TRITIUM CONCENTRATION IN THE HEAVY WATER UPGRADING PLANTS

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ABSTRACT

In the course of time heavy water used in CANDU nuclear power plants, as moderator or coolant, degrades, as a result of its impurification with light water and tritium. Concentration diminution below 99.8% mol for moderator and 99.75% mol for coolant causes an inefficient functioning of CANDU reactor. By isotopic distillation, light water is removed. Simultaneously tritium concentration takes place. The heavy water upgrading plant from Cernavoda is an isotopic separation cascade with two stages. The paper presents, for this plant, a theoretical study of the tritium concentration

Key words: heavy water, tritium, distillation, simulation

1. Introduction

Heavy water used in CANDU nuclear power plants, as moderator or coolant, degrades as a result of its contamination with light water and tritium. Diminution of deuterium concentration below 99.8% mol in moderator and 99.75% mol in heat agent causes an inefficient functioning of CANDU reactor. Light water is removed by isotopic distillation. In this plant simultaneously takes place tritium concentration. Using a simulation program it has been studied the tritium concentration in heavy water upgrading plant from CNE Cernavoda.

2. Heavy water upgrading plant

The heavy water upgrading plant from CNE Cernavoda is a distillation cascade with two stages. Each stage has two serialised distillation columns, one boiler and one condenser. The columns are equipped with structured packing. Figure 1 presents the scheme of this plant. The plant processes water with deuterium concentrations held in 1-99% domain. Following values are imposed on product and waste concentrations: 99,9% D/(D+H), 0.2% D/(D+H) respectively.

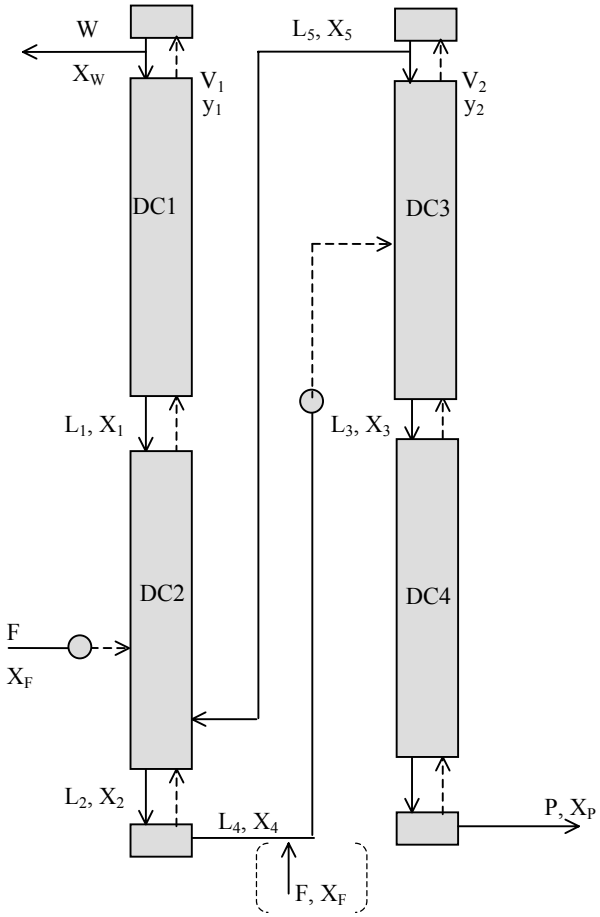

Fig. 1 Scheme of heavy water upgrading plant

3. Liquid - vapour equilibrium

Since there are spontaneous isotope equilibrium reactions:

$$2\,HDO \Leftrightarrow H_2O + D_2O \tag{1}$$

$$2\,HTO \Leftrightarrow H_2O + T_2O \tag{2}$$

The separation factors are calculated with relations:

$$\alpha_D = \frac{K_{H_2O}}{K_{D_2O}} = \sqrt{\frac{P_{H_2O}}{P_{D_2O}}} \tag{3}$$

$$\alpha_T = \frac{K_{H_2O}}{K_{T_2O}} = \sqrt{\frac{P_{H_2O}}{P_{T_2O}}} \tag{4}$$

These equilibrium quantities are depended on temperature. Tab. 1 presents the values of separation factors for a few temperatures. The highlighted values belong to the usual domain for high water distillation columns [1,2,3].

t (°C)	separation factors	
	deuterium	tritium
40	1.0615	1.0129
50	1.0535	1.0108
60	1.0463	1.0090
70	1.0400	1.0076
80	1.0347	1.0066
100	1.0266	1.0057

Tab. 1 Separation factors

3. Theoretical estimation of tritium concentration

The feed and product flow rates of heavy water upgrading plants (F, P) depend on the feed concentration. They were determinate using a simulation program. It was respect the imposed concentrations, Xp and Xw. Tab. 2 shows as a function of feed concentration.

Considering that the tritium concentration level is about 1 Ci/kg it was determinate, by simulation, the tritium separation during water processing. Tritium separation, S_T, representing the rate between product and feed concentration, $\frac{X_P^T}{X_F^T}$, is presented in tab. 2 also.

Tab. 2 Tritium separation

X_F (deuterium)	F/P	X_P/X_F (tritium)
1	138.40	125.65
10	11.20	11.17
20	5.48	5.48
30	3.60	3.61
40	2.67	2.68
50	2.11	2.12
60	1.74	1.74
70	1.48	1.48
80	1.28	1.28
90	1.12	1.12
99	1.01	1.01

High values of S_T are achieved at low values of F/P rate, therefore on processing off the deuterium dilute solutions. Because tritium concentration is very low, comparatively with deuterium concentration, tritium separation has the same variation with F/P rate. Figure 2 shows the theoretical level of the heavy water activity in the four columns of the upgrading plant when $X_{F\ (deuterium)} = 50\%$.

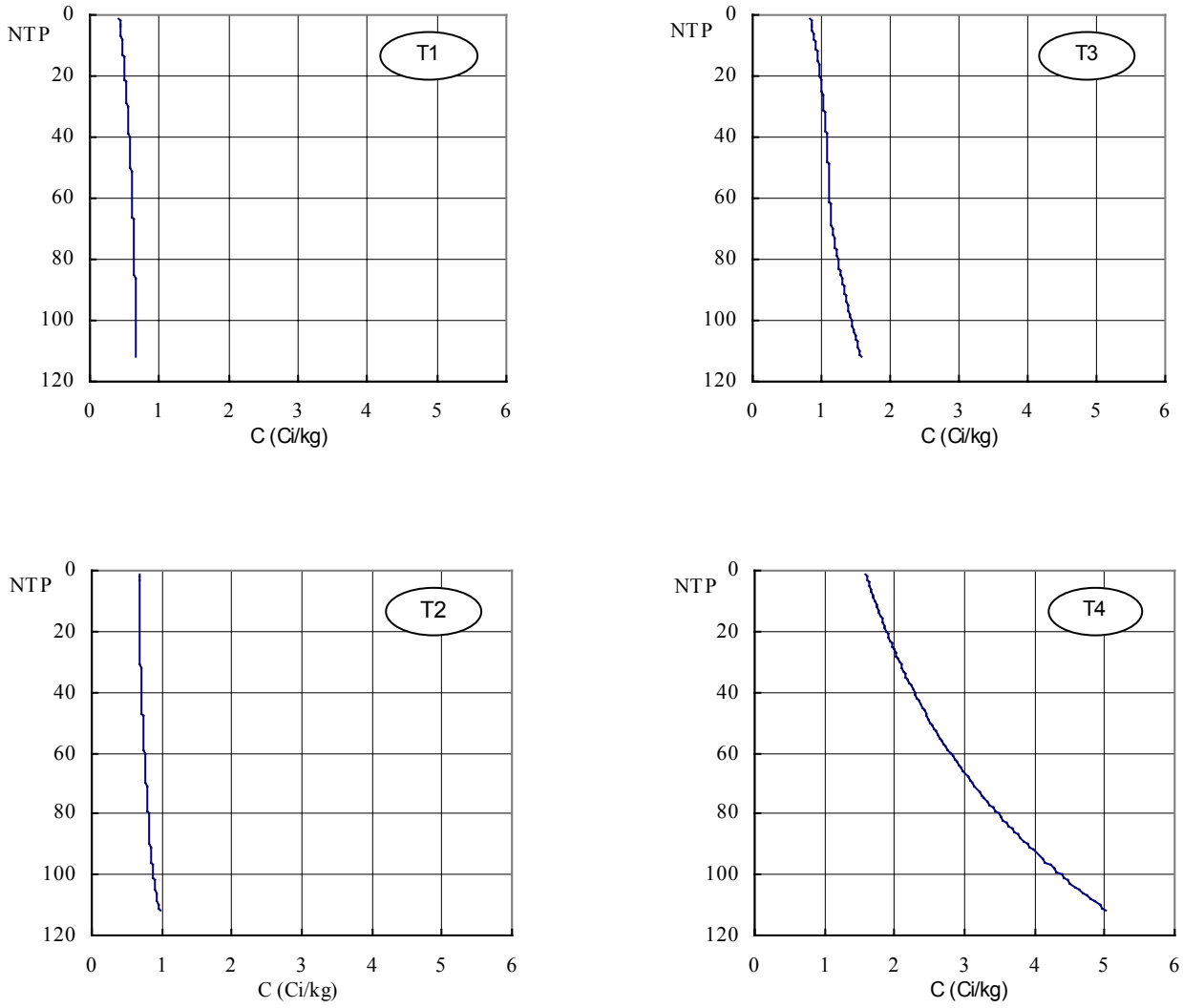

Fig. 2 Theoretical level of the tritium concentration in the four columns of the upgrading plant

Knowledge of the tritium concentration level is very important to assure protection measures of personnel and environment.

2. References

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