LDRD
Laboratory Directed Research and Development

SAND2020-3218C

# Experimental Method Development to Evaluate Cements at Elevated Pressure and Temperature

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*GRC/SPE Cement Workshop*
*Thanks Arlene Anderson, US DOE GTO*





Geothermal Technologies Office
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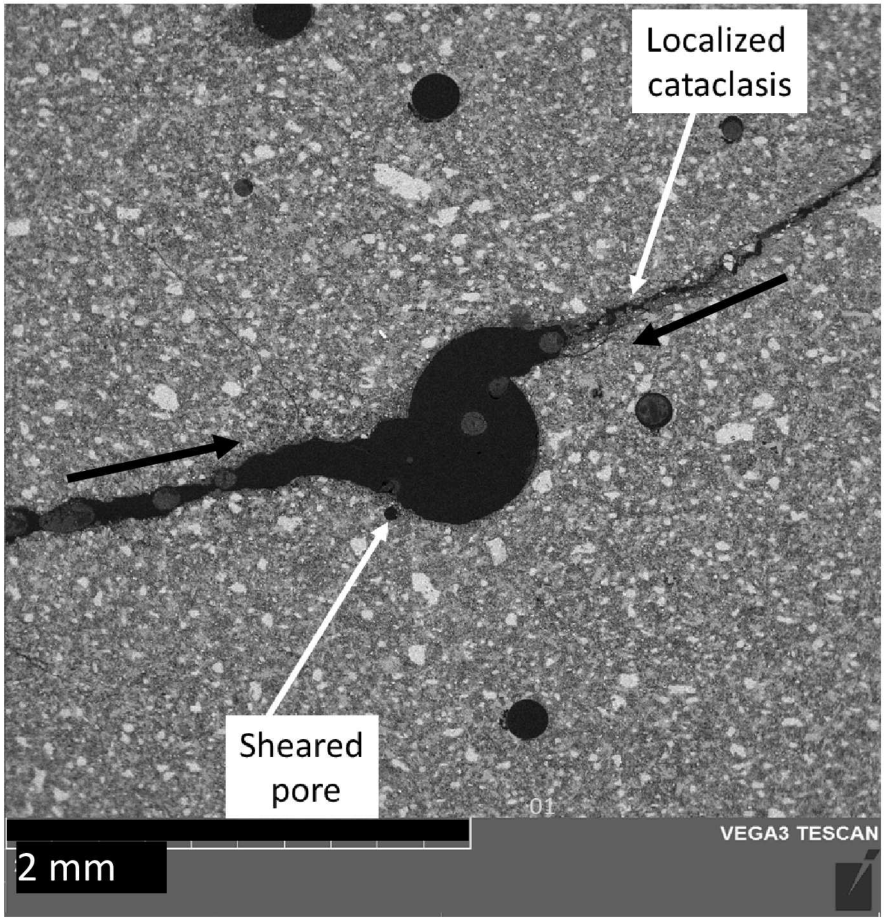
# Thoughts

1. Cement is a barrier to protect the casing
2. Poor cement, poor cement jobs, cement shrinkage, adverse conditions, cement torture, etc. **potentially leads to leaks through cement and casing degradation.
3. We can study (2) in the lab to try to better understand cement behavior
4. Fluid flow and observations used to evaluate cement

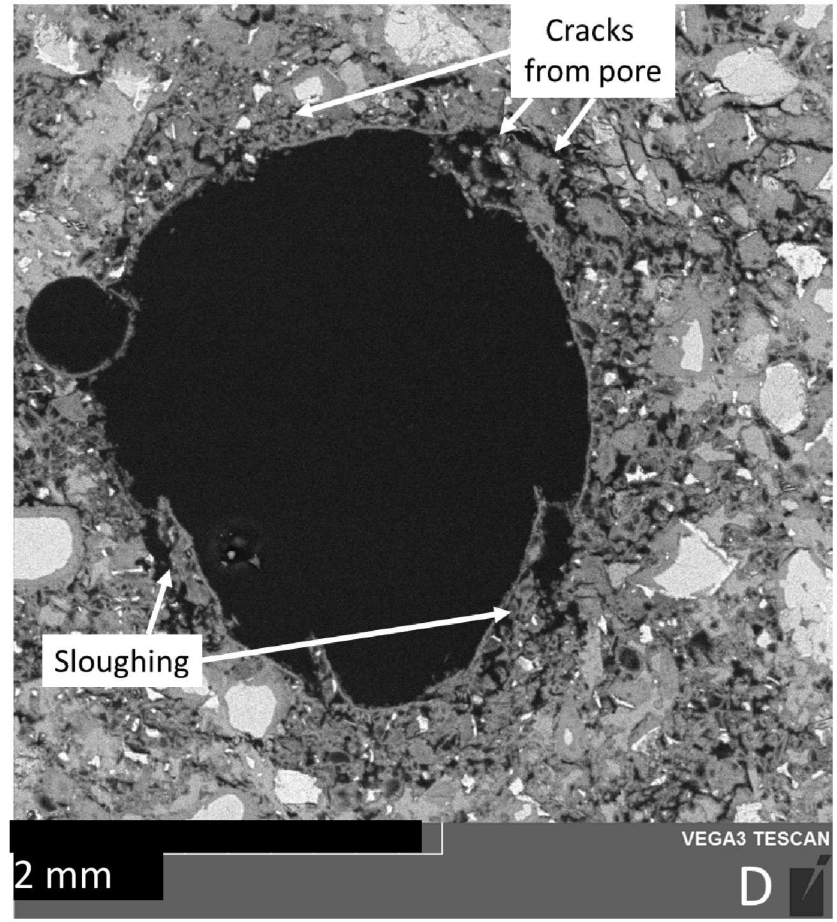
Question: What is the state of stress in cement?

# Neat cement room temperature gas permeant

## lab studies of neat cement permeability f(deformation)



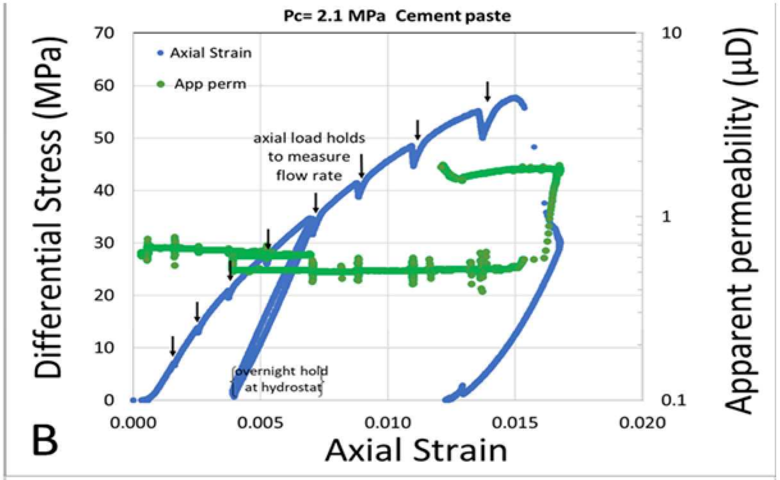

Sheared pore with cataclasis
Pc= 13.8 MPa

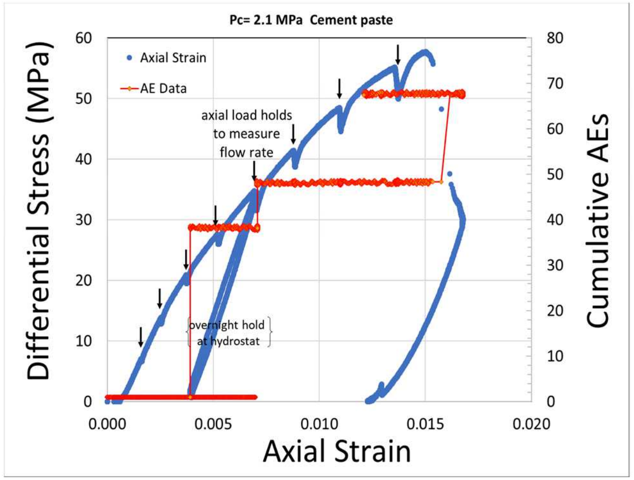



Sloughing from pore and microcracking associated with pore Pc= 2.1 MPa

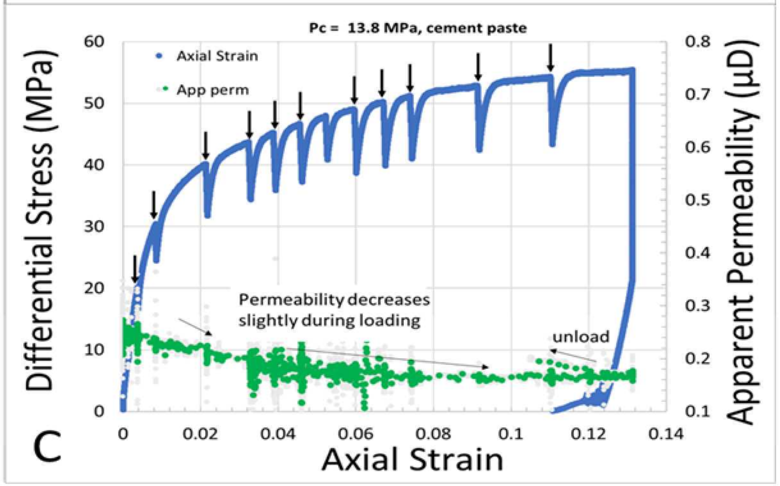
# Neat cement room temperature gas permeant

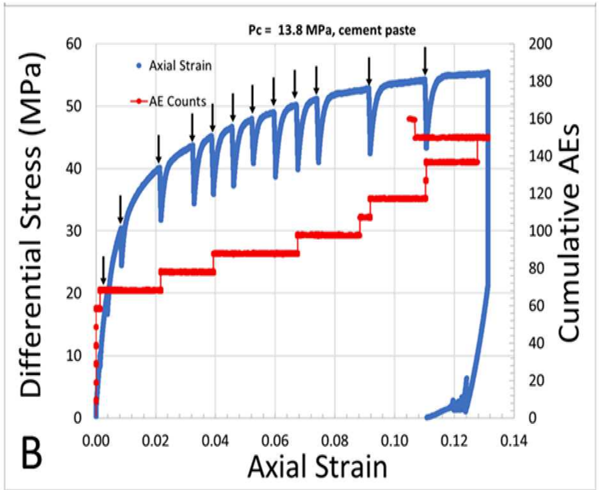
## lab studies of neat cement permeability f(deformation)




At low confining pressure cement fractures: flow rate increases by a factor of 5



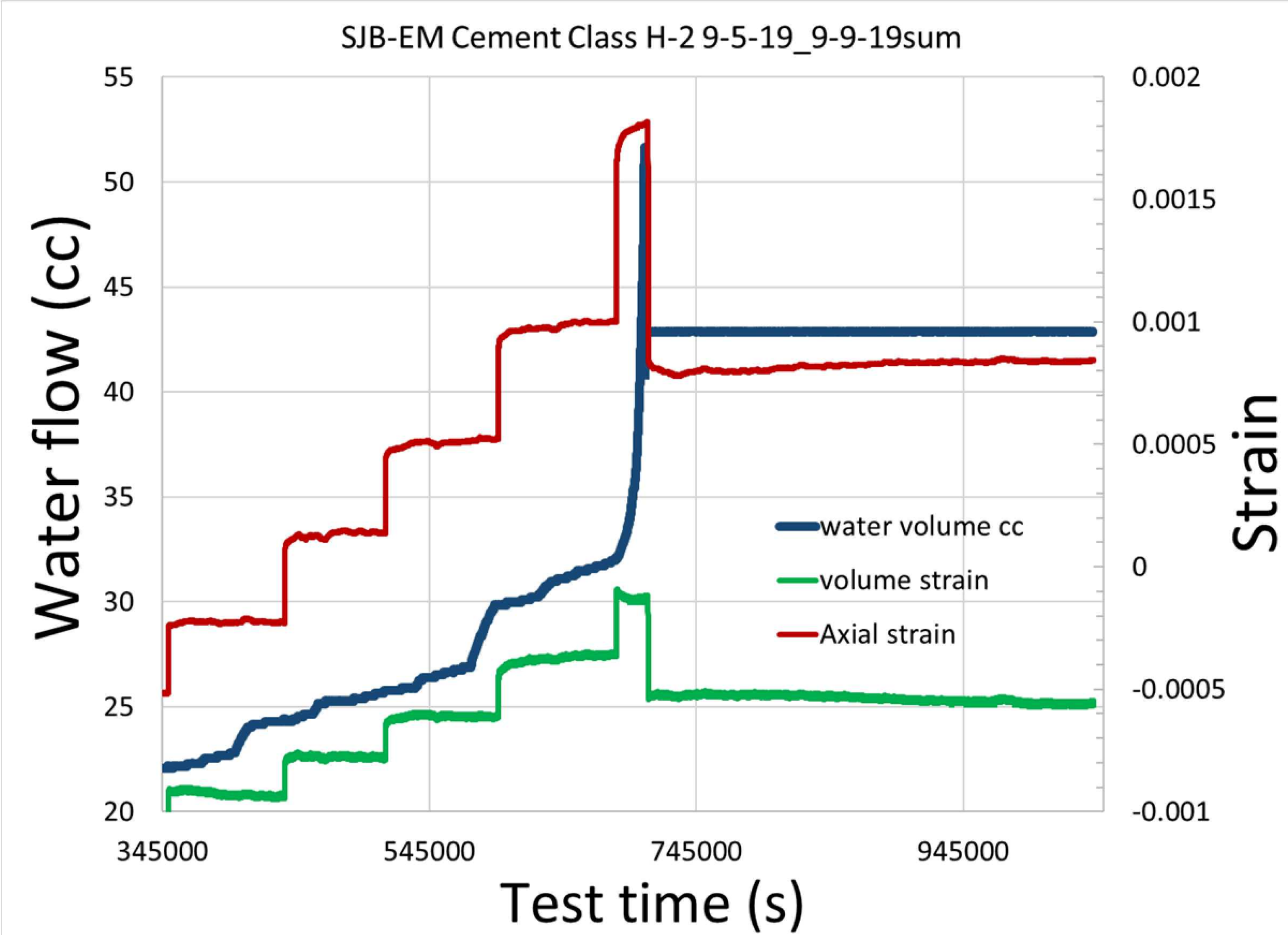




At greater confining pressure cement deforms predominantly by compaction: flow rate decreases

Sandia National Laboratories

SJBauer GRC/SPE cement workshop 2020

# Water permeant, neat cement, Pc=2.1 MPa




Similar to gas permeant, much longer test time

# High T&P Evaluations

***There exist geothermal conditions where geothermal wells are thermally cycled (rapidly), implying special cement formulations are needed:***

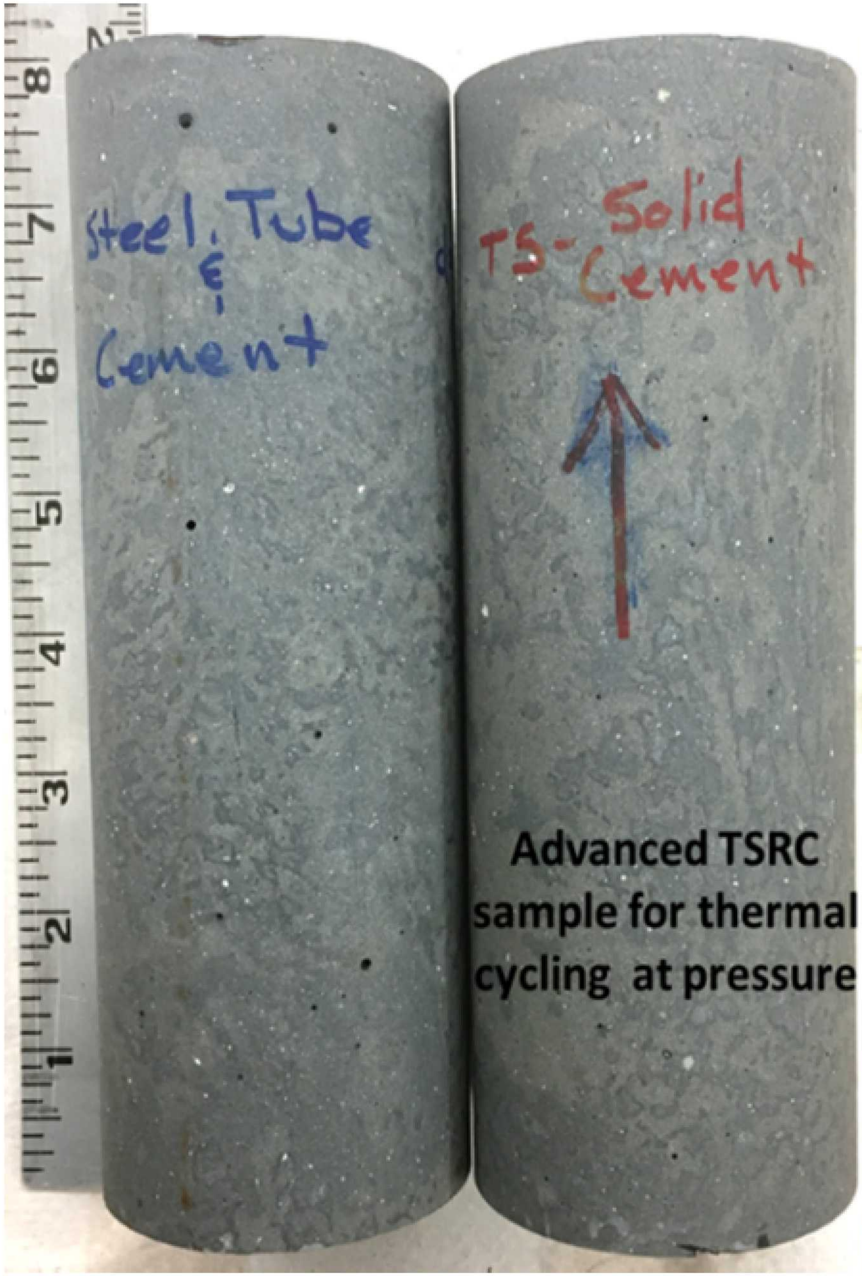
- ***Brookhaven Natl Lab is developing cement formulations***
- ***Sandia Natl Labs evaluating water-saturated cements at elevated P&T***

Sandia's work evaluates Thermal Shock-Resistant Cement (TSRC) developed by BNL. Sandia focused on determining thermal expansion, and fluid flow through cement, and application of thermal shock to a steel/cement sheathed sample.

Key contributions to the geothermal community include:

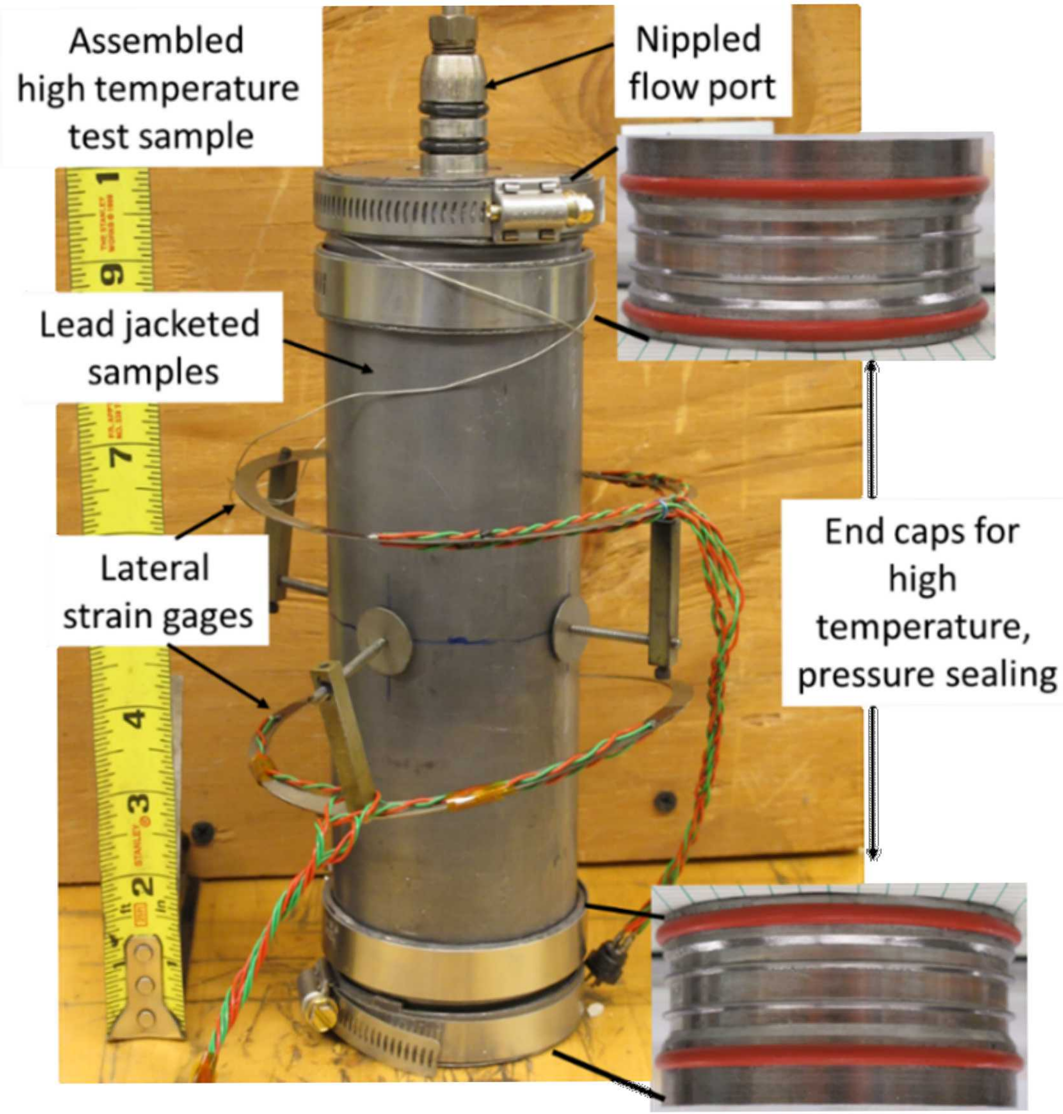
***(1)Development of a test system for thermal expansion and fluid flow measurements through TSRC at elevated P&T conditions relevant to in situ geothermal conditions,***

***(2) Development of a test system to thermally shock a steel/TSRC sheathed sample at elevated temperature and pressure conditions relevant to in situ geothermal conditions*** and,

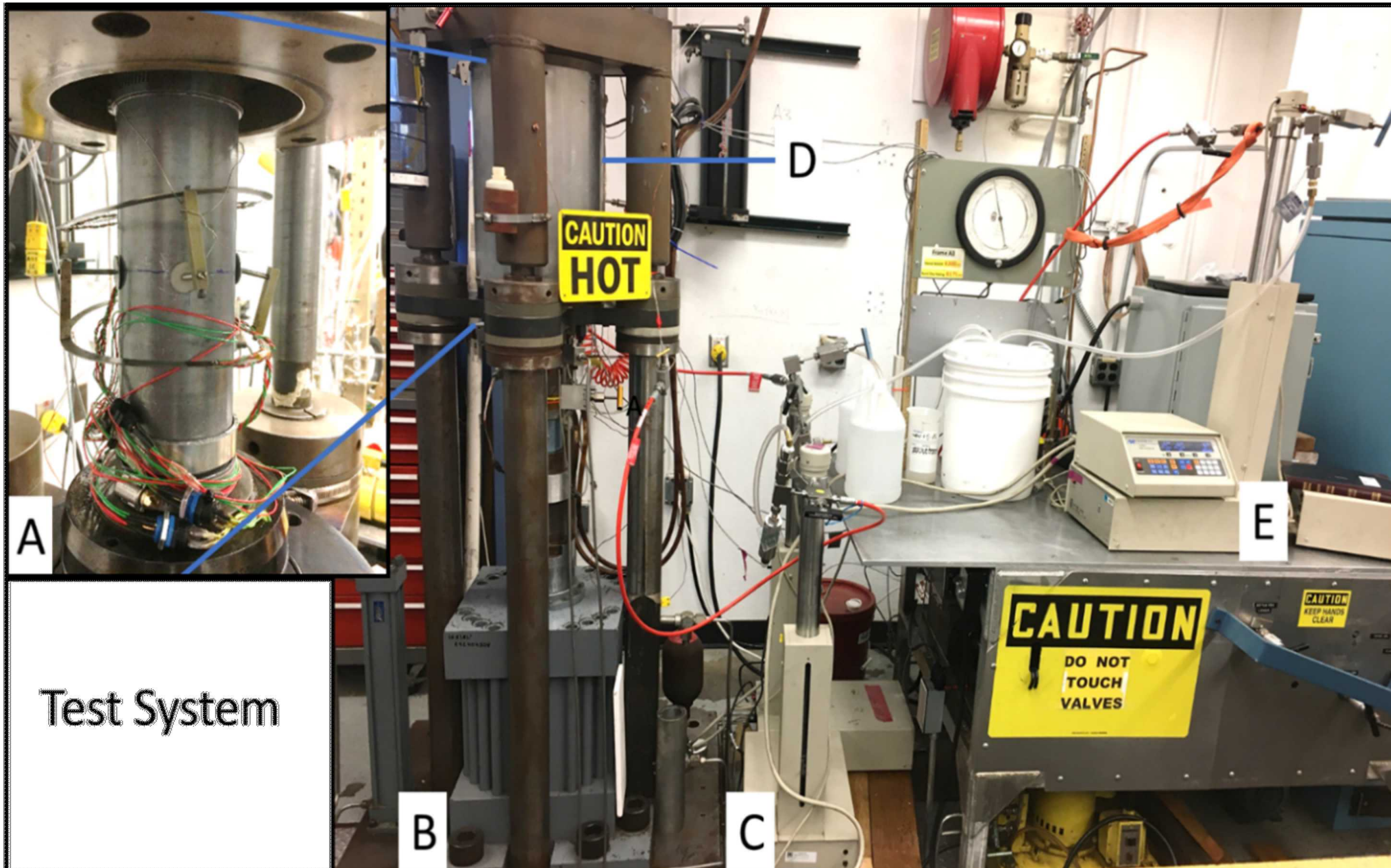

Steel Tube & Cement
TS- Solid Cement
Advanced TSRC sample for thermal cycling at pressure


Advanced TSRC sheathed upon steel for thermal cycling at pressure

## Test Condition goals:
## 250°C
## 13.8 MPa confining pressure
## 10 MPa pore water pressure




Schuler gage

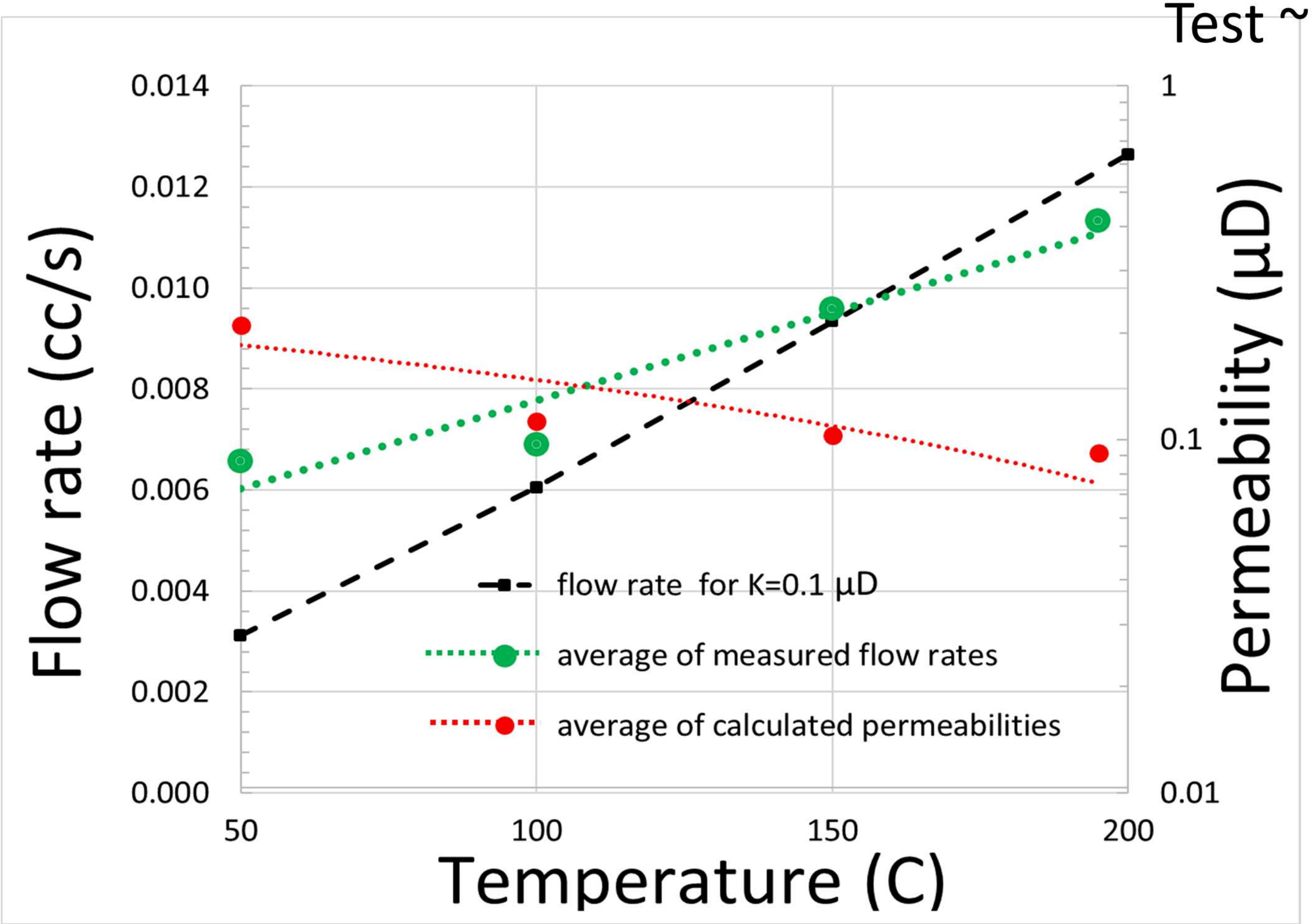

A
B
C
D
E
CAUTION
HOT
CAUTION
DO NOT
TOUCH
VALVES
CAUTION
KEEP HANDS
CLEAR

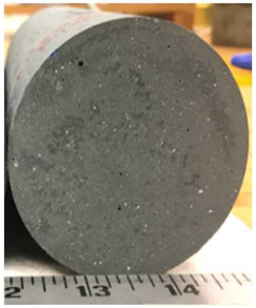
# Test System


CAUTION
HOT
Sandia Laboratories
CREEP BENCH SYSTEM
DO NOT CHANGE SCREEN RESOLUTION
A-FRAME SYSTEM
CAUTION
DO NOT TOUCH VALVES
CAUTION
KEEP HANDS CLEAR
TENSION
COMPRESSION

# Water flowed-through-cement testing

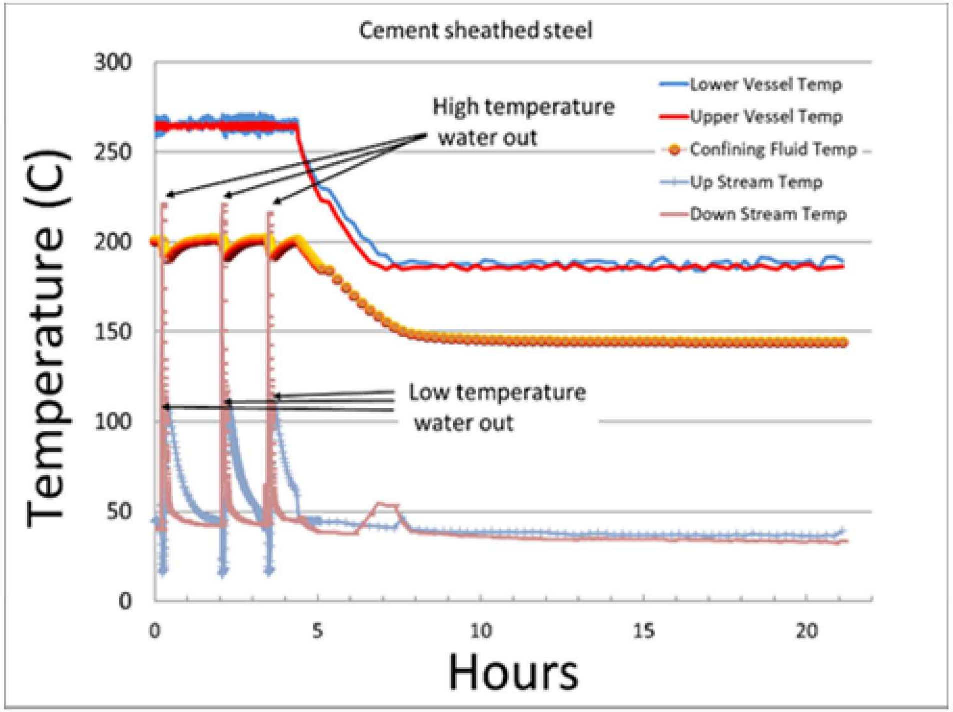
Pc =13.8,
Pp=10.3 MPa
T°C as below
Test ~ 2weeks

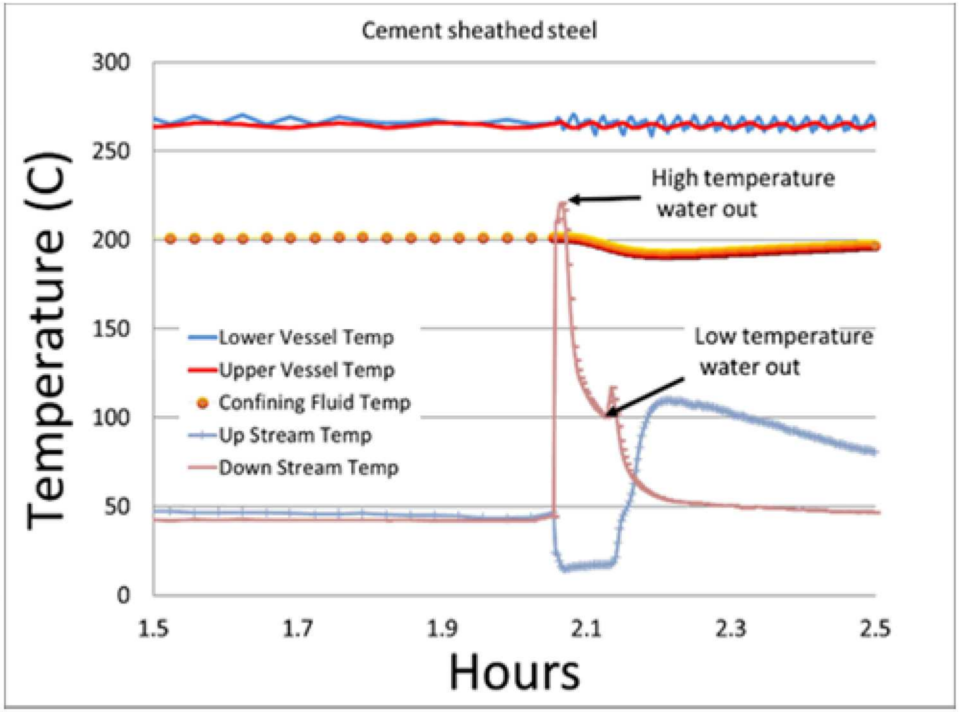



**Average of measured flow rates, average of calculated permeabilities**


Thermal shock sample subjected to ~12 thermal shock cycles over 8 days

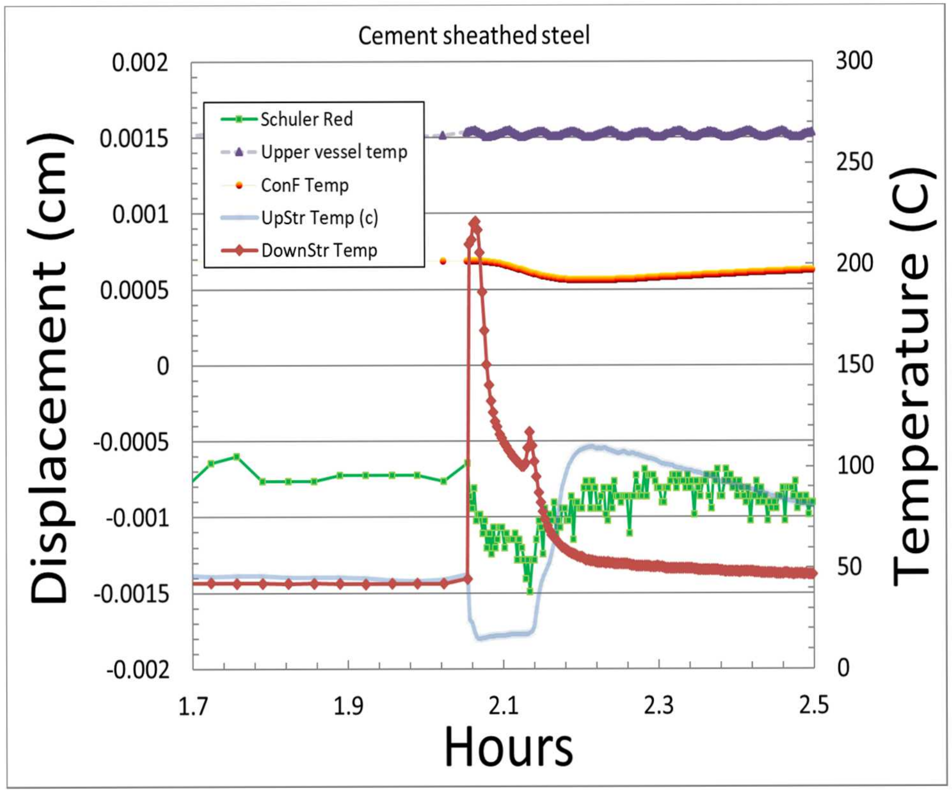


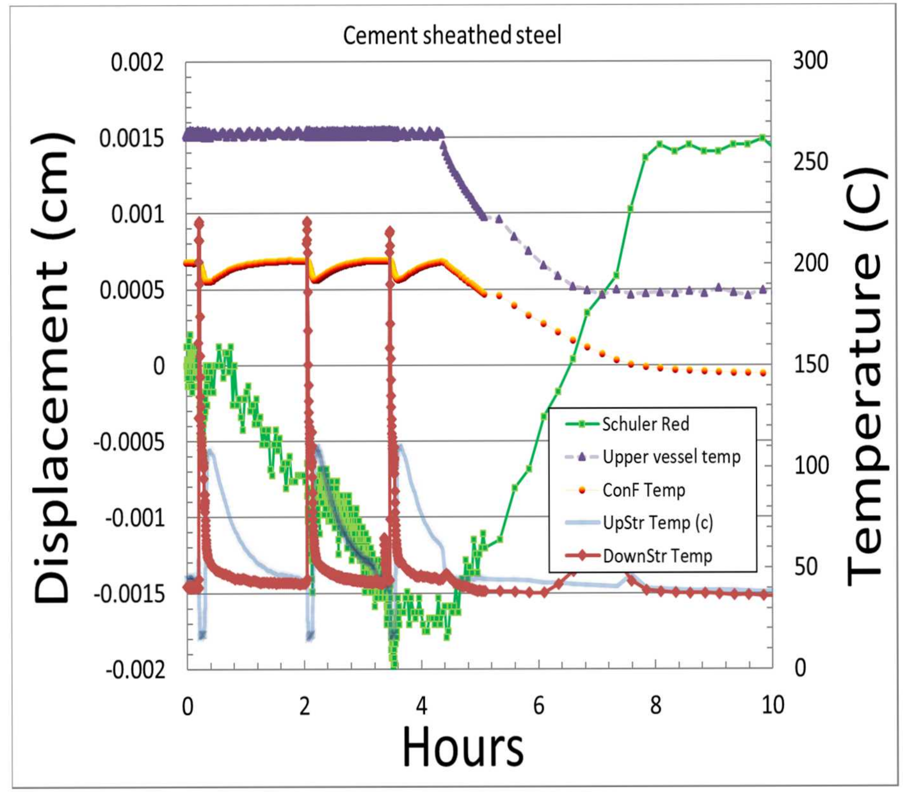

**Test time versus temperature for components of the cement sheathed steel test.**




**Test time versus temperature for components of the cement sheathed steel test with 2.5 hour time scale**

# Cement sheathed steel, thermal shock testing



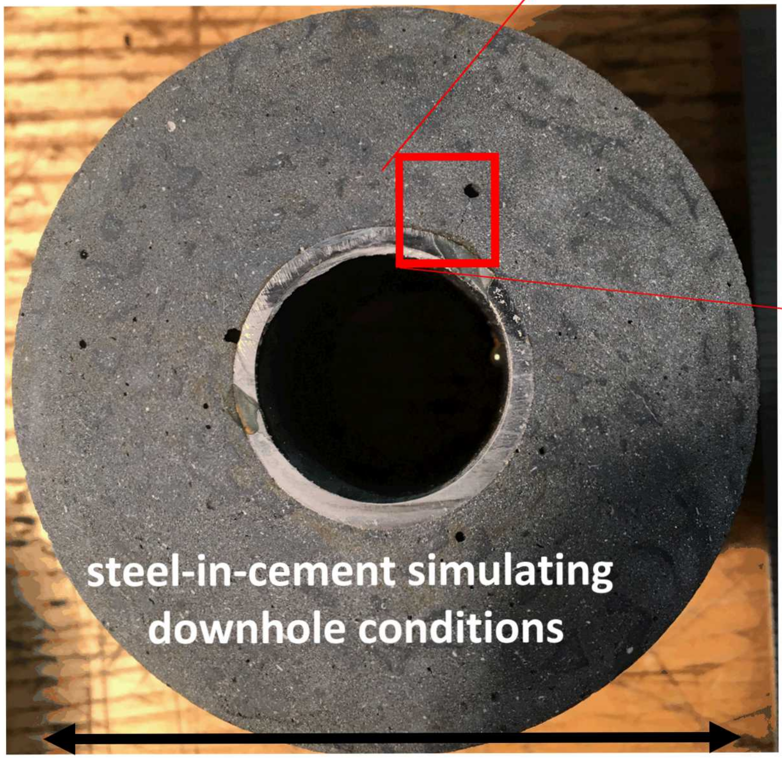




**Test time versus sample displacement and temperature during flow periods for cement sheathed steel sample.**

# High temperature cements evaluations: thermal shock at in situ conditions

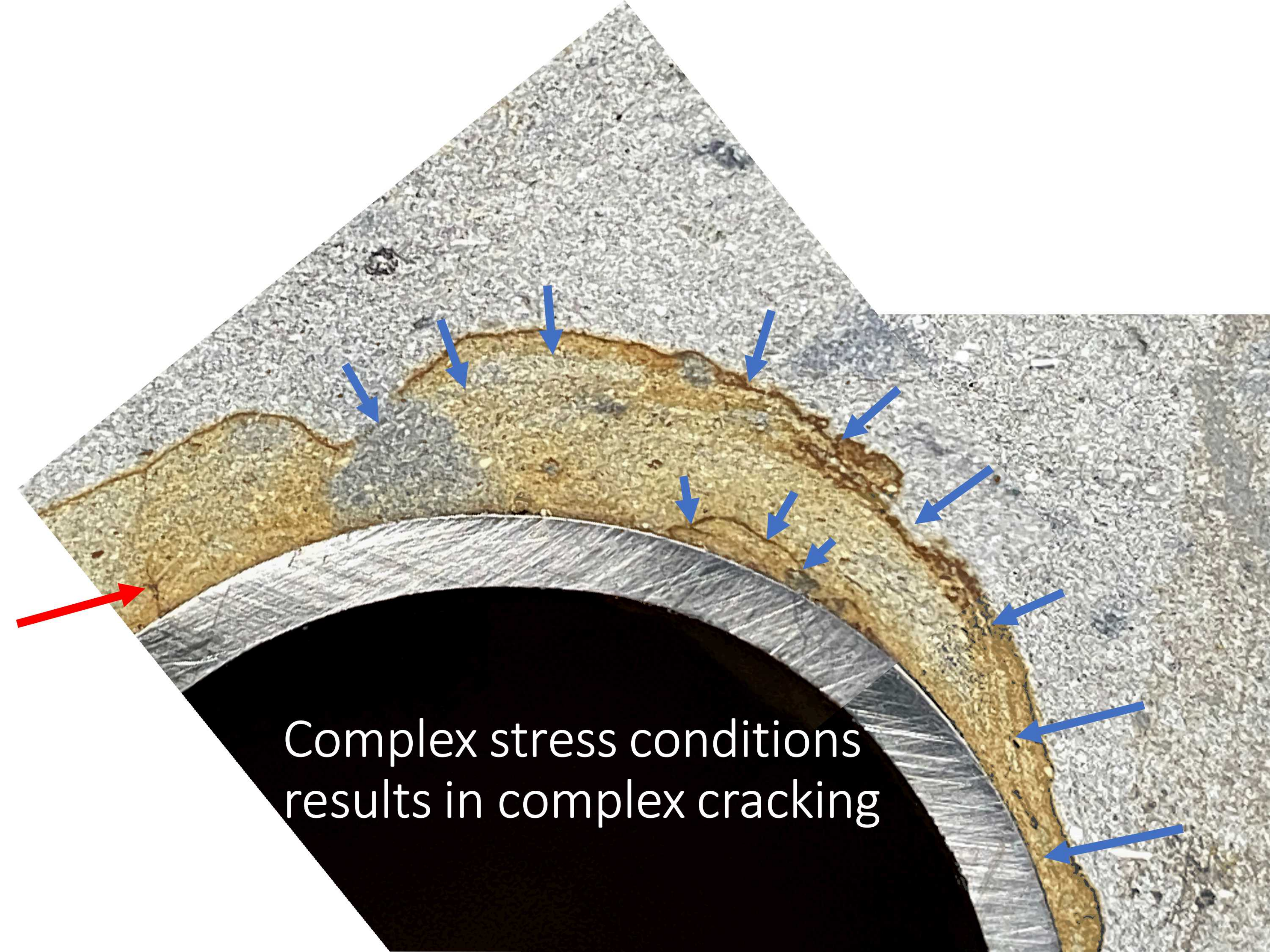
220C, 13.8 MPa confining pressure

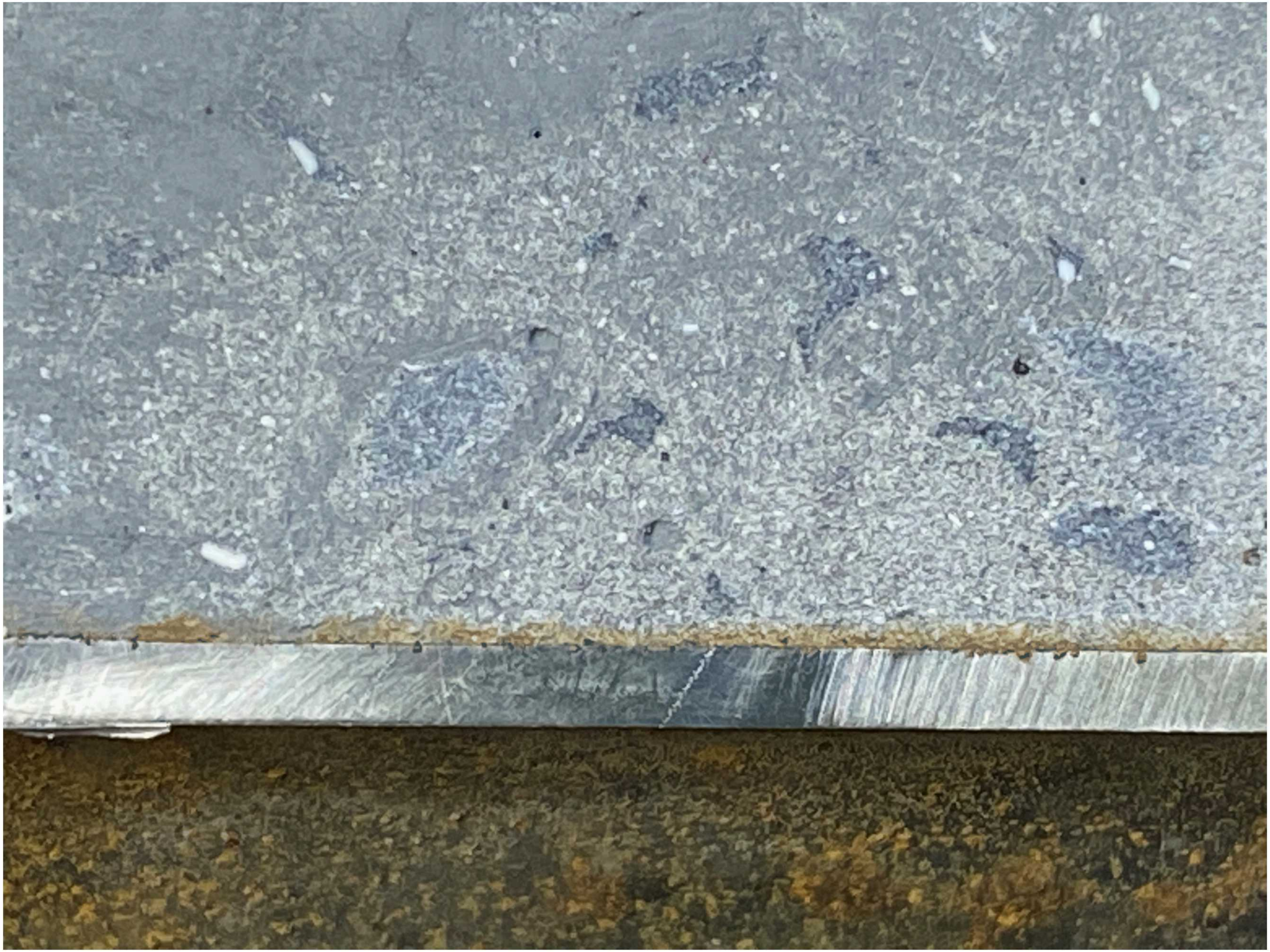
Steel-cement sample subjected to ~12 thermal shock cycles over 8 days




7.5 cm

**Crack growth from steel-cement interface**


Complex stress conditions
results in complex cracking



# FOR DISCUSSION

Room temperature testing and observations suggest cement deformed at low confining pressure will crack.

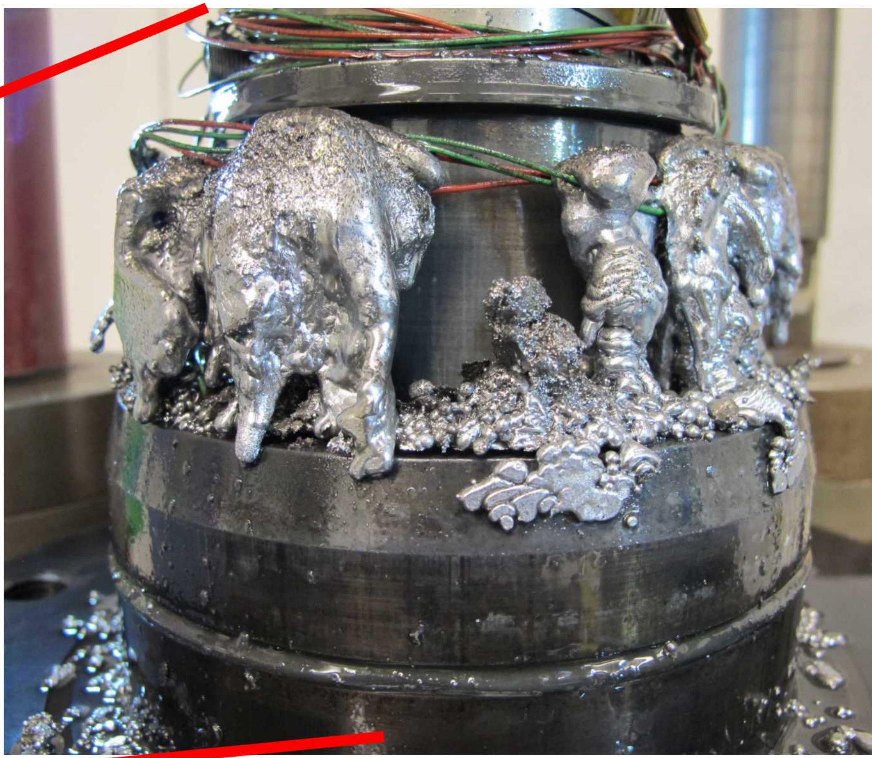
A test system was described  to evaluate fluid flow through cement at elevated temperature and pressure
*****estimates of permeability
AND, to thermally shock a steel/cement sheathed sample at elevated T&P,
***Successfully created a 100°C radial thermal gradient in about five minutes.
***Thermal fracturing observed

Laboratory work of this nature is important to study cement response to adverse conditions.

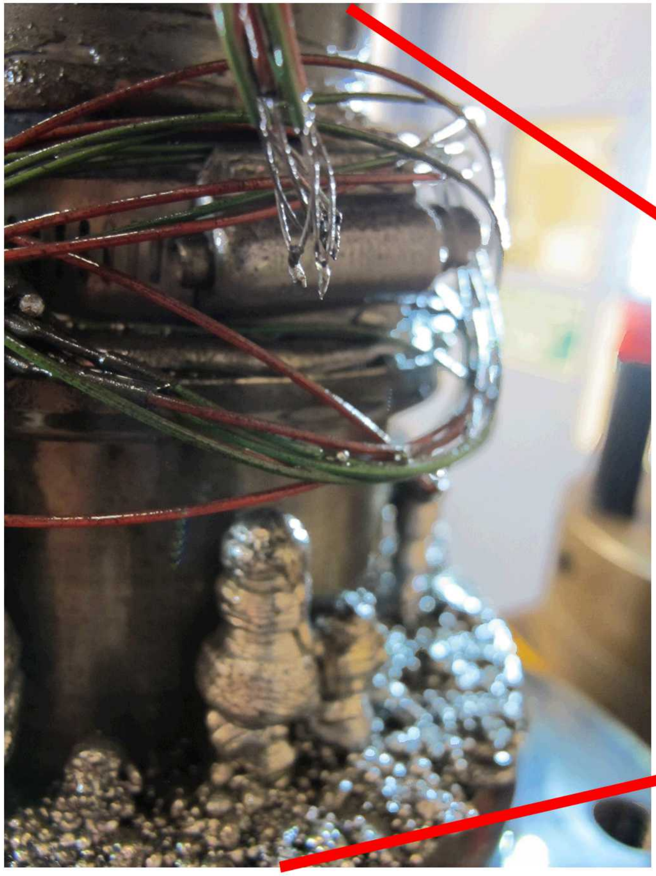
# Thanks!

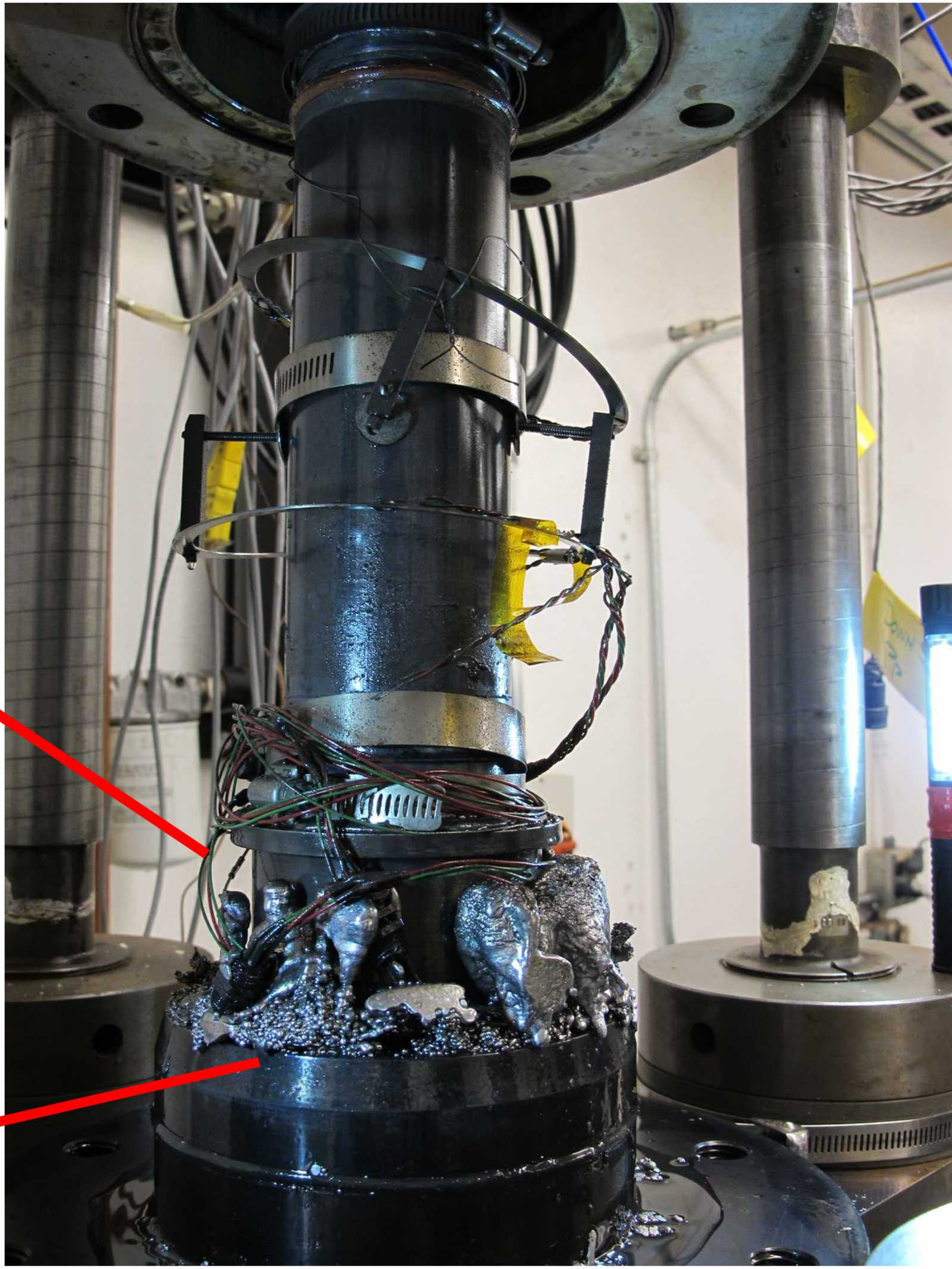
*Questions?*

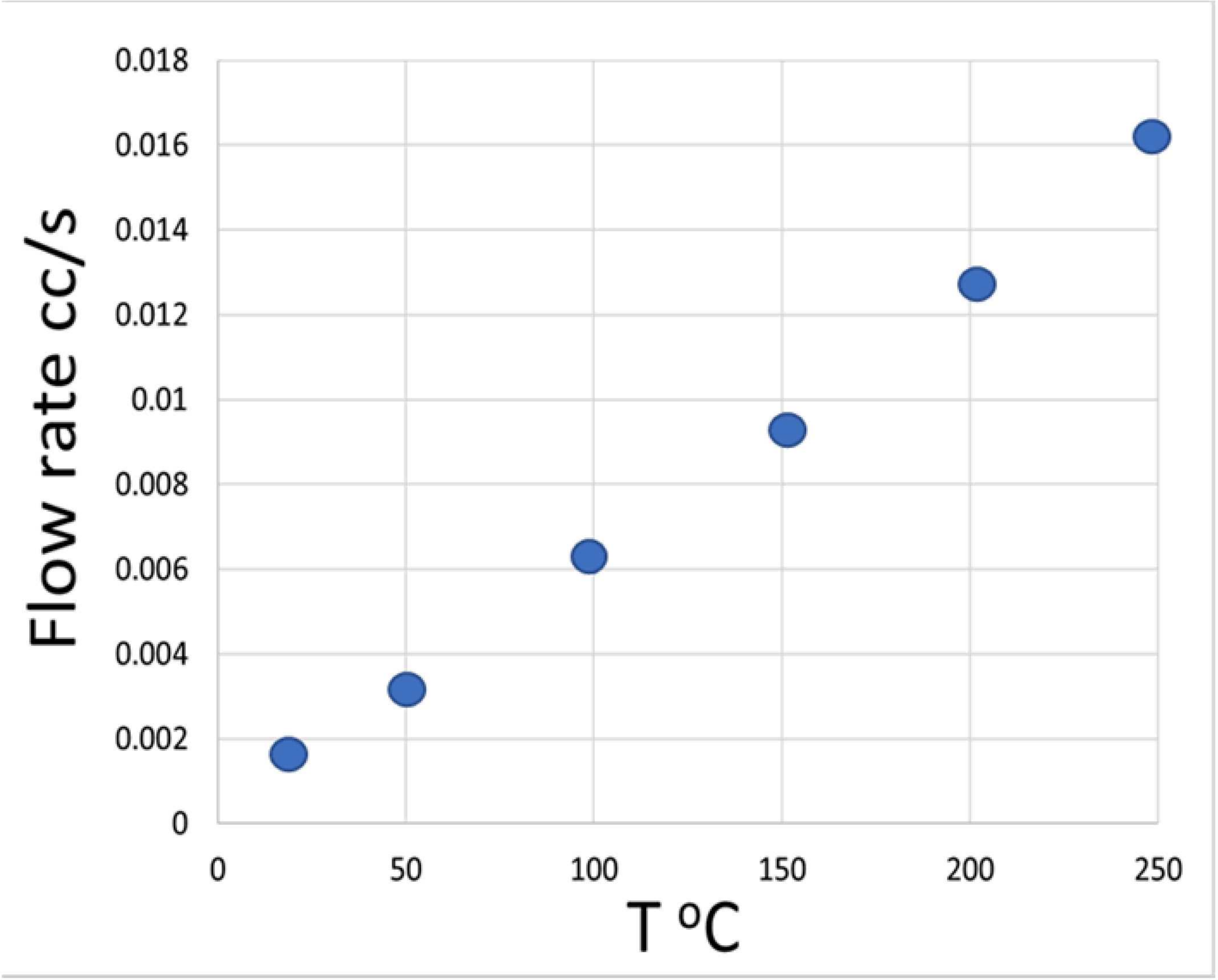
## Don’t try this at home



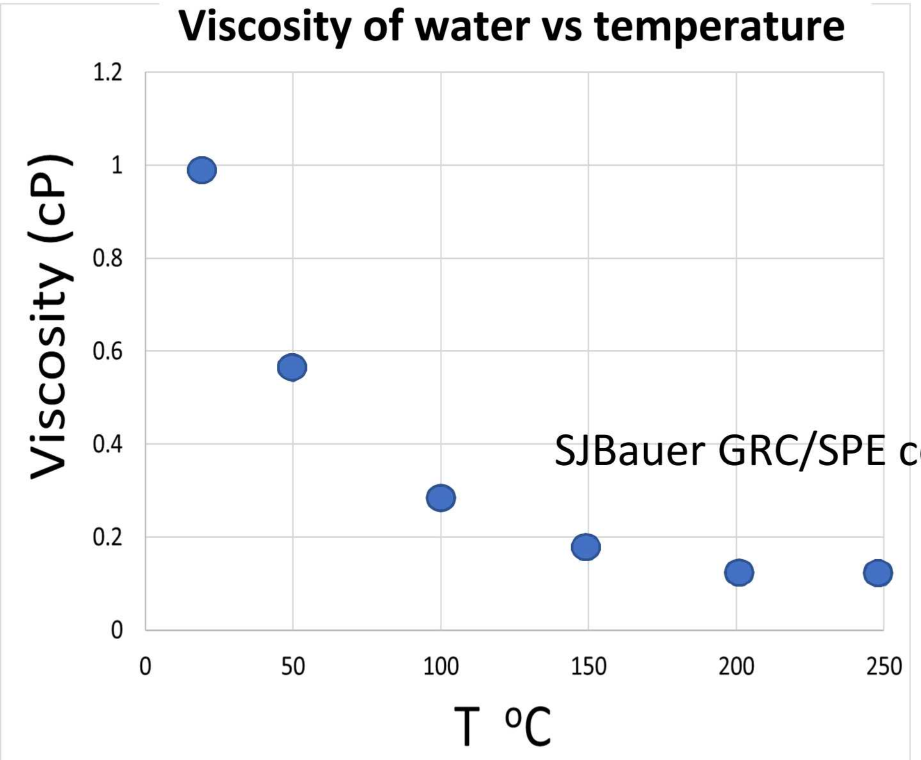
# Don’t try this at home

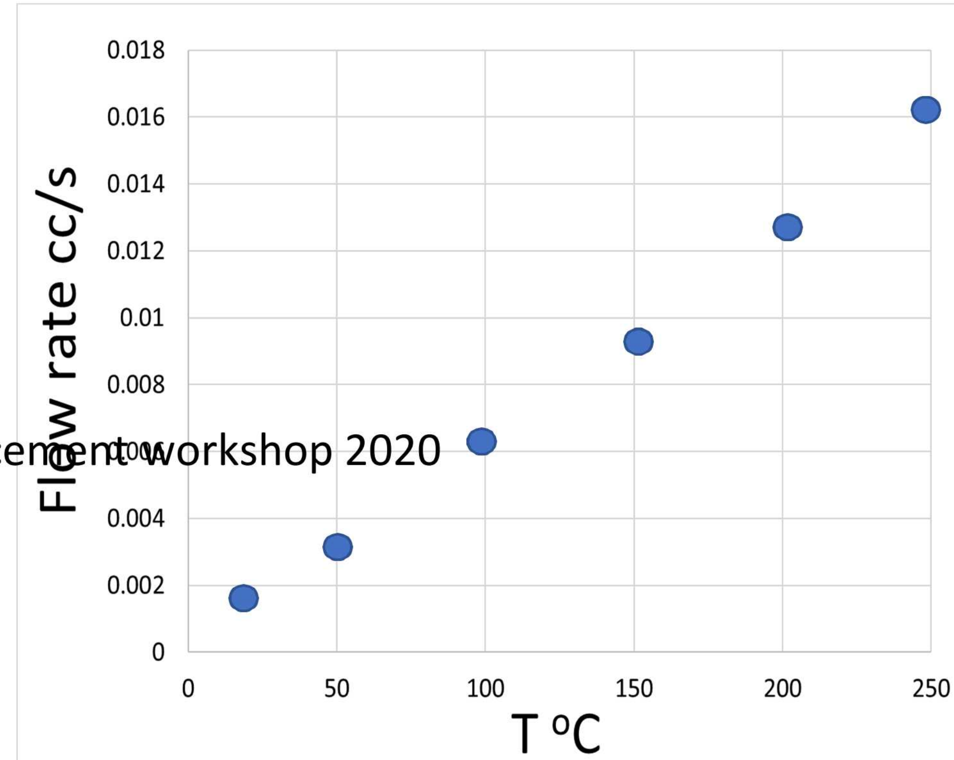







**Flow rate change for a 0.1 μD material considering temperature dependent water viscosity.**

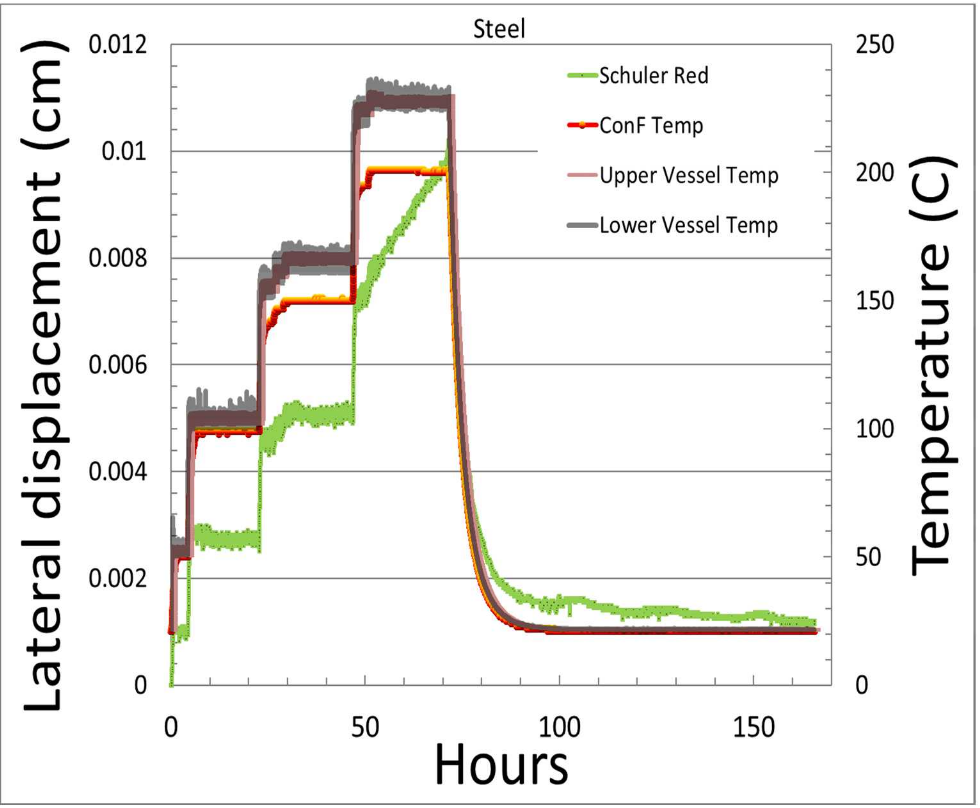


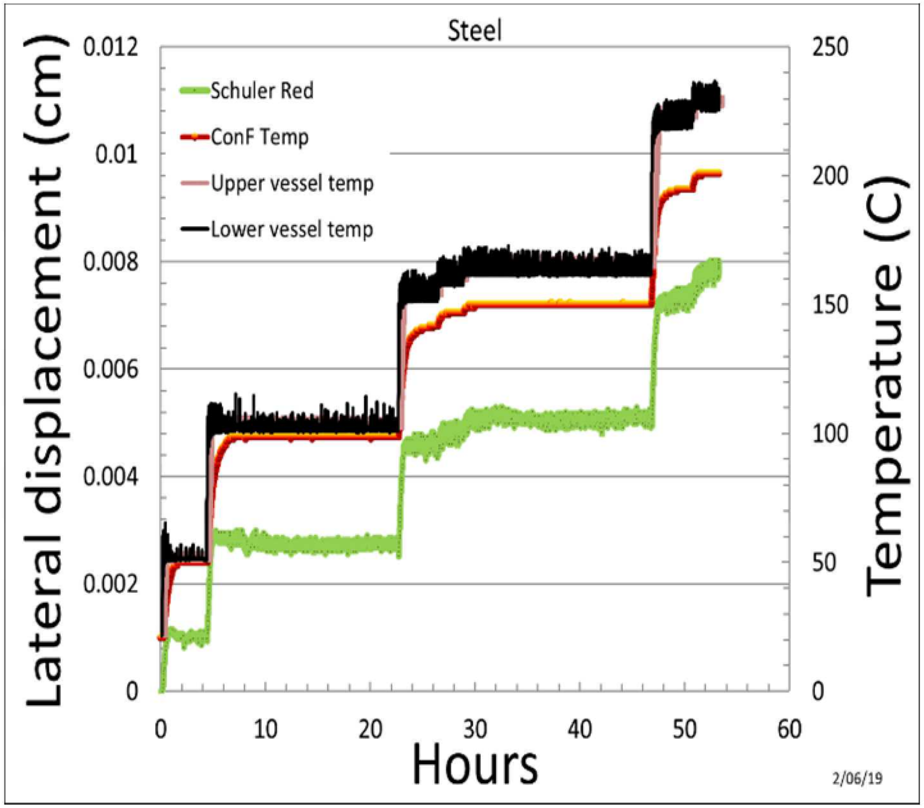






**Flow rate change for a 0.1 µD material considering temperature dependent water viscosity.**

# Steel: 3x180 hours to 220/°C




Displacement, T°C for 1st and 2nd heating cycles for steel at 13.8 MPa confining pressure.

We calculate CTE= 2 to 5 x $10^{-5}$/°C, CTE of carbon steel = 1.2 x$10^{-5}$/°C