# ON SITE STORAGE OF LOW LEVEL RADIOACTIVE WASTE AT VERMONT YANKEE.

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## ABSTRACT:

This paper concerns storage of Low Level Radioactive Waste (Radwaste) at Vermont Yankee Nuclear Power Plant located in Vernon, Vermont.

On January 31, 1989, Vermont Yankee was restricted from the three U.S low level radwaste burial facilities. Having anticipated this, Vermont Yankee planned to provide long term temporary storage of low level radwaste on site. This paper outlines:

- 1) The steps taken to establish the most cost effective method for storing the waste.
- 2) Performance of a 10CFR50.59 safety evaluation.
- 3) Preparation of the storage area and installation of storage containers.
- 4) Operation of the facility including dose calculations, shielding considerations, problems experienced, and advice for others who may want to pursue a similar course of action.

## ON SITE STORAGE OF LOW LEVEL RADIOACTIVE WASTE AT VERMONT YANKEE.

This paper concerns storage of Low Level Radioactive Waste (Radwaste) at Vermont Yankee Nuclear Power Corporation located in Vernon, Vermont.

The Low Level Radioactive Waste Policy Act of 1980 - PL 96- 573 (the Act), declared each state responsible "for providing for the availability of capacity either within or outside the state for the disposal of low-level waste generated within its borders". Burial sites were given authority to refuse wastes originating in states not meeting the Act's objective after January 1, 1986. The State of Vermont was unable to meet the Act's deadline. Therefore, early in 1985, Vermont Yankee developed plans to store waste on site. Because many other states were also slow to respond, Congress amended the Act in 1985, to extend the deadline for compliance. The Amendment Act provided a management plan whereby states were required to meet specific milestones as proof that the Act's objectives were being achieved. Extension of the Act's deadlines allowed Vermont Yankee to continue shipment of waste to disposal facilities through January 31, 1989.

The State of Vermont failed to meet the milestones of the Amendment Act. Beginning January 31, 1989, Vermont Yankee was restricted from shipping radwaste for burial.

The Vermont State Government is pursuing solutions to the low level waste disposal problem, however, as yet, actions taken on the part of the State to solve the problem have been neither substantive nor effective.

Vermont Yankee's 1985 plans for long term temporary storage of waste were implemented early in 1989. Currently, about 6000 cubic feet of waste are stored in VY's Low Level Waste Storage Facility.

This paper discusses:

1. Steps taken to establish the best method for storing the waste.
2. Performance of a 10CFR50.59 safety evaluation.
3. Preparation of the storage area and installation of storage modules.
4. Operation of the facility including dose calculations, shielding considerations, and problems experienced.

## BACKGROUND INFORMATION

### Types of Waste

Resin - Vermont Yankee uses ion exchange resin to purify water in plant systems. Spent powdered resin and filter overlay material from filter demineralizers accounts for most of the resin waste. A small amount of bead resin accounts for the rest. Resin from all systems other than the Reactor Water Cleanup (RWCU) System is mixed in the condensate phase separator tanks. The mixture, generally referred to as condensate resin, is about 100 times less radioactive than RWCU resin. The RWCU System resin is processed separately. Both types of resin have the texture and consistency of sand. Water is removed from the resin by means of a centrifuge. Following dewatering, condensate resin is transferred to a 150 Cubic Foot capacity High Integrity Container (HIC). RWCU resin is transferred to a smaller 75 Cubic Foot Capacity HIC. The smaller HIC simplifies handling highly radioactive RWCU resin.

The HICs are right circular cylinders with conical top sections. For corrosion resistance, HICs are constructed of High Density Polyethylene (HDPE). They may be used after storage without modification for shipment and burial.

Dry Active Waste (DAW) - Dry Active Waste is radioactively contaminated or activated discarded equipment, parts, materials, and trash. DAW is compacted in LSA boxes to an average density of 45 pounds of waste per cubic foot. The LSA boxes are considered strong tight containers. Like the HICs, they may be used after storage without modification for shipment and burial.

## SELECTION OF STORAGE METHODS

Bulk Resin Storage In Tanks - Installed systems at Vermont Yankee provide about six months worth of storage capacity. Storage is provided in the Condensate and RWCU phase separator tanks. The phase separators are used for settling and mixing. Addition of more bulk storage tanks to the system was the first option considered for long term resin storage. Bulk storage in tanks was eliminated as a viable option due to reports of biological and radiological degradation of resin experienced during long term bulk storage.

## OTHER OPTIONS EVALUATED

Three basic combinations of storage modes were examined while taking into account six different waste volume reduction techniques.

Storage Modes

1. Building storage for both Resin and DAW.
2. Building Storage for DAW with modular resin storage.
3. Modular storage for both Resin and DAW.

Volume Reduction (V/R) Techniques

1. No volume reduction.
2. A Rockwell International spray dryer for resins (V/R = 2.3).
3. A Waste-Chem asphalt extruder for resins (V/R = 2.0).
4. A Babcock and Wilcox incineration contract for DAW (V/R = 4.3).
5. A combination of the Rockwell International spray dryer for resins and the Babcock and Wilcox incineration contract for DAW.
6. A combination of the Waste-Chem asphalt extruder for resins and the B&W incineration contract for DAW.

A financial analysis was performed to compare the costs of each combination of storage mode and volume reduction method.

The following data were used in the analysis:

1. Waste generation volumes
2. Burial Costs
3. Inflation rates
4. Storage building construction costs
5. Module costs
6. HIC and LSA box costs
7. Transportation costs
8. Electricity costs
9. Maintenance costs 10. Module disposal costs
10. The analysis assumed five years of storage with waste being shipped in year six. The economic evaluation was done on a net present value, pretax basis.

## SELECTION

Storage of waste in discrete concrete modules was chosen as the most cost effective approach. The volume reduction method chosen for resin was asphalt extrusion. However, due to its high initial cost, and uncertainty over the duration of conditions requiring storage, purchase of the resin volume reduction system has been delayed. The volume reduction method selected for DAW was compaction.

Waste storage in modules is cost effective, however, in addition to its economic merit, this approach also presents certain other benefits. Listed below are the non-economic advantages, and also the disadvantages of modular waste storage.

## NON-ECONOMIC BENEFITS OF MODULAR STORAGE

1. Modular storage is the most flexible option. Short lead times allow for delaying acquisition of storage equipment until required.
2. If storage is required beyond five years, additional modules could be easily added.
3. If storage is required less than five years, the modular form of storage would permit less of an investment than construction of new buildings.

Disadvantages of Modular Storage

1. There is an unsheltered work environment.
2. Space and materials are not efficiently used. Shielding is provided at each module rather than one shield wall around all of the waste.

3. The modules must be disposed of at the end of the project instead of having a building for further use.

Once Concrete modules were chosen as the storage method, the number of modules needed was estimated. The amount of space required was determined and a potential site identified for placement of the modules. The next step in the planning process was performance of a formal safety evaluation per 10CFR50.59.

## SAFETY ANALYSIS

The purpose of the safety evaluation was to evaluate whether an unreviewed safety question resulted from increasing Vermont Yankee's capability to temporarily store low level radioactive waste. The analysis was performed by Yankee Atomic Electric Company, Nuclear Services Division.

Criteria for determining whether an unreviewed safety question exists are codified in 10CFR50.59. The criteria serve to identify whether or not the planned activity is within the scope of the plant's Final Safety Analysis Report (FSAR). If the activity is not within the scope of the FSAR, a formal analysis may be necessary.

The analysis performed evaluates man made concerns such as container handling accidents, and hydrogen gas generation. It examines the effects of natural disasters such as fire, flooding, tornado, earthquake and other seismic events. It also estimates dose to workers and to the public as a result of pad operation.

## MAN MADE SAFETY CONCERNS

The LLW storage facility is relatively passive in nature. The only credible accidents involve dropping radioactive material containers, or sections of the massive concrete modules during handling. The limiting such accident is that in which an RWCU resin HIC containing the maximum expected amount of radioactivity is dropped.

The RWCU HIC drop accident was compared to an accident involving a dropped fuel assembly. The fuel assembly accident is analyzed in the plant's FSAR. The comparison showed that the dropped HIC accident produced less off site exposure than the previously analyzed dropped fuel assembly accident. Since the limiting waste storage accident is less severe than the previously analyzed dropped fuel assembly accident, the HIC handling accident presents no new safety concerns.

Calculations predict hydrogen gas generation in the most radioactive RWCU modules could cause hydrogen concentrations to build up over the 5 year storage period. Most stored waste will not approach the activity level used in the calculations. Nevertheless, storage modules will be routinely sampled to determine if hydrogen gas build-up is a problem.

## NATURAL DISASTERS

Fire - The material stored in the concrete modules is moderately flammable. Calculations were performed to predict storage module internal temperatures. The results indicate temperatures too low to cause fires. If ignition did occur, there would not be sufficient oxygen within the modules to support combustion. Consequently, fires internal to the storage modules are not expected. There is no significant flammable material stored in the vicinity of the modules. The waste is protected from external fires by the mass of the concrete storage modules. As a result, external fires, if they do occur, will not reach the contents of the modules. Thus, the safety analysis concluded that fires were not a concern.

Flooding - Flooding is not expected to be a problem because the storage pad is located one foot above the maximum probable flood plain. The module base section is one foot high with one foot wall extensions. Water would have to reach a height of two feet above the pad, three feet above the maximum probable flood plain, to reach the waste.

Tornado/Seismic - The structural integrity of storage modules during seismic events, tornados, and earthquakes was evaluated to determine if failures would occur. The analysis assumes the storage modules fail under seismic/tornado conditions. The source term contained in all the modules is limited by procedure to less than that of the single RWCU HIC analyzed in the container drop analysis. If all modules fail, the resulting exposures would be less than those for the container drop accident.

## OPERATIONAL EXPOSURES

As part of the safety analysis, the on site and off site dose resulting from operation of the storage facility was calculated. The estimate assumes a five year inventory of waste. Doses were calculated at distances to approximate doses to waste handlers, office personnel, and the site boundary. The analysis predicts acceptable doses to workers and office personnel. A site boundary annual dose with a five year inventory of waste of 1.02 milliRem was determined.

After reviewing the impact of plausible man made and natural events, the analysis concluded that there were no new unanswered safety questions arising from operation of the low level waste storage facility. The Safety Evaluation

Report (SER) was reviewed by the NRC during an inspection covering on site storage prior to the first use of the pad.

## LOW LEVEL WASTE PAD (LLW PAD) DESCRIPTION

In 1985, a gravel pad on which to place the concrete storage modules was constructed. The location for the pad was chosen because of its proximity to the plant's radwaste processing area.

The size of the pad, 180 feet by 175 feet, is based on providing space for waste modules to contain 5 years worth of waste. The maximum expected rate of waste generation is 14,200 cubic feet per year (based on 1985 figures). The pad is designed with enough space to handle the maximum generation rate. The design also allows room for crane movement and radiological monitoring.

The pad is located one foot above the maximum probable flood plain. It was constructed by excavating to an average depth of one foot and backfilling with two feet of bank run gravel. The entire pad was then compacted, and tested to determine its load bearing capacity. The resulting surface met the load bearing criteria of 4 to 6 tons per square foot. Gravel was chosen over concrete because of its lower cost, and because concrete offered no advantage over gravel. Originally, it had been thought that a concrete pad would provide containment in the case of an uncontrolled release or spill. The engineer's position was that concrete would not provide an additional boundary. Inevitably, cracks would form in the pad and cause leakage. If provided to prevent cracking, expansion joints would provide a leak path to the ground.

The facility produces dose rates exceeding 10CFR20 limits for unrestricted areas. A chain link fence eight feet in height surrounds the pad to provide positive control over access. To eliminate full time protected area security surveillance, the area is located outside of the plant's protected area. Truck access to the pad is provided by a gate arrangement consisting of two opposing gates (see Figure 1). When opened, the gates extend across the intervening space between the protected area fence, and the LLW pad fence to form a channel through which vehicles may pass. Vehicles must first enter the protected area through the main gate, and then pass into the LLW pad via the Truck access.

## STORAGE MODULE DESCRIPTION

The storage modules chosen for waste storage were developed by Atcor. Modules have been provided by Chem Nuclear under a contract with Duratek, and by Dufrane Associates. The modules are large concrete tanks similar to those used by telephone companies as underground junction boxes. Vermont Yankee's containers are 11 feet wide, 18 feet long, and 11 feet high, with 6-inch thick walls.

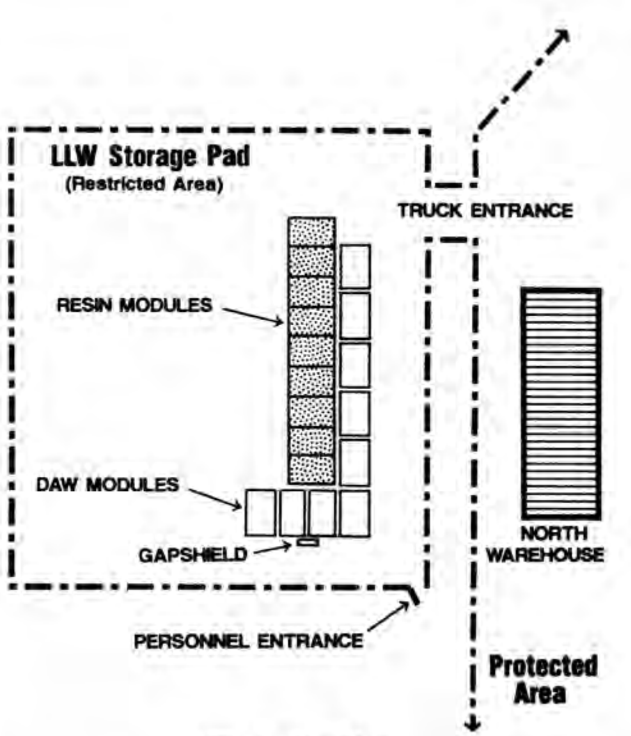


Fig. 1. Site Plan.

The dimensions are based on providing storage capacity within each module for 8 LSA boxes, or three condensate HICs. Each module weighs about 50 tons and has a load capacity of 40 tons.

The modules are designed to be stacked two high, with a one- foot thick concrete shield placed on top of the uppermost container. The top shield is in addition to the 10 inch thick module cover. The top shield and module cover combine to provide a total of 22 inches of concrete shielding.

Modules currently in use are either three or four piece concrete construction. The base is one foot thick, side sections are six inches thick, and the top is ten inches thick. Shiplap joints are used between sections with the upper edge of the joint towards the interior of the module. Joints are sealed with neoprene gaskets. Construction of the joints prevents radiation streaming, and makes the module weather tight.

Each module is fitted with two sample ports. The ports are angled to limit radiation streaming. Piping is installed to provide both high point and low point sampling capability.

A cylindrical module has been designed but will not be used until year 2 or year 3 of pad operation. The walls of the cylindrical module are approximately two feet thick.

Cylindrical modules are designed to contain the highly radioactive RWCU resin.

## OPERATION

The low level waste facility was constructed in 1985. It was not used until the spring of 1989. During the interim, the effects of weather and the growth of vegetation reduced the load bearing capacity of the gravel surface. A compaction machine was brought in to restore the surface, the pad was defoliated, and soil tests were performed to ensure that the pad met load bearing capacity requirements.

Prior to the first use of the facility, procedures were written covering storage methods, and incorporating as requirements limits specified in the Safety Analysis. The NRC conducted an audit of Vermont Yankee's plans, and required a few minor changes before authorizing waste storage.

The first eleven modules were supplied by Chem Nuclear Inc., under contract with Duratek. The modules were manufactured by Rotondo Inc., of Avon, CT. Each module was delivered using three flatbed trucks. The module base section was so heavy that it required its own flatbed. A hydraulic crane was rented for unloading the trucks, and assembling the modules.

Gaskets were installed on the module sections at each joint, then the modules were assembled by stacking the sections. After assembly, sampling tubing and plastic sheeting were installed in each module. The second batch of modules was obtained from Dufrane Associates. The concrete manufacturer was Chase Precast of Brookfield, MA. The Dufrane modules were redesigned with one middle section instead of two. They were cast one section at a time starting with the base. Each section was cast on top of the previous section. This technique yielded some improvement in fit-up between sections compared with the previous modules. The Dufrane modules were built with their lifting fixtures on the interior to facilitate placing the modules adjacent to one another.

Changing suppliers required performance of additional design review. This resulted in some delay in delivery of the Dufrane modules. The availability of a second supplier is considered advantageous from a procurement perspective. Effort required to develop additional sources is expected to produce long term cost benefits.

The Chase Precast delivery truck is equipped with a hydraulic crane mounted on the rear of truck. It was used to deliver and assemble the Dufrane modules. This eliminated both the need to rent a separate crane, and also the need to have Vermont Yankee maintenance personnel involved with the delivery.

Modules were arranged according to a site plan (see Fig. 1 - Site Plan). The plan calls for modules containing DAW to form a row around the perimeter of the pad. Modules containing resin are positioned on the interior of the pad with respect to the DAW modules. The low activity DAW modules act as a shield for the more highly radioactive resin waste.

Once the modules were positioned, they were loaded with DAW and resin waste. The first use of the pad for waste storage occurred on May 26, 1989.

Periodic inspection and testing requirements for operation of the pad consist of the following:

1. Weekly dose rate and contamination surveys.
2. Quarterly sampling of each module for standing water.
3. Semi-Annual sampling of each resin containing module for hydrogen gas buildup.
4. Quarterly visual inspection of the oldest LSA box in storage to detect unexpected changes.
5. Annual evaluation of off site dose rate from operation of the facility.
6. Annual soils analysis to ensure load bearing capacity.
7. Annual defoliation of the facility.

In addition to periodic inspection and testing requirements, operation of the pad is limited by the number of Curies which can be allowed to accumulate. The limit for operation is 770 Curies in rectangular modules and 2800 Curies in cylindrical modules. Up to date inventories of activity concentration must be maintained to show compliance. The Curie limits are necessary to reduce the impact of accidents involving releases of radioactivity to the environment.

In order to accurately and completely document storage conditions for posterity, a US Weather Bureau approved instrument shelter, and a hygrothermograph were installed on the pad. Records of storage temperature and humidity will be maintained until the waste is finally buried.

Samples of resin from each HIC are maintained in a specially built shielded storage cabinet. If future re-analysis of the resin is required, samples will be available without having to open the HICs.

## DOSE CALCULATIONS

For operation of the waste storage facility, the most limiting dose rate occurs at the West site boundary. The West site boundary is located 250 meters West of the LLW Pad. Because the dose rate at this point resulting from other plant sources approaches the Vermont State limit, exposure resulting from operation of the LLW facility is limited to one milliRem per year. This increase in dose rate is too low to be accurately measured. Therefore, it must be calculated.

As each HIC and each LSA box is placed on the pad, its contribution to the annual site boundary dose is determined. The contributions to the boundary dose from each waste container is summed to determine the annual dose. The incremental doses change when shielding is added to the facility. The dose increment for each affected parcel of waste must be calculated for the time before and after a shield is installed. The dose increments are summed to determine the total annual dose contribution for the item.

Gamma radiation from each parcel of waste reaches the site boundary either directly - travelling on a straight line path, or indirectly - by scattering interactions with air molecules (shyshine). To determine the total dose to the site boundary, both paths are considered.

## PROBLEMS ENCOUNTERED

Because the gravel base upon which modules are placed is not perfectly flat, storage modules are not necessarily level. Modules cannot be placed side-by-side in contact with one another because the sides of the modules are not at right angles to the ground. Even if the pad were level, it is expected that the action of frost would cause the modules to shift. The modules were placed about two inches apart to allow for present and future variances in the plane of the pad.

Lifting fixtures provided on the first set of modules were installed on the exterior sides and ends of the modules, therefore, in some cases, a one foot gap was required between modules to allow access to the lifting fixtures.

Intermodule gaps produced most of the dose to the West site boundary in 1989. During a one month period at the beginning of pad operation, the one critically placed gap was opposite a condensate resin HIC containing 47 Curies of radioactivity. By the time the problem was identified and corrected (by swapping a lower activity HIC to that location, and adding shielding) a dose of 0.4 mRem - 40% of the annual limit, had reached the site boundary.

The original plan was to store more highly radioactive HICs in the lower tier of double stacked modules. The low activity upper tier would act as a shyshine shield for the high activity lower tier. This approach could not be implemented because the outer perimeter of DAW modules is not in place on the upper tier. Purchase of additional DAW modules simply to act as shielding is considered too costly. Because high activity resin liners are stored in the lower tier without the upper tier in place, radiation penetrating the top of the lower tier modules causes appreciable skyshine dose at the site boundary. After the bottom tier of resin modules was loaded, it became clear that additional shielding was needed to reduce skyshine.

During the 1989 refueling outage, fuel inspection work was carried out in the plant's fuel pool. This work involved cleaning spent fuel rods with a wire brush. The cloud of highly radioactive rust produced by this cleaning was primarily removed from the pool by the fuel pool filters. Fuel pool filter resin is mixed with condensate resin in the radwaste system. As a result, condensate resin after the outage was 20 times more radioactive than the conservative values used to predict radiological performance of the facility. The maximum number of Curies stored in rectangular modules is limited to 770. In the first six months of facility operation, 410 Curies, most of which resulted from fuel inspection, was placed on the pad. Fortunately, the predominant isotope, Zn-65, is relatively short lived, and future condensate resin is expected to have more normal activity levels.

The Direct dose from the West facing DAW modules is calculated based on the highest reading obtainable at a distance of 3 feet from each module. It became clear from survey data obtained after the initial loading of DAW modules that additional shielding would be required to meet the West boundary dose limit.

Yankee Atomic Electric Company designed gap shields, top shields, and DAW interior shields to reduce the West site boundary dose rate to acceptable levels. They were produced by a local cement contractor. The gap shields are a one foot thick, two foot wide, 11 foot high column. The top shields are 18 feet long, 11 feet wide and 1 foot thick. The DAW interior shields are shiplap columns that fit inside the outward facing wall(s) of DAW containing modules, and are held in place with specially designed hardware. The shields provide a dose reduction factor of about 20.

As mentioned earlier, vehicles entering the LLW facility must pass through the site's protected area. Such vehicles are searched by the security staff when entering and exiting. Delays are sometimes experienced because the security staff is not always available.

## SUGGESTIONS

The following advice is offered to any organization choosing to store waste using the modular storage concept.

Gaps between modules should be anticipated. Modules should be arranged in even rows with all modules in the same orientation. The intermodule gaps should be aligned such that no source is positioned behind a gap. This will eliminate the need for intermodule gap shields.

Shielding placed on the interior of DAW modules after the modules contain waste can lead to unnecessary radiation exposure. Careful evaluation of shielding requirements should be done before waste is loaded to preclude unnecessary exposure. One proposed design for DAW modules involves making the outward facing wall(s) 18 inches thick instead of 6. Thicker walls would eliminate the need to install additional shielding inside the module. Another alternative to internal shielding is construction of an earth wall adjacent to the LLW Pad. The earth wall would be cost competitive with installation of interior shielding, and it would involve less radiation exposure.

The facility should be accessible without having to traverse the site's security protected area. Each module delivered requires at least three flatbed trucks and possibly a crane. The number of modules expected at Vermont Yankee over a 5 year period is about 150. If all the modules are delivered, at least 900 vehicle searches will have been conducted. Vermont Yankee is currently evaluating provision of an externally accessible gate.

Weather conditions have at times stopped work at Vermont Yankee's LLW facility. This should be considered in the design of such a facility. Depending on the site specific impact of such delays, and the frequency of foul weather, weather protection may be necessary. If work after dark is expected, lighting should be provided.

The facility should be provided with electrical power. Although the modules themselves do not require electrical power, there are many support activities conducted in the facility that do. For example, power tools used for shielding and sample line installation, sample pumps, air samplers, and other analytical gear, require electricity.

Communication should be provided because considerable time can be wasted going back and forth between the LLW facility and the plant when a phone call would suffice.

## CONCLUSION

Vermont Yankee currently has about 8 months of experience storing waste on site. The 1989 site boundary dose was 0.86 milliRem. Future annual doses are expected to be much lower. Based on a relatively short experience with waste storage, it seems likely that Vermont Yankee's goal to store waste for five years will be attained if no burial option presents itself first. The problems experienced thus far have been challenging. They highlight the need for careful management and thoughtful planning.

Further information regarding storage of low level radwaste at Vermont Yankee is available by contacting Vermont Yankee's Radwaste Assistant.

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