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TRITIUM STORAGE

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ABSTRACT

A general synthesis about tritium storage is achieved in this paper and a particular attention is given to practical application which concerns many people in the Fusion Technology Program. After indicating the main storage particularities as regards tritium, storage under gaseous form and solid form are discussed (characteristics, advantages, disadvantages and equipments). The way of tritium storage is then discussed and a choice established as a function of a logic which takes into account the main working parameters.

INTRODUCTION

Since a tenth of years, a number of tritium laboratories have been built or are under construction worldwide, for the needs of fusion. Most of them, where basic studies are or will be achieved, use substantial tritium amounts which are to be stored while respecting fundamental criteria such as safety and reliability. In another way, important projects of Tokamaks where very large tritium amounts will be manipulated are under realization or project. At this level, tritium storage represents an important basic element inside the Tritium Plant (TP) associated to the reactor.

So, it appears necessary to rationally consider that subject of wide extent, in a synthetic manner, for being able to take optimized choices concerning the tritium storage modes.

In this paper, after indicating the main storage particularities as regards tritium, storages under gaseous and solid forms (at room temperature, that representing the industrial reality) are examined before establishing logical choices. By another way, tritium storage under liquid form will not be discussed here, that not constituting a general reliable way for tritium storing.

PARTICULAR POINTS INHERENT TO TRITIUM STORAGE

Recall of several specific properties of tritium

Tritium (T) is the radioactive isotope of hydrogens (β emission and helium three, He, generation) with an half-life of 12.3 years, a mean β energy of about 6 keV and an activity of 10^4 Curies per gram. In addition to the "classical" physico-chemical properties of hydrogen, T exhibits particular properties inherent to its intrinsic energy, such as: spontaneous reaction with oxygen with formation of tritiated water, spontaneous reaction with carbon oxides with generation of tritiated methanes and water, isotopic exchanges with practically all hydrogenated or deuterated molecules, degradation of organic compounds by breaking of carbon-carbon bonds, generation of free radicals leading to complex reactive mechanisms...

Main consequences for tritium storage

They mainly concern safety, the storage characteristics, the involved materials, maintenance and wastes.

Concerning safety, drastic measures have to be adopted because storages, by definition, include, important T inventories inside a TP. These ones are in tight connection with the technology which has to assure a perfect tightness while taking into account tritium permeation through confinement materials.

Concerning the storage characteristics, He generation involves an increase of the initial gaseous tritium pressure, P_0^T , and the total storage pressure, $P_s(t)$, evaluates as a function of time according: $P_s(t) = P_0^T (2 - e^{-\lambda t})$, with λ the radioactive decreasing constant. In another way, He generation induces an evolution of the stored gas composition. Finally, for a solid storage, a He retention phenomena can be observed inside the tritides when aging, that leading to eventual modifications of the thermodynamical properties of the compounds and of the storage characteristics (pressure, capacity, tritides decomposition temperature).

Concerning the involved materials, all contact between tritium and organic materials such as elastomers (commonly used for the seals) or oils (used for the lubrication of pumping systems) has to be avoided.

Concerning maintenance, materials being tritium contaminated, all operations have to be done in hot area, that representing penalizing working conditions. So, it's necessary to conceive, as far as possible, storage systems of "easy" technology and maintenance.

Concerning tritiated wastes, they have to be managed and they represent a potential tritium release source. Therefore they have to be minimized by conceiving systems of optimized reliability.

STORAGE UNDER GASEOUS FORM

Characteristics of the storage

They mainly concern the storage pressure, the storage capacity and the gas composition.

The initial storage pressure, $P_s(0)$, will generally be below the atmospheric pressure for safety reasons and it will be necessary to take into account its evolution for a tritium storage of long duration. As a guide, for a pure tritium storage, the pressure increase is of about 5.5 % in a year. For particular working needs, high pressures can be, of course, set up.

The storage capacity, V_s , is a function of the tank volume, V , and of the storage pressure for a given temperature, $T(^{\circ}K)$. If the gas can be considered as ideal (low pressures), then the equation of state

is: $P_s(0) \bar{V} = RT$, where \bar{V} is the volume corresponding to one mole and R the constant of ideal gas, that relation allowing to easily determine the number, n , of stored moles : $n = P_s(0) V/RT$. That relation is not valid when the gas is stored at high pressures and, even at atmospheric pressure, deviations from this ideal gas law are appreciable. In these conditions, the equation of state can be written with the polynomial relation [1]: $P_s(0)\bar{V} = RT [1 + B(T)/\bar{V} + C(T)/\bar{V}^2 + D(T)/\bar{V}^3 + \dots]$ which is called the "virial equation of state" and where the temperature dependent functions $B(T)$, $C(T)$... are the "virial coefficients". Another expression [2] can be considered for practical use, introducing the notion of "Amagat density", ρ , which corresponds to the number of moles confined in an unitary molar volume:
 $\rho = P_s(0) [a(T) + b(T) P_s(0) + c(T) P_s^2(0) + \dots]$.

That relation allows to easily deduct V_s ($V_s = \rho V$) from the measured pressure (in atm.), knowing the values of the coefficients which are indicated (from [2]) here after for deuterium, at different temperatures.

T (°C)	a	10 ³ b	10 ⁶ c
0	1.0000	- 0.61244	0.20471
25	0.91615	- 0.53250	0.19774
50	0.84527	- 0.46231	0.16088
75	0.78457	- 0.40737	0.14909

For $0 < T(^{\circ}\text{C}) < 50$, the variation of the coefficients is practically linear as a function of the temperature (in $^{\circ}\text{C}$):

$$a(T) \sim 1 - 0.3 \cdot 10^{-2} T$$

$$b(T) \sim 10^{-3} (- 0.612 + 0.29 \cdot 10^{-2} T)$$

$$c(T) \sim 10^{-6} (0.2047 - 6.10^{-4} T)$$

For a low pressure (< 10 atm.) storage, the simplified relation $V_s \sim [1 - 0.3 \cdot 10^{-2} T(^{\circ}\text{C})] V P_s(0)$ can be used. For higher pressures the polynomial relation will be considered.

Remark: these evaluations implicate that the gas is pure enough, the presence of impurities modifying the equations of state.

The gas composition is a function of time. If a pure initial H, D, T mixture is considered, with:

- C_T^0 , the initial global tritium concentration
- n_T^0 , the corresponding number of moles
- C_{H+D}^0 , the initial global hydrogen-deuterium concentration
- n_{H+D}^0 , the corresponding number of moles
- $C_T(t)$ and $C_{H+D}(t)$, the concentrations as a function of time
- $C_{He}(t)$, the helium three concentration as a function of time
- $n_{He}(t)$, the corresponding number of moles
- τ_0 , the initial ratio n_T^0/n_{H+D}^0

We can write:

$$\left. \begin{aligned} n_T(t) &= n_T^0 e^{-\lambda t} \\ n_{He}(t) &= 2 n_T^0 (1 - e^{-\lambda t}) \\ n_{H+D}(t) &= n_{H+D}^0 \end{aligned} \right\} \Sigma n$$

Then, the gas composition is given by:

$$C_T(t) = \frac{n_T^0 e^{-\lambda t}}{\Sigma n} = \frac{e^{-\lambda t}}{2 - e^{-\lambda t} + 1/\tau_0}$$

$$C_{H+D}(t) = \frac{n_{H+D}^0}{\Sigma n} = \frac{1}{\tau_0(2 - e^{-\lambda t}) + 1}$$

$$C_{He}(t) = \frac{2 n_T^0 (1 - e^{-\lambda t})}{\Sigma n} = \frac{2 (1 - e^{-\lambda t})}{2 - e^{-\lambda t} + 1/\tau_0}$$

Advantages of the storage under gaseous form

They mainly concern the gas quality, the gas supply, the gas control, safety, technology, costs and maintenance.

The gas to be stored can be impure, contrary to the storage under solid form (as we shall see later), that representing a very important practical advantage, because, in fact, storage of impure gases is commonly needed in a tritium unit.

That mode of storage allows a very reliable, fast and flexible gas supply. Indeed a simple opening of valves can directly assure a gas transfer by expansion or by means of a pumping.

The storage control is very easy by measuring $P_S(t)$, that allowing a determination in real time of the tritium inventory, knowing V and $C_T(t)$. For low pressures (<10 atm.) $V_S \sim [1 - 0.3 \cdot 10^{-2} T(^{\circ}C)] P_S V C_T = f(T, P_S, V, C_T)$. The accuracy on the estimation of V_S can be done easily according a method developed in [3]: if s_i represents the estimation of the standart deviation for a i variable and f'_i the derivative with regard to i , we can write:

$$s_{V_S}^2 = s_T^2 \frac{f'_T{}^2}{T} + s_{P_S}^2 \frac{f'_{P_S}{}^2}{P_S} + s_V^2 \frac{f'_V{}^2}{V} + s_{C_T}^2 \frac{f'_{C_T}{}^2}{C_T}$$

Then:

$$\left(\frac{s_{V_S}}{V_S}\right)^2 = \left(\frac{s_T}{T}\right)^2 \left(\frac{0.3 \cdot 10^{-2} T}{1 - 0.3 \cdot 10^{-2} T}\right)^2 + \left(\frac{s_{P_S}}{P_S}\right)^2 + \left(\frac{s_V}{V}\right)^2 + \left(\frac{s_{C_T}}{C_T}\right)^2$$

That leads to an uncertainty on V_S of about 0.7 % (for a 95 % level of confidence), taking the following data:

$$s_T/T \sim 2.5 \%, \quad s_{P_S}/P_S \sim 0.2 \%, \quad s_V/V \sim 0.1 \%, \quad s_{C_T}/C_T \sim 0.25 \%$$

Safety represents an essential point in tritium handling. Gaseous storage and transfers being achieved at room temperature, tritium permeation through materials is negligible, that constituting an important safety element.

Technology is very simple (tank, valves and associated instrumentation: manometer, pressure transducer, thermocouple), that leading to comparatively low costs of about eight thousands dollars for an equipped tank of 200 l.

Maintenance is practically null.

Disadvantages of the storage under gaseous form

They mainly concern the required space, the storage weight and the gas quality when aging.

If the gas has to be stored under the atmospheric pressure, the tank volume has to be higher than the required capacity. For a storage at one atmosphere, the value of the ratio stored volume/storage volume is about 1, that value being much more lower than for storages under solid form, as seen later.

The storage weight is a very important parameter in a structure where a minimum load factor is wished, that is to say a ratio stored volume/storage weight, r , maximum. For example if we consider a 200 l cylindrical tank of 31.7 cm radius, 63.4 cm length and 0.4 cm thickness, r value is about 3.4 l/kg, that value being comparatively lower than for solid storages.

The gas quality decreasing when aging, that kind of storage doesn't allow to supply pure tritium after a certain time of storage. Generally, tritium and DT mixtures have to be without impurities when used and, then, a purification will be needed for a gas which has been stored even during a small time. For example, pure tritium stored during one week will contain about 2150 v.p.m. of He.

Associated equipments

Equipments associated to gas storage don't correspond to sophisticated technological means: tanks made of austenitic stainless steel (such as 304 L or 316 L) and isolated from the process by tritium compatible valves. For controlling the storage, the tank will be equipped with a precision manometer (accuracy better than 0.4 % in the range 0-1 bar), a pressure transducer, a vacuum gage and a thermocouple. An analytical sampling (eprouvettes or capillary connected to the analytical instrumentation) has to be foreseen for fast and accurate determination of gas composition.

STORAGE UNDER SOLID FORM

Recall of useful generalities about hydrides

A good documentation of wide extent [4] exists concerning metal hydrides and only several brief recalls are useful.

Metal hydrides are usually characterized by their isotherms representing the evolution of hydrogen pressure, P , as a function of the stoichiometry, x , (according the reversible reaction $M + x/2 H_2 \rightleftharpoons MH_x$) for a given temperature, T . For the $M-H_2$ systems leading to a single hydride phase, the shape of isotherms can be schematized as here after, on Fig. 1.

Three areas can be considered:

- area of solubility (α phase, variance = 2)
- area of hydride (β phase, variance = 2)
- mixt area ($\alpha + \beta$ phases, variance = 1), corresponding to a pressure plateau characterizing the system: the pressure plateau represents the storage pressure and the maximum stoichiometry, x_M , the storage capacity, for a given temperature (generally room temperature).

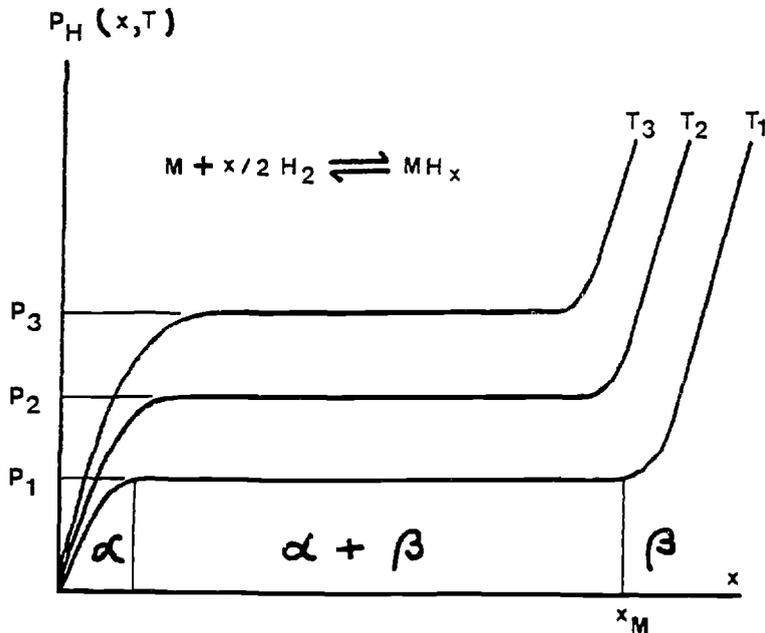


Figure 1 - Schematic representation of isotherms

If the chemical equilibrium is realized in the two-phases area, laws of thermodynamics can be used, with ΔH , ΔS and ΔG , the standart enthalpy, entropy and energy of the system:

$$\frac{d}{dT} \ln K_p = \frac{\Delta H}{RT^2} \quad \text{with } K_p \text{ the equilibrium constant at a constant}$$

pressure ($K_p = P^{-1}$)

$$\ln P = \Delta H/RT + \text{constant}$$

$$\Delta G = - RT \ln K_p \quad RT \ln P = \Delta H - T \Delta S \quad \implies \quad \ln P = \Delta H/RT - \Delta S/R$$

That well known relation allows to deduct the evolution of the equilibrium pressure as a function of T knowing ΔH and ΔS from experimental measurements. The practical interest of that relation is to easily estimate the storage pressure (at room temperature) and the temperature required for desorbing the hydride at a given pressure (for example one bar).

General characteristics of a solid storage

In comparison with a gaseous storage, a solid storage includes two important practical consequences:

- The hydrogen-metal interaction which conditions the capacity and pressure of the storage.
- The helium-metal interaction which conditions the helium retention during the tritium storage (when aging) and consequently the composition of the gaseous phase and possibly the thermodynamical characteristics of the system.

The general characteristics (hydrogen pressure, capacity, helium retention, total pressure, gas composition and absorption-desorption kinetics) of the storage will mainly depend on these interactions for a given metal-hydrogen system:

The hydrogen (tritium) pressure will be as low as possible and many materials allow to store tritium at compatible pressures, as regards safety. For that, many materials such as U, Zr, Ti, Pd, ZrCo, LaNi_4Mn ... offer the possibility of tritium storing at pressures lower than 50 mbar for example, as seen after.

The storage capacity is in direct relation with the maximum stoichiometry of the two-phases area and many hydrides offer storage capacities higher than 100 ml per gram, such as UH_3 , ZrH_2 , TiH_2 , ZrCoH_3 , $\text{LaNi}_4\text{MnH}_5$...

The helium retention phenomena is essential. It has been already studied for various tritides: $ZrNiT_3$, Mg_2NiT_4 and $LaNi_5T_6$ [5], TiT_2 [6], UT_3 [7], $PdTx$ [8], $ErTx$ [9] ... If there is no retention, the material will keep its thermodynamical properties. If not, they may evaluate when aging, that modifying the isotherms. Consequently, the storage pressure and gas composition become dependent of the retention level. Tritides often offer a good enough retention during a certain period (about one year for UT_3), then desorb helium. Several compounds such as $LaNi_5T_6$ offer a total retention during longer periods.

The storage pressure (tritium plus helium), $P(t)$, is a function of the tritium initial pressure, p_0 , of its evolution $p_T(t)$ when aging, of the helium retention level, $R(t)$ [$R(t)$ = helium volume retained in the solid phase/theoretical volume generated in the solid phase], of the tritium volume (n.t.p.) initially stored in the solid phase, v_0^S , and of the dead volume of the storage system, V_M . Let:

- $v_T^G(t)$, the n.t.p. tritium volume in the gaseous phase
- $v_T^S(t)$, the equivalent n.t.p. tritium volume in the solid phase
- $v_{He}^G(t)$, the n.t.p. helium volume generated in the gaseous phase
- $v_{He}^S(t)$, the n.t.p. helium volume generated in the solid phase.

Considering the gas as ideal, at 273°K, we can write:

$$\left. \begin{aligned}
 v_T^G(t) &= p_T(t) V_m \\
 v_T^{S+G}(t) &= (v_0^S + p_0 V_M) e^{-\lambda t}
 \end{aligned} \right\} \implies$$

$$v_T^S(t) = v_0^S e^{-\lambda t} + V_M [p_0 e^{-\lambda t} - p_T(t)]$$

$$v_{He}^G(t) = 2 \lambda V_M \int_0^t p_T(t) dt$$

$$v_{He}^S(t) = 2 \lambda \int_0^t [v_0^S e^{-\lambda t} + V_M (p_0 e^{-\lambda t} - p_T(t))] dt$$

$$v_{T+He}^G(t) = v_T^G(t) + v_{He}^G(t) + [1 - R(t)] v_{He}^S(t)$$

$$P(t) \# v_{T+He}^G(t) / V_M \implies$$

$$P(t) \# p_T(t) + (2 v_o^S / V_M + 2p_o)(1 - e^{-\lambda t}) [1-R(t)] \\ + 2\lambda R(t) \int_0^t p_T(t) dt$$

For a nul retention ($R=0$) : $P(t) \# p_T(t) + (2v_o^S/V_M+2p_o)(1-e^{-\lambda t})$.

Insofar as $p_T(t)$ is relatively negligible: $P(t) \# (2 v_o^S/V_M) (1-e^{-\lambda t})$.

For a total retention ($R=1$): $P(t) \# p_T(t) + 2\lambda \int_0^t p_T(t) dt$, re-

mains low. So, $P(t)$ can become important if $R=0$. For example, with $V_M = 100$ ml, $v_o^S = 100$ l and p_o negligible, the value of $P(t)$ (in bar) is about 3 for 10 days, 9.2 for 30 days... That rough estimation indicates that it's absolutely necessary to use a material offering a good retention during the representative storage period. That also signifies that, if tritium has to be stored during a long period, it will be necessary to know the aging behaviour of the used tritide.

The gas composition for use is a function of the retention level when storing (at room temperature) and when desorbing at higher temperatures. If $R = 0$, it's of practical interest to recover helium by pumping (at a pressure slightly higher than $p_T(t)$) and then to recover tritium of good quality by heating. If $R=1$, when storing and desorbing, the compound will allow to directly recover a tritium of good quality, that representing a fundamental advantage.

The absorption kinetics are of basic interest because they strongly condition the reliability of such a storage. They depend on numerous parameters:

- activation of the material,
- gas purity, the presence of impurities, even at low level (0.1 % vol.) reducing the absorption kinetics [10],
- absorption reaction exothermicity, $|\Delta H|$ [11] and thermal conductivity of the material, which condition the temperature and then the isotherm pressure

- loading pressure and conductance of the storage line,
- initial hydride stoichiometry ...

In the same manner, the desorption kinetics depend on the reaction endothermicity and thermal conductivity (which condition heating), on line conductance, on initial stoichiometry, on the level of the isotherm plateau at a given temperature...

Selection of the storage material

The selection of materials for tritium storing depends on various criteria which are to be examined before taking choices.

The main criteria to consider are given here after:

- the capacity per unit of volume characterized by the ratio stored volume/hydride volume, R_1
- the capacity per unit of mass characterized by the ratio stored volume/hydride mass, R_2
- the helium retention
- the equilibrium pressure at room temperature, P_R , which has to be low enough ($< 10^{-2}$ bar for example) for safety reasons. At this level, it's not useful to look for too low pressures, taking into account the important helium contribution, insofar as the material doesn't offer a total retention.
- the temperature, T_1 , corresponding to the desorption pressure. T_1 has to be as low as possible ($< 500^\circ\text{C}$ for example) for obtaining a sufficient tritium pressure (1 bar for example), so that to minimize tritium permeation through the confinement material (and useful energy).

These two last criteria directly concern the ΔH and ΔS values. If we consider the relation $\ln P = \Delta H/RT - \Delta S/R$, the criteria can be expressed in a quantified manner:

$$\text{For } T = 293^\circ\text{K}, P < 10^{-2} \text{ bar} \implies$$

$$\Delta H \text{ (cal/mole)} < \sim 2680 + 293 \Delta S \text{ (cal/}^\circ\text{K/mole)}$$

$$\text{For } P_R = 1 \text{ bar}, T_1 < 773^\circ\text{K} \implies \Delta H > 773 \Delta S$$

So, it's a priori useful to select materials verifying these two inequations, that is to say, having $[\Delta H, \Delta S]$ values placed in the not

hachured area of the graphic representation (fig. 2) on which several compounds are noticed.

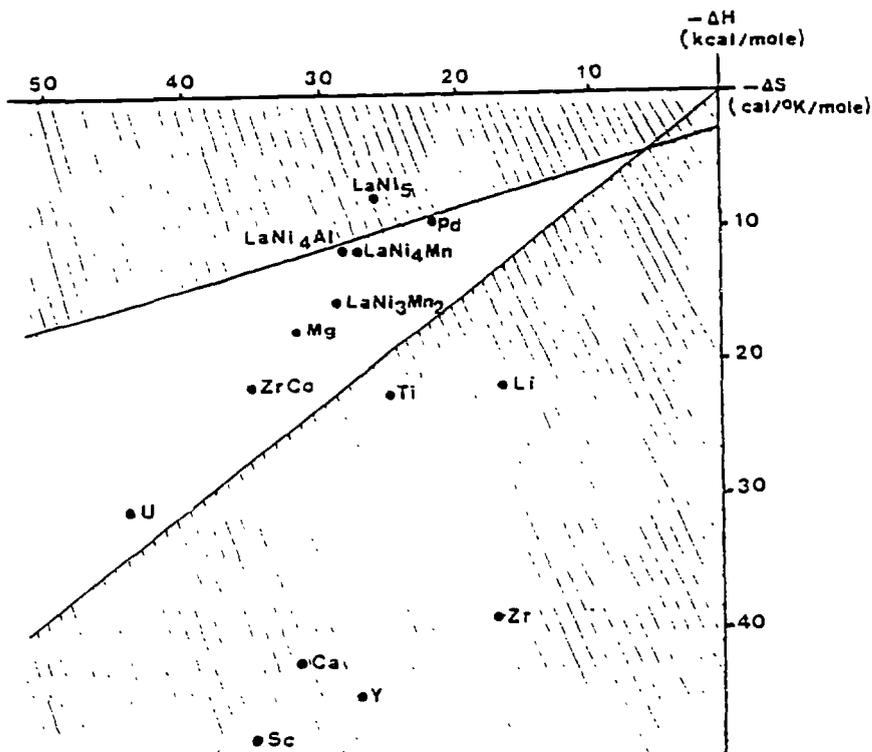


Figure 2 - Graphic representation for material selection

Several other important criteria can be mentioned such as:

- the sensitivity to impurities which has to be low
- the material activation which has to be easy
- the absorption-desorption kinetics, as fast as possible
- the pyrophoricity which has to be minimum.

For selecting materials, characteristics of several compounds are summarized in Table I. That list is evidently not exhaustive but includes potential candidates (Note that the values of the characteristics have to be considered as approached because very dependent on the material purity).

Preliminary choices are possible: rare earthes hydrides have too high T_1 and are very expensive. ZrH_2 has a too high T_1 , is sensitive to impurities and the absorption kinetics are bad below 600°C . LaNi_5H_6 has a too high P_R . Mg , although offering good characteristics, necessitates high pressures for hydridation and is sensitive to impurities.

Hydride	R_1 (l/ml)	R_2 (l/g)	P_R (bar)	Tl ($^{\circ}$ C)
Rare earthes	1.7 (Ce H ₂)	0.32 (Ce H ₂)	$< 10^{-20}$	> 1000
Zr H ₂	1.34	0.24	$< 10^{-9}$	880
Ti H ₂	1.70	0.45	$< 10^{-9}$	650
U H ₃	1.52	0.14	$< 10^{-9}$	430
ZrCOH ₃		0.22	$< 10^{-7}$	335
Mg H ₂	1.21	0.85	$< 10^{-5}$	280
LaNi ₃ Mn ₂ H ₄	0.6	0.10	$< 10^{-4}$	250
LaNi ₄ MnH ₅	0.75	0.13	$< 10^{-2}$	150
LaNi ₅ H ₆	0.93	0.15	2	< 20
Pd H _{0.7}	0.78	0.073	$2 \cdot 10^{-2}$	130

Table 1 - Useful characteristics of several compounds

TiH₂ offering a very good capacity but having a high enough Tl can be used for storages of long duration which don't require frequent desorptions. Pd is interesting but expensive. LaNi₃Mn₂ has a poor capacity. U, ZrCo and LaNi₄Mn can represent a good compromise for hydrogen storage.

Final choices have to take into account the helium retention criteria. For U, the retention is good enough [7] during about one year (depending also on the tritide grain size). For ZrCo, no data are now available. For LaNi₄Mn a strong retention is probable by analogy with

preliminary observations [5,12] and aging studies are now in progress [13] for several Lanthanum - Nickel - Manganese intermetallic compounds. Future results will allow to take definitive choices as regards their use for tritium storage.

Advantages of a solid storage

They mainly concern the storage capacity, storage safety and gas quality.

Capacity of hydrides can be important and several compounds allow to store tritium amounts with a volumic capacity better than 0.7 l/ml, that representing a considerable advantage as regards the space factor and storage weight.

Storage safety is increased with the possibility of tritium storing at low pressure. Nevertheless, that improvement is only partial because gas desorption requires pressure levels comparable to those of a gaseous storage in the presence of a under heating system. In another way that advantage can be fictitious insofar as the material doesn't offer a good helium retention.

The quality of the disposable gas can constitute an important advantage as a function of the helium retention level. If retention is total when storing and desorbing, a pure tritium can be recovered after a pumping of the dead volume for eliminating helium from the gaseous phase. If retention is null, all generated helium can be easily recovered from the gaseous phase before desorbing a gas of good quality. If retention is partial, it's less easy to recover a gas of good quality: for that, it's firstly necessary to totally desorb tritium and helium by heating, to after absorb tritium at room temperature and to eliminate helium by pumping before desorbing a gas of quality.

Disadvantages of a solid storage

They mainly concern the purity of the gas to store, the storage reliability, the storage control, technology, maintenance and costs.

For all storage materials, the gas to store has to be pure for avoiding material consumption (with several impurities such as oxygen)

that decreasing the capacity and for optimizing the absorption kinetics as seen.

The reliability of the storage is conditioned by several operations (material activation, gas loading and gas desorption) which are slow enough and then penalizing for reliability.

The control of the storage tritium inventory requires inlet-outlet balances for each absorption-desorption operation, that leading to cumulate uncertainties about inventory.

The associated technology is heavy enough for safety reasons and, in any case, more complex than for a gaseous storage, that leading to penalizing maintenance operations independently of consumed materials replacement operations which generate tritiated solid wastes.

The costs are comparatively important: a storage system of about 200 l capacity costs about fifty thousand dollars including its necessary instrumentation.

Associated equipments

They include the main following elements:

- a first confinement (of the storage material), generally a steel having a good mechanical behaviour in temperature, for example the austenitic XN26
- metallic porous allowing gas flow while confining the material without particles transfers. A porosity of 20 μm often corresponds to a good compromise
- a heating system allowing optimized desorption kinetics
- a cooling system (possibly) for optimizing the absorption kinetics
- a double confinement for confining tritium from permeation through the first one and/or from the storage itself in case of accident
- thermal screens between the confinements for minimizing the double confinement temperature when desorbing
- gas inlet-outlet valves and vacuum valve for the double confinement
- a thermal exchanger for cooling the desorbed gas
- an instrumentation: thermocouples, pressure transducers, vacuum gage...

Various equipments have been set up in different laboratories [10, 11, 14, 15] for hydrogens storage and their sophistication level mainly depends on their use. In any case, experience demonstrates that simplicity has to be searched for as far as possible.

SELECTION OF THE STORAGE MODE

Selection of a storage mode doesn't appear very easy taking into account the mentioned advantages and disadvantages. In any case a preliminary examination of the main criteria is necessary before making a rational selection.

Selection criteria of a storage mode

The gas quality is essential. Indeed, if tritium or deuterium-tritium mixtures contain reactive impurities (gas before purification or tritiated effluents), then a solid storage is not adequate.

The use frequency of the stored gas is also an important criteria, that conditioning the very reliability and flexibility of the storage. For a storage of long duration, all times inherent to absorption-desorption operations are comparatively less penalizing.

The tritium amounts to store can be various as a function of the tritium unit and working posts and the stored tritium inventory represents an essential element as regards safety.

Several other criteria can be considered such as the storage control, maintenance, costs ...

Selection of the storage mode

That selection can be roughly made according a logic (fig. 3) which takes into account :

- the gas quality defined by the impurities level, I (in v.p.m.)
- the use frequency, F (in number of absorption-desorption operations per day)
- the gas amount to store defined by the volume, V (in l.).

Of course, that logic only constitutes a selection way of first level but can nevertheless be helpful in many circumstances for taking a reasonable choice.

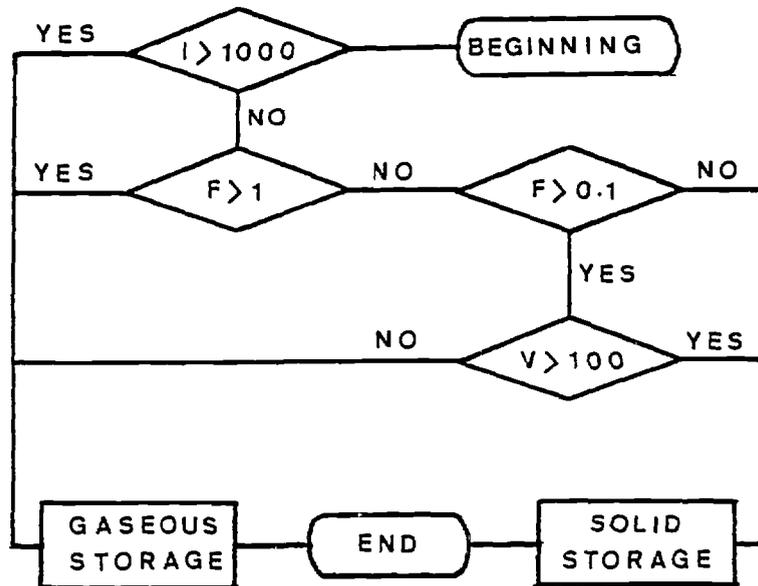


Figure 3 - Logic of storage mode selection

CONCLUSION

In that paper, useful generalities relative to tritium storage under gaseous and solid form have been indicated, that allowing to take rational choices as regards the storage mode inside tritium units of different dimensions (study laboratories and/or Tritium Plants for Fusion application).

In another way, it has been pointed out that a solid storage, although very attractive, doesn't constitute an universal solution and that, in any case, the storage material (metal or intermetallic compound) can only be definitely selected after extensive aging studies.

Finally, the general considerations presented here, although not attempting to solve all tritium storage problems, can be helpful for "tritium beginners".

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