中国核能电力股份有限公司
China National Nuclear Power Co., Ltd.

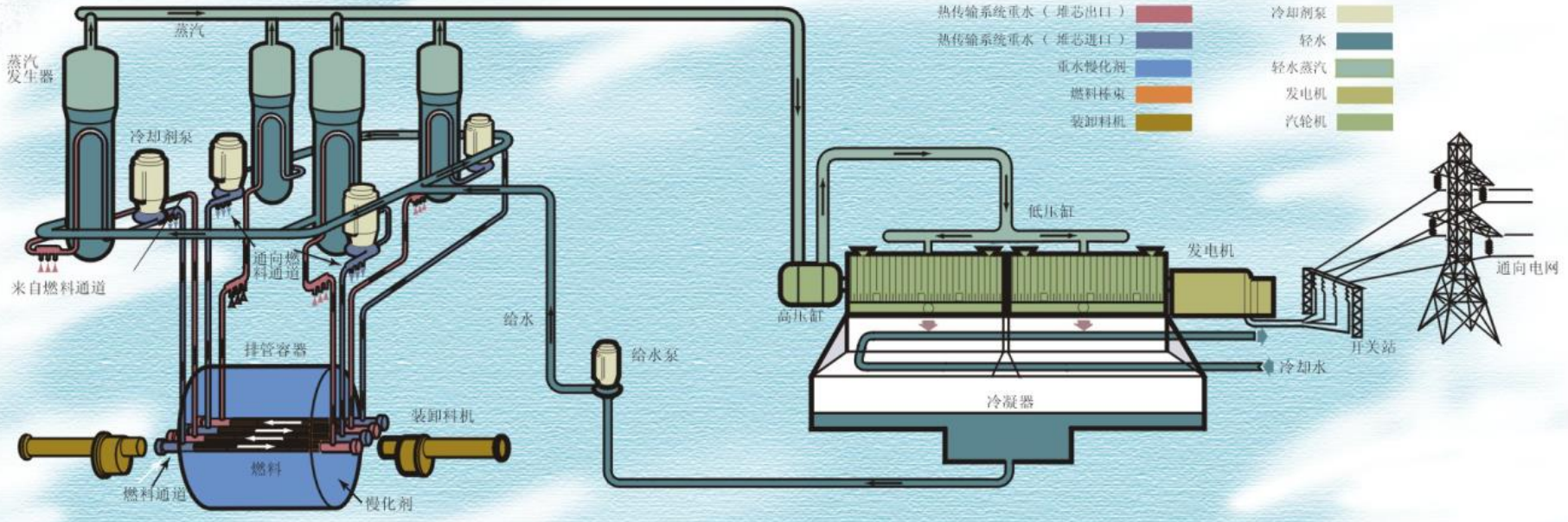
追求卓越 超越自我

Dose Survey In a Tritium Intake Accident

Xiong kouhong, CNNO,China

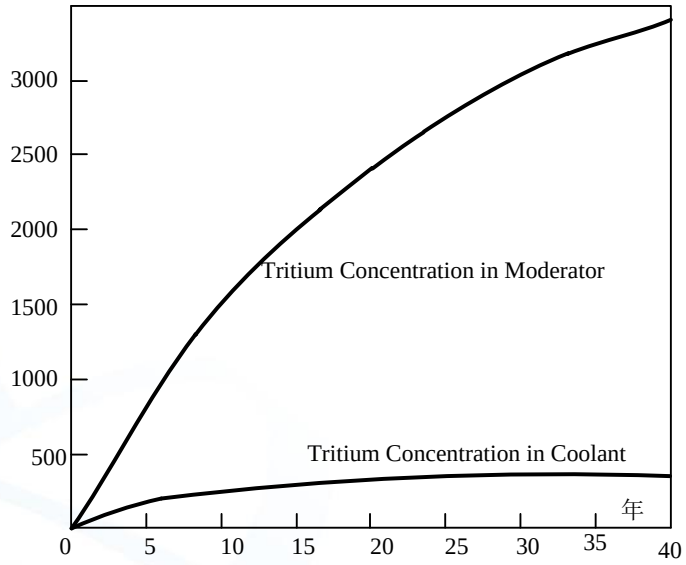
23 Oct. 2019

1. Third Qinshan Nuclear Power Plant



Coolant: **~200T** heavy water; Moderator: **~260T** heavy water

2. Tritium



$$n + {}_{1}^{2}H \rightarrow {}_{1}^{3}H + \gamma$$

1.04×10^{3}TBq/y in Coolant

5.40×10^{4}TBq/y in Moderator

3. The Abstract of The Accident

On Feb 25,2011, a modification including MOD pipe cutting and welding was done in service building. A negative pressure shed was setted up to prevent the tritiated vapor from spreading.

One welder Who firstly engage work related to heavy water was exposed to tritiated atmosphere and bedewed by heavy water during welding the MOD heavy water pipe in QinshanⅢ, and lead to a tritium intake accident.

The welder received the timely remedy for tritium promotion excretion, and the tritium concentration in the urine were measured. The tritium effective dose of the welder during the accident was 13.44mSv.

4. Process of The Accident

Feb 25th 11:15~11:30	• Plumber , cutting pipe and recovering heavy water ,ventilation hood and plastic suit • Heavy water outflow from pipe ,11L was recovered, some falling on the ground
Feb 25th 11:30~13:15	• Welder , pipe welding, ice box • 3 seconds and 1 drops' heavy water leaking through pipe • The tritium concentration in negative pressure shed is 400~600DAC
Feb 25th 13:15	• Finish up job
Feb 25th 16:00	• Sample the urine
Feb 26th 11:00	• Measure the urine， tritium concentration of the welder: **66100 Bq/ml**
Feb 26th 13:30	• Sample an measure the urine of the welder again, **58500Bq/ml**
Feb 26th 19:00~ Mar 6th 22:00	• Sent the welder to hospital and medical promotion excretion for tritium • drinking water, diuretic and furosemide, vitamin and electrolytes supplement, • Average volume of urine per day:>10L • Collect the urine and measure the tritium, totally **133 samples**
Mar 6th 22:00~Mar 28th 2:40	• Rest in home • Collect the urine and measure the tritium, totally **18 samples**

5. Measurement of Tritium in Urine

LSC:
PerkinElmer Tricarb 2900TR/2910TR

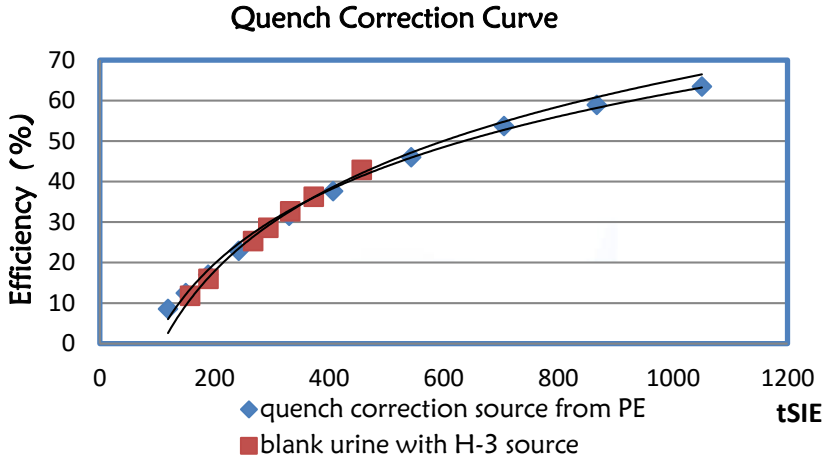
Scintillation Solution:
PerkinElmer Ultima GOLD LLT （10L）

Urine Sample Direct Analysis:
Urine Sample(2ml) + Scintillation Solution(10ml) darkened for 30 min, measured directly by LSC.

5. Measurement of Tritium in Urine

Quench correction: TSIE

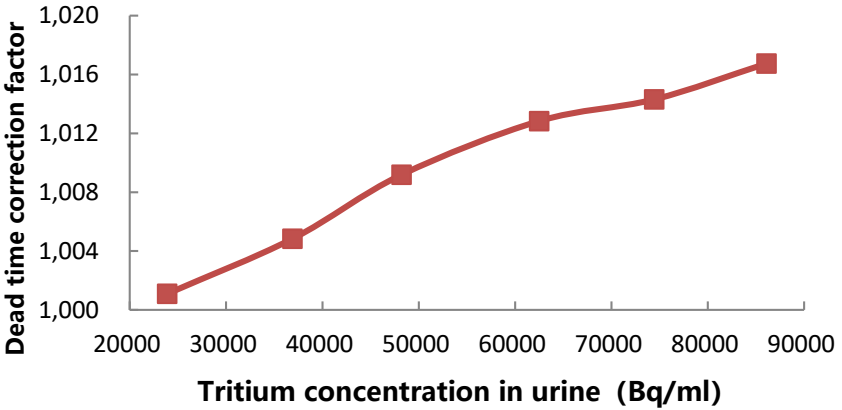
During the accident, we had used the correction curve from quench source of PE to determine the efficiency . After the accident , we used the blank urine with H-3 source to measure the correction curve, and it is almost same as the curve from quench source of PE.



Dead time correction:

When tritium concentration is under 2.0×10^{4}Bq/ml, dead time would not effect the measure result;

In this accident, the max concentration was 6.61×10^{4}Bq/ml, and the dead time effluence is about 1.3%, so we had not corrected measuring result for dead time.



6. Uptake and Ingestion Route

- **Ingestion time:** middle time between 11:30 and 13:15 **Feb 25th 12:23**
- **Urine sample time**: Feb 25th 16:00, 0.15d after ingestion time
- **Uptake**
  - Total uptake $$I = \frac{6.61\times10^{7}}{(0.97\times e^{-0.06947\times0.15}+0.03\times e^{-0.01748\times0.15})/42}$$ **=2.8 ×10⁹Bq**
  - Respiratory intake: 600DAC ×4 ×10⁵m³/ DAC ×1.75h ×60min ×0.02m³/min=**5.0 ×10⁸Bq**
  - Skin intake from tritiated vapor:5.0 ×10⁸Bq ×0.5=**2.5 × 10⁸Bq**
  - Skin permeation uptake :2.8 ×10⁹-5.0 ×10⁸-2.5 ×10⁸**=2.05 ×10⁹Bq**

The tritium concentration in the MOD heavy water is 1.296×10¹²Bq/kg, and the welder may be bedewed by MOD heavy water and uptake **1.58g**.

7. Internal Exposure Dose Assessing

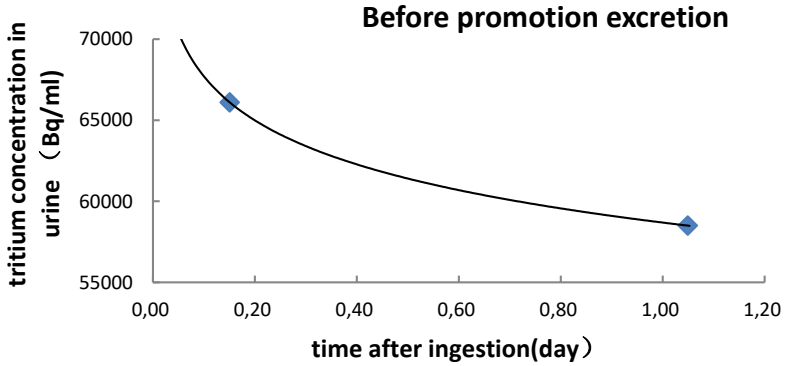
- **Internal exposure dose preliminary assessing**

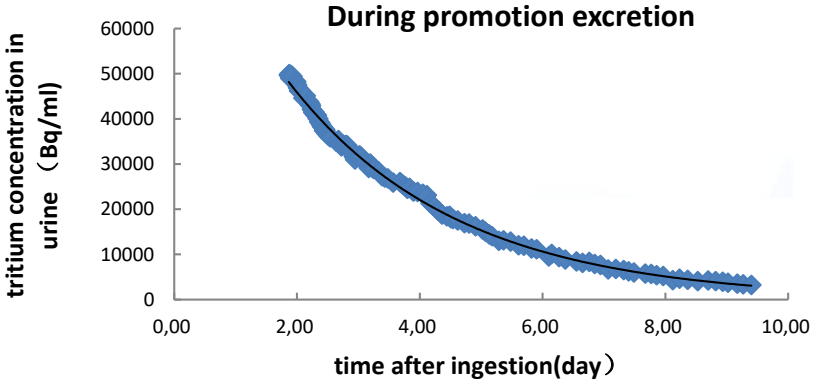
6.61×10^{4}Bq/ml $\times$ 7.6 $\times 10^{-10}$Sv·L/Bq=**50.23mSv**

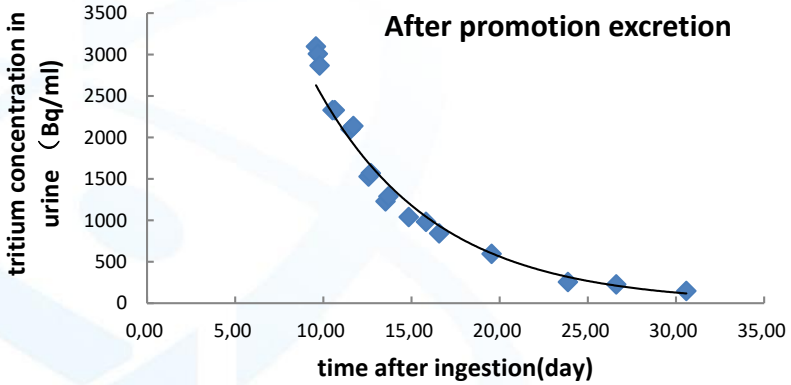
2.8×10^{9}Bq $\times$ 1.8×10^{-11}Sv/Bq=**50.4mSv**

According to above result, we decide to do medical promotion excretion for tritium.

Internal exposure dose assessing







Exponential Fitting($y=Ae^{Bx}$)

Parameter	Before	During	After
A	67468	95320	10874
B	0.136	0.366	0.148
R^2	1	0.9982	0.9807

Internal exposure dose assessing

$$E_1 = \int_0^{1.28} 67468e^{-0.136t}dt \times 1000 \times 5.3 \times 10^{-11} \times 1000 = 4.19mSv$$

$$E_2 = \int_{1.28}^{9.40} 95320e^{-0.366t}dt \times 1000 \times 5.3 \times 10^{-11} \times 1000 = 8.21mSv$$

$$E_3 = \left(\int_{9.40}^{30.60} 10874e^{-0.148t}dt \times 1000 \times 5.3 \times 10^{-11} + 148 \times 1000 \times 7.6 \times 10^{-10}\right) \times 1000 = 1.04mSv$$

$E=E_1+E_2+E_3=$**13.44 mSv**

8. Conclusion

- During the work related to heavy water, it is not easily found when skin was bedewed by heavy water, and the tritium can permeation into skin quickly, so besides the respiratory protection, we should also take measures to aviod bedewed by heavy water .
- Timely special monitoring is very important during tritium dose control. In this accident, the dose in the first two days account for about 30%, and if we can take medical promotion excretion first time, the effect may be better.

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