

Why Tools Fail

SMU: Geothermal Energy Utilization 2008



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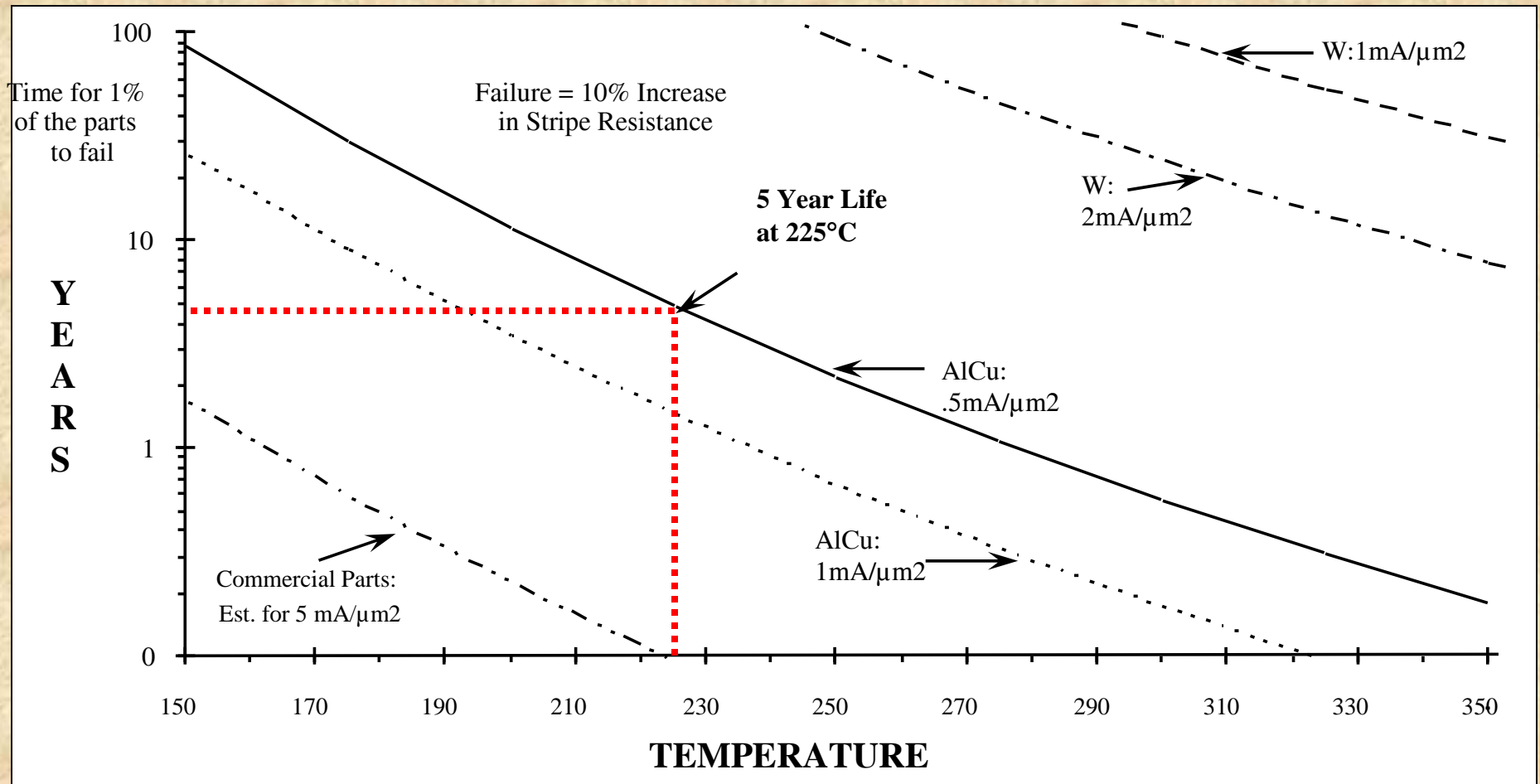
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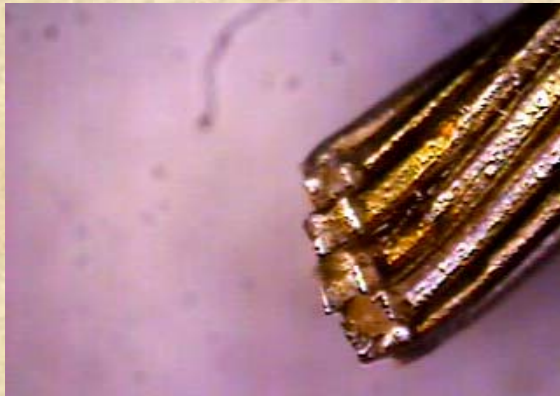
Did You Know

- Standard electronics are sold in mass quantities with little profit margin
 - Operating life times and temperature margins have been lost since the 1980s!
 - Components are rated to 85C & 125C but without ANY life data!
 - Mil-standard devices went out of favor back in the early 1990s
 - Metal migration of the aluminum to silicon bond is the #1 life limiting factor

Operating Life of Electronics

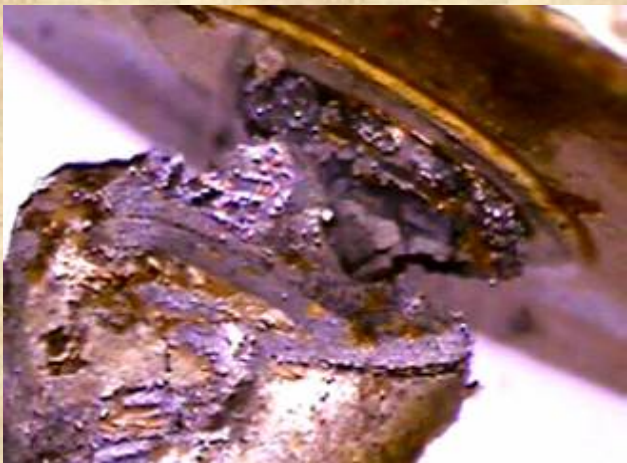
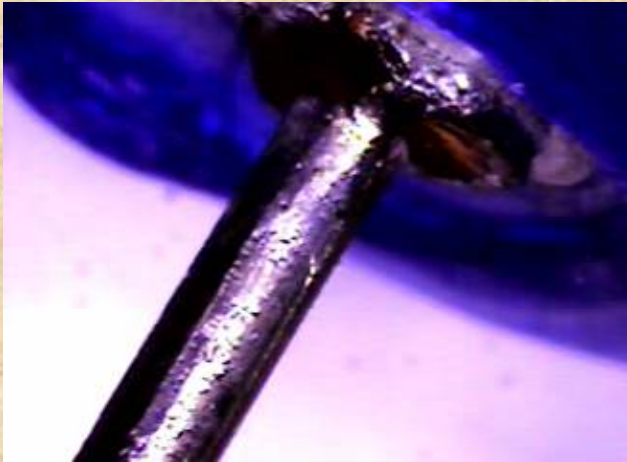


Copper and Tin Don't Mix



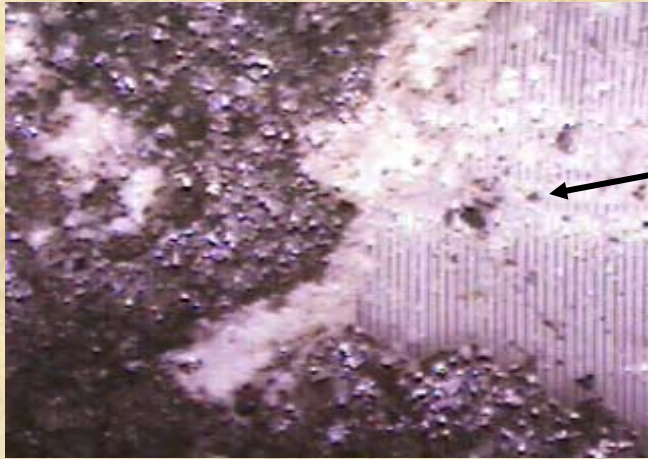
- Top image shows a clean 'cut' silver-plated copper wire rated for 250C by the manufacturer
- The copper reacts with the tin (found in the solder) to form bronze crystals
- This is a solid-phase interaction which leaves the wire joint fragile as can be seen in the lower photo.

Automotive Components Are A Gamble



- The top photo is of an untested “new” capacitor lead designed for automotive use, 125C continuous with 200C extrusions.
- The photo below is of a capacitor lead coming out of a geothermal well.
- The automotive industry can sneak by with conventional solder tinned copper leads the drilling industry cannot.

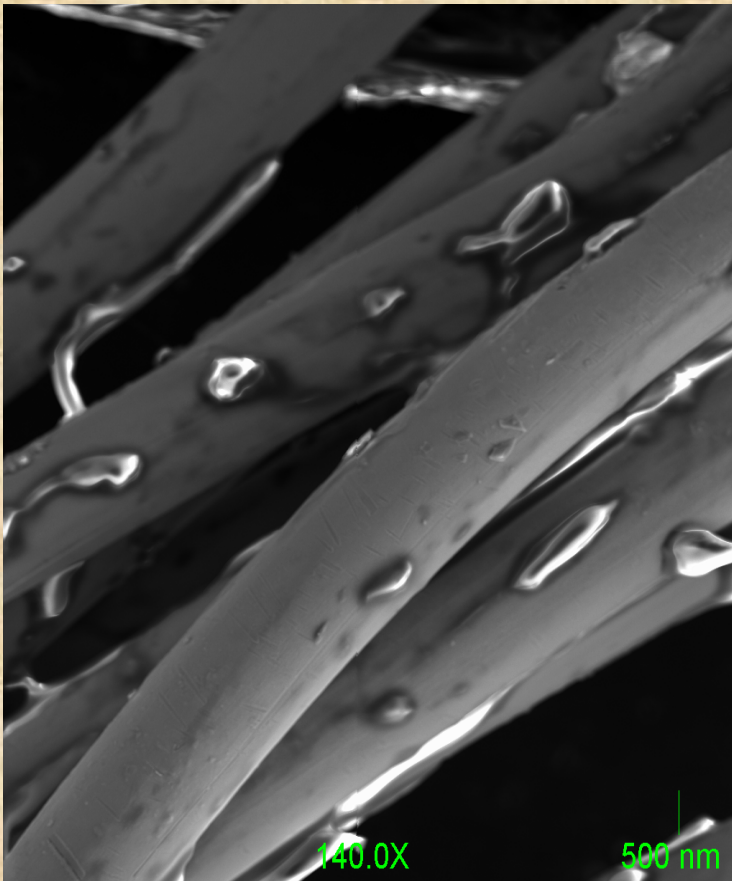
Microscopic Leaks



The wound wire is exposed and can be seen in this photo.

- Dale 1W, 250C, wire wound resistor (RS-1A)
- The *silicone based insulation* became ash
- An unknown oil was found in the tool following well exposure.

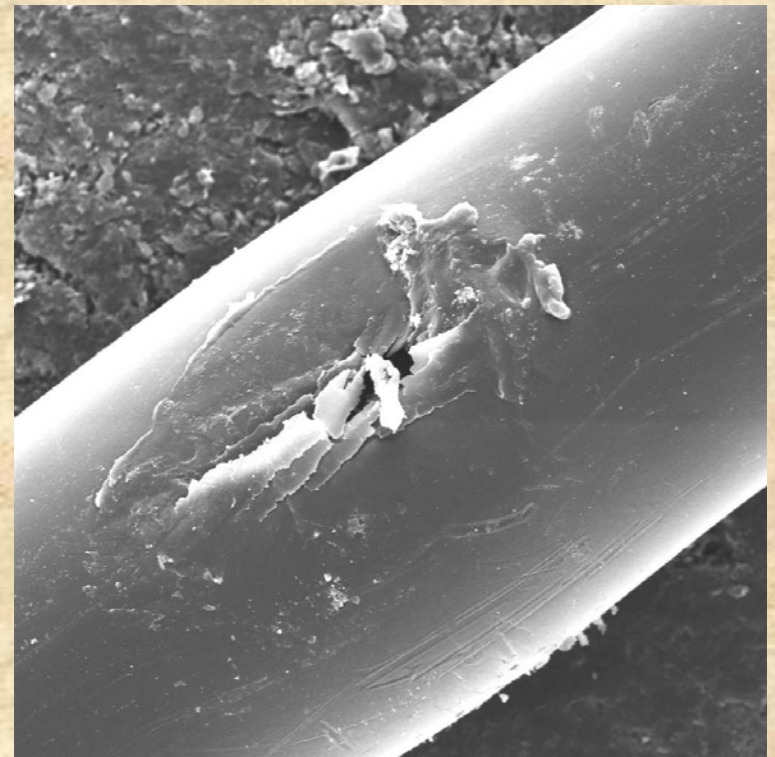
Silicon Materials Transformed



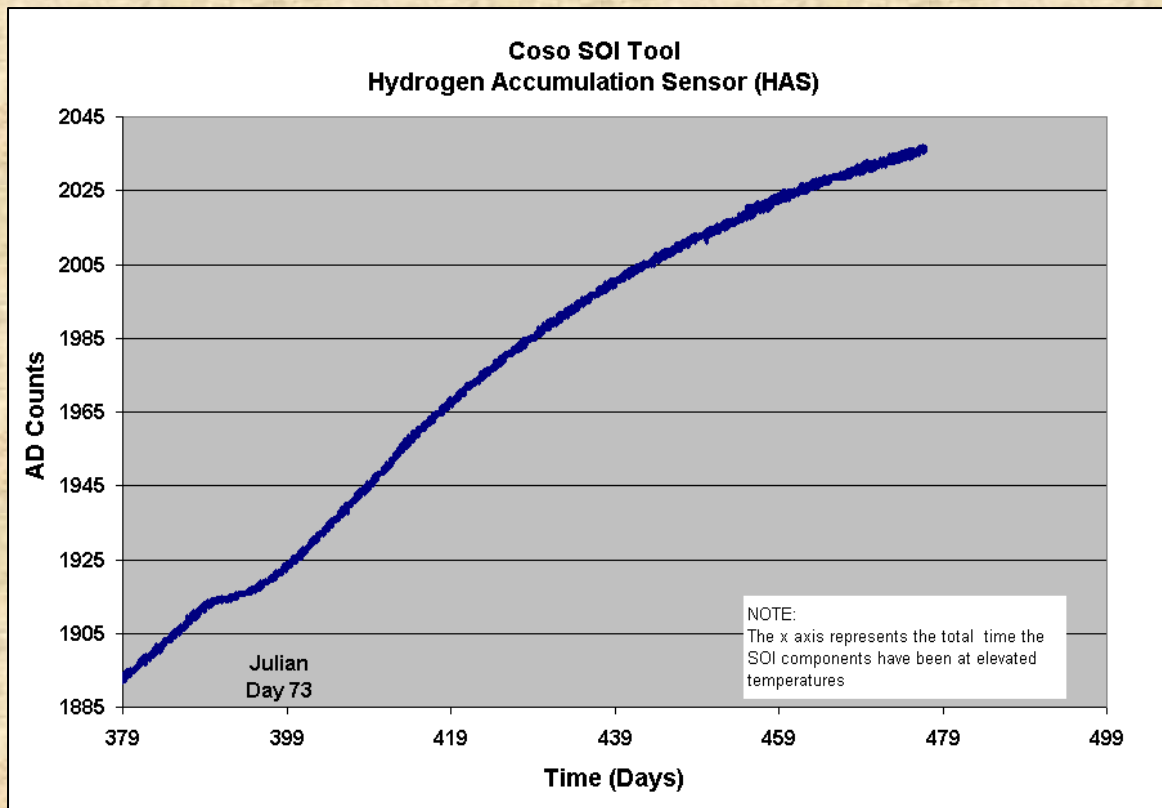
SEM image of blobs of silicone “grease or oil?” found internal to the tool. Sandia’s team determined this to be the missing silicon. Extremely small amounts of well brine was entering the tool past ‘metal’ seals!!

Water Exploited Fiber Flaw

- Microscopic flaws can be exploited by H₂O at elevated temperatures causing the fiber to break
- The fiber was examined under an SEM after exposure to steam in a lab test



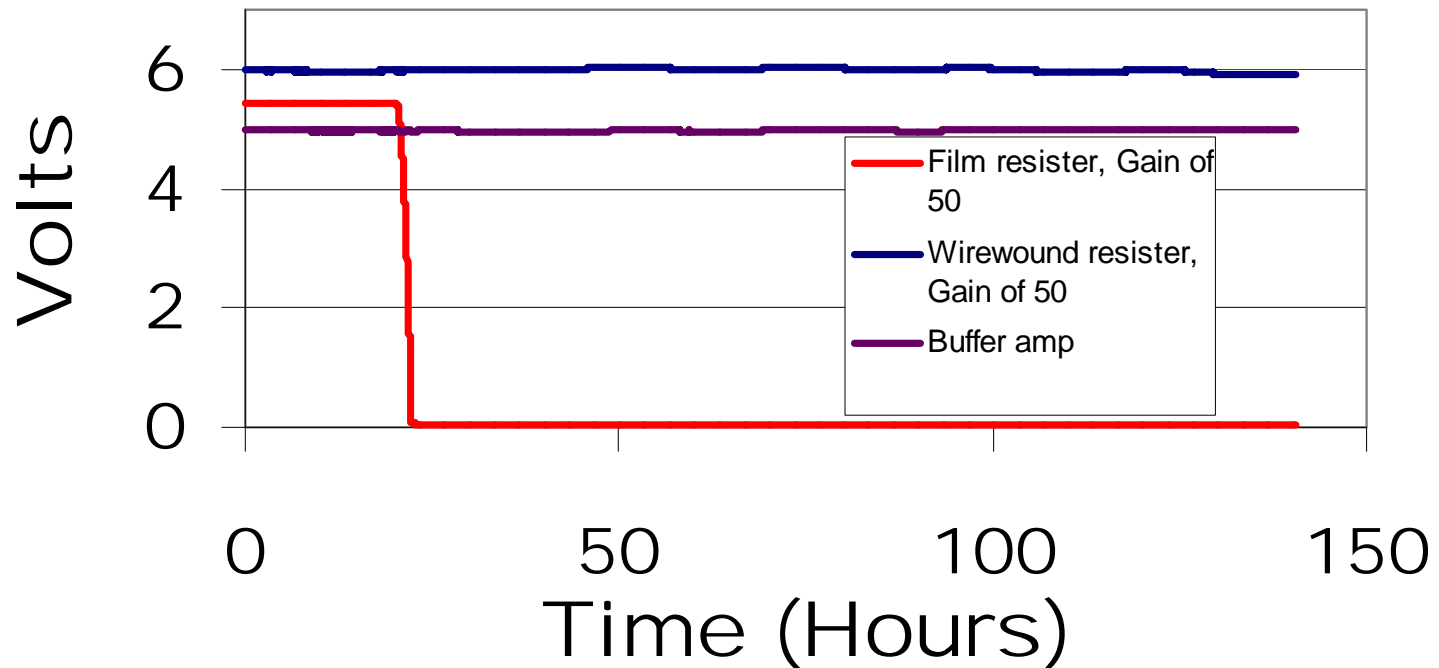
Hydrogen Penetrates Steel



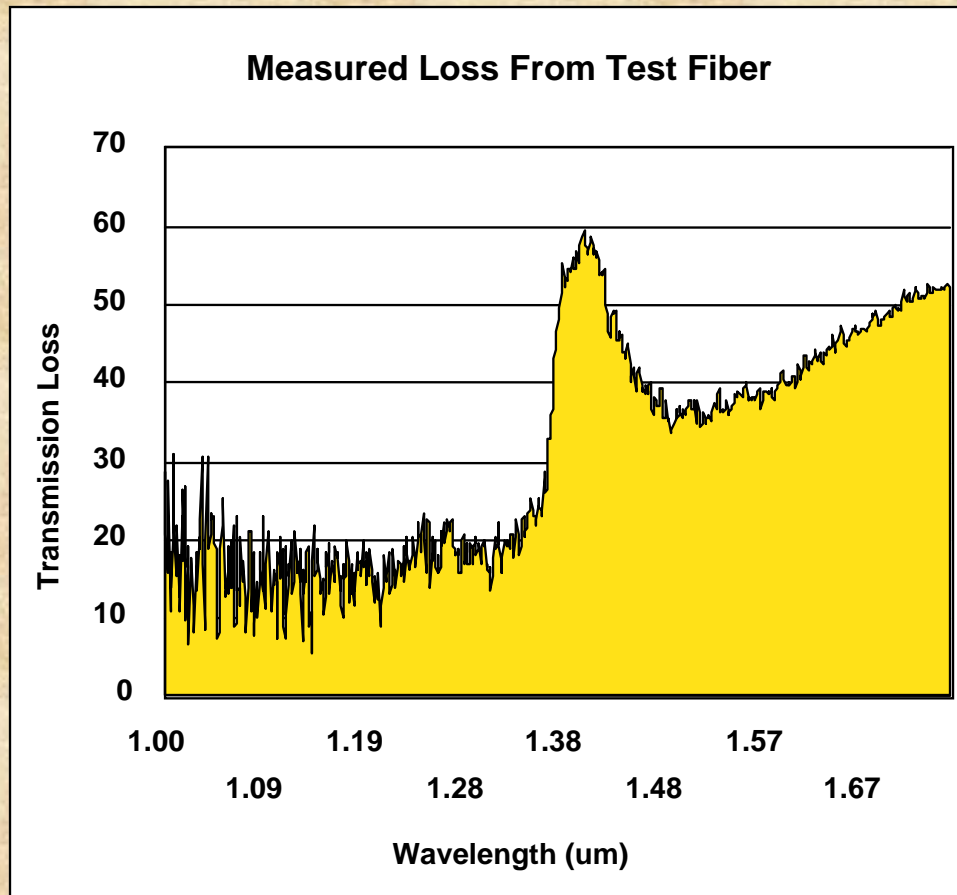
Hydrogen sensor inside the tool measures hydrogen entering the tool. Free hydrogen is created as brine interacts with well casing

Hydrogen Sensitivity in Resistors

Hydrogen Sensitivity Test (Film vs. Wirewound)



Fiber Optics: Nothing but Glass?



- Light loss in a 50ft section of 300C fiber after 1 year in a 180C well!!
- Hydrogen from the well bonds in the fiber creating OH and massive light loss

Long-Term HT SOI Tool Demonstration



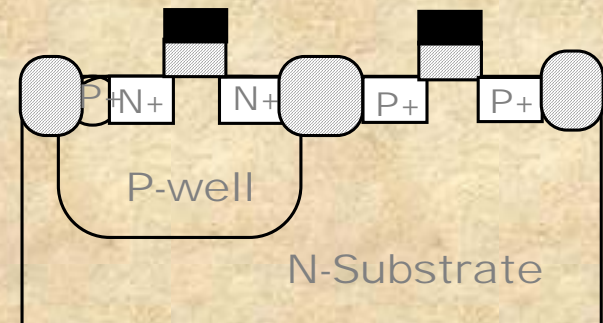
Objective: Demonstrate a microprocessor controlled, multi-channel data collection system for well monitoring.

A geothermal well was chosen at 193C. The tool monitored the well for 800 days before being lost due to operator error.

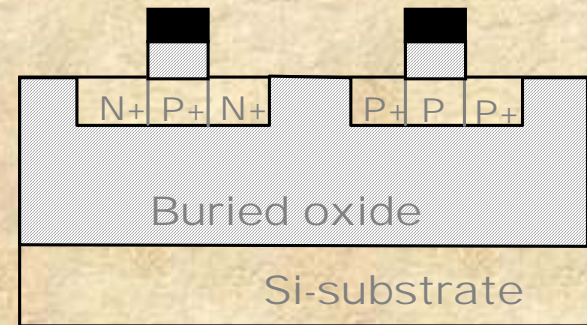
A major service company rates their tools for only 400 hrs at 175C.

New HT SOI

- Silicon-On-Insulator (SOI) isolates transistors on an insulating material providing:
 - Reduced leakage currents by almost 100 times!
 - 25% Faster switching
 - Better isolation for analog and digital on the same die
- SOI process is used for Pentium Processors



A: Cross-section of bulk CMOS inverter



B: Cross-section of a SOI CMOS inverter

Conclusion

- New electronic devices are available for incredibly long operating life times matching that of the well itself
- However, care must be taken to remove all failure modes inside the electronic components, sensors, tool housings and cables
- Thanks to Sandia National Labs and DOE Geothermal Program for research in geothermal instrumentation development.