Tritium- Control Technologies for TMSR in CAS

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2015-10-28

TMSR 钍基熔盐核能系统

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Outline

I. **Background**

II. **Roadmap** of Tritium-control technologies for TMSR in CAS

III. **Performances** at the tritium-control technologies for TMSR in CAS

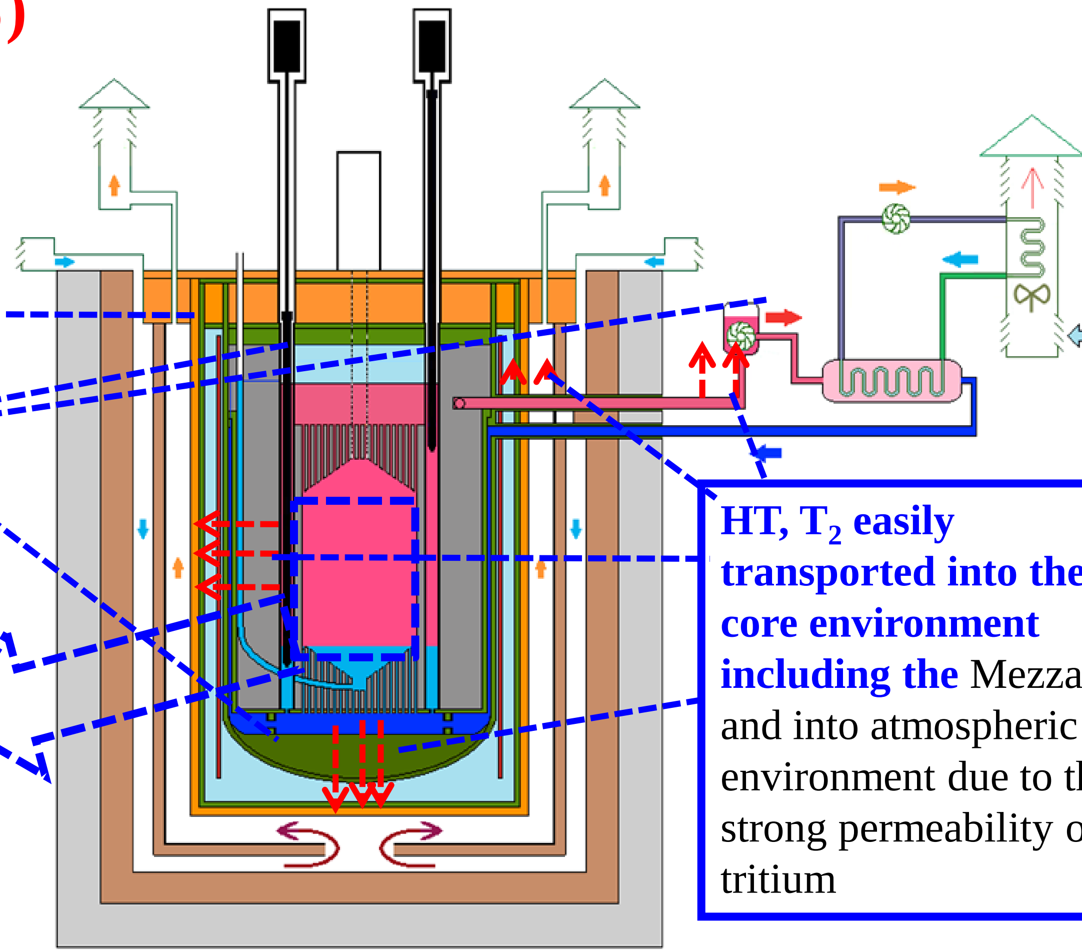
IV. **Summary**

I. Background

1. Tritium production in TMSR (FLiBe as primary coolant, ^{7}Li abundance: 99.99%)

Mezzanine of reactor core

Cover gas（Ar/He）



Main Gaseous radioactive Nuclides

① T (HT, T_2, TF)

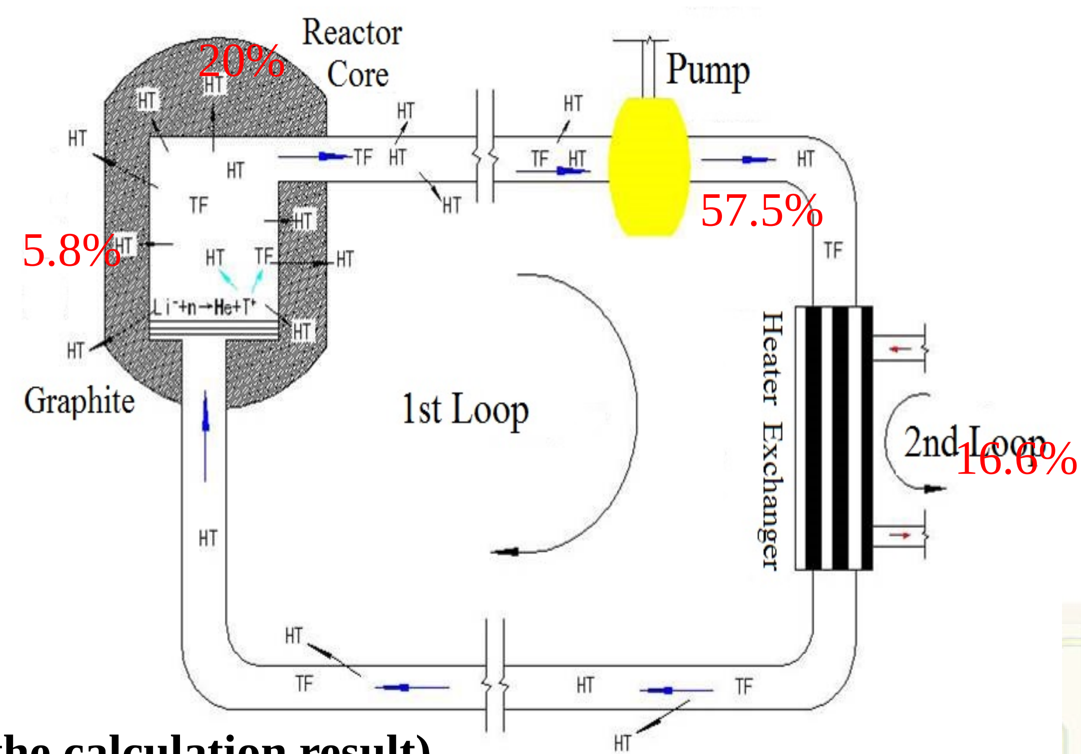
② Inert gas (Kr, Xe

HT, T_2 easily transported into the core environment including the Mezzanine, and into atmospheric environment due to the strong permeability of tritium

2. Distribution of Tritium in TMSR

Tritium distribution in TMSR-SF1

Position	%	Bq/a*
Core	20 (Cited from MSRE)	5.5E14
Graphite		
Mezzanine	5.8	1.6E14
1st Loop	57.5	1.6E15
2nd Loop	16.6(Cited from MSRE)	4.6E14
Total	100	2.8E15



* $10MW_{th}$, ^{7}Li99.99%, 300-days run (**the calculation result**)

Emission limit of tritium in 3000MW nuclear power station in China:1.5E13Bq/a (LWR), 4.5E14 Bq/a (HLR)

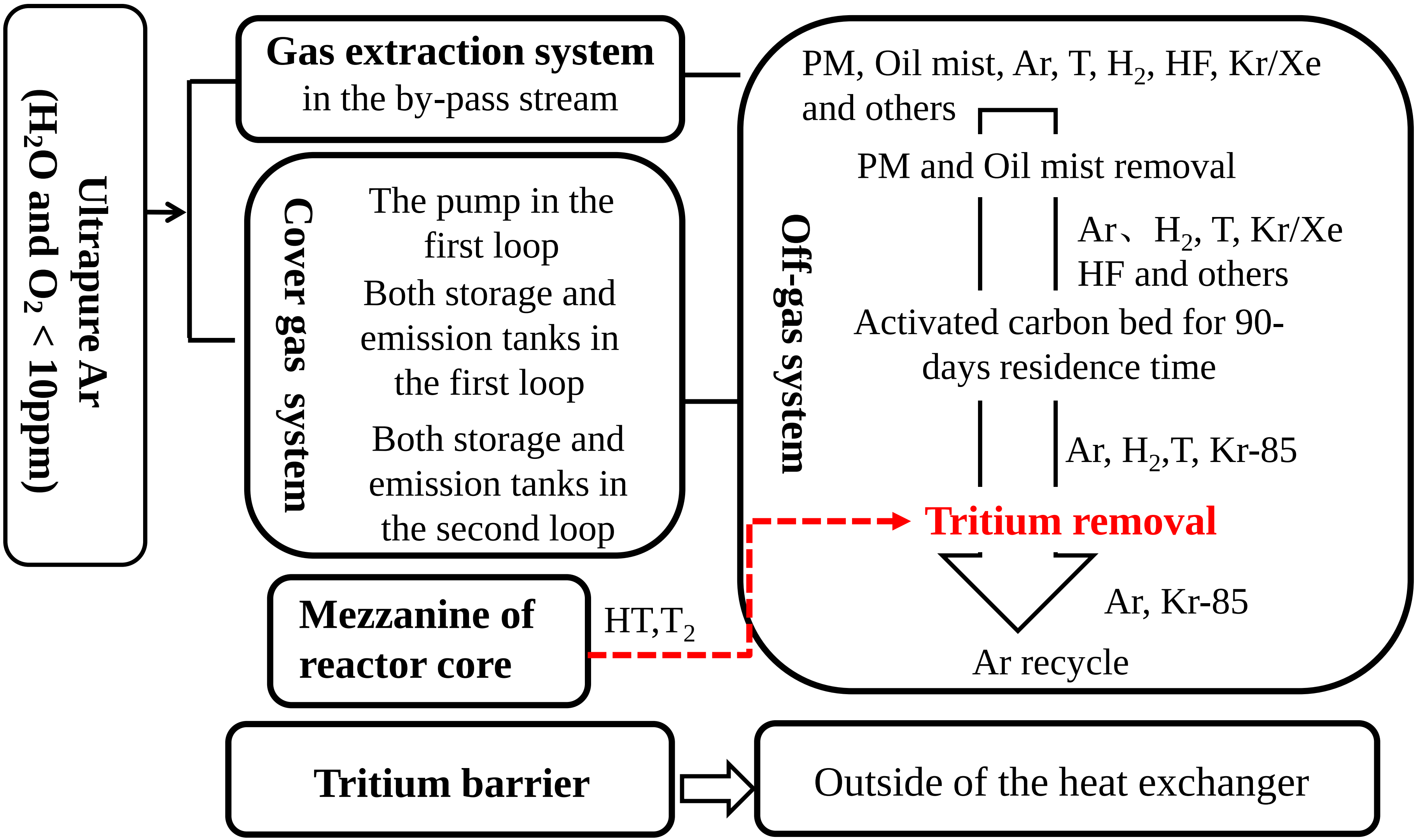
Does tritium transport into the cover gas completely? What is the chemical form of tritium?

Tritium removal: necessary and difficult

3. Considerations of Tritium control for TMSR

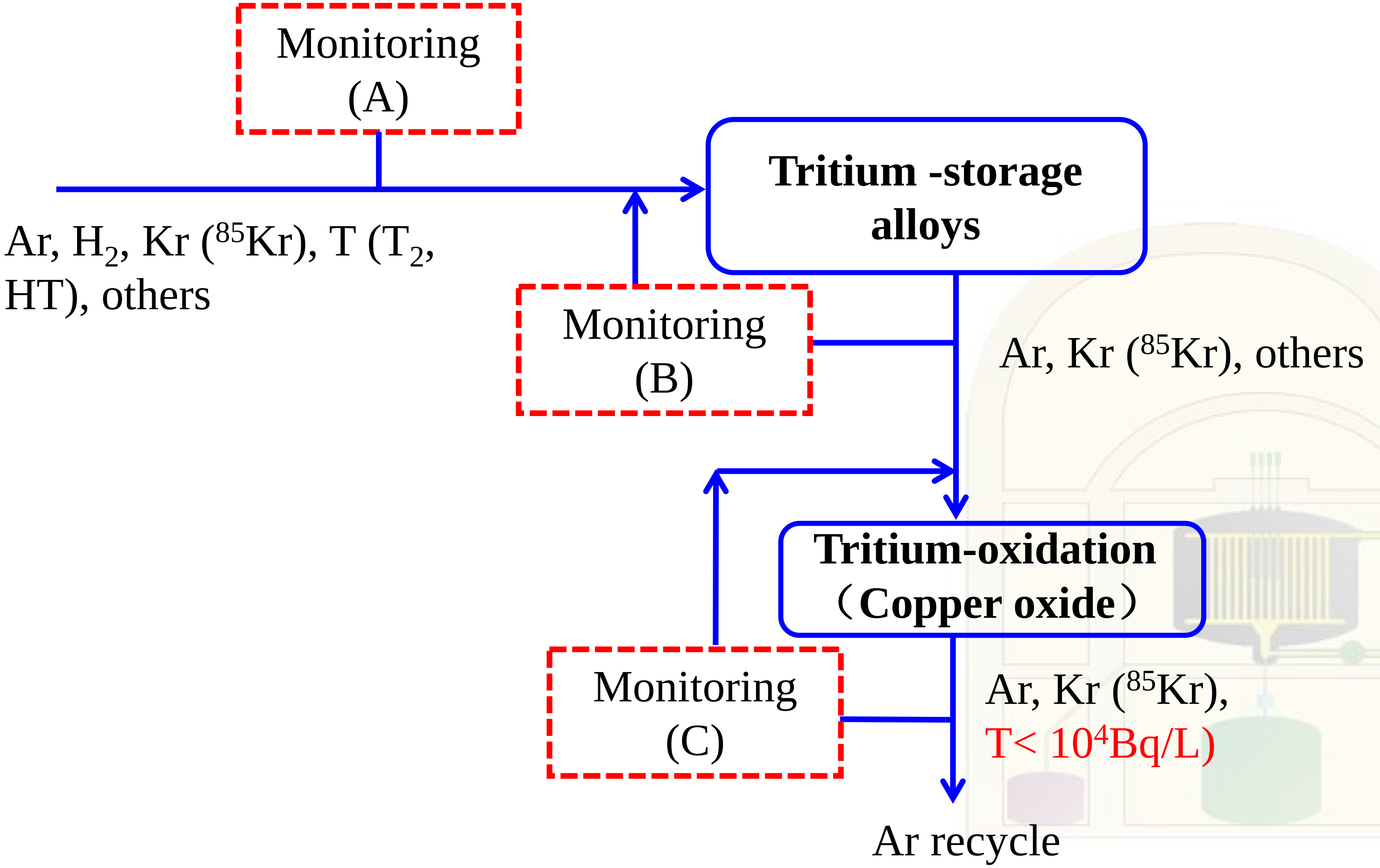
Remove tritium in the first loop as much as possible

Prevent tritium permeation into the second loop as much as possible



Tritium removal

Combination of **tritium -storage alloys** and **tritium-oxidation** with the **on-line tritium monitoring**



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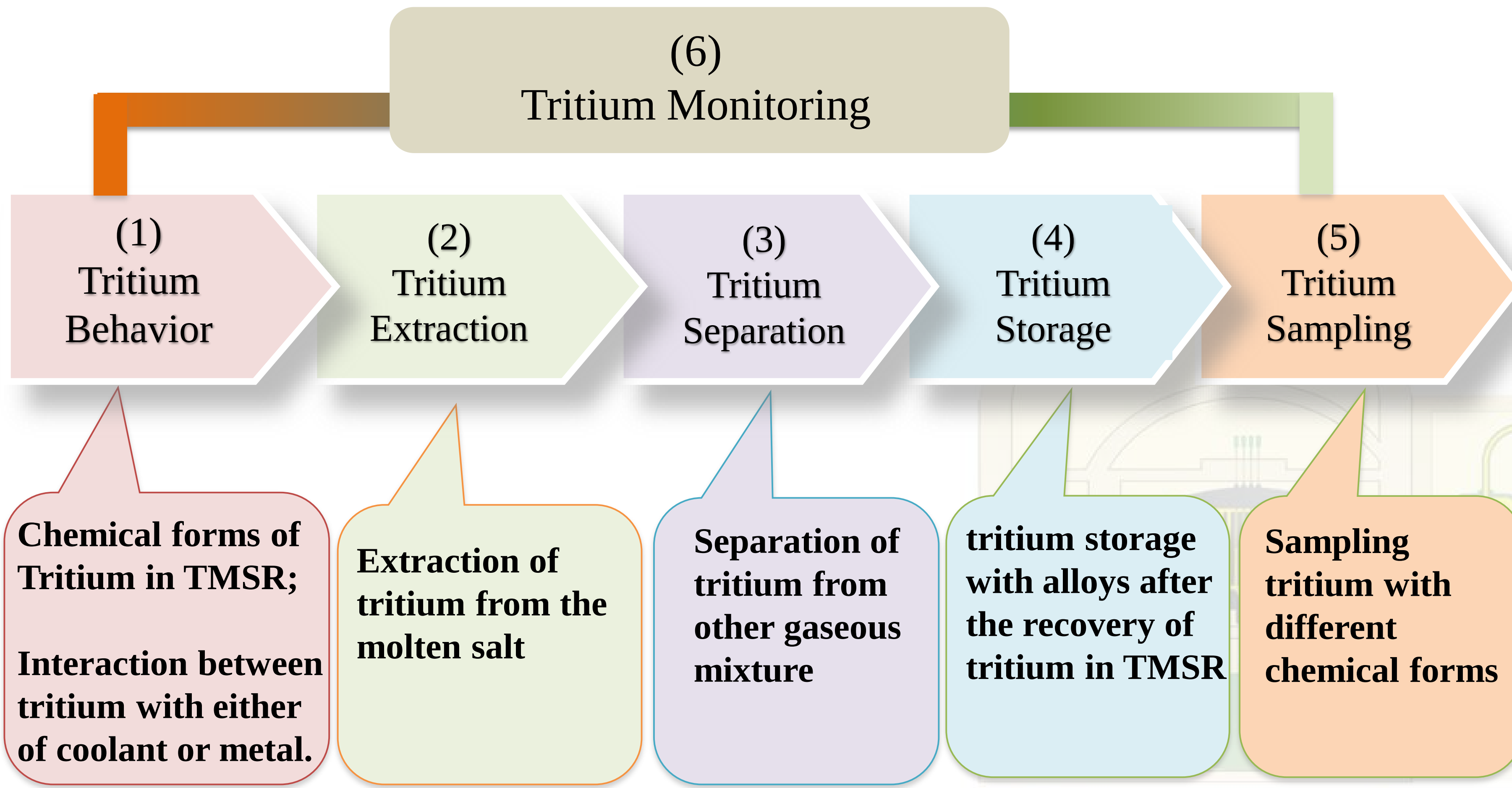
II. The Roadmap of tritium-control technologies for TMSR in CAS



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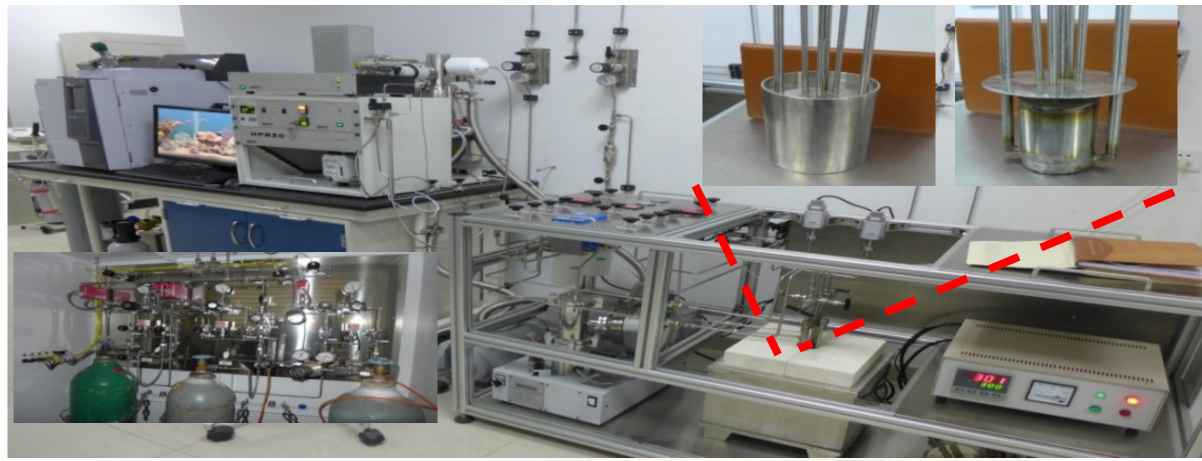
1. Tritium behavior

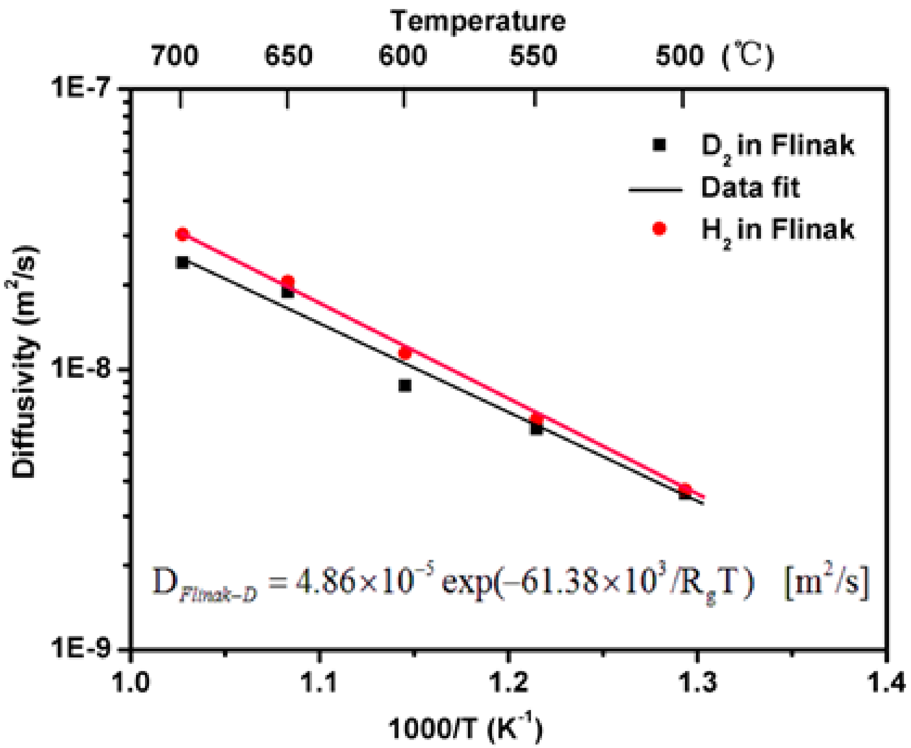
Interaction of hydrogen isotopes with either of high-temperature molten salt or structural materials

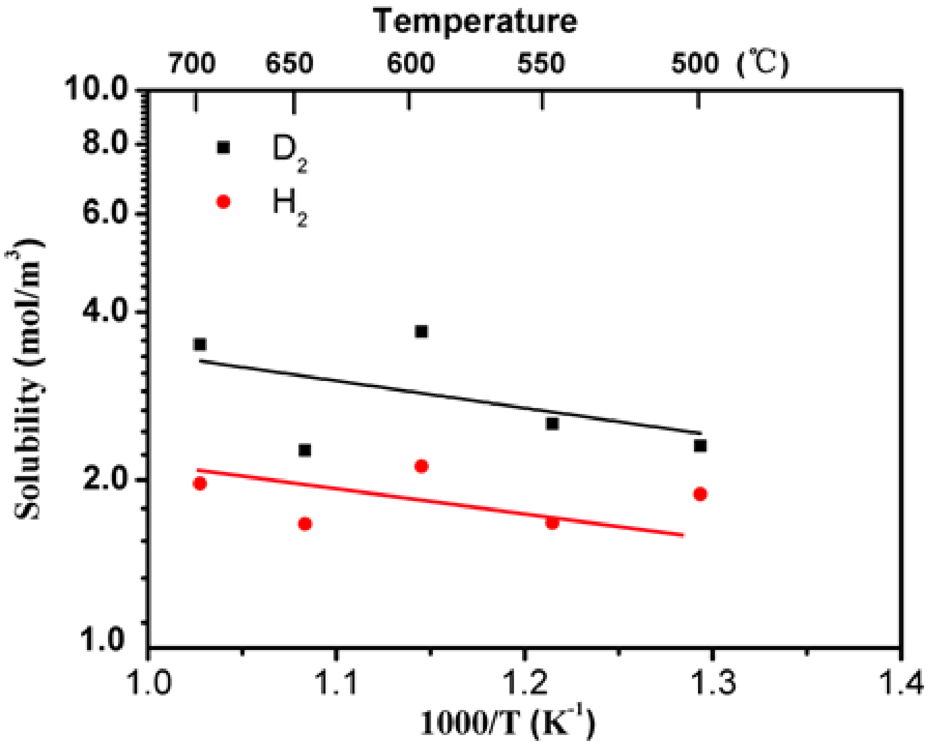
- Test apparatus for diffusion of hydrogen isotopes **in high-temperature molten salt**



- Test apparatus for permeation of hydrogen isotopes **in structural materials**

➢ Diffusion of Hydrogen isotopes (H_2, D_2) in high-temperature FLiNaK

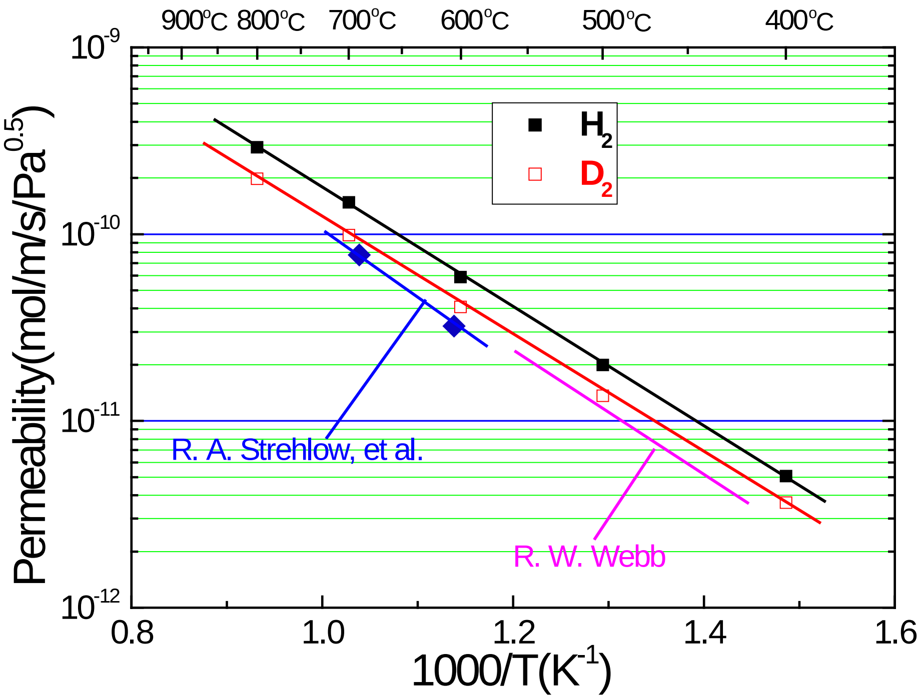


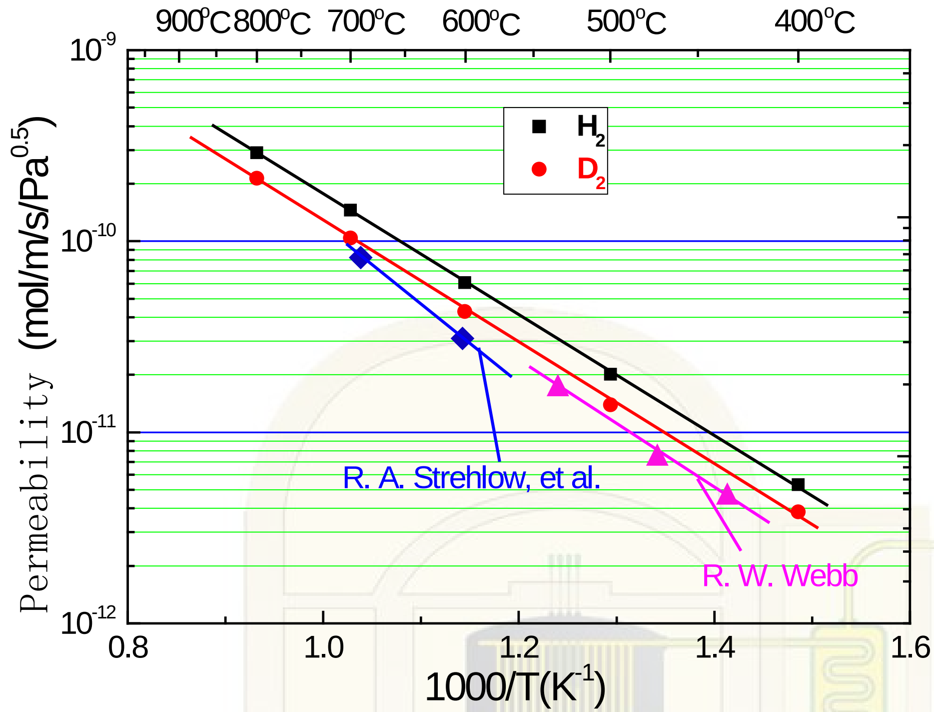


Little difference of diffusion coefficient between Deuterium and hydrogen in FLiNaK

Much more solubility of deuterium than hydrogen in FLiNaK at 500-700°C

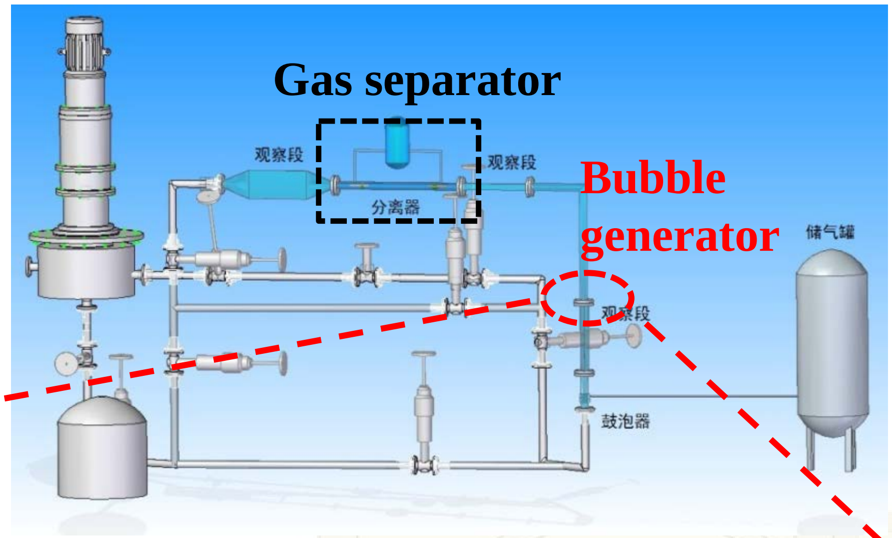
➢ Permeability of hydrogen isotopes in Hastelloy N (left) and GH 3535 (right) alloy

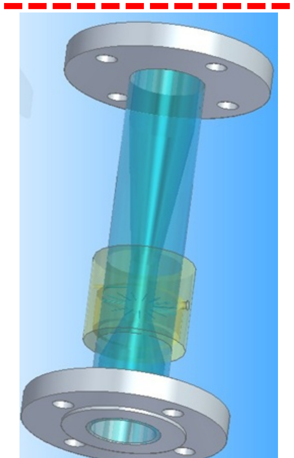


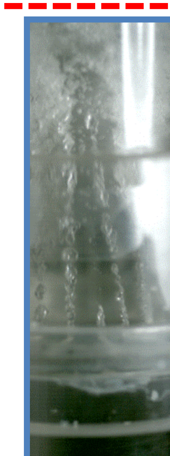


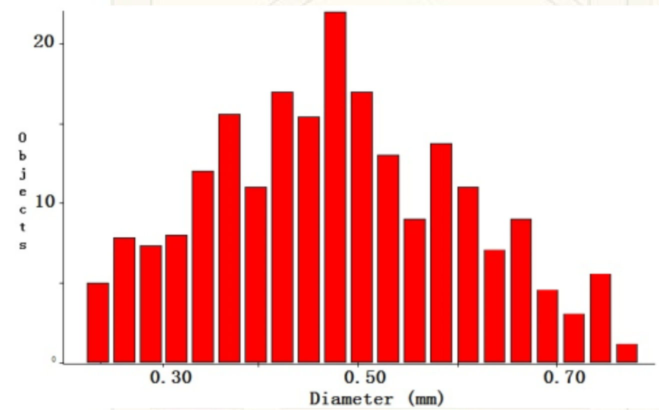
2. Tritium Extraction

Set up gas extraction system in water test loop and the separation efficiency was qualitatively analyzed









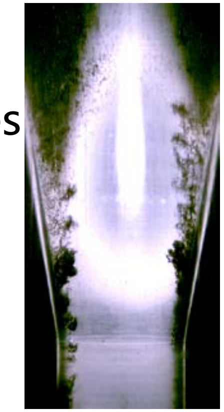
Average bubble diameter： 0.55mm

Bubble generator

1 hole

2 holes

4 holes



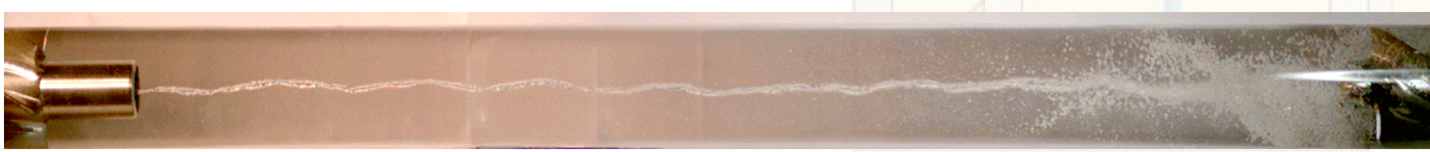
Little effect of number of holes on the bubble size distribution at the flow rate greater than 15 m^3/h,

Gas separator

Negative Press 0.009MPa

Balance 0.012MPa

Positive Press 0.030MPa

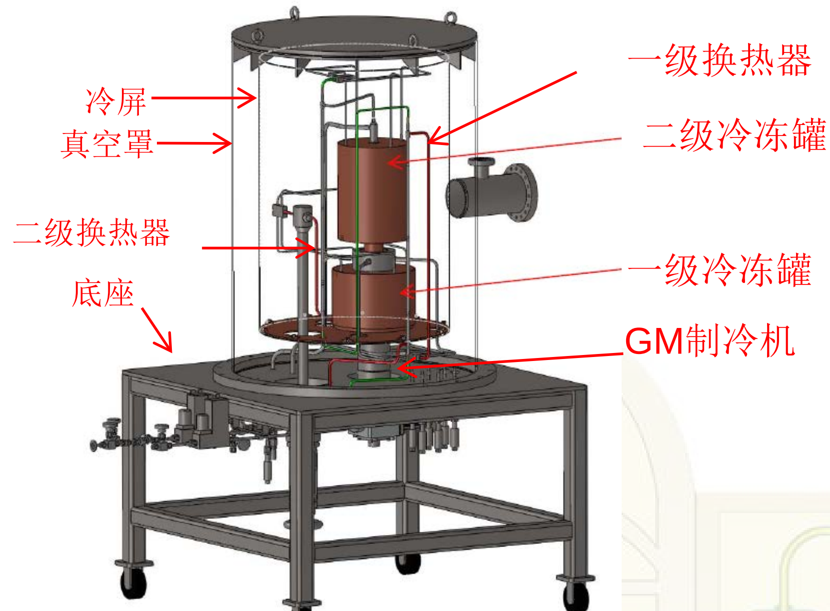


Separation efficiency of separator relating with the outlet pressure

3. Tritium Separation

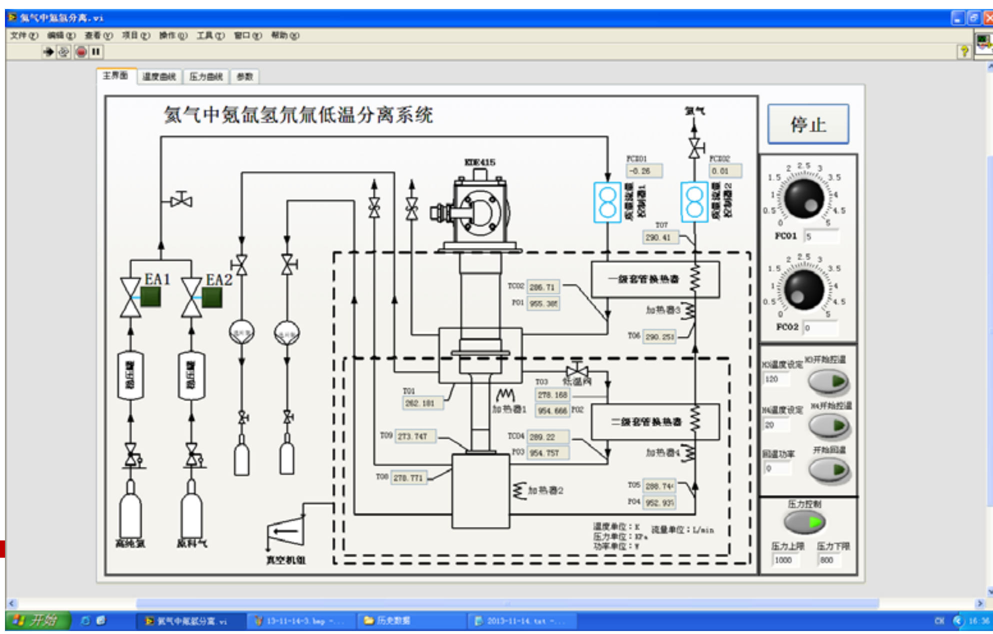
Successful separating xenon, krypton and hydrogen from helium environment using cryogenic technology for tritium separation

Kr、Xe <1PPb and H_2<0.1PPM after two-step frozen



Labview interface

(In-site monitoring 9-way temperature and 4-way pressure pressures as well as data acquisition)



examination of gaseous leak

Detection of temperature and pressure

4. Tritium Storage

Complete research platform for tritium storage using alloy

Testing system for selecting tritium-storage material

(Low pressure)

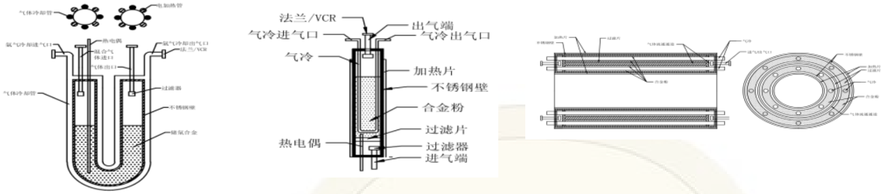
Pressure range：
0.1Pa-50KPa

(High Pressure)

Pressure range：
20KPa-10MPa

Testing system of tritium-reservoir performance

Tritium reservoir



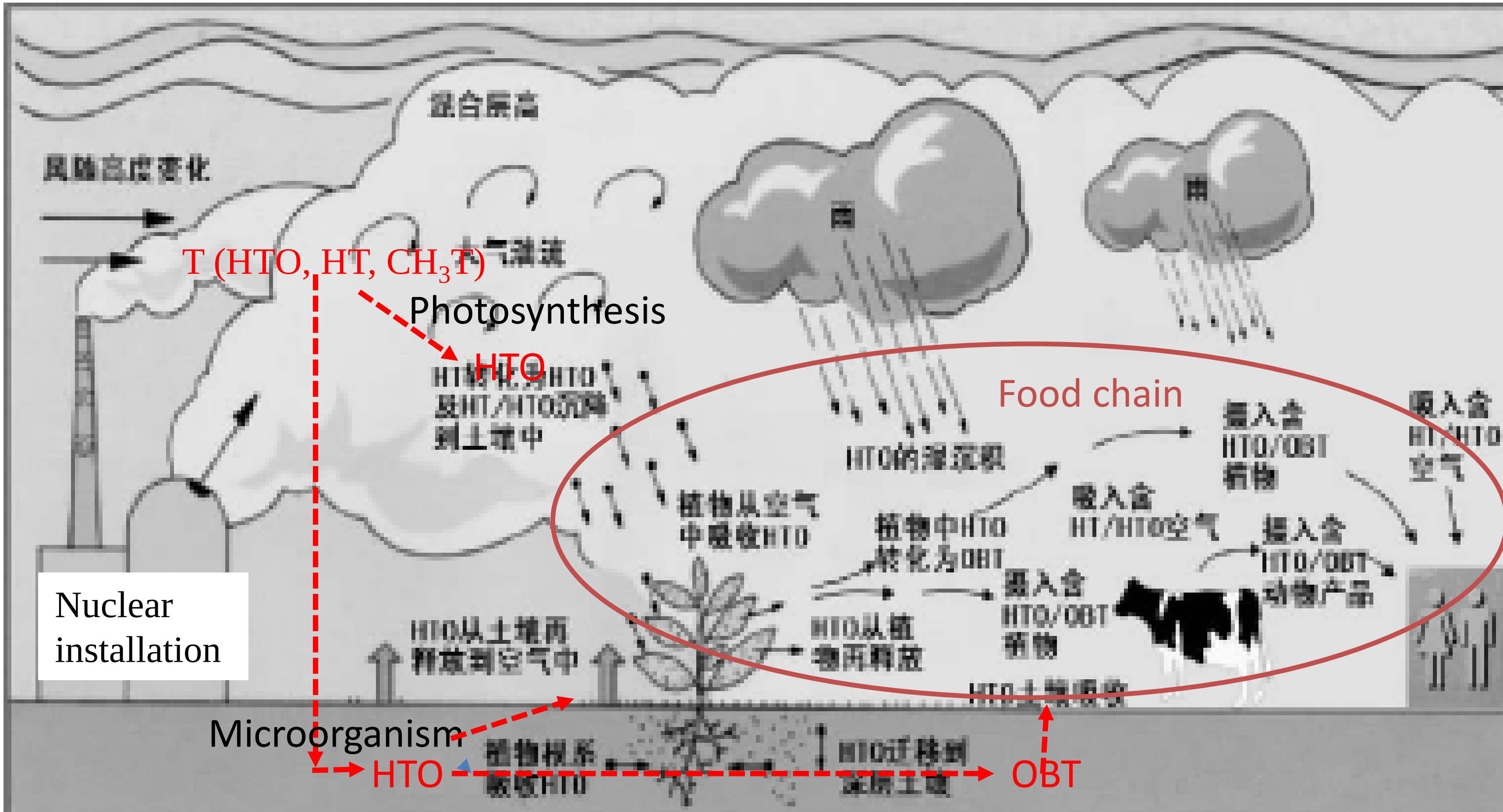
tritium-reservoir performance **Control**

Gas distribution

Detection

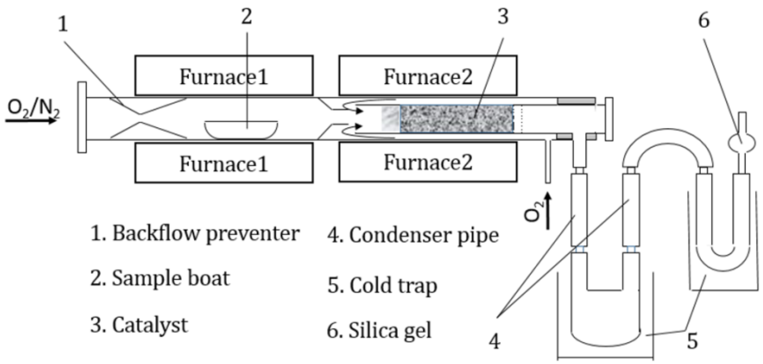
5. Tritium Sampling

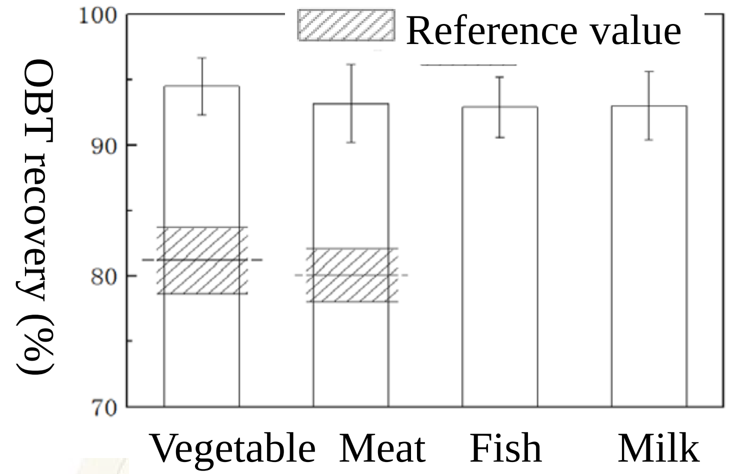
Tritium transport in environment

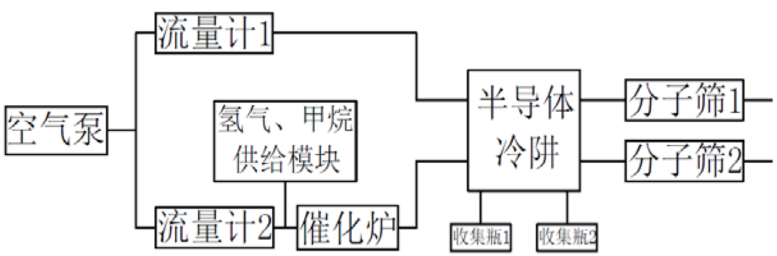


Sampling tritium (HTO, HT, CH3T, OBT): Necessary

Successful development of OBT-oxidation collection and tritium sampler







Sampling HTO, HT and CH_3T simultaneously;
Collecting efficiency >95%

6. Tritium Monitoring

➢ Off-line Measurement

Tritium measurement platform (Detected limit of HTO< 0.5Bq/L)

Sampling ⇒ **Pretreatment** ⇒ **Measurement**

OBT collection

Tritium sampler

Distillation

Electrolytic enrichment

LSC

➢ Online monitoring

On line monitoring of HTO, HT and Kr, Xe, simultaneously ;

HT,HTO： 1-10^7μCi/m^3

Kr and Xe: 1-10^6μCi/m^3

Other studies

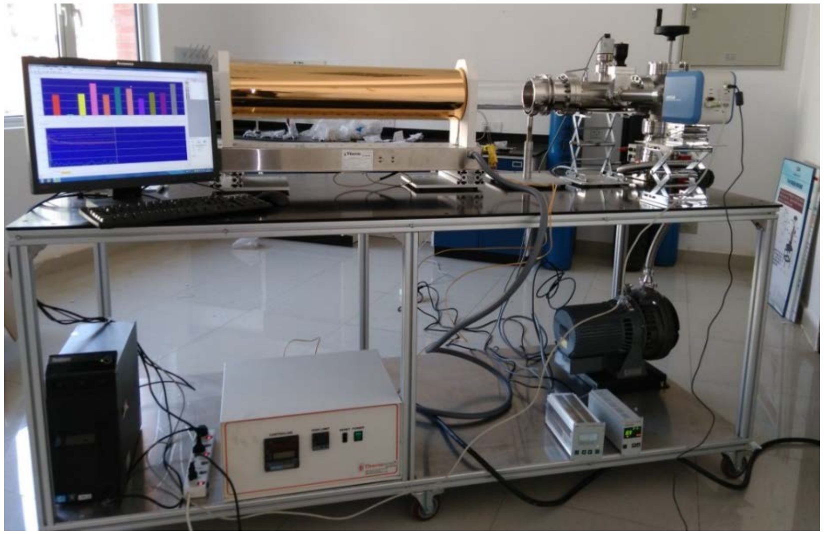
Tritium barrier

Selection of tritium barrier

Barrier	Base Metal	PRF*
Al_2O_3	SS316, MANET, TZM, Ni, Hastalloy-X	10 to >10,000
TiC, TiN, TiO_2	SS316, MANET, TZM, Ti	3 to >10,000
Cr_2O_3	SS316	10 to 100
Si	Steels	10
BN	304SS	100
N	Fe	10 to 20
Er_2O_3	Steels	40 to 700

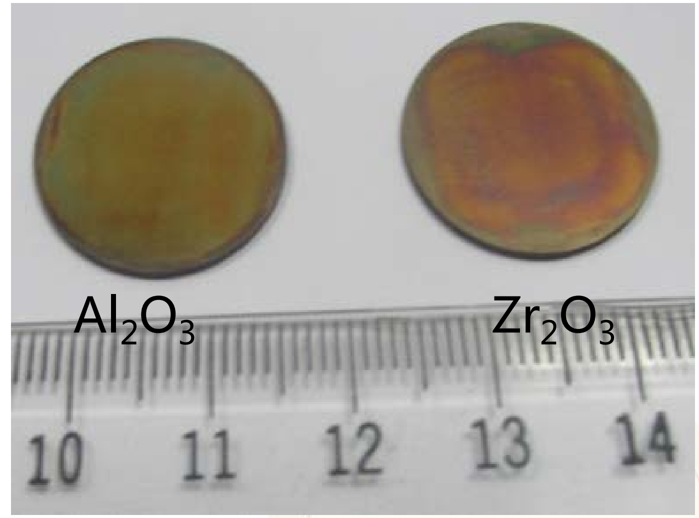
*permeation reduction factor

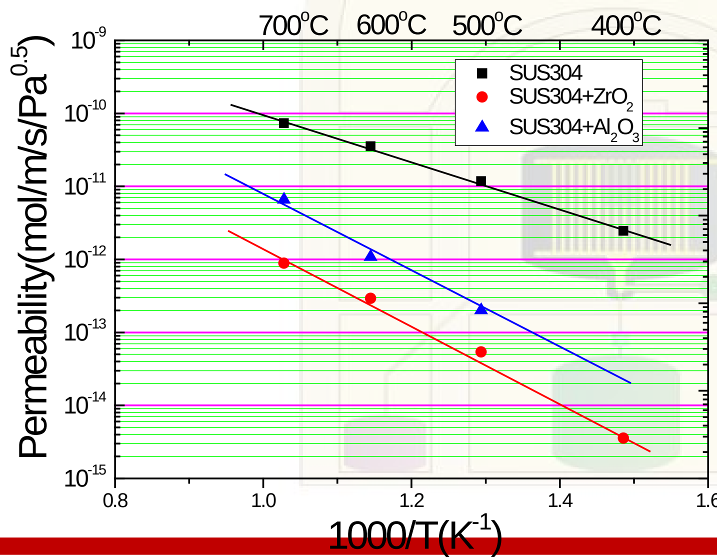
Experimental results of tritium barrier



Fabrication for tritium barrier by pack cementation

Measurement of FRF of tritium barrier





FRF
Al_2O_3: 200
ZrO_3:30

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1. Several test platforms for tritium control have been set up in CAS
2. Sampling and monitoring technologies have been mastered in CAS
3. Several experiments are conducting in CAS, those consist of interaction of hydrogen isotope with graphite, gas extraction in high-temperature molten salt loop
4. The chemical form of tritium in both irradiation high-temperature molten salt and graphite will be determined along with the cooperation between SINAP and MIT


Thanks for Your Attention