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Improved Design Features for ACR-700 Radioactive Waste Management Systems

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ABSTRACT

The management of radioactive waste produced by nuclear power plants is receiving increased international attention. With the first generation of nuclear reactors coming to a close, many plant records have shown that integrated radioactive waste management; covering the management of all types of radioactive waste, are economically as well as environmentally beneficial.

The paper discusses the sources of radioactive wastes and improved design features introduced in ACR-700™[*] in comparison to CANDU 6®[†] that reduce the generation of wastes and presents the Radioactive Waste Management design of ACR-700. The philosophy throughout the design of Radioactive Waste Management Systems (RWMS) of ACR-700 has been to optimize systems by exploiting operating experience from existing CANDU plants to ensure that the radioactive waste is managed in a manner that protects both human health and the environment now and in the future.

1. INTRODUCTION

The ACR-700 RWMS are designed so the radiological exposure of the public meets the dose limits and waste management requirements of Canada as well as other regulatory environments such as U.S. Nuclear Regulatory Commission (NRC).

The RWMS for ACR-700 manage waste streams from light and heavy water as well as gaseous process systems. The paper describes how and where these different process systems have impacted the RWMS. For example the light water coolant and the depleted lithium used for chemistry control in the coolant ensures that tritium level in the high-pressure coolant system is reduced. Consequently tritium releases from the coolant are expected to be small. In addition the use of a tighter lattice pitch with the light water coolant and SEU fuel ensures that neutron fluxes in the heavy water moderator are lower than in CANDU 6. Thus the production of tritium and carbon-14 in the moderator system of ACR is reduced.

The radioactive waste management of ACR-700 includes the collection, treatment, storage and/or release of all radioactive solid, liquid and gaseous wastes generated in the

* ACR™ (Advanced CANDU Reactor™) is a trademark of Atomic Energy of Canada Limited (AECL).

† CANDU® (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited (AECL).

plant during normal or anticipated operational occurrences including any increase in waste volume and activity during periods of major maintenance.

2. RADIOACTIVE SOLID WASTE MANAGEMENT SYSTEM

The ACR-700 design follows the three "R's" approach for the Radioactive Solid Waste Management System (RSWMS) Reduce, Reuse and Recycle. Radioactive wastes have various types, and a suitable waste management methodology was needed for each type. The overall strategy considers three stages of solid waste management.

a) Production of waste: Processes would be designed to minimize the *amount* and specific *activity* of *radioactive* waste to levels as low as reasonably achievable (ALARA). The production of waste is marginalized by:
   1. Identifying the waste produced during normal operation, maintenance, and adverse reactor operation.
   2. Separating the waste according to their activity, noting that, preventing the mixing of different active-level waste assures the efficient reuse and recycling of low activity or inactive materials.
   3. Recognizing waste specific treatments, including decontamination, to minimize the amount and activity, while giving due consideration to secondary as well as primary waste.

b) Storage of waste: Systems would be needed for the safe temporary storage of all solid wastes. The design of temporary storage systems must consider all applicable regulatory requirements and international recommendations that meet acceptable criteria for operational safety. These storage systems would temporarily accommodate radioactive waste that,
   - cannot be released to the environment and must undergo a disposal path or,
   - can be released to the environment after suitable treatment.

c) Disposal of radioactive waste: Identification of potential disposal routes with the necessary facilities and treatment to control these routes is required for each solid radioactive waste. This stage would present design considerations for applicable heat removal and critical control (where applicable) involved with the interim disposal of waste spanning the *lifetime of the plant*. Disposal containment shall require adequate shielding, conditioning and monitoring to house solid radioactive waste.

2.1 Types and Sources of Solid Radioactive Wastes

The radioactive solid waste management includes the facilities to handle the following waste streams:

- Spent fuel
- Spent resins (from light and heavy water systems).
- Spent filter cartridge (from light and heavy water systems).
- Low activity solid compactable and non-compactable wastes

The average annual estimated quantities of solid radioactive waste produced at a 2-unit CANDU 6 and at a 2-unit ACR-700 are compared in Table 1.

The design of the RSWMS is based on a two unit integrated plan. Thus the design is based as much as practicable on shared facilities. One feature of the RSWMS is the temporary storage area provided in the Maintenance Building (MB) for solid wastes that are subsequently transferred either to an on-site Solid Radioactive Waste Storage Facility (SRWSF) or to an off-site disposal facility as shown in Figure 1.

Table 1
Comparison of Average Annual Quantities of Solid Waste Produced at CANDU 6 and ACR-700 Two Unit plant

Category of Waste	CANDU 6 (Qinshan)[1]	ACR-700[2]
High Level		
Fuel Bundles (approximate number per annum)	5260	1970
Intermediate/Low Level		
Spent Resin (m^3/a)	17	12.2
Low level compactable (m^3/a)	53.4[3]	34.5[4]
Low level non-compactable wastes (m^3/a)	15.6	12.5
Filters (m^3/a)	3.8	3.8
Total (m^3/a)	92.6	65.8

2.1.1 Spent Fuel

In the ACR-700, the Slightly Enriched Uranium (SEU) CANFLEX®‡ fuel bundles are discharged from the core after reaching an average burn-up of 20,500 MWD/MgU, that is, almost three times the burn-up of Natural Uranium (NU) fuel bundles discharged from CANDU 6. Consequently, the numbers of fuel bundles discharged annually from ACR-700 are about one-third the number discharged from CANDU 6. The highly radioactive fuel bundles are transferred under water to the spent fuel bay and transferred to “baskets” which hold 36 fuel bundles rather than the 60 fuel bundles of CANDU 6. The fuel bundles are initially stored in the spent fuel bay for 10 years as the decay heat drops to 11.8 watts from an average-powered bundle. In CANDU 6, the natural uranium fuel bundles reach an average exit burnup of 7500 MWD/MgU and are stored in the spent fuel bay for 6 years when the decay heat of a bundle has dropped to 6 watts.

After 10 years the baskets of SEU fuel are transferred to an interim dry storage system such as MACSTOR for 50 years. This type of dry storage system provides multiple containment barriers because the baskets and the storage cylinders of MACSTOR are welded with a capability to monitor the environment in the storage cylinder.

The space required for storage and disposal per unit energy generated depends on used fuel volume and decay heat. The footprint or plan area of a repository is primarily a

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[1] The above quantities are based on solid radioactive waste produced at four CANDU 6 plants over a 14-year period (Point Lepreau, Gentilly-2, Wolsong-1, and Embalse). It is realised that each CANDU 6 plant is individual and that actual operating experience may lead to changes in operating procedures, thus both the volume and radioactivity content of the wastes will vary amongst plants.

[2] The estimated waste volume provided in this Table for ACR-700 are preliminary.

[3] This volume assumes compaction and/or processing of the waste prior to storage.

‡ CANFLEX® is a registered trademark of AECL and the Korea Atomic Energy Research Institute (KAERI).

function of the electrical energy produced by the spent fuel (TWh). Thus taken in account all factors, the ACR spent fuel space required for storage and disposal is approximately the same to CANDU 6 fuel storage area.

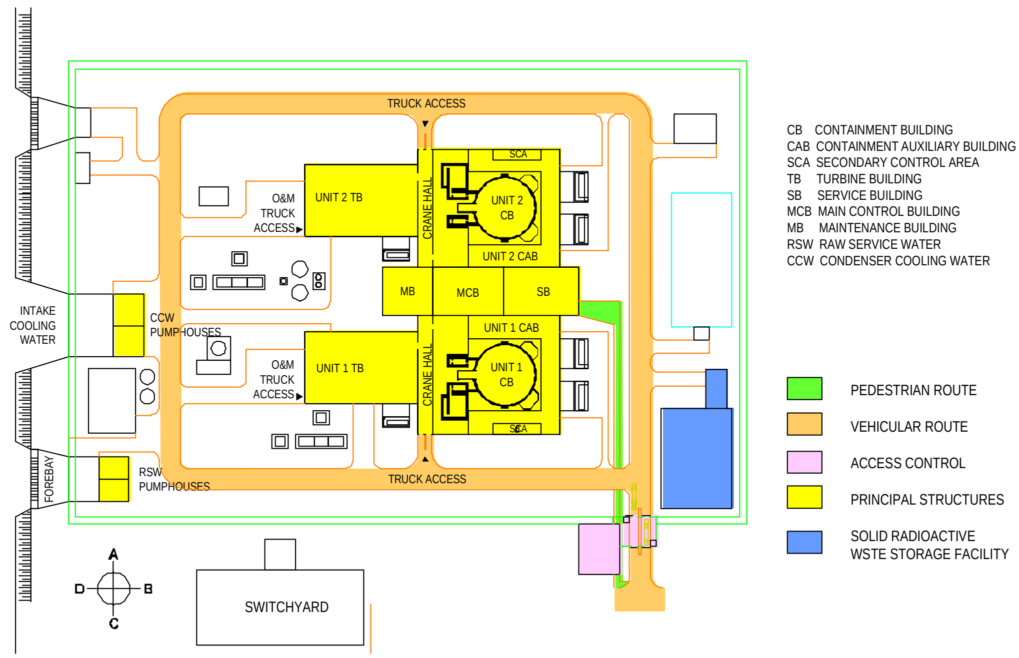

Figure 1 ACR-700 - 2-Unit Site Layout

2.1.2 Spent Resins

The CANDU 6 design includes two concrete spent resin tanks each expected to supply sufficient capacity for the spent resins arising over the lifetime of a CANDU 6 reactor.

AECL's original recommendation was first to fill one tank and then the other. However, the operators at Gentilly 2 and Point-Lepreau adopted a spent resin management practise that stores "fuel-contact" resins (e.g., resins generated by purification systems associated with heat transport, spent fuel bay, etc.) separately from "non-fuel contact" (e.g., resins generated by purification systems associated with the moderator and shield cooling systems).

The most recent CANDU 6, Qinshan plant was equipped with the following improvements:

- Two 200-m^3 concrete-tanks for both units lined with stainless steel.
- Internal pipe structures, valves, and connections for customer hook up between the storage tanks and a transport cask to allow transfer of spent resin after a client-specified decay period.
- An air blower to suspend the spent resin and a resin slurry pump to mix and transfer spent resins.

Ontario Power Generation (OPG) stations have insufficient storage space for resins over the life of the plant. Therefore, OPG ship spent resins in specially designed containers to a central waste management facility (i.e., Western Waste Management Facility at Bruce) for storage.

The spent resin systems of ACR-700 were developed to handle the estimated spent resin waste arising from a 2-unit station, 12.2 m^3/a (Table 1), and to address the unique design features of ACR compared with CANDU 6:

- The ACR uses light water as coolant rather than heavy water;
- The lattice pitch of ACR-700, 220 mm, is smaller than that of CANDU 6, 285.75 mm, so less heavy water is exposed to thermal neutron irradiation, and
- The thermal neutron fluxes in the moderator of an ACR-700 are lower than those in a CANDU 6 reactor.

As a result, the production rate of ^{14}C in the moderator system of ACR-700 is approximately one-quarter that of CANDU 6. Virtually all this ^{14}C is collected on the ion exchange resins in the moderator purification system and, for the projected resin usage about 1 m^3 per annum, the concentration of ^{14}C on the spent moderator resins will be about 140 Ci/m^3. This concentration is "Greater-Than Class C" (GTCC) according to US regulation 10 CFR Part 61[4] [3]. Thus, in planning the overall waste management of resin waste in ACR, the presence of the isotope ^{14}C must be considered and, to address the recommendation from the International Atomic Energy Agency (IAEA) that solid waste containing radioisotopes of different half-lives be stored separately for special treatment [1], [2], the spent resins of ACR-700 are segregated into moderator-spent resins and non-moderator spent resins. Hence the two types of resin are handled through separate spent resin management systems.

In addition, the resin waste management strategy needed to take into account the absence of an on-site D_2O upgrader.

For ACR-700 duplicate resin-handling systems are located in the basement of each Reactor Auxiliary Building (RAB) and provide the function of storage, mixing, sampling, and a capability to transfer spent resins and filtration media to a mobile system for dewatering or solidification. The moderator resin management system shown in Figure 2 is equipped with two spent resin tanks per unit with storage capacity for 60 years of operation. If a disposal facility for this resin becomes available then the waste could be shipped off-site. Alternatively removal of ^{14}C from the spent resins by acid or thermal stripping might be developed that would leave other radioisotopes on the resins for final disposal [4], [5], [6], [7].

With the elimination of the upgrader, de-deuteration was eliminated from the resin handling protocol for moderator resins in ACR-700 to minimize downgrading. Thus, spent resin is transferred to the moderator spent resin tanks (Figure 2) by:

- Backwashing moderator grade D_2O through the IX column to transfer the moderator spent resin to the deuteration/slurry tank
- Recovering D_2O by decanting and dewatering from the deuteration/slurry tank.
- Slurrying the dewatered spent resin from the deuteration/slurry tank to moderator spent resin storage tank using water drawn from the spent resin storage tanks.

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4 According to 10 CFR Part 61 if the Carbon-14 level is greater than 8 Ci/m3 then the resin is classified as GTCC.

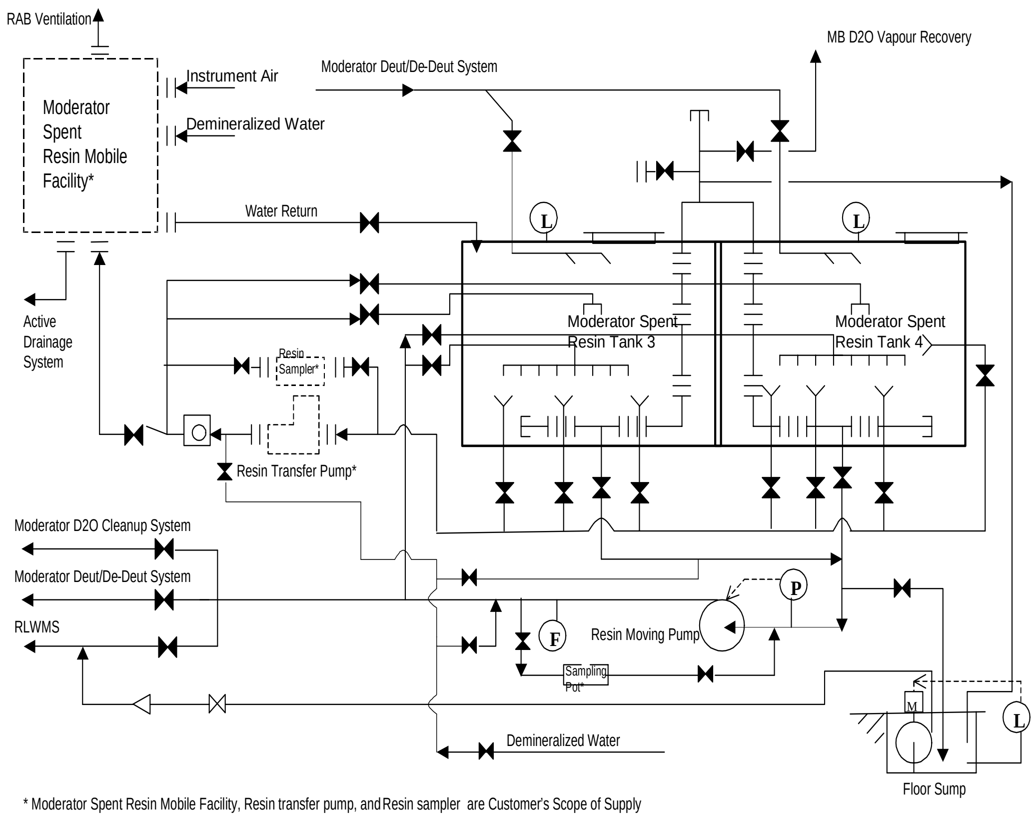

Figure 2 ACR-700 Moderator Spent Resin Management, Simplified Flowsheet

Some exchange of heavy water retained by the spent resin beads with the initial inventory of demineralized water in the moderator spent resin tanks will occur. After some time the supernatant above these spent resins will contain sufficient heavy water to justify recovery of the heavy water from the moderator spent resin tanks. Thus, the moderator spent resin tanks will contain a large volume of highly active material and some tritiated heavy water. Consequently, the spent resin storage tanks are seismically qualified to DBE Category A up to the first isolation valve and moderator spent-resin processing equipment including spent-resin tanks are enclosed in an airtight room with a connection for temporary ventilation to MB Vapour Recovery System (VRS).

Non-moderator resins are slurried to the two non-moderator spent resin tanks with a maximum interim storage capacity for 5-years operation, with demineralized water. The non-moderator spent resin can be transferred to a mobile system after a suitable decay time either to a SRWSF for temporary storage or to off-site for permanent storage as shown in Figure 3.

Spent resin collected in the spent resin tanks are re-suspended by tank water circulation via tank mixing eductors then pumped to the container in the mobile system by resin moving pump as shown in Figure 3. Dewatered flow from the mobile system is returned to the spent resin tank and excess water from the non-moderator spent resin tanks are pumped to the Radioactive Liquid Waste Management System (RLWMS) via the non-moderator spent resin tanks as shown in Figure 3.

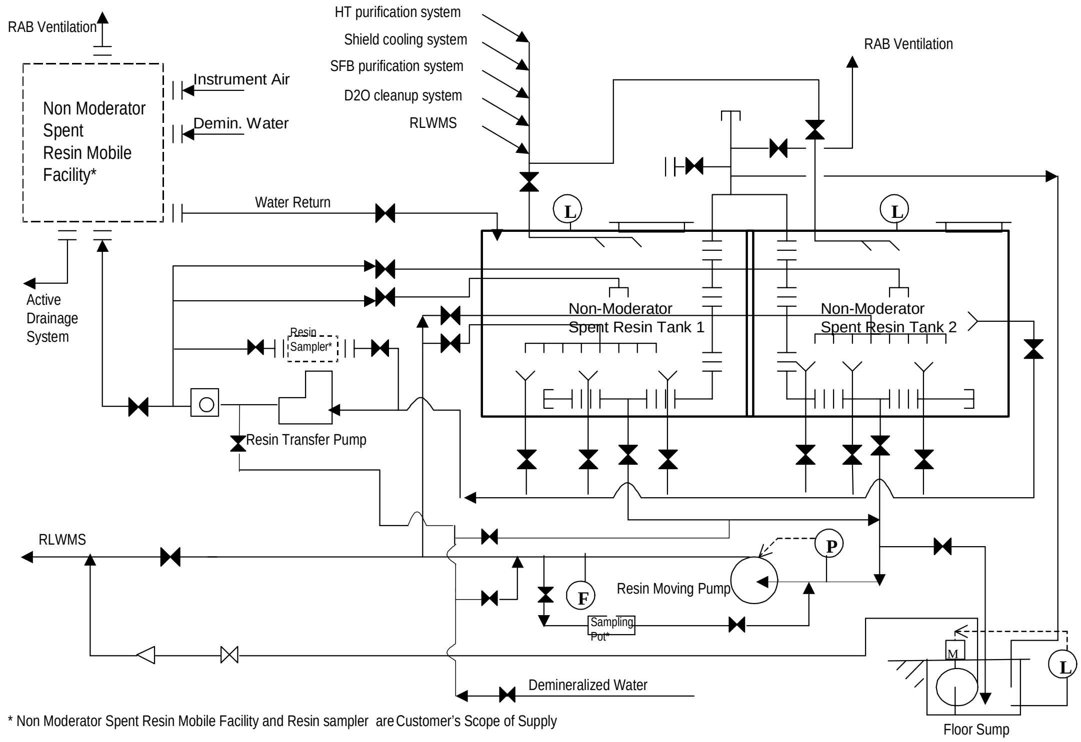

Figure 3 ACR-700 Non-Moderator Spent Resin Management, Simplified Flowsheet

2.1.3 Spent Filter Cartridges

Spent filter cartridges arise from the different purification systems. Operating experience with CANDU 6 shows that the filter cartridges from the spent fuel bay are a large contributor to the volume of this waste. Eliminating the algae that accumulate on these filters can reduce the number of filter cartridges from the Spent Fuel Bay (SFB). The algae can be eliminated with improved chemistry control of the SFB water. Thus on ACR-700 the use of an algaecide is expected to reduce the volume of this waste form below the CANDU 6 experience (not reflected in Table 1).

In addition the spent fuel filters from the heat transport system ACR-700 will have only trace amounts of tritium in comparison with filters from CANDU 6 thereby eliminating any need to dry the filters before transfer either to the on-site waste storage facility or to an off-site disposal facility.

2.1.4 Non-Compactable and Compactable Wastes

The cleaning materials, protective clothing, contaminated metal parts and miscellaneous items originating in the normal day-to-day reactor operations are the largest source of non-compactable and compactable wastes. When large volumes of these wastes are produced, the costs of volume reduction are usually less than the cost of storage and/or disposal space as described in Reference [8].

To reduce the costs of handling and storage of the non-compactable and compactable wastes, segregation and minimization techniques have been exploited on the ACR-700.

These techniques have reduced the projected volumes of compactable and non-compactable wastes from ACR-700 compared with CANDU 6 because:

- The permanent staff working in the Reactor Building at a 2-unit ACR-700 plant will be 475, down from 588 for a 2-unit CANDU 6 plant.
- As specified by IAEA a three-container system of compactable, non-compactable and likely clean was adopted for the ACR-700 for the different categories of waste produced [1]. In this system the likely-clean category of wastes is free of contamination and, after monitoring, can be released to a conventional waste landfill. Consequently, plastic bins or bags are provided at the boundaries between radiation and non-radiation zones for the collection of compactable and non-compactable. The contamination criteria for determining the waste as inactive to allow disposal as ordinary non-active solid wastes will be based on federal, provincial or municipal government regulations.
- Low-level active non-compactable waste are accumulated in 200-litre drums and either transported directly to an on-site SRWSF or stored for a short period of time in the MB before transfer to an off-site final disposal facility.
- The separation of inactive from radioactive wastes ensures the volume of radioactive waste is significantly smaller than it would be if both types of refuse were disposed of together. In addition material-handling procedures can separate products from their packages before the product is introduced into a potentially contaminated area.

Thus the compactable and non-compactable volumes are projected to be ~65 & 80% respectively of the wastes from a CANDU 6 plan.

In addition decontamination [9,10] and compaction will reduce the waste volumes and/or convert the waste into a form suitable for handling, storage and disposal. Thus, the ACR-700 features a compactor shared between two units and located in the MB. Since a typical volume reduction by compaction is at least 4, the estimated compactable waste volume for a 2-unit ACR-700 plant is 34.5 m^3/a after compaction and 12.5 m^3/a for non-compactable wastes as shown in Table 1. Any low-level compacted wastes are surveyed and either transported to the on-site SRWSF or stored for short period of time at the MB before sent off-site for final disposal. Non-compactable wastes are transferred to 200-litre drums and handled in a similar manner.

3 RADIOACTIVE LIQUID WASTE MANAGEMENT

3.1 Radioactive Liquid Waste Management System of CANDU 6 Plants

The liquid effluence generated by a CANDU plant varies widely. The active liquid waste stream represents a mixed-waste containing radioactive and chemical contaminants. The concentrations of the contaminants can vary widely depending on the plant-operating practise (e.g., extent of laundry operations during maintenance outage, cleaning of equipment and components).

The Qinshan CANDU 6 RLWMS is shared between two units and is located in the Service Building of Unit-1. It consists of five epoxy-lined concrete storage tanks (two active and three low activity tanks), each with its own mixing pump and eductor. The system also includes a decontamination facility consisting of a pump, a filter, and an ion exchanger. The RLWM tanks including the first isolation valve are seismically qualified to DBE Category A.

Because of Municipal Industrial Strategy for Abatement (MISA) regulations concerning the release of chemical contaminants, Ontario CANDU stations have initiated studies and in some areas implemented advanced treatment systems to improve removal of contaminants from active liquid waste effluents. For example, Bruce 1-4 implemented an improved RLWMS. The RLWMS at Bruce 1-4 produces a bitumen-stabilized waste form for its secondary waste generated by the membrane-evaporator treatment facility. Also Pickering installed an improved Advanced Liquid Waste Treatment System (ALWTS) consisting of UV-oxidation, filtration, activated carbon absorption, cation-exchanger and neutralizer to reduce non-radiological contaminants (organics and metals) in their RLWMS.

3.2 Radioactive Liquid Waste Management System of ACR-700

The projected liquid waste volumes from a 2-unit ACR-700 are compared with the projected liquid waste volumes from a 2-unit CANDU 6 in Table 2.

Table 2
Estimates of Monthly Liquid Wastes (m^3) from ACR-700 and CANDU 6

SOURCE	2-unit ACR-700[5]			2-unit CANDU 6[6]	
	Detergent Wastes	Low Activity Wastes	Active Wastes	Low Activity Wastes	Active Wastes
Laundry				135	
Showers	244			270	
Laboratories		195	65	195	65
Floor Drains, Service Building		100	35	100	35
D2O Areas			30		30
Upgrading Column[7]			n/a		10
Decontamination Centre			90		90
Rubber Goods Laundry			9		45
Reactor Building Drain[8]		100	62	100	50
Resin Slurry H_2O			25		25
Spent Fuel Bay			30		30
Sub Totals	244	395	346	800	340

The ACR-700 RLWMS will store wastewater based on a two-reactor unit plant in order to reduce capital cost similar to CANDU 6 design. The concept of the ACR design is based on improved segregation of the waste sources. Thus, the RLWMS is designed to

5 The design values were defined after having been compared against actual operating feedback from Embalse, Wolsong-1, Wolsong-2 and Point Lepreau and specific ACR-700 design changes.

6 The values given are nominal volumes that have been compared against actual operating feedback from Embalse, Wolsong-1, Wolsong-2 and Point Lepreau.

7 Applicable to Unit 1 only

8 Does not include 86 m3 from Reactor Building Fire Protection System

process radioactively contaminated wastes in three major categories (detergent, low activity and active wastes).

The current design includes two active tanks, two low-activity tanks and two detergent tanks as shown in Figure 4 and is located in the MB. When a tank is approximately half-full, it is taken off line and another put on line. The half-full tank of the active and low-active waste should be processed as soon as possible. The detergent tank normally would be directly discharged to the raw service water discharge line upon sampling of the tanks. Should a tank reach the high level unexpectedly, an alarm will annunciate at a field control panel and in the control room. The RLWM tanks are seismically qualified to DBE Category A and are stainless steel-lined to prevent leakage and facilitate decommissioning.

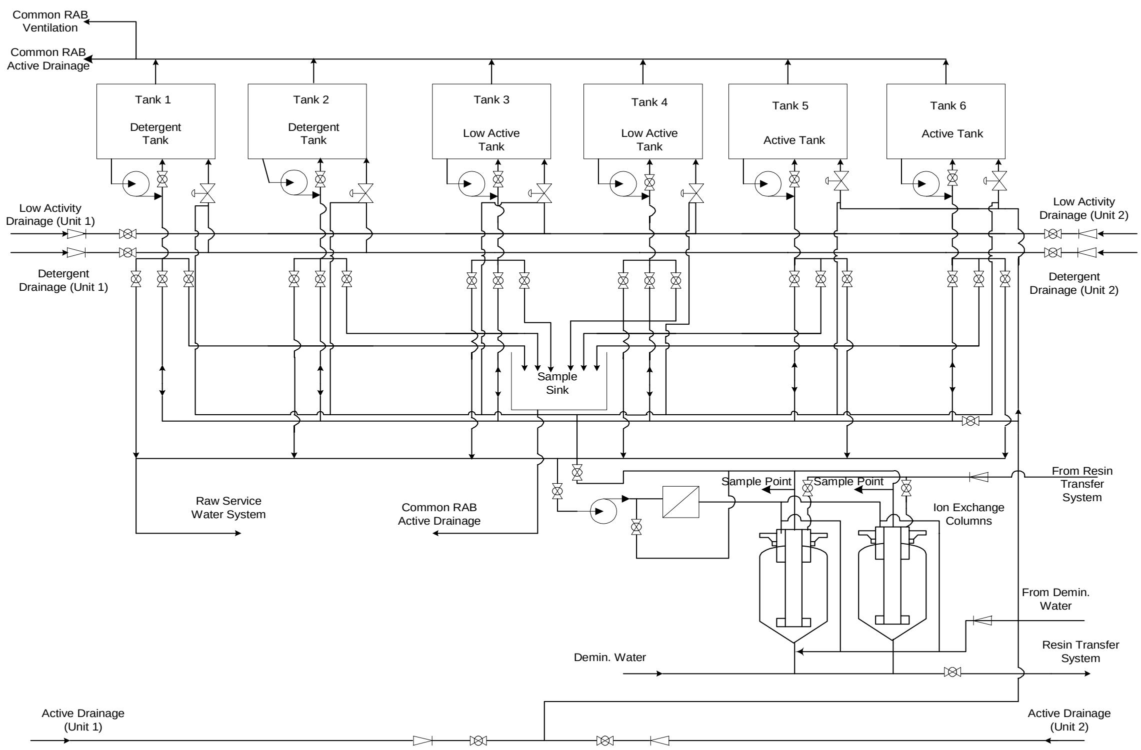

Figure 4 ACR Radioactive Liquid Waste Management System Schematic

The purification sub-system includes a filter and two ion-exchange columns in order to reduce radioactive contamination. The effluent downstream of the ion-exchanger is sampled and, depending upon its state, is either discharged to the Raw Service Water (RSW) duct or else returned to one of the storage tanks for further treatment. A sample is drawn from the effluent before discharge into the RSW duct and its activity monitored by an effluent monitor.

The first diluting stream that this active liquid stream reaches is the discharge duct, which leaves the plant site and flows into the river/lake/ocean on which the plant is located. The water in the discharge duct comes from the Condensing Cooling Water (CCW) and the RSW streams. The flow in the discharge duct, for a 2-unit plant, is

~1,140,000 Usgpm. Thus, there is a very large diluting factor. A periodic sampling from the outfall point could be provided in order to monitor the non-radioactive sources (e.g. Zinc, and Oil) inserted into river/lake/ocean.

The working capacity (overflow volume) of all six concrete storage tanks is 35 m^3 (each) for operational flexibility. The monthly estimates of wastes from various sources are shown in Table 3. The adopted concept assumed that the ACR cotton laundry would be done off-site. Therefore, the daily average waste discharge to the RLWMS is reduced significantly as shown in Table 3 in comparison to CANDU 6 plants.

In case of an emergency, when more active liquid waste may be collected by the RLWM tanks, such as water from the Fire Protection System or during an exceptional condition such as a significant Steam Generator (SG) tube leak, the working volume of the four 35 m^3 active and low-activity tanks will be adequate to accommodate this requirement. If additional capacity is required to accommodate the exceptional or emergency flow then one of the detergent tanks could be used.

4. RADIOACTIVE GASEOUS WASTE MANAGEMENT SYSTEM OF ACR-700 AND COMPARISON TO CANDU 6 DESIGN

A gaseous radioactive waste management system is used in ACR-700 in order to treat potentially active airborne discharges.

All active or potentially active gases, vapours or airborne particulates, which occur in the station, are monitored, and filtered if necessary, prior to release to the atmosphere. The gaseous waste control of an ACR-700 involves:

a) Moderator enclosure driers for removal of tritiated heavy water,
b) filters for particulates and radio iodine removal, and
c) Off-Gas Management System (OGMS) to limit the release of radioactive noble gases from the station.

The effluent is discharged through a ventilation exhaust duct or stack. Stack effluent monitors are used to ensure that the release limits are not exceeded.

4.1 Radioactive Gaseous Effluence

Tritium present as tritiated water vapour, carbon-14 in carbon dioxide, radioactive noble gases, radioiodine and particulate are the airborne radioactive wastes or effluents that must be managed in CANDU reactors including ACR-700. In ACR-700 the principal management effort has been directed at reducing these effluents at source.

For tritium, the adoption of a light water coolant reduces one source of tritiated water. In addition, the operator is directed to use lithium that is depleted in lithium-6 for chemistry control of the coolant. These two changes ensure that almost no tritium is present in the coolant so that the high-pressure high-temperature coolant system is eliminated as a source of airborne tritium.

The moderator system continues to be a source of tritiated water vapour but the concentration of tritium in the heavy water at end of life will be only 2/3 of the concentration in a CANDU 6 because of the lower thermal neutron flux in the moderator. In addition the layout of the reactor building has grouped the moderator and moderator auxiliary systems in the same area of the reactor building. This grouping has facilitated the provision of a D_2O vapour recovery system for the equipment in these systems. A D_2O vapour recovery system has also been introduced to serve the heavy water management equipment located in the maintenance building.

For these reasons airborne releases of tritiated heavy water are projected to be a fraction of those on CANDU 6.

As stated above, the production of carbon-14 in ACR-700 is one quarter of that in CANDU 6. The circulation of moderator cover gas through the reactivity mechanism thimbles and the design of the moderator spent resin storage tanks are both projected to reduce the carbon-14 escape. Segregation of the spent resins is also projected to reduce carbon-14 releases.

4.2 Filters

The reactor building and potentially contaminated areas of the reactor auxiliary building (including the spent fuel bay exhaust systems and the off-gas management) are each equipped with a filter bank, which consists of a pre-filter, a high efficiency particulate (HEPA) filter, a charcoal filter and an additional HEPA filter. The contaminated air passes through these filters before being discharged via the common exhaust stack. Also a separate filtering unit exists for each of the long term cooling confinements volumes.

4.3 Vapour Recovery System

The heavy water Vapour Recovery System (VRS) consists of process trains in both RB and MB. The heavy water vapour recovery dryers for the reactor building consists of two desiccant dryers in order to reduce tritium levels in the moderator auxiliaries rooms and main moderator rooms by removing the heavy water from the air and collect it on the desiccant. In order to achieve this it is necessary to separate the dryer air circulation loops serving the main moderator rooms from the one serving the moderator auxiliaries rooms. This permits taking advantage of the lower D_2O leakage estimated for the moderator auxiliaries compared to that from the main moderator. The 2 dryer loops are interconnected at the dryer inlet and the dryer outlet so that if one dryer is not available to operate the other dryer can dry both loops as shown in Figure 5. The desiccant is then regenerated and the heavy water entrained radioactive material is transferred to the heavy water cleanup system for cleanup. The ACR-700 MB VRS is located inside the MB and consists of a single rotary desiccant wheel dryer unit. The dryer recovers heavy water vapour leakage to the atmosphere in the D_2O Cleanup system, drumming and D_2O supply area of the MB and includes a vent connection from the moderator spent resin storage tanks, located in the RAB of each unit.

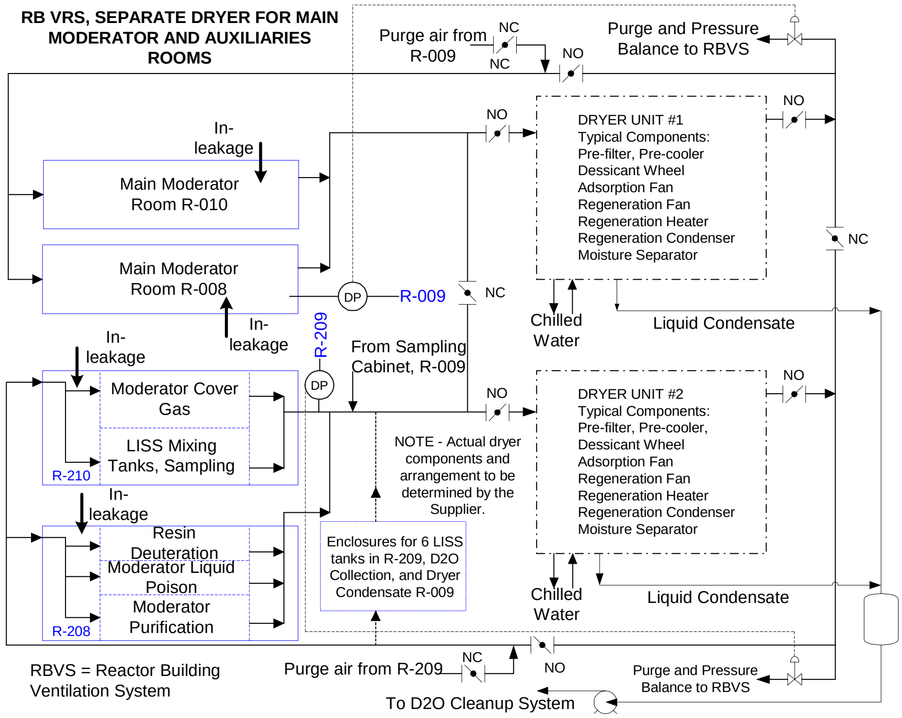

Figure 5 RB VRS, Simplified Flowsheet

4.4 Off-Gas Management System

The radioactive noble gases are introduced by air into process systems and krypton and xenon fission gases from defected fuel. The principal methods of controlling radioactive noble gases are provision of an Off-Gas Management System (OGMS).

However, credit shall be also given in the design of the refuelling and fail fuel systems, since CANDU and ACR reactors have provision for on-power refuelling and a failed fuel location system. An OGMS was installed in the Wolsong and Qinshan CANDU 6 reactors. However, at other CANDU plants no OGMS is in-service.

The CANDU 6 OGMS limits the release of radioactive noble gases from the station by delaying their release long enough to permit their decay. The off-gas delay ensures that Xe-133 undergoes an activity reduction factor of 40 (i.e. a delay of 28 days).

The OGMS of Wolsong and Qinshan is maintained under vacuum due to the compressor providing suction throughout the whole system and treats one off-gas stream from either of the fuel carousels or the D_2O-coolant collection tank condensers. The vacuum prevents the release of noble gases into the service building and consists of a chiller condenser, a moisture separator, an adsorber tank, which is filled with activated charcoal to delay noble gases and a compressor.

The design of the ACR-700 OGMS is based on the release of radioactive nobles gases in the HT Auxiliary Systems resulting from 24 defective fuel elements in the reactor core as the bounding case.

The OGMS achieves an activity reduction factor of at least 40 similar to CANDU 6 design by delaying the noble gases in an adsorber bed prior to exhausting the resulting low activity gases to atmosphere via the Active Ventilation System.

Furthermore the gas streams were carefully defined to ensure that the right streams, which required off gassing, were purged into the ACR-700 design.

The ACR-700 OGMS is a once through passive system without a compressor and flow rates attained by the purging pressures of the various purging streams from interfacing systems. It consists of a Recombiner, two heaters, two flame arrestors, a condenser, a moisture separator, and an absorber bed, as well as associated piping, valves and instrumentation.

The ACR-700 OGMS will have the capability to purge the gas from specified tanks and gas spaces of the HT Auxiliary Systems and the F/H Systems, resulting in 8 streams from each of its two units. The OGMS is a shared system for the two-units of ACR-700 NPP, resulting in a total of 16 streams that will be piped to the treatment portion of the OGMS in the basement of the MB located between the two Units.

The OGMS will monitor and control the process streams for their H_2/O_2 concentrations to prevent the buildup of H_2/O_2 mixtures coming from the HT Auxiliary Systems. The OGMS will use H_2/O_2 gas analysers and a recombiner using wetproofed catalyst upstream of the adsorber delay bed. The OGMS will also monitor and control the process stream for its humidity or steam content to achieve the required efficiency of the adsorption equipment, using moisture analysers, a condenser with chilled water, and moisture separator.

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REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, “Management of Tritium at Nuclear Facilities”, Technical Reports Series No. 234, Vienna, 1984.

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, “Treatment of Off-Gas from Radioactive Waste Incinerations”, Technical Reports Series No. 302, Vienna, 1989.

[3] U.S. Nuclear Regulatory Commission, “Code of Federal Regulations, 10 Part 61 - Licensing Requirements for Land Disposal of Radioactive Waste”, U.S. Printing Office, Washington, D.C.

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, “Application of Ion Exchange Processes for the Treatment of Radioactive Waste and Management of Spent Ion Exchangers”, Technical Reports Series No. 408, Vienna, 2002.

[5] Conference Paper, “ Processing Nuclear Waste for Isotope Production”, Proc. Int. Conf. Tucson, AZ, 1991, Arizona Board of Regents, Phoenix, AZ, Waste Management ’91, Vol. 1, Pg. 781-787, F. Chang.

[6] Technical Paper, “ Carbon-14 Removal from Spent Ion-Exchange Resins Phase III-Pilot Evaluation”, Rep. No. 91-19H, Ontario Hydro Research Division, Toronto Ontario, F. Chang.

[7] Technical Report, “Treatment of Spent Ion-exchange Resins for Disposal”, Rep. AECL-7411, Atomic Energy of Canada, Chalk River, Ontario, 1981, R.A. Speranzini and L.P., Buckley.

[8] INTERNATIONAL ATOMIC ENERGY AGENCY, “Handling and Processing of Radioactive waste from Nuclear Applications”, Technical Reports Series No. 402, Vienna, 2001.

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, “Decontamination of Nuclear Facilities to Permit Operation, Inspection, MAINTENANCE, modification or Plant Decommissioning”, Technical Reports Series No. 249, Vienna, 1985.

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, “Decontamination and Decommissioning of Nuclear Facilities”, IAEA-TECDOC-716, Vienna, 1993.