Storage, the New Frontier of Integrity: What's in it for Oil & Gas?

Nicolas Bonnier
Geostock

Webinars

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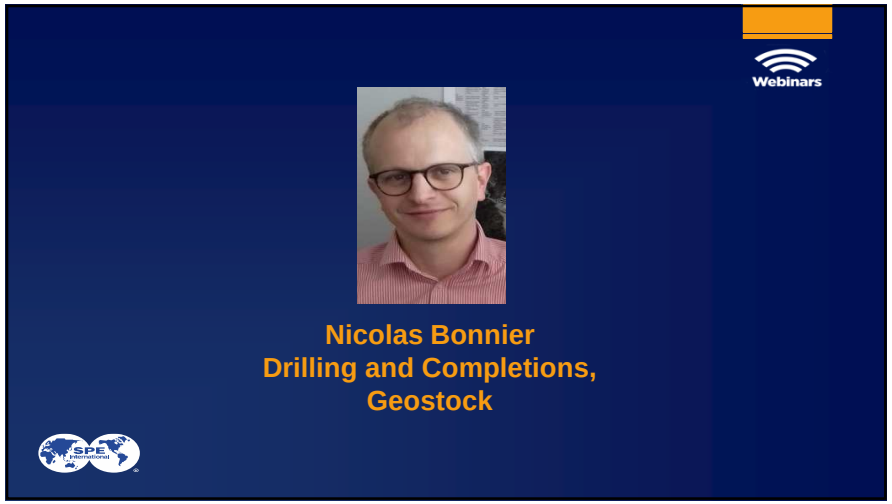


Goals of this Webinar

- Set the scene, introduce the storage industry and its challenges
- What's so special about storage?
  - Safety record and accidents
  - Regulations and standards
  - Key challenges for managing integrity
- Take away points – for O&G

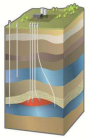
Storage Industry & Challenges

Webinars

- Technologies - three storage types

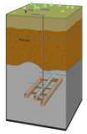
Salt caverns

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



Depleted fields & aquifers

- Natural Gas
- Compressed Air
- CO_2
- Effluents



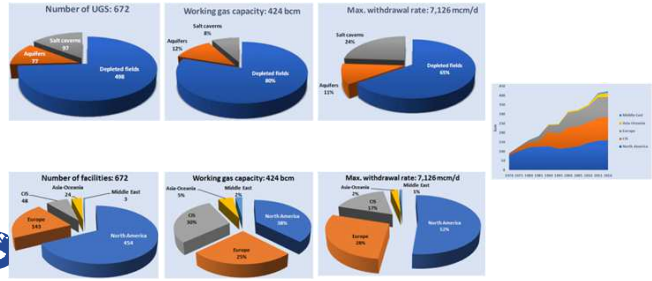
Mined rock caverns (unlined)

- Liquid Hydrocarbons
- Liquefied Hydrocarbons

Storage Industry & Challenges

Webinars

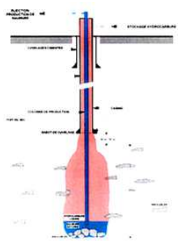
- What? Where? When?



Source : Cornot-Gandolphe, S., 2017, Underground Gas Storage in the World – 2017 Status, Cedigaz Insights No. 22

Storage Industry & Challenges

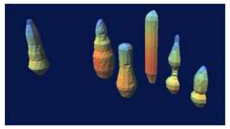
- Operating salt caverns



Manosque, France, Liquid

Byley, UK, Gas

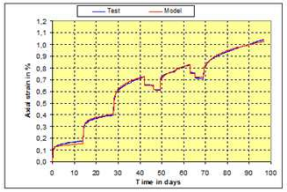
North Dayton Dome, USA



Londe, 2017

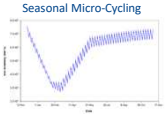
Storage Industry & Challenges

- Operating salt caverns
  - Salt creeps and cavern shrinks
  - Operating envelope from complex geomechanics models



Purely Seasonal Cycling

Seasonal Micro-Cycling

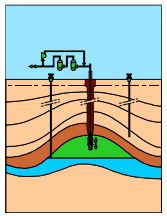


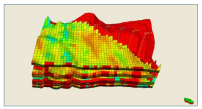
Multiple Macro-Cycling

Karimi et al. York 2011

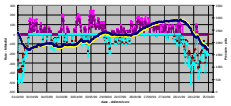
Storage Industry & Challenges

- Operating porous media storage





Reservoir Mapping



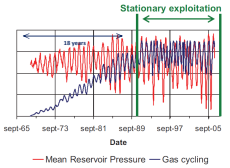
Reservoir Studies – History Matching

Loenhout, Belgium

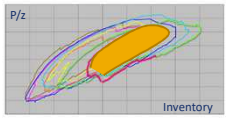
Storage Industry & Challenges

- Operating porous media storage

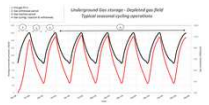
Cycling aquifer



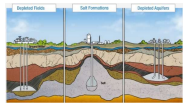
Snail Plot



Cycling depleted field



Storage Industry & Challenges



Life time : 100 years ??

→ Monitoring Data
Data Flow

→ Inspection Data
Ponctual Report/Visit

→ Maintenance Data
Routine intervention

Professional life: ~40 years

Storage Industry & Challenges

WIMS for whom?

- Shareholders
  - Feel that « all processes are under control and safe »
  - Avoid unanticipated costs, looking 5 to 10 yrs ahead.
  - Return on investment

Storage Investors

- Local Regulators / Communities
  - Demonstrate integrity

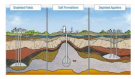
Regulators

Storage Industry & Challenges

WIMS for whom?

- Storage Clients
  - Storage availability and reliability
- Storage Operator
  - Asset integrity: Effectively, Efficiently, Safely
  - Optimize the gas storage envelope to client's need.
    - Define peak production? (1hr/1day)
    - Optimize Pmin/Pmax?
    - Optimize Time@Pmin and Time@Pmax

Storage Client

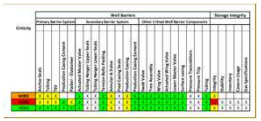


The Asset Operator

Storage Industry & Challenges

- WIMS typical implementation
  1. Hazard Review
  2. Potential Leak path Description & Barrier Identifications
  3. Main Failure Mode Review
  4. Well Barrier Element Inspection (methodology, acceptance criteria)
  5. Well & Storage Barrier Schematics
  6. Determination of Integrity Ranking
  7. Monitoring Well
  8. Monitoring Asset

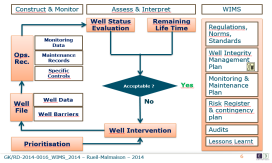
Integrity Management Process

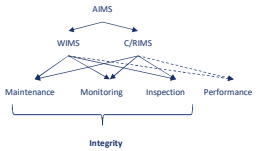


Asset Value

Storage Industry & Challenges

- WIMS typical workflow





Safety Records & Accidents

What's so special about storage?

- Safety record and accidents
- Regulations and standards
- Some key challenges for integrity

Safety Records & Accidentology

Main Reference Littérature

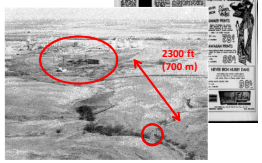
- Papanikolau et al (2006)
- Quintessa report, Watson et al., 2007.
- Evans 2008, 2009.
- Failure rates for UGS, Keeley, 2008.
- Appraisal of UGS technologie and incident for the dev. Of risk assessement methodology, Evans, 2008
- US NGS Risk-Based Ranking Methodology & Result, Folga et Al (2016)
- Past salt caverns incidents database, Reveillere and Al, 2017.
- Analysis of occurrences at UFS facilities and assessment of the main mechanism leading to loss of Storage Integrity, Evans and Al, 2017.
- UGS Regulatory Considerations, 2017.

Safety Records & Accidents

Elk City, OK, USA (1973)

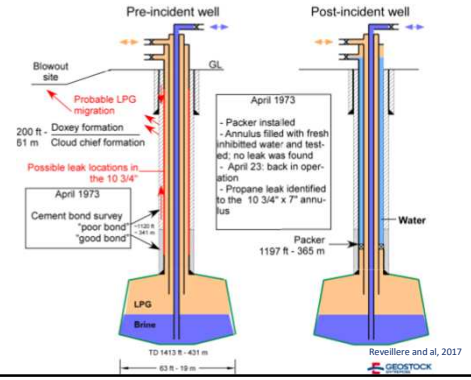
- February 23, 1973

- Following weeks:
  - Feb 28 , Milwaukee Journal: "Boulders Suddenly Fill Oklahoma Pasture"
  - March 3 , Albuquerque Journal: "mysterious force that erected a wall of giant boulders"
- March 1
  - Soil gas sampling, soon revealing 1% of hydrocarbons, of which 4% was methane, 21% ethane and 75% propane
- March 9
  - Oklahoma Geological Survey press release relates the blow-out to a nearby LPG storage site



Reveillere and al, 2017

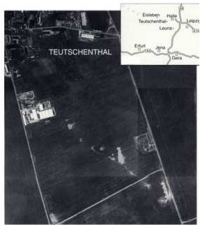
Safety Records & Accidents



Reveillere and al, 2017

Safety Records & Accidents

- Teutschenthal / Bad Lauchstädt, Germany (1988)
  - 1971: Construction of an ethylene storage in a salt cavern
  - March 29, 1988:
    - Drop of annulus pressure from 75 bar to 40 bar (1090 psi to 540 psi)
    - first eruption of an ethylene – water mixture 1 h later, 50 m (150 ft) away from the well
    - Followed by additional eruptions remarkably aligned in N-W direction
  - Continued several days until an estimated 60 – 80% of the cavern inventory was released. No ignition occurred.



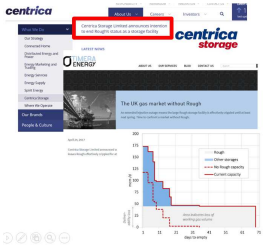
Reveillere and al, 2017

Safety Records & Accidents

- Rough Gas Storage, Centrica Offshore, UK North Sea, 2017
  Preventive gas storage closure case.

March 18, 2015
Start Testing Well Integrity 2nd envelope
June 27, 2016
Barrier failure on 1 well < reservoir pressure
Start testing on other wells and attempt repair program
April 2017
Decision to stop gas storage operations

Sce: Centrica
"as a result of the high operating pressures involved, and the fact that the wells and facilities are at the end of their design life and have suffered a number of different failure modes while testing, CSL cannot safely return the assets and facilities to injection and storage operations."

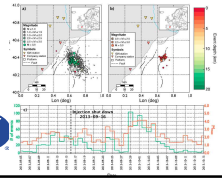


Safety Records & Accidents

- Amposta Depleted Oil Field, Escal, Spain, 2013
  Induced seismicity, fracture reactivation

- Castor is a Depleted Oil Field, offshore Barcelona, Spain.
- Injection of cushion gas for storage
- Oct2013>1k earthquakes max M4,3
- Felt across 200km coastine.
- ~2 Billion Euros Costs

Lessons Learnt
- Low ΔP can induce seismicity leading to M4 earthquakes
- Changes in injection and/or extraction rates appear to be important factors in activating/inhibiting seismicity.
- Potential for forecasting of seismicity during operation based on weighted average magnitude method and analysis of log-periodic corrections.

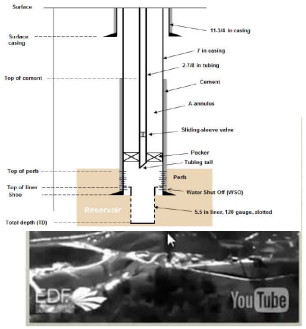


Safety Records & Accidents

Webinars

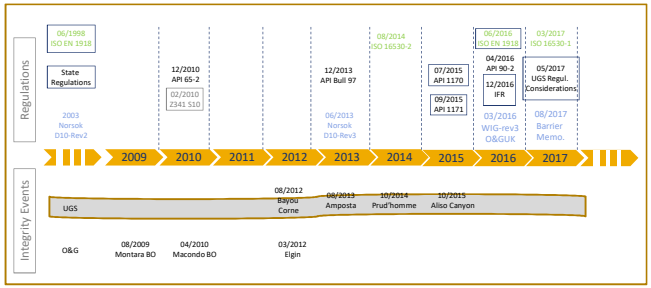
Aliso Canyon, SoCal, California, US, 08/2015

- Uncontrolled natural gas release (blowout) in underground natural gas storage facility in former oilfield, October 23, 2015
- Failure (blowout) of repurposed injection well (drilled in 1953, safety valve removed in 1979)
- 109,000 metric tons methane released (equivalent to 9,156,000 tons CO_2. (Up to 60t(CH4)/hr)
- Operator (SoCal Gas) worked ~4 months to control the well; leak stopped February 11, 2016
- Event driving new State and Federal regulations for underground natural gas storage



Regulations

Webinars



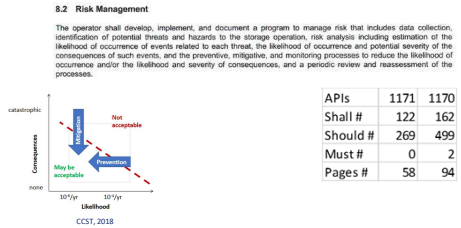
Regulations

- Foccus on the US

After Schultz and Vereide, (2017) *Oil and Gas Journal*

Regulations

- API 1170 - "Design and Operation of Solution-Mined Salt Caverns Use for Natural Gas Storage"
- API 1171 "Functional Integrity of Natural Gas Storage in Depleted Hydrocarbon Reservoirs and Aquifer Reservoirs"



8.2 Risk Management

The operator shall develop, implement, and document a program to manage risk that includes data collection, identification of potential threats and hazards to the storage operation, risk analysis including estimation of the likelihood of occurrence of events related to each threat, the likelihood of occurrence and potential severity of the consequences of such events, and the preventive, mitigative, and monitoring processes to reduce the likelihood of occurrence and/or the likelihood and severity of consequences, and a periodic review and reassessment of the processes.

CCST, 2018

APIs	1171	1170
Shall #	122	162
Should #	269	499
Must #	0	2
Pages #	58	94

Regulations

- Goal setting: what is an unacceptable risk?
- US Food and Drug Administration,
  - 1973, risks > 10^{-9} (fatalities/year) unsafe
  - 1977, risks > 10^{-6} unsafe, Kelly and Cardon 1994.
- US Environmental Protection Agency
  - Risks 10^{-4} to 10^{-6} for carcinogens in drinking water (Cotruvo 1988),
- World Health Organization
  - 10^{-5} lifetime cancer risk.
- UK HSE
  - 10^{-6} annual cancer risk.

Regulations

- Published Statistics
  - Understanding statistics, a requirement.
  - Storage incident databases, an asset.
  - Failure rate scenarios associated w. release rate.
  - Benchmarking :
    - Other industries: LNG, methane gas from landfill, offshore blow out, pipelines.
    - Geographical area.
  - Beware: Assumptions, Robustness, Consistency (Methodology, Time, Industry, Reporting Incentive). Possible JIP to support consistency?

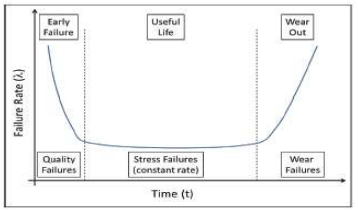
Key challenges

"What gets measured gets managed"

- As Built
- Baselining for Long Term Review
- Geomechanics

Key challenges

- As Built, an industry wide a long term challenge



ISO 16530

Key challenges

- Baselining for Long Term Review, Time Lapse Analysis

Image 1
As-Built
Baseline

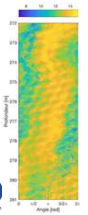
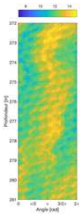
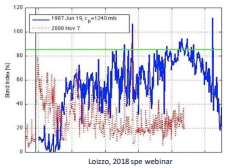


Image 2
Today



Assessment Methodology
Object Environment
Object Conditions
Tool Selection
Tool Calibration



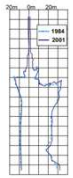
Loizzo, 2018 spe webinar

Key challenges

Image 1
Sonar

Image 2
Sonar

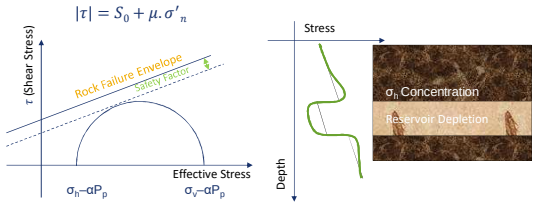
Image 3
Sonar & Laser



Comparing Cavern Imaging Through Time

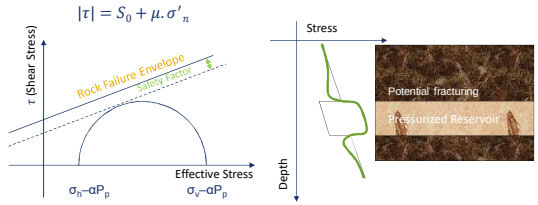
Key challenges

- Operating porous media storage – P<Pini

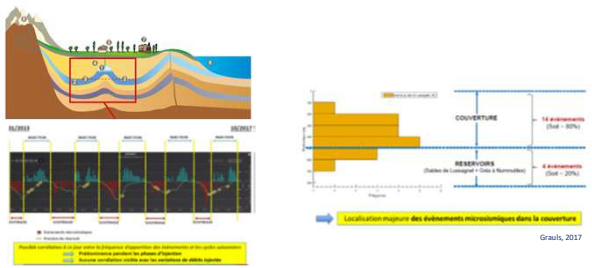


Key challenges

- Operating porous media storage – P<Pini



Key challenges



Grauls, 2017

Take Away Points

- No design life for gas storage
- Specific risks & hazards
  - Storages don't deplete but cycle between inventory min and max
- Rich incident database
  - Critical scenarios
  - Focus on priorities
  - Exchange with O&G?

Thank you