GORLEBEN -

"the endless story"

(Insights from site characterization of a proposed high-level waste repository at Gorleben, Federal Republic of Germany)

Klaus Kühn
GSF - Institut für Tieflagerung
Braunschweig
Germany

NWTRB - Siting Critical Facilities
Reno, 12. April 1994
ELECTRICITY GENERATION
IN GERMANY

Total in 1992: 460.8 billion kWh

<table>
<thead>
<tr>
<th>Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear power</td>
<td>34.2 %</td>
</tr>
<tr>
<td>Lignite</td>
<td>30.7 %</td>
</tr>
<tr>
<td>Coal</td>
<td>24.2 %</td>
</tr>
<tr>
<td>Natural gas</td>
<td>4.4 %</td>
</tr>
<tr>
<td>Water</td>
<td>4.1 %</td>
</tr>
<tr>
<td>Oil</td>
<td>1.6 %</td>
</tr>
<tr>
<td>Others</td>
<td>0.8 %</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100.0 %</strong></td>
</tr>
</tbody>
</table>
NUCLEAR POWER
IN GERMANY

20 Nuclear Power Plants in operation
with a total installed capacity of 22.5 MWe
- 13 Pressurized Water Reactors with 15.3 MWe
- 7 Boiling Water Reactors with 7.2 MWe

(Projects for High Temperature Gas Cooled Reactor and Fast Breeder Reactor have been given up)
NUCLEAR FUEL CYCLE (1/2)

- Interim Storage Facilities for spent nuclear fuel in operation at
  - Gorleben (Lower Saxony) 1,500 t HM
  - Ahaus (Northrhine-Westphalia) 1,500 t HM
  - Greifswald (Mecklenburg-Vorpommern) 740 t HM

- Reprocessing contracts with
  - Cogéma, France, at La Hague 4,653 t HM
    (Option) (1,645 t HM)
  - BNFL, United Kingdom, at Sellafield 885 t HM
    (Option) (1,365 t HM)

- Return of vitrified high-level waste from
  - Cogéma 2,800 canisters
    (Option) (1,150 canisters)
  - BNFL 700 canisters
    (Option) (1,100 canisters)

First vitrified HLW will arrive in Germany in November 1994
NUCLEAR FUEL CYCLE (2/2)

- Direct disposal of spent fuel from HTRs already legally possible

- Direct disposal of spent fuel from LWRs under legislation

- Pilot conditioning plant for spent fuel under construction at Gorleben

- Repositories for radioactive waste:
  - Morsleben (Sachsen-Anhalt) for low- and intermediate-level waste: in operation since 1981
  - Konrad (Lower Saxony) for non-heat generating waste: under licensing
  - Gorleben (Lower Saxony) for all types of radioactive waste, with emphasis on heat generating waste (vitrified HLW + spent fuel): site under exploration
GORLEBEN SITE SELECTION

- Nuclear Fuel Cycle Center with reprocessing plant, waste treatment facilities, and repository was planned in the early 70's

- Three proposed sites with salt domes in the State of Lower Saxony:
  - Wahn
  - Weesen-Lutterloh
  - Lichtenhorst

- Not accepted by the State Government

- Proposal by the State Government in February 1977: G O R L E B E N

- Proposal accepted by the Federal Government in June 1977

- Gorleben Hearing in March 1979

- Decision by the State Government in May 1979:
  - Reprocessing Plant rejected (with the fatal statement of then acting Prime Minister Ernst Albrecht: "Can be realized from a safety point of view, but cannot be carried through politically")
  - Site exploration of salt dome accepted

- Start of first exploratory drilling in May 1979

NWTRB - Siting Critical Facilities
Reno, 12. April 1994

Klaus Kühn
GSF - Institut für Tieflagerung
GORLEBEN SITE
EXPLORATION PROGRAM (1/3)

  - 145 exploration boreholes
  - 322 wells for groundwater monitoring
  - 4 wells for long-time pumping tests

- Seismic investigations (1984)
  - 16 profiles with a total length of 150 km were shot and the data were processed and evaluated

- Cap rock and salt dome surface (1979 - 1985):
  - 44 exploration boreholes until about 30 m into the salt
  - 1 exploration borehole until 230 m into the salt

  - 4 deep exploration boreholes were drilled into the flanks of the salt dome, each fully cored borehole about 2000 m deep
GORLEBEN SITE
EXPLORATION PROGRAM (2/3)

- Shaft exploration boreholes (1982):
  - 2 exploratory boreholes were drilled to a depth of 900 m for detailed information to locate the two planned shafts

- Summary report of all results in May 1983 by BfS formed the basis for the decision to continue with underground site exploration

- Shaft sinking started in September 1986

- Updated summary report by BfS in April 1990 confirmed "expected site suitability"

- Target depth for the two shafts is about 840 m

- Detailed underground site investigation is absolutely necessary

- A coordinated program for underground exploration with drifts, boreholes, and geophysical investigations has been set up
Main target is to get a complete detailed picture of geology

Rock-mechanical and thermo-mechanical data of salt were previously elaborated. Therefore, only on site-confirmation is necessary

Possible presence of brines (e.g. brine pockets or brine inclusions) is not expected to cause problems
**LICENSING** (1/3)

- German Atomic Act of 1957 delegates licensing authorization for all nuclear installations to the Federal States with supervision by the Federal Government (presently BMU)

- Political impacts by State Governments on their licensing authorities, especially by Red or Red/Green Governments who want to phase out nuclear energy

- Continuous discussions and differences between Federal and State Governments

- Directions by the Federal Government according to Article 85 (3) of the German Constitution

- Licensing of the Gorleben exploration mine according to:
  - German Atomic Act
  - German Mining Law
Consequences of using the Mining Law:

- Mining Law does not provide for participation of the public
- Mining Authorities are State Authorities
- No directions by the Federal Government possible
- Mineral rights of salt belong to the land owner
- No expropriation possibility for an exploration mine
- Continuous and numerous law suits

Specific licensing procedure (Planfeststellungsverfahren) according to § 9 b of the German Atomic Act for construction and operation of a repository:

- Partial licenses not possible
- Concentration of all other relevant laws (e.g. construction, water, nature protection)
- New licensing procedure necessary if substantial changes occur
LICENSING (3/3)

- Prescribes public layout of planning documents and public hearing with intervenors
UNEXPECTED TECHNICAL PROBLEMS - SHAFT SINKING (1/4)

- Freezing technology has to be used for sinking the two shafts "Gorleben 1" and "Gorleben 2" because of the specific geological and hydrogeological situation above a salt dome.

- Shaft "Kolenfeld" for the potash mine "Sigmunds- hall" near Hannover was sunk with the same technology within 4 years (1965 - 1969) to a total depth of 940 m (freezing section to 243 m).

- Sinking of shaft "Gorleben 1" started on September 16, 1986, after completion of freezing.

- Unexpected inhomogeneous stress distribution occurred within frozen Tertiary clays at a depth of 234 m which endangered the preliminary precast concrete-block shaft lining.
UNEXPECTED TECHNICAL PROBLEMS - SHAFT SINKING (2/4)

- Supporting steel rings were installed within the endangered zone. One of those steel rings was not properly welded, broke, fell down and caused an accident.

- Shaft accident occurred on May 12, 1987, which killed one miner and injured five.

- Sinking was stopped and a new concept for the outer preliminary shaft lining was developed.

- Shaft sinking could only be resumed on January 23, 1989, after 20 months' interruption with a new preliminary lining system.

- Shaft "Gorleben 1" reached a depth of 312 m in December 1991. Sinking was interrupted because of brine detection in pre-drillholes within the fracture zone caused by contraction of the salt through freezing.

- Tightening of this fracture zone by drilling and injection was performed between December 1991 and June 1992.
UNEXPECTED TECHNICAL PROBLEMS - SHAFT SINKING (3/4)

- After resuming shaft sinking, the shaft reached its interim target depth at 350 m in November 1992

- Foundation for the final inner lining was installed between November 1992 and March 1993

- Subsequently, the final inner lining was mounted until August 1993

- Shaft "Gorleben 2" met the same fate:
  - Surface of salt dome was reached at 258 m in June 1992
  - Drilling and injection of contraction zone between June and October 1992
  - Interim target depth of 357 m reached in June 1993
  - Foundation installed from July until December 1993
  - Final inner lining subsequently mounted until March 1994
UNEXPECTED TECHNICAL PROBLEMS - SHAFT SINKING (4/4)

- Present situation of shaft "Gorleben 1":
  - Upper part penetrating the overburden is completed with final lining in place since August 1993
  - Freezing pumps were shut off on August 12, 1993, having been in operation since October 24, 1985
  - Standstill since September 15, 1993, because of lacking license for continuation of sinking

- Present situation of shaft "Gorleben 2":
  - Upper part penetrating the overburden is completed with final lining in place since March 1994
  - Freezing pumps were shut off on March 24, 1994, having been in operation since April 2, 1986
  - Standstill beginning end of April 1994 because of lacking license for continuation of sinking

NWTRB - Siting Critical Facilities
Reno, 12. April 1994
Klaus Kühn
GSF - Institut für Tieflagerung
UNEXPECTED GEOLOGICAL RESULTS -
THE GORLEBEN GROOVE (1/3)

- Multiple barrier system is internationally accepted

- Host rock "salt" is the most important barrier

- Geological overburden above the salt dome is one further barrier

- Generic information about overburden and caprock on top of a salt dome was available

- Tertiary and Quarternary clay layers were expected to form aquicludes above the Gorleben salt dome

- By extensive drilling exploration the "Gorleben groove" was detected

- This groove was cut into the overburden and partially into the caprock by a glacier during the Elster glaciation period in Quarternary (500,000 to 350,000 years before now)
The Gorleben groove is partially filled with Quarternary loose sediments.

The overburden above the salt dome is a complicated system of aquicludes, aquitards, and aquifers.

Hydrogeological investigations proved that the deeper part of the Gorleben groove is filled with saturated salt solutions.

Groundwater flow velocity was determined to be between 1.4 and 8.8 m/a in the aquifers.

There is, however, no flow within the saturated salt solution. Radionuclide transportation could only occur by diffusion.

Groundwater travel modelling was performed in the mid 80's using fresh water data.

At present, there is no fast computer program available which can include saturated salt solution.
A program was initiated to develop such a computer code

The political critics of the Gorleben project, supported by so-called "critical scientists", claim that the plain existence of the Gorleben groove is a "k.o.-criterion" for the site

The overburden above the salt dome is only one barrier in the total system

It can be proved - in spite of the existence of the Gorleben groove - that the total system of the Gorleben repository is able to meet the safety goals

These criteria were enacted in January 1983 by the then responsible Bundesminister des Innern (BMI) through publishing in the Federal Register.

The criteria define the overall safety goal according to the German Radiation Protection Ordinance:

Maximum dose of an individual shall be less than 0.3 mSv/a

(has to be proved for about 10,000 years)

This has to be achieved by a site specific safety analysis.

The criteria make use of the system's approach and the multiple barrier system:

- Waste form
- Waste packages
- Backfill and sealing
- Host rock formation
- Overburden and adjacent rock formations
- Biosphere
Criteria cover the normal expected behaviour of the repository system as well as the consequences of accident scenarios.

Criteria take into account "the general geological situation which cannot be standardized".

Consequently, the criteria do not specify figures or numbers, but establish deliberately some "margins of discretion".

The licensing procedure for the repository shall be performed within these margins of discretion "according to the level of science and technology" taking into account the site specific situation.

Consequently,

it is not necessary to find
the best site for the repository

but a site which is able to meet the safety goal within the system's approach.
SITE EVALUATION (1/2)

- The Gorleben salt dome is investigated with
  - an exploration program from the surface
  - an underground exploration program

- Exploration program from the surface was performed from 1979 until 1985

- Results achieved formed the basis to continue with underground site exploration ("expected site suitability")

- Underground site exploration of the Gorleben salt dome is absolutely necessary to get a detailed picture of the internal geological structure of the salt dome

- Two approaches for site evaluation:
  - Site evaluation can be done straight forward by application of the present state of knowledge in geological exploration and of mining experience
  - Site evaluation can only be done by a complete performance assessment (a safety or risk analysis) for the planned repository with a perfect set of site specific data
SITE EVALUATION (2/2)

- Yardsticks for site evaluation:
  - Legal requirements
  - Technical requirements
  - Performance assessment methodology
  - Multiple barrier system
  - Experience from prospecting and mining
  - Underground research laboratories

- Concurrence on site suitability is necessary between applicant and licensing authority
LESSONS LEARNED (1/3)

- Consensus on nuclear energy is desirable

- Understanding for the need of a repository must be established in spite of the NIMBY- and NIMEP-syndroms

- In a Federal System, basic understanding between the Federal Government and the State and Local Governments is required for siting a repository

- Legal situation should be clarified in advance as detailed as possible

- Clear licensing requirements and responsibilities are indispensable

- Criteria for site selection and site evaluation should make allowances for the system's approach and should not be too specified

- Positive basic understanding between licensing authority and applicant is necessary
LESSONS LEARNED (2/3)

- Certain flexibility within the licensing procedure is recommended

- Time schedules for site investigation and repository construction should be as realistic as possible, but must continuously be adjusted

- Quantities and qualities of radioactive wastes to be disposed of in the repository must be kept "à jour"

- Unexpected geological results and technical problems will occur

- Procedure for site evaluation and acceptance should be established

- Experiences (positive and negative) in geological exploration and mining should be used as much as possible

- Costs are not to be completely neglected

- Positive interaction with the public should be strived for without the possibility that public opinion prevents the project
LESSONS LEARNED (3/3)

- International Commission on Nuclear Waste Disposal (ICND) should be established with reference to ICRP

- Discussions on international repositories should not be a taboo any longer
INTERACTION WITH THE PUBLIC

(1/2)

- Gorleben Hearing on the planned Nuclear Fuel Cycle Center in March 1979
  (Chairman: Prof. Carl-Friedrich von Weizsäcker)

- Public Hearing by the then responsible Committee of Interior of the Deutscher Bundestag (German Parliament) on Gorleben in 1984

- Public Hearing by the State Government of Lower Saxony in June 1987

- Second Public Hearing by the Committee for Environment, Nature Conservation and Reactor Safety of the Deutscher Bundestag after the shaft accident in April 1988

- Government changed in the State of Lower Saxony to a Red/Green-Coalition in May 1990: Installation of a committee with the objective "to consult the State Government for its target to phase out nuclear energy"

- "Braunschweig-Hearing on Radioactive Waste Disposal" by the State Government in September 1993
INTERACTION WITH THE PUBLIC

(2/2)

- Continuous information of the public about all technical and scientific results of the Gorleben project

- Public hearing with the intervenors is prescribed in the licensing procedure

- Public hearings and discussions were not interested in solving the problem of siting and constructing a repository, but in fighting "a religious or ideological war against nuclear power"