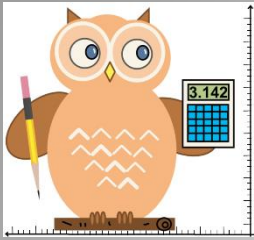


Platform for Testing Sensors in Hot Geothermal Wells

By Randy Normann, CTO

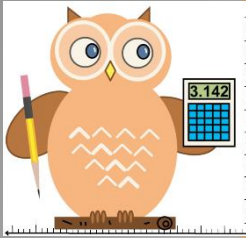
On Measurement 4U LLC

Randy@onmeasurement.com

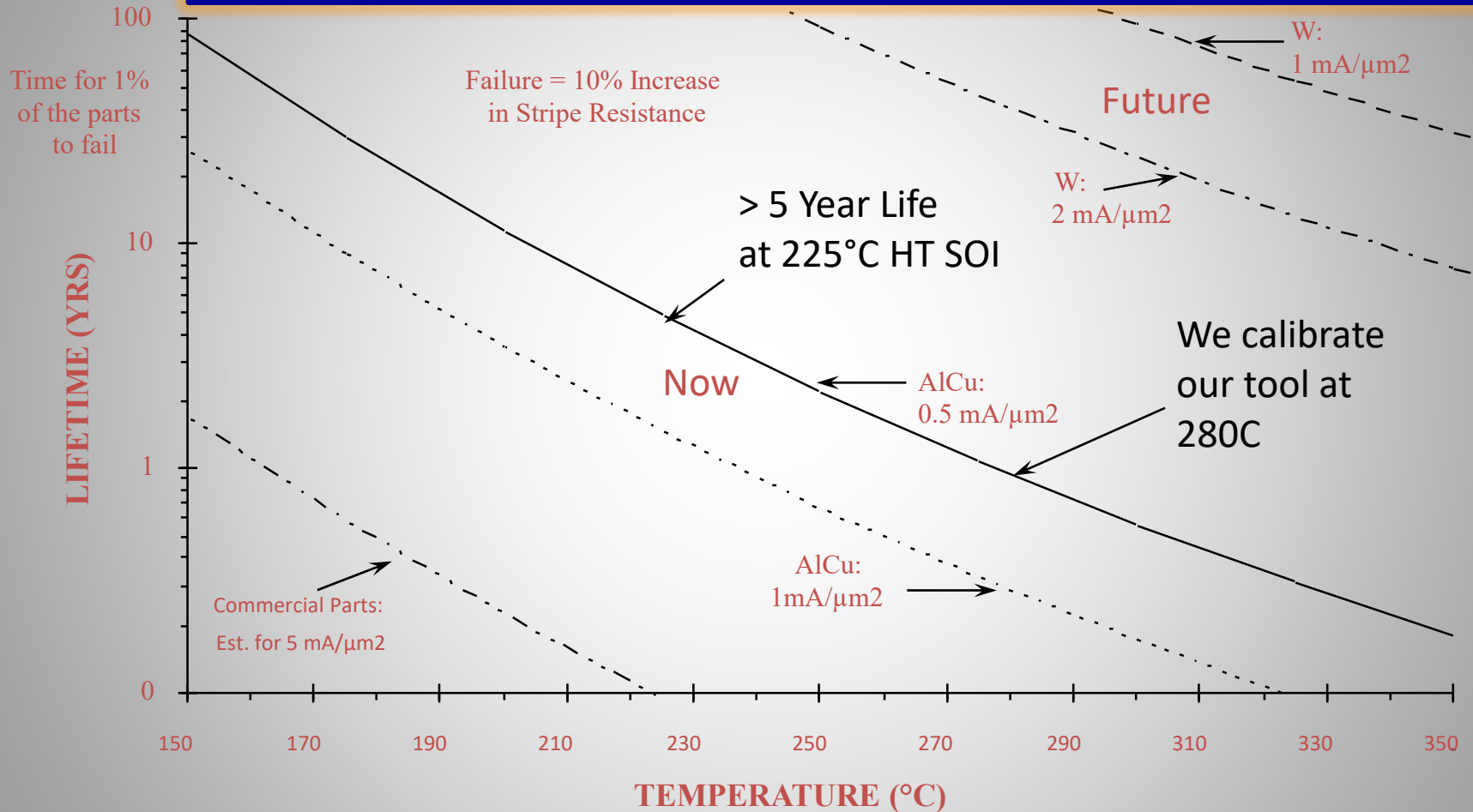


Anyone Can Test a HT Sensor Inside a Geothermal Well

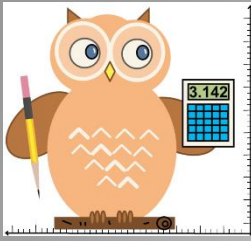
- This presentation describes at a set of general purpose HT SOI electronics created for operation inside a geothermal logging tool. Use of the electronics is free, so that anyone can test a new high temperature sensor inside an oven or actual geothermal well.
- The tool electronics are 100% high-temperature silicon-on-insulator devices. All are rated for 5 years at 225C.
- We can actually calibrate this tool at much higher temperatures: 280C.
- **Randy Normann has a written document with greater detail than provided here. Email him, see slide 1.**



High-Temperature Silicon-On-Insulator Electronics Rated for High Temperatures and Long Life

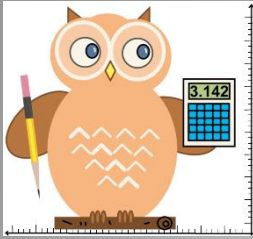


Metal migration failure is a function of Current Density, Time and Temp.
Plot is from Honeywell SOI group, Bruce Ohme



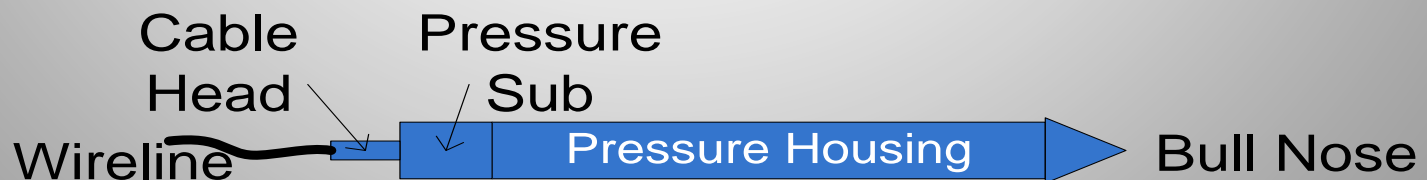
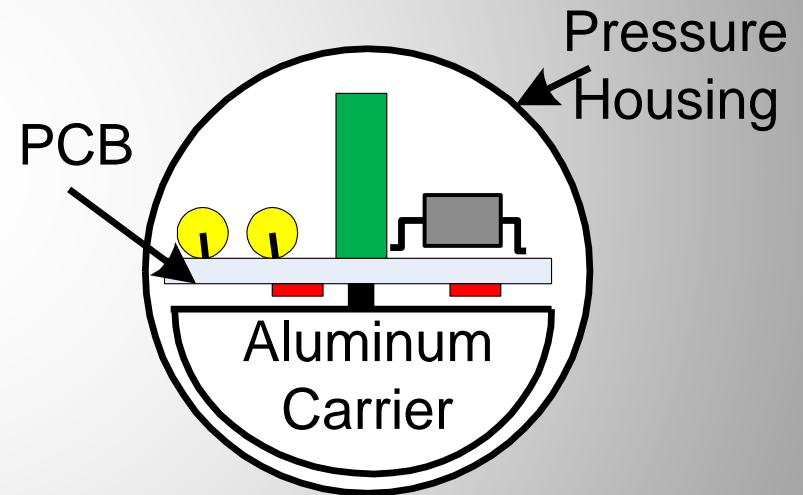
Tool and Cable for Deployment

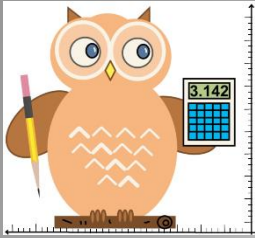




Basic Sensor Interface

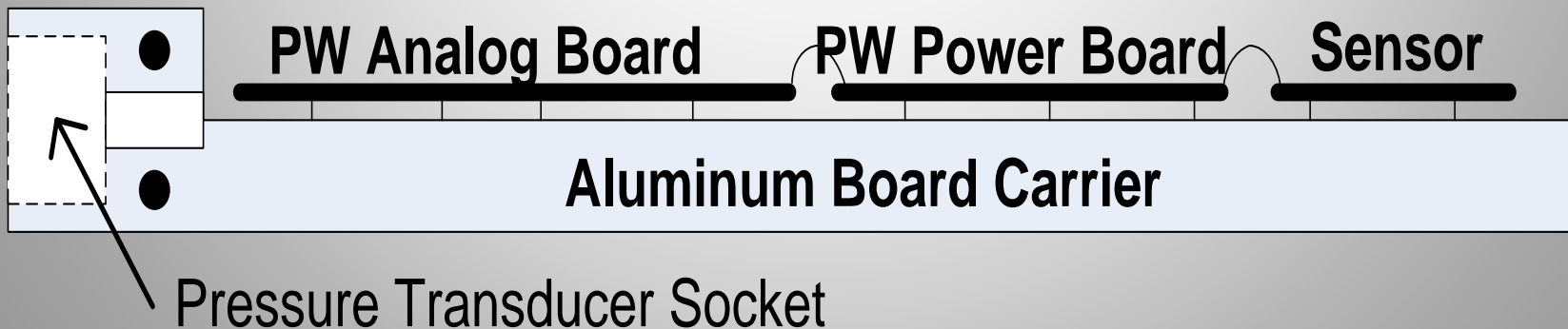
- Available PCB space 1X8 in
- Tool head is 1in ID
- Tool Pres/Temp installed at the top of the tool to
 - Validate your sensor operation
 - Benefits the well owner
- Single conductor OR two conductor logging cable.

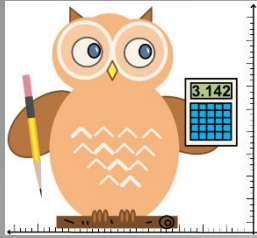




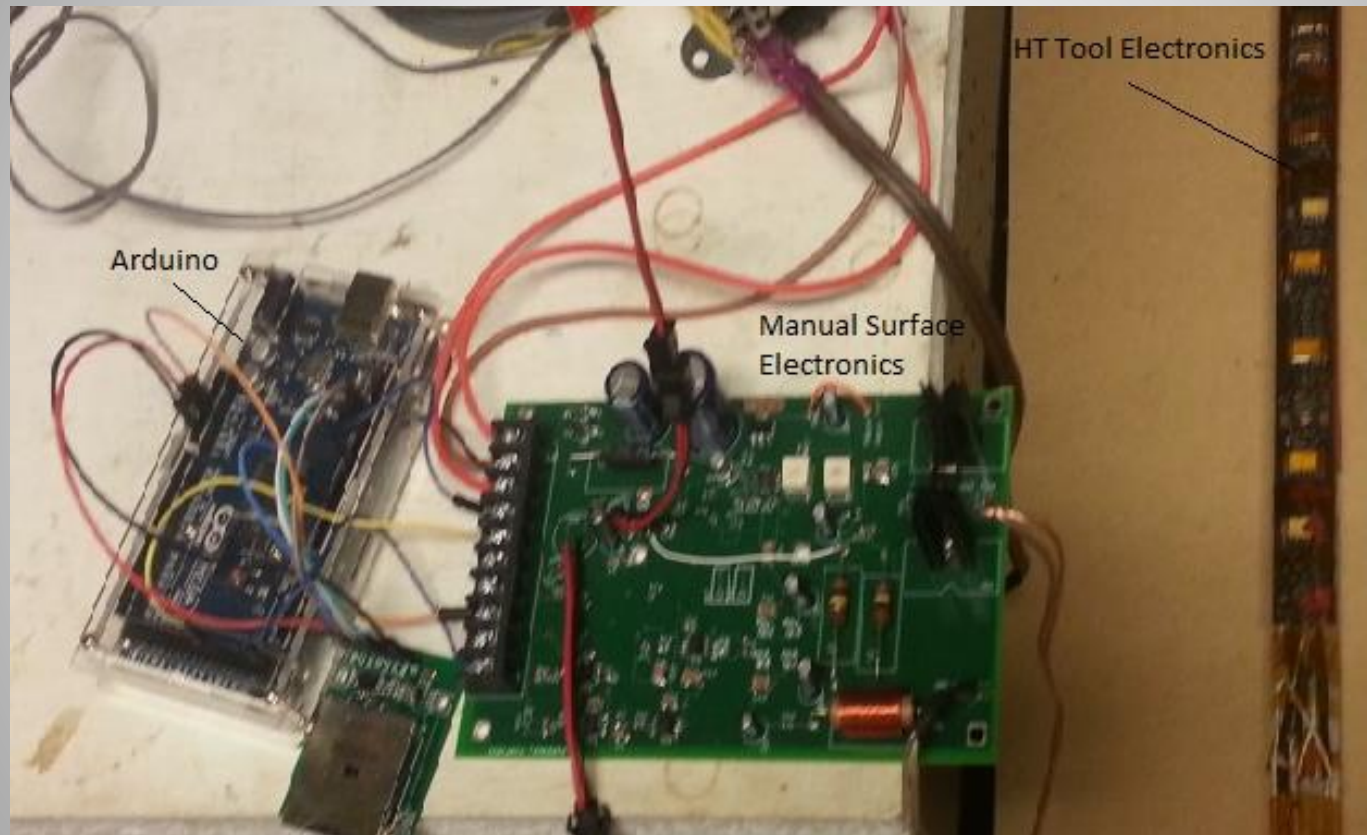
Basic Sensor Interface

- SOI electronics 100% HT SOI – 275C continuous
 - 2.5V Ref
 - 5.0V DC
- Three analog channels are open
- Limited bandwidth is switchable within the well!
 - 1 reading every ~5 seconds for full set of readings
 - Up to 50 readings per second for any one data channel

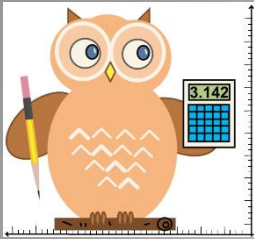




Laboratory Oven Testing Supported

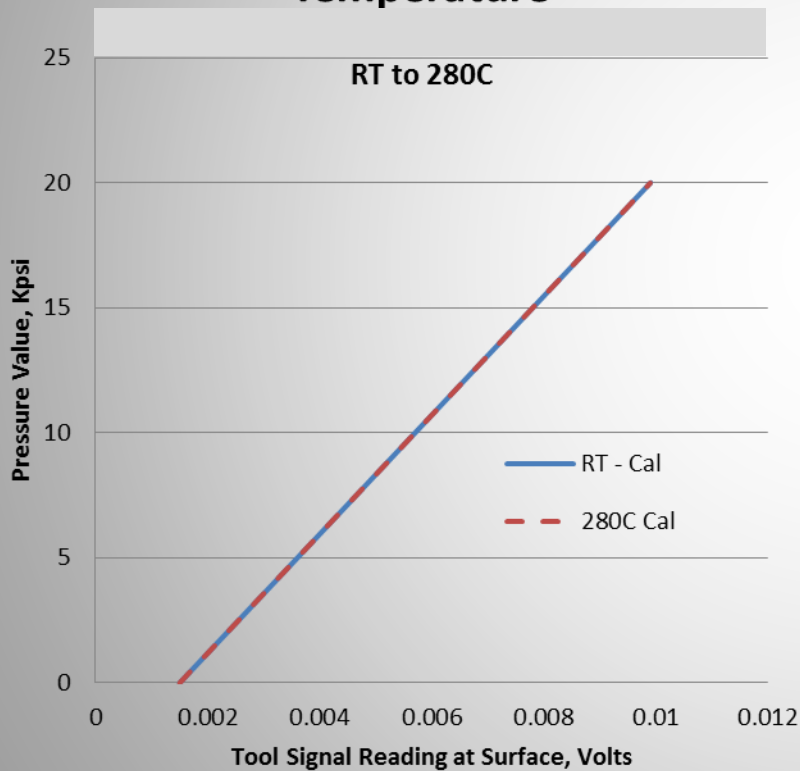


OM surface electronics interface to the tool's logging cable. An Arduino processor controls the tool and records the measurements. This system can be programmed by many high-school robotic students using with aid from Randy's book, "Arduino for Projects In Scientific Measurement"

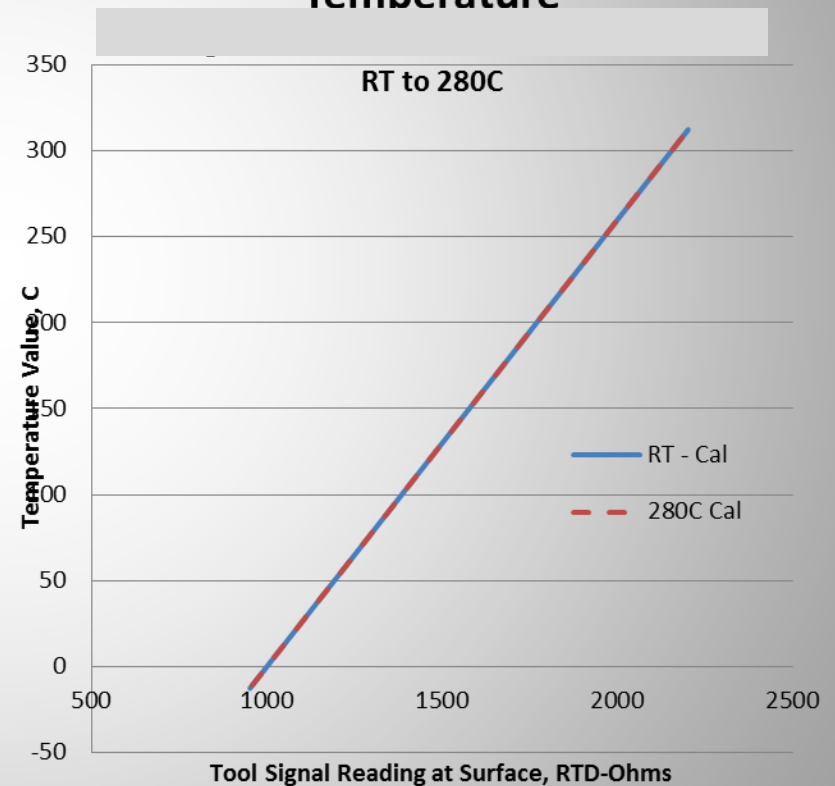


HT SOI Pressure/Temperature Cal

Calibration of Pressure over Temperature



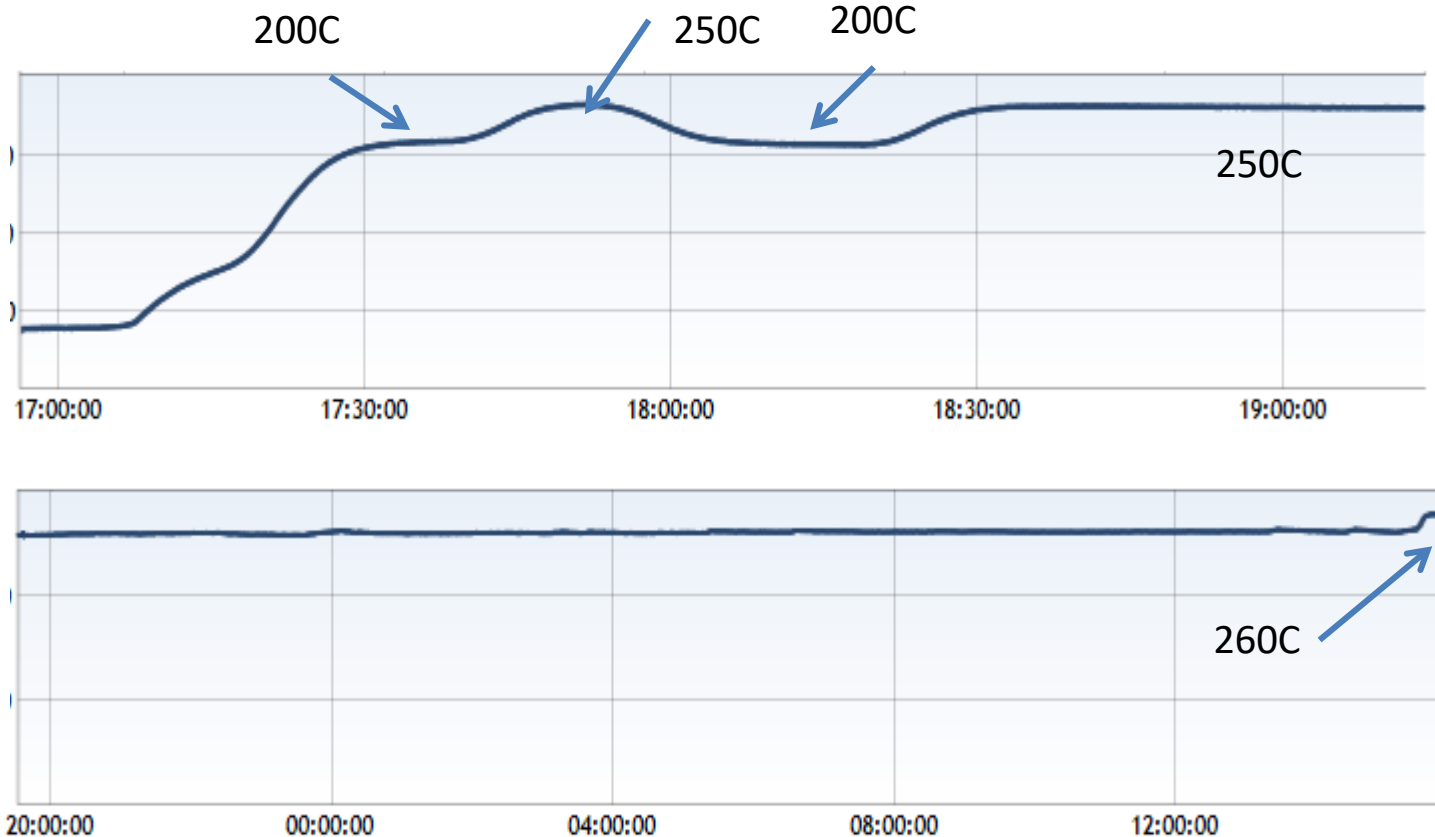
Calibration of Temperature over Temperature



No correction factor has been applied to this data. The tool electronics are self compensating



HT SOI Well Monitoring Tool



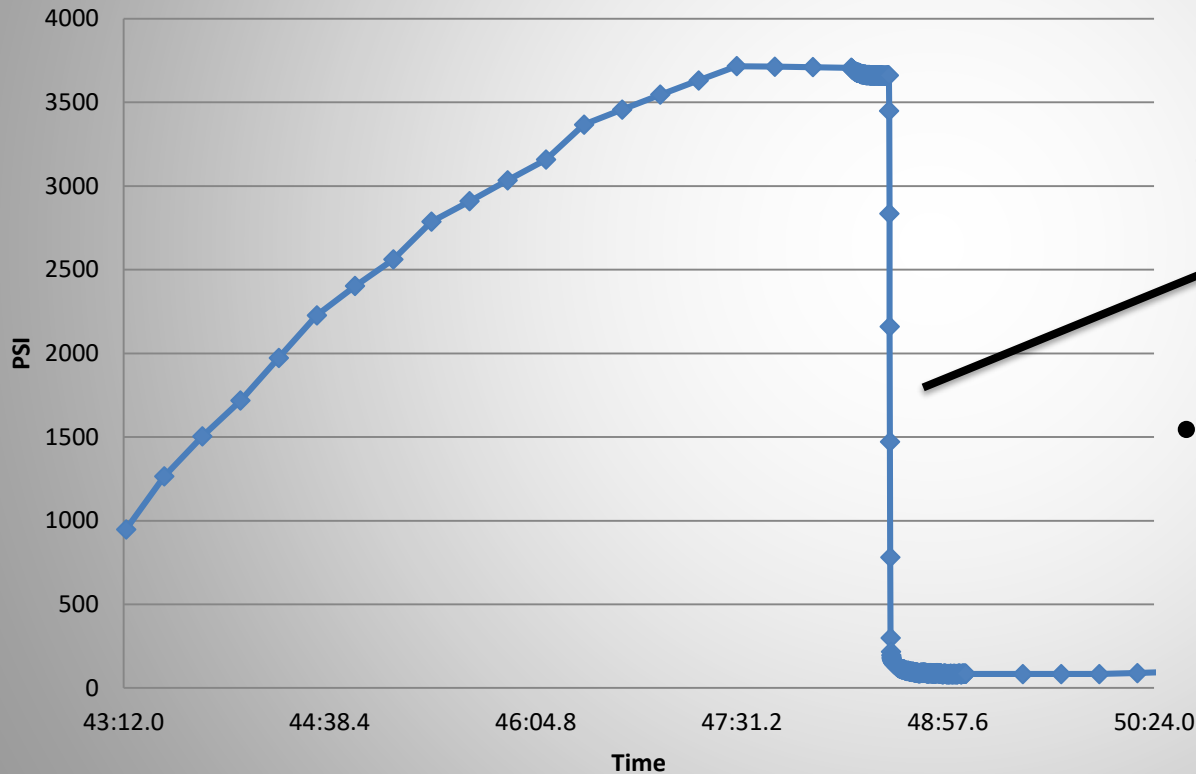
Here the tool NEVER leaves the well for ~24 hrs. This tool can support hydraulic fracturing up to 25,000 psi/275C



HT SOI Tool Fast Record Readings

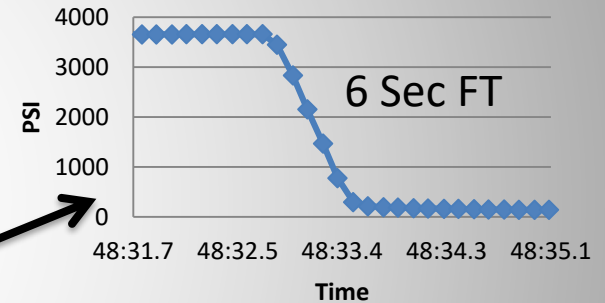
Pressure Data Lab

HS Capture of Fall Off, 10sps



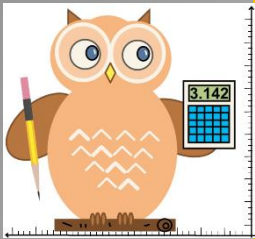
Pressure Data Lab

HS Capture Measure Pressure
Fall Time



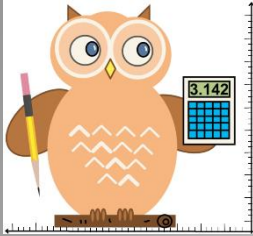
- You can target capturing fracturing events as speed and volume of fluid entering the fracture.

Two way communication allows the operator to change data formats as well testing requires without removing the tool.



Mounting Your Sensor

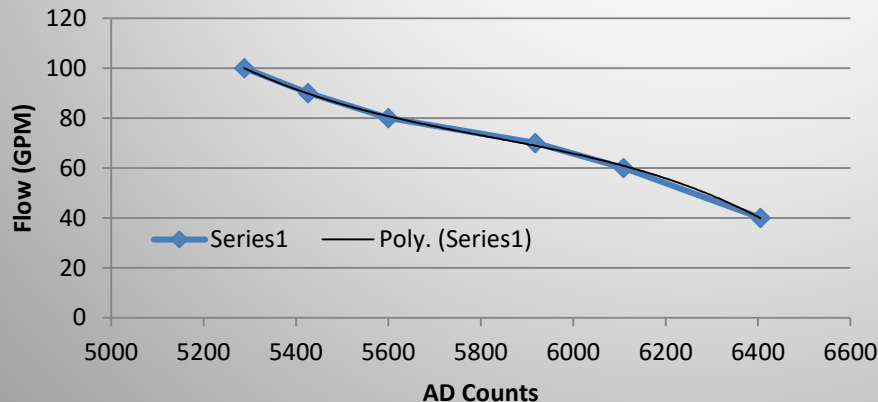
- The front (bull nose) of the tool is open for your use. The Press/Temp sensors in the tool are located behind the cable head.
- A simple double O-ring seal is used and your electronics/sensors can have access to the wellbore fluids, if needed.
- There is no fixed sensor size limitation other than most geothermal wells have a 'tool valve' with a 3 inch ID. The well owner may require we use it.

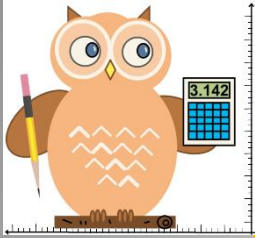


Replacing the Front End

- Example: Prototype fluid flow tool sensor increased the diameter to 2.5 inches
- We have two pressures housing: 10K and 25Kpsi.

Downhole Flow Meter Preliminary Calibration
5/31/2013





Conclusion

- OM has a tool designed for testing sensors in a hot geothermal well up to 275C
- Demonstrating your sensor in geothermal can aid in gaining new markets
- The existing design has
 - Three analog channels with amplifiers are available
 - 5v @ 40mA, and a 2.5V Ref
 - Limited BW
 - Tool comes with well temperature and pressure