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TRITIUM SEPARATION TECHNOLOGY

by Gas Hydrate Method

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TRITIUM SEPARATION TECHNOLOGY by Gas Hydrate Method

INTRODUCTION & PROCESS

Gas hydrates are ice-like crystalline materials that form when low molecular weight gas (such as methane, ethane, or carbon dioxide) combines with water and freezes into a solid under low temperatures and moderate pressure conditions.

The gas hydrate method is different in such a way as to being able to remove pure water from solutions that contain unwanted substances rather than storing gas in a gas hydrate form. Additionally, we can treat water that contain ultra-low or high concentrations of unwanted substances. Also, we can treat large amounts of water, faster and cheaper than existing methods.

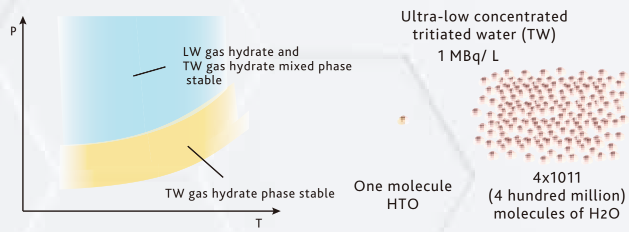
Applications of the new gas hydrate method:

1. Remove tritiated water from wastewater, ultra-low and high concentrations.
2. Purify seawater by removing H_2O.
3. Remove H_2O from nuclear wastewater.

Additionally, we can treat light water, heavy water, and tritiated water by using the same novel process.

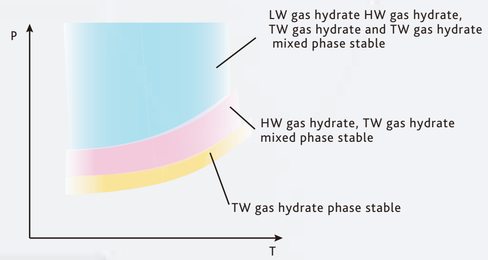
GAS HYDRATE-BASED DETRITIATION USING SOLID-LIQUID SEPARATION

The slight difference in the physicochemical properties of light water (LW) and tritiated water theoretically enable tritiated water (TW) to be removed from LW. In the temperature and pressure regions where only the gas hydrate phase of TW is stable, the reaction of LW containing TW to guest gas solidifies the TW only. The very small quantity precludes that separation method from being applied. However, at extremely low TW concentrations, the amount of gas hydrate to be separated is negligible and not amenable to industrial solid-liquid separation methods.



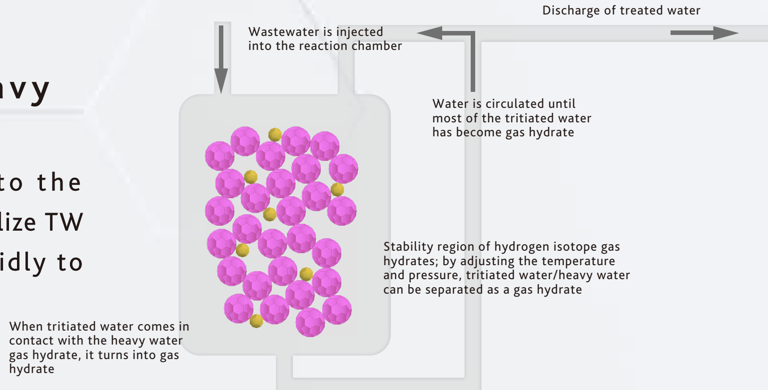
Addition of heavy water (HW) (as a co-precipitant)

Addition of a sufficient amount of heavy water (HW), which has physicochemical properties intermediate between those of LW and TW, allows tritiated water to be separated from LW as a gas hydrate mixed solid phase with HW. Reaction of the water to be traeted with a guest gas at temperatures and pressures where both TW and HW form gas hydrates results in the formation of a sufficient amount of gas hydrate solid phase.



Detritiation with pre-synthesized heavy water (HW) gas hydrate

The contact reaction of the LW containing TW onto the pre-synthesized HW gas hydrate enable efficiently to crystallize TW on the HW gas hydrate as well as continuously and rapidly to remove TW from the LW.



Factors Impacting Overall Cost

This tritiated water separation technology is especially important when dealing with low concentrations of tritium.

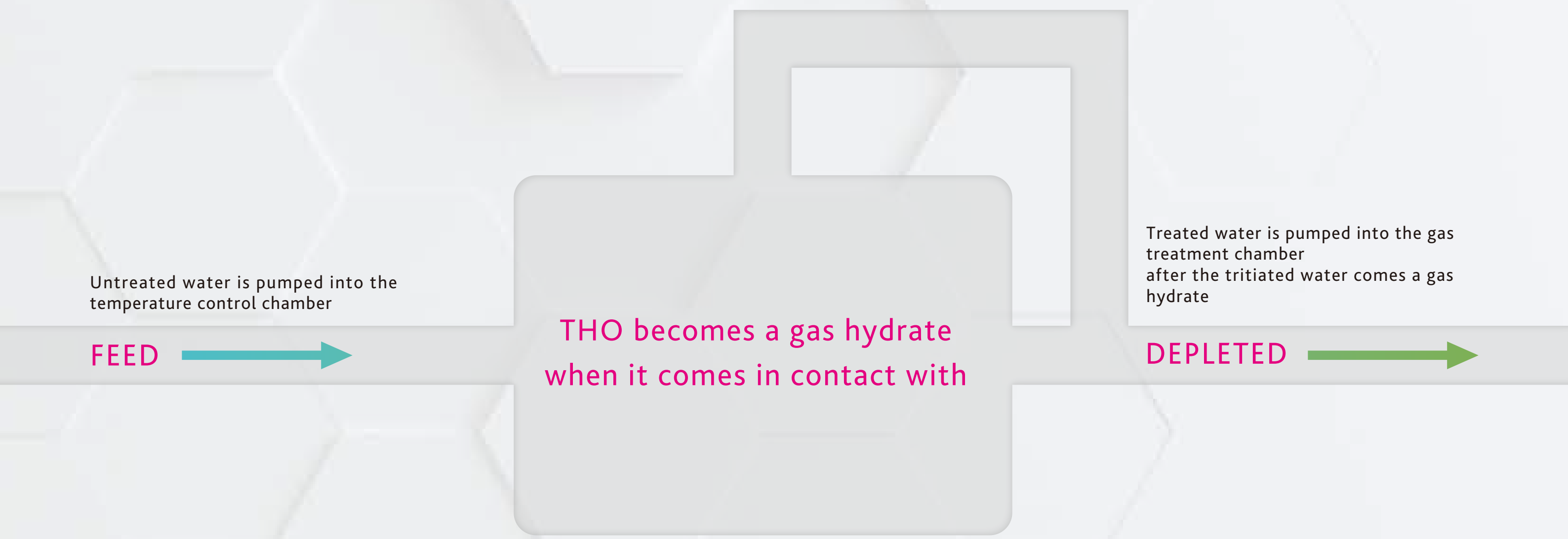
Traditional methods are not economically viable to use so this new method is cheaper and is great for handling low concentrations of tritium. This technology can be used for ultra-low concentration of tritium and large amount of tritiated water. For example, the treatment of wastewater at Fukushima NPP contains 2 Million Bq/L and will treat over 100 m3/day.

Energy cost is low because of the short cyclic process (processing time is approx. 60 minutes per cycle). Another factor that keeps the cost low are the temperature and pressure requirements. Ideally, the temperature should be approximately 20 °C with an atmospheric pressure around 1-2 MPa. The power consumption is approximately 100kWh/m3.

The processing capacity is 100 m3/day, the facility area is less than 1,000 m^2, and the height is less than 5 m.

Byproducts are not generated, and heavy water and gas can be recovered and reused.

Conceptual image of a cyclic process of tritiated water separation and accumulation



Experimental Data

Heavy water → **Generation of heavy water gas hydrate** → Heavy water (liquid phase)

↓

Tritiated water
Approx. 2,000,000 Bq/L → **First separation process** → Treated water after separation process
Approx. 2,000Bq/L

↓

Tritiated water
Approx. 2,000,000 Bq/L → **Second separation process** → Treated water after separation process
Approx. 1,500 Bq/L

↓

Wash water → **Liquification of gas hydrate**

↓

Tritiated water, heavy water, and wash water

The Future Application of Gas Hydrate Technology

Objective 1

CANDU reactors

Treatment of light/heavy water from the reactor pressure vessel and the primary cooling system

Benefits:

(1) Cost reduction (OPEX & CAPEX)

(2) Recovery and reuse of valuable substances (tritium)

(3) Supports environmental conservation

Objective 2

Reprocessing facilities

Removal & recovery of large amounts of tritiated water found in steam condensate after acid recovery process

Benefits:

(1) Cost reduction (OPEX & CAPEX)

(2) Promotion of environmental conservation

(3) Recovery and reuse of valuable substances (tritium)

Objective 3

Contaminated water from radioactive incidents or nuclear tests

Remove tritiated water and other radionuclides from contaminated water (including groundwater) derived from radioactive incidents or nuclear tests.

Benefits:

(1) Prevent pollution of rivers and oceans

(2) Prevent radioactive hazards to human and animal health

(3) Prevent destruction of the Earth' s ecosystem

Objective 4

Nuclear Fusion Reactors

Recovery of tritium in tritiated water to be used as fuel in nuclear fusion reactors

Benefits:

(1) Cost reduction (OPEX & CAPEX)

(2) Utilization of tritium fuel; tritium concentrations as low as 50,000 Bq/kg can be recovered

Outline of Objective 1:
CANDU Reactors Compared to Gas Hydrate Technology

Below are two tritiated water removal facilities

Darlington, Canada: maximum treatment is 8.6 m3/day (8.9×1017 Bq/y) / uses gas phase isotope exchange (electrolysis) + hydrogen distillation

Wolsong, Korea: maximum treatment is 2.1 m3/day (2.6 x 1017 Bq/y) / uses liquid phase isotope exchange (electrolysis) + hydrogen distillation

Heavy water containing excess tritiated water (or degraded heavy water) → Preprocessing (impurity removal) → Concentration and gasification of heavy water and tritiated water → Recovery of high-purity heavy water → Tritium gas recovery and storage

Combined Electrolysis Catalytic Exchange (CECE) Process (liquid-phase isotope exchange method + electrolysis) | Hydrogen Distillation

Challenges are high cost, and the CECE process has only a proven track record of small volume processing

*** As the wastewater is treated in a liquid state, the heavy water can be returned directly to the reactor after tritiated water removal is complete.**

*** It can be applied to remove tritiated water from the primary cooling water of light water reactors if necessary.**

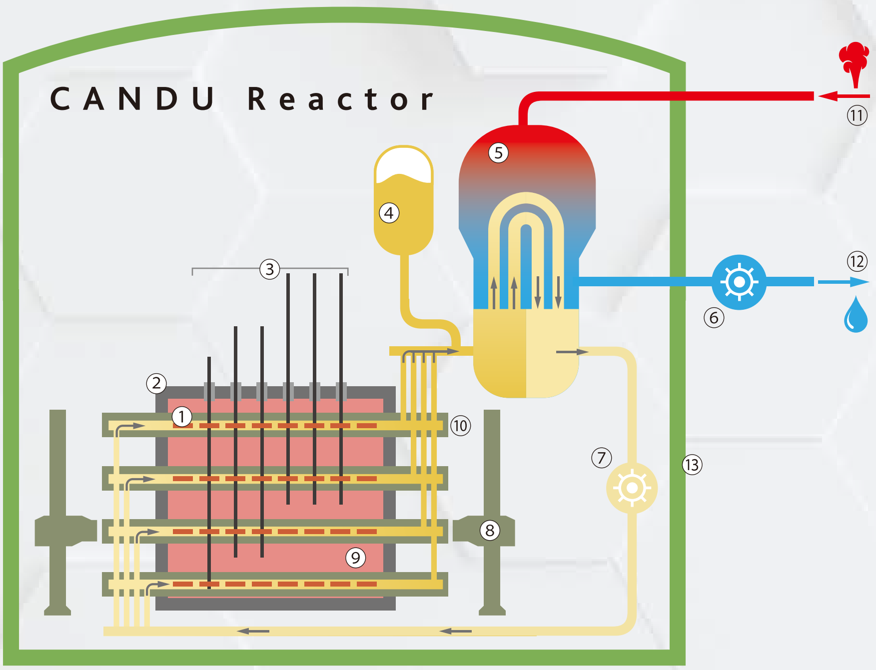
Applying Gas Hydrate Method to CANDU reactors: Gas Hydrate Method | Gas Hydrate Method | Electrolysis | Hydrogen Distillation

Using gas hydrate, the heavy water can be treated and reused without electrolysis.

Two-Stage Gas Hydrate Method: Gas Hydrate Method | Two Stage Gas Hydrate Method

Recovery and storge as condenced tritiated water

Benefits:
(1) Cost reduction (OPEX & CAPEX),
(2) Supports environmental conservation,
(3) Recovery of valuable substances, i.e. tritium



① Fuel assembly
② Calandria (reactor pressure vessel)
③ Control rod
④ Pressurizer
⑤ Steam generator
⑥ Water supply pumps
⑦ Recirculation pumps
⑧ Fuel Exchanger
⑨ Heavy water (moderator)
⑩ Pressure tube
⑪ Steam
⑫ Cold secondary cooling water
⑬ Concrete radiation shielding

Effectiveness / Issues That This Technology Can Solve

The gas hydrate method allows for the recovery and reuse of tritiated water as a fuel in nuclear fusion reactors, removing tritiated water from the wastewater is an environmentally responsible technology.

Also, separating tritiated water from heavy water in CANDU reactors and nuclear reprocessing facilities may use this method as well.

Applying the Technology

When other compounds are mixed in the wastewater, such as salt, this new hydrate method can still be effective in removing tritiated water.

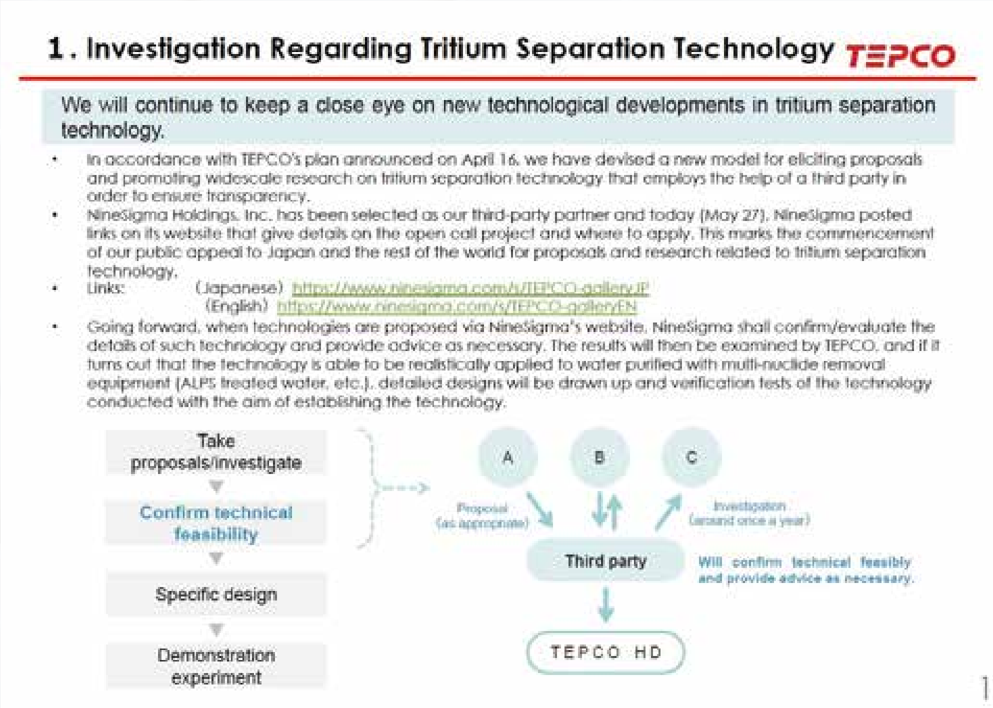
If there are other radionuclides in the wastewater, this same technology can remove them if desired, and may be used before the tritiated water separation process begins.

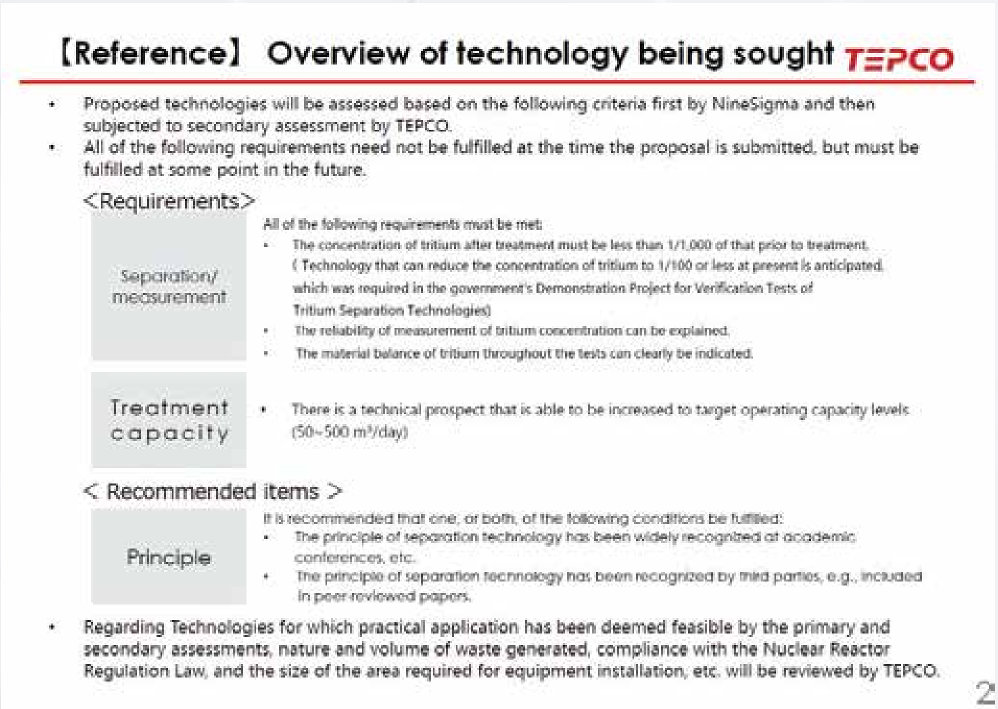
The largest, existing gas hydrate production facilities have a maximum generating capacity of 5 m^3/day of gas hydrate for safe transportation of natural gas.

Sample Image

Status of Tritiated Water Treatment for Fukushima NPP

TEPCO has put out a call for technology that can decontaminate tritiated water located at the Fukushima Daiichi Nuclear Power Plant. Currently, there is a feasibility study with TEPCO.





May 27, 2021 Tokyo Electric Power Company Holdings, Inc. :Commencement of Open Call for Tritium Separation Technology in Cooperation with a Third-Party

https://www4.tepco.co.jp/en/decommission/progress/watertreatment/images/20210527.pdf