



FAIRE DE LA TERRE LE MEILLEUR ESPACE
POUR LE STOCKAGE DE TOUTES LES ÉNERGIES

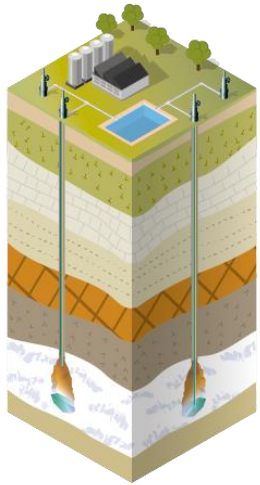


UNDERGROUND STORAGE OF AMMONIA (NH₃)

Review of possibilities

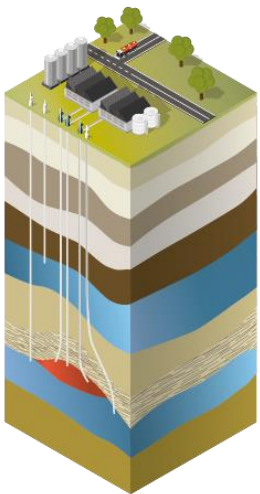
M. TORQUET - 23/05/2023

Underground storage techniques



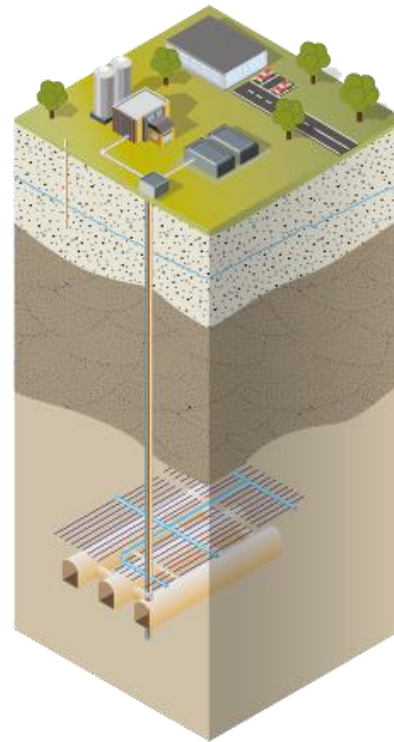
Salt caverns

- Natural Gas
- Liquid Hydrocarbons
- Liquefied Hydrocarbons
- Compressed Air
- Hydrogen
- Effluents



Depleted fields & aquifers

- Natural Gas
- Compressed Air
- Hydrogen
- CO₂
- Effluents



Mined rock caverns (unlined)

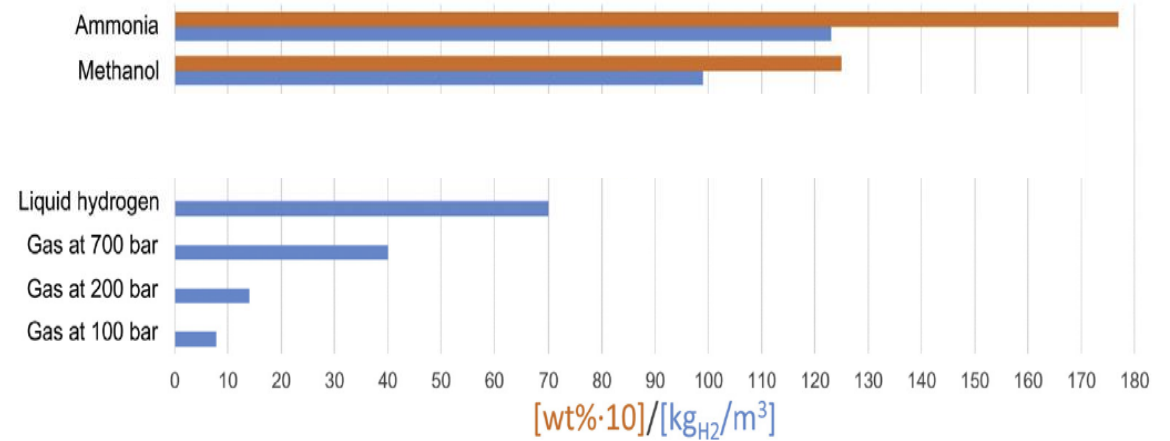
- Liquid Hydrocarbons
- Liquefied Hydrocarbons
- Natural Gas

Mined rock caverns (lined)

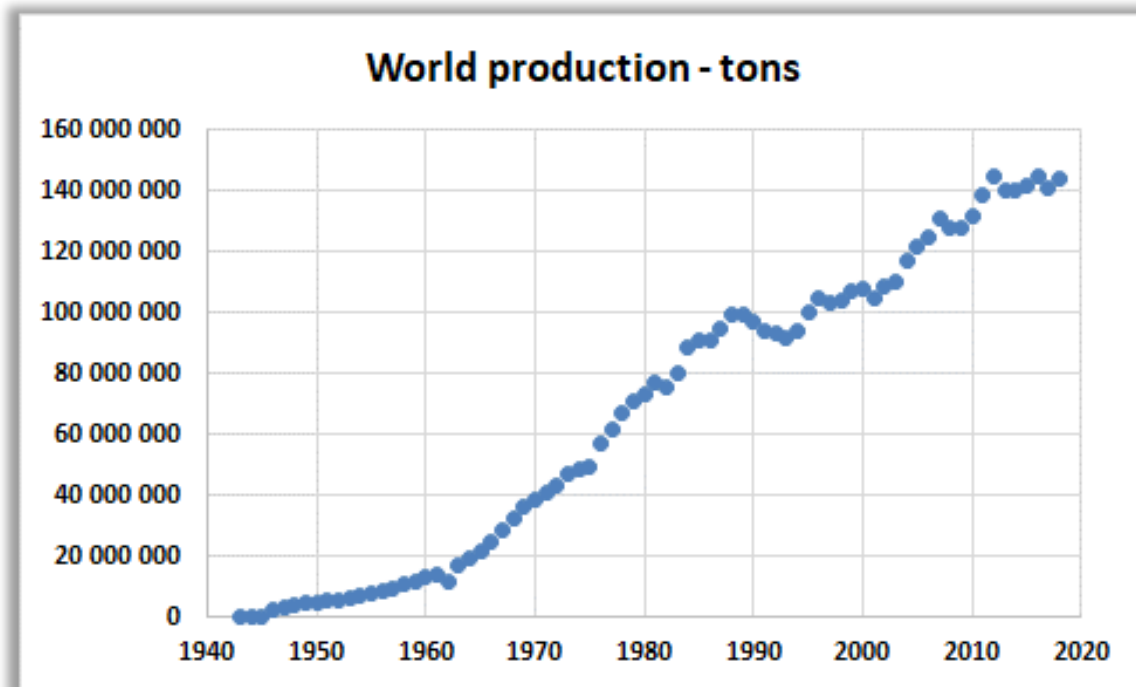
- LNG (Liquefied Natural Gas)
- CNG (Compressed Natural Gas)

Why storing ammonia ?

- Energy density important;
- Easily shipable ;
- Easily storable at low pressure and ambient temperature.



With these points, NH_3 is a good candidate for energy carrier. Therefore NH_3 is getting a lot of attention as a « transportable » H_2 .



TODAY : NH_3 production is done with natural gas reaction (Haber-Bosch process) to produce mainly fertilizer.

TOMORROW : Green H_2 will replace natural gas reforming for H_2 production involved in all ammonia processes.

SPECIFICITIES OF AMMONIA (NH₃)

Ammonia reacts with water ! And it's exothermic !

2000 kJ/kg of NH₃ dissolved.

HSE :

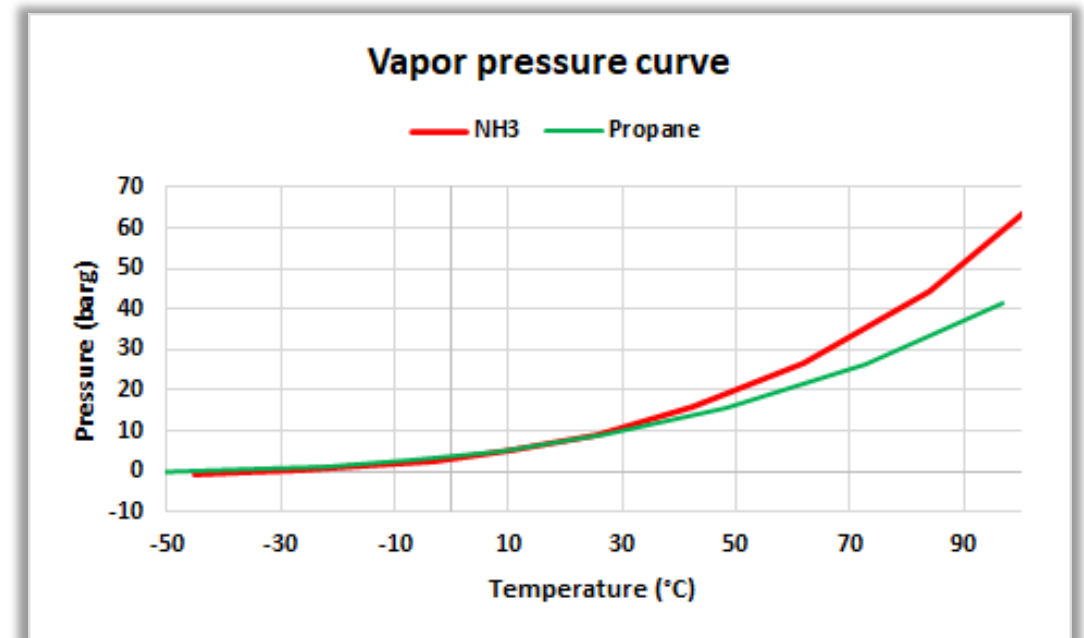


AMMONIAC ANHYDRE

Ammonia solubility in water :

Temperature (°C)	Solubility (g/L)
0	895
20	529
40	316
60	168

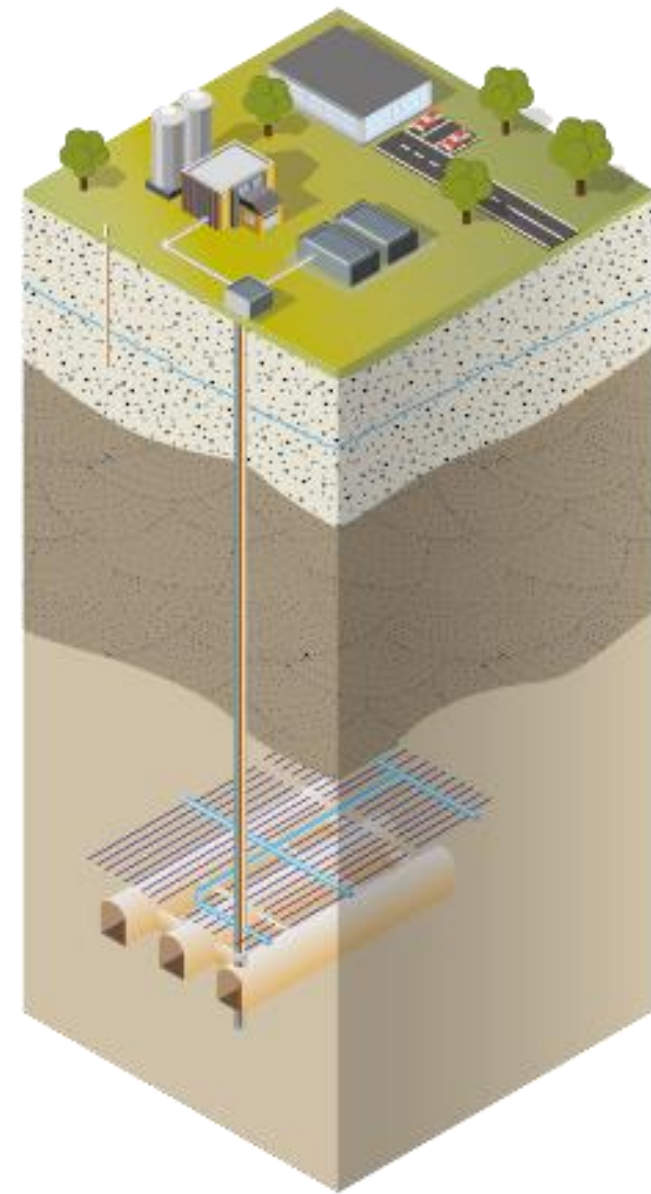
Vapor pressure curve is similar to propane vapor curve





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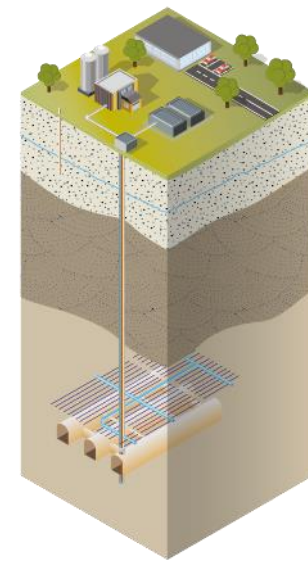
EXISTING STORAGES IN UNLINED MINED ROCK CAVERN



Pictures of Unlined Mined Rock Cavern – LPG storages



Underground storages of Ammonia - existing



All storages presented here are **UNLINED** mined rock cavern:

- Norsk-Hydro storage in Porsgrunn (1967) near Oslo (Norway) : decommissioned.

Pressurised storage then transformed to refrigerated storage due to contamination of the product by seepage water.

Commissioning year	Volume (m3)	Length x heigth (m)	Temperature (°C)	Pressure (bara)
1968	50 000	10 x 12	6-8	8

- Dupont de Nemours storage in the U.S.A. (Gibbtown - New Jersey) : Decommissioned. Possible reversion to LPG in **2016**.

NH₃ Refrigerated storage at -33° C and Patm.

Commissioning year	Volume (m3)	Length x heigth (m)	Temperature (°C)	Pressure (bara)
1967	29 000	Rooms and pillars	-33	1

- Norsk Hydro storage in Glomfjord (Norway) – Still in operation

Commissioning year	Volume (m3)	Length x heigth (m)	Temperature (°C)	Pressure (bara)
1986	60 000	16 x 20	-28 à -33	1 à 2 max

ALL THESE CAVERNS ARE UNLINED CAVERNS

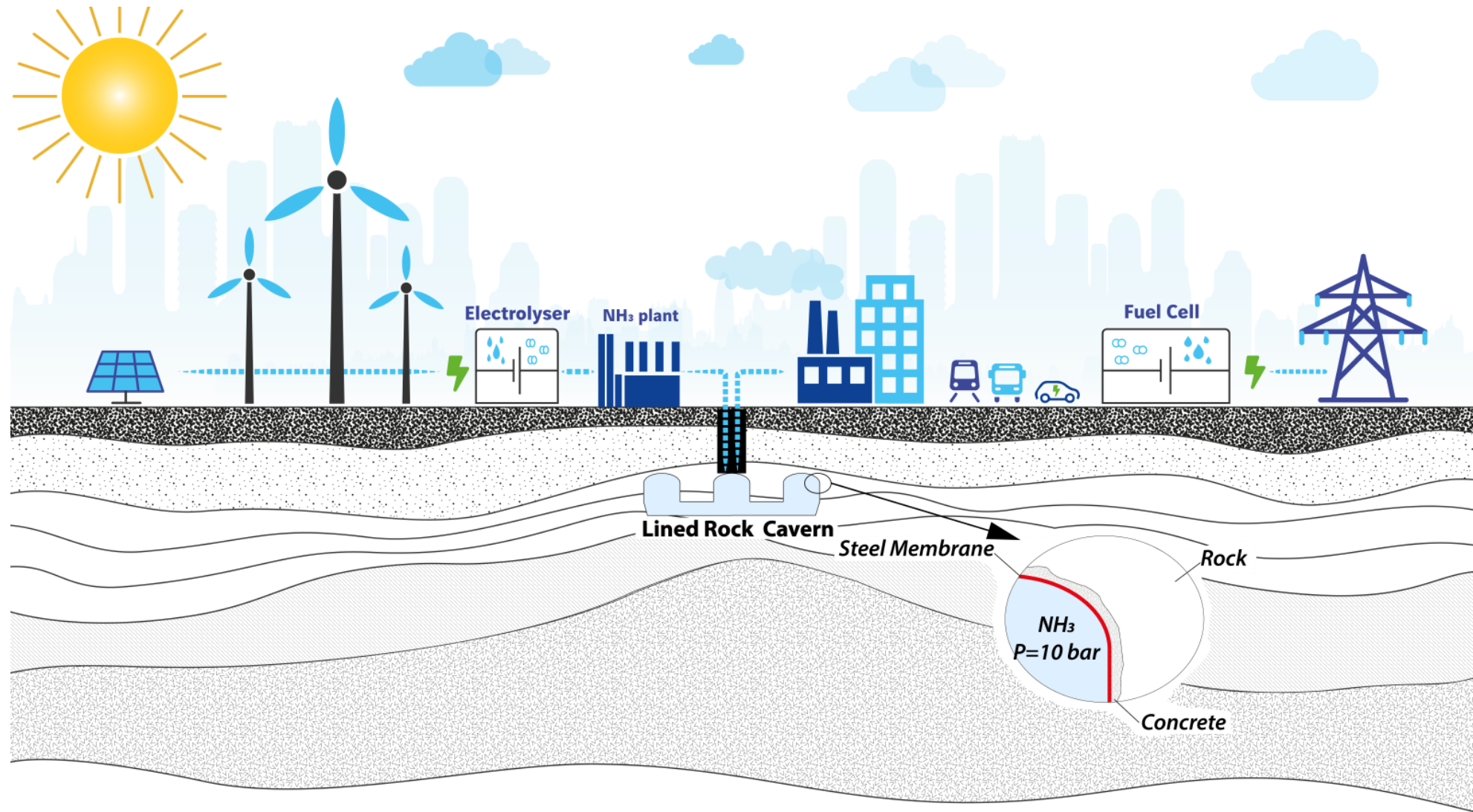


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LINED MINED CAVERN STORAGE



Lined rock cavern for liquid H₂ carrier : NH₃

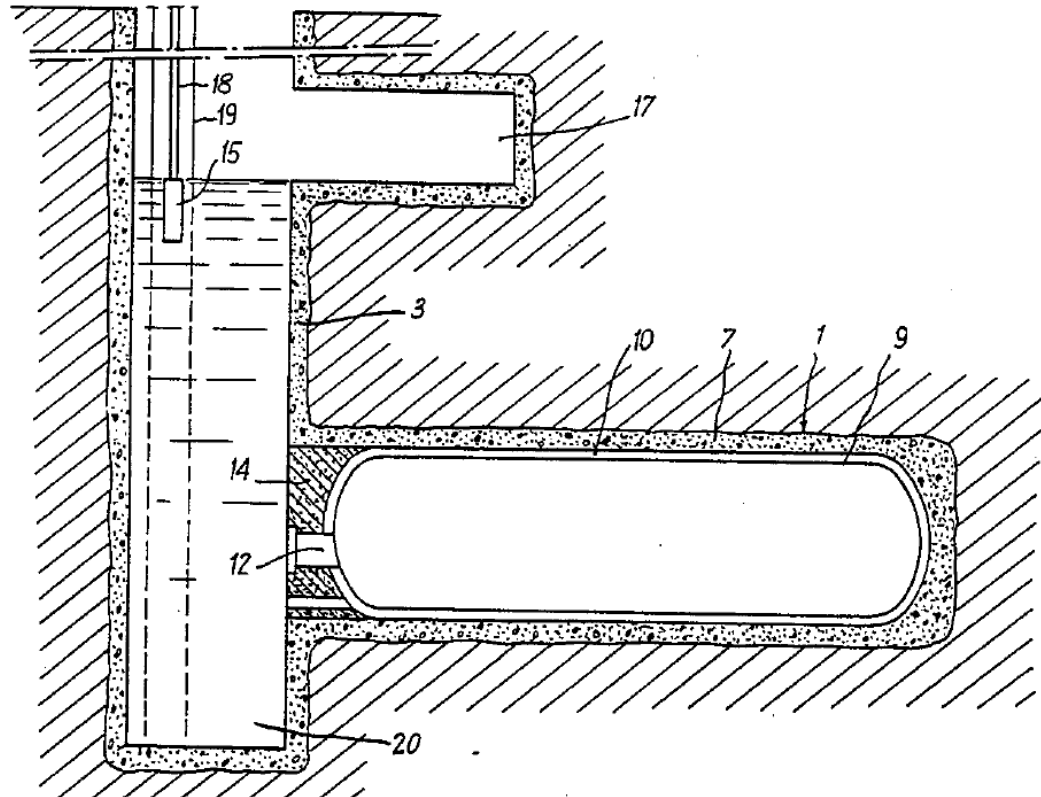


LINED MINED CAVERN

In the 1980-1990, lot of studies to store NH_3 underground.

GEOSTOCK Patent 30 years ago. US4542626 :

No construction by GEOSTOCK.



United States Patent [19] Colin

- [54] **METHOD AND APPARATUS FOR UNDERGROUND STORAGE OF AMMONIA AND ANALOGOUS PRODUCTS**
- [75] Inventor: **Pierre Colin**, Chavilly Larue, France
- [73] Assignee: **Societe Francaise de Stockage Geologique GEOSTOCK, France**
- [21] Appl. No.: **604,289**
- [22] Filed: **Mar. 26, 1984**
- [30] **Foreign Application Priority Data**

<https://patents.google.com/patent/US4542626>

NH₃ lined rock cavern – easier than H₂ lined rock cavern

Ammonia = Very well known molecule by the Industry

Storage of ammonia at ambient temperature (Pressure = 8 à 10 barg). Similar to LPG.

Lining to be used should be more simple than the one for H₂.

- No permeation through the membrane of NH₃
- Narrow range of operating pressure
- Narrow range of operating temperature

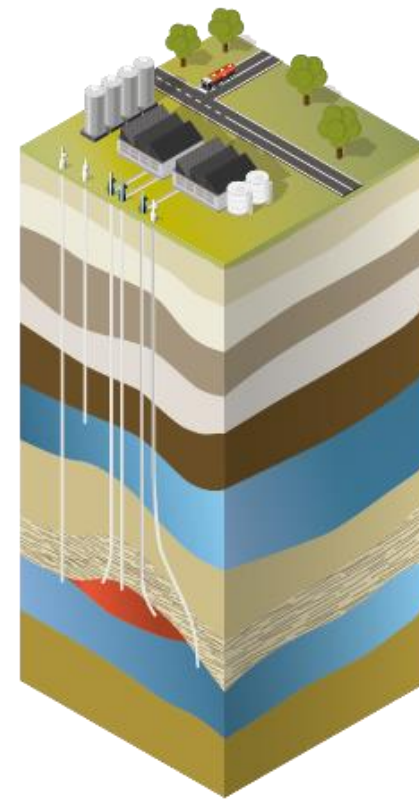
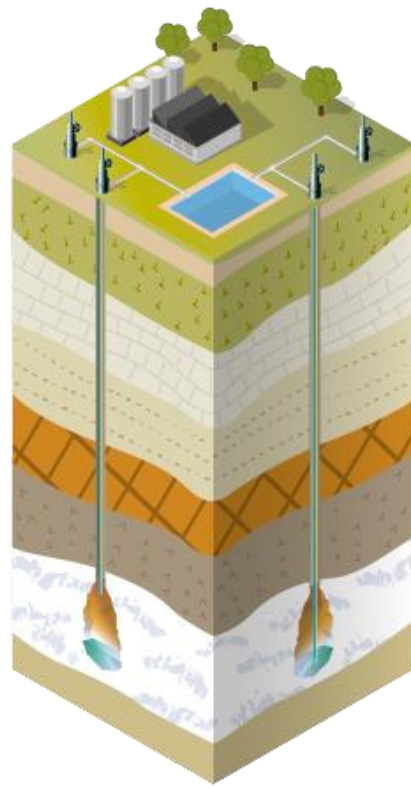


**Lined cavern under construction for Natural Gas
(Source: Thermie B - Project N° OG./270/97/SE/FR)**



03

SALT CAVERN and POROUS MEDIA



Salt cavern and porous media

Ammonia is a polar molecule similar to water.

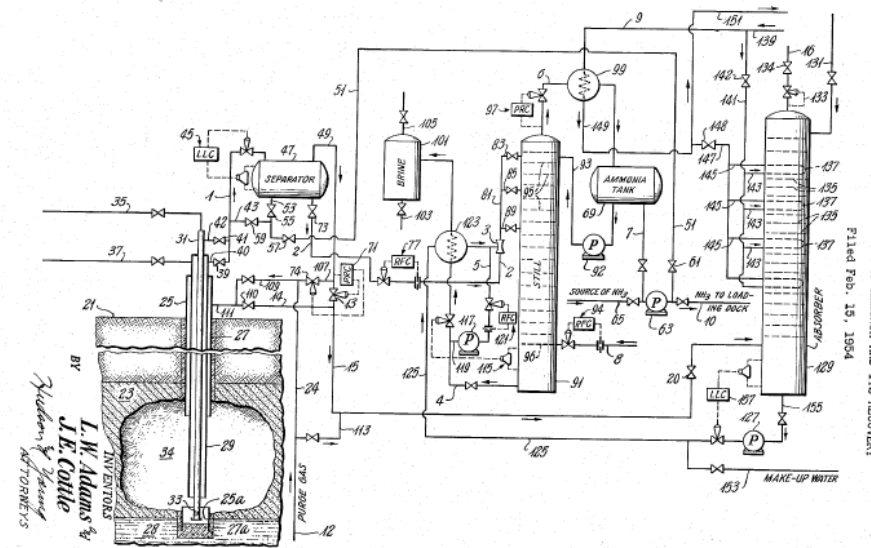
Concern: Salt dissolution: 24,5 g/L for NH_3 . For water it is more than 300 gNaCl/L.

5 patents in the USA in the 60's about NH_3 storage in salt cavern.

The patents are dealing with different kind of processes to treat the salt dissolved in the ammonia.

On pilot unit in Texas: « The only actual underground storage of ammonia that I know of in salt was an experiment that Phillips Petroleum made out in West Texas some years ago. I assume from what I've heard that it was not successful and do know they haven't continued it or gone into it in other places. » from Mined Underground Storage of Ammonia.

VERY DIFFICULT to store inside salt caverns – NOT POSSIBLE to store inside porous media due to reactivity with water.



Bring Back to Office

- **Salt caverns and porous rock reservoirs are not suitable for Ammonia storage.**
- **Unlined Rock Cavern for ammonia requires very low seepage rate or low temperature storage. The economics of such storages need to be studied case by case based on geology and commercial opportunities**
- **Lined Rock Caverns (LRCs) for pressurised ammonia or pressurised hydrogen could be ready for commercialisation in the near future.**





THANKS

