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Highlights of US German Salt Repository Collaborations

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5th US/German Workshop on
Salt Repository Research, Design and Operation

Santa Fe, New Mexico, USA

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Federal Ministry
for Economic Affairs
and Energy

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Perspectives α to Ω

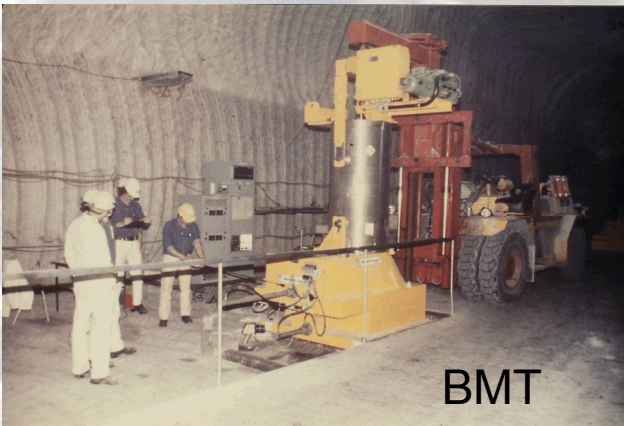
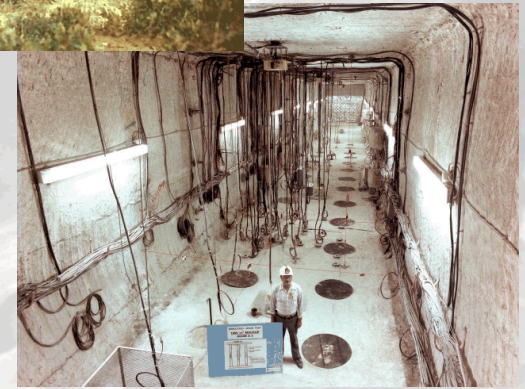
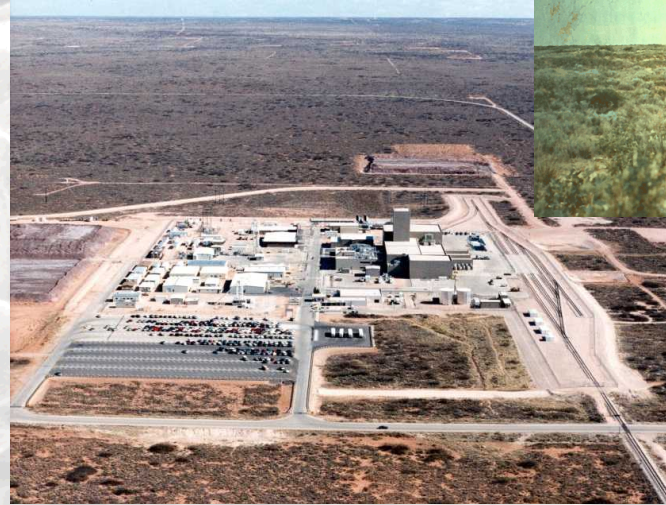


On March 16 1943 J. Robert Oppenheimer met Dorothy Scarritt McKibbin in the La Fonda and hired her to run a discreet office that would become Los Alamos.

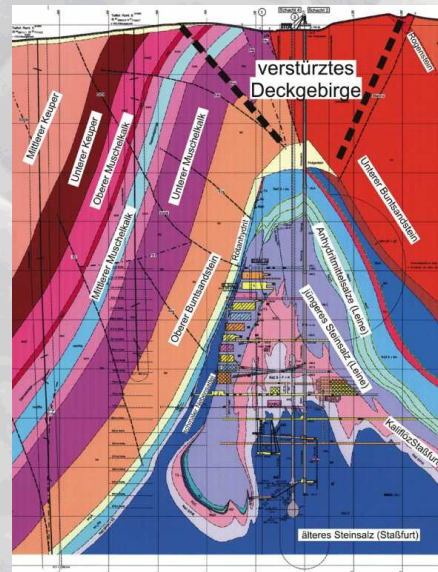


Welcome to the continuation of history

General Chronology of Salt Repository Research

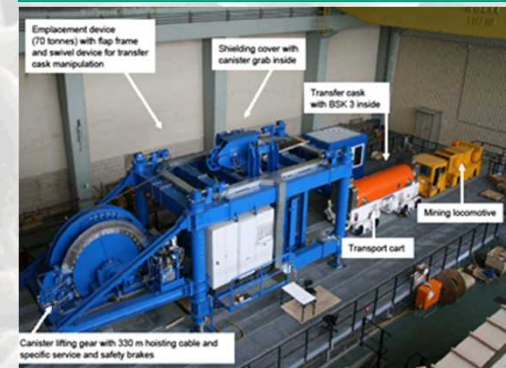
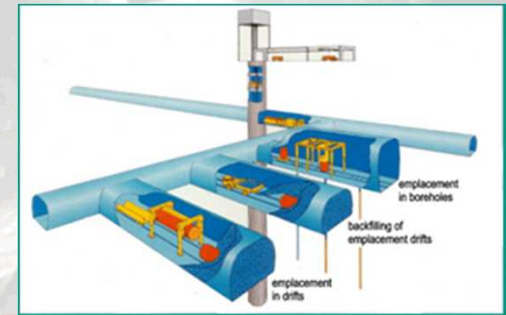


BMT



German Accumulation of Expertise in the Past Decades

- Techniques for waste emplacement were developed (Direct Disposal = reference repository concept)
- Feasibility of vertical borehole emplacement of spent fuel & HLW (BSK-3 canister) was shown
- Instruments, tools, and methodologies for modeling and safety analysis were substantially further developed and have been applied in several exercises (e.g. vSG)
- In Germany underground disposal facilities for chemical-toxic wastes are licensed and are operational for years
- A lot of experience in rock salt available from practical application and excellent RD&D



USA Accumulation of Expertise in the Past Decades

- Sandia, as Science Advisor, developed much of the salt expertise for the Waste Isolation Pilot Plant.
- WIPP was a successful operation 1999-2014.
- Solution Mining Research, Strategic Petroleum Reserve, American Rock Mechanics Assoc., Salt Mechanics Symposia
- Salt mining is a world-wide, proven and reliable technology
- Rock salt is highly suitable for hosting a repository for heat-generating nuclear waste



Hansen, F.D. and C.D. Leigh. 2011. *Salt Disposal of Heat-Generating Nuclear Waste*. SAND2011-0161, Sandia National Laboratories Albuquerque New Mexico.

Benefits of the Strategic Partnership in National and International Cooperation

- Collaboration hibernated for more than 10 years (different priorities in Germany and US)
- Re-start of collaboration in 2010 with a common US-German Workshop in Mississippi (organized by PT-KA, Sandia NL, DBE TEC)
- Benefits

- to exchange experiences and know-how, get external expertise and feedback
- expertise and knowledge to make science-based recommendations on the pros and cons of different host rocks
- Mutual added value, the appropriate investment of money, cost sharing and the gain of confidence
- Internationally accepted is the opinion to cooperate with foreign partners because of the importance for any national program

■ Topics emphasized

- Safety Case
- Salt repository concepts & designs
- Modeling of groundwater flow and radionuclide transport
- Geotechnical barriers
- Site characterization & host rock characterization



US/German Salt Repository Research Sandia National Laboratories

- Collaborations between the US and West Germany began in the 1970's (Asse: Temp.Tests)
- Technical evaluations for salt disposal of heat-generating waste experienced a rather long hiatus because of “priority changes” in both countries
- Salt repository research in Germany slowed down somewhat since 2000 (political decisions, moratorium), but increased in 2010.
- Representatives of institutions in both countries wished to renew collaborations and cooperation on overall salt repository science, to coordinate a potential research agenda of mutual interest, and to leverage collective efforts for the benefit of their respective programs.
- By the first US/German Workshops on Salt Repository Research, Design and Operation collaboration was re-initiated.
- A coordinated research agenda has been pursued to maximize mutual benefit.
- The **fifth workshop** will highlight ***Repository Design and Operations*** and this topic will be the focus of the first day. The focus of the second day will be the ***Thermomechanical Behavior Of Salt, Plugging And Sealing, And The Safety Case***. Special topics will be addressed on the third day.

Accomplishments and Ongoing Activities

- Five consecutive workshops (information: http://energy.sandia.gov/page_id=17258, includes workshop proceedings and all presentations)
- Memorandum of Understanding between the German Ministry of Economic Affairs and Energy and the US-Department of Energy [Environment Management (EM) and Nuclear Energy (NE)]
- Founding of the OECD/NEA “Salt Club” (Participants: Germany, US, The Netherlands, Poland)
 - Natural analogues workshop for rock salt
 - Features, Events, and Procedures (FEP) catalogue for rock salt
 - State-of-the-art report on salt reconsolidation
 - Salt knowledge archive
- Workshops on actinide brine chemistry (ABC) with Los Alamos National Laboratory

Kuhlman, K. L., S. Wagner, D. Kicker, R. Kirkes, C. Herrick, D. Guerin. 2012. Review and Evaluation of Salt R&D Data for Disposal of Nuclear Waste in Salt. Fuel Cycle Research & Development. FCRD-UFD-2012-000380. SAND2012-8808P

Accomplishments and Ongoing Activities

- Collaboration in the Joint Project on “benchmarking constitutive models for rock salt” (Sandia & German organizations) (funding by BMWi and US-DOE)
- Contributions to conferences and workshops (American Rock Mechanics Association, Mechanical Behavior of Salt Symposia, Waste Management)
- Notably the ARMA conference had five sessions on “salt” with many contributions made by US/German collaborators
- Collaborative efforts were also completed in the EC (Euratom)-Project (7th Framework Program) “Monitoring Developments for Safe Repository Operation and Staged Closure” (MoDeRn)
- Collaboration/information exchange in the area of safety case
- Common “joint activity on Handling of Uncertainties” in the framework of the IGD-TP (Implementing Geological Disposal - Technology Platform)

Steininger, W., F.D. Hansen, E. Biurrun and W. Bollingerfehr. 2013. *US/German Collaboration in Salt Repository Research, Design and Operation*. WM2013 Conference, February 24-28, 2013, Phoenix, Arizona, USA.

Activity Overview 5th US/German Workshop

- **Ongoing collaborations**
- Operational Safety—Key Note Rottler/Kennedy/v. Berlepsch/Hardin presentations
- Retrievability and Repository Design—Wagner/Bollingerfehr/URL
- Benchmark modeling (Joint Project III)—Hampel/Arguello presentations
- Laboratory testing of WIPP salt—Düsterloh/Popp/Plischke/Pusch presentations
- Plugging and sealing--Müller-Hoeppel/Glaubach/Hansen Presentations
- Safety case and performance assessment—
Mönig/Hammond/Wieczorek/Freeze/Wolf/Becker/Sallaberry/Rempe presentations
- Nuclear Energy Agency Salt Club—Mönig presentation
- Special topics--Researcher-to-researcher collaborations

- **Next steps**
- Proposals for joint collaboration—wrap-up session
- SALT MECH VIII
- Field-scale natural analogue observations
- Underground laboratory in the context of salt research and development

German Testing of WIPP Salt

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
0.2	1.00E-05	27	1	2
0.5	1.00E-05	27	1	2
1	1.00E-05	27	1	2
2	1.00E-05	27	1	2
3	1.00E-05	27	1	2
5	1.00E-05	27	1	2
20	1.00E-05	27	1	2

$\Sigma = 7$ $\Sigma = 14$

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
0.2	1.00E-05	100	1	2
0.5	1.00E-05	100	1	2
1	1.00E-05	100	1	2
2	1.00E-05	100	1	2
3	1.00E-05	100	1	2
5	1.00E-05	100	1	2
20	1.00E-05	100	1	2

$\Sigma = 7$ $\Sigma = 14$

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
0.2	1.00E-04	27	1	1
1	1.00E-04	27	1	1
2	1.00E-04	27	1	1
5	1.00E-04	27	1	1
20	1.00E-04	27	1	1

$\Sigma = 5$ $\Sigma = 5$

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
0.2	1.00E-05	60	1	2
0.5	1.00E-05	60	1	2
1	1.00E-05	60	1	2
2	1.00E-05	60	1	2
3	1.00E-05	60	1	2
5	1.00E-05	60	1	2
20	1.00E-05	60	1	2

$\Sigma = 7$

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
0.2	1.00E-06	27	1	2
0.5	1.00E-06	27	1	2
1	1.00E-06	27	1	2
2	1.00E-06	27	1	2
3	1.00E-06	27	1	2
5	1.00E-06	27	1	2
20	1.00E-06	27	1	2

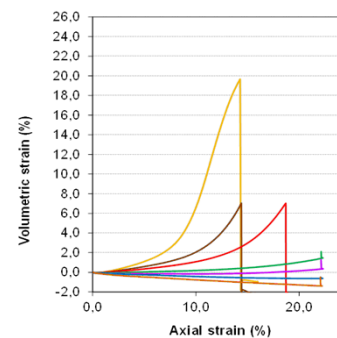
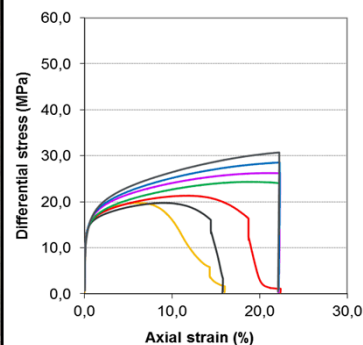
$\Sigma = 7$

σ_1 MPa	strain rate 1/s	T °C	quantity lab pure salt -HG	quantity lab clay salt -TUC
?	?	?	?	?
?	?	?	?	?
?	?	?	?	?
?	?	?	?	?
?	?	?	?	?
?	?	?	?	?

$\Sigma = 7$

σ_1 MPa	σ_3 MPa	T °C	load level	duration d	loading / unloading	above below dilation strength	quantity lab pure salt	quantity lab clay salt
20	>10	27	2	60:60	LU	b/b	2	3
20	>10	60	2	60:60	LU	b/b	5	5
20	>10	80	2	60:60	LU	b/b	1	2
20	<10	60	1	120	L	b	2	2
20	<10	27/60/80	3	60:60:60	L/L/L	b	1	2
5	>3S	27	1		L	a	1	0
different	different	27	4	60:60:30:30	L/L/L/L	b/b/a/a	2	3

$\Sigma = 17$ $\Sigma = 20$



Perceptions--Future Work

- US and German proposals/ideas for future collaboration
- Reconsolidation of granular salt
 - Final porosity
 - Additives for construction and sealing properties
 - Numerical modeling verification
 - Further analogue experience
- Underground research lab in the context of salt R&D
 - Viability of salt formations for repository is established
 - Need a Framework for URL implementation
 - Justification required in context of all salt repository R&D
- The SALT Primer
 - Reference for college classroom
 - Basics, experimental techniques, isochoric deformation, damage and healing
 - Modeling
 - Applications, cavities, boreholes, repository