Nuclear Byproduct Materials Risk Review Group Report

I. Introduction

The Nuclear Byproduct Materials Risk Review Group's goals were to

1. Identify and document a technical basis for a risk-informed approach to regulation of byproduct material

2. Develop plans for a graded approach to regulation of byproduct material using risk information.

The Risk Review Group was comprised of four NRC representatives and one Agreement State representative with experience in health physics, engineering, risk assessment, and human factors. The Group outlined the information needed to complete its goals and established a contract to assist in gathering data and evaluating the risk from uses of byproduct material. The Group provided guidance to the contractor, including the review and approval of its proposed evaluation methods. The Group focused on ensuring that the contractor's work was of sufficient scope and accuracy to be useful in developing plans for a risk-informed regulation of the use of byproduct material.

The contractor's results are reported in NUREG/CR-6642, "Risk Analysis and Evaluation of Regulatory Options for Nuclear Byproduct Material Systems." The Group developed and conducted a survey of NRC and Agreement State regulatory personnel who perform licensing and inspection to gather information about the use of byproduct materials to assist in this study. The full survey results are reported in NUREG-1712, "Nuclear Byproduct Material Risk Review, Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel." The Group also identified areas of concern in gathering information, performing the risk assessment, and using the results of the risk assessment.

Radiological risks of various activities were assessed using a single method so that the resulting risk values could be compared. Risk values are high or low only in comparison to the risk values in the category under consideration, and do not represent a judgement as to what risk values are acceptable at this time. If radiological risk values are to be used in developing changes to the regulations, acceptable levels of risk need to be defined. For example, this study does not attempt to relate the risk of whole-body dose (used to express the consequence) to expected fatalities, or cancers, or any other potential harm due to that dose. Neither does it attempt to determine the acceptable probability for failures of barriers.

Other costs and benefits of the uses of byproduct material were also considered but were not quantified. These included: financial risk to users from accidents, financial risks to users and regulatory agencies from lost or stolen sources, the regulatory burden to users and regulatory agencies, risks of costs from contamination, non-radiological health risks, the benefits of using byproduct material, and the perceived risks of using byproduct material. Although these costs and benefits could not be quantified at this time, for some uses of byproduct material, one or more of these costs and benefits may need to be considered in developing regulations.

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The Nuclear Byproduct Materials Risk Review Group Report is divided into the following sections:

A. Scope of the Risk Assessment
B. Categories of Radiological Risk Evaluated in this Assessment
C. Uncertainties in Radiological Risk Calculations
D. Method of Radiological Risk Assessment
E. Survey of Materials Licensing and Inspection Personnel
F. Use of “Consequences” in Developing a Risk-Informed Regulatory Approach
G. Results of the Radiological Risk Assessment
H. Discussion of Tables

Attachments: Tables

II. Nuclear Byproduct Materials Risk Review Group Report

A. Scope of the Risk Assessment

The scope of the risk review is limited to nuclear byproduct materials regulated by the Nuclear Regulatory Commission under 10 CFR Parts 30-36 and 39 and the equivalent regulations of Agreement States.

"Risk" is defined as the product of "consequence" multiplied by "probability". The consequence considered in the study is the annual whole-body dose, expressed in millirem per year. Probability is expressed as a fraction representing the number of times an event may happen during a particular activity with byproduct material compared to the number of times that activity occurs. Because probability has no units, when consequence and probability are multiplied to obtain the risk value, the risk value also has the units of annual whole-body dose.

To facilitate risk comparisons, the Group focused the risk assessment on discrete nuclear byproduct material systems as opposed to regulated entities such as licensees or certificate holders. The initial list of 40 nuclear byproduct material systems grouped together materials used in similar ways or processes and in similar quantities and forms. The list has been refined on the same basis; in some cases systems were consolidated, and in others, systems were expanded.

This use of systems differs somewhat from current regulatory categorizations (such as program codes and fee categories), which focus on the regulated entity that may produce, distribute, possess, use, or dispose of material from one or more nuclear byproduct material systems. A regulated entity may be authorized to use materials that fall under several systems assessed in this study. A simple example is a hospital nuclear medicine department that uses radiopharmaceuticals from the nuclear byproduct material system for diagnostic nuclear medicine and sealed sources from the nuclear byproduct material systems for check and calibration sources.

Each system is characterized in terms of the radiological risk to workers and the radiological risk to the public under normal and off-normal conditions. A worker is defined as a person who works directly with licensed material. A member of the public is defined as a person who does not work with licensed material, but may include co-workers in the area where radioactive materials are used or stored (e.g., flagman on a road crew where a portable gauge is used), and family members of a patient to whom radioactive materials were administered. Normal conditions are defined as the routine activities associated with the use of byproduct material, with all physical and administrative controls in place. Off-normal conditions are defined as events in which one or more physical or administrative controls fail.

Doses to patients from the medical use of byproduct material were excluded from the evaluation of risk. Patients are neither workers nor members of the public as defined in this study.

Transportation of byproduct material in commerce (i.e., in the furtherance of a commercial enterprise) is excluded from the nuclear byproduct material risk review. Transportation of hazardous material in commerce, including nuclear byproduct material, is regulated by the Department of Transportation (DOT). However, movement of nuclear byproduct material, in contrast to transportation as regulated by DOT, is included in the risk review where appropriate. Movement is a normal part of the process of using nuclear byproduct materials within some systems (e.g., movement to and from a loading dock or from one room or building to another). The impact of movement is expected to be on the likelihood of off-normal conditions and on the potential consequences of such conditions.

Developing and future technologies are excluded from this risk assessment. However, as new technologies come into use, the methodology developed for this project can be used to assess the risk of new technologies in a comparable manner .

Risks other than radiological were also considered, such as chemical hazards, physical hazards, public perception, etc. Given the difficulty encountered in determining radiological risks, the evaluation of other risks was not pursued in a quantitative manner. The other risks were considered qualitatively, and were assigned a value of low, medium, or high based on a literature search.

B. Categories of Radiological Risk Evaluated in this Assessment

Eight categories of radiological risk were evaluated for each system: (i) individual workers under normal conditions, (ii) individual members of the public under normal conditions, (iii) individual workers under off-normal conditions, (iv) individual members of the public under off-normal conditions, (v) industry-wide, workers under normal conditions, (vi) industry-wide, members of the public under normal conditions, (vii) industry-wide, workers under off-normal conditions, and (viii) industry-wide, members of the public under off-normal conditions. It is important to look at the radiological risks assessed for the systems in each risk category to determine where risk values are of concern and what regulatory changes could be made.

Although all categories of radiological risk are expressed in the same unit, a single risk value was not determined for the systems because the risk categories differ enough that it is not appropriate to consolidate (or sum) the risk values into a single number. For example, for teletherapy (System 12), the risk value for individual workers under off-normal conditions (5 millirem per year) is much lower than the risk value for individual members of the public under off-normal conditions (100 millirem per year). In this case, the off-normal event is loss or abandonment of the teletherapy source leading to public access, and changes to regulations may need to reflect the public risk from off-normal events but not worker risks. In this case, a single value would obscure the main concern.

The "industry risk" incorporates the total estimated number of facilities performing the activities of a system into a risk value for maximally exposed individuals. (A true "collective dose" would include all persons potentially exposed to the source, not just the maximally exposed individuals.) The size of an industry greatly affects the ranking of the systems by industry risk, and may indicate a need to consider the magnitude of the industry in the regulations. For example, the risk values for individual workers and individual members of the public from use of specifically licensed portable gauges under normal conditions (System No. 24S) are 200 millirem per year for an individual worker and 7 millirem per year for an individual member of the public; these risk values rank this system 15th and 19th among the 46 sub-systems. However, the risks assessed because of the size of the industry are 3,000 rem per year and 300 rem per year, which rank this system 5th and 8th for risk from industry-wide activities. In this case, changes to the regulations may need to consider the "industry size," that is, the number of devices that are in use and the frequency with which the devices are used.

C. Uncertainties in Radiological Risk Calculations

Uncertainties in calculating risk result from the uncertainties inherent in the information available on the use of byproduct material in the various systems, uncertainties in dose calculations, and uncertainties in the probabilities assigned to the success or failure of barriers. These uncertainties are discussed in more detail below.

A database was established to perform the large number of calculations needed to determine the value of the risk for each system. Required data for each system included: a description of the general system; task and receptor-type data; sequence data including description, sequence type (normal or accident), safety function status probabilities, receptor time, distance, airborne and ingestion dilution parameters and release fractions; shielding dose reduction factors; other consequence parameters for up to four source forms; and radionuclide data including nuclide, frequency of use, number of licensees or devices and source strength. Assumptions were required in many of these data fields.

The contractor estimates that the total uncertainties in risk values are at least one order of magnitude for normal operations in most systems, and at least two orders of magnitude for accident conditions in most systems. Thus, although the contractor provided the risk assessment results to two significant figures, the results are better expressed to one significant figure. In fact, it may be more appropriate to express the results in orders of magnitude. Tables 1A through 1H and 2A through 2H compare the results provided to two significant figures to those shown to one significant figure and expressed as a power of ten. This comparison demonstrates that, although order-of-magnitude values may be most appropriate, they often result in values very different than those expressed to one significant figure, which were selected to make all other comparisons.

1. Uncertainties in System Information

One uncertainty is the accuracy of information on each system, particularly that used to establish the normal or typical parameters of byproduct material use for each system. The total number of users of material is not known with great certainty. The use of byproduct material varies considerably among users even within the same system, including differences in the radionuclides used, the quantities stored, the quantities handled, the frequency of use, and the types of activities performed with the material. This is especially true for systems involving unsealed materials. The use of barriers typical to each system also can vary considerably. This information affected the choice of representative scenarios, referred to as "sequences" that lead to dose.

The contractor was limited to gathering information from published materials and NRC databases, personal knowledge, interaction with the Group and other NRC personnel, and interactions with fewer than 9 licensees. Much of the information regarding types and quantities of material came from the Licensing Tracking System (LTS), the Sealed Source and Device Registry (SSD), and the General License Database (GLDB). Although the LTS provides the number of NRC specific licensees, the number of licensees performing activities in a given system is less certain, as a given primary program code may include multiple systems. Little information for this study was available from Agreement State licensees. The number of general licensees using materials in various systems can be estimated from the GLDB but cannot be determined with certainty because name changes, ownership changes, and return of devices is not tracked for individual general licensees. For similar reasons, the number of generally licensed devices in use is also not known. Although both the LTS and SSD list the radionuclides and the maximum activities that users are authorized to possess, neither lists the types and quantities of radionuclides that actually are possessed. Furthermore, no information is available regarding how frequently material is handled, or how much material is purchased and disposed of over any given period of time.

Some of this descriptive information for some systems was obtained from NUREG documents, texts, journals, other documents, and by interviews with users. Uncertainties in this data may range from as low as a factor of 2 to a factor of 10 or higher.

2. Uncertainties in Dose Calculations (Consequences)

Consequences evaluated for the radiological risk assessment included external radiation doses from byproduct material, and internal radiation doses resulting from inhalation, ingestion, or skin absorption of byproduct material. Calculation of external radiation doses is well-understood, but calculation of an internal radiation dose involves more uncertainties. The uncertainties in internal dose assessment depends in part on how much is known from direct information on

humans, direct information from animal studies, and chemical analogy of humans and animals. Uncertainties also result from study populations, sampling and analysis methods, the biokinetics of the radionuclides and compounds, and the dosimetry. For example, although much is known about tritium, uncertainty in the internal dose assessment for tritium is estimated to be as low as a factor of three -- that is, the actual dose may be three times lower or three times higher than calculated. By contrast, for radionuclides about which little is known, the uncertainty is usually reported as greater than 10.

The Group decided to accept the recommendations of ICRP Publication 30 "Limits for Intakes of Radionuclides by Workers" (ICRP 30), published in July 1978, as used in Federal Guidance Report No. 11 (FGR-11) to determine internal dose for this study. ICRP 30 internal dose concepts and dose limits were adopted for use in the current 10 CFR Part 20 regulations, which includes the ALIs and DACs derived from those published in FGR-11. The ALIs and DACs in FGR-11 are identical to those in ICRP 30, except for a few nuclides, of which americium-241 is the main one of interest to this review.

The Group acknowledges that more recent ICRP publications contain improved internal dosimetry models. However, values for ALIs and DACs based on the newer models are not available for all of the models or all of the radionuclides. The nuclear byproduct material risk review is organized in such a way that, when ALIs and DACs become available for the revised internal dosimetry models, these values can be replaced in the risk review of nuclear byproduct material systems as appropriate, and new doses can be calculated as necessary.

The ALIs and DACs recommended by ICRP 30 and used in FGR-11 are based on models chosen to provide conservative values for worker protection. The doses calculated from these values therefore may not be the most probable but may represent highest possible doses. The Group believes that acceptance of the ALIs and DACs based on ICRP-30 recommendations is valid because it allows for ease of updating doses as new dosimetry models are accepted. The doses calculated are directly comparable to limits used in the current 10 CFR Part 20. The uncertainties in all the models are high, and the differences in doses calculated using the different models may not be significant for most of the radionuclides actually used in the various nuclear byproduct material systems.

3. Uncertainties in Probabilities

Most of the information used to establish the frequency, or likelihood, of a particular sequence occurring was based on data from the Nuclear Materials Events Database (NMED). NMED is not consistent over time because the number of Agreement States using the database has changed since the database was established and some reporting requirements have changed. Using only NRC data from NMED also creates uncertainties because the number

of NRC States has decreased since use of NMED began. Furthermore, it is not known how many events were not reported as required, especially for generally licensed material. In addition, many of the accident sequences are not required to be reported; therefore NMED contains little or no information regarding those sequences. For example, most spills of unsealed materials would not result in conditions (such as high doses) that require the event to be reported; sealed sources with detectable leakage that do not exceed the applicable limit are not required to be reported.

Some published data were available on the frequency of some sequences for some systems, principally those systems using high-activity sealed sources. Some users provided estimates of frequencies of various sequences based on their experience. Other frequencies were assumed or extrapolated from similar known activities. Uncertainties in these data may range from factors of 2 or 3 for sequences that require reporting to a factor of 10 or higher for sequences that do not require reporting and for which little or no data were available.

D. Method of Radiological Risk Assessment

The contractor was asked to use qualitative and, to the extent possible and reasonable, quantitative tools to identify and evaluate risks associated with nuclear byproduct material systems, and to develop an analytical risk-ranking model to compare the systems.

Hazard-Barrier-Target analysis was selected for the quantitative assessment of radiological risk. There are many types of analyses that were considered, ranging from Expert Elicitation to Probabilistic Risk Assessment. A single methodology was required in order to compare systems; the Hazard-Barrier-Target was deemed best suited because it can be used for the whole range of byproduct material activities. In this study, a Hazard is the radioactive source (type, form, quantity) for a particular system (or subset of a system); a Target is a worker or the public; a Barrier is any physical control (i.e., process or engineered control) or administrative control that prevents or reduces harm from the Hazard to the Target.

The description and risk analysis of each system take into consideration all the barriers typical to that system that are necessary and sufficient to maintain doses at specified levels without regard to the current approaches to regulation of that system. Because it is difficult to describe the systems without regard to current regulations, all barriers known to be commonly used and/or necessary are included in the descriptions. Each barrier for each system is described as required by regulation (with the regulation specified), required by license condition, or ascribed to “good practices”.

The contractor first defined four categories of “safety functions” that affect consequences: source characteristics, i.e. nuclide and strength (Q); shielding (S), confinement (C); and access (A). Barriers were categorized by one or more of the

safety functions S, C, or A. They developed representative scenarios, called sequences, that lead to dose, and described each in terms of success and/or failure of each safety function S, C, and/or A. (These were graphed as Event Trees.) Realistic, not necessarily worst-case, sequences were chosen. The contractor evaluated the consequence in terms of whole-body dose for the possible sequences of the systems for two receptors: worker and public.

The contractor then determined the frequency of the possible sequences of the systems; that is, the likelihood of that sequence occurring. NMED or other data were used to establish frequencies where available; other frequencies were assumed or extrapolated from similar known activities. The frequency (freq) of a particular sequence (seq) is defined as the frequency of a task being performed, multiplied by the probability (Pr) of an initiating (init) event, multiplied by the probability of the success or failure of each safety function (S, C, or A) for that sequence:

$$\text{Freq(seq)} = \text{Freq(task)} * \text{Pr(init event)} * \text{Pr(S)} * \text{Pr(C)} * \text{Pr(A)}$$

The contractor established a database to perform the large number of calculations needed to determine the value of the risk for each system. Inputs to the database are described in Section C above. Using the database, values for "expected risk" (expressed as annual radiation exposure) were evaluated for the possible sequences of the systems for two receptors: worker and public. The total expected risk was the sum, for all possible sequences, of the values of the product of each consequence multiplied by its frequency, for the receptor of concern.

$$\text{expected risk} = \text{Sum [frequency(sequence i)} * \text{consequence(seq i)]}$$

The resulting database is very large, and was provided to the NRC on the compact disk "BMS-Risk." It documents the information and calculations used in the risk assessment. For the 40 systems analyzed, 56 different radionuclides were considered. The database includes a total of 518 tasks analyzing more than 4,000 normal and off-normal sequences, which are supported by more than 27,000 individual calculations.

E. Survey of Materials Licensing and Inspection Personnel

As part of this study, the Group conducted a survey of NRC and Agreement State personnel who perform inspection and licensing of byproduct material activities. The survey was performed to gather information about the byproduct material systems, based on the knowledge and experience of personnel who license and inspect a large number and variety of licensed activities. This information was intended to supplement the data used by the contractors in the risk assessment, and to confirm if assumptions made in the risk assessment were reasonable. Of particular interest was information related to the types and quantities of radionuclides known to be used in the various byproduct material systems, where the byproduct materials actually used may differ from the maximum quantities and types listed on a license.

Also of interest was information regarding the typical frequency of off-normal events that are not required to be reported (but may be reviewed during inspections), and the typical doses to workers using the various byproduct material systems (this information is not required to be reported for most byproduct material users, but is reviewed during inspection). As part of the survey, personnel were also requested to provide opinions regarding the safety of the various byproduct material systems and of regulatory decision-making. The results of this survey are reported in NUREG-1712 "Nuclear Byproduct Material Risk Review, Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel."

F. Use of "Consequences" in Developing a Risk-Informed Regulatory Approach

The actual values of the radiological consequences are shown only in the database that supports the NUREG/CR-6642. However, the magnitude of the consequences is reflected in the identification of the barriers and level of assurance that must be maintained for each system. The levels of assurance were "very high," "high," and "moderate." These evaluations indicate for each system those areas that need more attention and areas where less attention may be warranted. That is, where risks are of concern, these evaluations can be used to determine where improvements in regulation would be most effective in preventing or reducing consequences.

Confinement and shielding integrity are two very important barriers for many sealed sources and devices. For most sealed sources and devices, the design of the source holder and/or the device and the manufacturing of the sealed source and/or device are controlled by the manufacturers, not the licensees. For those items, risk-informed regulation must also consider the manufacturers.

The other major barriers that must be maintained are prevention of loss or abandonment, and prevention of access to the material. Overall, the risk of contamination from lost sources was determined to be low; because the probability of such loss resulting in contamination is very low, the overall risk was not greatly affected by the magnitude of the consequences of such a loss. This may need to be considered in determining if regulatory changes are appropriate.

These evaluations also are important for identifying areas where dose consequences may be so high that, even though the risk is low, regulatory controls remain important. For example, the risk of off-normal conditions from use of a pool irradiator is small. However, the consequences of off-normal activities with a pool irradiator could result in lethal doses to individuals, and certain barriers must be maintained with very high assurance. In this case, the risk is low because of the very small probabilities of failure of the barriers, and the risk values alone are insufficient to evaluate the appropriateness of regulations. A review of the report indicated that regulations exist for maintenance of all barriers that must be maintained with "very high" assurance. No consequences identify previously unknown safety and health hazards that require immediate changes in regulations or policy.

G. Results of the Radiological Risk Assessment

1. The risk value alone is not sufficient as a basis for regulation of a system. In some cases, such as pool irradiators (System 20), even a small probability of events resulting in acute lethal doses cannot be tolerated.

2. No previously unknown radiological consequences that require immediate changes in regulations or policy were identified.

3. Comparing risk results points to the following general trends:

    - Risks under normal conditions are higher than risks under off-normal conditions by several orders of magnitude. The risk values of off-normal conditions are low because the probability of off-normal conditions is low enough to outweigh conditions where the consequences may be large.

    - Under normal conditions, the risk to individual workers is higher than the risk to individual members of the public by a factor of 10 to 100.

    - Under off-normal conditions, the risk to individual workers is higher than the risks to individual members of the public by a factor of 2 to 10.

    - The relative ranking of the systems in the individual categories is much different than the relative ranking of systems in the industry-wide categories, because many of the systems that present higher individual risks are used in very small industries, and many systems that present lower individual risks are used in industries that are very large.

    - The risks to individual workers from normal operations are small fractions of the worker dose limit of 5,000 mrem per year, with the largest fraction 0.4, and only 9 systems with fractions greater than 0.1 (500 millirem per year).

    - The risks to individual members of the public from normal operations are large fractions of the dose limit of 100 millirem per year for members of the public, with three systems having fractions greater than 0.3 (30 millirem per year).

    - The risk values for individual workers under normal conditions agree with the mean annual doses estimated in a survey of regulatory personnel. Some significant differences in certain systems were noted, which may indicate the need to determine if the systems were accurately characterized, or if an additional study of annual doses received by workers is needed.

    - There is no clear relationship between the risk values for individuals under normal conditions for each system and the inspection priority assigned to each system. This may indicate that inspection priority assignment may require additional review, or that additional study of certain systems is needed to determine if those systems were accurately characterized for the risk assessment. Also, it is important to note that the risk assessment did not include

evaluation of risks to patients from medical use of byproduct materials, which may have been considered in assignment of inspection priority.

4. Systems with low risk values may be considered for reduction in regulatory burden. Some systems that should be considered include laboratories handling very small quantities of pre-labeled compounds (System 3); strontium-90 eye applicator (system 11); and gas chromatographs (Systems 27S and 27G). Note that risks to the patient from the strontium-90 eye applicator was not considered in the risk assessment, however, and may affect the decisions made for reduction of regulatory burden.

5. The total uncertainties in radiological risk values are in the range of orders of magnitude. However, expressing the risk values in powers of ten rather than using one significant figure can greatly change the values, resulting in less effective comparisons.

6. Ranking the systems allows easy identification of the systems of higher risk for a given risk category. However, ranking does not provide the comparison of risk that using the actual risk value allows. The relative risk ranking of systems alone is not a sufficient basis for making risk-informed decisions.

H. Discussion of Tables

Tables 1A through 1H and 2A through 2H: "Risk Assessment Results by Category"

Tables 1A through 1H (System Number order) and 2A through 2H (risk order) show the results of the risk assessments for all systems in each category. The units of risk are expressed in units of dose per year. NUREG/CR-6642 provides the risk assessment results to two significant figures as shown on the tables in the column labeled "2 sf." Because of the high uncertainties in the risk assessment results, it is more correct to express the risk assessment results to only one significant figure, as shown in the column labeled "1 sf." It may be argued that, if the total uncertainties are in the range of orders of magnitude, then the risk assessment values should be expressed in powers of ten; the column labeled "10^x" rounds the risk assessment value to the nearest power of ten that is not less than the actual value. The numerical rank of each system compared to the others within the same risk category is shown in the column labeled "Rank."

Table 3: Comparison of Rankings by Relative Risk for Systems, in the 8 Risk Assessment Categories, by System Number

Table 3 compares the systems by rank from 1, the highest risk, to 46, the lowest risk, according to the risk values (expressed in units of annual dose) analyzed by the contractor. Forty systems were evaluated, with separate evaluations in 6 systems of generally licensed devices. Table 3 lists systems by type, so that with a few exceptions denoted with an asterisk, the list is in System Number order. The systems were ranked in order of relative risk for each of the following eight categories of risk assessment:

Category	Description
(a)	normal conditions, individual risk to a single worker
(b)	normal conditions, individual risk to a member of the public
(c)	off-normal conditions, individual risk to a single worker
(d)	off-normal conditions, individual risk to a member of the public
(e)	normal conditions, industry risk for workers
(f)	normal conditions, industry risk for public
(g)	off-normal conditions, industry risk for workers
(h)	off-normal conditions, industry risk for public

Categories (a) through (d) pertain to the ranking of risk to a maximally-exposed single individual worker or a single individual member of the public from use of that system by one licensee. Categories (e) through (h) pertain to the ranking of risk to the maximally exposed individual workers or members of the public, incorporating the size of the industry into the risk. This is not truly a collective dose but takes into consideration the number of facilities that perform activities of a system type, and is referred to in NUREG/CR-6642 as the “industry risk.”

Ranking systems allows easy identification of the systems that are of higher risk than others within a risk category. However, it does not provide the relative comparison of risk that use of the actual risk value allows. Although it would be simple to sum the rank values of the categories to determine an overall rank value for each system, this is inappropriate because (1) it does not consider the magnitude of the risks, (2) worker risks and public risks have different regulatory limits and different concerns, and (3) individual risks and industry risks have different issues to consider. It is important to review the results of the risk assessments for the various systems and various categories, in order to understand the context of the system ranking. The following items are identified by the comparison of risk rankings:

1. Two systems, field site radiography (System 40) and therapeutic nuclear medicine (System 6), are ranked high in all categories, indicating that the sources and uses have higher risks in normal and off-normal conditions, to both workers and the public, and are in wide use by their respective industries.

2. Teletherapy (System 8), veterinary (System 16), and fixed-site radiography (System 19) have high rank values primarily to individuals, particularly members of the public, under both normal use and off-normal conditions; however, the rank values for industry-wide risks are generally lower than those for individuals in these two systems. This is primarily because few licensees are using byproduct materials under these systems.

3. For several systems, the rank values for use by individuals under normal and accident conditions are lower than the rank values for industry-wide use. These include laboratory synthesis (System 1), fixed gauges and similar sources (Systems. 22S, 22G, 23S and 23G), and portable gauges (Systems. 24S and 24G). This is due to the large number of facilities that use byproduct material in these systems.

4. The systems of low-dose-rate and high-dose-rate afterloader brachytherapy (Systems 9 and 10), fixed-room radiography (System 19), and generally licensed portable gauges (System 24G) have higher rankings under off-normal conditions. This occurs because, although under normal conditions good radiation safety practices prevent significant consequences, using these systems can have high consequences if the sources are lost or unaccounted for.

5. Laboratories handling very small quantities of pre-labeled compounds (System 3), gas chromatographs (Systems 27S and 27G) and other generally licensed measuring devices (System 28G), have consistently low rank values in all risk categories. This is due to the small quantities of material handled and the low values of consequences from these materials. These systems may be considered for changes in regulation.

Tables 4A through 4F: "Comparison of Risk Assessment Results by Category"

Table 4A shows the results of the risk assessments for individual workers from normal operations and off-normal operations, and a total risk to workers from both normal and off-normal operations. Table 4B shows the results of the risk assessments for individual members of the public from normal operations and off-normal operations, and a total risk to individual members of the public from both normal and off-normal operations. Tables 4C and 4D are similar, showing the results of the risks when considering the industry size for each system.

Comparison of the normal and off-normal risks is useful here, because it can clearly be seen for which systems off-normal operations are of particular concern. The summation of normal and off-normal risks in this manner is valid, but the total risk number may obscure the source of the risk and lead to incorrect conclusions as to where changes in regulations would be useful.

A review of the risk assessment results for the categories of the various systems identifies the following general conclusions:

1. Risks under normal conditions are higher than risks under off-normal conditions in all but four cases. The magnitude of the difference is typically several orders of magnitude. This is because the frequency of off-normal events is very low compared to the frequency of use of byproduct materials under normal conditions (essentially a probability of 1 that some dose consequences result under normal conditions). Three of the four exceptions occur when comparing risks to individual members of the public under normal conditions to those to individual members of the public under off-normal conditions. For teletherapy (System 12), the public risk is 90 millirem per year under normal conditions, compared to 100 millirem per year under off-normal conditions. For fixed-site radiography, the normal public risk is 30 millirem per year, compared to 40 millirem per year under off-normal conditions. And for field-site radiography, the normal public risk is 20 millirem per year, compared to 30 millirem per year under off-normal conditions. The fourth example occurs in the category of industry-wide risks to the public, where teletherapy (System 12) has an industry-wide normal public risk of 20 rem per year compared to 30 rem per year under off-normal conditions.

Whether or not these differences are significant needs to be established, as there currently is no regulatory limit or policy that addresses risk values. In this study, the risk value for normal conditions is reasonably close to the expected consequences (the annual dose received) because the probability of receiving that dose is close to 1. However, for off-normal conditions, the risk value represents the product of some dose consequence multiplied by some probability that the dose will be received. For example, if public access to a lost source could result in a dose of 500 rem to some individual, but the likelihood of the source becoming lost in any given year is only 1 in 10,000 (or 0.0001), then the individual public risk would be 0.5 rem per year.

2. Under normal conditions, the risk to individual workers is higher than the risk to individual members of the public, for all systems. The magnitude of the difference can be very great, typically a factor of 10 to 100. This is because workers are generally closer to the byproduct material for longer periods, and have fewer or different barriers. Where the members of the public may be co-located employees, the values of risk tend to be closer. These data support separate consideration of regulatory changes concerning the general public.

3. The risk to individual workers under off-normal conditions is higher than the risk to individual members of the public in all but two cases. The magnitude of the difference is not great, typically a factor of 2 to 10. In addition to the risk under off-normal conditions, the dose that is likely to result must also be considered because, although the probability of off-normal operations occurring may be low, for some systems, the dose consequences are high enough that they must be considered. This is the case for the teletherapy and gamma stereotactic devices (Systems 12 and 13) which have higher off-normal risks than normal risks. These devices contain sources that can result in high consequences (i.e., they can be lethal). Although the probabilities of loss or abandonment are very low, such losses are known to have occurred among the several hundred teletherapy devices in use world-wide. (Such losses have not occurred from the use of pool irradiator sources, System 20, for which there are fewer licensees and very prescriptive regulations. Lost sources were not postulated for the risk assessment of pool irradiator sources.)

4. Although the risk values to individuals [categories (a), (b), (c) and (d) given in millirem per year] are generally lower than risk values industry-wide [categories (e), (f), (g) and (h) given in rem per year], there is no consistent trend in the relative ranking of the systems in the individual categories compared to the industry-wide categories. This is because the size of the industries considered to be in the systems varies greatly. Regulatory changes based on risks may have to consider the impact of industry size on risk, especially if the linear-no-threshold (LNT) model of radiation effects is accepted. How this would be accomplished, however, will need careful consideration.

Tables 5A through 5B: Comparison of Risk Assessment Results to NRC Dose Limits

It is useful to compare the results of the risk assessment to the current limits for dose to workers (5 rem per year) and to members of the public (100 millirem per year). Because the probability of consequences (dose) under normal conditions is close to 1, the risks under normal conditions are expected to be close to the expected annual doses from those activities with byproduct material. Under off-normal conditions, the probabilities are typically much lower than 1 and it must be remembered that, at this time, there is no regulatory limit for risk. Only the risks to individual workers and individual members of the public are compared, because there is no industry-wide dose limit or collective dose limit.

Table 5A compares the risks to individual workers from normal and off-normal operations to the worker's dose limit, and shows the fractions of the limit represented by those risks. The highest fraction of the worker limit is 0.4, from the normal risk from field radiography (System 40). The next highest fractions are 0.18 (well-logging with tracers, System 17), 0.16 (manual brachytherapy, System 8; teletherapy, System 12; and veterinary, System 16), 0.14 (manufacturing of solid sources, System 32), and 0.12 (well-logging with sealed sources, System 18; other specifically-licensed measuring devices, System 28S [due to a particular device]; and manufacturing of gaseous sources, System 34). All other systems had fractions of 0.1 or less. The fractions of the limit represented by risks from off-normal activities range from 0 to 0.08.

Table 5B compares the risks to individual members of the public from normal and off-normal operations to the fraction of the dose limit for members of the public, and lists the fraction of the public dose limit represented by those risks. Of particular interest is the risk to members of the public from therapeutic nuclear medicine (System 6), which is 3 times the public dose limit. This is due mainly to the dose to a close family member (spouse) from a patient who has been treated and released after a therapeutic nuclear medicine procedure involving iodine-131. Teletherapy (System 12) and veterinary use (System 16) both have a fraction of 0.9. All other systems have risks from normal operations which are less than 0.3. The risks from off-normal operations to individual members of the public also are fractions of the public limit, with the exception of teletherapy (System 12) which has a fraction of 1, due to the lost-source scenario. Radiography (Systems 19 and 40) also have large fractions of 0.4 and 0.3, respectively, compared to the other systems whose fractions are all less than 0.06.

Systems having low risk values, and therefore very low fractions of the limit for normal and off-normal conditions for both worker and public, may be considered for reduction in regulatory burden. For example, laboratories handling very small quantities of pre-labeled compounds (System 3, fractions 0.000001, 0.00000002, 0.00004 and 0.0000009) currently use byproduct material under a specific license if they are a research laboratory but may use material under a general license if they are a clinical laboratory. The strontium-90 eye applicator (System 11, fractions 0, 0.00004, 0, 0.0000004) must be used under a specific license. It must be noted for this system, however, that risks to patients from medical use of byproduct materials were not evaluated. These risks may need to be considered in determining if regulatory changes are appropriate. Gas chromatographs may be used under a specific license (System 27S) or general license (System 27G) but have identical risks which are small fractions of the limit (0.00006, 0.0000002, 0.002, 0.000007). Other examples can be identified, notably in waste handling systems.

Table 6: Comparison of Results for Category (a) Individual, Workers, Normal Conditions to Results of Estimated Annual Worker Doses (Taken from NUREG-1712 "Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel")

This table compares the results of the risk to individual workers from normal operations using byproduct materials to the estimated annual worker doses provided by a survey of NRC and Agreement State personnel based on their experiences reviewing dosimetry records during inspections of licensed facilities. This is a reasonable comparison. The risk results from normal operations assume a probability of 1 that byproduct materials are handled appropriately, so the dose consequences and the risk values are expected to be similar. There is only a limited requirement for certain licensees (radiographers and certain manufacturers) to report the results of individual monitoring, so there is little dosimetry information in NRC records. However, during the course of inspection, individual monitoring records are reviewed by regulatory personnel. The survey asked experienced inspectors to estimate the percentage of workers that typically receive annual whole- body doses in specified ranges. NUREG-1712 reports the results of the survey.

Table 6, in System Number order, shows the risk for the various systems compared to the mean, modal range, and median range doses estimated in the survey. NUREG-1712 notes that the design of the survey disproportionately weighted the mean-dose values towards the higher dose ranges. However, because there is only one mean value for each system, the mean values are easiest to use in this comparison. Most of the mean doses are in good agreement with the risk value for each system. Generally, the risk value is higher than the mean dose. This may be explained, in part, by the assumption in the risk assessment that one individual performs all work with the byproduct material of a given system, from receipt to disposal, which is not usually what occurs in actual practice. Other factors, including assumptions about the frequency of use, also affect the risk value. However, there are several systems for which the risk value is much different than the mean dose, indicating areas that may require additional review to determine if the risk value is correct, or if changes in the regulations are needed. Some items of interest are detailed below.

1. The risk value for other measuring devices (System 28S) is about 50 times higher than the survey results (600 millirem per year (mrem/y) compared to the mean estimated annual dose of 11 mrem/y). Although some factors listed above contribute to this difference, most of the dose ascribed to this system results from the inclusion of a 100-curie krypton-85 device. Other large differences noted include self-shielded irradiators (System 21, 400 mrem/y vs. 13 mrem/y), fixed gauges using beta emitters (System 23S, 200 mrem/y vs. 11 mrem/y) and teletherapy (System 12, 800 mrem/y vs. 56 mrem/y). The large differences in these systems may be due to assumptions made in the risk assessment regarding the frequency of use and length of time spent in proximity to these devices.

2. Risk estimates for certain systems are 4 to 8 times higher than the mean estimated annual doses. These include manual brachytherapy (System 8, 800 mrem/y vs. 231 mrem/y), veterinary use (System 16, 800 mrem/y vs. 125 mrem/y), well-logging

using tracers or sealed sources (System 17, 900 mrem/y vs 171 mrem/y and System 18, 600 mrem/y vs. 135 mrem/y), field-site radiography (System 40, 2000 mrem/y vs. 482 mrem/y) and specifically-licensed portable gauges (System 24S, 200 mrem/y vs. 58 mrem/y). These differences may be a function of the single individual used in the risk assessment, or may indicate a need for better understanding of the systems. For example, uncertainties in information regarding the types and quantities of materials and the frequency at which byproduct materials are actually used could result in such differences.

3. The risk value is lower than the mean estimated annual dose for only a few systems. All of these systems have risk and dose values well below the dose limit for workers, but the differences, especially for the nuclear pharmacy system, may indicate that more information is needed to assess the risks accurately. In the case of nuclear pharmacy (System 15, 50 mrem/y vs. 355 mrem/y), the survey's modal and median ranges are 101-200 mrem/y, indicating that a few responses given in higher dose ranges may weight the mean too heavily. For this system, it may also indicate that the system requires additional characterization, or that radiation safety practices described may not be used routinely. In the case of incineration of waste (System 35, 3 mrem/y vs. 44 mrem/y), the mean and modal ranges are ND-50 mrem/y. Three systems are related to laboratory activities (System 1, 10 mrem/y vs, 66 mrem/y; System 2, 2 mrem/y vs. 26 mrem/y; and System 3, 0.005 mrem/y vs. 9 mrem/y). These three systems all have low values of risk, with modal and median ranges of ND to 50 mrem/y.

   Finally, nuclear medicine is a unique issue because this study separated the use of generators in a nuclear medicine department (System 4, risk of 70 mrem/y) from all other nuclear medicine activities (System 5, risk of 500 mrem). However, the survey requested information about nuclear medicine activities covered by 10 CFR 35.200, which would include facilities that use generators. The mean estimated dose of 294 mrem/y is higher than the 70 mrem/y estimate for generator use, but lower than the 500 mrem/y for other nuclear medicine activities.

4. Pursuant to 10 CFR 20.2206, licensees who perform radiography and licensees who use specified byproduct materials must report the results of individual monitoring to the NRC each year. These reports are summarized annually in NUREG-0713. It is useful to compare this information, based on actual data, to the risk estimates and to the mean estimated annual doses resulting from the survey. Overall, the survey results are in good agreement with the information summarized from actual data, but they are different from the risk estimates. With the exception of the nuclear pharmacy system, the risk estimates are conservative when compared to the information summarized from actual data.

   The NUREG-0713 report does not distinguish between field site radiography and shielded room radiography; in practice, many licensees perform both types. The annual doses reported for the 10-year period from 1987 through 1996 range from 250 to 440 millirem per year averaged over all radiography workers monitored during those years. Some individuals received no measurable doses, and the average measured dose to

radiographers over that period ranged from 410 to 600 millirem per year. These numbers are well below the risk estimated to individual workers under normal conditions for field site radiography (2,000 millirem per year) but are close to the risk value for fixed site radiography (200 millirem per year). The average doses from individual monitoring reported to the NRC are also similar to the mean estimated annual dose results of the survey (482 millirem per year for field site radiography and 262 millirem for fixed site radiography). This higher risk value estimate may be due to the single person assumed in the risk estimate, or to other assumptions regarding frequency, types, and quantities of byproduct materials actually used in field site radiography.

The NUREG-0713 report does not distinguish between different types of materials handled by manufacturers, including nuclear pharmacies. The annual doses reported for all workers at all manufacturers required to make reports over the 10-year period from 1987 through 1996 range from 140 to 220 millirem per year averaged over all workers who were monitored during those years. For workers with measurable doses, the average measured doses ranged from 300 to 490 millirem per year. These values are in good agreement with the mean estimated annual doses from the survey (167, 362, 236, and 223 millirem per year for manufacturers of sealed sources, solids, liquids and gases, respectively; and 355 millirem per year from nuclear pharmacies). The risk estimate for manufacturers of radioactive products (System 31, 400 mrem/y; System 32, 700 mrem/y; System 33, 500 mrem/y; and System, 34, 600 mrem/y) are close to the average dose for workers with measurable doses. However, the risk estimate for nuclear pharmacy is low by comparison (50 millirem per year) as discussed in Item 3 above.

Tables 7A through 7F: Comparison of Risks to Individuals to NRC Inspection Prioritization

The NRC assigns inspection priorities to the various activities performed using byproduct materials. An inspection priority determines the frequency that a facility is routinely inspected. Priority 1 requires annual inspection, Priority 2 requires inspection every 2 years, Priority 3 requires inspection every 3 years, Priority 5 requires inspection every 5 years, and Priority 7 requires an inspection within a year of initial issuance of a license, but no routine re-inspection. There are currently no Priority 4 or 6 categories. Specific licenses of broad scope, which authorize a variety of activities (encompassing multiple systems) that may be approved by a Radiation Safety Committee or a Radiation Safety Officer, are categorized as Priority 1, 2, 3, or 5 depending on the type of broad scope license issued.

Tables 7A and 7B are in System Number order. Table 7A compares the individual worker and public risks under normal conditions to the inspection priority assigned to each system. Table 7B compares the individual worker and public risks under off-normal conditions to the inspection priority assigned each system. Tables 7C and 7D show the same risk information, but in order of worker risk. Tables 7E and 7F compare the same risk information in order of priority. In general, there is not any clear relationship between the risk assessment values and priority. However, several items are noted below.

1. Of systems in the Priority 1 category, only field site radiography has a risk value to workers under normal operations in the top 10 (2000 millirem per year); the risk values to workers under off-normal operations and to individual members of the public under normal and off-normal operations also rank this system in the top 10 of those categories. However, the remaining systems in the Priority 1 category (high-dose-rate afterloading brachytherapy, nuclear pharmacy, fixed site radiography, pool irradiators, and all waste processors) have risk values that rank them in the middle or lower half of the systems. All have risk values for individual workers under normal operations of less than 200 millirem per year.

2. All systems categorized as Priority 3 have risk values to individual workers under normal operations in the range of 100 to 900 millirem per year, except for the strontium-90 eye applicator (System 11), which has a risk value of 0. Therapeutic nuclear medicine (System 6) also has a normal risk value to the public of 300 millirem, the highest normal risk to the public of any system. Most of the other systems in this category have public risks of 10 or less millirem per year. The risk values for off-normal conditions for many of these systems would rank them in the top third of the systems evaluated. Some of these activities may be categorized as Priority 5 where some limitations are in place.

3. A number of the systems that would be categorized as Priority 7, and those that are generally licensed, have risk values that are similar to those for systems of higher priority. Portable gauges (Systems 24S and 24G) have risk values under off-normal operations that rank these systems in the top half of all systems; the risk values are higher for the generally licensed gauges than for the portable gauges because of the higher probability of off-normal conditions occurring (mostly due to lost, stolen, or damaged devices). Two systems, veterinary use (System 16) and other measuring devices (System 28S), are classified as Priority 5. However, the normal worker risk values for these systems (800 mrem/y and 600 mrem/y, respectively) rank them in the top 10 of all systems in this risk category. Veterinary use includes use of 100-200 millicuries of technetium-99m for bone scans of horses, which creates a large field of radiation and requires close handling by workers. System 28S includes a device containing krypton-85, for which high consequences and high risk values were calculated. Both systems may require additional review to determine if they are correctly described in the risk assessment, and if they are assigned to the right priority cateogry.

ATTACHMENTS:TABLES

Tables 1A through 1H: Risk Assessment Results by Category in System Number Order

Tables 2A through 2H: Risk Assessment Results by Category in Risk Order

Table 3: Comparison of Rankings by Relative Risk for Systems, in the 8 Risk Assessment Categories, by System Number

Tables 4A through 4F: Comparison of Risk Assessment Results for Normal and Off-Normal Conditions

Tables 5A through 5B: Comparison of Risk Assessment Results for Individuals to NRC Dose Limits

Table 6: Comparison of Results for Category (a) Individual, Worker, Normal Conditions to Results of Estimated Annual Worker Doses (Taken from NUREG-1712 “Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel)

Tables 7A through 7F: Comparison of Risks to Individuals to NRC Inspection Prioritization

Table 1A: Risk Assessment Results for Category (a) Individual, Worker, Normal Conditions in System Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(38)	13	10	10
2.	labs, prepared compounds	(41)	2.2	2	10
3.	labs, very small quantities	(45)	0.0048	0.005	0.01
4.	nuc med, generator	(25)	65	70	100
5.	diag nuc med, w/o generator	(12)	400	500	1000
6.	therapeutic nuc med	(14)	230	300	1000
7.	brachytherapy - seeds	(20)	130	100	100
8.	brachytherapy, manual	(4-)	790	800	1000
9.	brachytherapy, LDR	(21)	100	100	100
10.	brachytherapy, HDR	(29-)	46	50	100
11.	brachytherapy - Sr-90 eye	(46)	0	0	0
12.	teletherapy - single source	(4-)	790	800	1000
13.	teletherapy - gamma stereo	(19)	140	100	100
14.	human use research	(17-)	180	200	1000
*39.	diagnostic device, fixed	(35-)	33	30	100
15.	nuclear pharmacy	(27)	52	50	100
16.	veterinary	(6)	740	800	1000
17	well-logging, tracers etc	(3)	890	900	1000
18	well-logging, sealed sources	(10)	560	600	1000
19.	radiography, shielded room	(16)	190	200	1000
*40.	radiography, field site	(2)	2000	2000	10000
20.	irradiators, pool	(35-)	33	30	100
21.	irradiators, self-shielded	(13)	390	400	1000
22S	fixed gauges etc, gamma	(26)	54	60	100
22G	fixed gauges etc, gamma	(23)	78	80	100
23S	fixed gauges etc, beta	(17-)	180	200	1000
23G	fixed gauges etc, beta	(22)	91	90	100
24S	portable gauges	(15)	210	200	1000
24G	portable gauges	(29-)	46	50	100
25.	animal research	(31)	42	40	100

Table 1A, continued: Risk Assessment Results for Category (a) Individual, Worker, Normal Conditions, in System Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(33)	39	40	100
26G	measuring systems - XRF	(28)	47	50	100
27S	measuring systems - GC	(43-)	0.32	0.3	1
27G	measuring systems - GC	(43-)	0.32	0.3	1
28S	measuring - other	(8)	640	600	1000
28G	measuring - other	(42)	1.2	1	1
29S.	other small sealed sources	(37)	14	10	10
29G.	other small sealed sources	(39)	8.8	9	10
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		
31.	mfr/dist - sealed sources	(1)	3900	400	1000
32.	mfr/dist - unsealed solids	(7)	670	700	1000
33.	mfr/dist - unsealed liquids	(11)	510	500	1000
34.	mfr/dist - unsealed gases	(9)	630	600	1000
35.	waste disposal - incineration	(40)	2.9	3	10
36.	waste disposal - compacting	(34)	36	40	100
37.	waste disposal - packaging	(24)	67	70	100
38.	waste...other, solidification	(32)	40	40	100

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1B: Risk Assessment Results for Category (b) Individual, Public, Normal Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(22)	5.8	6	10
2.	labs, prepared compounds	(39)	1.3	1	1
3.	labs, very small quantities	(46)	0.0039	0.004	0.01
4.	nuc med, generator	(29)	3.1	3	10
5.	diag nuc med, w/o generator	(17)	7.5	8	10
6.	therapeutic nuc med	(1)	270	300	1000
7.	brachytherapy, seeds	(14-)	11	10	10
8.	brachytherapy, manual	(14-)	11	10	10
9.	brachytherapy, LDR	(18)	7.1	7	10
10.	brachytherapy, HDR	(19-)	6.9	7	10
11.	brachytherapy - Sr-90 eye	(47)	0	0	0
12.	teletherapy - single source	(2)	90	90	100
13.	teletherapy - gamma stereo	(7)	24	30	100
14.	human use research	(26-)	3.7	4	10
*39.	medical diagnostic devices	(9)	22	20	100
15.	nuclear pharmacy	(13)	12	10	10
16.	veterinary	(3)	85	90	100
17	well-logging, tracers etc	(33-)	2.2	2	10
18	well-logging, sealed sources	(40-)	1.0	1	1
19.	radiography, shielded room	(4)	32	30	100
*40.	radiography, field site	(8)	23	20	100
20.	irradiators, pool	(25)	4.1	4	10
21.	irradiators, self-shielded	(12)	13	10	10
22S	fixed gauges etc, gamma	(14-)	11	10	10
22G	fixed gauges etc, gamma	(11)	15	20	100
23S	fixed gauges etc, beta	(5-)	27	30	100
23G	fixed gauges etc, beta	(10)	16	20	100
24S	portable gauges	(19-)	6.9	7	10
24G	portable gauges	(33-)	2.2	2	10
25.	animal research	(40-)	1.0	1	1

Table 1B, continued: Risk Assessment Results for Category (b) Individual, Public, Normal Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(42)	0.80	0.8	1
26G	measuring systems - XRF	(38)	1.4	1	1
27S	measuring systems - GC	(43-)	0.17	0.2	1
27G	measuring systems - GC	(43-)	0.17	0.2	1
28S	measuring - other	(5-)	27	30	100
28G	measuring - other	(45)	0.013	0.01	0.01
29S.	other small sealed sources	(37)	1.6	2	10
29G.	other small sealed sources	(34)	1.9	2	10
30.	very small sealed sources	(28)	3.3	3	10
31.	mfr/dist - sealed sources	(36)	1.8	2	10
32.	mfr/dist - unsealed solids	(21)	6.3	7	10
33.	mfr/dist - unsealed liquids	(30)	2.9	3	10
34.	mfr/dist - unsealed gases	(26-)	3.7	4	10
35	waste disposal - incineration	(31)	2.5	3	10
36	waste disposal - compacting	(24)	4.4	5	10
37	waste disposal - packaging	(23)	5.5	6	10
38	waste...other, solidification	(32)	2.4	2	10

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1C: Risk Assessment Results for Category (c) Individual, Worker, Accident Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(26)	0.19	0.2	1
2.	labs, prepared compounds	(31)	0.082	0.08	0.1
3.	labs, very small quantities	(44)	0.00012	0.0001	0.0001
4.	nuc med, generator	(4)	31	30	100
5.	diag nuc med, w/o generator	(21)	0.35	0.4	1
6.	therapeutic nuc med	(1)	140	100	100
7.	brachytherapy, seeds	(17)	0.85	0.9	1
8.	brachytherapy, manual	(2)	61	60	100
9.	brachytherapy, LDR	(9)	8.9	9	10
10.	brachytherapy, HDR	(13)	1.7	2	10
11.	brachytherapy - Sr-90 eye	(37)	0.0019	0.002	0.01
.12.	teletherapy - single source	(10)	4.5	5	10
13.	teletherapy - gamma stereo	(23)	0.32	0.3	1
14.	human use research	(30)	0.095	0.1	0.1
*39.	medical diagnostic devices	(22)	0.34	0.3	1
15.	nuclear pharmacy	(7)	12	10	10
16.	veterinary	(12)	1.8	2	10
17.	well-logging, tracers etc	(8)	9.4	9	10
18	well-logging, sealed sources	(15)	1.1	1	1
19.	radiography, shielded room	(3)	52	60	100
*40.	radiography, field site	(6)	17	20	100
20.	irradiators, pool	(25)	0.21	0.2	1
21.	irradiators, self-shielded	(24)	0.28	0.3	1
22S	fixed gauges etc, gamma	(34)	0.031	0.03	0.1
22G	fixed gauges etc, gamma	(36)	0.014	0.01	0.01
23S	fixed gauges etc, beta	(41)	0.00031	0.0003	0.001
23G	fixed gauges etc, beta	(42-)	0.00014	0.0001	0.0001
24S	portable gauges	(14)	1.4	1	1
24G	portable gauges	(5)	18	20	100
25.	animal research	(18-)	0.68	0.7	1

Table 1C, continued: Risk Assessment Results for Category (c) Individual, Worker, Accident Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(29)	0.10	0.1	0.1
26G	measuring systems - XRF	(27)	0.12	0.1	0.1
27S	measuring systems - GC	(39-)	0.0014	0.001	0.001
27G	measuring systems - GC	(39-)	0.0014	0.001	0.001
28S	measuring - other	(38)	0.0018	0.002	0.01
28G	measuring - other	(42-)	0.00014	0.0001	0.0001
29S.	other small sealed sources	(45)	0.000012	0.00001	0.00001
29G.	other small sealed sources	(46)	0.0000073	0.000007	0.00001
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		
31.	mfr/dist - sealed sources	(16)	0.93	1	1
32.	mfr/dist - unsealed solids	(33)	0.043	0.04	0.1
33.	mfr/dist - unsealed liquids	(35)	0.022	0.02	0.1
34.	mfr/dist - unsealed gases	(28)	0.11	0.1	0.1
35.	waste disposal - incineration	(11)	4.0	4	10
36.	waste disposal - compacting	(32)	0.071	0.07	0.1
37.	waste disposal - packaging	(18-)	0.68	0.7	1
38.	waste...other, solidification	(20)	0.47	0.5	1

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1D: Risk Assessment Results for Category (d) Individual, Public, Accident Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(23-)	0.022	0.02	0.1
2.	labs, prepared compounds	(19)	0.052	0.05	0.1
3.	labs, very small quantities	(44)	0.000086	0.00009	0.0001
4.	nuc med, generator	(20)	0.051	0.05	0.1
5.	diag nuc med, w/o generator	(35)	0.0050	0.005	0.01
6.	therapeutic nuc med	(9)	0.69	0.7	1
7.	brachytherapy - seeds	(32)	0.0079	0.08	0.1
8.	brachytherapy - manual	(21)	0.032	0.03	0.1
9.	brachytherapy - LDR	(13-)	0.22	0.2	1
10.	brachytherapy - HDR	(16)	0.15	0.2	1
11.	brachytherapy - Sr-90 eye	(45)	0.000037	0.00004	0.0001
12.	teletherapy - single source	(1)	100	100	100
13.	teletherapy - gamma stereo	(4)	5.8	6	10
14.	human use research	(25-)	0.020	0.02	0.1
*39.	medical diagnostic devices	(12)	0.23	0.2	1
15.	nuclear pharmacy	(29-)	0.010	0.01	0.01
16.	veterinary	(7)	1.7	2	10
17	well-logging, tracers etc	(37)	0.0031	0.003	0.01
18	well-logging, sealed sources	(5)	2.0	2	10
19.	radiography, shielded room	(2)	42	40	100
*40.	radiography, field site	(3)	28	30	100
20.	irradiators, pool	(23-)	0.022	0.02	0.1
21.	irradiators, self-shielded	(6)	1.8	2	10
22S	fixed gauges etc, gamma	(33)	0.0069	0.007	0.01
22G	fixed gauges etc, gamma	(36)	0.0042	0.004	0.01
23S	fixed gauges etc, beta	(43)	0.00011	0.0001	0.0001
23G	fixed gauges etc, beta	(42)	0.00012	0.0001	0.0001
24S	portable gauges	(22)	0.026	0.03	0.1
24G	portable gauges	(11)	0.41	0.4	1
25.	animal research	(13-)	0.22	0.2	1

Table 1D, continued: Risk Assessment Results for Category (d) Individual, Public, Accident Conditions, in System Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(28)	0.012	0.01	0.01
26G	measuring systems - XRF	(27)	0.015	0.01	0.01
27S	measuring systems - GC	(38)	0.00067	0.0007	0.001
27G	measuring systems - GC	(39)	0.00064	0.0006	0.001
28S	measuring - other	(40)	0.00029	0.0003	0.001
28G	measuring - other	(46)	0.000029	0.00003	0.0001
29S.	other small sealed sources	(41)	0.00017	0.0002	0.001
29G.	other small sealed sources	(47)	0.000021	0.00002	0.0001
30.	very small sealed sources	(29-)	0.010	0.01	0.01
31.	mfr/dist - sealed sources	(10)	0.45	0.5	1
32.	mfr/dist - unsealed solids	(25-)	0.020	0.2	1
33.	mfr/dist - unsealed liquids	(31)	0.0092	0.009	0.01
34.	mfr/dist - unsealed gases	(15)	0.19	0.2	1
35.	waste disposal - incineration	(8)	1.1	1	1
36.	waste disposal - compacting	(34)	0.0053	0.005	0.01
37.	waste disposal - packaging	(18)	0.062	0.06	0.1
38.	waste...other, solidification	(17)	0.073	0.07	0.1

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1E: Risk Assessment Results for Category (e) Industry, Worker, Normal Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(8)	1400	1000	1000
2.	labs, prepared compounds	(16)	250	300	1000
3.	labs, very small quantities	(44)	0.54	0.5	1
4.	nuc med, generator	(35)	19	20	100
5.	diag nuc med, w/o generator	(3)	5900	6000	10000
6.	therapeutic nuc med	(9)	920	900	1000
7.	brachytherapy - seeds	(21-)	140	100	100
8.	brachytherapy, manual	(7)	1500	2000	10000
9.	brachytherapy, LDR	(31)	48	50	100
10.	brachytherapy, HDR	(33)	24	20	100
11.	brachytherapy - Sr-90 eye	(46)	0	0	0
12.	teletherapy - single source	(17)	200	200	1000
13.	teletherapy - gamma stereo	(34)	28	30	100
14.	human use research	(15)	270	300	1000
*39.	medical diagnostic devices	(30)	59	60	100
15.	nuclear pharmacy	(21-)	140	100	100
16.	veterinary	(28)	80	80	100
17	well-logging, tracers etc	(25)	110	100	100
18	well-logging, sealed sources	(13)	350	400	1000
19.	radiography, shielded room	(24)	120	100	100
*40.	radiography, field site	(4)	5300	5000	10000
20.	irradiators, pool	(39)	6.5	7	10
21.	irradiators, self-shielded	(19-)	160	200	1000
22S	fixed gauges etc, gamma	(11)	580	600	1000
22G	fixed gauges etc, gamma	(6)	1600	2000	10000
23S	fixed gauges etc, beta	(1-)	6100	6000	10000
23G	fixed gauges etc, beta	(1-)	6100	6000	10000
24S	portable gauges	(5)	3300	3000	10000
24G	portable gauges	(12)	490	500	1000
25.	animal research	(32)	32	30	100

Table 1E, continued: Risk Assessment Results for Category (e) Industry, Worker, Normal Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(14)	290	300	1000
26G	measuring systems - XRF	(10)	620	600	1000
27S	measuring systems - GC	(38)	9.2	9	10
27G	measuring systems - GC	(36)	18	20	100
28S	measuring - other	(26)	100	100	100
28G	measuring - other	(43)	0.6	0.6	1
29S	other small sealed sources	(40)	4.3	4	10
29G	other small sealed sources	(21-)	140	100	100
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		
31.	mfr/dist - sealed sources	(19-)	160	200	1000
32.	mfr/dist - unsealed solids	(18)	170	200	1000
33.	mfr/dist - unsealed liquids	(29)	77	80	100
34.	mfr/dist - unsealed gases	(27)	94	90	100
35.	waste disposal - incineration	(45)	0.07	0.07	0.1
36.	waste disposal - compacting	(42)	1.9	2	10
37.	waste disposal - packaging	(37)	14	10	10
38.	waste disposal - other	(41)	2.3	2	10

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1F: Risk Assessment Results for Category (f) Industry, Public, Normal Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(12)	130	100	100
2.	labs, prepared compounds	(2)	15	20	100
3.	labs, very small quantities	(23-)	0.11	0.1	0.1
4.	nuc med, generator	(34)	0.61	0.7	1
5.	diag nuc med, w/o generator	(40)	13000	10000	10000
6.	therapeutic nuc med	(3-)	2700	3000	10000
7.	brachytherapy - seeds	(13)	96	100	100
8.	brachytherapy, manual	(10)	220	200	1000
9.	brachytherapy, LDR	(30)	4.2	4	10
10.	brachytherapy, HDR	(29)	4.3	4	10
11.	brachytherapy - Sr-90 eye	(47)	0	0	0
12.	teletherapy - single source	(19)	23	20	100
13.	teletherapy - gamma stereo	(32)	1.8	2	10
14.	human use research	(11)	190	200	1000
*39.	medical diagnostic devices	(15)	59	60	100
15.	nuclear pharmacy	(26)	11	10	10
16.	veterinary	(31)	2.3	2	10
17	well-logging, tracers etc	(22)	17	20	100
18	well-logging, sealed sources	(20-)	19	20	100
19.	radiography, shielded room	(16)	50	50	100
*40.	radiography, field site	(6)	1800	2000	10000
20.	irradiators, pool	(33)	0.62	0.6	1
21.	irradiators, self-shielded	(23-)	15	20	100
22S	fixed gauges etc, gamma	(9)	240	200	1000
22G	fixed gauges etc, gamma	(7)	790	800	1000
23S	fixed gauges etc, beta	(5)	2300	2000	10000
23G	fixed gauges etc, beta	(3-)	2700	3000	10000
24S	portable gauges	(8)	320	300	1000
24G	portable gauges	(14)	70	70	100
25.	animal research	(36)	0.51	0.5	1

Table 1F, continued: Risk Assessment Results for Category (f) Industry, Public, Normal Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(25)	12	10	10
26G	measuring systems - XRF	(17)	36	40	100
27S	measuring systems - GC	(27)	9.4	9	10
27G	measuring systems - GC	(20-)	19	20	100
28S	measuring - other	(28)	9.2	9	10
28G	measuring - other	(45)	0.013	0.01	0.01
29S	other small sealed sources	(37)	0.48	0.5	1
29G	other small sealed sources	(18)	31	30	100
30.	very small sealed sources	(1)	40000	40000	100000
31.	mfr/dist - sealed sources	(43)	0.020	0.02	0.1
32.	mfr/dist - unsealed solids	(42)	0.025	0.03	0.1
33.	mfr/dist - unsealed liquids	(46)	0.012	0.01	0.1
34.	mfr/dist - unsealed gases	(44)	0.015	0.02	0.1
35.	waste disposal - incineration	(41)	0.086	0.09	0.1
36.	waste disposal - compacting	(39)	0.14	0.1	0.1
37.	waste disposal - packaging	(35)	0.55	0.6	1
38.	waste disposal - other	(38)	0.19	0.2	1

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1G: Risk Assessment Results for Category (g) Industry, Worker, Accident Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(8)	21	20	100
2.	labs, prepared compounds	(12)	6.2	6	10
3.	labs, very small quantities	(39)	0.014	0.01	0.01
4.	nuc med, generator	(10)	9.2	9	10
5.	diag nuc med, w/o generator	(13)	5.2	5	10
6.	therapeutic nuc med	(1)	550	500	1000
7.	brachytherapy - seeds	(21)	0.87	0.9	1
8.	brachytherapy - manual	(3)	120	100	100
9.	brachytherapy - LDR	(15)	3.0	3	10
10.	brachytherapy - HDR	(20)	0.9	0.9	1
11.	brachytherapy - Sr-90 eye	(43)	0.0058	0.006	0.01
12.	teletherapy - single source	(18-)	1.1	1	1
13.	teletherapy - gamma stereo	(33)	0.062	0.06	0.1
14.	human use research	(30)	0.14	0.1	0.1
*39.	medical diagnostic devices	(22)	0.79	0.8	1
15.	nuclear pharmacy	(6)	32	30	100
16.	veterinary	(29)	0.18	0.2	1
17	well-logging, tracers etc	(18-)	1.1	1	1
18	well-logging, sealed sources	(24)	0.66	0.7	1
19.	radiography, shielded room	(14)	3.3	3	10
*40.	radiography, field site	(5)	45	50	100
20.	irradiators, pool	(35)	0.041	0.04	0.1
21.	irradiators, self-shielded	(27)	0.47	0.5	1
22S	fixed gauges etc, gamma	(9)	17	20	100
22G	fixed gauges etc, gamma	(7)	28	30	100
23S	fixed gauges etc, beta	(40)	0.013	0.01	0.01
23G	fixed gauges etc, beta	(42)	0.010	0.01	0.01
24S	portable gauges	(4)	68	70	100
24G	portable gauges	(2)	140	100	100
25.	animal research	(26)	0.51	0.5	1

Table 1G, continued: Risk Assessment Results for Category (g) Industry, Worker, Accident Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(23)	0.72	0.7	1
26G	measuring systems - XRF	(17)	1.5	2	10
27S	measuring systems - GC	(36)	0.039	0.04	0.1
27G	measuring systems - GC	(32)	0.077	0.08	0.1
28S	measuring - other	(11)	7.3	7	10
28G	measuring - other	(46)	0.000069	0.00007	0.0001
29S	other small sealed sources	(31)	0.092	0.09	0.1
29G	other small sealed sources	(16)	2.8	3	10
30.	very small sealed sources	(47)	not applicable - no “workers in this system		
31.	mfr/dist - sealed sources	(28)	0.33	0.3	1
32.	mfr/dist - unsealed solids	(41)	0.011	0.01	0.01
33.	mfr/dist - unsealed liquids	(45)	0.0033	0.003	0.01
34.	mfr/dist - unsealed gases	(38)	0.017	0.02	0.1
35.	waste disposal - incineration	(37)	0.026	0.3	1
36.	waste disposal - compacting	(44)	0.0038	0.004	0.01
37.	waste disposal - packaging	(25)	0.65	0.7	1
38.	waste disposal - other	(34)	0.042	0.04	0.1

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 1H: Risk Assessment Results for Category (h) Industry, Public, Accident Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
1.	labs, synthesis quantities	(16)	0.50	0.5	1
2.	labs, prepared compounds	(18)	0.33	0.3	1
3.	labs, very small quantities	(42)	0.0024	0.002	0.01
4.	nuc med, generator	(35)	0.010	0.01	0.01
5.	diag nuc med, w/o generator	(27)	0.058	0.06	0.1
6.	therapeutic nuc med	(10)	1.4	1	1
7.	brachytherapy - seeds	(29)	0.041	0.04	0.1
8.	brachytherapy, manual	(14)	0.74	0.7	1
9.	brachytherapy, LDR	(24)	0.093	0.1	0.1
10.	brachytherapy, HDR	(23)	0.094	0.1	0.1
11.	brachytherapy - Sr-90 eye	(38)	0.0059	0.006	0.01
12.	teletherapy - single source	(2)	26	30	100
13.	teletherapy - gamma stereo	(19)	0.28	0.3	1
14.	human use research	(33)	0.020	0.02	0.1
*39.	medical diagnostic devices	(13)	0.82	0.8	1
15.	nuclear pharmacy	(22)	0.098	0.1	0.1
16.	veterinary	(28)	0.050	0.05	0.1
17	well-logging, tracers etc	(31)	0.024	0.02	0.1
18	well-logging, sealed sources	(15)	0.66	0.7	1
19.	radiography, shielded room	(8)	2.5	2	10
*40.	radiography, field site	(1)	40	40	100
20.	irradiators, pool	(41)	0.0033	0.003	0.01
21.	irradiators, self-shielded	(4)	9.6	10	10
22S	fixed gauges etc, gamma	(12)	0.89	0.9	1
22G	fixed gauges etc, gamma	(9)	2.0	2	10
23S	fixed gauges etc, beta	(36)	0.01	0.01	0.01
23G	fixed gauges etc, beta	(32)	0.021	0.02	0.1
24S	portable gauges	(6)	4.1	4	10
24G	portable gauges	(3)	11	10	10
25.	animal research	(21)	0.11	0.1	0.1

Table 1H, continued: Risk Assessment Results for Category (h) Industry, Public, Accident Conditions, in System Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
26S	measuring systems - XRF	(20)	0.14	0.1	0.1
26G	measuring systems - XRF	(17)	0.35	0.3	1
27S	measuring systems - GC	(30)	0.038	0.04	0.1
27G	measuring systems - GC	(25)	0.073	0.07	0.1
28S	measuring - other	(5)	6.8	7	10
28G	measuring - other	(47)	0.000029	0.00003	0.0001
29S	other small sealed sources	(34)	0.013	0.01	0.01
29G	other small sealed sources	(11)	1.3	1	1
30.	very small sealed sources	(7)	4.0	4	10
31.	mfr/dist - sealed sources	(26)	0.065	0.07	0.1
32.	mfr/dist - unsealed solids	(43)	0.00082	0.0008	0.001
33.	mfr/dist - unsealed liquids	(45)	0.00037	0.0004	0.001
34.	mfr/dist - unsealed gases	(44)	0.00076	0.0008	0.001
35.	waste disposal - incineration	(37)	0.0094	0.009	0.01
36.	waste disposal - compacting	(46)	0.00018	0.0002	0.001
37.	waste disposal - packaging	(39)	0.0057	0.006	0.01
38.	waste disposal - other	(40)	0.0056	0.006	0.01

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2A: Risk Assessment Results for Category (a) Individual, Worker, Normal Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
31.	mfr/dist - sealed sources	(1)	3900	4000	10000
*40.	radiography, field site	(2)	2000	2000	10000
17.	well-logging, tracers etc	(3)	890	900	1000
8.	brachytherapy, manual	(4-)	790	800	1000
12.	teletherapy - single source	(4-)	790	800	1000
16.	veterinary	(6)	740	800	1000
32.	mfr/dist - unsealed solids	(7)	670	700	1000
28S	measuring - other	(8)	640	600	1000
34.	mfr/dist - unsealed gases	(9)	630	600	1000
18.	well-logging, sealed sources	(10)	560	600	1000
33.	mfr/dist - unsealed liquids	(11)	510	500	1000
5.	diag nuc med, w/o generator	(12)	400	500	1000
21.	irradiators, self-shielded	(13)	390	400	1000
6.	therapeutic nuc med	(14)	230	300	1000
24S	portable gauges	(15)	210	200	1000
19.	radiography, shielded room	(16)	190	200	1000
14.	human use research	(17-)	180	200	1000
23S	fixed gauges etc, beta	(17-)	180	200	1000
13.	teletherapy - gamma stereo	(19)	140	100	100
7.	brachytherapy - seeds	(20)	130	100	100
9.	brachytherapy, LDR	(21)	100	100	100
23G	fixed gauges etc, beta	(22)	91	90	100
22G	fixed gauges etc, gamma	(23)	78	80	100
37.	waste disposal - packaging	(24)	67	70	100
4.	nuc med, generator	(25)	65	70	100
22S	fixed gauges etc, gamma	(26)	54	60	100
15.	nuclear pharmacy	(27)	52	50	100
26G	measuring systems - XRF	(28)	47	50	100
10.	brachytherapy, HDR	(29-)	46	50	100
24G	portable gauges	(29-)	46	50	100

Table 2A, continued: Risk Assessment Results for Category (a) Individual, Worker, Normal Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
25.	animal research	(31)	42	40	100
38.	waste...other, solidification	(32)	40	40	100
26S	measuring systems - XRF	(33)	39	40	100
36.	waste disposal - compacting	(34)	36	40	100
20.	irradiators, pool	(35-)	33	30	100
*39.	diagnostic device, fixed	(35-)	33	30	100
29S	other small sealed sources	(37)	14	10	10
1.	labs, synthesis quantities	(38)	13	10	10
29G	other small sealed sources	(39)	8.8	9	10
35.	waste disposal - incineration	(40)	2.9	3	10
2.	labs, prepared compounds	(41)	2.2	2	10
28G	measuring - other	(42)	1.2	1	1
27S	measuring systems - GC	(43-)	0.32	0.3	1
27G	measuring systems - GC	(43-)	0.32	0.3	1
3.	labs, very small quantities	(45)	0.0048	0.005	0.01
11.	brachytherapy - Sr-90 eye	(46)	0	0	0
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		

*system number out of order, grouped with like systems

G - generally-licensed
S - specifically-licensed
CF - commercial system
GF - generator facility

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2B: Risk Assessment Results for Category (b) Individual, Public, Normal Conditions, in Risk Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
6.	therapeutic nuc med	(1)	270	300	1000
12.	teletherapy - single source	(2)	90	90	100
16.	veterinary	(3)	85	90	100
19.	radiography, shielded room	(4)	32	30	100
23S	fixed gauges etc, beta	(5-)	27	30	100
28S	measuring - other	(5-)	27	30	100
13.	teletherapy - gamma stereo	(7)	24	30	100
*40.	radiography, field site	(8)	23	20	100
*39.	medical diagnostic devices	(9)	22	20	100
23G	fixed gauges etc, beta	(10)	16	20	100
22G	fixed gauges etc, gamma	(11)	15	20	100
21.	irradiators, self-shielded	(12)	13	10	10
15.	nuclear pharmacy	(13)	12	10	10
7.	brachytherapy, seeds	(14-)	11	10	10
8.	brachytherapy, manual	(14-)	11	10	10
22S	fixed gauges etc, gamma	(14-)	11	10	10
5.	diag nuc med, w/o generator	(17)	7.5	8	10
9.	brachytherapy, LDR	(18)	7.1	7	10
24S	portable gauges	(19-)	6.9	7	10
10.	brachytherapy, HDR	(19-)	6.9	7	10
32.	mfr/dist - unsealed solids	(21)	6.3	7	10
1.	labs, synthesis quantities	(22)	5.8	6	10
37	waste disposal - packaging	(23)	5.5	6	10
36	waste disposal - compacting	(24)	4.4	5	10
20.	irradiators, pool	(25)	4.1	4	10
14.	human use research	(26-)	3.7	4	10
34.	mfr/dist - unsealed gases	(26-)	3.7	4	10
30.	very small sealed sources	(28)	3.3	3	10
4.	nuc med, generator	(29)	3.1	3	10
33.	mfr/dist - unsealed liquids	(30)	2.9	3	10

Table 2B, continued: Risk Assessment Results for Category (b) Individual, Public, Normal Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
35	waste disposal - incineration	(31)	2.5	3	10
38	waste...other, solidification	(32)	2.4	2	10
17	well-logging, tracers etc	(33-)	2.2	2	10
24G	portable gauges	(33-)	2.2	2	10
29G.	other small sealed sources	(35)	1.9	2	10
31.	mfr/dist - sealed sources	(36)	1.8	2	10
29S.	other small sealed sources	(37)	1.6	2	10
26G	measuring systems - XRF	(38)	1.4	1	1
2.	labs, prepared compounds	(39)	1.3	1	1
18	well-logging, sealed sources	(40-)	1.0	1	1
25.	animal research	(40-)	1.0	1	1
26S	measuring systems - XRF	(42)	0.80	0.8	1
27S	measuring systems - GC	(42-)	0.17	0.2	1
27G	measuring systems - GC	(42-)	0.17	0.2	1
28G	measuring - other	(45)	0.013	0.01	0.01
3.	labs, very small quantities	(46)	0.0039	0.004	0.01
11.	brachytherapy - Sr-90 eye	(47)	0	0	0

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2C: Risk Assessment Results for Category (c) Individual, Worker, Accident Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
6.	therapeutic nuc med	(1)	140	100	100
8.	brachytherapy, manual	(2)	61	60	100
19.	radiography, shielded room	(3)	52	60	100
4.	nuc med, generator	(4)	31	30	100
24G	portable gauges	(5)	18	20	100
*40.	radiography, field site	(6)	17	20	100
15.	nuclear pharmacy	(7)	12	10	10
17.	well-logging, tracers etc	(8)	9.4	9	10
9.	brachytherapy, LDR	(9)	8.9	9	10
.12.	teletherapy - single source	(10)	4.5	5	10
35.	waste disposal - incineration	(11)	4.0	4	10
16.	veterinary	(12)	1.8	2	10
10.	brachytherapy, HDR	(13)	1.7	2	10
24S	portable gauges	(14)	1.4	1	1
18	well-logging, sealed sources	(15)	1.1	1	1
31.	mfr/dist - sealed sources	(16)	0.93	1	1
7.	brachytherapy, seeds	(17)	0.85	0.9	1
25.	animal research	(18-)	0.68	0.7	1
37.	waste disposal - packaging	(18-)	0.68	0.7	1
38.	waste...other, solidification	(20)	0.47	0.5	1
5.	diag nuc med, w/o generator	(21)	0.35	0.4	1
*39.	medical diagnostic devices	(22)	0.34	0.3	1
13.	teletherapy - gamma stereo	(23)	0.32	0.3	1
21.	irradiators, self-shielded	(24)	0.28	0.3	1
20.	irradiators, pool	(25)	0.21	0.2	1
1.	labs, synthesis quantities	(26)	0.19	0.2	1
26G	measuring systems - XRF	(27)	0.12	0.1	0.1
34.	mfr/dist - unsealed gases	(28)	0.11	0.1	0.1
26S	measuring systems - XRF	(29)	0.10	0.1	0.1
14.	human use research	(30)	0.095	0.1	0.1

Table 2C, continued: Risk Assessment Results for Category (c) Individual, Worker, Accident Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = millirem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
2.	labs, prepared compounds	(31)	0.082	0.08	0.1
36.	waste disposal - compacting	(32)	0.071	0.07	0.1
32.	mfr/dist - unsealed solids	(33)	0.043	0.04	0.1
22S	fixed gauges etc, gamma	(34)	0.031	0.03	0.1
33.	mfr/dist - unsealed liquids	(35)	0.022	0.02	0.1
22G	fixed gauges etc, gamma	(36)	0.014	0.01	0.01
11.	brachytherapy - Sr-90 eye	(37)	0.0019	0.002	0.01
28S	measuring - other	(38)	0.0018	0.002	0.01
27S	measuring systems - GC	(39-)	0.0014	0.001	0.001
27G	measuring systems - GC	(39-)	0.0014	0.001	0.001
23S	fixed gauges etc, beta	(41)	0.00031	0.0003	0.001
23G	fixed gauges etc, beta	(42-)	0.00014	0.0001	0.0001
28G	measuring - other	(42-)	0.00014	0.0001	0.0001
3.	labs, very small quantities	(44)	0.00012	0.0001	0.0001
29S.	other small sealed sources	(45)	0.000012	0.00001	0.00001
29G.	other small sealed sources	(46)	0.0000073	0.000007	0.00001
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2D: Risk Assessment Results for Category (d) Individual, Public, Accident Conditions, in Risk Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
12.	teletherapy - single source	(1)	100	100	100
19.	radiography, shielded room	(2)	42	40	100
*40.	radiography, field site	(3)	28	30	100
13.	teletherapy - gamma stereo	(4)	5.8	6	10
18	well-logging, sealed sources	(5)	2.0	2	10
21.	irradiators, self-shielded	(6)	1.8	2	10
16.	veterinary	(7)	1.7	2	10
35.	waste disposal - incineration	(8)	1.1	1	1
6.	therapeutic nuc med	(9)	0.69	0.7	1
31.	mfr/dist - sealed sources	(10)	0.45	0.5	1
24G	portable gauges	(11)	0.41	0.4	1
*39.	medical diagnostic devices	(12)	0.23	0.2	1
25.	animal research	(13-)	0.22	0.2	1
9.	brachytherapy, LDR	(13-)	0.22	0.2	1
34.	mfr/dist - unsealed gases	(15)	0.19	0.2	1
10.	brachytherapy, HDR	(16)	0.15	0.2	1
38.	waste...other, solidification	(17)	0.073	0.07	0.1
37.	waste disposal - packaging	(18)	0.062	0.06	0.1
2.	labs, prepared compounds	(19)	0.052	0.05	0.1
4.	nuc med, generator	(20)	0.051	0.05	0.1
8.	brachytherapy, manual	(21)	0.032	0.03	0.1
24S	portable gauges	(22)	0.026	0.03	0.1
1.	labs, synthesis quantities	(23-)	0.022	0.02	0.1
20.	irradiators, pool	(23-)	0.022	0.02	0.1
32.	mfr/dist - unsealed solids	(25-)	0.020	0.02	1
14.	human use research	(25-)	0.020	0.02	0.1
26G	measuring systems - XRF	(27)	0.015	0.01	0.01
26S	measuring systems - XRF	(28)	0.012	0.01	0.01
15.	nuclear pharmacy	(29-)	0.010	0.01	0.01
30.	very small sealed sources	(29-)	0.010	0.01	0.01

Table 2D, continued: Risk Assessment Results for Category (d) Individual, Public, Accident Conditions, in Risk Order

Systems			Unit of risk = millirem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
33.	mfr/dist - unsealed liquids	(31)	0.0092	0.009	0.01
7.	brachytherapy - seeds	(32)	0.0079	0.008	0.01
22S	fixed gauges etc, gamma	(33)	0.0069	0.007	0.01
36.	waste disposal - compacting	(34)	0.0053	0.005	0.01
5.	diag nuc med, w/o generator	(35)	0.0050	0.005	0.01
22G	fixed gauges etc, gamma	(36)	0.0042	0.004	0.01
17	well-logging, tracers etc	(37)	0.0031	0.003	0.01
27S	measuring systems - GC	(38)	0.00067	0.0007	0.001
27G	measuring systems - GC	(39)	0.00064	0.0006	0.001
28S	measuring - other	(40)	0.00029	0.0003	0.001
29S.	other small sealed sources	(41)	0.00017	0.0002	0.001
23G	fixed gauges etc, beta	(42)	0.00012	0.0001	0.0001
23S	fixed gauges etc, beta	(43)	0.00011	0.0001	0.0001
3.	labs, very small quantities	(44)	0.000086	0.00009	0.0001
11.	brachytherapy - Sr-90 eye	(45)	0.000037	0.00004	0.0001
28G	measuring - other	(46)	0.000029	0.00003	0.0001
29G.	other small sealed sources	(47)	0.000021	0.00002	0.0001

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (millirem per year) X probability (unitless), the units of risk are also millirem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2E: Risk Assessment Results for Category (e) Industry, Worker, Normal Conditions, in Risk Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
23S	fixed gauges etc, beta	(1-)	6100	6000	10000
23G	fixed gauges etc, beta	(1-)	6100	6000	10000
5.	diag nuc med, w/o generator	(3)	5900	6000	10000
*40.	radiography, field site	(4)	5300	5000	10000
24S	portable gauges	(5)	3300	3000	10000
22G	fixed gauges etc, gamma	(6)	1600	2000	10000
8.	brachytherapy, manual	(7)	1500	2000	10000
1.	labs, synthesis quantities	(8)	1400	1000	1000
6.	therapeutic nuc med	(9)	920	900	1000
26G	measuring systems - XRF	(10)	620	600	1000
22S	fixed gauges etc, gamma	(11)	580	600	1000
24G	portable gauges	(12)	490	500	1000
18	well-logging, sealed sources	(13)	350	400	1000
26S	measuring systems - XRF	(14)	290	300	1000
14.	human use research	(15)	270	300	1000
2.	labs, prepared compounds	(16)	250	300	1000
12.	teletherapy - single source	(17)	200	200	1000
32.	mfr/dist - unsealed solids	(18)	170	200	1000
21.	irradiators, self-shielded	(19-)	160	200	1000
31.	mfr/dist - sealed sources	(19-)	160	200	1000
7.	brachytherapy - seeds	(21-)	140	100	100
15.	nuclear pharmacy	(21-)	140	100	100
29G	other small sealed sources	(21-)	140	100	100
19.	radiography, shielded room	(24)	120	100	100
17	well-logging, tracers etc	(25)	110	100	100
28S	measuring - other	(26)	100	100	100
34.	mfr/dist - unsealed gases	(27)	94	90	100
16.	veterinary	(28)	80	80	100
33.	mfr/dist - unsealed liquids	(29)	77	80	100
*39.	medical diagnostic devices	(30)	59	60	100

Table 2E, continued: Risk Assessment Results for Category (e) Industry, Worker, Normal Conditions, in Risk Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
9.	brachytherapy, LDR	(31)	48	50	100
25.	animal research	(32)	32	30	100
10.	brachytherapy, HDR	(33)	24	20	100
13.	teletherapy - gamma stereo	(34)	28	30	100
4.	nuc med, generator	(35)	19	20	100
27G	measuring systems - GC	(36)	18	20	100
37.	waste disposal - packaging	(37)	14	10	10
27S	measuring systems - GC	(38)	9.2	9	10
20.	irradiators, pool	(39)	6.5	7	10
29S	other small sealed sources	(40)	4.3	4	10
38.	waste disposal - other	(41)	2.3	2	10
36.	waste disposal - compacting	(42)	1.9	2	10
28G	measuring - other	(43)	0.6	0.6	1
3.	labs, very small quantities	(44)	0.54	0.5	1
35.	waste disposal - incineration	(45)	0.07	0.07	0.1
11.	brachytherapy - Sr-90 eye	(46)	0	0	0
30.	very small sealed sources	(47)	not applicable - no “workers” in this system		

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2F: Risk Assessment Results for Category (f) Industry, Public, Normal Conditions, in Risk Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
30.	very small sealed sources	(1)	40000	40000	100000
5.	diag nuc med, w/o generator	(2)	13000	10000	10000
6.	therapeutic nuc med	(3-)	2700	3000	10000
23G	fixed gauges etc, beta	(3-)	2700	3000	10000
23S	fixed gauges etc, beta	(5)	2300	2000	10000
*40.	radiography, field site	(6)	1800	2000	10000
22G	fixed gauges etc, gamma	(7)	790	800	1000
24S	portable gauges	(8)	320	300	1000
22S	fixed gauges etc, gamma	(9)	240	200	1000
8.	brachytherapy, manual	(10)	220	200	1000
14.	human use research	(11)	190	200	1000
1.	labs, synthesis quantities	(12)	130	100	100
7.	brachytherapy - seeds	(13)	96	100	100
24G	portable gauges	(14)	70	70	100
*39.	medical diagnostic devices	(15)	59	60	100
19.	radiography, shielded room	(16)	50	50	100
26G	measuring systems - XRF	(17)	36	40	100
29G	other small sealed sources	(18)	31	30	100
12.	teletherapy - single source	(19)	23	20	100
18	well-logging, sealed sources	(20-)	19	20	100
27G	measuring systems - GC	(20-)	19	20	100
17	well-logging, tracers etc	(22)	17	20	100
2.	labs, prepared compounds	(23-)	15	20	100
21.	irradiators, self-shielded	(23-)	15	20	100
26S	measuring systems - XRF	(25)	12	10	100
15.	nuclear pharmacy	(26)	11	10	10
27S	measuring systems - GC	(27)	9.4	9	10
28S	measuring - other	(28)	9.2	9	10
10.	brachytherapy, HDR	(29)	4.3	4	10
9.	brachytherapy, LDR	(30)	4.2	4	10

Table 2F, continued: Risk Assessment Results for Category (f) Industry, Public, Normal Conditions, in Risk Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
16.	veterinary	(31)	2.3	2	10
13.	teletherapy - gamma stereo	(32)	1.8	2	10
20.	irradiators, pool	(33)	0.62	0.6	1
4.	nuc med, generator	(34)	0.61	0.7	1
37.	waste disposal - packaging	(35)	0.55	0.6	1
25.	animal research	(36)	0.51	0.5	1
29S	other small sealed sources	(37)	0.48	0.5	1
38.	waste disposal - other	(38)	0.19	0.2	1
36.	waste disposal - compacting	(39)	0.14	0.1	0.1
3.	labs, very small quantities	(40)	0.11	0.1	0.1
35.	waste disposal - incineration	(41)	0.086	0.09	0.1
32.	mfr/dist - unsealed solids	(42)	0.025	0.03	0.1
31.	mfr/dist - sealed sources	(43)	0.020	0.02	0.1
34.	mfr/dist - unsealed gases	(44)	0.015	0.02	0.1
28G	measuring - other	(45)	0.013	0.01	0.01
33.	mfr/dist - unsealed liquids	(46)	0.012	0.01	0.01
11.	brachytherapy - Sr-90 eye	(47)	0	0	0

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2G: Risk Assessment Results for Category (g) Industry, Worker, Accident Conditions, in Risk Order

Systems			Unit of risk = rem per year[1]		
No.	Description	Rank	Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
6.	therapeutic nuc med	(1)	550	500	1000
24G	portable gauges	(2)	140	100	100
8.	brachytherapy - manual	(3)	120	100	100
24S	portable gauges	(4)	68	70	100
*40.	radiography, field site	(5)	45	50	100
15.	nuclear pharmacy	(6)	32	30	100
22G	fixed gauges etc, gamma	(7)	28	30	100
1.	labs, synthesis quantities	(8)	21	20	100
22S	fixed gauges etc, gamma	(9)	17	20	100
4.	nuc med, generator	(10)	9.2	9	10
28S	measuring - other	(11)	7.3	7	10
2.	labs, prepared compounds	(12)	6.2	6	10
5.	diag nuc med, w/o generator	(13)	5.2	5	10
19.	radiography, shielded room	(14)	3.3	3	10
9.	brachytherapy - LDR	(15)	3.0	3	10
29G	other small sealed sources	(16)	2.8	3	10
26G	measuring systems - XRF	(17)	1.5	2	10
12.	teletherapy - single source	(18-)	1.1	1	1
17.	well-logging, tracers etc	(18-)	1.1	1	1
10.	brachytherapy - HDR	(20)	0.9	0.9	1
7.	brachytherapy - seeds	(21)	0.87	0.9	1
*39.	medical diagnostic devices	(22)	0.79	0.8	1
26S	measuring systems - XRF	(23)	0.72	0.7	1
18	well-logging, sealed sources	(24)	0.66	0.7	1
37.	waste disposal - packaging	(25)	0.65	0.7	1
25.	animal research	(26)	0.51	0.5	1
21.	irradiators, self-shielded	(27)	0.47	0.5	1
31.	mfr/dist - sealed sources	(28)	0.33	0.3	1
16.	veterinary	(29)	0.18	0.2	1
14.	human use research	(30)	0.14	0.1	0.1

Table 2G, continued: Risk Assessment Results for Category (g) Industry, Worker, Accident Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = rem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
29S	other small sealed sources	(31)	0.092	0.09	0.1
27G	measuring systems - GC	(32)	0.077	0.08	0.1
13.	teletherapy - gamma stereo	(33)	0.062	0.06	0.1
38.	waste disposal - other	(34)	0.042	0.04	0.1
20.	irradiators, pool	(35)	0.041	0.04	0.1
27S	measuring systems - GC	(36)	0.039	0.04	0.1
35.	waste disposal - incineration	(37)	0.026	0.03	0.1
34.	mfr/dist - unsealed gases	(38)	0.017	0.02	0.1
3.	labs, very small quantities	(39)	0.014	0.01	0.01
23S	fixed gauges etc, beta	(40)	0.013	0.01	0.01
32.	mfr/dist - unsealed solids	(41)	0.011	0.01	0.01
23G	fixed gauges etc, beta	(42)	0.010	0.01	0.01
11.	brachytherapy - Sr-90 eye	(43)	0.0058	0.006	0.01
36.	waste disposal - compacting	(44)	0.0038	0.004	0.01
33.	mfr/dist - unsealed liquids	(45)	0.0033	0.003	0.01
28G	measuring - other	(46)	0.000069	0.00007	0.0001
30.	very small sealed sources	(47)	not applicable - no “workers in this system		

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 2H: Risk Assessment Results for Category (h) Industry, Public, Accident Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = rem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
*40.	radiography, field site	(1)	40	40	100
12.	teletherapy - single source	(2)	26	30	100
24G	portable gauges	(3)	11	10	10
21.	irradiators, self-shielded	(4)	9.6	10	10
28S	measuring - other	(5)	6.8	7	10
24S	portable gauges	(6)	4.1	4	10
30.	very small sealed sources	(7)	4.0	4	10
19.	radiography, shielded room	(8)	2.5	2	10
22G	fixed gauges etc, gamma	(9)	2.0	2	10
6.	therapeutic nuc med	(10)	1.4	1	1
29G	other small sealed sources	(11)	1.3	1	1
22S	fixed gauges etc, gamma	(12)	0.89	0.9	1
*39.	medical diagnostic devices	(13)	0.82	0.8	1
8.	brachytherapy, manual	(14)	0.74	0.7	1
18	well-logging, sealed sources	(15)	0.66	0.7	1
1.	labs, synthesis quantities	(16)	0.50	0.5	1
26G	measuring systems - XRF	(17)	0.35	0.3	1
2.	labs, prepared compounds	(18)	0.33	0.3	1
13.	teletherapy - gamma stereo	(19)	0.28	0.3	1
26S	measuring systems - XRF	(20)	0.14	0.1	0.1
25.	animal research	(21)	0.11	0.1	0.1
15.	nuclear pharmacy	(22)	0.098	0.1	0.1
10.	brachytherapy, HDR	(23)	0.094	0.1	0.1
9.	brachytherapy, LDR	(24)	0.093	0.1	0.1
27G	measuring systems - GC	(25)	0.073	0.07	0.1
31.	mfr/dist - sealed sources	(26)	0.065	0.07	0.1
5.	diag nuc med, w/o generator	(27)	0.058	0.06	0.1
16.	veterinary	(28)	0.050	0.05	0.1
7.	brachytherapy - seeds	(29)	0.041	0.04	0.1
27S	measuring systems - GC	(30)	0.038	0.04	0.1

Table 2H, continued: Risk Assessment Results for Category (h) Industry, Public, Accident Conditions, in Risk Order

Systems No.	Description	Rank	Unit of risk = rem per year[1] Risk (2 sf[2])	Risk (1 sf)	Risk (10^x)
17	well-logging, tracers etc	(31)	0.024	0.02	0.1
23G	fixed gauges etc, beta	(32)	0.021	0.02	0.1
14.	human use research	(33)	0.020	0.02	0.1
29S	other small sealed sources	(34)	0.013	0.01	0.01
4.	nuc med, generator	(35)	0.010	0.01	0.01
23S	fixed gauges etc, beta	(36)	0.010	0.01	0.01
35.	waste disposal - incineration	(37)	0.0094	0.009	0.01
11.	brachytherapy - Sr-90 eye	(38)	0.0059	0.006	0.01
37.	waste disposal - packaging	(39)	0.0057	0.006	0.01
38.	waste disposal - other	(40)	0.0056	0.006	0.01
20.	irradiators, pool	(41)	0.0033	0.003	0.01
3.	labs, very small quantities	(42)	0.0024	0.002	0.01
32.	mfr/dist - unsealed solids	(43)	0.00082	0.0008	0.001
34.	mfr/dist - unsealed gases	(44)	0.00076	0.0008	0.001
33.	mfr/dist - unsealed liquids	(45)	0.00037	0.0004	0.001
36.	waste disposal - compacting	(46)	0.00018	0.0002	0.001
28G	measuring - other	(47)	0.000029	0.00003	0.0001

*system number out of order, grouped with like systems
G - generally-licensed
S - specifically-licensed

Note 1: Because Risk = consequences (rem per year) X probability (unitless), the units of risk are also rem per year. Because the probabilities are values less than or equal to 1, the risk values are always less than the consequence values. Please note that the risk values may have uncertainties up to one or more orders of magnitude, primarily because of the uncertainties in the probability values.

Note 2: Significant figures - NUREG/CR-6642 reported calculations to 2 sf.

Table 3: Comparison of Rankings of Relative Risk for 8 Categories of Risk, in System Number Order

Systems		Risk Analysis Categories							
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
No.	Description	Ranking							
1.	labs, synthesis quantities	38	22	26	23-	8	12	8	16
2.	labs, prepared compounds	41	39	31	19	16	2	12	18
3.	labs, very small quantities	45	46	44	44	44	23-	39	42
4.	nuc med, generator	25	29	4	20	35	34	10	35
5.	diag nuc med, w/o generator	12	17	21	35	3	40	13	27
6.	therapeutic nuc med	14	1	1	9	9	3-	1	10
7.	brachytherapy, ...seeds	20	14-	17	32	21-	13	21	29
8.	brachytherapy, manual	4-	14-	2	21	7	10	3	14
9.	brachytherapy, LDR	21	18	9	13-	31	30	15	24
10.	brachytherapy, HDR	29-	19-	13	16	33	29	20	23
11.	brachytherapy - SR-90 eye	46	47	37	45	46	47	43	38
12.	teletherapy - single source	4-	2	10	1	17	19	18-	2
13.	teletherapy - gamma stereo	19	7	23	4	34	32	33	19
14.	human use research	17-	26-	30	25-	15	11	30	33
*39	med diag devices - fixed	35-	9	22	12	30	15	22	13
15.	nuclear pharmacy	27	13	7	29-	21-	26	6	22
16.	veterinary (diag & therapy)	6	3	12	7	28	31	29	28
17	well-logging, tracers etc	3	33-	8	37	25	22	18-	31
18	well-logging, sealed sources	10	40-	15	5	13	20-	24	15
19.	radiography, shielded room	16	4	3	2	24	16	14	8
*40.	radiography, field site	2	8	6	3	4	6	5	1
20.	irradiators, pool	35-	25	25	23-	39	33	35	41
21.	irradiators, self-shielded	13	12	24	6	19-	23-	27	4
22S	fixed gauges etc, gamma	26	14-	34	33	11	9	9	12
22G	fixed gauges etc, gamma	23	11	36	36	6	7	7	9
23S	fixed gauges etc, beta	17-	5-	41	43	1-	5	40	36
23G	fixed gauges etc, beta	22	10	42-	42	1-	3-	42	32
24S	portable gauges	15	19-	14	22	5	8	4	6
24G	portable gauges	29-	33-	5	11	12	14	2	3
25.	animal research	31	40-	18-	13-	32	36	26	21
26S	measuring systems - XRF	33	42	29	28	14	25	23	20
26G	measuring systems - XRF	28	38	27	27	10	17	17	17
27S	measuring systems - GC	43-	43-	39-	38	38	27	36	30
27G	measuring systems - GC	43-	43-	39-	39	36	20-	32	25
28S	measuring - other	8	5-	38	40	26	28	11	5
28G	measuring - other	42	45	42-	46	43	45	46	47
29S	other small sealed sources	37	37	45	41	40	37	31	34
29G	other small sealed sources	39	34	46	47	21-	18	16	11
30.	very small sealed sources	47	28	47	29-	47	1	47	7

Table 3, continued: Comparison of Rankings of Relative Risk for 8 Categories of Risk, in System Number Order

Systems No.	Description	Risk Analysis Categories (a) Ranking	(b)	(c)	(d)	(e)	(f)	(g)	(h)
31.	mfr/dist - sealed sources	1	36	16	10	19-	43	28	26
32.	mfr/dist - solids	7	21	33	25-	18	42	41	43
33.	mfr/dist - liquids	11	30	35	31	29	46	45	45
34.	mfr/dist - gases	9	26-	28	15	27	44	38	44
35.	waste disposal - incineration	40	31	11	8	45	41	37	37
36.	waste disposal - compacting	34	24	32	34	42	39	44	46
37.	waste disposal - packaging	24	23	18-	18	37	35	25	39
38.	waste... solidification	32	32	20	17	41	38	34	40

Table 4A: Comparison of Risk Assessment Results - Individual Worker Risk Categories, in System Number Order

Systems No.	Description	Risk (unit = millirem per year, using 1 sf) Categories (a) normal	(c) off-normal	Total Risk
1.	labs, synthesis	10	0.2	10
2.	labs, prepared	2	0.08	2
3.	labs, very small	0.005	0.0001	0.005
4.	nuc med, generator	70	30	100
5.	diag nuc med	500	0.4	500
6.	therapeutic nuc med	300	100	400
7.	brachy - seeds	100	0.9	100
8.	brachy - manual	800	60	900
9.	brachy - LDR	100	9	100
10.	brachy - HDR	50	2	50
11.	brachy - Sr-90 eye	0	0.002	0.002
12.	teletherapy	800	5	800
13.	gamma stereotactic	100	0.3	100
14.	human use research	200	0.1	200
*39.	medical devices	30	0.3	30
15.	nuclear pharmacy	50	10	60
16.	veterinary	800	2	800
17.	well-logging, tracers	900	9	900
18.	well-logging, sealed	600	1	600
19.	radiography, room	200	60	300
*40.	radiography, field	2000	20	2000
20.	irradiators, pool	30	0.2	30
21.	irradiators, self-shi	400	0.3	400
22S	fixed gauges, gamma	60	0.03	60
22G	fixed gauges, gamma	80	0.01	80
23S	fixed gauges, beta	200	0.0003	200
23G	fixed gauges, beta	90	0.0001	90
24S	portable gauges	200	1	200
24G	portable gauges	50	20	70
25.	animal research	40	0.7	40

*system number out of order, grouped with like systems

Table 4A, continued: Comparison of Risk Assessment Results - Individual Worker Risk Categories, in System Number Order

Systems		Risk (unit = millirem per year, using 1 sf) Categories (a) normal	(c) off-normal	Total Risk
26S	measuring - XRF	40	0.1	40
26G	measuring - XRF	50	0.1	50
27S	measuring - GC	0.3	0.001	0.3
27G	measuring - GC	0.3	0.001	0.3
28S	measuring - other	600	0.002	600
28G	measuring - other	1	0.0001	1
29S	other small sealed	10	0.00001	10
29G	other small sealed	9	0.000007	9
30.	very small sealed	NA	NA	NA
31.	mfr/dist - sealed	400	1	400
32.	mfr/dist - solids	700	0.04	700
33.	mfr/dist - liquids	500	0.02	500
34.	mfr/dist - gases	600	0.1	600
35.	waste - incineration	3	4	7
36.	waste - compacting	40	0.07	40
37.	waste - packaging	70	0.7	70
38.	waste - other	40	0.5	40

*system number out of order, grouped with like systems

Table 4B: Comparison of Risk Assessment Results - Individual Member of the Public Risk Categories, in System Number Order

Systems No.	Description	Unit = Millirem per year; Risk (1 sf) Categories (b) normal	(d) off-normal	Millirem per year Total
1.	labs, synthesis	6	0.02	6
2.	labs, prepared	1	0.05	1
3.	labs, very small	0.004	0.00009	0.004
4.	nuc med, generator	3	0.05	3
5.	diag nuc med	8	0.005	8
6.	therapeutic nuc med	300	0.7	300
7.	brachy - seeds	10	0.08	10
8.	brachy - manual	10	0.03	10
9.	brachy - LDR	7	0.2	7
10.	brachy - HDR	7	0.2	7
11.	brachy - Sr-90 eye	0	0.00004	0.00004
12.	teletherapy	90	100	200
13.	gamma stereotactic	30	6	40
14.	human use research	4	0.02	4
*39.	medical devices	20	0.2	20
15.	nuclear pharmacy	10	0.01	10
16.	veterinary	90	2	90
17.	well-logging, tracers	2	0.003	2
18	well-logging, sealed	1	2	3
19.	radiography, room	30	40	70
*40.	radiography, field	20	30	50
20.	irradiators, pool	4	0.02	4
21.	irradiators, self-shi	10	2	10
22S	fixed gauges, gamma	10	0.007	10
22G	fixed gauges, gamma	20	0.004	20
23S	fixed gauges, beta	30	0.0001	30
23G	fixed gauges, beta	20	0.0001	20
24S	portable gauges	7	0.03	7
24G	portable gauges	2	0.4	2
25.	animal research	1	0.2	1

*system number out of order, grouped with like systems

Table 4B, continued: Comparison of Risk Assessment Results - Individual Member of the Public Risk Categories, in System Number Order

Systems		Unit = Millirem per year; Risk (1 sf) Categories (b) normal	(d) off-normal	Millirem per year Total
No.	Description			
26S	measuring - XRF	0.8	0.01	0.8
26G	measuring - XRF	1	0.01	1
27S	measuring - GC	0.2	0.0007	0.2
27G	measuring - GC	0.2	0.0006	0.2
28S	measuring - other	30	0.0003	30
28G	measuring - other	0.01	0.00003	0.01
29S	other small sealed	2	0.0002	2
29G	other small sealed	2	0.00002	2
30.	very small sealed	3	0.01	3
31.	mfr/dist - sealed	2	0.5	3
32.	mfr/dist - solids	7	0.2	7
33.	mfr/dist - liquids	3	0.009	3
34.	mfr/dist - gases	4	0.2	4
35.	waste - incineration	3	1	4
36.	waste - compacting	5	0.005	4
37.	waste - packaging	6	0.06	6
38.	waste - other	2	0.07	2

*system number out of order, grouped with like systems

Table 4C: Comparison of Risk Assessment Results, Industry Worker Risk Categories, in System Number Order

Systems No.	Description	Risk (unit = rem per year, 1 sf) Categories (e) normal	(g) off-normal	Total
1.	labs, synthesis	1000	20	1000
2.	labs, prepared	300	6	300
3.	labs, very small	0.5	0.01	0.5
4.	nuc med, generator	20	9	30
5.	diag nuc med	6000	5	6000
6.	therapeutic nuc med	900	500	1400
7.	brachy - seeds	100	0.9	100
8.	brachy - manual	2000	100	2000
9.	brachy - LDR	50	3	50
10.	brachy - HDR	20	0.9	20
11.	brachy - Sr-90 eye	0	0.006	0.006
12.	teletherapy	200	1	200
13.	gamma stereotactic	30	0.06	30
14.	human use research	300	0.1	300
*39.	medical devices	60	0.8	60
15.	nuclear pharmacy	100	30	130
16.	veterinary	80	0.2	80
17	well-logging, tracers	100	1	100
18	well-logging, sealed	400	0.7	400
19.	radiography, room	100	3	100
*40.	radiography, field	5000	50	5000
20.	irradiators, pool	7	0.04	7
21.	irradiators, self-shi	200	0.5	200
22S	fixed gauges, gamma	600	20	600
22G	fixed gauges, gamma	2000	30	2000
23S	fixed gauges, beta	6000	0.01	6000
23G	fixed gauges, beta	6000	0.01	6000
24S	portable gauges	3000	70	3070
24G	portable gauges	500	100	600
25.	animal research	30	0.5	30

*system number out of order, grouped with like systems

Table 4C, continued: Comparison of Risk Assessment Results, Industry Worker Risk Categories, in System Number Order

Systems No.	Description	Risk (unit = rem per year, 1 sf) Categories (e) normal	(g) off-normal	Total
26S	measuring - XRF	300	0.7	300
26G	measuring - XRF	600	2	600
27S	measuring - GC	9	0.04	9
27G	measuring - GC	20	0.08	20
28S	measuring - other	100	7	100
28G	measuring - other	0.6	0.00007	0.6
29S	other small sealed	4	0.09	4
29G	other small sealed	100	3	2
30.	very small sealed	NA	NA	NA
31.	mfr/dist - sealed	200	0.3	20
32.	mfr/dist - solids	200	0.01	200
33.	mfr/dist - liquids	80	0.003	80
34.	mfr/dist - gases	90	0.02	90
35.	waste - incineration	0.07	0.3	0.4
36.	waste - compacting	2	0.004	2
37.	waste - packaging	10	0.7	10
38.	waste - other	2	0.04	2

*system number out of order, grouped with like systems

Table 4D: Comparison of Risk Assessment Results, Industry-Wide Public Risk Categories, in System Number Order

Systems No.	Description	Unit = Rem per year; Risk (1 sf) Categories (f) normal	(h) off-normal	Rem per year Total
1.	labs, synthesis	100	0.5	100
2.	labs, prepared	20	0.3	20
3.	labs, very small	0.1	0.002	0.1
4.	nuc med, generator	0.7	0.01	0.7
5.	diag nuc med	10000	0.06	10000
6.	therapeutic nuc med	3000	1	3000
7.	brachy - seeds	100	0.04	100
8.	brachy, manual	200	0.7	200
9.	brachy, LDR	4	0.1	4
10.	brachy, HDR	4	0.1	4
11.	brachy - Sr-90 eye	0	0.006	0.006
12.	teletherapy	20	30	50
13.	gamma stereotactic	2	0.3	2
14.	human use research	200	0.02	200
*39.	medical devices	60	0.8	60
15.	nuclear pharmacy	10	0.1	10
16.	veterinary	2	0.05	2
17	well-logging, tracers	20	0.02	20
18	well-logging, sealed	20	0.7	20
19.	radiography, room	50	2	50
*40.	radiography, field	2000	40	2000
20.	irradiators, pool	0.6	0.003	0.6
21.	irradiators, self-shi	20	10	30
22S	fixed gauges, gamma	200	0.9	200
22G	fixed gauges, gamma	800	2	800
23S	fixed gauges, beta	2000	0.01	2000
23G	fixed gauges, beta	3000	0.02	3000
24S	portable gauges	300	4	300
24G	portable gauges	70	10	80
25.	animal research	0.5	0.1	0.6

*system number out of order, grouped with like systems

Table 4D, continued: Comparison of Risk Assessment Results, Industry-Wide Public Risk Categories, in System Number Order

Systems No.	Description	Unit = Rem per year; Risk (1 sf) Categories (f) normal	(h) off-normal	Total Rem per year
26S	measuring - XRF	10	0.1	10
26G	measuring - XRF	40	0.3	40
27S	measuring - GC	9	0.04	9
27G	measuring - GC	20	0.07	20
28S	measuring - other	9	7	20
28G	measuring - other	0.01	0.00003	0.01
29S	other small sealed	0.5	0.01	0.5
29G	other small sealed	30	1	30
30.	very small sealed	40000	4	40000
31.	mfr/dist - sealed	0.02	0.07	0.09
32.	mfr/dist - solids	0.03	0.0008	0.03
33.	mfr/dist - liquids	0.01	0.0004	0.01
34.	mfr/dist - gases	0.02	0.0008	0.02
35.	waste - incineration	0.09	0.009	0.1
36.	waste - compacting	0.1	0.0002	0.1
37.	waste - packaging	0.6	0.006	0.6
38.	waste - other	0.2	0.006	0.2

*system number out of order, grouped with like systems

Table 5A: Comparison of Risk Assessment Results to NRC Worker Dose Limits - Individual Risk Categories, in System Number Order

Systems No.	Description	Risk (millirem per year) (a)	Risk (millirem per year) (c)	Fraction of 5,000 mrem Worker Limit (Unitless) (a)	Fraction of 5,000 mrem Worker Limit (Unitless) (c)
1.	labs, synthesis	10	0.2	0.002	0.00004
2.	labs, prepared	2	0.08	0.0004	0.000016
3.	labs, very small	0.005	0.0001	0.000001	0.00000002
4.	nuc med, generator	70	30	0.014	0.006
5.	diag nuc med	500	0.4	0.1	0.00008
6.	therapeutic nuc med	300	100	0.06	0.02
7.	brachy - seeds	100	0.9	0.02	0.00018
8.	brachy - manual	800	60	0.16	0.012
9.	brachy - LDR	100	9	0.02	0.0018
10.	brachy - HDR	50	2	0.01	0.0004
11.	brachy - Sr-90 eye	0	0.002	0	0.0000004
12.	teletherapy	800	5	0.16	0.001
13.	gamma stereotactic	100	0.3	0.02	0.00006
14.	human use research	200	0.1	0.04	0.00002
*39.	medical devices	30	0.3	0.006	0.00006
15.	nuclear pharmacy	50	10	0.01	0.002
16.	veterinary	800	2	0.16	0.0004
17	well-logging, tracers	900	9	0.18	0.0018
18	well-logging, sealed	600	1	0.12	0.0002
19.	radiography, room	200	60	0.04	0.012
*40.	radiography, field	2000	20	0.4	0.004
20.	irradiators, pool	30	0.2	0.006	0.00004
21.	irradiators, self-shi	400	0.3	0.08	0.00006
22S	fixed gauges, gamma	60	0.03	0.012	0.000006
22G	fixed gauges, gamma	80	0.01	0.016	0.000002
23S	fixed gauges, beta	200	0.0003	0.04	0.00000006
23G	fixed gauges, beta	90	0.0001	0.018	0.00000002
24S	portable gauges	200	1	0.04	0.0004
24G	portable gauges	50	20	0.01	0.004
25.	animal research	40	0.7	0.008	0.00014

Table 5A, continued: Comparison of Risk Assessment Results to NRC Worker Dose Limits - Individual Risk Categories, in System Number Order

Systems No.	Description	Risk (millirem per year) (a)	Risk (millirem per year) (c)	Fraction of 5,000 mrem Worker Limit (Unitless) (a)	Fraction of 5,000 mrem Worker Limit (Unitless) (c)
26S	measuring - XRF	40	0.1	0.008	0.00002
26G	measuring - XRF	50	0.1	0.01	0.00002
27S	measuring - GC	0.3	0.001	0.00006	0.0000002
27G	measuring - GC	0.3	0.001	0.00006	0.0000002
28S	measuring - other	600	0.002	0.12	0.0000004
28G	measuring - other	1	0.0001	0.0002	0.00000002
29S	other small sealed	10	0.00001	0.002	0.000000002
29G	other small sealed	9	0.000007	0.0018	0.0000000014
30.	very small sealed	NA	NA		
31.	mfr/dist - sealed	400	1	0.08	0.0002
32.	mfr/dist - solids	700	0.04	0.14	0.000008
33.	mfr/dist - liquids	500	0.02	0.1	0.000004
34.	mfr/dist - gases	600	0.1	0.12	0.000004
35.	waste - incineration	3	4	0.0006	0.0008
36.	waste - compacting	40	0.07	0.008	0.000014
37.	waste - packaging	70	0.7	0.014	0.00014
38.	waste - other	40	0.5	0.008	0.0001

Table 5B: Comparison of Risk Assessment Results to NRC Public Dose Limits - Individual Risk Categories, in System Number Order

Systems No.	Description	Risk Categories Risk (millirem per year) (b)	(d)	Fraction of 100 mrem Public Limit (Unitless) (b)	(d)
1.	labs, synthesis	6	0.02	0.06	0.0002
2.	labs, prepared	1	0.05	0.01	0.0005
3.	labs, very small	0.004	0.00009	0.00004	0.0000009
4.	nuc med, generator	3	0.05	0.03	0.0005
5.	diag nuc med	8	0.005	0.08	0.000005
6.	therapeutic nuc med	300	0.7	3	0.007
7.	brachy - seeds	10	0.08	0.1	0.0008
8.	brachy, manual	10	0.03	0.1	0.0003
9.	brachy, LDR	7	0.2	0.07	0.002
10.	brachy, HDR	7	0.2	0.07	0.002
11.	brachy - Sr-90 eye	0	0.00004	0	0.0000004
12.	teletherapy	90	100	0.9	1
13.	gamma stereotactic	30	6	0.3	0.06
14.	human use research	4	0.02	0.04	0.002
*39.	medical devices	20	0.2	0.2	0.002
15.	nuclear pharmacy	10	0.01	0.1	0.0001
16.	veterinary	90	2	0.9	0.02
17	well-logging, tracers	2	0.003	0.02	0.00003
18	well-logging, sealed	1	2	0.01	0.02
19.	radiography, room	30	40	0.3	0.4
*40.	radiography, field	20	30	0.2	0.3
20.	irradiators, pool	4	0.02	0.04	0.0002
21.	irradiators, self-shi	10	2	0.1	0.02
22S	fixed gauges, gamma	10	0.007	0.1	0.00007
22G	fixed gauges, gamma	20	0.004	0.2	0.00004
23S	fixed gauges, beta	30	0.0001	0.3	0.000001
23G	fixed gauges, beta	20	0.0001	0.2	0.000001
24S	portable gauges	7	0.03	0.07	0.0003
24G	portable gauges	2	0.4	0.02	0.004
25.	animal research	1	0.2	0.01	0.002

Table 5B, continued: Comparison of Risk Assessment Results to NRC Public Dose Limits - Individual Risk Categories, in System Number Order

Systems No.	Description	Risk Categories Risk (millirem per year) (b)	(d)	Fraction of 100 mrem Public Limit (Unitless) (b)	(d)
26S	measuring - XRF	0.8	0.01	0.008	0.0001
26G	measuring - XRF	1	0.01	0.01	0.0001
27S	measuring - GC	0.2	0.0007	0.002	0.000007
27G	measuring - GC	0.2	0.0006	0.002	0.000006
28S	measuring - other	30	0.0003	0.3	0.000003
28G	measuring - other	0.01	0.00003	0.0001	0.0000003
29S	other small sealed	2	0.0002	0.02	0.000002
29G	other small sealed	2	0.00002	0.02	0.0000002
30.	very small sealed	3	0.01	0.03	0.0001
31.	mfr/dist - sealed	2	0.5	0.02	0.005
32.	mfr/dist - solids	7	0.2	0.07	0.002
33.	mfr/dist - liquids	3	0.009	0.03	0.00009
34.	mfr/dist - gases	4	0.2	0.04	0.002
35.	waste - incineration	3	1	0.03	0.01
36.	waste - compacting	5	0.005	0.05	0.00005
37.	waste - packaging	6	0.06	0.06	0.00006
38.	waste - other	2	0.07	0.02	0.0002

Table 6: Comparison of Results for Category (a) Individual, Worker, Normal Conditions to Results of Estimated Annual Worker Doses (Taken from NUREG-1712 "Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel")

Systems		Risk	Estimated Doses (mrem/year)		
No.	Description	(mrem/year)	Mean[a]	Modal Range[b]	Median Range[c]
1.	labs, synthesis	10	66	ND	ND-50
2.	labs, prepared	2	26	ND	ND
3.	labs, very small	0.005	9	ND	ND
4.	nuc med, generator [d]	70	294	201-500	101-200
5.	diag nuc med[d]	500	155	101-200	101-200
6.	therapeutic nuc med	300	211	101-200	101-200
7.	brachy, seeds	100	154	51-100	51-100
8.	brachy, manual	800	231	ND-50	51-100
9.	brachy, LDR	100	91	ND-50	ND-50
10.	brachy, HDR	50	76	ND-50	ND-50
11.	brachy - Sr-90 eye	0	56	ND-50	ND-50
12.	teletherapy	800	56	ND	ND-50
13.	gamma stereotactic	100	88	ND-50	ND-50
14.	human use research [e]	200	102	101-200	51-100
*39.	medical devices	30	25	ND-50	ND-50
15.	nuclear pharmacy [f]	50	355	101-200	101-200
16.	veterinary use	800	125	ND-50	51-100
17	well-logging, tracers	900	171	201-500	51-100
18	well-logging, sealed	600	135	ND-50	51-100
19.	radiography, room [f]	200	262	ND-50	101-200
*40.	radiography, field [f]	2000	482	201-500	201-500
20.	irradiators, pool	30	65	ND-50	ND-50
21.	irradiators, self-shi	400	13	ND	ND
22S	fixed gauges, gamma	60	20	ND	ND
22G	fixed gauges, gamma	80			
23S	fixed gauges, beta	200	11	ND	ND
23G	fixed gauges, beta	90			
24S	portable gauges	200	58	ND-50	ND-50
24G	portable gauges	50			
25.	animal research	40	63	ND-50	ND-50

Table 6, continued: Comparison of Results for Category (a) Individual, Worker, Normal Conditions to Results of Estimated Annual Worker Doses (Taken from NUREG-1712 "Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel)

Systems No.	Description	Risk (mrem/year)	Estimated Doses (mrem/year) Mean[a]	Modal Range[b]	Median Range[c]
26S	measuring - XRF	40	27	ND	ND-50
26G	measuring - XRF	50			
27S	measuring - GC	0.3	6	ND	ND
27G	measuring - GC	0.3			
28S	measuring - other	600	11	ND	ND
28G	measuring - other	1			
29S	other small sealed	10	21	ND	ND
29G	other small sealed	9			
30.	Very small sealed	NA?	5	ND	ND
31.	mfr/dist - sealed [f]	400	167	ND	ND-50
32.	mfr/dist - solids [f]	700	362	ND-50	101-200
33.	mfr/dist - liquids [f]	500	236	ND-50	51-100
34.	mfr/dist - gases [f]	600	223	ND-50	ND-50
35.	waste - incineration	3	44	ND-50	ND-50
36.	waste - compacting	40	89	ND-50	ND-50/51-100
37.	waste - packaging	70	129	ND-50	51-100
38.	waste - other [g]	40	111	ND-50	51-100
xx	decon services[h]	xx	785	501-1000	501-1000
xx	nuclear laundries[h]	xx	210	101-200	101-200

Notes

a - This mean was calculated using unequal class intervals provided to respondents, therefore low dose estimates received less weight than high dose estimates. The mean doses listed are therefore somewhat higher than a true mean. This is further demonstrated by the modal and median ranges shown.

b - The modal range is that dose range most frequently listed by respondents.

c - The median range is the dose range with the middle value of those ranges listed by respondents.

d - The risk assessment for System 4 was limited only to the use of generators in a nuclear medicine department; System 5 accounted for risk from activities performed in a nuclear medicine department, other than use of a generator. The survey categories for nuclear medicine were 35.200 including use of generators, and 35.200 without the use of generators.

Table 6, continued: Comparison of Results for Category (a) Individual, Worker, Normal Conditions to Results of Estimated Annual Worker Doses (Taken from NUREG-1712 "Results of Survey of NRC and Agreement State Materials Licensing and Inspection Personnel)

Notes, continued

e - The risk assessment focused only on human use research, most of which can be performed under 35.100. Other types of human use research were not included in the calculation of the risk.

f - The NRC requires radiographers and manufacturers (including nuclear pharmacies) to report the results of individual monitoring. Below are some results for comparison with the above data:

Radiographers: In 1996, 144 radiography licensees reported individual monitoring of 3,631 individuals, of whom 2,537 had measurable doses. The average dose was 380 millirem and the average measurable dose was 550 millirem. Over the period of 1987 through 1996, the number of licensees reporting and the number of workers monitored decreased by more than half, and average doses and average measurable doses increased.

Manufacturers (and nuclear pharmacies): In 1996, 36 manufacturers reported individual monitoring for 2,628 individuals of whom 1,239 had measurable doses. The average dose was 210 millirem and the average measurable dose was 450 millirem. Over the period of 1987 through 1996, the number of licensees reporting increased through 1992 (peak 67) then decreased, the number of workers increased through 1992 (peak 5,210) then decreased again. The average doses decreased as the number of workers increased, but the average measurable doses generally increased over that period.

g - The risk assessment considered primarily "solidification" as an "other" method of waste treatment. Other processes, such as crushing of liquid scintillation vials and decay-in-storage, were also evaluated, but solidification was by far the biggest contributor to dose and risk. The survey listed only solidification of waste.

h - The risk assessment did not include the activities of licensees who perform decontamination services, or nuclear laundries, which were suggested by individuals who took part in the survey. Other activities that were not included in either the risk assessment or the survey were those of licensees who perform services such as installation, removal, and maintenance of devices such as fixed gauges, teletherapy units, and irradiators; calibration services; leak-test services; and laboratories that perform sample analysis for others.

Table 7A: Comparison of Individual Worker and Public Risks to NRC Inspection Prioritization

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
1.	labs, synthesis	10	6	5 [1, 2, 3,5]
2.	labs, prepared	2	1	5 [1, 2, 3,5]
3.	labs, very small	0.005	0.004	5, GL, exempt [1, 2, 3,5]
4.	nuc med, generator	70	3	3, 5 [1]
5.	diag nuc med	500	8	3, 5 [1]
6.	therapeutic nuc med	300	300	3, 5 [1]
7.	brachy - seeds	100	10	3, 5 [1]
8.	brachy - manual	800	10	3, 5 [1]
9.	brachy - LDR	100	7	3, 5 [1]
10.	brachy - HDR	50	7	1
11.	brachy - Sr-90 eye	0	0	3, 5 [1]
12.	teletherapy	800	90	3
13.	gamma stereotactic	100	30	3
14.	human use research	200	4	3, 5 [1]
*39.	medical devices	30	20	5 [1]
15.	nuclear pharmacy	50	10	1
16.	veterinary	800	90	5
17	well-logging, tracers	900	2	3
18	well-logging, sealed	600	1	3
19.	radiography, room	200	30	1
*40.	radiography, field	2000	20	1
20.	irradiators, pool	30	4	1
21.	irradiators, self-shi	400	10	3, 5
22S	fixed gauges, gamma	60	10	5
22G	fixed gauges, gamma	80	20	GL
23S	fixed gauges, beta	200	30	5
23G	fixed gauges, beta	90	20	GL
24S	portable gauges	200	7	5
24G	portable gauges	50	2	GL
25.	animal research	40	1	5 [1, 2, 3, 5]

Table 7A, continued: Comparison of Individual Worker and Public Risks to NRC Inspection Prioritization

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
26S	measuring - XRF	40	0.8	7
26G	measuring - XRF	50	1	GL
27S	measuring - GC	0.3	0.2	7
27G	measuring - GC	0.3	0.2	GL
28S	measuring - other	600	30	5, 7
28G	measuring - other	1	0.01	GL
29S.	other small sealed	10	2	5 [1, 2, 3, 5]
29G.	other small sealed	9	2	GL
30.	very small sealed	NA	3	5, GL, exempt [1, 2, 3, 5]
31.	mfr/dist - sealed	400	2	3, [1, 2, 3]
32.	mfr/dist - solids	700	7	3, [1, 2, 3]
33.	mfr/dist - liquids	500	3	3, [1, 2, 3]
34.	mfr/dist - gases	600	4	3, [1, 2, 3]
35.	waste - incineration	3	3	1
36.	waste - compacting	40	5	1
37.	waste - packaging	70	6	1
38.	waste - other	40	2	1

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.

Table 7B: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Prioritization

Systems No.	Description	Risk (Millirem/year) Categories (C)	(D)	NRC NRC Inspection Priority
1.	labs, synthesis	0.2	0.02	5 [1, 2, 3,5]
2.	labs, prepared	0.08	0.05	5 [1, 2, 3,5]
3.	labs, very small	0.0001	0.00009	5, GL, exempt [1, 2, 3,5]
4.	nuc med, generator	30	0.05	3, 5 [1]
5.	diag nuc med	0.4	0.005	3, 5 [1]
6.	therapeutic nuc med	100	0.7	3, 5 [1]
7.	brachy - seeds	0.9	0.08	3, 5 [1]
8.	brachy - manual	60	0.03	3, 5 [1]
9.	brachy - LDR	9	0.2	3, 5 [1]
10.	brachy - HDR	2	0.2	1
11.	brachy - Sr-90 eye	0.002	0.00004	3, 5 [1]
12.	teletherapy	5	100	3
13.	gamma stereotactic	0.3	6	3
14.	human use research	0.1	0.02	3, 5 [1]
*39.	medical devices	0.3	0.2	5, [1]
15.	nuclear pharmacy	10	0.01	1
16.	veterinary	2	2	5
17	well-logging, tracers	9	0.003	3
18	well-logging, sealed	1	2	3
19.	radiography, room	60	40	1
*40.	radiography, field	20	30	1
20.	irradiators, pool	0.2	0.02	1
21.	irradiators, self-shi	0.3	2	3, 5
22S	fixed gauges, gamma	0.03	0.007	5
22G	fixed gauges, gamma	0.01	0.004	GL
23S	fixed gauges, beta	0.0003	0.0001	5
23G	fixed gauges, beta	0.0001	0.0001	GL
24S	portable gauges	1	0.03	5
24G	portable gauges	20	0.4	GL
25.	animal research	0.7	0.2	5 [1, 2, 3, 5]

Table 7B, continued: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Prioritization

Systems No.	Description	Risk (Millirem/year) Categories (C)	(D)	NRC NRC Inspection Priority
26S	measuring - XRF	0.1	0.01	7
26G	measuring - XRF	0.1	0.01	GL
27S	measuring - GC	0.001	0.0007	7
27G	measuring - GC	0.001	0.0006	GL
28S	measuring - other	0.002	0.0003	7
28G	measuring - other	0.0001	0.00003	GL
29S.	other small sealed	0.00001	0.0002	5
29G.	other small sealed	0.000007	0.00002	GL
30.	very small sealed	NA	0.01	5, GL, exempt
31.	mfr/dist - sealed	1	0.5	3, [1,2,3]
32.	mfr/dist - solids	0.04	0.2	3, [1,2,3]
33.	mfr/dist - liquids	0.02	0.009	3, [1,2,3]
34.	mfr/dist - gases	0.01	0.2	3, [1,2,3]
35.	waste - incineration	4	1	1
36.	waste - compacting	0.07	0.005	1
37.	waste - packaging	0.7	0.06	1
38.	waste - other	0.5	0.07	1

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.

Table 7C: Comparison of Risks to Individuals to NRC Inspection Prioritization, by Worker Normal Risk Order

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
*40.	radiography, field	2000	20	1
17	well-logging, tracers	900	2	3
8.	brachy - manual	800	10	3, 5 [1]
12.	teletherapy	800	90	3
16.	veterinary	800	90	5
32.	mfr/dist - solids	700	7	3, [1, 2, 3]
18	well-logging, sealed	600	1	3
28S	measuring - other	600	30	5, 7
34.	mfr/dist - gases	600	4	3, [1, 2, 3]
5.	diag nuc med	500	8	3, 5 [1]
33.	mfr/dist - liquids	500	3	3, [1, 2, 3]
21.	irradiators, self-shi	400	10	3, 5
31.	mfr/dist - sealed	400	2	3, [1, 2, 3]
6.	therapeutic nuc med	300	300	3, 5 [1]
14.	human use research	200	4	3, 5 [1]
19.	radiography, room	200	30	1
23S	fixed gauges, beta	200	30	5
24S	portable gauges	200	7	5
7.	brachy - seeds	100	10	3, 5 [1]
9.	brachy - LDR	100	7	3, 5 [1]
13.	gamma stereotactic	100	30	3
23G	fixed gauges, beta	90	20	GL
22G	fixed gauges, gamma	80	20	GL
4.	nuc med, generator	70	3	3, 5 [1]
37.	waste - packaging	70	6	1
22S	fixed gauges, gamma	60	10	5
10.	brachy - HDR	50	7	1
15.	nuclear pharmacy	50	10	1
24G	portable gauges	50	2	GL
26G	measuring - XRF	50	1	GL

Table 7C, continued: Comparison of Risks to Individuals to NRC Inspection Prioritization, by Worker Normal Risk Order

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
25.	animal research	40	1	5 [1, 2, 3, 5]
26S	measuring - XRF	40	0.8	7
36.	waste - compacting	40	5	1
38.	waste - other	40	2	1
*39.	medical devices	30	20	5 [1]
20.	irradiators, pool	30	4	1
1.	labs, synthesis	10	6	5 [1, 2, 3,5]
29S.	other small sealed	10	2	5 [1, 2, 3, 5]
29G.	other small sealed	9	2	GL
35.	waste - incineration	3	3	1
2.	labs, prepared	2	1	5 [1, 2, 3,5]
28G	measuring - other	1	0.01	GL
27S	measuring - GC	0.3	0.2	7
27G	measuring - GC	0.3	0.2	GL
3.	labs, very small	0.005	0.004	5, GL, exempt [1, 2, 3,5]
11.	brachy - Sr-90 eye	0	0	3, 5 [1]
30.	very small sealed	NA	3	5, GL, exempt [1, 2, 3, 5]

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.

Table 7D: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Prioritization, in Worker Off-Normal Risk Order

Systems No.	Description	Risk (millirem/year) Categories (c)	(d)	NRC Inspection Priority(ies)
6.	therapeutic nuc med	100	0.7	3, 5 [1]
8.	brachy - manual	60	0.03	3, 5 [1]
19.	radiography, room	60	40	1
4.	nuc med, generator	30	0.05	3, 5 [1]
*40.	radiography, field	20	30	1
24G	portable gauges	20	0.4	GL
15.	nuclear pharmacy	10	0.01	1
9.	brachy - LDR	9	0.2	3, 5 [1]
17	well-logging, tracers	9	0.003	3
12.	teletherapy	5	100	3
35.	waste - incineration	4	1	1
10.	brachy - HDR	2	0.2	1
16.	veterinary	2	2	5
18	well-logging, sealed	1	2	3
24S	portable gauges	1	0.03	5
31.	mfr/dist - sealed	1	0.5	3, [1,2,3]
7.	brachy - seeds	0.9	0.08	3, 5 [1]
25.	animal research	0.7	0.2	5 [1, 2, 3, 5]
37.	waste - packaging	0.7	0.06	1
38.	waste - other	0.5	0.07	1
5.	diag nuc med	0.4	0.005	3, 5 [1]
13.	gamma stereotactic	0.3	6	3
*39.	medical devices	0.3	0.2	5, [1]
21.	irradiators, self-shi	0.3	2	3, 5
1.	labs, synthesis	0.2	0.02	5 [1, 2, 3,5]
20.	irradiators, pool	0.2	0.02	1
14.	human use research	0.1	0.02	3, 5 [1]
26S	measuring - XRF	0.1	0.01	7
26G	measuring - XRF	0.1	0.01	GL
2.	labs, prepared	0.08	0.05	5 [1, 2, 3,5]

Table 7D, continued: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Prioritization, in Worker Off-Normal Risk Order

Systems No.	Description	Risk (millirem/year) Categories (c)	(d)	NRC Inspection Priority(ies)
36.	waste - compacting	0.07	0.005	1
32.	mfr/dist - solids	0.04	0.2	3, [1,2,3]
22S	fixed gauges, gamma	0.03	0.007	5
33.	mfr/dist - liquids	0.02	0.009	3, [1,2,3]
22G	fixed gauges, gamma	0.01	0.004	GL
34.	mfr/dist - gases	0.01	0.2	3, [1,2,3]
11.	brachy - Sr-90 eye	0.002	0.00004	3, 5 [1]
28S	measuring - other	0.002	0.0003	7
27S	measuring - GC	0.001	0.0007	7
27G	measuring - GC	0.001	0.0006	GL
23S	fixed gauges, beta	0.0003	0.0001	5
3.	labs, very small	0.0001	0.00009	5, GL, exempt [1, 2, 3,5]
23G	fixed gauges, beta	0.0001	0.0001	GL
28G	measuring - other	0.0001	0.00003	GL
29S.	other small sealed	0.00001	0.0002	5
29G.	other small sealed	0.000007	0.00002	GL
30.	very small sealed	NA	0.01	5, GL, exempt

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.

Table 7E: Comparison of Risks to Individuals, Normal Conditions, to NRC Inspection Prioritization, by NRC Priority Order

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
10.	brachy - HDR	50	7	1
15.	nuclear pharmacy	50	10	1
19.	radiography, room	200	30	1
*40.	radiography, field	2000	20	1
20.	irradiators, pool	30	4	1
35.	waste - incineration	3	3	1
36.	waste - compacting	40	5	1
37.	waste - packaging	70	6	1
38.	waste - other	40	2	1
12.	teletherapy	800	90	3
13.	gamma stereotactic	100	30	3
17	well-logging, tracers	900	2	3
18	well-logging, sealed	600	1	3
31.	mfr/dist - sealed	400	2	3 [1, 2, 3]
32.	mfr/dist - solids	700	7	3 [1, 2, 3]
33.	mfr/dist - liquids	500	3	3 [1, 2, 3]
34.	mfr/dist - gases	600	4	3 [1, 2, 3]
4.	nuc med, generator	70	3	3, 5 [1]
5.	diag nuc med	500	8	3, 5 [1]
6.	therapeutic nuc med	300	300	3, 5 [1]
7.	brachy - seeds	100	10	3, 5 [1]
8.	brachy - manual	800	10	3, 5 [1]
9.	brachy - LDR	100	7	3, 5 [1]
11.	brachy - Sr-90 eye	0	0	3, 5 [1]
14.	human use research	200	4	3, 5 [1]
21.	irradiators, self-shi	400	10	3, 5
16.	veterinary	800	90	5
22S	fixed gauges, gamma	60	10	5
23S	fixed gauges, beta	200	30	5
24S	portable gauges	200	7	5

Table 7E, continued: Comparison of Risks to Individuals, Normal Conditions, to NRC Inspection Prioritization, by NRC Priority Order

Systems No.	Description	Risk (millirem per year) Categories (a)	(b)	NRC Inspection Priority(ies)
*39.	medical devices	30	20	5 [1]
1.	labs, synthesis	10	6	5 [1, 2, 3,5]
2.	labs, prepared	2	1	5 [1, 2, 3,5]
25.	animal research	40	1	5 [1, 2, 3, 5]
29S.	other small sealed	10	2	5 [1, 2, 3, 5]
28S	measuring - other	600	30	5, 7
3.	labs, very small	0.005	0.004	5, GL, exempt [1, 2, 3,5]
30.	very small sealed	NA	3	5, GL, exempt [1, 2, 3, 5]
26S	measuring - XRF	40	0.8	7
27S	measuring - GC	0.3	0.2	7
22G	fixed gauges, gamma	80	20	GL
23G	fixed gauges, beta	90	20	GL
24G	portable gauges	50	2	GL
26G	measuring - XRF	50	1	GL
29G.	other small sealed	9	2	GL
28G	measuring - other	1	0.01	GL
27G	measuring - GC	0.3	0.2	GL

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.

Table 7F: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Priority, in NRC Priority Order

Systems No.	Description	Risk (millirem/year) Categories (c)	(d)	NRC Inspection Priority(ies)
10.	brachy - HDR	2	0.2	1
15.	nuclear pharmacy	10	0.01	1
19.	radiography, room	60	40	1
*40.	radiography, field	20	30	1
20.	irradiators, pool	0.2	0.02	1
35.	waste - incineration	4	1	1
36.	waste - compacting	0.07	0.005	1
37.	waste - packaging	0.7	0.06	1
38.	waste - other	0.5	0.07	1
12.	teletherapy	5	100	3
13.	gamma stereotactic	0.3	6	3
17.	well-logging, tracers	9	0.003	3
18.	well-logging, sealed	1	2	3
31.	mfr/dist - sealed	1	0.5	3 [1,2,3]
32.	mfr/dist - solids	0.04	0.2	3 [1,2,3]
33.	mfr/dist - liquids	0.02	0.009	3 [1,2,3]
34.	mfr/dist - gases	0.01	0.2	3 [1,2,3]
4.	nuc med, generator	30	0.05	3, 5 [1]
5.	diag nuc med	0.4	0.005	3, 5 [1]
6.	therapeutic nuc med	100	0.7	3, 5 [1]
7.	brachy - seeds	0.9	0.08	3, 5 [1]
8.	brachy - manual	60	0.03	3, 5 [1]
9.	brachy - LDR	9	0.2	3, 5 [1]
11.	brachy - Sr-90 eye	0.002	0.00004	3, 5 [1]
14.	human use research	0.1	0.02	3, 5 [1]
21.	irradiators, self-shi	0.3	2	3, 5
16.	veterinary	2	2	5
22S	fixed gauges, gamma	0.03	0.007	5
23S	fixed gauges, beta	0.0003	0.0001	5
24S	portable gauges	1	0.03	5

Table 7F, continued: Comparison of Risks to Individuals, Off- Normal Conditions, to NRC Inspection Priority, in NRC Priority Order

Systems No.	Description	Risk (millirem/year) Categories (c)	(d)	NRC Inspection Priority(ies)
*39.	medical devices	0.3	0.2	5, [1]
1.	labs, synthesis	0.2	0.02	5 [1, 2, 3,5]
2.	labs, prepared	0.08	0.05	5 [1, 2, 3,5]
25.	animal research	0.7	0.2	5 [1, 2, 3, 5]
29S.	other small sealed	0.00001	0.0002	5 [1, 2, 3, 5]
28S	measuring - other	0.002	0.0003	5, 7
3.	labs, very small	0.0001	0.00009	5, GL, exempt [1, 2, 3,5]
30.	very small sealed	NA	0.01	5, GL, exempt
26S	measuring - XRF	0.1	0.01	7
27S	measuring - GC	0.001	0.0007	7
22G	fixed gauges, gamma	0.01	0.004	GL
23G	fixed gauges, beta	0.0001	0.0001	GL
24G	portable gauges	20	0.4	GL
26G	measuring - XRF	0.1	0.01	GL
27G	measuring - GC	0.001	0.0006	GL
28G	measuring - other	0.0001	0.00003	GL
29G.	other small sealed	0.000007	0.00002	GL

Priority 1 - inspected each year
Priority 2 - inspected every 2 years
Priority 3 - inspected every 3 years
Priority 5 - inspected every 5 years
Priority 7 - inspected once, no routine re-inspection

[ ] indicates inspection frequency for a specific license of broad scope which could include this activity. Medical licenses of broad scope and Type A manufacturing broad scope licenses are inspected each year; Type A research broad scope licenses, Type A academic broad scope licenses, and Type B manufacturing broad scope licenses are inspected every 2 years; Type C manufacturing broad scope licenses, Type B research broad scope licenses and Type B academic broad licenses are inspected every 3 years; Type C research broad scope licenses and Type C academic broad scope licenses are inspected every 5 years.

GL general licenses are not routinely inspected.