Downhole Tools in the Oilfield Services Industry

Transformation to improve reliability

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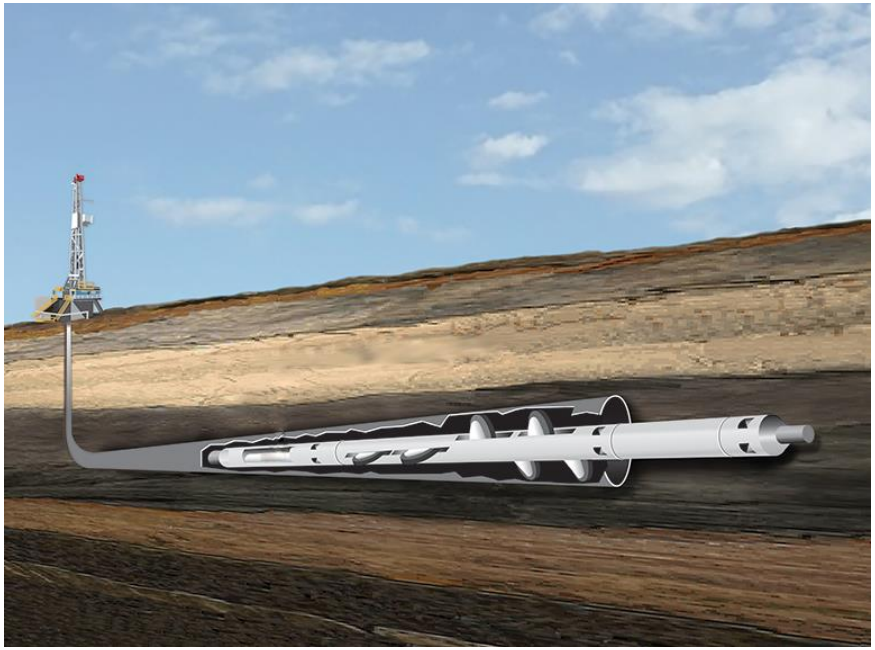
Presentation Outline

- Power Electronics for Downhole Tools
- High Temperature Disconnect
- Workarounds: Pressure, Temperature, Shock & Vibration
- Today's Capacitor Technologies & Critical Problem
- Oil & Gas Industry Trends
- New Option for Film Dielectric
- Industry Transformation Opportunity

Power Electronics for Oil & Gas Downhole Tools

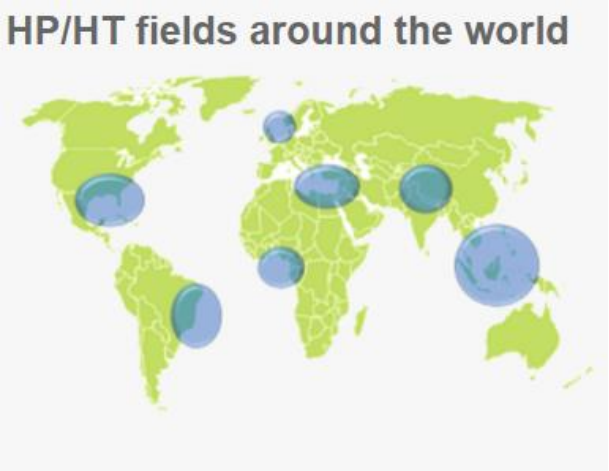
- **Drilling**: geo-location & steering instrumentation
- **Well logging**: determine characteristics of the formation - resistivity, radioactivity, acoustic travel time, magnetic resonance, etc
- **Conveyance / Tractoring**: extending reach in highly deviated wells
- **Production**: monitor pressure, temperature, vibration, and multiphase flow—and actively control valves in completion & production



Challenging Downhole Conditions

High Temperature

- Routinely 150 - 175°C within the deep shale gas wells in the U.S.
- Offshore as high as 200°C, particularly in SouthEast Asia
- Currently niche, but Ultra High Temperature (>200°C) expected to develop over the next several years

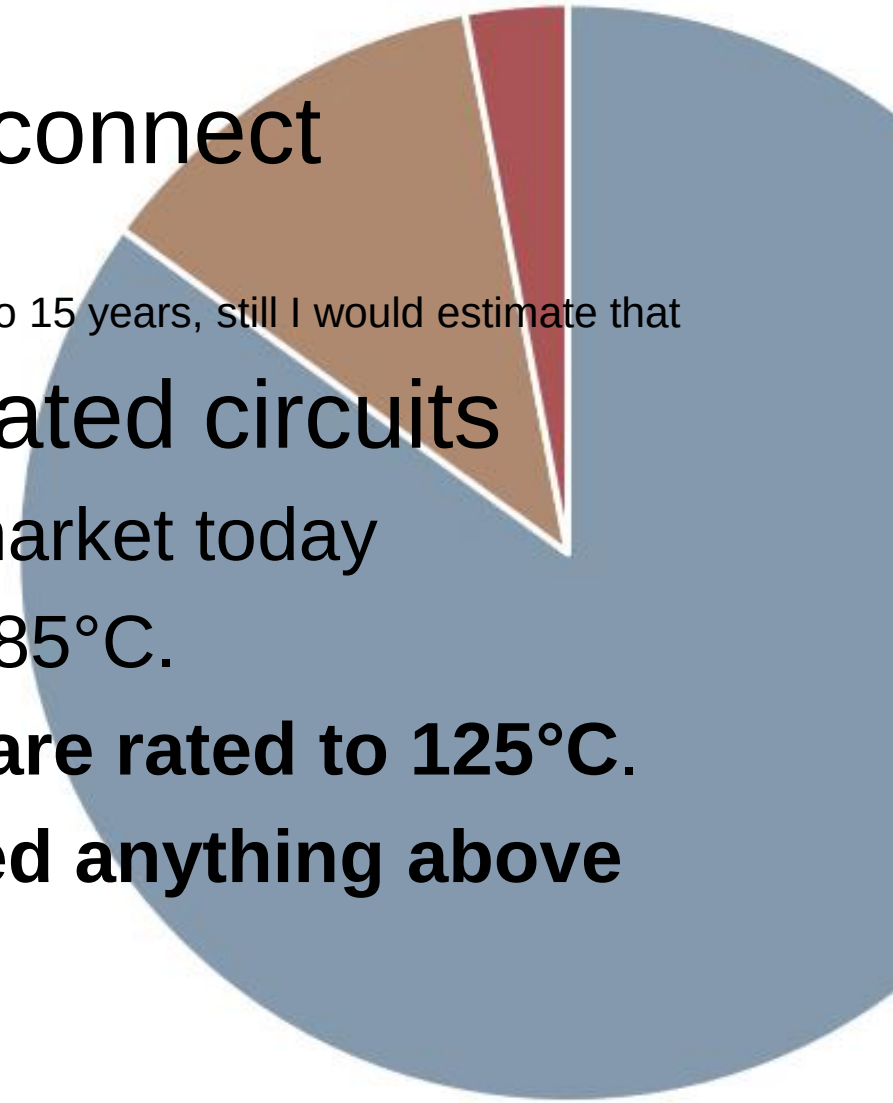


Variable amounts of vibration

Intermittent Shock

- Test protocols to 100,000 shocks @ 500G, 2ms

High Temperature Disconnect



"Even though its come a long way in the last 10 to 15 years, still I would estimate that

85% of the integrated circuits

and parts on the market today

are rated at 85°C.

And another **10% to 12% are rated to 125°C**.

Maybe **2% or 3% are rated anything above that**."

Matthew White, director of engineering at Ryan Directional Services

Beckwith, R. JPT (August 2013)

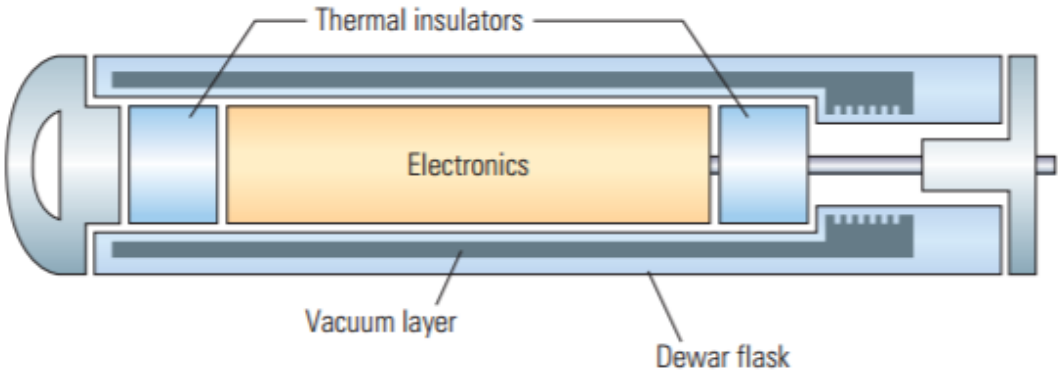
Industry Creativity

- Leverage capacitor technologies primarily designed for consumer markets and the automotive industry
- Extensive component screening capabilities to discern good quality capacitors from others
- Many incremental improvements over the years

Pressure: Sealed Housing Vessels

- Maintain atmospheric pressure
- Shields electronics from the downhole hydrostatic pressure 10-20k psi or more
- Protection from corrosive / conductive downhole fluids

Temperature:
Dewar or Vacuum Flasks



- Available technologies cite the ability to limit temperature rise to 150°C in a 230°C environment over the course of 24 hours.
- Suitable for short duration missions (ie. Wireline) that are rarely downhole more than 5-10 hours.
- Downsides:
  - Measuring While Drilling (MWD) tools, however, typically have runs that extend 1-2 weeks.
  - Traps internally generated heat

Beckwith, R. JPT (August 2013) Oilfield Review (Autumn 2012).

Shock & Vibration: Mounting Improvements

- Solid rail mount design for circuit boards vs. mounting to a central mandrel
- Advanced elastomer vibration isolation and damping
- Plastic molded encapsulation techniques

Oilfield Review (Autumn 2012).

Drawbacks of Current Technology:
Ceramics / Wet Tantalum

Shared

- Temperature Coefficient of Capacitance (TCC)
- Voltage DeRating
- Failing Short

End Effect

Requires multiple capacitors in series and/or parallel to meet capacitance / voltage needs

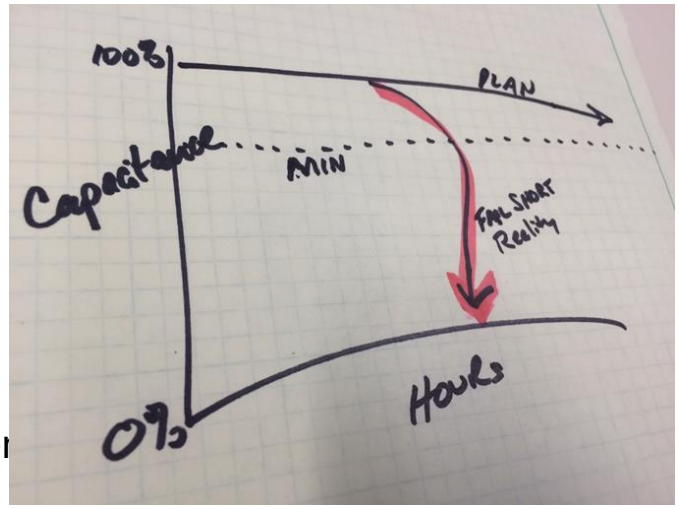
Tool functionality can shut down!

Ceramics (X7R)

- Flex cracking: Dominant cause of failure
- Aging
- Piezoelectric noise: @ higher frequencies

Wet Tantalum

- Polar
- Exothermic ignition failure
- RC-Ladder effects: Loss of Cp with increasing frequen
- Higher leakage: order of magnitude > ceramics



Prymak, J. (November 2008).

Key Problem: Risk of Failing Short

Financial Impact

- Costs of Downhole Failure
- Unplanned Maintenance

"Shock is bad for ceramics. They get brittle with temperature and then crack."

Component Manager

"Greater reliability and avoiding catastrophic failure would be attractive."

Downhole Tool Project Manager

"Generally, the rigs will run tools to failure vs. doing preventative maintenance, and it happens routinely."

Industry Consultant

"It is always the capacitor that fails."

Specialty Component Design Engineer

Industry Trends

Deeper / Hotter Wells

- In the past, drilling operations maxed out at temperatures of 150°C to 175°C
- Declining reserves & advances in technology have motivated the industry to drill deeper, and in hotter geothermal regions

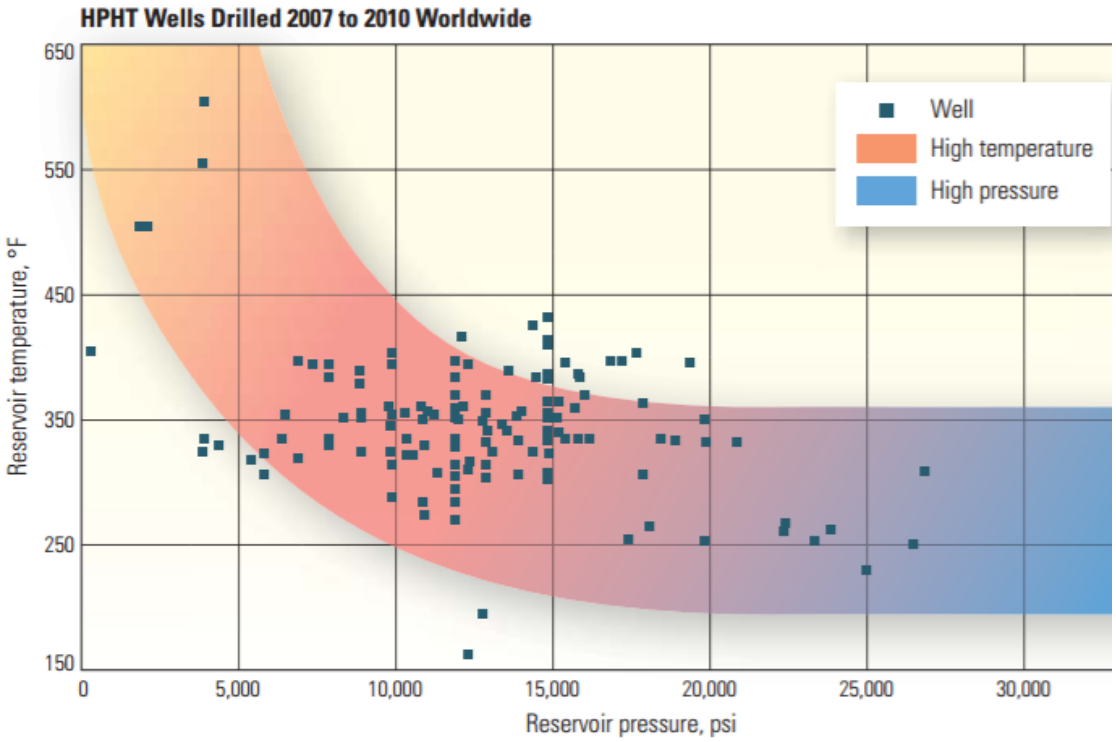
Lower Oil Prices / Transformation

- Focus on cost, efficiency, and speed
- Continuous improvement to drive out inefficiencies of equipment and operations
- Predictive vs. reactive maintenance

Growth of HPHT wells

(150-205°C / 10-20kpsi)

- 1600 HPHT wells drilled in 2012 out of 107,000 total (1.5%)
- Historically small segment; however this represents a 10X acceleration since 2002.
- HPHT wells in production will double 2012-2016, and increase by 10X by 2020.



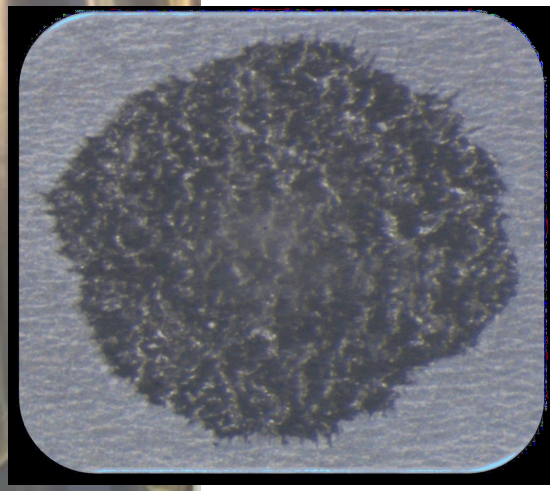
Vallourec (October 2012) Oilfield Review (Autumn 2012)

Film Capacitors: Dielectric options

- Today the dielectric films that are used are mainly polypropylene (PP) or polyethyleneterephthalate (PET)
- Formerly, paper (PA) was used in film foil technology—either pure paper or mixed with polypropylene (DM)
- In special applications, where high temperatures are required, polyethylenenaphthalene (PEN) up to 125°C or polyphenylene sulfide (PPS) up to 150°C are used

Gallay, R. (May 2014).

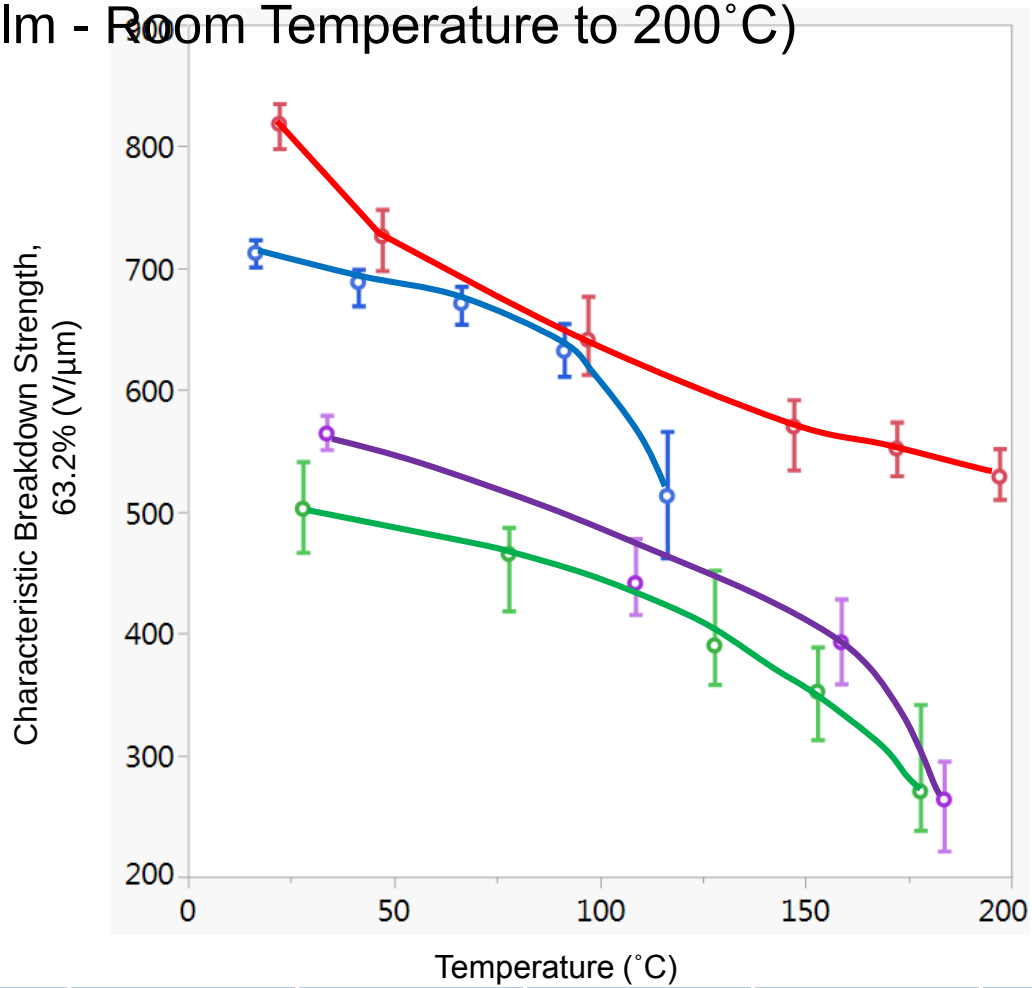
Graceful Failure of Film Capacitors



- “Self-healing” properties in which electrode point-defects vaporize away due to over-voltages
- Negligible drop in capacitance
- Don’t fail short like currently used ceramics and wet tantalum capacitors
- Historically, film dielectrics have seldom been used over 105°C. Many fail to maintain high dielectric and mechanical strength at elevated temperatures.

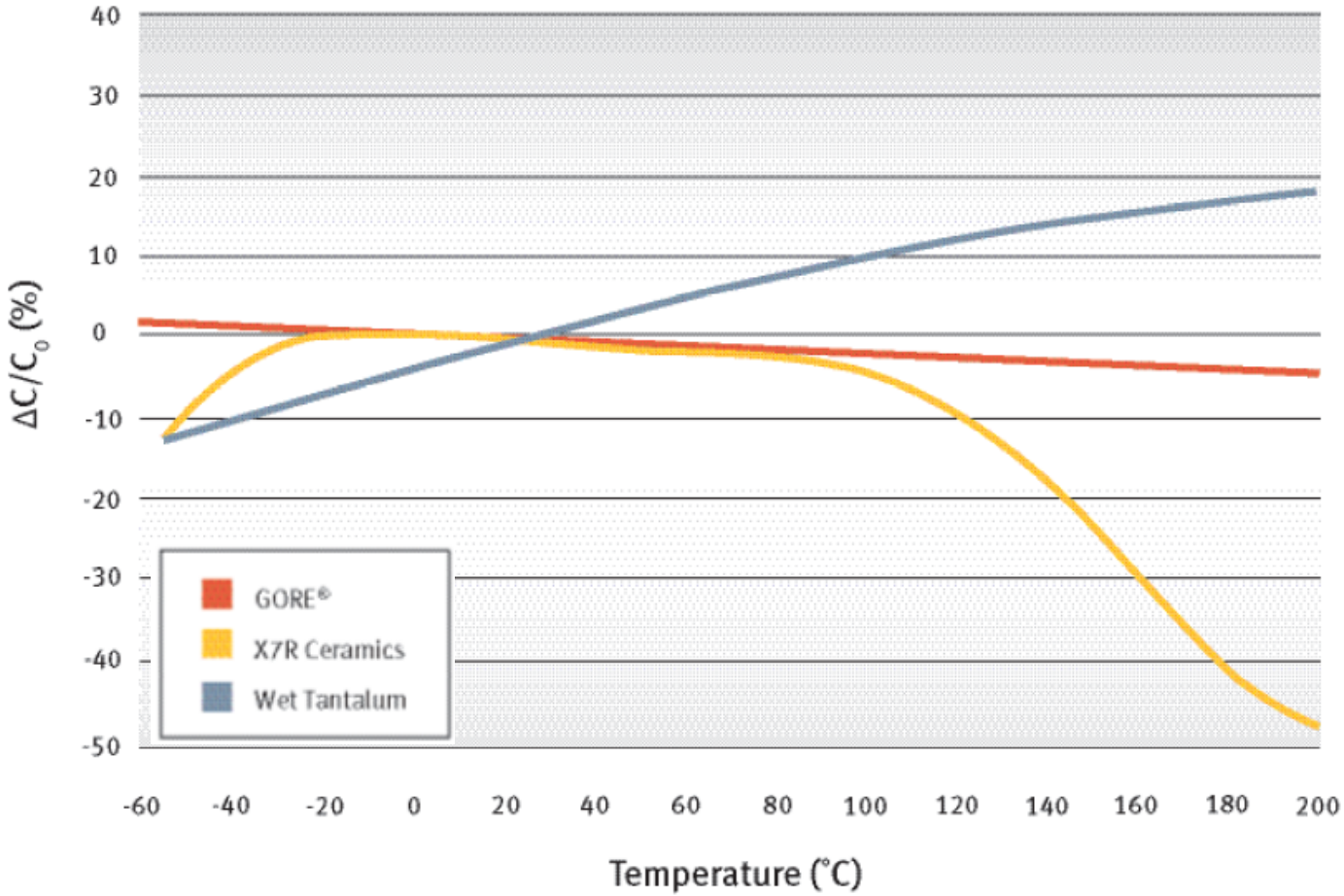
Dielectric Breakdown Strength Over Temperature

(Film - Room Temperature to 200˚C)

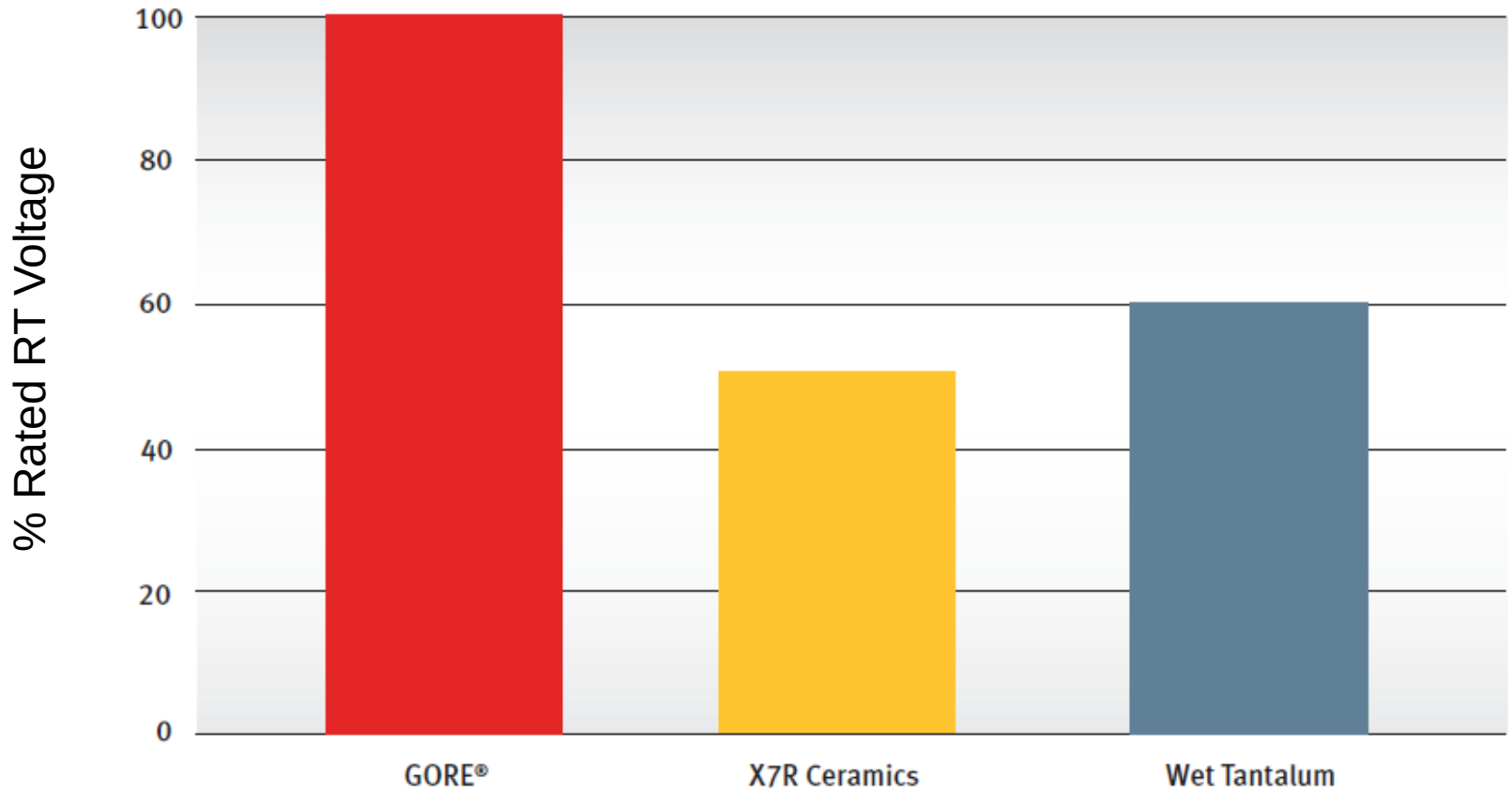


- Gore Film
- Polypropylene (BOPP)
- Polyether ether ketone (PEEK)
- Polyethylene naphthalate (PEN)

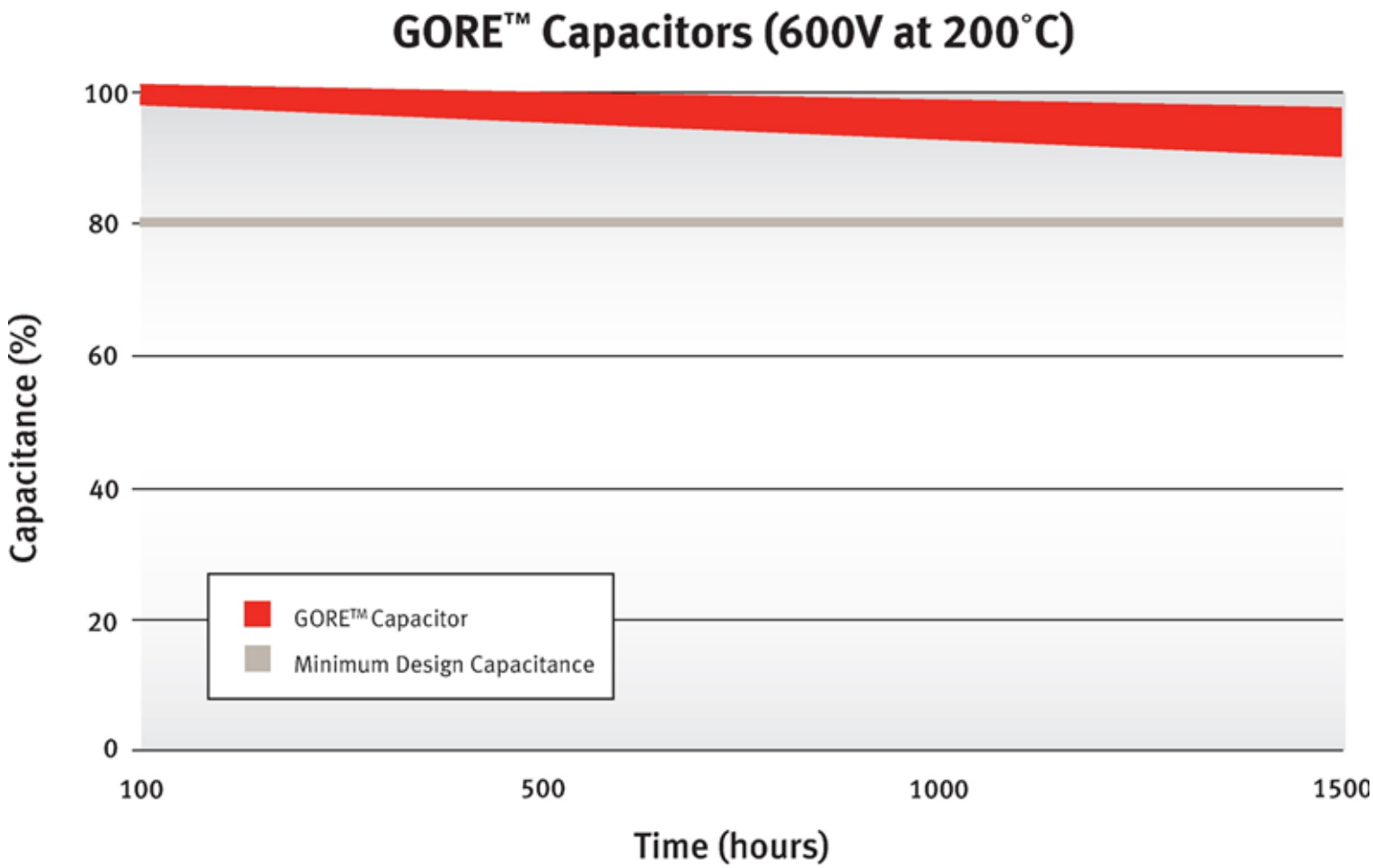
Capacitance Stability Across Temperature



Category Voltage at Temperature
(175-200°C)



Endurance Testing



Transformation Challenge / Opportunity

- Global energy demand projected to increase 48% by 2040
- Easily accessible reserves in decline
- Price is depressed / volatile
- Industry cost trends
  - 4X increase in cost per barrel from 1996 to 2014
    - Regulatory
    - Industry Practices

Opportunity:

- Innovation to tap new resources
- Innovation to drive out inefficiencies
- Increased reliability
- Predictive maintenance

Downhole Tools → High Temp Disconnect → Workarounds → Critical Problem → O&G Trends → New Film Dielectric → Transformation Opportunity

Associates

GORE Creative Technologies Worldwide

Beckwith, R. JPT (August 2013) Brekelmans, H. (May 2016) US Energy Information Association

Thank You

APPENDIX

Citations

- Beckwith, R. (August 2014). Downhole Electronic Components. JPT, 43-57
- Brekelmans, H. (May 2016). Now's the Time to Tackle Costs. OTC2016. Day 2.
- Gallay, R. (May 2014). Metallized Film Capacitor Lifetime Evaluation and Failure Mode Analysis.
- Oilfield Review. Schlumberger (Autumn 2012). Testing the limits in extreme well conditions.
- Prymak, J. (November 2008). Kemet Charged. Technical Update – Comparison of Ceramic and Tantalum Capacitors.
- US Energy Information Association (May 2016). International Energy Outlook 2016. www.eia.gov/outlooks/ieo/world.cfm
- Vallourec. (October 2012). HP/HT Wells a Global, Fast Growing, and Technically Challenging Market. www.connection-mag.com/?p=1838.
- Watt Consulting. Hi Temp / Hi Rel Design guide
- Zogbi, D. (March 2016). www.ttieurope.com. Article posted: articles, passives.

Downhole Tools in the Oilfield Industry – Transformation to eliminate catastrophic failure

Short Description:
The Oilfield Service Majors are undergoing a transformation in the mindset and management for design, maintenance & repair of field equipment. Ongoing adoption of cutting-edge innovation is required to pursue hotter, harder to reach reservoirs to meet the ever-increasing global demands for energy. And in the midst of a major market downturn, continuous improvement is critical to improve operational reliability, productivity, and profitability. This presentation will highlight the challenges of the industry as it pertains to downhole tool electronics (principally capacitors) and the transformative approach to shift from incremental technology improvements to address the critical weakness – unpredictable failure.

Target Audience:
Individuals from varying technical / non-technical backgrounds who would appreciate learning about a particular market segments' power electronic challenges from the perspective of how the market has compensated for current technology's drawbacks…and how adoption of a new technology requires a broader understanding of value drivers beyond the simple product or technology attributes.

Additional Detail:
While the focus will be the industry challenges and transformation to improve equipment reliability, the presentation will cover Gore's high temperature, high voltage capacitors designed to eliminate catastrophic failure.

Rob Haywood

Product Specialist
GORE™ High Temperature Capacitors
for Oil & Gas

- BS in Chemical Engineering 1995 - University of Delaware
- MBA with Strategic Marketing Honors 2002 - University of Delaware
- Twenty+ years Industrial Market experience with roles in Sales, Marketing, Technical Support, Product Management, Product and Business Development

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