Appendix G

Radiological Hazards

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Appendix G1

Baseline Conditions for the Management, Storage, Transportation, and Disposal of Spent Nuclear Fuel and High-Level Waste at Diablo Canyon Power Plant

Appendix G1 Baseline Conditions for the Management, Storage, Transportation, and Disposal of Spent Nuclear Fuel and High-Level Waste at Diablo Canyon Power Plant

The purpose of this appendix is to summarize the requirements and assumptions that Pacific Gas & Electric Company (PG&E) has made in its planning documents and the current ("baseline") plan and schedule for the management of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) associated with the decommissioning of the Diablo Canyon Power Plant (DCPP), including on-site storage and off-site transportation and disposal. By definition, HLW includes the spent (or used) nuclear fuel produced by the operation of commercial nuclear power plants, as well as the waste materials remaining after spent fuel is reprocessed (for example at the defense reprocessing facilities at DOE's Hanford site in Washington and Savannah River site in Georgia, and the commercial spent fuel reprocessing facility at DOE's West Valley site in New York). At DCPP, all of the HLW is SNF.

This report describes the current regulatory requirements and contractual agreements relevant to the storage and disposal of SNF and HLW, and assesses whether PG&E's assumptions represent an appropriate baseline for analysis in this EIR. It also identifies and evaluates whether alternative assumptions might be appropriate to consider, given that circumstances beyond PG&E's control could impact the plan. Several potentially feasible alternatives to continued on-site storage are discussed that have been proposed by stakeholders or members of the public.

Description of the Current Plan and Schedule

The Post Shutdown Decommissioning Activities Report (PSDAR) (PG&E, 2019a), the Irradiated Fuel Management Plan (IFMP) (PG&E, 2019b), and the Site Specific Decommissioning Cost Estimate (SSDCE) (PG&E, 2019c) for DCPP Units 1 and 2, describe the assumptions and schedule for decommissioning of the DCPP site. These planning documents are based on regulatory and contractual requirements related to the on-site storage and eventual off-site shipment of SNF, HLW, and Greater Than Class C Waste (GTCC). GTCC is Low Level Radioactive Waste (LLRW) with concentrations of radionuclides that exceed the limits established by the NRC for Class C LLRW.

The key elements of the IFMP for decommissioning include:

- Wet storage of SNF in spent fuel pools until it can be transferred to dry storage at the Diablo Canyon Independent Spent Fuel Storage Installation (ISFSI);
- Dry storage of SNF from decommissioning activities at the Diablo Canyon ISFSI, and a separate facility for GTCC waste; and
- Transportation of SNF and HLW to a geologic repository for disposal by the US Department of Energy (DOE).

This report focuses primarily on the spent fuel and waste stored on-site at DCPP, which currently includes both dry storage in an existing ISFSI and wet storage in the spent fuel pools (SFPs) for both Units 2 and 3. That fuel is currently expected to remain in storage until it is shipped to the DOE for disposal between 2038 and 2067.

The initial interim storage of DCPP Units 1 and 2 SNF will be "wet storage" in each unit's respective SFP, which are located in the Fuel Handling Building (FHB). The FHB is a shared structure that encloses the SFPs, the fuel handling cranes, fuel racks, and related equipment. The equipment in the FHB must be operated and maintained properly to provide the capability to safely store SNF, remove decay heat generated by SNF, and provide shielding from the radiation emitted by SNF. The operational activities involve the monitoring of system parameters, periodic testing of important equipment functions, performing inspections, and facility security. The SFP facility equipment requiring maintenance includes instrumentation, pumps, valves, heat exchangers, filters, ventilation fans, ducting, and dampers.

Approximately 18 months after shutdown, the SFPs will be isolated from the existing support systems and those systems will be replaced by a spent fuel pool island (SFPI). The implementation of a SFPI will allow use of a smaller system that discharges heat to the ambient air outside of the FHBs rather than relying on existing plant systems. The implementation of the SFPI will reduce the footprint and facilitate abandonment of the buildings and parallel decommissioning activities.

Transfer of SNF and HLW to On-site Dry Storage

After the shutdown, the remaining irradiated fuel will be removed and transferred to the SFPs, where it will cool for approximately four years. It will then be transferred to dry storage at the ISFSI, which is licensed under a Nuclear Regulatory Commission (NRC) Part 72 site-specific license. In addition to SNF, the nuclear industry typically stores fuel debris and damaged SNF assemblies (which are HLW), and GTCC waste in dry cask storage systems. Consistent with industry standard practice, PG&E also plans to store these materials in dry cask storage systems. The current dry cask storage system utilized at the ISFSI includes several components to transfer and store SNF and GTCC waste:

- A HI-STORM 100 System
  - A Multi Purpose Canister (MPC) capable of storing up to 32 SNF assemblies
  - a dry cask storage overpack for SNF, referred to as a HI-STORM 100SA
  - a HI-TRAC1250 transfer cask
- A low-profile transporter
- A vertical cask transporter
- A cask transfer facility

The ISFSI Technical Specifications limit the materials that can be stored in the MPC-32 canisters. Specifically, the MPC-32 is currently allowed to contain only intact SNF assemblies and non-fuel hardware with specific dimensions, enrichment, and cladding material. Fuel debris, damaged SNF assemblies, and GTCC waste cannot be stored in the MPC-32 under current ISFSI Technical Specifications. PG&E plans to obtain NRC approval to store the fuel debris and damaged assemblies at the ISFSI, and the GTCC waste at a GTCC Storage Facility that would be constructed near the ISFSI. This plan is consistent with the assumptions included in the SSDCE. Dry storage of these items is also considered interim storage pending transfer to the DOE (PG&E, 2019b).

The ISFSI is a separately licensed facility (from the operating reactors) located approximately 0.22 miles northeast of the Unit 1 Containment Building at an elevation of approximately 310 feet situated directly on bedrock. It consists of a security boundary and concrete storage pads that securely anchor the casks storing the SNF (PG&E, 2019b).

The IFMP describes PG&E's plans to expand the size and capability of the storage system in the future to include:

- non-fuel waste storage canisters for GTCC waste (similar to an MPC)
- non-fuel waste storage overpack dry casks or storage modules for GTCC waste
- an MPC capable of storing SNF (intact and damaged) and fuel debris
- a dry cask storage overpack capable of storing SNF (intact and damaged) and fuel debris

PG&E announced on April 6, 2022, that it had selected Orano USA as its vendor to safely transfer the remaining spent fuel from the DCPP spent fuel pools to the existing ISFSI. The Orano NUHOMS EOS System differs in several respects from the current Holtec HI-Storm 100 System, but both systems perform the same key functions to safely store SNF while protecting workers and the public from radiation. In addition to the remaining SNF, the Orano system will be used to store the materials that cannot currently be stored in the existing Holtec system, including GTCC waste and damaged fuel and fuel debris. Table G1-1 summarizes the key components and characteristics of the existing and planned systems.

Table G1-1. Summary Comparison of the Holtec and Orano Systems for the DCPP ISFSI

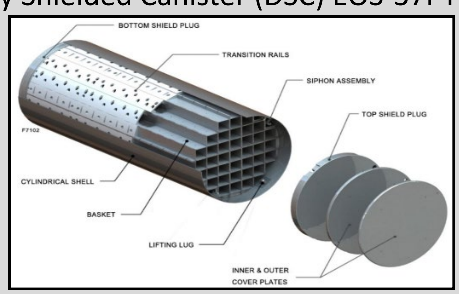
Attributes	Holtec HI-STORM 100 System	Orano NUHOMS EOS System
Licenses	NRC Certificate of Compliance (CoC) 72-1014 (initially in 2000)	CoC 72-1042 (initially in 2016)
	ISFSI site-specific 72-26	N/A
	CoC 71-9261 (low/med burnup only)	CoC 71-9382 not-yet-licensed (under NRC review as of Dec 2020)
	Must meet the site-specific hazards and accidents, including seismic	
Canisters	Multi-Purpose Canister (MPC)-32 	Dry Shielded Canister (DSC) EOS-37PTH 
Allowable Contents	Spent fuel assemblies (including high burnup), nonfuel assembly hardware	Spent fuel assemblies (incl. high burnup), nonfuel assembly hardware, damaged fuel, fuel debris
Capacity	32 spent fuel assemblies	37 spent fuel assemblies
Canister Max. Heat Load	28.7 kW	50 kW

Table G1-1. Summary Comparison of the Holtec and Orano Systems for the DCPP ISFSI

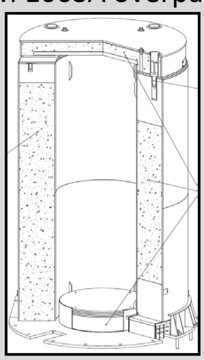
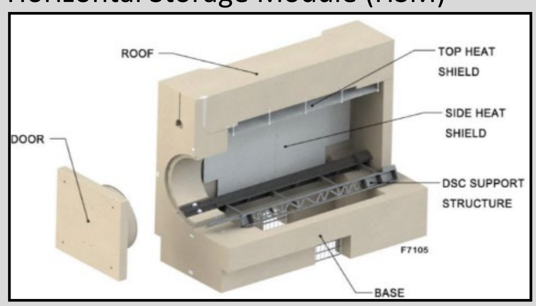
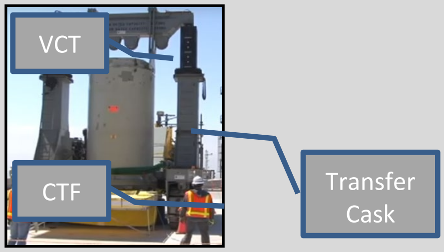
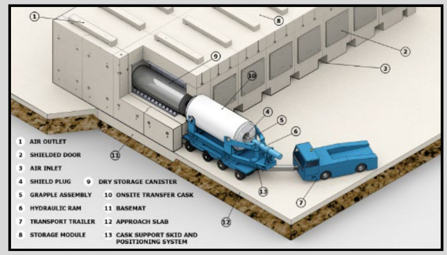
Attributes	Holtec HI-STORM 100 System	Orano NUHOMS EOS System
Max. Assembly Heat Load	~0.9 kW	4.5 kW (in upcoming CoC amd. request)
Dimensions (outer)	~69" diam.; 181" long	~76" diam.; length: site-specific
Shell Thickness	0.5"	0.5"
Loaded Weight	90,000 lbs. (45 tons) – 32 assemblies	124,000 lbs. (62 tons) – 37 assemblies
Shell Materials	Stainless steel Grades 304, 304/304L, and 316/316L (Dual Certs)	Stainless steel Grade 316L
Overpacks	HI-STORM 100SA overpack 	Horizontal Storage Module (HSM) 
Dimensions	~12' diam. ~19' tall Concentric metal shells: 1" thick 30"-thick concrete Baseplate: 2" thick Bolted lid: 19" thick	~25' long ~20' tall 4'-thick roof, front/back walls
Concrete Volume	~42 cubic yards per overpack (~3,360 cubic yards for 80 overpacks needed for full offload)	~72 cubic yards per HSM (~4,968 cubic yards for 69 HSMs needed for full offload)
Color	Metal shell painted grey	Sealed concrete (natural grey color)
Storage Config.	Vertical (MPC on pedestal)	Horizontal (DSC on rails)
Tip-Over Design	Anchorages preclude tip-over	HSMs rely on sliding and low center-of-gravity to preclude tip-over
Cooling Method	Convection via air vents	Convection via air vents

Table G1-1. Summary Comparison of the Holtec and Orano Systems for the DCPP ISFSI

Attributes	Holtec HI-STORM 100 System	Orano NUHOMS EOS System
Transportation Components		
Transfer Cask	HI-TRAC 125D transfer cask	EOS TS-125 Transfer Cask
Dimensions	94" diam. for majority; 192" tall	95" diam.; 208" tall
Weight	125 tons fully loaded	93 tons fully loaded
Transporter	Vertical Cask Transporter (VCT)	Transfer Trailer (TT)
Configuration	Vertical transport; suspended	Horizontal transport
Power	Self-powered	Self-powered or towed by conventional heavy-haul truck tractor
Rated Load	425,000 lbs. (212.5 tons)	291,000 lbs. (145.5 tons)
Loading Process		
Closure Activities in FHB	Loaded MPC/transfer cask → cask washdown area for drying/ helium backfill (via forced helium dehydration); MPC lid welding	Loaded DSC/transfer cask → cask washdown area for vacuum drying/ helium backfill and DSC lid welding
Transfer to Transporter	Cask washdown area → low-profile transporter → VCT	Cask washdown area → TT
Transporter Movement	VCT transports → Cask Transfer Facility (CTF) for transfer from the transfer cask to the overpack	TT transports → ISFSI pad
Loading at ISFSI	Overpack CTF → ISFSI pad via VCT	Hydraulic ram pushes DSC into HSM
Estimated Total Worker Dose	~340 mrem per canister (actuals from DCPP loading of 24kW)	~157 mrem per canister (actuals from PWR loading of 30-33kW)

Source: PG&E, 2022.

Both systems use welded steel canisters to store the SNF: in the Holtec system, the canisters are stored vertically, while the Orano system stores them horizontally. Both canister types have baskets inside that provide structural support and assist in fuel heat transfer. Although the basket materials are different for each system, the basket performs the same function and determines the heat load capacity as approved by the NRC.

In both systems, the canister is stored within a larger structure designed to reduce radiation dose to workers and the public by providing shielding, and to physically protect the canisters. The Holtec outer container (called an overpack) uses steel and concrete (~ 32 inches thick on the sides), whereas the Orano outer container (called a horizontal storage module) uses steel and concrete (~ 48 inches thick on the tops/sides) to shield from radiation. This means hotter fuel can be stored with no impact to radiation shielding. Although the size and shape of the structures differ, both are approved by the NRC. The larger capacity of the Orano system means that fewer storage systems are required (69) than with the Holtec system (80).

Both of the dry cask storage systems provide radiation shielding, heat transfer capability, missile protection, and protection against natural phenomena and accidents. The ISFSI Updated Final Safety Analysis Report (FSAR) provides additional information related to the design and performance of the ISFSI (PG&E, 2018a). An update to the FSAR will be necessary to revise the analyses to incorporate the Orano System in addition to the existing Holtec system.

The safe and secure operation of the ISFSI also requires that PG&E maintain and operate the transfer equipment properly, deploy qualified and trained resources to monitor and oversee storage operations, and provide forces to maintain security during SNF transfer operations. This includes implementing the measures required by NRC to control personnel, vehicles, and materials during the transfers of SNF and GTCC waste from the power plant to the ISFSI, and to ensure adequate protection of worker and public health and safety and the environment.

At present, there are 1,856 SNF assemblies stored at the ISFSI in 58 casks with 32 assemblies per cask. As of August 2019, there were 828 and 768 SNF assemblies stored in the Unit 1 and 2 SFPs, respectively. Assuming no loading campaigns between now and the end of operations, PG&E anticipates at the time of shut down, there will be approximately 1,261 and 1,281 SNF assemblies stored in the Unit 1 and 2 SFPs, respectively. As a result, with the use of the Orano storage systems (which accommodate 37 assemblies per canister), there will be up to a total of 127 casks of SNF stored at the ISFSI once all transfers are complete (58 Holtec, and 69 Orano). Although the ISFSI system has adequate capacity for all fuel-related storage (including fuel debris and damaged SNF assemblies), it does not have capacity for GTCC waste. Therefore, PG&E plans to design, license, and construct an additional storage pad near the Security Building to address these additional GTCC waste capacity requirements. GTCC waste will be stored and transported using the Orano NUHOMS EOS systems. The SSDCE includes the approximate costs to perform these activities (PG&E, 2019c). PG&E plans to store up to 10 casks of GTCC waste at the GTCC storage facility. Table G1-2 shows the current schedule for transferring the existing and planned inventory of spent fuel assemblies from wet storage in the SFPs to dry storage at the ISFSI.

Table G1-2. Schedule for Transferring Fuel Assemblies from SFPs to the ISFSI

	Assemblies in Wet Storage[2]		Assemblies in Dry Storage		Casks at ISFSI[3]	
Year[1]	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
2025	1261	1281	928	928	29	29
2026	1261	1281	928	928	29	29
2027	1261	1281	928	928	29	29
2028	1261	1281	928	928	29	29

Table G1-2. Schedule for Transferring Fuel Assemblies from SFPs to the ISFSI

Year[1]	Assemblies in Wet Storage[2]		Assemblies in Dry Storage		Casks at ISFSI[3]	
	Unit 1	Unit 2	Unit 1	Unit 2	Unit 1	Unit 2
2029	1261	1281	928	928	29	29
2030	877	1281	1312	928	41	29
2031	0	654[4]	2189	1555	69	48
2032	0	0	2189	2209	69	69

Note 1 – Inventories are as of end of the year
Note 2 – Actual number of assembles depends on final fuel cycle design
Note 3 – Schedule assumes no transfers to ISFSI until after both units are shutdown
Note 4 – Based on estimated number of assemblies, the last Unit 1 cask will contain Unit 2 assemblies

Source: PG&E, 2019b - Table 2a.
Note: The total number of casks has changed because of the switch to the Orano System.

Transfer of SNF and HLW for Off-Site Disposal

The DOE's repository program assumes that SNF allocations will be accepted for disposal from the nation's commercial nuclear plants, with limited exceptions, in the order (the "queue") in which it was discharged from the reactor (10 CFR 961.11). PG&E's SNF management plan for the DCPP SNF is based on two assumptions:

- DOE will begin transferring commercial SNF to a federal facility in 2031, and DCPP will begin transferring SNF to DOE in 2038, and
- SNF and GTCC waste receipt will be completed by year 2067 (PG&E, 2018b).

The start date for the off-site transfer shipments was established in accordance with the Standard Contract between PG&E and DOE in 10 CFR Part 961.11 (DOE, 2004a). DOE's schedule for completion of the shipments is based upon DOE's generator allocation/receipt schedules which assume the oldest fuel receives the highest priority for DOE acceptance. In accordance with the annual allotment in the Standard Contract, and as described in the IFMP (PG&E 2019b), PG&E would be able to load a maximum of five full MPCs into five DOE-supplied transportation casks each year, beginning in the year 2038. The schedules do not represent a contractual commitment by the DOE or the utilities and are used only as a planning basis (DOE, 2004a). The Standard Contracts do contain provisions allowing for "exchanges" of acceptance obligations, and priority for retired units such as DCPP would become, so it is possible that PG&E could negotiate an alternative schedule, if a facility becomes available. If the assumptions described in the IFMP are valid, the ISFSI would be subsequently decommissioned by the ISFSI's 2076 final license termination date.

The DOE's recent lack of progress on the repository program (or another alternative storage facility) would indicate that PG&E's schedule is achievable only if significant progress restarting the US nuclear waste management program is made in the near future. As a result, there is a chance that extended on-site storage in the ISFSIs may be necessary.

Existing Regulatory Framework and Federal Program Plans

This section describes the current status of the Federal (DOE) efforts to develop facilities for the storage and disposal of SNF in the US, as well as recent activities in Congress to restart the waste management program. These programs represent a range of potential opportunities to provide for the transport of SNF from the DCPP site, but none are currently progressing.

The Nuclear Waste Policy Act and the Repository Program

The Nuclear Waste Policy Act (NWPA) of 1982, as amended in 1987 (DOE, 2004b), established the Federal program, requirements, and process applicable to the management, storage, and disposal of SNF and HLW. The primary goal of the NWPA was "to provide for the development of repositories for the disposal of high-level radioactive waste and spent nuclear fuel." The NWPA created the Office of Civilian Radioactive Waste Management (OCRWM) within the DOE to implement Federal government responsibilities specified by the Act, and also established the Nuclear Waste Fund (Section 302), which imposed a fee of 0.1 cents per kilowatt-hour (approximately $750 million per year) on electricity generated by civilian nuclear power reactors. As of the end of 2020 (the date of the most recent audit), the Nuclear Waste Fund had a balance of about $45.1 billion (DOE, 2021a). In exchange for the payment of this fee, utilities were authorized to enter into contracts with the Secretary of Energy for the acceptance of title, transportation, and long-term storage and disposal of SNF and HLW. PG&E entered into a single Standard Contract on June 10, 1983, covering the two DCPP units. The NWPA further specified that the Secretary "shall take title to the high-level radioactive waste or spent nuclear fuel involved as expeditiously as practicable, upon the request of the generator or owner, … beginning not later than January 31, 1998." (DOE, 2004)

The NWPA defined a process for the identification and selection of candidate repository sites, and the characterization and analysis of these sites, to determine whether they were suitable for the development of a repository. In 1986, the DOE published a Final Environmental Assessment that documented the selection of three sites for further characterization (i.e., Yucca Mountain, Nevada; the Hanford Site in Washington; and a site in salt deposits in Deaf Smith County, Texas). However, in the 1987 Amendment to the Act, Congress directed the DOE to characterize only the Yucca Mountain site in Nevada and to develop the repository there, if it was found to be suitable.

Following the process prescribed in the amended NWPA, the Secretary recommended to the President in February 2002, and the President recommended to Congress, that Yucca Mountain be developed as the nation's first geologic repository (DOE, 2002). In accordance with the NWPA, the governor of Nevada exercised his right to veto the President's recommendation, a veto which could only be overturned by majority votes in both houses of Congress. The House passed a resolution on April 25, 2002, approving Yucca Mountain by a margin of 306 to117, and the Senate voted (by voice vote) on July 9, 2002, to override the governor's veto.

Although the selection of Yucca Mountain was confirmed by the congressional resolutions, the site recommendation was not the final step in the regulatory approval process, because the NWPA further required that the DOE must demonstrate that the proposed repository meets the radiological health and safety standards established and regulated by the NRC. That process is not complete, and is described below.

Status of the License Application for Yucca Mountain

The DOE submitted an application to the NRC on June 3, 2008, for a license to construct the repository at Yucca Mountain (DOE, 2008). The NRC's role is to assess whether the proposed facility meets NRC's regulatory requirements. The NRC staff's technical review, documented in its Safety Evaluation Report (SER), is one part of the licensing process. The process also includes hearings before the NRC's Atomic Safety and Licensing Board (ASLB), which will adjudicate challenges by a number of parties to the technical and legal aspects of the DOE application, and the Commission's review of contested and uncontested issues. On March 3, 2010, the DOE filed a motion with the Board asking to withdraw its application. The Board denied that request on June 29, 2010, finding that "… the [NWPA] does not permit the Secretary [of the DOE] to withdraw the Application that the NWPA mandates the Secretary file. Specifically, the NWPA does not give the Secretary the discretion to substitute his policy for the one established by Congress in the NWPA that, at this point, mandates progress towards a merits decision by the [NRC] on the construction permit" (NRC, 2010). On appeal, the Commission found itself evenly divided on whether to overturn or uphold the Board's decision. During this time period, Congress had reduced funding for the NRC's review of the application, with no funds appropriated for fiscal year 2012 (and none in subsequent years). Recognizing the budgetary limitations, the Commission directed the Board to complete case management activities by the end of September 2011, and the Board suspended the adjudicatory proceeding on September 30. At the same time, the NRC staff also completed orderly closure of its Yucca Mountain technical review activities.

The Obama Administration had decided to terminate the Yucca Mountain Project during fiscal year (FY) 2009, claiming that it was "unworkable." In February 2010, the President issued the FY 2011 Budget Request with a zero budget request for OCRWM. Despite the ASLB ruling denying the DOE's motion to withdraw its license application, the Administration directed the DOE to dissolve OCRWM. Cases were filed in the U.S. Court of Appeals by the states of Washington and South Carolina, and several other parties, challenging the termination of the Yucca Mountain repository proceedings. Nevertheless, on October 1, 2010, the DOE shifted OCRWM program responsibilities to various DOE Offices, and, as of September 30, 2010, OCRWM employed no staff (DOE, 2010).

In August 2013, the D.C. Circuit Court of Appeals ordered the NRC to resume its review using existing funds from previous appropriations. The NRC staff completed and published the five-volume SER in January 2015. In the SER, the NRC staff found that the DOE's license application met the regulatory requirements for the proposed repository, with two exceptions: the DOE had not obtained certain land withdrawal and water rights necessary for construction and operation of the repository. Therefore, the NRC staff recommended that the Commission not authorize construction of the repository until, among other things, these regulations were met and a supplement to the DOE's environmental impact statement was completed. After the DOE declined to complete the supplement and deferred to the NRC, the Commission directed the NRC staff to develop the supplement, which was completed in early 2016.

Although the program has not been funded since 2010 and the OCRWM has been dismantled, the NWPA remains the legislation applicable to nuclear waste management in the US, and the license application to the NRC remains active. The adjudicatory process undertaken by the ASLB remains suspended. According to the NWPA, the ASLB hearings were required to be completed within 18 months (NRC may request a 12-month schedule extension if necessary). Additional funding from Congress for both the NRC and DOE would be required to support resumption of the License Application hearings.

At the time that the DOE attempted to withdraw the License Application in 2010, DOE's schedule for the licensing and construction of the repository showed Construction Authorization by NRC in 2012, initial receipt of waste in 2017, and full operation of the facility in 2020 (DOE, 2008). Therefore, the schedule projected that a fully-funded program would require on the order of 7 to 10 years to reach operational readiness, not counting the time associated with re-starting the program. Start-up costs and schedules would need to include the re-establishment of OCRWM or an alternative management organization (within or independent from the DOE) that would take its place.

Nuclear Waste Fund Suspension

After termination of the Yucca Mountain Project, the Nuclear Energy Institute (NEI) and the National Association of Regulatory Utility Commissioners filed a lawsuit challenging the DOE's continued collection of the surcharge to pay for SNF and HLW management. In a unanimous decision, the US Court of Appeals for the D.C. Circuit found that, "Because the Secretary is apparently unable to conduct a legally adequate fee assessment, the Secretary is ordered to submit to Congress a proposal to change the [nuclear waste] fee to zero until such time as either the Secretary chooses to comply with the [Nuclear Waste Policy] Act as it is currently written, or until Congress enacts an alternative waste management plan."

"Today's decision confirms that the Federal government cannot continue to defy Congress' explicit direction to implement a viable program to manage reactor fuel from America's nuclear power plants. The court's ruling reinforces the fundamental principle that the federal government's obligation is to carry out the law, whether or not the responsible agency or even the president agrees with the underlying policy" (US Court of Appeals, 2013).

As noted above, the Nuclear Waste Fund balance at the end of 2020 was approximately $45.1 billion. Although the courts have barred the DOE from continuing to collect fees, investment income continues to accrue at about $1.5 billion per year (DOE, 2021a).

DOE Interim Storage Activities

Although the primary focus of the NWPA was on developing a solution for the permanent final disposal of SNF and HLW (i.e., the repository), the Act does contain provisions that guide the development of facilities for interim storage. Section 111(a)(5) specified that the generators and owners of SNF and HLW have the primary responsibility to provide for, and to pay the costs of, interim storage until such waste and spent fuel is accepted by the Secretary of Energy. Subtitle B of the NWPA (Sections 131 through 137) authorizes interim storage of spent fuel until a geologic repository is ready, and it encouraged the development of expanded at-reactor interim storage facilities. In the event that any operator of civilian nuclear power reactor could not reasonably provide adequate spent nuclear fuel storage capacity, Subtitle B authorized the DOE to develop a federally owned and operated interim storage system with not more than 1,900 metric tons of capacity to prevent disruptions to the orderly operation of the plant.

The NWPA also authorized the siting and construction of a large-scale federally operated Monitored Retrievable Storage (MRS) Facility that could store larger volumes (up to 15,000 metric tons) of SNF and HLW (Subtitle C, Sections 141 through 149). However, the implemen-tation of the MRS program was subject to several conditions designed to ensure that the MRS did not become a de facto repository. Most significantly, construction of such a facility may not begin until the Commission has issued a license for the construction of a repository (Section 148(d)(1)).

A Congressionally chartered MRS Commission (authorized by the 1987 Amendment to the NWPA) in 1989 recommended a 2,000-ton Federal Emergency Storage facility and a 5,000-ton User-Funded Interim Storage Facility. However, the MRS Commission's recommendations were not pursued, and no effort to develop a federally-operated interim storage facility was ever authorized when the Yucca Mountain Repository program was active.

Lawsuits Resulting from DOE's Failure to Receive Waste

After passage of the NWPA, DOE entered into 68 Standard Contracts with nuclear utilities, including PG&E. As a result of the DOE's failure to begin receiving waste in 1998, every nuclear utility, including PG&E, has sued the DOE to recover the costs associated with the DOE's breach of contract (i.e., the costs incurred by the requirement to store SNF and HLW for a longer period of time than originally anticipated). PG&E filed suit (Case No. 04-74C) on January 28, 2004, with the US Court of Federal Claims, seeking damages in the amount of $92.1 Million to cover costs incurred through December 31, 2004. After several amendments to the lawsuit, the Court awarded PG & E approximately $42.76 million in damages in 2006 (Pac. Gas & Elec. Co. v. United States, 73 Fed.Cl. 333, 432 (2006). The major categories of costs included construction of the ISFSI.

PG&E will continue to file claims in the future (and be reimbursed) for costs incurred after 2004 for the continued storage resulting from the DOE's breach, including construction of the expanded ISFSI. These reimbursements are made from the Federal Judgment Fund administered by the US Department of the Treasury, which is paid for by taxpayers, and is used to pay awards and settlements from claims against the federal government. The Nuclear Waste Fund can only be used for the purposes defined in the NWPA; therefore, it cannot be used to pay for the judgments related to the DOE's breach of contract. Over the past 20 years, the Judgment Fund has paid approximately $9 billion in settlements or judgments resulting from 110 lawsuits, and 17 cases are still pending that will likely result in additional liabilities. Estimates of future liability calculated by DOE's Office of the Inspector General are approximately $30.9 billion (DOE, 2021a).

Blue Ribbon Commission and Recent DOE Activities

Following termination of the Yucca Mountain Project, the DOE chartered the Blue Ribbon Commission (BRC) on America's Nuclear Future to recommend a new strategy for managing the back end of the nuclear fuel cycle. Over the course of nearly two years, the BRC conducted numerous public meetings and hearings, and developed a series of recommendations (DOE, 2012). The strategy they recommended in their final report has eight key elements:

(1) A consent-based approach to siting future nuclear facilities
(2) A new organization dedicated solely to implementing the waste management program
(3) Access to the funds nuclear utility ratepayers are providing for nuclear waste management
(4) Prompt efforts to develop one or more geologic disposal facilities

(5) Prompt efforts to develop one or more consolidated storage facilities
(6) Prompt efforts to prepare for large-scale transport of SNF and HLW
(7) Support for continued U.S. innovation in nuclear technology
(8) Active US leadership in international efforts.

After the release of the Blue Ribbon Commission Report in 2012, the DOE published a document describing a proposed revised schedule and strategy for the siting and construction of facilities for the storage and disposal of SNF and HLW (DOE, 2013). Because the proposed strategy is not consistent with the NWPA, the implementation of the revised strategy is contingent on the passage by Congress of new legislation and funding that would allow the implementation of the DOE's revised strategy (referred to here as the DOE 2013 Strategy):

The revised strategy proposed to implement a program over the next 10 years that would:

- Site, design, license, construct, and begin operations of a federally operated pilot interim storage facility by 2021, with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advance toward the siting and licensing of a larger interim storage facility to be available by 2025 that would have sufficient capacity to provide flexibility in the waste management system and allow for the acceptance of enough used nuclear fuel to reduce expected government liabilities; and
- Make demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048.

In the nine years since the publication of the revised strategy, Congress has not authorized any funding for its implementation, or made the changes to the NWPA that would be required to allow it. The DOE has not developed or submitted proposed legislation to Congress. The schedules proposed in the revised strategy assumed that funding and modifications to the NWPA would be made expeditiously, so it is reasonable to assume that the 9-year delay in implementation of the program would result in at least a 9-year delay in the target dates identified (i.e., 2030 for a pilot project, 2034 for a larger interim facility).

In the absence of progress toward the the development of a waste management system that included a repository, DOE began in 2015 to develop a consent-based process for siting storage or disposal facilities collaboratively with members of the public, communities, stakeholders, and governments at the Tribal, State, and local levels. As part of this initiative, the Department issued an Invitation for Public Comment and conducted a series of public meetings to seek feedback and inform future efforts. Based on that feedback, as well as the findings of several expert groups, DOE developed and requested public comment on the *Draft Consent-Based Siting Process for Consolidated Storage and Disposal Facilities for Spent Nuclear Fuel and High-Level Radioactive Waste (* the " *Draft Consent-Based Siting Process,"*) in January 2017(DOE, 2017).

In 2021, Congress appropriated funds for DOE to begin analyzing how to implement a nuclear waste management program focused (in the near term) on the use of a consent-based siting process to identify a site or sites suitable for the development of a Federal consolidated interim storage facilitys. Interim storage could be an important component of a comprehensive waste management system and could enable near-term consolidation and temporary storage of spent nuclear fuel. This strategy could allow for removal of spent nuclear fuel from stranded or decommissioned reactor sites, provide useful research opportunities, and build trust and confidence with stakeholders and the public by demonstrating a consent-based approach to siting. DOE anticipates that an interim storage facility would need to operate until the fuel can be moved to final disposal. The duration of the interim period would depend on the completion of a series of significant steps, such as the need to modify the NWPA; identify, license, and construct a facility; and plan, develop, and operate a transportation system to move the SNF to an interim facility. At the same time, progress on siting and developing a geologic repository would also be necessary to ensure that interim facilities can eventually be closed. Therefore, on December 1, 2021, DOE issued a "*Request for Information (RFI) on Using a Consent-Based Siting Process to Identify Federal Interim Storage Facilities*" (DOE, 2021b) in the Federal Register (86 FR 68244). The RFI specifically requested input into three areas of consideration, and included a series of detailed questions related to how consent based siting could and should be implemented, and to what extent the consent based siting process should be linked to the development of geologic repository for final disposal. The three areas are:

- Area 1: Consent-Based Siting Process
- Area 2: Removing Barriers to Meaningful Participation, especially for groups and communities who have not historically been well-represented in these conversations
- Area 3: Interim Storage as Part of a Waste Management System

The comment period for the RFI remained open for 90 days and closed on March 4, 2022.

DOE received 225 submissions in response to the RFI from a wide variety of commenters, including Tribal, State, and local governments; non-governmental organizations; members of academia and industry; other stakeholders; and individual commenters. In September 2022, DOE released a document entitled "*Consent Based Siting Request for Information Comment Summary and Analysis*" (DOE, 2022). This document summarizes DOE's analysis and response to the comments received. DOE identified six major themes in the responses received. They include:

- Distrust of DOE and of the federal government's nuclear waste management efforts more broadly;
- An emphasis on "fairness"— both in the way the siting process itself is conducted and in terms of outcomes from the siting process;
- An appreciation of the challenges inherent in defining consent and successfully implementing a consent-based siting process;
- Significant differences of opinion about whether the federal government should pursue consolidated interim storage for commercial spent nuclear fuel, including related concerns about progress toward a deep geologic repository and transportation requirements and risks;
- Support for changes in the Nation's overall approach to nuclear waste management and for a new, independent organization to lead waste management efforts; and
- Strong differences of opinion about the need for and merits of nuclear energy technology.

DOE indicated that they recognize a successful consent-based siting process for a federal consolidated interim storage facility for spent nuclear fuel requires strong and trusting relationships—built on a foundation of collaboration, two-way communication, information sharing, and accountability—among DOE, potential host communities, and other partners and stakeholders.

To build and sustain these relationships, the DOE committed to (1) implementing congressional direction in a way that maximizes the potential benefits of consolidated interim storage, (2) addressing the current deficit of trust in DOE by making changes internally and externally, (3) ensuring that its consent-based siting process is fair and inclusive, (4) focusing on fairness in siting outcomes by putting communities' needs and well-being at the center of the siting process, (5) continuing and expanding ongoing efforts to address transportation issues and related planning needs, and (6) rigorously applying safety, security, and other criteria in all aspects of the siting process, including by supporting communities that wish to conduct independent studies related to safety and other issues of concern.

DOE intends to use public feedback and other outreach efforts to inform development of a consent-based siting process, the strategy for an integrated waste management system, and consideration of a funding opportunity for interested groups and communities. DOE anticipates that consent-based siting should be done in close collaboration with the public, interested groups, and governments at the Tribal, state, and local levels.

Recent Congressional Efforts to Address Nuclear Waste Management Issues

In response to the lack of progress since the dissolution of OCRWM, and termination of the Yucca Mountain Project, several members of Congress have proposed legislative initiatives to restart or reinvigorate the repository program, and to accelerate the establishment of interim storage alternatives to provide near-term alternatives for the storage of SNF.

In the Senate, Senator Bingamon proposed a new Nuclear Waste Administration Act in 2012, and Senators Alexander, Murkowski, Feinstein, and Cantwell proposed the Nuclear Waste Administration Act of 2013 with a revised version in 2015. Their proposal would have implemented some (but not all) of the recommendations of the Blue Ribbon Committee, and DOE's 2013 Strategy. The 2015 Act would have:

- Established an independent agency to manage the country's nuclear waste program in place of the DOE;
- Defined a consent-based process for the development of consolidated storage facilities and a repository;
- Established a new working capital fund in the U.S. Department of the Treasury, into which the fees collected from the utilities would be deposited; and
- Authorized the Secretary of Energy to revisit the decision to commingle defense waste with commercial spent fuel.

In the House of Representatives, Rep. Robert Dold of Illinois introduced the Stranded Nuclear Waste Accountability Act (H.R. 5632) in July 2016, which would have directed the Secretary of Energy to implement a program to provide compensation to communities that are hosts to closed nuclear power plants that must continue to store spent nuclear fuel onsite because of the government's failure to establish a geologic repository.

On June 26, 2017, Rep. John Shimkus (R-IL) introduced H.R. 3053, the Nuclear Waste Policy Amendments Act of 2017. That bill would have amended the 1982 NWPA in several significant ways. Title I of the bill would have directed DOE to initiate a program to consolidate and temporarily store commercial SNF during the development, construction, and initial operation of a repository, with preference for the Department to take ownership of SNF from facilities that have ceased commercial operation. It also would have authorized DOE to enter into an agreement with a non-Federal entity for the purposes of storing SNF to which the Department holds title.

Title II would have addressed Federal "land withdrawal," and related management issues associated with the licensing and construction of a permanent geologic repository at Yucca Mountain, including the permanent withdrawal of Federal land for a repository, and removed potential impediments to the NRC licensing process and conditions for the repository. It also would have limited activities relating to a separate repository for HLW generated by atomic energy defense activities.

Title III would have provided DOE with consolidated storage options to help fulfill the Federal government's obligations to take title to SNF, including provisions to amend the NWPA to authorize DOE to modify contracts to allow the transfer of commercial SNF to DOE for monitored retrievable storage in addition to DOE's existing legal obligations to ensure the permanent disposal of commercial spent fuel.

Title IV would have provided benefits to the repository host State and units of local governments, including provisions to requalify the State of Nevada to enter into an agreement with DOE to help mitigate potential impacts that may result from hosting the repository. The title also would have allowed qualified covered units of local government to enter into separate benefits agreements with DOE.

Title V would have amended the method by which DOE funds its nuclear waste management activities through the collection and usage of the Nuclear Waste Fund. The bill would have made specific portions of of the fund available to DOE without further appropriation throughout the multi-decade life cycle of the repository program.

Title VI would have made additional changes to the NWPA, including updating the generic (non-Yucca Mountain specific) standards for a repository, setting a fixed-term appointment for the OCRWM Director, and expanding the qualified usage of DOE financial assistance to state and local organizations to support SNF transportation activities.

The House of Representatives held several hearings related to H.R. 3053, and the bill was passed by a bipartisan majority of the House on a roll call vote on May 10, 2018. The bill was forwarded to the Senate Committee on Environment and Public Works on May 14, but was never considered by the full Senate.

In 2019, Representative McNerney (D-CA) introduced the Nuclear Waste Policy Amendments Act of 2019. This bill included numerous provisions to address the storage and disposal of nuclear waste. Among other things, it would have:

- Directed the DOE to initiate a program to consolidate and temporarily store commercial spent nuclear fuel during the development, construction, and operation of a permanent nuclear waste repository;
- Addressed federal land withdrawal and related management issues, including the permanent withdrawal of specific federal land for repository use by DOE;
- Updated the NRC licensing process and conditions for the permanent repository;

- Limited activities relating to developing a separate defense waste repository used for storing high-level radioactive waste and spent nuclear fuel derived from the atomic energy defense activities of DOE;
- Authorized DOE to enter into agreements to provide benefits to state, local, and tribal governments that might host or be affected by facilities related to storing nuclear waste;
- Revised the method by which DOE funds its nuclear waste management activities though the collection and usage of the Nuclear Waste Fund;
- Created an Office of Spent Nuclear Fuel within DOE; and
- Required DOE to establish a Stranded Nuclear Waste Task Force to study existing resources and funding for communities that contain stranded nuclear waste and develop economic adjustment plans for such communities.

The Nuclear Waste Policy Amendments Act of 2019 never advanced in either the House or the Senate. As a result, efforts to update the regulatory framework for nuclear waste management have not progressed. In addition to the efforts in both the House and Senate to authorize revisions to the regulatory framework for the program, the House of Representatives included funding for both DOE and NRC in their budgets for licensing of the Yucca Mountain repository program from 2011 through 2017, including $150 Million in 2016 and 2017. The Trump Administration also requested $120 Million in their budget requests for 2018, 2019, and 2020 for the restart of the licensing of the Yucca Mountain Repository. However, neither Yucca Mountain funding, nor funding for a revised program to implement the Administration's 2013 Strategy, has been authorized in any year since 2010.

Private Initiatives for Spent Fuel Storage

In addition to DOE's current effort to develop a federal facility, there have been several initiatives in the past 30 years to develop a privately funded, commercially operated Consolidated Interim Storage Facility (CISF). In theory, the availability of such a facility could enable operators of closed and/or decommissioned nuclear power plants such as DCPP to transfer SNF and reactor-related GTCC waste to an off-site CISF, which is not included in the current planning or baseline. There is no regulatory prohibition on the development of a private facility to provide interim storage of SNF. However, there are significant regulatory and management issues and challenges that would need to be overcome in order for a commercial facility to become a viable option. Three private entities that have attempted to establish interim storage programs are discussed briefly below. The first (Private Fuel Storage LLC [PFS] in Utah) was an effort funded by multiple utilities that was licensed but never opened due mainly to opposition at the state level. Two other commercial ventures are currently in development: these proposed CISFs are located in Andrews County, Texas and in Lea County, New Mexico. The proposed facility in Texas is now licensed for construction and operation (NRC, 2021). In January 2023, the NRC indicated that they had received Holtec's final revision to the safety analysis report, and supplemental analyses of the license application; and their staff had determined that the supplements contained sufficient information for them to complete their review. NRC expects to publish the final safety evaluation report and the licensing decision for the CISF in New Mexico in Spring 2023 (NRC, 2023).

Private Fuel Storage, LLC

PFS was formed by multiple nuclear utilities in the mid-1990s to provide an option for storage of spent fuel when it became apparent that DOE would be unable to meet their contract date for initial waste acceptance in 1998. The member utilities originally included PG&E, but PG&E withdrew from the project shortly after it was organized. The Private Fuel Storage project would have stored approximately 44,000 metric tons of SNF from over 100 power plants in Holtec International dry casks on 98 acres of Goshute land in Utah and cost approximately $3 billion. The license application was initially submitted in 1997, and after a long and highly contentious review process, the PFS facility was issued a license by the NRC in 2006. Opposition to the project by the State of Utah, and many other parties resulted in the extended period of review. Although licensed, the facility was never opened due to the refusal of the US Department of the Interior (regarding right-of-way for rail access to the site) and the Bureau of Indian Affairs (regarding uncertainties over land trust issues) to grant needed approvals, which precluded the facility from becoming operational (PFS, 2014). PFS notified the NRC in 2012 that they intended to terminate their license unless they were granted an exemption from Part 171 Annual Fees as long as the facility is not operational. After review, the NRC granted the exemption, so the license remains in effect, but the access issues remain unresolved.

Interim Storage Partners LLC

Interim Storage Partners LLC (ISP), a joint-venture between Waste Control Specialists LLC (WCS) in Andrews County, Texas, and Orano USA, prepared and submitted a license application to the NRC on April 28, 2016 for a CISF, in accordance with the requirements of 10 CFR Part 72. The CISF would be constructed and operated on an approximately 100-acre initial footprint within a 320-acre parcel, where security would be maintained, within the currently controlled WCS property of 14,000 acres. The site is approximately 32 mile west of Andrews Texas. ISP requested initial authorization to store up to 5,000 metric tons of uranium (MTU) in Phase 1, but has analyzed the environmental impacts of storing up to 40,000 MTU at the CISF (WCS, 2015).

The license application was accepted by the NRC for review on January 26, 2017. NRC approved the Environmental Impact Statement for the site on July 29, 2021, and approved the license application on September 14, 2021 (NRC, 2021). ISP is continuing to pursue the CISF project, but no progress regarding agreements with DOE or individual utilities has been reported publically since the NRC approval of the license application.

Eddy Lea Energy Alliance, LLC

A second private venture for a CISF has been proposed by the Eddy Lea Energy Alliance, LLC (ELEA), a partnership of Holtec International and the Cities of Carlsbad & Hobbs and the Counties of Eddy & Lea in New Mexico (Alliance). The Alliance has purchased 1,000 acres of land approximately halfway between Carlsbad and Hobbs, New Mexico for potential use, and has proposed using Holtec's existing designs for below-grade SNF storage (HISTORM UMAX).

Holtec International submitted a license application for the facility on March 31, 2017. Their application included a Final Safety Analysis Report and Technical Specifications for a HI-STORM UMAX canister storage system (Holtec, 2016). Holtec and the Alliance originally proposed a development schedule similar to that proposed by ISP, with licensing completed before 2020 and construction and initial operation possible by 2021. However, delays in the licensing process have extended their proposed schedule. NRC review of the license application is continuing; NRC approved the Environmental Impact Statement for the CISF in July, 2022 (NRC, 2022 – NUREG 2237), and ELEA reportedly expects approval of the license application in 2023.

Potential Constraints to the Use of Private Fuel Storage Facilities

Although in theory there are no regulatory barriers to the construction and operation of private fuel storage facilities, there are significant legal and contractual constraints that would have to be overcome in order for PG&E to contemplate shipment of DCPP SNF to a private facility. These relate to both the costs and potential liabilities that would be associated with the transfer of the SNF to a third party.

Cost Issues: The question of who would pay for PG&E to move and store SNF and HLW from DCPP to an off-site facility is not simple to answer. As noted previously, the NWPA specifies that owners and generators of SNF and HLW are responsible for interim storage until the DOE accepts it for transportation and disposal. As a result, PG&E (and other utilities) decommissioning plans (such as the PSDAR, IFMP, and the SSDCE) and trust funds for decommissioning activities do not include any money for transportation or storage at off-site facilities, because those costs are solely the responsibility of the DOE. The Decommissioning Trust Funds are funded by charges to utility ratepayers and overseen by the California Public Utilities Commission, and it seems unlikely they would approve the use of the Trust Funds for costs that are the responsibility of the Federal government. The DOE does not currently have authority or access to any funds to pay for transportation or interim storage of SNF. The Nuclear Waste Fund can only be used for the development and construction of a permanent repository, and according to the NWPA, funds could only be expended on interim storage after construction of a repository was in progress. Title I of H.R. 3053 (discussed above) which passed the House but not the Senate in 2018, would have authorized DOE to develop a plan to assume ownership of SNF at decommissioned reactors during the development of the repository, and then transport it and store it at a non-federal commercial site. Since 2018, Congress has not authorized DOE to enter into negotiations regarding the transportation or interim storage of SNF.

Additionally, the breach of contract lawsuit settlements administered by the Department of the Treasury do not currently anticipate costs that would be incurred for off-site transportation and temporary storage, and include only costs incurred by the utilities (e.g., PG&E) resulting from the DOE's breach. It is not clear whether the administrators of the Judgment Fund would approve the reimbursement of third party vendors for transportation or storage above and beyond the costs already incurred for on-site storage. Currently, utilities such as PG&E are reimbursed for their costs, but may not collect a fee or profit. Private vendors could not be expected to participate if they could not earn a profit.

In order for the DOE to contribute in any way, Congress would have to authorize funding, either through access to the Fund, or through another source of new appropriations. As noted previously, the primary focus of the program historically (and the primary purpose of the fund) was the development of a repository for permanent disposal. Given the lack of progress on the direction of the US nuclear waste management policy and program over the last 12 years, it seems unlikely that Congress would authorize the use of the Waste Fund for interim storage.

As discussed above, some of the Senate proposals for reform of the nuclear waste management program did include a proposal for a new "working capital" fund (separate from the Nuclear Waste Fund) that could in theory be used to support interim storage, but it is not clear how or if such funding will materialize.

Contractual (Liability) Issues: The issue of responsibility or liability for SNF and HLW is similar in many ways to the cost issue. Under the NWPA, utilities hold title to and responsibility for managing SNF and HLW until the DOE accepts it (and title) for transportation and disposal. The NWPA did not contemplate the addition of third parties to the waste management equation, and therefore does not explicitly address it. If PG&E decided to transport and store waste at an off-site facility, it would presumably want to be released from future liability, in the unlikely event of any accidents or other incidents.

A third party that was storing waste temporarily would likely not be willing to accept long-term liability for SNF or HLW, particularly in the absence of a permanent disposal option such as a repository. As a result, it appears that the proposals by ISP and ELEA assume that DOE would be willing to negotiate a contract that would take legal title and pay them for interim storage until a repository is available for permanent disposal. On their website describing the Holtec ELEA CISF, Holtec does state that they believe the Price Anderson Act would apply to transportation and storage at a commercial CISF. Therefore, a modification of the NWPA by Congress would likely be required to implement private storage. Since OCRWM was disbanded in 2010, there is no single organization within the government that is currently responsible for the management of nuclear waste, although many of the legal functions of OCRWM were assigned to other departments or offices within the DOE.

In summary, although some of the earlier proposed amendments to the NWPA did include provisions that would enable DOE to accept title, and pay a third party to store SNF at an interim storage facility, such as the proposed facilities at ISP and ELEA, Congress is not currently considering any such modifications.

Moving DCPP SNF and HLW to another Existing ISFSI

As is the case for potential storage of SNF at a private facility, there is no regulatory prohibition on the possible use of an existing ISFSI for interim storage. However, there are no operating ISFSI's in the US that currently accept SNF or HLW from outside parties.

Although it is true that another ISFSI could theoretically be expanded to accommodate DCPP waste, many of the same cost and liability issues that would apply to a private facility would also apply to an existing ISFSI. Neither PG&E nor any of the existing nuclear generating stations has access to funds to pay for transportation or off-site storage (the Judgment Fund only pays the costs of on-site storage). It is possible that the DOE or a new Nuclear Waste Administration could be authorized and funded to pay the costs of and assume liability for off-site storage of SNF from DCPP through the passage of legislation, but there has been no indication that DOE or any new waste management organization would consider the possibility of using an existing facility or what the other requirements new legislation might impose.

Expanding the capacity of an existing ISFSI would also require amendment of the NRC license for the facility, and would presumably trigger additional review by state regulatory agencies (e.g., the California Public Utilities Commission), as well as other State and Federal agencies responsible for land use. Estimating the likelihood of success of such efforts, or the time that would be required, would be speculative.

Summary

The plan and schedule for the management of SNF and HLW during DCPP decommissioning are based on assumptions consistent with existing law (the Nuclear Waste Policy Act) and contracts (the Standard Contracts) that provide a defensible basis for projections of the activities and time required to complete decommissioning. Current nuclear waste management policy in the U.S. encourages on-site ("at reactor") storage of SNF and HLW until it can be shipped to the DOE for permanent disposal in a geologic repository. The schedule for the transportation of waste from DCPP to the repository is constrained by the rate at which the DOE can receive shipments from all of the operating and closed commercial nuclear power plants, as well as DOE sites shipping HLW and SNF. Based on the assumption that the DOE will be ready to begin accepting fuel in 2031 (at a repository if the Yucca Mountain Project is restarted, or at an interim storage facility if one becomes available), the IFMP projection that all of the DCPP SNF and HLW will be shipped by 2067 is reasonable and would support the projected completion of DCPP decommissioning activities in 2075.

There are certain scenarios (e.g., involving interim storage facilities) that could potentially support a faster transfer of SNF and HLW to off-site facilities, but there is presently no reliable basis for defining them in more detail or analyzing them. Such scenarios would require modifications of current regulations and other policy changes that cannot currently be reliably predicted.

In any event, it is clear that the broad sequence of waste management events required to complete DCPP decommissioning will not change: (1) transfer of SNF from the Spent Fuel Pools to the on-site ISFSIs; (2) extended storage in the ISFSIs; and (3) transportation of SNF and HLW off-site to a repository or interim storage facility. As a result, despite uncertainty regarding the timing of the availability of a final disposal or interim storage facility, the schedule reflected in DCPP's PSDAR, IFMP, and other planning documents represents a reasonable baseline for analysis in the DCPP Decommissioning EIR.

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Appendix G2

Radioactive Materials Transportation Experience and Risk Assessments

Appendix G2
Radioactive Materials Transportation Experience and Risk Assessments

As discussed in Section 1.0, *Introduction*, and in Section 2, *Project Description (Phases 1 and 2)*, the US Nuclear Regulatory Commission (NRC) has exclusive jurisdiction and regulatory authority over the radiological aspects of decommissioning nuclear power plants including activities related to the approved Independent Spent Fuel Storage Installation (ISFSI) and the transportation and off-site storage of spent nuclear fuel (SNF). Pacific Gas and Electric (PG&E) announced on April 6, 2022, that Orano USA was selected as the vendor to transfer remaining spent fuel from operations to dry storage. As indicated in Table 2-1, Decommissioning Project Activities Summary, after a cooling and decay period (i.e., time to reduce radioactivity), SNF and Greater Than Class C (GTCC) waste would be moved to the ISFSI and new GTCC Waste Storage Facility, respectively, for storage (SNF will be transferred to dry cask storage within approximately 4 years after each reactor shutdown).

To maximize disclosure to the public, this appendix has been prepared to provide background information on transportation of SNF, High-Level Radioactive Waste (HLW), and radioactive materials generally. It also provides an overview of the transportation of radioactive materials both nationally and internationally, including a discussion of some of the issues and constraints associated with the handling, packaging, and preparation of SNF and HLW for transport off-site, and identification of the regulatory permits and certifications that are required. The appendix summarizes several aspects of the transportation of SNF and HLW, including the respective roles and responsibilities of federal, state, and local agencies (in regulation, security, and accident/ emergency response), evaluation of the risks associated with transportation, assessment of the impacts associated with transportation of SNF and HLW to a geologic repository, and discussion of the physical protection and safeguards regulations require which are designed to protect against sabotage, terrorism, or acts of malice.

National and International Experience

The United States and many other countries have successfully managed, stored, and transported SNF and HLW since the advent of commercial nuclear power over 40 years ago. Internationally, over that time, there have been approximately 20,000 shipments of over 80,000 tons of used nuclear fuel covering a total distance of over 30 million kilometers (Stahmer, 2009). In the US alone, there have been more than 3,000 used nuclear fuel shipments covering a total distance of over 1.55 million miles (2.5 million kilometers [km]). Only nine transportation accidents have been reported to the US Atomic Energy Commission and the US Department of Energy (DOE) (Nuclear Energy Institute [NEI], 2019) in over 40 years of used nuclear fuel transport. Four of these involved empty casks (Holt, 1998). In the most severe accident, a tractor-trailer carrying a 25-ton used nuclear fuel cask swerved to avoid a head-on collision and overturned. The cask separated from the trailer and came to rest in a ditch. The cask was slightly damaged but did not release any radioactive materials. No accident involving SNF or HLW has resulted in a release of radioactive materials causing damage to the environment, workers, or the public.

In addition to SNF and HLW, DOE has also managed the transportation and disposal of transuranic waste[1] to the Waste Isolation Pilot Plant (WIPP) in New Mexico for over 20 years, using transportation practices and methods that are similar to those that would be used for SNF. During that time, WIPP has received approximately 13,000 shipments that traveled over 15 million cumulative miles without a radiological release (DOE, 2022).

The United States nuclear industry has a well-demonstrated track record for safety during decommissioning; 10 reactors have completed decommissioning safely to either the point of license termination or the point where the remaining activities are limited to management of an ISFSI. Currently, 18 commercial power reactors are in decommissioning, with no significant radiological issues (NEI, 2021). The decommissioning of reactors includes the safe transportation of radioactive wastes to an ISFSI or to a licensed and approved repository.

PG&E has expertise in the decommissioning process as evidenced by the successful remediation and recent termination of the license for PG&E's Humboldt Bay Unit 3 nuclear power plant near Eureka, California, on November 18, 2021. That site has been released for unrestricted use. Humboldt Bay Unit 3 was a 65-megawatt boiling water reactor plant, operated commercially from 1963 to 1976 (NRC, 2021c).

At Humboldt Bay, the NRC conducted performance-based in-process inspections of the licensee's Final Status Survey (FSS) program during the decommissioning process. The purpose of the inspections was to verify that the FSSs were being conducted in accordance with the commitments made by the PG&E in the License Termination Plan (LTP), and to evaluate the quality of the FSSs by reviewing the FSS procedures, methodology, equipment, surveyor training and qualifications, document quality control, and survey data supporting the FSS Reports. In addition, the NRC conducted numerous independent confirmatory surveys to verify the FSS results obtained and reported by PG&E. Confirmatory surveys consisted of surface scans for beta and gamma radiation, direct measurements for total beta activity, and collection of smear samples for determining removable radioactivity levels (NRC, 2021c).

After decommissioning Humboldt Bay to meet the NRC's radiation protection standards, PG&E submitted FSSs of the Unit 3 site and requested license termination. The NRC said that its staff evaluated the surveys, conducted inspections, and reviewed confirmatory analyses before concluding that the site meets its criteria for license termination for unrestricted use (NRC, 2021c).

International experience has been similarly successful. France has 56 commercial nuclear reactors that provide approximately 399 terawatt-hour electricity or 70 percent of all electricity consumed. Orano, the French company in charge of nuclear fuel cycle activities, provides the fuel for and manages the waste (1,150 tonnes of used nuclear fuel produced each year) from the country's nuclear power plants. The nuclear fuel recycling process involves converting spent

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[1] Transuranic radioactive waste is waste that contains manmade elements heavier than uranium (with atomic numbers greater than 92) on the periodic table. By definition (40 CFR 191.02), it is waste containing more than 100 nanocuries of alpha-emitting transuranic isotopes, with half-lives greater than twenty years, per gram of waste. It is produced during nuclear fuel assembly, nuclear weapons research and production, and during the reprocessing of SNF. Transuranic waste generally consists of protective clothing, tools, and equipment used in these processes. The WIPP Land Withdrawal Act specifically excludes high-level waste and SNF from the definition, as neither is allowed to be disposed of at the WIPP.

plutonium, formed in nuclear power reactors as a by-product of burning uranium fuel, and uranium into a "mixed oxide" (MOX) that can be reused in nuclear power plants to produce more electricity. Reprocessing is carried out at the La Hague reprocessing plant on the Normandy coast and at Marcoule MOX fuel manufacturing plant (International Atomic Energy Agency, 2019). HLW in France is predominantly shipped by rail. About 300 fresh fuel, 250 used nuclear fuel, 30 "Mixed Oxide" MOX fuel, and 60 plutonium oxide powder shipments are made annually in France (Stahmer, 2009).

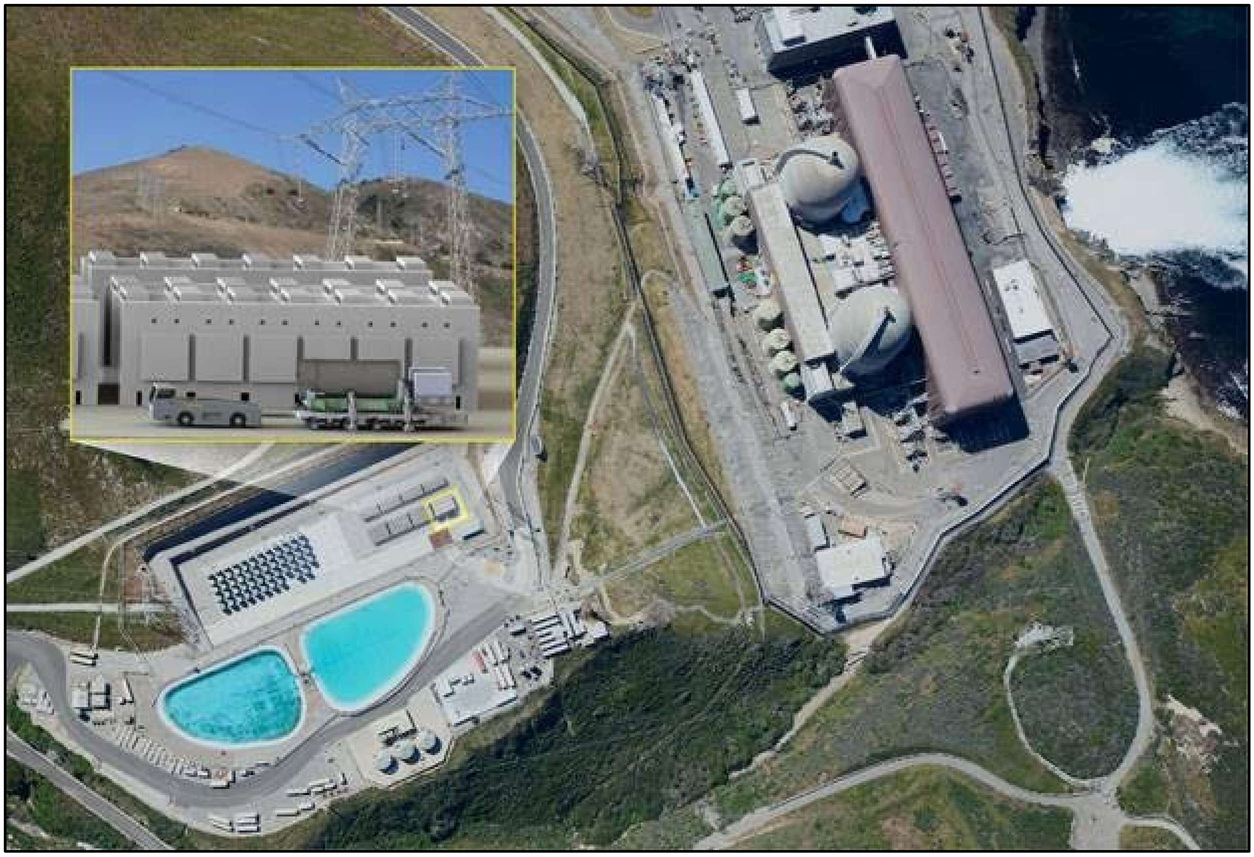
The United Kingdom, Canada, Germany, Sweden, Japan, and other countries are currently safely and successfully managing the storage and transportation of SNF and HLW. According to Stahmer (2009), in over 45 years of used nuclear fuel transport, not a single incident or accident has resulted in a significant radiological impact on people or the environment.

Transportation Packaging and Casks

The current dry cask storage system at the Diablo Canyon Power Plant (DCPP) uses the Holtec International HI-STORM 100SA overpack, HI-TRAC 125D transfer cask, and Multi-Purpose Canister (MPC) capable of holding 32 fuel assemblies (MPC-32). This system is approved for use by general licensees under NRC Docket Number 72-1014. The canisters are half-inch thick stainless steel nestled within a concrete "overpack" that is 27-1/2 inches thick and lined with a 1 inch thick stainless steel liner around both the inner and outer diameters. No mechanism for inspecting the canisters for cracking or loss of helium currently exists, though research is underway. As stated in Section 2, *Project Description (Phases 1 and 2)*, the ISFSI consists of seven storage pads containing space for 20 fuel storage casks each. PG&E began transferring spent fuel to the ISFSI in 2009. On January 19-21, 2021, NRC inspectors evaluated the licensee's operation of the ISFSI during an on-site inspection. The DCPP ISFSI consists of seven concrete pads for a total area of 49,980 square feet. Each pad was designed to hold 20 Holtec International HI-STORM 100SA storage casks which are securely anchored to steel embedment plates in the concrete. At the time of the inspection, the ISFSI contained 58 storage casks (out of 140 total possible) loaded with Multi-Purpose Canisters, each with 32 spent fuel assemblies (MPC-32) (NRC, 2021b).

The Orano contract includes engineering and licensing to implement their NUHOMS® system at DCPP, design of a new Greater Than Class C waste (GTCC) dry storage facility, fabrication of storage canisters at Orano's Trans Nuclear Fuel manufacturing facility in North Carolina, construction and installation of onsite concrete storage modules utilizing the existing ISFSI storage pads, and conducting the pool-to-pad transfer operations for both the SNF and GTCC waste. The Orano system design to be used at DCPP includes enhanced thermal and seismic capabilities, which will require additional NRC safety reviews. Once approved, the transfer of all SNF to dry storage is planned to be completed by 2029. The site concept provided by Orano is shown in Figure G2-1.

Figure G2-1. NUHOMS® Installation Concept at DCPP



Source: Orano, 2022.

The UCLA-PG&E study evaluated the risks associated with transportation of both radiological and non-radiological materials away from DCPP for disposal at off-site facilities out of state. The analysis considered multiple transport modes (truck, rail and barge) along multiple different routes, and thoroughly assessed both conventional risks (i.e., accident, injury and fatality rates for transport by truck, rail and barge respectively) and radiological risks resulting from the potential exposure of workers and the public to radiation and/or radiological materials. The study found that risks are very low for all the scenarios examined, and that radiological risks were a small fraction of natural background radiation (PG&E, 2020).

Section 2 provides a discussion regarding the approved and licensed sites to accept the radio-active waste from DCPP. Table G2-1 presents the disposal site options discussed.

Table G2-1. Potential Disposal Sites of Radioactive Waste Shipped Off-site

Classification	Potential Destination
LLRW	Energy Solutions, Clive Utah
	WCS, Andrews, Texas
	US Ecology, Idaho
Class A	Energy Solutions, Clive Utah
	WCS, Andrews, Texas
Class B/C	WCS, Andrews, Texas

The non-radioactive materials would be transported in standard 20-foot dry containers in batches of 40,000 pounds or in industrial bags that can hold the same quantity. LARW and Class A wastes would also be transported in the same industrial packaging. The Class B/C wastes would be transported in robust, certified casks that are designed to withstand most traffic accidents. The GTCC wastes and SNF would be transported in highly engineered certified casks that have been shown by analysis and field testing to withstand impacts and fires that are beyond the events expected in traffic accidents (NRC, 2021a; NEI, 2019). Example photos of Special Purpose Modular Transporters, the Class A waste packaging, and Class B/C waste packaging are provided in Figures 2-16, 2-17, and 2-18, respectively.

REGULATION OF TRANSPORTATION OF SNF AND RADIOACTIVE MATERIALS

The NRC and the US Department of Transportation (DOT) jointly oversee the transportation of radioactive materials including SNF (NRC, 2021a).

The DOT's role is to:

- Regulate shippers of hazardous materials, including radioactive material
- Oversee vehicle safety, routing, shipping papers, emergency response, and shipper training

DOT has published a review with guidance on the DOT Hazardous Materials Regulations contained in Title 49, Code of Federal Regulations (49 CFR) Parts 171-185, which govern the packaging and shipment of radioactive material. Radiological materials packaged, labeled, marked, and transported in accordance with these regulations have an excellent safety record. This review is found in its entirety as Appendix G5 – DOT Radioactive Material Regulation Review December 2008 (DOT, 2008).

The role of the NRC is to:

- Maintain all radiological controls of nuclear power plants.
- Regulate other users of radioactive material in 13 states (37 states, including California, regulate users within their borders)
- Approve the design, fabrication, use, and maintenance of shipping containers for the most hazardous radioactive materials, including SNF
- Regulate the physical protection of commercial SNF in transit against malicious acts

The NRC requires radioactive materials shipments to comply with the DOT's safety regulations (49 CFR Parts 171-185) for transporting hazardous materials. Millions of packages of radioactive material are shipped throughout the US each year by rail, air, sea, and road. They contain small amounts of radioactive material that are used in industry and medicine. Examples include smoke detectors, watch dials, nuclear material to diagnose and treat illnesses, and slightly contaminated equipment such as syringes used for radioactive medicines.

More stringent DOT packaging requirements apply as the potential risk posed by the contents increase. DOT regulations limit how much radioactivity can be transported in each package. That way, the dose from any accident does not pose a serious health risk.

NRC regulations for the safety of transport packages for large quantities of radioactive materials, including SNF, can be found in 10 CFR Part 71. The NRC requires packaging of SNF, under both normal and accident conditions of transport, to:

- Prevent the loss of radioactive contents
- Provide shielding and heat dissipation
- Prevent nuclear criticality (a self-sustaining nuclear chain reaction)

Normal conditions that a SNF transport package must be able to withstand include hot and cold environments, changes in pressure, vibration, water spray, impact, puncture, and compression. To show that it can withstand accident conditions, a package must pass stringent impact, puncture, fire, and water immersion tests. Transportation packages must survive these tests in sequence, including a 30-foot drop onto a rigid surface followed by a fully engulfing fire of 1,475 degrees Fahrenheit (°F) for 30 minutes. These very severe tests equate to the package hitting a concrete highway overpass at high speed and being involved in a severe and long-lasting fire. The test sequence encompasses more than 99 percent of vehicle accidents.

The NRC reviews each package design to confirm that it meets the required conditions. Before a package can be used to transport SNF, the NRC must issue an approval certificate.

The NRC's regulatory controls apply to every US shipment of SNF from commercial reactors. For more than 40 years, this oversight has resulted in an outstanding record of safety and security. Thousands of domestic SNF shipments have been completed safely. After the September 11, 2001, terrorist attacks, the NRC further enhanced controls and monitoring of shipments of SNF.

NRC regulations reflect the International Atomic Energy Agency transportation safety standards and supplement DOT regulations. The NRC looks at its transportation regulations every few years and proposes changes, if needed, to address new requirements, policies, or technical improvements.

To ensure that large quantities of radioactive materials are transported safely, the NRC:

- Reviews and certifies transport package designs
- Requires designers to follow strict quality assurance programs for package design, fabrication, use, and maintenance
- Inspects package designers and fabricators to ensure that packages conform to NRC-approved designs and quality assurance programs and
- Inspects some shipments

Many additional requirements help to ensure shipments of radioactive materials are safe:

- DOT regulations require shipper and carrier training
- The DOT and the Federal Emergency Management Agency oversee emergency response coordination, training, and communication
- The DOT carries out its own transportation inspection and enforcement programs

There is no way to completely eliminate risk. Still, the NRC has found both the likelihood of an accident that releases nuclear material and the risk to the public to be small. The NRC regulates the transportation of radioactive waste as an essential part of its mission.

Transportation Risks (NRC Risk Assessments and Safety Studies)

The NRC has carefully studied and evaluated the risks associated with the transportation of SNF and other radiological materials for over 40 years. Over time, these analyses have incorporated increasingly complex methods, technology, and more comprehensive datasets. As computer modeling programs have become more sophisticated, simulations have addressed and incorporated more data and scenarios taken from actual SNF transportation experience, including the simulation of numerous actual and postulated severe accidents.

In 1977, the NRC published the *Final Environmental Impact Statement on the Transportation of Radioactive Material by Air and Other Modes* (NUREG-0170) (NRC, 1977), which showed that the NRC's transportation regulations adequately protect public health and safety. Additional studies by the NRC and their contractors (e.g., Fischer et al., 1987; Sprung et al., 2000) found the risks were even smaller than the 1977 study predicted. The 2000 study used improved risk assessment techniques to analyze the ability of containers to withstand an accident.

In 2014, the NRC published a comprehensive *Spent Fuel Transportation Risk Assessment* (NRC, 2014). This study modeled the radiation doses people might receive if SNF is shipped from reactors to a central facility. The results indicate that NRC regulations for SNF transport are adequate to ensure safety of the public and the environment. The study found:

- Doses from routine transport would be less than 1/1000 the amount of radiation people receive from background sources each year.
- There is less than a 1 in 1 billion chance that radioactive material would be released in an accident.
- If an accident did release radioactive material, the dose to the most affected individual would not cause immediate harm.

The NRC also studies major transportation accidents across the country to understand the actual accident conditions. These studies allow NRC to determine whether its regulations would protect the public if large quantities of radioactive materials were involved. These studies, coupled with the risk assessments, give the NRC added confidence in the safety of SNF shipments.

Transportation Security

The NRC and DOE jointly operate a system to track domestic and foreign nuclear materials shipments. The NRC also requires those involved in SNF or HLW shipments to:

- Follow only approved routes
- Provide armed escorts through heavily populated areas
- Provide monitoring and redundant communications
- Coordinate with law enforcement agencies before shipments
- Notify, in advance, the NRC, local tribes, and states through which the shipments will pass

After the terrorist attacks on September 11, 2001, the NRC enhanced security requirements for transporting SNF and large quantities of radioactive materials. Through advisories and orders to licensees, the NRC requires:

- More pre-planning and coordination with affected states
- Additional advance notification of shipments

- Enhanced control and monitoring
- Trustworthiness checks for individuals with access to or information about the shipment
- Stronger security controls over shipment routes and schedules

These newer requirements and other enhancements were formally added to the NRC's transport regulations through a rulemaking, finalized in May 2013 (NRC, 2013).

Accident Response Assistance

State and local governments have primary responsibility to oversee the response to any accident involving a nuclear materials shipment. They would ensure the carrier and others take the actions required to protect public health and safety.

Any event involving NRC-licensed material that could threaten public health and safety or the environment would trigger special NRC procedures. The NRC may activate its Headquarters Operations Center. It also may activate one of its four Regional Incident Response Centers (Region I-King of Prussia, Pennsylvania; Region II-Atlanta, Georgia; Region III-Lisle, Illinois; and Region IV-Arlington, Texas).

The NRC's highest priority in any accident is to provide expert consultation, support, and assistance to state and local responders. Teams of NRC specialists evaluate information, assess the potential impact on the public and environment, and evaluate possible recovery strategies. Other experts consider the effectiveness of different protective actions, including sheltering in place or evacuation.

Transportation Impacts (Yucca Mountain)

DOE studied the effects associated with the transportation of SNF and HLW in detail as part of the Environmental Impact Statement (EIS) for the proposed Yucca Mountain Repository (DOE, 2002; DOE, 2008). If the repository is opened, 72 commercial and five DOE sites would begin loading and shipping waste. Most shipments would be on legal-weight trucks and trains travelling on the nation's highways and railroads. Barges and heavy-haul trucks could be used for the short-distance transport of SNF from some commercial sites to nearby railroads. Shipments of SNF and HLW arriving in Nevada would travel to the Yucca Mountain site by legal-weight truck, rail, or heavy-haul truck. Legal-weight truck shipments would use existing highways in accordance with DOT regulations. The EIS identified nationwide routes and alternatives for legal-weight highway and rail shipping. Within the State of Nevada, DOE also identified and analyzed alternative rail corridor and intermodal transfer station locations, and associated heavy-haul truck routes, respectively.

DOE then analyzed the impacts of transporting SNF and HLW to the repository under the mostly legal-weight truck and mostly rail scenarios. Under the mostly legal-weight truck scenario, most of the SNF and HLW would be shipped to Nevada by legal-weight truck, while naval fuel would be shipped by rail. Under the mostly rail scenario, commercial SNF from most sites, and DOE and naval SNF and HLW, would arrive in Nevada by rail. However, commercial fuel from a few commercial sites would initially be shipped by legal-weight truck because those sites do not currently have the capability to load a rail cask.

The EIS evaluated the impacts of these two alternative scenarios for transporting SNF and HLW to the Yucca Mountain site. Much of the difference in the impacts between the mostly legal-weight truck and mostly rail scenarios results from the differing number of shipments over the 24-year transportation period and differences in the characteristics of the truck and rail modes of transport. The mostly legal-weight truck scenario would involve about 53,000 shipments (2,200 annually), and the mostly rail scenario would involve approximately 10,700 shipments (450 annually). Because of the larger number of shipments, the mostly legal-weight truck scenario would have somewhat greater radiological impacts during routine operations, even though each individual truck shipment would carry less radioactive material than a rail shipment.

The EIS analysis also considered potential accidents based on various accident cases presented in NUREG-6672, Reexamination of Spent Fuel Shipment Risk Estimates (Sprung et al., 2000). The analysis estimated impacts of postulated releases from accidents in three population zones: urban, suburban, and rural, under a set of meteorological (weather) conditions that represent the national average meteorology. The analysis used state-specific accident data, the lengths of routes in the population zones in states through which the shipments would pass, and the number of shipments that would use the routes to determine accident probabilities (Sprung et al., 2000).

In addition to the risk due to accidents involving a release of radioactive material, the analysis examined the impacts of loss-of-shielding accidents. The loss-of-shielding scenarios range from an accident with no loss of shielding to a low-probability severe accident involving both a loss of shielding (and any increased direct exposure) and a release of some of the contents of the cask.

The EIS analysis also estimated impacts from an unlikely but severe accident called a maximum reasonably foreseeable accident to provide perspective about the consequences for a population that might live nearby. For maximum reasonably foreseeable accidents, the consequences were estimated for each of the accidents and for both truck and rail casks from the spectrum of accidents presented in NUREG-6672. For each accident, the possible combinations of weather conditions, population zones, and transportation modes were considered. The accidents were then ranked according to those that would have a likelihood greater than 1 in 10 million per year and that would have the greatest consequences.

Although every potential accident that could occur cannot feasibly be analyzed, the EIS analyzed several types of accidents that represent groups of initiating events and conditions having similar characteristics. For example, the EIS analyzed the impacts of a collection of collision accidents in which a cask would be exposed to impact velocities in the range of 60 to 90 miles (97 to 145 km) per hour. The EIS also analyzes a maximum reasonably foreseeable accident in which a collision would not occur, but where the temperature of a rail cask containing SNF would rise to between 1,400°F and 1,800°F (between 750°C and 1,000°C). The conditions of the maximum reasonably foreseeable accident analyzed in the EIS envelop conditions reported for the Baltimore Tunnel fire (a train derailment and fire that occurred in July 2001 in a tunnel in Baltimore, Maryland). Temperatures in that fire were reported to be as high as 1,500°F (820°C), and the fire was reported to have burned for up to 5 days.

The estimated radiological accident risk of a single latent cancer fatality for the entire population within 80 kilometers (50 miles) of the rail and truck transportation routes would be about 0.0025 (1 chance in 400) during as many as 50 years of shipments to the repository. Because this risk is for the entire population of individuals along the transportation routes, the risk for any single individual would be very small (DOE, 2008).

The maximum reasonably foreseeable transportation accident analyzed in the EIS was estimated to occur with a frequency of about 8 × 10-6 per year (DOE, 2008). If the accident occurred in an urban area, DOE estimated that there would be 9 cancer fatalities in the exposed population. If the accident occurred in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.012 (1 chance in 80) in the exposed population.

DOE also evaluated the potential consequences of an accidental crash of a large jet aircraft into a truck cask or rail cask. The analysis determined that penetration of the cask would not occur; however, potential seal failure could result in releases of radiological materials. The consequences associated with this event would be very low (less than 1 latent cancer fatality in an urban population).

The consequences of the maximum reasonably foreseeable transportation accident would be higher under the mostly rail scenario than under the mostly legal-weight truck scenario, principally because the amount of material in a rail shipment would be larger than that in a legal weight truck shipment.

Protection from Intentional Acts of Malice

The NRC has developed a set of rules specifically aimed at protecting the public from harm that could result from sabotage of SNF casks, which may also be used for HLW. Known as physical protection and safeguards regulations (10 CFR 73.37), these security rules are distinguished from other regulations that deal with issues of safety affecting the environment and public health. The objectives of the regulations are to:

- Minimize the possibility of sabotage
- Facilitate recovery of SNF shipments that could come under control of unauthorized persons

The same cask safety features that provide containment, shielding, and thermal protection also provide protection against sabotage. The casks are massive, and the SNF in a cask would typically be only about 10 percent of the gross weight; the remaining 90 percent would be shielding and structure.

It is not possible to predict with any certainty whether sabotage events would occur and, if they did, the nature of such events. Nevertheless, DOE examined various accidents, including an intentional aircraft crash into a transportation cask. The analysis (DOE, 2002; DOE, 2008) evaluated the ability of large aircraft parts to penetrate shipping casks and found that that neither the engines nor shafts would penetrate a cask and cause a release of radiological materials if an aircraft were to crash into a SNF cask.

DOE also evaluated the potential consequences of a sabotage event in which a high-energy density device penetrates a rail or truck cask. The results of this analysis (DOE, 2008) indicate that the risk of the maximally exposed individual incurring a fatal cancer would increase when compared to the current risk of incurring a fatal cancer from all other causes. DOE estimated that there would be 28 latent cancer fatalities in the exposed population if the sabotage event occurred in an urban area. If the sabotage event took place in a rural area, DOE estimated that the probability of a single latent cancer fatality in the exposed population would be 0.055 (1 chance in 20).

CONCLUSION

This review describes the existing conditions related to temporary on-site storage at the existing approved ISFSI (SNF storage), GTCC Waste Storage Facility, and DCPP plans for transportation and disposal of radiological materials generated during decommissioning, as well as SNF, HLW and GTCC waste. National and international experience in the storage and transportation of SNF and HLW (as well as lower levels of radioactive and hazardous waste) were also described briefly, and the risks associated with transportation summarized. The Orano USA NUHOMS® system to be installed at DCPP, design of a new GTCC Waste Storage Facility, fabrication of storage canisters at Orano's Trans Nuclear Fuel manufacturing facility in North Carolina, construction and installation of on-site concrete storage modules, and conducting the pool-to-pad transfer operations for both the SNF and GTCC waste in compliance with NRC and EPA regulatory standards will ensure that decommissioning, storage and transport operations at DCPP will protect the health and safety of workers, the public and the environment.

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Appendix G3

US Nuclear Regulatory Commission
Environmental Impact Evaluation

Appendix G3
US Nuclear Regulatory Commission Environmental Impact Evaluation

As discussed in Section 1.0, *Introduction*, and in Section 2, *Project Description (Phases 1 and 2),* the US Nuclear Regulatory Commission (NRC) has exclusive jurisdiction over the radiological aspects of decommissioning and has prepared National Environmental Policy Act (NEPA) documents relating to the decommissioning of nuclear facilities. (See Section 1.2.3.1, *US Nuclear Regulatory Commission*, for additional discussion.) To maximize disclosure to the public, the EIR includes this appendix to provide an overview of how these NEPA documents evaluate environmental impacts of the decommissioning of nuclear facilities.

The NRC uses terms from NEPA documents, such as those for license renewal or new reactors, to define the standard of significance for assessing environmental issues (NRC, 2014), as shown below.

- SMALL: Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- MODERATE: Environmental effects are sufficient to alter noticeably, but not to destabilize, important attributes of the resource.
- LARGE: Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Pacific Gas and Electric Company (PG&E) describes the potential environmental impacts from decommissioning activities at the Diablo Canyon Power Plant (DCPP) in the Post-Shutdown Decommissioning Report (PSDAR) (PG&E, 2019). Each resource area was assessed using evaluations in NUREG-0586, Supplement 1 *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities,* (issued in 2002) as a guide (NRC, 2002). Like the evaluations in NUREG-0586, the analysis assumed that operational mitigation measures are continued and would not rely on the implementation of new mitigation measures unless specified. Environmental releases, waste volumes, and other environmental interfaces were estimated. These data were assessed against the potential for impact and the existing radiological environmental conditions at DCPP to identify impacts. A significance level of SMALL was determined (PG&E, 2019).

The NRC reviewed the potential environmental impacts of stored SNF in NUREG-2157, *Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel* (GEIS), published in September 2014 (NRC, 2014). The NUREG-2157 generically determines the environmental impacts of continued storage, including those impacts identified in the remand by the Court of Appeals in the *New York v. NRC* decision, and provides a regulatory basis for a revision to 10 CFR 51.23 that addresses the environmental impacts of continued storage for use in future NRC environmental reviews. In this context, “the environmental impacts of continued storage” means those impacts that could occur as a result of the storage of SNF at “at-reactor” and “away-from-reactor” sites after a reactor’s licensed life for operation and until a permanent repository becomes available. The GEIS evaluates potential environmental impacts to a broad range of resources. Cumulative impacts are also analyzed (NRC, 2014).

Because the timing of repository availability is uncertain, the GEIS analyzes potential environmental impacts over three possible timeframes (NRC, 2014):

- The *short-term storage timeframe* (60 years of continued storage after the end of the reactor's licensed life) includes routine maintenance and monitoring of the spent fuel pool and ISFSI, and transferring SNF from pools to dry cask storage. Because decommissioning is required to be completed within 60 years after a reactor shuts down (unless additional time is necessary to protect public health and safety), the NRC assumes that all SNF would be moved from spent fuel pools to dry cask storage by the end of the short-term storage timeframe.
- The *long-term storage timeframe* (100 years beyond the initial 60-year [short-term] storage timeframe) includes activities such as continued facility maintenance, construction and operation of a Dry Transfer System (DTS), and replacement of ISFSI and DTS facilities, including casks.
- The *indefinite storage timeframe*, which addresses the possibility that a repository never becomes available, assumes that the activities associated with long-term storage continue indefinitely, with ISFSI and DTS facilities being replaced at least once every 100 years.

All potential impacts in each resource area are analyzed for each continued storage timeframe. The GEIS also contains several appendices that discuss specific topics, including the technical feasibility of continued storage and repository availability as well as the two technical issues involved in the remand of *New York v. NRC* — spent fuel pool leaks and spent fuel pool fires.

The SNF storage facility is part of the fuel handling building and is a Seismic Category I structure.[1] SNF assemblies are stored under water in SNF storage racks in the spent fuel pool. A separate fuel-handling building is provided for each reactor unit. The SNF storage racks and spent fuel pool provide for storage of fuel assemblies in the spent fuel pool, while maintaining spacing between assemblies for adequate cooling water flow. This prevents nuclear criticality and protects the fuel assemblies from excess mechanical or overheating. Without these preventative actions, overheating could lead to loss of water through boiling and then potential fires, nuclear criticality, and meltdown. The design basis of the spent fuel pool must meet the requirements of 10 CFR 50.68 (PG&E, 2019).

The NRC also looked at ongoing regulatory activities that could affect the continued storage of SNF, including regulatory changes resulting from lessons learned from the September 11, 2001, terrorist attacks and the March 11, 2011, earthquake and tsunami that damaged the Fukushima Daiichi plant in Japan.

NUREG-2157 summarizes the NRC's conclusions related to the evaluation of the following topics, which are detailed below (NRC, 2014):

- Environmental Impacts of Postulated Accidents
- Potential Acts of Sabotage or Terrorism
- Natural Phenomena Hazards

[1] Seismic Category I – SSCs that are designed and built to withstand the maximum potential earthquake stresses for the particular region where a nuclear plant is built.

- Spent Fuel or ISFSI Leakage
- Spent Fuel Pool Fire

ENVIRONMENTAL IMPACTS OF POSTULATED ACCIDENTS

Because the accident risks for spent fuel pool storage only apply during the short-term timeframe and the accident risks for dry cask storage are substantially the same across the three timeframes, the GEIS does not present the various accident types by timeframe, but rather by accident type (i.e., design basis and severe) and storage facility type (i.e., spent fuel pool and dry cask storage system).

- **Design Basis Accidents in SNF Pools.** Impacts would be SMALL. The postulated design basis accidents considered in this GEIS for spent fuel pools include hazards from natural phenomena, such as earthquakes, floods, tornadoes, and hurricanes; hazards from activities in the nearby facilities; and fuel handling related accidents. In addition, potential effects of climate change are also considered. Based on the NRC's assessment, the environmental impacts of these postulated accidents involving continued storage of SNF in pools are SMALL because all important safety SSCs involved with the SNF storage are designed to withstand these design basis accidents without compromising the safety functions.
- **Design Basis Accidents in Dry Cask Storage Systems and Dry Transfer Systems**. Impacts would be SMALL. All NRC-licensed dry cask storage systems are designed to withstand all postulated design basis accidents without any loss of safety functions. A DTS or a facility with equivalent capabilities may be needed to enable retrieval of SNF for inspection or repackaging. Licensees of DTS facilities are required to design the facilities so that all safety-related SSCs can withstand the design basis accidents without compromising any safety functions. Based on the GEIS assessment, the environmental impact of the design basis accidents is SMALL because safety-related SSCs are designed to function in case of these accidents.
- **Severe Accidents in Spent Fuel Pools.** Probability-weighted impacts would be SMALL. A spent fuel pool may encounter severe events, such as loss of off-site power or beyond design basis earthquakes. Although it is theoretically possible that these events may lead to loss of spent fuel pool cooling function resulting in a spent fuel pool fire, the likelihood of such events is extremely small. Although some handling accidents, such as a postulated drop of a canister, could exceed NRC's public dose standards, the likelihood of the event is very low. Therefore, the environmental impact of severe accidents in a dry storage facility is SMALL.
- **Severe Accidents in Dry Cask Storage Systems.** Probability-weighted impacts would be SMALL. Although some handling accidents such as a postulated drop of a canister could exceed NRC's public dose standards, the likelihood of the event is very low. Therefore, the environmental impact of severe accidents in a dry storage facility is SMALL.

POTENTIAL ACTS OF SABOTAGE OR TERRORISM

The GEIS finds that even though the environmental consequences of a successful attack on a spent fuel pool beyond the licensed life for operation of a reactor are large, the very low probability of a successful attack ensures that the environmental risk is SMALL. Similarly, for an operational ISFSI or DTS during continued storage, the NRC finds that the environmental risk of a successful radiological sabotage attack is SMALL (NRC, 2014).

The potential for theft or diversion of light water reactor SNF from the ISFSI with the intent of using the contained special nuclear material for nuclear explosives is not considered credible because of (1) the inherent protection afforded by the massive reinforced concrete storage module and the steel storage canister; (2) the unattractive form of the contained special nuclear material, which is not readily separable from the radioactive fission products; and (3) the immediate hazard posed by the high radiation levels of the SNF to persons not provided radiation protection (NRC, 2014).

Although a successful act of sabotage or terrorism by an armed attack is low in probability, the consequences of such an act could be severe. A discussion of a postulated spent fuel pool fire resulting from loss of pool water resulting from a successful attack was assessed in the GEIS. The conditional consequences described include downwind collective radiation doses above one million person-rem, up to 191 early fatalities, and economic damages exceeding $50 billion. However, given the very low probability of a successful attack with these consequences, the NRC determined that the risk of successful attack is SMALL (NRC, 2014).

NATURAL PHENOMENA HAZARDS

The postulated design basis accidents considered in the GEIS for spent fuel pools include hazards from natural phenomena, such as earthquakes, flood, tornadoes, and hurricanes; hazards from activities in the nearby facilities; and fuel-handling-related accidents. In addition, the potential effects of climate change are also considered. Based on the GEIS analysis, the environmental risk of these postulated accidents involving continued storage of SNF in pools is SMALL. The SSCs involved with the fuel storage are designed to withstand these design basis accidents without compromising the safety functions. If climate change influences on natural phenomena create conditions adverse to safety, the NRC has sufficient time to require corrective actions to ensure SNF storage continues with minimal impacts (NRC, 2014).

SPENT FUEL POOL OR ISFSI LEAKAGE

Continued storage of SNF could result in non-radiological and radiological impacts to groundwater quality. In the unlikely event a spent fuel pool leak remained undetected for a long period of time, contamination of a groundwater source above a regulatory limit could occur (e.g., a Maximum Contaminant Level for one or more radionuclides). The GEIS analysis concludes that (1) there is a low probability of a leak of sufficient quantity and duration to affect off-site locations; and (2) physical processes associated with radionuclide transport, site hydrologic characteristics, and environmental monitoring programs, ensure that impacts from spent fuel pool leaks would be unlikely. Impacts to groundwater from continued storage in ISFSIs would be minimal because ISFSI storage requires minimal water and produces minimal, localized, and easy-to-remediate liquid effluents on or near ground surface.

The GEIS estimated an annual discharge rate for leakage from the spent fuel pool of 100 gallons per day with contaminants at certain concentrations assumed to be present at the start of short-term storage. The GEIS compared these concentrations to annual effluent ranges for reactors. Even in the unlikely event that spent fuel pool leakage flowed continuously (24 hours per day, 365 days per year) undetected to local surface waters, the quantities of radioactive material discharged to nearby surface waters would be comparable to values associated with permitted, treated effluent discharges from operating nuclear power plants. Based on these considerations, the NRC concluded that the impact of spent fuel pool leaks on surface water would be SMALL (NRC, 2014).

SPENT FUEL POOL FIRE

A spent fuel pool accident could develop into a spent fuel pool fire in a number of ways. Spent fuel pool accidents can arise from either the loss of spent fuel pool cooling, drainage of the spent fuel pool, or the dropping of heavy items into the spent fuel pool. Additionally, the NRC has assessed various accident sequences including spent fuel pool failure due to wind-driven missiles, aircraft crashes, heavy-load drop, seal failure, inadvertent draining, loss of cooling, and seismic events (NRC, 2014). The GEIS describes the NRC's finding that the probability-weighted consequences of atmospheric releases, fallout onto open bodies of water, and societal and economic impacts of spent fuel pool fires are SMALL (NRC, 2014).

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Appendix G4

Radiation Basics

Appendix G4
Radiation Basics

As discussed in Section 1.0, *Introduction*, and in Section 2, *Project Description (Phases 1 and 2),* the US Nuclear Regulatory Commission (NRC) has exclusive jurisdiction and regulatory authority over the radiological aspects of decommissioning.

To maximize public disclosure and understanding, the EIR includes this appendix that provides an overview of the various types of radiation and introduces the concepts of human health impacts as a result of exposure to radiation and potentially toxic materials.

RADIATION

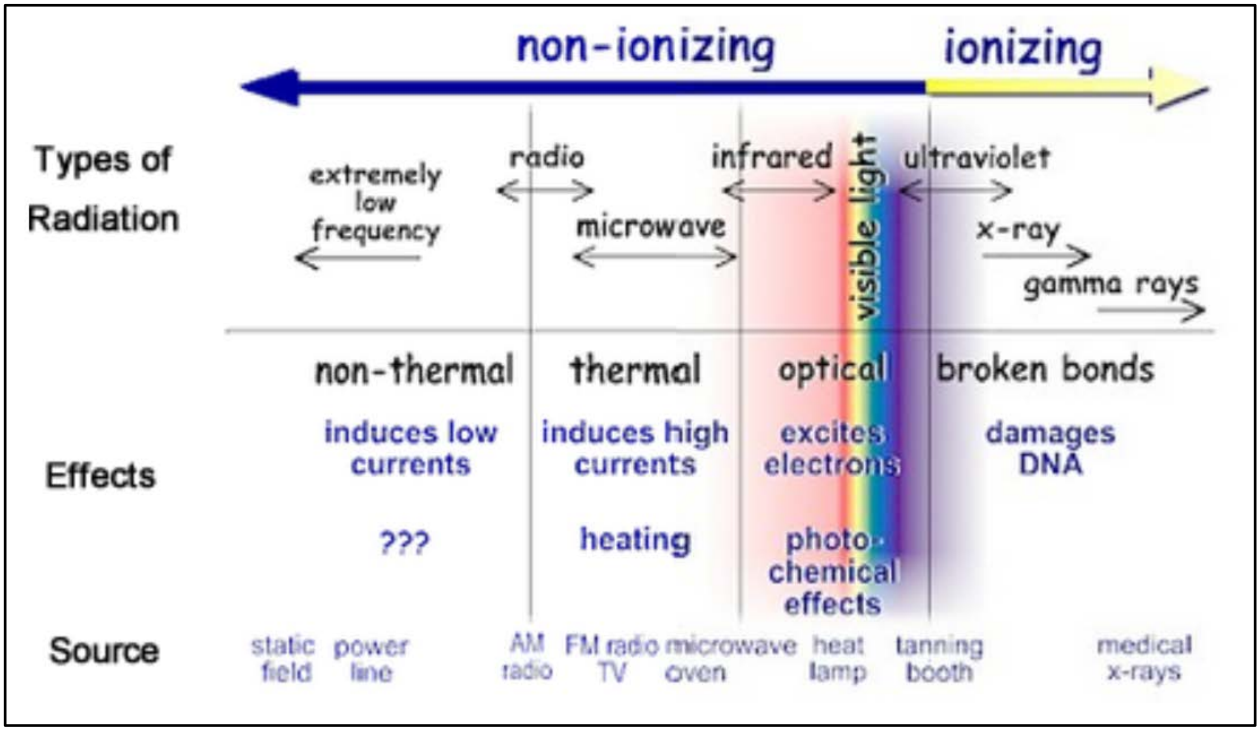
Radiation is the emission and propagation of energy through space or through a material in the form of waves or bundles of energy called photons, or in the form of high-energy subatomic particles. Radiation generally results from atomic or subatomic processes that occur naturally.

The most common kind of radiation is **electromagnetic radiation**, which is transmitted as photons. Electromagnetic radiation is emitted over a range of wavelengths and energies. Visible light is the most familiar form of electromagnetic radiation. Radiation of longer wavelengths and lower energy includes infrared radiation, which transmits heat and radio waves. Electromagnetic radiation of shorter wavelengths and higher energy, which is more penetrating, includes ultraviolet radiation (the cause of sunburn), x-rays, and gamma radiation. Figure G4-1 illustrates the types of radiation that compose the electromagnetic spectrum. As shown in Figure G4-1, electromagnetic energy increases from left to right as the frequency increases. An increase in energy and frequency corresponds with a decrease in wavelength.

RADIATION

Radiation occurs on Earth in many forms, either naturally or as the result of human activities. Natural forms include light, heat from the sun, and the decay of unstable radioactive elements in the Earth and the environment. Some elements that exist naturally in the human body and in the environment are radioactive and emit ionizing radiation. For example, one of the naturally occurring isotopes of potassium (essential for health) is radioactive. In addition, isotopes of the naturally occurring uranium and thorium decay series are widespread in the human environment. Human activities have also led to sources of ionizing radiation for various uses, such as diagnostic and therapeutic medicine and nondestructive testing of pipes and welds. Nuclear power generation produces ionizing radiation as well as radioactive materials, which undergo radioactive decay and can continue to emit ionizing radiation for long periods of time.

Figure G4-1. Types of Radiation in the Electromagnetic Spectrum



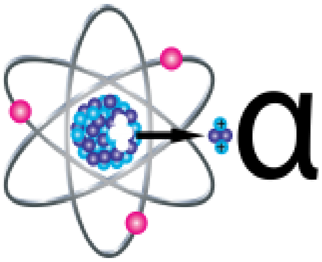
Source: U.S. Environmental Protection Agency (USEPA), 2017.

Ionizing radiation is radiation that has sufficient energy to displace electrons from atoms or molecules to create ions. Some forms of ionizing radiation are electromagnetic (for example, X-rays or gamma radiation), while other forms of ionizing radiation are subatomic particles (for example, alpha and beta radiation). The ions formed by ionizing radiation have the ability to interact with other atoms or molecules. In biological systems, this interaction can cause damage in the tissue or organism.

Radioactive Decay and Fission

Radioactivity is the property or characteristic of an unstable atom to undergo spontaneous transformation (to *disintegrate* or *decay*) with the emission of energy as radiation. Usually, the emitted radiation is ionizing radiation. The result of the process, called **radioactive decay**, is the transformation of an unstable atom (a *radionuclide*) into a different atom, accompanied by the release of energy (as radiation) as the atom reaches a more stable, lower energy configuration.

Radioactive decay produces three main types of ionizing radiation: (1) alpha particles, (2) beta particles, and (3) gamma or X-rays. These types of ionizing radiation, which are described below, have different characteristics and levels of energy, as well as varying abilities to penetrate and interact with atoms in the human body.

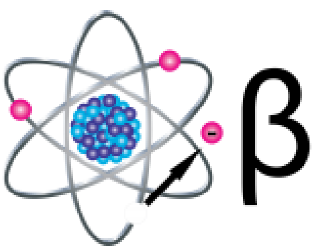


Alpha Particles

Alpha particles (α) are positively charged and made up of two protons and two neutrons from the atom's nucleus. Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium, and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances and are unable to travel very far from the atom.

The health risk from exposure to alpha particles depends greatly on how a person is exposed. Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Alpha particles can be stopped by a thin layer of material such as a single sheet of paper. Inside the body, however, these particles can be very harmful. If alpha-emitters or radioactive atoms (called radionuclides) are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue. The ionizations caused by alpha-emitters are very close together, which results in more severe damage to cells and DNA. For this reason, alpha particles are more dangerous than other types of radiation (USEPA, 2017).

Beta Particles

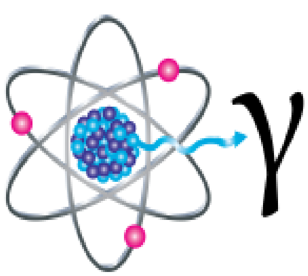


Beta particles (β) are small, fast-moving particles with a negative electrical charge that are emitted from an atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (tritium), carbon-14, and strontium-90.

Beta particles are more penetrating than alpha particles but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing, several reams of paper, several inches of wood or water, or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating skin and causing damage such as skin burns. As with alpha-emitters, beta-emitters are most hazardous when inhaled or swallowed (USEPA, 2017).

Gamma Rays

Gamma rays (γ) are packets of energy called photons. Gamma rays are similar to visible light but have higher energy. Unlike alpha and beta particles, which have both energy and mass, gamma rays are pure energy. Gamma rays are often emitted along with alpha or beta particles during radioactive decay.



Gamma rays are a radiation hazard for the entire body. They can easily penetrate barriers that can stop alpha and beta particles, such as skin and clothing. Gamma rays have substantial penetrating power and require a dense material to be stopped, such as several inches to several feet of heavy material (for example, concrete or lead). The energy associated with gamma radiation is dispersed across the body in contrast to the local energy deposition caused by alpha particles. In fact, some gamma rays can pass completely through the human body; as they pass through, they can cause ionizations that damage tissue and DNA (USEPA, 2017).

X-Rays

Because of their use in medicine, x-rays are a familiar type of radiation. X-rays are similar to gamma rays in that they are photons of pure energy. X-rays and gamma rays have the same basic properties but come from different parts of the atom. X-rays are emitted from processes outside the nucleus, while gamma rays originate inside the nucleus. X-rays are also generally lower in energy and therefore less penetrating than gamma rays. X-rays can be produced naturally or by machines using electricity.

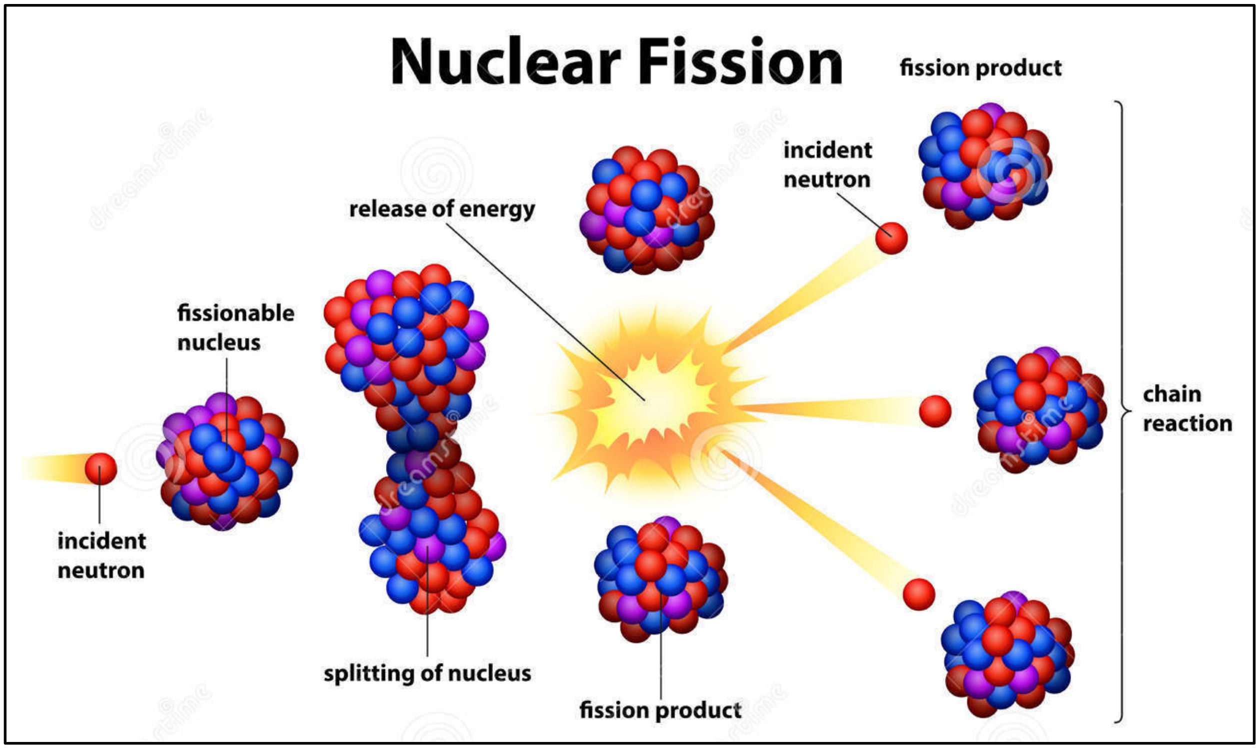
FISSION

In a nuclear reactor, heavy atoms such as uranium and plutonium undergo a process called fission after the absorption of a subatomic particle (usually a neutron). In fission, a heavy atom splits into two lighter atoms and releases energy in the form of radiation and the kinetic energy of the two new lighter atoms (see Figure G4-2). The new lighter atoms are called fission products. The fission products are often unstable and undergo further radioactive decay to reach a more stable state.

FISSION

Fission is the process whereby a large nucleus (for example, uranium-235) absorbs a neutron, becomes unstable, and splits into two fragments, resulting in the release of large amounts of energy per unit of mass. Each fission releases an average of two or three neutrons that can go on to produce fissions in nearby nuclei. If one or more of the released neutrons on the average causes additional fissions, the process keeps repeating. The result is a self-sustaining chain reaction and a condition called criticality. When the energy released in fission is controlled (as in a nuclear reactor), it can be used for various benefits such as to propel submarines or to provide electricity that can light and heat homes.

Figure G4-2. Nuclear Fission Chain Reaction



Source: ExtremeTech, 2017.

Some heavy atoms do not immediately undergo fission after absorbing a subatomic particle. Rather, a new nucleus is formed that tends to be unstable (like fission products) and undergoes radioactive decay.

The radioactive decay of fission products and unstable heavy atoms is the source of radiation from spent nuclear fuel and high-level radioactive waste, which makes these materials hazardous in terms of risk to human health.

EXPOSURE TO RADIATION AND RADIATION DOSE

Radiation that originates outside an individual's body is called external or direct radiation. Such radiation can come from an x-ray machine or from radioactive materials (materials or substances that contain radionuclides), such as radioactive waste or radionuclides in soil. Internal radiation originates inside a person's body following intake of radioactive material or radionuclides through ingestion or inhalation. Once in the body, the fate of a radioactive material is determined by its chemical behavior and how it is metabolized. If the material is soluble, it might be dissolved in bodily fluids and deposited in various body organs; if insoluble, it might move rapidly through the gastrointestinal tract or be deposited in the lungs. Whether it emits alpha or beta particles, gamma rays, x-rays, or neutrons, a quantity of radioactive material is expressed in terms of its radioactivity, which refers to the amount of ionizing radiation released by a material (i.e., how many atoms in the material decay in a given time period). The units of measurement for radioactivity are the curie (Ci, U.S. unit) and becquerel (Bq, the international unit). One becquerel represents the amount of a radioactive material that will undergo one transformation per second. Becquerels are not used to measure radiation dose or radiation exposure.

Exposure describes the amount of radiation traveling through the air. Many types of radiation monitors measure exposure. The units for exposure are the roentgen (R, U.S. unit) and coulomb/kilogram (C/kg, international unit).

Absorbed dose describes the amount of radiation absorbed by an object or person. The unit for absorbed radiation dose is the rad (U.S. unit) or the gray (Gy, international unit). One gray is equal to 100 rads.

Effective dose describes the amount of radiation absorbed by a person, adjusted to account for the type of radiation received and the effect on particular organs. The unit used for effective dose is rem (U.S. unit) or sievert (Sv, international unit). More commonly, dose is measured in much smaller units defined as millirems (**mrem**) or millisieverts. The millirem is the U.S. unit used to measure effective dose, and is one-thousandth of a rem. The potential effects from a one-time ingestion or inhalation of radioactive material are calculated over a period of 50 years as adults to account for radionuclides that have long half-lives and long residence time in the body. The result is called the *committed effective dose equivalent (CEDE).* The unit of effective dose equivalent is also the *rem. Total effective dose equivalent (TEDE)* is the sum of the committed effective dose equivalent from radionuclides in the body plus the dose equivalent from radiation sources external to the body (also in rem).

The NRC has adopted a concept of a “critical group” to regulate radiation dose to the public following license termination. The "critical group" is that group of individuals reasonably expected to receive the highest exposure to residual radioactivity within the assumptions of a particular scenario. The average dose to a member of the critical group is represented by the average of the doses for all members of the critical group, which in turn is assumed to represent the most likely exposure situation. For example, when considering whether it is appropriate to “release” a building that has been decontaminated (allow people to work in the building without restrictions), the critical group would be the group of employees who would regularly work in the building. If radiation in the soil is the concern, then the scenario used to represent the maximally exposed individual is that of a resident farmer. The assumptions used for this scenario are prudently conservative and tend to overestimate the potential doses. The added “sensitivity” of certain members of the population, such as pregnant women, infants, children, and any others who may be at higher risk from radiation exposures, are accounted for in the analysis (NRC, 2002).

1 mrem Dose Equals…

3 days of background radiation in Atlanta.

2 days of background radiation in Denver.

1 year of wearing a watch with a luminous dial.

1 coast-to-coast airline flight.

1 year of living next door to a normally operating nuclear power plant.

The radiation dose to an individual or to a group of people can be expressed as the total dose received or as a **dose rate**, which is dose per unit time (usually an hour or a year). The NRC has established a 0.25 mSv/year (25 mrem/year) total effective dose equivalent (TEDE) to an average member of the critical group as an acceptable criterion for release of any site for unrestricted use.

Collective dose is the total dose to an exposed population. Person-rem is the unit of collective dose. Collective dose is calculated by summing the individual dose to each member of a population. For example, if 100 workers each received 0.1 rem, then the collective dose would be 10 person-rem (100 × 0.1 rem).

Dose conversion factors are the factors used to convert estimates of radionuclide intake (by inhalation or ingestion) to dose. The external dose rate conversions used by the NRC are obtained directly from the USEPA Federal Guidance Report (FGR) No. 12[1] developed by Oak Ridge National Laboratory (Eckerman and Ryman, 1993). These factors provide the external effective dose equivalent by summing the product of individual organ doses and organ weighting factors over the body organs. For inhalation and ingestion of radioactive materials, unit CEDE conversion factors are obtained from USEPA Federal Guidance Report No. 11 (Eckerman et al., 1988). These factors are generally consistent with International Commission on Radiological Protection (ICRP) Publication 26 (1977) and ICRP Publication 30 (1979-1988) (NRC, 1992).

All estimates of dose presented in this Environmental Impact Report, unless specifically noted as something else, are total effective dose equivalents, which are quantified in terms of rem or millirem.

BACKGROUND RADIATION FROM NATURAL SOURCES

Natural background radiation comes from the following three sources:

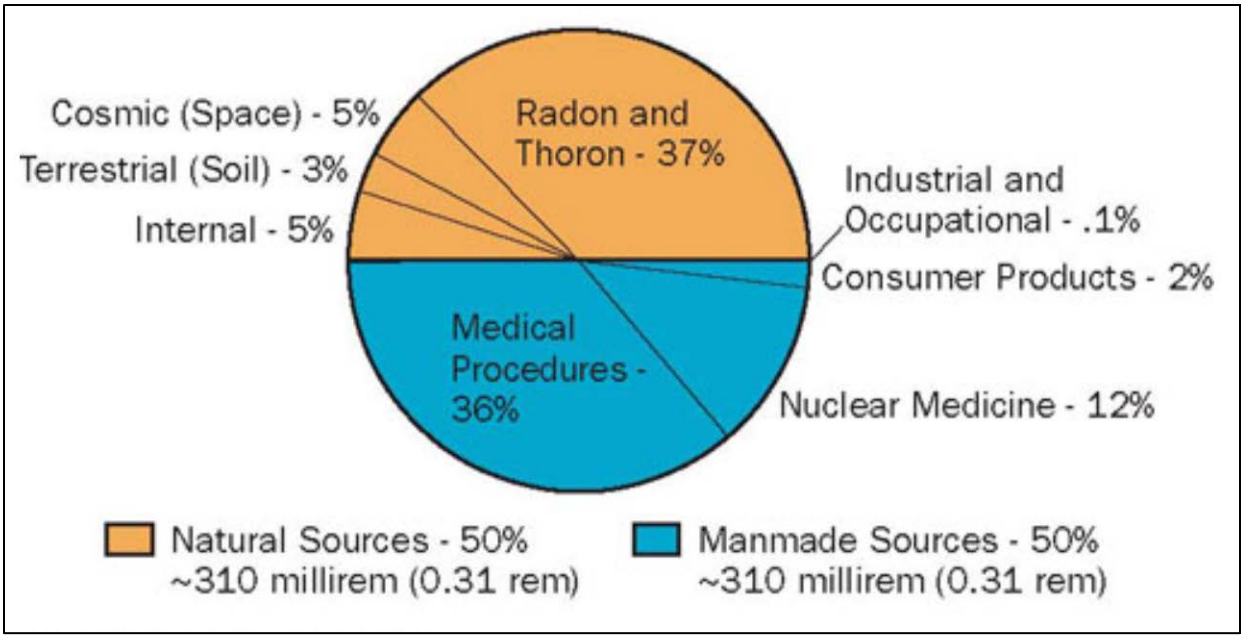
- **Cosmic Radiation.** The sun and stars send a constant stream of cosmic radiation to Earth. Differences in elevation, atmospheric conditions, and the Earth's magnetic field can change the amount of cosmic radiation exposure.
- **Terrestrial Radiation.** The Earth is a source of terrestrial radiation. Radioactive elements (e.g., uranium, thorium, and radium) exist naturally in the minerals in soils and rock. The atmosphere contains radon, which is responsible for most of the dose that people receive each year from natural sources. Water contains small amounts of dissolved uranium and thorium, and all organic matter (both plant and animal) contains radioactive carbon and potassium. Some of these materials are ingested with food and water, while others (such as radon) are inhaled.
- **Internal Radiation.** All people have internal radiation, mainly from radioactive potassium-40 and carbon-14 inside their bodies from birth. This internal radiation is a source of exposure to others.

There can be large variances in natural background radiation levels from place to place, as well as changes in the same location over time (USEPA, 2017). Nationwide, on average, members of the public are exposed to approximately 620 millirem per year from natural and manmade sources (National Council on Radiation Protection and Measurements [NCRP], 2009). Figure G4-

[1] FGR 12 was superseded by FGR 15 (Belamy, 2019) but the NRC has not yet updated.

3 shows the relative contributions of radiation sources to people living in the U.S. (NRC, 2017; NCRP, 2009).

Figure G4-3. Sources of Radiation Exposure



Source: NRC, 2017; NCRP, 2009.

As illustrated in the above figure, natural sources of radiation account for about 50 percent of radiation exposure in the U.S., while man-made sources account for the remaining 50 percent. The largest natural sources are radon-222 and its radioactive decay products in homes and buildings, which contribute approximately 229 millirem per year or 37 percent of the total annual dose. Additional natural sources include radioactive material in the Earth (primarily the uranium and thorium decay series, and potassium-40) and cosmic rays from space filtered through the atmosphere.

With respect to exposures resulting from human activities, medical exposure accounts for about 48 percent of the annual dose, and the combined doses from weapons testing fallout, consumer and industrial products, and air travel (cosmic radiation) account for the remaining 2 percent of the total annual dose. Nuclear fuel-cycle facilities contribute less than 0.1 percent (0.005 millirem per year per person) of the total dose (NRC, 2017; NCRP, 2009).

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Appendix G5

DOT 2008 Radiological Review

U.S. Department
of Transportation

Pipeline and Hazardous Materials Safety Administration

RADIOACTIVE MATERIAL

December 08

Regulations Review

Note: This document is for general guidance only and must not be used to determine compliance with 49 CFR Parts 100-185.

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I. INTRODUCTION

This review provides guidance on the Department of Transportation (DOT) Hazardous Materials Regulations (HMR) contained in Title 49, Code of Federal Regulations (49 CFR) Parts 171-185, which govern the packaging and shipment of radioactive material. These materials have an excellent safety record when packaged, labeled, marked and transported in accordance with these regulations.

This review serves as a reference document and is not an official interpretation or restatement of the regulations. This review of the radioactive material regulations was designed as a guidance document and should not be used without simultaneous reference to all applicable and current regulations pertaining to the transportation of radioactive material. **Users of this review are strongly encouraged to obtain the latest copy of the HMR** from the Government Printing Office (http://bookstore.gpo.gov). Amendments to the HMR are published in the Federal Register (http://www.gpoaccess.gov/fr/index.html). The current HMR may be found at: http://www.gpoaccess.gov/cfr/index.html.

Additional information on DOT's hazardous materials transportation regulations and programs may be found at http://hazmat.dot.gov.

The first version of this document was issued in 1972, with subsequent revisions issued in 1974, 1976, 1977, 1980, 1983, and 1998. This version updates the contents to be consistent with changes in the regulations since the last edition. These changes include those made in rulemaking RSPA-99-6283 (HM-230) to be compatible with changes contained in the International Atomic Energy Agency (IAEA) publication, "IAEA Safety Standards Series: Regulations for the Safe Transport of Radioactive Material," 1996 Edition, No. TS-R-1.

Comments, suggestions, corrections or requests for additional training aids should be mailed to: U.S. Department of Transportation, Office of Hazardous Materials Initiatives and Training, PHH-50, 1200 New Jersey Avenue, SE, Washington, DC 20590.

II. BACKGROUND

A. Uses of Radioactive Material

Radioactive materials are used for a wide range of purposes, including the generation of electric power, research, manufacturing, industrial processes, and medical diagnosis and therapy. Industrial applications of radioactive material include inspection and gauging operations such as examining the integrity of welded joints or measuring the thickness of paper as it is produced. Sealed radioactive sources are also used extensively in oil and gas exploration drilling operations and to check the compactness of roadbeds during paving operations. Every major hospital in the United States has a nuclear medicine department in which radionuclides are used to diagnose and treat a wide variety of diseases.

Millions of radioactive materials packages are shipped annually in the United States; a large percentage of these are radiopharmaceutical shipments. To date, there have been no known deaths or injuries to transport workers, emergency services personnel, or the general public as a result of the radioactive nature of materials in transport. This safety record can be attributed to the proper packaging of radioactive material and the effectiveness of the transportation safety standards and regulations.

B. Review of Radioactivity and Radiation

If there are too few neutrons or too many neutrons in the nucleus of an atom, the atom is unstable. Such an unstable atom will try to become more stable by emitting energy in the form of radiation, and it is said to be radioactive. When it emits radiation to become more stable, it is said to disintegrate or decay.

Each radioactive isotope has a specific known time in which half of the atoms will decay, called the "half-life," measured in years, days, hours, minutes or seconds. The activity of a radioactive material is the number of decays per unit of time measured in becquerels (Bq) (or curies (Ci)). The activity per unit mass is called the "specific activity," often measured in becquerels (or curies) per gram.

When an isotope decays, one or more of the following may be emitted:

- A particle consisting of two neutrons and two protons, called an alpha particle (α-radiation),
- Electrons or positrons, called beta particles (β-radiation),
- Electromagnetic energy in the form of gamma radiation (γ-radiation) or X-rays, and/or
- Neutrons.

Alpha radiation consists of high-energy particles that are relatively large, heavy, and only travel a short distance. Alpha particles lose their energy very rapidly, have a low penetrating ability and a short range of travel - only a few inches in air. Because of the alpha particle's short range and limited penetrating ability, external shielding is not required. A few inches of air, a sheet of paper, or the dead (outer) layer of skin that surrounds our bodies easily stops alpha particles. Alpha radiation poses minimal biological hazard outside the body. The greatest hazard from alpha-emitting material occurs when the material is inhaled, ingested, or absorbed through open wounds. Once inside the body, the alpha radiation can cause harm to individual cells or organs. Common alpha emitters transported include smoke detectors containing americium-241.

Beta radiation consists of particles that are smaller, lighter, and travel farther than alpha radiation. Beta radiation is more penetrating than alpha radiation. The range of penetration in human tissue is less than ¼ inch. In air, beta radiation can travel several feet. Beta radiation may be blocked or shielded by plastic, aluminum, thick cardboard, several layers of clothing or the walls of a building. Outside the body, beta radiation constitutes only a slight hazard. Because beta radiation penetrates only a fraction of an inch into living skin tissue, it does not reach the major organs of the body. However, exposure to high levels of beta radiation can cause damage to the skin and eyes. Internally, beta radiation is less hazardous than alpha radiation because beta particles travel farther than alpha particles and, as a result, the energy deposited by the beta radiation is spread out over a larger area. This causes less harm to individual cells or organs. Common beta emitters transported include medical isotopes such as iodine-131, carbon-14, tritium (H-3), and sulfur-35.

Gamma radiation frequently accompanies the emission of alpha and beta radiation. Gamma radiation, like X-rays, is electromagnetic radiation. This means that it does not consist of particles like alpha and beta radiation but, rather, waves of energy that have no mass and no electrical charge. Because they have no mass and no electrical charge, they are able to travel great distances and require dense material for shielding. Gamma radiation poses a hazard to the entire body because it can easily penetrate human tissue. Lead, steel, and concrete are commonly used to shield gamma radiation. Common gamma emitters transported include radiography sources such as cobalt-60 and iridium-192.

Neutron radiation can travel great distances and is highly penetrating like gamma radiation. Thus, neutron radiation is an external and internal hazard. It is best shielded with material having a high hydrogen content (e.g., water, plastic). The ease with which neutrons can be shielded and detected depends on their energy; fast neutrons can be shielded by hydrogenous material while cadmium or boron can be used to shield slow thermal neutrons. In transportation situations, neutron radiation is not commonly encountered. Neutron emitters transported include californium-252 and spent nuclear fuel.

C. Radiation Protection Principles

A key principle of radiation protection is the minimization of dose. The external dose received is the product of the dose rate and the time exposed. Dose from external radiation can be reduced by either:

- reducing the activity of the source,
- increasing shielding around the source
- increasing the distance from the source, or
- reducing the time spent near the source.

Transport packages provide distance and shielding from the contained material, as needed to maintain safe dose rates at the surface of the package. Transport packages also provide for containment of the radioactive material. If the containment is breached, the material can contaminate objects and potentially be inhaled or ingested by people. Contamination can be either fixed or removable. Removable, or non-fixed contamination, is contamination that is deposited on the surface of objects or personnel that can readily be picked up or wiped up by physical or mechanical means during a survey or through decontamination efforts. Fixed contamination is bound to the contaminated surface and not easily removed and so presents primarily a radiation hazard and not a contamination hazard.

D. SI and Customary Radiological Units

To ensure compatibility with international transportation standards, units of measure in the HMR are expressed using International System of Units (SI) units. U.S. standard or customary units, which appear in parentheses following the SI units, are for informational purposes only and are not intended to be the regulatory standard. Shipping papers and labels must use the International System of Units (SI) units, which may be followed by customary units in parentheses.

The basic SI unit for quantity of radioactive material is the becquerel (Bq), and the customary unit is the curie (Ci). One becquerel is equivalent to one atom decaying (or disintegrating) each second. A curie (Ci), originally defined as the activity of 1.0 g of radium, is equal to 3.7×10^{10} Bq.

For radiation levels, or dose rates, the basic SI unit is the sievert per hour (Sv/h), and the customary unit is rem per hour (rem/h). The information in Appendix A may be useful in converting values between SI Units and customary units.

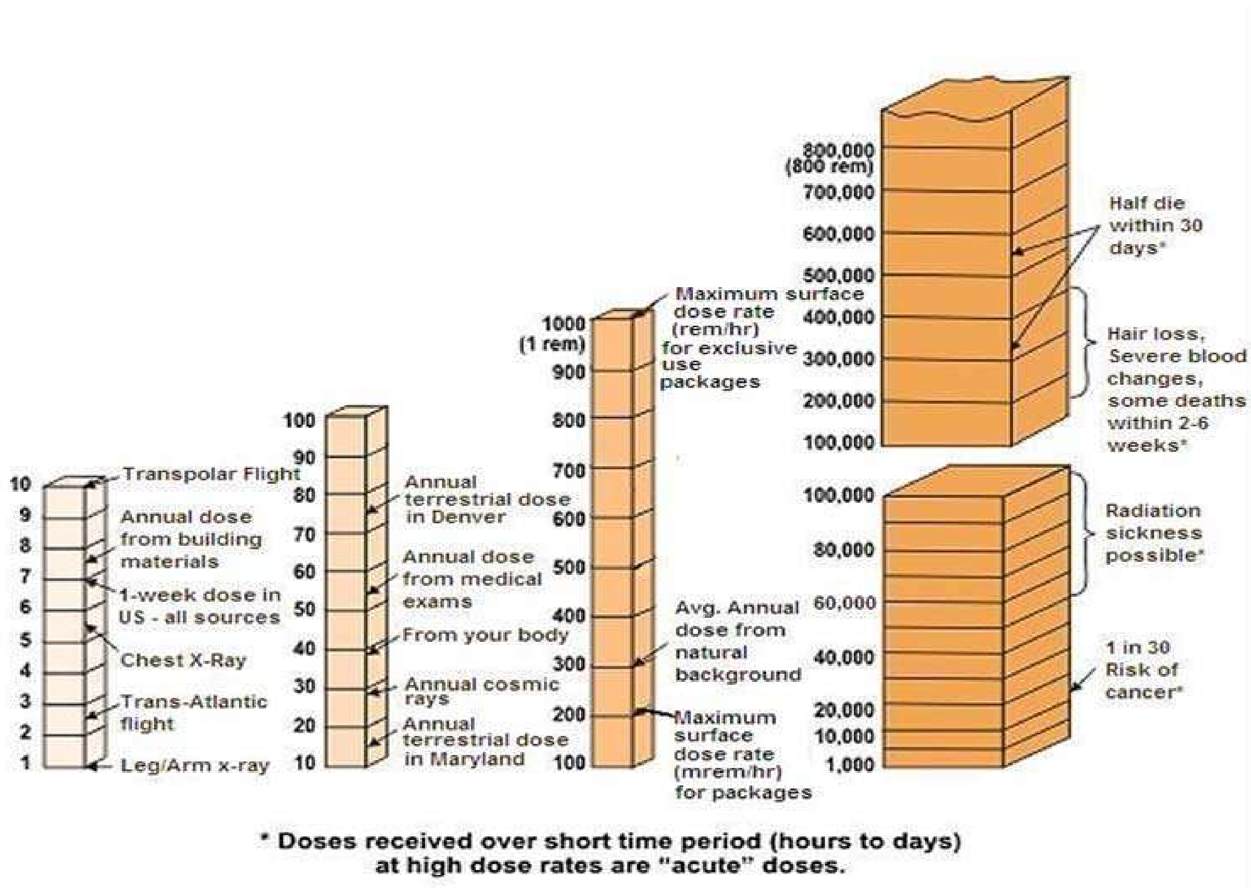
E. Radiation Exposures and Biological Effects

The average annual radiation exposure from natural sources to an individual in the United States is about 3 millisieverts (mSv) (equivalent to 300 millirem (mrem)); however, levels of background radiation vary greatly from one location to the next. Radon gas accounts for two-thirds of this exposure, while cosmic, terrestrial, and internal radiation account for the remaining third. Man-made sources of radiation from medical, commercial, and industrial activities contribute about another 0.6 mSv (60 mrem) annually, with diagnostic medical procedures accounting for about 0.4 mSv (40 mrem) of this. Consumer products such as tobacco, fertilizer, welding rods, gas mantles, luminous watch dials, and smoke detectors contribute another 0.1 mSv (10 mrem) to annual radiation exposure.

Radiation is known to be carcinogenic at high doses. The association between radiation exposure and the development of cancer is mostly based on populations exposed to high levels of radiation. Currently there are no data to unequivocally establish the occurrence of cancer following exposure to low doses and dose rates, i.e., those below about 100 mSv (10,000 mrem). However, it is conservatively assumed that any amount of radiation exposure may pose some risk for causing cancer and hereditary effects, and that the risk is higher for higher radiation exposures.

The following figure provides some radiation doses in perspective.

Figure 1 – Radiation Doses In Perspective
(in millirem)



III. TRANSPORT SAFETY REGULATIONS

A. International Regulations

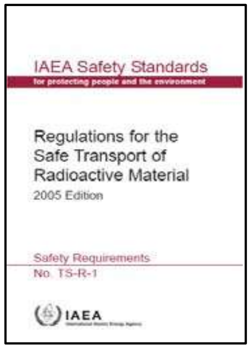
There are a number of international bodies and organizations which deal with the transportation of radioactive material. The majority of these international bodies are sanctioned by or affiliated with the United Nations (UN). These agencies write regulations and recommend their adoption by member states as a basis for national regulations. Additional information on international standards may be found at: http://hazmat.dot.gov/regs/intl/intstandards.htm. A list of suppliers of these documents may be found at: http://hazmat.dot.gov/regs/intl/interpub.htm.

1. United Nations

The United States participates as a member of the United Nations (UN) Committee of Experts on the Transportation of Dangerous Goods which produces the "Recommendations on the Transport of Dangerous Goods - Model Regulations" commonly referred to as the UN "Orange Book." The Model Regulations cover principles of classification and definition of classes, lists of the principal dangerous goods, general packing requirements, testing procedures, marking, labeling or placarding, and transport documents. There are, in addition, special requirements related to particular classes of goods, including performance standards for packaging. Although only recommendations, the Model Regulations are written in the mandatory sense (i.e., the word "shall" is used rather than "should") in order to facilitate direct use of the Model Regulations as a basis for national and international transport regulations.

The United Nations Economic Commission for Europe (UNECE) publishes "European Agreement Concerning the International Carriage of Dangerous Goods by Road" (ADR). The UNECE also coordinates the ADR with the "Regulations Concerning the International Carriage of Dangerous Goods by Rail" (RID) (produced by the Intergovernmental Organisation for International Carriage by Rail) which regulate rail shipments in Europe.

2. International Atomic Energy Agency

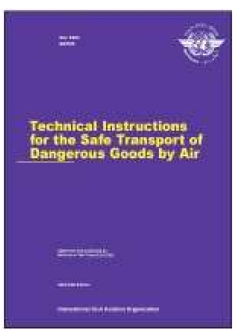


Beginning in the 1950s, there was an effort to develop an international consensus on how radioactive materials should be transported. The initial effort relied heavily on the standards used in the United States, which at that time were found in the Bureau of Explosives regulations. The first publication of the international standards was the 1961 edition of Regulations for the Safe Transport of Radioactive Materials, Safety Series No. 6, issued by the International Atomic Energy Agency (IAEA). The 1967 edition of Safety Series No. 6 was adopted into the domestic regulations in 1968. Since that time, the United States has continued to incorporate these standards (with certain exceptions) into its domestic regulations.

3. International Maritime Organization

The International Maritime Organization (IMO) implements the UN recommendations in the International Maritime Dangerous Goods (IMDG) Code. The IMDG Code contains regulations applicable to the transport of dangerous goods by sea. If all or part of a shipment of hazardous materials is made by vessel to, from, or within the United States, the HMR allow the shipment to be made in accordance with the IMDG Code, provided certain additional provisions are satisfied. These additional provisions are found in 49 CFR, §§ 171.22, 171.23, and 171.25.

4. International Civil Aviation Organization



The International Civil Aviation Organization's "Technical Instructions on the Safe Transport of Dangerous Goods by Air" (ICAO TI) establishes requirements necessary to ensure hazardous materials are safely transported in aircraft while providing a level of safety that protects the aircraft and its occupants from undue risk. The ICAO TI is based on the UN Recommendations on the Transport of Dangerous Goods and the International Atomic Energy Agency Regulations for the Safe Transport of Radioactive Material.

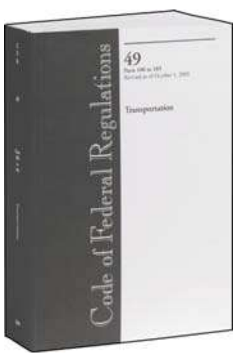
Virtually all shipments of hazardous materials transported internationally by air, as well as most domestic U.S. shipments, are transported in accordance with the ICAO TI. The U.S. Hazardous Materials Regulations authorize transport in accordance with the ICAO TI provided all of the conditions of 49 CFR §§ 171.22, 171.23, and 171.24 are met. Note that shipments made in accordance with the ICAO TI remain subject to Part 175 of the HMR and the emergency response information provisions of Subpart G of Part 172.

Air carriers have adopted their own regulations through the International Air Transportation Association (IATA). These IATA dangerous goods regulations are based on the ICAO TI, but they are generally more restrictive in certain operational respects. Most domestic carriers have chosen to only accept shipments prepared under the ICAO TI as implemented by the IATA.

B. Federal Regulations

The regulations of the United States of America concerning the transportation of radioactive materials are published by four agencies: DOT, the Nuclear Regulatory Commission (NRC), the Transportation Security Administration (TSA), and the United States Postal Service (USPS).

1. Department of Transportation



The Secretary of the Department of Transportation has the authority to regulate the transportation of hazardous materials per the Hazardous Materials Transportation Act (HMTA), as amended and codified in 49 U.S.C. 5101 et seq. The Secretary is authorized to issue regulations to implement the requirements of the statute.

DOT’s Pipeline and Hazardous Materials Safety Administration (PHMSA) (formerly the Research and Special Programs Administration (RSPA)) has been delegated the responsibility for the hazardous materials regulations, which are contained in 49 CFR Parts 100-185.

The hazardous materials regulations have changed significantly over the last several years. These changes include the harmonization of the United State's hazardous materials regulations with international standards, extension of the applicability of the hazardous materials regulations to all intrastate shipments of hazardous materials by highway, and the introduction of additional security requirements.

The hazardous materials regulations are applicable to the transportation of hazardous materials in commerce and apply to the following activities:

- Transport by interstate, intrastate, and foreign carriers by rail car, aircraft, motor vehicle and vessel.
- Shipper's pre-transportation activities to present for shipment a hazardous material in a package, container, rail car, aircraft, motor vehicle or vessel with accompanying marking, labeling, placarding and shipping papers.
- The manufacture, fabrication, marking, maintenance, reconditioning, repairing or testing of a package or container which is represented, marked, certified or sold for use in the transportation of hazardous materials.

The HMR defines nine Classes of hazardous materials. Radioactive material is Class 7.

The Parts of the HMR are as follows:

- 49 CFR 171 General information, regulations, and definitions
- 49 CFR 172 Hazardous materials table, special provisions, hazardous materials communications, emergency response information, and training requirements
- 49 CFR 173 Shippers-general requirements for shipments and packagings
- 49 CFR 174 Carriage by rail
- 49 CFR 175 Carriage by aircraft
- 49 CFR 176 Carriage by vessel
- 49 CFR 177 Carriage by public highway
- 49 CFR 178 Specifications for packagings
- 49 CFR 179 Specifications for tank cars
- 49 CFR 180 Continuing qualification and maintenance of packagings

Sections of the HMR specific to radioactive materials are:

- 49 CFR 173, Subpart I (§§ 173.401 – 173.477) Class 7 (Radioactive) Materials
- 49 CFR 174, Subpart K (§§ 174.700 – 174.750) Detailed Requirements for Class 7 (Radioactive) Materials
- 49 CFR 175, Subpart C, (§§ 175.700 – 175.706) Specific Regulations Applicable According to Classification of Material
- 49 CFR 176, Subpart M (§§ 176.700 – 176.720) Detailed Requirements for Radioactive Materials
- 49 CFR 177, Subpart B, (§§ 177.842) Class 7 (Radioactive) Material
- 49 CFR 178, Subpart K (§§ 178.350 – 178.360) Specifications for Packagings for Class 7 (Radioactive) Materials

DOT’s Federal Motor Carrier Safety Administration (FMCSA) has additional requirements for transporting radioactive materials by highway. FMSCA provides routing requirements for motor carriers and drivers who transport radioactive material in 49 CFR Part 397, Subpart D. FMCSA also requires motor carriers to obtain a Hazardous Materials Safety Permit (HMSP) prior to transporting certain highly hazardous materials, including a highway route controlled quantity of radioactive material (see 49 CFR 385, Subpart E).

2. Nuclear Regulatory Commission

Under the Atomic Energy Act of 1954, as amended, the NRC also has responsibility for safety in the possession, use and transfer (including transport) of by-product, source, and special nuclear materials, i.e., “licensed material.” Due to this overlap in statutory authorities of NRC and DOT, the two Agencies signed a 1979 Memorandum of Understanding (MOU) with regard to regulation of the transport of radioactive material. The principal objective of the MOU was to avoid conflicting and duplicative regulations and to clearly delineate the areas in which each Agency establishes regulations.

Except for certain small quantities and specific products, a license is required from the NRC for possession and use of licensed materials. The NRC has promulgated, in 10 CFR Part 71, requirements which must be met by licensees for packaging used to deliver certain types of licensed material to a carrier for transport if fissile material or quantities exceeding Type A are involved. NRC also assists and advises DOT in the establishment of both national and international safety standards and in the review and evaluation of packaging designs. In 1979, NRC adopted by reference (10 CFR § 71.5) portions of the DOT regulations, enabling NRC to inspect its licensees for compliance with DOT regulations applicable to shipper/licensees and to take enforcement actions on violations.

Many states have entered into formal agreements with the NRC whereby the NRC transfers to states the regulatory authority over licensed by-product, source, and less than critical quantities of special nuclear material (fissile materials). These 35 Agreement States (and 3 states that have filed intent to become Agreement States) are illustrated in Figure 2**.**

Figure 2 – NRC Agreement States
(Source: Nuclear Regulatory Commission)

3. Transportation Security Administration

Under the Aviation and Transportation Security Act (ATSA), Public Law 107-71, 115 Stat. 597 (November 19, 2001), and delegated authority from the Secretary of Homeland Security (DHS), the Assistant Secretary of DHS for the Transportation Security Administration (TSA) has broad responsibility and authority for “security in all modes of transportation". TSA's authority with respect to transportation security is comprehensive and supported with specific powers related to the development and enforcement of regulations, security directives, security plans, and other requirements. On September 28, 2004, DOT and DHS signed a Memorandum of Understanding (MOU) on Roles and Responsibilities and on August 7, 2006, PHMSA and TSA signed an annex to the MOU. The MOU recognizes that DHS has primary responsibility for security in all modes of transportation.

4. United States Postal Service

The carriage of U.S. mail by the Postal Service (USPS) is not subject to the HMR as commercial carriers are. However, for legal and safety reasons, the postal mailing standards for hazardous materials not only closely adhere to the HMR, but also include many additional limitations and prohibitions. Radioactive materials are prohibited in domestic mail via air transportation. Quantities of radioactive material in excess of those authorized in USPS Publication 52, “Hazardous, Restricted, or Perishable Mail” are prohibited in surface mail. For international mail, the standards in Section 135.6 of the “Mailing Standards of the United States Postal Service, International Mail Manual” apply.

IV. RADIOACTIVE MATERIALS TERMINOLOGY

This section explains the various terms used to define and categorize radioactive materials in the HMR. The regulatory definitions for these terms and other terms specific to radioactive materials transportation may be found in § 173.403; other terms used throughout the HMR are defined in § 171.8.

A. Radioactive Material

Prior to 2004, the HMR used a specific activity threshold of 70 Bq/g (0.002 μCi/g) for defining a material as radioactive for purposes of transportation, and material was not subject to the requirements of the HMR if its specific activity was equal to or below that value. In 2004, the HMR was revised and the single activity concentration threshold of 70 Bq/g was replaced with radionuclide-specific values. In addition, the 2004 revision established threshold values for the total activity in a consignment, below which the risk is so small that the material could be transported without being subject to transportation regulatory requirements ("consignment" means a package or group of packages or load of radioactive material offered by a person for transport in the same shipment). To be considered a radioactive material under the HMR, the material must exceed ***both*** the nuclide specific exemption concentration limit ***and*** the consignment exemption activity limit.

These nuclide specific values are given in § 173.436. Those nuclides shown with a reference to footnote (b) have the activity of their daughters included, and therefore, shippers need only compare the activity and activity concentration of the parent nuclide to the exemption value. If the daughter products are not included, or if other radionuclides are present, the mixture of nuclides must be evaluated using the equations in §§ 173.433(d)(6) and (7) to determine if the material is radioactive material under the HMR. (Some materials which may be exempt from regulation during transportation still might be subject to licensing requirements of NRC, or an Agreement State with respect to use, possession, materials control or waste disposal; or they may be subject to EPA requirements as a hazardous substance or hazardous waste.)

For example, using § 173.436, it can be seen that ^{241}Am has a concentration exemption value of 1 Bq/gram (g) and a consignment activity exemption value of 10,000 Bq. Therefore, a material containing ^{241}Am would be regulated as radioactive material if it is shipped with more than 10,000 Bq in a single consignment ***and*** in a concentration greater than 1 Bq/g.

B. Special Form Radioactive Material

Special form materials are those materials which, if released from a package, would present a hazard due to direct external radiation only. Usually, due to the high physical integrity of a special form material, radioactive material contamination is not expected even under severe accident conditions. Therefore, larger quantities can typically be shipped in any given package than if the material were not special form (i.e., “normal form”). This high physical integrity is occasionally the result of inherent natural properties of the material, such as its being in an indispersible solid form. Most often, however, it is an acquired characteristic, resulting from being welded (encapsulated) into an extremely durable metal capsule.

Special form sources must have at least one external physical dimension which exceeds 5 mm (0.197”). The minimum dimension requirement makes the capsule easier to see and recover in the event of its release from the package during an accident. Special form encapsulations are required to be constructed in a manner that they can only be opened by destroying the capsule. This requirement prevents the inadvertent loosening or opening of the capsule, either during transport or following an accident.

The testing requirements for determination of whether radioactive materials qualify as “special form” are found in § 173.469, which describes tests for high temperature, impact, percussion, bending, and leakage. (An encapsulated sealed source need not be subjected to the impact and percussion tests of § 173.469(b)(1) and (2), provided that it satisfies the Class 4 impact test prescribed in International Standards Organization (ISO) document ISO 2919, Sealed Radioactive Sources Classification. Also, it need not be subjected to the heat test listed in § 173.469(b)(4) if it satisfies the Class 6 temperature test specified in ISO 2919.)

For the purposes of import or export, a shipper must furnish the carrier and the foreign consignee a Certificate of Competent Authority for the special form material. For domestic shipments, the DOT does not require special form certificates when offering the material as special form. However, the shipper must have evidence that the source, if offered as special form radioactive material, meets the special form standards. Such evidence must be maintained on file by the shipper for at least one year after shipment in accordance with § 173.476(a).

A special form certificate issued by the DOT or by a foreign competent authority is acceptable evidence of a source being special form. Special form source manufacturers or suppliers often provide customers with special form Certificates of Competent Authority. The requirements for certification of special form sources are listed in § 173.476.

Figure 3 displays several typical special form radioactive material sources.

Figure 3- “Special Form” Radioactive Material

Figure A - Neutron Source
(showing empty inner and outer capsules with plugs to be welded for sealing)

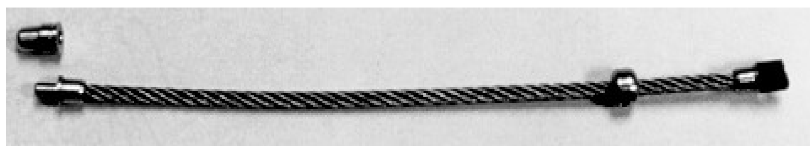


Figure B - Industrial Radiography Source
(with 15 cm connector cable “pigtail”)

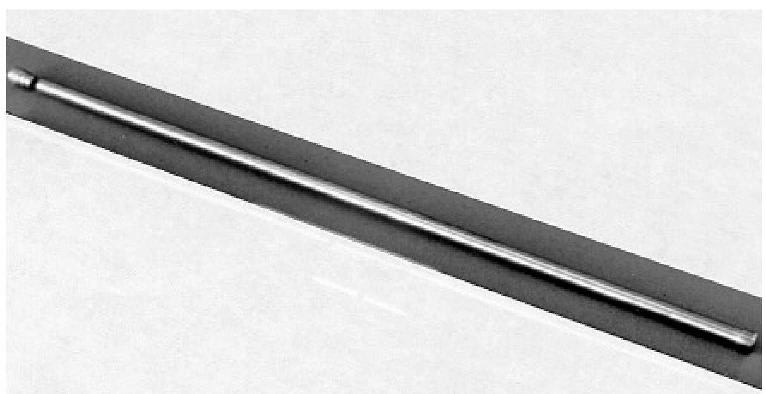
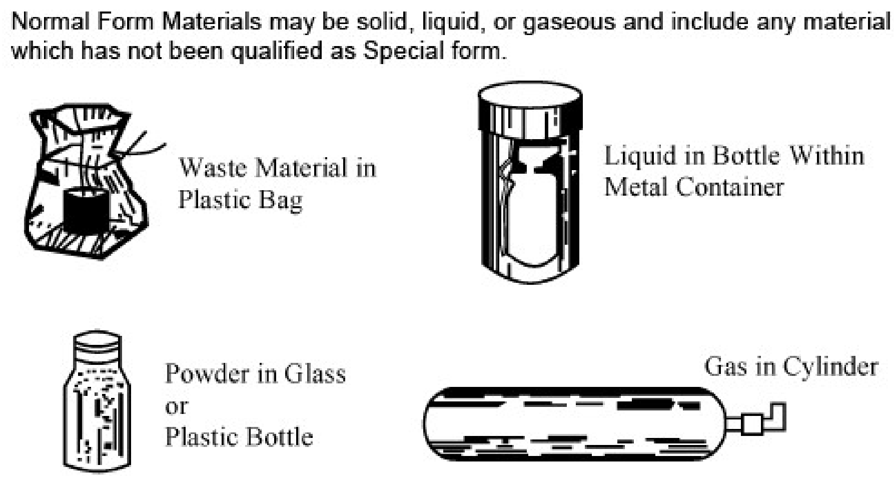


Figure C - Industrial Radiography Source Sterilizer/Process Irradiator Source

C. Normal Form Radioactive Material

Normal form radioactive material means a radioactive material which does not qualify as a “special form material”. Illustrated in Figure 4 are typical physical forms for normal form radioactive material.

Figure 4- “Normal Form” Radioactive Material



D. A_1 and A_2 Quantity Limits

A_1 and A_2 are quantities of radioactivity which are used in the regulations to determine such things as the type of packaging necessary for a particular radioactive material shipment. Each radionuclide is assigned an A_1 and an A_2 value. **A_1** applies to **special form** and **A_2** applies to **normal form** material; A_1 is the maximum activity of special form material that is permitted in a type of package called a Type A package, and A_2 is the maximum activity of normal form radioactive material that is permitted in a Type A package.

A_1 and A_2 values have been determined for most common radionuclides and are listed in the table in § 173.435 (instructions are provided in § 173.433 for unlisted radionuclides and § 173.433(d) details how to determine Type A quantities for mixtures of radionuclides). For each radionuclide, both the A_1 value for materials in special form and the A_2 value for materials in normal form are listed in terabecquerels (TBq) and curies (Ci) (the values in curies are approximate and for information only; the regulatory standard units are terabecquerels, equal to 10^{12} becquerels). Table 1 gives examples of A_1 and A_2 values for a number of typical radionuclides.

Table 1 - Type A Package Quantity Limits for Selected Radionuclides

Symbol of radionuclide	Element and Atomic number	A_1 TBq (Ci) (Special Form)	A_2 TBq (Ci) (Normal Form)
^{14}C	Carbon (6)	40 (1100)	3 (81)
^{137}Cs	Cesium (55)	2 (54)	0.6 (16)
^{226}Ra	Radium (88)	0.2 (5.4)	0.003 (0.081)
^{60}Co	Cobalt (27)	0.4 (11)	0.4 (11)
^{192}Ir	Iridium (77)	1 (27)	0.6 (16)
Thorium (Natural)	Thorium (90)	Unlimited	Unlimited
Uranium (Natural)	Uranium (92)	Unlimited	Unlimited
Uranium (Enriched 20% or less and unirradiated)	Uranium (92)	Unlimited	Unlimited
^{99}Mo	Molybdenum (42)	1 (27)	0.6 (16) {0.74 TBq (20 Ci) for domestic shipments}

The A_1 and A_2 values are used in the regulations as a normalized measurement of radiological risk for all radionuclides. Their uses go beyond the activity limits for Type A packages. Other uses involving large multiples of A_1 or A_2 or different fractions of A_1 or A_2 include the following:

- Special routing of packages with large quantities,
- Total activity in packages and conveyances,
- Designating the limits for packages excepted from most requirements, and
- Designating the specific activity of a contaminated material and associated packaging.

The derivation of the A_1 and A_2 values in the IAEA regulations is based on a series of dosimetric models. The limiting value for A_1 results from the worst case assumptions of external direct γ radiation levels from an unshielded source at a certain distance. Generally, the A_1 value for a radionuclide is the quantity of that radionuclide that will result in a dose rate of 0.1 Sv/h (10 rem/h) at a distance of 1 meter. The A_2 value, however, is based on the applicability of the most conservative worst case value for five different scenarios, which include the A_1 scenario plus external β radiation to skin, inhalation, ingestion, and external γ radiation from immersion in a gaseous cloud of material released from a breached package.

As a result of a limitation established by the IAEA, no radionuclides have been assigned A_1 or A_2 values greater than 40 TBq (1,080 Ci). However, based on their low specific activity and low toxicity, some radionuclides have been assigned "unlimited" A_1 and A_2 values.

E. Excepted Quantities

When a small fraction of the A_1 or A_2 activity is being shipped, some shipments are excepted from some of the requirements of the HMR and can be shipped in an "excepted package" (see Section V.B). The following types of materials may be eligible for such exceptions:

- limited quantity of radioactive material
- radioactive instruments or articles
- articles manufactured from natural or depleted uranium or natural thorium
- empty packagings.

A "limited quantity of radioactive material" is a quantity of radioactive material that does not exceed the material's package limits specified in § 173.425 (see Table 2) and conforms to the requirements specified in § 173.421.

"Radioactive instruments or articles" are manufactured items such as instruments, clocks, electronic tubes, gauges, smoke detectors, electronic apparatus or similar devices having radioactive material in gaseous or non-dispersible solid form as a component part. Allowance is made for the additional protection provided by the structure of the instrument or article and they are considered excepted quantities if they do not exceed the limits in § 173.425 (see Table 2) and conform to the requirements specified in § 173.424. As shown in Table 2, there are two sets of limits: one for the item and another for the package.

Table 2 - Activity Limits for Limited Quantities, Instruments, and Articles

Nature of contents	Instruments and articles		Limited quantity package limits[1]
	Limits for each instrument or article[1]	Package Limits[1]	
Solids:			
Special Form	10^{-2} A_1	A_1	10^{-3} A_1
Normal Form	10^{-2} A_2	A_2	10^{-3} A_2
Liquids:			
Tritiated water:			
<0.0037 TBq/L (0.1 Ci/L)			37 TBq (1,000 Ci)
0.0037 TBq to 0.037 TBq/L (0.1 Ci to 1.0 Ci/L)			3.7 TBq (100 Ci)
>0.037 TBq/L (1.0 Ci/L)			0.037 TBq (1.0 Ci)
Other Liquids	10^{-3} A_2	10^{-1} A_2	10^{-4} A_2
Gases:			
Tritium[2]	2×10^{-2} A_2	2×10^{-1} A_2	2×10^{-2} A_2
Special Form	10^{-3} A_1	10^{-2} A_1	10^{-3} A_1
Normal Form	10^{-3} A_2	10^{-2} A_2	10^{-3} A_2

[1]For mixtures of radionuclides see § 173.433(d).
[2]These values also apply to tritium in activated luminous paint and tritium adsorbed on solid carriers.

A manufactured article in which the sole radioactive material is natural uranium, unirradiated depleted uranium, or natural thorium may be transported in any quantity in an excepted package. This is under the condition that the outer surface of the uranium or thorium is enclosed in an inactive sheath of metal or some other durable protective material as stated in § 173.426.

The empty packaging provisions in § 173.428 provide exceptions for a radioactive material packaging which has been emptied of its radioactive contents as far as practicable, but still contains residual radioactivity. The residual radioactivity limit on internal contamination is 100 times the removable (non-fixed) contamination limits for exterior package surfaces. Wipe contamination sampling techniques are often not practical or feasible for the interior of the containment system of some radioactive material packages; if total (fixed and non-fixed) can be measured, and is below the limit, then the non-fixed component would be below the limit. If it cannot be demonstrated that the non-fixed contamination is less than 100 times the limits in § 173.443, the empty classification cannot be used.”

F. Highway Route Controlled Quantities (HRCQ)

"Highway route controlled quantity" is defined as a quantity of radioactive material within a single package which exceeds:

- 3,000 times the A_1 value of the radionuclides for special form material or 3,000 times the A_2 value of the radionuclides for normal form material; or
- 1,000 TBq (27,000 curies), whichever is less.

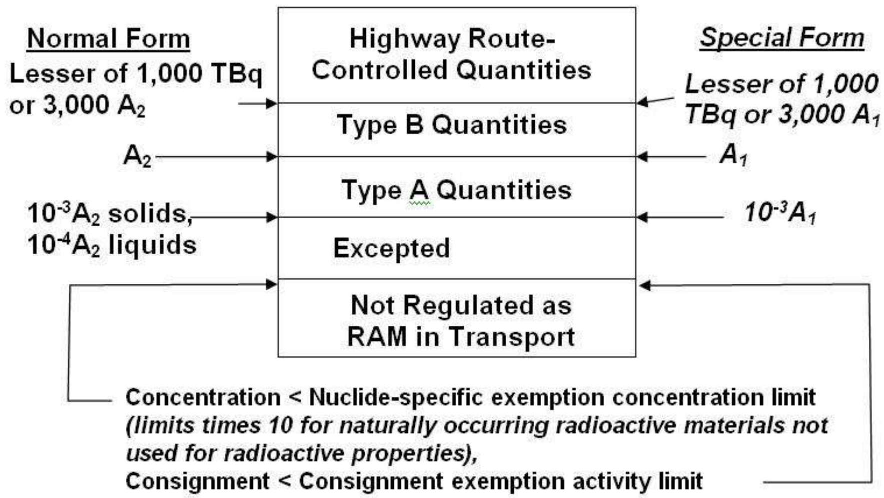
For example, consider a package which contains 777 TBq of cobalt-60 in special form. The A_1 value for cobalt-60 is 0.4 TBq. Since 3,000 times 0.4 TBq = 1,200 TBq and this is greater than 1,000 TBq, the 777 TBq quantity should be compared to 1,000 TBq. Since the amount in the package does not exceed 1,000 TBq, the amount in the package is not an HRCQ.

It is important to note that HRCQ shipments can be made by all modes of transport, not just by highway. If a package contains a quantity in excess of the HRCQ definition, it is an HRCQ shipment, regardless of the mode used.

There are specific requirements for the highway routing of HRCQ shipments as discussed in Section XI of this document. In addition, § 173.22(c) requires shippers of highway route controlled quantities to notify the consignee of the expected arrival date and any special loading/unloading requirements.

Figure 5 illustrates HRCQ in relation to the other categories of radioactive materials discussed previously.

Figure 5 - Material Quantity Categories



G. Low Specific Activity (LSA) Material

Low specific activity (LSA) material is radioactive material that has a low activity per unit mass (specific activity). LSA material is divided into three groups of increasing specific activities: LSA-I, LSA-II, and LSA-III. Most LSA materials have a characteristic of presenting limited radiation hazard, because of their relatively low concentration of radioactivity. When the specific activity of an LSA material is computed, the radioactivity is divided by the mass of material in which the radioactivity is distributed; the mass of the packaging that may surround the LSA is excluded from the calculation.

LSA-1 generally consists of unirradiated natural or depleted uranium and thorium compounds and processing ores, other radionuclides with unlimited A_2 values, or material with a specific activity not exceeding 30 times the exempt concentration. The radioactive concentration is such that a person cannot physically breathe or ingest enough of the material to give significant radiation exposures.

LSA-II material includes material for which the average specific activity does not exceed 10^{-4} A_2/g for solids and gases and 10^{-5} A_2/g for liquids. The activity must be distributed throughout the material. For water with tritium, the concentration limit is 0.8 TBq/L.

LSA-III material consists of solids in which radioactive material is distributed throughout, or is essentially uniformly distributed in a solid binding agent such as concrete, bitumen, or ceramic. It must be relatively insoluble with a leach rate of 0.1 A_2, or less, per week and have a specific activity not exceeding 2×10^{-3} A_2/g. Test requirements for LSA-III material are given in § 173.468.

The quantity of LSA material in a single package must be restricted so that the external radiation level from the unshielded material does not exceed 10 mSv/h (1 rem/h) at 3 meters from the unshielded material.

The definitions of LSA-I, LSA-II, and LSA-III all use the term "*distributed throughout*". The definition of LSA-III also uses "*essentially uniformly distributed*". "*Distributed throughout*" means that the activity should not be localized in small portions of the volume of the material, but there may be some degree of non-homogeneity. In LSA-III, "*essentially uniformly distributed"* in a solid compact binding agent indicates a greater degree of homogeneity. While not defined in the regulations, activity *distributed throughout* should not vary by more than a factor of 10 and activity *essentially uniformly distributed* should not vary by more than a factor of 3.

Further information on shipment of LSA materials is provided in Section VII of this document.

H. Surface Contaminated Objects (SCO)

A surface contaminated object (SCO) is a solid object which is not itself radioactive but which has *radioactive material* distributed on its surfaces (rather than distributed within the material as for LSA materials). There are two categories of SCO, and SCO-II allows for higher contamination levels than SCO-I. The limits for the categories are shown in Table 3.

Table 3 - Contamination Limits for SCOs

Contamination Type	Limits in Bq/cm^{2*}		Limits in $\mu Ci/cm^{2*}$	
On Accessible Surfaces	**SCO-I**	**SCO-II**	**SCO-I**	**SCO-II**
Non-fixed, most α	0.4	40	10^{-5}	10^{-3}
Non-fixed, β, γ, low-toxicity α**	4.0	400	10^{-4}	10^{-2}
Fixed, most α	4×10^{3}	8×10^{4}	0.1	2.0
Fixed, β, γ, low-toxicity α**	4×10^{4}	8×10^{5}	1.0	20
On Inaccessible Surfaces	**SCO-I**	**SCO-II**	**SCO-I**	**SCO-II**
Fixed + non-fixed, most α	4×10^{3}	8×10^{4}	0.1	2.0
Fixed + non-fixed, β, γ, low-toxicity α**	4×10^{4}	8×10^{5}	1.0	20

* Contamination values are to be averaged over 300 cm^2, or the area of the surface if it is less than 300 cm^2.

** Low toxicity alpha emitters means natural uranium; depleted uranium; natural thorium; uranium-235 or uranium-238; thorium-232; thorium-228 and thorium-230 when contained in ores or physical and chemical concentrates; and alpha emitters with a half-life of less than 10 days.

SCO-II limits exceed SCO-I limits by a factor of twenty, except for non-fixed contamination on accessible surfaces of objects, in which case, the SCO-II limits exceed SCO-I by a factor of 100. For both SCO-I and SCO-II, the beta, gamma and low-toxicity alpha limits are a factor of ten greater than the limits for other alpha contamination. For inaccessible surfaces of both SCO-I and SCO-II, the total fixed plus non-fixed contamination limits are the same as the fixed contamination limits on accessible surfaces of both SCO-I and SCO-II.

The quantity of SCO in a single package must be restricted so that the external radiation level from the unshielded material does not exceed 10 mSv/h (1 rem/h) at 3 meters from the unshielded material.

The definition of SCO uses several terms which must be understood to properly categorize an item as an SCO. These terms are: *contamination, fixed radioactive contamination, non-fixed radioactive contamination, accessible surfaces,* and *inaccessible surfaces*.

Contamination means the presence of a radioactive substance on a surface in quantities in excess of 0.4 Bq/cm^2 for beta and gamma emitters and low toxicity alpha emitters or 0.04 Bq/cm^2 for all other alpha emitters. Contamination exists in two phases:

- *Fixed radioactive contamination* means radioactive contamination that cannot be removed from a surface during normal conditions of transport.

- *Non-fixed radioactive contamination* means radioactive contamination that can be removed from a surface during normal conditions of transport.

An *accessible surface* is any surface which can readily be wiped by hand, using standard radiation-measuring techniques; any other surface is an *inaccessible surface*. Examples of *inaccessible surfaces* are:

- Inner surfaces of pipes the ends of which have been securely closed with end plugs or caps;
- Inner surfaces of equipment which are suitably blanked off or formally closed;
- Interiors of glove boxes with access ports blanked off.

A solid object which is not radioactive that has contamination on its surface is not an SCO unless the contamination is in sufficient quantity to meet the definition of radioactive material. The radioactive material definition given in §173.403 notes that to be considered radioactive material, the material must exceed both the nuclide specific exemption concentration limit and the consignment exemption activity limits. Thus, if the total activity of the contamination on the surface of items in a consignment does not meet the consignment limit needed to meet the definition of radioactive material, those items, while slightly contaminated, would not be considered to be SCO.

Problems in determining the proper classification for an object with surface contamination may involve methods of measuring the non-fixed and fixed contamination and determining whether the surfaces should be considered accessible or inaccessible. The joint DOT/NRC document "Categorizing and Transporting Low Specific Activity Materials and Surface Contaminated Objects" (NUREG-1608) provides guidance on these issues (available online at http://www.rampac.energy.gov/NRCinfo/NUREG_1608.pdf).

Further information on shipment of SCO materials is provided in Section VII.

I. Fissile Material

Fissile material is material that has the capability of undergoing nuclear fission with the potential to produce a criticality event which would result in significant releases of radiation and heat. Thus, fissile material requires additional package design considerations and controls to assure nuclear criticality safety during transport. Fissile material is defined as plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. The definition applies to the nuclides themselves and not the material containing them. For example, fissile mass restrictions in the regulations apply to the mass of uranium-235 and not to the mass of uranium metal containing the uranium-235. While there are other nuclides that are fissionable, the HMR only regulates as fissile material those materials that are capable of having a sustained criticality by accumulation of mass alone. Therefore, the fissile material definition does not apply to unirradiated natural uranium and unirradiated depleted uranium, or to natural uranium or depleted uranium that has been irradiated in thermal reactors only.

Certain quantities and configurations of fissile material cannot become critical under any circumstances associated with transportation. To allow for this, there are several exceptions to the fissile material requirements in the HMR. Generally, the exceptions are for small quantities. If fissile material meets the requirements of § 173.453, it is excepted from the packaging and controls that are required for fissile materials. Paragraphs (a)-(f) of § 173.453 are independent, and only one paragraph needs to be met to take the fissile exception.

J. Radioactive Materials Not Covered by the HMR

There are several categories of radioactive material that are not subject to the HMR, as follows (see § 173.401):

- Materials that are not in transportation,
- Materials that have been implanted or incorporated into, and are still in, a person or live animal for diagnosis or treatment,
- Material that is an integral part of the means of transport,
- Natural material and ores containing naturally occurring radionuclides which are not intended to be processed for use of these radionuclides, provided the activity concentration of the material does not exceed 10 times the values specified in § 173.436.

Materials not in transport may be covered by other regulations, but are not subject to transportation regulations. § 171.1 explains the applicability of the HMR to persons and functions. The HMR apply to the transportation of hazardous materials in commerce, the manufacture and maintenance of packagings used for such transportation, pre-transportation functions (such as filling a package, marking, labeling, and shipping paper preparation), and transportation functions. Movement of materials within facility boundaries where public access is restricted is not subject to the HMR.

Material that is an integral part of the means of transport refers to such items as thoriated metallic engine parts, depleted uranium counterweights, tritium exit signs, and similar items containing radioactive material which are an integral part of, and are routinely used in the normal operation of a transport vehicle.

The radioactive material transport regulations are intended to apply to natural materials or ores that form part of the nuclear fuel cycle, or that will be processed in order to utilize their radioactive properties. They do not apply to other natural materials or ores that may contain small amounts of naturally occurring radionuclides, when those materials or ores are to be used because of some other physical or chemical characteristics, provided that their activity concentrations do not exceed 10 times the exemption values given in the table in § 173.436. Examples of such natural occurring radioactive materials (NORM) are cement, coal, fertilizers, non-radioactive metals, gypsum, and residues from mining and smelting processes.

V. CATEGORIES OF RADIOACTIVE MATERIALS PACKAGES

In the HMR, "package" means the packaging together with its radioactive contents as presented for transportation. For radioactive materials, "packaging" means the assembly of components necessary to ensure compliance with the packaging requirements of the HMR. The packaging may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, service equipment for filling, emptying, venting and pressure relief, and devices for cooling or absorbing mechanical shocks. The conveyance, tie-down system, and auxiliary equipment may sometimes be designated as part of the packaging.

Fundamental to a good understanding of radioactive material transportation safety and packaging requirements is the basic premise that:

Safety in transporting radioactive material primarily depends upon the use of the proper packaging for the type, quantity, and form of the radioactive material to be transported. In addition, packaging design is performance oriented, with the packaging integrity being dictated by the hazards of the radioactive content.

That is, proper packaging is the primary means of providing safety, and contents which present higher hazards are to be contained in stronger packagings.

The following categories of radioactive material packages are defined in the HMR:

- Excepted packages
- Industrial packages (IP-1, IP-2, IP-3)
- Type A packages
- Type B packages
- Fissile material packages
- Packages containing uranium hexafluoride

Each of these is discussed below.

A. General Packaging Requirements

Unless excepted, all packages are subject to applicable general requirements in 49 CFR Part 173, Subparts A and B. General requirements for packagings and packages may be found in § 173.24, additional requirements for non-bulk packagings and packages are given in § 173.24a and requirements for bulk packagings are given in § 173.24b. Radioactive materials packages are also subject to § 173.410, "General Design Requirements."

An example of a requirement that is applicable to all packages is the performance capability requirement for vibration in §§ 173.24a (a)(5) and 173.410(f). Packages do not require vibration-testing in a laboratory. Demonstrating compliance by methods other than testing is allowed in § 173.461(a)(4). The DOT has provided letters of interpretation that the vibration requirement in § 178.608 is a performance capability requirement that may be reasonably satisfied by documented evidence that packages of a particular design have been transported extensively without failure.

B. Excepted Packages

As described in Section IV.E of this document, packages containing excepted quantities of materials (limited quantity of radioactive material, radioactive instruments or articles, articles manufactured from natural or depleted uranium or natural thorium, and empty packagings) are excepted from some requirements of the HMR.

Excepted packages are not required to be tested or designed to survive any transportation accidents, and it is assumed that under accident conditions all the contents could be potentially released. Therefore, the total activity and maximum allowable dose rates associated with these packages are significantly lower than those allowed for other packages. By severely limiting the contents, excepted packages provide a standard of safety comparable to that of more robust packages.

Excepted packages are excepted from specification packaging, marking (except for the UN identification number marking), labeling, and shipping paper requirements. However, they are not exempt from regulation during transportation as would materials not meeting the definition of "radioactive material" for purposes of transportation. In addition to the general packaging requirements for all hazardous material packaging, excepted packaging must meet the general requirements for radioactive material packaging in § 173.410.

Excepted packages must meet the following:

- The general design requirements cited above;
- The outside of each package must be marked with the four digit UN identification number for the material preceded by the letters **UN**, as shown in column (4) of the Hazardous Materials Table in § 172.101;

- Non-fixed contamination limits on package surfaces must not exceed the limits of § 173.443(a);
- The radiation level at any point on the surface of the package must not exceed 0.005 mSv/h (0.5 mrem/h);
- For limited quantities, the outside of the inner packaging, or if there is no inner packaging, the outside of the package itself must bear the marking "**Radioactive"**;
- An "**Empty**" label is required on empty packagings;
- For instruments or articles, the radiation level at four inches from any point on the surface of the unpackaged instrument or article shall not exceed 0.1 mSv/h (10 mrem/h).

The specific sections of 49 CFR for the various categories of excepted radioactive packages are:

- § 173.421 Excepted packages for limited quantities of Class 7 (radioactive) materials
- § 173.422 Additional requirements for excepted packages containing Class 7 (radioactive) materials
- § 173.423 Requirements for multiple hazard limited quantity Class 7 (radioactive) materials
- § 173.424 Excepted packages for radioactive instruments and articles
- § 173.426 Excepted packages for articles containing natural uranium or thorium
- § 173.428 Empty Class 7 (radioactive) materials packaging.

Figure 6 shows an example of an excepted packaging and its contents.

Figure 6 - Example Excepted Package

C. Industrial Packages (Type IP-1, IP-2, IP-3)

"Industrial packagings" (IP) may be used for materials with sufficiently limited specific activity (LSA materials) and certain SCO. There are three categories of IP: IP-1, IP-2, and IP-3. The requirements for each IP category are given in § 173.411. IP-1 packagings must meet the general packaging requirements of § 173.410 and are, therefore, equivalent in design requirements to excepted packagings.

IP-2 packagings must also meet the general design requirements and, when subjected to the free drop and stacking (compressive load) tests specified in § 173.465(c) and (d) or evaluated against these tests by any of the authorized methods of § 173.461(a), each IP-2 must prevent the following:

- Loss or dispersal of the radioactive contents
- Any significant increase in the radiation levels recorded or calculated at the external surfaces for the condition before the test.

IP-3 packaging must meet the requirements of an IP-1 and IP-2 and must also meet the requirements specified in § 173.412(a)-(j). IP-3 packagings are, therefore, identical to Type A packagings authorized for solid Type A quantities of radioactive materials.

The following types of packagings may be ***used as*** IP-2 and IP-3 packages if they meet requirements for an IP-1 and the cited requirements, including containment and shielding requirements (they do not need to meet the other IP-2 and IP-3 requirements):

- Tank containers meeting the requirements of § 173.411 (b)(4)
- Other tanks meeting the requirements of § 173.411(b)(5)
- Freight containers (for solid materials only) that are built to the ISO 1496-1 standards meeting the requirements in § 173.411 (b)(6)
- Metal intermediate bulk containers meeting the requirements in § 173.411 (b)(7).

Shippers of any IP-2 and IP-3 packages must maintain the packaging documentation on file for one year after shipment that shows, by test results or analysis, that the packaging met the IP-2 or IP-3 criteria.

Figure 7 shows two examples of IP packages.

Figure 7 - Industrial Packages (IP)

Figure A – An IP-1 Package

Figure B - An IP-2 Package

D. <u>Type A Packages</u>

Type A packages are required to maintain their integrity under conditions of normal transport. However, it is assumed that a Type A package may be damaged in a severe accident and could then release some of its contents. Therefore, the maximum amount of radioactivity that can be transported in such packages is limited to Type A quantities (A_1 for special form materials, A_2 for normal form materials).

Type A packaging must comply with the applicable general packaging requirements of §§ 173.24, 173.24a (non-bulk) or § 173.24b (bulk), and § 173.410, and the additional requirements of § 173.412, and § 173.415. These packagings must prevent the loss or dispersal of the radioactive contents and maintain the radiation shielding properties during normal conditions of transportation, which include rough handling conditions, for which tests are specified in § 173.465. These rough handling conditions include: falling from a transport vehicle or handling equipment; being struck by irregularly shaped freight or other packages with sharp corners; sitting on an uncovered loading dock during inclement weather; and having heavy freight loaded on top of the package. The packaging, with contents, must be capable of withstanding the water spray, free drop, stacking and penetration tests described below. One prototype may be used for all tests if the requirements of § 173.465(b) are met. The water spray test must precede each test or test sequence.

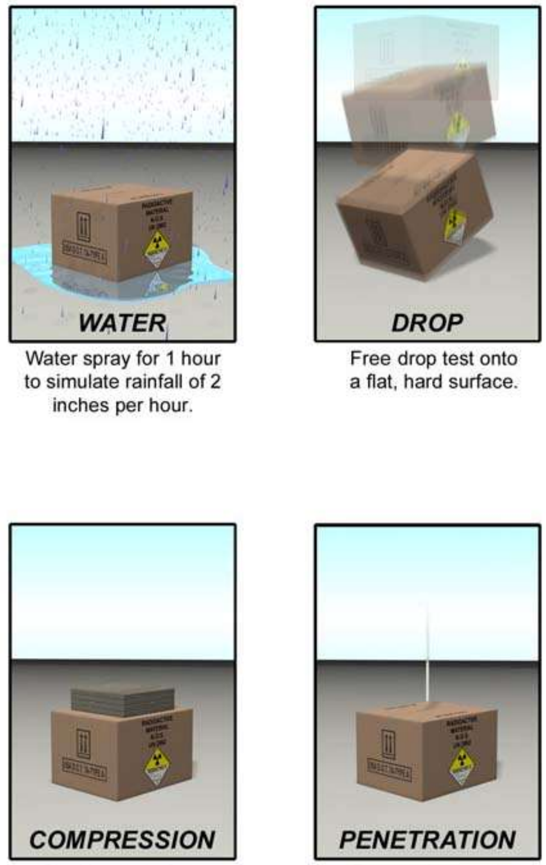
The tests that simulate the types of damage that could result from these conditions are:

- **Water Spray Test**, which simulates the package having been left in rain at a rate of about 2 inches/h for a period of at least one hour, followed by;
- **Free Drop Test** of 1- 4 feet (depending on the package mass, with 4 feet for packages under 11,000 pounds) onto a hard surface, in a most damaging orientation - simulating falling off a vehicle or loading platform (there are additional requirements for fiberboard, wood, and fissile material packages),
- **Stacking Test** equal to a force of at least 5 times the weight of the package for at least 24 hours - simulating the damp package being at the bottom of a stack of packages, and
- **Penetration Test** with a 13.2 pound, 1.25 inch diameter steel rod being dropped at least 3.3 feet onto the damp package - simulating a loose object hitting the package.

The performance requirements for Type A packages containing liquids and gases are more stringent than the requirements for solids, because of the greater potential for materials spreading if the package containment system fails. The more stringent requirements relate to containment, and the height in the drop (30 feet) and puncture (5.5 feet) tests, and are found in § 173.412 (k) and § 173.466.

Figure 8 illustrates the Type A packaging tests.

Figure 8 - Type A Packaging Tests



Water spray for 1 hour to simulate rainfall of 2 inches per hour.

Free drop test onto a flat, hard surface.

Stacking test of at least 5 times the weight of the package. This test is conducted for at least 24 hours.

Penetration test by dropping a 13-pound, 1.25-inch diameter bar vertically onto the package from a height of 3.3 feet.

Essentially, the only authorized Type A package in the DOT regulations is the DOT specification 7A (see § 178.350), which is based totally on performance test conditions rather than on hardware or design requirements. This provides the package designer with maximum latitude in the use of engineering creativity to produce optimally useful and economic designs. Using any of the methods authorized in § 173.461, each shipper of a DOT-7A package must determine if the design meets the performance requirements in §§ 173.412 and 173.465, and then must document and maintain this evaluation or "self-certification" on file for at least one year after the latest shipment, per § 173.415(a). Consequently, each design must be specifically certified as meeting the DOT-7A requirements. Each time the *contents or packaging components* change, the performance capability of the modified package must be re-evaluated with respect to the requirements before the Type A designation may be assigned.

Shippers are cautioned that often, additional documentation beyond that provided by the packaging supplier is needed to fulfill all of the requirements for a particular shipment; most importantly that the contents to be shipped have been evaluated for compatibility with the packaging and that their characteristics have been bounded by the simulated contents used in qualification testing (see § 173.461). To satisfy the documentation requirements of § 173.415(a), each shipper must maintain complete documentation of tests and an engineering evaluation or comparative data showing that the construction methods, packaging design, and materials of construction comply with the 7A specification. It is recommended that the documentation identify each requirement and state how each is met. The statements can contain references to supporting documentation, such as engineering evaluations. The documentation shall be provided to DOT upon request.

DOT-7A designs do **not** require the approval of either DOT or NRC, for domestic shipment or for international transportation of non-fissile radioactive material. Type A quantities may also be shipped in certified fissile or Type B packaging or in foreign-made Type A packaging which meets IAEA TS-R-1 requirements. If foreign-made packages are to be used for domestic shipments, the domestic shipper must obtain and maintain on file the applicable Type A evaluation and documentation performed by the foreign package designer.

Each packaging built to DOT Specification 7A Type A must be marked on the outside as "**USA DOT 7A Type A**" and also in accordance with the marking requirements in § 178.3. Section 178.350 (c) requires that the package also be marked with the name and address of the person certifying that the package (including the contents) meets the applicable requirements. This may be the shipper, if the packaging supplier has not tested for contents comparable to what is being shipped.

Figure 9 illustrates several representative Type A packaging configurations.

Figure 9 - Typical Type A Packaging Configurations

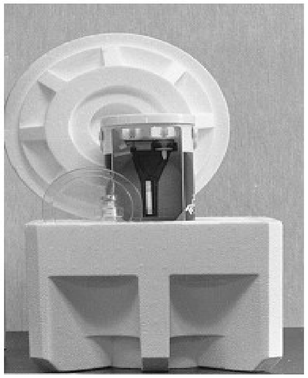


Figure A - Molybdenum 99 Generator
(Cutaway shows outer carton, foam spacer, shielding, ion column, and tubing for saline solution)

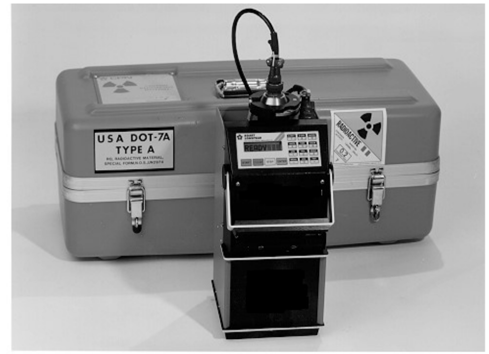


Figure B - Moisture Density Gauge & Carrying Case

Figure C - 55 Gallon Steel Drum

Figure D - Components of a Type A Package for Isotopes

E. Type B Packages

Type B packages must meet the general packaging and performance standards for Type A packages and additionally must have the ability to survive serious accident damage tests (hypothetical accident conditions). After testing, there may be only a very limited loss of shielding capability and no loss of containment, as measured by leak-rate testing of the containment system of the package.

Most domestic Type B packages are fabricated to designs certified by the NRC. Each design is approved under a NRC certificate of compliance and general license issued pursuant to 10 CFR 71.17. DOT authorizes use of NRC-approved Type B packages in § 173.416(a) and the standard requirements applicable to their use are in § 173.471. In addition, numerous Type B packages are approved by the U.S. Department of Energy (DOE) under the authority provided by DOT in § 173.7(d). Many of these DOE-certified packages are also certified by the NRC.

Type B Packages of foreign origin which meet the applicable requirements of TS-R-1, and for which the foreign competent authority certificate has been revalidated by DOT pursuant to § 173.473, are authorized only for export shipments from, import shipments into, and shipments traveling through the U.S. For purely domestic shipments of such packages, NRC certification of the package must be obtained.

The performance criteria which the package designer must use to assess a Type B package design against the established hypothetical accident conditions are prescribed in 10 CFR 71.73 of the NRC regulations and include the following tests, which are to be done sequentially (except the immersion test for all packages which may be done on a separate specimen):

- **Free Drop**: A 9 m (30 ft) free fall of the test package onto an unyielding surface in a position for which maximum damage is expected;
- **Crush**: For packages with mass not greater than 500 kg (1,100 lb), overall density not greater than 1,000 kg/m^3 (62.4 lb/ft^3) and for normal form non-fissile material, contents greater than 1,000 A_2 - subjecting the test specimen to a dynamic crush test by positioning the specimen on a flat unyielding horizontal surface so as to suffer maximum damage by the drop of a 500 kg (1,100 lb) steel plate mass from 9 meters (30 ft) onto the test package;
- **Puncture**: A puncture test as a free drop of the test package from a height of 1 m (40 in) onto a 15 cm (6 in) diameter vertical steel peg which has a length as to cause maximum damage to the package, at least 20 cm (8 in) long;
- **Thermal**: Exposure to a fully engulfing thermal environment of at least 800^{o}C (1,475^{o}F) for 30 minutes;
- **Immersion – fissile material:** For fissile packages where water in-leakage is not assumed in the criticality analysis, immersion of the test package under a head of water of at least 0.9 meters (3 ft) in the attitude for which maximum leakage is expected; and

- **Immersion – all packages**: Water immersion of the test package under at least 15 meters (50 ft) depth.
  In addition, packages containing more than 10^5 A_2 must be designed to withstand an external water pressure of 2 MPa (290 psi) for a period of not less than one hour without collapse, buckling, or in-leakage of water (see 10 CFR § 71.61).

  Figure 10 illustrates the hypothetical accident conditions for Type B packages except for the crush test and the fissile material package immersion test.

Figure 10 - Type B Hypothetical Accident Conditions

Certified Type B packagings are designated as Type B(U), or Type B(M). The (U) designation indicates a design requiring only unilateral approval—approval by the country of origin only. The receiving country does not need to review these designs, but in general, they will revalidate the certification. The (M) indicates a design requiring multilateral approval, i.e., approval by all countries into or through which the package is transported. A Type B(U) and a Type B(M) package are identical except that a Type B(M) package design has a maximum normal operating pressure greater than 700 kiloPascal or a pressure-relief device that allows the release of radioactive material to the environment under the hypothetical accident condition tests. Certificates of Type B packaging that are authorized for fissile materials have an "F" in the identification, e.g., USA/9126/B(U)F-85.

Type B(U) and B(M) package designs without a -85 or -96 at the end of their designation were approved to the 1973 IAEA regulations and were approved prior to April 1, 1996. Package designs with the -85 designation were approved after April 1, 1996, and meet the 1985 IAEA regulations. Package designs with -96 designations meet the 1996 IAEA regulations. Use or fabrication of package designs without the -96 designation is restricted in 10 CFR § 71.19.

Type B Packages cover a wide range of physical sizes, from small radiographic devices to large waste casks and spent nuclear fuel casks.

Figure 11 provides illustrations of several Type B Packages.

Figure 11 - Example Type B Packages

Figure A - RH-TRU 72B Cask

Figure B - CNS 10-160B

Figure C - 3 TRUPACT-II Packages

Figure D - Industrial Radiography Exposure Device (cutaway shows "S" tube for source in the shielding material)

F. Fissile Radioactive Material Packages

As discussed in Section IV.I, fissile material is defined as plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. Authorized fissile material packages are provided in § 173.417; acceptable Type A packages are listed in paragraph (a) and acceptable Type B packages are listed in paragraph (b) (paragraph (c) provides the DOT Specification Type A and Type B packages that are being phased out after October 1, 2008).

All Type A and Type B fissile packages are certified by the NRC as indicated in § 173.417(a)(4) and (b)(3) or by DOE pursuant to the authority of § 173.7(d). Fissile packages of foreign origin are subject to the same DOT requirements as non-fissile Type B packages, and they must be revalidated by the DOT before they can be used for import or export of shipments.

When the DOT Specification 7A, Type A package is used for fissile material contents, the package must have been evaluated for the additional drop test from a height of 1 foot on each corner, or in the case of cylindrical packages, onto each of the quarters of each rim (see § 172.465(b)(2)).

In addition to the accident condition tests for Type B packaging, fissile material packaging designs for air transport must remain subcritical after being subjected to enhanced puncture, thermal, and drop tests in addition to the 10 CFR§ 71.73 free drop and crush tests. These additional requirements are stated in 10 CFR § 71.55(f). In addition, 10 CFR §§ 71.74 and 71.88 address additional requirements for shipments of plutonium by air.

Figure 12 illustrates some typical packages used in the transportation of fissile radioactive material.

Figure 12 - Fissile Radioactive Material Packaging

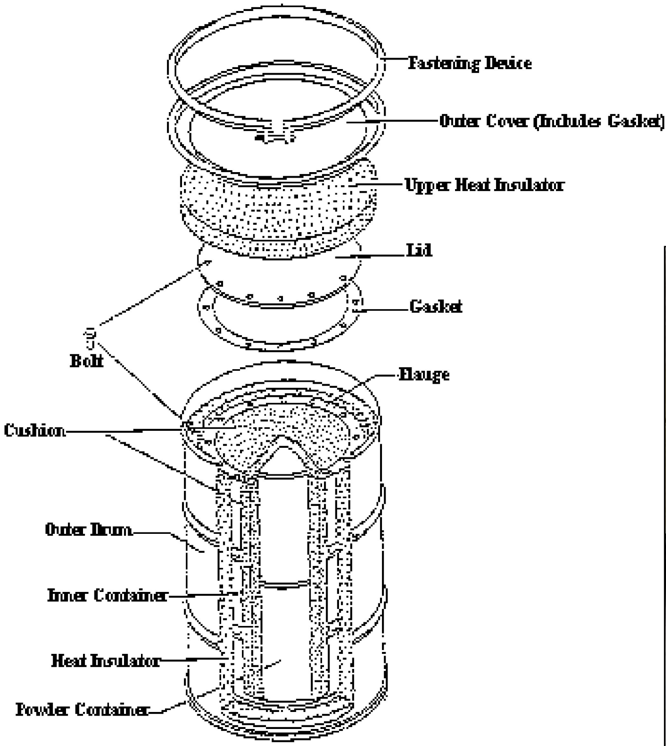


Figure A - Type A Drum for UO_2

Figure B - Power Reactor Spent Fuel

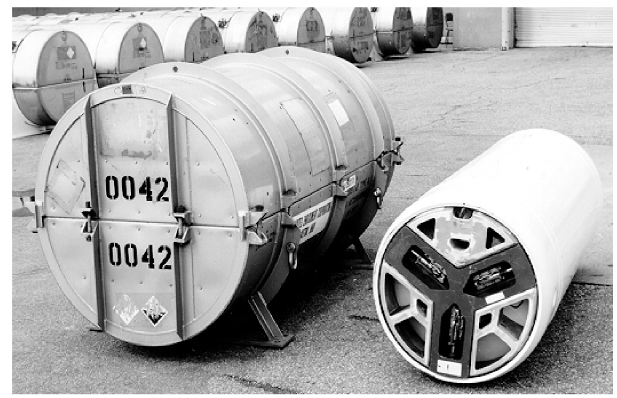


Figure C - Uranium Hexafluoride (UF_6) Overpack and Bare 30" Cylinder

G. Packages Containing Uranium Hexafluoride

Uranium hexafluoride (UF_6) is a radioactive material having a significant chemical hazard. During transportation, UF_6 exists as a crystalline solid and is shipped in metal cylinders at slightly reduced atmospheric pressure. The material presents hazards due to its radioactivity, as well as its corrosivity; breach of a cylinder of solid UF_6 would result in a reaction product of the material with the moisture in the air to produce highly corrosive hydrogen fluoride gas along with moderately radioactive uranyl fluoride solid particulates. Under the HMR, the radioactive nature of the material takes precedence, and the chemical hazard is treated as a subsidiary risk.

Depending on the degree of enrichment and the amount of fissile U present, UF_6 may be transported in excepted, industrial, Type A, or fissile packaging. The packaging requirements for UF_6, both fissile and LSA, are in § 173.420. This section contains references to American National Standards Institute (ANSI) Standard N14.1, *Nuclear Materials - Uranium Hexafluoride - Packaging for Transport*, and to ASME Code. All UF_6 cylinders with greater than 100g of UF_6 must comply with the provisions in § 173.420 that require each UF_6 package be designed to withstand:

- A hydraulic test at internal pressure of 200 lb per square inch without leakage.
- The free drop test in § 173.465(c) without loss or dispersal of the UF_6.
- The thermal test in 10 CFR § 71.73(c)(4) without rupture of the containment.

These tests do not have to be conducted sequentially or on the same package.

In addition to the provisions in § 173.420, UF_6 shipments are subject to the provisions in either § 173.427 or § 173.417. UF_6 that is enriched to not more than 1% is considered non-fissile, since it will meet the fissile exemption in § 173.453(d); as such, it can be shipped using the LSA shipping provisions in § 173.427. UF_6 that is enriched to more than 1% must be shipped in the authorized Type A or Type B fissile packages that are referenced in § 173.417(a)(2) and (3) and in § 173.417(b)(3).

The quantity limits for shipment of enriched (fissile) UF_6 in the form of residual "heels" of material in "empty" cylinders are provided in § 173.417(a)(2).

The quantity limits for fissile UF_6 in metal cylinders overpacked in DOT Specification 20PF and 21PF protective overpacks are contained in § 173.417(b)(3) or in the certificates for NRC-certified UF_6 packages. The specifications for the DOT overpacks are provided in