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Thermal expansion, fluid flow, and thermal shock of cement and a cement/steel interface at elevated pressure and temperature

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Geothermal Technologies Office
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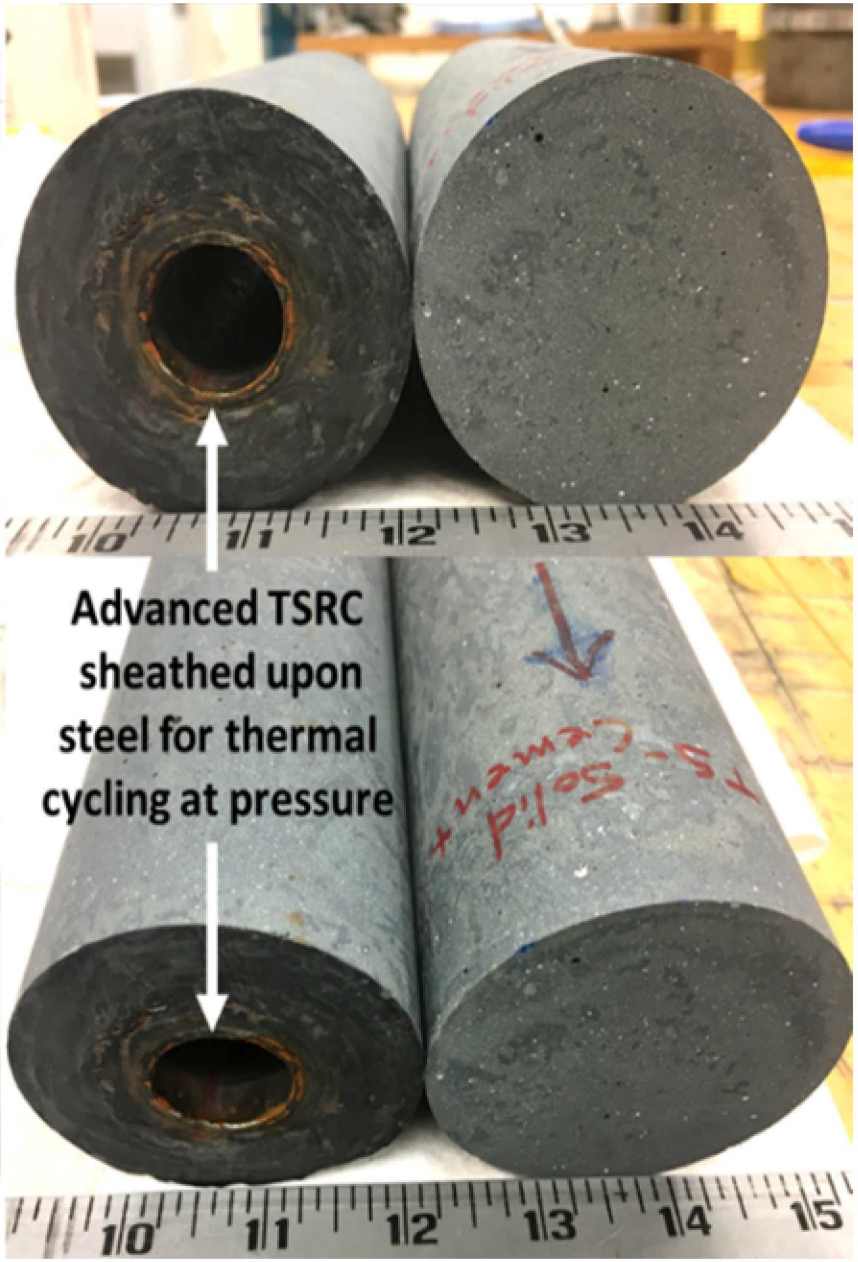
Background & Purpose

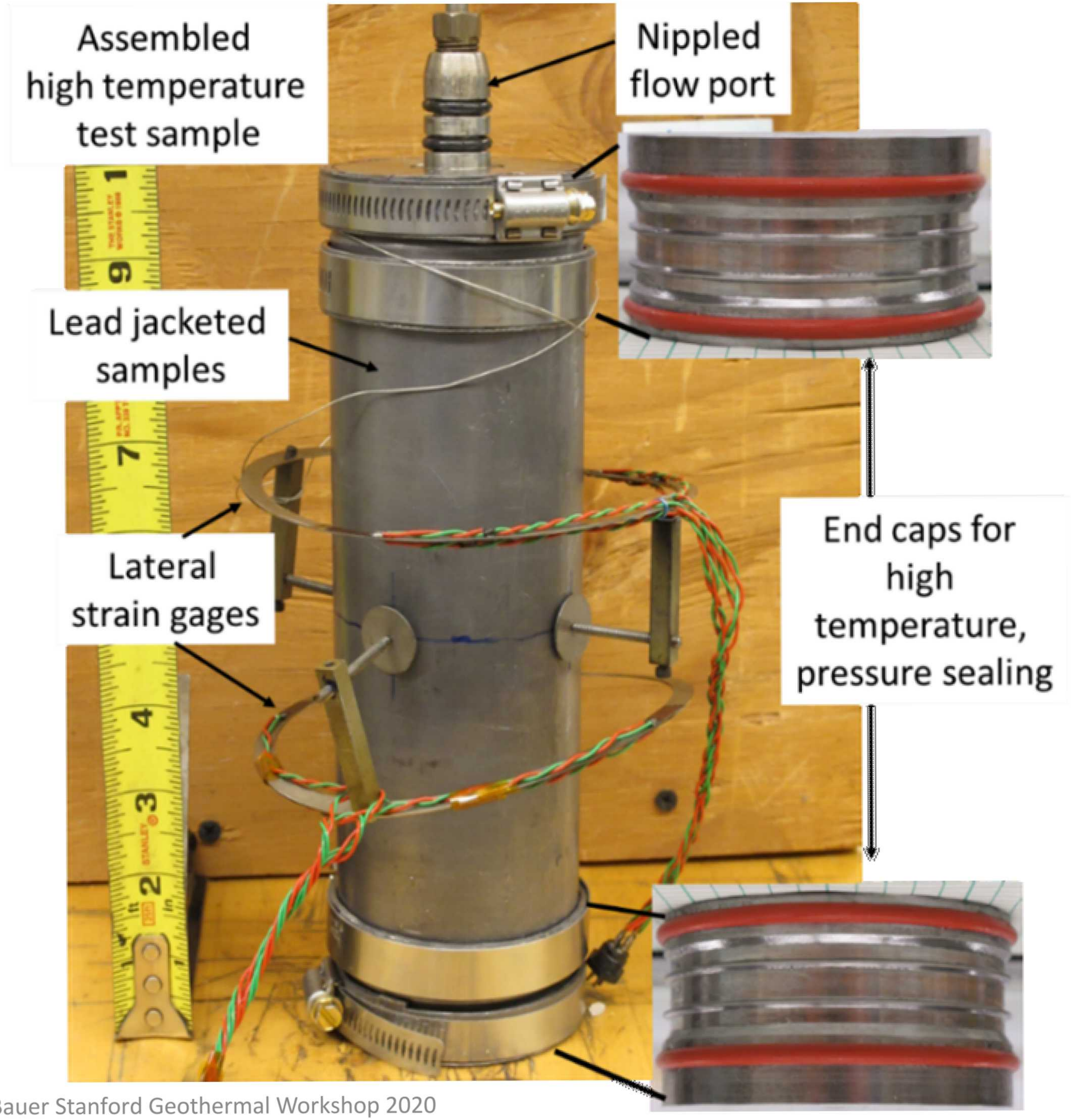
There exist geothermal conditions where geothermal wells are thermally cycled rapidly, implying special cement formulations are needed:

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

This work evaluates Thermal Shock-Resistant Cement (TSRC) developed by BNL.
Sandia focused on determining thermal expansion, and fluid flow through the TSRC, and the application of thermal shock to a steel/TSRC sheathed sample.
The key contributions of this work to the geothermal community are
(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,
(3) Evaluation of comparative performance of TSRC and common high-temperature ordinary Portland Cement (OPC)-based sheath samples under conditions of dry heat thermal shock at ambient pressures.

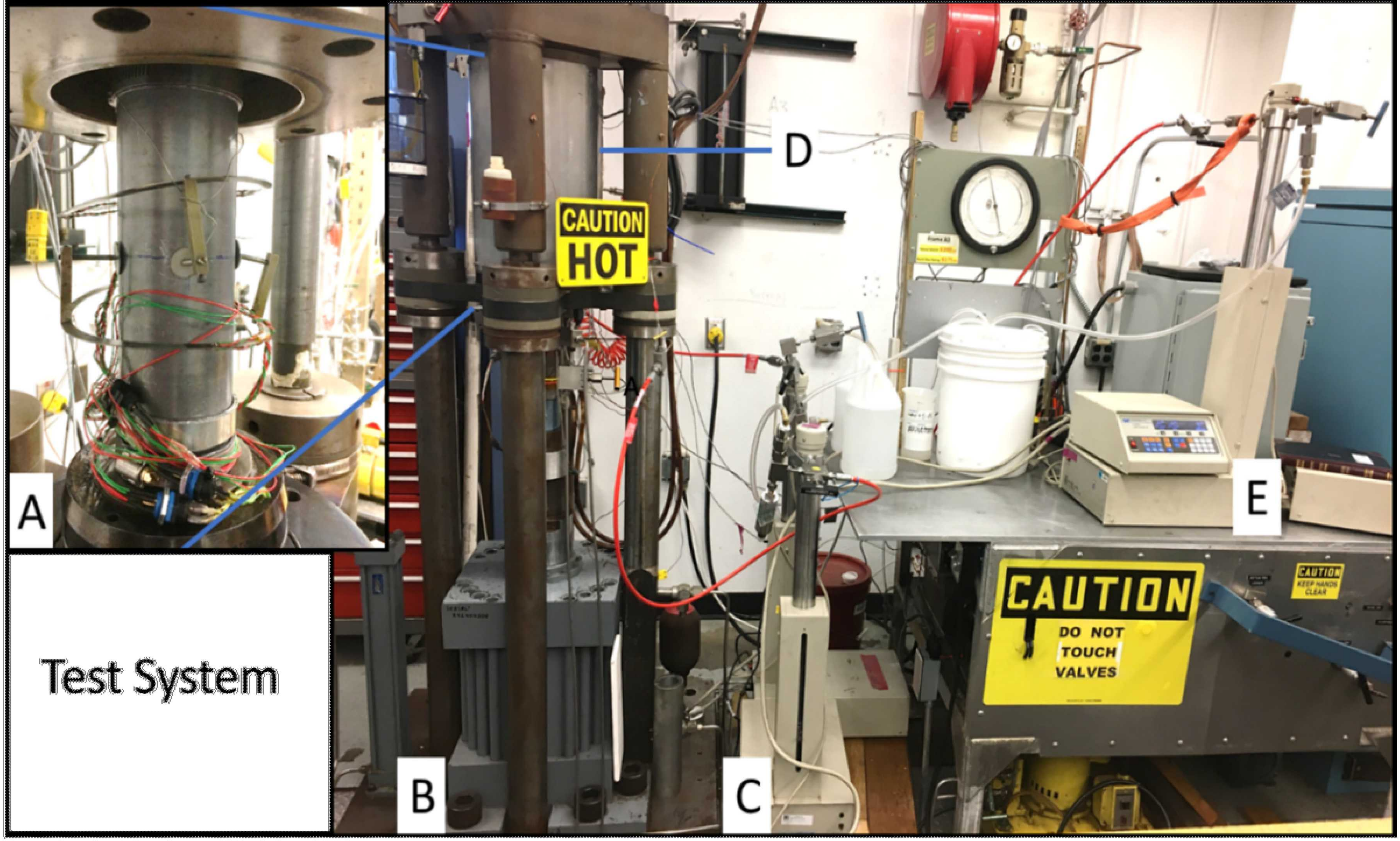

Steel Tube & Cement
TS- Solid Cement
Advanced TSRC sample for thermal cycling at pressure


Advanced TSRC sheathed upon steel for thermal cycling at pressure
TS- Solid Cement



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

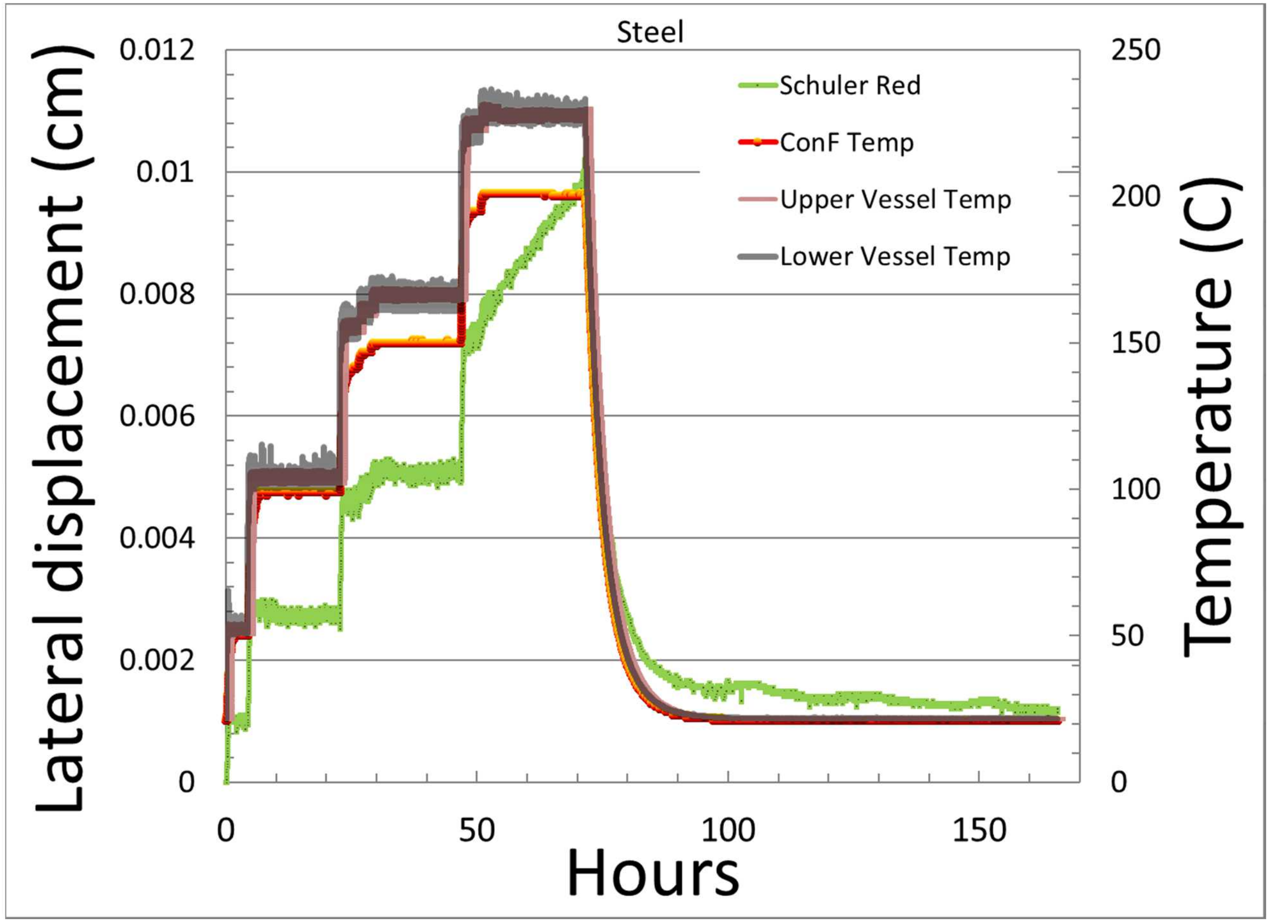
Schuler gage

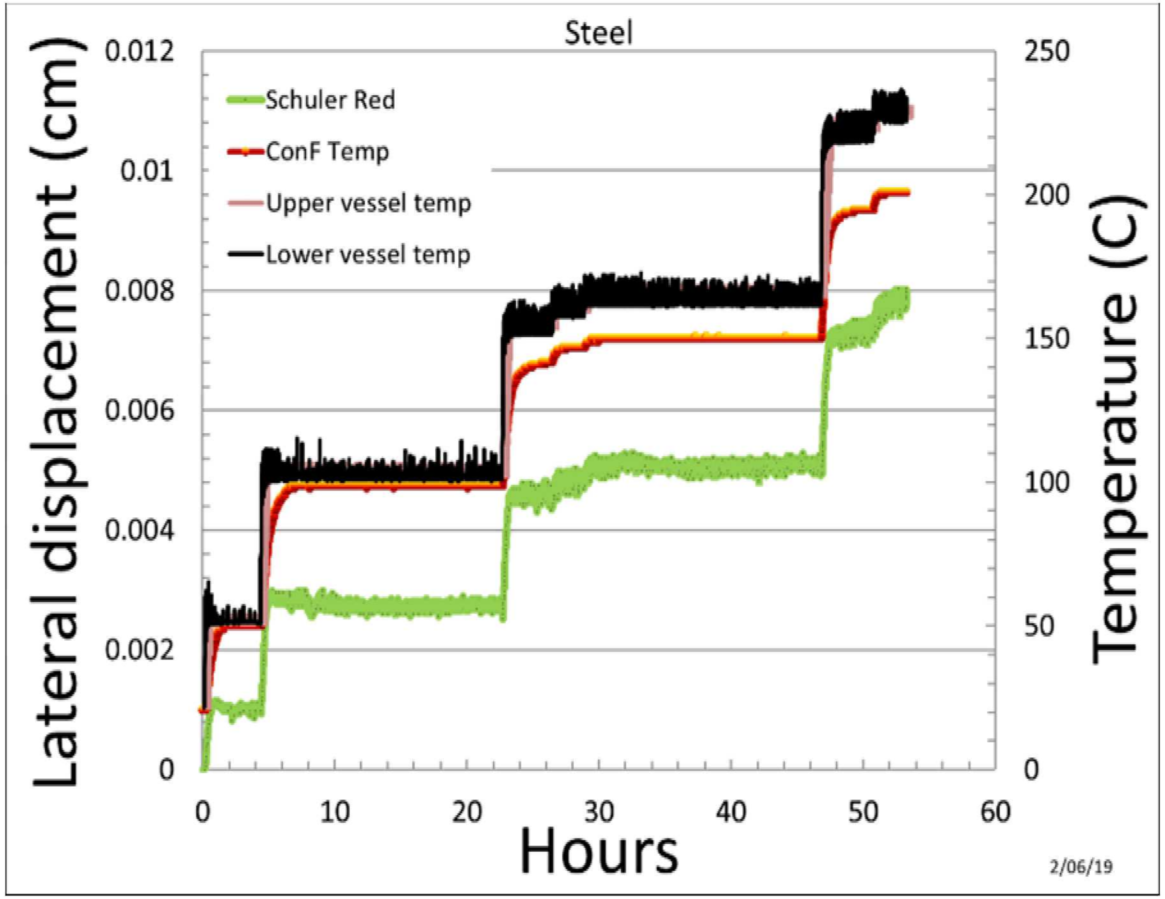

A
B
C
D
E
CAUTION
HOT
CAUTION
DO NOT
TOUCH
VALVES
CAUTION
KEEP HANDS
CLEAR

Test System


CAUTION
HOT
CAUTION
DO NOT TOUCH VALVES
CAUTION
KEEP HANDS CLEAR
CAT
Sandia Laboratories
CREEP BENCH SYSTEM
SYSTEM PWR
HTR ON
DAS ON
OPER ON
ALARM
RESET
EMERGENCY
A-FRAME SYSTEM
DO NOT CHANGE SCREEN RESOLUTION
Screen Resolution 1024 X 768 For Wonder Viewer
TENSION
COMPRESSION
ACTUATOR LOWER
ACTUATOR RAISE

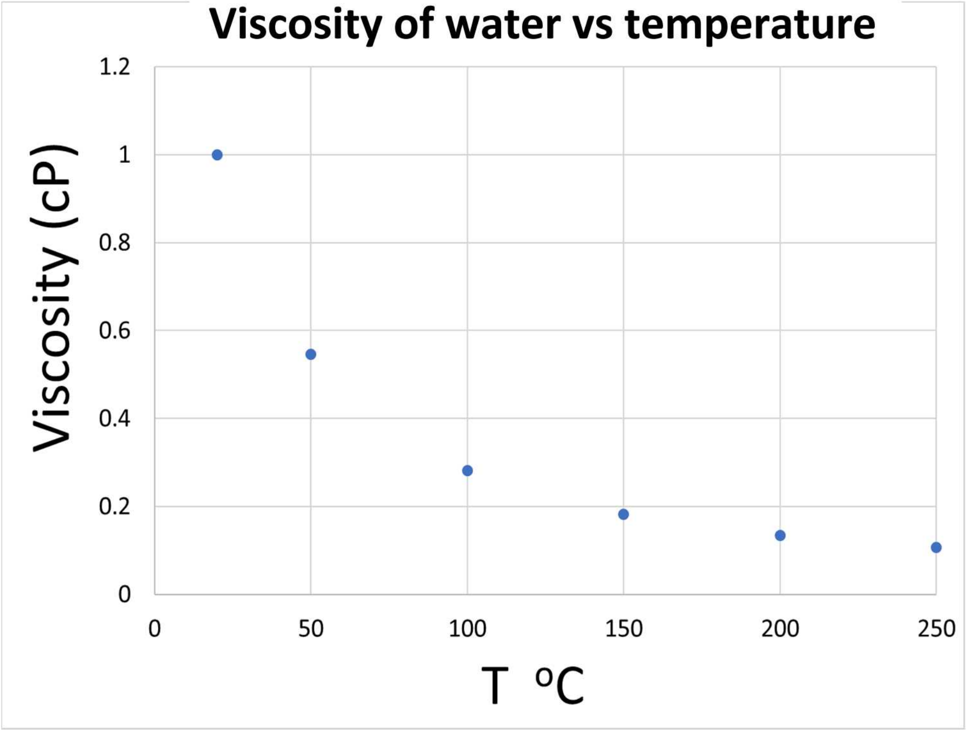
Steel: 3x180 hours to 220/°C

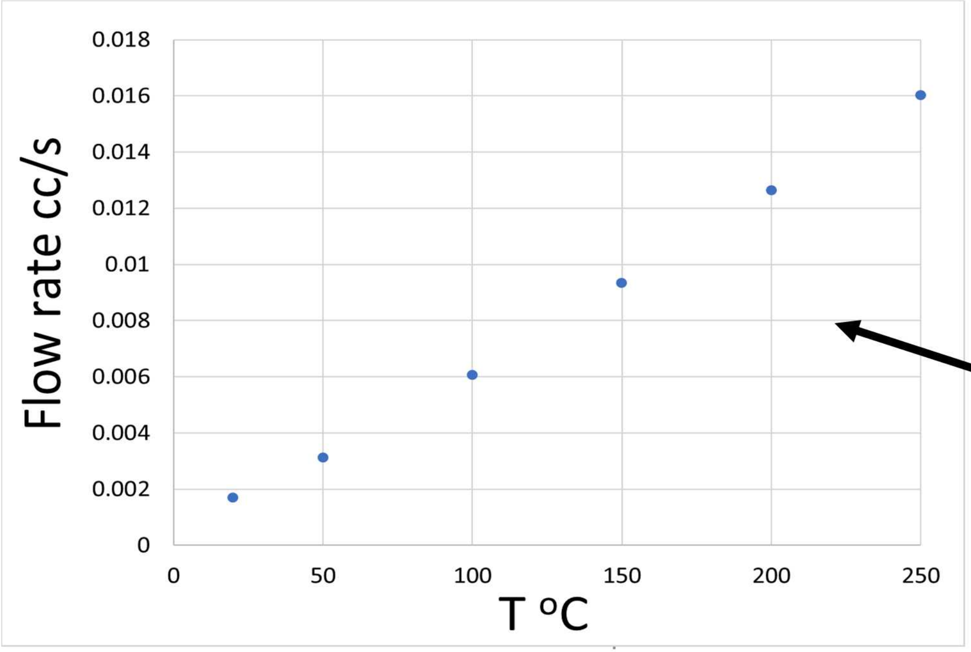


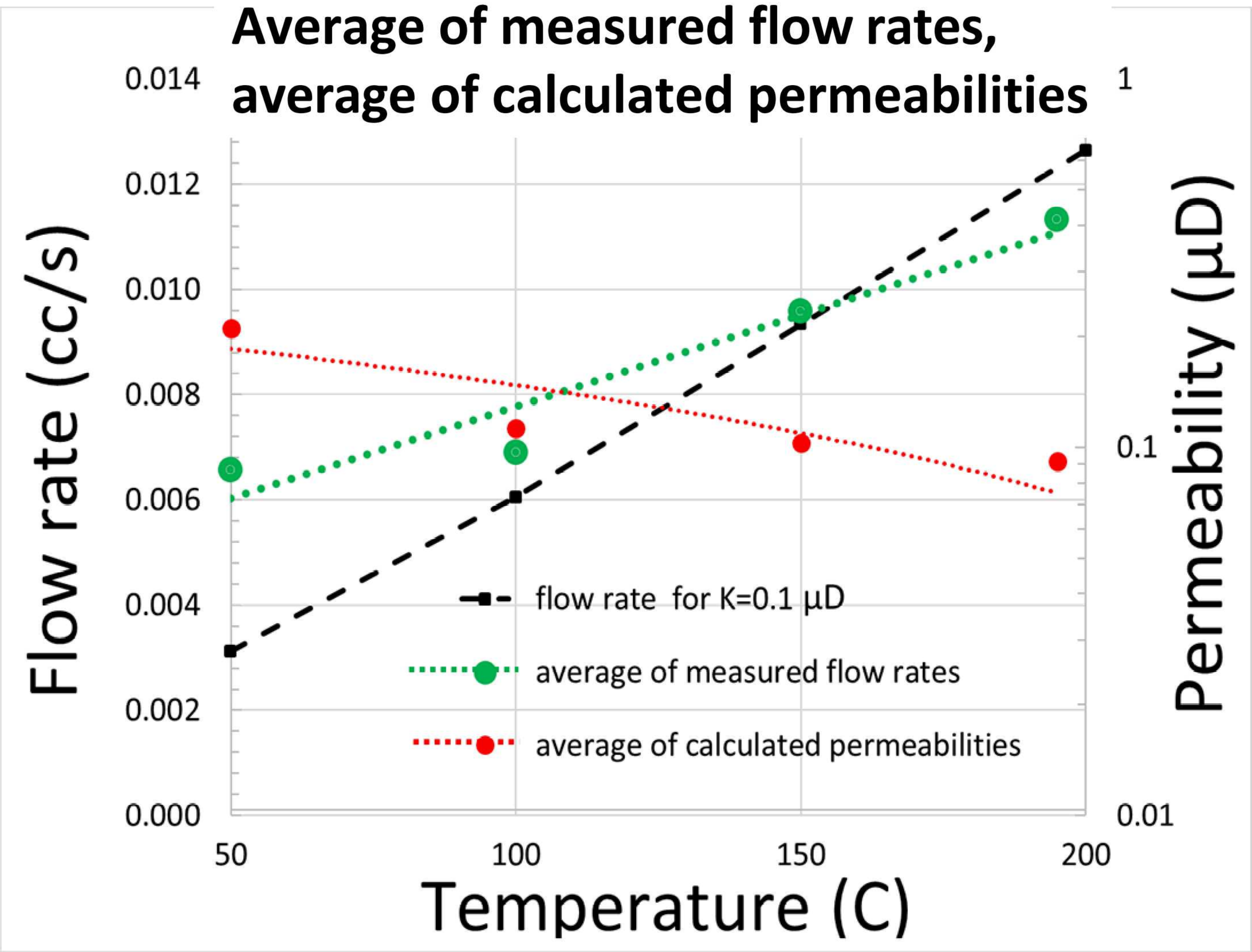


Displacement, T°C for 1st and 2nd heating cycles for steel at 13.8 MPa confining pressure.

We calculate CTE= 2 to 5 x 10^{-5}/°C, CTE of carbon steel = 1.2 x10^{-5}/°C

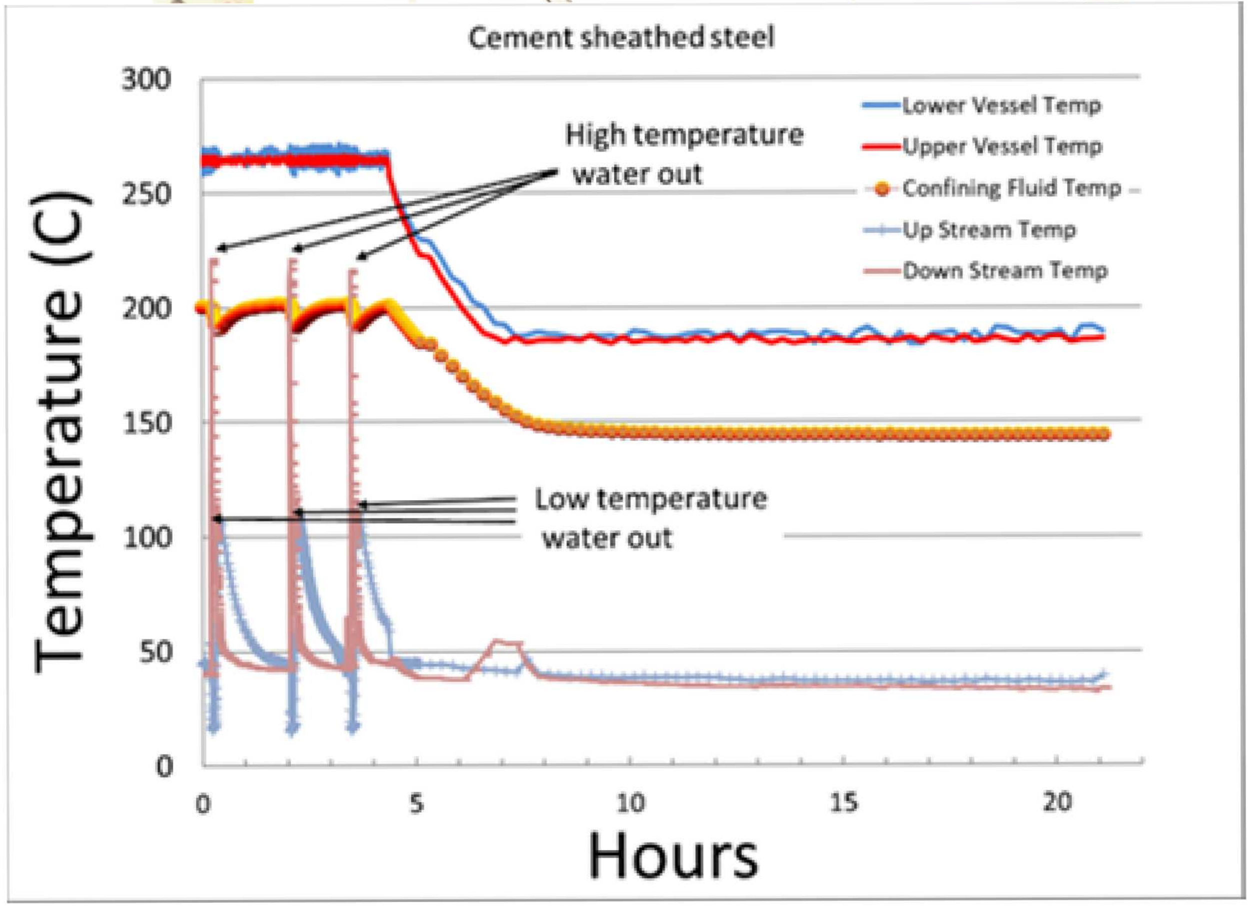




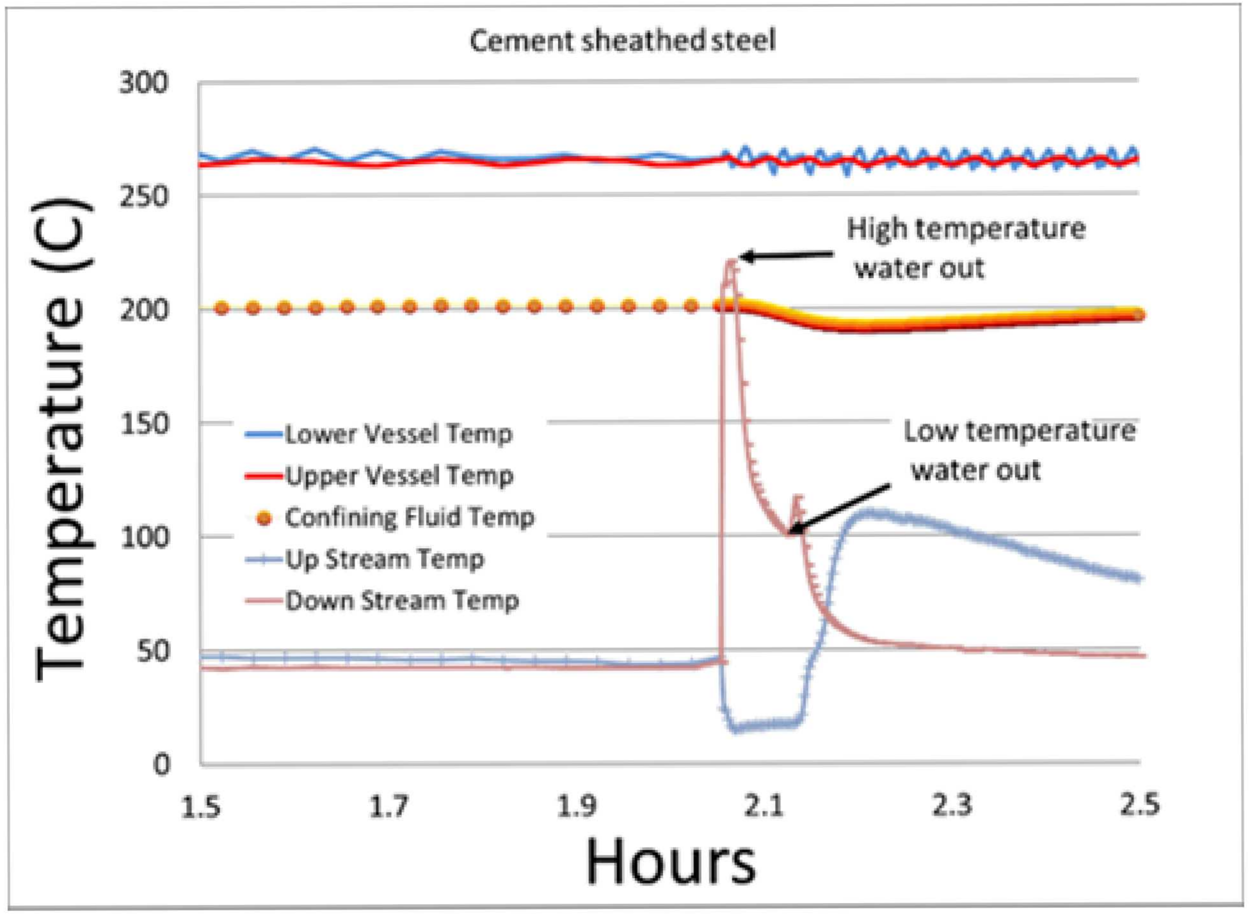


Flow rate change for a 0.1 µD material considering temperature dependent water viscosity.

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

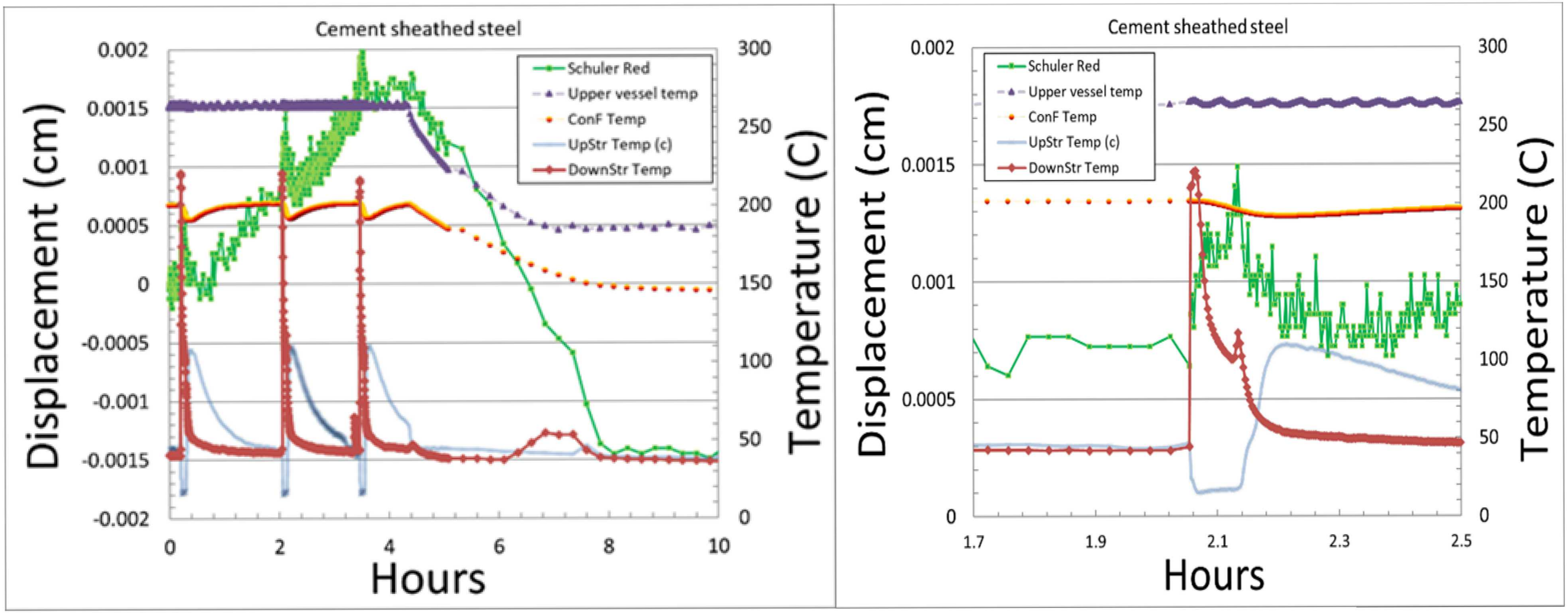


Test time versus temperature for components of the cement sheathed steel test.



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.

CONCLUSIONS

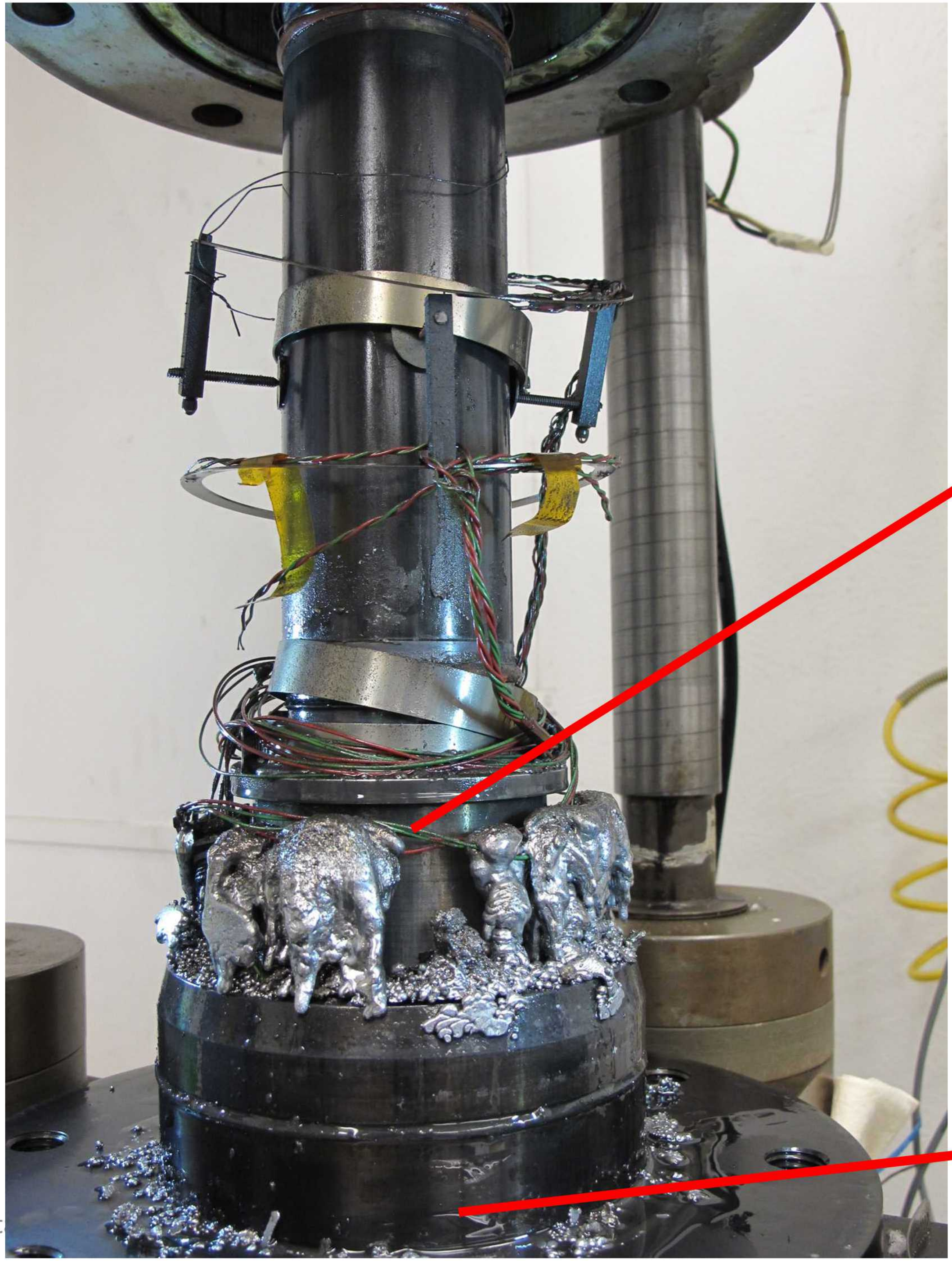
This work documents additional evaluations of Thermal Shock-Resistant Cement (TSRC) developed by BNL with focus on thermal expansion, fluid flow through the TSRC, and the application of thermal shock to a steel/TSRC sheathed sample.

The key contributions of this work to the geothermal community are centered about development of a test system to make measurements of cement thermal expansion and fluid flow at elevated T°C and confining pressure (13.8 MPa) and pore water pressure (10.3 MPa) relevant to geothermal systems.

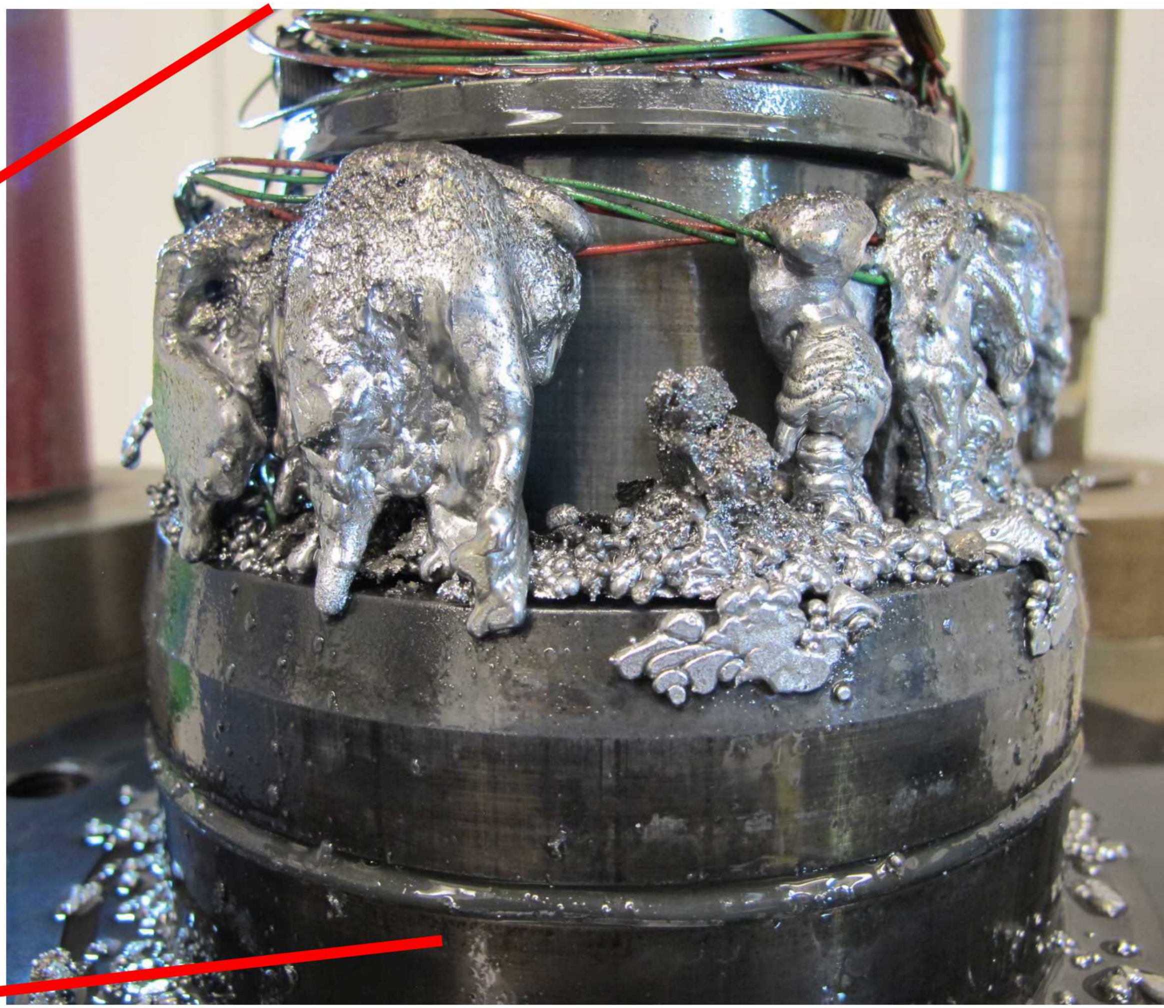
The thermal expansion coefficient of the water-saturated TSRC is in the range of 1 to 5 x 10^{-5}/°C. Over this temperature range at 3.5 MPa effective confining pressure, the estimated permeability of the TSRC may be temperature dependent and is on the order of 0.1µD.

The test system, modified to thermally shock a steel/TSRC sheathed sample at elevated temperature and pressure conditions, successfully created a 100°C radial thermal gradient in about five minutes. Some thermally induced cracking may be present.


Thanks!
Questions?



Don’t try this at home



Don’t try this at home