FSIS Docket 97-076P: “Irradiation of Meat and Meat Products”

Review of Risk Analysis Issues

Office of Policy, Program Development, and Evaluation
Food Safety and Inspection Service
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INTRODUCTION

On December 3, 1997, The Food and Drug Administration (FDA) of the Department of Health and Human Services published a final rule (FDA Docket No. 94F-0289; 63FR 64107) expanding the list of products in 21 CFR 179.26(b) for which ionizing irradiation may be safely used to control food borne pathogens and extend shelf life. Added to the list were refrigerated and frozen uncooked meat, meat byproducts (e.g., edible organs such as the liver and the kidneys), and certain meat food products (e.g., ground beef and hamburger). The Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) now is proposing to amend its meat inspection regulations to provide for the safe use of ionizing radiation for the treatment of these same meat products.

Ionizing irradiation can significantly reduce, and in some circumstances eliminate, pathogenic microorganisms in or on food products, including meat products. FSIS anticipates that the benefits resulting from the irradiation of meat products, due to the consequent reduction of food borne illness, could exceed $100 million. The Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994 (P.L. 103-354) requires that any regulation published by USDA concerning human, health, safety or the environment and having an annual economic impact of at least $100 million in 1994 dollars contain a risk assessment and cost-benefit analysis. The risk assessment and cost-benefit analysis must be “performed consistently and use reasonably obtainable and sound scientific, technical, economic, and other data.” The USDA Office of Risk

Assessment and Cost-Benefit Analysis (ORACBA), also established by the 1994 Act, must ensure that major rules include such analyses.

However, if the risk assessment and cost-benefit analyses "are not practicable for compelling circumstances," the Act states that an explanation of those circumstances may be provided instead. ORACBA and FSIS have agreed that FDA has already conducted a definitive risk analysis concerning the safety of meat food products treated with ionizing radiation in developing their final rule, "Irradiation in the Production, Processing and Handling of Food" (62 FR 64107; December 3, 1997). Also, ORACBA and FSIS also have agreed that the cost-benefit and economic impact analyses that FSIS has performed for this proposed rule, as required by E.O. 12866 and the Regulatory Flexibility Act, satisfy the cost-benefit analysis requirements of the Reorganization Act. Consequently, FSIS, with assistance from ORACBA, has produced only this review addressing existing research, risk assessments, and Federal and State regulatory programs that address the safety of food irradiation for consumers and the related risks posed by irradiation, including worker safety and environmental concerns.

Some of the literature concerning these risks addresses either irradiation operations in general or the irradiation of specific commodities other than meat, such as fruit or spices. However, because the same technologies and facilities are used to irradiate all foods (generally only dosages differ), FSIS has determined that any and all of these risk assessments would be applicable to the irradiation of meat products.

FDA'S EVALUATION OF THE SAFETY OF IRRADIATION

As stated above, FSIS and ORACBA agree that FDA has conducted a definitive food safety risk assessment concerning the irradiation of meat and meat products. An explanation of the events precipitating the FDA assessment and a summary of the assessment follow.

Section 201(s) of the Federal Food, Drug and Cosmetic Act (FFDCA) defines sources of radiation used to treat food as "food additives." FDA has the primary responsibility for determining whether or not food additives are safe for particular uses. FDA lists uses of food additives it has concluded are safe in 21 CFR parts 172 through 180.

On August 25, 1994 (59 FR 43848), FDA announced that it had received a petition from Isomedix, Inc., requesting that FDA amend the food additive regulations in 21 CFR part 179 (Irradiation in the Production, Processing and Handling of Food) to authorize the use of ionizing radiation to:

> control microbial pathogens in raw, fresh-chilled, and frozen intact and comminuted edible tissue of the skeletal muscle and organ meat of domesticated mammalian food sources; with concomitant control of infectious parasites, and, extension of acceptable edible/marketable life of chilled/refrigerated and defrosted meat through the reduction in levels of spoilage microorganisms.

The petition further specified that the proposed foods were to be ``primarily from bovine, ovine, porcine, and equine sources.'' Also, Isomedix requested that a maximum dose of 4.5 kiloGray (kGy) be established for the irradiation of fresh (chilled, not frozen) meat, and that a maximum dose of 7.0 kGy be established for the irradiation of frozen meat.

On December 3, 1997, FDA published a final rule (FDA Docket No. 94F-0289; 62 FR 64107) granting this petition. In that publication, FDA expanded the list of products for which ionizing irradiation may be safely used (21 CFR 179.26(b)) to include refrigerated and frozen uncooked meat, meat byproducts (e.g., edible organs such as the liver and the kidneys), and certain meat food products (e.g., ground beef and hamburger). Specifically, the foods that may be irradiated are: meat, as defined by FSIS in 9 CFR 301.2(rr); meat byproducts, as defined by FSIS in 9 CFR 301.2(tt); and other meat food products within the meaning of 9 CFR 301.2(uu), with or without nonfluid seasoning, that are otherwise composed solely of intact or ground meat or meat byproducts.

Under § 409(c)(3)(A) of the FFDCA, a food additive cannot be listed for a particular use unless a fair evaluation of the evidence establishes that the additive is safe for that use. In response to the Isomedix petition, FDA identified the various effects that can result from the irradiation of meat and then assessed whether any of these effects could pose a human health risk. FDA did not consider whether irradiation of meat would bring about health or other benefits for consumers.

FDA examined data submitted by Isomedix, as well as other information in its files relevant to the safety and nutritional adequacy of meat treated with irradiation. Specifically, FDA evaluated:

- Data regarding the radiation chemistry of food components and whole foods, including flesh foods (“radiation chemistry” refers to the chemical reactions that occur as a result of absorbing radiation);

- Toxicity studies of irradiated beef, pork, chicken, and fish;
- Studies of the nutritional adequacy of irradiated products derived from livestock and poultry, in light of the dietary consumption patterns for these products; and
- Studies of the effects of irradiation on both pathogenic and nonpathogenic microorganisms. [1]

Based on its evaluation of available data, FDA concluded that irradiation of meat, meat byproducts, and certain meat food products under the conditions requested in the petition would not present toxicological or microbiological hazards and would not adversely affect the nutritional adequacy of these products. FDA therefore granted the petition and added meat, meat byproducts, and certain meat food products to the list in 21 CFR 179.26(b) of foods that may be treated with ionizing radiation.

ENVIRONMENTAL IMPACT

In this section, FSIS examines Federal programs for mitigating possible adverse effects of food irradiation on the environment, published risk assessments concerning the environmental impact of food irradiation, and USDA and FDA programs for preventing and responding to the accidental radioactive contamination of food.

1. NRC Regulation of Irradiators that use Radioisotopes

[1] Because Clostridium botulinum spores are very resistant to the effects of irradiation and would be more likely to survive irradiation than other pathogens and most spoilage bacteria, and because the illness associated with botulinal toxin is so severe, FDA, in its evaluation, focused particularly on the effects of irradiation on the probability of significantly increased growth of, and subsequent toxin production by, C. botulinum. FDA determined that irradiation of meat food products under the conditions set forth in its regulation will not result in any additional health hazard from C. botulinum or from other common pathogens.

The possession and use of nuclear materials is controlled through licensing with the U.S. Nuclear Regulatory Commission (NRC). In some cases, individual states (Agreement States) have assumed regulatory oversight from the NRC. Agreement State regulations for licensing must be at least as strict as NRC regulations.

Licensing of facilities that employ radioisotopes is contingent upon an environmental impact assessment, unless exempted by NRC. NRC has specifically exempted irradiators that use radioisotopes (including food irradiators that use Cobalt-60 or Cesium-137) from conducting environmental impact assessments (10 CFR 51.22(c)(14)(vii)). This exemption is based upon an NRC finding that such irradiators do "not individually or cumulatively have a significant effect on the human environment" (10 CFR 51.22(a)).

2. Linear Accelerators

Food irradiation facilities that employ machine sources of radiation, such as linear accelerators, are regulated not by NRC, but by the States in which they operate, acting under the authority of the Occupation Safety and Health Administration (OSHA), Department of Labor. Currently, there is only one food irradiation facility using a machine source of radiation: a linear accelerator constructed at Iowa State University for the experimental irradiation of agricultural commodities.

In 1990, the Department of Energy (DOE) prepared an environmental assessment (EA DOE/EA-434) to assess the potential environmental impact of this facility. Because DOE financially and technically supported the construction

and initial operation of the accelerator, it was required by the National Environmental Policy Act (NEPA) to conduct an environmental assessment. The DOE determined that the linear accelerator did not significantly affect the quality of the human environment within the meaning of NEPA and issued a "finding of no significant impact to the environment."

3. Irradiation of Fruits and Vegetables

In October 1997, the Animal and Plant Health Inspection Service (APHIS) published an environmental assessment entitled "Irradiation for Phytosanitary Regulatory Treatment." APHIS conducted the assessment, in accordance with NEPA, to support several proposed regulations that would allow irradiation as a phytosanitary treatment for certain fruits and vegetables as a condition of being moved in import, export, or interstate commerce. APHIS concluded that the risk to the environment associated with irradiation of fruits and vegetables would be negligible. The proposed APHIS regulations required irradiators to demonstrate compliance with the safety procedures already required by NRC, FDA, and the Department of Transportation (DOT). APHIS concluded that such compliance would ensure that there would be no exposure of ambient air, water, or soil to radiolysis or radioactive particles. APHIS also cited a 1982 environmental assessment in which FDA determined that no adverse environmental effects were anticipated at food processing plants designed to irradiate fruits and vegetables.

4. Isomedix Petition

In 1994, Isomedix, Inc. submitted an "Abbreviated Environmental Assessment for Radiation Sources as Components of the Food Contact Surfaces of Permanent of Semi-permanent Equipment" with its petition to FDA requesting that the Agency permit the ionizing irradiation of meat food products. Isomedix concluded that the irradiation of meat food products, by either gamma ray energy sources or machine sources of radiation, would pose no significant risk to the environment.

Interestingly, Isomedix examined the small amounts of ozone that are generated by ionizing energy within irradiation facilities. This ozone is routinely exhausted into the atmosphere via an irradiator's ventilation system once the interior ozone concentrations reach the maximum continuous exposure concentration allowed by OSHA. Isomedix concluded that the irradiation of meat food products would result in releases of ozone at or below levels allowed by the National Ambient Air Quality Standards (40 CFR 50.9).

Notably, in response to the petition submitted by Isomedix, FDA concluded that approval of the petition will not significantly affect the quality of the human environment and issued a "finding of no significant impact." FDA approved the petition and published a final rule allowing the irradiation of meat food products.

5. Radioactive Contamination of Food

In regard to environmental impacts on agricultural resources, both USDA and FDA have developed programs and policies for addressing the impact radiological emergencies on food.

In 1980, the Secretary of Agriculture designated FSIS as the lead Agency within USDA for radiological emergency planning and response. The FSIS Emergency Program Staff was given the responsibility for developing policy, plans, and procedures for all USDA response activities at the Federal, State, and local levels. The Emergency Programs Staff has developed an USDA Radiological Emergency Response Plan to mitigate the effects of radiological emergencies on agricultural resources, as well as the processing, distribution, and consumption of food. The level of Federal response and USDA involvement to specific emergencies is based on the type and/or amount of radioactive material involved, location, actual or potential impact on the public and environment and the size of the affected area. Emergencies occurring at fixed nuclear facilities or during the transportation of radioactive materials, including nuclear weapons are covered in the scope of this Plan.

After the accident in Chernobyl nuclear facility in April 1986, FSIS developed a plan to evaluate the impact on domestically produced and imported meat and poultry products. FSIS established intervention levels and monitor response levels for five radionuclides: cesium-134 and cesium-137, strontium-89 and strontium-90, and iodine-131. FSIS also analyzed radionuclides in air, milk, and water within the United States. Sampling and monitoring activities determined that total cesium levels exceeded background levels but that iodine and total strontium levels were not distinguishable from background levels. FSIS analyzed approximately 6195 samples of imported meat and poultry products from 14 European countries before ending their activities in 1988. Products with

detectable levels of radiation were denied entry into the United States. FSIS concluded its monitoring program once it was convinced that imported and exported meat and poultry products possibly exposed to radionuclides from the Chernobyl accident no longer posed a threat to the public health.

FDA recently made available recommendations for responding to the accidental radioactive contamination of human food and animal feeds (63 FR 43402; August 13, 1998). The recommendations provide guidance to State and local agencies to aid in emergency response planning and execution of protective actions associated with production, processing, distribution, and use of human food and animal feeds accidentally contaminated with radionuclides. Limits, called Derived Intervention Levels, are set on the radionuclide activity concentration permitted in food, and protective actions for reducing the amount of contamination are discussed. The recommendations are applicable to accidents at nuclear power plants and many other types of accidents where a significant radiation dose could be received as a result of consumption of contaminated food.

WORKER SAFETY

Some of the environmental assessments reviewed above briefly address worker safety in irradiation facilities. However, FSIS was unable to find any risk assessment literature focused upon this issue. What follows is a brief review of relevant worker safety regulations and summaries of two accidents reported at irradiation facilities.

1. Federal and State Regulations

As with environmental protection and transportation safety, worker safety relevant to food irradiation is governed by multiple Federal and State agencies. NRC regulations in 10 CFR Part 20 set forth worker safety standards governing facilities that use radioactive materials, including food irradiation facilities. These regulations include requirements for written safety programs, dose limits, respiratory protection, storage of radioactive materials, waste disposal, and recordkeeping. Specifically, the regulations in § 20.1101 require that each licensee develop and implement a "radiation safety plan" that documents that procedures and other controls used to achieve occupational doses and doses to members of the public that are as low as reasonably achievable. The plan must be periodically reviewed, at least annually.

Recently, NRC published a proposal to amend the regulations concerning the use of respiratory protection and other controls to restrict internal exposure to radioactive materials (FR 63 38511; July 17, 1998). The proposed amendments are intended to make these regulations more consistent with the philosophy of controlling the sum of internal and external radiation exposure, reflect current guidance on respiratory protection from the American National Standards Institute, and make the requirements less prescriptive without reducing worker protection. The proposed amendments would provide greater assurance that worker exposures will be maintained as low as is reasonably achievable and that recent technological advances in respiratory protection equipment and procedures are reflected in NRC regulations and are thus clearly approved for use by licensees.

Current NRC regulations also address accidents involving radioactive materials. The regulations in 10 CFR 30.32 direct licensees to develop an emergency plan for responding to an accidental release of radioactive materials. Within the emergency plan, the licensee must provide training for the workers, indicate the frequency of training, and performance objectives. Further, § 30.33 requires that license applicant be qualified by training and experience on the materials for the purpose requested on their application, addresses the application procedures for specific licenses including the required signature of the person responsible for the operation and possession of the materials.

OSHA has issued regulations governing worker safety in all food irradiation facilities, applicable to facilities that employ gamma ray or machine sources of radiation, in 29 CFR 1910.1096. In paragraph (b) of this section, OSHA has set limits and controls on the cumulative absorbed dose that each employee can receive per calendar year from occupational exposure. In paragraph (b)(2)(iii) of this section, OSHA requires employers to keep record of past and current exposure. In paragraph (d), OSHA requires employers to supply each employee with the appropriate personnel monitoring device capable of recording the absorbed dose of exposure. And, in paragraph (e), OSHA has established requirements for caution signs, labels, and signals. Finally, OSHA has a memorandum of understanding with NRC designed to ensure that there will be no gaps in worker protection at NRC-licensed facilities where OSHA also has health and safety jurisdiction and to avoid duplication of effort on the part of the two agencies.

The Agricultural Research Service (ARS) administers an USDA wide "Radiological Safety" program for all USDA employees working around sources of radiation. The ARS issues personnel dosimeter devices, and monitors and maintains radiation exposure records. Notably, the NRC has cited ARS for several violations observed during unannounced inspections. However, while there have been various citations issued concerning ARS facilities, NRC has not commented on the ability of ARS to develop and implement a radiation safety program.

In regard to the irradiation of specific commodities, FSIS and APHIS have requirements governing worker safety in facilities that irradiate poultry and plant products, respectively. Both Agencies require that irradiation facilities have worker safety programs in place and in compliance with the OSHA regulations. Both Agencies also require that irradiation facilities have on file documentation demonstrating that the facility is licensed and possesses either gamma radiation sources registered with the NRC or machine sources are registered with the OSHA. FSIS regulations regarding the irradiation of poultry products are contained in 9 CFR 381.149; APHIS regulations regarding the irradiation of plant products are contained in 7 CFR 301.78-10 and 318 .13-4f.

2. Accidents

In June 1988, Radiation Sterilizers Inc. (RSI) reported an accident at an irradiation facility located in Georgia that sterilizes disposable medical products using Cesium-137. A Task Force made up of officials from the NRC, DOE, and state representatives convened to evaluate the incident, provide

recommendations, and outline lessons learned from the accident. Their findings were published in a preliminary report entitled “Leakage of an Irradiator Source—the June 1988 Georgia RSI Incidence.” The Task Force concluded that this incident was “low probability, high consequence” event, and there was no evidence of discharge to the environment or any immediate threat to public health and safety. Although there was evidence of exposure to RSI employees, there was no evidence of overexposure or that established regulations were exceeded.

In 1986 in Czechoslovakia, an accident was reported at a medical irradiation facility using gamma ray irradiation. As a result of a electrical malfunction within the facility, two employees were exposed to the source of radiation. Specifically, a safety control light did not indicate the source had reached its resting position within the unit. The employees used self-designed improvised tools to attempt to bring the accident under control. Twelve to twenty-four hours following the accident some biological effects in the employees were noted, such as general malaise, watery eyes and unusual nose bleeding. The overall exposure resulted in injuries to the hand, and ophthalmologic and psychological adverse conditions were noted. The corrective action used in this accident would not be in compliance with the current United States regulations that govern the use and possession of radioactive materials.

TRANSPORTATION SAFETY

1. Regulation of the Transport of Radioactive Material

Regulations to control the transport of radioactive material were initiated around 1935 by the Postal Service. Currently, there are at least five groups which promulgate rules governing the transport of radioactive material: DOT, NRC, Postal Service, DOE, and the States. Of these agencies, the DOT and NRC are the primary ones issuing regulations based on the standards developed by the International Atomic Energy Agency. NRC and DOT share responsibility for the control of radioactive material transport based on a Memorandum of Understanding. In general, DOT regulations (49 CFR) are more detailed. They cover all aspects of transportation, including packaging, shipper and carrier responsibilities, documentation and all levels of radioactive material from exempt quantities to very high levels. The NRC regulations (10 CFR 71) are primarily concerned with special packaging requirements for higher level quantities. NRC regulation 10 CFR 71.5 requires NRC licensees transporting radioactive material to comply with DOT regulations when NRC regulations do not comply.

2. NRC Study Regarding Transportation of Radioactive Materials

In 1977, NRC published a “Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes”. According to the summary, this document was prepared for a general examination review and a need to discuss the safety and security aspects of transporting nuclear fuel cycle materials. The report indicates that the largest percentage of population exposure to radiation is from the shipment of medical use radionuclides, industrial shipments, waste shipments, and nuclear fuel cycle shipments. The

individual radiation exposure in all modes are generally at low levels and produce only a slight increase in background radiation.

NRC reported nonradiological impacts for safety were estimated at two injuries per year and one fatality every five years from accidents involving "exclusive use" transportation vehicles. Exclusive use is use by a single consignor of a conveyance for which all initial, intermediate, and final loading and unloading of the radioactive materials are carried out in accordance with the direction of the consignor or cosignee. Additionally, for exclusive use shipments, the risk that the driver will be injured or killed in an accident is from the accident itself and not from radiological causes from the shipment being transported.

3. Sandia National Laboratories Accident Database

Sandia National Laboratories in Albuquerque, New Mexico, a DOE facility, maintains a Radioactive Material Incident Report (RMIR) database. Specifically included in the database is information on accidents involving radioactive material in Type B packages. Type B packages must withstand normal and accident test conditions as prescribed in 10 CFR 71.71 and 71.73 and are subjected to leak-rate criteria as discussed in the NRC Regulatory Guide 7.4. Cobalt 60 and Cesium 137, the radioisotopes primarily used in food irradiation processing are packaged in Type B packages and transported.

The appended table gives a summary from the database of transportation accidents and incidents involving radioactive materials that occurred between 1971 and 1997. Of the fifty-two accidents noted in the table, only one of the accidents involved damage to the shipping container. However, the packaging

integrity was not compromised and there was no release of radioactive materials to the environment.

4. Study of Radioactive Fuel Casks

In 1989 and 1991, Bennett, et. al., published papers addressing problems of radioactive fuel cask contamination weeping and the efforts to understand the phenomenon and to eliminate its occurrence during spent fuel transport. The authors suggest the "weeping or sweating" phenomenon is due to the conversion of fixed contamination on the external surface of the cask to a removable form. Bennett, et al., noted that weeping has been observed on a variety of cask surfaces in transit and in storage both loaded and empty. Cesium 137 appears to be the primary contaminant in weeping followed by Cobalt 60 and Cesium 134. The authors suggest cask submersion time could affect depth of diffusion and the extent of surface adsorption. Also, the parameters of a reactor spent fuel storage pool, such as temperature, contaminant concentration and the chemical form, and pH could conceivably affect reaction of contaminant with the cask surface. Additionally, expansion and concentration due to changing temperature or gradients produced by interior heat sources and varying ambient temperatures could provide mechanical release from the substrate. However, in a food irradiation facility the source(s) are delivered to and from the facility by the supplier, therefore, the supplier would be governed by the regulations established by NRC and exclusive use vehicles.

At the time of publication of the Bennet paper, a DOE program was underway at Sandia National Laboratories to determine the physical and

chemical processes involved in radionuclide contamination and release on transportation cask surfaces. The program activities were to provide a basis for the development of more effective decontamination procedures and the development of contaminant blocking methods to prevent initial cask surface contamination.

CONCLUSION

Based on the risk assessment literature described above and in consideration of the numerous Federal and State requirements governing the use, storage and transportation of radioactive materials, FSIS has determined the allowing the irradiation of fresh and frozen meat food products would pose no significant risk to the environment, worker or transportation safety. In summary, proper design and operating procedures of commercial irradiators have been shown to operate without significant radiation risk to workers or the public. NRC has set stringent environmental protection requirements for any facilities that use radionuclide sources (10 CFR Parts 20, 30, 51, and 71). There are special carrier requirements for transport of hazardous materials (such as the radionuclides used at the facility) set by the DOT. Any extraneous radiation from radionuclides would be contained in plants by shielding required by the NRC and the Bureau of Radiological Health at FDA. The risk of radiation exposure to workers is very low with adherence to the required NRC, OSHA, and other safety

requirements. And finally, FSIS ensures that the risks food irradiation are insignificant by its requirement that all irradiation facilities adhere to the safety regulations of the NRC, DOT, and FDA.

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SUMMARY OF ACCIDENTS INVOLVING TYPE B PACKAGES

(1971-1997)

Date of Accident	Mode	Package Description	RAM Involved	Packages Shipped/Damaged
07/10/71	Highway	Lead container	C0-60	1/0
12/05/71	Highway	Radiography camera	Ir-192	1/0
12/08/91	Highway	Cask, spent fuel	Spent Fuel	1/1
03/10/74	Highway	Container	Ir-192	1/0
03/29/74	Rail	Cask, spent fuel	Spent Fuel	1/0
08/09/75	Highway	Cask	U-235, U-238, Pu 239	1/0
05/06/77	Highway	Radiography camera	Ir-192	1/0
08/11/77	Highway	Radiography camera	Ir-192	1/0
08/25/77	Rail	Cylinders	UF6	4/0
10/03/77	Highway	Radiography source	Ir-192	1/0
02/09/78	Highway	Cask, spent fuel	Spent Fuel	1/0
04/10/78	Highway	Radiography camera	Ir-192	1/0
07/07/78	Highway	Cask	Mixed fission	1/0
07/26/78	Highway	Steel cask, lead	Cs-137	2/0
08/13/78	Highway	Cask, spent fuel	Spent Fuel	1/0
08/27/78	Highway	Radiography camera	Ir-192	1/0
09/15/78	Highway	Radiography camera	Ir-192	1/0
11/28/78	Highway	Radiography camera	Ir-192	1/0
01/10/79	Highway	Cylinder	Empty	5/0
8/12/79	Highway	Cask	Empty	2/0
12/11/79	Highway	Cylinder	UF6	5/0

Date of Accident	Mode	Package Description	RAM Involved	Packages Shipped/Damaged
01/31/80	Highway	Cask	Low level Waste	2/0
07/21/80	Highway	Source	Ir-192	1/0
08/22/80	Highway	Cylinder, 30B	UF6	5/0
09/06/80	Rail	Cylinder, 30B	UF6	8/0
09/29/80	Rail	Radiography source	Sr-90, Y-90	3/0
06/09/81	Highway	Source, shielded	Am-241/be	1/0
09/02/81	Highway	Source	Ir-192	1/0
10/26/81	Highway	Radiography camera	Ir-192	1/0
11/03/82	Highway	Cask	Empty LLW	2/0
03/11/83	Highway	Cask	LLW	1/0
05/10/83	Highway	Radiography source	Ir-192	1/0
07/14/83	Air	Cask	Y-90, Ir-192	2/0
12/09/83	Highway	Cask, spent fuel	Spent fuel	1/0
07/16/84	Air	Container	Ir-192	1/0
08/08/84	Highway	Container	Reactor waste	1/0
02/13/85	Highway	Steel drum	Ir-192	1/1
12/04/85	Highway	Radiography camera	Ir-192	1/0
01/10/86	Highway	Source	Cs-137	1/0
08/15/86	Highway	Cylinder, 30B	UF6	3/0
03/24/87	Rail	Cask, spent fuel	Spent fuel	2/0
10/26/87	Highway	Radiography source	Ir-192	1/0
01/09/88	Rail	Cask, spent fuel	Spent fuel	1/0
01/23/88	Highway	Radiography camera	Ir-192	1/0
09/23/89	Highway	Radiography camera	Ir-192	1/0
06/08/91	Highway	Radiography camera	Ir-192	1/0

Date of Accident	Mode	Package Description	RAM Involved	Packages Shipped/Damaged
11/03/91	Highway	Radiography camera	Ir-192	1/0
02/07/92	Highway	Radiography camera	Ir-192	1/0
03/04/93	Highway	LLW Cask	LLW	1/0
12/23/94	Rail	Cylinder (14 ton)	UF6	1/0
09/06/96	Air	Packages (no details)	Ir-192	1/0
01/24/97	Highway	UF6 Cylinders	UF-6	4/0