TRITIUM CONTROL FIELD STUDY AT AN 'OPEN-CONCEPT' CANDU (PHWR) STATION

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The CANDU nuclear power generation concept is that of a pressurized heavy water reactor fuelled by natural uranium in the form of uranium dioxide.

Within the reactor core, neutron activation converts some of the deuterium in heavy water to the radioactive isotope of hydrogen, tritium. At present the average tritium concentrations in the moderator and heat transport liquids at the Bruce 'A' Generating Station are 7 Ci/Kg and 0.3 Ci/Kg respectively. In the absence of tritium removal measures, it is anticipated that the moderator equilibrium concentrations could be 6 to 10 fold higher, while those of the heat transport would have increased 7 fold.

There are two areas of interest: (1) occupational exposure (2) environmental emissions

Both of these occur as a consequence of heavy water escape from systems. Tritium control is therefore directly related to heavy water escape and, it is an essential component in the design and operation of CANDU reactors for both safety and economic reasons.

TRITIUM CONTROL CONCEPTS

The design features in support of tritium control can be considered as conceptual barriers which prevent or minimize occupational exposure to and/or environmental emissions of tritium. They are illustrated in Figure 1.

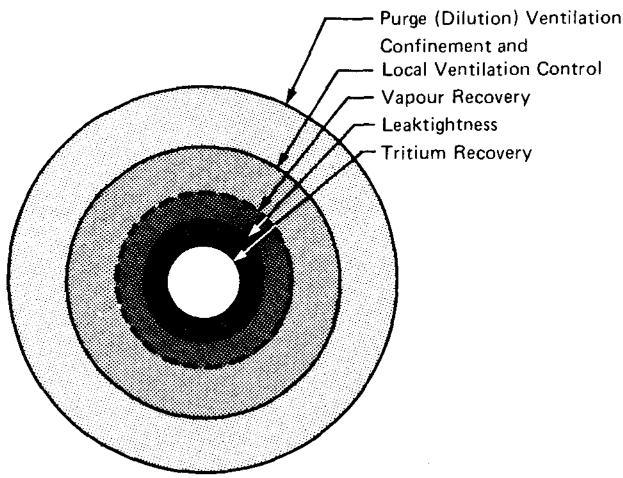

FIGURE 1 IDEALIZED CONCEPTUAL BARRIERS FOR TRITIUM CONTROL

The illustrated sequence corresponds to their relative capabilities in controlling environmental emissions and occupational exposures. The essential action and effectiveness of each barrier is summarized in Table I.

Tritium recovery is the most fundamental method available to reduce tritium concentrations in the heavy water. Thus, the consequences of the tritiated heavy water escape could be mitigated at the source. The subsequent barriers – Leak Tightness, Vapour Recovery, Confinement, etc. are progressively less effective in the order shown.

THE BRUCE 'A' "OPEN-CONCEPT"

The design of the Bruce 'A' CANDU is such that all 4 reactors share a common containment structure. In addition, a single building shell without major internal dividing walls, surrounds the containment structure, the active equipment Confinement rooms, the Reactor Auxiliary Bays, and the Turbine areas. These "Open Concept" features are illustrated schematically in Figure 2.

TABLE I
Conceptual Tritium Control Barriers

Barrier Name	Barrier Action Reduces: Occupational Exposures	Environmental Emissions
Tritium Removal	Yes	Yes
Leaktightness	Yes	Yes
Vapour Recovery	Yes	Yes
Confinement and Local Control Ventilation	Yes	No
Purge Ventilation	Yes	No

TABLE II
Tritium Concentration Design Targets

Area	Design Target (MPC_A)
Turbine Areas	$\leqslant$ 0.01
Reactor Auxiliary Bay Areas	$\leqslant$ 0.1
Confinement Rooms	$\leqslant$ 1

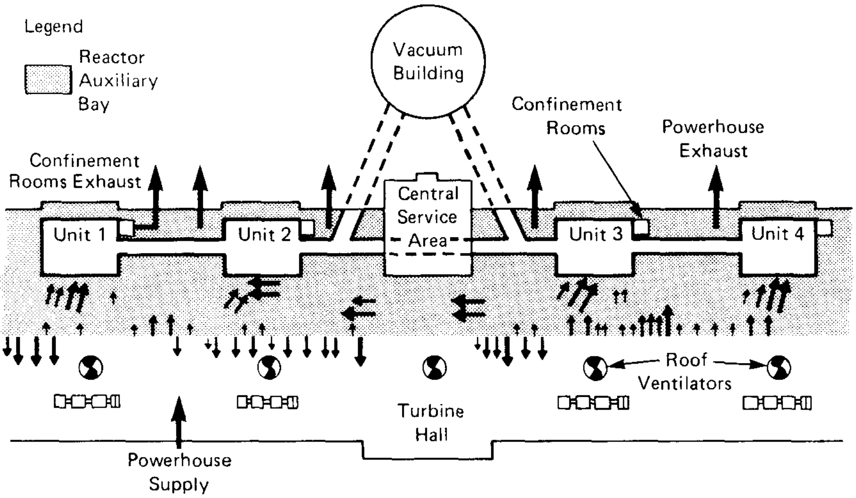

FIGURE 2 BASIC VENTILATION LAYOUT AND AIR VELOCITIES

BRUCE 'A' TRITIUM SOURCE POTENTIALS AND CONTROL

Most of the heavy water systems are located within the reactor containment structure. As such, they are inaccessible during operation. The design and operation of the containment structure prevents the escape of tritiated water vapour. This, coupled to a closed cycle vapour recovery system, ensures that the containment is a minimal source of environmental emissions.

Ventilated plastic suits are generally used for work in this area to control occupational exposure to tritium. For these reasons the study did not address tritium control within the containment structure.

Some heavy water containing equipment (usually for low pressure service) with a defined on-power access requirement, is located outside the containment. Most of this equipment, however, is located in Confinement Rooms which function as an additional barrier, preventing the spread of contamination into the surrounding reactor auxiliary bay area. The Confinement Rooms are ventilated to maintain desirable air quality, by means of purge ventilation. They are not currently serviced by vapour recovery systems. Vapour leakage within them is therefore exhausted to the environment via the filtered and monitored exhaust. Again, ventilated protective clothing may be used in these areas, when required.

Outside Confinement, i.e. within the Reactor Auxiliary Bay areas are located those systems that are/were deemed to possess a wholly insignificant vapour leakage potential. In this area, contamination control is achieved by means of purge ventilation, exhausting via a monitored, non-filtered exhaust.

Occupational exposure control is obtained both by this ventilation purge and at the source by leak tightness maintenance. Environmental emission control is provided by leak tightness only.

MOTIVATION AND SCOPE FOR THE FIELD STUDY

The tritium control field study was motivated by a requirement for design feedback on the performance and adequacy of the tritium control barriers engineered into Bruce 'A'. The gathered information is to be applied to the tritium control engineering for Bruce 'B' and Darlington 'A', two new stations presently in their design and construction phases.

The scope of the study was fourfold:

(1) Identify and quantify the tritium sources.

(2) Assess the adequacy of the ventilation system performance including confinement capabilities, capture and flushing of airborne contamination as well as determining air flow directions, velocities and volumes of exhausted air.

(3) Determine the present levels of contamination throughout the plant's accessible areas and estimate the associated maturity environmental emission and occupational exposure consequences.

(4) Make recommendations to ensure that both environmental emissions and occupational exposures remain below their maturity operating targets.

METHODOLOGY FOR THE FIELD STUDY

As a first step, the study defined the airborne tritiated vapour concentration limits which would have acceptable maturity environmental emission and occupational exposure consequences (summarized in Table II). These limits were arrived at by considering emission targets, exhaust flow rates, and station area occupancy factors.

In order to identify and quantify tritium sources, a technique was developed that made possible finding and measuring heavy water leakage-rates as low as 10 milligrams/day from individual valves or fittings. A portable infra-red spectrometer was the core of this technique.

The assessment of the ventilation system performance was performed by means of a propeller-type anemometer, backed up by smoke tests, and mappings of ventilation velocities on station layout grids. The airborne contamination assessment was done by long term sampling using some 50 molecular sieve tritium traps distributed throughout the study area. These measurements were repeated during three separate one week sampling periods. The station logbooks prior to and during these periods were reviewed to confirm that normal operating routine prevailed at these times.

STUDY FINDINGS

Source Identification: Approximately 6% of the process system components of one unit were leaktested. Although the selection of individual components was random, the selection of types and classes was not. A marked preference was given to component types and classes which in the past had exhibited leaktightness failures. The data should therefore be interpreted with caution. Of those tested, 70% were found to leak less than 0.1 g/day. Only 10% leaked the in excess of 1.0 g/day. However, this 10% contributed 95% of the assessed total leakage.

Ventilation Performance Assessment: The smoke tests gave qualitative indications that in the large open Reactor and Turbine areas the purge ventilation flows were frequently in a random direction. This was confirmed by the quantitative anemometer readings. The turbulences were mostly induced by thermal currents producing "weather-like" systems of drafts and air currents with velocities nearly an order of magnitude greater than net design purge ventilation flow. A typical flow velocity distribution pattern is illustrated in Figure 2.

Airborne Contamination Assessment: The findings of this assessment are summarized in Figure 3. While the average concentrations do not exceed design targets, local concentrations exceed targets in some cases.

CONCLUSIONS

The earlier identified absence of vapour recovery in the Confinement areas implies that for these areas, environmental emission control currently depends entirely on leaktightness (see also Fig. 1: Bruce GS 'A'). The extension of leaktightness maintenance will have a particularly significant impact on occupational exposures in areas having inadequate purge ventilation flows. Figures 4 and 5 plot the potential development of the occupational and environmental consequences as a function of time to 1988 for a hypothetical leaktightness deterioration of 10% per year. The projections include the expected buildup of system tritium concentrations assuming no "tritium recovery" is practiced.

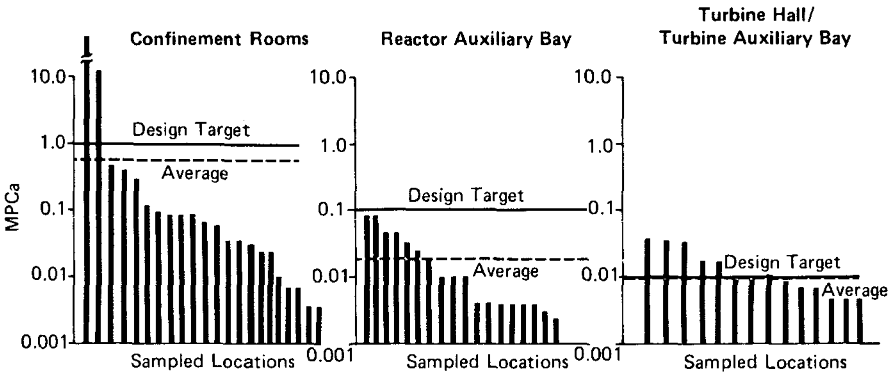

FIGURE 3 AVERAGE TRITIUM CONCENTRATIONS

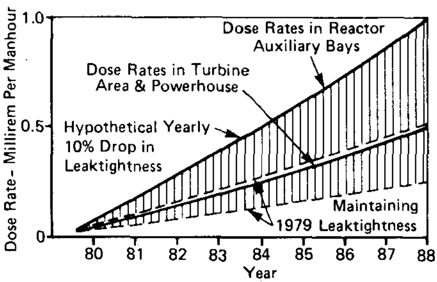

FIGURE 4 OCCUPATIONAL CONSEQUENCES PROJECTED TO 1988

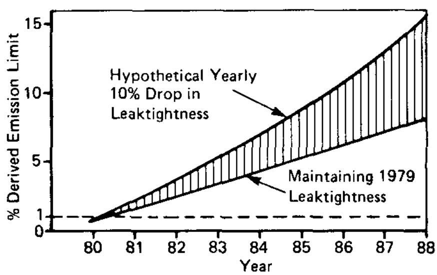

FIGURE 5 ENVIRONMENTAL CONSEQUENCES PROJECTED TO 1988 – ASSUMING NO TRITIUM RECOVERY

RECOMMENDATIONS

The recommendations were formulated to be applicable to both existing stations as well as to those under design and construction.

Leaktightness: it was recommended that leak performance data be compiled for all types and classes of components so that statistically derived leakage rates can be assigned during the design phases and give direction to tritium control engineering.

Vapour Recovery: It was recommended that all components and collections of components with the potential for contributing chronically 10^{-5} of the Derived Emission Limit or greater to the station tritium emissions be located in an enclosure serviced by the tritiated vapour recovery systems. This likely will require a significant extension of both Confinement enclosures, and drying capacity.

Confinement and Local Control Ventilation: It was recommended that all components and collections of components with the potential for contributing chronically greater than 0.1 MPC_a to the tritium contamination levels in the surrounding occupational area, either be located inside Confinement, or be subjected to local control ventilation.

Purge Ventilation: It was recommended that purge ventilation not be relied upon as a method for controlling airborne contamination in large open areas containing thermal sources.

Tritium Recovery: A decision to implement a tritium recovery program to process system heavy water will be dependent on its cost effectiveness relative to other control options, e.g. advanced dryers, increased component leaktightness, and extended confinement.

SUMMARY

An assessment was made of the future tritium control requirements for a CANDU "Open Concept" Pressurized Heavy Water Nuclear Generating Station. Data was gathered. Projections were made. Recommendations focussing on achievable improvements were formulated. A work program implementing these recommendations is presently underway.