An apparatus for measurement of tritium in expiration with plastic scintillator

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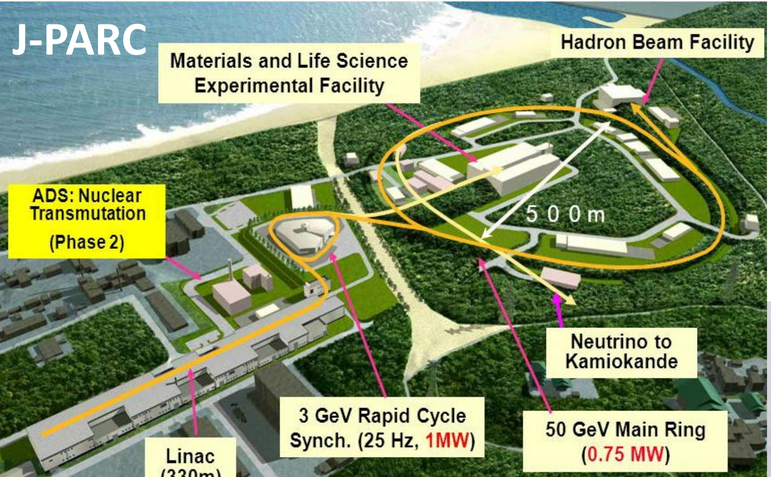
Fukushima Daiiti Nuclear Power Plant Accident ets.




The Fast Breeder Reactor “Monzyu”

Radioactive materials are treated at the accident site, normal nuclear power plants, accelerators, and fast breeder reactors by skilled laborers in all over the world.

They wear filter-masks among their work like this photo.

However, they worry about their safety because………

How to know the internal exposure?

For gamma- and high energy beta-rays

- Normal internal exposure is measured using a whole body counter like these photos.

For low energy beta-rays

- There is no apparatus to measure radioactivities included in breath, directly.

  (It is estimated by calculation

  using radioactivity of in the air.)

How to know the internal exposure?

EAM-101
(ALOKA Co Ltd.,Japan)

10 mL absorber (water)

⇩

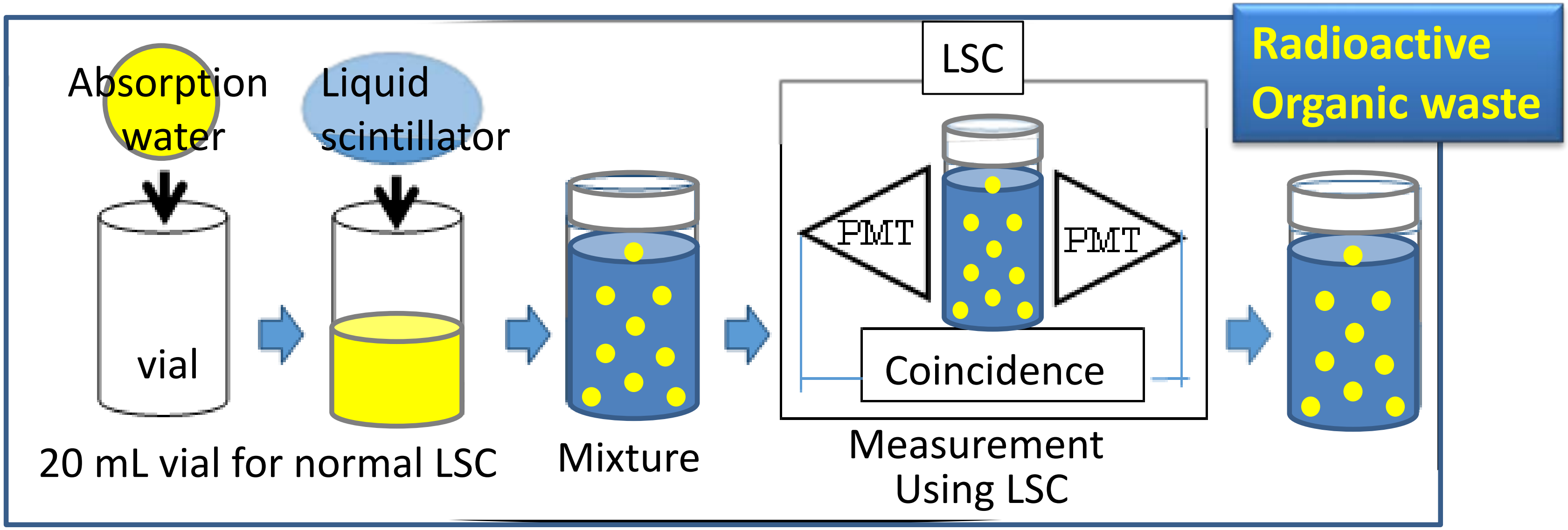
LSC measurement

Once, in Japan, there was an apparatus to measure radioactivities with collecting 10 L breath, which was stored into 10 mL water as an absorber, for one check.

- 10L breath was too much for normal lung volume.
- Many workers lined up in a row.
- When the breathing was too strong, the absorption water was scattered.

After radioactivities were stored into 10 mL water

With LSC measurement



- To measure tritiated water in a absorption water, an LSC with liquid scintillators is necessary because of it low beta-ray energy.
- For one worker, 20 mL liquid organic waste was generated after the measurement with 10 mL sample.

Purpose

To make an apparatus for measurement of tritiated water in expiration with plastic scintillator using LSC

At the same time, these issues are considered:

✓Organic wastes are not generated.

✓Workers do not need to line up on a row for collection of expiration, even when one apparatus is used.

Experimental

1. Expiration test bag: UBiT-POCone (Otsuka, Japan)
2. Vial: Teflon 100 mL (Sanplatec Co., Japan)
3. Special cap for the vial:
   + 2 sockets (CPSE3-4, PISCO, Japan)
4. Plastic scintillator pellets: EJ-200 (G-teck, Japan)
5. LSC: AccuFLEX LSC-LB7 (Hitachi Ltd., Japan)
6. Radioactivity: Tritiated water (Moravek Biochemicals Inc., USA)

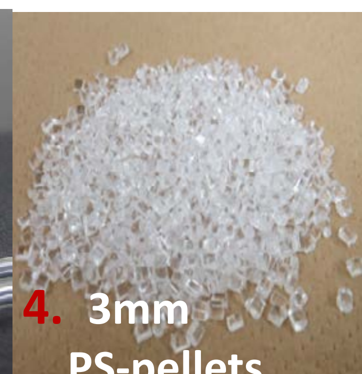
A cap for stopping leakage

1.

2. Teflon vial

3. Special cap vial

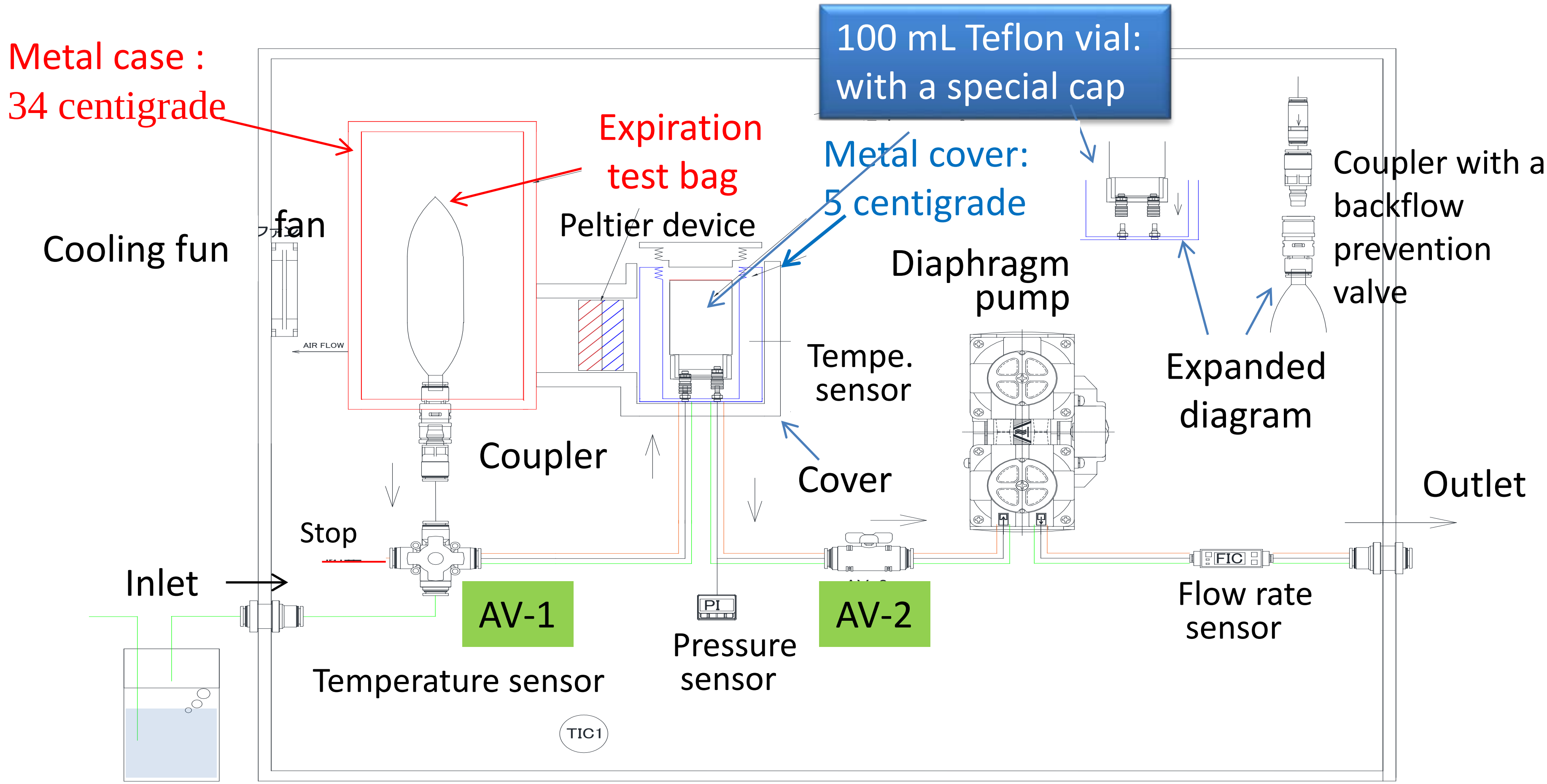
Two sockets



4. 3mm PS-pellets

Inside of sample changer box of LSC-LB7: max 20 vials are available

A design for testing expiration

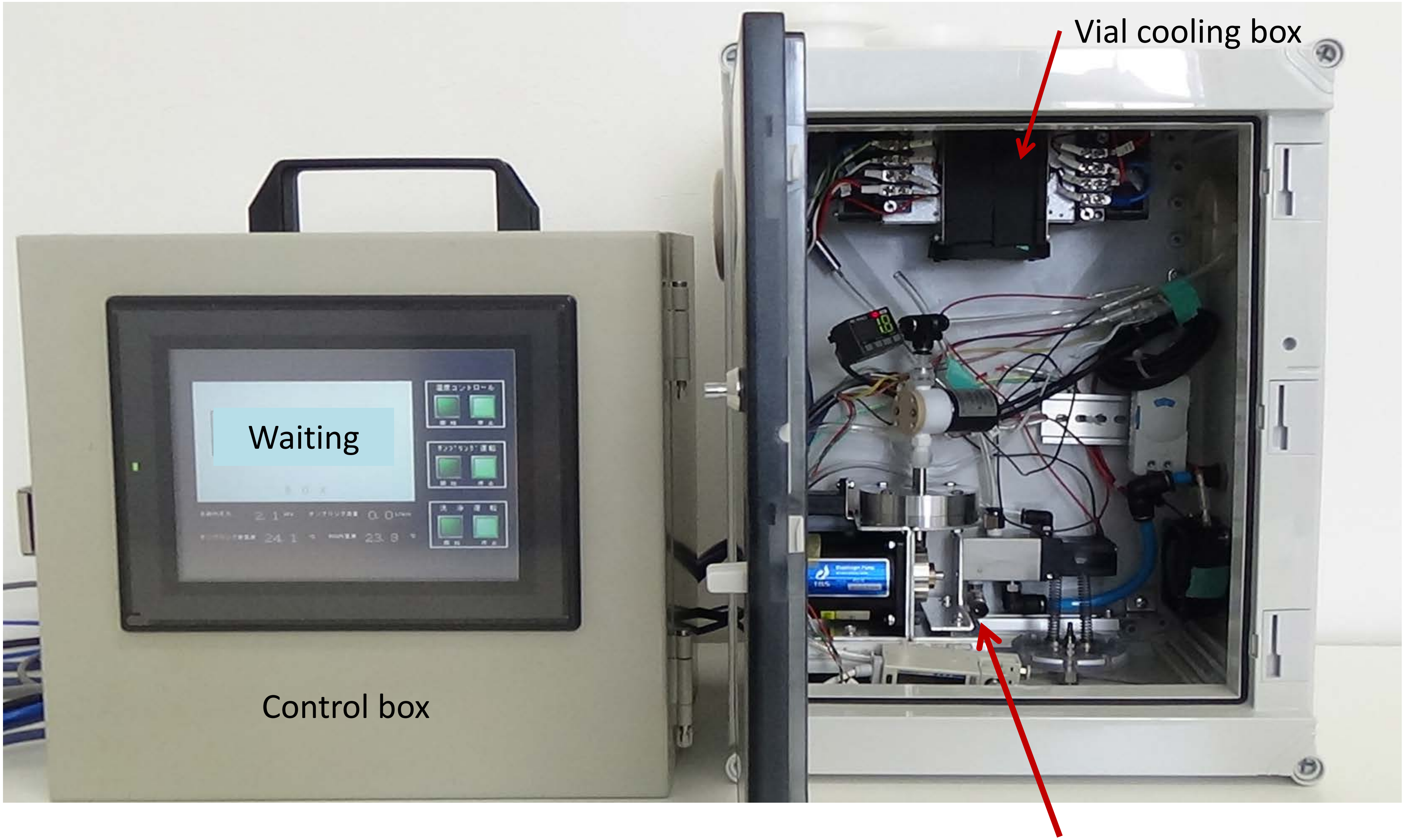


Bottle of a
pure water
⇒ vapor
for cleaning

In a 5L expiration, the water is included 0.154 mg in an average, and the efficiency to recover HTO at 5 centigrade is 82%.

Calculated from the saturated pressure at each temperature.

Photos of a prototype apparatus



Photos of parts of the apparatus

Top of the apparatus: the Teflon vial insert port

Side of the apparatus: a cleaning vapor bottle

Pressure gas for the motor-connection-change operation

For radiation measurement with LSC-LB7

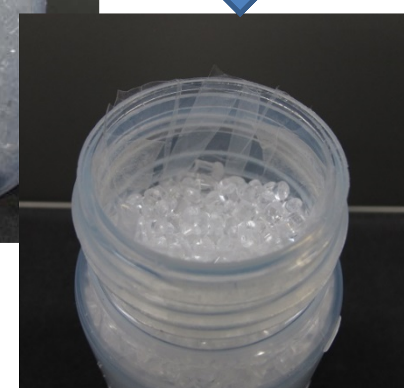
Preparation of vial with an inner bag

20 mL Glass

Normal vials for LSC-LB7

LSC-LB7 measurement

Special cap with 2 sockets



Polyethylene bags (75 mm × 150 mm × 0.3 mm), a Teflon vial with a special cap and plastic scintillator pellets

Results

Counting efficiency of HTO with PS-pellets and LSC-LB7

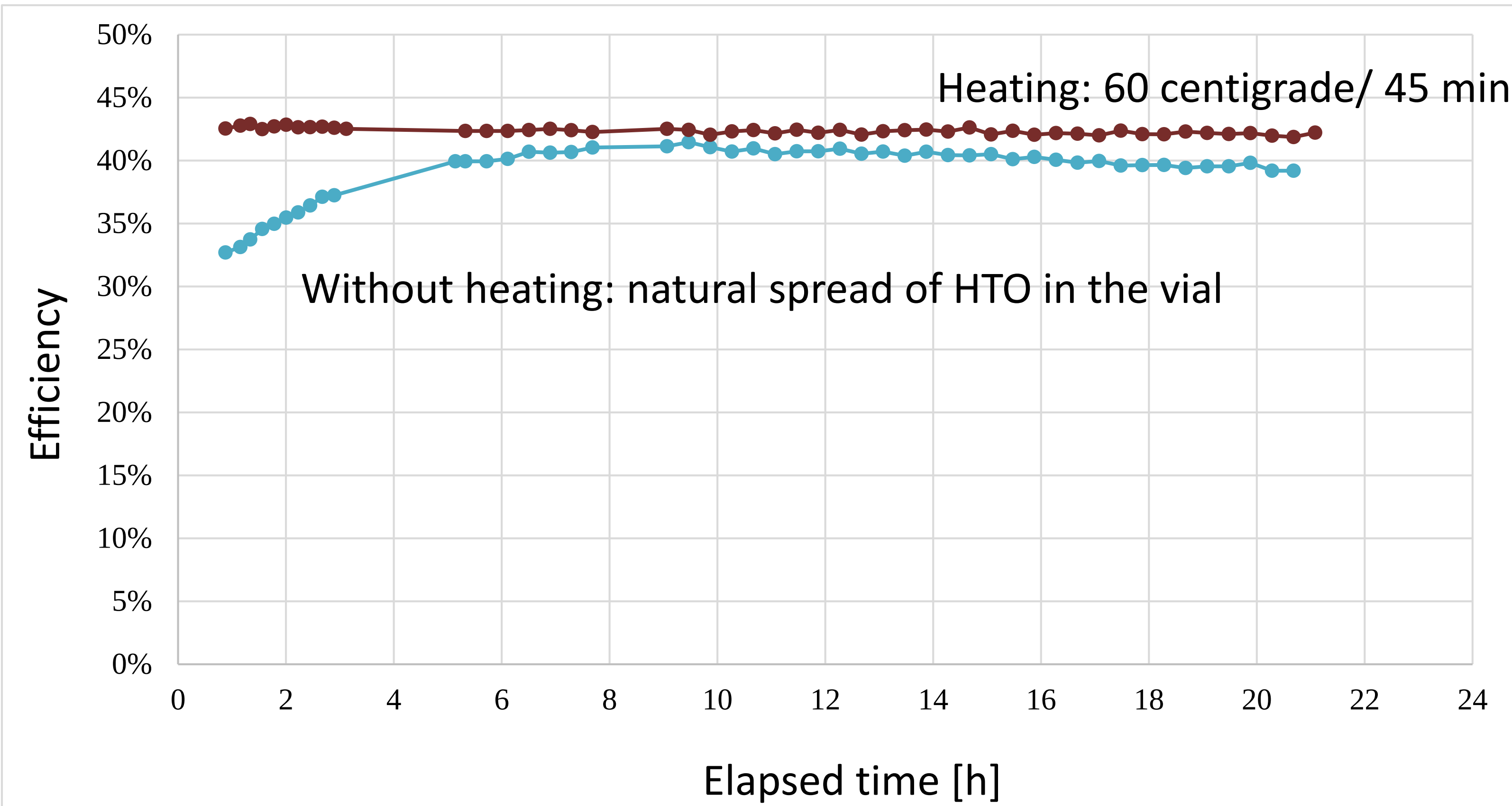
Eff%=cpm/dpm × 100

HTO volume	LS	a normal cap	Special cap with 2 sockets: preliminary reduction	Special cap with 2 sockets: reduction of pressure
5 μL	Approx. 39%		44.89 ±0.82	69.00 ±3.34
25 μL			44.37± 0.32	62.48 ±0.76
50 μL		46.42 ± 0.90	43.80 ±0.42	38.91 ±0.51
100 μL			37.11 ± 0.28	32.35 ± 0.55
500 μL			20.28± 0.43	10.08± 0.24
1 mL		5.79± 0.020	11.08± 0.12	5.88± 0.082
3 mL		2.34± 0.083	3.74± 0.044	1.87 ± 0.031
5 mL			1.26 ± 0.020	1.71 ± 0.027
7 mL			0.96 ± 0.0056	1.66± 0.010
10 mL			0.64 ± 0.011	0.64 ± 0.0061
full*		0.18±0.0047	-	-
ave. pellets weight (g)		117	in a polyethylene bag: 72.5	

At reduction: 5 sec passed, a handy manometer (Copal PG-100-102RP) indicated -99 kPa.

By the PS-pellets method

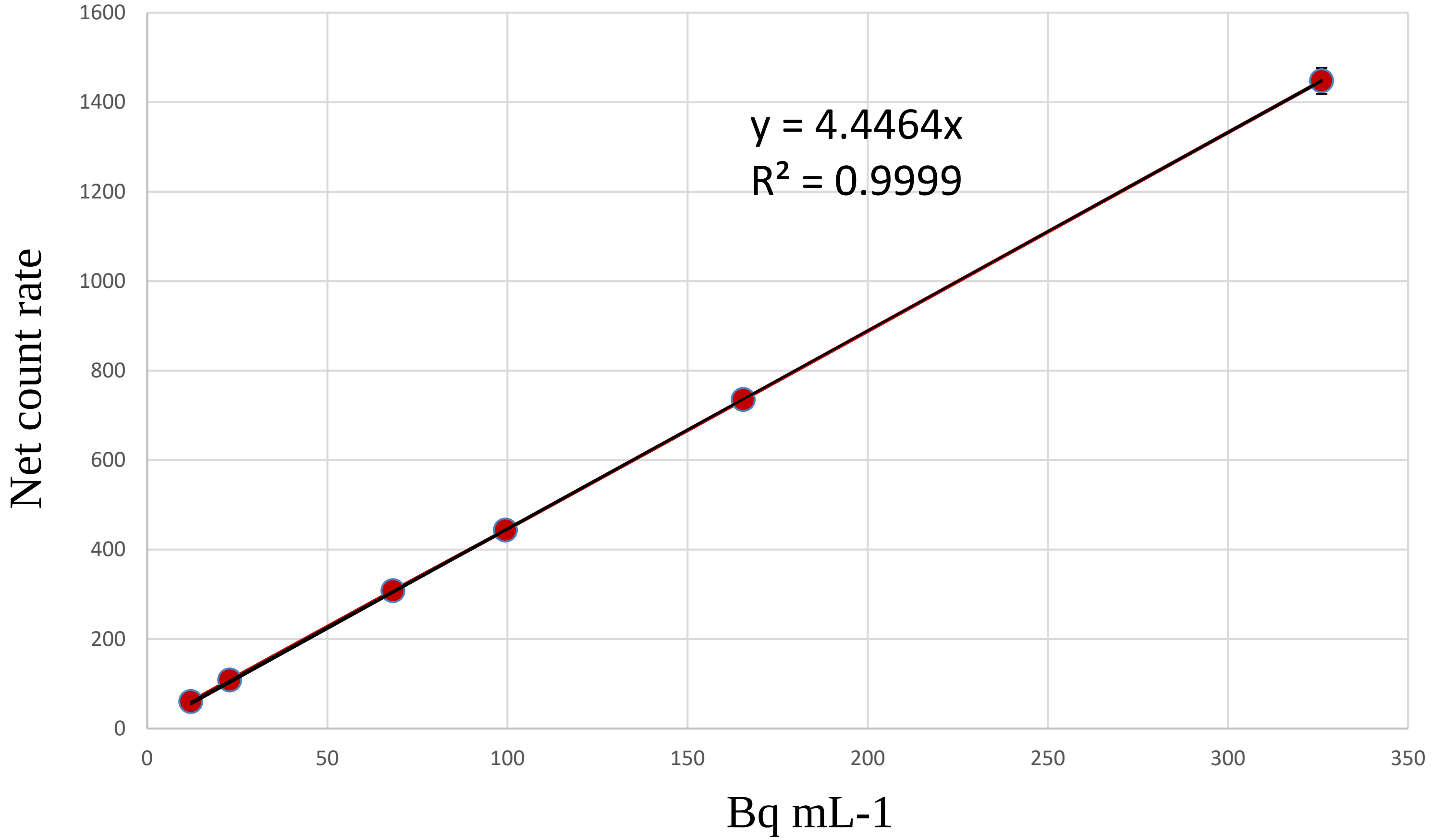
Heating effect



Tritiated water: 5 µL with a normal cap

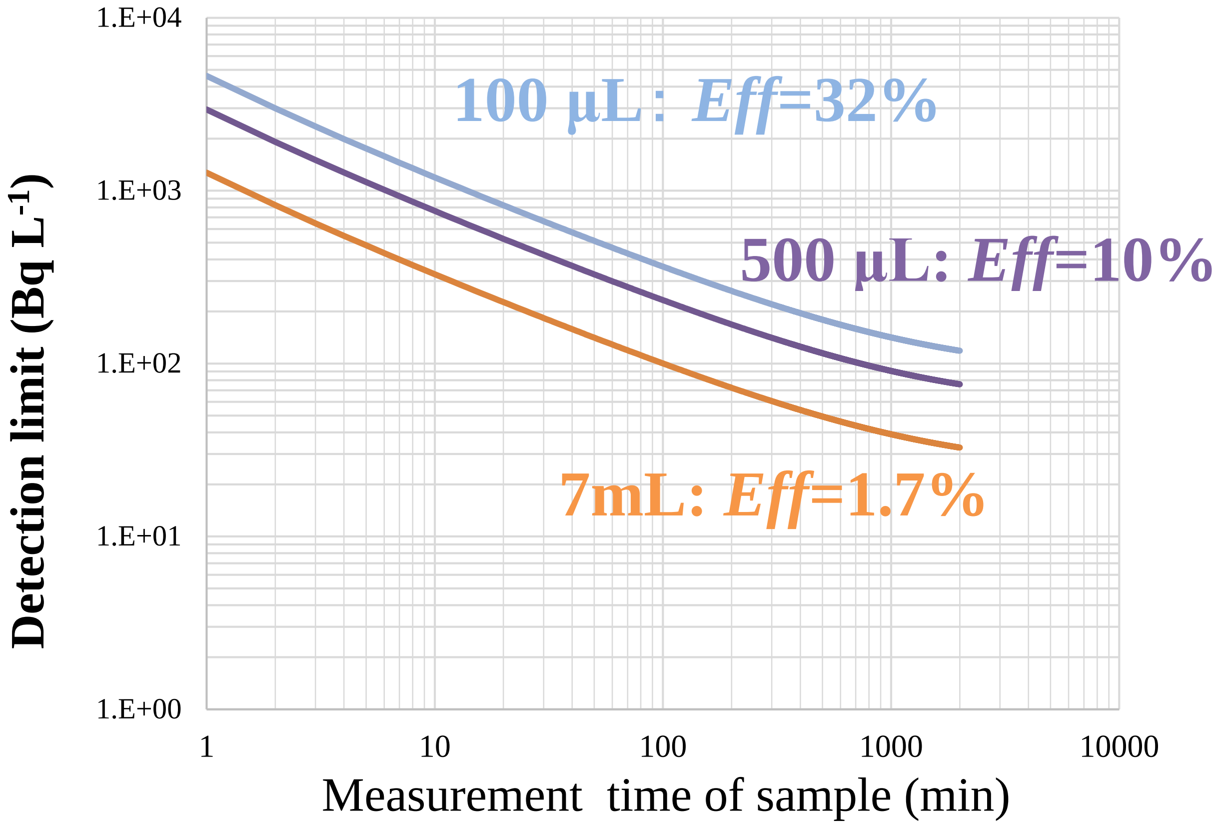
Linearity of the PS-pellets method

Quantitative analysis



By the PS-pellets method

Detection limit



Detection limit of HTO with PS-pellets in 100 mL Teflon vial

$$n_D = \frac{k^2}{2}\left[\frac{1}{t_S} + \sqrt{\frac{1}{{t_S}^2} + \frac{4n_B}{k^2}\left(\frac{1}{t_S} + \frac{1}{t_B}\right)}\right]$$

$$A_D = \frac{n_D}{\alpha \cdot \epsilon}$$

k=2, t_B=1440 min
n_B=10.75 cpm

Parameters to assess HTO in drinking water

WHO guidance level	**10,000 Bq/L**
Canada	7,000 Bq/L
The COUNCIL DIRECTIVE of EURATOM	**100 Bq/L**

Summery

Merits of this expiration apparatus

- Using the PS-pellets for the apparatus, the detection limit is enough to measure HTO included in expiration.
- There are no organic waste generated with measurement .
- Use of smaller amounts of the PS-pellets is possible when a inner bag for a vial is used, even when the PS-pellets are reusable.
- Because expiration of workers is stocked in each test bags, workers do not have to line up in the row and to wait for a long time for safety check of their expiration.
- Estimation of internal exposure is calculated with activities in expiration. This apparatus is useful for individual safety management of workers treating radioactive materials.

The next step

We started to study factors as follows:

1. To measure actual expiration added HTO to use a prototype apparatus.
2. To check the cleaning system is enough or not
3. A vial of LSC needs resistant for liquid scintillator; however, the Teflon vial is expensive. For PS-pellets use, it is able to change a cheaper one, for example a PET vial.

Thank you for your attention!!

Factors

1) 34°C from a expiration test bag to vial for collection expiration
2) PS-pellets in the vial is 5°C
3) The amounts of saturated water at 34[°C]: 0.0376[g/L]

In 5L expiration: 5[L] x 0.0376[g/L] = 0.188[g]

4) Also at 5[°C]:0.0068[g/L]

In 5L expiration: 5[L] x 0.0068[g/L] = 0.034[g]

Collectable water : 0.188[g]- 0.034[g] =0.154[g]