Lessons from Three Major Fires in the UK Non-Nuclear Sector

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ABSTRACT

Three major fires have occurred in radiation employer's (non-nuclear sector) premises in the UK during the last ten years. The fires involved radioactive materials in the form of large quantities of unsealed materials, bulk storage of ionising chamber smoke detector sealed sources, and anti-static bars in a manufacturing environment. Fortunately none involved physical injuries to employees but the costs of clean-up, decontamination, demolition, re-construction, and loss of business were significant. This presentation summarises the incidents themselves through a series of photographs, discusses the common factors and outcomes, and identifies the data from which various professional groups may be able to evaluate and develop some of the possible lessons that may be learned. These groups include industries with known ignition sources, equipment manufacturers, employers using radioactive materials, emergency responders and civil contingencies, the insurance industry, and radiation protection professionals such as radiation experts, supervisors, and regulators.

KEY WORDS: radioactive materials, fire, accident, emergency, contamination, radioactive waste

INTRODUCTION

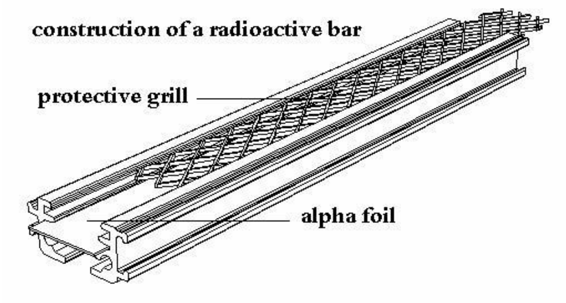
This paper describes the experiences of the author and other inspectors in the HSE Radiation Team of three fires involving radioactive materials that occurred in the UK non-nuclear sector in the past ten years and which the dutyholders sustained significant clean-up costs and loss of business. These fires have involved radioactive materials in the form of large quantities of unsealed materials, bulk storage of ionising chamber smoke detector sealed sources, and anti-static bars in a manufacturing environment respectively. It concludes by drawing together the lessons that can be learnt by a wide range of stakeholders and proposes where further research may be considered.

Fire in a foil manufacturing plant (^{210}Po anti-static bars)

Intrinsically safe alpha foil static eliminator bars containing ^{210} Po were severely damaged in a major fire on part of a foil production plant belonging to a leading manufacturer of specialised materials for packaging.

Figure 1: Polyester coating machine

Figure 2: ^{210}Po anti-static bar



Three ^{210} Po anti-static devices (total activity 5.55GBq) were fitted to a polyester coating machine which, together with the coating machine, were damaged beyond repair. The Company's Radiation Protection Adviser identified significant contamination at various locations inside the plant and protection measures were immediately put in place. There was no evidence of contamination spreading outside the building.

A specialist decontamination contractor was employed and it took up to 20 days, involving dismantling an exhaust ventilation system and decontaminating large sections of plant and the building itself, to complete the work. A large quantity of alpha contaminated waste was produced and sent for disposal.

Figures 3 and 4: Decontamination of industrial plant

The cause of the fire was thought to have been the result of static build-up in a toluene rich environment. Clean-up and disposal costs were thought to have been approximately £0.25M.

Fire in a radio-chemical production facility (^{3}H and ^{14}C labelled compounds)

This fire occurred at approximately 8 am in a modern radio-chemical facility that produces and distributes radio-labelled compounds for pharmacology and neuro-chemistry research organisations in the UK and internationally. The facility was located on a modern industrial estate and incorporated production laboratories, offices, and transportation loading areas. The company employed 75 workers and was licensed to hold large quantities of tritium and ^{14}C and smaller quantities of other radionuclides.

Figure 5: Radio-chemical facility building prior to remediation

The fire originated within a refrigerator containing quantities of both ^{3}H and ^{14}C in a variety of different solvents located in the radiochemistry laboratory. Upon ignition of an explosive atmosphere, the refrigerator door was blown across the laboratory, the fridge was destroyed, the adjacent freezer was destroyed, and flames engulfed the entire room, melting the plastic extract duct work and spalling the wall plaster. The sole occupant of the room at the time happened to be near the door and immediately left without injury. The building was evacuated and the fire was quickly contained and extinguished by the local fire brigade. However, smoke from the fire spread to many parts of the building, possibly back flowing through the air distribution system that was shut down when the fire started. It rapidly became apparent that both ^{3}H and ^{14}C had migrated throughout the facility inclusive of the office space and laboratories.

Figure 6: Radiochemistry lab Figure 7: Refrigerator Figure 8: Fire service personnel arriving

On the day of the fire the refrigerator held 740 GBq ^{3}H and 3.7 GBq ^{14}C. The radiochemical laboratory also contained 30 TBq on a tritium manifold which was fortunately not fire damaged due to its location at the opposite end of the laboratory to the ignition source.

Total ^{3}H plus ^{14}C on smear samples taken of surfaces throughout the building ranged from 1.53Bq/cm^{2} to 5021 Bq/cm^{2}, with an average of 142 Bq/cm^{2}. Significantly higher levels were detected in the laboratory itself.

As a result it became necessary to undertake major remediation works at the site. It was initially hoped that major parts of the building fabric could be retained for reuse. However the extent that ^{3}H had penetrated the concrete construction materials was not anticipated and this led to the complete removal of the building. The decontamination/decommissioning operation took 16 months to complete. The early part of the work consisted of characterisation processes together with the design, procurement and installation of the decommissioning ventilation system. The work resulted in the complete removal of the building contents followed by demolition of the structure down to the base slab. The major radiological work was completed by a team of 6 - 8 personnel from NSG Environmental Ltd greatly and a radiochemist from the client.

Over 1000 Tonnes of authorised Very Low Level Waste (VLLW) was consigned to local landfill sites and 308 x 200 litre containers of solid Low Level Waste (LLW) were consigned for incineration.

Figure 9: Remediation of building

Figure 10: Base slab of building post remediation

Despite the large amounts of activity involved, the total dose accrued by workers in the remediation process was only approximately 1.7 mSv. Risk assessment demonstrates that the residual activity, below statutory control concentrations, remaining in the slab will result in negligible risks to future construction workers and occupiers of the site. Additionally it is anticipated that these residual activity concentrations will rapidly drop with time as the tritium disperses into the wider environment and as a result of radioactive decay.

Fire in a warehouse (^{241}Am ionisation chamber smoke detectors)

Due to a fault with a standard type of forklift truck, a fire broke out during the early evening in a warehouse containing 275,000 Ionisation Chamber Smoke Detectors (ICSDs), each containing approximately 35 kBq ^{241}Am (total activity on site 10 GBq).

The fire grew quickly, eventually consuming virtually all combustible material within the warehouse. However, there were no injuries since the only occupant, after trying to extinguish the fire with a hand-held extinguisher, was able to evacuate the premises on foot and call the Fire and Rescue services by mobile telephone from outside.

The Fire Service let the fire burn throughout the night and under the UK National Arrangements for Incidents involving Radioactivity (NAIR) scheme two health physicists from a nearby nuclear power station attended during the night. The Health Protection Agency Radiation Protection Division also attended. Although the immediate vicinity and roads leading to it were closed until sometime later the following day, since no radioactive materials were detected during air sampling in the plume and sampling on the ground, the decision was taken by the Fire Service not to evacuate any nearby residential areas. Local residents were advised that the smoke may be toxic and therefore to keep windows shut until morning. A junction of the nearby motorway was temporarily closed after smoke drifted across large areas.

The Fire Service commenced watering down the fire the following morning and all fire-water was retained in the local drainage system. The Environment Agency set up an Incident Centre in their local offices and deployed an environment management team to monitor the water. No gross contamination was detected. Fortunately there was very little contamination outside the perimeter of the warehouse and no significant radiation doses were received by the public or emergency services. As expected, low radiation dose rates were detected from a fire damaged pile of smoke detector remains located on the forecourt immediately outside the warehouse entrance.

Figure 11: Fire service personnel arriving

Figure 12: Remains of warehouse and contents

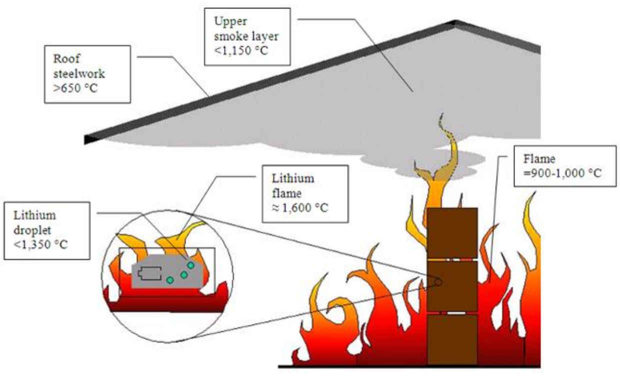
The fire destroyed the building and contents and, due to the temperatures of the fire, significant levels of contamination were present and specialist radiation contractors were required to clean up. The insurers initially estimated the costs to be around £2.5M. The cause of the fire was deemed to be combination of a design flaw and inadequate maintenance leading to a leak of high pressure hydraulic fluid over an electrical ignition source within the forklift truck.

Fortunately, in the weeks after the fire, the weather conditions were extremely favourable. The climate remained damp throughout, thereby keeping the ashes damp, and the predicted heavy rain did not materialise locally, thereby avoiding excessive water which would have resulted in contaminated run-off. With winter approaching however, HSE were concerned that although actions were being taken, progress on make the site physically and radiologically safe and the appointment of a specialist remediation contractor was slow; ten days after the fire the site remained physically the same as it had on the day following the fire. Discussions were held with the employer and their insurers to clarify the urgency of the situation and the containment priority. Options were discussed for placing a tent or shroud over the building and using hardening foam to give wind and rain protection for the ashes.

The employer estimated that approximately 500,000 lithium-iron 9V batteries had been present in the building and information was that these ignited at 170°C and burned at around 600°C. Many of these had exploded and been flung up to 50m from the building. This raised the issue of potential chemical contamination and also localised temperature peaks immediately adjacent to the Am-241 foils within each ICSD. The fire service estimated the fire to be between 600° and 900°C and unlikely to exceed 1200°C.

Figure 13: Schematic of fire temperatures

Figure 14: Remains of ICSD ^{241}Am foil



Retrieved ^{241}Am foil fragments were coated with extraneous material, possibly ferrous oxide and this made estimation of their activity by monitoring extremely difficult and inaccurate. However, it was estimated that in excess of 96% of the ^{241}Am activity remained attached to the source backing plates. From a health physics perspective this project was problematic as the gamma emissions from the sources were easily masked and there was therefore a considerable amount of loose radioactive contamination below limits of detection for conventional health physics instruments. In order to gain a high degree of confidence a layered monitoring strategy was adopted.

Plans for removal of the building and its contents had to account for the additional safety hazards of the steel building and shelving framework that had collapsed or been significantly distorted in the heat of the fire and were hanging dangerously in some places. This prevented all contractors entering the building on foot.

Figure 15: Warehouse after fire extinguished

Figure 16: Decontamination personnel

Waste was segregated in a vacant neighbouring warehouse that had not been damaged by the fire. It was placed into half-height ISO containers in a manner that minimised the potential for airborne contamination. In total twenty six containers were sealed, monitored and dispatched as LLW at a rate of two to three containers per week.

Figure 17: Packaged waste for disposal

Figure 18: Final site clearance

Eighteen months after the fire the radioactive waste in the warehouse had been removed and packaged, the remains of the building had been demolished, the radioactive and non-radioactive wastes had been cleared from site, and work commenced rebuilding the warehouse. The smoke detector distribution company now operates from a separate location, where an automatic fire sprinkler system is installed.

LESSONS

Risk assessments and contingency plans for emergencies involving radioactive materials should always address the possibilities of both small and major fires in the premises and during transportation between premises and during delivery to customers. These assessments should include analysis of the ignition sources, the potential for the spread of radioactive materials, the potential remediation and loss of business costs, and the benefits of the installation of fire detection and prevention systems. Some of these are expanded upon below:

Ignition sources

In the laboratory environment;

1. 'Spark free' is not a defined term in refrigerator standards. Manufacturers and suppliers use the term to describe fridges and freezers that have had sources of electrical sparking, typically the interior light, removed from the storage chamber.
2. It is not clear which additional potential sources of ignition, such as fan motors and heaters, are made intrinsically safe by manufacturers and suppliers.
3. The term 'spark free' does not imply that the storage chamber will contain any potentially explosive atmosphere. A refrigerator is likely to have a drain hole at the back.
4. An explosive atmosphere may originate within the storage chamber and escape to an external ignition source.
5. The suitability of 'spark free' refrigerators and freezers to store flammable or volatile liquids would be dependant on a risk assessment.

Users should:

1. Avoid refrigerators if possible – use 'spark free' if not possible.
2. Limit, control, segregate and monitor quantities of flammable liquids within and between refrigerators.
3. Use minimum quantities and high flash-point flammable liquids.
4. Seal containers of flammable liquids – use secondary seals.
5. Store flammable liquids upright on a stable base.
6. Consider ½ hour fire resistant compartments in refrigerators.
7. Consider further mitigation for high risks such as local ventilation and temperature controlled areas.

In the transport and storage of Ionisation Chamber Smoke Detectors;

Manufacturers, importers, distributors, storage, and sales merchants must consider and minimise all potential sources of ignition. This must include assessment of all vehicles such as lorries and forklift trucks transporting the devices as well as the flammability of surrounding goods. The fire in the incident described began as a result of damage to flexing electrical cables. This is a generic property of this type of FLT and particular attention must be given to the construction and condition of cables and hydraulic lines during maintenance procedures.

Potential for spread of radioactive materials

Internationally it appears that there is very limited data on the fire hazards involved in the storage and distribution of large numbers of ICSDs or of radioactive materials in general. In the warehouse fire, despite the relatively high temperatures and manufacturer's data showing that there could theoretically be significant releases of radioactive materials, it was evident that whilst the radioactive foils were effectively destroyed, the radioactivity remained in place for the most part. This led to significant contamination in the local area but very little contamination beyond. However, for a significantly smaller fire involving only a few thousand ICSDs this could still result in significant doses if not cleaned up correctly. Two similar situations are known to have arisen during lorry fires on UK and French motorways some years ago. In the radio-chemical facility and the foil plant fires the spread of radioactive materials appears to only have been limited by both the size of the fires and partial containment by the buildings themselves.

Potential remediation and loss of business costs

Although basic notification of work with radioactive materials had previously been provided to the emergency services, in all three incidents described, the emergency services primarily were notified of the radioactive materials present by employees present on the scenes. Users of significant quantities of radioactive materials should ensure that they have undertaken adequate consultation with local emergency services and also considered the risks to emergency responders in their risk assessments.

Whilst all three fires described were fortunately limited in their damage and radiological consequences, extensive contamination of the premises themselves did occur and costs for decontamination and waste disposal were significant.

Fire detection and prevention systems

The use of fire detection, automatic extinguishing systems, and features that limit ventilation, should be considered for such facilities. For example, open warehouse roller-doors and plastic skylights which melt at relatively low temperatures significantly increase fire development.

CONCLUSIONS

These fires all had significant consequences for the respective employers but these employers can also be regarded as fortunate since it would be fair to accept that none of them were particularly prepared for the radiological consequences of a fire on their premises. They are fortunate that no employees, other workers such as the emergency service personnel, or members of the public, were either physically injured as a result of the fire or received significant radiation doses as a result of the airborne and surface contamination. Certainly the radiological consequences could have been far more serious if for instance:

Incident 1: More than the three static elimination bars had been involved in the fire; the fire had spread beyond the foil production part of the plant; employees had been in closer vicinity; or there had been airborne off-site releases.

Incident 2: Higher quantities of radioactivity had been stored in the refrigerator the previous night; more radiologically significant radionuclides had been present; the fire had taken longer to bring under control and had involved the tritium manifold containing 30 TBq; the staff had been positioned elsewhere within the radiochemistry laboratory; or there had been off-site airborne releases.

Incident 3: Higher numbers of smoke detectors had been present in the warehouse on the evening; significantly more ^{241}Am had been released from each smoke detector foil leading to potential employee and public exposures; weather conditions during the few weeks after the fire had not been so favourable; or there had been off-site airborne or fire/rain water releases.

For these reasons it is important that through policies, procedures, risk assessments and audits the following groups all learn the lessons of both preparing and responding to these types of incidents:

- Manufacturers, distributors, and users of radioactive materials;
- The radiation protection community (including radiation protection experts, operational supervisors, and decommissioning & waste contractors);
- The insurance industry;
- Emergency responders and civil contingencies (including emergency response services, local authorities, and civil contingency/ security planners); and
- Radiation regulators.

All three incidents described would make excellent basses for worst-case scenario desktop case study evaluations examining what the consequences would have been should any one or more of the parameters described above had been less favourable.

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