HAZARDS AND PROTECTION FROM TRITIUM PRODUCED IN AN EXPERIMENTAL REACTOR LOOP

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1. INTRODUCTION

The neutron flux reaching fuel bundles in an experimental loop of the NRX reactor at CRNL is being controlled by introducing ^3He into a stainless steel coil in the annular space around the fuel. The pressure of ^3He (and hence the mass of helium in the neutron flux) is varied from 100 kPa to 1 MPa by a metal bellows which, with other out-of-core control components, is in a ventilated glove box (Figure 1). The expanded volume of the ^3He system is 15 litres. The (n,p) reaction on ^3He produces both ^1H and ^3H (or T), the latter at 1.4 mCi/s (120 Ci/d or 50 MBq/s) when the reactor power and helium pressure are both maximum. Because hydrogen affects the flux control characteristics the gases are cycled over hot copper oxide (CuO) to catalytically oxidize the hydrogen so that it may be removed from the ^3He by collection on a Linde molecular sieve.

Operators are therefore protected from the tritium by the integrity of the components containing the helium, by retaining the tritium oxide (HTO) on molecular sieve in the helium system, and by enclosing the accessible parts of the system in a ventilated glove box kept at a pressure several hPa below ambient. Also, as shown on Figure 1, the ambient and effluent air is monitored for tritium and the ^3He in the system is monitored in the lines leading to and from the CuO/molecular sieve units. The air monitors and the differential pressure (ΔP) monitor have alarms.

2. ANALYSIS

The steps considered in estimating the distribution of tritium in the ^3He system are illustrated in Figure 2 and the steps by which tritium might reach an operator are illustrated in Figure 3. The dose from tritium was calculated for each pathway through the steps in Figures 2 and 3 (46 in all) for operating times from one day to one year. Six operational or system faults were considered in the analysis:

- ^3He containment fails;
- the physical barriers of the glove box fail;
- the pressure differential of the glove box is lost;
- oxidized tritium is not collected on molecular sieve;
- HTO pervades the complete system before being collected;
- tritium is not oxidized.

Since the last three faults are mutually exclusive, the maximum number of simultaneous faults was four.

Assumed in calculating the doses were the following:

- contact between the operating and contaminated glove box air or component was long enough for the exposure to be determined by the ventilation rate of the glove box. (The analysis therefore included both acute and chronic releases.)

- All unbound gas, vapour, and water in the system goes into the glove box air.
- The operator took no heed of warnings of a release, a procedural error, or a system failure.

3. RESULTS OF THE ANALYSIS

Figure 4 summarizes the doses for an operating time (at maximum production rate of tritium) of ten days. The doses are plotted according to the number of operational or system faults that would have to occur for the particular pathways to be possible.

If the ventilation also fails, the ordinate scale in Figure 4 becomes approximately "rems per minute" except for a few pathways that involve handling contaminated objects.

Thirteen of the doses are less than 1 mrem and involve more than one fault. These pathways are not considered in detail here. The other pathways are related as shown by the letters in Figure 4.

In Groups A, B, and C the tritium is released as HTO. Within each group the estimated doses are in pairs for a given number of faults. The higher value of each pair is for oxidation of HT over CuO; the lower is for auto-oxidation of HT. Further details are as follows:

Group A: HTO is not collected on sieve and is released into the glove box air. Intake of the tritium is by inhalation (which requires 4 faults), by permeation through the unprotected skin (3 faults), and by permeation through gloves (2 faults).

Group B: HTO has pervaded the entire system before the daily collection on sieve. Intake is by contacting contaminated components by bare hands (3 faults) and by gloved hands (2 faults).

Group C: The same sorbed layer of HTO is released to the glove box air from all the inner surfaces. Intake of tritium is by inhalation (4 faults), by permeation through unprotected hands (3 faults), and by permeation through glove hands (2 faults).

In groups D, E, and F the tritium is distributed within the ^{3}He system as HT. Details are as follows:

Group D: Elemental tritium is sorbed on the walls of the system during normal operation and intake occurs by inhalation of desorbed HTO (3 faults), by contacting contaminated surfaces with unprotected hands (2 faults), by permeation of desorbed HTO through bare hands (2 faults), by contacting contaminated surfaces with gloved hands (1 fault), and by permeation of desorbed HTO through gloves (1 fault).

Group E: No HTO has been formed in the 10 days; the intake pathways are then similar to those in Group D.

Group F: HT is inhaled. The higher dose results if no oxidation has occurred in the ten days; the lower dose results if the release occurs just prior to the normal daily oxidation and collection.

The results for one fault require only the opening of the ^{3}He system - an operation that may be part of a maintenance task. The highest two doses have already been noted (Group D). The two doses, 'G' are for intake of HT through gloves after the daily build-up of tritium has been released before oxidation (the higher dose) or the tritium sorbed on the walls is released. The other doses ('H') are all for the intake of HTO through gloves; by contact with HTO-contaminated parts, or by release of HTO to air with ^3He or from surfaces.

4. DISCUSSION

Obviously all the pathways are not mutually exclusive and an exposure may be a mixture of paths. The intent of this analysis was to evaluate the individual paths and assess whether the proposed protection was sufficient to make each exposure pathway sufficiently unlikely. Figure 4 indicates that, generally, the higher doses only occur if several faults have occurred. Quantitative estimates of probabilities for failures etc. were not attempted.

Alarm levels on the effluent and ambient air monitors may be set to trip on releases of tritium that would result in a dose of only 1 mrem and 100 μrem/min respectively for any intake pathway. Hence for all pathways that involved dispersing tritium into the air, the stack monitor and the room monitor would alarm within seconds of releases assumed in the analysis illustrated here.

Detailed discussion of all the dose calculations, the pathways and their likelihoods will be published elsewhere. Briefly, the analysis indicates that signals from the in-line monitors, abnormalities in the operating characteristic of the loop, operating procedures and the other protective devices and monitors provided sufficient protection.

Permissible doses would only be exceeded if several protective devices fail, normal procedures are not followed and monitor alarms are ignored.

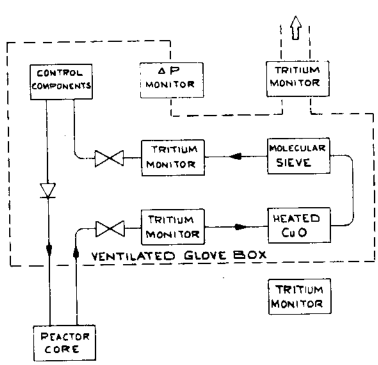

Figure 1. ^3He power cycling system showing components pertinent to the tritium hazard analysis.

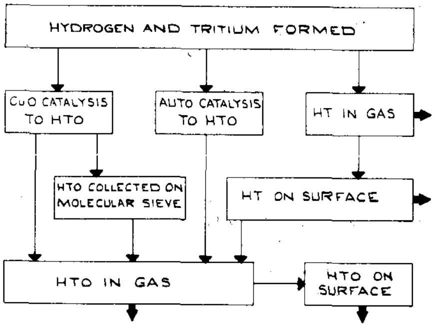

Figure 2. Distribution of tritium in the ^{3}He system. The broad arrows indicate the sources of tritium if the system is opened. HT refers to elemental tritium; HTO to tritiated water.

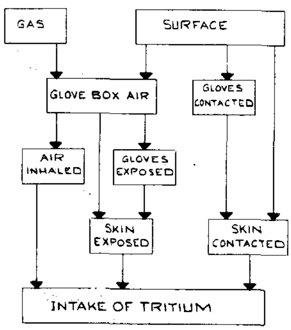

Figure 3. Exposure to tritium released from the ^{3}He system.

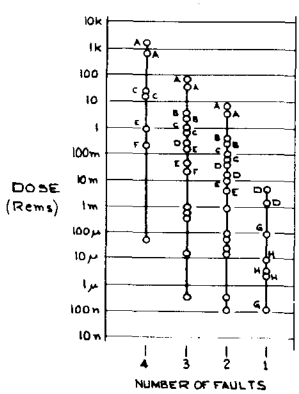

Figure 4. Doses from tritium released from the ^{3}He system. The doses are plotted against the number of faults that would have to occur for each particular dose to occur. The lettered groups are sets of doses that occur by related pathways as discussed in the text.