

Geothermal Technologies Program 2010 Peer Review

U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy



With Sub-Awards to
Electrochemical Systems Inc.
Frequency Management Inc.

Well Monitoring Systems for EGS

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Principal Investigator
Randy Normann
Perma Works LLC



- Purpose: Perma Works will release one new EGS tool each year for permanent well monitoring
 - Phase 1: 300°C, 30K psi Pressure and Temperature Well Monitoring Tool
 - Phase 2: 250°C, Digital Pressure, Temperature and Flow Tool
 - Phase 3: 275-300°C Digital PT-Flow with an optical driver for communication on DTS fiber
- Timeline
 - Started: Jan. 2009
 - End Date: Dec. 2011
 - Phase I tool is complete
- Budget
 - Funding DOE/Awardee: \$2,100,000 / \$769,978
 - FY09: \$401,161.51
 - FY10: \$1,063,115



- **Barriers:**
 - Reservoir Creation
 - Reservoir Validation
 - Inter Well Connectivity
 - Reservoir Sustainability
 - Management of EGS Reservoirs

- **Partners:** Draka Cableteq, Eclipse NanoMed, ElectroChemical Systems Inc, Electronic Workmanship Standards Inc, Frequency Management International, Honeywell SSEC, Tiger Wireline Inc, Viking Engineering, Red Rock Research, Falmer
 - Sub-contract awardees:
 - Electrochemical Systems Inc.
 - Frequency Management Inc.



- In general, EGS well monitoring tools offer a unique set of solutions which will lower costs and increase confidence in future geothermal projects
 - Existing technology is limited to only a few hours of exposure
 - Perma Works tools can stay in the well during testing for months/years
 - Logging crews and trucks can leave, saving money
 - Data is improved by being collected from the same tool located in the place in the well
 - Reduced lost in hole charges as well monitoring tools can withstand the well temperatures without a time limit
 - Monitoring production wells and injection wells allows operators to better adjust to changing conditions
 - Project investors value reservoir measurements over speculation

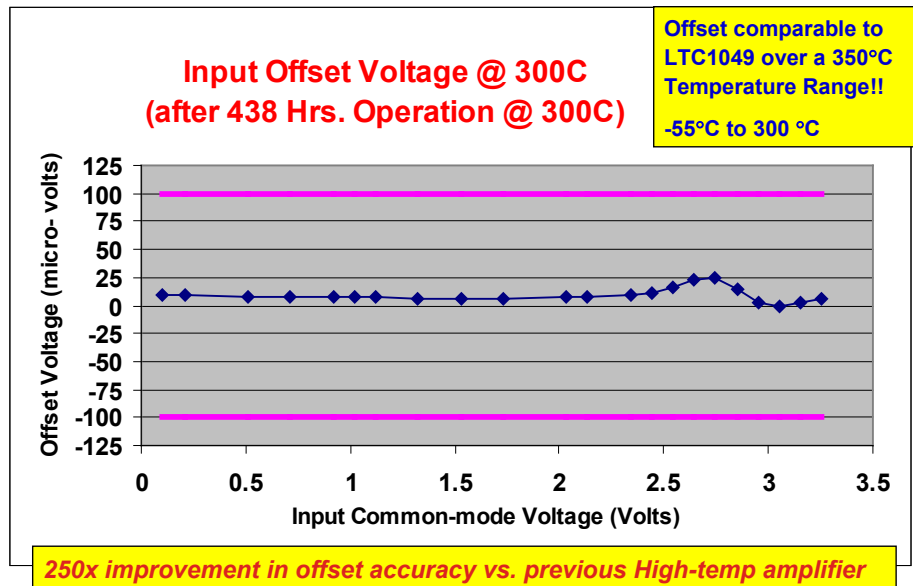


- In application examples:
 - Reservoir Creation
 - With a 30,000psi pressure rating, our tools can stay in the well while well stimulation activities are taking place
 - Reservoir Validation
 - Flow testing and reservoir recover testing will now be possible for tracking small changes over a period of months
 - Interwell Connectivity
 - By monitoring one well while others are moved in and out of production, well interconnections and reservoir dynamics can be studied
 - Reservoir Sustainability
 - Our well monitoring tools are unique in the ability to extend monitoring to well controls for creating a sustainable EGS power production



- To accomplish this mission:
 - Perma Works is commercializing the Sandia/DOE HT SOI chipset.
 - Perma Works is working closely with American suppliers, addressing the most troubling issues found when designing for long-term exposure to the geothermal well environment. Such issues as:
 - Printed circuit board delaminating
 - Ceramic capacitors shorting
 - Lack of a safe HT battery
 - Cable failure at long-term exposure at >280C
 - Among others issues
 - Life testing for a period of years is planned for both in the lab and geothermal well

- Building on Technology Developed for Commercial Aircraft Engines
 - Aircraft require 80,000 hours at 225°C within specifications
 - Failure is graceful
 - To meet these requirements components must be over designed



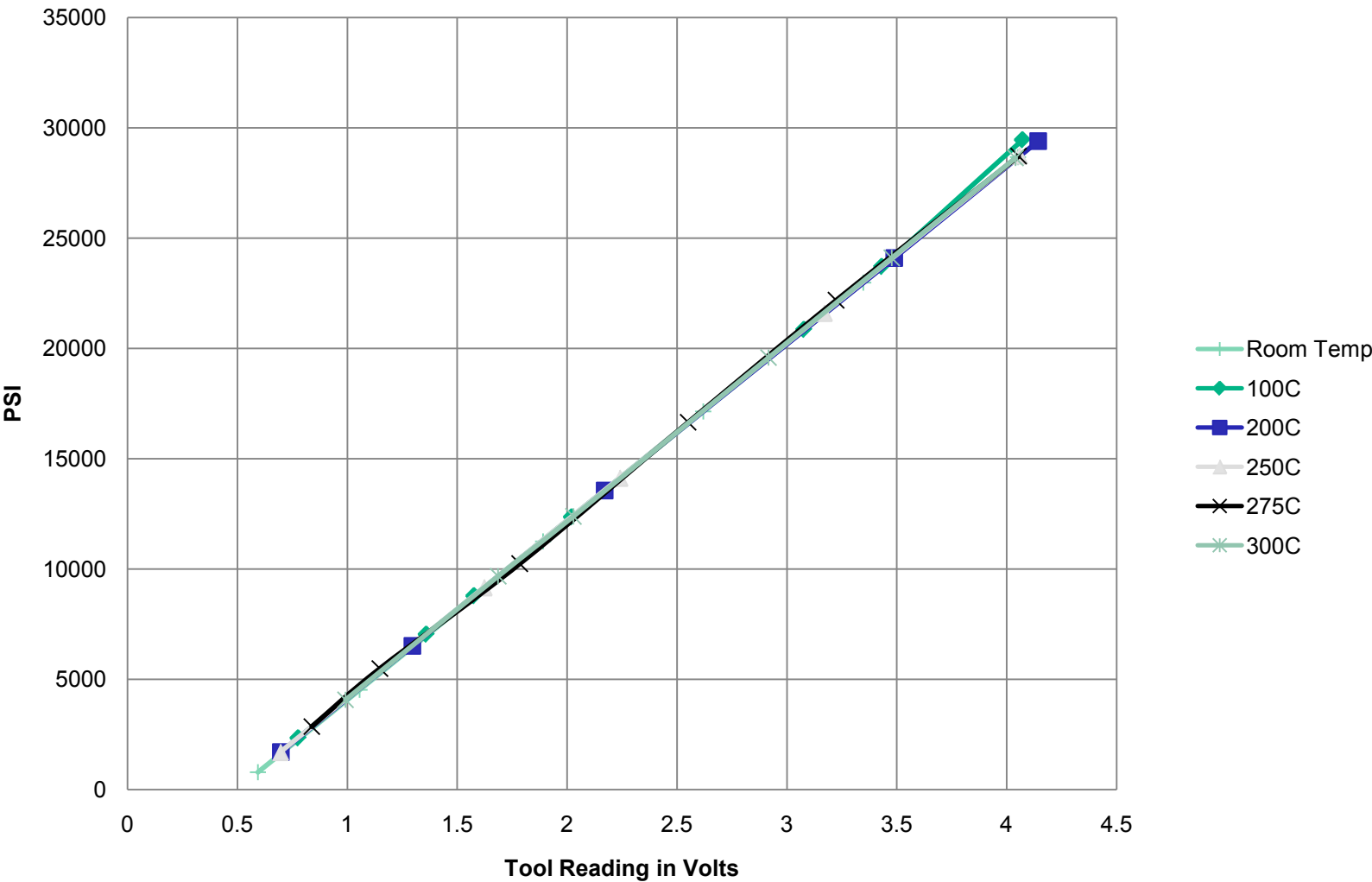
**HT amplifier operates
up to 350C with no more
than 25pmm error!!**



- Accomplishments of Phase I:
 - Perma Works is commercializing PW-PT550A tool
 - Tool electronics oven tested at 300°C
 - 100% of the tool is produced from HT inorganic materials
 - 320°C capable acoustic transducer lab tested
 - Draka Cableteq provided PW with 2200ft of 350°C rate cable
 - Cable section oven tested at 500°C
 - Eclipse NanoMed provided PW with 300°C ceramic capacitors
 - Capacitors oven tested 4700 hrs at 300°C (testing is still underway)
 - Capacitors are the life limiting component of all high temperature electronics
 - Perma Works demonstrated a circuit board design up to 400°C
 - Starting a new product line for other HT manufacturers
 - Electrochemical Systems produced HT rechargeable battery
 - However, a failed seal requires a tightening of machining

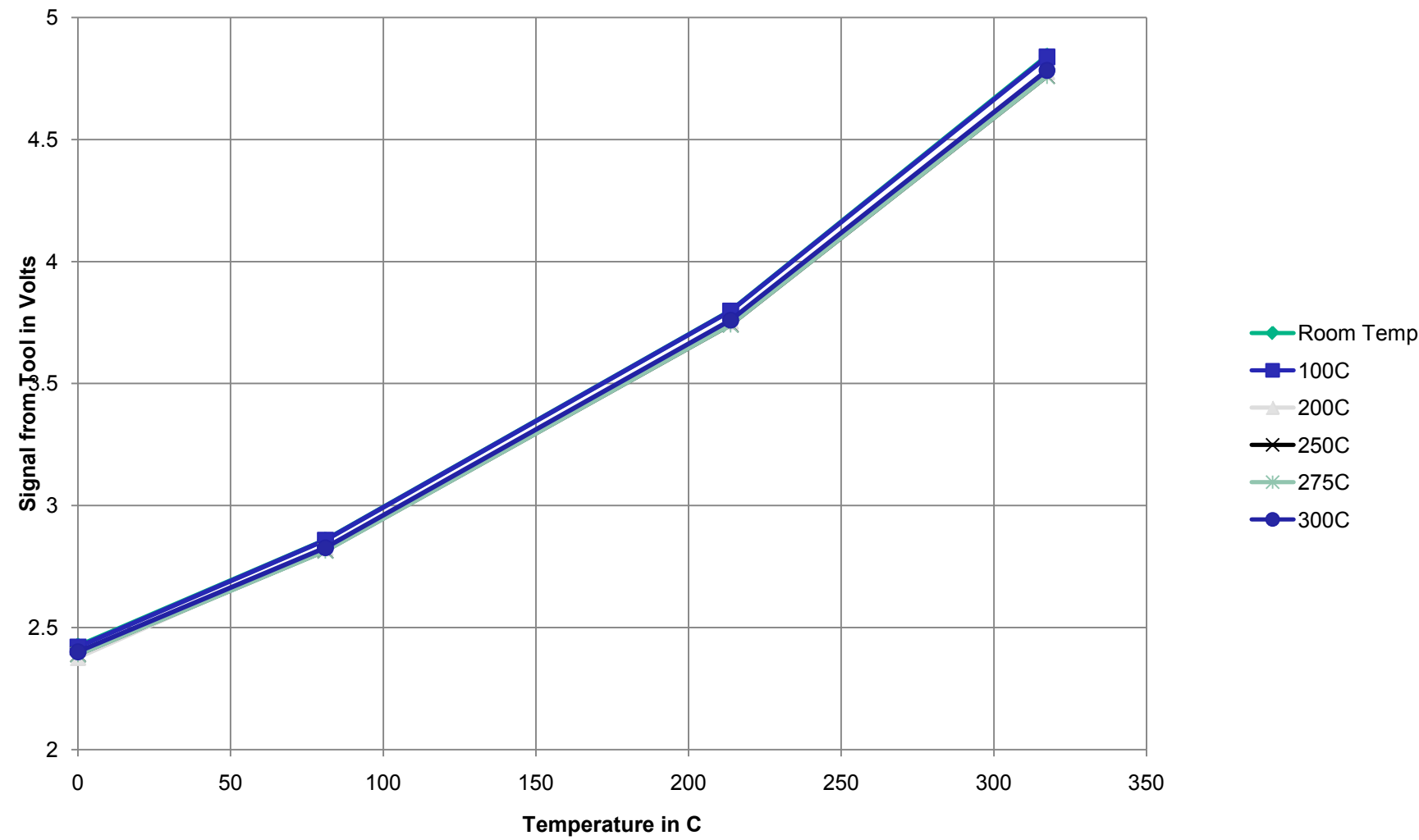


Pressure Signal W/O Temp. Correction





Temperature Signal W/O Temp. Correction



Accomplishments, Expected Outcomes and Progress 3



Complete well monitoring system is now available: Tool-Cable-Surface Recorder

Working on contractual agreements with four potential service providers

Hoping to have an agreement soon with two of them with sharing the US market an issue



- Expected Outcome of Phase II:
 - Perma Works is commercializing PW-PTS480D tool
 - Digital tool with HT batteries with memory mode
 - Frequency Management Inc to release 300°C digital clock
 - Addition of an acoustic flow sensor
 - Interface to the Warrior Logging System for 70% market coverage
 - Start life testing for testing until failure at 250°C and 300°C
 - Perma Works to add new circuit boards for 320°C operation of the analog tool
- Expected Outcomes of Phase III:
 - Perma Works to commercialize PW-PTS575D tool
 - Optical interface for hybrid fiber & electronic well monitoring system

Schedule: Each phase is managed to culminate in a new tool deliverable while report milestones are aligned with key conferences.

Industry Coordination: Perma Works uses industry conferences as the best method of interaction and dissemination of information within the industry.

- Conferences Attended 2009:



- Geothermal Resources Council Reno, NV
- Southern Methodist University Dallas, TX



- Conferences Scheduled 2010:

- High-Temperature Electronics Conf., NM
- Geothermal Resources Council, Ca



- Remaining FY10:
 - Build 8 test systems for life testing
 - Deliver 300C analog tool to Iceland for long-term testing
 - Complete commercial release of the Digital HT SOI tool with spinner and acoustic flow sensor
- Major Activities FY11:
 - Addition of a HT optical driver for the digital tool
 - Demonstrate the digital tool with a DTS fiber optic cable
 - Nearly ideal well monitoring system – PT, Flow, DTS