THE MANAGEMENT OF TRITIUM REDUCTION AT ONTARIO HYDRO

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ABSTRACT

Tritium is produced in operating CANDU reactors by neutron capture in the deuterium atom. Workers at CANDU installations are occasionally exposed to radiation dose from tritiated heavy water (TDO) from the moderator and the coolant (heat transport) systems. The production and buildup of tritium in these heavy water systems and the escape of tritium via tritiated heavy water influence occupational dose and environmental emissions. An effective tritium management program to reduce occupational dose and environmental emissions due to tritium is an essential component of management practice at Ontario Hydro nuclear stations.

Ontario Hydro has corporate programs to meet these objectives. Some approaches used at Ontario Hydro are,

1. Maintaining system integrity

2. recovery of escaped tritiated heavy water

3. displacement of tritium from the heavy water systems, and

4. removal of tritium from the moderator and the heat transport systems (HTS).

A program to manage tritium concentrations in the heavy water (HW) systems and details associated with tritium removal are described.

INTRODUCTION

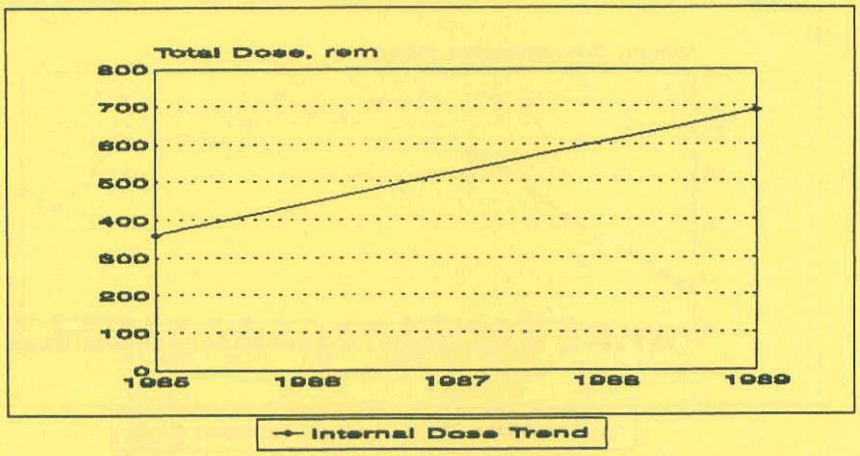
In the CANDU type nuclear stations, tritium is present in the form of tritiated heavy water, TDO, in the heat transport and moderator systems. On exposure, tritium enters the body in the liquid or the vapour form through absorption, ingestion, or inhalation. Once inside the body, tritium being a weak beta emitter, can damage internal organs. If it escapes to the environment outside the CANDU Station, tritium could contaminate water and the food chain.

A tritium management program, consisting of control methods to minimize the undesirable effects of tritium, has been used for several years at Ontario Hydro. The approaches used were and continue to be, to minimize the escape of tritiated heavy water at source, to recover the escaped water and vapour for worker safety and environmental protection, and to minimize worker exposure while working in the tritiated heavy water environment. The methods corresponding to the approaches include improved surveillance, detection and correction of HW escape paths from the heavy water systems, improved vapour recovery systems, the use of protective equipment and clothing and strict adherence to radiation protection procedures while in the vicinity of tritiated heavy water or vapour.

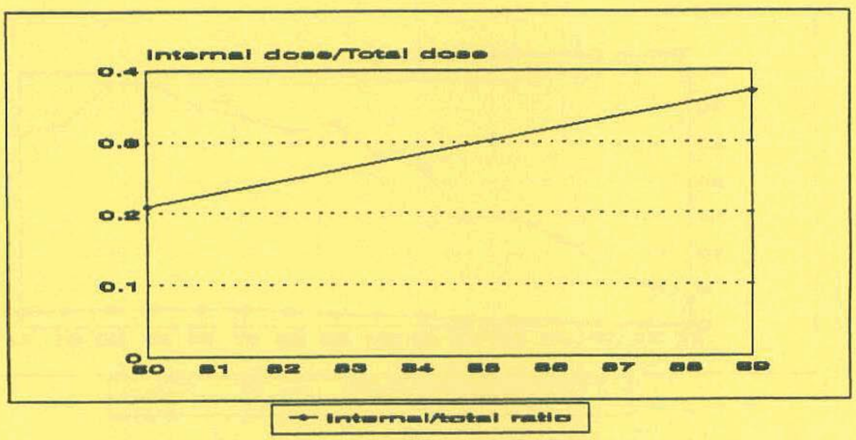
The displacement of heavy water with heavy water of lower tritium content has also been used to augment the above approach. The displacement program has delayed the approach to tritium equilibrium, which is estimated to be 60 to 80 Ci/kg for the moderator, but has not lowered the tritium concentration significantly. Some reactors have >30 Ci/kg in the moderator and >2.0 Ci/kg in the HTS. The tritium displacement program only postpones the need for actual removal. The dose records since 1980 show that the collective annual internal dose due to tritium is rising (Figure 1). The fraction of the collective annual internal dose due to tritium in the total dose is also increasing (Figure 2). However, all environmental emissions are within the design and operating target of 1% Derived Emission Limit. Since the tritium buildup will continue to rise to the equilibrium value if left unchecked, a more aggressive tritium reduction program is needed to boost the effectiveness of the control methods.

HISTORICAL TRITIUM BUILDUP

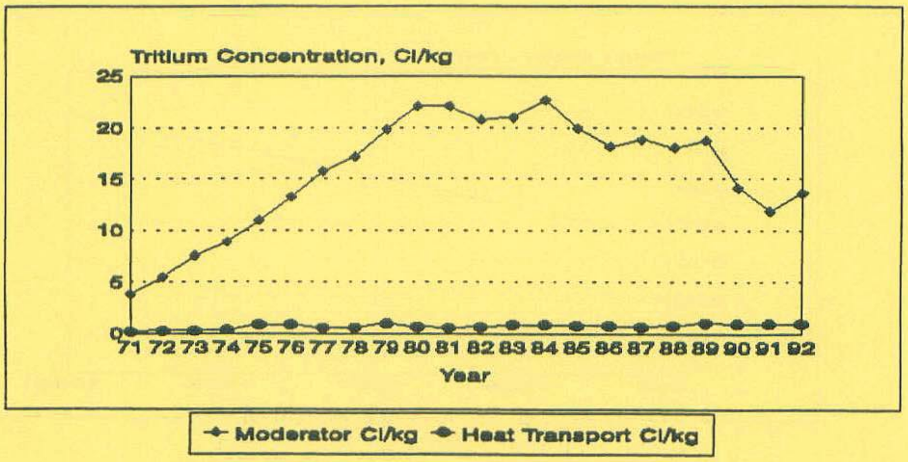
Historical buildup of tritium in Ontario Hydro CANDU reactors is shown in Figures 3 through 6. The data suggest that the tritium levels will continue to rise despite the displacement program.



Collective Internal Dose Nuclear Operations Branch
Figure 1

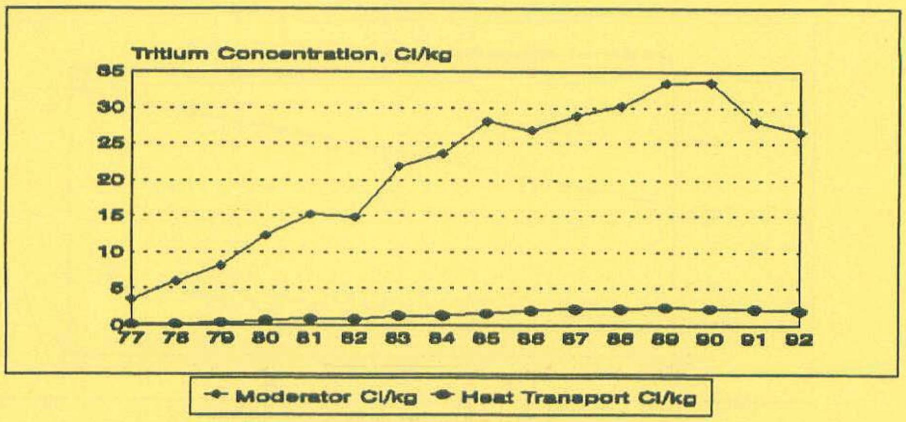


Collective Internal Dose Nuclear Operations Branch
Figure 2



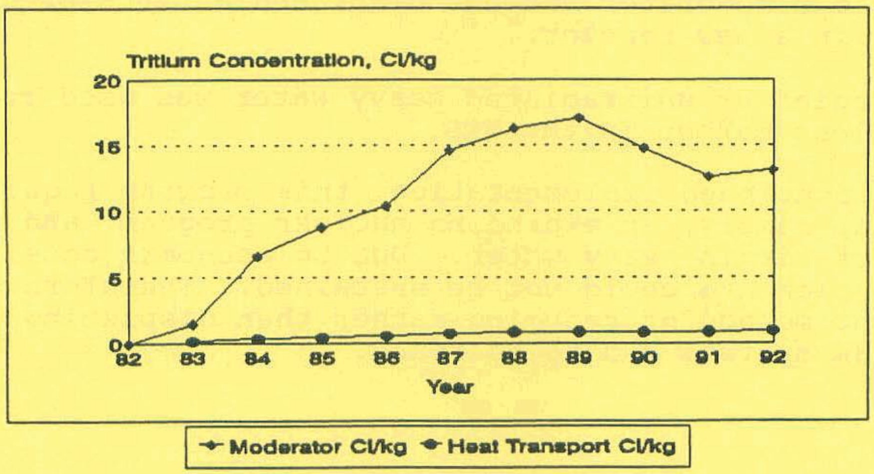
Historical Buildup of Tritium in PNGS-A Reactors

Figure 3

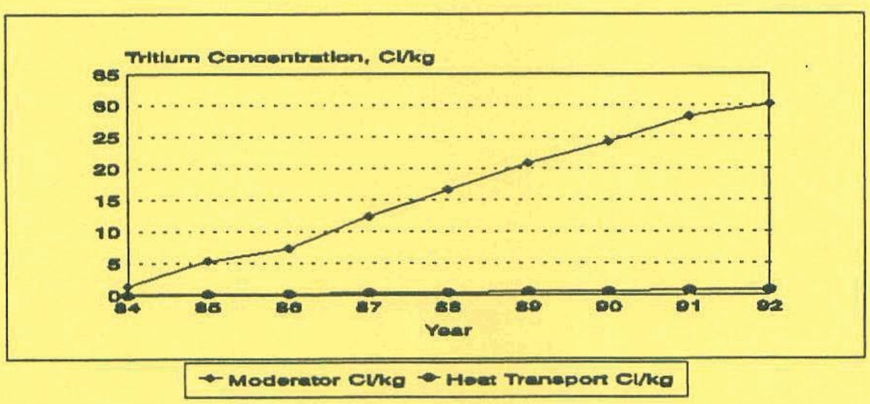


Historical Buildup of Tritium in BNGS_A Reactors

Figure 4



Historical Buildup of Tritium in PNGS_B Reactors
Figure 5



Historical Buildup of Tritium in BNGS-B Reactors
Figure 6

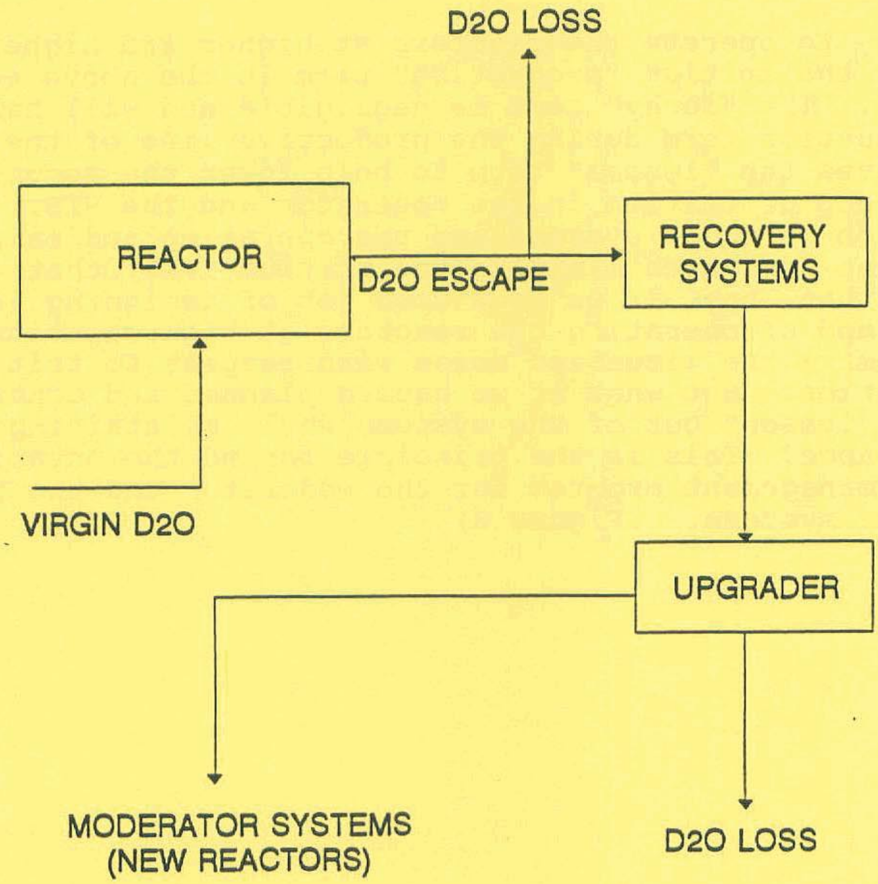
TRITIUM DISPLACEMENT PROGRAM

The tritium displacement program that was carried out can be briefly summarized as follows: (Figure 7)

1. Tritiated heavy water recovered from HTS was upgraded and was used to displace an equivalent quantity of water from its own moderator and the displaced water stored for future use in a new reactor.

2. "Virgin" or unirradiated heavy water was used for recovery or loss makeup in the HTS.

For its continued implementation, this program required two elements, namely, an expanding nuclear program, and a continuous supply of virgin heavy water. Due to economic considerations, the two elements could not be sustained. Therefore a more permanent method of reducing rather than displacing the tritium in the HW systems had to be found.



TRITIUM DISPLACEMENT PROGRAM

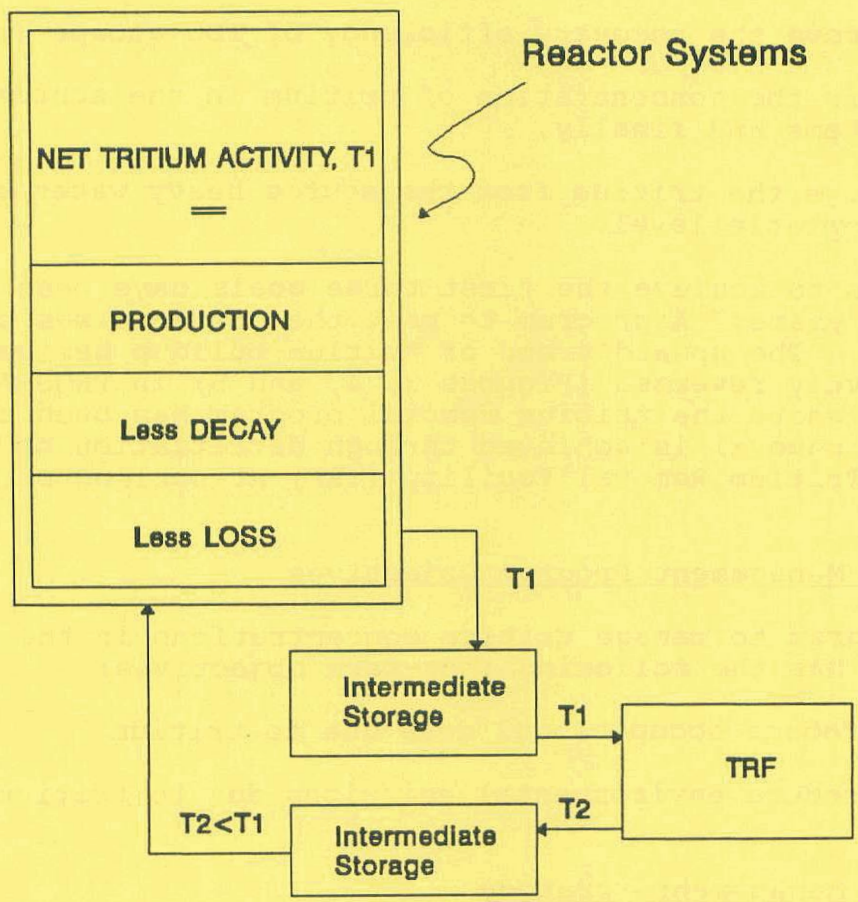
Figure 7

TRITIUM REDUCTION PRINCIPLE

A simple mass balance on tritium in the heavy water systems could be written as

ACCUMULATION = PRODUCTION - DECAY - LOSSES

As we try to operate the reactors at higher and higher capacity factors, the tritium "production" term in the above equation will increase. The "decay" term is negligible and will hardly offset the production term during the productive life of the reactor. That leaves the "losses" term to help lower the accumulation or the buildup of tritium in the moderator and the HTS. However, the design of these systems and the operating and maintenance procedures strive to minimize the tritium (TDO) that escapes. It appears then, that if we do a good job of designing leak tight systems and of operating the reactors at high capacity factors, we only make the situation worse with respect to tritium accumulation. But what if we caused planned and controlled tritium "losses" out of the systems while maintaining heavy water mass balance? This is the principle behind the Ontario Hydro tritium management program for the moderator and the heat transport systems. (Figure 8)



TRITIUM MANAGEMENT PRINCIPLE

Figure 8

TRITIUM MANAGEMENT

In increasing order of effectiveness in reducing worker dose, the tritium management strategy has been directed to achieve the following goals:

1. Minimize the escape of TDO.

2. Improve the recovery efficiency of TDO escape (release).

3. Lower the concentration of tritium in the source heavy water systems and finally,

4. Remove the tritium from the source heavy water systems to an acceptable level.

Programs to achieve the first three goals have been in place for several years. A program to meet the last one was put in place in 1990. The upward trend of tritium buildup has been effectively reversed (Figures 3, 4, and 5) in PNGS-A, PNGS-B, and BNGS-A, where the tritium removal program has been applied. Tritium removal is achieved through detritiation of heavy water in the Tritium Removal Facility (TRF) at Darlington.

Tritium Management Program Objectives

The program to manage tritium concentrations in the heavy water systems has the following long-term objectives:

1. To reduce occupational dose due to tritium.

2. To reduce environmental emissions due to tritium.

Tritium Management Strategy

1. Provide detritiated heavy water to commission DNGS.

2. Detritiate all in-service reactors to an intermediate tritium concentration. The initial target was to get the moderators to less than 15 Ci/kg and the HTS to less than 1 Ci/kg by the end of 1993.

3. Thereafter, maintain each Station at an appropriate equilibrium tritium concentration to sustain acceptable worker dose and environmental emissions. The general target area is 10 Ci/kg and 0.8 Ci/kg respectively for the moderator and HTS.

Assignment of Detritiation Priorities

For the one TRF, we have sixteen operating reactors with three reactors at various stages of commissioning, and one requiring detritiated heavy water for the initial fill. Therefore, a process has been put in place to assign priorities to service these reactors to meet the short and long term objectives. The following criteria are used:

1. Meeting commissioning deadlines.

2. Evidence of high internal dose due to tritium.

3. High tritium concentrations in the heavy water systems.

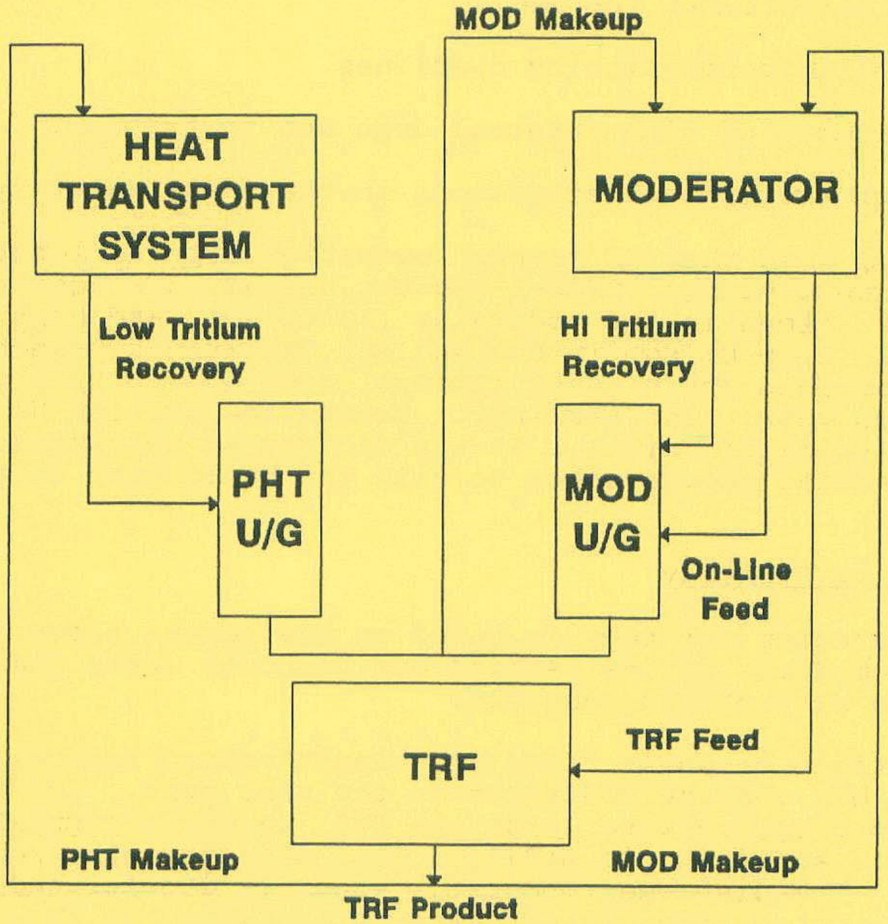
In 1990, when the TRF resumed operation after a lengthy maintenance outage, BNGS-A had the highest average tritium concentrations in the moderator (33 Ci/kg), and heat transport systems (2.35 Ci/kg) in the Nuclear Operations Branch. However, PNGS recorded the highest internal dose due to tritium the previous year. Also Darlington needed low tritium heavy water for initial fill of Unit 1. It was decided to detritiate PNGS and also provide enough water to fill the Darlington Unit.

Operating Strategy

The operating strategy is based on the scheme shown in Fig.9. The procedures can be carried out on-power (feed and bleed) as well as on shutdown reactors.

The optimum on-power "feed and bleed" method reduces the tritium in the HTS and the moderator in the same pass. Low tritium HW is used to displace water from the HTS, which in turn after suitable chemical and isotopic modification, displaces the moderator water. The displaced moderator water is detritiated in the TRF and the detritiated water (product) returned to the Station to repeat the cycle. This method not only has the advantage of detritiating the two heavy water systems simultaneously but also provides the highest concentration feed to the TRF.

When a reactor is shut down bulk detritiation may be carried out. It is not unusual to detritiate the entire contents of the moderator, as was done with Pickering Unit 3 in 1990 during the retube outage. This method is most efficient in removing tritium but is carried out only if it does not prolong the outage and if it does not violate the usual Operating Policies and Principles applicable to a shutdown reactor.



D2O MANAGEMENT SYSTEM AT PNGS & BNGS WITH TRF OPERATING

Figure 9

Results

At the end of 1991 2500 Mg of heavy water had been detritiated. In 1990, 1400 Mg were detritiated. This brought the average tritium levels in the Pickering moderator systems down by approximately 50% and also supplied over 400 Mg of detritiated heavy water to fill Darlington Unit 1 HTS in 1990.

SUMMARY OF OPERATING DETAILS

Equipment

We have provided licensed (Type B) containers for shipping tritiated heavy water between the Stations and TRF. Two containers of 5 Mg capacity each, attached to a flat bed is called a TDO assembly. Each station is equipped with transfer systems to allow interfacing with the containers.

The Management Process

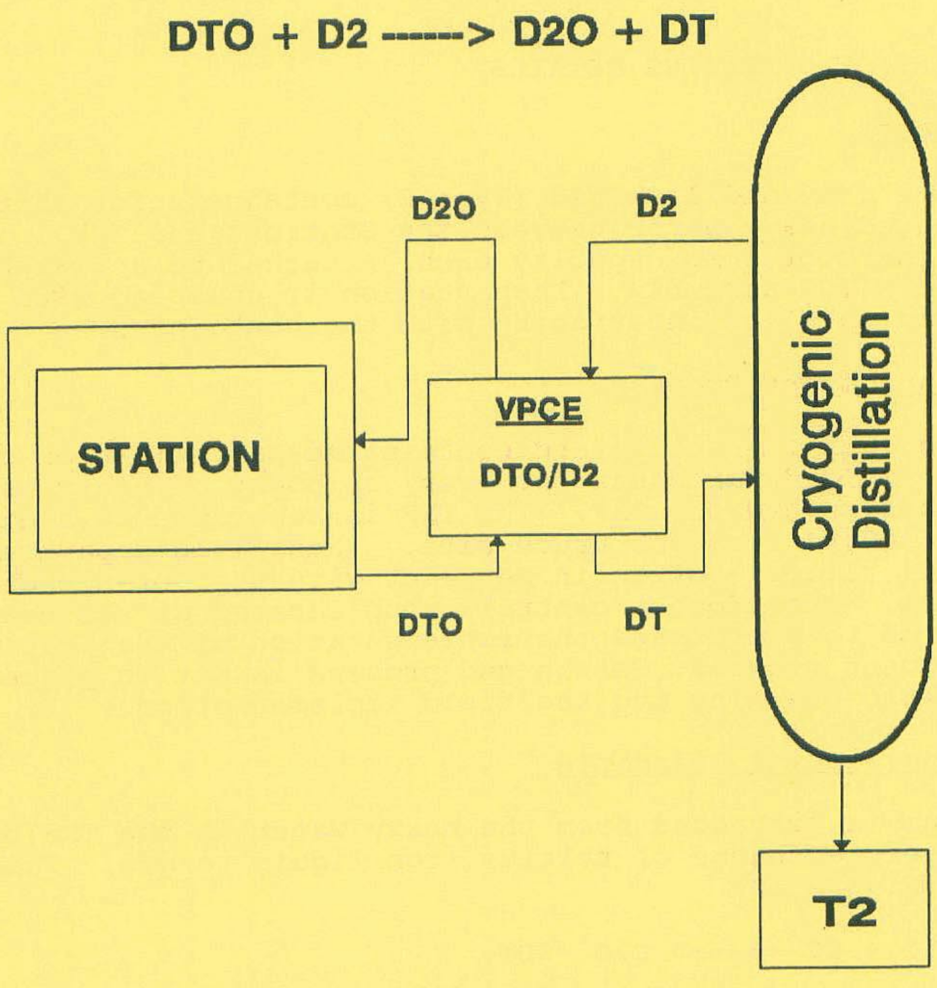
It requires the active and coordinated participation of at least three field departments for every shipment of heavy water between the Station and the TRF. The TRF is separated by a distance of about 300 km from the Bruce site. Each field department has its own priorities - often in conflict with that of the detritiation program. Therefore a central group located at the Head Office is required to coordinate the implementation of the tritium management program. A managed process is put in place to do the strategic planning and the field implementation.

Tritium Removal Principle

Tritium is extracted from the heavy water in the TRF by the catalytic exchange of tritium from liquid to gas. This process is: (Figure 10)

$$DTO + D_2 \longrightarrow D_2O + DT$$

The design feed rate is 360 kg/h of tritiated HW. Per design the product concentration is reduced to 1/35.7 of the initial tritium concentration. The detritiated heavy water is returned to the Station and the D_2 is purified and returned to the process. The tritium is removed, immobilized and stored.



TRITIUM REMOVAL SYSTEM

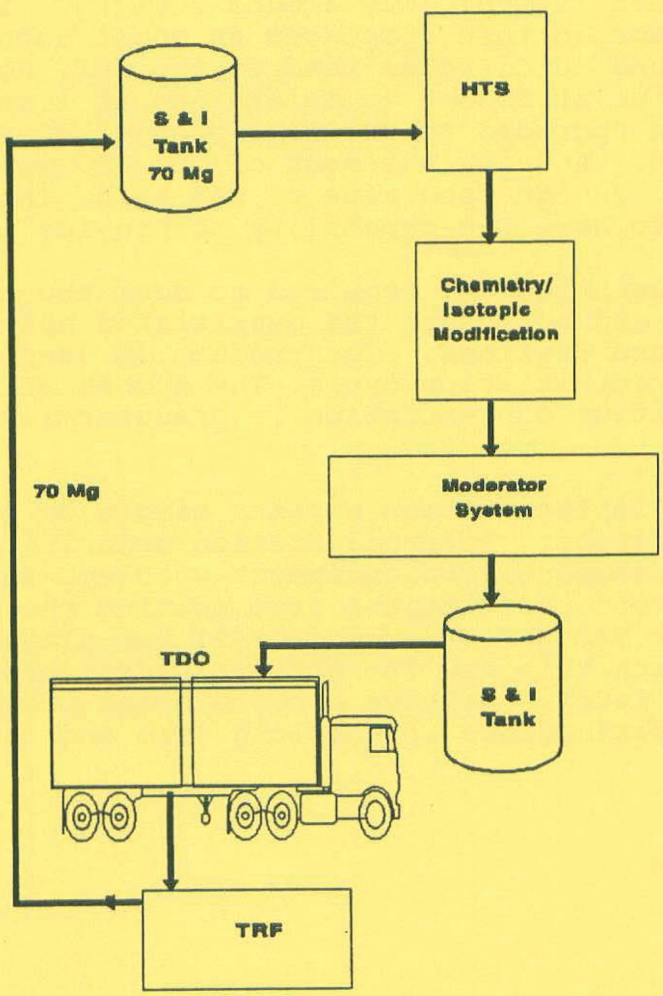
Figure 10

Implementation

Using BNGS-A as a typical example (Figure 11), the on-power detritiation cycle begins with the displacement of heavy water from the HTS with low tritium content water. The water used for displacement is either virgin heavy water or TRF product which is in the range of 0.5 to 0.8 Ci/kg. The tritium content of the displaced water is typically around 2 Ci/kg. The displaced heat transport water in turn displaces an equal amount of moderator water at around 30 Ci/kg as feed to the TRF. However, the heat transport water at BNGS-A is maintained at less than 99% isotopic and has to be upgraded to 99.92% isotopic before it can be put in the moderator. A daily shipment of one TDO assembly is required to maintain a design feed rate of 360 kg/h. Therefore, the Station has to have the capability to provide 10 Mg/d of feed.

Three TDO assemblies are required to meet the continuous TRF feed requirements and to return the detritiated heavy water (TRF product) to the Stations. The product is used to repeat the displacement/detritiation cycle. The number of cycles required to lower the tritium concentration is predetermined using computer models.

Although the implementation appears simple on paper, the reality is quite different. Internal Station priorities, lack of human resources, transportation equipment problems and TRF incapability sometime prevent the Stations from meeting the detritiation targets. The TRF performance in 1991 was plagued by problems associated with this new (to Ontario Hydro) process and with equipment failures. We have a coordinated program in place to improve TRF performance in the long term and current results are encouraging.



TRITIUM MANAGEMENT USING TRITIUM REMOVAL

Figure 11