Chemistry - PI 24

RADIOACTIVE MATERIALS/MANAGEMENT

Objectives:

1. List typical sources for low, medium and high level radioactive material.

2. Briefly describe the in-station handling of low, medium and high level radioactive material.

3. Briefly note the specification for transporting low level material, the same for medium level material.

4. Briefly describe the processing and storage of low level material at BNPD.

5. Briefly describe the in-station storage of irradiated fuel in fuel bays and the chemical control of the water in the bays.

Lesson 324.10-1 deals extensively with these objectives and has been reproduced here with the omission of some extraneous material.

A. What is low, medium and high level waste?

More than 99% of the radioactive by-products created in a nuclear reactor are contained inside the fuel bundles. (Fuel bundles remain in the reactor for about one year.) The fragments resulting from the splitting of the uranium atom are called fission products. These fission products are almost all radioactive, and remain inside intact fuel bundles.

Some other uranium atoms in the fuel are changed into heavier atoms as a result of the intense neutron flux inside the reactor. These heavier atoms are called Actinides. Plutonium is one example of these heavier atoms.

Some of these radioactive by-products are valuable. In particular, plutonium could be extracted and used for the production of other nuclear fuel.

The radioactive products contained in the fuel bundles which are not valuable are referred to as high level waste. Thus the irradiated fuel bundles are not a waste, but they do contain waste as well as valuable material.

The concentration of corrosion products is quite low, but when radioactive, they can be the source of strong radiation fields. These radioactive corrosion products, together with a small fraction of radioactive materials contained in the fuel bundles, form the activity in low and medium level wastes.

We have thus identified the sources of activity in low, medium and high level waste. But for radioactive materials to end up as a waste, they have to leave the reactor.

The fuel bundles which contain the high level waste are removed from the reactor by remotely controlled fuelling machines.

Medium level waste is made up mainly of spent filters and spent ion exchangers.

The material not removed by the purification systems may remain in the water to adhere to surfaces of the various components of the circulating water systems. Maintenance of these components results in contamination of materials such as paper, plastic suits, mops, rags. Low level waste consists mainly of such materials.

Inactive waste collected in areas of the station where radioactive material may be present, is also treated as low level waste. See Figure 1.

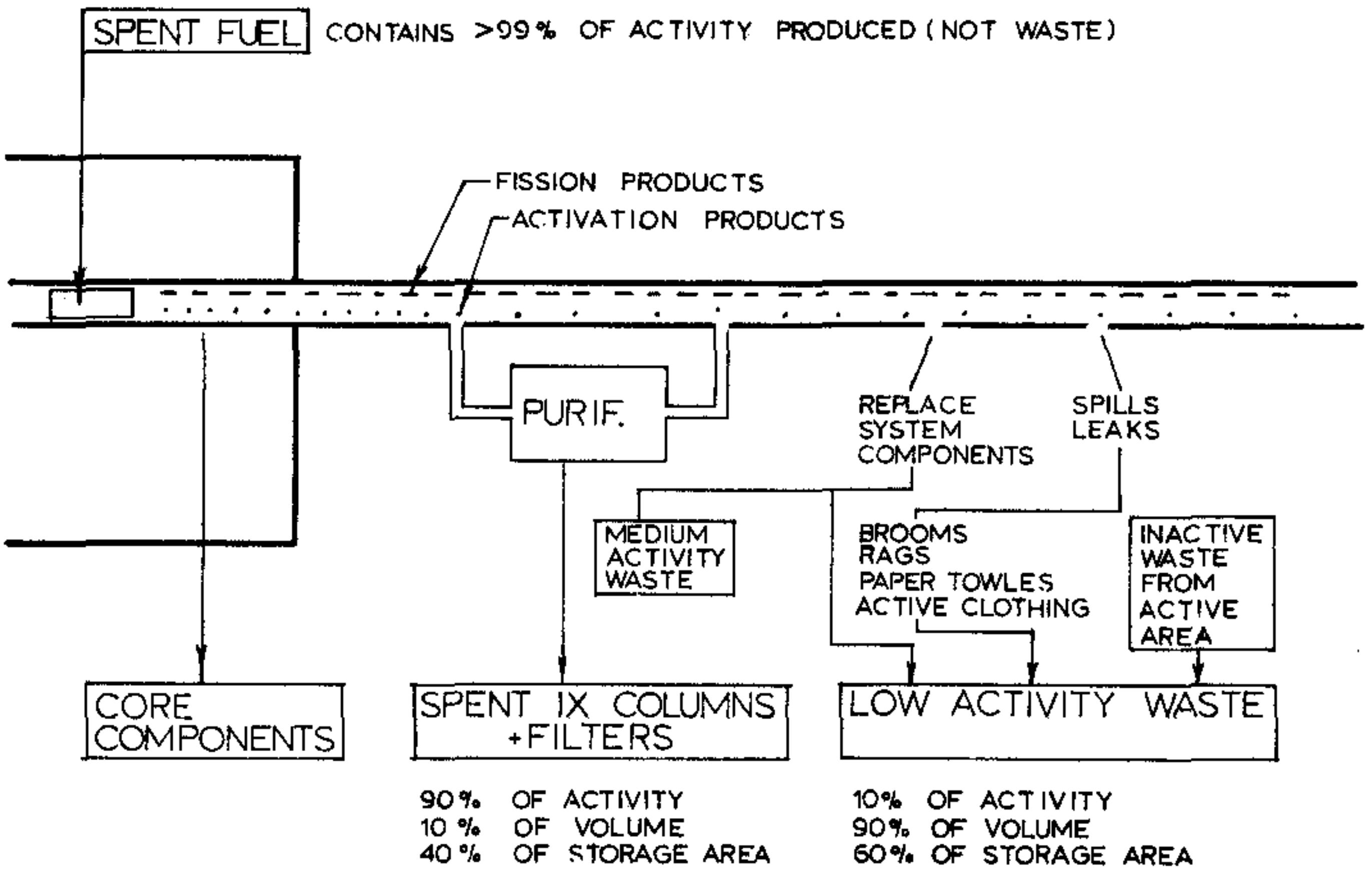

Figure 1

Radioactive Solid Waste in a Nuclear Station

B. What are we doing with radioactive waste?

Radioactive materials are hazardous materials and therefore have to be managed properly. The hazards differ with the level of activity, therefore different methods are used for waste with different levels of activity. The basic steps in managing the radioactive waste are the following:

Collection, Transportation, Processing and Storage. We will now discuss what this means for low and medium level waste, and irradiated fuel.

1. Departments Involved

The management of radioactive waste involves several Ontario Hydro departments, as well as the AECB. Some of the activities of these departments with regard to radioactive waste are as follows:

- The nuclear generating stations collect and package the radioactive waste in a suitable form for shipment.
- BNPD Services schedules the shipments, and places the waste into the storage facilities.
- Generation Projects designs waste handling storage and processing facilities.
- Hydro Research investigates new processes.
- Health and Safety Division provides the relevant radiation protection regulations.
- RMEP provides assistances to and coordination between the various departments.
- AECB issues licenses for transportation of the waste, and for construction and operation of storage and processing facilities.

2. Collection of low and medium level waste

Low level waste represents more than 90 percent of the combined volume of low and medium level waste, but less than 10 percent of the combined activity. As mentioned it consists mainly of paper, rags, mops, etc. used for maintenance of active equipment. The activity of this waste is so low that no radiation shielding is required for handling these materials. They are collected by hand in plastic bags and placed in steel drums or other adequate containers for shipment to the waste storage facility.

Medium level waste, which consists mainly of spent filters and ion exchange resins, generally does require some radiation shielding while it is being handled. They are located in shielded areas in the generating station. An ion exchange column may contain 0.2 m^3 of resin. The spent IX column is isolated from the purification system by valving procedures. At this time it is still in the shielding pit. After being drained of water, it is lifted by hoist out of the shielding pit and lowered into a transportable shielding flask. The weight of this shielding flask is approximately 5450 kg; it is made of lead inside a steel shell. The flask is taken out of the reactor building, after which heavy water is removed from the IX column. The column is then ready for transportation to the waste storage site, (at BNPD). They are transported there in special containers called "Super Tigers". The particular storage facilities for IX resins are called tile holes (to be briefly described later).

3. How let's have a look at <u>handling, transporting and storage of the low level waste</u>.

   (a) This waste is collected in plastic bags in garbage cans located thoughout the station. Once a shift the plastic bags with the low level waste are removed from the garbage can and taken to a central area where they are placed inside steel drums. These steel drums are transported to the central waste storage site.

   (b) <u>Transportation of radioactive waste</u>

   Because radioactive wastes are hazardous materials, there are special conditions for their transportation. The special requirements depend on the level of activity in the waste. In Canada, as in most other countries, the regulations for the safe transport of radioactive materials are based on Regulations from the International Atomic Energy Agency. In Canada, all shipments of radioactive material from nuclear generating stations are packaged, loaded and shipped in accordance with regulations from the Atomic Energy Control Board. These regulations require that all transportation of radioactive material be in accordance with the regulation of the body having jurisdiction over the proposed mode of transport. For road and air transport, the regulations from the Canadian Transport Commission apply, unless stated otherwise by the AECB. These regulations define limits for activity of radiation and contamination. They also specify packaging performance tests.

Packages are designed to limit radiation dose to an acceptable level in case of an accident. There are two major types of packages for transportation of radioactive materials; Type A and Type B. Type A are used for low level radioactive materials. The basic requirement for type A packages, is that they be capable of withstanding the condition of normal transport without degredation of overall integrity.

Our medium level waste is transported in type B containers. These must withstand accident conditions with a very limited reduction in containment and shielding efficiency. Type B package designs must be individually approved by the AECB. The testing requirements are considerably more severe than for type A packages.

Our low and medium level waste in transport represents a much smaller hazard than that presented by the transport of chlorine, propane or dynamite.

(c) Storage of radioactive waste

Both storage and disposal are required to provide isolation of the material from the environment. Storage means that the waste remains under control; during storage the waste is retrievable.

Disposal means that no further control is exercised. Disposal requirements are more stringent than storage requirements in order to provide isolation from the environment.

At the present time all our radioactive waste is stored in a retrievable manner and remains under our control.

Low and medium level waste is taken to a central storage facility at BNPD. Before a storage facility can be built it is necessary to satisfy the AECB that the design of the facility is adequate to properly protect the public and the environment. Once the facility is in use, there has to be a yearly report to the AECB with details on the waste stored in the facilities. (Only storage of solid waste; no storage of fuel.) Irradiated fuel bundles (which contain high level waste) are stored initially at the individual station under water in bays.

At the present time there is only storage of low level waste in trenches and medium level waste in tile holes.

New facilities under construction include an incinerator, a compactor and an above ground facility for spent resins called quadricells. A brief description of these facilities follows.

C. Facilities for the Processing and Storage of Low and Medium Level Waste at BNPD

There are two storage sites at BNPD. Site #1, which was built as a part of Douglas Point NGS and is now filled to capacity, is in the "caretaking" stage. Site #2, located in the BNPD Central Services Area and operated by BNPD Services, is being developed in stages:

Stage 1: - trenches (2000 m^3) and 80 tile holes
Stage 2: - waste volume-reduction facility
Stage 3: - trenches (1440 m^3) and 144 tile holes
Stage 4: - 15 quadricells (360 m^3)

Two barriers between the waste and the environment are always provided. All storage structures are designed to provide for retrievability of stored waste.

1. Concrete Trenches

There are two types of trenches (reinforced concrete) in stage 1: wide (6.1 m) trenches, divided into six components and having about 660 m^3 storage space; narrow (3.0 m) trenches, divided into three compartments and having about 350 m^3 storage space.

In stage 3 there are narrow trenches only. These offer easier handling and placement of waste, and easier handling of trench covers. A sub-surface water drainage system is installed to ensure that any water permeating the surface is collected and drained away from the storage structures.

The walls (380 mm thick) provide the first barrier; impervious fill provides the second.

2. Tile Holes

These are in-ground concrete structures. Those in stage 3 are pre-cast reinforced structures 3.5 m deep (670 mm I.D.). Each has a volume of one cubic metre and will store two IX columns or filter units. They are placed on individual reinforced concrete slabs and the outside surfaces waterproofed.

The area around the tile holes is backfilled with impervious fill, and an asphalt surface is provided to ensure adequate drainage of surface water away from the holes. Here again the concrete is the first barrier, and the fill the second.

3. Quadricells

The quadricells are above-ground concrete structures designed for storage of IX resin in bulk quantities, or storage of large reactor core components. Each unit contains four cells arranged back-to-back. Each cell has a volume of 6 m^3, and will hold two bulk resin containers. The concrete outer wall (650 mm) and inner (250 mm) liner provide the required shielding.

4. Monitoring

After the emplacement operation is complete, the structures must be monitored for integrity and radiation levels. All storage structures are routinely monitored for ingress of water. The water drained away from the storage site via the surface and sub-surface drainage systems is sampled and analyzed regularly. To date (Feb. 1978), water discharged into the lake has never exceeded 1% of the Derived Emission Limit. The water sampling holes (drilled into the bed-rock at the site perimeter) are routinely sampled for radioactivity. The results have so far shown no evidence of structural failure.

5. Waste Volume-Reduction Facility

To minimize the requirements for storage space and to minimize the total cost of waste storage service, it is necessary to reduce the volume of waste that must be stored. The Waste Volume-Reduction Facility was built to enable us to process the compactible and incinerable waste. A volume reduction of 8-fold for compactible (eg, metallics and plastic suits, 5-200 mrem/hr) and 60-fold for incinerable waste was expected by Design. The facility houses the Radioactive Waste Compactor, the Radioactive Waste Incinerator, the Inactive Waste Incinerator and the necessary auxiliary systems.

The vertical-type, hydraulic-operated compactor is used to compact the waste into standard 45 gal (208 l) drums. The radioactive waste incinerator is batch-operated. To ensure minimum possible release of radioactivity to the environment, the flue gases (after cooling in a heat exchanger) are filtered through a set of cloth bags prior to being discharged to the stack. It is estimated that 99% of the radioactivity remains in the ash inside the incinerator. Only very low level waste is incinerated.

6. Experience (1977)

All waste handling and storage operations were performed successfully, with no major problems having been experienced. A total of 1700 m^3 low level solid waste was received; of this 500 m^3 were incinerated (34 batches), giving an 80-fold reduction in volume. The compactor processed 330 m^3 of waste; unfortunately only a 4-fold reduction in volume was attained. The total volume of waste processed (880 m^3) was reduced to 180 m^3 of ash and compacted waste. Also, 142 filter units and IX columns were received for storage. The overall cost objective of .08 m\$/kWh was just met, this in spite of the fact that the cost of transporting and storing (tile hole) IX resins is currently (March 1978) 45 k\$/m^3.

D. Management of Irradiated Fuel

1. Interim Storage

The plan for the management of irradiated wastes in Canada is as follows. For the first five years after removal from the reactor, the fuel will be stored in water-filled bays at the reactor site. This will allow the heat production to decay (to about 0.5 watts per kgU). After this five year decay period, it will be transferred in specially designed flasks to a central interim irradiated fuel storage facility, where it will be held pending a decision to recycle or not recycle the plutonium. If the decision is to use the plutonium to extend nuclear fuel resources, the fission products (and the actinides remaining with them) will be immobilized as an essentially insoluble glass and placed in an ultimate disposal facility. If the decision is not to recycle the plutonium, the irradiated fuel will be packaged in a form suitable for ultimate disposal and transferred directly to the ultimate disposal facility. The ultimate disposal facility will be located deep underground in a rock formation that has remained geologically stable for periods of the order of 500 million to 2 billion years.

The amount of irradiated fuel produced per unit of electricity is not great, about 130 tons per year per 1,000 megawatts of generated electric power. To date, (Summer 1977) over 1,500 tons have been produced in Canadian power reactors and this is stored in water-filled, double-walled concrete tanks (fuel bays) at the various stations. The storage volume needed is about two cubic metres per ton of fuel. The 2,000 megawatt Pickering GS-A generating station produces about 260 tons of irradiated fuel each year and all the irradiated fuel produced in its reactors by the year 2000 could be stored in a water-filled, concrete tank 160 metres long by 10 metres wide and 8 metres deep.

The storage of irradiated fuel in water-filled bays is the method used world-wide. There is thus considerable accumulated experience, and the designs of the facilities are such that little hazard is associated with this method (see Figure 2).

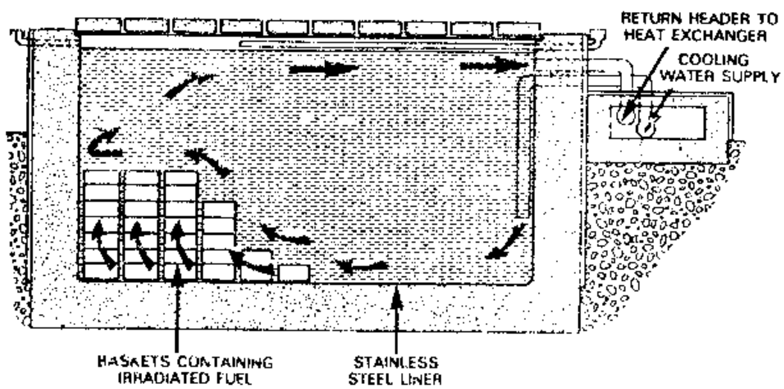

Figure 2

Water Pool Concept

The storage capacity in the bays at Pickering GS-A is slightly greater than 80,000 bundles (about 1,600 tons U) and that at Bruce GS-A will hold about 30,000 bundles (600 tons). Auxiliary bays are under construction at both stations to provide additional storage capacity. Beginning in about 1986 further additional storage will be needed for Pickering fuel, while the bays at Bruce will be full by 1989.

Since it is unlikely that Canada will be in a position to start commercial processing of irradiated fuel, or to have a geological disposal site ready within the next 15 to 25 years, additional interim fuel storage capacity will clearly be needed, even if no new nuclear power plants are built. AECL and Ontario Hydro have agreed on a joint program involving further development of canisters and pools. AECL is developing and testing concrete canisters and Ontario Hydro is studying the engineering and economic aspects of the concepts.

The essential purposes of any irradiated fuel storage facility are to provide sufficient shielding that the radiation levels outside the storage are acceptable, and to provide containment of any radioactive materials that might escape from fuel if, owing to corrosion or other processes, the fuel cladding should fail.

A layout of a pool storage facility is shown in Figure 2. Each tank or bay is an integral, reinforced concrete structure subdivided into six sections by cover support beams and is lined with stainless steel. When filled with fuel, it would be covered first with a metal cover and then with a concrete one. There is a loading cell that moves from bay to bay and the operation is such that fuel is transferred from the shipping flask under water. At no time during or after filling would the inside of the bays be exposed to the weather. The water would be circulated through coolers to remove the heat and through ion exchange columns to remove any dissolved radioactivity that might have escaped from the fuel. As in storage bays at the power stations, enough water - about 4 metres - is left over the fuel to provide shielding from the radiation.

Another concept under development and being considered for commerical use is the concrete canister. It is shown schematically in Figure 3. This is a dry method of storage, consisting of three inner containment cans inside an outer containment can, all within the cylindrical concrete vessel. Lead shot is used to fill the cavities and to increase the radiation shielding provided by the concrete. The heat from the fuel is conducted through the walls of the inner and outer cans, through lead shot and through the concrete canister walls to the outside surface, where natural convection takes the heat away. Any leakage of radioactivity from the fuel would be contained within the double canning.

The canisters are about 2.5 metres in diameter and 5 metres high. When filled they would contain 4.4 tons of irradiated fuel and weigh a total of 50 tons. They would be stored outside. For most soil conditions, a gravel base would be adequate to carry the load. The present design is planned for fuel that has been stored and cooled for five years in the station storage bays. To store the estimated 50,000 tons accumulated over the next 25 years, about 12,000 canisters would be needed.

The use of these canisters is being demonstrated by AECL at their Whiteshell Laboratories. Concrete canisters have been built and tested using electric heaters to simulate the heat load and to do tests well above the expected operating levels. A canister has been loaded with irradiated fuel from the Douglas Point Generating Station and the monitoring of this test canister indicated no problems with the method.

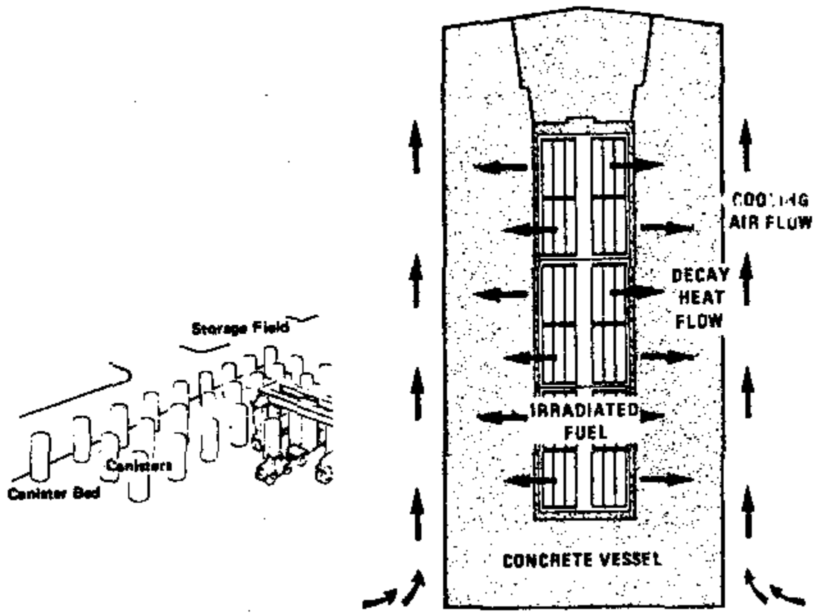

Figure 3

Concrete Canister Concept

2. Shipping of Irradiated Fuel

If a central storage site separate from the nuclear power generating stations is to be set up, or if the irradiated fuel is to be processed or disposed of in a geologically acceptable formation, shipment of the fuel will be required. About 500 such shipments have been made in Canada in the past, using very heavy shielded containers called shipping flasks, without any significant problems.

The shipping flasks, typically weighing about 50 tons, are 3 metres long by 2 metres in diameter and can hold 3 to 4 tons of fuel. They are designed to dissipate the heat produced in the fuel and to provide adequate shielding to reduce the radiation outside the flask to non-dangerous levels. They have been designed to withstand all conceivable accidents - such as train wrecks, truck accidents and fire - without loss of containment. Many thousands of shipments are made in the world each year and good experience has been obtained. The regulations for such shipments have been agreed internationally and are proving to be adequate.

In 25 years, using the prediction of 75,000 MWe of installed nuclear power in Canada, about 2,500 shipments of irradiated fuel would be made each year or about eight per day. If rail shipments are used, this would not present a big load to the railways. The biggest hazard associated with road shipments would probably be traffic accidents caused by the presence of these very big trucks on the highways. The frequency of these accidents, however, would be too low to present a significant hazard to the public.

Practice Exercise

Gather in a group of four or five people and consider the following assignment:

You work at a NGS and have been assigned to prepare a hand-out for an open house on radio-active materials management, it will fill about one typed page and appear in tabular form similar to the following:

Level	Source	In Plant Handling	Transport Specification	Storage
Low	-	-	-	-
Med	-	-	-	-
High	-	-	-	-

Recommended Reading:

Management of Irradiated Fuel Storage Siting Options; Design & Development Division; Report No. GP-79418; 1979.

Available on loan from the Course Manager.

P.D. Dodgson