

Nuclear Material Events Database

LAS Events Involving Category 1 and 2 Sources (Fiscal Year 2006-2015)

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During the most recent 10-year period (FY 2006-2015), 92 Lost/Abandoned/Stolen Material (LAS) events occurred involving Category 1 and 2 events as defined by the International Atomic Energy Agency's *Code of Conduct on the Safety and Security of Radioactive Sources (2004)*:

Category 1 events - 2 events involving multiple Ir-192 wafers/disks

Category 2 events - 32 events involving 48 sources (other than irretrievable well logging sources)

Category 2 events - 58 events involving 131 irretrievable well logging sources

The LAS data presented in this report are limited to reportable events that occurred between October 1, 2005, and September 30, 2015 (FY 2006-2015). The data were downloaded from the NMED on January 13, 2016. Because the NMED is a dynamic database that is updated daily, variations in data may be encountered over time. The FY 2015 data is most susceptible to change as subsequent updates and late reports are received.

Figure 1 displays the number of LAS events involving Category 1 and 2 sources, excluding irretrievable well logging source events. This data does not represent a statistically significant trend. Appendices A and B provide summaries of each Category 1 and 2 event, respectively.

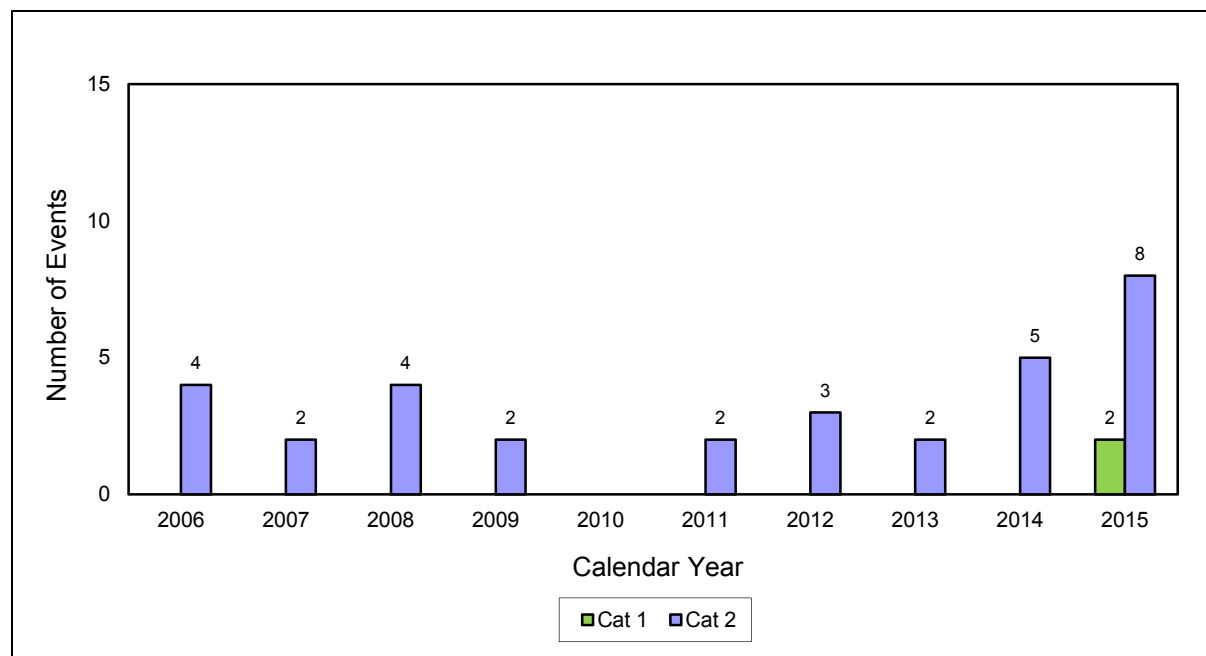


Figure 1. LAS Events Involving Category 1 and 2 Sources, Excluding Irretrievable Well Logging Sources (34 total events)

Category 1 Events - Two events occurred in the 10-year period that involved the loss and recovery of Category 1 levels of Ir-192 sources during shipment by common carrier.

In the first event (February 9, 2015), a radioactive source manufacturer shipped a container of Ir-192 wafers/disks (to be assembled into sealed sources) to an international customer. The container held 432.16 TBq (11,680 Ci) of Ir-192. Due to an error at the common carrier's Memphis, Tennessee, hub, the container was inadvertently delivered to another facility (in the U.S.) owned by the same radioactive source manufacturer.

In the second event (event date February 13, 2015), an international shipment of Ir-192 wafers/disks was to be delivered to a radioactive source manufacturer (same as above). The shipment contained 2,701 TBq (73,000 Ci) of Ir-192. The common carrier (same as above) notified the manufacturer that the shipment was missing. A day later, the carrier found the shipment in their Memphis, Tennessee, hub.

It is interesting to note the similarities in these two events. These were the only two Category 1 events in the 10-year period, they occurred a few days apart, involved shipments from/to the same source manufacturer, and involved errors at the same common carrier facility.

Category 2 Events (other than irretrievable well logging source events) - Thirty-two events occurred in the 10-year period involving 48 Category 2 sealed sources, all of which were recovered except one. Forty-seven of these sources were Ir-192 radiography sources. The remaining source was a Cs-137 irradiator source. Figure 2 displays the types of losses associated with the events.

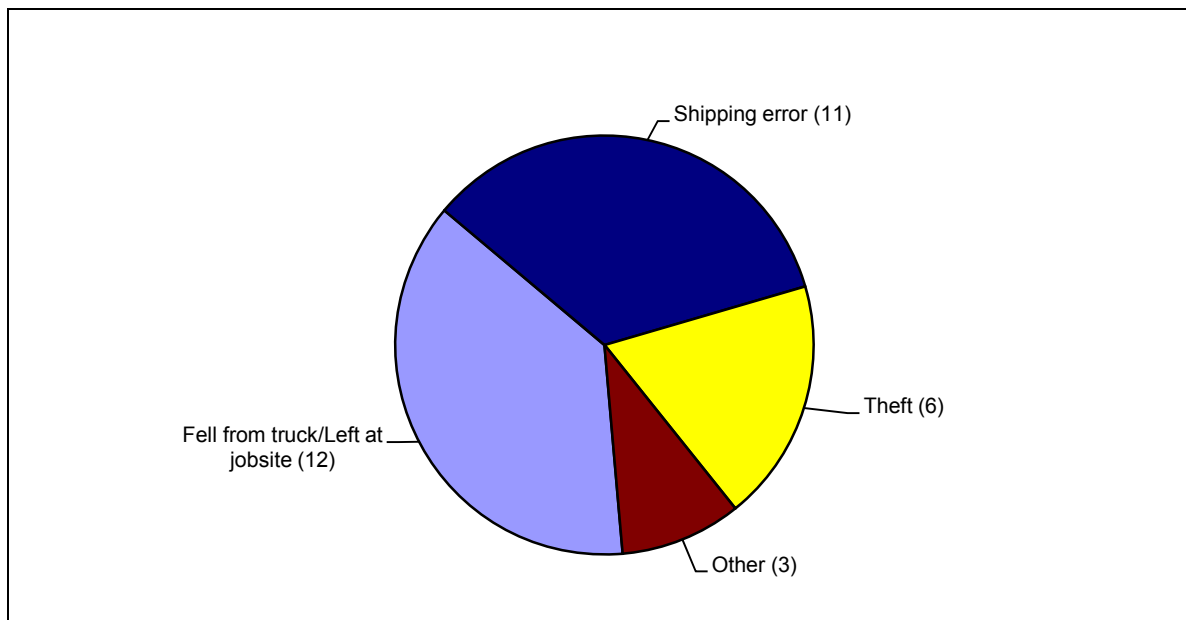


Figure 2. LAS Category 2 Events Loss Type (32 total events)

Of the 32 events:

- Six events involved the theft of radiography devices. Five of these were either thefts of a device from a truck or theft of an entire truck containing a device. The sixth event involved the theft of a device from a locked storage area in a company's office. All but one of the devices was recovered. The only device not recovered was stolen in July 2011 from the darkroom of a radiography truck parked at a hotel. An extensive search was performed, including a fly-over survey conducted by the Department of Energy using a fixed wing plane, but the device was not located.
- Twelve events resulted from errors made by radiography crews; seven where a device fell from a radiography vehicle in transit because the device was not properly secured (the device was recovered by a member of the public in six of these events and found in a ditch in the remaining event), and five where the device was left at a jobsite (or an airport in one case). Eight of these events (67%) occurred in the last two fiscal years (FY 2014 and 2015), indicating that the "lessons learned" process undertaken by the radiography industry and regulators has not been totally effective. All of these devices were recovered.

- Eleven events resulted from shipping errors. In these events, sources/devices were temporarily lost in a common carrier's shipping process, but had actually never left the carrier's possession. A typical example would be a package that was not delivered on the date expected. However, after the carrier is notified and performs a search, the package is eventually found at the carrier's shipping facility. All of these sources/devices were recovered.
- Three other events occurred. In one of these events, a tornado ripped the darkroom from a radiography truck. In another event, a truck was swept away when a radiographer tried to cross a creek. The final event involved an irradiator that was abandoned at a biotechnology facility during an eviction process. All of these devices were recovered.

Figure 3 displays the number of LAS events involving Category 2 irretrievable well logging source events. This data represents a statistically significant decreasing trend.

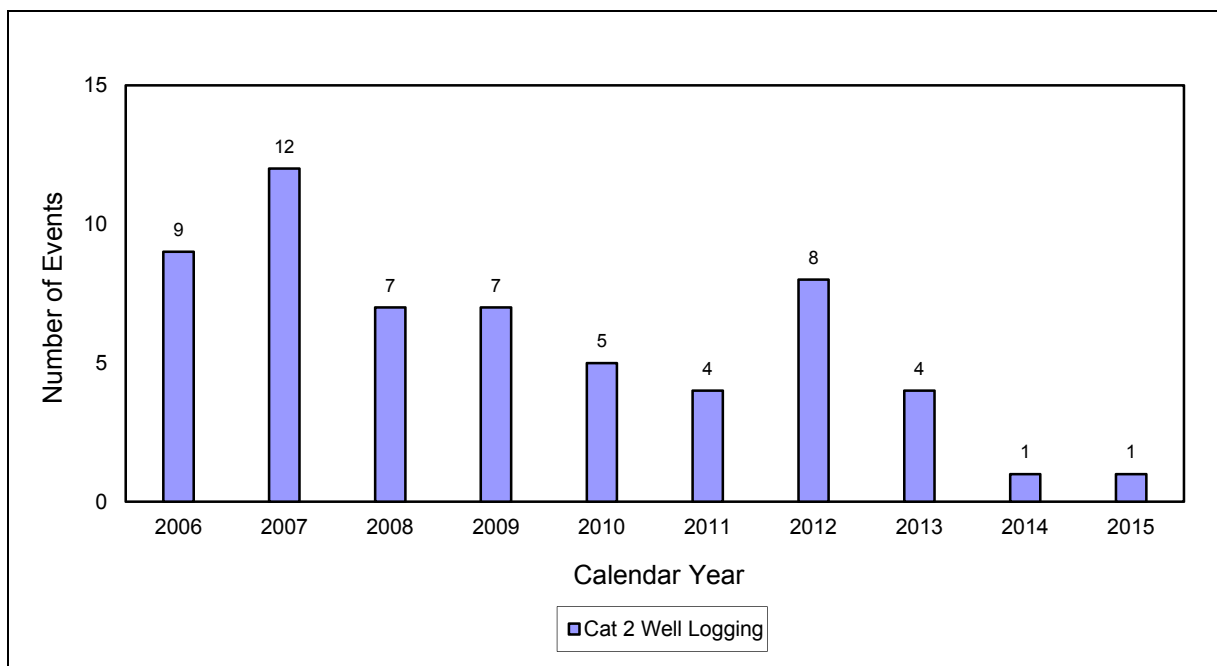


Figure 3. LAS Events Involving Category 2 Irretrievable Well Logging Sources (58 total events)

Category 2 Events (irretrievable well logging source events) - Fifty-eight events occurred in the 10-year period involving irretrievable well logging tools containing an aggregate activity of Category 2. In each event, a single well logging tool was determined to be irretrievable and abandoned where it became stuck/lost in the well. Each well logging tool is typically comprised of a single Am-Be source combined with one, two, or three Cs-137 sources. The 58 events involved a total of 131 sources. The tools are typically:

- abandoned several thousand feet deep in a well
- covered with a cement plug and possibly with a device to deflect any future drilling attempt
- placarded at the well head

NMED uses a Sum of the Ratios methodology (see Appendix C) for evaluating combinations of multiple sources or multiple radionuclides aggregated at a single location. Each NMED record contains an aggregate category value as well as the individual source category values. Note that the Sum of the Ratios methodology can result in an aggregate category greater than any of the individual source categories.

- Fifteen of the 58 events have an aggregate category of 2 and contain a source that is individually a Category 2 source.
- Forty-three of the 58 events have an aggregate category of 2, but involve sources that are all individually less than Category 2.
- Fifteen of the 131 sources were individually Category 2 sources (all were Am-Be sources). The remaining 116 sources were all individually less than Category 2.

Appendix A – Category 1 Source Events

(2 events involving multiple sources)

Item Number 150091 - A radioactive source manufacturer reported that a shipment of Ir-192 wafers/disks was delivered to the wrong address by a common carrier on 2/9/2015. Three containers of Ir-192 wafers/disks (to be assembled into sealed sources) were being shipped from the manufacturer's Burlington, Massachusetts, facility. Each container held IAEA Category 1 quantities of Ir-192. Two containers were destined for South Korea and one for the manufacturer's Baton Rouge, Louisiana, facility. The label on one of the South Korean containers was either not legible or missing and that container was incorrectly bound to the container going to Baton Rouge by the common carrier at their Memphis, Tennessee, hub. The incorrectly bound container held 432.16 TBq (11,680 Ci) of Ir-192 and was delivered to the Baton Rouge facility. The common carrier was notified of the incorrect delivery. The common carrier was scheduled to pick up the container on 2/10/2015 and forward it to South Korea.

Item Number 150098 - A radioactive source manufacturer reported the loss and recovery of six packages that contained a total of 2,701 TBq (73,000 Ci) of Ir-192. Two of the packages each contained four special form capsules and the other four packages each contained three special form capsules. All of the special form capsules contained Ir-192 wafers/disks. The manufacturer was notified on 2/13/2015 by the common carrier that they had initiated a trace on the lost packages. The shipment originated from the Netherlands and was intended for Burlington, Massachusetts. The packages were located by the common carrier at their Memphis, Tennessee, facility on 2/13/2015. The packages were then delivered to the manufacturer on 2/16/2015.

Appendix B – Category 2 Source Events (other than irretrievable well logging sources)

(32 events involving 48 sources)

Item Number 050727 - A radiography services company reported the theft and recovery of a radiography exposure device that contained an Ir-192 source with an activity of 2.37 TBq (64 Ci). The device was stolen from a locked storage area in the company's office. It was last used on 10/28/2005 and was logged in on 10/29/2005. A radiographer went to the storage area on 10/31/2005 to get the gauge and discovered that it was missing. The local police department was notified. The device was recovered on 11/2/2005. Due to local media coverage in the area, a private citizen contacted the Oklahoma Department of Environmental Quality and provided information. The citizen saw the device near the freeway entrance in West Tulsa, Oklahoma. The device was found in a grassy area near a privacy fence and was intact with the source in the shielded position. The licensee surveyed the site and stated that the radiation readings were consistent with a shielded radiography source. The source was inspected and leak tested. Corrective actions taken by the licensee included changing the combination for the lock to the storage room.

Item Number 060508 - A radiography services company reported the theft and recovery of a radiography exposure device that contained an Ir-192 source with an activity of 2.78 TBq (75 Ci). The device was locked and secured inside a truck that was stolen from the parking lot of a hotel in Everett, Washington, on 8/8/2006. The truck was equipped with an alarm and disabling device, but the device was not used. The keys to the vehicle were reported to have been left in the door of the truck. The Everett Police Department was notified of the incident. The truck was found by police on 8/9/2006. It had been abandoned in a strip-mall parking lot near Everett, Washington. Washington Department of Health (DOH) staff was at the scene, performing measurements and assuring radiation safety for police and fire personnel during the recovery effort. It appeared that the darkroom had not been entered. The radiography exposure device was still in its stowed position. The truck and device were returned to the licensee. Corrective actions taken by the licensee included providing additional training to radiography personnel, testing all security alarms, and repairing or replacing deficiencies. The alarm system on the vehicle that was stolen was completely replaced. A protocol was implemented that separates truck keys from darkroom and camera keys. Problematic plunger switches were replaced on all darkrooms. All darkroom door hinges were modified to include through bolts to prohibit removal of the door. Additional steps were taken including the installation of a global positioning satellite system in all company trucks.

Item Number 060568 - A radiography services company reported the theft and recovery of a radiography exposure device that contained an Ir-192 source with an activity of between 3.5 and 3.7 TBq (95 and 100 Ci). The device was stored in a radiography truck that was stolen while parked at a gas station on 9/13/2006. The radiographer/driver went into the store to talk with his supervisor and left the keys on the floorboard. The local police department was notified and responded to the scene. The Texas Department of Health reported on 9/15/2006 that the stolen truck and radiography equipment were recovered at a business park in Dallas, Texas, approximately three miles from the location of the theft. The gauge was found intact in the vehicle and was in the possession of law enforcement authorities while they investigated the person(s) responsible for the theft. The involved radiographer was reprimanded. All licensee employees received further instruction in the security requirements for transporting radioactive material and the importance of constant security awareness in the transportation and storage of radioactive materials. The licensee also had LoJack monitors installed on all darkroom vehicles during the week of 9/25/2006. All keyed locks, which may have compromised security, were replaced.

Item Number 070050 - A radiography services company reported the loss and recovery of a radiography exposure device that contained an Ir-192 source with an activity of 3.7 TBq (100 Ci). On 1/21/2007, the radiographer was traveling on a lease road in his truck with a darkroom on the back. The device was secured in a yellow box in the darkroom. When the radiographer attempted to cross moving water, the

truck engine stalled. The water flowed into the truck over the doors and the radiographer exited the truck. The truck was subsequently swept away. Oklahoma Emergency Management, local law enforcement, and Oklahoma State Police were notified and initiated a search for the lost exposure device. Searches on 1/22/2007 located the truck. Searchers decided to wait until the creek returned to a more normal level to enable safe access to the truck. The licensee recovered the exposure device on 1/24/2007. It appeared to be intact. As a precautionary measure, DEQ staff will take surveys and wipe tests of the device and return to the office.

Item Number 070260 - A radiography services company reported the loss and recovery of a radiography exposure device that contained an Ir-192 source with an activity of 1.15 TBq (31 Ci). The exposure device was missing while in common carrier transit from Anchorage, Alaska, to Baton Rouge, Louisiana. The device was being shipped to the manufacturer for source replacement. Three devices were shipped, but only two of them arrived as scheduled on 4/26/2007. Each device was assigned a separate common carrier tracking number, but all three were shipped at the same time. The RSO was not notified of the missing shipment by the manufacturer until 4/30/2007. The RSO attempted to track the shipment, but was unable to receive priority attention from the common carrier. The carrier's tracking system still showed the device in transit in Oakland, California. The RSO later stated that following a high priority trace by the common carrier, the package was confirmed to still be in Oakland, California. The device was delivered to its intended destination on 5/1/2007.

Item Number 070738 - A radiography services company reported the loss and recovery of a radiography exposure device that contained an Ir-192 source with an activity of 888 GBq (24 Ci). On 12/3/2007, a radiography crew left a temporary jobsite north of Saginaw, Texas, with the device on the tailgate of their truck. The crew drove approximately 15 minutes towards Justin, Texas, prior to remembering that the device was on the tailgate. It was then noticed that the device was missing. The crew retraced their route, but did not locate the device. A member of the public found the device on Blue Mound Road in Saginaw on the evening of 12/3/2007 and took it to their home, storing it there overnight. A Texas Department of State Health Services inspector traveled to the residence on 12/4/2007 and noted that the device was not damaged and the source was retracted in the shielded position. A leak test was performed on 12/5/2007 and no leakage was identified. The radiography services company took possession of the device. Corrective actions included personnel reprimanded, personnel received additional and new training, and new personnel were hired.

Item Number 080005 - A radioactive source manufacturer reported a missing and recovered shipment that contained seven Ir-192 sources in four containers with a total activity of 28.86 TBq (780 Ci). The shipment was dispatched from the manufacturer on 12/5/2007, but did not reach its final destination in Argentina. The common carrier was to deliver the shipment to an air cargo company at the Miami International Airport. However, a sub-broker had cancelled the shipment due to incomplete permitting requirements, without notifying anyone except the air cargo company. When the common carrier delivered the shipment to the air cargo company, they would not accept it. During the subsequent search for the missing shipment, it was determined that the air cargo company had inadvertently signed some paperwork indicating that they had accepted the shipment on 12/11/2008. The shipment was eventually located at the common carrier's terminal dock on 12/23/2007. The source manufacturer's corrective actions included retraining distribution staff to immediately notify the regulatory department if a shipment does not arrive on time, not using a carrier until all appropriate documentation is obtained and reviewed, obtaining after hours contact numbers of appropriate carrier representatives, affixing a highly visible label on radioactive material shipments, and integrating other shipment quality management policies.

Item Number 080115 - A radioactive source manufacturer reported the loss and recovery of a transport container/source changer that held two Ir-192 sources. One source contained an activity of 2.9 TBq (77.5 Ci) and the other source contained an activity of 2.1 TBq (57.2 Ci). The source manufacturer was advised on 2/19/2008 that the shipment of radioactive material bound for Hong Kong was declared to be missing.

The package was physically located on 2/21/2008 at the common carrier's facility in Newark, New Jersey. The cause of the loss was that the paperwork for the shipment became separated from the shipment itself and the paperwork went to Hong Kong. The source manufacturer worked with the carrier and the customer to locate and delivered the shipment. The shipment was confirmed delivered to the customer in Hong Kong on 2/28/2008.

Item Number 080283 - A radioactive source manufacturer reported that a shipment containing an Ir-192 source with an activity of 5.52 TBq (149.2 Ci) was missing and recovered. The source was originally shipped on 5/7/2008, with a final destination of Trinidad. It arrived in Miami, Florida, and was transferred from a common carrier to an air cargo company. The air cargo company reported that the shipment could not be found on 5/9/2008, at the time of its originally scheduled flight to Trinidad. They stated that the signature that the common carrier had on record as receiver was not an eligible air cargo company receiver. The air cargo company located the missing shipment in their Miami facility on 5/12/2008. The package was undamaged and resumed transport to Trinidad.

Item Number 090554 - A radiography services company reported the loss and recovery of a radiography exposure device on 6/22/2009. The device contained a 1.998 TBq (54 Ci) Ir-192 source. When a radiographer left the shop to travel to a work site on 6/22/2009, he placed the exposure device on the tailgate of his work truck. The device was not secured and the tailgate remained in the open position. Approximately 25 minutes later, the radiographer realized that the device had fallen off the truck. The radiographer proceeded back along the same route he had taken to the work site. He noticed a police vehicle traveling on the same remote rural road and he stopped the officer for assistance. The police officer had just recovered the device from a private individual, who had found the device on the road approximately one-half mile from the shop and contacted the police. The device was not damaged and had been out of the radiographer's control for about 40 minutes. Corrective actions included additional training for the radiographer. Based on the results of an NRC inspection, the NRC license for the radiography services company was revoked.

Item Number 090661 - A refinery reported finding a radiography exposure device that contained a 1.81 TBq (49 Ci) Ir-192 source. A radiographer had completed a job at the refinery at approximately 2030 PDT on 8/5/2009. The radiographer loaded gear into his truck, but left the exposure device at the job site. Approximately 10 to 15 minutes later, refinery maintenance personnel noticed the device and notified their fire department. Another radiographer at the refinery heard the call on the radio and responded to the incident location. However, he did not have a radiation survey meter to approach the device. He noticed that the plug was in and the device appeared to be locked with no key in the lock. They barricaded the area and kept the device under surveillance until a survey meter was brought to the scene. The radiographer surveyed the device and confirmed that the source was in the shielded position. The device was transported to the storage location.

Item Number 100415 - A radioactive source manufacturer reported the loss and recovery of a 3.7 TBq (100 Ci) Ir-192 radiography source. The manufacturer shipped the source to a radiography services company on 9/15/2006. The shipment was due to arrive on 9/18/2006 and was reported as overdue. It was last scanned by the common carrier on 9/19/2006 in Providence, Rhode Island. The Massachusetts Department of Health was notified on 9/25/2006 that the shipment was delivered to the radiography services company on 9/21/2006.

Item Number 100561 - A radioactive source manufacturer reported the loss and recovery of a shipment that contained a 3.28 TBq (88.7 Ci) Ir-192 source. On 11/5/2010, the source was shipped to a radiography services company to be delivered by an air cargo company in Anchorage, Alaska. The Ir-192 source was shipped priority overnight along with a small non-radioactive device that contained a leak test kit. The shipment was scheduled to be delivered to the air cargo company on 11/8/2010. The leak test kit was delivered without issue. However, the Ir-192 source did not arrive. On 11/9/2010, the common

carrier was contacted and put a trace on the shipment. The carrier stated on 11/10/2010 that the packaged was located and forwarded to its destination.

Item Number 110363 - A radiography services company reported the theft of a radiography exposure device that contained a 1.25 TBq (33.7 Ci) Ir-192 source. The company discovered on the morning of 7/19/2011 that the darkroom of their truck had been broken into. Local law enforcement was contacted and responded to the scene. The hotel security camera was reviewed and the thief's vehicle type and manufacturer were identified. The time of the theft was determined to be between 0400 and 0409 CDT on 7/19/2011. A Texas Department of Health (DOH) inspector responded to the site. The darkroom alarm system was tested and found to be functioning properly. However, the radiographers failed to set the alarm when they returned to their hotel from dinner. The tailgate was not locked, but the darkroom was locked and the device was locked to the darkroom. Several searches were conducted using portable radiation detection equipment in vehicles, but the device was not located. A fly-over survey was also conducted by the Department of Energy using a fixed wing plane between the cities of Austin and San Antonio, Texas. No abnormalities were noted. The radiography services company conducted a company-wide stand-down to review the incident with all employees, they inspected all their trucks to verify the alarm systems were operating, and all employees were required to view a video that showed the proper way to lock and secure radioactive material. In addition, procedures will be modified. As of 7/22/2011, this incident had a final INES Rating Level of 2.

Item Number 120176 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 962 GBq (26 Ci) Ir-192 source. The radiographer had completed work on a pipeline near De Beque, Colorado, on 3/13/2012 and failed to secure the device in his pickup truck when he drove to the next location. Upon arriving at that location, the radiographer realized the device was missing and retraced his route. The radiographer did not find the device. The RSO was notified of the incident. A member of the public who was working at the jobsite found the device and placed it in the back of his truck. Approximately two hours later, he saw the radiographer and returned the device to him. It was determined that the source was intact and had not been tampered with. Corrective actions included terminating the employment of the involved radiographer, generating a new procedure, and providing additional training to the rest of the staff.

Item Number 120478 - On 8/15/2012, a radiography services company reported the theft and recovery of a radiography exposure device that was stolen out of the darkroom of one of their trucks, which was parked at their facility. The radiographer had left the device in the truck instead of transferring it to the storage vault. The device contained a 3 TBq (81 Ci) Ir-192 source. A thief broke into five radiography trucks, taking various items including the exposure device. It was determined that the thief had not taken a crank-out assembly or guide tube. A police report was filed. Local law enforcement recovered the device around 1130 CDT on 8/15/2012. The truck used by the thief was identified on a surveillance camera. The exposure device was found in the back of that truck at the thief's residence. The Texas Department of State Health Services investigated the incident. A wipe test was conducted and the device was inspected. The device was returned to service. Employment of the radiographer that left the device in the truck was terminated. Corrective actions included providing additional training to personnel, increasing video surveillance, and installing improved lighting.

Item Number 120550 - A radiography services company reported the loss and recovery of a radiography exposure device that contained an Ir-192 source. The device was shipped by a transportation company, but had not been delivered to the radiography services company's facility. It had been shipped from a jobsite in Montoursville, Pennsylvania, on 9/11/2012 and was scheduled to arrive at the facility on 9/14/2012. The device was shipped in an overpack cardboard container. A company investigation verified that the device was not at the Pennsylvania location as of 9/17/2012. The Arkansas Department of Health also performed an investigation into the location of the device. The device and source were found in the transportation company's Newark, New Jersey, facility on 9/17/2012 and subsequently

delivered on 9/18/2012. The NRC Registry of Radioactive Sealed Sources and Devices indicates that this exposure device contains an Ir-192 source with a maximum activity of 5.55 TBq (150 Ci).

Item Number 130218 - A radioactive source manufacturer reported the loss and recovery of a shipment containing eight Ir-192 radiography sources. Each source contained an activity of 3.7 TBq (100 Ci). The source manufacturer expected the shipment to arrive at their facility in Baton Rouge, Louisiana, on the morning of 5/6/2013. When the shipment did not arrive, they contacted the common carrier to locate the shipment. The last known location of the shipment was in Memphis, Tennessee. Later in the evening of 5/6/2013, the common carrier contacted the manufacturer and stated that the shipment had been located in Memphis.

Item Number 130230 - A radioactive source manufacturer reported the loss and recovery of two Ir-192 radiography sources. One source contained 1.14 TBq (30.9 Ci) and the other source contained 3.73 TBq (100.9 Ci). The sources had been loaded into a source changer on 5/6/2013 and were shipped to a shipyard. The source changer was expected to be delivered on 5/8/2013. The shipyard notified the manufacturer when the source changer did not arrive as scheduled. The transportation company was then notified. The transportation company searched their facilities in Newark, New Jersey, and Boston, Massachusetts. The sources were found in the Newark facility and were expected to arrive at the shipyard on 5/10/2013.

Item Number 140049 - A radiography services company reported leaving a radiography exposure device, which contained a 1.27 TBq (34.4 Ci) Ir-192 source, unattended at a jobsite at a chemical company's tank farm. Miscommunication between radiographers led to the incident and the device was left unattended overnight on 1/8/2014. The device was retrieved on the morning of 1/9/2014. The two involved radiographers were suspended pending further investigation.

Item Number 140092 - A radiography services company reported leaving a radiography exposure device containing a 3.85 TBq (104 Ci) Ir-192 source unattended for approximately 2 hours and 15 minutes on 2/9/2014. Operations were being performed at a refinery. The radiographers using the device believed that there were other radiographers in the area. They left the device unattended, suspended two feet from the floor, to process film. A refinery employee discovered the device and notified the radiography services company. Shortly thereafter, the radiography services company took possession of the device. Corrective actions included reprimanding personnel and providing additional training to those involved personnel. Those personnel will also be monitored and audited to assure competency and compliance with regulations and procedures.

Item Number 140095 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.11 TBq (30 Ci) Ir-192 source. Following radiography operations at a refinery on 2/9/2014, a radiographer left the exposure device on the bumper of his truck. The device fell to the pavement when he drove away. A refinery employee noticed the device in the parking lot and contacted his manager. The radiography services company was contacted and their RSO drove to the refinery and took possession of the device. Corrective actions included reprimanding involved personnel and providing additional training to all radiographers. In addition, a simple form has been developed that requires a double-check of radiography exposure devices prepared for transport or storage. The radiography services company will also add a level of supervision to prevent recurrence.

Item Number 140284 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.44 TBq (39 Ci) Ir-192 source. The radiography crew was at a refinery to perform weld testing. The crew was in their vehicle waiting out a storm when a tornado ripped the darkroom off of the vehicle. The exposure device was found within the refinery boundary and appeared to be undamaged with the source in the shielded position. Radiation surveys of the device revealed

background levels. The device was sent to the manufacturer for leak testing and mechanical evaluation. Leak tests revealed negative results.

Item Number 140558 - A radiography services company reported the loss and recovery of a radiography exposure device during a shipment from a job site in California to their office in Oklahoma. The device contained a 2.11 TBq (57 Ci) Ir-192 source and was picked up by a common carrier on 9/30/2014. The device was scheduled to arrive at the Oklahoma facility on 10/3/2014. However, on 10/6/2014 the device had not arrived and was declared missing. The common carrier determined that the device entered their Memphis, Tennessee, hub on 10/1/2014, but did not leave. On 10/11/2014, the radiography exposure device was found at the common carrier's facility in San Jose, California. When found, both Yellow II labels had been removed from the package. The shipping document attached to it had also been removed and replaced with an older copy. The endcap which fits over the drive cable connection fitting was not installed on the device, but was in the package (the radiography services company employee who packaged the device could not remember if the endcap was installed when the device was packaged). It appears that the device arrived in Memphis with the labels and shipping papers removed. Common carrier staff found a sticker with a barcode on the package which had been attached when it was originally shipped from Oklahoma to California. They scanned the barcode and were able to retrieve a copy of the original (Oklahoma to California) shipping papers. These old shipping papers were attached to the package, causing it to be sent back to California.

Item Number 140728 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.7 TBq (46 Ci) Ir-192 source. Operations were being performed at a gas pipeline compressor station near Perkins, Oklahoma. Radiographers unintentionally left the exposure device at the site at about 1:00 a.m. on 11/6/2014. The client's inspector found the device at about 7:30 a.m. that morning. The client contacted the radiography services company, who recovered the exposure device and source. There was no evidence of tampering. The Oklahoma Department of Environmental Quality investigated the incident. Corrective actions included providing additional training to personnel.

Item Number 140740 - A radiography services company reported the loss and recovery of a radiography exposure device, which contained a 1.41 TBq (38 Ci) Ir-192 source. The radiography services company was notified by local law enforcement on 11/12/2014 that the radiography exposure device had been found on the side of the road, approximately three miles from the company's facility. The company determined that the device had fallen from one of their trucks en route to a temporary job site. The device had not been secured inside the truck, but had been left on the tailgate due to miscommunication. The company retrieved the device and there was no apparent damage. They estimated that the device was out of their possession for approximately 2.5 hours. The device had been locked and the keys were not with it while lost. Corrective actions included additional training for involved personnel.

Item Number 140740 - A radiography services company reported the loss and recovery of a radiography exposure device, which contained a 1.41 TBq (38 Ci) Ir-192 source. The radiography services company was notified by local law enforcement on 11/12/2014 that the radiography exposure device had been found on the side of the road, approximately three miles from the company's facility. The company determined that the device had fallen from one of their trucks en route to a temporary job site. The device had not been secured inside the truck, but had been left on the tailgate due to miscommunication. The company retrieved the device and there was no apparent damage. They estimated that the device was out of their possession for approximately 2.5 hours. The device had been locked and the keys were not with it while lost. Corrective actions included additional training for involved personnel.

Item Number 150038 - A radioactive source manufacturer reported two missing Ir-192 sources that contained 3.8036 and 3.7999 TBq (102.8 and 102.7 Ci), respectively. They had shipped the sources in a source changer to a customer. The customer notified the manufacturer on 1/13/2015 that the shipment had not arrived as expected. The customer contacted the common carrier and was told that the shipment could not be located. A trace of the shipment was initiated. The carrier believed that the shipment was in

the U.S. Postal Service facility in Charleston, South Carolina. The source manufacturer was later notified by the carrier that the shipment had been located in the carrier's Memphis, Tennessee, hub. The shipment had no indication of tampering and was shipped to the customer. The carrier will provide additional training to their personnel.

Item Number 150243 - A radiography services company reported the loss and recovery of a radiographic exposure device that contained a 2.92 TBq (79 Ci) Ir-192 source. On 4/6/2015, an assistant radiographer was distracted and left the device on the truck's tailgate prior to traveling to a temporary jobsite. The crew passed the jobsite and made a U-turn, causing the device to fall from the truck. After arriving at the jobsite and beginning to setup for the job, the radiographers discovered that the device was missing. Retracing their route failed to locate the device, because it had already been recovered. A private citizen had discovered the device in some weeds on the side of the road in the area where the radiographer's had made their U-turn. The private citizen contacted the New Iberia Fire Department. Based on documentation with the device, the Fire Department contacted the radiography services company. The company's RSO responded to the location, surveyed the device, and returned it to the company's facility. Involved personnel were reprimanded and required to complete additional training. In addition, a procedure was generated allowing only radiographers to remove devices from vaults and secure them inside transport vehicles.

Item Number 150332 - A radiography services company reported leaving a radiography exposure device, which contained a 1.26 TBq (34 Ci) Ir-192 source, unattended while in a company radiography truck parked at the Baton Rouge Metro Airport in Louisiana. A radiographer left the device in the truck and boarded a plane on 6/8/2015, which departed at 7:00 am. The individual that was to retrieve the truck did not arrive at the airport until 8:40 am. The alarm system was set off and the alarming device was unmanned for approximately two hours.

Item Number 150362 - A radiography services company reported the loss and recovery of a radiography exposure device that contained a 1.78 TBq (48.2 Ci) Ir-192 source. The device was intended to be loaded into a radiography truck and transported to a temporary jobsite. However, the device was left on the bumper of the truck and not secured in the vault/overpack. The radiography crew left their facility and went from Highway 30 to U.S. East Interstate 10 and had been on the Interstate for five miles before realizing the error. They stopped and discovered that the device was missing at 0830 on 6/25/2015. The Louisiana State Police were notified. The Louisiana Department of Environmental Quality was notified and dispatched personnel. The media was notified and alerted the public. The Department and the radiography services company searched for the device. The device was recovered at about 1900 approximately 1.5 miles away on LA-61, east of U.S. East I-10. It was in a wet, muddy, ditch area off the side of the road. A health and safety survey was conducted and the shielding appeared intact. The exposure device was loaded into another company vehicle and returned to their facility. Leak tests revealed negative results.

Item Number 150439 - A radiography services company reported that a radiography truck containing a radiography exposure device with a 3.7 TBq (100 Ci) Ir-192 source was stolen from a convenience store on 7/30/2015 in Tulsa, Oklahoma. The crew went inside the store and left the keys in the vehicle. Surveillance video from the store showed a dark blue truck pull up next to the radiography truck, a person got out of the blue truck and into the radiography truck, then both were driven away. The radiography services company used the truck's global positioning system to locate it and contacted police. A company employee traveled to the truck's location and observed two men removing equipment, including the radiography exposure device, from the truck. The two men fled when he approached. The device was locked when it was recovered and radiation surveys confirmed that the source was in its shielded position.

Item Number 150587 - A biotechnology company abandoned an irradiator in a facility in Philadelphia. The irradiator contained 15.24 TBq (411.91 Ci) of Cs-137. The company was one year behind on their

rent payment and was about to be evicted from the property. The facility landlord had no knowledge of the irradiator, entered the building on 5/27/2015 and began changing all of the locks, giving himself access to the irradiator. The alarms were triggered and the local law enforcement agency responded to the facility. The Pennsylvania Department of Environmental Protection was contacted and performed an emergency inspection. They confirmed that the Cs-137 source was present in the irradiator. The Department allowed the company to retain their license, provided that they settle with the landlord and secure a letter of credit as financial assurance. The company modified their procedures to prevent future occurrence.

Appendix C – Sum of the Ratios Methodology

The IAEA calculated a D value for each radionuclide, which is used to compare the relative hazards between radionuclides. These D values are expressed in activity (TBq) and are listed in IAEA publication EPR-D-Values 2006, *Dangerous Quantities of Radioactive Material (D Values)*. The D values are used to categorize sources into one of five categories, ranging from extremely dangerous (Category 1) to most unlikely to be dangerous (Category 5).

The specific category for an individual source is determined by dividing the source activity (TBq) by the D value (TBq). The resulting ratio is used to determine the source's IAEA Category as follows (see IAEA Safety Guide No. RS-G-1.9, *Categorization of Radioactive Sources*):

Category 1: Ratio $\geq 1,000$

Category 2: Ratio ≥ 10 but less than 1,000

Category 3: Ratio ≥ 1 but less than 10

Category 4: Ratio ≥ 0.01 but less than 1

Category 5: Activity greater than the exempt value but Ratio less than 0.01

When multiple sources or multiple radionuclides are collocated, the aggregate category is determined using the "Sum of the Ratios" methodology. In this case, the ratios calculated for each individual source are summed. The total is compared to the same category descriptions shown above.

Note that the Sum of the Ratios method can result in an aggregate category greater than any of the individual source categories. For example, consider an event involving a well logging tool containing a 0.592 TBq (16 Ci) Am-Be source and a 0.0629 TBq (1.7 Ci) Cs-137 source. The associated D values are 0.06 and 0.1 TBq, respectively. The individual source categories and the aggregate category are calculated as follows:

Am-Be Source: Ratio = $0.592 \text{ TBq} / 0.06 \text{ TBq} = 9.867 \Rightarrow$ Category 3

Cs-137 Source: Ratio = $0.0629 \text{ TBq} / 0.1 \text{ TBq} = 0.629 \Rightarrow$ Category 4

Aggregate Category: $9.867 + 0.629 = 10.496 \Rightarrow$ Category 2