, 120.100, 120.200, 120.750 and 120.770 apply to applications and licenses subject to 105 CMR 120.620. Nothing in 105 CMR 120.620 relieves the licensee from complying with other applicable Federal, State and local regulations governing the siting, zoning, land use, and building code requirements for industrial facilities.

(B) 105 CMR 120.620 applies to panoramic irradiators that have either dry or wet storage of the radioactive sealed sources and to underwater irradiators in which both the source and the product being irradiated are under water. Irradiators whose dose rates exceed five grays (500 rads) per hour at one meter from the radioactive sealed sources in air or in water, as applicable for the irradiator type, are covered by 105 CMR 120.620.

(C) 105 CMR 120.620 does not apply to self-contained dry-source-storage irradiators (those in which both the source and the area subject to irradiation are contained within a device and are not accessible by personnel), medical radiology or teletherapy, radiography (the irradiation of materials for nondestructive testing purposes), gauging, or open-field (agricultural) irradiations.

120.622: Definitions

Annually means either:

- (1) at intervals not to exceed one year; or
- (2) once per year, at about the same time each year (plus or minus one month).

120.622: continued

Doubly Encapsulated Sealed Source means a sealed source in which the radioactive material is sealed within a capsule and that capsule is sealed within another capsule.

Irradiator means a facility that uses radioactive sealed sources for the irradiation of objects or materials and in which radiation doses rates exceeding five grays (500 rads) per hour exist at one meter from the sealed radioactive sources in air or water, as applicable for the irradiator type, but does not include irradiators in which both the sealed source and the area subject to irradiation are contained within a device and are not accessible to personnel.

Irradiator Operator means an individual who has successfully completed the training and testing described in 105 CMR 120.671 and is authorized by the terms of the license to operate the irradiator without a supervisor present.

Panoramic Dry-source-storage Irradiator means an irradiator in which the irradiations occur in air in areas potentially accessible to personnel and in which the sources are stored in shields made of solid materials. The term includes beam-type dry-source-storage irradiators in which only narrow beam of radiation is produced for performing irradiations.

Panoramic Irradiator means an irradiator in which the irradiations are done in air in areas potentially accessible to personnel. The term includes beam-type irradiators.

Panoramic Wet-source-storage Irradiator means an irradiator in which the irradiations occur in air in areas potentially accessible to personnel and in which the sources are stored under water in a storage pool.

Pool Irradiator means any irradiator at which the sources are stored or used in a pool of water including panoramic wet-source-storage irradiators and underwater irradiators.

Product Conveyor System means a system for moving the product to be irradiated to, from, and within the area where irradiation takes place.

Radiation Room means a shielded room in which irradiations take place. Underwater irradiators do not have radiation rooms.

Sealed Source means any radioactive material that is used as a source of radiation and is encased in a capsule designed to prevent leakage or escape of the byproduct material.

Seismic Area means any area where the probability of horizontal acceleration in rock more than 0.3 times the acceleration of gravity in 250 years is greater than 10%, as designated by the U.S. Geological Survey.

Underwater Irradiator means an irradiator in which the sources always remain shielded under water and humans do not have access to the sealed sources or the space subject to irradiation without entering the pool.

120.631: Application for a Specific License

(A) Applications for specific licenses shall be filed in duplicate on a form prescribed by the Agency.

(B) The Agency may, at any time after the filing of the original applications and before issuance of the license, require further statements in order to enable the Agency to determine whether the application should be granted or denied.

(C) Each application shall be signed by the applicant or licensee, or a person duly authorized to act for and on the applicant's or licensee's behalf.

(D) An application for a license may include a request for a license authorizing one or more activities. The Agency may require the issuance of separate specific licenses for those activities.

120.631: continued

(E) Applications and documents submitted to the Agency may be made available for public inspection except that the Agency may withhold any document or part thereof from public inspection in accordance with 105 CMR 120.010. The Agency may also request additional information after the license has been issued to enable the Agency to determine whether the license should be modified or revoked.

(F) Each application for a specific license, unless otherwise exempted by the Agency, shall be accompanied by the fee prescribed by the Executive Office for Administration and Finance.

120.633: Specific Licenses for Irradiators

The Agency will approve an application for a specific license for the use of licensed material in an irradiator if the applicant meets the requirements contained in 105 CMR 120.633.

(A) The applicant shall satisfy the general requirements specified in 105 CMR 120.100 and the requirements contained in 105 CMR 120.620.

(B) The application must describe the training provided to irradiator operators including:

- (1) Classroom training;
- (2) On-the-job or simulator training;
- (3) Safety reviews;
- (4) Means employed by the applicant to test each operator's understanding of the Agency's regulations and licensing requirements and the irradiator operating, safety, and emergency procedures; and
- (5) Minimum training and experience of personnel who may provide training.

(C) The application must include an outline of the written operating, safety, and emergency procedures listed in 105 CMR 120.673 that describes the radiation safety aspects of the procedures.

(D) The application must describe the organizational structure for managing the irradiator, specifically the radiation safety responsibilities and authorities of the radiation safety officer and those management personnel who have important radiation safety responsibilities or authorities. In particular, the application must specify who, within the management structure, has the authority to stop unsafe operations. The application must also describe the training and experience required for the position of radiation safety officer.

(E) The application must include a description of the access control systems required by 105 CMR 120.643, the radiation monitors required by 105 CMR 120.649, the method of detecting leaking sources required by 105 CMR 120.679, including the sensitivity of the method, and a diagram of the facility that shows the locations of all required interlocks and radiation monitors.

(F) If the applicant intends to perform leak testing of dry-source-storage sealed sources, the applicant shall establish procedures for leak testing and submit a description of these procedures to the Agency. The description must include the:

- (1) instruments to be used;
- (2) methods of performing the analysis; and,
- (3) pertinent experience of the individual who analyzes the samples.

(G) If licensee personnel are to load or unload sources, the applicant shall describe the qualifications and training of the personnel and the procedures to be used. If the applicant intends to contract for source loading or unloading at its facility, the loading or unloading must be done by an organization specifically authorized by the Agency, the Commission, an Agreement State, or a Licensing State to load or unload irradiator sources.

(H) The applicant shall describe the inspection and maintenance checks, including the frequency of the checks required by 105 CMR 120.681.

120.635: Commencement of Construction

Commencement of construction of a new irradiator may not occur prior to the submission to the Agency of both an application for a license for the irradiator and the prescribed fee. As used in 105 CMR 120.620 through 120.693, the terms "commencement of construction" and "construction" are defined in 105 CMR 120.102. Any activities undertaken prior to the issuance of a license are entirely at the risk of the applicant and have no bearing on the issuance of a license with respect to the requirements of M.G.L. c. 111, §§ 3, 5M, 5N, 5O, and 5P, rules, regulations, and orders issued under M.G.L. c. 111, §§ 3, 5M, 5N, 5O, and 5P.

120.637: Applications for Exemptions

Any application for a license or for amendment of a license authorizing use of a teletherapy-type unit for irradiation of materials or objects may include proposed alternatives for the requirements of this part. The Agency will approve the proposed alternatives if the applicant provides adequate rationale for the proposed alternatives and demonstrates that they are likely to provide an adequate level of safety for workers and the public.

120.639: Request for Written Statements

Each license is issued with the condition that the licensee will, at any time before expiration of the license, upon the Agency's request, submit written statement to enable the Agency to determine whether the license should be modified, suspended, or revoked.

120.641: Performance Criteria for Sealed Sources

- (A) Requirements for sealed sources installed after July 1, 1993:
- (1) Must have been registered in accordance with 105 CMR 120.128(N);
 - (2) Must be doubly encapsulated;
 - (3) Must use radioactive material that is as nondispersible as practical and that is as insoluble as practical if the source is used in a wet-source-storage or wet-source-change irradiator;
 - (4) Must be encapsulated in a material resistant to general corrosion and to localized corrosion, such as 316L stainless steel or other material with equivalent resistance if the sources are for use in irradiator pools; and,
 - (5) In prototype testing of the sealed source, must have been leak tested and found leak-free after each of the tests described in 105 CMR 120.641(B) through (G).
- (B) Temperature: The test source must be held at -40°C for 20 minutes, 600°C for one hour, and then be subjected to thermal shock test with a temperature drop from 600°C to 20°C within 15 seconds.
- (C) Pressure: The test source must be twice subjected for at least five minutes to an external pressure (absolute) of two million newtons per square meter.
- (D) Impact: A 2-kilogram steel weight, 2.5 centimeters in diameter, must be dropped from a height of one meter onto the test source.
- (E) Vibration: The test source must be subjected three times for ten minutes each to vibrations sweeping from 25 hertz to 500 hertz with a peak amplitude of five times the acceleration of gravity. In addition, each test source must be vibrated for 30 minutes at each resonant frequency found.
- (F) Puncture: A 50-gram weight and pin, 0.3-centimeter pin diameter, must be dropped from a height of one meter onto the test source.
- (G) Bend: If the length of the source is more than 15 times larger than the minimum cross-sectional dimension, the test source must be subjected to a force of 2000 newtons at its center equidistant from two support cylinders, the distance between which is ten times the minimum cross-sectional dimension of the source.

120.643: Access Control

- (A) Each entrance to a radiation room at a panoramic irradiator must have a door or other physical barrier to prevent inadvertent entry of personnel if the sources are not in the shielded position. Product conveyor systems may serve as barriers as long as they reliably and consistently function as a barrier. It must not be possible to move the sources out of their shielded position if the door or barrier is open. Opening the door or barrier while the sources are exposed must cause the sources to return promptly to the shielded position. The personnel entrance door or barrier must have a lock that is operated by the same key used to move the sources. The doors and barriers must not prevent any individual in the radiation room from leaving.
- (B) In addition, each entrance to a radiation room at a panoramic irradiator must have an independent backup access control to detect personnel entry while the sources are exposed. Detection of entry while the sources are exposed must cause the sources to return to their fully shielded position and must also activate a visible and audible alarm to make the individual entering the room aware of the hazard. The alarm must also alert at least one other individual who is onsite of the entry. That individual shall be trained on how to respond to the alarm and prepared to promptly render or summon assistance.
- (C) A radiation monitor must be provided to detect the presence of high radiation levels in the radiation room of a panoramic irradiator before personnel entry. The monitor must be integrated with personnel access door locks to prevent room access when radiation levels are high. Attempted personnel entry while the monitor measures high radiation levels, must activate the alarm described in 105 CMR 120.643(B). The monitor may be located in the entrance (normally referred to as the maze) but not in the direct radiation beam.
- (D) Before the sources move from their shielded position in a panoramic irradiator, the source control must automatically activate conspicuous visible and audible alarms to alert people in the radiation room that the sources will be moved from their shielded position. The alarms must give individuals enough time to leave the room before the sources leave the shielded position.
- (E) Each radiation room at a panoramic irradiator must have a clearly visible and readily accessible control that would allow an individual in the room to make the sources return to their fully shielded position.
- (F) Each radiation room of a panoramic irradiator must contain a control that prevents the sources from moving from the shielded position unless the control has been activated and the door or barrier to the radiation room has been closed within a preset time after activation of the control.
- (G) Each entrance to the radiation room of a panoramic irradiator and each entrance to the area within the personnel access barrier of an underwater irradiator must be posted as required by 105 CMR 120.238. Radiation postings for panoramic irradiators must comply with the posting requirements of 105 CMR 120.238, except that signs may be removed, covered, or otherwise made inoperative when the sources are fully shielded.
- (H) If the radiation room of a panoramic irradiator has roof plugs or other movable shielding, it must not be possible to operate the irradiator unless the shielding is in its proper location. The requirement may be met by interlocks that prevent operation if shielding is not placed properly or by an operating procedure requiring inspection of shielding before operating.
- (I) Underwater irradiators must have a personnel access barrier around the pool which must be locked to prevent access when the irradiator is not attended. Only operators and facility management may have access to keys to the personnel access barrier. There must be an intrusion alarm to detect unauthorized entry when the personnel access barrier is locked. Activation of the intrusion alarm must alert an individual (not necessarily onsite) who is prepared to respond or summon assistance.

120.645: Shielding

(A) The radiation dose rate in areas that are normally occupied during operation of a panoramic irradiator may not exceed 0.02 millisievert (two millirems) per hour at any location 30 centimeters or more from the wall of the room when the sources are exposed. The dose rate must be averaged over an area not to exceed 100 square centimeters having no linear dimension greater than 20 centimeters. Areas where the radiation dose rate exceeds 0.02 millisievert (two millirems) per hour must be locked, roped off, or posted.

(B) The radiation dose at 30 centimeters over the edge of the pool of a pool irradiator may not exceed 0.02 millisievert (two millirems) per hour when the sources are in the fully shielded position.

(C) The radiation dose rate a one meter from the shield of a dry-source-storage panoramic irradiator when the source is shielded may not exceed 0.02 millisievert (two millirems) per hour and at five centimeters from the shield may not exceed 0.2 millisievert (20 millirems) per hour.

120.647: Fire Protection

(A) The radiation room at a panoramic irradiator must have heat and smoke detectors. The detectors must activate an audible alarm. The alarm must be capable of alerting a person who is prepared to summon assistance promptly. The sources must automatically become fully shielded if a fire is detected.

(B) The radiation room at a panoramic irradiator must be equipped with a fire extinguishing system capable of extinguishing a fire without the entry of personnel into the room. The system for the radiation room must have a shut-off valve to control flooding into unrestricted areas.

120.649: Radiation Monitors

(A) Irradiators with automatic product conveyor systems must have a radiation monitor with an audible alarm located to detect loose radioactive sources that are carried toward the product exit. If the monitor detects a source, an alarm must sound and product conveyors must stop automatically. The alarm must be capable of alerting an individual in the facility who is prepared to summon assistance. Underwater irradiators in which the product moves within an enclosed stationary tube are exempt from the requirements of 105 CMR 120.649(A).

(B) Underwater irradiators that are not in a shielded radiation room must have a radiation monitor over the pool to detect abnormal radiation levels. The monitor must have an audible alarm and a visible indicator at entrances to the personnel access barrier around the pool. The audible alarm may have a manual shut-off. The alarm must be capable of alerting an individual who is prepared to respond promptly.

120.651: Control of Source Movement

(A) The mechanism that moves the sources of a panoramic irradiator must require a key to actuate. Actuation of the mechanism must cause an audible signal to indicate that the sources are leaving the shielded position. Only one key may be in use at any time, and only operators or facility management may possess it. The key must be attached to a portable radiation survey meter by a chain or cable. The lock for source control must be designed so that the key may not be removed if the sources are in an unshielded position. The door to the radiation room must require the same key.

(B) The console of a panoramic irradiator must have a source position indicator that indicates when the sources are in the fully shielded position, when they are in transit, and when the sources are exposed.

(C) The control console of a panoramic irradiator must have a control that promptly returns the sources to the shielded position.

(D) Each control for a panoramic irradiator must be clearly marked as to its function.

120.653: Irradiator Pools

- (A) For licenses initially issued after July 1, 1993, irradiator pools must either:
 - (1) Have a water-tight stainless steel liner or a liner metallurgically compatible with other components in the pool; or
 - (2) Be constructed so that there is a low likelihood of substantial leakage and have a surface designed to facilitate decontamination. In either case, the licensee shall have a method to safely store the sources during repairs of the pool.
- (B) For licenses initially issued after July 1, 1993, irradiator pools must have no outlets more than 0.5 meter below the normal low water level that could allow water to drain out of the pool. Pipes that have intakes more than 0.5 meter below the normal low water level and that could act as siphons must have siphon breakers to prevent the siphoning of pool water.
- (C) A means must be provided to replenish water losses from the pool.
- (D) A visible indicator must be provided in a clearly visible location to indicate if the pool water level is below the normal low water level or above the normal high water level.
- (E) Irradiator pools must be equipped with a purification system designed to be capable of maintaining the water during normal operation at a conductivity of 20 microsiemens per centimeter or less and with a clarity so that the sources can be seen clearly.
- (F) A physical barrier, such as a railing or cover, must be used around or over irradiator pools during normal operation to prevent personnel from accidentally falling into the pool. The barrier may be removed during maintenance, inspection, and service operations.
- (G) If long-handled tools or poles are used in irradiator pools, the radiation dose rate on the handling areas of the tools may not exceed 0.02 millisievert (two millirems) per hour.

120.655: Source Rack Protection

If the product to be irradiated moves on a product conveyor system, the source rack and the mechanism that moves the rack must be protected by a carrier or guides to prevent products and product carriers from hitting or touching the rack or mechanism.

120.657: Power Failures

- (A) If electrical power at a panoramic irradiator is lost for longer than ten seconds, the sources must automatically return to the shielded position.
- (B) The lock on the door of the radiation room of a panoramic irradiator must remain locked in the event of a power failure.
- (C) During a power failure, the area of any irradiator where sources are located may be entered only when using an operable and calibrated radiation survey meter.

120.659: Design Requirements

Irradiators whose construction began after July 1, 1993, must meet the design requirements of 105 CMR 120.659.

- (A) Shielding: For panoramic irradiators, the licensee shall design shielding walls to meet generally accepted building code requirements for reinforced concrete and design the walls, wall penetrations, and entranceways to meet the radiation shielding requirements of 105 CMR 120.645. If the irradiator will use more than five million curies (2×10^{17} becquerels) of activity, the licensee shall evaluate the effects of heating of the shielding walls by the irradiator sources.
- (B) Foundations: For panoramic irradiators, the licensee shall design the foundation, with consideration given to soil characteristics, to ensure it is adequate to support the weight of the facility shield walls.

120.659: continued

(C) Pool Integrity: For pool irradiators, the licensee shall design the pool to assure that it is leak resistant, that it is strong enough to bear the weight of the pool water and shipping casks, that a dropped cask would not fall on sealed sources, that all outlets or pipes meet the requirements of 105 CMR 120.653(B), and that metal components are metallurgically compatible with other components in the pool.

(D) Water Handling System: For pool irradiators, the licensee shall verify that the design of the water purification system is adequate to meet the requirements of 105 CMR 120.653(E). The system must be designed so that water leaking from the system does not drain to unrestricted areas without being monitored.

(E) Radiation Monitors: For all irradiators, the licensee shall evaluate the location and sensitivity of the monitor to detect sources carried by the product conveyor system as required by 105 CMR 120.649(A). The licensee shall verify that the product conveyor is designed to stop before a source on the product conveyor would cause a radiation overexposure to any person. For pool irradiators, if the licensee uses radiation monitors to detect contamination under 105 CMR 120.679(B), the licensee shall verify that the design of radiation monitoring systems to detect pool contamination includes sensitive detectors located close to where contamination is likely to concentrate.

(F) Source Rack: For pool irradiators, the licensee shall verify that there are no crevices on the source or between the source and source holder that would promote corrosion on a critical area of the source. For panoramic irradiators, the licensee shall determine that source rack drops due to loss of power will not damage the source rack and that source rack drops due to failure of cables (or alternate means of support) will not cause loss of integrity of sealed sources. For panoramic irradiators, the licensee shall review the design of the mechanism that moves the sources to assure that the likelihood of a stuck source is low and that, if the rack sticks, a means exists to free it with minimal risk to personnel.

(G) Access Control: For panoramic irradiators, the licensee shall verify from the design and logic diagram that the access control system will meet the requirements of 105 CMR 120.643.

(H) Fire Protection: For panoramic irradiators, the licensee shall verify that the number, locations, and spacing of the smoke and heat detectors are appropriate to detect fires and that the detectors are protected from mechanical and radiation damage. The licensee shall verify that the design of the fire extinguishing system provides the necessary discharge patterns, densities, and flow characteristics for complete coverage of the radiation room and that the system is protected from mechanical and radiation damage.

(I) Source Return: For panoramic irradiators, the licensee shall verify that the source rack will automatically return to the fully shielded position if offsite power is lost for more than ten seconds.

(J) Seismic: For panoramic irradiators to be built in seismic areas, the licensee shall design the reinforced concrete radiation shields to retain their integrity in the event of an earthquake by designing to the seismic requirements of an appropriate source such as American Concrete Institute Standard ACI 318-89, *Building Code Requirements for Reinforced Concrete*, Chapter 21, *Special Provisions for Seismic Design*, or local building codes, if current.

(K) Wiring: For panoramic irradiators, the licensee shall verify that electrical wiring and electrical equipment in the radiation room are selected to minimize failures due to prolonged exposure to radiation.

120.661: Construction Monitoring and Acceptance Testing

The requirements of 105 CMR 120.661 must be met for irradiators whose construction began after July 1, 1993. The requirements must be met prior to loading sources.

120.661: continued

- (A) Shielding: For panoramic irradiators, the licensee shall monitor the construction of the shielding to verify that its construction meets design specifications and generally accepted building code requirements for reinforced concrete.
- (B) Foundations: For panoramic irradiators, the licensee shall monitor the construction of the foundations for verify that their construction meets design specifications.
- (C) Pool Integrity: For pool irradiators, the licensee shall verify that the pool meets design specifications and shall test the integrity of the pool. The licensee shall verify that outlets and pipes meet the requirements of 105 CMR 120.653(B).
- (D) Water Handling System: For pool irradiators, the licensee shall verify that the water purification system, the conductivity meter, and the water level indicators operate properly.
- (E) Radiation Monitors: For all irradiators, the licensee shall verify the proper operation of the monitor to detect sources carried on the product conveyor system and the related alarms and interlocks required by 105 CMR 120.649(A). For pool irradiators, the licensee shall verify the proper operation of the radiation monitors and the related alarm if used to meet 105 CMR 120.679(B). For underwater irradiators, the licensee shall verify the proper operation of the over-the-pool monitor, alarms, and interlocks required by 105 CMR 120.649(B).
- (F) Source Rack: For panoramic irradiators, the licensee shall test the movement of the source racks for proper operation prior to source loading; testing must include source rack lowering due to simulated loss of power. For all irradiators with product conveyor systems, the licensee shall observe and test the operation of the conveyor system to assure that the requirements in 105 CMR 120.655 are met for protection of the source rack and the mechanism that moves the rack; testing must include tests of any limit switches and interlocks used to protect the source rack and mechanism that moves that rack from moving product carriers.
- (G) Access Control: For panoramic irradiators, the licensee shall test the completed access control system to assure that it functions as designed and that all alarms, controls, and interlocks work properly.
- (H) Fire Protection: For panoramic irradiators, the licensee shall test the ability of the heat and smoke detectors to detect a fire, to activate alarms, and to cause the source rack to automatically become fully shielded. The licensee shall test the operability of the fire extinguishing system.
- (I) Source Return: For panoramic irradiators, the licensee shall demonstrate that the source racks can be returned to their fully shielded positions without offsite power.
- (J) Computer Systems: For panoramic irradiators that use a computer system to control the access control system, the licensee shall verify that the access control system will operate properly if offsite power is lost and shall verify that the computer has security features that prevent an irradiator operator from commanding the computer to override the access control system when it is required to be operable.
- (K) Wiring: For panoramic irradiators, the licensee shall verify that the electrical wiring and electrical equipment that were installed meet the design specifications.

120.671: Training

- (A) Before an individual is permitted to operate an irradiator without a supervisor present, the individual must be instructed in:
- (1) The fundamentals of radiation protection applied to irradiators (including the differences between external radiation and radioactive contamination, units of radiation dose, dose limits, why large radiation doses must be avoided, how shielding and access controls prevent large doses, how an irradiator is designed to prevent contamination, the proper use of survey meters and personnel dosimeters, other radiation safety features of an irradiator, and the basic function of the irradiator);

120.671: continued

- (2) The requirements of 105 CMR 120.620 and 120.750 that are relevant to the irradiator;
- (3) The operation of the irradiator;
- (4) Those operating, safety, and emergency procedures listed in 105 CMR 120.673 that the individual is responsible for performing; and
- (5) Case histories of accidents or problems involving irradiators.

(B) Before an individual is permitted to operate an irradiator without a supervisor present, the individual shall pass a written test on the instruction received consisting primarily of questions based on the licensee's operating, safety, and emergency procedures that the individual is responsible for performing and other operations necessary to safely operate the irradiator without supervision.

(C) Before an individual is permitted to operate an irradiator without a supervisor present, the individual must have received on-the-job training or simulator training in the use of the irradiator as described in the license application. The individual shall also demonstrate the ability to perform those portions of the operating, safety, and emergency procedures that he or she is to perform.

(D) The licensee shall conduct safety reviews for irradiator operators at least annually. The licensee shall give each operator a brief written test on the information. Each safety review must include, to the extent appropriate, each of the following:

- (1) Changes in operating, safety, and emergency procedures since the last review, if any;
- (2) Changes in rules and license conditions since the last review, if any;
- (3) Reports on recent accidents, mistakes, or problems that have occurred at irradiators, if any;
- (4) Relevant results of inspections of operator safety performance;
- (5) Relevant results of the facility's inspection and maintenance checks; and
- (6) A drill to practice an emergency or abnormal event procedure.

(E) The licensee shall evaluate the safety performance of each irradiator operator at least annually to ensure that regulations, license conditions, and operating, safety, and emergency procedures are followed. The licensee shall discuss the results of the evaluation with the operator and shall instruct the operator on how to correct any mistakes or deficiencies observed.

(F) Individuals who will be permitted unescorted access to the radiation room of the irradiator or the area around the pool of an underwater irradiator, but who have not received the training required for operators and the radiation safety officer, shall be instructed and tested in any precautions they should take to avoid radiation exposure, any procedures or parts of procedures listed in 105 CMR 120.673 that they are expected to perform or comply with, and their proper response to alarms required in this part. Tests may be oral.

(G) Individuals who must be prepared to respond to alarms required by 105 CMR 120.643(B) and (I), 105 CMR 120.647(A), 120.649(A) and (B), and 120.679(B) shall be trained and tested on how to respond. Each individual shall be retested at least once a year. Tests may be oral.

120.673: Operating, Safety, and Emergency Procedures

- (A) The licensee shall have and follow written operating procedures for:
- (1) Operation of the irradiator, including entering and leaving the radiation room;
 - (2) Use of personnel dosimeters;
 - (3) Surveying the shielding of panoramic irradiators;
 - (4) Monitoring pool water for contamination while the water is in the pool and before release of pool water to unrestricted areas;
 - (5) Leak testing of sources;
 - (6) Inspection and maintenance checks required by 105 CMR 120.681;
 - (7) Loading, unloading, and repositioning sources, if the operations will be performed by the licensee; and,
 - (8) Inspection of movable shielding required by 105 CMR 120.643(H), if applicable.

120.673: continued

(B) The licensee shall have and follow emergency or abnormal event procedures, appropriate for the irradiator type, for:

- (1) Sources stuck in the unshielded position;
- (2) Personnel overexposures;
- (3) A radiation alarm from the product exit portal monitor or pool monitor;
- (4) Detection of leaking sources, pool contamination, or alarm caused by contamination of pool water;
- (5) A low or high water level indicator, an abnormal water loss, or leakage from the source storage pool;
- (6) A prolonged loss of electrical power;
- (7) A fire alarm or explosion in the radiation room;
- (8) An alarm indicating unauthorized entry into the radiation room, area around pool, or another alarmed area;
- (9) Natural phenomena, including an earthquake, a tornado, flooding, or other phenomena as appropriate for the geographical location of the facility; and,
- (10) The jamming of automatic conveyor systems.

(C) The licensee may revise operating, safety, and emergency procedures without Agency approval only if all of the following conditions are met:

- (1) The revisions do not reduce the safety of the facility;
- (2) The revisions are consistent with the outline or summary of procedures submitted with the license application;
- (3) The revisions have been reviewed and approved by the radiation safety officer; and
- (4) The users or operators are instructed and tested on the revised procedures before they are put into use.

120.675: Personnel Monitoring

(A) Irradiator operators shall wear a personnel dosimeter that is processed and evaluated by an accredited National Voluntary Laboratory Accreditation Program (NVLAP) processor while operating a panoramic irradiator or while in the area around the pool of an underwater irradiator. The personnel dosimeter processor must be accredited by the National Voluntary Laboratory Accreditation Program for high energy photons in the normal and accident dose ranges) *see* 105 CMR 120.225(C)). Each personnel dosimeter must be assigned to and worn by only one individual. Film badges must be processed at least monthly, and other personnel dosimeters must be processed at least quarterly.

(B) Other individuals who enter the radiation room of a panoramic irradiator shall wear a dosimeter, which may be a pocket dosimeter. For groups of visitors, only two people who enter the radiation room are required to wear dosimeters. If pocket dosimeters are used to meet the requirements of 105 CMR 120.675(B), a check of their response to radiation must be done at least annually. Acceptable dosimeters must read within $\pm 30\%$ of the true radiation dose.

120.677: Radiation Surveys

(A) A radiation survey of the area outside the shielding of the radiation room of a panoramic irradiator must be conducted with the sources in the exposed position before the facility starts to operate. A radiation survey of the area above the pool of pool irradiators must be conducted after the sources are loaded but before the facility starts to operate. Additional radiation surveys of the shielding must be performed at intervals not to exceed three years and before resuming operation after addition of new sources or any modification to the radiation room shielding or structure that might increase dose rates.

(B) If the radiation levels specified in 105 CMR 120.645 are exceeded, the facility must be modified to comply with the requirements in 105 CMR 120.645.

120.677: continued

(C) Portable radiation survey meters must be calibrated at least annually to an accuracy of $\pm 20\%$ for the gamma energy of the sources in use. The calibration must be done at two points on each scale or, for digital instruments, at one point per decade over the range that will be used. Portable radiation survey meters must be of a type that does not saturate and read zero at high radiation dose rates.

(D) Water from the irradiator pool, other potentially contaminated liquids, and sediments from pool vacuuming must be monitored for radioactive contamination before release to unrestricted areas. Radioactive concentrations must not exceed those specified in 105 CMR 120.296: *Appendix B, Table II, Column 2 or Table III, Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage.*

(E) Before releasing resins for unrestricted use, they must be monitored before release in an area with a background level less than 0.5 microsievert (0.05 millirem) per hour. The resins may be released only if the survey does not detect radiation levels above background radiation levels. The survey meter used must be capable of detecting radiation levels of 0.5 microsievert (0.05 millirem) per hour.

120.679: Detection of Leaking Sources

(A) Each dry-source-storage sealed source must be tested for leakage at intervals not to exceed six months using a leak test kit or method approved by the Agency, the Commission, an Agreement State, or a Licensing State. In the absence of a certificate from a transferor that a test has been made within the six months before the transfer, the sealed source may not be used until tested. The test must be capable of detecting the presence of 200 becquerels (0.005 microcurie) of radioactive material and must be performed by a person approved by the Agency, the Commission, an Agreement State, or a Licensing State to perform the test.

(B) For pool irradiators, sources may not be put into the pool unless the licensee tests the sources for leaks or has a certificate from a transferor that leak test has been done within the six months before the transfer. Water from the pool must be checked for contamination each day the irradiator operates. The check may be done either by using a radiation monitor on a pool water circulating system or by analysis of a sample of pool water. If a check for contamination is done by analysis of a sample of pool water, the results of the analysis must be available within 24 hours. If the licensee uses a radiation monitor on a pool water circulating system, the detection of above normal radiation levels must activate an alarm. The alarm set-point must be set as low as practical, but high enough to avoid false alarms. The licensee may reset the alarm set-point to a higher level if necessary to operate the pool water purification system to clear up contamination in the pool if specifically provided for in written emergency procedures.

(C) If a leaking source is detected, the licensee shall arrange to remove the leaking source from service and have it decontaminated, repaired, or disposed of by an Agency, Commission, Agreement State, or Licensing State licensee that is authorized to perform these functions. The licensee shall promptly check its personnel, equipment, facilities, and irradiated product for radioactive contamination. No product may be shipped until the product has been checked and found free of contamination. If a product has been shipped that may have been inadvertently contaminated, the licensee shall arrange to locate and survey that product for contamination. If any personnel are found to be contaminated, decontamination must be performed promptly. If contaminated equipment, facilities, or products are found, the licensee shall arrange to have them decontaminated or disposed of by an Agency, Commission, Agreement State, or Licensing State licensee that is authorized to perform these functions. If a pool is contaminated, the licensee shall arrange to clean the pool until the contamination levels do not exceed the appropriate concentration in 105 CMR 120.296: *Appendix B, Table II, Column 2.* (See 105 CMR 120.282 for reporting requirements.)

120.681: Inspection and Maintenance

- (A) The licensee shall perform inspection and maintenance checks that include, as a minimum, each of the following at the frequency specified in the license or license application:
- (1) Operability of each aspect of the access control system required by 105 CMR 120.643.
 - (2) Functioning of the source position indicator required by 105 CMR 120.651(B).
 - (3) Operability of the radiation monitor for radioactive contamination in pool water required by 105 CMR 120.679(B) using a radiation check source, if applicable.
 - (4) Operability of the over-pool radiation monitor at underwater irradiators as required by 105 CMR 120.649(B).
 - (5) Operability of the product exit monitor required by 105 CMR 120.649(A).
 - (6) Operability of the emergency source return control required by 105 CMR 120.651(C).
 - (7) Leak-tightness of systems through which pool water circulates (visual inspection).
 - (8) Operability of the heat and smoke detectors and extinguisher system required by 105 CMR 120.647 (but without turning extinguishers on).
 - (9) Operability of the means of pool water replenishment required by 105 CMR 120.653(C).
 - (10) Operability of the indicators of high and low pool water levels required by 105 CMR 120.653(D).
 - (11) Operability of the intrusion alarm required by 105 CMR 120.643(I), if applicable.
 - (12) Functioning and wear of the system, mechanisms, and cables used to raise and lower sources.
 - (13) Condition of the barrier to prevent products from hitting the sources or source mechanism as required by 105 CMR 120.655.
 - (14) Amount of water added to the pool to determine if the pool is leaking.
 - (15) Electrical wiring on required safety systems for radiation damage.
 - (16) Pool water conductivity measurements and analysis as required by 105 CMR 120.683(B).
- (B) Malfunctions and defects found during inspection and maintenance checks must be repaired without undue delay.

120.683: Pool Water Purity

- (A) Pool water purification system must be run sufficiently to maintain the conductivity of the pool water below 20 microsiemens per centimeter under normal circumstances. If pool water conductivity rises above 20 microsiemens per centimeter, the licensee shall take prompt actions to lower the pool water conductivity and shall take corrective actions to prevent future recurrences.
- (B) The licensee shall measure the pool water conductivity frequently enough, but no less than weekly, to assure that the conductivity remains below 20 microsiemens per centimeter. Conductivity meters must be calibrated at least annually.

120.685: Attendance During Operation

- (A) Both an irradiator operator and at least one other individual, who is trained on how to respond and prepared to promptly render or summon assistance if the access control alarm sounds, shall be present onsite:
- (1) Whenever the irradiator is operated using an automatic product conveyor system; and
 - (2) Whenever the product is moved into or out of the radiation room when the irradiator is operated in a batch mode.
- (B) At a panoramic irradiator at which static irradiations (no movement of the product) are occurring, a person who has received the training on how to respond to alarms described in 105 CMR 120.671(G) must be onsite.
- (C) At an underwater irradiator, an irradiator operator must be present at the facility whenever the product is moved into or out of the pool. Individuals who move the product into or out of the pool of an underwater irradiator need not be qualified as irradiator operators; however, they must have received the training described in 105 CMR 120.671(F) and (G). Static irradiations may be performed without a person present at the facility.

120.687: Entering and Leaving the Radiation Room

(A) Upon first entering the radiation room of a panoramic irradiator after an irradiation, the irradiator operator shall use a survey meter to determine that the source has returned to its fully shielded position. The operator shall check the functioning of the survey meter with a radiation check source prior to entry.

(B) Before exiting from and locking the door to the radiation room of a panoramic irradiator prior to a planned irradiation, the irradiator operator shall:

- (1) Visually inspect the entire radiation room to verify that no one else is in it; and
- (2) Activate a control in the radiation room that permits the sources to be moved from the shielded position only if the door to the radiation room is locked within a preset time after setting the control.

(C) During a power failure, the area around the pool of an underwater irradiator may not be entered without using an operable and calibrated radiation survey meter unless the over-the-pool monitor required by 105 CMR 120.649(B) is operating with backup power.

120.689: Irradiation of Explosive or Flammable Materials

(A) Irradiation of explosive material is prohibited unless the licensee has received prior written authorization from the Agency. Authorization will not be granted unless the licensee can demonstrate that detonation of the explosive would not rupture the sealed sources, injure personnel, damage safety systems, or cause radiation overexposures of personnel.

(B) Irradiation of more than small quantities of flammable material (flash point below 140°F) is prohibited in panoramic irradiators unless the licensee has received prior written authorization from the Agency. Authorization will not be granted unless the licensee can demonstrate that a fire in the radiation room could be controlled without damage to sealed sources or safety systems and without radiation overexposures of personnel.

120.691 Records and Retention Periods

The licensee shall maintain the following records at the irradiator for the periods specified.

(A) A copy of the license, license conditions, documents incorporated into a license by reference, and amendments thereto until superseded by new documents or until the Agency terminates the license for documents not superseded.

(B) Records of each individual's training, tests, and safety reviews provided to meet the requirements of 105 CMR 120.671(A), (B), (C), (D), (F), and (G) until three years after the individual terminates work.

(C) Records of the annual evaluations of the safety performance of irradiator operators required by 105 CMR 120.671(E) for three years after the evaluation.

(D) A copy of the current operating, safety, and emergency procedures required by 105 CMR 120.673 until superseded or the Agency terminates the license. Records of the radiation safety officer's review and approval of changes in procedures as required by 105 CMR 120.673(C)(3) retained for three years from the date of the change.

(E) Evaluations of personnel dosimeters required by 105 CMR 120.675 until the Agency terminates the license.

(F) Records of radiation surveys required by 105 CMR 120.677 for three years from the date of the survey.

(G) Records of radiation survey meter calibrations required by 105 CMR 120.677 and pool water conductivity meter calibrations required by 105 CMR 120.683(B) until three years from the date of calibration.

120.691: continued

(H) Records of the results of leak tests required by 105 CMR 120.679(A) and the results of contamination checks required by 105 CMR 120.679(B) for five years from the date of each test.

(I) Records of inspection and maintenance checks required by 105 CMR 120.681 for three years.

(J) Records of major malfunctions, significant defects, operating difficulties or irregularities, and major operating problems that involve required radiation safety equipment for three years after repairs are completed.

(K) Records of the receipt, transfer and disposal, of all licensed sealed sources as required by 105 CMR 120.009 and 120.140.

(L) Records on the design checks required by 105 CMR 120.659 and the construction control checks as required by 105 CMR 120.661 until the license is terminated. The records must be signed and dated. The title or qualification of the person signing must be included.

(M) Records related to decommissioning of the irradiator as required by 105 CMR 120.125(C)(1)(g).

120.693: Reports

(A) In addition to the reporting requirements in other parts of 105 CMR 120.000, the licensee shall report the following events if not reported under other parts of 105 CMR 120.000:

- (1) Source stuck in an unshielded position.
- (2) Any fire or explosion in a radiation room.
- (3) Damage to the source racks.
- (4) Failure of the cable or drive mechanism used to move the source racks.
- (5) Inoperability of the access control system.
- (6) Detection of radiation source by the product exit monitor.
- (7) Detection of radioactive contamination attributable to licensed radioactive material.
- (8) Structural damage to the pool liner or walls.
- (9) Abnormal water loss or leakage from the source storage pool.
- (10) Pool water conductivity exceeding 100 microsiemens per centimeter.

(B) The report must include a telephone report within 24 hours as described in 105 CMR 120.142(C)(1), and a written report within 30 days as described in 105 CMR 120.142(C)(2).

120.700: RADIATION SAFETY REQUIREMENTS FOR PARTICLE ACCELERATORS

120.701: Purpose and Scope

(A) 105 CMR 120.700 establishes procedures for the registration and the use of particle accelerators.

(B) In addition to the requirements of 105 CMR 120.700, all registrants are subject to the requirements of 105 CMR 120.001, 120.020, 120.750, 120.100 and 120.200. Registrants engaged in industrial radiographic operations are subject to the requirements of 105 CMR 120.300, and registrants engaged in the healing arts are subject to the requirements of 105 CMR 120.430 and/or 105 CMR 120.500, and registrants engaged in wireline operations are subject to 105 CMR 120.900. Registrants whose operations result in the production of radioactive material are subject to the requirements of 105 CMR 120.100.

120.702: Registration Requirements

No person shall receive, possess, use, transfer, own, or acquire a particle accelerator except as authorized in a registration issued pursuant to 105 CMR 120.020 or 120.100.

120.703: General Requirements for the Issuance of a Registration for Particle Accelerators

In addition to the requirements of 105 CMR 120.020 or 120.100, a registration application for use of a particle accelerator will be approved only if the Agency determines that:

- (A) The applicant is qualified by reason of training and experience to use the accelerator in question for the purpose requested in accordance with 105 CMR 120.700, 120.200 and 120.750 in such a manner as to minimize danger to public health and safety or property;
- (B) The applicant's proposed or existing equipment, facilities, and operating and emergency procedures are adequate to protect health and minimize danger to public health and safety or property;
- (C) The issuance of the registration will not be inimical to the health and safety of the public, and the applicant satisfies any applicable special requirement in 105 CMR 120.704;
- (D) The applicant has appointed a radiation safety officer;
- (E) The applicant and/or the applicant's staff has substantial experience in the use of particle accelerators and training sufficient for application to its intended uses;
- (F) The applicant has established a radiation safety committee to approve, in advance, proposals for uses of particle accelerators, whenever deemed necessary by the Agency; and,
- (G) The applicant has an adequate training program for operators of particle accelerators.

120.704: Human Use of Particle Accelerators

In addition to the requirements of 105 CMR 120.020, a registration for use of a particle accelerator in the healing arts will be issued only if the applicant or registrant meets the requirements of 105 CMR 120.430 "THERAPEUTIC RADIATION MACHINES".

120.705: Limitations

- (A) No registrant shall permit any individual to act as an operator of a particle accelerator until such individual:
 - (1) Has been instructed in radiation safety and shall have demonstrated an understanding thereof;
 - (2) Has received copies of and instruction in 105 CMR 120.700 and the applicable requirements of 105 CMR 120.200 and 120.750, pertinent registration conditions and the registrant's operating and emergency procedures, and shall have demonstrated understanding thereof; and,
 - (3) Has demonstrated competence to use the particle accelerator, related equipment, and survey instruments which will be employed.
- (B) The radiation safety committee or the radiation safety officer shall have the authority to terminate the operations at a particle accelerator facility if such action is deemed necessary to minimize danger to public health and safety or property.

120.706: Shielding and Safety Design Requirements

- (A) A qualified expert, acceptable to the Agency, shall be consulted in the design of a particle accelerator installation and called upon to perform a radiation survey when the accelerator is first capable of producing radiation.
- (B) Each particle accelerator installation shall be provided with such primary and/or secondary barriers as are necessary to assure compliance with 105 CMR 120.211 and 120.221.

120.707: Particle Accelerator Controls and Interlock Systems

- (A) Instrumentation, readouts, and controls on the particle accelerator control console shall be clearly identified and easily discernible.

120.707: continued

- (B) Each entrance into a target room or other high radiation area shall be provided with a safety interlock that shuts down the machine under conditions of barrier penetration.
- (C) Each safety interlock shall be on a circuit which shall allow it to operate independently of all other safety interlocks.
- (D) All safety interlocks shall be designed so that any defect or component failure in the safety interlock system prevents operation of the accelerator.
- (E) When a safety interlock system has been tripped, it shall only be possible to resume operation of the accelerator by manually resetting controls at the position where the safety interlock has been tripped and, lastly, at the main control console.
- (F) A scram button or other emergency power cutoff switch shall be located and easily identifiable in all high radiation areas. Such a cutoff switch shall include a manual reset so that the accelerator cannot be restarted from the accelerator control console without resetting the cutoff switch.

120.708: Warning Devices

- (A) Each location designated as high radiation area, and each entrance to such location, shall be equipped with easily observable warning lights that operate when, and only when, radiation is being produced.
- (B) Except in facilities designed for human exposure, each high radiation area shall have an audible warning device which shall be activated for 15 seconds prior to the possible creation of prompt radiation. Such warning device shall be clearly discernible in all high radiation areas.
- (C) Barriers, temporary or otherwise, and pathways leading to high radiation areas shall be posted in accordance with 105 CMR 120.227 and 120.247.

120.709: Operating Procedures

- (A) Particle accelerators, when not in operation, shall be secured to prevent unauthorized use.
- (B) The safety interlock system shall not be used to turn off the accelerator beam except in an emergency.
- (C) All safety and warning devices, including interlocks, shall be checked for proper operation at intervals not to exceed three months. Results of such tests shall be maintained at the accelerator facility for inspection by the Agency.
- (D) Electrical circuit diagrams of the accelerator and the associated safety interlock systems shall be kept current and maintained for inspection by the Agency and shall be available to the operator at each accelerator facility.
- (E) If, for any reason, it is necessary to intentionally bypass a safety interlock or interlocks, such action shall be:
 - (1) Authorized by the radiation safety committee and/or radiation safety officer;
 - (2) Recorded in a permanent log and a notice posted at the accelerator control console; and,
 - (3) Terminated as soon as possible.
- (F) A copy of the current operating and the emergency procedures shall be maintained at the accelerator control panel.

120.710: Radiation Monitoring Requirements

- (A) There shall be available at each particle accelerator facility appropriate portable monitoring equipment which is operable and has been appropriately calibrated for the radiations being produced at the facility. Such equipment shall be tested for proper operation before use or once every three months, whichever is the lesser.
- (B) A radiation protection survey shall be performed and documented by a qualified expert, acceptable to the Agency, when changes have been made in shielding, operation, equipment, or occupancy of adjacent areas.
- (C) Radiation levels in all high radiation areas shall be continuously monitored. The monitoring devices shall be electrically independent of the accelerator control and safety interlock systems and capable of providing a readout at the control panel.
- (D) All area monitors shall be calibrated at intervals not to exceed one year and after each servicing and repair.
- (E) Whenever applicable, periodic surveys shall be made to determine the amount of airborne particulate radioactivity present.
- (F) Whenever applicable, periodic smear surveys shall be made to determine the degree of contamination.
- (G) All surveys shall be made in accordance with the written procedures established by a qualified expert, acceptable to the Agency, or the radiation safety officer.
- (H) Records of all radiation protection surveys, calibrations, and instrumentation tests shall be maintained at the accelerator facility for inspection by the Agency.

120.711: Ventilation Systems

- (A) Ventilation systems shall be provided to ensure that personnel entering any area where airborne radioactivity may be produced will not be exposed to airborne radioactive material in excess of those limits specified in 120.296: *Appendix B*, Table I.
- (B) A registrant, as required by 105 CMR 120.221, shall not vent, release, or otherwise discharge airborne radioactive material to an unrestricted area which exceeds the limits specified in 105 CMR 120.296: *Appendix B*, Table II, except as authorized pursuant to 105 CMR 120.221(A)(3) or 120.222(C). For purposes of 105 CMR 120.711(B), concentrations may be averaged over a period not greater than one year. Every effort should be made to maintain releases of radioactive material to unrestricted areas as far below these limits as is reasonably achievable.

120.750: NOTICES, INSTRUCTIONS, AND REPORTS TO WORKERS; INSPECTIONS

120.751: Purpose and Scope

105 CMR 120.750 establishes requirements for notices, instructions and reports by licensees or registrants to individuals engaged in activities under a license or registration and options available to such individuals in connection with Agency inspections of licensees or registrants to ascertain compliance with the provisions of M.G.L. c. 111, §§ 3, 5M, 5N, 5O, and 5P and regulations, orders, and licenses issued thereunder regarding radiological working conditions. 105 CMR 120.750 applies to all persons who receive, possess, use, own, or transfer sources of radiation registered with or licensed by the Agency pursuant to 105 CMR 120.020 and 105 CMR 120.100.

120.752: Posting of Notices to Workers

- (A) Each licensee or registrant shall post current copies of the following documents:
 - (1) 105 CMR 120.750 and in 105 CMR 120.200;

120.752: continued

- (2) The license, certificate of registration, conditions or documents incorporated into the license by reference and amendments thereto;
- (3) The operating procedures applicable to activities under the license or registration; and,
- (4) Any notice of violation involving radiological working conditions, proposed imposition of civil penalty, or order issued pursuant to 105 CMR 120.001, and any response from the licensee or registrant.

(B) If posting of a document specified in 105 CMR 120.752(A)(1), (2), or (3) is not practicable, the licensee or registrant may post a notice which describes the document and states where it may be examined.

(C) Form MRCP 120.750-1 "Notice to Employees" shall be posted by each licensee or registrant as required by 105 CMR 120.000.

(D) Agency documents posted pursuant to 105 CMR 120.752(A)(4) shall be posted within five working days after receipt of the documents from the Agency; the licensee's or registrant's response, if any, shall be posted within five working days after dispatch from the licensee or registrant. Such documents shall remain posted for a minimum of five working days or until action correcting the violation has been completed, whichever is later.

(E) Documents, notices, or forms posted pursuant to 105 CMR 120.752 shall appear in a sufficient number of places to permit individuals engaged in work under the license or registration to observe them on the way to or from any particular work location to which the document applies, shall be conspicuous, and shall be replaced if defaced or altered.

120.753: Instructions to Workers

(A) All individuals who in the course of employment are likely to receive in a year an occupational dose in excess of one mSv (100 mrem)

- (1) shall be kept informed of the storage, transfer, or use of sources of radiation in the licensee's or registrant's workplace;
- (2) shall be instructed in the health protection problems associated with exposure to radiation or radioactive material to the individual and potential offspring, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed;
- (3) Shall be instructed in, and instructed to observe, to the extent within the worker's control, the applicable provisions of 105 CMR 120.000 and licenses for the protection of personnel from exposures to radiation or radioactive material;
- (4) Shall be instructed of their responsibility to report promptly to the licensee or registrant any condition which may constitute, lead to, or cause a violation of the Act, 105 CMR 120.000, and licenses or unnecessary exposure to radiation or radioactive material;
- (5) Shall be instructed in the appropriate response to warnings made in the event of any unusual occurrence or malfunction that may involve exposure to radiation or radioactive material; and,
- (6) Shall be advised as to the radiation exposure reports which workers shall be furnished pursuant to 105 CMR 120.754.

(B) In determining those individuals subject to the requirements of 105 CMR 120.753(A), licensees must take into consideration assigned activities during normal and abnormal situations involving exposure to radiation and/or radioactive material which can reasonably be expected to occur during the life of a licensed facility. The extent of these instructions shall be commensurate with potential radiological health protection problems present in the workplace.

120.754: Notifications and Reports to Individuals

(A) Radiation exposure data for an individual and the results of any measurements, analyses, and calculations of radioactive material deposited or retained in the body of an individual shall be reported to the individual as specified in 105 CMR 120.750. The information reported shall include data and results obtained pursuant to 105 CMR 120.000, orders, or license conditions, as shown in records maintained by the licensee or registrant pursuant to 105 CMR 120.267.

120.754: continued

Each notification and report shall:

- (1) Be in writing;
- (2) Include appropriate identifying data such as the name of the licensee or registrant, the name of the individual, and the individual's social security number;
- (3) Include the individual's exposure information; and,
- (4) Contain the following statement:

"This report is furnished to you under the provisions of 105 CMR 120.750. You should preserve this report for future reference."

(B) Each licensee or registrant shall furnish to each worker annually a written report of the worker's exposure to radiation or radioactive material as shown in records maintained by the licensee or registrant pursuant to 105 CMR 120.267. The licensee shall provide an annual report to each individual monitored under 105 CMR 120.226 of the dose received in that monitoring year if:

- (1) The individual's occupational dose exceeds one mSv (100 mrem) TEDE or one mSv (100 mrem) to any individual organ or tissue; or
- (2) The individual requests his or her annual dose report.

(C) Each licensee or registrant shall furnish a written report of the worker's exposure to sources of radiation at the request of a worker formerly engaged in activities controlled by the licensee or registrant. The report shall include the dose record for each year the worker was required to be monitored pursuant to 105 CMR 120.226. Such report shall be furnished within 30 days from the date of the request, or within 30 days after the dose of the individual has been determined by the licensee or registrant, whichever is later. The report shall cover the period of time that the worker's activities involved exposure to sources of radiation and shall include the dates and locations of work under the license or registration in which the worker participated during this period.

(D) When a licensee or registrant is required pursuant to 105 CMR 120.282, 120.283 or 120.284 to report to the Agency any exposure of an individual to radiation or radioactive material, the licensee or the registrant shall also provide the individual a report on his or her exposure data included in the report to the Agency. Such reports shall be transmitted at a time not later than the transmittal to the Agency.

(E) At the request of a worker who is terminating employment with the licensee or registrant in work involving exposure to radiation or radioactive material, during the current year, each licensee or registrant shall provide at termination to each such worker, or to the worker's designee, a written report regarding the radiation dose received by that worker from operations of the licensee or registrant during the current year or fraction thereof. If the most recent individual monitoring results are not available at that time, a written estimate of the dose shall be provided together with a clear indication that this is an estimate.

120.755: Presence of Representatives of Licensees or Registrants and Workers During Inspection

(A) Each licensee or registrant shall afford to the Agency at all reasonable times opportunity to inspect materials, machines, activities, facilities, premises, and records pursuant to 105 CMR 120.000.

(B) During an inspection, Agency inspectors may consult privately with workers as specified in 105 CMR 120.756. The licensee or registrant may accompany Agency inspectors during other phases of an inspection.

(C) If, at the time of inspection, an individual has been authorized by the workers to represent them during Agency inspections, the licensee or registrant shall notify the inspectors of such authorization and shall give the workers' representative an opportunity to accompany the inspectors during the inspection of physical working conditions.

(D) Each worker's representative shall be routinely engaged in work under control of the licensee or registrant and shall have received instructions as specified in 105 CMR 120.753.

120.755: continued

(E) Different representatives of licensees or registrants and workers may accompany the inspectors during different phases of an inspection if there is no resulting interference with the conduct of the inspection. However, only one workers' representative at a time may accompany the inspectors.

(F) With the approval of the licensee or registrant and the workers' representative, an individual who is not routinely engaged in work under control of the licensee or registrant, for example, a consultant to the licensee or registrant or to the workers' representative, shall be afforded the opportunity to accompany Agency inspectors during the inspection of physical working conditions.

(G) Notwithstanding the other provisions of 105 CMR 120.755, Agency inspectors are authorized to refuse to permit accompaniment by any individual who deliberately interferes with a fair and orderly inspection. With regard to areas containing information classified by an agency of the U.S. Government in the interest of national security, an individual who accompanies an inspector may have access to such information only if authorized to do so. With regard to any area containing proprietary information, the workers' representative for that area shall be an individual previously authorized by the licensee or registrant to enter that area.

120.756: Consultation with Workers During Inspections

(A) Agency inspectors may consult privately with workers concerning matters of occupational radiation protection and other matters related to applicable provisions of 105 CMR 120.000 and licenses to the extent the inspectors deem necessary for the conduct of an effective and thorough inspection.

(B) During the course of an inspection, any worker may bring privately to the attention of the inspectors, either orally or in writing, any past or present condition which the worker has reason to believe may have contributed to or caused any violation of M.G.L. c. 111, §§, 5N, and 5P, 105 CMR 120.000, or license condition, or any unnecessary exposure of an individual to sources of radiation under the licensee's or registrant's control. Any such notice in writing shall comply with the requirements of 105 CMR 120.757(A).

(C) The provisions of 105 CMR 120.756(B) shall not be interpreted as authorization to disregard instructions pursuant to 105 CMR 120.753.

120.757: Requests by Workers for Inspections

(A) Any worker or representative of workers believing that a violation of the Act, 105 CMR 120.000, or license conditions exists or has occurred in work under a license or registration with regard to radiological working conditions in which the worker is engaged may request an inspection by giving notice of the alleged violation to the Agency. Any such notice shall be in writing, shall set forth the specific grounds for the notice, and shall be signed by the worker or representative of the workers. A copy shall be provided to the licensee or registrant by the Agency no later than at the time of inspection except that, upon the request of the worker giving such notice, his name and the name of individuals referred to therein shall not appear in such copy or on any record published, released, or made available by the Agency, except for good cause shown.

(B) If, upon receipt of such notice, the Agency determines that the complaint meets the requirements set forth in 105 CMR 120.757(A), and that there are reasonable grounds to believe that the alleged violation exists or has occurred, an inspection shall be made as soon as practicable to determine if such alleged violation exists or has occurred. Inspections pursuant to 105 CMR 120.757 need not be limited to matters referred to in the complaint.

(C) No licensee, registrant, or contractor or subcontractor of a licensee or registrant shall discharge or in any manner discriminate against any worker because such worker has filed any complaint or instituted or caused to be instituted any proceeding under 105 CMR 120.000 or has testified or is about to testify in any such proceeding or because of the exercise by such worker on behalf of himself or others of any option afforded by 105 CMR 120.750.

120.758: Inspections not Warranted; Informal Review

(A) (1) If the Agency determines, with respect to a complaint under 105 CMR 120.757, that an inspection is not warranted because there are no reasonable grounds to believe that a violation exists or has occurred, the Agency shall notify the complainant in writing of such determination. The complainant may obtain review of such determination by submitting a written statement of position with the Department. The Department will provide the licensee or registrant with a copy of such statement by certified mail, excluding, at the request of the complainant, the name of the complainant. The licensee or registrant may submit an opposing written statement of position with the Department. The Department will provide the complainant with a copy of such statement by certified mail.

(2) Upon the request of the complainant, the Department may hold an informal conference in which the complainant and the licensee or registrant may, orally present their views. An ~~sssss~~informal conference may also be held at the request of the licensee or registrant, but disclosure of the identity of the complainant will be made only following receipt of written authorization from the complainant. After considering all written and oral views presented, the Department shall affirm, modify, or reverse the determination of the Agency and furnish the complainant and the licensee or registrant a written notification of the decision and the reason therefor.

(B) If the Agency determines that an inspection is not warranted because the requirements of 105 CMR 120.757(A) have not been met, the complainant shall be notified in writing of such determination. Such determination shall be without prejudice to the filing of a new complaint meeting the requirements of 105 CMR 120.757(A).

120.760: Emergency Plans

The user should formulate suitable emergency plans as may be indicated to protect his employees and the public against potential hazards due to his specific source(s), and should make known the details and existence of such plans to the Agency and such other public agencies having a concern; including, but not limited to, boards of health, fire departments and police departments.

120.770: TRANSPORTATION OF RADIOACTIVE MATERIAL

120.771: Purpose and Scope

(A) 105 CMR 120.770 establishes requirements for packaging, preparation for shipment, and transportation of licensed material.

(B) The packaging and transport of licensed material are also subject to other sections of 105 CMR 120.000 and to the regulations of other agencies (such as the United States Department of Transportation, the United States Postal Service and the United States Nuclear Regulatory Commission) having jurisdiction over means of transport. The requirements of 105 CMR 120.770 are in addition to, and not in substitution for, other requirements

(C) 105 CMR 120.770 applies to any licensee authorized by specific or general license issued by the Agency to receive, possess, use, or transfer licensed material, if the licensee delivers that material to a carrier for transport, transports the material outside the site of usage as specified in the Agency license, or transports that material on public highways. No provision of 105 CMR 120.770 authorizes possession of licensed material.

(D) Exemptions from the requirement for license **in 105 CMR 120.773** are specified in 105 CMR 120.774**5**. General licenses for which no **NRC** package approval is required are issued in 105 CMR 120.777**80** through 120.782. The general license in 105 CMR 120.777 requires that an NRC certificate of compliance or other package approval be issued for the package to be used under this general license. The transport of licensed material or delivery of licensed material to a carrier for transport is subject to the operating control **and procedures** requirements **and procedures** of 105 CMR 120.785**4** through 120.793**0**, to the quality assurance requirements of 105 CMR 120.794**1 through 120.797**, and to the general provisions of 105 CMR 120.771 through 120.775**4**, including referenced United States Department of Transportation regulations.

120.771: continued

(E) 105 CMR 120.770 applies to any person required to obtain a certificate of compliance or an approved compliance plan from the NRC pursuant to 10 CFR 76 if the person delivers radioactive material to a common or contract carrier for transport or transports the material outside the confines of the person's plant or other authorized place of use.

120.772: Definitions

The following terms are as defined here for the purpose of 105 CMR 120.770. To ensure compatibility with international transportation standards, all limits in this part are given in terms of dual units: The International System of Units (SI) followed or preceded by U.S. standard or customary units. The U.S. customary units are not exact equivalents but are rounded to a convenient value, providing a functionally equivalent unit. For the purpose of 105 CMR 120.770, either unit may be used.

A₁ means the maximum activity of special form radioactive material permitted in a Type A package. This value is either listed in 105 CMR 120.770~~98~~: *Appendix A, Table A-1*, or may be derived in accordance with the procedures prescribed in 105 CMR 120.770~~98~~: *Appendix A*.

A₂ means the maximum activity of radioactive material, other than special form material, LSA, and SCO material, permitted in a Type A package. This value is either listed in 105 CMR 120.770~~98~~: *Appendix A, Table A-1*, or may be derived in accordance with the procedures prescribed in 105 CMR 120.770~~98~~: *Appendix A*.

Carrier means a person engaged in the transportation of passengers or property by land or water as a common, contract, or private carrier, or by civil aircraft.

Certificate Holder means a person who has been issued a certificate of compliance or other package approval by the Commission.

Certificate of Compliance (CoC) means the certificate issued by the Commission under subpart D of 10 CFR 71 which approves the design of a package for the transportation of radioactive material.

Consignment means each shipment of a package or groups of packages or load of radioactive material offered by a shipper for transport.

Contamination means the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm² (1 x 10⁻⁵ µCi/cm²) for beta and gamma emitters and low toxicity alpha emitters, or 0.04 Bq/cm² (1 x 10⁻⁶ µCi/cm²) for all other alpha emitters.

(1) Fixed Contamination means contamination that cannot be removed from a surface during normal conditions of transport.

(2) Non-fixed Contamination means contamination that can be removed from a surface during normal conditions of transport.

Conveyance means:

- (1) For transport by public highway or rail any transport vehicle or large freight container;
- (2) For transport by water any vessel, or any hold, compartment, or defined deck area of a vessel including any transport vehicle on board the vessel; and
- (3) For transport by any aircraft.

Criticality Safety Index (CSI) means the dimensionless number (rounded up to the next tenth) assigned to and placed on the label of a fissile material package, to designate the degree of control of accumulation of packages, **overpacks or freight containers** containing fissile material during transportation. Determination of the criticality safety index is described in §§ 71.22, 71.23 **105 CMR 120.781 and 120.782**, and **10 CFR 71.59**. **The criticality safety index for an overpack, freight container, consignment or conveyance containing fissile material packages is the arithmetic sum of the criticality safety indices of all the fissile material packages contained within the overpack, freight container, consignment or conveyance.**

Deuterium means, for the purposes of §§ 71.15 and 71.22, deuterium and any deuterium compounds, including heavy water, in which the ratio of deuterium atoms to hydrogen atoms

exceeds 1:5000.

DOT means the U.S. Department of Transportation.

Exclusive Use means the sole use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading are carried out in accordance with the direction of the consignor or consignee. The consignor and the carrier must ensure that any loading or unloading is performed by personnel having radiological training and resources appropriate for safe handling of the consignment. The consignor must issue specific instructions, in writing, for maintenance of exclusive use shipment controls, and include them with the shipping paper information provided to the carrier by the consignor.

120.772: continued

Fissile Material means the radionuclides uranium-233, uranium-235, plutonium-239, and plutonium-241, or any combination of these radionuclides. Fissile material means the fissile nuclides themselves, not material containing fissile nuclides. Unirradiated natural uranium and depleted uranium, and natural uranium or depleted uranium that has been irradiated in thermal reactors only are not included in 105 CMR 120.772: Fissile Material.¹ Certain exclusions from fissile material controls are provided in 105 CMR 120.775.

Graphite means, for the purposes of 105 CMR 120.775 and 120.781, graphite with a boron equivalent content less than five parts per million and density greater than 1.5 grams per cubic centimeter.

Indian Tribe means an Indian or Alaska Native Tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges to exist as an Indian Tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. 479a.

Low Specific Activity (LSA) Material means radioactive material with limited specific activity which is nonfissile or **is** excepted under 105 CMR 120.775(D), and which satisfies the descriptions and limits set forth below. Shielding materials surrounding the LSA material may not be considered in determining the estimated average specific activity of the package contents. **The LSA material must be in one of three groups:**

- (1) LSA-I.
 - (a) Uranium and thorium ores, concentrates of uranium and thorium ores, and other ores containing naturally occurring ~~radioactive~~ radionuclides ~~which that~~ are ~~not~~ intended to be processed for the use of these radionuclides;
 - (b) ~~Solid unirradiated n~~Natural uranium, ~~or~~ depleted uranium, ~~or~~ natural thorium or their ~~solid or liquid~~ compounds or mixtures, **provided they are unirradiated and in solid or liquid form;**
 - (c) Radioactive material, other than fissile material, for which the A_2 value is unlimited; or
 - (d) Other radioactive material in which the activity is distributed throughout and the estimated average specific activity does not exceed 30 times the value for exempt material activity concentration determined in accordance with Appendix A.
- (2) LSA-II.
 - (a) Water with tritium concentration up to 0.8 TBq/liter (20.0 Ci/liter); or
 - (b) Other **radioactive** material in which the activity is distributed throughout and the **estimated** average specific activity does not exceed $10^{-4} A_2/g$ for solids and gases, and $10^{-5} A_2/g$ for liquids.
- (3) LSA-III. Solids (*e.g.*, consolidated wastes, activated materials), excluding powders, that satisfy the requirements of 10 CFR 71.77, in which:
 - (a) The radioactive material is distributed throughout a solid or a collection of solid objects, or is essentially uniformly distributed in a solid compact binding agent (such as concrete, bitumen, ceramic, *etc.*);
 - (b) The radioactive material is relatively insoluble, or it is intrinsically contained in a relatively insoluble material, so that, even under loss of packaging, the loss of radioactive material per package by leaching, when placed in water for seven days, ~~would~~ **will** not exceed $0.1 A_2$; and,
 - (c) The estimated average specific activity of the solid, **excluding any shielding material**, does not exceed $2 \times 10^{-3} A_2/g$.

Low Toxicity Alpha Emitters means natural uranium, depleted uranium, natural thorium; uranium-235, uranium-238, thorium-232, thorium-228 or thorium-230 when contained in ores or physical or chemical concentrates; or alpha emitters with a half-life of less than ten days.

Maximum Normal Operating Pressure means the maximum gauge pressure that would develop in the containment system in a period of one year under the heat condition specified in 10 CFR 71.71(c)(1), in the absence of venting, external cooling by an ancillary system, or operational controls during transport.

Natural Thorium means thorium with the naturally occurring distribution of thorium isotopes (essentially 100 weight percent thorium-232).

Normal Form Radioactive Material means radioactive material which has not been demonstrated to qualify as special form radioactive material.

¹ Agency jurisdiction extends only to “special nuclear material in quantities not sufficient to form a critical mass” as defined in 105 CMR 120.005.

120.772: continued

Nuclear Waste means a quantity of source, byproduct or special nuclear material required to be in US Nuclear Regulatory Commission-approved specification packaging while transported to, through or across a state boundary to a disposal site, or to a collection point for transport to a disposal site.

Package means the packaging together with its radioactive contents as presented for transport.

(1) Fissile material package or Type AF package, Type BF package, Type B(U)F package, or Type B(M)F package means a fissile material packaging together with its fissile material contents.

(2) Type A package means a Type A packaging together with its radioactive contents. A Type A package is defined and must comply with the DOT regulations in 49 CFR part 173.

(3) Type B package means a Type B packaging together with its radioactive contents. On approval, a Type B package design is designated by NRC as B(U) unless the package has a maximum normal operating pressure of more than 700 kPa (100 lbs/in²) gauge or a pressure relief device that would allow the release of radioactive material to the environment under the tests specified in §71.73 (hypothetical accident conditions), in which case it will receive a designation B(M). B(U) refers to the need for unilateral approval of international shipments; B(M) refers to the need for multilateral approval of international shipments. There is no distinction made in how packages with these designations may be used in domestic transportation. To determine their distinction for international transportation, see DOT regulations in 49 CFR Part 173. A Type B package approved before September 6, 1983, was designated only as Type B. Limitations on its use are specified in §71.19.

Packaging means the assembly of components necessary to ensure compliance with the packaging requirements of 49 CFR Part 173. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shocks. The vehicle, tie-down system, and auxiliary equipment may be designated as part of the packaging.

Regulations of the U.S. Department of Transportation (DOT) means the regulations in 49 CFR Parts 100 through 189 and Parts 390 through 397.

Regulations of the U.S. Nuclear Regulatory Commission (NRC) means the regulations in 10 CFR 71 for purposes of 105 CMR 120.770.

Special Form Radioactive Material means radioactive material which satisfies the following conditions:

~~(1) It is either a single solid piece or is contained in a sealed capsule that can be opened only by destroying the capsule;~~

~~(2) The piece or capsule has at least one dimension not less than five millimeters (0.2 inch); and~~

~~(3) It satisfies the test requirements specified by the Nuclear Regulatory Commission. A special form encapsulation designed in accordance with the Nuclear Regulatory Commission requirements in effect June 30, 1983, and constructed prior to July 1, 1985, may continue to be used. A special form encapsulation designed in accordance with the Nuclear Regulatory Commission requirements in effect on March 31, 1996, and constructed prior to April 1, 1998, may continue to be used. A special form encapsulation either designed or constructed after April 1, 1998, must meet requirements of this definition applicable at the time of its design or construction.~~

Specific Activity of a radionuclide means the activity of a radionuclide per unit mass of that nuclide. The specific activity of a material in which the radionuclide is essentially uniformly distributed is the activity per unit mass of the material.

Surface Contaminated Object (SCO) means a solid object that is not itself classed as radioactive material, but which has radioactive material distributed on any of its surfaces. SCO must be in one of two groups with surface activity not exceeding the following limits:

120.772: continued

- (1) SCO-I: A solid object on which:
- The non-fixed contamination on the accessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed four Bq/cm² (10⁻⁴ microcurie/cm²) for beta and gamma and low toxicity alpha emitters, or 0.4 Bq/cm² (10⁻⁵ microcurie/cm²) for all other alpha emitters;
 - The fixed contamination on the accessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed 4x10⁴ Bq/cm² (1.0 microcurie/cm²) for beta and gamma and low toxicity alpha emitters, or 4x10³ Bq/cm² (0.1 microcurie/cm²) for all other alpha emitters; and,
 - The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed 4x10⁴ Bq/cm² (one microcurie/cm²) for beta and gamma and low toxicity alpha emitters, or 4x10³ Bq/cm² (0.1 microcurie/cm²) for all other alpha emitters.
- (2) SCO-II: A solid object on which the limits for SCO-I are exceeded and on which:
- The non-fixed contamination on the accessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed 400 Bq/cm² (10⁻² microcurie/cm²) for beta and gamma and low toxicity alpha emitters or 40 Bq/cm² (10⁻³ microcurie/cm²) for all other alpha emitters;
 - The fixed contamination on the accessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed 8x10⁵ Bq/cm² (20 microcuries/cm²) for beta and gamma and low toxicity alpha emitters, or 8x10⁴ Bq/cm² (two microcuries/cm²) for all other alpha emitters; and,
 - The non-fixed contamination plus the fixed contamination on the inaccessible surface averaged over 300 cm² (or the area of the surface if less than 300 cm²) does not exceed 8x10⁵ Bq/cm² (20 microcuries/cm²) for beta and gamma and low toxicity alpha emitters, or 8x10⁴ Bq/cm² (two microcuries/cm²) for all other alpha emitters.

Transport Index means the dimensionless number (rounded up to the next tenth) placed on the label of a package to designate the degree of control to be exercised by the carrier during transportation. The transport index is the number determined by multiplying the maximum radiation level in millisievert (mSv) per hour at one meter (3.3 ft) from the external surface of the package by 100 (equivalent to the maximum radiation level in millirem per hour at one meter (3.3 ft)).

Tribal Official means the highest ranking individual that represents Tribal leadership, such as the Chief, President, or Tribal Council leadership.

Type A Quantity means a quantity of radioactive material, the aggregate radioactivity of which does not exceed A₁ for special form radioactive material or A₂ for normal form radioactive material, where A₁ and A₂ are given in 105 CMR 120.7958: *Appendix A* or may be determined by procedures described in 105 CMR 120.7958: *Appendix A*.

Type B Quantity means a quantity of radioactive material greater than a Type A quantity.

Unirradiated Uranium means uranium containing not more than 2 x 10³ Bq of plutonium per gram of uranium 235, not more than 9 x 10⁶ Bq of fission products per gram of uranium 235, and not more than 5 x 10⁻³ g of uranium 236 per gram of uranium 235.

Uranium - Natural, Depleted, Enriched.

- Natural Uranium means uranium (**which may be chemically separated**) with the naturally occurring distribution of uranium isotopes (approximately 0.711 weight percent uranium-235, and the remainder by weight essentially uranium-238).
- Depleted Uranium means uranium containing less uranium-235 than the naturally occurring distribution of uranium isotopes.
- Enriched Uranium means uranium containing more uranium-235 than the naturally occurring distribution of uranium isotopes.

GENERAL REGULATORY PROVISIONS

120.773: Requirement for License

Except as authorized in a general license or a specific license issued by the Agency, or as exempted in 105 CMR 120.775, no licensee may:

120.773: continued

- (A) Deliver licensed material to a carrier for transport; or
- (B) Transport licensed material.

120.774: Transportation of Licensed Material

(A) Each licensee who transports licensed material outside the site of usage, as specified in the Agency license, or where transport is on public highways, or who delivers licensed material to a carrier for transport, shall comply with the applicable requirements of the U.S. Department of Transportation regulations in 49 CFR parts 107, 171 through 180, and 390 through 397, appropriate to the mode of transport.

- (1) The licensee shall particularly note DOT regulations in the following areas:
 - (a) Packaging - 49 CFR Part 173: Subparts A and B and I.
 - (b) Marking and labeling - 49 CFR Part 172: Subpart D, §§ 172.400 through 172.407, §§ 172.436 through 172.441, and Subpart E.
 - (c) Placarding - 49 CFR Part 172: Subpart F, especially §§ 172.500 through 172.519, 172.556, and Appendices B and C.
 - (d) Accident reporting - 49 CFR Part 171: §§ 171.15 and 171.16.
 - (e) Shipping papers and emergency information - 49 CFR Part 172: Subparts C and G.
 - (f) Hazardous material employee training - 49 CFR Part 172: Subpart H.
 - (g) Security plans - 49 CFR Part 172: Subpart I
 - (h) Hazardous material shipper/carrier registration - 49 CFR Part 107: Subpart G.
- (2) The licensee shall also note DOT regulations pertaining to the following modes of transportation:
 - (a) Rail - 49 CFR Part 174: Subparts A through D and K.
 - (b) Air - 49 CFR Part 175
 - (c) Vessel - 49 CFR Part 176: Subparts A through F and M.
 - (d) Public Highway - 49 CFR Part 177 and Parts 390 through 397.
- (3) Assure that any special instructions needed to safely open the package are sent to or have been made available to the consignee in accordance with 105 CMR 120.242(E).

(B) If, for any reason, the regulations of the U.S. Department of Transportation are not applicable to a shipment of licensed material, the licensee shall conform to the standards and requirements of 49 CFR Parts 107, 171 through 180 and 390 through 397 appropriate to the mode of transport to the same extent as if the shipment was subject to the regulations. A request for modification, waiver, or exemption from those requirements, and any notification referred to in those requirements, must be filed with, or made to, the Director, Radiation Control Program.

120.775: Exemptions

(A) Any physician licensed by a State to dispense drugs in the practice of medicine is exempt from 105 CMR 120.774 with respect to transport by the physician of licensed material for use in the practice of medicine. However, any physician operating under 105 CMR 120.775 must be licensed under 10 CFR Part 35 or the equivalent Agreement State regulations.

(B) Common and contract carriers, freight forwarders, and warehouse workers who are subject to the requirements of the U.S. Department of Transportation in 49 CFR 170 through 189 or the U.S. Postal Service in the Postal Service Manual (Domestic Mail Manual), Section 124.3 incorporated by reference, 39 CFR 111.11 (1974), and the U.S. Postal Service are exempt from the requirements of 105 CMR 120.770 to the extent that they transport or store radioactive material in the regular course of their carriage for others or storage incident thereto. Common and contract carriers who are not subject to the requirements of the U.S. Department of Transportation or U.S. Postal Service are subject to 105 CMR 120.773 and other applicable requirements of 105 CMR 120.000.

(C) A licensee is exempt from all requirements of 105 CMR 120.770, with respect to shipment or carriage of the following low-level materials:

- (1) Natural material and ores containing naturally occurring radionuclides that are **either in their natural state, or have only been processed for purposes other than for the extraction of the radionuclides, and which are** not intended to be processed for **the** use of these radionuclides, provided the activity concentration of the material does not exceed

ten times the **applicable radionuclide activity concentration** values specified in 105 CMR 120.79~~5~~**8**: *Appendix A, Table A-2, or Table A-3.*

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(2) Materials for which the activity concentration is not greater than the activity concentration values specified in 105 CMR 120.7958: *Appendix A, Table A-2, or Table A-3*, or for which the consignment activity is not greater than the limit for an exempt consignment found in 105 CMR 120.7958: *Appendix A, Table A-2, or Table A-3*.

(3) Non-radioactive solid objects with radioactive substances present on any surfaces in quantities not in excess of the levels cited in the definition of contamination in 105 CMR 120.772.

(D) Fissile materials meeting one of the following requirements are exempt from the classification as fissile material and from the fissile material package standards of 10 CFR 71.55 and 10 CFR 71.59, but are subject to all other requirements of 10 CFR 71, except as noted.

(1) Individual package containing two grams or less fissile material.

(2) Individual or bulk packaging containing 15 grams or less of fissile material provided the package has at least 200 grams of solid nonfissile material for every gram of fissile material. Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass for solid nonfissile material.

(3) (a) Low concentrations of solid fissile material commingled with solid nonfissile material, provided that:

1. There is at least 2000 grams of solid nonfissile material for every gram of fissile material, and
2. There is no more than 180 grams of fissile material distributed within 360 kg of contiguous nonfissile material.

(b) Lead, beryllium, graphite, and hydrogenous material enriched in deuterium may be present in the package but must not be included in determining the required mass of solid nonfissile material.

(e4) Uranium enriched in uranium-235 to a maximum of 1% by weight, and with total plutonium and uranium-233 content of up to 1% of the mass of uranium-235, provided that the mass of any beryllium, graphite, and hydrogenous material enriched in deuterium constitutes less than 5% of the uranium mass, and that the fissile material is distributed homogeneously and does not form a lattice arrangement within the package.

(d5) Liquid solutions of uranyl nitrate enriched in uranium-235 to a maximum of 2% by mass, with a total plutonium and uranium-233 content not exceeding 0.002% of the mass of uranium, and with a minimum nitrogen to uranium atomic ratio (N/U) of two. The material must be contained in at least a DOT Type A package.

(e6) Packages containing, individually, a total plutonium mass of not more than 1000 grams, of which not more than 20% by mass may consist of plutonium-239, plutonium-241, or any combination of these radionuclides.

120.776: General Licenses for Carriers

(A) A general license is hereby issued to any common or contract carrier not exempt under 105 CMR 120.775 to receive, possess, transport, and store radioactive material in the regular course of their carriage for others or storage incident thereto, provided the transportation and storage is in accordance with the applicable requirements, appropriate to the mode of transport, of the U.S. Department of Transportation insofar as such requirements relate to the loading and storage of packages, placarding of the transporting vehicle, and incident reporting.³

(B) A general license is hereby issued to any private carrier to transport radioactive material, provided the transportation is in accordance with the applicable requirements, appropriate to the mode of transport, of the U.S. Department of Transportation insofar as such requirements relate to the loading and storage of packages, placarding of the transporting vehicle, and incident reporting.³

(C) Persons who transport radioactive material pursuant to the general licenses in 105 CMR 120.776(A) or (B) are exempt from the requirements of 105 CMR 120.200 and 120.750 to the extent that they transport radioactive material.

³ Notification of an incident shall be filed with, or made to, the Agency as prescribed in

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49 CFR, regardless of, and in addition to, notification made to U.S. Department of Transportation or other agencies.

120.777: General License: Nuclear Regulatory Commission - Approved Packages

- (A) A general license is hereby issued to any licensee **of the Agency** to transport, or to deliver to a carrier for transport, licensed material in a package for which a license, certificate of compliance, or other approval has been issued by the Nuclear Regulatory Commission.
- (B) This general license applies only to a licensee who has a quality assurance program approved by the Agency as satisfying the provisions of 105 CMR 120.790~~1~~ through 120.793~~7~~.
- (C) ~~This~~ **Each licensee issued a** general license **under 105 CMR 120.777(A) shall:** ~~applies only to a licensee who:~~
- (1) ~~Has~~ **Maintain** a copy of the ~~specific license,~~ **NRC issued** certificate of compliance, or other approval by the Nuclear Regulatory Commission of the package, and ~~has~~ the drawings and other documents referenced in the approval relating to the use and maintenance of the packaging and to the actions to be taken prior to shipment;
 - (2) ~~Complies~~ **Comply** with the terms and conditions of the license, certificate, or other approval by the Nuclear Regulatory Commission, as applicable, and the applicable requirements of 105 CMR ~~120.770~~ **120.771 through 120.774 and 105 CMR 120.784 through 120.797; and**
 - (3) **Submit in writing** ~~Before the licensee's first use of the package,~~ ~~submits in writing to:~~ ATTN: Document Control Desk, Director, **Division of Spent Fuel Project Office Storage and Transportation**, Office of Nuclear Material Safety and Safeguards, using an appropriate method listed in 10 CFR 71.1(a), the licensee's name and license number and the package identification number specified in the package approval.
- (D) The general license in 105 CMR 120.777(A) applies only when the package approval authorizes use of the package under this general license.
- (E) For a Type B or fissile material package, the design of which was approved by the Nuclear Regulatory Commission before April 1, 1996, the general license is subject to the additional restrictions of 10 CFR 71.19.

120.779: General License: U.S. Department of Transportation Specification Container

- (A) A general license is issued to any licensee to transport, or to deliver to a carrier for transport, licensed material in a specification container for fissile material or for a Type B quantity of radioactive material as specified in 49 CFR Parts 173 and 178.
- (B) This general license applies only to a licensee who:
- (1) Has a copy of the specification;
 - (2) Complies with the terms and conditions of the specification and the applicable requirements of 105 CMR 120.770; and,
 - (3) Has a quality assurance program as required by 105 CMR 120.790~~1~~.
- (C) This general license in 105 CMR 120.779(A) is subject to the limitation that the specification container may not be used for a shipment to a location outside the United States except by multilateral approval as defined in 49 CFR 173.403.
- (D) The general license specified in 105 CMR 120.779 expires on October 1, 2008.

120.780: General License - Use of Foreign Approved Package

- (A) A general license is issued to any licensee **of the Agency** to transport, or to deliver to a carrier for transport, licensed material in a package, the design of which has been approved in a foreign national competent authority certificate which has been revalidated by the U.S. Department of Transportation as meeting the applicable requirements of 49 CFR 171.~~1223~~.
- (B) This general license applies only to shipments made to or from locations outside the United States.
- (C) **Except as otherwise provided in 105 CMR 120.780,** ~~the~~ general license applies only to a licensee who **has a quality assurance program approved by the Agency as satisfying the**

applicable provisions of 105 CMR 120.791 through 120.797. †

~~(1) Has a quality assurance program approved by the Agency.~~

~~(2) Has a copy of the applicable certificate, the revalidation, and the drawings and other documents referenced in the certificate relating to the use and maintenance of the packaging and to the actions to be taken prior to shipment; and~~

~~(3) Complies with the terms and conditions of the certificate and revalidation, and with the applicable requirements of 105 CMR 120.770 with respect to the quality assurance provisions 105 CMR 120.790, the licensee is exempt from design, construction, and fabrication considerations.~~

(D) Each licensee issued a general license under 105 CMR 120.780(A) shall:

(1) Maintain a copy of the applicable certificate, the revalidation, and the drawings and other documents referenced in the certificate, relating to the use and maintenance of the packaging and to the actions to be taken before shipment; and

(2) Comply with the terms and conditions of the certificate and revalidation, and with the applicable requirements of 105 CMR 120.771 through 120.774 and 105 CMR 120.784 through 120.797.

~~120.780: continued~~120.781: General License: Fissile Material, Limited Quantity per Package

(A) A general license is hereby issued to any licensee to transport fissile material, or to deliver fissile material to a carrier for transport, if the material is shipped in accordance with 105 CMR 120.781. The fissile material need not be contained in a package which meets the standards of subparts E and F of 10 CFR 71; however, the material must be contained in a Type A package. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a).

(B) The general license applies only to a licensee who has a quality assurance program approved by the Agency as satisfying the provisions of 105 CMR 120.790~~1~~ through 120.793~~7~~.

(C) The general license applies only when a package's contents:

- (1) Contain less than a Type A quantity of fissile material; and,
- (2) Contain less than 500 total grams of beryllium, graphite, or hydrogenous material enriched in deuterium.

(D) The general license applies only to packages containing fissile material that are labeled with a CSI which:

- (1) Has been determined in accordance with 105 CMR 120.781(E);
- (2) Has a value less than or equal to ten; and
- (3) For a shipment of multiple packages containing fissile material, the sum of the CSIs must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 (for shipment on an exclusive use conveyance).

(E)(1) The value for the CSI must be greater than or equal to the number calculated by the following equation:

$$CSI = 10 \left[\frac{\text{grams of } ^{235}\text{U}}{X} + \frac{\text{grams of } ^{233}\text{U}}{Y} + \frac{\text{grams of Pu}}{Z} \right]$$

- (2) The calculated CSI must be rounded up to the first decimal place;
- (3) The values of X, Y, and Z used in the CSI equation must be taken from Tables I or II, as appropriate;
- (4) If Table II is used to obtain the value of X, then the values for the terms in the equation for uranium 233 and plutonium must be assumed to be zero; and,
- (5) Table I values for X, Y, and Z must be used to determine the CSI if:
 - (a) Uranium 233 is present in the package;
 - (b) The mass of plutonium exceeds 1% of the mass of uranium 235;
 - (c) The uranium is of unknown uranium 235 enrichment or greater than 24 weight percent enrichment; or
 - (d) Substances having a moderating effectiveness (*i.e.*, an average hydrogen density greater than H₂O) (*e.g.*, certain hydrocarbon oils or plastics) are present in any form, except as polyethylene used for packing or wrapping.

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120.781: continued

TABLE I -- Mass Limits for General License Packages Containing Mixed Quantities of Fissile Material or Uranium-235 of Unknown Enrichment per 105 CMR 120.781(E)

Fissile Materials	Fissile material mass mixed with moderating substances having an average hydrogen density less than or equal to H ₂ O (grams)	Fissile material mass mixed with moderating substances having an average hydrogen density greater than H ₂ O ^a (grams)
²³⁵ U (X)	60	38
²³³ U (Y)	43	27
²³⁹ Pu or ²⁴¹ Pu (Z)	37	24

^a When mixtures of moderating substances are present, the lower mass limits shall be used if more than 15% of the moderating substance has an average hydrogen density greater than H₂O.

Table II Mass Limits for General License Packages Containing Uranium-235 of Known Enrichment per 105 CMR 120.781(E)

Uranium Enrichment in Weight Percent of ²³⁵ U Not Exceeding	Fissile Material Mass of ²³⁵ U (X) (grams)
24	60
20	63
15	67
11	72
10	76
9.5	78
9	81
8.5	82
8	85
7.5	88
7	90
6.5	93
6	97
5.5	102
5	108
4.5	114
4	120
3.5	132
3	150
2.5	180
2	246
1.5	408
1.35	480
1	1,020
0.92	1,800

120.782: General License: Plutonium Beryllium Special Form Material

(A) A general license is issued to any licensee to transport fissile material in the form of plutonium beryllium (Pu Be) special form sealed sources, or to deliver Pu Be sealed sources to a carrier for transport, if the material is shipped in accordance with 105 CMR 120.782. This material need not be contained in a package which meets the standards of subparts E and F of 10 CFR 71; however, the material must be contained in a Type A package. The Type A package must also meet the DOT requirements of 49 CFR 173.417(a).

(B) The general license applies only to a licensee who has a quality assurance program approved by the Agency as satisfying the provisions of 105 CMR 120.790~~1~~ through 120.793~~7~~.

(C) The general license applies only when a package's contents:

- (1) Contain no more than a Type A quantity of radioactive material; and,
- (2) Contain less than 1000 g of plutonium, provided that: plutonium-239, plutonium-241, or any combination of these radionuclides, constitutes less than 240 g of the total quantity of plutonium in the package.

(D) The general license applies only to packages labeled with a CSI which:

- (1) Has been determined in accordance with 105 CMR 120.782(E);
- (2) Has a value less than or equal to 100; and,
- (3) For a shipment of multiple packages containing Pu Be sealed sources, the sum of the CSIs must be less than or equal to 50 (for shipment on a nonexclusive use conveyance) and less than or equal to 100 (for shipment on an exclusive use conveyance).

(E)(1) The value for the CSI must be greater than or equal to the number calculated by the following equation:

$$CSI = 10 \left[\frac{\text{grams of } ^{239}\text{Pu} + \text{grams of } ^{241}\text{Pu}}{24} \right];$$

- (2) The calculated CSI must be rounded up to the first decimal place.

PACKAGE APPROVAL STANDARDS

120.783: External Radiation Standards for All Packages

(A) Except as provided in 105 CMR 120.783(B), each package of radioactive materials offered for transportation must be designed and prepared for shipment so that under conditions normally incident to transportation the radiation level does not exceed 2 mSv/h (200 mrem/h) at any point on the external surface of the package, and the transport index does not exceed ten.

(B) A package that exceeds the radiation level limits specified in 105 CMR 120.783(A) must be transported by exclusive use shipment only, and the radiation levels for such shipment must not exceed the following during transportation:

- (1) 2 mSv/h (200 mrem/h) on the external surface of the package, unless the following conditions are met, in which case the limit is 10 mSv/h (1000 mrem/h):
 - (a) The shipment is made in a closed transport vehicle;
 - (b) The package is secured within the vehicle so that its position remains fixed during transportation; and,
 - (c) There are no loading or unloading operations between the beginning and end of the transportation;
- (2) 2 mSv/h (200 mrem/h) at any point on the outer surface of the vehicle, including the top and underside of the vehicle; or in the case of a flat-bed style vehicle, at any point on the vertical planes projected from the outer edges of the vehicle, on the upper surface of the load or enclosure, if used, and on the lower external surface of the vehicle; and
- (3) 0.1 mSv/h (10 mrem/h) at any point two meters (80 in) from the outer lateral surfaces of the vehicle (excluding the top and underside of the vehicle); or in the case of a flat-bed style vehicle, at any point two meters (6.6 feet) from the vertical planes projected by the outer edges of the vehicle (excluding the top and underside of the vehicle); and

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(4) 0.02 mSv/h (2 mrem/h) in any normally occupied space, except that this provision does not apply to private carriers, if exposed personnel under their control wear radiation dosimetry devices in conformance with 105 CMR 120.226.

(C) For shipments made under the provisions of 105 CMR 120.783(B), the shipper shall provide specific written instructions to the carrier for maintenance of the exclusive use shipment controls. The instructions must be included with the shipping paper information.

(D) The written instructions required for exclusive use shipments must be sufficient so that, when followed, they will cause the carrier to avoid actions that will unnecessarily delay delivery or unnecessarily result in increased radiation levels or radiation exposures to transport workers or members of the general public.

OPERATING CONTROLS AND PROCEDURES

120.784: Assumptions as to Unknown Properties of Fissile Material

When the isotopic abundance, mass, concentration, degree of irradiation, degree of moderation, or other pertinent property of fissile material in any package is not known, the licensee shall package the fissile material as if the unknown properties have credible values that will cause the maximum neutron multiplication.

120.785: Preliminary Determinations

Prior to the first use of any packaging for the shipment of licensed material, **the licensee shall ascertain that the determinations in 10 CFR 71.85(a) through (c) have been made.:**

~~(A) The licensee shall ascertain that there are no cracks, pinholes, uncontrolled voids, or other defects that could significantly reduce the effectiveness of the packaging;~~

~~(B) Where the maximum normal operating pressure will exceed 35 kPa (five lbf/in²) gauge, the licensee shall test the containment system at an internal pressure at least 50% higher than the maximum normal operating pressure to verify the capability of that system to maintain its structural integrity at that pressure;~~

~~(C) The licensee shall conspicuously and durably mark the packaging with its model number, serial number, gross weight, and a package identification number assigned by NRC. Before applying the model number, the licensee shall determine that the packaging has been fabricated in accordance with the design approved by the Nuclear Regulatory Commission.~~

120.786: Routine Determinations

Prior to each shipment of licensed material, the licensee shall ensure that the package with its contents satisfies applicable requirements of 10 CFR 71 and of the license. The licensee shall determine that:

(A) The package is proper for the contents to be shipped;

(B) The package is in unimpaired physical condition except for superficial defects such as marks or dents;

(C) Each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects;

(D) Any system for containing liquid is adequately sealed and has adequate space or other specified provision for expansion of the liquid;

(E) Any pressure relief device is operable and set in accordance with written procedures;

(F) The package has been loaded and closed in accordance with written procedures;

120.786: continued

- (G) For fissile material, any moderator or neutron absorber, if required, is present and in proper condition;
- (H) Any structural part of the package which could be used to lift or tie down the package during transport is rendered inoperable for that purpose unless it satisfies design requirements specified in 10 CFR 71.45;
- (I) The level of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for shipment is as low as reasonably achievable, and within the limits specified in DOT regulations in 49 CFR 173.443;
- (J) External radiation levels around the package and around the vehicle, if applicable, will not exceed the limits specified in 10 CFR 71.47 at any time during transportation; and
- (K) Accessible package surface temperatures will not exceed the limits specified in 10 CFR 71.43(g) at any time during transportation.

120.787: Air Transport of Plutonium

Notwithstanding the provisions of any general licenses and notwithstanding any exemptions stated directly in 105 CMR 120.770 or included indirectly by citation of the U.S. Department of Transportation regulations, as may be applicable, the licensee shall assure that plutonium in any form, whether for import, export, or domestic shipment, is not transported by air, or delivered to a carrier for air transport, unless:

- (A) The plutonium is contained in a medical device designed for individual human application;
- (B) The plutonium is contained in a material in which the specific activity is not greater than or equal to the activity concentration values for plutonium specified in 105 CMR 120.770~~98~~: *Appendix A, Table A-2*, and in which the radioactivity is essentially uniformly distributed;
- (C) The plutonium is shipped in a single package containing no more than an A₂ quantity of plutonium in any isotope or form and is shipped in accordance with 105 CMR 120.774;
- (D) The plutonium is shipped in a package specifically authorized (in the Certificate of Compliance issued by the Nuclear Regulatory Commission for that package) for the shipment of plutonium by air; or
- (E) For a shipment of plutonium by air which is subject to 105 CMR 120.787(D), the licensee shall, through special arrangement with the carrier, require compliance with 49 CFR 175.704, U.S. Department of Transportation regulations applicable to the air transport of plutonium.
- (F) Nothing in 105 CMR 120.787 is to be interpreted as removing or diminishing the requirements of 10 CFR 73.24.

120.788: Opening Instructions

Before delivery of a package to a carrier for transport, the licensee shall ensure that any special instructions needed to safely open the package have been sent to, or otherwise made available to, the consignee for the consignee's use in accordance with 105 CMR 120.242(E).

120.789: Records

- (A) Each licensee shall maintain, for a period of three years after shipment, a record of each shipment of licensed material not exempt under 105 CMR 120.775(C), showing where applicable:**
- (1) Identification of the packaging by model number and serial number;**
 - (2) Verification that there are no significant defects in the packaging, as shipped;**
 - (3) Volume and identification of coolant;**
 - (4) Type and quantity of licensed material in each package, and the total quantity of each shipment;**

(5) For each item of irradiated fissile material:

- (a) Identification by model number and serial number;**
 - (b) Irradiation and decay history to the extent appropriate to demonstrate that its nuclear and thermal characteristics comply with license conditions; and**
 - (c) Any abnormal or unusual condition relevant to radiation safety;**
- (6) Date of the shipment;**
- (7) For fissile packages and for Type B packages, any special controls exercised;**
- (8) Name and address of the transferee;**
- (9) Address to which the shipment was made; and**
- (10) Results of the determinations required by 105 CMR 120.786 and by the conditions of the package approval.**

(B) The licensee shall make available to the Agency for inspection, upon reasonable notice, all records required by 105 CMR 120.770 through 120.798. Records are only valid if stamped, initialed, or signed and dated by authorized personnel, or otherwise authenticated.

(C) The licensee shall maintain sufficient written records to furnish evidence of the quality of packaging. The records to be maintained include: results of the determinations required by 105 CMR 120.785; design, fabrication, and assembly records; results of reviews, inspections, tests, and audits; results of monitoring work performance and materials analyses; and results of maintenance, modification, and repair activities. Inspection, test, and audit records must identify the inspector or data recorder, the type of observation, the results, the acceptability, and the action taken in connection with any deficiencies noted. These records must be retained for three years after the life of the packaging to which they apply.

120.78990: Advance Notification of Shipment of Nuclear Waste

(A)(1) As specified in 105 CMR 120.78990(B) through (D), each licensee shall provide advance notification to the governor of a State, or the governor's designee, of the shipment of licensed material, within or across the boundary of the State, before the transport, or delivery to a carrier, for transport, of licensed material outside the confines of the licensee's plant or other place of use or storage.

120.78990: continued

(2) As specified in 105 CMR 120.78990(B) through (D) each licensee shall provide advance notification to the Tribal official of participating Tribes referenced in 105 CMR 120.78990(C)(3)(c), or the official's designee, of the shipment of licensed material, within or across the boundary of the Tribe's reservation, before the transport, or delivery to a carrier, for transport, of licensed material outside the confines of the licensee's plant or other place of use or storage.

(B) Advance notification is required under 105 CMR 120.78990 for shipment of licensed material meeting the following three conditions:

- (1) The licensed material is required by 10 CFR 71 to be in Type B packaging for transportation;
- (2) The licensed material is being transported into, within, or through a state en route to a disposal facility or to a collection point for transport to a disposal facility; and,
- (3) The quantity of licensed material in a single package exceeds the least of the following:
 - (a) 3000 times the A1 value of the radionuclides as specified in 105 CMR 120.7958: *Appendix A, Table A-1* for special form radioactive material;
 - (b) 3000 times the A2 value of the radionuclides as specified in 105 CMR 120.7958: *Appendix A, Table A-1* for normal form radioactive material; or,
 - (c) 1000 TBq (27,000 Ci).

(C) Procedures for Submitting Advance Notification.

- (1) The notification must be made in writing to the office of each appropriate governor or governor's designee, the office of each appropriate Tribal official or Tribal official's designee, and to the Director of the Agency.
- (2) A notification delivered by mail must be postmarked at least seven days before the beginning of the seven-day period during which departure of the shipment is estimated to occur.
- (3) A notification delivered by any other means than mail must reach the office of the governor or of the governor's designee or the Tribal official or Tribal official's designee at least four days before the beginning of the seven-day period during which departure of the shipment is estimated to occur.
 - (a) A list of the names and mailing addresses of the governors' designees receiving advance notification of transportation of nuclear waste was published in the Federal Register on June 30, 1995 (60 FR 34306).
 - (b) Contact information for each State, including telephone and mailing addresses of governors and governors' designees, and participating Tribes, including telephone and mailing addresses of Tribal officials and Tribal official's designees, is available on the NRC Web site at: <https://scp.nrc.gov/special/designee.pdf>.
 - (c) A list of the names and mailing addresses of the governors' designees and Tribal officials' designees of participating Tribes is available on request from the Director, Division of Material Safety, State, Tribal, and Rulemaking Programs, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.
- (4) The licensee shall retain a copy of the notification as a record for three years.

(D) Information to be Furnished in Advance Notification of Shipment. Each advance notification of shipment of nuclear waste must contain the following information:

- (1) The name, address, and telephone number of the shipper, carrier, and receiver of the nuclear waste shipment;
- (2) A description of the nuclear waste contained in the shipment, as specified in the regulations of DOT in 49 CFR 172.202 and 172.203(d);
- (3) The point of origin of the shipment and the seven-day period during which departure of the shipment is estimated to occur;
- (4) The seven-day period during which arrival of the shipment at State boundaries or Tribal reservation boundaries is estimated to occur;
- (5) The destination of the shipment, and the seven-day period during which arrival of the shipment is estimated to occur; and
- (6) A point of contact, with a telephone number, for current shipment information.

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(E) Revision Notice. A licensee who finds that schedule information previously furnished to a governor or governor's designee or a Tribal official or Tribal official's designee, in accordance with 105 CMR 120.78990, will not be met, shall telephone a responsible individual in the office of the governor of the State or of the governor's designee or the Tribal official or the Tribal official's designee and inform that individual of the extent of the delay beyond the schedule originally reported. The licensee shall maintain a record of the name of the individual contacted for three years

(F) Cancellation Notice.

(1) Each licensee who cancels a nuclear waste shipment for which advance notification has been sent shall send a cancellation notice to the governor of each State or to the governor's designee previously notified, each Tribal official or to the Tribal official's designee previously notified, and to the Director of the Agency.

(2) The licensee shall state in the notice that it is a cancellation and identify the advance notification that is being canceled. The licensee shall retain a copy of the notice as a record for three years.

QUALITY ASSURANCE

120.7901: Quality Assurance Requirements

(A) Purpose. 105 CMR 120.7901 **through 120.797** describes quality assurance requirements applying to design, purchase, fabrication, handling, shipping, storing, cleaning, assembly, inspection, testing, operation, maintenance, repair, and modification of components of packaging that are important to safety. As used in ~~this subpart~~ **105 CMR 120.791 through 120.797**, "quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a system or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to control of the physical characteristics and quality of the material or component to predetermined requirements. ~~The licensee, certificate holder, and applicant for a CoC are responsible for the quality assurance requirements as they apply to design, fabrication, testing, and modification of packaging.~~ Each licensee is responsible for the quality assurance provision **requirements that apply** which applies to its use of a packaging for the shipment of licensed material subject to ~~this subpart~~ **105 CMR 120.791 through 120.797**.

(B) Establishment of Program. Each licensee, ~~certificate holder, and applicant for a CoC~~ shall establish, maintain, and execute a quality assurance program satisfying each of the applicable criteria of **105 CMR 120.791 through 120.797** and satisfying any specific provisions that are applicable to the licensee's activities including procurement of packaging. ~~The licensee, certificate holder, and applicant for a CoC shall execute the applicable criteria in a graded approach to an extent that is commensurate with the quality assurance requirement's importance to safety.~~

(C) Approval of Program. Before the use of any package for the shipment of licensed material subject to 105 CMR 120.7901 **through 120.797**, each licensee shall obtain Agency approval of its quality assurance program. **Using an appropriate method listed in 105 CMR 120.013, each licensee shall file a description of its quality assurance program, including a discussion of which requirements of 105 CMR 120.791 through 120.797 are applicable and how they will be satisfied, by submitting the description to the Agency.**

(D) Radiography Containers. A program for transport container inspection and maintenance limited to radiographic exposure devices, source changers, or packages transporting these devices and meeting the requirements of 10 CFR 34.31(b) or equivalent Agreement State requirement, is deemed to satisfy the requirements of 105 CMR 120.777(B) and 120.7901(B).

120.7912: Quality Assurance Organization

(A) The **licensee** "licensee" ~~[while the term "licensee" is used in these criteria, the requirements are applicable to whatever design, fabrication, assembly, and testing of the package is accomplished with respect to a package before the time a package approval is issued], certificate holder, and applicant for a CoC shall be responsible for the establishment and execution of the quality assurance program. The licensee, certificate holder, and applicant for a CoC may~~

delegate to others, such as contractors, agents, or consultants, the work of establishing and executing the quality assurance program, or any part of the quality assurance program, but shall retain responsibility for the program. These activities include performing the functions associated with attaining quality objectives and the quality assurance functions.

120.791~~2~~: continued

(B) The quality assurance functions are:

- (1) Assuring that an appropriate quality assurance program is established and effectively executed; and
- (2) Verifying, by procedures such as checking, auditing, and inspection, that activities affecting the functions that are important to safety have been correctly performed.

120.793: Quality Assurance Program

(A) The licensee, ~~certificate holder, and applicant for a CoC~~ shall establish, at the earliest practicable time consistent with the schedule for accomplishing the activities, a quality assurance program that complies with the requirements of ~~10 CFR 71.101 through 71.137~~ **105 CMR 120.791 through 120.797**. The licensee, ~~certificate holder, and applicant for a CoC~~ shall document the quality assurance program by written procedures or instructions and shall carry out the program in accordance with those procedures throughout the period during which the packaging is used. The licensee, ~~certificate holder, and applicant for a CoC~~ shall identify the material and components to be covered by the quality assurance program, the major organizations participating in the program, and the designated functions of these organizations.

(B) The licensee, ~~certificate holder, and applicant for a CoC~~ shall base the requirements and procedures of its quality assurance program on the following considerations concerning the complexity and proposed use of the package and its components:

- (1) The impact of malfunction or failure of the item to safety;
- (2) The design and fabrication complexity or uniqueness of the item;
- (3) The need for special controls and surveillance over processes and equipment;
- (4) The degree to which functional compliance can be demonstrated by inspection or test; and
- (5) The quality history and degree of standardization of the item.

(C) The licensee, ~~certificate holder, and applicant for a CoC~~ shall provide for indoctrination and training of personnel performing activities affecting quality, as necessary to assure that suitable proficiency is achieved and maintained. The licensee, ~~certificate holder, and applicant for a CoC~~ shall review the status and adequacy of the quality assurance program at established intervals. Management of other organizations participating in the quality assurance program shall review regularly the status and adequacy of that part of the quality assurance program they are executing.

120.794: Changes to Quality Assurance Program

(A) Each quality assurance program approval holder shall submit, in accordance with 105 CMR 120.013, a description of a proposed change to its Agency-approved quality assurance program that will reduce commitments in the program description as approved by the Agency. The quality assurance program approval holder shall not implement the change before receiving Agency approval. The description of a proposed change to the Agency-approved quality assurance program must identify the change, the reason for the change, and the basis for concluding that the revised program incorporating the change continues to satisfy the applicable requirements of 105 CMR 120.791 through 120.797.

(B) Each quality assurance program approval holder may change a previously approved quality assurance program without prior Agency approval, if the change does not reduce the commitments in the quality assurance program previously approved by the Agency. Changes to the quality assurance program that do not reduce the commitments shall be submitted to the Agency every 24 months, in accordance with 105 CMR 120.013. In addition to quality assurance program changes involving administrative improvements and clarifications, spelling corrections, and non-substantive changes to punctuation or editorial items, the following changes are not considered reductions in commitment:

- (1) The use of a quality assurance standard approved by the Agency that is more recent than the quality assurance standard in the applicant's current quality assurance program at the time of the change;**
- (2) The use of generic organizational position titles that clearly denote the position function, supplemented as necessary by descriptive text, rather than specific titles, provided that there is no substantive change to either the functions of the position or**

reporting responsibilities;

(3) The use of generic organizational charts to indicate functional relationships, authorities, and responsibilities, or alternatively, the use of descriptive text, provided that there is no substantive change to the functional relationships, authorities, or responsibilities;

(4) The elimination of quality assurance program information that duplicates language in quality assurance regulatory guides and quality assurance standards to which the quality assurance program approval holder has committed to on record; and

(5) Organizational revisions that ensure that persons and organizations performing quality assurance functions continue to have the requisite authority and organizational freedom, including sufficient independence from cost and schedule when opposed to safety considerations.

(C) Each quality assurance program approval holder shall maintain records of quality assurance program changes.

120.795: Corrective Action

The licensee shall establish measures to assure that conditions adverse to quality, such as deficiencies, deviations, defective material and equipment, and nonconformances, are promptly identified and corrected. In the case of a significant condition adverse to quality, the measures must assure that the cause of the condition is determined and corrective action taken to preclude repetition. The identification of the significant condition adverse to quality, the cause of the condition, and the corrective action taken must be documented and reported to appropriate levels of management.

120.796: Quality Assurance Records

The licensee shall maintain sufficient written records to describe the activities affecting quality. These records must include changes to the quality assurance program as required by 105 CMR 120.794. The records must include the instructions or procedures that establish a records retention program that is consistent with applicable regulations and designates factors such as duration, location, and assigned responsibility. The licensee shall retain these records for three years beyond the date when the licensee last engaged in the activity for which the quality assurance program was developed. If any portion of the quality assurance program, written procedures or instructions is superseded, the licensee shall retain the superseded material for three years after it is superseded.

120.797: Audits

The licensee shall carry out a comprehensive system of planned and periodic audits to verify compliance with all aspects of the quality assurance program and to determine the effectiveness of the program. The audits must be performed in accordance with written procedures or checklists by appropriately trained personnel not having direct responsibilities in the areas being audited. Audited results must be documented and reviewed by management having responsibility in the area audited. Followup action, including re-audit of deficient areas, must be taken where indicated.

120.7958: Appendix A -- Determination of A_1 and A_2

- I. Values of A_1 and A_2 for individual radionuclides, which are the bases for many activity limits elsewhere in 105 CMR 120.000 are given in Table A-1. The curie (Ci) values specified are obtained by converting from the Terabecquerel (TBq) figure. ~~The curie values are expressed to three significant figures to assure that the difference in the TBq and Ci quantities is one tenth of one percent or less.~~ **The Terabecquerel values are the regulatory standard. The curie values are for information only and are not intended to be the regulatory standard.** Where values of A_1 or A_2 are unlimited, it is for radiation control purposes only. For nuclear criticality safety, some materials are subject to controls placed on fissile material.
- II. (a) For individual radionuclides whose identities are known, but which are not listed in Table A-1, the A_1 and A_2 values contained in Table A-3 may be used. Otherwise, the

licensee shall obtain prior Agency approval of the A_1 and A_2 values for radionuclides not listed in Table A-1, before shipping the material.

(b) For individual radionuclides whose identities are known, but which are not listed in Table A-2, the exempt material activity concentration and exempt consignment activity values contained in Table A-3 may be used. Otherwise, the licensee shall obtain prior Agency approval of the exempt material activity concentration and exempt consignment activity values for radionuclides not listed in Table A-2, before shipping the material.

(c) The licensee shall submit requests for prior approval, described in Appendix AII(a) and II(b), to the Agency, in accordance with ~~10 CFR 71.1~~ **105 CMR 120.013**.

NON-TEXT PAGE

Appendix A: continued

III. In the calculations of A_1 and A_2 for a radionuclide not in Table A-1, a single radioactive decay chain, in which radionuclides are present in their naturally occurring proportions, and in which no daughter nuclide has a half-life either longer than ten days, or longer than that of the parent nuclide, shall be considered as a single radionuclide, and the activity to be taken into account, and the A_1 or A_2 value to be applied, shall be those corresponding to the parent nuclide of that chain. In the case of radioactive decay chains in which any daughter nuclide has a half-life either longer than ten days, or greater than that of the parent nuclide, the parent and those daughter nuclides shall be considered as mixtures of different nuclides.

IV. For mixtures of radionuclides whose identities and respective activities are known, the following conditions apply:

(a) For special form radioactive material, the maximum quantity transported in a Type A package is as follows:

$$\sum_i \frac{B(i)}{A_1(i)} \leq 1$$

where $B(i)$ is the activity of radionuclide i **in special form**, and $A_{1i}(i)$ is the A_1 value for radionuclide i .

(b) For normal form radioactive material, the maximum quantity transported in a Type A package is **as follows**:

$$\sum_i \frac{B(i)}{A_2(i)} \leq 1$$

where $B(i)$ is the activity of radionuclide i **in normal form**, and $A_{1i}(i)$ and $A_{2i}(i)$ are the A_1 and A_2 values **value** for radionuclide i .

(c) If the package contains both special and normal form radioactive material, the activity that may be transported in a Type A package is as follows:

$$\sum_i \frac{B(i)}{A_1(i)} + \sum_j \frac{C(j)}{A_2(j)} \leq 1$$

where $B(i)$ is the activity of radionuclide i as special form radioactive material, $A_1(i)$ is the A_1 value for radionuclide i , $C(j)$ is the activity of radionuclide j as normal form radioactive material, and $A_2(j)$ is the A_2 value for radionuclide j .

(ed) Alternatively, the A_1 value for mixtures of special form material may be determined as follows:

$$A_1 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_1(i)}}$$

where $f(i)$ is the fraction of activity of **for** radionuclide i in the mixture and $A_1(i)$ is the appropriate A_1 value for **radionuclide** i .

(de) Alternatively, the A_2 value for mixtures of normal form material may be determined as follows:

$$A_2 \text{ for mixture} = \frac{1}{\sum_i \frac{f(i)}{A_2(i)}}$$

where $f(i)$ is the fraction of activity of **for** radionuclide i in the mixture and $A_2(i)$ is the appropriate A_2 value for **radionuclide** i .

Appendix A: continued

(ef) The exempt activity concentration for mixtures of nuclides may be determined as follows:

$$\text{Exempt activity concentration for mixture} = \frac{1}{\sum_i \frac{f(i)}{[A](i)}}$$

where f(i) is the fraction of activity of radionuclide **i** in the mixture, and [A](i) is the activity concentration for exempt material containing radionuclide **i**.

(fg) The activity limit for an exempt consignment for mixtures of radionuclides may be determined as follows: Exempt consignment activity limit for mixture

$$\text{Exempt consignment activity limit for mixture} = \frac{1}{\sum_i \frac{f(i)}{A(i)}}$$

where f(i) is the fraction of activity of radionuclide **i** in the mixture, and A(i) is the activity limit for exempt consignments for radionuclide **i**.

V. (a) When the identity of each radionuclide is known, but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped, and the lowest A₁ or A₂ value, as appropriate, for the radionuclides in each group may be used in applying the formulas in paragraph IV. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest A₁ or A₂ values for the alpha emitters and beta/gamma emitters.

(b) When the identity of each radionuclide is known but the individual activities of some of the radionuclides are not known, the radionuclides may be grouped and the lowest [A] (activity concentration for exempt material) or A (activity limit for exempt consignment) value, as appropriate, for the radionuclides in each group may be used in applying the formulas in paragraph IV of this appendix. Groups may be based on the total alpha activity and the total beta/gamma activity when these are known, using the lowest [A] or A values for the alpha emitters and beta/gamma emitters, respectively.

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES

Symbol of radionuclides	Element and atomic number	Specific activity					
		A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	(TbBq/g)	(Ci/g)
Ac-225 (a)	Actinium (89)	8.0X10 ⁻¹	2.2X10 ¹	6.0X10 ⁻³	1.6X10 ⁻¹	2.1X10 ³	5.8X10 ⁴
Ac-227 (a)		9.0X10 ⁻¹	2.4X10 ¹	9.0X10 ⁻⁵	2.4X10 ⁻³	2.7X10 ⁰	7.2X10 ¹
Ac-228		6.0X10 ⁻¹	1.6X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	8.4X10 ⁴	2.2X10 ⁶
Ag-105	Silver (47)	2X10 ⁰	5.4X10 ¹	2X10 ⁰	5.4X10 ¹	1.1X10 ³	3.0X10 ⁴
Ag-108m (a)		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	9.7X10 ⁻¹	2.6X10 ¹
Ag-110m (a)		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.8X10 ²	4.7X10 ³
Ag-111		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	5.8X10 ³	1.6X10 ⁵
Al-26	Aluminum (13)	1.0X10 ⁻¹	2.7X10 ⁰	1.0X10 ⁻¹	2.7X10 ⁰	7.0X10 ⁻⁴	1.9X10 ⁻²
Am-241	Americium (95)	1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	1.3X10 ⁻¹	3.4X10 ⁰
Am-242m (a)		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	3.6X10 ⁻¹	1.0X10 ¹
Am-243 (a)		5.0X10 ⁰	1.4X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	7.4X10 ⁻³	2.0X10 ⁻¹
Ar-37	Argon (18)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	3.7X10 ³	9.9X10 ⁴
Ar-39		4.0X10 ¹	1.1X10 ³	2.0X10 ¹	5.4X10 ²	1.3X10 ⁰	3.4X10 ¹
Ar-41		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.5X10 ⁶	4.2X10 ⁷
As-72	Arsenic (33)	3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	6.2X10 ⁴	1.7X10 ⁶
As-73		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	8.2X10 ²	2.2X10 ⁴
As-74		1.0X10 ⁰	2.7X10 ¹	9.0X10 ⁻¹	2.4X10 ¹	3.7X10 ³	9.9X10 ⁴
As-76		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	5.8X10 ⁴	1.6X10 ⁶

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As-77		2.0X10 ¹	5.4X10 ²	7.0X10 ⁻¹	1.9X10 ¹	3.9X10 ⁴	1.0X10 ⁶
At-211 (a)	Astatine (85)	2.0X10 ¹	5.4X10 ²	5.0X10 ⁻¹	1.4X10 ¹	7.6X10 ⁴	2.1X10 ⁶

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TbBq/g)	(Ci/g)
Au-193	Gold (79)	7.0X10 ⁰	1.9X10 ²	2.0X10 ⁰	5.4X10 ¹	3.4X10 ⁴	9.2X10 ⁵
Au-194		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.5X10 ⁴	4.1X10 ⁵
Au-195	Gold (79)	1.0X10 ¹	2.7X10 ²	6.0X10 ⁰	1.6X10 ²	1.4X10 ²	3.7X10 ³
Au-198		1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	9.0X10 ³	2.4X10 ⁵
Au-199		1.0X10 ¹	2.7X10 ²	6.0X10 ⁻¹	1.6X10 ¹	7.7X10 ³	2.1X10 ⁵
Ba-131 (a)	Barium (56)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	3.1X10 ³	8.4X10 ⁴
Ba-133		3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	9.4X10 ⁰	2.6X10 ²
Ba-133m		2.0X10 ¹	5.4X10 ²	6.0X10 ⁻¹	1.6X10 ¹	2.2X10 ⁴	6.1X10 ⁵
Ba-140 (a)		5.0X10 ⁻¹	1.4X10 ¹	3.0X10 ⁻¹	8.1X10 ⁰	2.7X10 ³	7.3X10 ⁴
Be-7	Beryllium (4)	2.0X10 ¹	5.4X10 ²	2.0X10 ¹	5.4X10 ²	1.3X10 ⁴	3.5X10 ⁵
Be-10		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻¹	1.6X10 ¹	8.3X10 ⁻⁴	2.2X10 ⁻²
Bi-205	Bismuth (83)	7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	1.5X10 ³	4.2X10 ⁴
Bi-206		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	3.8X10 ³	1.0X10 ⁵
Bi-207		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	1.9X10 ⁰	5.2X10 ¹
Bi-210		1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	4.6X10 ³	1.2X10 ⁵
Bi-210m(a)		6.0X10 ⁻¹	1.6X10 ¹	2.0X10 ⁻²	5.4X10 ⁻¹	2.1X10 ⁻⁵	5.7X10 ⁻⁴
Bi-212 (a)		7.0X10 ⁻¹	1.9X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	5.4X10 ⁵	1.5X10 ⁷
Bk-247	Berkelium (97)	8.0X10 ⁰	2.2X10 ²	8.0X10 ⁻⁴	2.2X10 ⁻²	3.8X10 ⁻²	1.0X10 ⁰
Bk-249 (a)		4.0X10 ¹	1.1X10 ³	3.0X10 ⁻¹	8.1X10 ⁰	6.1X10 ¹	1.6X10 ³
Br-76	Bromine (35)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	9.4X10 ⁴	2.5X10 ⁶
Br-77		3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	2.6X10 ⁴	7.1X10 ⁵
Br-82		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁴	1.1X10 ⁶
C-11	Carbon (6)	1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.1X10 ⁷	8.4X10 ⁸
C-14		4.0X10 ¹	1.1X10 ³	3.0X10 ⁰	8.1X10 ¹	1.6X10 ⁻¹	4.5X10 ⁰
Ca-41	Calcium (20)	Unlimited	Unlimited	Unlimited	Unlimited	3.1X10 ⁻³	8.5X10 ⁻²
Ca-45		4.0X10 ¹	1.1X10 ³	1.0X10 ⁰	2.7X10 ¹	6.6X10 ²	1.8X10 ⁴
Ca-47 (a)		3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁻¹	8.1X10 ⁰	2.3X10 ⁴	6.1X10 ⁵
Cd-109	Cadmium (48)	3.0X10 ¹	8.1X10 ²	2.0X10 ⁰	5.4X10 ¹	9.6X10 ¹	2.6X10 ³
Cd-113m		4.0X10 ¹	1.1X10 ³	5.0X10 ⁻¹	1.4X10 ¹	8.3X10 ⁰	2.2X10 ²
Cd-115 (a)		3.0X10 ⁰	8.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.9X10 ⁴	5.1X10 ⁵
Cd-115m		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	9.4X10 ²	2.5X10 ⁴
Ce-139	Cerium (58)	7.0X10 ⁰	1.9X10 ²	2.0X10 ⁰	5.4X10 ¹	2.5X10 ²	6.8X10 ³
Ce-141		2.0X10 ¹	5.4X10 ²	6.0X10 ⁻¹	1.6X10 ¹	1.1X10 ³	2.8X10 ⁴
Ce-143		9.0X10 ⁻¹	2.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.5X10 ⁴	6.6X10 ⁵
Ce-144 (a)		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	1.2X10 ²	3.2X10 ³
Cf-248	Californium (98)	4.0X10 ¹	1.1X10 ³	6.0X10 ⁻³	1.6X10 ⁻¹	5.8X10 ¹	1.6X10 ³
Cf-249		3.0X10 ⁰	8.1X10 ¹	8.0X10 ⁻⁴	2.2X10 ⁻²	1.5X10 ⁻¹	4.1X10 ⁰
Cf-250		2.0X10 ¹	5.4X10 ²	2.0X10 ⁻³	5.4X10 ⁻²	4.0X10 ⁰	1.1X10 ²
Cf-251		7.0X10 ⁰	1.9X10 ²	7.0X10 ⁻⁴	1.9X10 ⁻²	5.9X10 ⁻²	1.6X10 ⁰
Cf-252 (th)		5.1 1.0X10 ⁻¹	1.4 2.7X10 ⁰	3.0X10 ⁻³	8.1X10 ⁻²	2.0X10 ¹	5.4X10 ²
Cf-253 (a)		4.0X10 ¹	1.1X10 ³	4.0X10 ⁻²	1.1X10 ⁰	1.1X10 ³	2.9X10 ⁴
Cf-254		1.0X10 ⁻³	2.7X10 ⁻²	1.0X10 ⁻³	2.7X10 ⁻²	3.1X10 ²	8.5X10 ³
Cl-36	Chlorine (17)	1.0X10 ¹	2.7X10 ²	6.0X10 ⁻¹	1.6X10 ¹	1.2X10 ⁻³	3.3X10 ⁻²
Cl-38		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	4.9X10 ⁶	1.3X10 ⁸
Cm-240	Curium (96)	4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	7.5X10 ²	2.0X10 ⁴
Cm-241		2.0X10 ⁰	5.4X10 ¹	1.0X10 ⁰	2.7X10 ¹	6.1X10 ²	1.7X10 ⁴
Cm-242	Curium (96)	4.0X10 ¹	1.1X10 ³	1.0X10 ⁻²	2.7X10 ⁻¹	1.2X10 ²	3.3X10 ³
Cm-243		9.0X10 ⁰	2.4X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	1.9X10 ⁻³	5.2X10 ¹
Cm-244		2.0X10 ¹	5.4X10 ²	2.0X10 ⁻³	5.4X10 ⁻²	3.0X10 ⁰	8.1X10 ¹

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Cm-245		9.0X10 ⁰	2.4X10 ²	9.0X10 ⁻⁴	2.4X10 ⁻²	6.4X10 ⁻³	1.7X10 ⁻¹
Cm-246		9.0X10 ⁰	2.4X10 ²	9.0X10 ⁻⁴	2.4X10 ⁻²	1.1X10 ⁻²	3.1X10 ⁻¹
Cm-247 (a)		3.0X10 ⁰	8.1X10 ¹	1.0X10 ⁻³	2.7X10 ⁻²	3.4X10 ⁻⁶	9.3X10 ⁻⁵
Cm-248		2.0X10 ⁻²	5.4X10 ⁻¹	3.0X10 ⁻⁴	8.1X10 ⁻³	1.6X10 ⁻⁴	4.2X10 ⁻³
Co-55	Cobalt (27)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	1.1X10 ⁵	3.1X10 ⁶
Co-56		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.1X10 ³	3.0X10 ⁴
Co-57		1.0X10 ¹	2.7X10 ²	1.0X10 ¹	2.7X10 ²	3.1X10 ²	8.4X10 ³
Co-58		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.2X10 ³	3.2X10 ⁴
Co-58m		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	2.2X10 ⁵	5.9X10 ⁶
Co-60		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	4.2X10 ¹	1.1X10 ³
Cr-51	Chromium (24)	3.0X10 ¹	8.1X10 ²	3.0X10 ¹	8.1X10 ²	3.4X10 ³	9.2X10 ⁴
Cs-129	Cesium (55)	4.0X10 ⁰	1.1X10 ²	4.0X10 ⁰	1.1X10 ²	2.8X10 ⁴	7.6X10 ⁵
Cs-131		3.0X10 ¹	8.1X10 ²	3.0X10 ¹	8.1X10 ²	3.8X10 ³	1.0X10 ⁵
Cs-132		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	5.7X10 ³	1.5X10 ⁵
Cs-134		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	4.8X10 ¹	1.3X10 ³
Cs-134m		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻¹	1.6X10 ¹	3.0X10 ⁵	8.0X10 ⁶
Cs-135		4.0X10 ¹	1.1X10 ³	1.0X10 ⁰	2.7X10 ¹	4.3X10 ⁻⁵	1.2X10 ⁻³
Cs-136		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	2.7X10 ³	7.3X10 ⁴
Cs-137 (a)		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.2X10 ⁰	8.7X10 ¹
Cu-64	Copper (29)	6.0X10 ⁰	1.6X10 ²	1.0X10 ⁰	2.7X10 ¹	1.4X10 ⁵	3.9X10 ⁶
Cu-67		1.0X10 ¹	2.7X10 ²	7.0X10 ⁻¹	1.9X10 ¹	2.8X10 ⁴	7.6X10 ⁵
Dy-159	Dysprosium (66)	2.0X10 ¹	5.4X10 ²	2.0X10 ¹	5.4X10 ²	2.1X10 ²	5.7X10 ³
Dy-165		9.0X10 ⁻¹	2.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.0X10 ⁵	8.2X10 ⁶
Dy-166 (a)		9.0X10 ⁻¹	2.4X10 ¹	3.0X10 ⁻¹	8.1X10 ⁰	8.6X10 ³	2.3X10 ⁵
Er-169	Erbium (68)	4.0X10 ¹	1.1X10 ³	1.0X10 ⁰	2.7X10 ¹	3.1X10 ³	8.3X10 ⁴
Er-171		8.0X10 ⁻¹	2.2X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	9.0X10 ⁴	2.4X10 ⁶
Eu-147	Europium (63)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	1.4X10 ³	3.7X10 ⁴
Eu-148		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	6.0X10 ²	1.6X10 ⁴
Eu-149		2.0X10 ¹	5.4X10 ²	2.0X10 ¹	5.4X10 ²	3.5X10 ²	9.4X10 ³
Eu-150 (short lived)		2.0X10 ⁰	5.4X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	6.1X10 ⁴	1.6X10 ⁶
Eu-150 (long lived)		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	6.1X10 ⁴	1.6X10 ⁶
Eu-152		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	6.5X10 ⁰	1.8X10 ²
Eu-152m		8.0X10 ⁻¹	2.2X10 ¹	8.0X10 ⁻¹	2.2X10 ¹	8.2X10 ⁴	2.2X10 ⁶
Eu-154		9.0X10 ⁻¹	2.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	9.8X10 ⁰	2.6X10 ²
Eu-155		2.0X10 ¹	5.4X10 ²	3.0X10 ⁰	8.1X10 ¹	1.8X10 ¹	4.9X10 ²
Eu-156		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	2.0X10 ³	5.5X10 ⁴
F-18	Fluorine (9)	1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.5X10 ⁶	9.5X10 ⁷
Fe-52 (a)	Iron (26)	3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	2.7X10 ⁵	7.3X10 ⁶
Fe-55		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	8.8X10 ¹	2.4X10 ³
Fe-59		9.0X10 ⁻¹	2.4X10 ¹	9.0X10 ⁻¹	2.4X10 ¹	1.8X10 ³	5.0X10 ⁴
Fe-60 (a)		4.0X10 ¹	1.1X10 ³	2.0X10 ⁻¹	5.4X10 ⁰	7.4X10 ⁻⁴	2.0X10 ⁻²
Ga-67	Gallium (31)	7.0X10 ⁰	1.9X10 ²	3.0X10 ⁰	8.1X10 ¹	2.2X10 ⁴	6.0X10 ⁵
Ga-68		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	1.5X10 ⁶	4.1X10 ⁷
Ga-72		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.1X10 ⁵	3.1X10 ⁶
Gd-146 (a)	Gadolinium (64)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	6.9X10 ²	1.9X10 ⁴
Gd-148		2.0X10 ¹	5.4X10 ²	2.0X10 ⁻³	5.4X10 ⁻²	1.2X10 ⁰	3.2X10 ¹
Gd-153		1.0X10 ¹	2.7X10 ²	9.0X10 ⁰	2.4X10 ²	1.3X10 ²	3.5X10 ³
Gd-159		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.9X10 ⁴	1.1X10 ⁶
Ge-68 (a)	Germanium (32)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	2.6X10 ²	7.1X10 ³

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Ge-71		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	5.8X10 ³	1.6X10 ⁵
Ge-77		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.3X10 ⁵	3.6X10 ⁶
Hf-172 (a)	Hafnium (72)	6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	4.1X10 ¹	1.1X10 ³
Hf-175		3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	3.9X10 ²	1.1X10 ⁴
Hf-181		2.0X10 ⁰	5.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	6.3X10 ²	1.7X10 ⁴
Hf-182		Unlimited	Unlimited	Unlimited	Unlimited	8.1X10 ⁻⁶	2.2X10 ⁻⁴
Hg-194 (a)	Mercury (80)	1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.3X10 ⁻¹	3.5X10 ⁰
Hg-195m (a)		3.0X10 ⁰	8.1X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	1.5X10 ⁴	4.0X10 ⁵
Hg-197		2.0X10 ¹	5.4X10 ²	1.0X10 ¹	2.7X10 ²	9.2X10 ³	2.5X10 ⁵
Hg-197m		1.0X10 ¹	2.7X10 ²	4.0X10 ⁻¹	1.1X10 ¹	2.5X10 ⁴	6.7X10 ⁵
Hg-203		5.0X10 ⁰	1.4X10 ²	1	2.7X10 ¹	5.1X10 ²	1.4X10 ⁴
Ho-166	Holmium (67)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	2.6X10 ⁴	7.0X10 ⁵
Ho-166m		6.0X10 ⁻¹	1.6X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	6.6X10 ⁻²	1.8X10 ⁰
I-123	Iodine (53)	6.0X10 ⁰	1.6X10 ²	3.0X10 ⁰	8.1X10 ¹	7.1X10 ⁴	1.9X10 ⁶
I-124		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	9.3X10 ³	2.5X10 ⁵
I-125		2.0X10 ¹	5.4X10 ²	3.0X10 ⁰	8.1X10 ¹	6.4X10 ²	1.7X10 ⁴
I-126		2.0X10 ⁰	5.4X10 ¹	1.0X10 ⁰	2.7X10 ¹	2.9X10 ³	8.0X10 ⁴
I-129		Unlimited	Unlimited	Unlimited	Unlimited	6.5X10 ⁻⁶	1.8X10 ⁻⁴
I-131		3.0X10 ⁰	8.1X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	4.6X10 ³	1.2X10 ⁵
I-132		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	3.8X10 ⁵	1.0X10 ⁷
I-133		7.0X10 ⁻¹	1.9X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	4.2X10 ⁴	1.1X10 ⁶
I-134		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	9.9X10 ⁵	2.7X10 ⁷
I-135 (a)		6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.3X10 ⁵	3.5X10 ⁶
In-111	Indium (49)	3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	1.5X10 ⁴	4.2X10 ⁵
In-113m		4.0X10 ⁰	1.1X10 ²	2.0X10 ⁰	5.4X10 ¹	6.2X10 ⁵	1.7X10 ⁷
In-114m (a)		1.0X10 ¹	2.7X10 ²	5.0X10 ⁻¹	1.4X10 ¹	8.6X10 ²	2.3X10 ⁴
In-115m		7.0X10 ⁰	1.9X10 ²	1.0X10 ⁰	2.7X10 ¹	2.2X10 ⁵	6.1X10 ⁶
Ir-189 (a)	Iridium (77)	1.0X10 ¹	2.7X10 ²	1.0X10 ¹	2.7X10 ²	1.9X10 ³	5.2X10 ⁴
Ir-190		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	2.3X10 ³	6.2X10 ⁴
Ir-192		^(c) 1.0X10 ⁰	^(c) 2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.4X10 ²	9.2X10 ³
Ir-194		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	3.1X10 ⁴	8.4X10 ⁵
K-40	Potassium (19)	9.0X10 ⁻¹	2.4X10 ¹	9.0X10 ⁻¹	2.4X10 ¹	2.4X10 ⁻⁷	6.4X10 ⁻⁶
K-42		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	2.2X10 ⁵	6.0X10 ⁶
K-43		7.0X10 ⁻¹	1.9X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.2X10 ⁵	3.3X10 ⁶
Kr-79	Krypton (36)	4.0X10⁰	1.1X10²	2.0X10⁰	5.4X10¹	4.2X10⁴	1.1X10⁶
Kr-81	Krypton (36)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	7.8X10 ⁻⁴	2.1X10 ⁻²
Kr-85		1.0X10 ¹	2.7X10 ²	1.0X10 ¹	2.7X10 ²	1.5X10 ¹	3.9X10 ²
Kr-85m		8.0X10 ⁰	2.2X10 ²	3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁵	8.2X10 ⁶
Kr-87		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	1.0X10 ⁶	2.8X10 ⁷
La-137	Lanthanum (57)	3.0X10 ¹	8.1X10 ²	6.0X10 ⁰	1.6X10 ²	1.6X10 ⁻³	4.4X10 ⁻²
La-140		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	2.1X10 ⁴	5.6X10 ⁵
Lu-172	Lutetium (71)	6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	4.2X10 ³	1.1X10 ⁵
Lu-173		8.0X10 ⁰	2.2X10 ²	8.0X10 ⁰	2.2X10 ²	5.6X10 ¹	1.5X10 ³
Lu-174		9.0X10 ⁰	2.4X10 ²	9.0X10 ⁰	2.4X10 ²	2.3X10 ¹	6.2X10 ²
Lu-174m		2.0X10 ¹	5.4X10 ²	1.0X10 ¹	2.7X10 ²	2.0X10 ²	5.3X10 ³
Lu-177		3.0X10 ¹	8.1X10 ²	7.0X10 ⁻¹	1.9X10 ¹	4.1X10 ³	1.1X10 ⁵
Mg-28 (a)	Magnesium (12)	3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	2.0X10 ⁵	5.4X10 ⁶
Mn-52	Manganese (25)	3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.6X10 ⁴	4.4X10 ⁵
Mn-53		Unlimited	Unlimited	Unlimited	Unlimited	6.8X10 ⁻⁵	1.8X10 ⁻³
Mn-54		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	2.9X10 ²	7.7X10 ³

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Mn-56		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	8.0X10 ⁵	2.2X10 ⁷
Mo-93	Molybdenum (42)	4.0X10 ¹	1.1X10 ³	2.0X10 ¹	5.4X10 ²	4.1X10 ⁻²	1.1X10 ⁰
Mo-99 (a) (h)		1.0X10 ⁰	2.7X10 ¹	7.46.0 X10 ⁻¹	2.01.6 X10 ¹	1.8X10 ⁴	4.8X10 ⁵
N-13	Nitrogen (7)	9.0X10 ⁻¹	2.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	5.4X10 ⁷	1.5X10 ⁹
Na-22	Sodium (11)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	2.3X10 ²	6.3X10 ³
Na-24		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	3.2X10 ⁵	8.7X10 ⁶
Nb-93m	Niobium (41)	4.0X10 ¹	1.1X10 ³	3.0X10 ¹	8.1X10 ²	8.8X10 ⁰	2.4X10 ²
Nb-94		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	6.9X10 ⁻³	1.9X10 ⁻¹
Nb-95		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.5X10 ³	3.9X10 ⁴
Nb-97		9.0X10 ⁻¹	2.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	9.9X10 ⁵	2.7X10 ⁷
Nd-147	Neodymium (60)	6.0X10 ⁰	1.6X10 ²	6.0X10 ⁻¹	1.6X10 ¹	3.0X10 ³	8.1X10 ⁴
Nd-149		6.0X10 ⁻¹	1.6X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	4.5X10 ⁵	1.2X10 ⁷
Ni-59	Nickel (28)	Unlimited	Unlimited	Unlimited	Unlimited	3.0X10 ⁻³	8.0X10 ⁻²
Ni-63		4.0X10 ¹	1.1X10 ³	3.0X10 ¹	8.1X10 ²	2.1X10 ⁰	5.7X10 ¹
Ni-65		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	7.1X10 ⁵	1.9X10 ⁷
Np-235	Neptunium (93)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	5.2X10 ¹	1.4X10 ³
Np-236 (short-lived)		2.0X10 ¹	5.4X10 ²	2.0X10 ⁰	5.4X10 ¹	4.7X10 ⁻⁴	1.3X10 ⁻²
Np-236 (long-lived)		9.0X10 ⁰	2.4X10 ²	2.0X10 ²	5.4X10 ⁻¹	4.7X10 ⁻⁴	1.3X10 ⁻²
Np-237		2.0X10 ¹	5.4X10 ²	2.0X10 ⁻³	5.4X10 ⁻²	2.6X10 ⁻⁵	7.1X10 ⁻⁴
Np-239		7.0X10 ⁰	1.9X10 ²	4.0X10 ⁻¹	1.1X10 ¹	8.6X10 ³	2.3X10 ⁵
Os-185	Osmium (76)	1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	2.8X10 ²	7.5X10 ³
Os-191		1.0X10 ¹	2.7X10 ²	2.0X10 ⁰	5.4X10 ¹	1.6X10 ³	4.4X10 ⁴
Os-191m		4.0X10 ¹	1.1X10 ³	3.0X10 ¹	8.1X10 ²	4.6X10 ⁴	1.3X10 ⁶
Os-193		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.0X10 ⁴	5.3X10 ⁵
Os-194 (a)		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.1X10 ¹	3.1X10 ²
P-32	Phosphorus (15)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	1.1X10 ⁴	2.9X10 ⁵
P-33		4.0X10 ¹	1.1X10 ³	1.0X10 ⁰	2.7X10 ¹	5.8X10 ³	1.6X10 ⁵
Pa-230 (a)	Protactinium (91)	2.0X10 ⁰	5.4X10 ¹	7.0X10 ⁻²	1.9X10 ⁰	1.2X10 ³	3.3X10 ⁴
Pa-231		4.0X10 ⁰	1.1X10 ²	4.0X10 ⁻⁴	1.1X10 ⁻²	1.7X10 ⁻³	4.7X10 ⁻²
Pa-233		5.0X10 ⁰	1.4X10 ²	7.0X10 ⁻¹	1.9X10 ¹	7.7X10 ²	2.1X10 ⁴
Pb-201	Lead (82)	1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	6.2X10 ⁴	1.7X10 ⁶
Pb-202		4.0X10 ¹	1.1X10 ³	2.0X10 ¹	5.4X10 ²	1.2X10 ⁻⁴	3.4X10 ⁻³
Pb-203		4.0X10 ⁰	1.1X10 ²	3.0X10 ⁰	8.1X10 ¹	1.1X10 ⁴	3.0X10 ⁵
Pb-205		Unlimited	Unlimited	Unlimited	Unlimited	4.5X10 ⁻⁶	1.2X10 ⁻⁴
Pb-210 (a)		1.0X10 ⁰	2.7X10 ¹	5.0X10 ⁻²	1.4X10 ⁰	2.8X10 ⁰	7.6X10 ¹
Pb-212 (a)		7.0X10 ⁻¹	1.9X10 ¹	2.0X10 ⁻¹	5.4X10 ⁰	5.1X10 ⁴	1.4X10 ⁶
Pd-103 (a)	Palladium (46)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	2.8X10 ³	7.5X10 ⁴
Pd-107		Unlimited	Unlimited	Unlimited	Unlimited	1.9X10 ⁻⁵	5.1X10 ⁻⁴
Pd-109		2.0X10 ⁰	5.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	7.9X10 ⁴	2.1X10 ⁶
Pm-143	Promethium (61)	3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	1.3X10 ²	3.4X10 ³
Pm-144		7.0X10 ⁻¹	1.9X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	9.2X10 ¹	2.5X10 ³
Pm-145		3.0X10 ¹	8.1X10 ²	1.0X10 ¹	2.7X10 ²	5.2X10 ⁰	1.4X10 ²
Pm-147		4.0X10 ¹	1.1X10 ³	2.0X10 ⁰	5.4X10 ¹	3.4X10 ¹	9.3X10 ²
Pm-148m (a)		8.0X10 ⁻¹	2.2X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	7.9X10 ²	2.1X10 ⁴
Pm-149		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.5X10 ⁴	4.0X10 ⁵
Pm-151		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.7X10 ⁴	7.3X10 ⁵
Po-210	Polonium (84)	4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	1.7X10 ²	4.5X10 ³
Pr-142	Praseodymium (59)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	4.3X10 ⁴	1.2X10 ⁶
Pr-143		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.5X10 ³	6.7X10 ⁴

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Pt-188 (a)	Platinum (78)	1.0X10 ⁰	2.7X10 ¹	8.0X10 ⁻¹	2.2X10 ¹	2.5X10 ³	6.8X10 ⁴
Pt-191		4.0X10 ⁰	1.1X10 ²	3.0X10 ⁰	8.1X10 ¹	8.7X10 ³	2.4X10 ⁵
Pt-193		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	1.4X10 ⁰	3.7X10 ¹
Pt-193m		4.0X10 ¹	1.1X10 ³	5.0X10 ⁻¹	1.4X10 ¹	5.8X10 ³	1.6X10 ⁵
Pt-195m		1.0X10 ¹	2.7X10 ²	5.0X10 ⁻¹	1.4X10 ¹	6.2X10 ³	1.7X10 ⁵
Pt-197		2.0X10 ¹	5.4X10 ²	6.0X10 ⁻¹	1.6X10 ¹	3.2X10 ⁴	8.7X10 ⁵
Pt-197m		1.0X10 ¹	2.7X10 ²	6.0X10 ⁻¹	1.6X10 ¹	3.7X10 ⁵	1.0X10 ⁷
Pu-236	Plutonium (94)	3.0X10 ¹	8.1X10 ²	3.0X10 ⁻³	8.1X10 ⁻²	2.0X10 ¹	5.3X10 ²
Pu-237		2.0X10 ¹	5.4X10 ²	2.0X10 ¹	5.4X10 ²	4.5X10 ²	1.2X10 ⁴
Pu-238		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	6.3X10 ⁻¹	1.7X10 ¹
Pu-239		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	2.3X10 ⁻³	6.2X10 ⁻²
Pu-240		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	8.4X10 ⁻³	2.3X10 ⁻¹
Pu-241 (a)		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻²	1.6X10 ⁰	3.8X10 ⁰	1.0X10 ²
Pu-242		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	1.5X10 ⁻⁴	3.9X10 ⁻³
Pu-244 (a)		4.0X10 ⁻¹	1.1X10 ¹	1.0X10 ⁻³	2.7X10 ⁻²	6.7X10 ⁻⁷	1.8X10 ⁻⁵
Ra-223 (a)	Radium (88)	4.0X10 ⁻¹	1.1X10 ¹	7.0X10 ⁻³	1.9X10 ⁻¹	1.9X10 ³	5.1X10 ⁴
Ra-224 (a)		4.0X10 ⁻¹	1.1X10 ¹	2.0X10 ⁻²	5.4X10 ⁻¹	5.9X10 ³	1.6X10 ⁵
Ra-225 (a)		2.0X10 ⁻¹	5.4X10 ⁰	4.0X10 ⁻³	1.1X10 ⁻¹	1.5X10 ³	3.9X10 ⁴
Ra-226 (a)		2.0X10 ⁻¹	5.4X10 ⁰	3.0X10 ⁻³	8.1X10 ⁻²	3.7X10 ⁻²	1.0X10 ⁰
Ra-228 (a)		6.0X10 ⁻¹	1.6X10 ¹	2.0X10 ⁻²	5.4X10 ⁻¹	1.0X10 ¹	2.7X10 ²
Rb-81	Rubidium (37)	2.0X10 ⁰	5.4X10 ¹	8.0X10 ⁻¹	2.2X10 ¹	3.1X10 ⁵	8.4X10 ⁶
Rb-83 (a)		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	6.8X10 ²	1.8X10 ⁴
Rb-84		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.8X10 ³	4.7X10 ⁴
Rb-86		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	3.0X10 ³	8.1X10 ⁴
Rb-87		Unlimited	Unlimited	Unlimited	Unlimited	3.2X10 ⁻⁹	8.6X10 ⁻⁸
Rb(nat)		Unlimited	Unlimited	Unlimited	Unlimited	6.7X10 ⁶	1.8X10 ⁸
Re-184	Rhenium (75)	1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	6.9X10 ²	1.9X10 ⁴
Re-184m		3.0X10 ⁰	8.1X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.6X10 ²	4.3X10 ³
Re-186		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	6.9X10 ³	1.9X10 ⁵
Re-187		Unlimited	Unlimited	Unlimited	Unlimited	1.4X10 ⁻⁹	3.8X10 ⁻⁸
Re-188		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	3.6X10 ⁴	9.8X10 ⁵
Re-189 (a)		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.5X10 ⁴	6.8X10 ⁵
Re(nat)		Unlimited	Unlimited	Unlimited	Unlimited	0.0X10 ⁰	2.4X10 ⁻⁸
Rh-99	Rhodium (45)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	3.0X10 ³	8.2X10 ⁴
Rh-101		4.0X10 ⁰	1.1X10 ²	3.0X10 ⁰	8.1X10 ¹	4.1X10 ¹	1.1X10 ³
Rh-102		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	4.5X10 ¹	1.2X10 ³
Rh-102m		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	2.3X10 ²	6.2X10 ³
Rh-103m		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	1.2X10 ⁶	3.3X10 ⁷
Rh-105		1.0X10 ¹	2.7X10 ²	8.0X10 ⁻¹	2.2X10 ¹	3.1X10 ⁴	8.4X10 ⁵
Rn-222 (a)	Radon (86)	3.0X10 ⁻¹	8.1X10 ⁰	4.0X10 ⁻³	1.1X10 ⁻¹	5.7X10 ³	1.5X10 ⁵
Ru-97	Ruthenium (44)	5.0X10 ⁰	1.4X10 ²	5.0X10 ⁰	1.4X10 ²	1.7X10 ⁴	4.6X10 ⁵
Ru-103 (a)		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	1.2X10 ³	3.2X10 ⁴
Ru-105		1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.5X10 ⁵	6.7X10 ⁶
Ru-106 (a)		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	1.2X10 ²	3.3X10 ³
S-35	Sulphur (16)	4.0X10 ¹	1.1X10 ³	3.0X10 ⁰	8.1X10 ¹	1.6X10 ³	4.3X10 ⁴
Sb-122	Antimony (51)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.5X10 ⁴	4.0X10 ⁵
Sb-124		6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	6.5X10 ²	1.7X10 ⁴
Sb-125		2.0X10 ⁰	5.4X10 ¹	1.0X10 ⁰	2.7X10 ¹	3.9X10 ¹	1.0X10 ³
Sb-126		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	3.1X10 ³	8.4X10 ⁴

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TbBq/g)	(Ci/g)
Sc-44	Scandium (21)	5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	6.7X10 ⁵	1.8X10 ⁷
Sc-46		5.0X10 ⁻¹	1.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	1.3X10 ³	3.4X10 ⁴
Sc-47		1.0X10 ¹	2.7X10 ²	7.0X10 ⁻¹	1.9X10 ¹	3.1X10 ⁴	8.3X10 ⁵
Sc-48		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	5.5X10 ⁴	1.5X10 ⁶
Se-75	Selenium (34)	3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	5.4X10 ²	1.5X10 ⁴
Se-79		4.0X10 ¹	1.1X10 ³	2.0X10 ⁰	5.4X10 ¹	2.6X10 ⁻³	7.0X10 ⁻²
Si-31	Silicon (14)	6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.4X10 ⁶	3.9X10 ⁷
Si-32		4.0X10 ¹	1.1X10 ³	5.0X10 ⁻¹	1.4X10 ¹	3.9X10 ⁰	1.1X10 ²
Sm-145	Samarium (62)	1.0X10 ¹	2.7X10 ²	1.0X10 ¹	2.7X10 ²	9.8X10 ¹	2.6X10 ³
Sm-147		Unlimited	Unlimited	Unlimited	Unlimited	8.5X10 ⁻¹	2.3X10 ⁻⁸
Sm-151		4.0X10 ¹	1.1X10 ³	1.0X10 ¹	2.7X10 ²	9.7X10 ⁻¹	2.6X10 ¹
Sm-153		9.0X10 ⁰	2.4X10 ²	6.0X10 ⁻¹	1.6X10 ¹	1.6X10 ⁴	4.4X10 ⁵
Sn-113 (a)	Tin (50)	4.0X10 ⁰	1.1X10 ²	2.0X10 ⁰	5.4X10 ¹	3.7X10 ²	1.0X10 ⁴
Sn-117m		7.0X10 ⁰	1.9X10 ²	4.0X10 ⁻¹	1.1X10 ¹	3.0X10 ³	8.2X10 ⁴
Sn-119m		4.0X10 ¹	1.1X10 ³	3.0X10 ¹	8.1X10 ²	1.4X10 ²	3.7X10 ³
Sn-121m (a)		4.0X10 ¹	1.1X10 ³	9.0X10 ⁻¹	2.4X10 ¹	2.0X10 ⁰	5.4X10 ¹
Sn-123		8.0X10 ⁻¹	2.2X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	3.0X10 ²	8.2X10 ³
Sn-125		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ³	1.1X10 ⁵
Sn-126 (a)		6.0X10 ⁻¹	1.6X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.0X10 ⁻³	2.8X10 ⁻²
Sr-82 (a)	Strontium (38)	2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	2.3X10 ³	6.2X10 ⁴
Sr-85		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	8.8X10 ²	2.4X10 ⁴
Sr-85m		5.0X10 ⁰	1.4X10 ²	5.0X10 ⁰	1.4X10 ²	1.2X10 ⁶	3.3X10 ⁷
Sr-87m		3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	4.8X10 ⁵	1.3X10 ⁷
Sr-89		6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.1X10 ³	2.9X10 ⁴
Sr-90 (a)		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	5.1X10 ⁰	1.4X10 ²
Sr-91 (a)		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.3X10 ⁵	3.6X10 ⁶
Sr-92 (a)		1.0X10 ⁰	2.7X10 ¹	3.0X10 ⁻¹	8.1X10 ⁰	4.7X10 ⁵	1.3X10 ⁷
T(H-3)	Tritium (1)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	3.6X10 ²	9.7X10 ³
Ta-178 (long-lived)	Tantalum (73)	1.0X10 ⁰	2.7X10 ¹	8.0X10 ⁻¹	2.2X10 ¹	4.2X10 ⁶	1.1X10 ⁸
Ta-179		3.0X10 ¹	8.1X10 ²	3.0X10 ¹	8.1X10 ²	4.1X10 ¹	1.1X10 ³
Ta-182		9.0X10 ⁻¹	2.4X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	2.3X10 ²	6.2X10 ³
Tb-157	Terbium (65)	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	5.6X10 ⁻¹	1.5X10 ¹
Tb-158		1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	5.6X10 ⁻¹	1.5X10 ¹
Tb-160		1.0X10 ⁰	2.7X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	4.2X10 ²	1.1X10 ⁴
Tc-95m (a)	Technetium (43)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	8.3X10 ²	2.2X10 ⁴
Tc-96		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.2X10 ⁴	3.2X10 ⁵
Tc-96m (a)		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.4X10 ⁶	3.8X10 ⁷
Tc-97		Unlimited	Unlimited	Unlimited	Unlimited	5.2X10 ⁻⁵	1.4X10 ⁻³
Tc-97m		4.0X10 ¹	1.1X10 ³	1.0X10 ⁰	2.7X10 ¹	5.6X10 ²	1.5X10 ⁴
Tc-98		8.0X10 ⁻¹	2.2X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	3.2X10 ⁻⁵	8.7X10 ⁻⁴
Tc-99		4.0X10 ¹	1.1X10 ³	9.0X10 ⁻¹	2.4X10 ¹	6.3X10 ⁻⁴	1.7X10 ⁻²
Tc-99m		1.0X10 ¹	2.7X10 ²	4.0X10 ⁰	1.1X10 ²	1.9X10 ⁵	5.3X10 ⁶
Te-121	Tellurium (52)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	2.4X10 ³	6.4X10 ⁴
Te-121m		5.0X10 ⁰	1.4X10 ²	3.0X10 ⁰	8.1X10 ¹	2.6X10 ²	7.0X10 ³
Te-123m		8.0X10 ⁰	2.2X10 ²	1.0X10 ⁰	2.7X10 ¹	3.3X10 ²	8.9X10 ³
Te-125m		2.0X10 ¹	5.4X10 ²	9.0X10 ⁻¹	2.4X10 ¹	6.7X10 ²	1.8X10 ⁴
Te-127		2.0X10 ¹	5.4X10 ²	7.0X10 ⁻¹	1.9X10 ¹	9.8X10 ⁴	2.6X10 ⁶
Te-127m (a)		2.0X10 ¹	5.4X10 ²	5.0X10 ⁻¹	1.4X10 ¹	3.5X10 ²	9.4X10 ³
Te-129		7.0X10 ⁻¹	1.9X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	7.7X10 ⁵	2.1X10 ⁷

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
Te-129m (a)		8.0X10 ⁻¹	2.2X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.1X10 ³	3.0X10 ⁴
Te-131m (a)		7.0X10 ⁻¹	1.9X10 ¹	5.0X10 ⁻¹	1.4X10 ¹	3.0X10 ⁴	8.0X10 ⁵
Te-132 (a)		5.0X10 ⁻¹	1.4X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	1.1X10 ⁴	3.0X10 ⁵
Th-227	Thorium (90)	1.0X10 ¹	2.7X10 ²	5.0X10 ⁻³	1.4X10 ⁻¹	1.1X10 ³	3.1X10 ⁴
Th-228 (a)		5.0X10 ⁻¹	1.4X10 ¹	1.0X10 ⁻³	2.7X10 ⁻²	3.0X10 ¹	8.2X10 ²
Th-229		5.0X10 ⁰	1.4X10 ²	5.0X10 ⁻⁴	1.4X10 ⁻²	7.9X10 ⁻³	2.1X10 ⁻¹
Th-230		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	7.6X10 ⁻⁴	2.1X10 ⁻²
Th-231	Thorium (90)	4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	2.0X10 ⁴	5.3X10 ⁵
Th-232		Unlimited	Unlimited	Unlimited	Unlimited	4.0X10 ⁻⁹	1.1X10 ⁻⁷
Th-234 (a)		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	8.6X10 ²	2.3X10 ⁴
Th(nat)		Unlimited	Unlimited	Unlimited	Unlimited	8.1X10 ⁻⁹	2.2X10 ⁻⁷
Ti-44 (a)	Titanium (22)	5.0X10 ⁻¹	1.4X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	6.4X10 ⁰	1.7X10 ²
Tl-200	Thallium (81)	9.0X10 ⁻¹	2.4X10 ¹	9.0X10 ⁻¹	2.4X10 ¹	2.2X10 ⁴	6.0X10 ⁵
Tl-201		1.0X10 ¹	2.7X10 ²	4.0X10 ⁰	1.1X10 ²	7.9X10 ³	2.1X10 ⁵
Tl-202		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	2.0X10 ³	5.3X10 ⁴
Tl-204		1.0X10 ¹	2.7X10 ²	7.0X10 ⁻¹	1.9X10 ¹	1.7X10 ¹	4.6X10 ²
Tm-167	Thulium (69)	7.0X10 ⁰	1.9X10 ²	8.0X10 ⁻¹	2.2X10 ¹	3.1X10 ³	8.5X10 ⁴
Tm-170		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.2X10 ²	6.0X10 ³
Tm-171		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³
U-230 (fast lung absorption) (a)(d)	Uranium (92)	4.0X10 ¹	1.1X10 ³	1.0X10 ⁻¹	2.7X10 ⁰	1.0X10 ³	2.7X10 ⁴
U-230 (medium lung absorption) (a)(e)		4.0X10 ¹	1.1X10 ³	4.0X10 ⁻³	1.1X10 ⁻¹	1.0X10 ³	2.7X10 ⁴
U-230 (slow lung absorption) (a)(f)		3.0X10 ¹	8.1X10 ²	3.0X10 ⁻³	8.1X10 ⁻²	1.0X10 ³	2.7X10 ⁴
U-232 (fast lung absorption) (d)		4.0X10 ¹	1.1X10 ³	1.0X10 ⁻²	2.7X10 ⁻¹	8.3X10 ⁻¹	2.2X10 ¹
U-232 (medium lung absorption) (e)		4.0X10 ¹	1.1X10 ³	7.0X10 ⁻³	1.9X10 ⁻¹	8.3X10 ⁻¹	2.2X10 ¹
U-232 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ²	1.0X10 ⁻³	2.7X10 ⁻²	8.3X10 ⁻¹	2.2X10 ¹
U-233 (fast lung absorption) (d)	Uranium (92)	4.0X10 ¹	1.1X10 ³	9.0X10 ⁻²	2.4X10 ⁰	3.6X10 ⁻⁴	9.7X10 ⁻³
U-233 (medium lung absorption) (e)		4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	3.6X10 ⁻⁴	9.7X10 ⁻³
U-233 (slow lung absorption) (f)		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻³	1.6X10 ⁻¹	3.6X10 ⁻⁴	9.7X10 ⁻³
U-234 (fast lung absorption) (d)		4.0X10 ¹	1.1X10 ³	9.0X10 ⁻²	2.4X10 ⁰	2.3X10 ⁻⁴	6.2X10 ⁻³
U-234 (medium lung absorption) (e)		4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	2.3X10 ⁻⁴	6.2X10 ⁻³
U-234 (slow lung absorption) (f)		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻³	1.6X10 ⁻¹	2.3X10 ⁻⁴	6.2X10 ⁻³
U-235 (all lung absorption types) (a), (d), (e), (f)		Unlimited	Unlimited	Unlimited	Unlimited	8.0X10 ⁻⁸	2.2X10 ⁻⁶
U-236 (fast lung absorption) (d)		Unlimited	Unlimited	Unlimited	Unlimited	2.4X10 ⁻⁶	6.5X10 ⁻⁵
U-236 (medium lung absorption) (e)		4.0X10 ¹	1.1X10 ³	2.0X10 ⁻²	5.4X10 ⁻¹	2.4X10 ⁻⁶	6.5X10 ⁻⁵
U-236 (slow lung absorption) (f)		4.0X10 ¹	1.1X10 ³	6.0X10 ⁻³	1.6X10 ⁻¹	2.4X10 ⁻⁶	6.5X10 ⁻⁵
U-238 (all lung absorption types) (d), (e), (f)		Unlimited	Unlimited	Unlimited	Unlimited	1.2X10 ⁻⁸	3.4X10 ⁻⁷
U (nat)		Unlimited	Unlimited	Unlimited	Unlimited	2.6X10 ⁻⁸	7.1X10 ⁻⁷
U (enriched to 20% or less)(g)		Unlimited	Unlimited	Unlimited	Unlimited	N/A	N/A
U (dep)		Unlimited	Unlimited	Unlimited	Unlimited	0.0X10 ⁰	See Table A-3
V-48	Vanadium (23)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	6.3X10 ³	1.7X10 ⁵
V-49		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	3.0X10 ²	8.1X10 ³
W-178 (a)	Tungsten (74)	9.0X10 ⁰	2.4X10 ²	5.0X10 ⁰	1.4X10 ²	1.3X10 ³	3.4X10 ⁴
W-181		3.0X10 ¹	8.1X10 ²	3.0X10 ¹	8.1X10 ²	2.2X10 ²	6.0X10 ³
W-185		4.0X10 ¹	1.1X10 ³	8.0X10 ⁻¹	2.2X10 ¹	3.5X10 ²	9.4X10 ³

Appendix A: continued

Table A - 1: A₁ and A₂ VALUES FOR RADIONUCLIDES - continued

Symbol of radionuclides	Element and atomic number	A ₁ (TBq)	A ₁ (Ci) ^b	A ₂ (TBq)	A ₂ (Ci) ^b	Specific activity	
						(TBq/g)	(Ci/g)
W-187		2.0X10 ⁰	5.4X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	2.6X10 ⁴	7.0X10 ⁵
W-188 (a)		4.0X10 ⁻¹	1.1X10 ¹	3.0X10 ⁻¹	8.1X10 ⁰	3.7X10 ²	1.0X10 ⁴
Xe-122 (a)	Xenon (54)	4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	4.8X10 ⁴	1.3X10 ⁶
Xe-123		2.0X10 ⁰	5.4X10 ¹	7.0X10 ⁻¹	1.9X10 ¹	4.4X10 ⁵	1.2X10 ⁷
Xe-127		4.0X10 ⁰	1.1X10 ²	2.0X10 ⁰	5.4X10 ¹	1.0X10 ³	2.8X10 ⁴
Xe-131m		4.0X10 ¹	1.1X10 ³	4.0X10 ¹	1.1X10 ³	3.1X10 ³	8.4X10 ⁴
Xe-133		2.0X10 ¹	5.4X10 ²	1.0X10 ¹	2.7X10 ²	6.9X10 ³	1.9X10 ⁵
Xe-135		3.0X10 ⁰	8.1X10 ¹	2.0X10 ⁰	5.4X10 ¹	9.5X10 ⁴	2.6X10 ⁶
Y-87 (a)	Yttrium (39)	1.0X10 ⁰	2.7X10 ¹	1.0X10 ⁰	2.7X10 ¹	1.7X10 ⁴	4.5X10 ⁵
Y-88		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	5.2X10 ²	1.4X10 ⁴
Y-90		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	2.0X10 ⁴	5.4X10 ⁵
Y-91		6.0X10 ⁻¹	1.6X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	9.1X10 ²	2.5X10 ⁴
Y-91m		2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	1.5X10 ⁶	4.2X10 ⁷
Y-92		2.0X10 ⁻¹	5.4X10 ⁰	2.0X10 ⁻¹	5.4X10 ⁰	3.6X10 ⁵	9.6X10 ⁶
Y-93		3.0X10 ⁻¹	8.1X10 ⁰	3.0X10 ⁻¹	8.1X10 ⁰	1.2X10 ⁵	3.3X10 ⁶
Yb-169	Ytterbium (79)	4.0X10 ⁰	1.1X10 ²	1.0X10 ⁰	2.7X10 ¹	8.9X10 ²	2.4X10 ⁴
Yb-175		3.0X10 ¹	8.1X10 ²	9.0X10 ⁻¹	2.4X10 ¹	6.6X10 ³	1.8X10 ⁵
Zn-65	Zinc (30)	2.0X10 ⁰	5.4X10 ¹	2.0X10 ⁰	5.4X10 ¹	3.0X10 ²	8.2X10 ³
Zn-69		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.8X10 ⁶	4.9X10 ⁷
Zn-69m (a)		3.0X10 ⁰	8.1X10 ¹	6.0X10 ⁻¹	1.6X10 ¹	1.2X10 ⁵	3.3X10 ⁶
Zr-88	Zirconium (40)	3.0X10 ⁰	8.1X10 ¹	3.0X10 ⁰	8.1X10 ¹	6.6X10 ²	1.8X10 ⁴
Zr-93		Unlimited	Unlimited	Unlimited	Unlimited	9.3X10 ⁻⁵	2.5X10 ⁻³
Zr-95 (a)		2.0X10 ⁰	5.4X10 ¹	8.0X10 ⁻¹	2.2X10 ¹	7.9X10 ²	2.1X10 ⁴
Zr-97 (a)		4.0X10 ⁻¹	1.1X10 ¹	4.0X10 ⁻¹	1.1X10 ¹	7.1X10 ⁴	1.9X10 ⁶

^a A₁ and/or A₂ values include contributions from daughter nuclides with half-lives less than ten days-, as listed in the following:

Mg-28 **Al-28**
Ca-47 **Sc-47**
Ti-44 **Sc-44**
Fe-52 **Mn-52m**
Fe-60 **Co-60m**
Zn-69m **Zn-69**
Ge-68 **Ga-68**
Rb-83 **Kr-83m**
Sr-82 **Rb-82**
Sr-90 **Y-90**
Sr-91 **Y-91m**
Sr-92 **Y-92**
Y-87 **Sr-87m**
Zr-95 **Nb-95m**
Zr-97 **Nb-97m, Nb-97**
Mo-99 **Tc-99m**
Tc-95m **Tc-95**
Tc-96m **Tc-96**
Ru-103 **Rh-103m**
Ru-106 **Rh-106**
Pd-103 **Rh-103m**
Ag-108m **Ag-108**
Ag-110m **Ag-110**
Cd-115 **In-115m**
In-114m **In-114**

Sn-113	In-113m
Sn-121m	Sn-121
Sn-126	Sb-126m
Te-127m	Te-127
Te-129m	Te-129
Te-131m	Te-131
Te-132	I-132
I-135	Xe-135m
Xe-122	I-122
Cs-137	Ba-137m
Ba-131	Cs-131
Ba-140	La-140
Ce-144	Pr-144m, Pr-144
Pm-148m	Pm-148
Gd-146	Eu-146
Dy-166	Ho-166
Hf-172	Lu-172
W-178	Ta-178
W-188	Re-188
Re-189	Os-189m
Os-194	Ir-194
Ir-189	Os-189m
Pt-188	Ir-188
Hg-194	Au-194
Hg-195m	Hg-195
Pb-210	Bi-210
Pb-212	Bi-212, Tl-208, Po-212
Bi-210m	Tl-206
Bi-212	Tl-208, Po-212
At-211	Po-211
Rn-222	Po-218, Pb-214, At-218, Bi-214, Po-214
Ra-223	Rn-219, Po-215, Pb-211, Bi-211, Po-211, Tl-207
Ra-224	Rn-220, Po-216, Pb-212, Bi-212, Tl-208, Po-212
Ra-225	Ac-225, Fr-221, At-217, Bi-213, Tl-209, Po-213, Pb-209
Ra-226	Rn-222, Po-218, Pb-214, At-218, Bi-214, Po-214
Ra-228	Ac-228
Ac-225	Fr-221, At-217, Bi-213, Tl-209, Po-213, Pb-209
Ac-227	Fr-223
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208, Po-212
Th-234	Pa-234m, Pa-234
Pa-230	Ac-226, Th-226, Fr-222, Ra-222, Rn-218, Po-214
U-230	Th-226, Ra-222, Rn-218, Po-214
U-235	Th-231
Pu-241	U-237
Pu-244	U-240, Np-240m
Am-242m	Am-242, Np-238
Am-243	Np-239
Cm-247	Pu-243
Bk-249	Am-245
Cf-253	Cm-249

^b The values of A_1 and A_2 in Curies (Ci) are approximate and for information only; the regulatory standard units are Terabecquerels (TBq) (*see* 105 CMR 120.7958: *Appendix A – Determination of A_1 and A_2 , subsection I*).

^c The quantity **activity of Ir-192 in special form** may be determined from a measurement of the rate of decay or a measurement of the radiation level at a prescribed distance from the source.

^d These values apply only to compounds of uranium that take the chemical form of UF_6 , UO_2F_2 and $UO_2(NO_3)_2$ in both normal and accident conditions of transport.

^e These values apply only to compounds of uranium that take the chemical form of UO_3 , UF_4 , UCl_4 and hexavalent compounds in both normal and accident conditions of transport.

^f These values apply to all compounds of uranium other than those specified in notes (d) and (e) of this table.

^g These values apply to unirradiated uranium only.

~~^h $A_1 = 0.1$ TBq (2.7 Ci) and $A_2 = 0.001$ TBq (0.027 Ci) for Cf-252 for domestic use.~~

^{ih} $A_2 = 0.74$ TBq (20 Ci) for Mo-99 for domestic use.

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Ac-225	Actinium (89)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Ac-227		1.0X10 ⁻¹	2.7X10 ⁻¹²	1.0X10 ³	2.7X10 ⁻⁸
Ac-228		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ag-105	Silver (47)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ag-108m (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ag-110m		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ag-111		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Al-26	Aluminum (13)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Am-241	Americium (95)	1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Am-242m (b)		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Am-243 (b)		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Ar-37	Argon (18)	1.0X10 ⁶	2.7X10 ⁻⁵	1.0X10 ⁸	2.7X10 ⁻³
Ar-39		1.0X10 ⁷	2.7X10 ⁻⁴	1.0X10 ⁴	2.7X10 ⁻⁷
Ar-41		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁹	2.7X10 ⁻²
As-72	Arsenic (33)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
As-73		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
As-74		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
As-76		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
As-77		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
At-211	Astatine (85)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Au-193	Gold (79)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Au-194		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Au-195		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Au-198		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Au-199		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ba-131	Barium (56)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ba-133		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ba-133m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ba-140 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Be-7	Beryllium (4)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Be-10		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Bi-205	Bismuth (83)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Bi-206		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Bi-207		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Bi-210		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Bi-210m		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Bi-212 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Bk-247	Berkelium (97)	1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Bk-249		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Br-76	Bromine (35)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Br-77		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Br-82		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
C-11	Carbon (6)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
C-14		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Ca-41	Calcium (20)	1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁷	2.7X10 ⁻⁴
Ca-45		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Ca-47		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Cd-109	Cadmium (48)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Cd-113m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Cd-115		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Cd-115m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Ce-139	Cerium (58)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ce-141		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Ce-143		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ce-144 (b)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Cf-248	Californium (98)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cf-249		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Cf-250		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cf-251		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Cf-252		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cf-253		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Cf-254		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Cl-36	Chlorine (17)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Cl-38		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Cm-240	Curium (96)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Cm-241		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Cm-242		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Cm-243		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Cm-244		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cm-245		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Cm-246		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Cm-247		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Cm-248		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Co-55	Cobalt (27)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Co-56		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Co-57		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Co-58		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Co-58m		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Co-60		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Cr-51	Chromium (24)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Cs-129	Cesium (55)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Cs-131		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Cs-132		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Cs-134		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cs-134m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
Cs-135		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Cs-136		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Cs-137 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Cu-64	Copper (29)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Cu-67		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Dy-159	Dysprosium (66)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Dy-165		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Dy-166 (a)		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Er-169	Erbium (68)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Er-171		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-147	Europium (63)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-148		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-149		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Eu-150 (short lived)		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-150 (long lived)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-152		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-152 m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-154		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Eu-155		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Eu-156		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
F-18	Fluorine (9)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Fe-52	Iron (26)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Fe-55		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Fe-59		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Fe-60		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Ga-67	Gallium (31)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ga-68		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Ga-72		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Gd-146	Gadolinium (64)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Gd-148		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Gd-153		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Gd-159		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Ge-68	Germanium (32)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Ge-71		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁸	2.7X10 ⁻³
Ge-77		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Hf-172	Hafnium (72)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Hf-175		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Hf-181		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Hf-182		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Hg-194	Mercury (80)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Hg-195m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Hg-197		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Hg-197m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Hg-203		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Ho-166	Holmium (67)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
Ho-166m		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
I-123	Iodine (53)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
I-124		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
I-125		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
I-126		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
I-129		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
I-131		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
I-132		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
I-133		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
I-134		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
I-135		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
In-111	Indium (49)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
In-113m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
In-114m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
In-115m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ir-189	Iridium (77)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Ir-190		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ir-192		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Ir-194		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
K-40	Potassium (19)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
K-42		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
K-43		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Kr-79	Krypton (36)	1.0X10³	2.7X10⁻⁸	1.0X10⁵	2.7X10⁻⁶
Kr-81	Krypton (36)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Kr-85		1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁴	2.7X10 ⁻⁷
Kr-85m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ¹⁰	2.7X10 ⁻¹
Kr-87		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁹	2.7X10 ⁻²
La-137	Lanthanum (57)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
La-140		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Lu-172	Lutetium (71)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Lu-173		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Lu-174		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Lu-174m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Lu-177		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Mg-28	Magnesium (12)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Mn-52	Manganese (25)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Mn-53		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁹	2.7X10 ⁻²
Mn-54		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Mn-56		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Mo-93	Molybdenum (42)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁸	2.7X10 ⁻³
Mo-99		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
N-13	Nitrogen (7)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁹	2.7X10 ⁻²
Na-22	Sodium (11)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Na-24		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Nb-93m	Niobium (41)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Nb-94		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Nb-95		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Nb-97		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Nd-147	Neodymium (60)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Nd-149		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ni-59	Nickel (28)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁸	2.7X10 ⁻³
Ni-63		1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁸	2.7X10 ⁻³
Ni-65		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Np-235	Neptunium (93)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Np-236 (short-lived)		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Np-236 (long-lived)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Np-237 (b)		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Np-239		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Os-185	Osmium (76)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Os-191		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Os-191m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Os-193		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Os-194 (a)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
P-32	Phosphorus (15)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
P-33		1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁸	2.7X10 ⁻³
Pa-230 (a)	Protactinium (91)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Pa-231		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Pa-233		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Pb-201	Lead (82)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Pb-202		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Pb-203		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Pb-205		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Pb-210 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Pb-212 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Pd-103	Palladium (46)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁸	2.7X10 ⁻³
Pd-107		1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁸	2.7X10 ⁻³
Pd-109		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Pm-143	Promethium (61)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Pm-144		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Pm-145		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Pm-147		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Pm-148m		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Pm-149		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Pm-151		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Po-210	Polonium (84)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Pr-142	Praseodymium (59)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Pr-143		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Pt-188	Platinum (78)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Pt-191		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Pt-193		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Pt-193m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Pt-195m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Pt-197		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Pt-197m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Pu-236	Plutonium (94)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Pu-237		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Pu-238		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Pu-239		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Pu-240		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Pu-241)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Pu-242		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Pu-244		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Ra-223 (b)	Radium (88)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Ra-224 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Ra-225		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Ra-226 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Ra-228 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Rb-81	Rubidium (37)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Rb-83		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Rb-84		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Rb-86		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Rb-87		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Rb(nat)		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Re-184	Rhenium (75)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Re-184m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Re-186		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Re-187		1.0X10 ⁶	2.7X10 ⁻⁵	1.0X10 ⁹	2.7X10 ⁻²
Re-188		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Re-189		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Re(nat)		1.0X10 ⁶	2.7X10 ⁻⁵	1.0X10 ⁹	2.7X10 ⁻²
Rh-99	Rhodium (45)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Rh-101		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Rh-102		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Rh-102m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Rh-103m		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁸	2.7X10 ⁻³
Rh-105		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Rn-222 (b)	Radon (86)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁸	2.7X10 ⁻³
Ru-97	Ruthenium (44)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Ru-103		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Ru-105		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ru-106 (b)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
S-35	Sulphur (16)	1.0X10 ⁵	2.7X10 ⁻⁶	1.0X10 ⁸	2.7X10 ⁻³
Sb-122	Antimony (51)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁴	2.7X10 ⁻⁷
Sb-124		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Sb-125		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sb-126		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Sc-44	Scandium (21)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Sc-46		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Sc-47		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sc-48		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Se-75	Selenium (34)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Se-79		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Si-31	Silicon (14)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Si-32		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Sm-145	Samarium (62)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Sm-147		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Sm-151		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁸	2.7X10 ⁻³
Sm-153		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sn-113	Tin (50)	1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Sn-117m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sn-119m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Sn-121m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Sn-123		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Sn-125		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Sn-126		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Sr-82	Strontium (38)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Sr-85		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sr-85m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Sr-87m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Sr-89		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
Sr-90 (b)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁴	2.7X10 ⁻⁷
Sr-91		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Sr-92		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
T(H-3)	Tritium (1)	1.0X10 ⁶	2.7X10 ⁻⁵	1.0X10 ⁹	2.7X10 ⁻²
Ta-178 (long-lived)	Tantalum (73)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Ta-179		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Ta-182		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Tb-157	Terbium (65)	1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Tb-158		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tb-160		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tc-95m	Technetium (43)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tc-96		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tc-96m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Tc-97		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁸	2.7X10 ⁻³
Tc-97m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Tc-98		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tc-99		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
Tc-99m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Te-121	Tellurium (52)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Te-121m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Te-123m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Te-125m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Te-127		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Te-127m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Te-129		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Te-129m		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Te-131m		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Te-132		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Th-227	Thorium (90)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Th-228 (b)		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Th-229 (b)		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Th-230		1	2.7X10 ⁻¹¹	1.0X10 ⁴	2.7X10 ⁻⁷
Th-231		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Th-232		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
Th-234 (b)		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
Th (nat)(b)		1	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
Ti-44	Titanium (22)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
Tl-200	Thallium (81)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Tl-201		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Tl-202		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Tl-204		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁴	2.7X10 ⁻⁷
Tm-167	Thulium (69)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Tm-170		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Tm-171		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁸	2.7X10 ⁻³
U-230 (fast lung absorption) (b)(d)	Uranium (92)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
U-230 (medium lung absorption) (e)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-230 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-232 (fast lung absorption) (b), (d)	Uranium (92)	1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸

Appendix A: continued

Table A - 2: EXEMPT MATERIAL ACTIVITY CONCENTRATIONS AND EXEMPT CONSIGNMENT ACTIVITY LIMITS FOR RADIONUCLIDES - continued

Symbol of radionuclide	Element and atomic number	Activity concentration for exempt material (Bq/g)	Activity concentration for exempt material (Ci/g)	Activity limit for exempt consignment (Bq)	Activity limit for exempt consignment (Ci)
U-232 (medium lung absorption) (e)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-232 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-233 (fast lung absorption) (d)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-233 (medium lung absorption) (e)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
U-233 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
U-234 (fast lung absorption) (d)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-234 (medium lung absorption) (e)		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
U-234 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
U-235 (all lung absorption types) (b), (d), (e), (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-236 (fast lung absorption) (d)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-236 (medium lung absorption) (e)	Uranium (92)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
U-236 (slow lung absorption) (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U-238 (all lung absorption types) (b), (d), (e), (f)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁴	2.7X10 ⁻⁷
U (nat) (b)		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
U (enriched to 20% or less)(g)		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
U (dep)		1.0X10 ⁰	2.7X10 ⁻¹¹	1.0X10 ³	2.7X10 ⁻⁸
V-48	Vanadium (23)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶
V-49		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
W-178	Tungsten (74)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
W-181		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
W-185		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁷	2.7X10 ⁻⁴
W-187		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
W-188		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Xe-122	Xenon (54)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁹	2.7X10 ⁻²
Xe-123		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁹	2.7X10 ⁻²
Xe-127		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
Xe-131m		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁴	2.7X10 ⁻⁷
Xe-133		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁴	2.7X10 ⁻⁷
Xe-135		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ¹⁰	2.7X10 ⁻¹
Y-87	Yttrium (39)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Y-88		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Y-90		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁵	2.7X10 ⁻⁶
Y-91		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁶	2.7X10 ⁻⁵
Y-91m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Y-92		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Y-93		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁵	2.7X10 ⁻⁶
Yb-169	Ytterbium (79)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁷	2.7X10 ⁻⁴
Yb-175		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Zn-65	Zinc (30)	1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Zn-69		1.0X10 ⁴	2.7X10 ⁻⁷	1.0X10 ⁶	2.7X10 ⁻⁵
Zn-69m		1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Zr-88	Zirconium (40)	1.0X10 ²	2.7X10 ⁻⁹	1.0X10 ⁶	2.7X10 ⁻⁵
Zr-93 (b)		1.0X10 ³	2.7X10 ⁻⁸	1.0X10 ⁷	2.7X10 ⁻⁴
Zr-95		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁶	2.7X10 ⁻⁵
Zr-97 (b)		1.0X10 ¹	2.7X10 ⁻¹⁰	1.0X10 ⁵	2.7X10 ⁻⁶

Appendix A: continued

^a [Reserved]^b Parent nuclides and their progeny included in secular equilibrium are listed in the following:

Sr-90	Y-90
Zr-93	Nb-93m
Zr-97	Nb-97
Ru-106	Rh-106
Ag-108m	Ag-108
Cs-137	Ba-137m
Ce-134	La-134
Ce-144	Pr-144
Ba-140	La-140
Bi-212	Tl-208 (0.36), Po-212 (0.64)
Pb-210	Bi-210, Po-210
Pb-212	Bi-212, Tl-208 (0.36), Po-212 (0.64)
Rn-220	Po-216
Rn-222	Po-218, Pb-214, Bi-214, Po-214
Ra-223	Rn-219, Po-215, Pb-211, Bi-211, Tl-207
Ra-224	Rn-220, Po-216, Pb-212, Bi-212, Tl-208(0.36), Po-212 (0.64)
Ra-226	Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210
Ra-228	Ac-228
Th-226	Ra-222, Rn-218, Po-214
Th-228	Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
Th-229	Ra-225, Ac-225, Fr-221, At-217, Bi-213, Po-213, Pb-209
Th-nat	Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
Th-234	Pa-234m
U-230	Th-226, Ra-222, Rn-218, Po-214
U-232	Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212, Tl-208 (0.36), Po-212 (0.64)
U-235	Th-231
U-238	Th-234, Pa-234m
U-nat	Th-234, Pa-234m, U-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, Bi-214, Po-214, Pb-210, Bi-210, Po-210
U-240	Np-240m
Np-237	Pa-233
Am-242m	Am-242
Am-243	Np-239

^c [Reserved]^d These values apply only to compounds of uranium that take the chemical form of UF₆, UO₂F₂ and UO₂(NO₃)₂ in both normal and accident conditions of transport.^e These values apply only to compounds of uranium that take the chemical form of UO₃, UF₄, UCl₄ and hexavalent compounds in both normal and accident conditions of transport.^f These values apply to all compounds of uranium other than those specified in notes (d) and (e) of this table.^g These values apply to unirradiated uranium only.

Appendix A: continued

Table A-3: General Values for A₁ and A₂

Contents	A ₁		A ₂		Activity concentration for exempt material	Activity concentration for exempt material	Activity limits for exempt consignments	Activity limits for exempt consignments
	(TBq)	(Ci)	(TBq)	(Ci)	(Bq/g)	(Ci/g)	(Bq)	(Ci)
Only beta or gamma emitting radionuclides are known to be present	1 x 10 ⁻¹	2.7 x 10 ⁰	2 x 10 ⁻²	5.4 x 10 ⁻¹	1 x 10 ¹	2.7 x 10 ⁻¹⁰	1 x 10 ⁴	2.7 x 10 ⁻⁷
Only alpha Alpha emitting radionuclides, but no neutron emitters, are known to be present (a)	2 x 10 ⁻¹	5.4 x 10 ⁰	9 x 10 ⁻⁵	2.4 x 10 ⁻³	1 x 10 ⁻¹	2.7 x 10 ⁻¹²	1 x 10 ³	2.7 x 10 ⁻⁸
Neutron emitting radionuclides are known to be present or no relevant data are available	1 x 10 ⁻³	2.7 x 10 ⁻²	9 x 10 ⁻⁵	2.4 x 10 ⁻³	1 x 10 ⁻¹	2.7 x 10 ⁻¹²	1 x 10 ³	2.7 x 10 ⁻⁸

^a If beta or gamma emitting radionuclides are known to be present, the A₁ value of 0.1 TBq (2.7 Ci) should be used.

Table A-4 Activity-mass Relationships for Uranium

Uranium Enrichment ¹ wt % U-235 present	Specific Activity	
	TBq/g	Ci/g
0.45	1.8 x 10 ⁻⁸	5.0 x 10 ⁻⁷
0.72	2.6 x 10 ⁻⁸	7.1 x 10 ⁻⁷
1	2.8 x 10 ⁻⁸	7.6 x 10 ⁻⁷
1.5	3.7 x 10 ⁻⁸	1.0 x 10 ⁻⁶
5	1.0 x 10 ⁻⁷	2.7 x 10 ⁻⁶
10	1.8 x 10 ⁻⁷	4.8 x 10 ⁻⁶
20	3.7 x 10 ⁻⁷	1.0 x 10 ⁻⁵
35	7.4 x 10 ⁻⁷	2.0 x 10 ⁻⁵
50	9.3 x 10 ⁻⁷	2.5 x 10 ⁻⁵
90	2.2 x 10 ⁻⁶	5.8 x 10 ⁻⁵
93	2.6 x 10 ⁻⁶	7.0 x 10 ⁻⁵
95	3.4 x 10 ⁻⁶	9.1 x 10 ⁻⁵

120.800: LICENSING AND OPERATIONAL REQUIREMENTS FOR LOW-LEVEL RADIOACTIVE WASTE FACILITIES

120.801: Purpose and Scope

(A) 105 CMR 120.800 establishes procedures, performance objectives, criteria, terms and conditions governing the issuance of licenses for the treatment, storage or disposal of low-level radioactive wastes received from other persons, as well as the development, operation, closure, post-closure observation and maintenance, and institutional control of a low-level radioactive waste treatment, storage or disposal facility. The requirements of 105 CMR 120.800 are in addition to, and not in substitution for, other applicable requirements of 105 CMR 120.000.

(B) 105 CMR 120.800 is applicable to any low-level radioactive waste facility for treatment, storage, or disposal of all classes of waste, which are not exempt from regulation pursuant to 105 CMR 120.200 as well as any wastes that the Board has required to be treated, stored or disposed of at a low-level radioactive waste facility.

(C) 105 CMR 120.800 is applicable to any method of treatment, storage or disposal except shallow

land burial, as defined in 105 CMR 120.803. Shallow land burial is prohibited.

(D) Class A, B, C, as defined in 105 CMR 120.200, and mixed waste may be accepted for storage, treatment or disposal at a facility, if the Board so determines. Waste received at a facility shall be handled in accordance with the operational requirements of 105 CMR 120.800.

120.801: continued

(E) Any facility licensed pursuant to 105 CMR 120.800 may also accept NARM waste if the Board so determines. The limits of the quantities and concentrations of such NARM waste that may be accepted shall be specified as part of the waste acceptance criteria to be determined by the Board.

(F) No waste shall be acceptable for storage, treatment or disposal at a facility if either the Operator or the Department has reason to believe that the waste, as originally generated, was not radioactive. Acceptance of such waste shall be subject to penalty.

(G) No waste shall be accepted from an electric-power-generating facility if such waste requires regulations more stringent than the most stringent management required for any waste that may be accepted at the facility from another generator.

(H) In addition to the requirements of 105 CMR 120.800 all facility operations are subject to the requirements of 105 CMR 120.001, 120.100, 120.200 and 120.750. If a conflict in 105 CMR 120.000 exists, the more stringent provision shall apply.

(I) 105 CMR 120.800 does not authorize the treatment, storage or disposal of byproduct material as defined in 105 CMR 120.005: *Byproduct Material* in quantities greater than 10,000 kilograms containing more than five millicuries of radium-226. Nor do they apply to the disposal of radioactive material as provided for in 105 CMR 120.200.

120.802: Regulatory Authority

The authority for the Department of Public Health to promulgate 105 CMR 120.800 is found in: M.G.L. c. 111, §§ 3, 5M, 5N, 5O and 5P; M.G.L. c. 111H, §§ 1, 7, 8, 11, 13, 16 and 31.

120.803: Definitions

As used in 105 CMR 120.800 the following definitions apply:

Accident means any event arising from the storage, treatment, recycling or disposal of waste that causes a discharge or dispersal of waste or elements contained in the waste from its intended place of confinement.

Active Maintenance means any significant activity needed during the period of institutional control to maintain a reasonable assurance that the performance objectives in 105 CMR 120.811 and 120.812 are met. The term includes major remedial action such as replacement of disposal unit barrier. Active maintenance does not include custodial activities such as repair of fencing, repair or replacement of monitoring equipment, revegetation, minor additions to soil cover, minor repair of disposal unit barriers, and general disposal site upkeep such as mowing grass.

Adverse Effect means an injurious impact which is significant in relation to the public health, safety, or environmental interest being protected.

Affected Community means a community, other than a site community, which is identified in an environmental impact report prepared pursuant to M.G.L. c. 111H, § 30, and can be expected to experience significant impacts as a result of the location, development, operation, closure, post-closure observation and maintenance or institutional control of a facility.

ALARA [acronym for "as low as reasonably achievable"] means making every reasonable effort to maintain exposures to radiation as far below the dose limits in 105 CMR 120.200 as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.