U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: SELECTED DESIGN CALCULATIONS

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Outline of Presentation

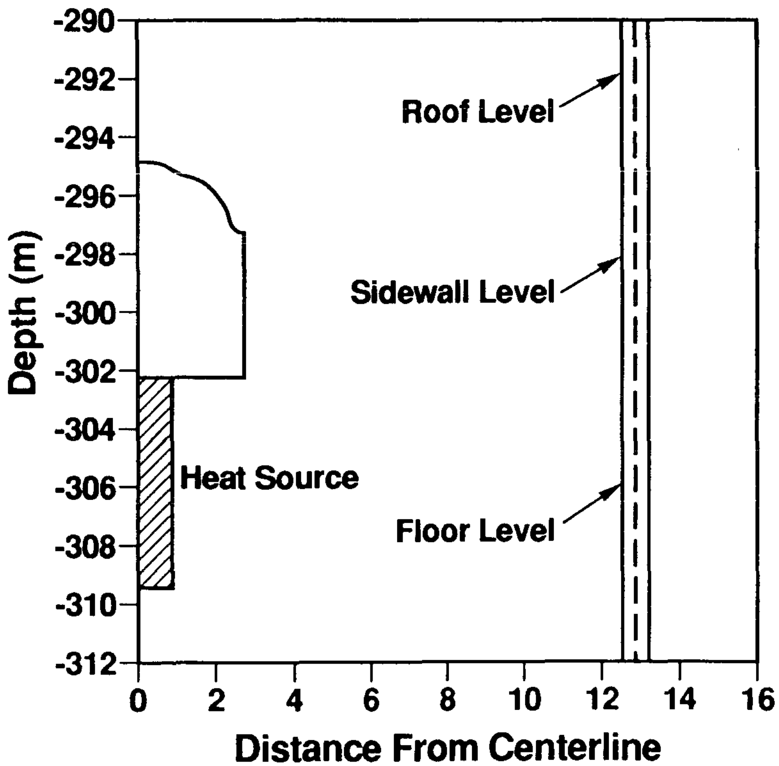
Selected Design Calculations to Developing a Sealing Strategy

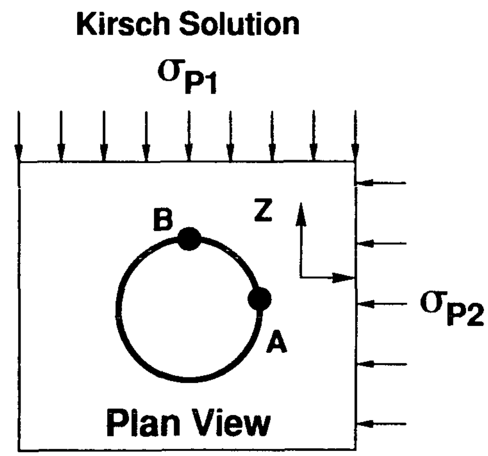
- **Evaluate stability of an open borehole near an excavation**
- **Evaluate buckling of a cased borehole near the repository**
- **Casing corrosion assessment**
- **Structural hydration calculations**

Objectives of Open Borehole Analysis Near an Excavation

- Determine state of stress on borehole surface near an excavation
- Establish minimum distance from entry
- Establish latest time for casing removal and seal placement

Borehole Near an Excavation





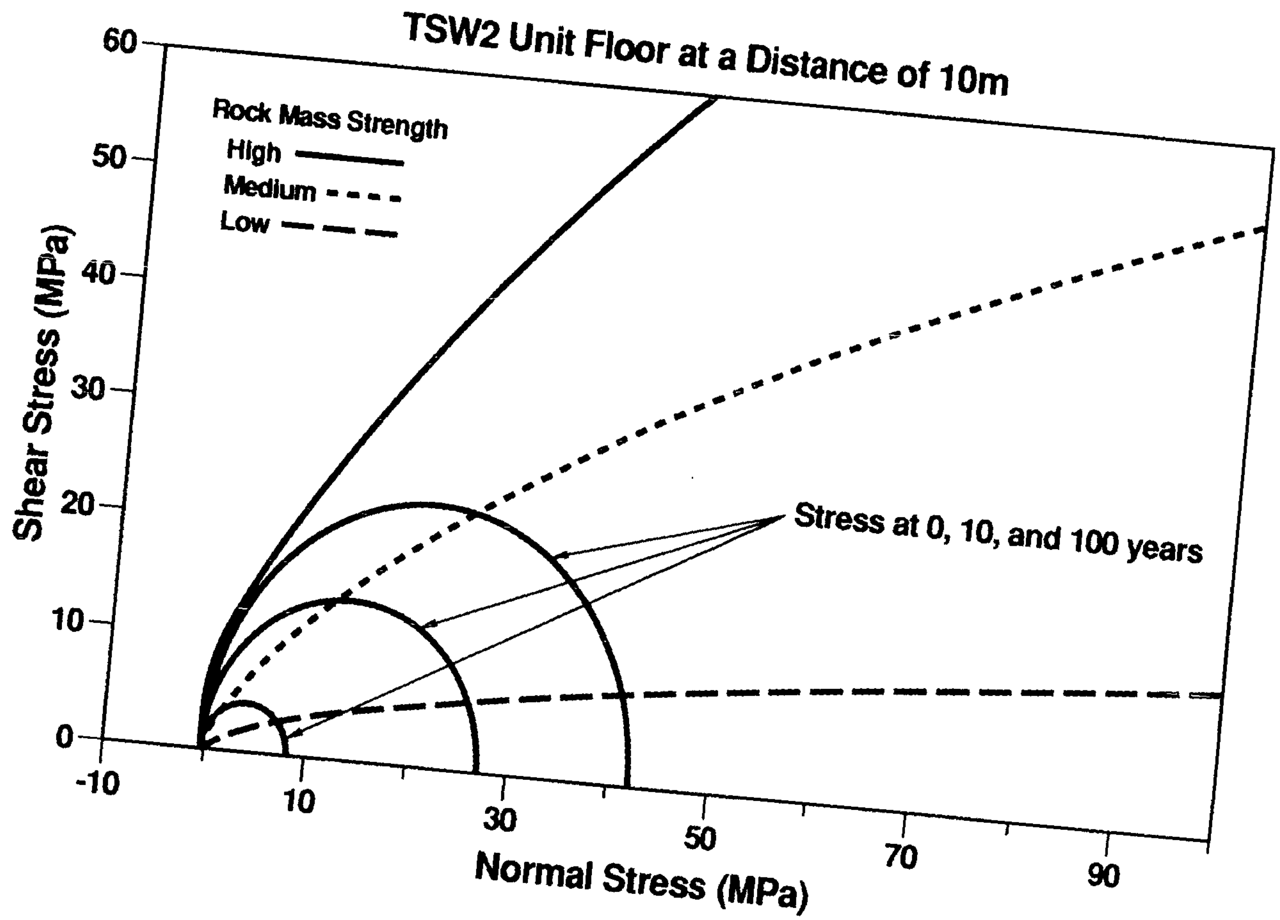
Tangential or Boundary Stress at A

$3\sigma_{P1} - \sigma_{P1}$

Tangential or Boundary Stress at B

$3\sigma_{P2} - \sigma_{P1}$

Mohr Failure Envelope



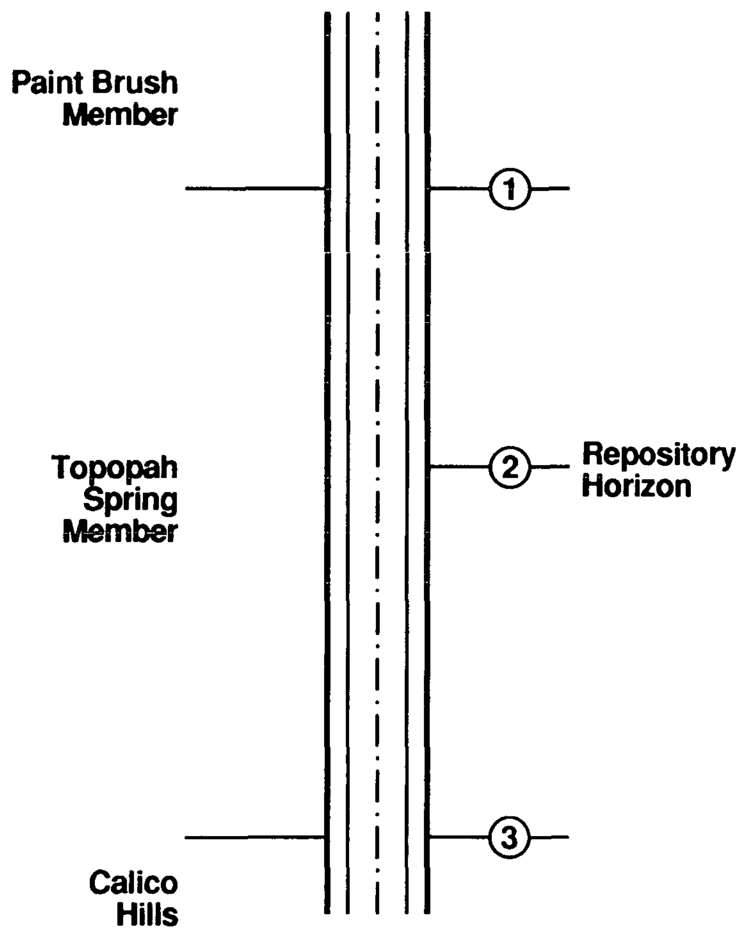
Preliminary Results From the Open Borehole Analysis

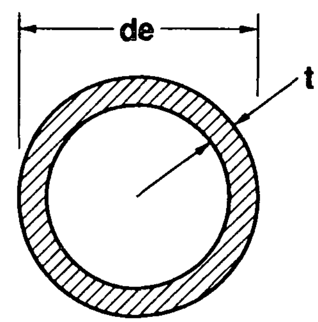
- Open boreholes stable for medium to high strength rock at ambient temperature
- Open boreholes undergo plastic deformation for low strength rock at ambient temperature
- Heating significantly elevates stress
- Open boreholes undergo plastic deformation for low to medium strength rock between 0 to 10 years

Preliminary Conclusions From the Open Borehole Analysis

- Locate seals away from repository horizon
- Potential borehole wall instability at repository horizon may require "early" sealing prior to waste emplacement
- Place seals in the Calico Hills and backfill concurrent with or before prior waste emplacement

Sealing Location for Casing Stability Analysis





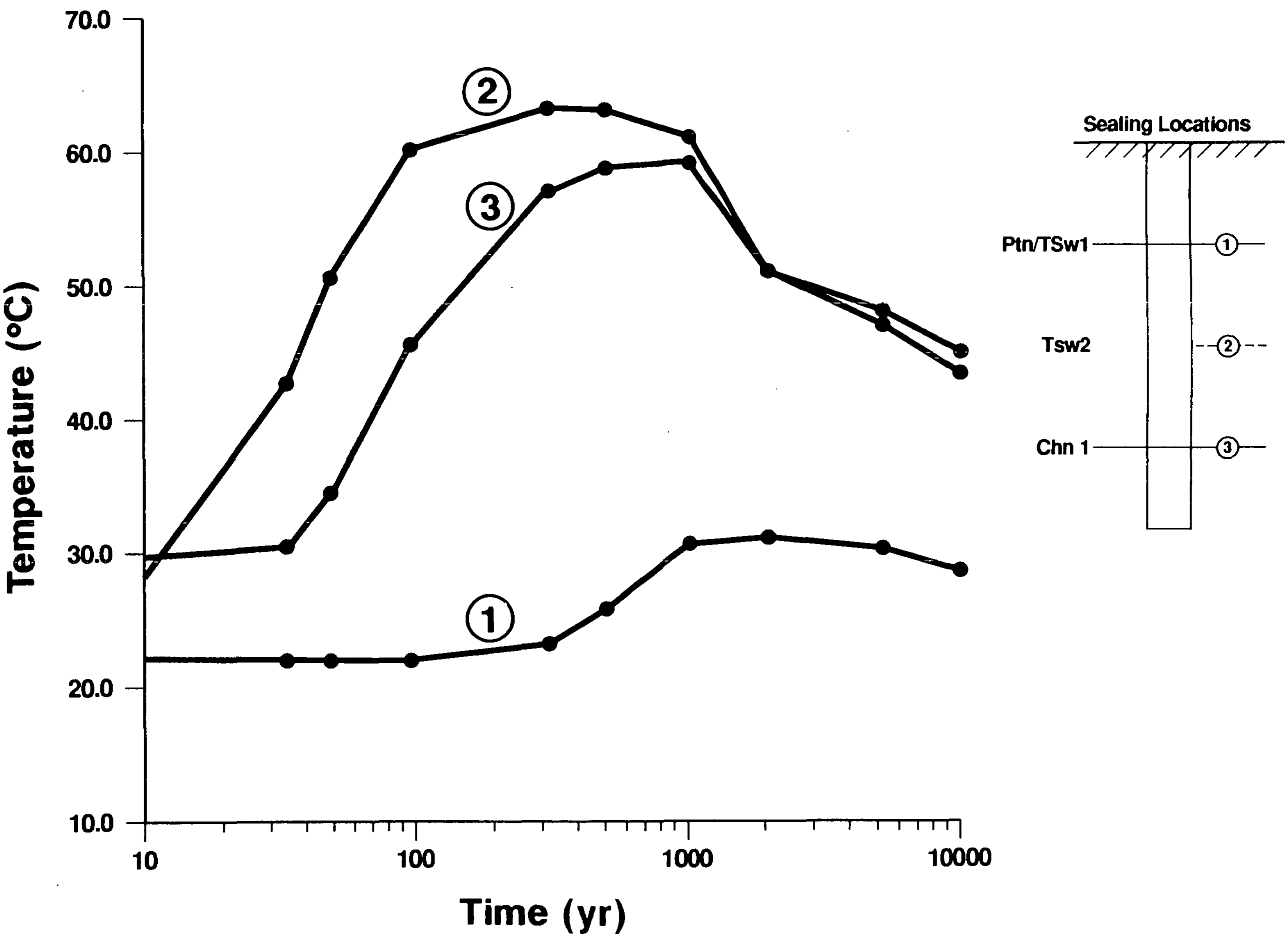
de = External Diameter
t = Wall Thickness

Plan View

Casing Stability

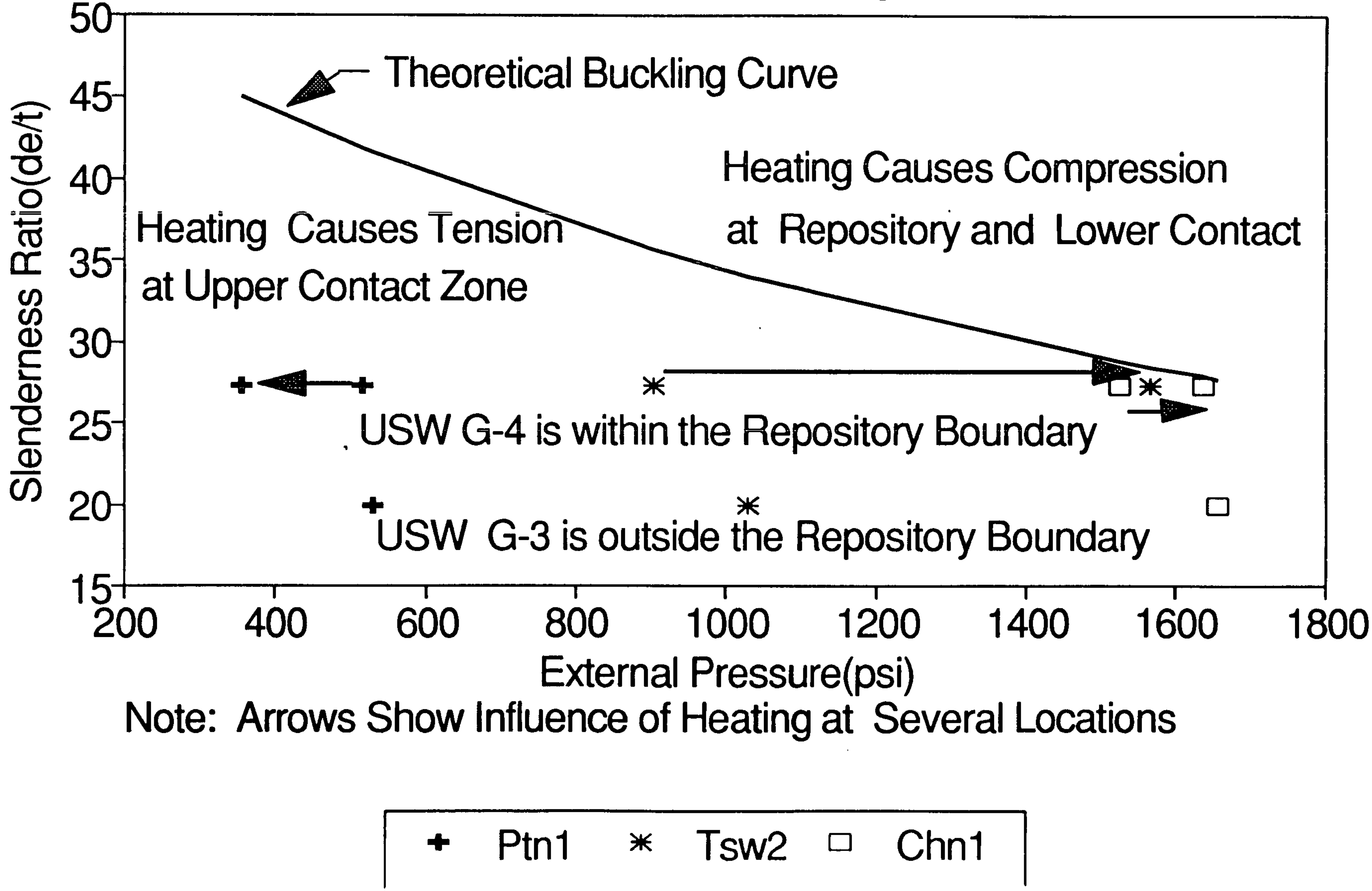
- Concern: Removal of buckled casing difficult
- Objective: Evaluate potential for casing
- Technical Approach:
  - Assume formation contacts the casing at prime sealing locations
  - Calculate increases in thermal stresses due to repository heating that are averaged in the horizontal plane
  - Steel casing (J55 or H40 steel)
  - Calculate elastic and plastic buckling stress

TEMPERATURE HISTORY AT H-5



Casing Stability

Influence of Heating



Note: Arrows Show Influence of Heating at Several Locations

Conclusions for Casing Stability Calculations

- Casing at sealing locations in the upper PTn unit is not expected to collapse
- Cased boreholes within repository interior such as USW H-5 and USW G-4 are marginally stable during repository heating
- Cased boreholes outside repository boundary are stable

Corrosion Assessment

Factors Affecting Corrosion of Steel Casing

- Contact between host rock and steel casing
  - Atmospheric corrosion
  - Soil/rock corrosion
- Composition and humidity of the air for free-standing column
- Host-rock resistivity, groundwater chemistry, and drainage affect corrosion
- No site-specific metallurgical evaluations made

Significance of Corrosion
Conclusions

- Penetration rate for atmospheric corrosion: 1 - 7 mils per year
- Penetration rate for soil corrosion variously reported as 5 to 100 mils per year
- Synergistic effects of stress and corrosion
- Existing collapsed zones expected to be isolated
- Metallurgical examination and logging of casing to address issue

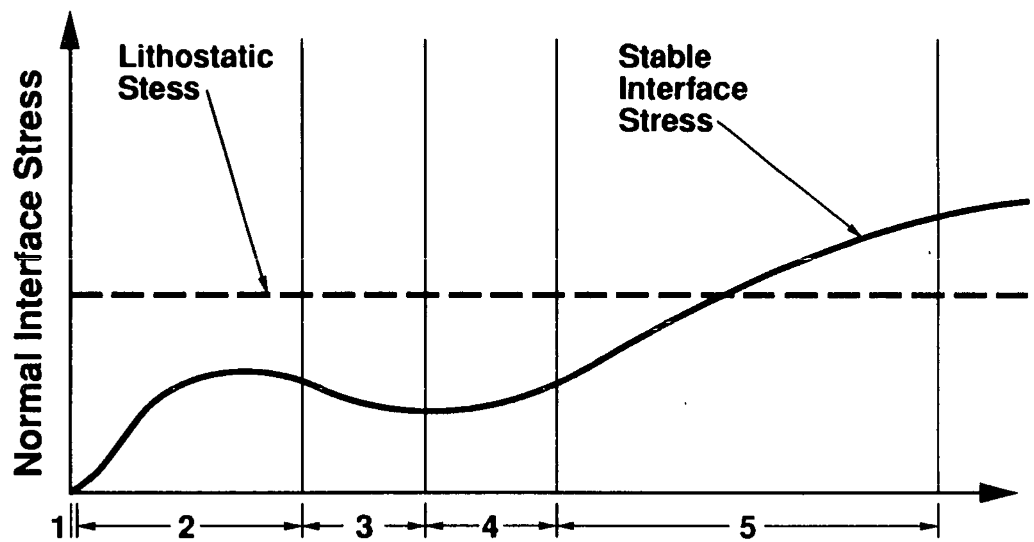
Structural Hydration Calculations

Objective

Evaluate structural hydration effects for

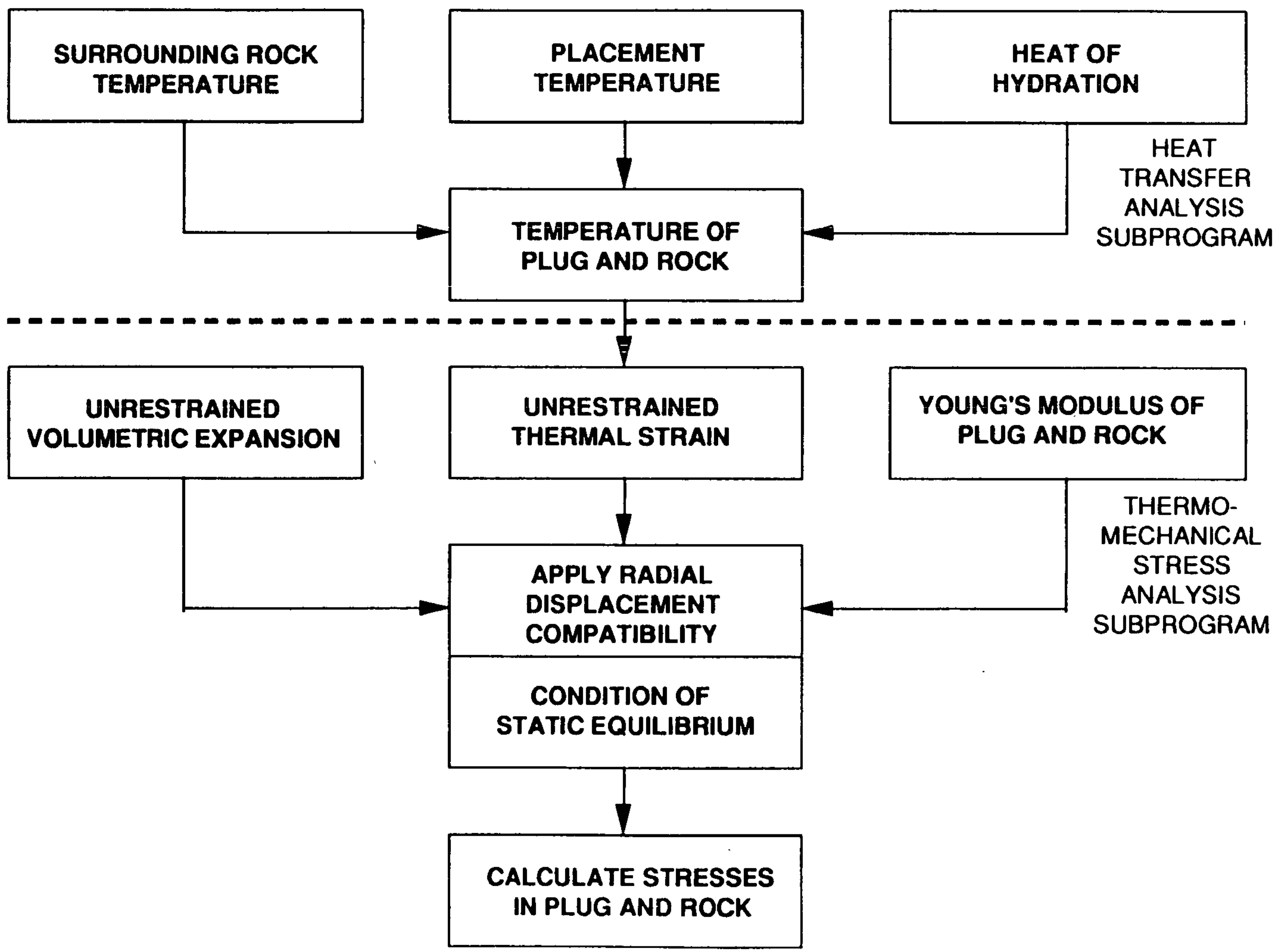
- Different materials
- Placement temperatures
- Seal locations

Stages in Plug Development



1. Initial mixing and placement
2. Volumetric and thermal expansion (cement hydration)
3. Thermal contraction during cooling
4. Primary creep of sealing material
5. Long-term operation

One-Dimensional Modeling and Analysis Using SHAFT.SEAL



Summary of Parametric Studies

Exploratory Borehole Seals

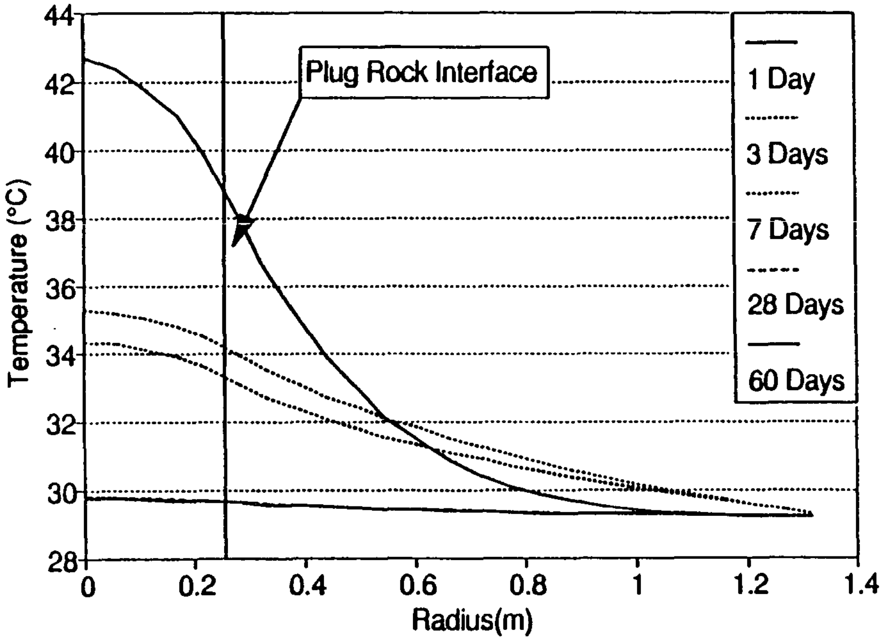
- Three sealing locations
  - PTn/TSw1 contact (#1)
  - Repository level (#2)
  - TSw3/CHn1 contact (#3)

- Two sealing materials
  - 82-22 mortar with Type K cement
  - 82-22 mortar with Type II cement

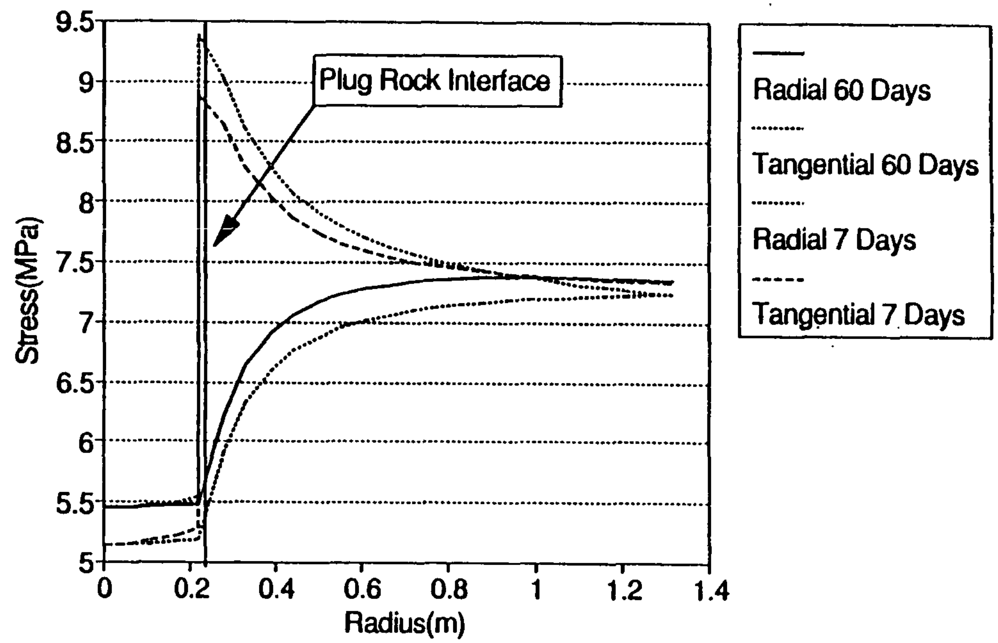
- Ultimate volumetric expansion
  - 0.6% for Type K mortar
  - 0.03% for Type II mortar

- Placement temperature
  - Ambient rock temperature at 25°C
  - Lower placement temperature to 4° C

Temperature Distribution in Plug and Adjacent Rock

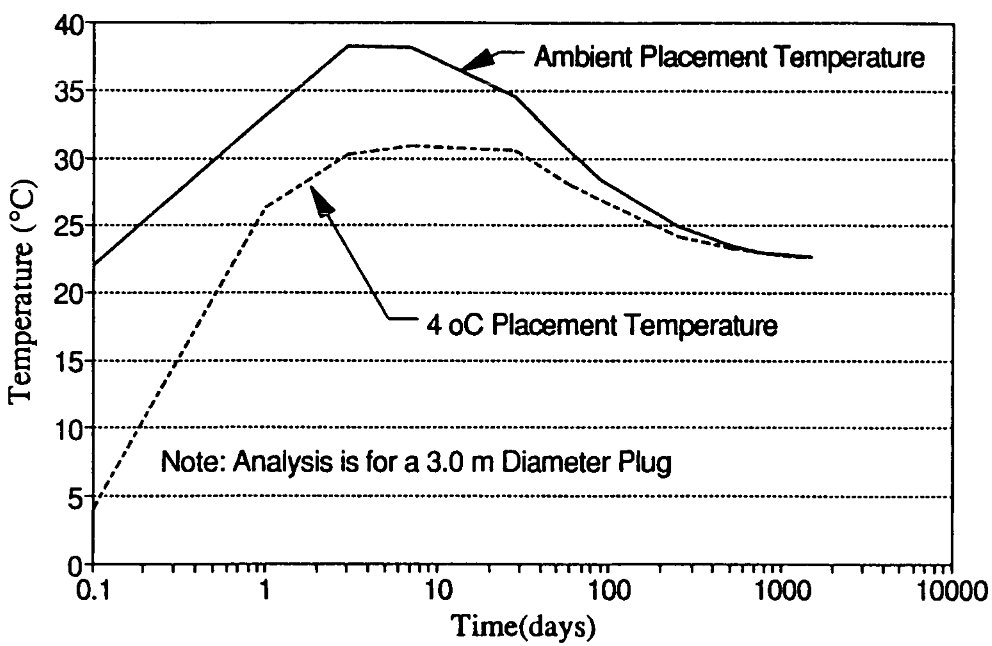


Stress Distribution in Plug and Adjacent Rock

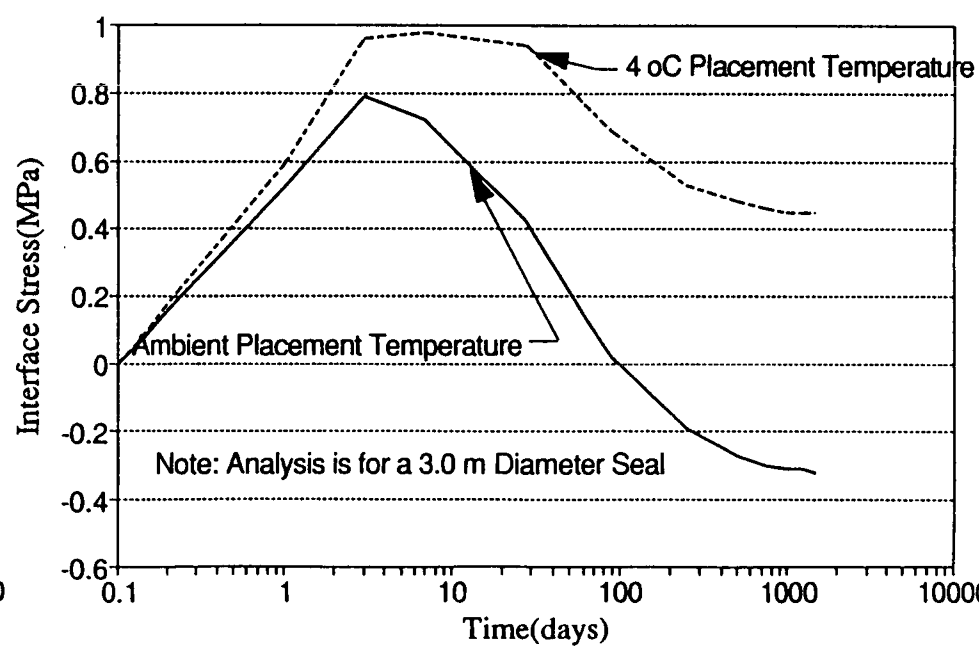


Influence of Placement Temperature on Temperature (a) and Interface Stress (b)

(a)



(b)



Conclusions From Seal Hydration Analysis

- Select design mix to develop compressive interface stress
- Reduce placement temperature (4°C)
- Use a slight injection pressure to develop compressive interface stress