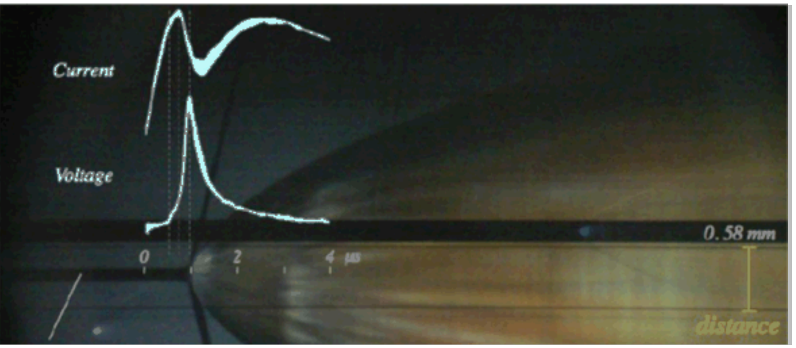
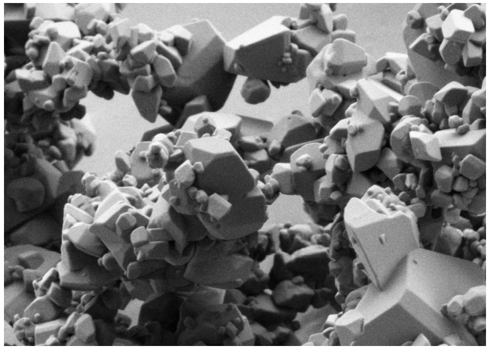
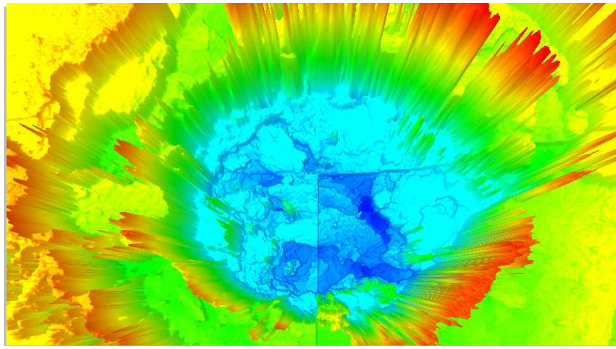
Exceptional service in the national interest

SAND2015-3173C

Sandia National Laboratories







HMX Hotwire Ignition and Performance Criteria

Cole Valancius, Ryan Marinis, Travis Kubal

cjvalan@sandia.gov, rtmarin@sandia.gov, tmkubal@sandia.gov

Sandia National Laboratories

New Mexico, USA

U.S. DEPARTMENT OF ENERGY

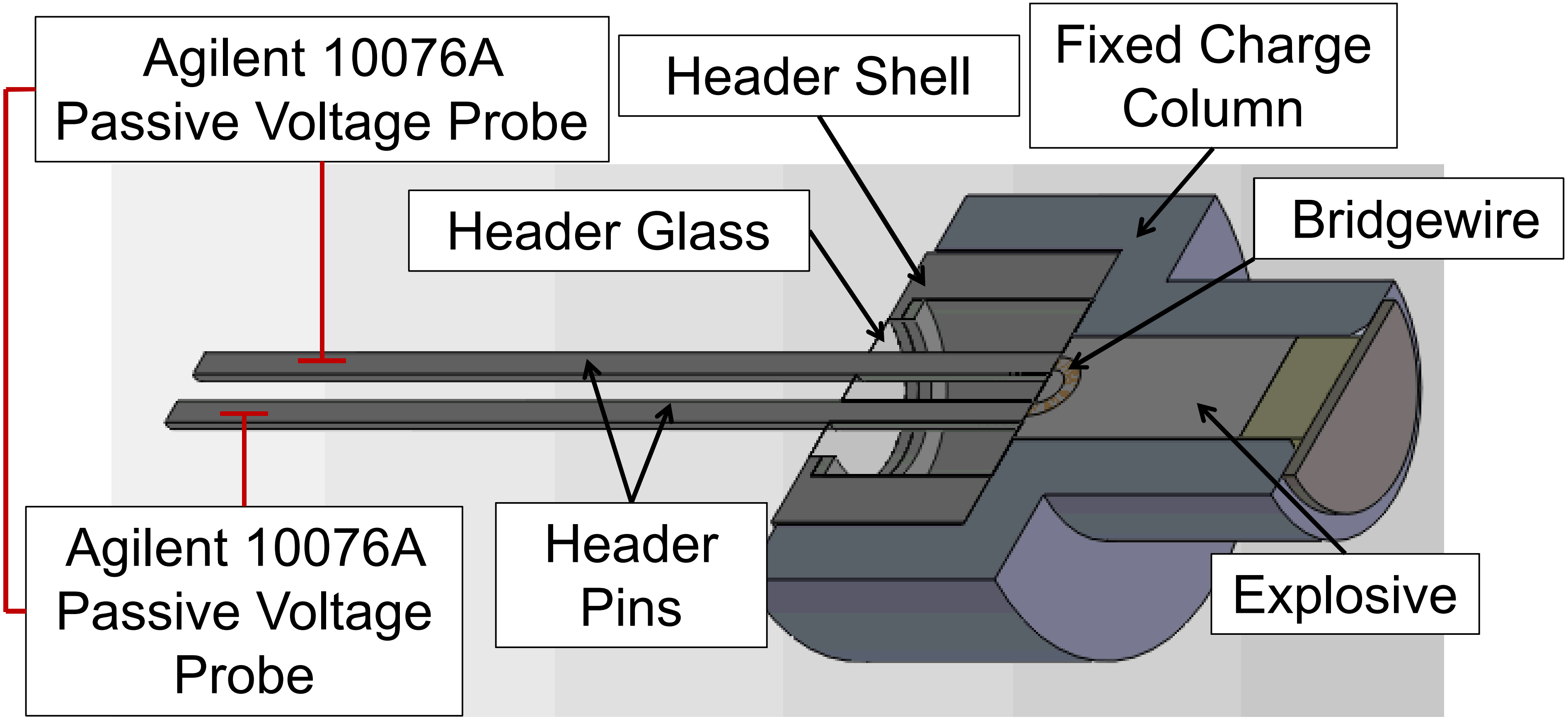
NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Acknowledgements

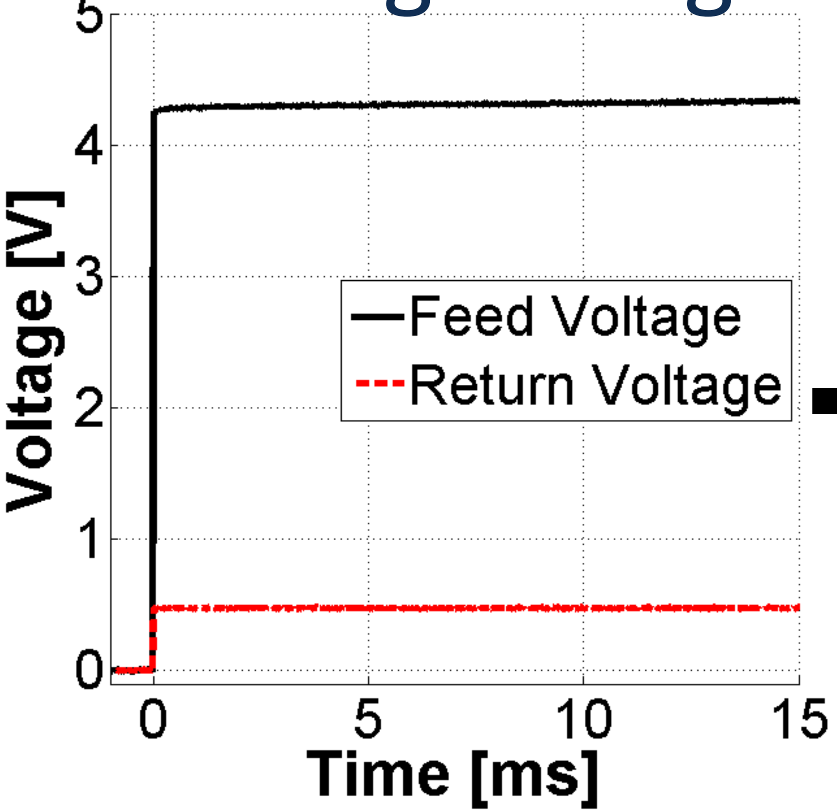
- Joe Bainbridge – Testing.
- Marlene Barela – Testing.
- Evan Dudley – Analysis and guidance.
- Chris Colburn – Testing.
- Matt Farrow – Chemistry Support.
- Chris Garasi – ALEGRA modeling, analysis and guidance.
- Cody Love – Test Unit Assembly.
- Jerome Norris – Test Setup and analysis.
- Joe Olles – Analysis, Theory, Sounding Board.
- Patrick O'Malley – Test setup/instrumentation, analysis and guidance.
- Sharon Petney – ALEGRA modeling.
- Todd Reedy – Testing, test unit design.
- Duane Richardson – Test unit assembly.
- Shawn Stacy – Analysis.
- Ryan Wixom – Experiments, theory.

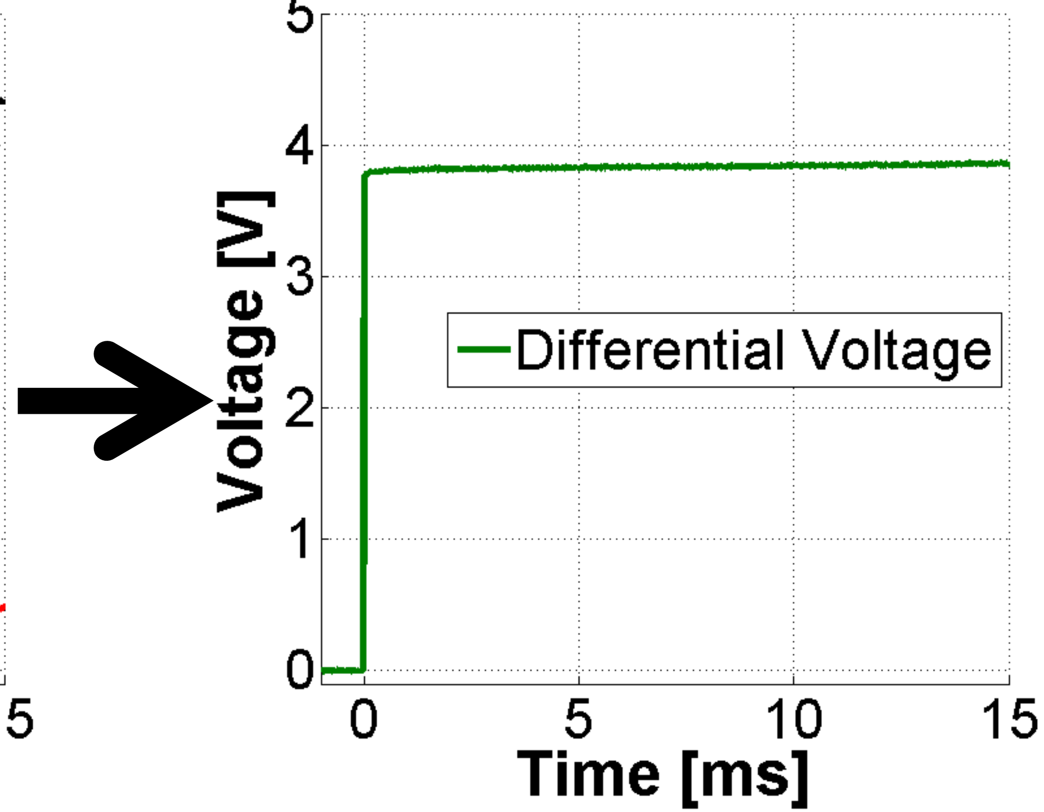
The Test Vehicle



- The test vehicle allows changing bridge length and the explosive pressing.
- Input is measured using a CVT for current and differential voltage probes for voltage.
- The output is detected via optical detection or pressure reading.

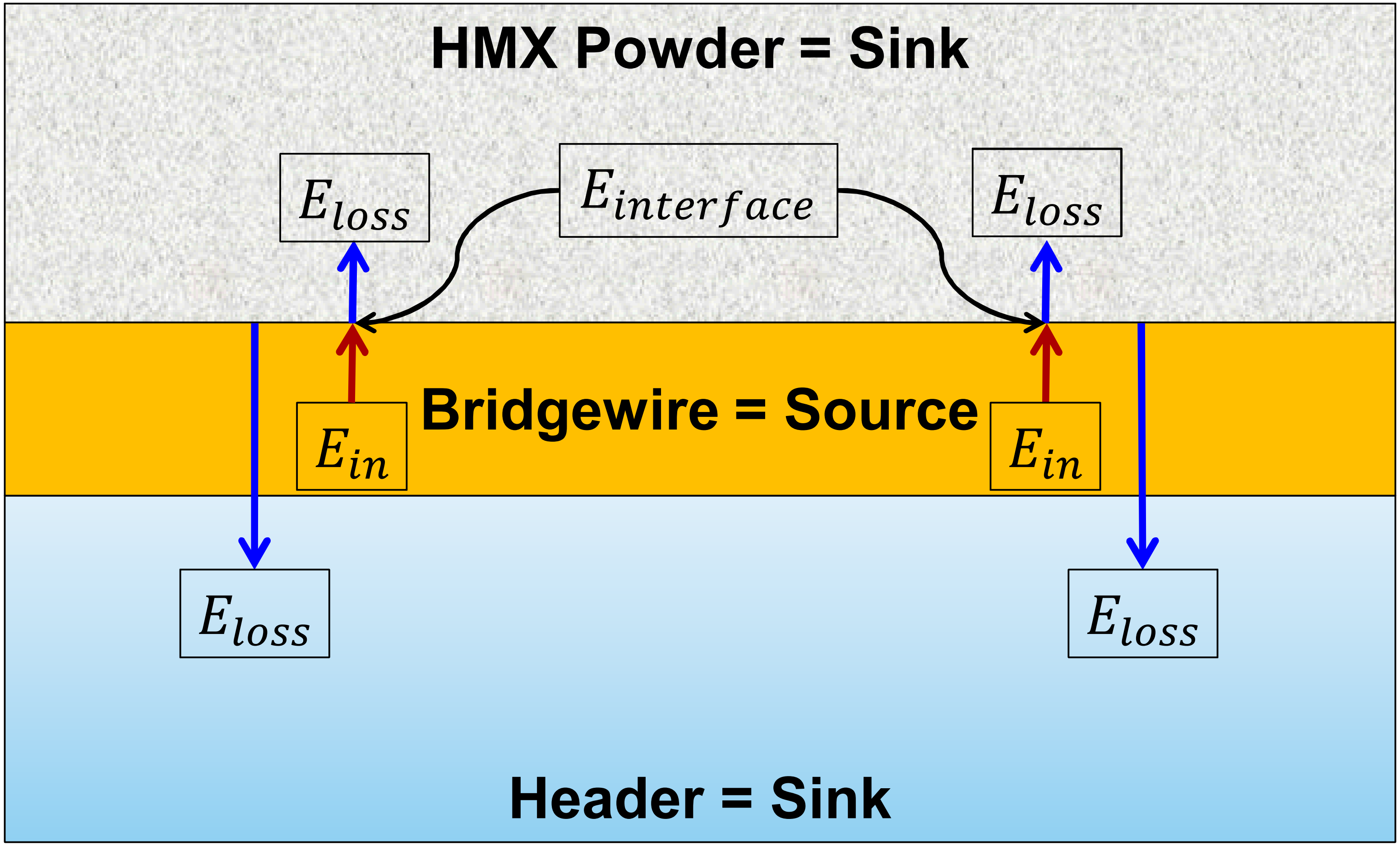
Obtaining Voltage with Differential Probes





- The two voltage signals are subtracted.
- The result is the true voltage across the bridge.
- This method works most reliably being as close to the bridge as possible with the two measurements.

The Ignition Problem

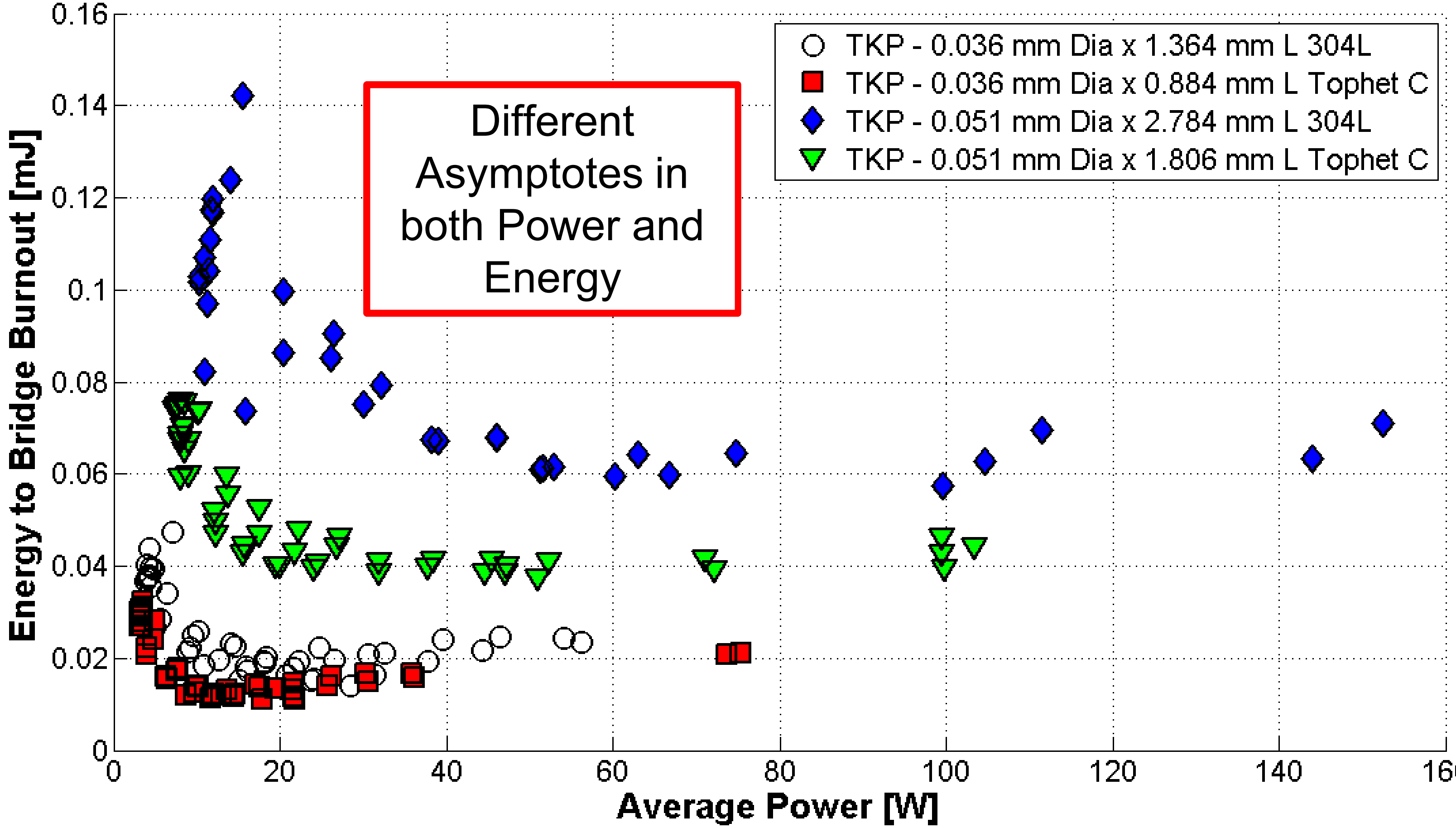


- Trying to find $E_{input} + E_{loss} \geq E_{ignition}$

or

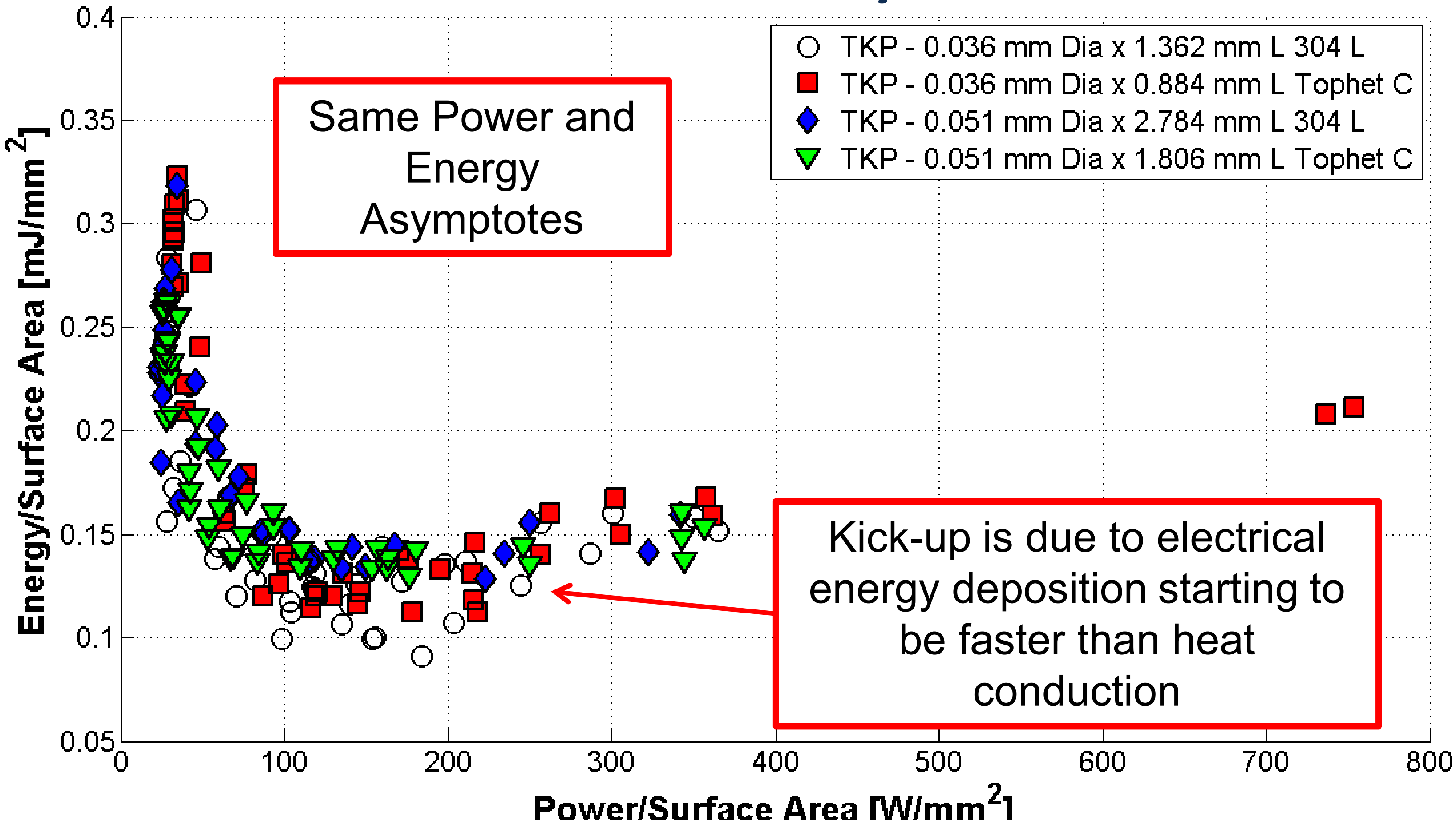
$$E_{interface} = E_{input} - (E_{header} + E_{powder}) \geq E_{ignition}$$

Observations from TKP Tests



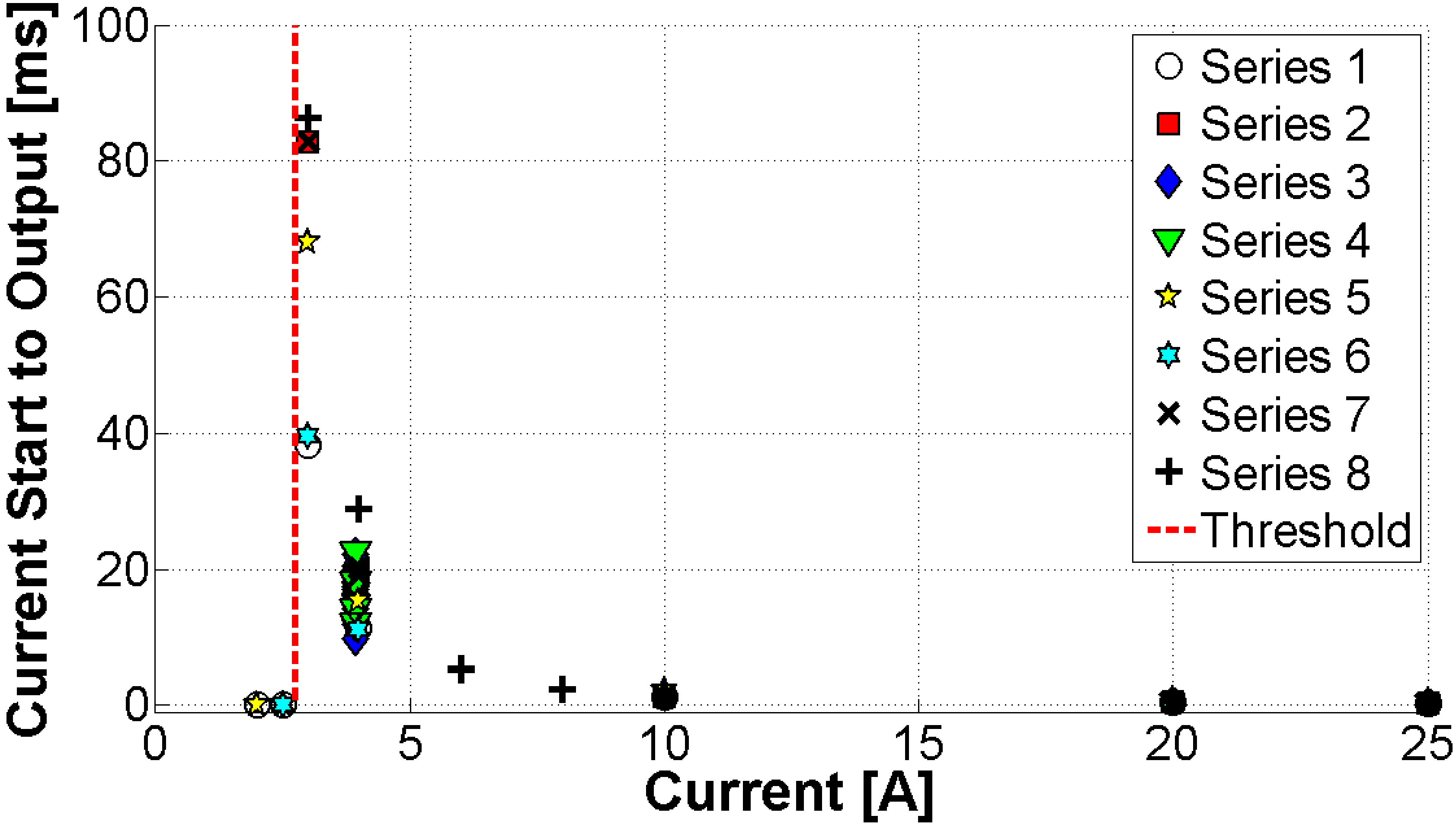
- All wires are 1 Ω.
- Changing bridge dimensions and material changes energy and power asymptotes.

The Curves are Related by Surface Area



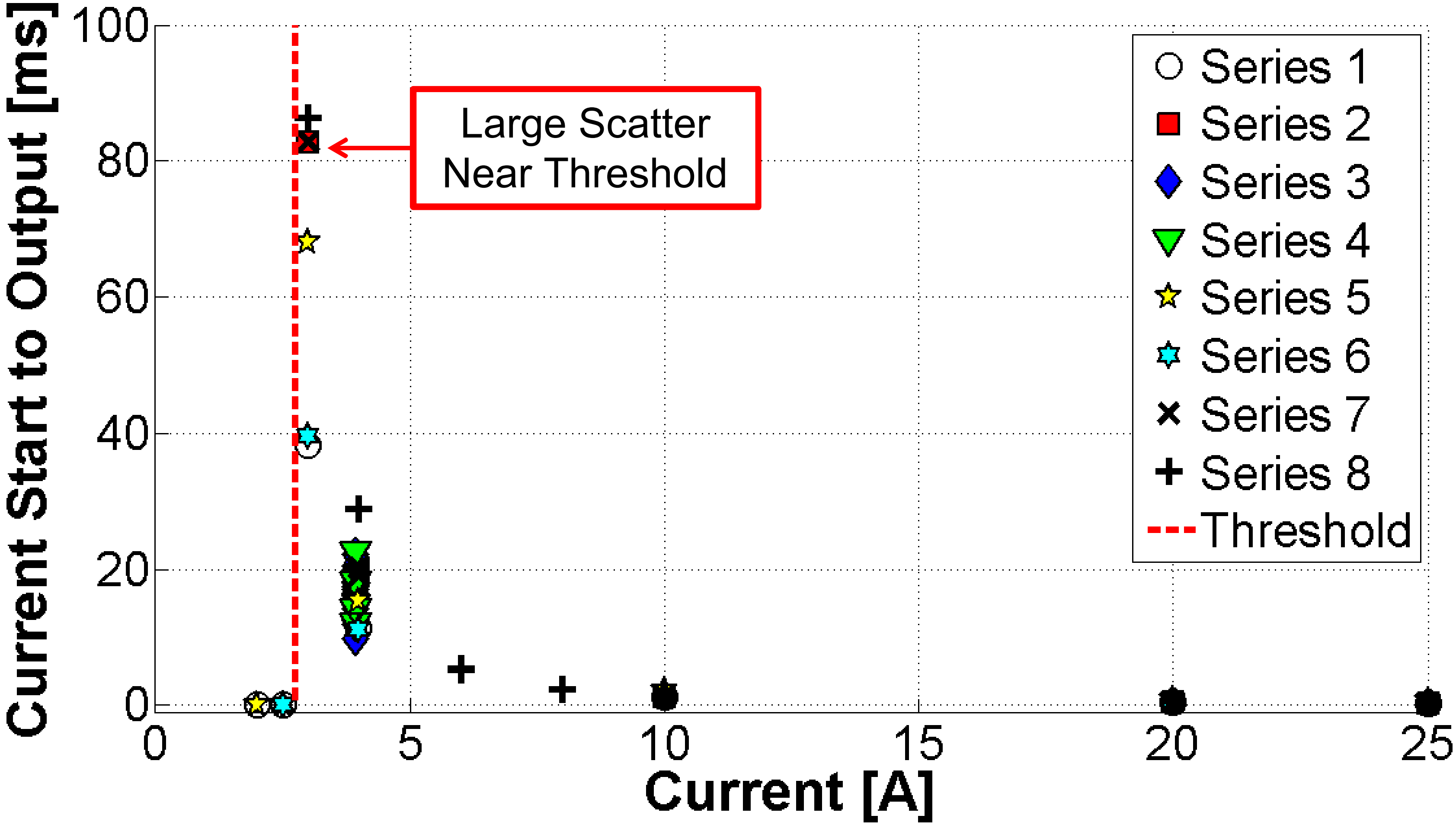
- The different bridge materials and dimensions can be related by their surface area.
- This allows translation between designs having only performed a single test series.

HMX Performance Data

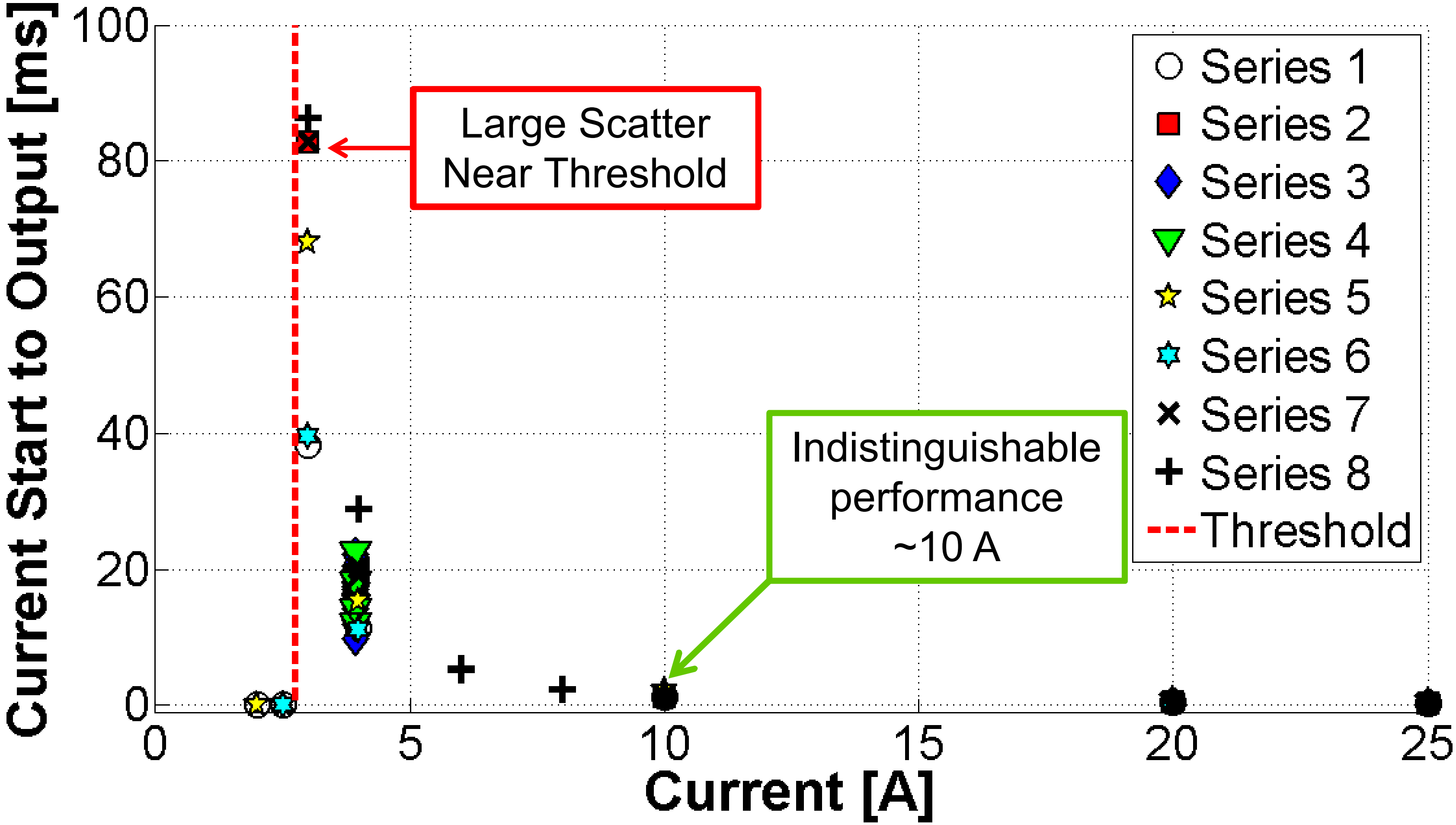


- Several tests conducted increasing firing current from 2 A to 25 A.
- Many tests performed at 4 A (near threshold).

HMX Performance Data

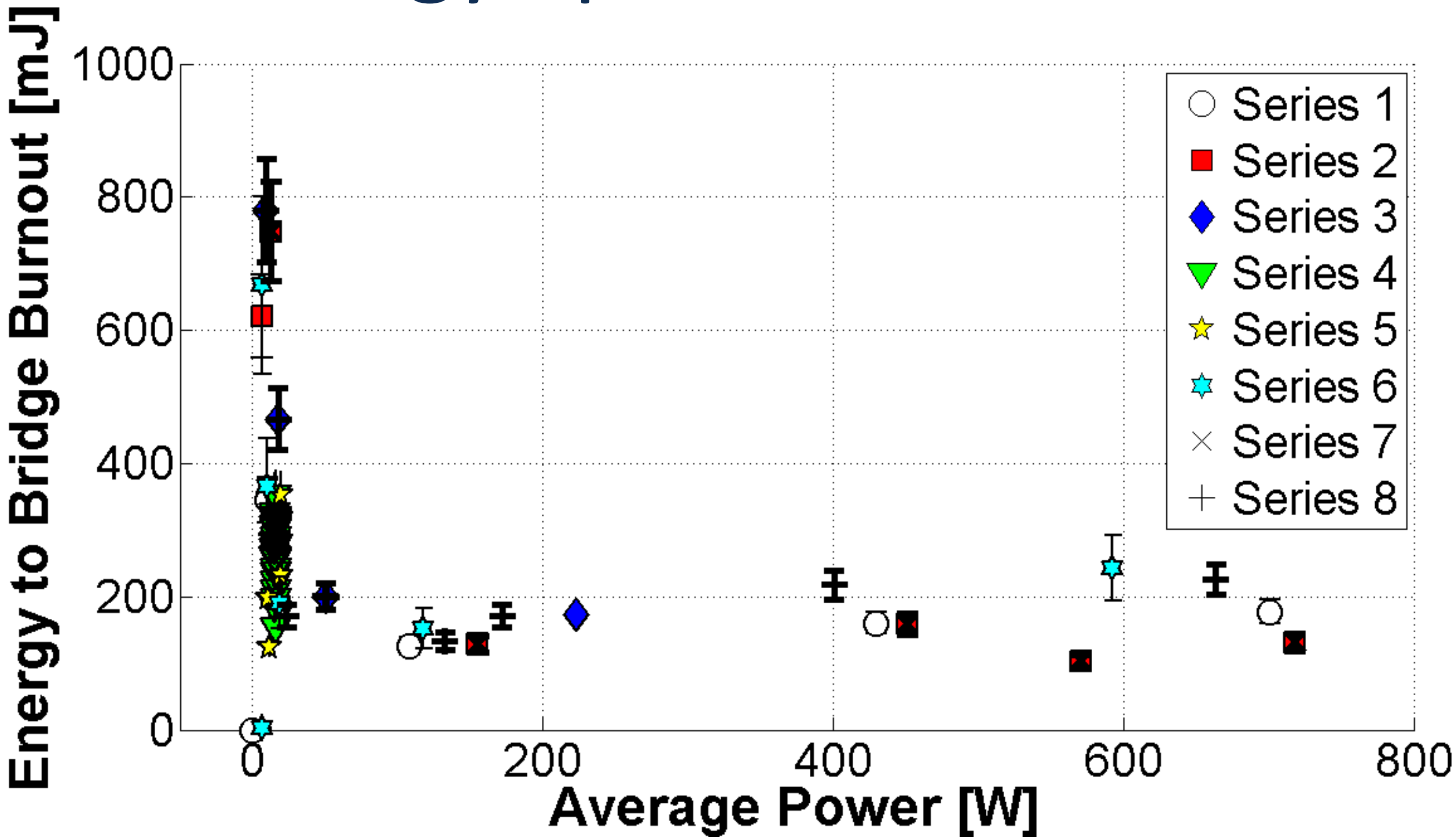


Performance Data



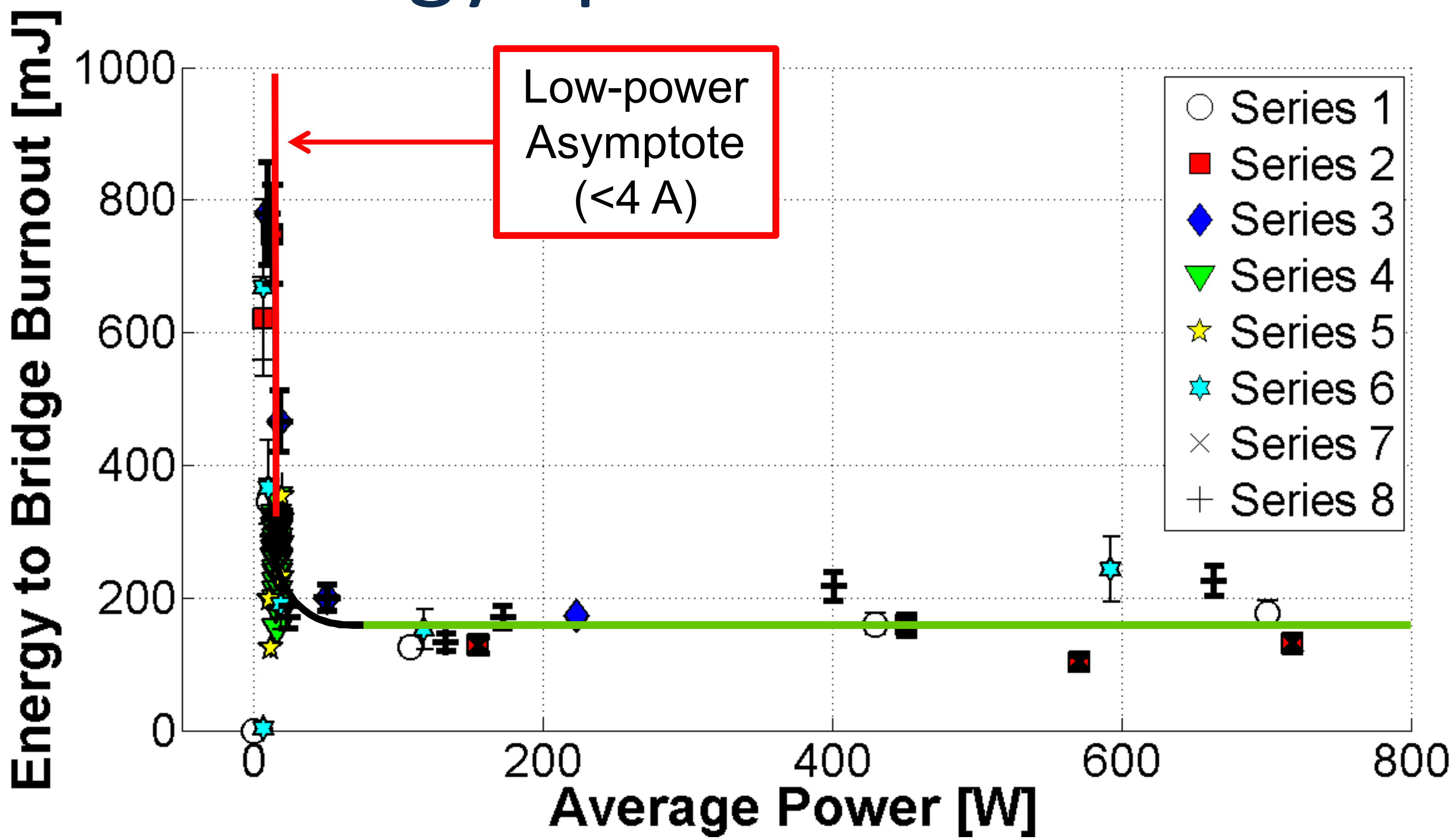
- Why is there a reduction in scatter as input is increased?
- Where in the design does the scatter come from?

Power-Energy Space



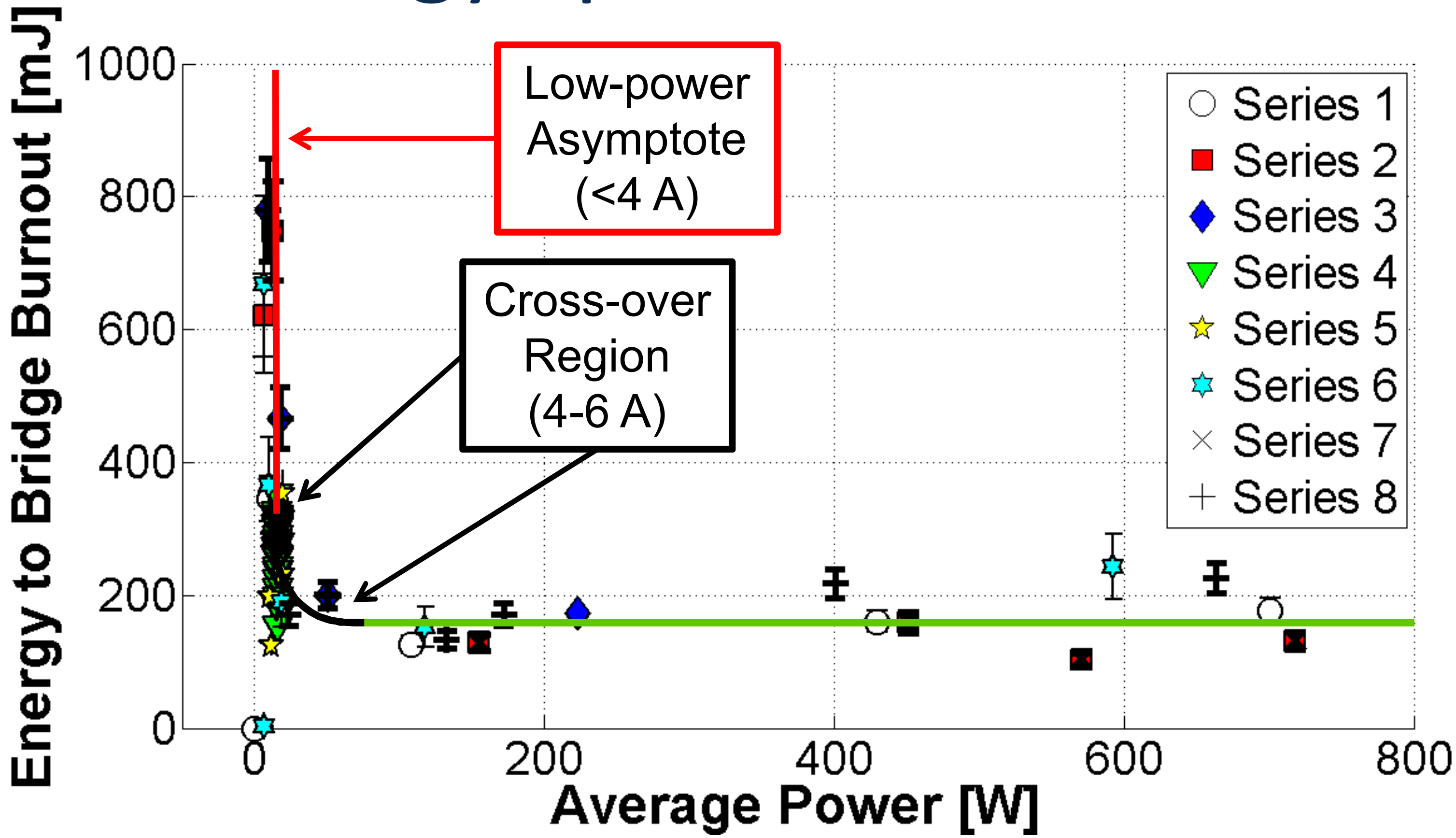
- Points taken at Peak Power, which corresponds to bridge burnout.
- In low-power region, burnout occurs when output occurs.
- In high-power region, bridge burns out before output.

Power-Energy Space



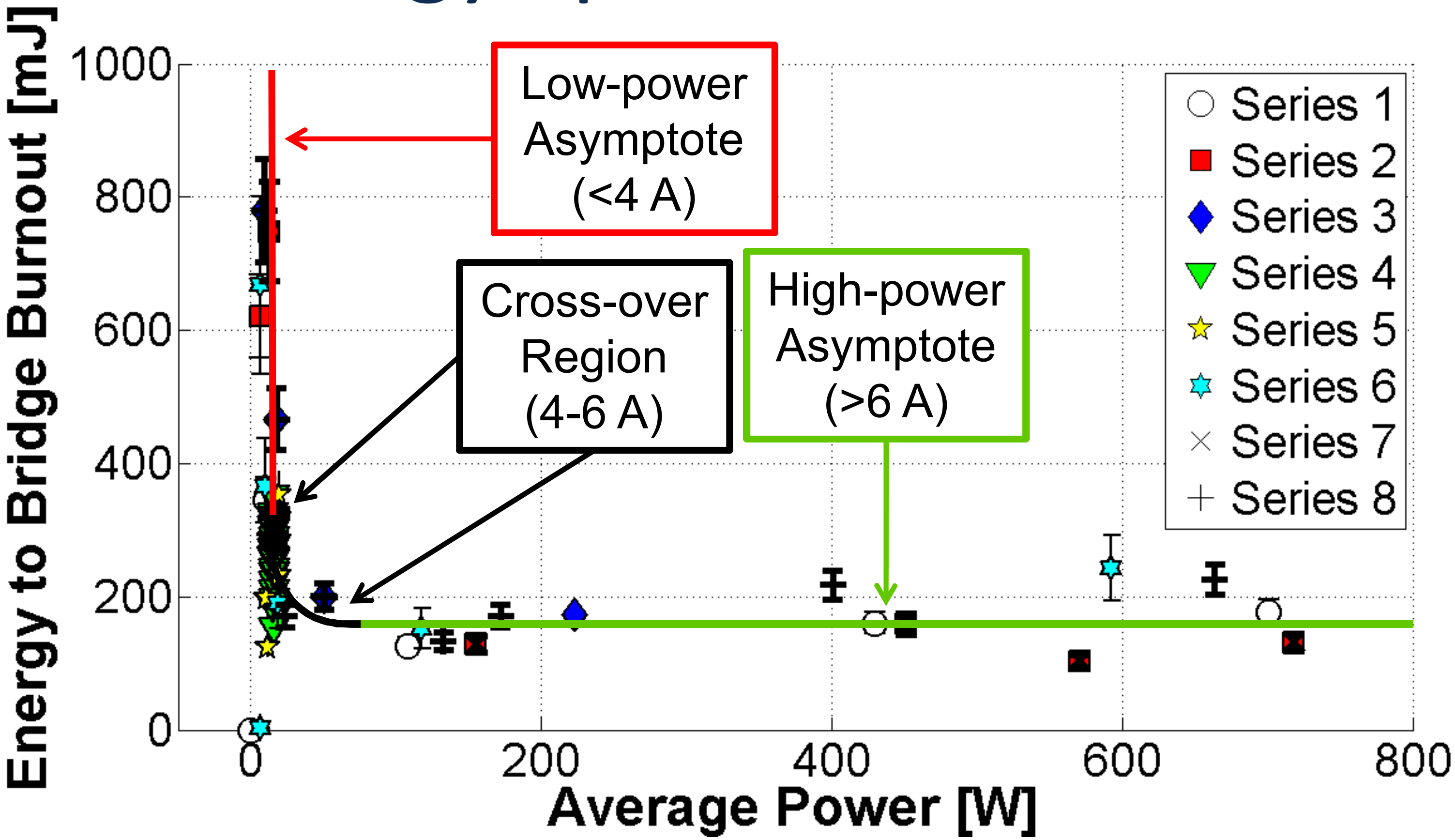
- In the low-power regime, heat gain and heat loss compete to ignite the explosive.

Power-Energy Space



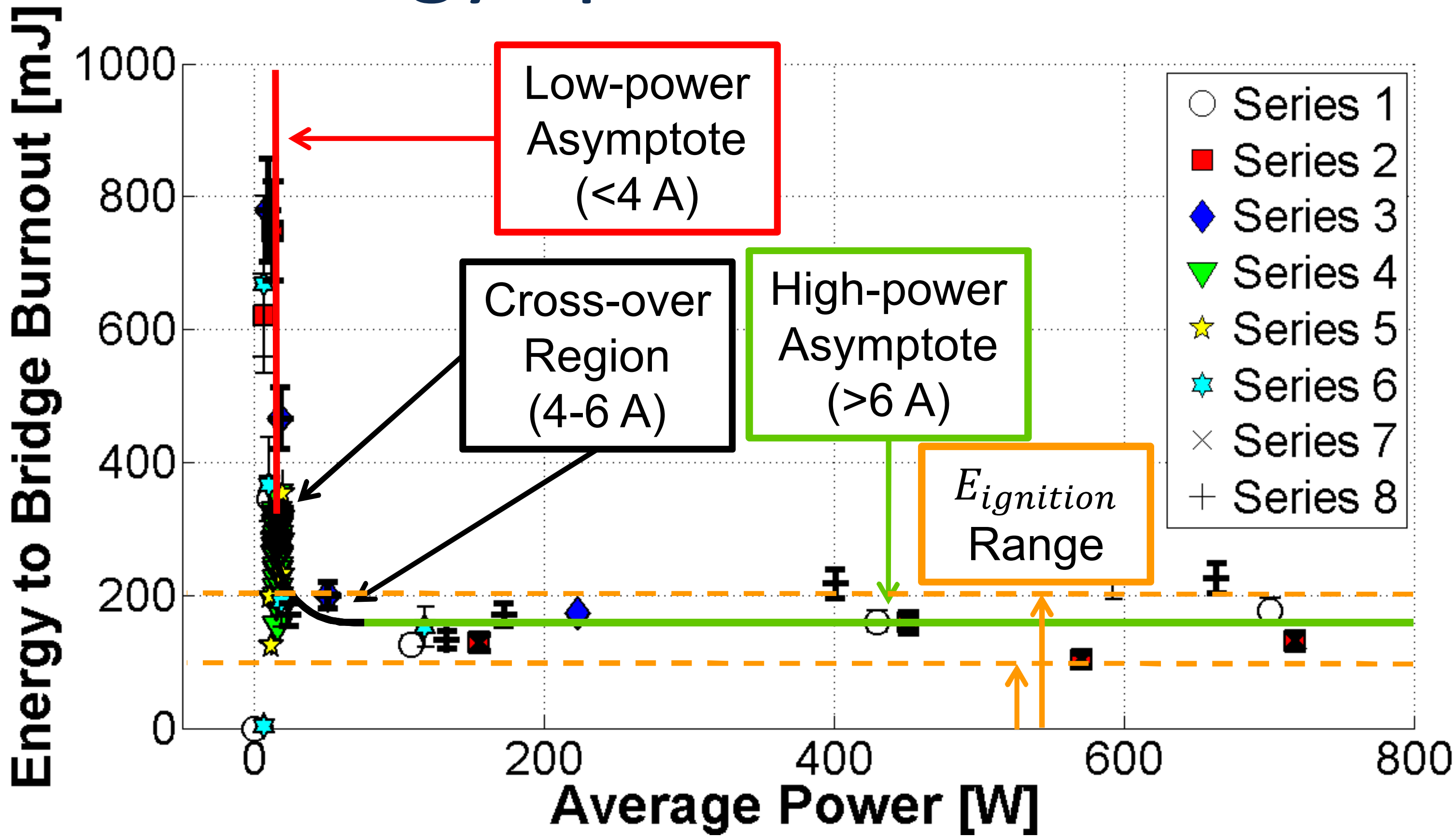
- In the low-power regime, heat gain and heat loss compete to ignite the explosive.

Power-Energy Space



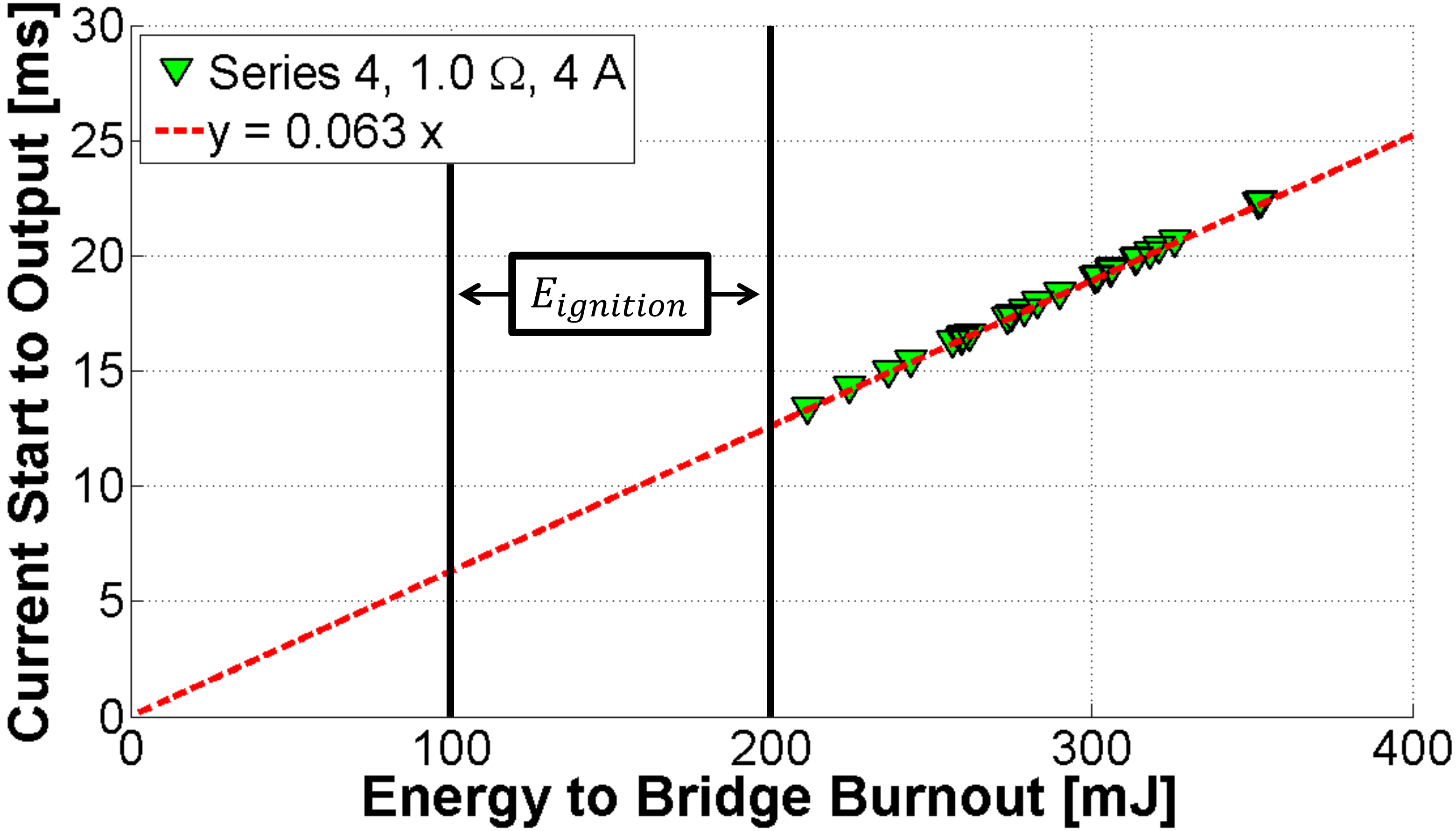
- In the low-power regime, heat gain and heat loss compete to ignite the explosive.
- At high-power, energy deposition is too fast for heat loss to occur and scatter becomes negligible.

Power-Energy Space



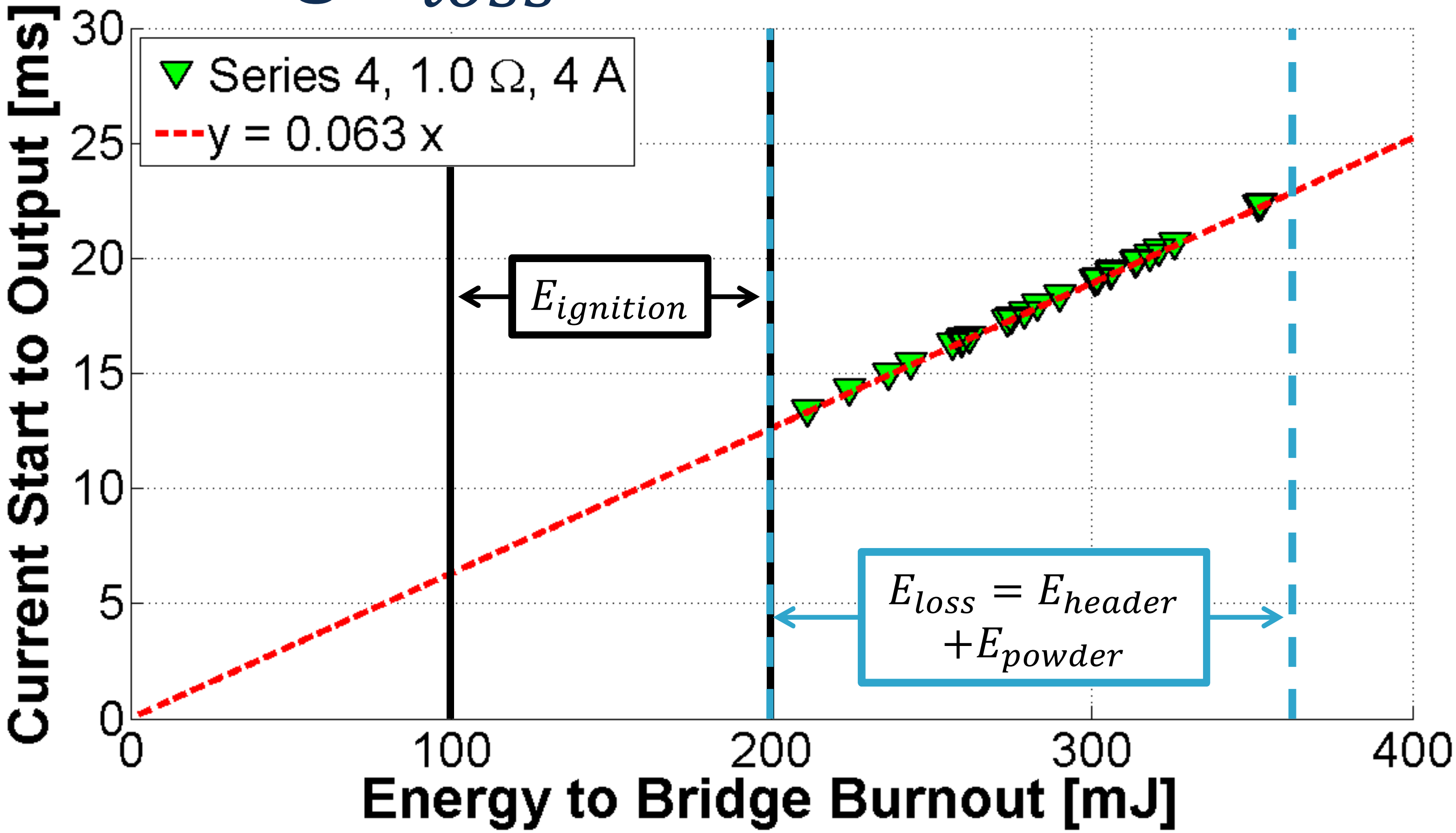
- In the low-power regime, heat gain and heat loss compete to ignite the explosive.
- At high-power, energy deposition is too fast for heat loss to occur and scatter becomes negligible.
- Since losses can be ignored at high power, $E_{input} = E_{ignition}$

Analyzing Single Test Series in Low Power Region



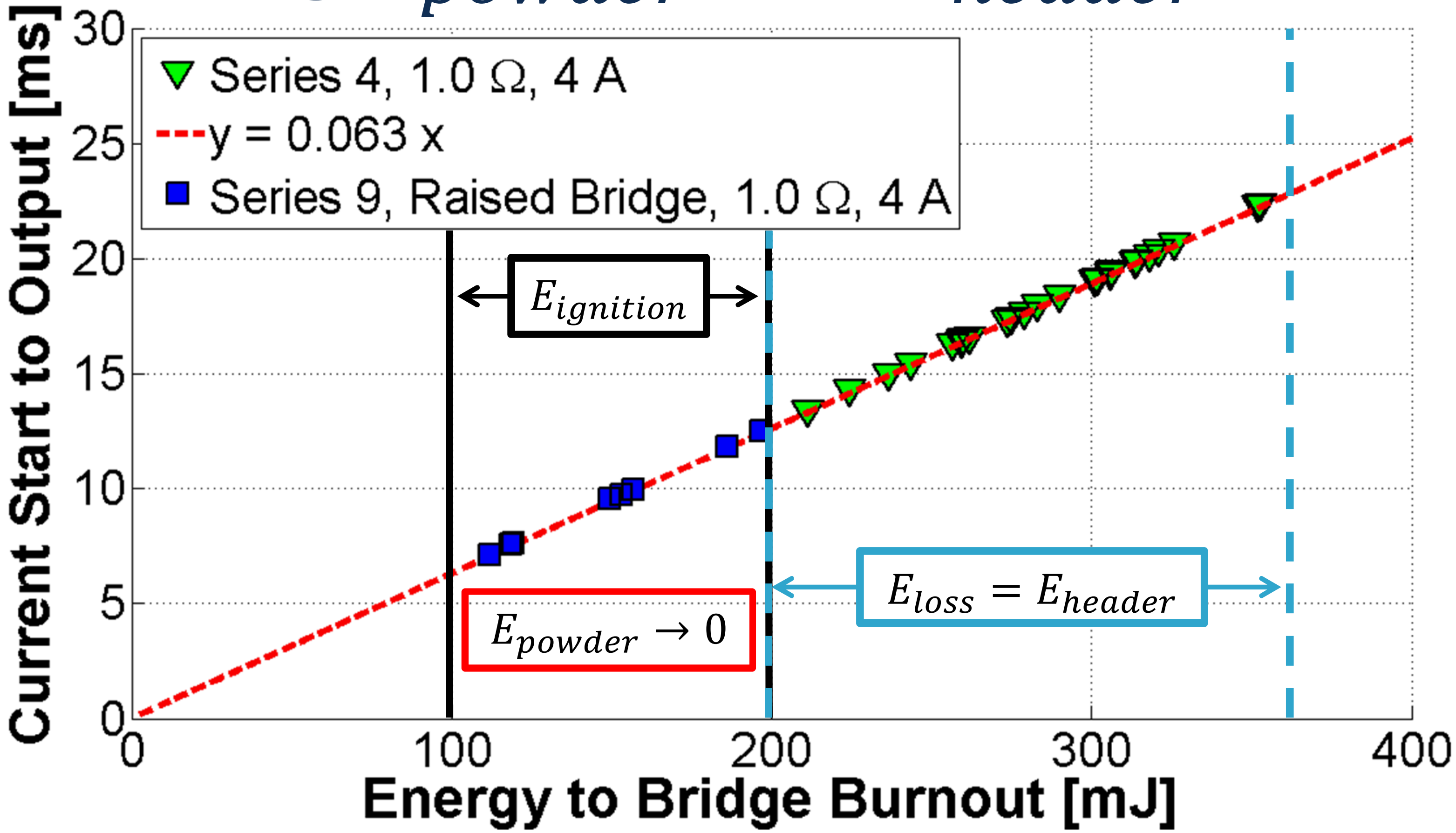
- Assume HMX ignites at same energy every time ($E_{ignition}$).
- Can observe design's inherent variability in heat loss.

Obtaining E_{loss}



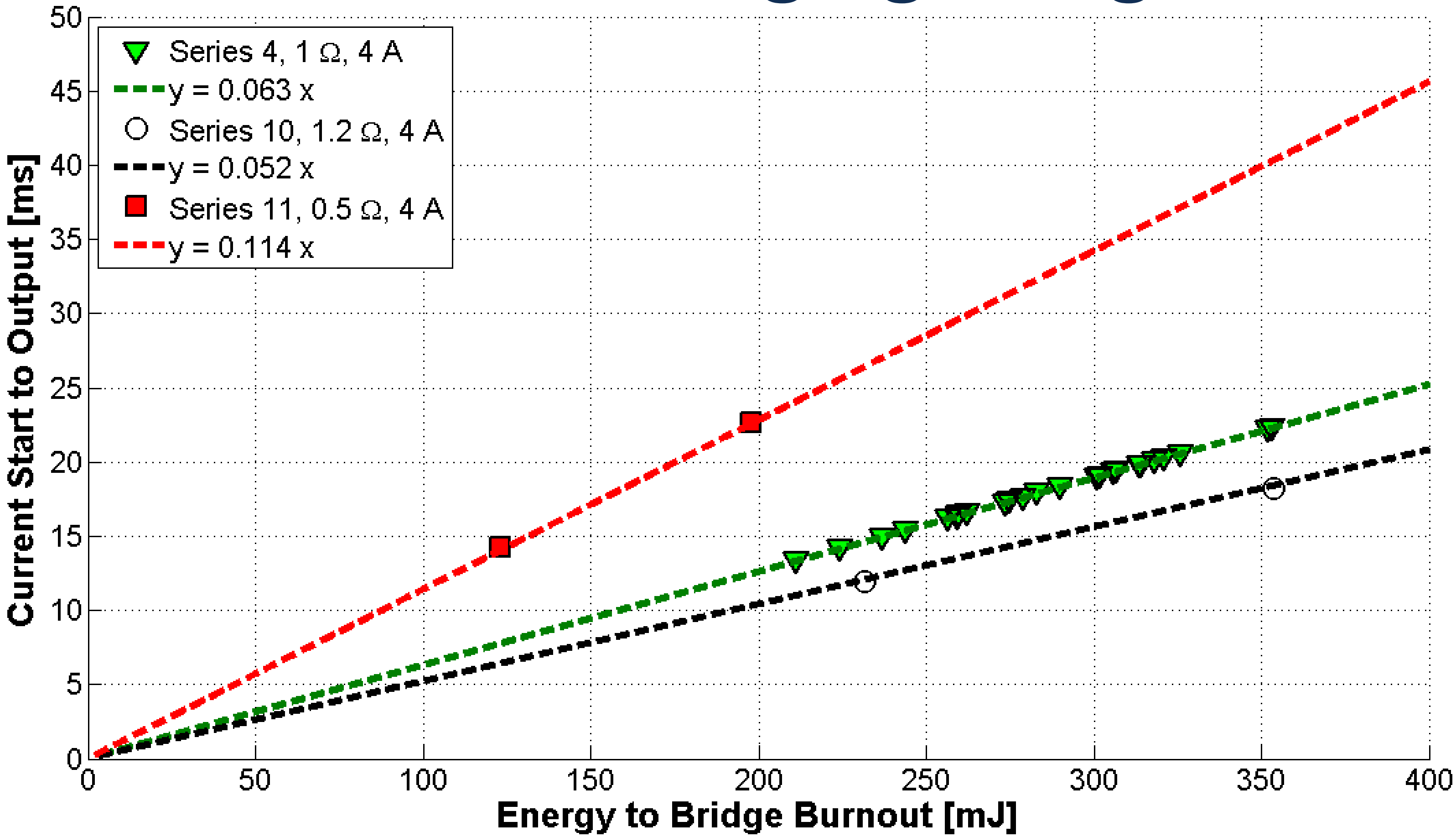
- Assume HMX ignites at same temperature independent of input.
- Large variability in initiation of HMX ($E_{ignition}$ range).
- Even larger variability in heat loss due to powder and header contact (E_{loss} range).

Obtaining E_{powder} and E_{header}



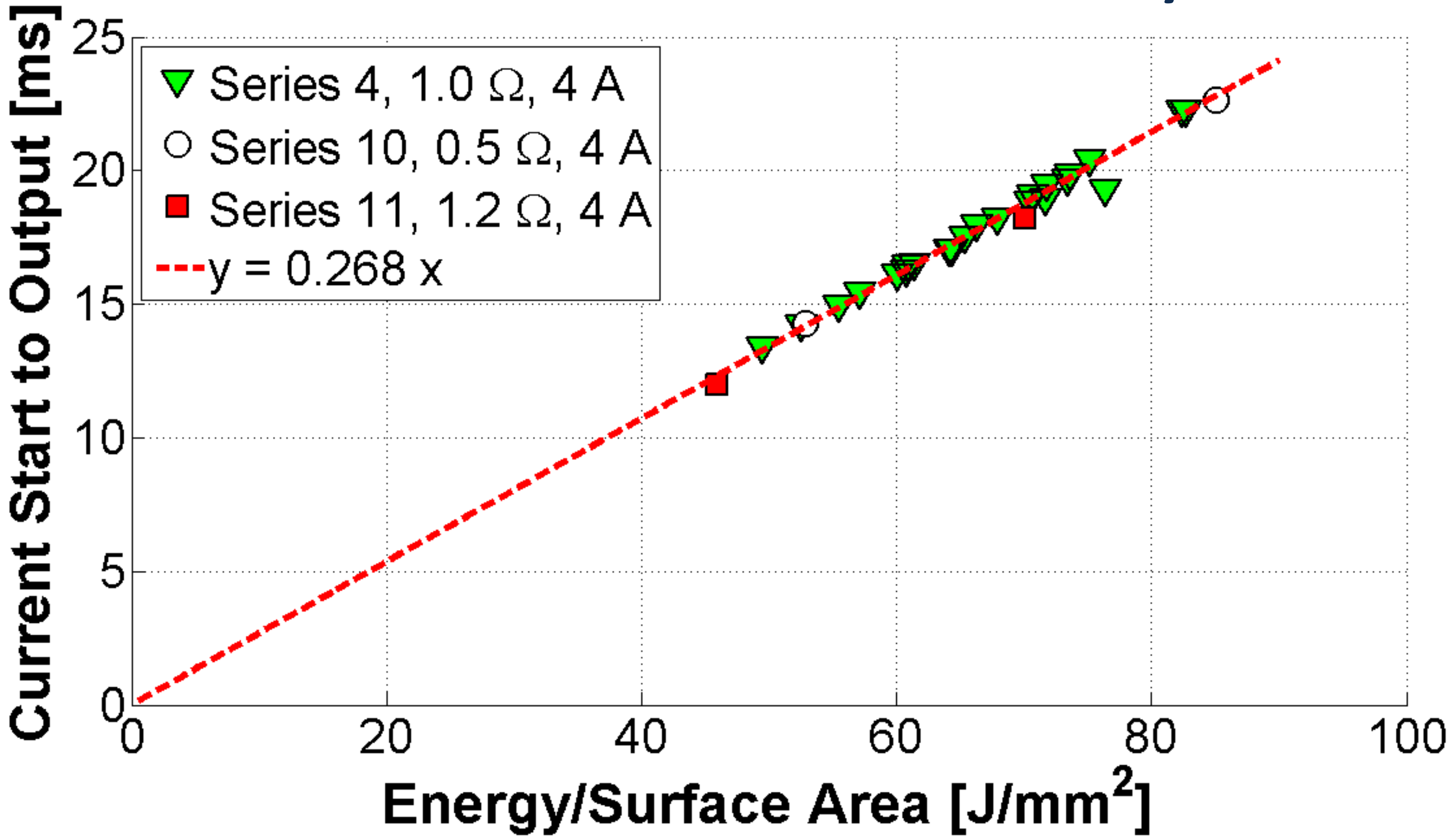
- Raising the bridge gives us the same energy to ignition as high-power testing.
- This implies the powder is an insulator on these time scales, and the energy loss to the powder goes to zero.
- This also implies the largest variability in ignition is due to heat loss to the header.

Back to HMX – Changing Bridge Size



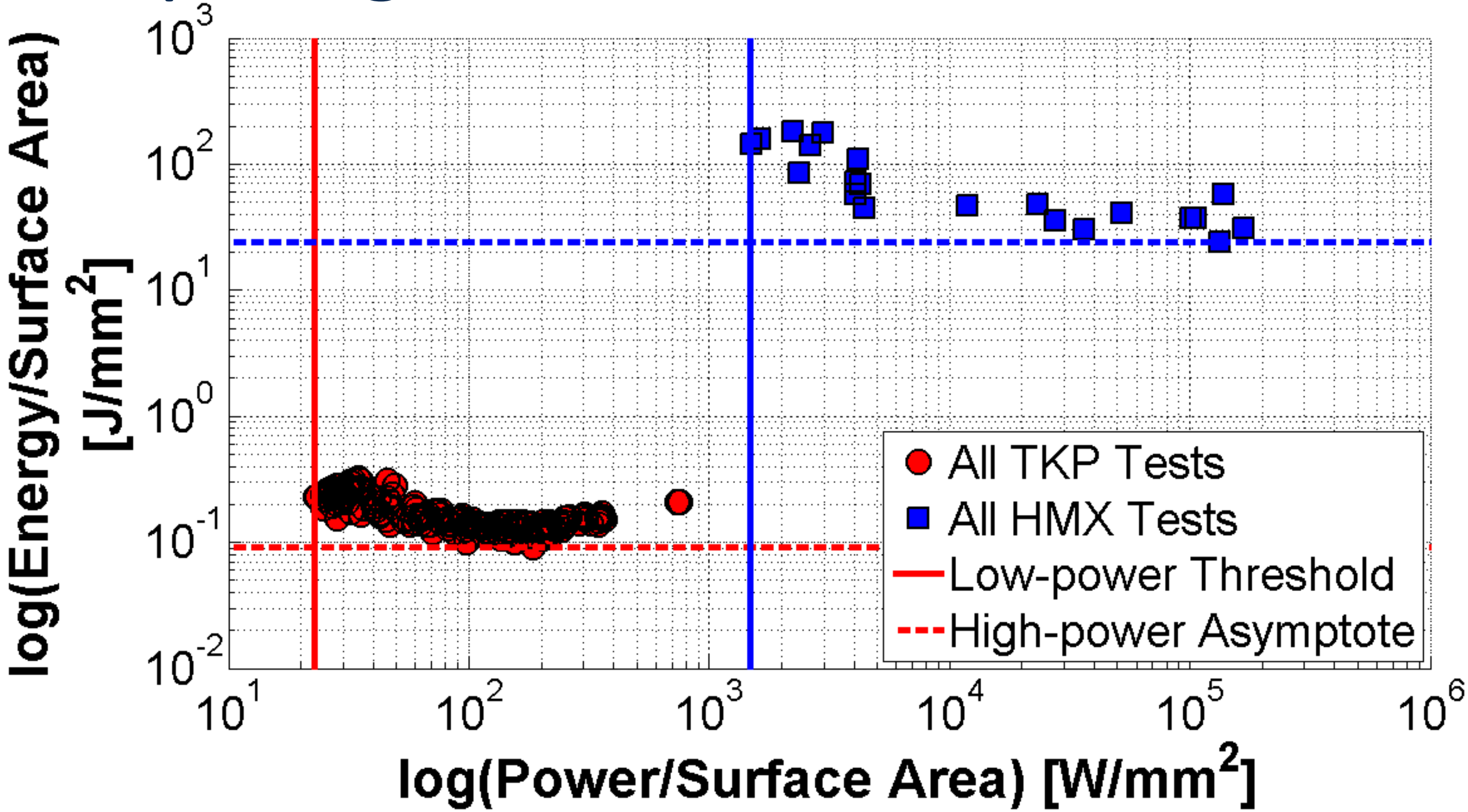
- This test changes the resistance by changing the bridge dimensions.
- These bridges were pressed onto the header.

These Tests are also Related by SA



- Surface area relates the different wire geometries.
- This implies the Power-Energy curve can be normalized by surface area.
- Now a new tool exists for scanning the design space of an HMX ignitor.
- Bridge dimensions and materials can be changed until the desired no-fire (energy asymptote) and desired hard-fire (power-asymptote) can be achieved.

Comparing HMX and TKP



- HMX requires ~2 orders of magnitude higher power/energy for ignition.
- This type of analysis can be performed on other explosives to further aid design decisions for both no-fire safety and performance criteria.

Conclusions

- Power-Energy Space governs hotwire performance.
- Any material and any bridgewire geometry can be compared using Power/SA vs Energy/SA.
- Doing a single test series produces the characteristic performance curve.
- Wire dimensions can now be changed until desired characteristics are achieved.
  - The energy asymptote (low-power) controls no-fire and safety criteria.
  - The power asymptote (low-energy) controls hard-fire characteristics.
- Different explosives can be compared readily in Power-Energy Space.
  - Compare no-fire requirements for safety.
  - Compare input requirements for performance.