Radioactive Materials Product Stewardship

A Background Report for the National Dialogue on Radioactive Materials Product Stewardship

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The principal authors of this report are Gregory J. Morose from the Product Stewardship Institute and Thomas P. Balf from Nexus Environmental Partners. We also wish to acknowledge the U.S. Environmental Protection Agency for their financial support of this project.

1. EXECUTIVE SUMMARY

Interest in the management of devices containing radioisotopes has increased substantially over the last year as a result of the potential terrorist threat of the detonation of a "radiological dispersal device" or "dirty bomb," created by combining traditional explosives with a source of radioactivity. The world has changed and the proper control of devices containing radiological materials has taken on new importance. In addition, there is ongoing concern with the environmental impact resulting from inadequate end of life management for products containing radioactive materials.

Radiation control professionals have long recognized that certain radioactive devices are often lost, stolen, abandoned, or improperly disposed. Lubenau and Yusko (2000) estimate as many as 500,000 registered devices are unused and no longer needed or wanted – "disused sources" – ready to be lost, stolen or abandoned. This report examines two types of devices, nuclear fixed gauges and tritium exit signs, which are more likely to be lost, stolen or abandoned because they have historically been subject to the minimal regulatory requirements of a general license. The improper management of these devices can (and has) lead to environmental problems – the subject of this report.

The purpose of this technical report is to evaluate the relevant product stewardship issues associated with nuclear fixed gauges and tritium exit signs. Nuclear fixed gauges are used for industrial process control to monitor or measure materials for such characteristics as density, thickness, and flow. A nuclear fixed gauge operates on the principle that the radiation emitted from the radioactive material will be reduced in intensity by matter between the radioactive material and the detector. Tritium exit signs are typically used in buildings to illuminate egress routes in areas where access to electrical service is unreliable, unavailable or costly. A tritium exit sign operates by creating a continuous light when phosphor, used to internally coat the glass sealed tube that contains the tritium, emits light in the presence of radiation.

Our review seeks to take a fresh and comprehensive look at some age old problems in a brand new era. We have used the wide-angle lens of the product stewardship perspective, which looks at environmental impacts associated with a product over its entire life cycle. Based on more than thirty interviews and extensive research, our findings suggest that improper management and disposal of Generally Licensed (GL) nuclear fixed gauges continues to pose environment risk. Consequently, product stewardship enhancements appear to be needed for these devices.

We have summarized our concerns in Table 1 on the next page. In the table, we distinguish between "Manufacturing and Use" and "End-of-Life Management" concerns. The levels of concern are based upon the likelihood of an event occurring and the impact of the event if it does occur. These are preliminary assessments based upon quantitative and qualitative data obtained during the research for this report. These assessments may be refined by feedback from the project stakeholders during the dialogue process.

Our research suggests there is "some concern" for environmental impacts associated with abnormal use conditions and improper disposal of tritium exit signs. With respect to nuclear fixed gauges, there is "high concern" for the potential of these gauges to cause disruptions at scrap metal processing facilities or to pass through undetected and cause contamination in the re-processing and melting of the recycled metal. We believe there is "some to moderate" level of environmental concern for the potential use of a nuclear fixed gauge to make a dirty bomb, and "moderate concern" that nuclear fixed gauges may be improperly disposed in solid waste or demolition/construction waste streams.

TABLE 1 SUMMARY OF KEY ISSUES

	Manufacturing and Use		**End-of-Life Management**		
	Device Manufacture & Transport[1]	**Abnormal Use Conditions**[2]	**Security/ Terrorism Threat**[3]	**Improper Disposal**[4]	**Scrap Metal Processing**[5]
Nuclear Fixed Gauges (general license)	1	2	2 - 3	3	3 - 4
Tritium Exit Signs	1	2	1	2	1

(1) – Minimal or no concern; (2) – Some concern; (3) – Moderate concern; and (4) – High concern.

Footnotes:

1. Device Manufacture and Transport: Refers to environmental issues (e.g., releases) during the manufacture of the devices or the transport to or from the end-user. Ranking based primarily on the limited number of entries in NRC's Nuclear Materials Events Database (NMED).
2. Abnormal Use Conditions: Refers to potential impacts to human health and the environment during abnormal conditions, which may include, but not be limited to, equipment failure or damage from malicious acts, fire, overheating, or breakage. Assessment based primarily on review of NMED Database.
3. Security/Terrorism: Refers to the potential for a device to be lost or stolen AND made into a dirty bomb. Evaluation based on recent articles referenced in the bibliography.
4. Improper Disposal: Refers to actual or potential administrative failures (e.g., loss of control of material, abandonment, stolen) and environmental impacts (e.g., disposal as solid or construction demolition waste) as a result of intentional or unintentional actions. Evaluation based on NMED database, articles, interviews.
5. Scrap Metal Processing. Refers to the actual or potential environmental impacts associated with devices improperly disposed as scrap metal. Evaluation based on NMED database, articles, interviews.

In the following paragraphs, we present a summary of our findings and observations corresponding to the relevant sections of this research report.

Regulatory System

Nuclear fixed gauges containing byproduct radionuclides and tritium exit signs are devices regulated primarily by the Nuclear Regulatory Commission (NRC) or by a state authorized to administer its own, comparable program ("Agreement States"). Other federal agencies play ancillary but important roles in the management of these devices, such as during transportation, importation or in the event of a release. Under the NRC regulatory framework, a user must receive a general license to own or operate the device. Over the last 20 years, approximately 73,000 nuclear fixed gauges and more than 1,000,000 tritium exit signs have been registered, under a general license, according to estimates derived from the NRC registration database. The NRC revised substantially the GL regulations in December 2000 for the purpose of improving oversight of nuclear fixed gauges. For example, the revisions imposed annual renewal registrations and fees for GL licensees using devices containing certain levels of cesium, strontium, cobalt and americium radioisotopes. Our findings include the following:

- Land burial options in the United States for nuclear fixed gauges and tritium exit signs are limited to two disposal facilities, located in Barnwell, SC. and Richland, WA. The low level waste commissions have not succeeded in the siting of additional land disposal facilities.
- The well-documented lack of accountability for GL licensed devices over the years has led to abandonment, loss, or improper disposal of nuclear fixed gauges and tritium exit signs.
- Agreement state programs have instituted differing licensing programs, requirements and interpretations.
- The December 12, 2000 Final Rule for Generally Licensed Devices addressed many of the previously cited weaknesses in the GL program. It is too early to fully evaluate the impact of this regulatory revision on (a) management of disused or orphan sources; (b) management of devices currently being used; and (c) the redesign of gauges to fall under threshold levels.
- Different standards and risk models are used by different agencies and standard setting bodies in the development of "safe" levels of exposure/cleanup.
- The threat of enforcement is not perceived as a serious deterrent to improper end-of-life management and disposal.
- Loopholes in the process of importing and exporting devices containing radioactive material are being addressed by multiple federal and state agencies.
- Many GL nuclear fixed gauges are sold to companies holding a specific license and the gauge may be managed under a specific license program.
- National estimates for the GL licensed nuclear fixed gauge and tritium exit sign registration data may be inaccurate, based on GL program differences in Agreement States and concerns expressed by manufacturers.

Marketplace

A steady marketplace exists for the sale of these devices in the United States. Based on NRC provided GL registration data for non-agreement states, and our estimates of national registrations, sales of nuclear fixed gauges decreased in the 90's. We have assumed that annual "registrations" are equal to annual sales. In the years 1983 to 1992, we found an average of 4,950 GL registrations per year. In the years 1993 to 2001, the number of annual GL registrations for nuclear fixed gauges had dropped to 1,705. Last year (2002), however, nearly 7,000 GL nuclear fixed gauges were sold. Based upon industry input, sales of tritium exit signs have remained steady over the past few years with total nationwide sales averaging approximately 80,000 to 110,000 signs per year. We had difficulty obtaining conclusive market data because there is no trade association that effectively serves the GL nuclear fixed gauge and tritium exit sign suppliers. It is our hope that feedback from the project stakeholders during the dialogue process will shed further light on fundamental issues relating to national sales figures and the size of the market.

The costs for a nuclear fixed gauge may range from $3,000 to $10,000. These gauges are typically sold as part of a larger and more costly process control system. Cesium-137 is the dominant isotope, although strontium-90, krypton-85, and americium-241 are also often used in nuclear fixed gauges. Tritium exit signs can be purchased for less than $125 for an exit sign with a 10-year life to as much as $350 for an exit sign rated with a 20-year life.

Our findings, categorized by type of devices includes the following:

Tritium Exit Signs

- Tritium exit signs are purchased for specific applications (e.g., no electricity servicing area) and comprise a small portion of the broader emergency exit sign market.

- Customer sales are based primarily on cost – both initial and total ownership costs.
- Exit signs using LED technology are the primary exit sign technology in the marketplace and significantly outsell incandescent and fluorescent exit signs.
- Fewer than ten manufacturers supply the majority of tritium exit signs sold in the United States.
- Manufacturers encourage the return of devices, usually for a fee, as part of their ongoing sales and service relationship with customers.

Nuclear Fixed Gauges

- The installation of nuclear fixed gauges and systems requires customized engineering and significant capital expenditure.
- The sale of nuclear fixed gauges using cobalt-60 has decreased over the past decade.
- The sale of nuclear fixed gauges using Cs-137 has increased over the past decade.
- Manufacturers of nuclear fixed gauge vendors are focusing their marketing and sales efforts on providing turnkey services, such as shutter testing, leak detection and routine maintenance, to customers.
- The required disclosure of projected disposal costs, at the time of initial sale, has not hindered customers from purchasing nuclear fixed gauges.
- Alternative non-nuclear products are available for numerous functions and applications.
- Facilities, and industrial sectors, are reluctant to seek alternative gauging technology when the traditional nuclear fixed gauge has been a reliable workhorse.
- The number of suppliers – radioactive source suppliers and manufacturers – is decreasing due to mergers, acquisitions and a competitive marketplace.
- Vendors encourage the return of devices as part of their ongoing sales and service relationship with customers.
- Many manufacturers have gone out of business, leaving a legacy of numerous devices that may still be in operation, storage, or otherwise outstanding.

End-of-Life Management

At the end of their useful life, nuclear fixed gauges and tritium exit signs are legally required to be transferred to an entity with a specific license or properly disposed at one of two approved low level radioactive waste land burial sites in the United States. As a result of limited disposal options, the legal disposal of these devices may cost thousands of dollars. These costs are often cited as an impediment to the proper end-of-life management of these devices (despite the lack of financial concern expressed today at the time of purchase). For example, owners of a nuclear fixed gauge may place the device in long-term storage and tritium exit signs may find their way to an industrial or construction debris landfill. Often, industrial personnel or construction/demolition workers may be unaware that the device contains radioactive material. As a result, devices may end up in landfills, incinerators and at scrap metal recycling facilities. An accidental melting of a radioactive source at a steel making facility has cost as much as $23 million in cleanup costs and lost production time. Since 1983, steel mills in the U.S. have accidentally melted radioactive sources on 20 occasions (Lubenau and Yusko, 2000). Most U.S. mill facilities have installed detection systems, but the equipment is not infallible.

There is some good news to report. Our research found that nuclear fixed gauges and tritium exit signs are often being returned to manufacturers and distributors. Upon transfer of a device from the end user to the supplier, vendors are seeking cost-effective recycling and reuse options, if available, as alternatives to the costly disposal at the two licensed low level radioactive waste burial sites in the United

States. While the regulatory framework and industry standard practice is in place to "collect" and properly manage these devices as they come out of service today, there continues to be a problem with older, disused devices and orphan sources, defined as radioactive material for which the custodian cannot afford the cost of dispostion, or for which he should not be held liable. Also, some materials currently have no legal option for disposition.

Our findings include the following:

- Vendors have improved their customer tracking capabilities and are contacting end-users during product use. Nuclear fixed gauge vendors often notify customers of leak/wipe test requirements, and tritium exit sign vendors notify customers of upcoming product expirations.
- A large percentage, perhaps as much as 25 percent, of spent nuclear fixed gauges are being returned by end-users to the manufacturers. Many of the devices containing Cs-137 and Kr-85 can be recycled. It is our hope that feedback and information provided during the dialogue process can also help determine a recycling rate for the industry.
- A significant percentage of spent tritium exit signs are being returned by end-users for recycling. It is our hope that feedback and information provided during the dialogue process can also help determine a recycling rate for the industry.
- Devices and byproduct materials are being recycled and reused, but the quantity or percentage of byproduct material diverted from disposal has not been quantified.
- Return of nuclear fixed gauges to the manufacturer/supplier is generally the preferred and least costly option.
- Return of tritium exit signs to a manufacturer/supplier is definitely the preferred and least costly option.
- Waste disposal at Barnwell or Richland is costly, and limited depending on origin, nuclide, and activity.
- Orphan gauge devices continue to be a serious problem.
- Various initiatives and efforts are addressing the orphan source problem, but financial, legal and educational challenges remain.
- "Disused devices" are a problem because there is no incentive for companies or institutions to identify and properly dispose of stored gauges and tritium exit signs.
- The potential for processing contaminated scrap metal continues to be a serious hazard and financial issue for the industry.
- The increased use of radiation detectors by mills and the scrap metal processing industry has significantly reduced, but not removed, the threat of "meltings".
- There is concern regarding the potential of a terrorist organization to use radioactive material from nuclear fixed gauges to manufacture a dirty bomb.
- Improper disposal of tritium exit signs during renovation and construction is a serious compliance issue. This problem may be caused by a lack of knowledge of the law by workers, or a disincentive (e.g., high disposal costs at Barnwell or Richland) to include disposal costs during the competitive bidding process for demolition/renovation work.
- The disposal of radioactive products, such as tritium exit signs and nuclear fixed gauges, in the municipal waste stream has generally not been perceived as a major problem, according to waste management professionals.

2. INTRODUCTION

The purpose of this report is to present background information for a national stakeholder dialogue on radioactive materials product stewardship. The dialogue, which will be convened and facilitated by the Product Stewardship Institute (PSI), aims to bring together representatives from industry associations, manufacturers, distributors, Federal and state government, environmental/consumer advocates, metal recyclers, waste management, and others, to jointly develop a strategy for addressing outstanding issues related to end-of-life management of nuclear fixed gauges and tritium exit signs.

PSI works with its 26 state government members and 23 local government and recycling industry members to reduce the health and environmental impacts from consumer products. The Institute's product stewardship model involves working closely with manufacturers, suppliers, environmental groups, and other stakeholders to develop agreements to reach common goals. Current projects, undertaken by PSI, also include work on electronic products, paint, thermostats, and propane tanks.

Why the Devices Covered in this Report?

PSI was asked to research the management of nuclear fixed gauges and tritium exit signs by the U.S. Environmental Protection Agency. While the EPA has no responsibility for the licensing and registration of these products, the Agency has concerns regarding improper waste disposal, potential public exposure and misuse of the devices at the end of their useful life.

Report Terminology

Curie - Refers to the basic unit to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion (or 3.7 x 10^{10}) disintegrations per second, which is approximately the disintegration rate of 1 gram of radium. One curie is equal to 37 billion becquerel (Bq).

Generally Licensed Device – A general license is required under 10 CFR 30.21(c) for the use of byproduct material contained in certain measuring, gauging or controlling devices, and devices used to produce light or an ionized atmosphere.

Ionizing Radiation -- Any radiation capable of displacing electrons from atoms or molecules, producing ions. Examples include: alpha, beta, gamma, x-rays, neutrons and ultraviolet light. High doses may produce severe skin or tissue damage.

Orphan Source -- Refers to a discrete source of radioactive material for which the custodian cannot afford the cost of dispostion, or for which he should not be held liable..

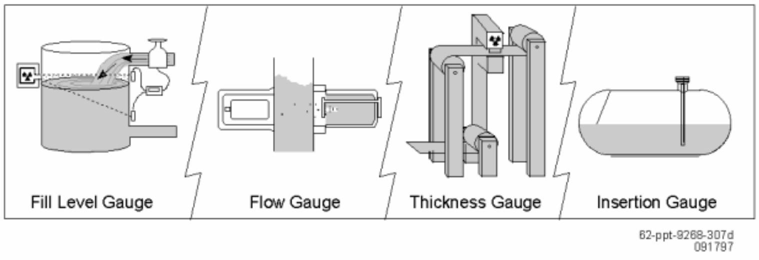
Radioactivity -- Refers to the spontaneous emission of radiation, from the nucleus of an unstable isotope.

Sealed Source -- Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal under the most severe conditions which likely to be encountered in normal use and handling. Nuclear fixed gauges and tritium exit signs are sealed sources.

The licensing and registration of most nuclear fixed gauges and tritium exit signs is overseen by either the Nuclear Regulatory Commission (NRC), or "Agreement States," which are approved by the NRC to operate their own radiation programs. The regulatory program is based on a three-tier regulatory framework for so-called sealed sources containing nuclear byproduct materials. The highest level of control, a Specific License, is required of those devices posing the greatest risk and requiring significant expertise to operate. Devices designed with inherent safety features, that can be operated without special radiation safety training, require a General License. Tritium exit signs and certain nuclear fixed gauges represent two of the six categories of devices that are considered Generally Licensed Devices. Minimal regulatory requirements are imposed on a General Licensee. The third category of sealed sources includes devices that are exempt in the regulations because of their minimal risk and radiation hazard. (See Section 5 for more detail on the regulatory system.)

Tritium exit signs are found in commercial and institutional buildings to illuminate exit doors and pathways in the event of an emergency. A tritium exit sign operates by creating a continuous light when a phosphor-coated tube emits light in the presence of radiation. Many people, from building owners to demolition contractors, are unaware that these exit signs contain a radioactive material. As a result, the devices may be improperly handled leading to potential human exposure or improperly and illegally disposed at a municipal or industrial landfill leading to a release to the environment.

Nuclear fixed gauges are found in industrial process control systems to monitor and measure for product density, weight, thickness and flow, among other properties. These devices are based on the principle that the radiation emitted from the radioactive material will be reduced in intensity by matter between the radioactive material and the detector. The loss of administrative control and improper disposal at the end of the device's useful life is of special concern to EPA and other stakeholders. It is suspected that many previously registered gauges are no longer in active use or have been improperly disposed because of ignorance of the law or unwillingness to pay for the high costs of disposal. Improper disposal has led to the contamination of metal scrap process recycling streams and, in a worst case, mill smeltings that resulted in significant environmental cleanup costs and potential worker exposure.



What Questions Will be Answered?

This report takes a life-cycle approach to its assessment of management problems associated with nuclear fixed gauges and tritium exit signs. Environmental issues that become manifest at the time of disposition may hide issues and solutions found earlier in the product's life cycle. Our goal in this technical document is to provide answers to the following questions:

1. How are nuclear fixed gauges and tritium exit signs managed?
2. What is the marketplace for these products and what is the nature of the relationship between the manufacturers, distributors and customers?
3. What are the environmental and safety problems associated with these products?
4. What has been done to address environmental problems?

The information in this Radioactive Materials Product Stewardship Report includes technical, regulatory and marketplace data. Many of the technical and regulatory topics identified in this report have been exhaustively and competently studied in the past. Our task is not to duplicate such studies, but rather to frame the relevant issues and provide sufficient background material to support a solutions-oriented dialogue going forward. We have provided an extensive bibliography and links to key web sites for those who seek additional information on the topics covered. Additionally, the report includes information obtained from conducting more than thirty interviews with key stakeholders. We have identified these stakeholders in the appendix of this report.

How to Use this Report?

We encourage all readers to review **Section 3**, the section on Product Stewardship that frames the product issues in their largest context. Newcomers to the field of radiation and radioactive materials regulation should review **Sections 4** (Radiation Basics) and **5** (Regulatory Framework) respectively. All readers may wish to review the brief summary of Environmental Incidents, found in Section 4.4, which includes current information from the NRC's Nuclear Materials Events Database (NMED).

The data in **Section 6** of this report defines the existing marketplace for nuclear fixed gauges and tritium exit signs and provides an introduction to alternative technologies. **Section 7** describes the practices and issues associated with the end-of-life management of these devices, and provides specific information with respect to environmental incidents. **Section 8** recognizes the many important stakeholders who assisted in this research project and will be critical players in forging any new solutions.

We have used tables and figures, where possible, to organize or illustrate information more clearly. Sidebars are used throughout the report to highlight certain information, or to augment the text. A "Summary of Findings" at the end of sections 5, 6 and 7 is designed to distill the narrative into the key issues, trends, observations and conclusions.

3. PRODUCT STEWARDSHIP

"Product Stewardship" is a principle that directs all those involved in the life cycle of a product to take responsibility for reducing the health and environmental impacts that result from the production, use, and disposal of the product. The stakeholders typically include manufacturers, suppliers, consumers, and government officials. The product stewardship approach provides incentives to manufacturers to consider the entire life cycle impacts of a product and its packaging - energy and materials consumption, air and water emissions, the amount of toxics in the product, worker safety, and waste disposal - in product design, and to take responsibility for the end-of-life management of the products they produce. The objective of product stewardship is to encourage manufacturers to redesign products with fewer toxics, and to make them more durable, reusable, and recyclable, and with recycled materials. Since waste disposal impacts and associated costs have been the basis for engaging manufacturers, attention has initially focused on waste management problems and solutions. However, the challenge of product stewardship is to move beyond disposal to facilitate a paradigm shift toward "zero waste" and "sustainable production."

3.1 The "Justification" Principle in Radiation Protection

Efforts to enhance product stewardship and minimize environmental, health or safety impacts are particularly relevant to devices containing radioactive materials.

Radiation protection regulations are based on three fundamental principles, first defined in 1977 (and later reaffirmed) by the International Commission on Radiological Protection (ICRP), a non-governmental organization established to advance for the public benefit the science of radiological protection. These generally recognized principles are:

1) **Justification** – No practice involving exposures to radiation should be adopted unless it produces enough benefit to the exposed individuals or to society to offset the radiation detriment it causes;
2) **Optimization** – Exposures to radiation should be "As Low As Reasonably Achievable" or ALARA; and
3) **Individual Dose and Risk Limitation** – No individual should receive radiation doses higher than the maximum allowable limits.

"The most difficult of these principles, and certainly the one that is rarely adequately addressed, is justification. Assessing the likelihood that any practice will produce a net benefit involves many value judgments that are difficult, if not impossible, to quantify," notes the ICRP on its web site.

The review of gauge and exit sign functionality and use in Section 7 and environmental issues in Section 8 may shed light on the application of the Justification Principle to these particular products and highlight opportunities to demonstrate product stewardship by further optimizing ALARA principles over the life cycle of the product. For example, manufacturers report improvements in detection technology that minimize the activity levels required for a device. Additionally, the emergence of alternative technologies proves promising to control or eliminate unnecessary radiation sources. "The availability of alternative technologies … is not well known among regulatory and even by persons using gauges. It must be acknowledged that alternative technologies that will prove to be technically feasible and economically competitive are not available as replacements for all situations. In keeping with the ICRP recommendations, however, justification should be reassessed in light of new information" (Lubenau, 2001).

3.2 Principles of Product Stewardship

The Product Stewardship Institute (PSI) and its member agencies developed the "Principles of Product Stewardship" to support state and local officials in promoting product stewardship policies and in developing voluntary agreements with industry and environmental groups that are designed to reduce adverse environmental, health and safety impacts from products. These principles and their relevance to this project are briefly described below.

RESPONSIBILITY

The responsibility for reducing product impacts should be shared among industry (designers, manufacturers, and sellers of products or product components), government, and end-users. The entity with the ability to control a product's life-cycle impacts should bear the primary responsibility for addressing those impacts. This principle is consistent with the ISO 14000 series of voluntary environmental standards.

INTERNALIZE COSTS

All product life-cycle costs – from using resources, to reducing health and environmental impacts throughout the production process, to managing products at the end-of-life – should be accounted for in the total product cost. Minimizing these costs of product manufacture, use, and disposal should benefit manufacturers, customers and society. Such costs should neither be hidden from the end-user nor borne by local or state government, or others. For example, according to the Steel Manufacturers Association, "the costs of accountability and control of nuclear fixed gauges has been placed on scrap processors, steel makers, insurers and the taxpayers." Manufacturers should have a direct financial incentive to capture these life-cycle costs and redesign their products and services to reduce costs associated with inefficiency, waste, and excessive regulatory requirements, and to satisfy customer's long-term needs.

INCENTIVES

There should be incentives for a manufacturer to: (a) design and produce "cleaner" products – ones made using less energy, materials, and hazardous materials, and which result in "cleaner" processes and operations -- using less energy and materials, and generating less (or no) waste; and (b) think in terms of providing the service that a product provides rather than thinking in terms of selling equipment. Regulations governing nuclear fixed gauges and tritium exit signs clearly provide a regulatory framework in 10 CFR 31.5 that supports – but doesn't require -- the return of devices to the manufacturer or distributor for proper disposal or source recovery. Many of these devices are, in fact, returned to the supplier, but there may be a perceived financial disincentive to return devices and pay for costly disposal.

Government can provide leadership by promoting product stewardship practices within its own organization and by addressing regulatory barriers. Industry can provide necessary leadership in applying these principles. Government and industry have previously collaborated on initiatives to address some of the problems identified in this report.

Government can set performance goals or policies and identify "what" should be done. Those that are responsible for reducing the environmental, health and safety impacts of products should have the flexibility to determine how best to achieve those goals or policies.

ROLES AND RELATIONSHIPS

FLEXIBLE MANAGEMENT SYSTEMS

3.3 Life Cycle Approach in this Project

A key underpinning of product stewardship is the need to look at relevant issues associated with a product over its entire life -- from "cradle-to-grave" or from "cradle-to-cradle." These issues include direct and indirect environmental, as well as economic and social (e.g., human health) impacts and costs. The general stages of a product's life cycle are identified on the right. Assessing a product or an end-of-life management challenge from a life cycle approach provides the framework to optimize product stewardship.

This report assesses the issues from a life-cycle approach for the purpose of comprehensively identifying the environmental and public health issues associated with the manufacture, use and disposal of nuclear fixed gauges and tritium exit signs.

With respect to the products addressed in this report, a few major suppliers of byproduct material (e.g., cesium-137 or tritium) provide radioactive isotopes to the manufacturers of tritium exit signs and nuclear fixed gauges. These materials are byproducts of the nuclear fuel cycle, or have been reclaimed for material reuse. These suppliers provide materials to a pool of manufacturers that sell directly or indirectly, through distributors and sales representatives, to end-users. Nuclear fixed gauges are used by certain industrial sectors, while tritium exit signs are found in commercial or institutional buildings.

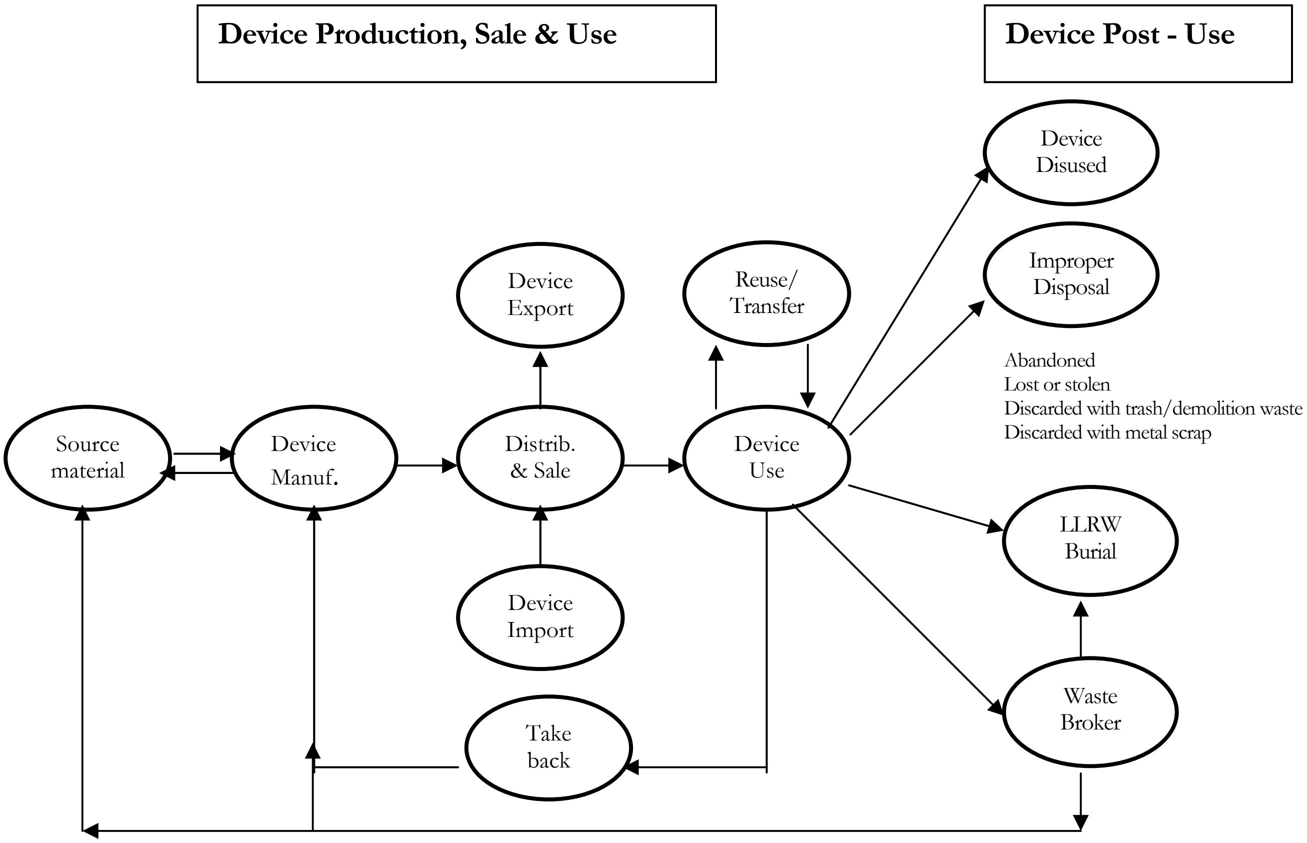
Figure 1 on the next page clearly illustrates the salient steps in the life cycle of these devices. Material, such as cesium-137, is obtained and incorporated into a sealed container or device. This "sealed source" is then assembled into a manufactured gauge or tritium exit sign, and sold to an end-user. Manufacturers are located in the United States as well as in other countries. After the device has served its useful life to the end-user, the device may be properly disposed or certain intentional or unintentional management problems may emerge. Proper disposal may include returning the device to the manufacturer for recycling, reconditioning or disposal. Proper disposal may also include contracting with a waste broker to manage the device's disposition, including proper burial or recycling. Improper disposal may occur when the device becomes disused (no longer used and stored indefinitely), stolen, disposed as solid waste, demolition waste or metal scrap, or abandoned in place.

A few caveats about the breadth of our life cycle approach. While a quantitative or qualitative Life Cycle Assessment is beyond the scope or the intent of this report, the authors recognize that:

- There are environmental impacts associated with the material acquisition, manufacture and use of these nuclear fixed gauges and tritium exit signs;
- Collection of radiation devices and reuse/recycling of the radioactive material can conserve materials;
- Nuclear fixed gauges may enhance conservation of materials and reduction of waste through effective and reliable process control;
- Emergency exit lighting serves a critical role in saving lives in the event of a fire or accident in a building; and
- A "safe" regulatory threshold for the disposal of certain low-level nuclear waste is a topic of debate.

Despite these caveats, the life-cycle approach pursued in this report has the potential to create value to interested stakeholders by: a) providing a comprehensive snapshot of the many issues related to end-of-life management; b) connecting specific issues to the life stages of a product; c) describing the regulatory, economic and environmental context within which these devices are manufactured, sold and disposed; and d) identifying specific locations in the life cycle where environmental impacts can be reduced.

FIGURE 1. LIFE CYCLE OF A NUCLEAR FIXED GAUGE OR TRITIUM EXIT SIGN



4. THE ENVIRONMENTAL AND HUMAN HEALTH HAZARDS

4.1 Radionuclides and Nuclear Fixed Gauges

Fixed gauges are non-portable gauges designed to measure or control flow, level, thickness, weight or material density. They are typically "fixed" as a component of a process control system in an industrial operation. Nuclear fixed gauges contain a sealed source of radioisotope, controlled by a shutter, that radiates through the substance being measured or reflects to a readout or controlling device. These devices may contain alpha, beta, neutron, or gamma emitters. This gauging is based on the principle that the radiation emitted from a radioisotope will be reduced in intensity by any matter between the radioisotope and the detector. The shutter controls the release of the radiation under normal operating conditions.

Table 3 outlines some of the most common radioisotopes in nuclear fixed gauges, including their radioactive emissions, the physical form of the material, and half-life.

TABLE 2. PRINCIPAL RADIOISOTOPES IN NUCLEAR FIXED GAUGES

Isotope	Emission	Physical Form	Half-life
Americium-241	Alpha Gamma	Solid (metal)	470 years
Cesium-137	Beta Gamma	Solid (powder)	30.1 years
Cobalt-60	Beta Gamma	Solid (metal)	5.3 years
Krypton-85	Beta Gamma	Gas	10.7 years
Strontium-90	Beta	Solid (metal)	29.1 years

In addition to the isotopes listed above, nuclear fixed gauges may include beta emitters such as Pr-147, gamma emitters such as Co-57, and neutron sources such as Cf-252 , Am/Be, and Pu/Be. Significant health effects are associated with exposure to these isotopes, depending on such factors as activity, shielding, distance from source, and biological half-life of material within the human body..

4.2 Radionuclides and Tritium Exit Signs

Tritium is a colorless, odorless, radioactive gas that is a form of hydrogen, found naturally in air, but in very small quantities. It is also naturally found dissolved in water. Like other radioactive material regulated by NRC, tritium is generated as a byproduct of nuclear energy production. The U.S. has not produced tritium on a large scale since 1988 when DOE closed its production facility at Savannah River, Georgia. Based on our research, the tritium used in newly manufactured emergency exit signs sold in this country comes from byproduct generation and tritium reclamation activities outside the United States, primarily in Canada.

The risks from tritium in exit signs are often considered small because of the low toxicity, low energy and short half-life in the human body. Each exit sign may contain as many as 27 curies of tritium, housed in 10-12 radioactive capsules. Tritium exit signs typically have between 7.5 to 11.5 curies per sign depending on intended life of the sign. Tritium exit signs may have greater than 11.5 curies to address additional illumination requirements. Information about tritium is described in the table below.

TABLE 3. TRITIUM RADIOISOTOPE IN SELF-LUMINOUS EXIT SIGNS

Isotope	Emission	Physical Form	Half-life	# of Devices General License
Tritium (H-3)	Beta	Gas	12.3 years (Biological half-life is about 10days)	~1,000,000

4.3 Risk Information

Generally licensed nuclear fixed gauges and tritium exit signs are designed to be intrinsically safe to workers/end-users and to withstand severe handling and environments. These devices can present radiological problems, however, if they enter the public domain and become damaged or broken. Nuclear fixed gauges may also be potentially used by terrorists as a dirty bomb.

What is the risk to the environment or public safety associated with the willful or inadvertent release of radioactivity from nuclear fixed gauges or tritium exit signs? In addressing this question, it is important to first understand how radiation levels are expressed and to compare potential exposure scenarios to background radiation levels and the regulatory standards designed to ensure safety.

There are several terms used in radiation protection to describe the aspects associated with the concept of dose and how radiation energy deposited in tissue affects humans (Health Physics Society). A full description of these terms is beyond the scope of this report. Appendix B provides a glossary of common terms and Appendix C provides a conversion chart between the various radiation measurement units.

The average person is exposed constantly to ionizing radiation from both natural and man-made sources. This annual radiation dose will vary depending on such factors as cosmic radiation (e.g., elevation of your residence), terrestrial radiation (e.g., geological area, house construction materials), and other variables.

Table 4 contains radiation dose information for certain common activities or locations.

TABLE 4. WHOLE BODY TOTAL DOSES FROM VARIOUS SOURCES
(Adapted from Health Physics Society, University of Michigan)

Source or Limit	Dose
Natural gas in home	0.09 mSv/year
Annual Dose Limit (EPA) – Public – air pathway	0.1 mSv/year
Average dose to US public from anthropogenic sources	0.6 mSv/year
Background radiation total (Colorado Plateau)	0.9 mSv/year
Annual Dose Limit (NRC) – General Public	1.0 mSv/year
Average dose to US public from natural sources	3.0 mSv/year
NCRP recommended occupational exposure limit Annual Dose Limit (NRC) – Radiation worker	50 mSv/year

The biological effects of radiation on living cells may result in three outcomes: (1) cells repair themselves, resulting in no damage; (2) cells die and are replaced through normal biological processes; or (3) cells change their reproductive structure. Biological effects of radiation may be classified as prompt or delayed effects. Delayed effects of radiation are effects that appear many years later. No one disputes that radiation has serious deleterious effects at elevated dosages. It is important to recognize that there is significant professional disagreement over "safe thresholds" that are based on the use of linear models that extrapolate health effects at higher dosage (i.e. greater than 1 sievert) to health effects at lower dosage (i.e. millisieverts).

Nuclear Fixed Gauges

The key properties that determine risk are energy and type of radiation; half-life of the radioisotope; amount of material; shape, size, shielding, and portability of the material; prevalence and use; and how dispersible is the material (Ferguson, Kazi, Perera, 2003). The International Atomic Energy Agency (IAEA) used some of these radiation safety hazards characteristics to categorize radioactive sources into three categories. They also looked at end-of-life and exposure scenarios. IAEA did not, however, fully evaluate security and terrorism (e.g., dirty bomb) issues (Ferguson, Kazi, Perera, 2003). According to the IAEA categorization of risk sources:

- Category 1 devices included irradiators and industrial radiography equipment.
- Category 2 included brachytherapy equipment, well logging gauges and some fixed nuclear gauges, such a gauges containing as much as 27 curies of Cs-137, 1 curie of Am-241, and greater than 0.027 curies of Co-60.
- Category 3, the lowest risk category, included most of the GL nuclear fixed gauges and other GL devices.

GL devices are designed to meet a worker exposure limit of 500 mrem/year maximum under ordinary use and 15 rem per accident. Many of today's GL gauges are designed to achieve much lower operating exposure levels. In the event that the radioactive material becomes separated from the housing, exposure to Cs-137 or Co-60, or other radioactive isotopes, can pose significant risk to workers or the general public and can contribute to contamination of materials requiring costly cleanup. Although known exposures from generally licensed nuclear fixed gauges are rare and have generally not exceeded the public dose limits in the United States, there is a potential for significant exposures under abnormal conditions.

Tritium Exit Signs

During normal use of a tritium exit sign, the radiation from tritium is entirely absorbed within a sign or light tube. The risks associated with a broken tritium capsule(s) from a tritium exit sign vary depending on the form of the radioisotope and the type of exposure. There are four mechanisms for the intake of tritium into the human body: inhalation, skin absorption, ingestion, and injection. If a tritium exit sign is broken or damaged, tritium gas may escape into the local area, but would generally be dispersed by ventilation. Tritium in gaseous form is inhaled and exhaled with only about 0.005 percent of activity deposited in the lungs. Inhalation is primarily a health concern only in a confined/non-ventilated location. The skin is also relatively impermeable to absorbing elemental tritium. As tritium exit signs age, the percentage of gaseous tritium decreases and the quantity of tritiated water become more predominant (Hicks, 2000). In a study conducted by the Brookhaven National Laboratory on tritium exit signs, the tritiated water content in the signs ranged from 2% to 12.2%. The newest signs had the least tritiated water, and the oldest sign had the greatest amount of tritiated water (Traub, R.J. 1995). Since tritiated water has near 100 percent uptake through inhalation and skin absorption, it poses much greater health risks than exposure to the gaseous elemental form of tritium.

Another pathway occurs when the tritium is ingested. This may occur if an individual has handled a device that has external contamination and then eats before washing his hands. If 5 percent of tritium in a 24Ci sign is ingested or absorbed, the dose would be equivalent to 77,000 millirems or 77 rems -- or 208 years of natural background radiation. This dose can be reduced significantly by the intake of liquids, however, which will expedite the elimination of tritium from the body. Injection may occur if someone handles a tritium exit sign that breaks and parts of the device (e.g. glass shards) penetrate the skin and force tritium into the body. When tritium passes through a human body, it can produce permanent changes to cells. Tritium exposure has been linked to developmental problems, reproductive problems, genetic abnormalities and other health problems in laboratory animals.

Manufacturers of tritium exit signs estimate the radiation exposure to the public from a broken sign is less than that received from naturally occurring radioactive sources during a year. According to one supplier of tritium exit signs, the maximum inhalation dose in a worst case scenario is minimal. They calculated a dose of 30 mrem if one of their signs was totally destroyed (e.g., all capsules) and the tritium gas was released into a small closed area (3,000 sq. ft). They assumed that a person would be continuously exposed for one hour in this small area with low ventilation (one air change per hour). They believe under a more likely scenario, the actual exposure would not exceed 10 mrem, or less exposure than a routine chest x-ray. Another tritium exit sign manufacturer estimates an exposure of 100 mrem if all tubes were broken. Actual incidents of tritium exposure from broken signs have occurred. In one incident, an adolescent handling the exposed radioactive material inadvertently ingested tritium particles, which lead to an exposure dose of 286 mrem. (see section 4.4 for further details).

At the Radiation Safety Conference in Argentina (December, 2000), key topics addressed were maintaining effective control of radiation sources; locating and regaining control over lost and abandoned sources; and establishing an effective regulatory control system in countries where none exists. See http://www.iaea.or.at/worldatom/Press/Events/RadSources/radsources_concl.shtml

Security

While there is minimal or no terrorist or security risk associated with the tritium exit signs, there is some concern with nuclear gauges. "Because industrial gauges need relatively low radioactivity, these radioactive sources generally pose minor security risks" (Ferguson, Kazi, Perera, 2003). This conclusion was based on the assumption that single gauges typically contain less than one curie of radioactivity. Some gauges, however, contain more radioactive material and a terrorist could accumulate multiple nuclear fixed gauges and collect a sufficient quantity of Cs-137 or Co-60 to create a dirty bomb. Of the 21 radioisotopes in the NRC's database, four (Am-241, Cs-137, Ir-192, Sr-90) have enough cumulative radioactivity amounts in the un-recovered sources to raise the potential for a heightened security concern (Ferguson, Kazi, Perera, 2003). Experts always say that security is only as good as its weakest link.

A number of recent studies and exercises have looked at potential effects from a terrorist act (Levi & Kelly, 2000). In one case, they examined the dispersal of two curies of Cs-137 by exploding ten pounds of TNT in Washington, DC. The predicted consequences, using EPA's linear extrapolations to assess risk, are that people residing "in an area of about five city blocks, if they remained, would have a one-in-a-thousand chance of getting cancer. A swath about one mile long covering an area of forty blocks would also exceed EPA contamination limits." Experts agree that the most significant impacts from such a terrorism act are psychological terror, the economic shutdown of a metropolitan enterprise zone and the costs associated with the cleanup.

4.4 Environmental Incidents in the NMED Database

The U.S. Nuclear Regulatory Commission (NRC) maintains a database of recorded incidents involving radioactive materials. Event records have been maintained since 1989 in the Nuclear Materials Events Database (NMED) http://nmed.inel.gov . PSI was provided access to the database for the purpose of evaluating incidents associated with Generally Licensed nuclear fixed gauges and tritium exit signs.

PSI evaluated reports from January 1, 1995 through April 1, 2003. We chose these dates because the NMED database, and the quality of the data, was significantly enhanced in 1993 and 1994. Our review found the following reported events or incidents for nuclear fixed gauges and tritium exit signs.

Nuclear Fixed Gauges

PSI found a total of 278 events or incidents for nuclear fixed gauges between 1995 and April 1, 2003. The number of reported events each year has been generally consistent as illustrated below in Table 5.

TABLE 5. YEARLY COMPARISON OF REPORTABLE EVENTS FOR NUCLEAR FIXED GAUGES

Year	Number of Report Events
2003 (Jan – March)	2
2002	33
2001	31
2000	28
1999	34
1998	41
1997	38
1996	32
1995	39
Total	278

Reported events listed above include nuclear fixed gauges that were registered to either a general licensee or to a specific licensee. For example, 21 of the 33 reported events in 2002 were for nuclear fixed gauges that could have been registered as a GL device. Some of those 21 events, however, occurred at a specific licensee facility. Table 6 summarizes NMED incidents for GL nuclear fixed gauges.

TABLE 6. SUMMARY OF INCIDENTS FOR NUCLEAR FIXED GAUGES, 1995 - 2003

Incident	# of Fixed Gauge Events	# of Events at GL Licensees
Radiation Overexposures	22	3
Release of Licensed Material or Contamination	0	0
Loss of Control of Material	92	37
Equipment Problems	150	14
Transportation	3	1
Leaking Sealed Sources	14	1
Totals	281	56

The database includes three reported radiation overexposures from a nuclear fixed gauge at a General Licensee. One incident involved a gauge containing 390 mCi Kr-85. The maximum exposure was determined to be 32 rem to an extremity. In a second incident, a gauge containing 100 mCi of Cs-137 was transported with the shutter open. The maximum exposure to a worker was determined to be 0.125 mSv (12.5 mrem). In the third overexposure incident, an open shutter of a gauge containing a Kr-85 source exposed a worker to an estimated maximum exposure of 7 rem to a hand.

Events at general licensees accounted for 20 percent (56) of the events for all nuclear fixed gauges. Loss of control of material, such as an abandoned or unsecured source, or lost devices, accounts for 66 percent of the reported events for general licensees. The lack of any reported events for "release of licensed material or contamination" indicates that there were no incidents in which a release exceeded the Maximum Permissible Concentrations, the Annual Limit on Intakes, or removable contamination limits.

These reports may not include events in which nuclear fixed gauges triggered a radiation detector at a scrap metal processing facility. Since 1995, reports have been filed with the NRC and Agreement States for over 600 incidents of radioactive materials found by the scrap metal recycling industry for man-made radioactive materials. Many of these incidents were likely caused by nuclear fixed gauges under general or specific license. (Yusko 2000). Our review of the NMED database for this period found 555 reported events involving contaminated metal scrap or roughly 75 reports per year. Records for the last two years found that all entries were for "detection" of radioactive material entering a scrap processing facility.

The NRC has previously estimated that as many as 375 sources have been reported as abandoned or orphaned in a single year (Meserve 2000). It is widely suspected that administrative loss or theft, or inadvertent disposal as solid waste, is not widely reported. The loss of administrative control of nuclear fixed gauges may also be underreported because many devices have been permanently stored or new business owners may be unaware of the existence of the stored devices.

Tritium Exit Signs

PSI found 83 total reportable events for tritium exit signs in the NMED database. These events are categorized below in Table 7. The total "# of events" recorded in the second column in the chart (92) exceeds the total reportable events (83) because more than one cause/accident scenario may pertain to a single event. The "% of total" was calculated based on the total (92). The number of unreported lost, stolen or inadvertently disposed tritium exit signs may far exceed the number of reported events, based on our understanding of common disposal practices during demolition and renovation.

TABLE 7. SUMMARY OF INCIDENTS FOR TRITIUM EXIT SIGNS
(January 1995 – April 1, 2003)

Incident	# of Events	% of Total
Broken or Damaged Capsules	14	15%
Broken sign but undamaged capsule	2	2%
Devices found	4	4%
Disassembly, but no exposure	2	2%
Known or likely exposures	6	7%
Fire – signs vaporized (e.g., 28)	2	2%
Inadvertent disposal (assumed or confirmed) during renovation or demolition	12	13%
Involved in a traffic accident	2	2%
Lost or Stolen	49	53%
Totals	93	100%

The NRC's Nuclear Materials Event Database (NMED) includes 14 incidents in which the sources in tritium exit signs were broken or damaged and individuals were potentially exposed to tritium. Six incidents involved known or likely exposure to the public, and four of these reported events included exposure data information in the NMED data entry. These events are summarized below.

- In May 1997, a Union City, New Jersey boy received adose of radiation after dismantling an exit sign he found at a demolition site near his home.

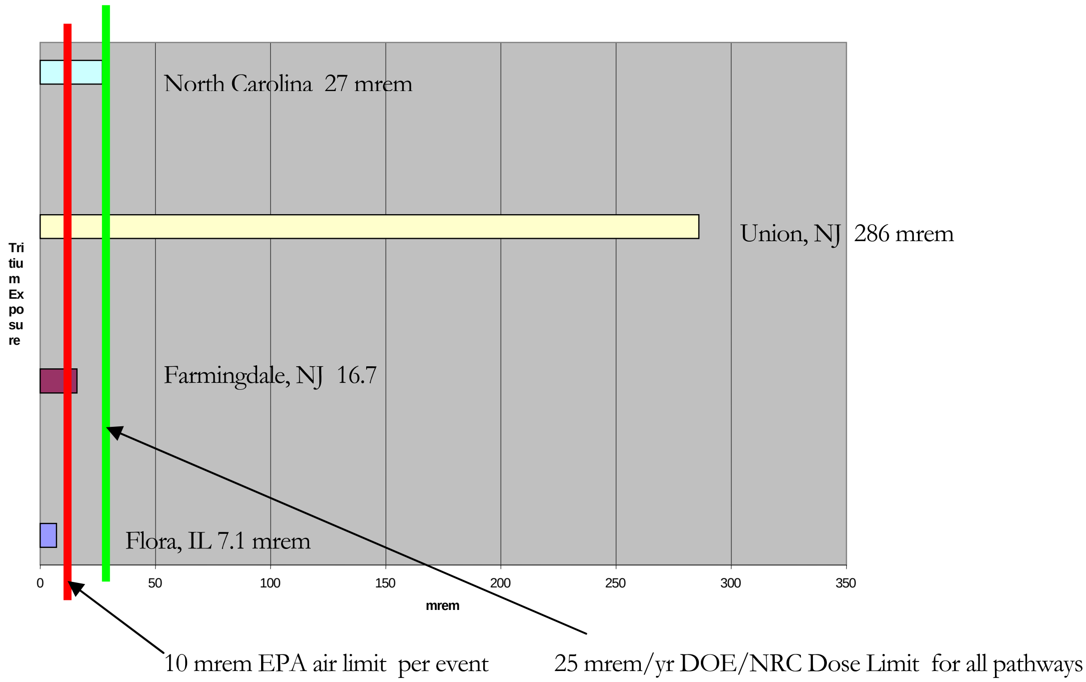
- In October 1997, a 14-year old patient at the New Jersey Arthur Brisbane Child Treatment Center in Farmingdale, NJ smashed a tritium exit sign which resulted in an evacuation of the entire facility.

- In November, 1999, a Flora, Illinois individual received a dose of radiation after dismantling an exit sign in his garage.

- In March, 1998, residents of a dormitory at a USDA Job Corps training Center in Franklin, NC found a tritium exit sign in the dormitory office and removed the vials believing they were "glow sticks."

The NMED database included exposure information for the above events in Illinois, New Jersey, and North Carolina. This information is presented in Figure 2.

FIGURE 2. DOCUMENTED TRITIUM EXPOSURES FROM FOUR INCIDENTS



10 mrem EPA air limit per event

25 mrem/yr DOE/NRC Dose Limit for all pathways

Information about the investigation and cleanup costs was available for three of these events, and is included in Table 8.

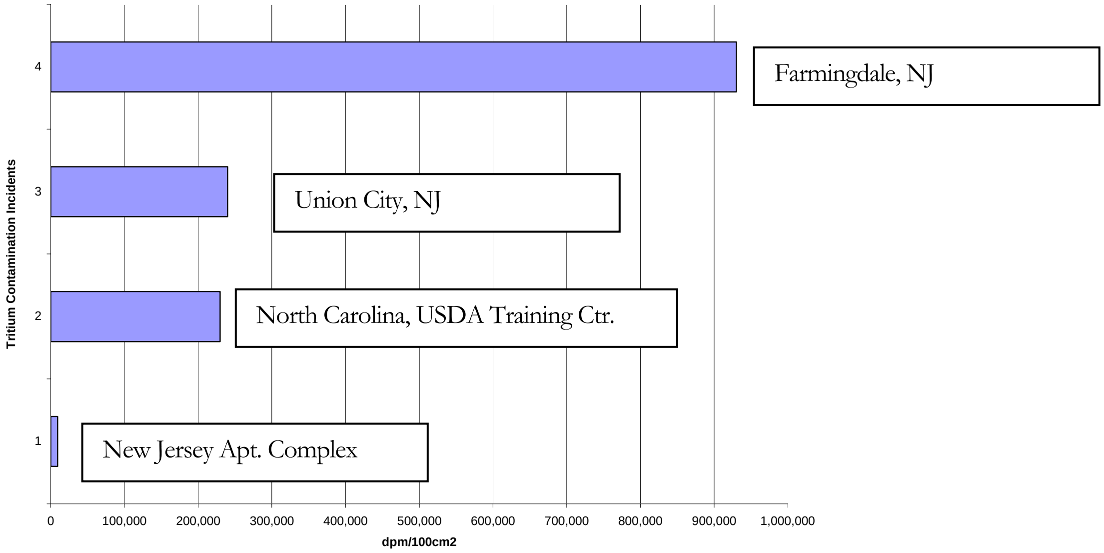
TABLE 8. TRITIUM EXIT SIGN INCIDENT COSTS

	Exposure	Investigation and Cleanup Cost
Illinois	7.1 mrem	$64,000
Farmingdale, NJ	16 mrem	$200,000 +
Union City, NJ	286 mrem	$100,000 +

While these are actual costs incurred in the testing and cleanup of the spill events, industry representatives, interviewed for this report, expressed the opinion that these cleanup costs were significantly inflated due to panic and overzealous contractors and agency officials. Other stakeholders have indicated that these costs are understated because they do not fully include government response and oversight efforts.

The NMED database also included tritium contamination levels for four of the fourteen exposure events. These levels are illustrated in Figure 3. The Farmingdale, NJ, Union City, NJ, and North Carolina incidents each exceeded the applicable ANSI and NRC standards for removable tritium.

FIGURE 3. CONTAMINATION LEVELS FROM TRITIUM EXIT SIGN INCIDENTS.



5. REGULATORY REQUIREMENTS

5.1 Federal Requirements

While the Nuclear Regulatory Commission regulates radioactive materials that are byproducts of the nuclear fuel cycle, a variety of Federal agencies are involved in the regulation of radioactive materials, radiation safety and response to radioactive incidents. Some of the key federal agencies and their functions are briefly described below.

TABLE 9. ROLE OF MAJOR FEDERAL AGENCIES AND DEPARTMENTS

Agency	Function
Nuclear Regulatory Commission	Regulates radioactive source, special nuclear, and byproduct materials as well as facilities producing, transferring, receiving, acquiring, owning, possessing and using these materials. General License Devices, including nuclear fixed gauges and tritium exit signs, are regulated under 10 CFR Part 31.5. NRC's authority comes from passage in 1954 of the U.S. Atomic Energy Act. Certain states, called Agreement States, have been authorized to administer their own programs.
Environmental Protection Agency	Sets (develops and issues) radiation protection standards for the safe management of radioactive and "mixed" (radioactive and hazardous) wastes, provides technical expertise during radioactive site cleanup and sets cleanup, air, and drinking water standards. Standards also include management standards under 40 CFR Subchapter F "Radiation Protection" in Parts 190 – 197 and 40 CFR 61 Subpart H governing radionuclide air emissions.
Department of Energy	Produces special nuclear material and byproduct material; responsible for recovery and management of unwanted radioactive sealed sources under Public Law 99-240 (LLW Policy Amendments Act of 1985). Primary standards for occupational radiation protection of its workers are issued at 10 CFR Part 835. Additionally, DOE has issued policies, orders, notices, manuals and guides relative to the safe handling, use, and disposal of radioactive materials.
Department of Transportation	Develops requirements for the safe transportation of radioactive materials and wastes under 10 CFR Part 71 , "Packaging and Transportation of Radioactive Materials" and applicable sections in 49 CFR Parts 170 – 189.
Federal Emergency Management Agency	Plans for, and responds to, federal emergencies and is the chair of the Federal Radiological Preparedness Coordination Committee (FRPCC) which develops coordination plans for responding to a nuclear incident and a terrorist attack, or multiple attacks, with a radiological component.
Homeland Security Department	Designed to protect the nation against terrorist attacks and enhancing disaster assistance. Comprised of 22 federal agencies.
Bureau of Customs and Border Protection	Inspects and enforces regulations on the import of radioactive materials at 19 CFR 146.
U.S. Dept. of Commerce	Regulates commerce requirements and restrictions with respect to the export of materials.
Occupational Safety and Health Administration	Sets occupational standards to protect workers from exposure to radioactive materials and chemicals.

The NRC and Agreement States regulate source materials (e.g., thorium, uranium), special nuclear material, and radioisotopes produced in nuclear reactors. Materials produced from the nuclear fuel cycle are referred to as byproduct materials. The NRC does not regulate radioactive materials that are produced by other methods, such as accelerator production. The NRC also does not regulate Naturally Occurring Radioactive Material (NORM). The individual states are responsible for regulating these sources.

Sealed sources completely enclose the radioactive material, which is also permanently bonded or fixed to a capsule or matrix designed to prevent its release under the most severe conditions of normal use and handling. The NRC or an Agreement State registers a sealed source or device after performing the appropriate engineering and radiation safety evaluations. These evaluations address the ability of sealed sources and devices to safely contain radioactivity under the conditions of their possession and use. The certificates contain detailed information for each registered source and device, such as how they are permitted to be distributed and possessed (i.e. specific license, general license, exempt), design and function, radiation safety, limitations and use, life expectancy and leak testing requirements. The NRC regulations require NRC licensees to use only sources and devices approved in the Sealed Source and Device Registry (SSDR).

The Sealed Source Registry Database is available for public review at http://www.hrsd.ornl.gov/nrc/sources/index.cfm. It includes a comprehensive listing of all registered sealed sources, including the manufacturer and model number.

Under the current law, there are three relevant regulatory categories for sealed sources of byproduct materials: specific license; general license and exempt sources. These were briefly defined in the Introduction and are further defined in Table 10 and this section.

TABLE 10. REGULATORY CATEGORIES FOR END USERS OF CERTAIN SEALED SOURCES

Category	Example	Requirements
Specific License	Irradiators, Industrial radiography, Some portable and fixed gauges	The NRC or an Agreement State issues a specific license to provide stricter controls to companies, individuals or institutions using certain radioactive devices containing higher levels of radioactivity or greater amounts of sources and for manufacturers and distributors (10 CFR Parts 30, 32, 33) of licensed devices. In the December 2000 final rule-making, NRC estimated 20,000 specific licenses and 260,000 devices.
General License	Nuclear fixed gauges, Tritium exit signs, Static Eliminators	The NRC or Agreement State issues a general license for the possession and use or ownership of byproduct material contained in certain devices. GL Devices have inherent radiation safety features built-in. In the December 2000 final rule-making,, NRC estimated 135,000 general licenses and 1.8 million devices
Exempt	Self-luminous (e.g., watches, dials and automatic locks), Smoke detectors, Spark gap irradiators, Ionizing radiation, Measurement instruments.	No requirements on the end user (e.g., consumer) because the product poses minimal hazard to the general public. Manufactures and distributors of these products must be licensed in order to initially transfer or distribute them to a person exempt from licensing.

A specific license is issued by a regulatory agency following the submittal of an application form (and fee) by the user. The license will specify authorized possession limits and conditions of use for each gauge. The application and approval for a specific license is based on several factors. Some gauges must be specifically licensed in that a specific license may be a "condition of use" identified on the source device registry certificate. Other nuclear fixed gauges may fall under a specific or general license depending on other factor such as: (1) whether the licensee will perform maintenance (specific) or contract the maintenance to a specific licensee (general), and (2) whether the device is to be relocated with the facility of use (specific).

A "general license" is granted to a person or organization that acquires, uses or possesses a generally licensed device. The NRC or an "Agreement State" may grant the general license (GL). The device must be obtained through an authorized transfer by the device manufacturer/distributor, or by change of company ownership where the device remains in use at a particular location. GL Devices are manufactured and distributed only by a company holding a specific license issued by the NRC or by an Agreement State. The text box on the right identifies the six categories of products covered by the GL license requirements. There is no regulatory threshold that delineates a generally licensed device from a specifically licensed device.

Under the General License (GL) program, the company, institution or individual acquiring a fixed nuclear gauge or tritium exit sign does not formally apply for a license. The applicable agency automatically considers the end-user a "general licensee" upon the legal transfer of the device from the manufacturer to the end-user and the appropriate quarterly notification to the regulatory agency by the supplier. As a result of this simplified licensing process (e.g., presumptive approval), there has been limited tracking and accountability of nuclear fixed gauges and tritium exit signs over the years.

General License Devices

- Gas chromatograph
- **Fixed gauges**
- Static Eliminators
- **Tritium Exit Signs**
- Luminous exit signs (aircraft)
- Certain in vitro or laboratory testing

General License Requirements

A general licensee holding a nuclear fixed gauge or tritium exit sign must meet the following obligations:

- Assure that all labels affixed to the device are maintained;
- Assure that the device is tested for leakage of radioactive material at six-month intervals (or alternative schedule specified in the instructions (tritium exit signs are generally exempt);
- Conform with manufacturer's instructions for usage and maintenance;
- Maintain proper records for a minimum period of three years (e.g., 3 years after most recent testing);
- Suspend operation of the device if there is a failure of, or damage to, the device or upon the detection of 185 becquerel (0.005 microcuries) or more removable radioactive material. The device can not be operated until it has been properly repaired by a licensed professional;
- Shall not abandon the device;
- Properly dispose of the device only by transferring it to a manufacturer/distributor or a radioactive waste broker holding a specific license. However, the device may be transferred to another GL licensee if the device remains in use at the same location or the device is held in storage and properly contained and maintained;
- Shall not export the device except in accordance with other relevant sections of the law;

- Report to NRC/Agreement State any lost, stolen or broken device;
- Inform NRC/Agreement State of a company name change or change of address;
- Make certain reports, as applicable, (Disposal or transfer report, transfer report for change of ownership, report if device becomes damaged, report name change of licensee, report change of address, report of incidents or lost or stolen, report all device transfers to the NRC even if a licensee is obtaining a replacement) to the NRC or Agreement State;
- Appoint a Responsible Individual to oversee management of the device(s); and
- Store device for no more than two years -- with exemptions for devices in standby use and flexibility from testing during storage

GL devices must have labels containing such words as: "Caution-Radioactive Material"; "The receipt, possession, use, and transfer of the device are subject to a general license": or identification of the radioactive material, such as "5 millicuries of cesium-137." In addition, information is required that identifies the manufacturer, distributor, serial number, UL listing and other identifying marks. This information, placed on the side or back of a tritium exit sign, may be difficult to see during renovation or demolition activities.

Labeling

Label information is required to minimize the risk of improper disposal. For example, one nuclear fixed gauge manufacturer provides the following information, in addition to the "caution radioactive material" words and symbol, on the gauge to meet the applicable requirements.

- The receipt, possession, use and transfer of this device are subject to a general license and the regulations of the U.S. Nuclear Regulatory Commission or Agreement State.
- Abandonment or disposal is prohibited.
- Only persons specifically authorized by the NRC or Agreement State may install, relocate, dismantle or repair the device.
- The general licensee shall test this device for leakage for radioactive material at intervals not to exceed three years, and maintain records on file.
- The general licensee shall perform shutter mechanism function checks at six month intervals and maintain records on file.
- Additional information on this device is contained in the operating manual.
- This label shall be maintained on the device in a legible condition.

Annual Registration Requirements for Certain Devices

In 1994, a joint Agreement State-NRC Working Group began to meet to address the problems associated with orphan sources and the management of generally licensed devices. This Working Group developed criteria contained in a broad report called NUREG-1551, to determine which sources, if improperly managed, posed additional risk. In the "Final Report of the NRC-Agreement State Working Group (WG) to Evaluate Control and Accountability of Licensed Devices," the WG determined that the problem it was addressing had four parts:

1. Inadequate regulatory oversight;
2. Inadequate control over and accountability for devices by users;
3. Improper disposal of devices; and
4. Problems associated with "orphaned devices."

To address the problems, the WG proposed five recommendations:

1. NRC and Agreement States ("AS") increase regulatory oversight for certain users of certain devices;
2. NRC and AS impose penalties on persons losing devices;
3. NRC and AS ensure proper disposal of orphaned devices;
4. NRC encourage states to implement similar oversight programs for users of Naturally-Occurring or Accelerator-Produced Material (NARM); and
5. NRC encourages non-licensed stakeholders to take appropriate actions, such as instituting programs for material identification.

Table 11 illustrates the timeline for the development of the revised GL Device regulations, finalized on December 18, 2000, that addressed the first recommendation of the Working Group.

TABLE 11. HISTORY OF REGULATIONS AND ACTIVITIES LEADING TO ENHANCED GL DEVICE REGISTRATION

Date	NRC Action
1984 – 1986	Sampled the effectiveness of GL program
December 27, 1991	Proposed rule for accountability of GL devices
October 1996	NUREG-1551 "Final Report of the NRC-Agreement States Working Group to evaluate Control and Accountability of Licensed Devices"
December 2, 1998	Proposed Rule (1) Enabled NRC to request information from GLs intended for registration program
July 26, 1999	Proposed Rule (2) Registration Process
August 4, 1999	Final Rule request for information from GLs intended for registration program
December 18, 2000	Final Rule; Requirements for Certain Generally Licensed Industrial Devices Containing Byproduct Material
February 16, 2001	Effective date of the 12/18/00 Final Rule

Additional registration requirements on certain GL Devices became effective February 16, 2001. These new requirements, also recommended by the NRC-Agreement State Working Group (NUREG-1551), provided greater assurance that "higher risk" GL Devices would be properly managed in the future. While certain nuclear fixed gauges were potentially covered by the additional registration requirements, tritium exit signs were excluded. According to the preamble in the August 4, 1999 notification of rulemaking, "most of the devices meeting the criteria are used in commercial and industrial applications measuring thickness or density."

The new requirements affect thousands of devices that contain more than:

- 370 MBq (10 mCi) of cesium-137
- 3.7 MBq (0.1 mCi) of strontium-90
- 37 MBq (1 mCi) of cobalt-60
- 37 MBq (1 mCi) of transuranics (e.g., americium –241)

Users of these GL Devices are required to annually register their devices, provide additional information and pay an annual $450 registration fee. NRC or the Agreement State annually mails the user the registration information and the licensee verifies or revises the information and submits the form to the NRC or Agreement State with its fee.

The annual registration process has generally been well-received by radiation safety professionals and suppliers who recognize the need for additional oversight and accountability. The registration process became effective in "non-Agreement" States in 2001 and must become effective in all Agreement States by February 16, 2004. An initial challenge, according to some stakeholders, was the inadequacy of the general licensee mailing list. As many as 20 percent of the mailings to general licensees, potentially covered by the new requirements, came back as "undeliverable" or "no forwarding address." This challenge proved to be an excellent opportunity to clean up old mailing lists and confirm the number of active licensees.

The rule has not significantly deflated sales of gauges. In fact, sales increased an unprecedented 100 percent in 2002 compared to 2001, based on NRC registration information. Based on our discussions with gauge manufacturers, many of the devices sold do exceed the registration thresholds defined in the new regulations – even as they see a decrease in the activity level required for their gauges. Some manufacturers have reportedly modified the design of their gauges (e.g., stacking capsules with reduced activity) so that the device will fall below the registration thresholds. It is generally too early to assess the effect of this revised rule in enhancing accountability, limiting the number of devices that are lost or abandoned, or in affecting the design of nuclear fixed gauges or the purchase of alternative, non-nuclear technologies.

The final rule also required manufacturers/distributors, under 10 CFR 32.51, to provide general licensees with a copy of the regulations (10 CFR 31.5), and information about disposal options, estimated costs of disposal, and the penalties for improper disposal. This information must be provided prior to, or at the time of, transfer of the device. Most suppliers provide the bulk of the information after the completion of the purchase. The regulatory requirements and the information about potential disposal costs are not seen as negatively affecting sales, according to our interviews. This educational information and training is generally limited to the "responsible individual" at the general licensee.

Gauge manufacturers are committed to providing improved educational and information materials to users. Purchasers are likely to receive pamphlets, brochures, "Frequently Asked Question" fact sheets as well as copies of the regulations.

Low Level Waste (LLW) Disposal Regulations

Nuclear fixed gauges and tritium exit signs must be disposed as Low Level Radioactive Waste (LLRW) if they cannot be recycled or reused. The disposal of LLRW is highly regulated and quite restricted.

LLRW is separated into classes depending on its hazard: Class A (lowest hazard), B, C and Greater than Class C (highest hazard). The hazard class is based on the radioactivity, its half-life, mobility in the ground, and the hazard of the radionuclide in the human body. About 95 percent (by volume) of all LLW is categorized as Class A and can be disposed at approved radioactive disposal sites. The only commercial LLRW facilities in the U.S., at present, are:

- Barnwell Waste Management, operated by Chem Nuclear Systems, LLC., South Carolina;
- U.S. Ecology which leases space at DOE's Hanford site in Richland, WA; and
- Envirocare of Utah, Inc. in Clive, Utah.

The Low-Level Radioactive Waste Policy Act of 1980, as amended, made states responsible for providing for LLRW disposal. The law encouraged states to form interstate agreements and to work together as compacts to establish and assure disposal capacity of Class A, B and C wastes. A new disposal facility has not opened since the law was passed. However, the Texas Senate has recently approved the creation of two privately run disposal facilities for low-level radioactive waste in Texas. The creation of these facilities requires approval from the governor of Texas.

Only the Barnwell, SC and Richland, WA sites accept nuclear fixed gauges and tritium exit signs.

Of the three disposal sites, Envirocare does not accept nuclear fixed gauges or tritium exit signs because of restrictions placed on its permit by the State of Utah. The Richland site restricts disposal to the Rocky Mountain Compact and the Northwest Compact. The Northwest Interstate Compact includes Alaska, Hawaii, Idaho, Montana, Oregon, Utah, Washington, and Wyoming. The Rocky Mountain Interstate Compact includes Colorado, Nevada and New Mexico.

The Barnwell facility can accept generally licensed devices from all states, although most states in the west will use the Richland facility. Under state law, the Barnwell facility is beginning to "ramp-down" the total annual volume received at the site through the six-fiscal year period that ends June 30, 2008. After that date, the facility will only receive waste from generators in South Carolina and the two other Atlantic Compact states (Connecticut and New Jersey).

The DOE is responsible for disposing of Greater than Class C and transuranic or "TRU" waste. TRU wastes are defined as containing more than 100 nCi/g of alpha emitting isotopes with atomic number greater than 92 (uranium) and half-lives greater than 20 years. Americium-241 is a TRU waste that can be found in certain nuclear fixed gauges. Most gauges containing americium-241 have no viable commercial disposal option. For example, Barnwell has an isotope limit of 500 uCi per disposal container for Am-241. Spent or unwanted sealed sources containing these radionuclides must often be stored for ultimate disposal through the DOE.

The DOE and NRC estimate that several thousand excess and unwanted sealed sources, held by licensees in the U.S., are potentially covered by the requirements of this law.

Under the Low-Level Radioactive Waste Policy Amendments of 1985-PL 99-240, the U.S. Department of Energy (DOE) has an obligation to recover certain sealed sources that are not wanted or needed. Section 7 of this Report describes a Federal and state initiative design to recover and properly manage these wastes (e.g., Am-241) that meet these criteria.

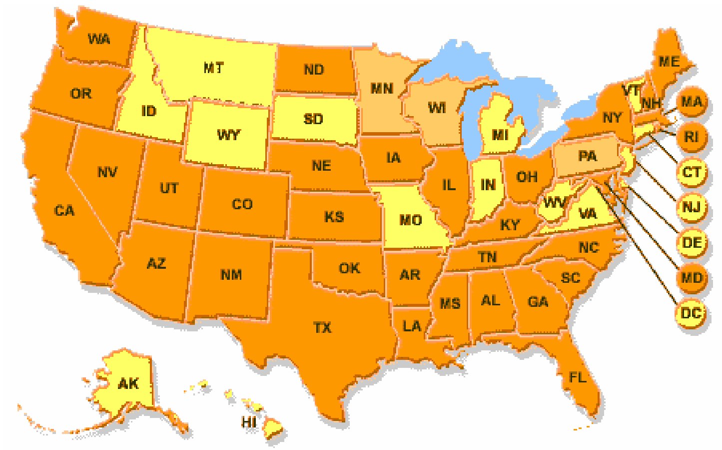
5.2 State Requirements and Programs

States that wish to establish and administer their own regulatory program for Atomic Energy Act materials may do so under the Atomic Energy Act. Under Section 274 of the Act, NRC relinquishes to the States portions of its regulatory authority to license and regulate byproduct materials, source materials and certain quantities of special nuclear materials. The mechanism for the transfer of NRC's authority to a

State is an agreement signed by the Governor of the State and the Chairman of the Commission. NRC must approve the State program, or portions of the program for which NRC has regulatory authority, and continue to provide oversight. There are thirty-two "Agreement States" that are currently authorized to administer their own programs. These states are identified in orange in Figure 4 below. .

States in yellow are non-Agreement states. States illustrated in light brown have initiated the process of becoming an Agreement State. A listing of non-Agreement states is also included below. Agreement states administer their own GL Device program and maintain relevant data concerning registrations and transfers, and enforce program requirements.

Figure 4. Map of Agreement and Non-Agreement States



Non-Agreement States
Alaska
Connecticut
Delaware
District of Columbia
Hawaii
Idaho
Indiana
Michigan
Minnesota
Missouri
Montana
New Jersey
Pennsylvania
South Dakota
Vermont
Virginia
West Virginia
Wisconsin

There is significant variation between states' GL programs. Some states operated their own registration program for GL devices prior to the December 18, 2000 final rule-making. For example, North Carolina, Oregon, Washington, Massachusetts, Illinois, Texas and California have operated their own registration program prior to the December 18, 2000 rule. These programs may require written programs, application fees, training, location and storage information, a Radiation Safety Officer, physical inventories or inspections, documented emergency procedures, additional testing for leakage and/or contamination, or renewal (e.g., annual) requirements. Some states (e.g., Texas) are considering modifying their more stringent GL registration programs to come into conformance with the December 2000 GL Device Final Rule. Other states are reportedly following suit to respond to marketplace pressure to implement a consistent, national set of regulatory requirements.

Some states have designed programs that require most companies using nuclear fixed gauges to obtain a specific license. For example, industries in New York using nuclear fixed gauges are typically required to obtain a specific license because the regulations allow general licenses only for certain low activity sources (e.g., < 1 mCi of gamma emitting material).

Finally, some state programs are based on unique policies or interpretations. For example, some manufacturers reported that certain state regulatory agencies are strongly encouraging licensees to automatically replace their gauges as soon as the device's lifetime expectancy (as identified in the Sealed Source Device Registry) approaches. The Device Registry estimate of a gauge's useful life was never meant as an expiration date, as the life expectancy of a gauge is based on various factors such as the frequency of use, the material evaluated, the isotope, and the activity level. Many gauges have a useful life of two to three times the estimate provided in the Registry, according to manufacturers. Requiring such disposition, in the absence of a recognized standard method to evaluate a gauge's continued efficacy, may be unnecessary and environmentally wasteful.

5.3 General License Registrations

Currently, the NRC or an Agreement State registers general licensees based on quarterly information submitted by manufacturers/distributors upon the sale or transfer of a product to a licensee. Most states and the NRC require the end user to provide written notification within 30 days of receipt of a generally licensed device. NRC maintains this information in general licensee database. NRC has spent considerable resources in recent years to improve the quality and accuracy of the information in this general licensee database.

The NRC database is limited to registrations from non-agreement states. An extrapolation method needs to be employed to estimate nationwide registrations. The nationwide estimates for nuclear fixed gauges were calculated by multiplying the actual registrations received by the NRC (from Non-Agreement States) by a factor of three to account for the Agreement States and generate a nationwide estimate. This estimation method has been previously employed by the NRC to estimate national figures, based on the previous work of Strom (1994). The accuracy of the nationwide estimates for nuclear fixed gauges presented in this report has been questioned by industry professionals. The lack of an efficient method of obtaining device registration from each Agreement State and the lack of a valid extrapolation method are ongoing challenges to obtaining more accurate nationwide estimates.

Based on nationwide estimates extrapolated from NRC registration data for Non-Agreement states, approximately 72,000 nuclear fixed gauges have been registered nationally to General Licensees during the last twenty years in all states. Annual registration information is presented below in Table 12.

TABLE 12. ESTIMATE OF ANNUAL NUCLEAR FIXED GAUGE GENERAL LICENSE REGISTRATIONS OVER THE LAST TWENTY YEARS IN ALL STATES

Year	# of Estimated Registrations	Year	# of Estimated Registrations
1983	7,083	**1993**	1,743
1984	5,934	**1994**	1,668
1985	5,802	**1995**	1,824
1986	2,523	**1996**	1,698
1987	3,267	**1997**	1,461
1988	3,207	**1998**	1,641
1989	10,020	**1999**	1,755
1990	2,226	**2000**	1,914
1991	2,253	**2001**	1,647
1992	7,191	**2002**	6,984

There has been a general decline in registrations over the last twenty years. From 1983 to 1992, an average of 4,950 annual registrations were filed. From 1993 to 2001, the annual registrations of nuclear fixed gauges decreased to an average of 1,705. For 2002, however, we estimated that nearly 7,000 GL nuclear fixed gauges were registered. This number is nearly double the annual, national average (3,592) for the past 20 years. It is unclear whether this increase in registrations is a result of the new GL license requirements, including the annual registration program, better information and education of general licensees by sales representatives, or a replacement of gauges occurring ten years after the heightened registrations in 1992.

Some manufacturers of nuclear fixed gauges believe the nationwide estimates based on non-Agreement state annual registration figures may be significantly higher than actual sales figures for GL gauges.

Based upon our interviews with tritium exit sign manufacturers, the annual nationwide market for tritium exit signs is believed to be between 80,000 – 110,000 units for the past three years. The largest markets for tritium exit signs seem to be in Agreement states such as California and Nevada. Therefore, a multiplier of 6 was used to extrapolate the NRC registration data for Non-Agreement states to obtain a nationwide estimate. According to our nationwide estimates based on the NRC data, more than 2,000,000 tritium exit signs have been sold during the last twenty years. This information is presented in Table 13.

TABLE 13. ESTIMATE OF ANNUAL TRITIUM EXIT SIGNS REGISTRATIONS OVER THE LAST TWENTY YEARS IN ALL STATES

Year	# of Estimated Registrations	Year	# of Estimated Registrations
1983	35,262	1993	151,854
1984	76,968	1994	142,128
1985	64,506	1995	112,182
1986	6,888	1996	89,256
1987	63,600	1997	74,478
1988	255,720	1998	77,916
1989	160,752	1999	105,522
1990	91,278	2000	114,588
1991	195,690	2001	81,636
1992	179,964	2002	88,152

Last year (2002), more than 88,000 tritium exit signs were registered. The average number of registrations per year is 108,400 over this twenty year period, according to our estimates. However, the average number of registrations has declined over the years. Registrations for the past eight years are 40 percent lower than the registrations for the previous eight years. The low and high registrations in 1986 and 1988 appear anomalous and may be artifacts of data collection problems.

All states maintain some form of a database of GL Devices. Table 14 below provides GL registration information from the state of Massachusetts. This table indicates that approximately half of the GL registrations are for devices covered by this report.

TABLE 14. GL DEVICE REGISTRATION INFORMATION FROM MASSACHUSETTS

Massachusetts General License Registry
Total Registrants: 288
Total Registered Devices 1901
Total Tritium Devices: 587 (31%)

Devices by Function:
Detecting: 148 (8%)
Thickness (123 (8%)
Level: 52 (3%)
Chemical Com: 65 (3%)
Static Elimin: 306 (16%)
Unknown: 401 (21%)
Measuring: 112 (6%)
Density: 85 (4%)
Radiation: 16 (1%)
Exit signs: 511 (27%)
Other: 82 (4%)

5.4 Enforcement

NRC or Agreement States infrequently take enforcement actions against individuals, corporations or institutions for failure to comply with requirements applicable to managing a generally licensed device. Some stakeholders commented that inspections are rarely performed at GL Device licensees.

Despite the NRC's 2001 Enforcement Policy revision, which increased the civil penalties for cases involving loss or unauthorized disposal of licensed sealed sources, proposed fines or penalties in 2002 were typically less than the cost of proper disposal. In FY 02, NRC took enforcement actions against 20 gauge users. Nine Notices of Violation (NOV), without monetary penalties, were given and nine civil penalties were issued. Additionally, NRC chose to exercise discretion and refrain from taking enforcement action in two cases. This discretion is allowed under the Interim Enforcement Policy for GL Devices Containing Byproduct Material.

In most circumstances involving GL devices, an offense is considered a Severity Level III violation, the least serious of NRC's violations. In many of these cases, discretion was warranted, argued NRC, because the licensee's actions were not willful and the licensee identified and reported the loss. In those instances in which a civil penalty was proposed, the penalties were never in excess of $10,000 and were typically in the $3,000 range. For example, a company was issued a Severity Level III violation for: (1) failure to transfer generally licensed devices only to authorized recipients (in this case a static eliminator device containing 11.25 millicuries of americium-241) and (2) failure to provide complete and accurate information to the NRC. The proposed penalty was in the amount of $3,000. Another company received a proposed $8,800 penalty in 2000 for an SLII Notice of Violation/Consent Order for failure to (1) obtain written consent from the NRC prior to transferring control of licensed material to unlicensed companies on two occasions; (2) secure or maintain constant surveillance of licensed material from unauthorized access; and (3) provide information to the NRC that was complete and accurate in all material aspects.

Many stakeholders expressed the opinion that limited enforcement activity and minimal penalties do not act as a deterrent to the abandonment or improper disposal of devices covered in this report.

5.5 Codes/Standards

In addition to the applicable federal and state regulatory requirements, certain codes and standards affect the design, manufacture, and use of nuclear fixed gauges and tritium exit signs. These standards are mentioned in this report (1) to highlight the fact that the manufacturer and user of a sealed source is highly regulated; and (2) to recognize that opportunities may exist within the voluntary standard development arena to address problems raised in this report.

It is also worth mentioning that the Commission of the European Communities has issued a "Proposal for a Council Directive on the control of high activity sealed radioactive sources." The directive is intended to address many of the management issues highlighted in this report.

Standards Relevant to Exit Signs

Exit signs installed in the United States must be designed and manufactured to conform with the following standards:

- UL 924 "Emergency Lighting and Power Equipment" which prescribes features, such as illumination levels, visibility, etc.
- National Fire Protection Association (NFPA) "101 Life Safety Code"

Additionally, UL and NFPA approved exit signs shall be installed to meet international, national, state and local building and electrical codes.

Standards Relevant to Nuclear Fixed Gauges

Many standards are relevant to the design, use, testing/calibrating, labeling and packaging of nuclear fixed gauges. In the United States, the American National Standards Institute (ANSI), a private non-profit organization administers and coordinates the U.S. voluntary standardization and conformity assessment systems. Many of these standards conform with or reference standards issued by the International Organization of Standardization (ISO) and the Deutsche Institut fur Normung. Examples include:

- ISO 2919:1999 Radiation Protection –Sealed Radioactive Sources – General Requirements and Classification
- ISO 361: 1975 Basic Ionizing radiation symbol (use of the symbol)
- ISO 9978:1992 Radiation Protection – Sealed Radioactive Sources – Leakage Test Methods
- DIN 25426-1: Sealed Radioactive Sources; requirements and classification
- ANSI N-542: Special Form Sources

ANSI announced recently the establishment of the Homeland Security Standards Panel (HSSP). This Panel will be a cross-sector coordinating body for the development and enhancement of Homeland Security and emergency preparedness standards. The design of products with radioactive components that could be incorporated into a "dirty bomb" would likely be addressed by the HSSP.

In addition, opportunities may exist to address improper disposal of devices through standards or guidelines for environmental due diligence (e.g., ISO 14015 Environmental Assessment of sites and organizations), quality system standards (e.g., ISO 9001), building codes, or standards of practice for building demolition. We are not aware that any of these standards or codes currently address issues associated with nuclear fixed gauges or tritium exit signs.

Standards Relevant to Cleanup and Exposure

A variety of U.S. regulators and professional associations have promulgated regulations, guidelines and standards for radiation cleanup for "release for unrestricted use." A summary of relevant standards is presented below. It is sufficient, for the purpose of this paper, to simply acknowledge that different standards exist and the differences are based on professional and technical differences of opinion. As noted previously, there is disagreement on the use of linear models to determine safe lower exposure levels and on varying assumptions and risk assessment methodologies.

TABLE 15. RELEVANT RADIATION CLEANUP STANDARDS.

Agency or Institution	Standard	Covers
NRC 10 CFR 20.1402 Radiological Criteria for Unrestricted Use	25 mrem/year TEDE	Including that from groundwater sources of drinking water plus ALARA
DOE Order 5400.5 Radiation Protection of the Public and the Environment	100 mrem/year	Operating facilities
EPA CERCLA	15 mrem/year dose limit	Soil contamination
EPA 40 CFR 141 and 142	4 mrem/year	Groundwater – consistent with the EPA Primary Drinking Water Regulations
ANSI N13.12 (1999) "Surface Volumetric Radioactivity Standards for Clearance"	Varies based on isotope	Contaminated property

5.6 Export/Import

The export and import of radioactive material present unique regulatory and management challenges. Inadequate tracking of devices, failure to use detection systems at ports and failure to ensure credible transfers have been identified as challenges that must be addressed (Ferguson, 2003).

The NRC regulations address the import and export of sealed sources of radioactivity (e.g., Specific and General License Devices) at 10 CFR 110. These requirements include notification, reporting and recordkeeping requirements.

Export

An export is any item that leaves the US to a foreign destination. In addition to the NRC regulations, applicable export regulations include the "Export Administration Requirements" developed by the Bureau of Industry and Security of the US Dept of Commerce (http://www.bis.doc.gov/) and the Foreign Trade Statistics Regulations 15 CFR Part 30. http://www.census.gov/foreign-trade/www/

How Export Actually Works

What is being shipped, where it is being shipped, who it is being shipped to, and what it is being used for are all important questions to answer prior to export. To export material, the shipper has the responsibility to first check the Commerce Control List. This is a list of all known "controlled commodities." For example, radiation equipment generally has an ECCN (Export Commodity Control Number) No. of 3A101B.

If an item is not listed, the shipper needs to check on the lists provided by the agency. Smoke detectors for instance, are not listed. It is therefore an EAR99 or NLR – No License Required. Tritium compounds and mixtures are listed. There are times when the shipper must request an analysis by the Agency to determine if a license might be needed if the item is not found on the list. However, if it is not listed as a regulated commodity the shipper still has a responsibility to ask the question of where it is going, as a license might still be required or the export might be prohibited (e.g., Cuba, Iraq).

The shipper then reviews the ECCN No. requirements, the reasons for control, the country list and the denied persons list. The shipper may have a license for a specified period of time and/or for specific materials. If not, the shipper may need to apply for a license with the agency.

Once the shipment is ready to go, a "Shippers Export Declaration" Form is filled out. This is governed by the Foreign Trade Statistics Regulations. However, this Form is only needed if the shipment is worth over $2500 (other exemptions might apply). The Form includes the license number and ECCN No. among many other items. This form is accompanied with the shipment and goes to a Freight Forwarder (FF).

A freight forwarder will typically assume that what is on the form is what is in the package and will not open the box. The Freight Forwarder gives the package/shipment to the transporter, such as an airlines or cargo ship. The Bureau of Customs and Border Protection performs spot inspections and any errors found on the Forms are fined at $10,000 per incident. Records of shipments must be retained for 5 years.

There are currently limited measures taken to ensure confirmation that the importing country has in place adequate controls and security measures or that the receiving entity is a legitimate and credible enterprise.

Import

An import is any item that enters the US from a foreign port of origin. Under 10 CFR 110, a foreign vendor of sealed source devices is required to establish an address in the United States to which the NRC can correspond and serve papers, as necessary. For example, many nuclear fixed gauges are manufactured in Europe or Canada and are shipped to the United States for further assembly or sale. In addition to the NRC regulations, applicable import regulations include Customs regulations at 19 CFR Part 146, applicable Tariff Schedules and the Foreign-Trade Zone Regulations (15 CFR Part 400).

In the past, the import of materials relied solely on written compliance with applicable notification, reporting, and fee payment requirements. Until last April 2002, U.S. Customs Service did not screen all packages for radioactive material and instead relied on profiling. Measures and equipment to monitor for radiation and ensure sealed source accountability are now being implemented because improvements in accountability and security are widely acknowledged as necessary.

Recent Import Initiatives to Enhance Accountability

Imported items go through the Bureau of Customs and Border Protectionat ports of entry in the US, or starting in some ports, at overseas locations.

- **Pushing Back the Borders**: Under this program, some overseas agents are checking items before they get to US ports. This is applicable to ocean transport only. This program falls under the Container Security Initiative (CSI).

- **24 Hour Rule**: Effective December 2, 2002, carriers and/or automated NVOCC's (non vessel operating common carriers) must submit a cargo declaration 24 hours before cargo is laden aboard the vessel at a port.

- **C-TPAT**: The Customs-Trade Partnership Against Terrorism (C-TPAT) is a cooperative and voluntary endeavor between the trade community and U.S. Customs Service to develop, enhance, and maintain effective security processes throughout the global supply chain. Businesses voluntarily apply to participate in C-TPAT and, if approved, sign an agreement specifying certain conditions of participation.

- **FAST**: In the Shared Border Accord with a 30-point action plan, the U.S. and Canadian governments have agreed to align, to the maximum extent possible, their customs commercial programs along their shared border. This agreement marked the creation of the Free and Secure Trade (FAST) program, which is the result of a shared objective to enhance the security and safety of Canadians and Americans, while enhancing the economic prosperity of both countries. The FAST program will allow importers on the U.S./Canada border to obtain expedited release for qualifying commercial shipments.

- **Foreign-Trade Zones (FTZ):** These are secure areas under U.S. Customs supervision that are generally considered to be outside the Customs territory upon activation. Located in or near U.S. Customs ports of entry, they are the United States version of what are known internationally as free-trade zones. The Foreign-Trade Zones Act is administered through two sets of regulations, the Foreign-Trade Zone Regulations (15 CFR Part 400) and the Customs Regulations (19 CFR Part 146).

- **US Ports of Entry**: In March 2003, the new Bureau of Customs and Border Protection reported that inspectors have enhanced the use of small, pager-like detectors at US ports of entry to check passengers for radiation. The goal is to have all 9,000 inspectors equipped with the devices to screen the more than 500,000 people entering the U.S. (Boston Globe, March 2, 2003)

5.7 Summary of Findings

- Land burial options in the United States for nuclear fixed gauges and tritium exit signs are limited to two disposal facilities, located in Barnwell, SC. and Richland, WA. The low level radioactive wasted commissions and independent state low level waste boards have been unsuccessful in the siting of additional land disposal facilities.
- The well-documented lack of accountability for GL licensed devices over the years has led to abandoned, lost, or improperly stored or disposed devices.
- Agreement states have instituted differing licensing programs, requirements and interpretations.
- Developing accurate nationwide registration data is difficult because NRC registration data is only available for non-agreement states and there is no industry association representing tritium exit sign and nuclear fixed gauge manufacturers.
- Information in the NRC Source and Device Registration inventory is potentially being used by states, or manufacturers, to encourage or require premature replacement of functional and accurate gauges.
- The December 18, 2000 Final Rule for Generally Licensed Devices addressed many of the previously cited weaknesses in the GL program. It is too early to fully evaluate the impact of this regulatory revision on (1) management of disused and orphan sources; (2) management of devices current in use; and (3) the redesign of gauges to fall under threshold levels.
- Many GL nuclear fixed gauges are sold to companies holding a specific license and the gauge is managed under the site-specific program.
- Different standards and risk models are used by different agencies and standard setting bodies to develop "safe" levels of exposure/cleanup.
- The threat of enforcement is not perceived as serious deterrent to improper end-of-life management and disposal.
- Loopholes in the process of importing and exporting devices containing radioactive material exist, but are being addressed by multiple federal and state agencies.
- There are emerging issues of regulatory overlap in the area of homeland security and radiological devices.
- There is limited and inconsistent enforcement of leak testing, shutter checks, registration and storage requirements generally licensed nuclear fixed gauges.
- The Commission of the European Communities is proposing requirements for sealed sources that is similar in many ways to requirements in the United States. The European proposal would, however, require upfront fees to fund the ultimate disposal of devices at the end of their useful life.
- Due diligence, quality management system and state building codes do not currently contemplate or provide guidance on the proper management of nuclear devices.

6. MANUFACTURING, SALES, AND USE

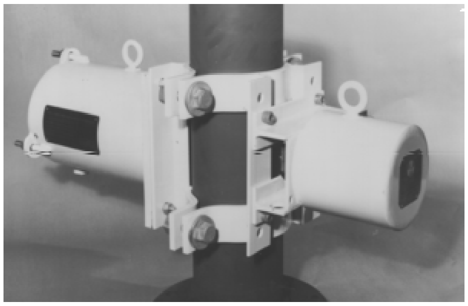
6.1 Nuclear Fixed Gauges

6.1.1 Product Functionality

Nuclear fixed gauges are based on the principle that the radiation emitted from the radioactive material will be reduced in intensity by matter between the radioactive material and the detector. The amount of this radiation can be used to determine the quantity of material between the source and the detector.

The industrial monitoring or measuring functions include the following:

- Detection
- Volumetric Flow Rate
- Density
- Basis Weight
- Level
- Resin Content
- Measurement
- Moisture content
- Thickness
- Mass per unit area
- Consistency
- Chemical Composition



Nuclear fixed gauges, such as the flow meter above, provide certain functional advantages because they are: non-intrusive; generally impervious to temperature, pressure, corrosives or toxic vapors; highly accurate; and reliable with limited maintenance.

6.1.2 Product Applications

Nuclear fixed gauges are used primarily by the manufacturing sector, including such industries as pulp and paper, beverage, chemical processing, food, tobacco, textiles, wood processing, cement, mineral processing, oil refining, mining, and materials processing. Nuclear fixed gauges are used for various material applications, including, but not limited to, cast film extrusion, blown film extrusion, sheet film, non-wovens, rubber, vinyl, composites, and others.

A gauge is designed and engineered (e.g., activity level, source holder) by the manufacturer to meet the company's specific application and use.

6.1.3 Radioactive Components

Table 16 describes representative industries, types of applications, and radioactive components.

TABLE 16. INDUSTRIES USING NUCLEAR FIXED GAUGES
(Source: Adapted from Trinity Engineering, 2002)

Industry	Function	Type of Radiation	Radioactive Source
Manufacturing	Thickness of metal components, thickness of coatings, moisture content in products	Gamma	Ba-133, Co-60, Cs-134, Cs-137, Sb-124, Se-75, Sr-90. Tm-170
Chemical Processing	Density, thickness of coatings, specific gravity, level, equipment parameters	Gamma Neutron source (level measurement)	Co-60, Cs-137 Am Be
Mineral Processing	Density and spectroscopy to measure levels of minerals in process streams	Gamma	Am-241, Co-57, Cs-137
Materials Processing (e.g., blown or cast film rubber, vinyl, coatings/laminates, composites, paper)	Thickness or weight, moisture content	Gamma Beta	Am-241 Pr-147, Kr-85, Sr-90

As indicated earlier in this report, the level of radioactivity in GL nuclear fixed gauges is in the range of 0.0027 Ci (Trinity Engineering, 2002) up to 27 Ci (IAEA, 2000). GL gauges more typically have activity levels less than 1 curie. For example, GL density and thickness gauges containing Cs-137 may have activity levels from 2.7 to 8,000 mCi. One manufacturer noted that while most current Cs-137 gauges are above 10 mCi, the trend is to manufacture gauges with less than 2mCi.

GL thickness gauges may contain Kr-85 (2.7 to 1350 mCi), Am-241 (27 to 1000 mCi), Ti-204 (up to 1080 mCi) or Sr-90 (2.7 to 108 mCi). Co-60 gauges typically have activity levels between 200 and 1000 mCi.

Isotopes, such as Cs-137, with longer half-lives are often preferred. Manufacturers reported an increase in sales of gauges containing Cs-137 and a significant decrease, over the last few years, in the manufacture and sales of gauges containing Co-60.

In NUREG-1551, GL nuclear fixed gauges were classified as “Category 3” for risk because of their lower activity levels. Certain GL nuclear fixed gauges, however, can have activity levels as high as 27 Ci. These high source activity gauges would be categorized as “Category 2” (high activity sources) while the IAEA (2000) categorization scheme would place most fixed industrial gauges in “Category 3”.

Based on our discussions with manufacturing representatives, gauges are currently being designed with lower activity levels. Technology is the primary driver. Lower activity levels can be achieved because of better detection technology. Additionally, there have reportedly been some efforts to minimize the activity levels, or design equipment in such a way, to avoid the GL registration fees and requirements.

One manufacturer reported that they would not use transuranic materials, such as Americium-241, for which there is no viable disposal option.

6.1.4 Major Product Manufacturers

Eighty-seven companies are "active" manufacturers or distributors of nuclear fixed gauges, according to March, 2003 data provided by the NRC. Acquisitions, mergers, closures, and a competitive global marketplace have led to a decrease in the number of device manufacturers, according to stakeholder interviews. Hundreds of manufacturers and distributors of radiation devices have ceased operations for diverse reasons, usually with many of their devices still in use or storage. The primary radioactive material suppliers for nuclear fixed gauges manufactured in the United States are AEA Technologies (formerly Amersham), Isotope Product Laboratories and Bebig Trade, Inc.

Accurate and precise information about the major players and the market has proven difficult to obtain. A single trade association does not serve this niche of the nuclear or process control industries. Manufacturers and distributors generally consider such financial and market data as proprietary.

6.1.5 Product Costs

Product costs vary widely depending on the device, functionality, precision, the isotope, the activity of the isotope, and its operational life. For example, the cost of a continuous level gauge will vary depending on such factors as the product, the product density, temperature, operating pressure, and the physical arrangement of the vessel or container. The cost of a density gauge may vary based on the product, product density, temperature, weight, maximum thickness and maximum line speed.

Nuclear fixed gauges are typically sold as part of a process control system, which includes a gauge, a detector, hardware/electronics, and software. The cost of a cesium-137 gauge may range from $3,000 to $8,000. The cost for an entire system can exceed $50,000. The system costs for generally licensed gauges using krypton-85, strontium-90 or americium-241, often used in the food packaging sector, vary widely. Total systems in the food packaging industry can be as high as $1.5 million and include multiple gauges. In such cases, the gauge is a small component of a much larger and more expensive system.

Gauge manufacturers are encouraging service agreements, but such agreements, or the leasing of products, has been slow to take hold in the marketplace.

The manufacturers we spoke to reported that their customers generally purchased, rather than leased, equipment. All manufacturers reported that they are promoting their field services, such as repair, leak testing, shutter examination or routine maintenance. The service business enhances customer relations and offers routine cash flow to a business in which devices are often designed to last a minimum of ten years. The servicing of customers has been enhanced by the improved customer databases that vendors now maintain. Customers often receive routine reminders from manufacturers with respect to leak testing and maintenance, for example. Manufacturers reported that they are promoting service contracts, but few customers are opting into the program. Service contracts may be more acceptable in certain critical process operations.

Most manufacturers have not accounted for disposal costs in the initial pricing of a device. As a result, they reported that they charge a "return" fee for the recycling, reuse or disposal of a device at the end of its useful life. Some manufacturers reportedly will accept the return of a device at no charge if they sell a new system. It is assumed that these costs have been factored into the total system purchase price. An explicit "up-front fee", as contemplated in the European legislation, has not been used in this country to our knowledge.

6.1.6 Major Distribution Channels

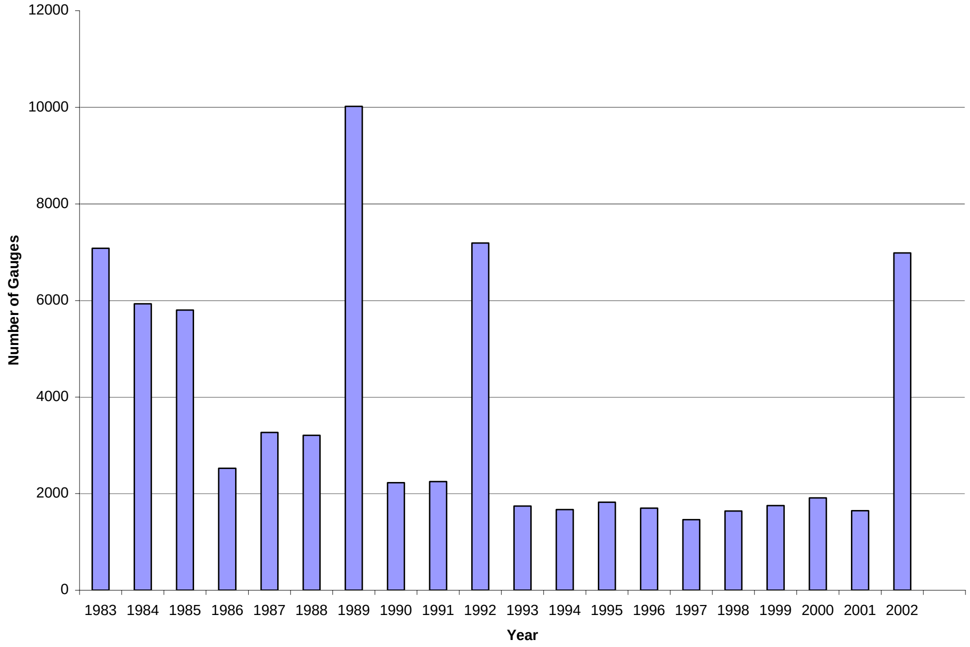
Nuclear fixed gauges are distributed through direct sales staff or independent sales representatives. Because of the application specific nature of the business, the manufacturer will interact directly with the end-user to ensure that the activity level and the source holder is appropriate for the application and use. A sales representative meets with a customer to understand their process and their needs. The sales representative will then submit preliminary information to the manufacturer. An engineer or radiation safety professional at the manufacturer will then work directly with the customer on a proposal or the design or requested equipment. Upon final design and manufacture, the system will be shipped to the end user. Often, the manufacturer will assist the user in the installation and initial quality checks (e.g., leak detection) of the new gauge. Nuclear fixed gauges are not generally sold or distributed through equipment supply companies.

Information about the regulations and the management of the device is generally discussed prior to the purchase of the equipment, but the more comprehensive packet of information is sent to the end-user after the purchase of the gauge. Manufacturers report that end-users of nuclear fixed gauges are generally familiar with the radiation and disposal issues associated with the gauges.

6.1.7 Quantity Produced/Sold Annually

For the purposes of this section, we assume that national device registrations are the same as sales. Further, we assume that nationwide sales data can be estimated by multiplying NRC device registrations for non-agreement states by a factor of three. According to our estimates, nearly 72,000 GL nuclear fixed gauges have been sold during the last twenty years. "Sales' data is presented in Figure 5. As indicated earlier in Section 5.3, however, there may be significant error.

FIGURE 5. NUCLEAR FIXED GAUGE SALES BASED ON ESTIMATED REGISTRATIONS.



An estimated 7,000 GL nuclear fixed gauges were registered in 2002 in Agreement and Non-Agreement states. This number is nearly double the national average (3,592) over the last twenty years and would suggest that the marketplace for these gauges continues to be strong. If these numbers are correct, the increase in sales may be due to: (1) gauges with lower activity levels which decreases the initial cost of equipment and makes nuclear gauges financially attractive to smaller companies; or (2) a marking, sales or regulatory "push" to replace devices that were originally listed in the Sealed Source Registry with a 10-year life cycle. Registration information in 2003 should provide more insight.

Some gauge manufactures suggested, however, that national sales figures are significantly less than the nationwide estimates extrapolated from the NRC registrations. A more accurate assessment of the marketplace and nationwide registrations may be an important and necessary first step for a national dialogue.

Despite these issues, PSI has calculated a gross estimate of the market for nuclear fixed gauges serving generally licensed enterprises. We have assumed an average of 1,700 to 3,000 gauge sales per year in the United States and an average cost of $5,000 per gauge. Based on these assumptions, annual sales of

GL nuclear fixed gauges would translate to a $8.5 to $15 million market niche. This figure is limited to the gauges. Sales of total "systems" would be significantly higher.

Quantitative information about the number of gauges imported to, or exported from, the United States was not available at the time of publication. This information would be helpful to better understand the marketplace and to identify the regulatory or management voids vis a vis our nation's efforts to ensure the administrative control of these devices.

6.1.8 Reuse/Transfer

Most of the manufacturers report that they encourage and accept the return of nuclear fixed gauges from customers once the customer has completed its use of the device. These manufacturers also report that they may accept the return of other manufacturer's gauges on a case-by-case, discretionary basis. For example, a manufacturer may accept the return of another company's gauge if the end user is purchasing a new gauge from the manufacturer. Upon the transfer of the gauge from the end-user to the manufacturer, the manufacture accepts ownership, and liability, of the source under its license. The manufacturer will subsequently determine the most cost-effective disposition option (e.g., recycling, land burial) for the device or radioactive material. Further information about end-of-life management disposition, including costs and recycling data, is included in Section 7.1.

6.1.9 Hazards During Manufacture, Sales and Use

The radiological hazards associated with nuclear fixed gauges may occur with breakage during manufacture, use, distribution, reuse or transportation. As noted earlier, a GL Device must meet stringent criteria with respect to its ability to operate safely and pose minimal risk to the operator or the public based on its reduced risk of breakage, leakage, and tampering.

In the rare event of a leaking or broken device, the end-user or individual finding the broken device (e.g., landfill operator) should immediately contact the NRC, the state agency approved to handle radiation issues and/or the local public health officer. The end-user of a GL Device should receive information or instruction with respect to breakage/leaking source upon initial purchase of the equipment. Further information about the hazards and reporting responsibilities should be found in the Operating Manual.

According to a review of the NMED Database, there were minimal incidents involving nuclear fixed gauges. As reported earlier (Section 4.4), three reported incidents of overexposure from a GL nuclear fixed gauge were reported between the years January 1995 and December 2002. Two of these events involved workers exposed to radiation due to an open shutter. One of these events occurred during transport from one facility site to another location.

Environmental issues may also be associated with facilities manufacturing or recycling the devices. American Ecology Recycling Center in Oak Ridge, TN has been cited for multiple safety violations and dose limits at the fence line bordering the residential neighborhood have exceeded the 100 mrem/year limit in 1999 and 2000.

6.1.10 Alternative Non-Radioactive Gauge Technologies

Viable non-radioactive, non-destructive gauging devices are available to replace some of the nuclear fixed gauges currently used in the marketplace. These are commercially available from manufacturers and distributors. Most suppliers specialize in one or two methods or technologies. The Trinity Report (2002) suggested that manufacturers of nuclear fixed gauges do not typically manufacture devices using alternative non-radioactive technologies. However, the device manufacturers that we spoke to manufacture and sell non-radioactive gauging devices and systems in addition to traditional nuclear fixed gauges.

The paper industry could potentially replace nuclear fixed gauges with non-nuclear technologies, such as laser or ultrasonic technologies, to measure thickness (Trinity, 2002). Levi and Kelly (2002) recommend funding less dangerous technologies for security purposes and the "Dirty Bomb Prevention Act," currently introduced in Congress, would establish a task force to evaluate the replacement of radioactive technologies with non-radioactive equipment.

According to Trinity (2002), the attitude of stakeholders regarding the use of alternative technologies is highly dependent upon the specific industry. Surveys suggested that there is inadequate knowledge of alternative technologies and that industry is generally reluctant to use new equipment when the old equipment has proven reliable. Our interviews with manufacturers and vendors confirmed this prevalent attitude.

Alternative technologies are identified in this report, but are not covered in great detail. Concurrent with this project, the EPA is conducting a feasibility study for the purpose of assessing four industries/applications of nuclear fixed gauges and less hazardous alternatives. This alternative product feasibility study is targeted for completion in September 2003. The four industries/applications covered will include:

- Beverage Industry: level gauges
- Paper industry: basis weight, thickness, and moisture content gauges
- Plastics industry: thickness gauges
- Textile industry: thickness gauges

Infra Red

Infrared technology can be used to measure basis weight, film thickness or moisture content. Its efficacy is limited by material thickness and can be affected by variations in texture and color of material. It can be used by cast film extrusion, blown film extrusion, sheet film extrusion, co-extruded films, paper and board manufacturer and converting, non-wovens and tissue industries. The cost for the technology is roughly 15 to 30 percent greater than conventional nuclear gauges.

Laser Technology

Laser technology can be used to measure thickness. It has the advantage of very high precision, unaffected by product density and insensitive to changes in color or texture. Its efficacy is limited by proper use of the laser; the need to frequently calibrate the machinery; orientation of the laser to the material; and limited types of material and process speed. Textile, foam, strip metal, laminated film, paper, copper foil, and rubber sheet industries can use this technology.

Ultrasonic

Ultrasonic technology can be used to measure thickness by transmitting sound into a material, from one side only, and measuring the response. It can be used with metals, plastics, ceramics, composites, epoxies, and glass. In-process measurement of extruded plastics or rolled metal is often possible, as is measurement of layers or coatings in multi-layer materials.

Capacitance

Capacitance technology can also be used to measure thickness by measuring the capacitance formed between the face of the capacitance probe sensing element and the target surface. The interruption of this field by a dielectric material predictably changes this capacitance based upon the dielectric constant of the material. The change is recorded as a direct voltage. Its efficacy is limited by the need to frequently calibrate the machinery; thermal expansion, improper positioning of the test piece; and alignment of sensors. It can be used to measure the thickness of any dielectric material, such as polymer films, papers, coatings, paint, foam, adhesives, ceramic and rubber.

Microwave

Microwave technology is also being incorporated into certain fixed industrial gauge applications.

6.2 Tritium Exit Signs

6.2.1 Product Functionality

A tritium (^{3}H) exit sign creates a continuous light when phosphorous, internally coating a glass sealed tube that also includes tritium, emits light in the presence of radiation and thus illuminates the "EXIT" stencil face. A tritium exit sign does not require external power, such as batteries or electricity, and is therefore often preferred in areas where accessing electricity is cost prohibitive or avoiding maintenance is preferred. Tritium exit signs have proven reliability and are inherently energy efficient during their useful life. Signs can be purchased with 10 - 20 year lives, depending on the quantity of radioisotope in the product.

Emergency lighting must be designed and manufactured in conformance with strict product design standards, such as UL 924 "Emergency Lighting and Power Equipment" and NFPA 101 Life Safety Code. These standards dictate conformance with such criteria as exit sign design, manufacture, and illumination levels.

6.2.2 Product Applications

Tritium exit signs are used to illuminate exit pathways/doors in commercial, institutional and industrial buildings in the event of an emergency power failure. Emergency exit signs are required by OSHA regulation (29 CFR 1910.37) and codes of compliance including fire, building and electrical codes. Tritium exit signs are typically used in areas (1) where electrical conduit does not exist; (2) electrical conduit is difficult and costly to install; and (3) there are unique hazards where one would not want electrical conduit. Tritium exit signs are also used for applications that would otherwise have higher installation and operating costs if non-radioactive exit sign technologies were used. In addition, tritium exit signs may provide enhanced life safety for facilities where light and battery maintenance capabilities are lacking, or where back-up power generation capabilities may be subject to failure under extreme conditions.

Based on an estimate of 100 million exit signs (Conway, 1997) installed in U.S. buildings, tritium exit signs would represent roughly 2% of the total universe of installed exit signs.

6.2.3 Radioactive Components

Tritium exit signs may contain up to 27 curies of tritium. Tritium exit signs typically have between 7.5 curies (10 year life) to 11.5 curies (20 year life) per sign depending on rate sign life. Tritium exit signs may have greater than 11.5 curies to address additional illumination requirements. A sign poses no safety hazard to end-users and the general public, unless the exit sign is damaged and the sealed tritium tubes are broken.

6.2.4 Major Product Manufacturers

There are no domestic producers of tritium filled tubes used for tritium exit signs. The tritium filled tubes are manufactured by the following five companies:

- Lumitech (South Africa)
- MB-Microtec (Switzerland)
- Shield Source (Canada)
- SRB Technologies, Inc. (Canada)
- Surelite (U.K.)

Shield Source and SRB Technologies manufacture a majority of the tritium light sources used in tritium exit signs in the United States. These companies are fully integrated manufacturers (i.e., they manufacture tritium light sources or capsules and manufacture or assemble the exit signs).

In addition to these integrated manufacturers, other "manufacturers" may purchase the tritium capsules and assemble components into tritium exit signs. There are fewer than ten major tritium exit sign manufacturers selling signs in the United States. A list of tritium exit sign suppliers, identified by the NRC, is included in Appendix D. Certain companies in Europe also manufacture tritium exit signs that may be sold in the United States. Many tritium exit sign manufacturers also sell non-radioactive (e.g., LED) exit signs.

6.2.5 Product Costs

Tritium exit signs can be purchased for less than $125 for an exit sign with a 10-year life to as much as $350 for a two-sided exit sign rated with a 20-year life. Initial purchase price and total operating cost over the lifetime of the sign are important to sales of tritium exit signs. A discount could be expected for larger quantities, and more significant discounts may be available for bulk purchasing. Small discounts may also be given if old or expired exit signs are returned or exchanged.

The following table, from the web site of Isolite, an emergency lighting manufacturer, provides their analysis of the costs for tritium exit signs when compared to certain alternatives. The table does not include disposal costs.

TABLE 17 EMERGENCY EXIT LIGHTING COST COMPARISON
Adapted from ISOLITE 10-Year Exit Sign Cost Comparison

Type	Compact Fluorescent	LED	ISOLITE Self Luminous
Lamps	2 PL7/10,000 hours	LED's/200,000 Hours	None
Power Consumption	21 watts (w/ ballast)	6 watts	0
Fixture	$120	$170	Range ($125 - $250) depending on quantity, brand, etc.
Labor to install	$80	$80	$15
Initial Installed Cost	$200	$250	$15 + initial fixture cost
10 YEAR COSTS			
Electric Power	$184	$53	0
Lamp Cost	$144	0	0
Lamp Replacement Labor	$45	0	0
Battery	$220	$40	0
Battery Replacement Labor	$40	$20	0
Operating Costs-Sub	$633	$113	0
Inflation Cost	$160	$15	0
Total 10-Year Cost	$993	$378	Initial Fixture Cost + $15

6.2.6 Major Distribution Channels

Distribution of products occurs primarily through manufacturers' sales representatives and electrical supply distributors. As a commodity product, emergency lighting products are widely available. Multiple companies on the internet (e.g., www.bulbs.com, www.standard-signs.com), for example, sell discounted lighting products, including tritium exit signs.

Sales representatives for the manufacturers identify and service customers. These customers may be industrial, institutional or commercial customers, as well as distributors. They are generally not familiar with radiation hazards and radiological regulatory requirements. Sales representatives will provide these customers with appropriate company, product, safety and environmental information. The environmental and regulatory information can be provided before, during, and after the purchase of the sign. Some manufacturers provide cleanup information to customers in the event that an exit sign is broken. Tritium exit signs will be sent to the customer from the manufacturer or a distribution warehouse, depending on the manufacturer.

A number of manufacturers noted that electrical supply distributors have an incentive to sell devices that require electrical components, as opposed to tritium exit signs that provide their own power.

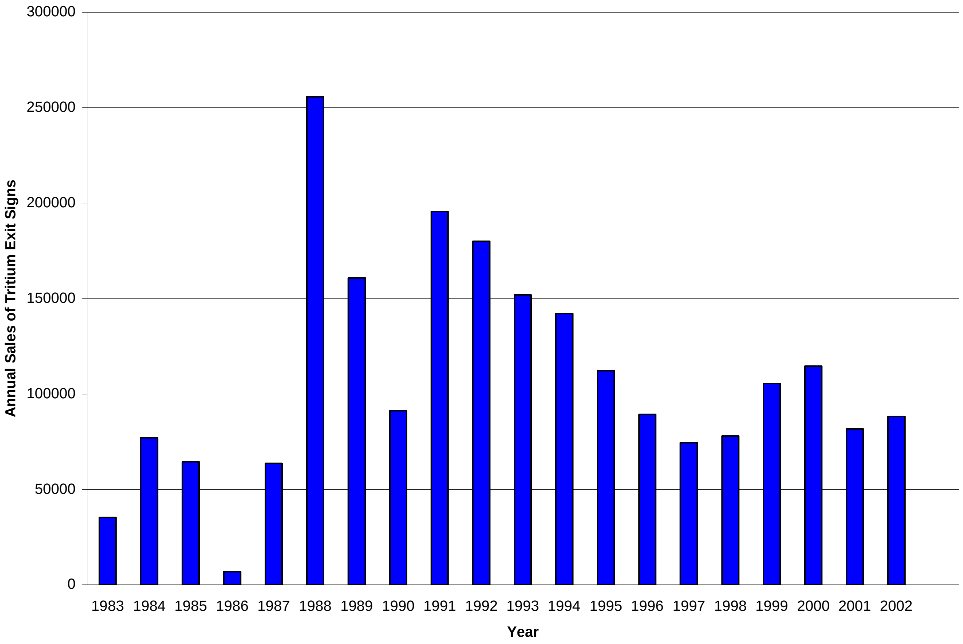
6.2.7 Quantity Produced/Sold Annually

As in the section on sales of nuclear fixed gauges, our estimates of national device registrations are assumed to be equal to sales. According to our estimates (the methodology is described in Section 5.3), the average number of sales per year over the last twenty years is 108,400. The volume of sales has varied substantially from year to year, however, and has gradually declined over the last decade. Figure 6 illustrates estimates of national "sales" for the last twenty years.

Approximately 88,000 tritium exit signs were sold in 2002. Assuming an average price of $200 per tritium exit sign and U.S. sales ranging from 80,000 to 110,000, the current market for tritium exit signs is approximately $16 to $22 million U.S. dollars.

Quantitative information about the number of tritium exit signs imported to, or exported from, the United States was not available at the time of publication.

FIGURE 6. TRITIUM EXIT SIGNS AS A FUNCTION OF ESTIMATED REGISTRATIONS



6.2.8 Reuse/Transfer

The major manufacturers have instituted policies to encourage and accept the return of tritium exit signs from customers once the customer has completed its use of the device. These manufacturers also report that they often accept the return of other manufacturer's devices. For example, a manufacturer may accept the return of another company's exit sign(s) if the end user is purchasing a new sign or is an existing customer. The manufacturer or sales representative has broad discretion in these decisions. Upon the transfer of the tritium exit sign from the end-user to the licensed manufacturer or supplier, the company accepts ownership, and liability, of the source under its license. The exit signs or the source capsules are subsequently shipped to an integrated manufacturer, outside the United States, where the radioactive material may be reused in exit signs or recycled and used in other tritium products. Further information about end-of-life management disposition, including costs and recycling data, is included in Section 7.

6.2.9 Hazards During Manufacture, Sales and Use

The radiological hazards associated with tritium exit signs may occur with breakage during manufacture, use, distribution, reuse or transportation. As noted earlier, a GL Device must meet stringent criteria with respect to its ability to operate safely and pose minimal risk to the operator or the public based on its reduced risk of breakage, leakage, and tampering. Tritium, as a low energy beta emitter, poses limited health risks except in certain conditions (e.g., ingestion, and exposure in small, poorly ventilated areas). There have been allegations by environmental organizations that the manufacturing of self-luminous signs may have environmental issues. However, our research did not identify any substantiated incidents in which tritium exit sign manufacturing plants received safety violations or exceeded dose limits.

According to the NMED Database, there were 82 reportable incidents involving tritium exit signs between the years January 1995 and April 2003. More than half of these incidents were for signs reported as lost or stolen. These incidents have been previously described in Section 4.4 of this report.

Due to the general lack of enforcement of using tritium exit signs beyond their rated product life, there is the possibility that end-users may continue to use these signs after their expiration date. This could result in a life safety issue if the illumination levels of these signs are insufficient during emergency situations. However, this lack of enforcement also extends to light and battery maintenance for non-radioactive exit signs as well. Improper light and/or battery maintenance may lead to life safety issues for non-radioactive exit signs.

6.2.10 Alternative Exit Sign Technologies

Most buildings in the United States are required by building codes to provide exit signs to mark the means of egress. Multiple local, state, and national building codes, such as the National Fire Protection's (NFPA) Life Safety Code (NFPA 101) and National Electrical Code (NFPA 70) require the installation and inspection of exit signs before an occupancy permit is issued. The following is a brief description of some of the non-radioactive exit sign technologies that are commercially available.

Incandescent

Incandescent exit signs typically use two incandescent lights to illuminate the sign. These lamps consist of a coiled tungsten filament in a clear or frosted tubular jacket. Incandescent lamps produce light by heating a filament to a high temperature by using resistance to an electric current. Illuminated exit signs use special incandescent bulbs that are often longer and thinner, in an attempt to increase the area of light behind the lettering. Typically, an exit sign requires two bulbs that are often rated between 15 and 25 watts each, for a total wattage of 30 to 50 watts. This can result in significant energy costs for the end-user.

Since these lamps, by code, must burn continuously, they may burn out after several months of use. Replacing the bulbs in every fixture is a resource intensive and costly procedure over the lifetime of the exit sign. Some state energy codes no longer allow this type of illumination for exit signs.

A variation of the incandescent technology is the use of light ropes. Light ropes use a number of small incandescent lamps within a clear, flexible plastic tube, somewhat similar in appearance to a small string of clear miniature Christmas lights. Light ropes have a considerably longer expected life and better energy efficiency than traditional incandescent lamps.

Photoluminescent

The photoluminescent exit signs absorb and store energy from any ambient visible or ultraviolet light, and then release this energy in the event of total darkness resulting from a power outage or other emergency. The photoluminescent exit signs use laminated film that glows in darkness after exposure to a light source. These signs require an external visible or ultraviolet light source of sufficient magnitude and duration to energize them.

The photoluminescent exit signs do not require internal lights and therefore do not require electricity or maintenance of an internal lighting source. Different photoluminescent products are available that can emit light for various lengths of time. Photoluminescent emergency exit lighting has been approved for use under UL 924, but has not been approved by the Canadian Standards Association.

Electroluminescent

The electroluminescent exit sign consists of thin panels of layered, processed phosphor materials that emit light when exposed to electricity. These signs provide uniform illumination and consume very little electrical power. The exact power requirement is a function of sign area and other factors, but some electroluminescent exit signs require less than one watt to operate.

LED (light-emitting diode)

An LED (light-emitting diode) is a semiconductor diode that emits visible light when conducting electric current. Visible light LEDs were first used for exit signs in 1985, and there are currently several different types of LED signs available in the market using a variety of LEDs in different configurations. There is a wide range in price, quality, and energy consumption for LED exit signs. The LED exit signs can use as few as four LEDs, and as many as 200 LEDs. Consequently, the rated energy consumption can thus range from as little as 1 watt up to 8 watts.

Direct-view exit signs use LEDs to actually spell out the word "EXIT" against an unlit background. This type of fixture requires the greatest number of LEDs. Cavity-lit or reflective fixtures might use as few as four LEDs placed in a row along the top or bottom of the interior of a stencil-face sign. Sometimes the LEDs are contained within flexible plastic tubes. The light from the LEDs reflects off the interior of the sign and illuminates the cut-out letters, usually with a diffusing panel to help even out the light. Low cost and low energy consumption appears to be the driving force behind LED exit signs increase in market share over the last decade.

Edge-Lit fixtures consist of a clear plastic panel that is stenciled or embossed with the word EXIT. The acrylic channels light from a strip of LEDs along the top of the sign. The signs may require as many as 35 LEDs, and often consume between 3 to 5 watts.

Sales of LED signs as a percentage of total non-nuclear emergency exit signs, have increased substantially over the last decade, according to data provided by the National Electrical Manufacturers Association (NEMA) in the table below.

TABLE 18. INCREASED SALES OF LED EMERGENCY LIGHTING
(Percentage of electrical light sales based on NEMA members)

Exit Sign Type	1997	2002
Incandescent	40.17%	7.16%
Fluorescent	11.32%	1.95%
LED	48.51%	90.89%

Compact Fluorescent Lamp

A compact fluorescent lamp (CFL) is an electric discharge lamp that produces light by the fluorescence of a phosphor coating. A fluorescent lamp consists of a glass tube filled with a mixture of argon and mercury vapor. Metal electrodes at each end are coated with an alkaline-earth oxide that gives off electrons easily. When current flows through the ionized gas between the electrodes, it emits ultraviolet radiation. When this coating is used up, the lamp ceases to operate. The inside of the tube is coated with phosphors, such as zinc silicate and magnesium tungstate.

CFL exit signs typically use 5 to 7 watt compact fluorescent lamps, and can consume up to 25 watts per sign. Similar to incandescent bulbs, compact fluorescent tubes are a point-source light, and will produce an uneven illumination in an emergency exit sign. The rated life of CFLs is usually just over a year, meaning that CFL exit signs do require regular maintenance. Since CFL exit signs contain mercury, they must be properly disposed at their end of useful life. A "cold cathode" CFL is a particular type of CFL that has a different type of electrode. This electrode extends the life of the tube and produces a brighter light.

Tritium Exit Signs – Solid Form

There has been interest in developing tritium exit signs where the tritium is incorporated into a solid material such as plastic or plexiglass. This would eliminate the danger of tritium gas release in the event the tritium tubes are broken in a conventional tritium exit sign. However, exit signs with tritium encapsulated in a solid form may present new challenges at the end of the useful product life. Currently, the tritium gas can be recycled from tritium exit signs at the end of their useful life. Exit signs with tritium encapsulated in a solid form would be difficult to recycle and may generate a radioactive solid waste issue. There have been some research and development efforts to develop exit signs with tritium in solid form, but none have yet proved to be commercially viable due to high production costs.

6.3 Summary of Findings

Nuclear Fixed Gauges

- The majority of GL gauges are sold to specific license holders, according to some manufacturers and state officials.
- Sales of nuclear fixed gauges often include customized engineering and upfront costs.
- Manufacturers report an increase in the use of nuclear fixed gauges containing cesium-137 and a decrease in the sale of nuclear fixed gauges using cobalt-60.
- The communication of projected disposal costs to potential customers is not an impediment to the purchase of a nuclear fixed gauge, according to manufacturers.
- Vendors of nuclear fixed gauge vendors are focusing sales efforts on improved customer service and service agreements. Improved customer and device tracking enhances end-of-life device management and replacement.
- Manufacturers report a decline in activity levels in gauges as a result of improved detection technologies and efforts to make the technology available to smaller businesses.
- Some manufacturers are reportedly modifying their generally licensed nuclear fixed gauges to fall below the activity levels for those GL devices that require annual registration and fees.
- A trade association does not specifically serve the nuclear fixed gauge industry. This limits access to market data and limits the industry's ability to coordinate initiatives (e.g., recycling, evaluation of non-nuclear technologies, etc.).
- There is reluctance in the manufacturing sector to seek gauging alternatives because the traditional nuclear fixed gauge has been a reliable workhorse.
- The number of suppliers – radioactive material suppliers and manufacturers – is decreasing due to mergers, acquisitions and a competitive marketplace.
- Purchasers of nuclear fixed gauges generally know that they are purchasing a radioisotope.
- NMED records of human exposure during manufacture, transport or use are limited.
- User's compliance with shutter testing (i.e., 6 months) and leak testing (e.g., every 3 years) varies widely.
- There is a lack of assessment, testing, and promotion of non-nuclear fixed gauges on an industry-wide basis.

Tritium Exit Signs

- The registration of tritium exit signs has declined over the past decade. Sales have remained steady over the past five years, according to manufacturers.
- Non-radioactive exit signs are available for most applications except where electricity is not available or where a hazardous environment exists. However, these alternatives may have higher total costs if electricity connection costs are significant.
- There has been a significant increase in the sale of LED emergency lighting for non-radioactive exit sign applications.
- Tritium exit signs continue to serve a market niche where electrical supply is not sufficiently reliable or access is cost prohibitive or undesirable.
- Tritium exit signs represent one to two percent of all installed exit signs.
- Sales representatives often provide safety and environmental information to customer prior to purchase. However, some safety and environmental information is typically provided to customers post-purchase.

- There have been limited reported or substantiated claims of acute injuries or illness as a result of human exposure during manufacture, transport and use.

7. END OF LIFE MANAGEMENT

This section of the report describes problems, issues and initiatives associated with the end-of-life management of nuclear fixed gauges and tritium exit signs. GL devices have the potential to enter the public domain because of a number of factors, such as:

- Lack of knowledge of applicable management and disposal requirements;
- Avoidance of costly disposal requirements; and
- Inadequate incentives to take responsibility for the proper disposal of these devices.

7.1 Current Collection and Disposal Practices

At the end of their useful life, nuclear fixed gauges and tritium exit signs must be disposed of as low level radioactive waste, transferred to a licensed LLRW waste broker, or returned to a specifically licensed product manufacturer or distributor for proper disposal or recycling. As discussed earlier in Sections 6.1.8 and 6.2.8, nuclear fixed gauges or tritium exit signs are commonly returned by end users to a manufacturer, as allowed by the NRC and Agreement State regulations, instead of directly sent as a manifested waste shipment to a burial site.

This next subsection discusses the recycling and reuse of the devices and the radioactive material. We distinguish between "reclamation" as the collection of the devices, "recycling" as the process of capturing the radioactive material from the capsule (e.g., krypton-85 or tritium) and using it in another device or product, and "reuse," which refers to the use of the capsule in another device or for another application. Reconditioning a gauge would also be considered a type of reuse.

Recycling and Reuse of Nuclear Fixed Gauges

Most of the active manufacturers report that they accept the return of nuclear fixed gauges for recycling or disposal once the customer has completed its use of the device(s). A fee is typically associated with the "take back" program and will vary depending on the device, the radioactive material, the activity level, the services provided (e.g., de-installation of the device), and shipping. This disposition fee may exceed the original cost of the gauge. Table 19 includes examples of fees charged by a gauge vendor for the return of cesium-137 or cobalt-60 gauges. This table does not include shipping or any on-site services, which could greatly increase the listed disposition price. All prices are based on original nominal activity. In general, the fees to return a device to a supplier are slightly less than the fees if the end user contracts directly with a waste broker. Upon transfer of a device, the vendor will determine the most cost-effective management option for the device or radioactive material.

TABLE 19. PRICES FOR SEALED SOURCE RETURN AND TRANSFER

Cs-137 Point Source Activity (mCi)	**Price**	**Co-60 Point Source Activity (mCi)**	**Price**
10	$655	10	$665
100	$900	100	$1,035
500	$2,050	500	$2,660
1000	$2,550	1,000	$3,125
4000	$7,570	4,000	$8,750

The return of the device to the manufacturer is often preferred by an end user because of transfer of ownership, cost factors, familiarity with the service providers, and the avoidance of a waste manifest and other regulatory requirements when transferring the device to the manufacturer.

Most manufacturers report that they will recycle returned gauges and radioactive material, if practical. Options include reusing the capsules, returning the capsules to the material supplier, or consolidating the gauges or radioactive materials for disposal as a low-level radioactive waste. Some manufacturers report that they may reuse the capsules in other devices and reportedly sell the devices for a discount.

Manufacturers report that a significant quantity of gauges are returned or reclaimed. Two large, fixed gauge manufacturers informed PSI that they each receive between 200 – 350 returned gauges per year from end-users. Most of the gauges are their own, but some of the returned gauges are from other manufacturers. If we assume annual national sales of 2,000 – 3,000 gauges, 20 to 30 percent (600 gauges) of this total are being returned by these two manufacturers. Most returned gauges contain Cs-137, which is more likely to be recycled. One manufacturer reported that 65 percent of returned radioactive material (primarily cesium-137) from gauges was recycled. Capsules of krypton-85 or americium-241 may also be recycled. Regulatory uncertainty, international regulations and the lack of a standard to re-certify devices may limit the reuse of radioactive materials in new or reconditioned gauges. Devices containing sources with short half-lives will be removed from the device and disposed of at licensed LLRW facility. Recyclable material may be disposed at Barnwell or Richland if there is no market for it.

The development of data to describe the breadth of recycling (e.g., returns/sales) for nuclear fixed gauges and tritium exit signs would be a most useful outcome of this radioactive dialogue process. There appears to be a good story to tell.

LLRW brokers may be engaged by end-users to assist with returns to a manufacturer or disposal of devices. Radioactive devices most frequently make their way to waste brokers when: (1) the device cannot be returned to the manufacturer; (2) a supplier contracts with the waste broker to dispose of devices; or (3) the device is discovered by a non-licensee who seeks proper disposal. Several firms provide radioactive waste broker services. Seventeen brokers are identified on the CRCPD web site, and the Barnwell web site currently identifies 11 qualified waste brokers. A list of the 17 waste brokers on the CRCPD website is included in Appendix E. If requested, brokers will try to arrange for recycling. An example of a vendor's estimated full service recycling costs (e.g., consulting, site visit, packing, shipping, recycling) is described below in Table 20. These fees are comparable to land disposal fees, according to the broker. However, many device owners do not require this "full service", and can reduce costs by conducting some of the services themselves.

TABLE 20. WASTE BROKER ESTIMATES OF RECYCLING/DISPOSAL COSTS.

Isotope	Activity	Cost Range
Cs-137	<500 mCi	\$2,500 - \$4,000
Cs-137	1 Ci < 5 Ci	\$9,500 -- \$11,500
Am-241	<500 mCi	\$5, 000 - \$7,500
Am-241	1 Ci < 2.5 Ci	\$8,000 - \$9,000
Sr-90	<100 mCi	\$2,500 - \$3,700
Sr-90	500 mCi < 1 Ci	\$7,500 - \$11,000
Other non-TRU isotopes	<1 mCi	\$1,500

According to one waste broker, recycling or reuse is generally limited to americium-241 and cesium-137 sources that exceed threshold criteria that preclude their disposal in a licensed facility. This same broker reported that they were unable to recycle any cesium-137 in 2002 due to market conditions. As described earlier, manufacturers reported that they were able to recycle Cs-137, as well as Am-241 and Kr-85, in 2002.

Recycling and Reuse of Tritium Exit Signs

Take-back programs for tritium exit signs are generally similar for most manufacturers.

1. A sales representative encourages the return and replacement of signs based on a customer call or notifies a customer that their tritium exit signs are nearing the end of their intended life (e.g., 10 years).
2. Returned signs are often accepted for no fee if a replacement sign is being purchased and/or other factors (e.g., existing customer, the manufacturer).
3. A fee may be charged (e.g., ranges from $30 to $100) if replacement signs will not be purchased, or the signs were manufactured from another company.
4. Returned signs, or removed capsules, are aggregated in the U.S. office and shipped directly to tritium tube manufacturing facilities outside the United States.
5. Plastic and aluminum housing may also be recycled.
6. Tritium is recycled into new tritium tubes for use in exit signs or other products.

These take-back/recycling programs are quite cost-effective in comparison to disposal options. Quotes from brokers for the disposal of tritium exit signs ranged from approximately $500 to several thousand dollars for the disposal of a single sign at Barnwell or Richland. The price per sign would decrease significantly for higher volumes.

Manufacturers report that a significant quantity of tritium exit signs are returned or reclaimed for recycling. According to two major integrated manufacturers, the reclamation of tritium exit signs has increased substantially during the last three years. Table 21 below illustrates this trend. The number of signs reclaimed by these manufactures has increased by 98% between 2000 and 2002. Based on manufacturers' claims that total current sales of tritium exit signs is between 80,000 to 110,000, these two manufacturers alone are recycling approximately 15 to 25 percent of tritium exit signs. However, to effectively calculate a recycling rate industry wide will require: 1) more accurate nationwide sales data, 2) recycling data from all tritium sign manufacturers, and 3) estimation of an average product life for all tritium exit signs.

TABLE 21. TOTAL NUMBER OF SIGNS RECYCLED BY TWO MANUFACTURERS FROM 2000 TO 2002

Year	Number of Signs Recycled
2000	9,000
2001	13,500
2002	17,800

The manufacturers report that signs are more frequently reclaimed from larger institutional, governmental, military, commercial and institutional customers. Smaller customers, and the maintenance staff at small and mid-sized businesses, are less likely to use the take-back program. The actual disposition of the signs from these smaller customers is not known. It is widely suspected that they are discarded as trash.

Land Disposal

Nuclear fixed gauges and tritium exit signs may be disposed at either the Barnwell or Richland radioactive waste disposal facilities. As discussed in Section 5, these are the only two licensed facilities in the United States that accept commercial radioactive waste for proper disposal. The Richland facility is limited to certain states in the west, while the Barnwell facility is open to customers nationwide.

While suppliers may consolidate returned devices and make one or two shipments per year to one of these facilities, the majority of shipments to these landfills are handled by radioactive waste brokers. Gauges containing Am-241 are difficult to dispose because no more than 150 pCi per disposal package is allowed at the Barnwell site. Options for Am-241 sources/gauges are often limited to recycling or no cost acceptance by the DOE Source Recovery Program that is described later in this section.

Licensed waste brokers minimize disposal costs by bulk packing and co-mingling similar source devices to minimize shipment and packaging fees. Fees vary depending on the scope of the services, the number of sources, its activity, size/weight, packaging requirements, geographic location, and other criteria. In the absence of direction from a customer to recycle a device, brokers will likely make disposal decisions based on the financial incentive to the broker. It appears that low level radioactive sources and devices handled by brokers will generally be disposed of at the Barnwell or Richland facilities.

The fees for disposal are high – and therefore are often cited as an impediment to the proper disposal of these devices. In addition, the waste generator or shipper retains financial liability for the radioactive devices even after burial at the disposal facility. The states of Washington and South Carolina set fees for the Richland and Barnwell facilities, respectively. These fees are based on projections of incoming waste streams and revenues. Washington fees are revised semi-annually. The revenues are important sources of income to the states. For example, the $40 - $70 million in fees generated annually at Barnwell funds educational programs in South Carolina.

The Richland, WA facility charges approximately $13,000 for waste that has an outside radiation level of 1 to 10 rem. Table 22 provides a full description of costs, which do not include any annual charges that may also have to be paid by the waste generator.

TABLE 22. DISPOSAL RATES AT US ECOLOGY, INC. RICHLAND, WA. EFFECTIVE JANUARY 1, 2003

Parameter	Cost
Volume	$49.80 per cubic foot
Shipment	$8,170 per manifest shipment
Container	$4,150 per container on each shipment
Exposure (Dose Rate at Container)	
- ≤ 200 mR/h	$70 per container
- 200 mR/h ≤ 1,000 mR/h	$4,980 per container
- 1000 mR/h ≤ 10,000 mR/h	$19,700 per container
- 10,000 mR/h ≤ 100,000 mR/h	$29,500 per container
- > 100,000 mR/h	$495,000 per container
Engineered Concrete Barriers	$7,422 to $8,938 (varies with size)
Additional Fees/Taxes	$16.25 per cubic foot 3.8% of rates and charges

The disposal rates for Richland and Barnwell are calculated differently. Richland charges flat fees per shipment and container, and a fee based on the exposure rate per container. Barnwell's rates are based on weight (lbs./ft3) and then surcharges (e.g., multipliers) are applied for exposure rate, and other factors, to determine the total charge. The disposal rate schedule for non-Atlantic compact waste is described in Table 23.

TABLE 23. DISPOSAL RATE SCHEDULE FOR NON-ATLANTIC COMPACT WASTE AT BARNWELL
(Information has been abbreviated for presentation in this table)

Charge	**Qualifier**	**Rate**
1. Base Disposal Charge	Equal to or greater than 120 lbs./ft^3	$4.59 per pound
	Equal to greater than 75 lbs./ft^3 and less than 120 lbs./ft^3	$5.05 per pound
	Equal to or greater than 60 lbs./ft^3 and less than 75 lbs./ft^3	$6.20 per pound
	Equal to or greater than 45 lbs./ft^3 and less than 60 lbs./ft^3	$8.04 per pound
	Less than 45 lbs./ft^3	$8.04 per pound times the ratio of 45 lbs./ft^3 divided by package density
	Millicurie Charge	.38 per mCi
2. Surcharges (multiplier of base weight rate)	0mR/hr to 200 mR/hr	1.00
	200 mR/hr to 1 R/hr	1.08
	>3R/hr – 4R/hr	1.22
	>5 R/hr – 10 R/hr	1.32
	>25R/hr – 50 R/hr	1.42
	>50R/hr	1.48
	Special Nuclear Material Surcharge	$10.44 per gram
	Administrative surcharge	$4 per cubic foot
	Base Charges + Surcharges =	**Total Charge**

The degree to which spent or unwanted GL devices are being managed through these disposal channels is open for speculation. The NRC has estimated that 4-6 percent of tritium exit signs are forgotten or misplaced. However, waste haulers and construction/demolition professionals, with whom we spoke, reported that few tritium exit signs are disposed at the Barnwell or Richland sites. According to one hazardous waste broker that frequently handles waste generated by construction/demolition firms serving higher education, healthcare and institutional facilities, this firm has not handled the disposal of a single tritium exit sign in the last five years. Bidding for demolition work is very competitive and few contractors include the cost of proper disposal in proposed bids. The inclusion in a proposal for disposal at Barnwell or Richland for tritium exit signs would likely result in the high cost bid – and the loss of the job.

Demolition contractors acknowledge that they often leave tritium exit signs in place and that proper disposal of these devices is not typically included in the bid for a project because competitors are unlikely to include it in their costs.

As a result of these limited disposal outlets and significant costs, GL licensees may simply “store” indefinitely their devices on-site or at an alternative site. Unfortunately, such stored devices are more likely to become vulnerable to loss, theft and abandonment. Radionuclide sources can also end up in landfills, waste to energy incinerators and at scrap recycling facilities.

7.2 Radioactive Devices in Solid Waste Streams

Waste to Energy Facilities

Some of the larger waste-to-energy plants (WTE) in North America have radioactive detectors installed, according to an internal survey in 2002 facilitated by the Integrated Waste Services Association. In many cases, these systems are designed (or required by local permitting agencies) to detect radioactivity in regulated medical waste. Based on the survey, only one WTE facility reported regular alarms. They received one detection per week, although there was no indication that any hits were caused by anything other than very short lived medical waste or false positives. Detection systems ranged greatly in cost depending on the size of the system. Some facilities had installed full radioactive detection systems costing greater than $100,000, while others used small hand-held detectors costing a few hundred dollars. These detection systems could detect many nuclear fixed gauges, but would not detect a tritium exit sign.

According to another waste to energy (WTE) plant, their radioactive monitor system at the incinerator and at the transfer system does occasionally (e.g., a few times per year) sound as the result of a radioactive device. The system is set to alarm at anything above background. While there may not be downtime associated with such an incident, it may take a few hours to survey a suspect truck or load and determine whether to reject the load.

In general, WTE representatives do not regard devices with radioactive materials as a significant contaminant of concern.

Solid Waste Landfills

In 1999, the Radiation Focus Group of the Association of State and Territorial Solid Waste Management Officials (ASTSWMO) conducted a survey of the ASTSWMO Solid Waste Subcommittee for the purpose of better understanding challenges associated with radioactive waste in the municipal solid waste stream. Forty two percent of the states responded to the survey. The highlights are summarized below.

- Seventy percent of the responding states have at least some monitoring system in place for radioactive waste at landfills. In most cases, the monitoring systems were not required by regulation;
- Most of the detected waste is short-lived medical waste;
- States did not indicate that radioactive materials in municipal solid waste landfills were an issue of major importance. Eighty-six percent indicated that their state was not planning any action (e.g., regulation, guidance, outreach) regarding the detection of radioactive contamination at solid waste facilities.

"Although significant problems such as sealed sources are rare, efforts should be made to concentrate detection and response efforts on these scenarios, especially since these are events that pose a significant health or environmental risk," according to the radiation focus group.

Some studies have suggested that disposal of radioactive materials at municipal and industrial landfills is a problem. Ground water leachate contaminated with radiation has been found in landfill leachate in California, Pennsylvania, Scotland and England. In these cases, the tritium levels fall below U.S. drinking water thresholds, but above background levels. Tritium concentrations in leachate from sites in Scotland that had received some industrial waste were, on average, about 50 percent higher than leachates from landfills that had only received domestic or commercial waste (Hicks 2000). Levels for the Pennsylvania, Scotland, and England sites ranged from <25 pCi/L to 12,040 pCi/L, and are below the EPA limit for drinking water 20,000 pCi/L. Hicks et al (2000) concluded that tritium exit signs must have been in the Scottish waste stream. A news item in February 2003 reported a study of California landfills that found 22 of 50 landfills with elevated levels of radioactive materials in the groundwater or leachate. Seven of the landfills allegedly exceeded the maximum drinking water safety standard for radiation and several contained elevated levels of tritium. Further information about the California study has not been made available.

7.3 Radioactive Materials in Recycled Metals

Radioactive contamination can enter our nation's metal supply in three ways: (1) sealed radioactive sources that fall out of established radiation control regulatory mechanisms (i.e., stray devices) and end up in scrap yards; (2) scrap metal that contains undetected radioactive contamination, often originating from overseas; and (3) metal from Department of Energy and Nuclear Regulatory Commission-licensed facilities. EPA has determined that stray devices and imports of foreign metals are the most likely origins of contaminated steel in the U.S.

Seventy percent of all U.S. steel manufacturing gets its raw material from recycled scrap. In the U.S., more than 60 million metric tons of recycled steel is used annually. Nearly all steel mills and most other mills have now installed radiation surveillance systems equipment because of past problems with contaminated metal. These radiation detection systems cost between $10,000 and $50,000 and, can exceed $100,000 when installation, operations and maintenance costs are included. More than half of all scrap processing facilities have also installed detection systems to safeguard against the return of contaminated scrap. Detectors at U.S. mini-mill and scrap processing facilities have identified 500 radioactive sources or devices containing radioactive sources in U.S. scrap metal since 1983 (Yusko, 2002). One half of these incidents have occurred over the years 1995-2001. More than 700 total "scrap metal" incidents have been reported between 1989 and 2003, according to the NRC database. The majority of these incidents involved detection of radiation in trucks or rail cars containing scrap metal.

In 1997, two Am-241 fill level gauges were improperly and unknowingly disposed of by a brewery as scrap metal. A scrap metal shredder separated one of the sources from the holder and ruptured it. This, in turn, contaminated the shredding equipment, requiring costly decontamination. (Yusko & Wolfson)

Such detection systems do not identify 100 percent of all radioactive sources in the scrap metal streams. Detection may be affected by several variables, including:

- Speed of shipment through the detector;
- Configuration of the load;
- Background radiation;
- Position of the detectors;
- Depth of source within the load (cannot often detect a radioactive device embedded more than 22 inches in scrap metal); and
- Type of source (e.g., tritium exit sign will not likely be identified).

If the detection alarm is sounded, the load may be reworked or, in many cases, the load rejected and returned to the supplier. Exemptions in the transportation regulations (40 CFR 107) allow the radioactive material to be sent back to the supplier/owner.

Since 1983, U.S. Steel Mills have accidentally melted radioactive sources on twenty occasions (Dicus, 1999). These meltings are not limited to steel mills, however. In the U.S., incidents have also occurred at aluminum (7), gold (2), lead (2), copper (4), and zinc mills. According to Dicus, more than 60 percent of these meltings involved Cs-137 or Co-60 at a range of 8.1 – 513 mCi and Am –241 at a range of 40.5 – 99.9 mCi. In 1997, a 100mCi Am-241 source in a gauge was inadvertently discarded as metal scrap by a licensee and sent with other metal scrap to a metal scrap processing facility.

Some recent U.S. reported meltings at mills are identified below in Table 24. A full listing of U.S. Reported Meltings and Cost Data (Yusko, 2002) is included in Appendix F. In the last two years, there have been more than 150 instances in which recycled metal scrap has set off alarms at mills or processing facilities, according to our review of the NRC database. The loads were often rejected and returned to the scrap processor or previous owner.

TABLE 24. U.S. REPORTED MELTINGS (YUSKO, 2002)

Year	Metal	Plant	State	Isotope	Activity
1997	Aluminum	White Salvage Co.	TN	Am-241	Unknown
1997	Steel	WCI	OH	Co-60	0.9(?) GBq
1997	Steel	Kentucky Electric	KY	Cs-137	1.3 GBq
1997	Steel	Birmingham Steel	AL	Cs-137, Am0241	7 Bq/g
1997	Steel	Bethlehem Steel	IN	Co-60	0.2 GBq
1998	Aluminum	S.Al Castings	AL	Th	Unknown
2001	Aluminum	IMCO Recycling	OH	DU	Unknown
2001	Steel	Ameristeel	FL	Cs-137	Unknown

An accidental melting of radioactive sources at a steel mini-mill results in an average loss of $8 to $10 million per event and in one case $23 million (Lubenau and Yusko, 98). A melting of a radioactive source at a conventional, integrated steel mill could reach as high as $100 million (Lubenau, 2001). Additionally, if a steel mill is contaminated, then the baghouse dust may be required to be handled as a radioactive mixed waste, adding additional regulatory challenges and costs.

Workers at scrap metal yards are generally familiar with the challenges associated with the improper disposal of radioactive materials in the recycling process stream. Guidance and educational materials have been previously developed by the Institute for Scrap Recycling Industries (ISRI) for member companies and their workers.

EPA is working to protect domestic markets from radioactively contaminated metals originating outside the U.S. through the development of consistent international standards for allowable radiation in metal products. Additionally, U.S. EPA and Customs have implemented a pilot project initiative at the ports of Daryl, LA and Charleston, SC to improve the detection radioactive materials entering the U.S.

"The potential for physical harm is tremendous," said Michael Mattia, Scrap Recycling Industries. "How long do we play such a deadly game before our luck runs out? (11/21/99, The New Jersey Record)

7.4 Management of Orphan Sources

An orphan source refers to radioactive material for which the custodian cannot afford the cost of dispostion, or for which he should not be held liable. An NRC survey conducted from 1983 – 1986 found that 15 percent of survey respondents could not account for their GL devices. The NRC has previously estimated that approximately 375 sources are reported lost, stolen or abandoned each year (Meserve, 2000) or more than 1,500 pieces of equipment containing radiological materials since 1996. Some of these lost sources are later found and this outcome is also listed in the Nuclear Material Events Database. Since 1995, there have been roughly 40 sealed sources found annually in the US by members of the public (Naraine, EPA, 1998) and unshielded radioactive sources have been reportedly found at waste disposal sites, scrap yards, incinerators, foundries, highway and construction sites. Our analysis of the NMED Database found only 37 events in which GL Devices were reported as lost between January 1, 1995 and April 1, 2003. However, underreporting of lost or abandoned devices is a significant concern (Health Physics Society 2002).

In the U.S., the individual who discovers an orphan source may be held responsible for the proper disposal of the source. For example, a scrap metal recycler that discovers a GL device in the wastestream may be held responsible for the proper – and costly – management of the device if the licensee or the manufacturer cannot be identified. While certain flexibility and discretion has been demonstrated by NRC and DOT in such circumstances, there is clearly a disincentive for the newfound "owner" to properly report and take responsibility for the disposition of the radioactive material.

Various federal and state initiatives have been initiated to help ensure the proper disposal of orphan sources, as described below.

7.4.1 "Orphan Source Project"

The EPA and the Conference of Radiation Control Program Directors (CRCPD), an organization of state and local government personnel responsible for radiological health programs in the U.S., began a program in the late 1990's to fund disposition of radiation sources when the custodian cannot afford an available outlet, or should not be held liable. The CRCPD orphan program usually can locate an affordable outlet for material, and so needs to actually fund very few. Most orphan sources can be taken care of by the owners, states or federal government (e.g., DOE). Some states, such as Texas and California, have their own funded collection programs.

There may be as many as 500,000 unwanted radioactive sources that may be appropriate to recycle or dispose. (Lubeneau & Yusko, 2000)

EPA funded an initial pilot program in Colorado and the NRC is funding the ongoing program. Additionally, DOE is contributing $100,000 to address orphans that are not byproduct materials. CRCPD, with assistance from Federal and state agencies, is administering the program.

The CRCPD Orphan Projects Program offers assistance in working with agencies, companies and institutions to find the most affordable, legal disposition for radioactive material through adoption by an individual, reuse by a device manufacturer; reprocessing of the material; acceptance by federal or state government; commercial storage; storage for decay; or proper legal disposal.

The program has accomplished the following:

- Contacted state radiation boards to determine the number and kinds of sources awaiting disposition.
- Developed a risk-based ranking system to prioritize disposition.
- Conducted a pilot in Colorado (completed in April 2001) in which 30 orphan sources were effectively managed, totaling 3.16 curies of Cs-137, which was returned to a manufacturer for reuse/disposal.
- Developed a program in which states may "sign" a contract with CRCPD to assist in disposing of orphan sources.
- Expanded the program to include, in addition to EPA and state regulatory agencies, members of the scrap metal recycling and steel manufacturing industries; and
- Developed an interactive CD-ROM training program.

CRCPD has a formal contractual program to operate this initiative. States with a contract as of May 2003 are: West Virginia, Maine, Illinois, Arizona, Maryland, Pennsylvania, Tennessee, and North Carolina. Participation is currently limited because of reluctance by states to sign a contract with CRCPD. Since CRCPD does not have assets, the states must assume indemnification and responsibility that the source was packaged, dispositioned and bid properly to vendors. In addition to these liability concerns, funding of this program, as well as programs in states with their own programs or funds, is constrained by governmental resources.

The CRCPD also provides relevant information and resources on their web site (www.crcpd.org) and has developed a video entitled "Dealing with Stray Radioactive Material" and a brochure "Detection and Prevention of Radioactive Contamination in Solid Waste Facilities."

7.4.2 Off-site Source Recovery project at LANL

The purpose of this Department of Energy project is to recover and manage unwanted radioactive sealed sources and to reduce to zero the backlog of unwanted sealed sources in the U.S., including those that:

- Present a risk to public health and safety;
- Are no longer controlled by the NRC or an Agreement State licensee;
- Are a DOE responsibility under Public Law 99-240 (LLW Policy Amendments Act of 1985); or
- Are DOE owned.

The objective of the project is to recover all sources and bring DOE into full compliance with PL 99-240 by the end of 2006. The NRC estimates 18,000 sealed sources and sealed source devices will become excess over the next decade. Of this total, NRC believes the most significant risk to public health and safety is posed by roughly 5,000 large neutron sources made excess from the well logging and other industries. The Los Alamos National Lab (LANL) has developed a database to register unwanted sources for which disposal options do not currently exist (e.g., transuranic wastes). Source owners and agencies are encouraged to register excess or unwanted sources through the Off-site Source Recovery Project.

As of March 2000, the project had recovered 91 unwanted Am-241 and Pu-238 sources (First Phase of Project). The priority and focus has been on recovering greater than Class C wastes covered by PL 99-240. There is a long"waiting list' for identified orphaned sources awaiting disposal through this initiative.

The program began in 1999 with a budget of $7 million, which was cut in fiscal year 2002 to $2.5 million. While the project was preparing for a cut in FY '03 to $1.8 million, the budget was reportedly supplemented with $10 million as a result of increased concern for radiological security after September 11, 2001.

7.4.3 Root Causes

According to the April 2002 Position Statement of the Health Physics Society "State and Federal Action is needed for Better Control of Orphan Sources," the root causes of the orphan problem are not being addressed:

1. *Existing U.S. programs do not encourage and facilitate the prompt disposition of unwanted or unneeded radioactive sources for disposal or transfer to environments which provide safe and secure storage, pending final decisions on their disposition. Many licensees possessing radioactive devices have had no contact with regulators and consequently are not familiar with obligations to provide for proper disposal.*

2. *Licensees in possession of unneeded or unwanted sources often discover that disposition options are severely limited. For example, the return of sources to manufacturers may be dependent upon whether the manufacturing company still exists, its willingness to accept the sources, conditions imposed by it upon such transfers and the cost for the service. Disposal of the source as waste is*

limited by low-level radioactive waste compact agreements on access to disposal sites, as well as limits on the types and quantities of radioactive material that may be disposed. Even when available, disposal has become so expensive that many licensees resort instead to unplanned, long-term storage. Disposal to the DOE is restricted to transuranics and to emergency situations when requested by the NRC.

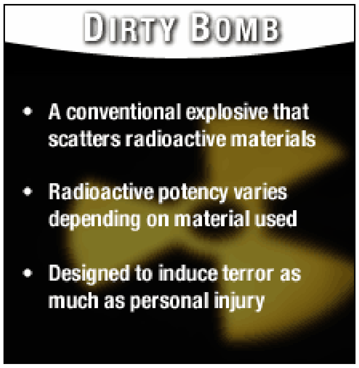
7.5 Security

In the aftermath of September 11th, the threat posed by a "dirty bomb," manufactured from a radioactive sealed source, is real. Al Qaeda sympathizer Jose Padilla (Abdullah al Mohair) was arrested in June 2002 in Chicago on suspicion of plotting to build and detonate a dirty bomb. In Congress, the "Dirty Bomb Prevention Act" was introduced in 2002 by Senator Hillary Rodham Clinton (D-New York) and Representative Edward J. Markey (D-Massachusetts) to help ensure the proper tracking, recovery and storage of radioactive material. Emergency response officials across the country have participated in tabletop exercises to plan and prepare for a dirty bomb scenario. They recognize that smaller, sealed sources are much more available than larger equipment or weapons grade sources.

In March 2003, U.S. and Russian governments sponsored a three-day gathering of world expects in Vienna to discuss the issue of dirty bombs and nuclear security. When it comes to safeguarding cesium, strontium and other radioactive sources, "what might have been sufficient in the past, may or may not be now," said U.S. Energy Secretary Spencer Abraham.

Experts agree that there are terrorists who wish to build a dirty bomb. There are sufficient orphan sources – and inadequate tracking of imports/exports – to obtain radiological material. Yet, while a dirty bomb is relatively simple in concept, constructing one is quite complicated.

Hypothetical radiation dispersal scenarios have been studied (Levi, Kelly 2002). They concluded that a dirty bomb could have drastic economic and psychological consequences, and that "programs to collect and safeguard unused materials, building on efforts such as the successful Los Alamos Offsite Source Recovery Project need to be expanded."



Various steps have been taken to minimize the terrorist threat of a "dirty bomb" or the improper import/export of radiological materials. Initiatives include the following:

- The Foreign Trade and Imports Initiative, under EPA's Clean Materials Program, is designed to minimize the import of contaminated recycled scrap metal.
- A Customs/EPA pilot project at Daryl, Louisiana is testing the use of a grapple radiation detection monitor. A second pilot project is also underway in Charleston, South Carolina.
- The Bureau of Customs and Border Protection has increased the radiation detection systems at ports in the U.S. The goal is to have a radiation detector for every inspector. The Bureau of Customs and Border Protection has also issued radiation detectors to foreign customs services and trained their inspectors.

- The “Dirty Bomb Prevention Act” was introduced in Congress in 2002 and reintroduced in the 2003 session of Congress.
- The IAEA is working closely with NRC, the Bureau of Customs and Border Protection and other international agencies to address the outstanding problems of the thousands of orphan radioactive sources that could be illegally imported into this country.
- EPA has chosen “Ports” as a sector, under its Sector Initiative Program, to assist in designing and implementing Environmental Management Systems (EMS) at U.S. seaports. This initiative may lead to enhanced detection of, and accountability for, radioactive sources as a component of an overall EMS.

Public sector initiatives – Orphan Source Program, Off-site Source Recovery, Enhanced Registration, and Improved Detection – have been developed to address many of the root causes associated with lost, abandoned and improperly disposed materials. Private sector initiatives include enhanced education and information to end users about compliance with NRC regulations, disposal and recycling options, and technology improvements.

7.6 Summary of Findings

- Devices and radioactive materials are being recycled, but the quantity or percentage recycled industry-wide cannot currently be quantified.
- The return of tritium exit signs to manufacturer/supplier is a cost-effective option for end users.
- The return of nuclear fixed gauges to a manufacturer/supplier is generally preferred and less costly than disposal as waste.
- Disposal of devices at Barnwell or Richland is costly and limited.
- Many older, disused nuclear fixed gauges have the potential to become orphan sources.
- “Orphans to Be” or disused sources are a problem because there is no clear incentive for companies or institutions to identify and properly dispose of stored gauges and tritium exit signs.
- Various initiatives and efforts are addressing the orphan source problem, but financial, legal, educational, and coordination challenges remain.
- Contamination of scrap metal processing continues to be a severe hazard and financial issue for the industry.
- The increased use of detectors by mills and the scrap metal processing industry has reduced, but not removed, the threat of smeltings.
- The use of radioactive material from nuclear fixed gauges to manufacture a dirty bomb is a concern.
- Improper disposal of tritium exit signs during renovation and construction is a compliance issue. This problem may be caused by lack of worker knowledge, and by a disincentive to include all disposal costs in the bid.
- While waste management officials are concerned about improper disposal of radioactive materials, the disposal of devices with radioactive materials in the municipal waste stream has generally not been perceived as a major problem.
- No standards exist for determining usable life for nuclear fixed gauges. No testing procedures, except for testing activity level, exist for assessing a gauge at the end of its rated useful life.
- ASTM due diligence and state building codes lack end-of-life considerations/guidance for radioactive devices.

- No funding source (e.g., deposit) exists when devices are initially purchased that would fund their future, proper disposal.
- Grapple radiation detectors are not present at all ports where scrap is imported into the United States.

8. STAKEHOLDER GROUPS

Stakeholder groups from government, industry and non-government organizations have been working for many years on issues associated with the improved management of nuclear fixed gauges and tritium exit signs. They have been involved in working groups, education campaigns, collection programs, and other initiatives to address management issues associated with products containing radioactive materials.

This section provides an overview of the various stakeholders that contributed to the development of this background report through interviews and have expressed interest in participating in the subsequent national dialogue. Appendix F provides a listing of all organizations and individuals that provided information that was incorporated into this background technical report.

Manufacturers and Distributors

Many of the companies that manufacture and distribute nuclear fixed gauges and tritium exit signs have taken steps to improve the management of these products during use and end of product life. Many of these companies also manufacture or distribute non-nuclear alternative products. The companies that have contributed to this report and have expressed an interest in participating in the upcoming national dialogue include:

Tritium Exit Signs:
Isolite
Self-Powered Lighting
Shield Source
SRB Technologies

Nuclear Fixed Gauges:
EGS Gauging Systems
Ohmart/Vega Corporation
Thermo Measure Tech

Letters have been recently sent to the manufacturers/distributors listed in Appendix D to notify them of this project. Several of these manufacturers/distributors have responded with interest to review this report in draft form and to potentially participate in ongoing efforts for this project.

Industry Associations

Institute of Scrap Recycling Industries (ISRI) – ISRI is the trade association of the scrap processing and recycling industry representing approximately 1,300 companies that process, broker, and industrially consume scrap commodities.

National Association of Demolition Contractors – The association was formed to foster goodwill and the exchange of ideas with the public, governmental agencies, and contractors engaged in the demolition industry.

Steel Recycling Institute (SRI) – SRI is a unit of the American Iron and Steel Institute, and is an industry association that promotes and sustains the recycling of all steel products.

Waste Brokers, Recyclers, & Disposal Facilities

David J. Joseph Company (DJJ) – DJJ is the largest scrap company in the United States. They provide numerous products and services including scrap trading, scrap processing, mill services, and industrial scrap services.

GTS Duratek – GTS Duratek is the parent company for Chem-Nuclear Systems, the operator of the commercial low-level radioactive waste disposal facility located in Barnwell, South Carolina. In addition, the commercial products division of GTS Duratek provides sealed source processing services.

U.S. Ecology – U.S. Ecology is a wholly owned subsidiary of American Ecology. They operate the full service Class A, B, and C low-level radioactive waste disposal facility located in Richland, Washington.

Government - Federal

Nuclear Regulatory Commission **--** Regulates radioactive source materials, special nuclear materials, and byproduct materials as well as facilities producing, transferring, receiving, acquiring, owning, possessing and using these materials. General License Devices, including nuclear fixed gauges and tritium exit signs, are regulated under 10 CFR Part 31.5. Its authority comes from passage in 1954 of the U.S. Atomic Energy Act. Certain states, called Agreement States, have been authorized to administer their own programs.

Environmental Protection Agency **--** Sets (develops and issues) radiation protection standards for the safe management of radioactive and "mixed" (radioactive and hazardous) wastes, provides technical expertise during radioactive site cleanup and sets cleanup and drinking water standards. Standards also include management standards under 40 CFR Subchapter F "Radiation Protection" in Parts 190 – 197 and 40 CFR 61 Subpart H governing radionuclide air emissions.

Department of Energy -- Produces byproduct material; responsible for recovery and management of certain categories of unwanted radioactive sealed sources under Public Law 99-240 (LLW Policy Amendments Act of 1985). Primary standards for occupational radiation protection of its workers are issued at 10 CFR Part 835. Additionally, DOE has issued policies, orders, notices, manuals and guides relative to the safe handling, use and disposal of radioactive materials.

Government - State

Representatives from five State agencies contributed information to this background technical report and have interest in participating in the subsequent national dialogue. Individuals from six states (Illinois, Massachusetts, New Jersey, Pennsylvania, Texas, and Washington) provided the following:

- Agreement state representation
- Non-agreement state representation
- Leaders for two closely related CRCPD committees
- Expertise in radiation management and protection

Participation from other states during the upcoming national dialogue will be considered.

Professional Organizations

Association of State and Territorial Solid Waste Management Officials (ASTSWMO) – ASTSWMO is an organization supporting the environmental agencies of the States and trust territories. ASTSWMO's mission is to enhance and promote effective state and territorial waste management programs and affect national waste management policies.

Conference of Radiation Control Program Directors (CRCPD) – CRCPD is a nonprofit organization of individuals that regulate and control the use of radioactive material and radiation sources. CRCPD has two committees that are working on closely related initiatives:

Committee on Resource Recovery and Radioactivity
Committee on Unwanted Radioactive Materials

Health Physics Society – The Health Physics Society is a scientific and professional organization whose members specialize in occupational and environmental radiation safety. The primary purpose of the Society is to support its members in the practice of their profession.

National Council on Radiation Protection and Measurements (NCRP) - NCRP is a nongovernmental, not for profit, public service organization that has been active in the areas of radiation protection and measurements since 1929. NCRP has produced more than one hundred scientific reports pertaining to radiation protection and measurement.

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Health Physics Society
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National Council on Radiation Protection and Measurements
http://www.ncrp.comNuclear Regulatory Commission
http://www.nrc.gov

Nuclear Materials Events Database
http://nmed.inel.gov

Off-Site Source Recovery Project at Los Alamos
http://osrp.lanl.gov/

Radioactive Materials Education Site

http://www.philrutherford.com/

Sealed Source Device Registry
http://www.nrc.gov/materials/miau/ssd/obtain-reports.html

University of Michigan Health Physics Society
http://www.umich.edu/~radinfo/

Waste Link
http://www.radwaste.org

APPENDIX A: ORGANIZATIONS PROVIDING RESEARCH AND INFORMATION FOR THIS PROJECT

Organization	**Individual(s)**
American Ref-Fuel	Matt Sears
Association of State and Territorial Solid Waste Management Officials (ASTSWMO)	Jeff Deckler, Jay Shepard, Dania Rodriquez
ATI Adaptive Technologies	Sam Silverberg
Conference of Radiation Control Program Directors (CRCPD)	Terry Devine, Ron Fraass
David J. Joseph	Ray Turner
Department of Energy	Lee Leonard
EGS (Eurotherm) Gauging Systems	Doug Beek
EPA Energy Star Program	Andrew Fanara, Darcy Hoffmeyer
EPA Office of Radiation and Indoor Air	Sally Hamlin
European Commission	Blanca Andres
GTS Duratek (Chem-Nuclear)	Greg McGinnis
Illinois Dept. of Nuclear Safety	Joe Klinger
Institute of Scrap Recycling Industries (ISRI)	Michael Mattia
Integrated Waste Services Association	Maria Zannes
Isolite	Bill Lynch
Lightpanel Technologies	Scott Kuhn
Massachusetts DPH	Kathleen McAllister
National Association of Demolition Contractors	Michael R. Taylor
National Council on Radiation Protection and Measurements (NCRP)	Thomas Tenforde
National Electrical Manufacturers Association (NEMA)	Ric Erdheim
New Jersey DEP	Jill Lipoti, Pat Gardner
Nuclear Regulatory Commission (NRC)	Binesh Tharakan, Samuel Pettijohn, John Hickey
Ohmart/Vega Corporation	Candy Brock, George Brown, Jack Rodgers
Pennsylvania DEP	Jim Yusko, Dwight Shearer, Terry Derstine, Ron Furlan
Philotechnics	Annette Leach
Richland, Washington (American Ecology)	Mike Ault
Self-Powered Lighting, Inc (SPL)	Bill Rowan

Organization	Individual(s)
Shield Source	Sue Tanney
SRB Technologies	Jim Roberts, Brian Pullen
Steel Recycling Institute (SRI)	Greg Crawford
Texas Dept. of Health	Pete Myers
Thermo Measure Tech	Ralph Heyer
Washington Department of Health	Anine Grumbles

APPENDIX B: GLOSSARY OF TERMS

(Source: Abbreviated glossary from the Radiation Safety Department at Harvard University)

Activity

The rate of disintegration (transformation) or decay of radioactive material. The units of activity are curie (Ci) and the becquerel (Bq).

Agreement State

Any state with which the U.S. Nuclear Regulatory Commission has entered into an effective agreement under subsection 274b. of the Atomic Energy Act of 1954, as amended. Under the agreement, the state regulates the use of by-product, source, and small quantities of special nuclear material within said state.

Airborne Radioactive Material

Radioactive material dispersed in the air in the form of dusts, fumes, particulates, mists, vapors, or gases.

ALARA

Acronym for "As Low As Reasonably Achievable". Making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken. It takes into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, societal and socioeconomic considerations, and in relation to utilization of radioactive materials and licensed materials in the public interest.

Alpha Particle

A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus, with a mass number of 4 and a charge of +2.

Background Radiation

Radiation from cosmic sources; naturally occurring radioactive materials, including radon and fallout from nuclear weapons tests.

Beta (particle)

High speed electrons, which are emitted from the nuclei of radioactive atoms during radioactive decay, as a result of the transformation of a neutron into a proton. They can be stopped by a thin (thickness varies for different radionuclides) sheet of plastic or glass.

Becquerel

A unit, in the International System of Units (SI), of measurement of activity equal to one decay per second.

Biological Half Life The time that is required by an organism to eliminate half the amount of a substance that has entered it

Charged Particle

An elementary particle or ion which carries a positive or negative electric charge.

Contamination

The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel. Can either be fixed or removable.

Curie (Ci)

The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium. Named for Marie and Pierre Curie, who discovered radium in 1898.

Decay, Radioactive

The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha, beta particles, or gamma rays.

Decontamination

The reduction or removal of contaminating radioactive material from a structure, area, object, or person.

Dose

A generic term referring to the amount of radiation received by a biological organism.

Dose Equivalent

The product of the absorbed dose in tissue, quality factor, and other modifying factors at the location of interest. The units are mrem.

Dose Rate

The ionizing radiation dose delivered per unit time, such as mrem/hour.

Dosimeter

A portable instrument for measuring the total accumulated exposure to ionizing radiation.

DPM (Disintegrations per Minute)

The number of radioactive disintegrations per unit time; there are 2.2E6 disintegrations per minute in a microcurie

Effective Dose Equivalent

The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Effective Half-Life

The time required for the amount of a radioactive element deposited in a living organism to be reduced by 50 percent from the combined removal mechanisms of radioactive decay and biological elimination.

Exposure

1) A measure of the ionization produced in air by x or gamma radiation. The unit of exposure is the roentgen (R).

2) Being exposed to ionizing radiation or to radioactive material.

Exposure Rate

The amount of ionization in air caused by x-ray or gamma ray radiation per unit time; unit of measurement is the roentgen per unit time (R/hr)

External Dose

The portion of the dose equivalent received from radiation sources outside the body.

Gamma Ray

Relatively short wavelength electromagnetic radiation released from the nucleus of an atom.

Half-life

The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half lives vary from millionths of a second to billions of years. Also referred to as the physical half-life.

Health Physics

The science concerned with recognition, evaluation, and control of health hazards from non-ionizing and ionizing radiation.

Internal Dose

That portion of the dose equivalent received from radioactive material taken into the body.

Ionization

The process of adding or removing one or more electrons from atoms or molecules. High temperatures, electrical discharges, or radiation can cause ionization.

Ionization Chamber

An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of electricity.

Ionizing Radiation

Any radiation capable of displacing electrons from atoms or molecules, producing ions. Examples: alpha, beta, gamma, x-rays, neutrons, and ultraviolet light. High doses may produce severe skin or tissue damage.

Irradiation

Exposure to radiation.

Isotope

One of two or more atoms with the same number of protons, but different number of neutrons, in their nuclei. Example: 12C, 13C, and 14C are isotopes of the same element. Isotopes have very nearly the same chemical properties, but often different physical properties (12C and 13C are stable, while 14C is radioactive).

Limits

The permissible upper bounds of radiation doses.

Nuclide

A general term referring to all known isotopes, both stable (~279) and unstable (~5000), of the chemical elements.

Physical Half Life

The time required for a radioisotope to reduce activity by half.

Rad

The special unit of absorbed dose. One rad is equivalent to 100 ergs/gram or 0.01 J/kg.

Radiation

Alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other charged particles capable of producing ions. Radiation, as used in this context, does not include non-ionizing radiation, such as radio waves, microwaves, or visible, infrared, or ultraviolet light.

Radiation Detection Instrument

A device that detects and records the characteristics of ionizing radiation.

Radiation Machine

Any device capable of producing radiation except those which produce radiation only from radioactive material.

Radiation Shielding

Reduction of radiation by placing a shield of absorbing material between any radioactive source and a person, work area, or radiation sensitive device.

Radiation Source

Usually a manmade sealed source of radiation used in teletherapy, radiography, as a power source for batteries, calibration, or in various industrial gauges. Machines such as accelerators, radioisotope generators, and natural radionuclides may be considered sources.

Radiation Standards

Exposure standards, permissible concentrations, rules for safe handling, regulations for transportation, regulations for industrial control of radiation and control of radioactive material by legislative means.

Radiation Warning Symbol

An officially prescribed symbol (a magenta trefoil) on a yellow background that must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received.

Radioactive waste

A solid, liquid, or gaseous material from experiment/research operations that is radioactive and for which there is no further use.

Radioactivity

The spontaneous emission of radiation, generally alpha particles, beta particles, or gamma rays from the nucleus of an unstable isotope.

Radioisotope

An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.

Rem

The special unit for dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rads, multiplied by the quality factor.

Roentgen (R)

A unit of exposure to ionizing radiation. It is that amount of gamma or x-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered x-rays in 1895.

Sealed Source

Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal under the most severe conditions which are likely to be encountered in normal use and handling.

Shielding

Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

Whole Body

Refers to the head, trunk (including gonads), arms above the elbow, and legs above the knee.

X-rays

Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. They can be produced by excitation of the electrons around certain nuclei (characteristic x-rays) or by the interaction of high speed electrons with the electric fields around nuclei.

APPENDIX C: RADIATION HAZARDS/CONVERSION CHART

SI RADIATION MEASUREMENT UNITS: CONVERSION FACTORS

1 terabecquerel (TBq)	27	curie (Ci)
1 gigabecquerel (GBq)	27	millicurie (mCi)
1 megabecquerel (MBq)	27	microcurie (µCi)
1 kilobecquerel (kBq)	27	nanocurie (nCi)
1 becquerel (Bq)	27	picocurie (pCi)
1 curie (Ci)	37	gigabecquerel (GBq)
1 millicurie (mCi)	37	megabecquerel (MBq)
1 microcurie	37	kilobecquerel (kBq)
1 nanocurie (nCi)	37	becquerel (Bq)
1 picocurie (pCi)	37	millibecquerel (mBq)
1 Gray (Gy)	100	rad (rad)
1 milligray (mGy)	100	millirad (mrad)
1 microgray (µGy)	100	microrad (µrad)
1 nanogray (nGy)	100	nanorad (nrad)
1 kilorad (krad)	10	gray (Gy)
1 rad (rad)	10	milligray (mGy)
1 millirad (mrad)	10	microgray (µGy)
1 microrad (µrad)	10	nanogray (nGy)
1 coulomb/kg (C/kg)	3876	roentgen (R)
1 millicoulomb/kg (mC/kg)	3876	milliroentgen (mR)
1 microcoulomb/kg (µC/kg)	3876	microroentgen (µR)
1 nanocoulomb/kg (nC/kg)	3876	nanoroentgen (nR)
1 kiloroentgen (kR)	258	millicoulomb/kg (mC/kg)
1 roentgen (R)	258	microcoulomb/kg (µC/kg)
1 milliroentgen (mR)	258	nanocoulomb/kg (nC/kg)
1 microroentgen (µR)	258	picocoulomb/kg (pC/kg)
1 sievert (Sv)	100	rem (rem)
1 millisievert (mSv)	100	millirem (mrem)
1 microsievert (µSv)	100	microrem (µrem)
1 kilorem (krem)	10	sievert (Sv)
1 rem (rem)	10	millisievert (mSv)
1 millirem (mrem)	10	microsievert (µSv)

APPENDIX D: SOME MANUFACTURERS AND DISTRIBUTORS OF NUCLEAR GAUGES/DEVICES AND TRITIUM EXIT SIGNS

LICENSE NAME		CITY NAME	STATE
NUCLEAR FIXED GAUGES			
1.	ABB AUTOMATION, INC.	Columbus	OH
2.	ACROWOOD CORPORATION	Everett	WA
3.	ADAPTIVE TECHNOLOGIES INDUSTRIES	Gaithersburg	MD
4.	ADVANCED GAUGING TECHNOLOGIES, LLC	Westerville	OH
5.	ADVANZ MEASUREMENT AND CONTROL SYSTEM	Dayton	OH
6.	ADVANZ MEASUREMENT AND CONTROL SYSTEM	Dayton	OH
7.	AEA TECHNOLOGY QSA, INC.	Burlington	MA
8.	AGILENT TECHNOLOGIES, INC.	Wilmington	DE
9.	AUTOMATION & CONTROL TECHNOLOGY, INC.	Columbus	OH
10.	BECKMAN COULTER, INC. (BSI)	Fullerton	CA
11.	BERTHOLD SYSTEMS, INC.	Aliquippa	PA
12.	BERTHOLD TECHNOLOGIES USA, LLC	Oak Ridge	TN
13.	BRUKER DALTONICS, INC.	Billerica	MA
14.	BARRINGER INSTRUMENTS, INC.	Warren	NJ
15.	BERTHOLD SERVICES	Sugarland	TX
16.	BETACONTROL OF AMERICA, INC.	Towaco	NJ
17.	CAMPBELL SECURITY EQUIPMENT COMPANY	Pleasant Hill	CA
18.	CANBERRA INDUSTRIES, INC.	Warrington	PA
19.	COATING MEASUREMENT INSTRUMENTS (CMI)	Elk Grove Village	IL
20.	CONCO SERVICES CORP.	Gaithersburg	MD
21.	CONSULTING ENGINEERING SERVICES, INC	Pensacola	FL
22.	DICKEY-JOHN CORP	Auburn	IL
23.	DELPHI CONTROL SYSTEMS, INC.	Pomona,	CA

LICENSE NAME		CITY NAME	STATE
24.	E.S.C. RESOURCES, INC.	Montgomery	IL
25.	EUROTHERM GAUGING SYSTEMS	Billerica	MA
26.	ENVIRONMENTAL TECHNOLOGIES GROUP, INC.	Baltimore	MD
27.	FISCHER TECHNOLOGY, INC.	Windsor	CT
28.	GAMMA INSTRUMENTS, INC.	South Chicago Hts	IL
29.	GRASBEY ANDERSEN	Smyrna	GA
30.	HEUFT USA, INC.	Downers Grove	IL
31.	HNU SYSTEMS	Newton	MA
32.	HONEYWELL INTERNATIONAL, INC.	Cupertino	CA
33.	HALLIBURTON ENERGY SERVICES, INC.	Duncan	OK
34.	HARREL, INCORPORATED	East Norwalk	CT
35.	HONEYWELL INC.	Phoenix	AZ
36.	HONEYWELL, INC.	Duluth	GA
37.	IMS MEASURING (ISOTOPE MEASURING SYS, INC.)	Atlanta	GA
38.	INDEV GAUGING SYSTEMS	Loves Park	IL
39.	INDUSTRIAL AND RESEARCH MEASUREMENT SYSTEMS	Grove City	OH
40.	INDUSTRIAL DYNAMICS CO., LTD.	Torrance	CA
41.	INTEGRATED INDUSTRIAL SYSTEMS, INC.	Yalesville	CT
42.	INDUSTRIAL DYNAMICS CO., LTD.	Torrance	CA
43.	INOVISION RADIATION MEASUREMENTS	Cleveland	OH
44.	ION TRACK INSTRUMENTS	Wilmington	MA
45.	KEY MASTER TECHNOLOGIES, INC	Kennewick	WA
46.	LAGUS APPLIED TECHNOLOGY, INC.	San Diego	CA
47.	LINC QUANTUM ANALYTICS, INC.	Foster City	CA
48.	LUDLUM MEASUREMENTS, INC.	Sweetwater	TX
49.	MAHLO AMERICA, INC.	Spartanburg	SC
50.	METOREX, INC	Ewing	NJ
51.	METSO AUTOMATION USA INC	Norcross	GA

	LICENSE NAME	CITY NAME	STATE
52.	MOLECULAR ANALYTICS, INC.	Sparks	MD
53.	N. SCHLUMBERGER (USA) INC.	Fort Mill	SC
54.	NDC INFRARED ENGINEERING, INC.	Irwindale	CA
55.	NITON CORPORATION	North Kingstown	RI
56.	NITON CORPORATION	Billerica	MA
57.	NOVA R&D, Inc.	Riverside	CA
58.			
59.	OHMART/VEGA CORPORATION	Cincinnati	OH
60.	ON-SITE INSTRUMENT, INC	Westerville	OH
61.	OXFORD, INSTRUMENT, INC.	Concord	MA
62.	PANTHER SYSTEMS, INC	Vancouver	WA
63.	PCP, INC.	West Palm Beach	FL
64.	PECO CONTROLS CORPORATION	Fremont	CA
65.	PERKIN ELMER INSTRUMENTS	Shelton	CT
66.	PERKINELMER LIFE SCIENCES	Downers Grove	IL
67.	PERKINELMER LIFE SCIENCES	Boston	MA
68.	PETTIT APPLIED TECHNOLOGIES	Gaithersburg	MD
69.	PHOTO RESEARCH, INC	Chatsworth	CA
70.	PRINCETON GAMMA-TECH, INC.	Princeton	NJ
71.	RONAN ENGINEERING COMPANY	Florence	KY
72.	SAINT GOBAIN/BICRON	Solon	OH
73.	SCAN TECHNOLOGIES, INC.	Poca	WV
74.	SCAN TECHNOLOGIES, INC.	Suwanee	GA
75.	SCIENCE APPLICATIONS INTERNATIONAL CORP.	San Diego	CA
76.	SCIENTECH, INC.	Pullman	WA
77.	SENSOR SERVICES, INC.	Sherrills Ford	NC
78.	SENTEX SYSTEMS, INC.	Fairfield	NJ
79.	SHIMADZU SCIENTIFIC INSTRUMENTS, INC.	Columbia	MD
80.	SIKORSKY AIRCRAFT CORPORATION	Stratford	CT
81.	SPECTRO	Marble Falls	TX

LICENSE NAME		CITY NAME	STATE
82.	STAN A. HUBER	New Lenox	IL
83.	STRANDBERG ENGINEERING LABORATORIES	Greensboro	NC
84.	THERMO ENVIRONMENTAL INSTRUMENTS, INC.	Franklin	MA
85.	THERMO MEASURETECH	Round Rock	TX
86.	THERMOFINNIGAN CORP/CE INSTRUMENTS	Austin	TX
87.	THERMORADIOMETRIE	Gaithersburg	MD
88.	TITERTEK INSTRUMENTS, INC.	Huntsville	AL
89.	TREK, INC.	Medina	NY
90.	TROXLER ELECTRONIC LABORATORIES, INC.	Research Triange	NC
91.	TSI INCORPORATED	St. Paul	MN
92.	VACUUM INSTRUMENT CORPORATION	Ronkonkoma	NY
93.	VARIAN ASSOCIATES, INC.	Walnut Creek	CA
94.	VALCO INSTRUMENTS CO., INC.	Houston	TX
TRITIUM EXIT SIGNS			
95.	BEST LIGHTING PRODUCTS, INC.	Santa Ana	CA
96.	ISOLITE CORPORATION	Berwyn	PA
97.	ISOLITE CORPORATION	San Luis Obispo	CA
98.	NRD, LLC	Grand Island	NY
99.	SAFETY LIGHT CORPORATION	Bloomsburg	PA
100.	SIGNTEX INC	Grasonville	MD
101.	SELF-POWERED LIGHTING, INC.	West Nyack	NY
102.	SRB TECHNOLOGIES, INC.	Winston-Salem	NC
103.	STUSSER ELECTRIC COMPANY	Anchorage	AK

APPENDIX E: SOME WASTE DISPOSAL AND SOURCE RECOVERY VENDORS

LICENSE NAME	CITY NAME	STATE
1. ADCO SERVICES	Tinley Park	IL
2. APPLIED HEALTH PHYSICS	Bethel Park	PA
3. BIONOMICS, INC.	Kingston	TN
4. CHASE ENVIRONMENTAL	Louisville	KY
5. ECOLOGY SERVICES	Columbia	MD
6. DURATEK	Oak Ridge	TN
7. NSSI	Houston	TX
8. PERMAFIX ENVIRONMENTAL SERVICES	Gainesville	FL
9. PHILOTECHNICS	Oak Ridge	TN
10. RACE	Memphis	TN
11. RADIAC RESEARCH	Brooklyn	NY
12. RADIATION SAFETY ASSOCIATES	Hebron	CT
13. R.M. WESTER & ASSOCIATES	St. Peters	MO
14. RSO, INC.	Laurel	MD
15. SOLUTIENT TECHNOLOGIES	North Canton	OH
16. THOMAS GRAY & ASSOCIATES	Orange	CA
17. WASTE CONTROL ASSOCIATES	Andrews	TX

INFORMATION IN THIS CHART COMES FROM CRCPD AND HEALTH PHYSICS SOCIETY'S WEB SITES.

APPENDIX F: SCRAP METAL MELTING INCIDENTS IN THE U.S.

(Yusko, 2002)

#	Year	Metal	Plant	State	Isotope	Activity	Decon $M
1	1983	Steel	Auburn Steel	NY	Co-60	930 GBq	4.4
2	1983	Gold	Unknown	NY	Am-241	Unknown	Unknown
3	1984	Steel	U.S. Pipe & Foundry	AL	Cs-137	0.37-1.9 GBq	0.6
4	1985	Steel	Tamco	CA	Cs-137	56 GBq	1.5
5	1987	Steel	Florida Steel	FL	Cs-137	0.93 GBq	0.2
6	1987	Aluminum	United Technology	IN	Ra-226	0.74 GBq	0.5
7	1988	Lead	ALCO Pacific	CA	Cs-137	0.74-0.93 GBq	0.2
8	1988	Copper	Warrington	MO	ARM	Unknown	Unknown
9	1989	Steel	Bayou Steel	LA	Cs-137	19 GBq	0.05
10	1989	Steel	Cytemp	PA	Thorium	Unknown	0.1
11	1990	Steel	NUCOR	UT	Cs-137	Unknown	2
12	1991	Aluminum	Alcan Recycling	TN	Thorium	Unknown	Unknown
13	1992	Steel	Newport Steel	KY	Cs-137	12 GBq	Unknown
14	1992	Aluminum	Reynolds	VA	Ra-226	Unknown	Unknown
15	1992	Steel	Border Steel	TX	Cs-137	4.6-7.4 GBq	0
16	1992	Steel	Keystone Wire	IL	Cs-137	Unknown	2.3
17	1993	Steel	Auburn Steel	NY	Cs-137	37 GBq	0.6
18	1993	Steel	Newport Steel	KY	Cs-137	7.4 GBq	Unknown
19	1993	Steel	Chaparral Steel	TX	Cs-137	Unknown	Unknown
20	1993	Zinc	Southern Zinc	GA	U dep	Unknown	Unknown
21	1993	Steel	Florida Steel	FL	Cs-137	Unknown	Unknown
22	1994	Steel	Austeel Lemont	IL	Cs-137	0.074 GBq	Unknown
23	1994	Steel	US Pipe & Foundry	CA	Cs-137	Unknown	Unknown
24	1996	Aluminum	Bluegrass Recycling	KY	Th-232	Unknown	Unknown
25	1997	Aluminum	White Salvage Co.	TN	Am-241	Unknown	Unknown
26	1997	Steel	WCI	OH	Co-60	0.9(?) GBq	Unknown
27	1997	Steel	Kentucky Electric	KY	Cs-137	1.3 GBq	Unknown
28	1997	Steel	Birmingham Steel	AL	Cs-137, Am0241	7 Bq/g	Unknown
29	1997	Steel	Bethlehem Steel	IN	Co-60	0.2 GBq	Unknown
30	1998	Aluminum	S.Al Castings	AL	Th	Unknown	Unknown
31	2001	Aluminum	IMCO Recycling	OH	DU	Unknown	Unknown
32	2001	Steel	Ameristeel	FL	Cs-137	Unknown	Unknown