A Method of Locating Leakage of Heavy Water Using Ratio of Tritium to Heavy Water

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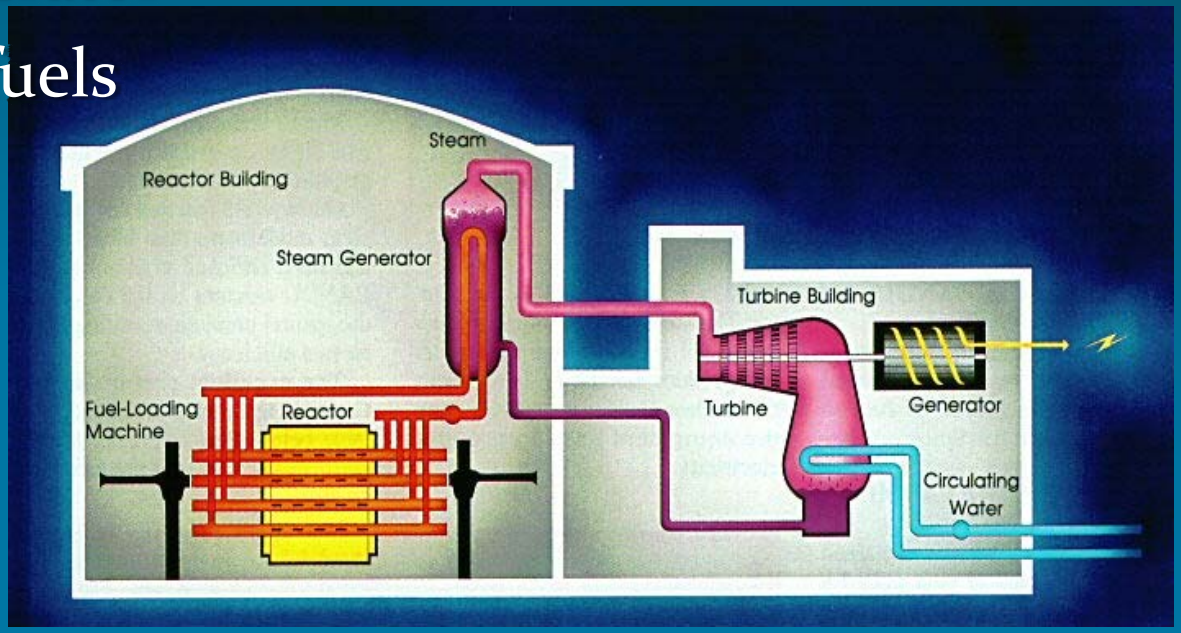
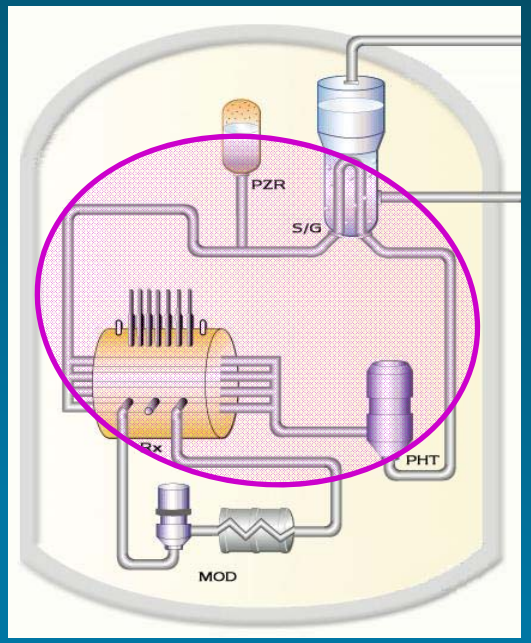
CANDU reactors

- CANDU : Canada Deuterium Uranium (Pressurized Heavy Water Reactor)
- Heavy water(D_2O) coolant
- Heavy water moderator
- Natural uranium fuels



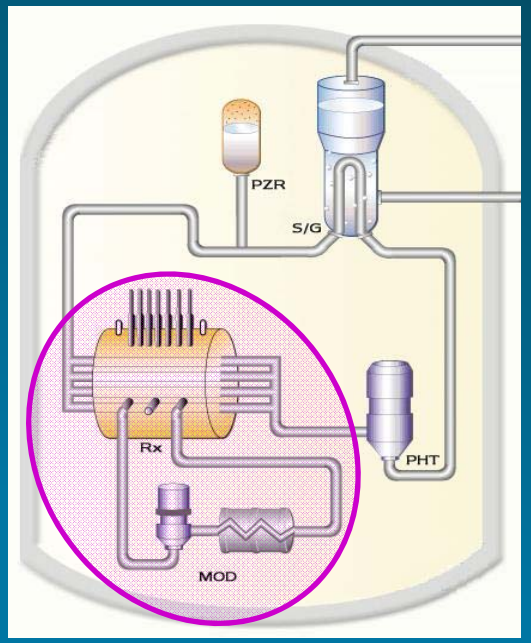
Two systems containing heavy water

- Primary Heat Transport System(PHT system)
  - Coolant : 190 ton
  - High temperature : 266 ~ 310 °C
  - High pressure : 100 bar
  - Tritium concentration : **~ 2 Ci/kg**
  - Usual leakage rate : ~ 10 kg/day (Wolsong Unit 3 & 4)



Two systems containing heavy water

- Moderator System(MOD system)
  - Moderator : 260 ton
  - Low temperature : 46 ~ 69 °C
  - Low pressure : 0.2 bar
  - Tritium concentration : **~ 40 Ci/kg**
  - Usual leakage rate : ~ 1 kg/day (Wolsong Unit 3 & 4)

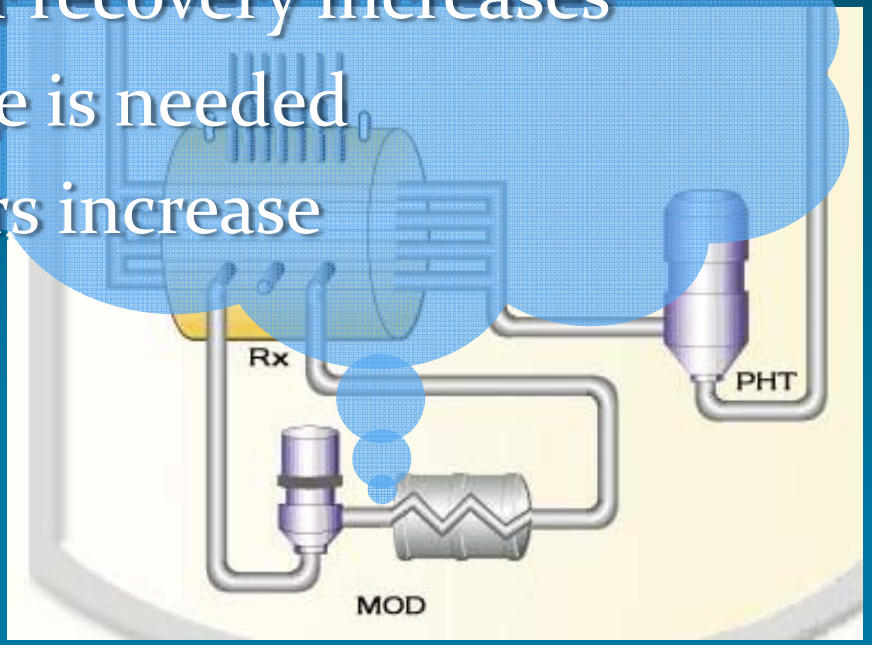


Features of a PHWR

- High tritium concentrations in coolant or moderator
- Inevitable leakage of coolant and moderator (not only at a PHWR)
- High tritium concentration in air of reactor building
- High concern about internal dose by tritium

What happens during sudden heavy water leakage?

- Tritium concentration in air soars high
- Amount of tritium release increases
- Amount of heavy water recovery increases
- Wide survey for leakage is needed
- Internal dose of workers increase



If we know which system heavy water leaks from…

- Survey time will shorten
- We can reduce
  - Heavy water leakage
  - Tritium release
  - Internal dose of workers

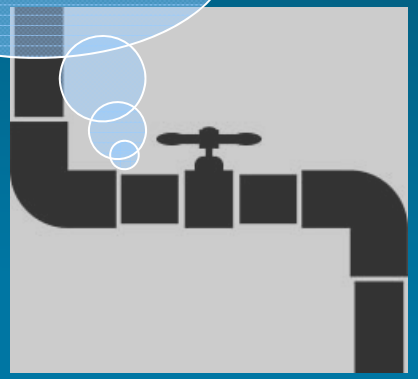
Tritium & heavy water in air

PHT heavy water : X
PHT tritium : AX

Heavy water : X+Y
Tritium : AX+BY

MOD heavy water : Y
MOD tritium : BY

PHT system



MOD system

System Equation for X & Y

- Equations for PHT & MOD heavy water

$$AX + BY = T$$
$$X + Y = H$$

$X = (T - BH) / (A - B)$
$Y = (T - AH) / (B - A)$

where A is tritium concentration in PHT heavy water (known)
B is tritium concentration in MOD heavy water (known)
T is tritium in the sample (measured)
H is heavy water in the sample (measured)
X is PHT heavy water in the sample (unknown)
Y is MOD heavy water in the sample (unknown)

Contribution to the leakage

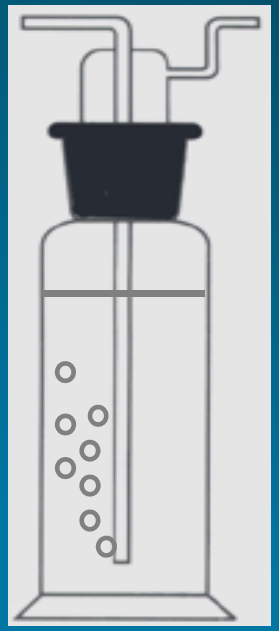
- X & Y show how much PHT heavy water and MOD heavy water exist in the sample
  - These are found by comparing the ratio of tritium (T) to heavy water (H) with the the ratios of tritium to PHT heavy water and MOD heavy water (A & B)
  - B is much bigger than A
  - If T/H is very close to A, most of heavy water and tritium must come from PHT system
  - If T/H is a little close to A, most of heavy water comes from PHT system but most of tritium comes from MOD system

Wolsong Power Plant II's experience 1
(Unit 3, Dec. 2008)

- Tritium concentration in air in the reactor building suddenly rose

Sampling & analysis

- Water vapor sampling from the air in the reactor building using gas washing bottle
  - Tritium in 1g (T) = 25.9 kBq
  - Heavy water in 1g (H) = 26.4 mg
  - Heavy water compensated for natural deuterium in 1g (H) = 9.7 mg



※Tritium concentration in PHT (A) = 1.714 Ci/kg
Tritium concentration in MOD (B) = 37.92 Ci/kg

Calculation result

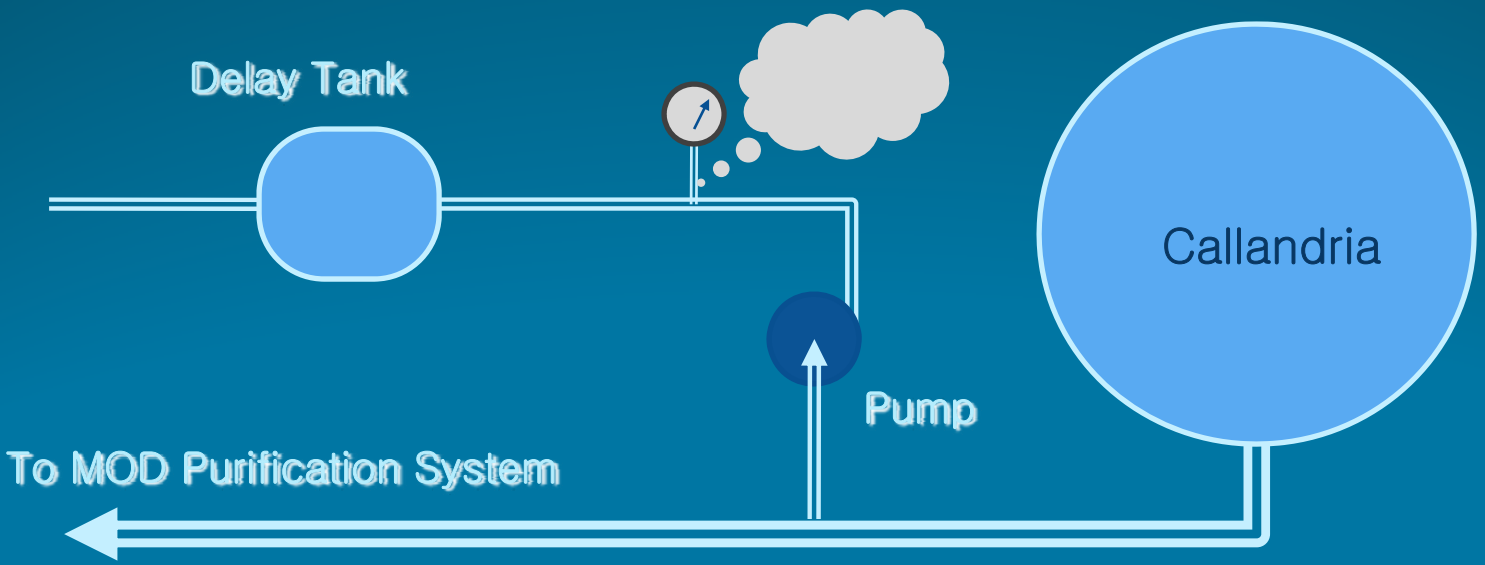
- 85% of leaked heavy water was from PHT system, and 15% from MOD system

- 20% of tritium in air was from PHT system, and 80% from MOD system

※ Ordinarily, more than 90% of tritium in air had been from PHT system

Follow-up actions

- An intensive survey on MOD system
- Finding out the leakage point at a junction near a pressure instrument of the MOD system

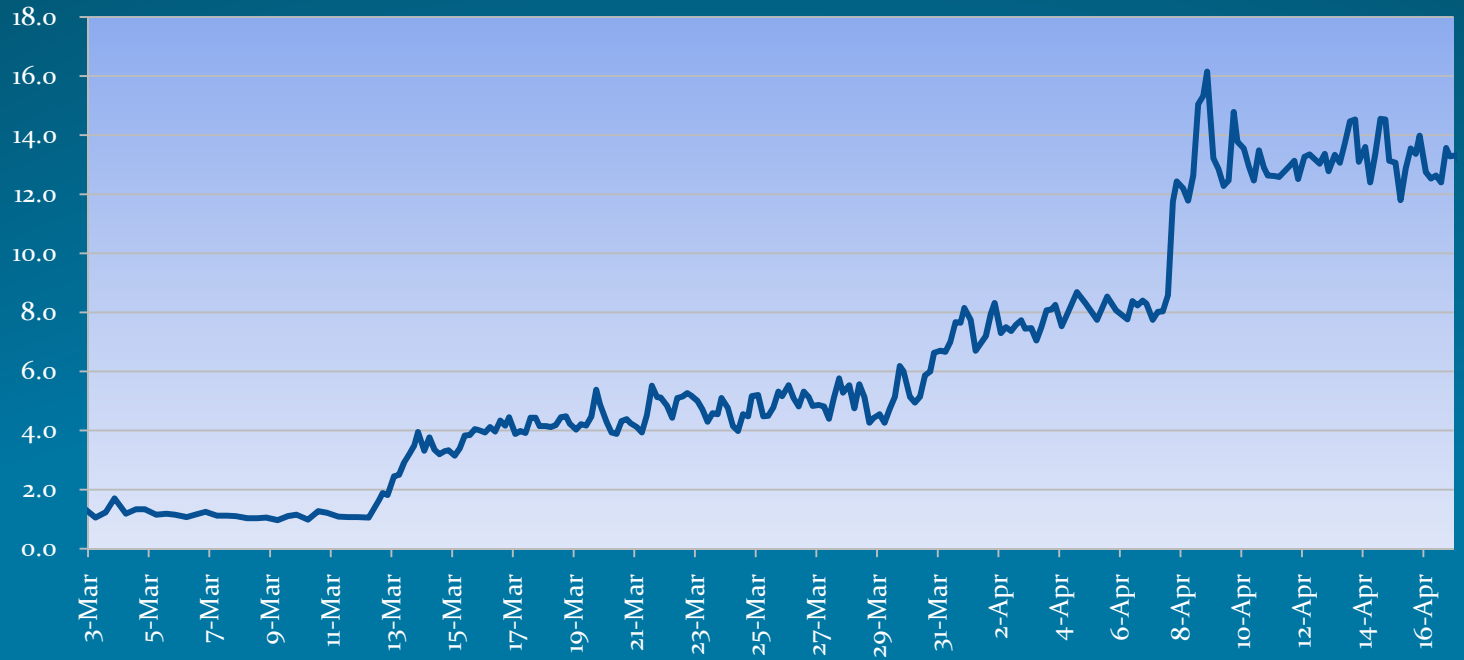


Follow-up actions

- The tritium concentration in air in the reactor building decreased after repair

Wolsong Power Plant II's experience 2 (Unit 4, Apr. 2009)

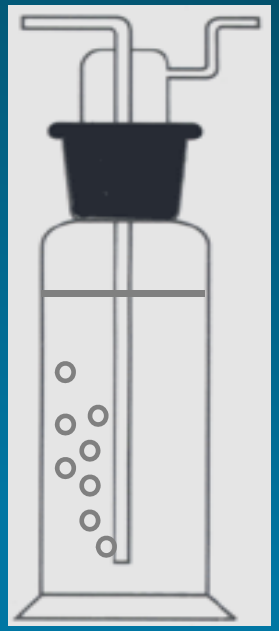
- Tritium concentration in air in the reactor building jumped



Sampling & analysis

- Water vapor sampling from the air in the reactor building using gas washing bottle
  - Tritium in 1g (T) = 50.3 kBq
  - Heavy water compensated for natural deuterium in 1g (H) = 93.0 mg

※Tritium concentration in PHT (A) = 1.513 Ci/kg
Tritium concentration in MOD (B) = 36.99 Ci/kg



Calculation result

- 100.14% of leaked heavy water was from PHT system, and -0.14% from MOD system

- 103.7% of tritium in air was from PHT system, and -3.7% from MOD system

※ This irrational result was thought as due to an experimental error but such results were repeated in more samples

Further Investigation

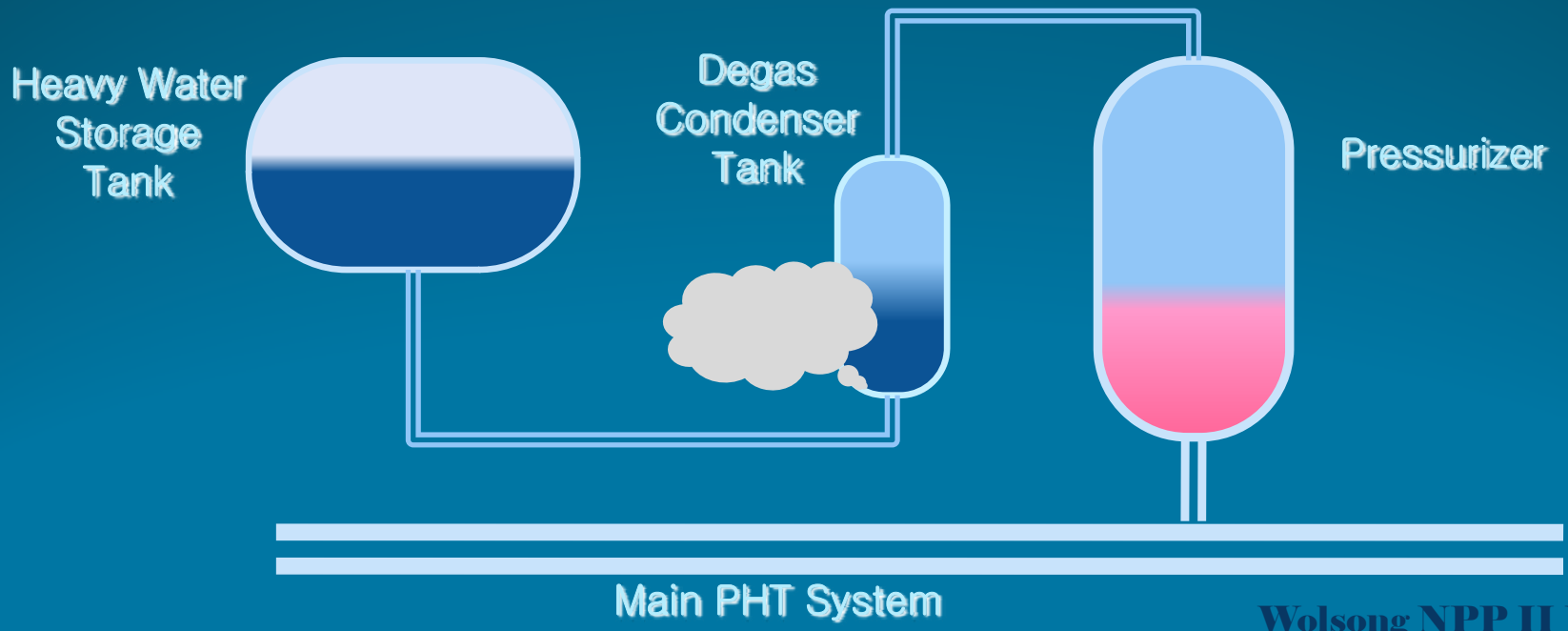
- The ratio of tritium to heavy water in the water vapor sample
  - was supposed to be between the tritium concentrations in the PHT heavy water and MOD heavy water, that is, between 1.513 Ci/kg and 36.99 Ci/kg
  - but, was measured as 1.46 Ci/kg.
- We started to think about the possibility of leaking of another heavy water which has lower tritium concentration.

Further Investigation

- Stagnant heavy water in the PHT system
  - isolated for a long time from circulating coolant
  - had a little less tritium concentration than main PHT heavy water
  - like one in Coolant Storage Tank and more
- Tritium concentration of heavy water in Coolant Storage Tank was measured as 1.40 Ci/kg
- This result could explain the ratio of tritium to heavy water in the water vapor sample from the reactor building, 1.46 Ci/kg

Follow-up actions

- A careful survey on isolated systems
- Finding out the leakage point on Degas Condenser Tank, a semi-isolated system



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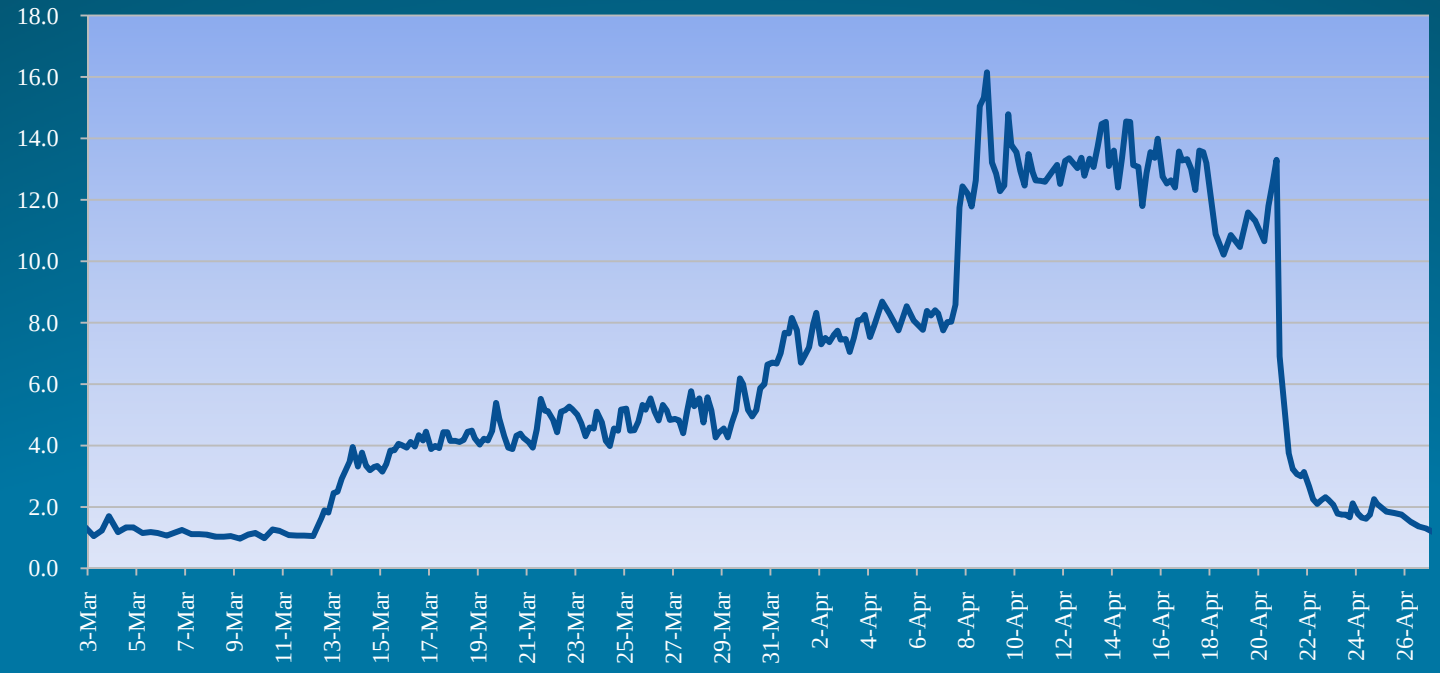

Conclusions

- You can discriminate which system heavy water leaks from, the PHT system or the MOD system.
- You can also know how much one of these systems contributes the heavy water leakage or the increased tritium concentration in air in the reactor building.
- Using this information, you can locate the leakage point more quickly.
- If it works, you can reduce the inner dose of the workers.

Thanks for your attention.

Do you have any questions?