TWENTY-SEVENTH ANNUAL

TestConX™

Archive

DoubleTree by Hilton
Mesa, Arizona
March 1-4, 2026

The Impact of Time, Pressure, Thickness and Patterning on Compressible Metal Thermal Interface Materials

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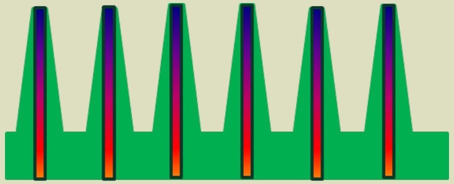
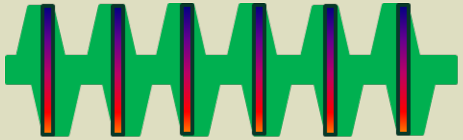
Compressible Metal TIM - Principles

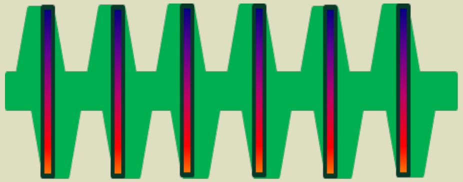
- Pattern applied to metal shim to form array of compressible columns
- Metal TIMs possess high thermal conductivity
  – Pure indium: 86 W/mK
- Multiple patterns available
  – Application-specific
- Various thicknesses possible
  – Defined pre-patterning



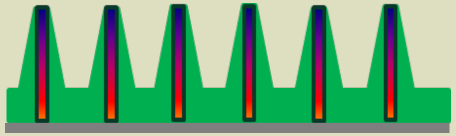
~250µm peaks



~75µm peaks



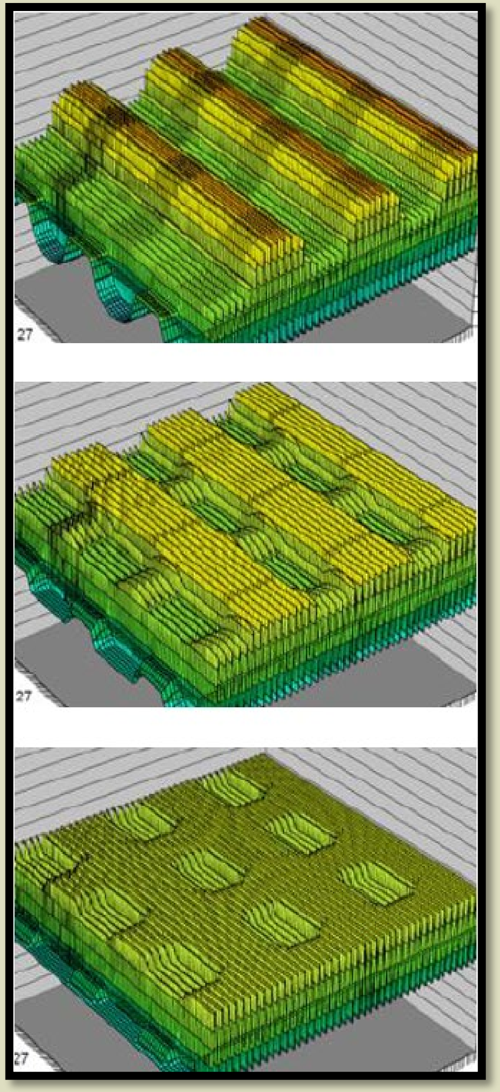
~150µm peaks



~100µm peaks,
Al-Clad

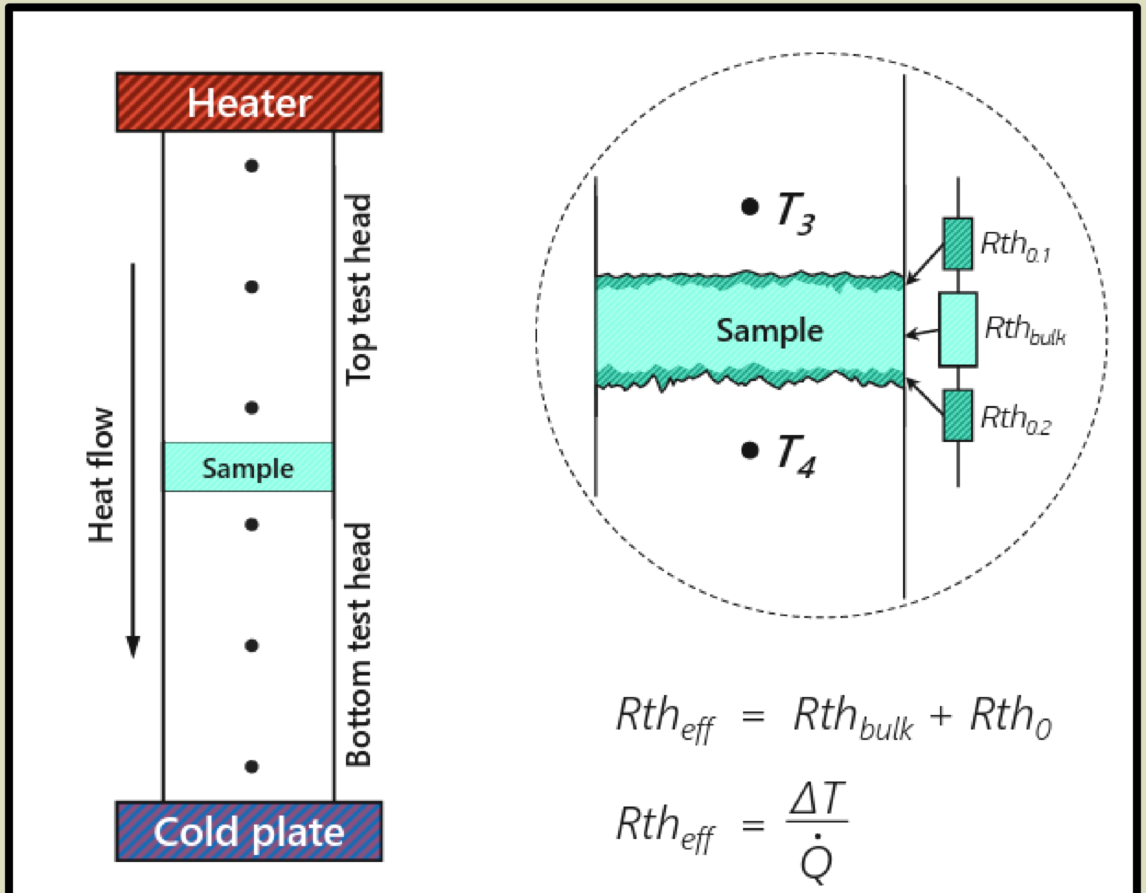
Compressible Metal TIM - Principles

- Under pressure, metal plastically deforms to the interfaces
  - Inelastic deformation through creep
  - Thermal resistance decreases with increasing pressure
  - Thermal resistance decreases over time



The Principle of ASTM D5470

- Test heads have known geometry and physical properties
  - Planar and parallel surfaces
- Temperature gradient and heat flow are measured
- Effective thermal resistance (Rth_{eff}) is calculated as output
- Pressure, bond line thickness (BLT), and temperature are controlled and/or measured



$$Rth_{eff} = Rth_{bulk} + Rth_0$$

$$Rth_{eff} = \frac{\Delta T}{\dot{Q}}$$

The Principle of ASTM D5470

- (Rth_{eff}) is the sum of bulk TIM thermal resistance (Rth_{bulk}) and all interfacial thermal resistances (Rth_0)
- Rth_{bulk} is a function of TIM bulk thermal conductivity (λ_{bulk}), bond line thickness (BLT), and area

$$Rth_{eff} = Rth_{bulk} + Rth_0$$

$$Rth_{eff} = \frac{1}{\lambda_{bulk} \cdot A} \cdot BLT + Rth_0$$

Theoretical Ideal TIM:

- High (λ_{bulk})
- Low BLT
- Allows for low (Rth_0)

TIM Bulk Thermal Resistance Comparison

$$Rth_{bulk} = \frac{BLT}{\lambda_{bulk} \times A}$$

Assume:

$$A = 50mm \times 60mm$$

Rth (K/W)	Traditional / Polymer Phase Change TIMs				Liquid Metals/ Phase Change Alloys			Pure Indium
λ_{bulk} (W/mK) / BLT (µm)	1	5	8.5	10	15	30	50	86
25	0.0083	0.0017	0.0010	0.0008	0.0006	0.0003	0.0002	0.0001
50	0.0167	0.0033	0.0020	0.0017	0.0011	0.0006	0.0003	0.0002
75	0.0250	0.0050	0.0029	0.0025	0.0017	0.0008	0.0005	0.0003
100	0.0333	0.0067	0.0039	0.0033	0.0022	0.0011	0.0007	0.0004
125	0.0417	0.0083	0.0049	0.0042	0.0028	0.0014	0.0008	0.0005
150	0.0500	0.0100	0.0059	0.0050	0.0033	0.0017	0.0010	0.0006
175	0.0583	0.0117	0.0069	0.0058	0.0039	0.0019	0.0012	0.0007
200	0.0667	0.0133	0.0078	0.0067	0.0044	0.0022	0.0013	0.0008
225	0.0750	0.0150	0.0088	0.0075	0.0050	0.0025	0.0015	0.0009
250	0.0833	0.0167	0.0098	0.0083	0.0056	0.0028	0.0017	0.0010
275	0.0917	0.0183	0.0108	0.0092	0.0061	0.0031	0.0018	0.0011
300	0.1000	0.0200	0.0118	0.0100	0.0067	0.0033	0.0020	0.0012
325	0.1083	0.0217	0.0127	0.0108	0.0072	0.0036	0.0022	0.0013
350	0.1167	0.0233	0.0137	0.0117	0.0078	0.0039	0.0023	0.0014
375	0.1250	0.0250	0.0147	0.0125	0.0083	0.0042	0.0025	0.0015
400	0.1333	0.0267	0.0157	0.0133	0.0089	0.0044	0.0027	0.0016
425	0.1417	0.0283	0.0167	0.0142	0.0094	0.0047	0.0028	0.0016
450	0.1500	0.0300	0.0176	0.0150	0.0100	0.0050	0.0030	0.0017
475	0.1583	0.0317	0.0186	0.0158	0.0106	0.0053	0.0032	0.0018
500	0.1667	0.0333	0.0196	0.0167	0.0111	0.0056	0.0033	0.0019

Thermal Conductivity

BLT

TIM Bulk Thermal Resistance Comparison

$$Rth_{bulk} = \frac{BLT}{\lambda_{bulk} \times A}$$

Assume:

$$A = 50mm \times 60mm$$

Ex. Rth Comparison:

PCM (8.5 W/mK)

50 µm BLT

>

Indium (86 W/mK)

500 µm BLT

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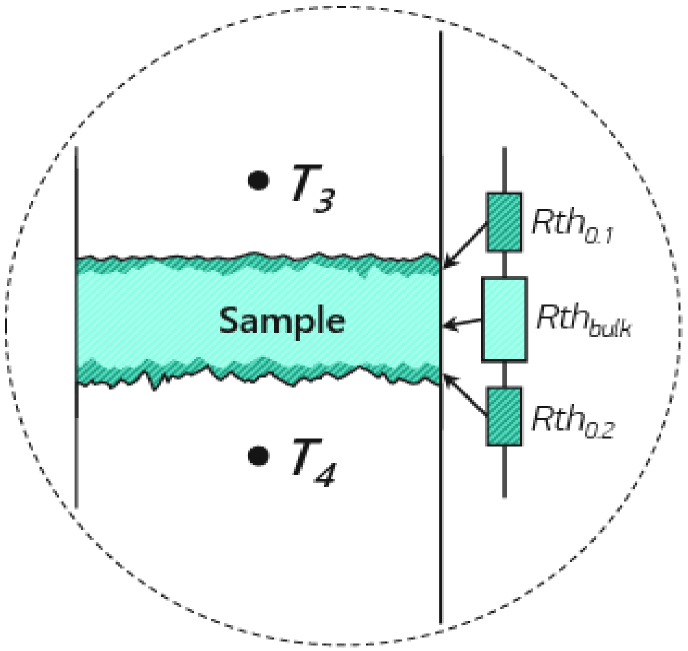
500	0.1667	0.0333	0.0196	0.0167	0.0111	0.0056	0.0033	0.0019

Thermal Conductivity

BLT

TIM Interfacial Resistance

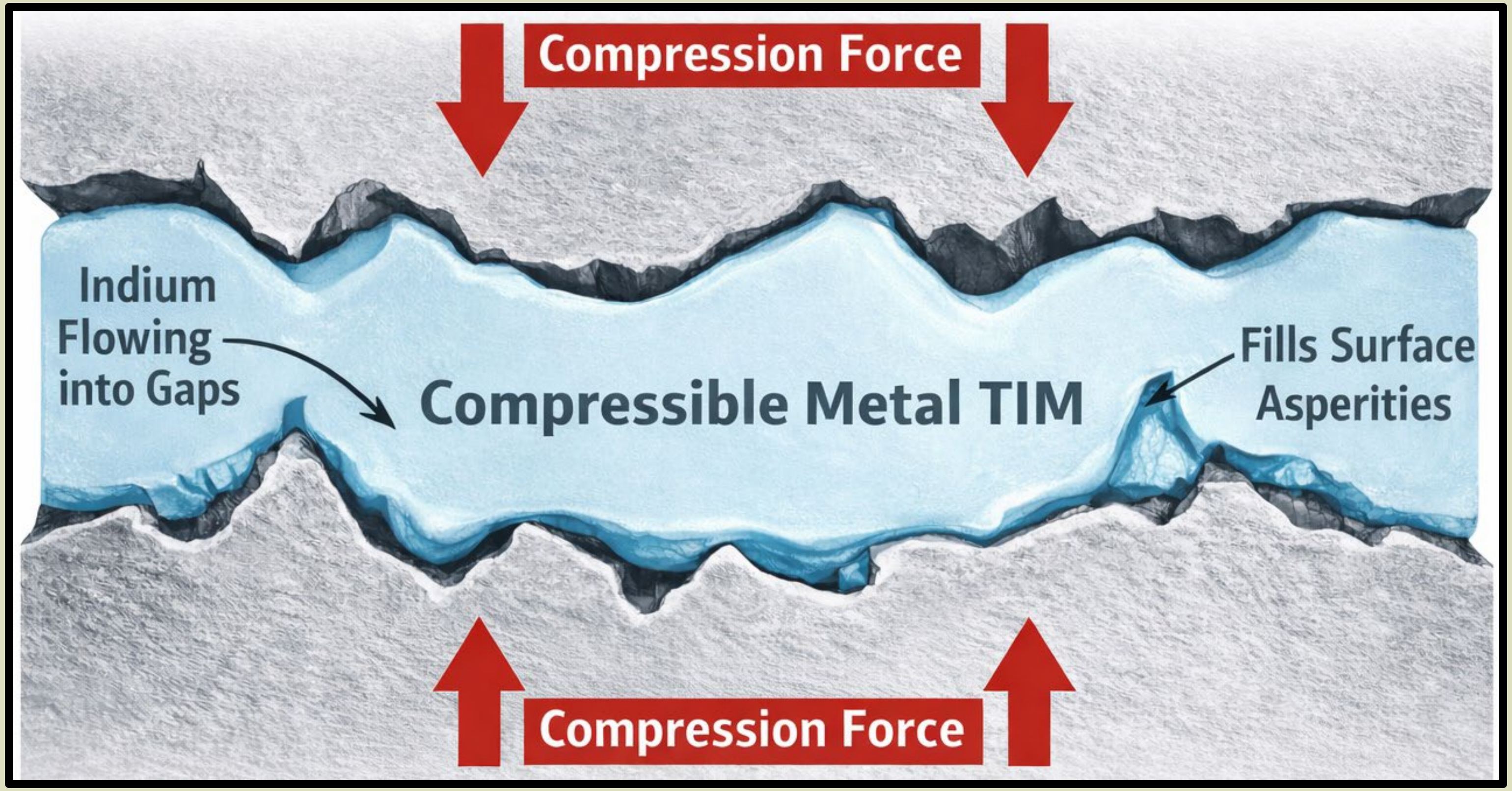
- Rth_0: resistance resulting from imperfections in contact at each surface
  - – Surface roughness and asperities
- TIMs fluid in operation: ✓
- Solder TIMs: ✓ ✓
- Compressible TIMs: material-dependent



$$Rth_{eff} = Rth_{bulk} + Rth_0$$

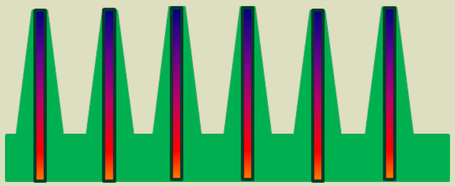
TIM Interfacial Resistance

- Indium metal: low flow stress
- Conforms to surfaces over time under pressure
- Patterning:
  - Focuses pressure on peaks
  - Accommodates surface non-coplanarity

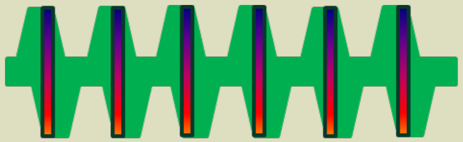


Experiment – Test Parameters

- Material
  - 99.99% Indium
- Pattern
  - High peak, one-sided "X"
    - 0.012" thick
    - 0.020" thick
  - Low peak, two-sided "D"
    - 0.004" thick
- Pressure
  - 20 PSI
  - 30 PSI
  - 40 PSI
  - 50 PSI
- Time
  - Up to 72 hours
  - Readings every 0.5 – 5 minutes
- Sample temperature
  - 85°C



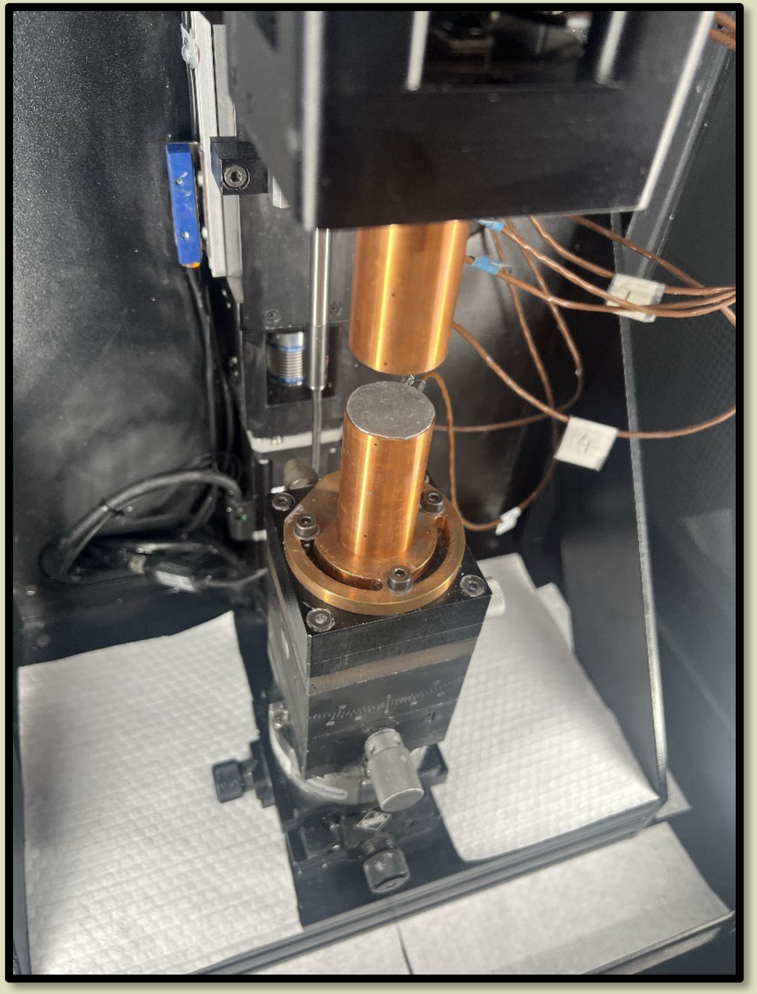
Pattern "X"
~250µm peaks



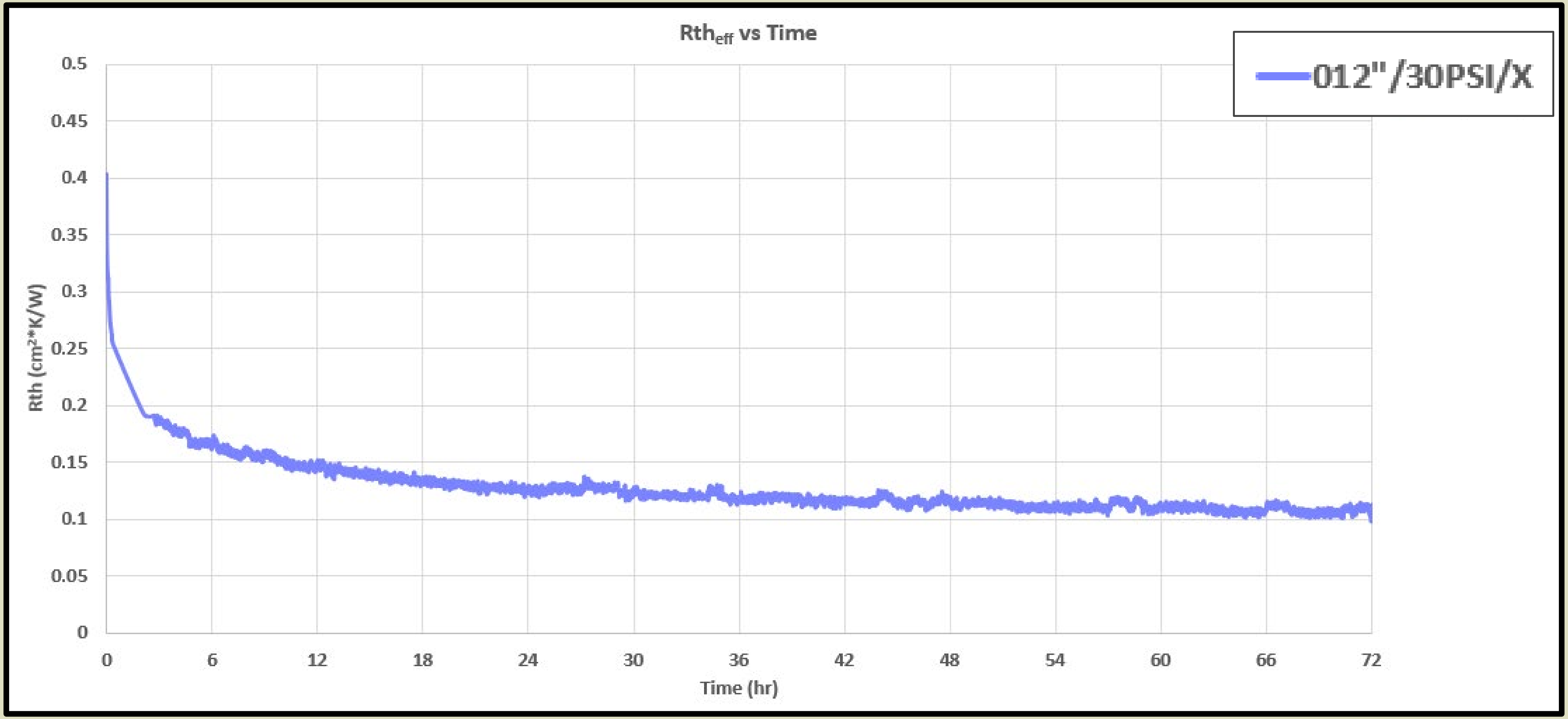
Pattern "D"
~75µm peaks

Experiment – Method

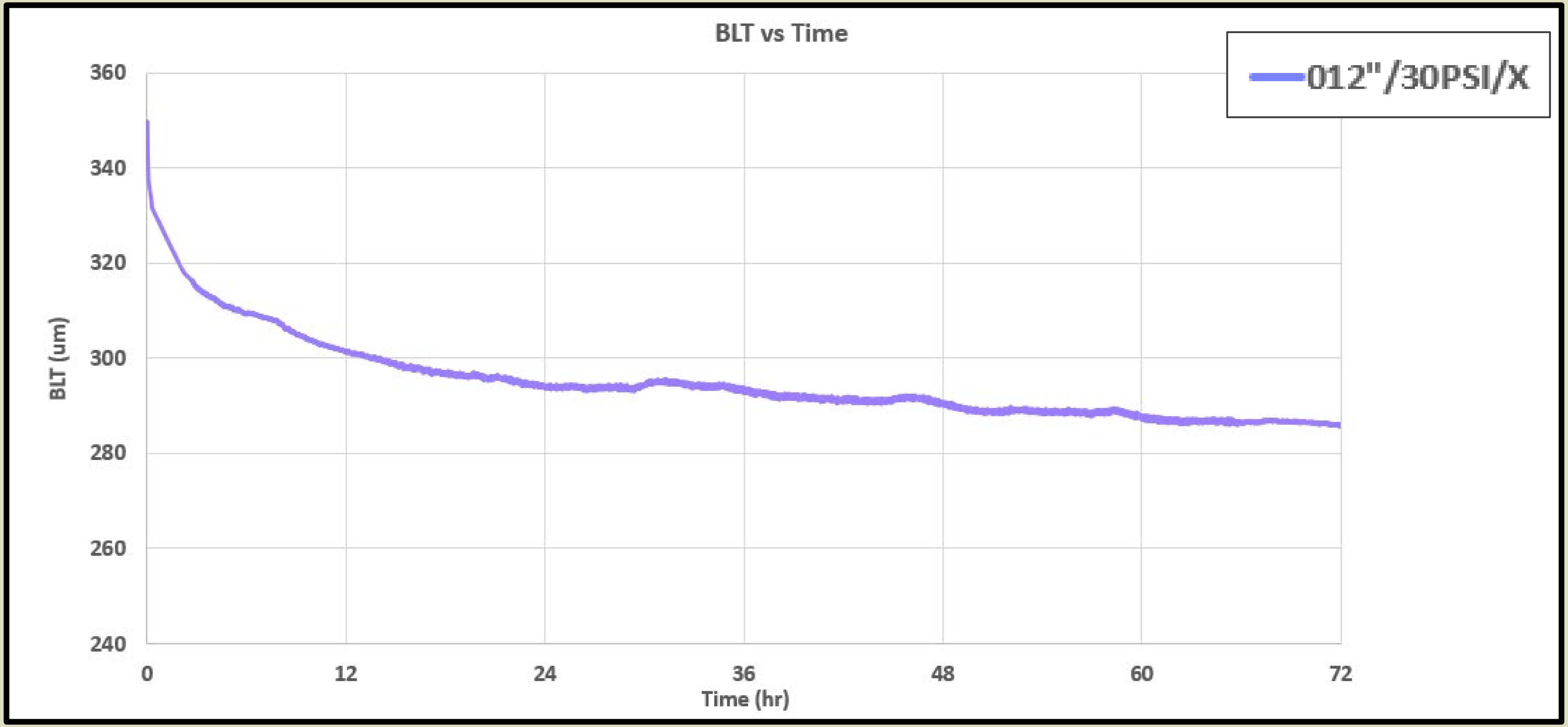
- Initialize equipment
  - Install and align test heads
  - Activate heat and tare BLT
- Install sample, apply designated pressure
- Take Rth_{eff} and BLT measurements over 72 hours
  - Manual measurements prior to thermal stabilization
  - Automatic readings until completion



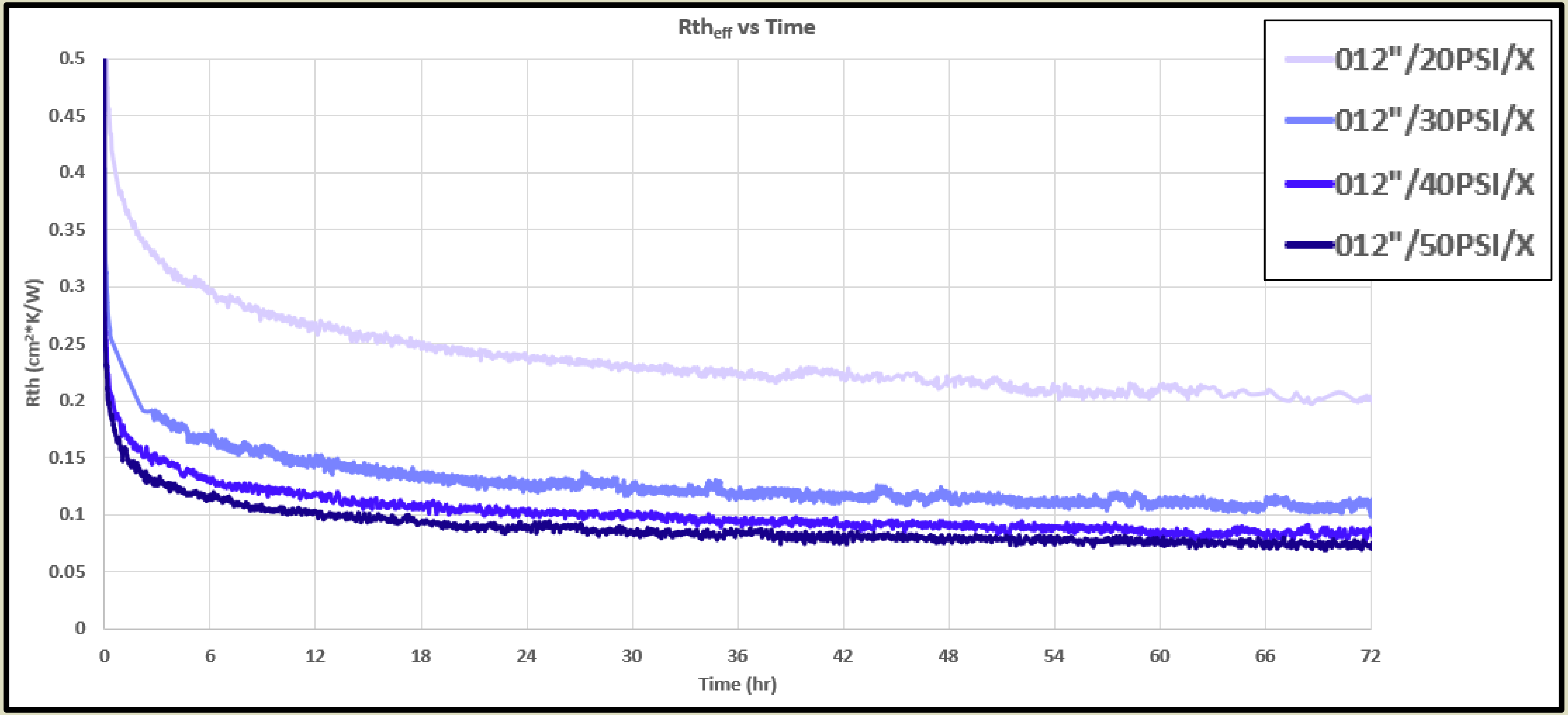
Rth_{eff} – Effect of Time



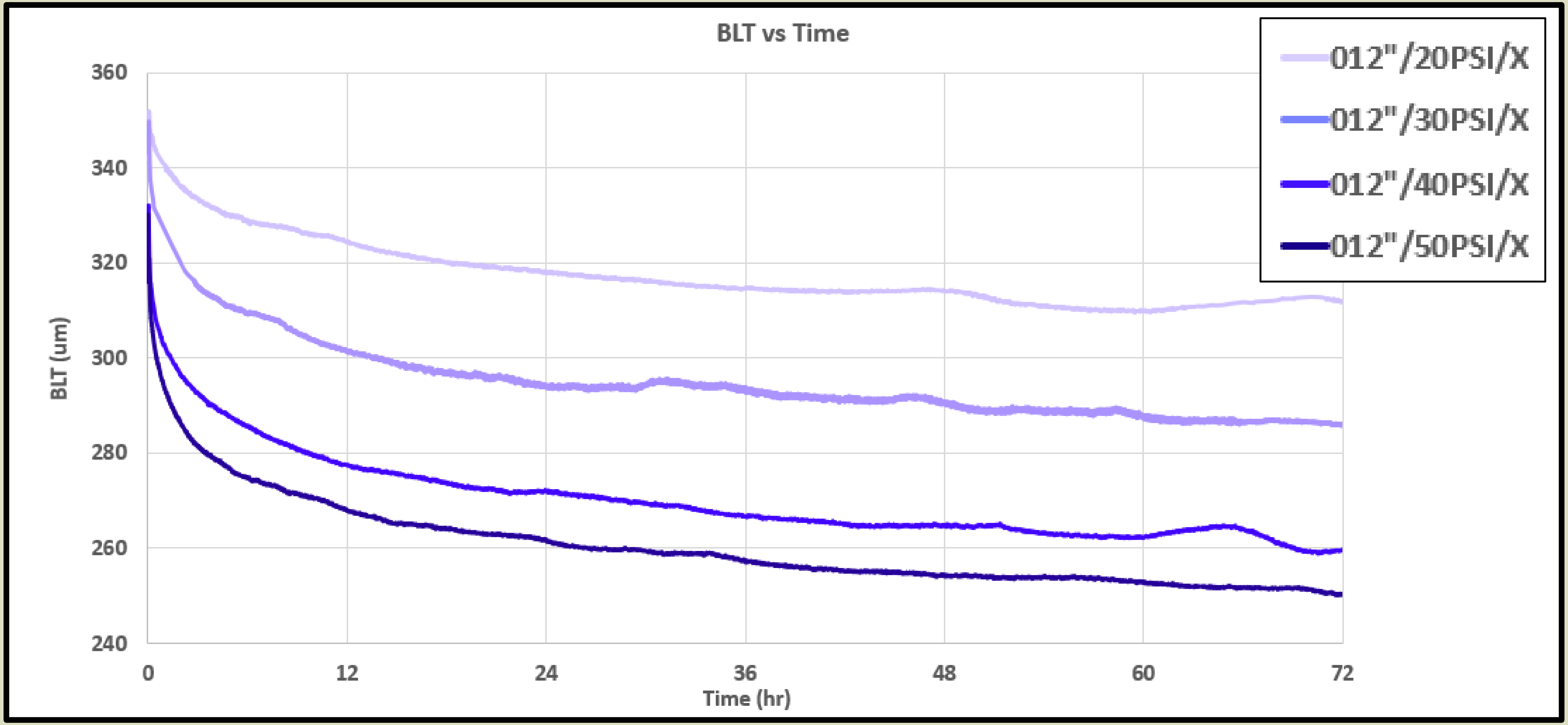
Rth_{eff} – Effect of Time



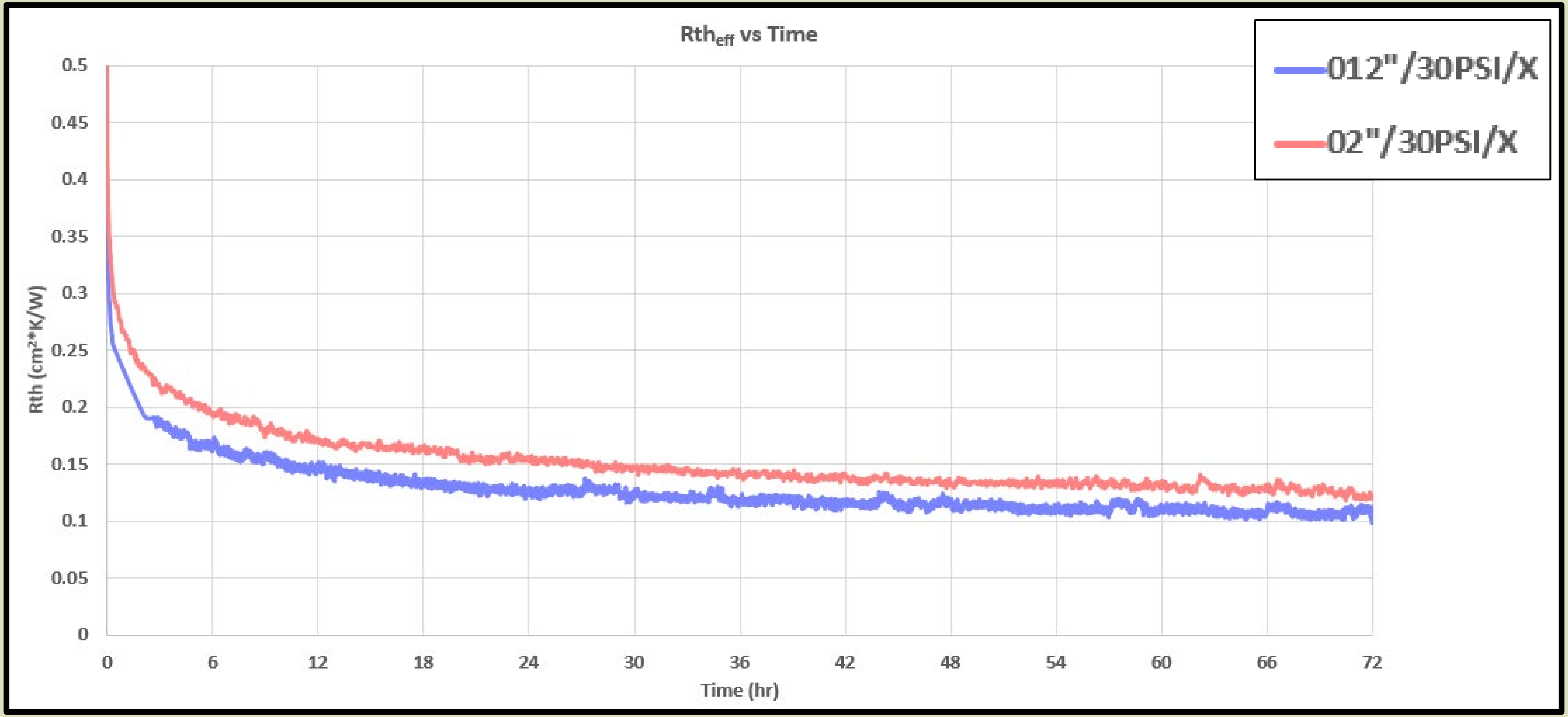
Rth_{eff} – Effect of Pressure



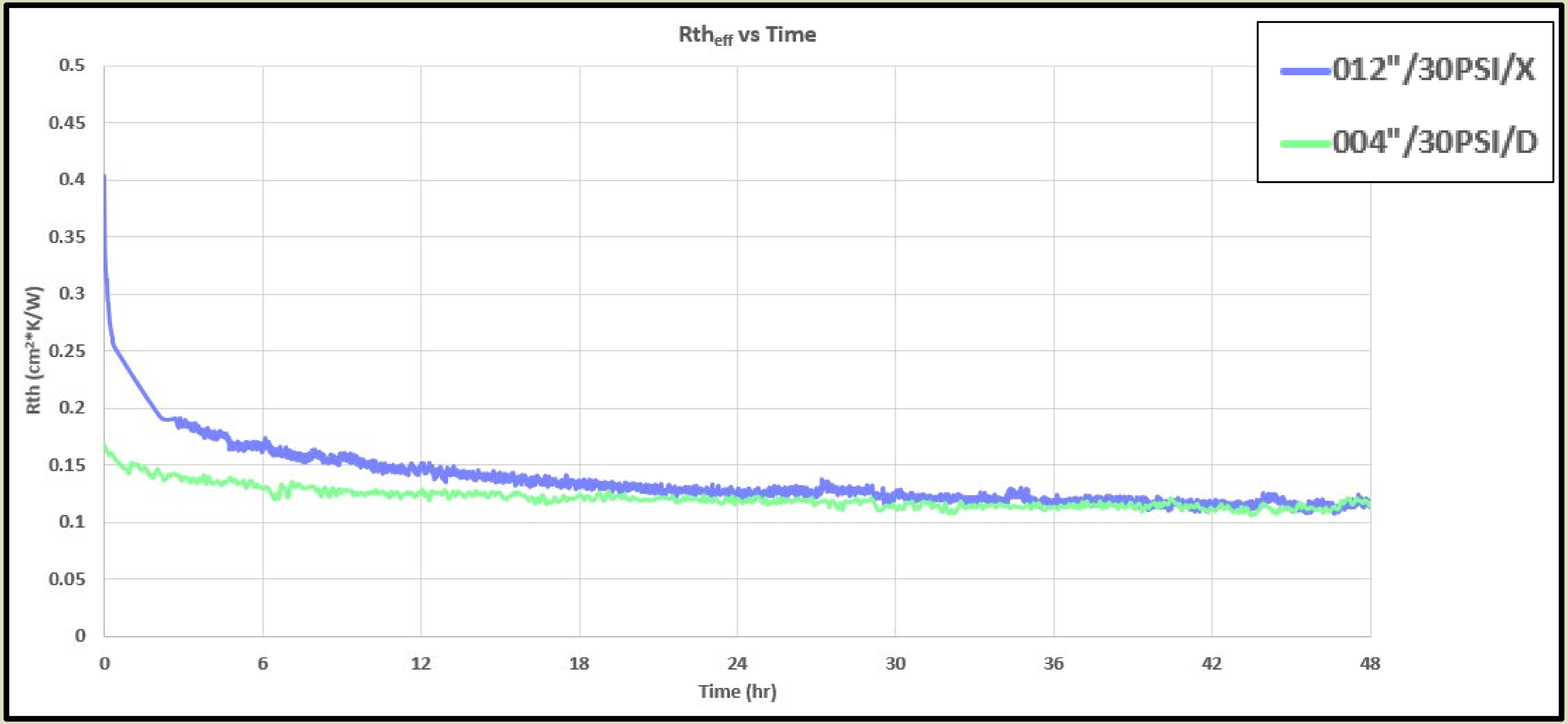
Rth$_{eff}$ – Effect of Pressure



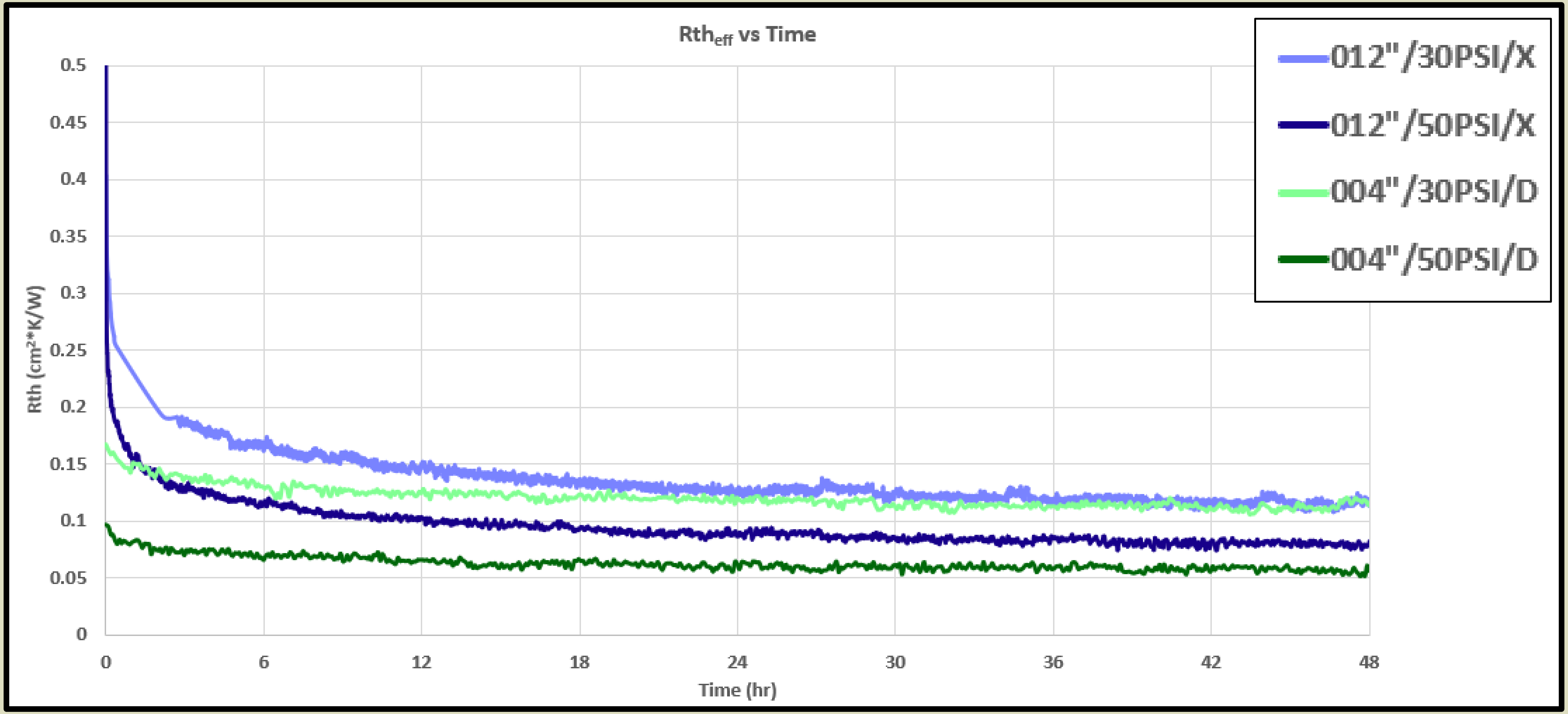
Rth_{eff} – Effect of Thickness



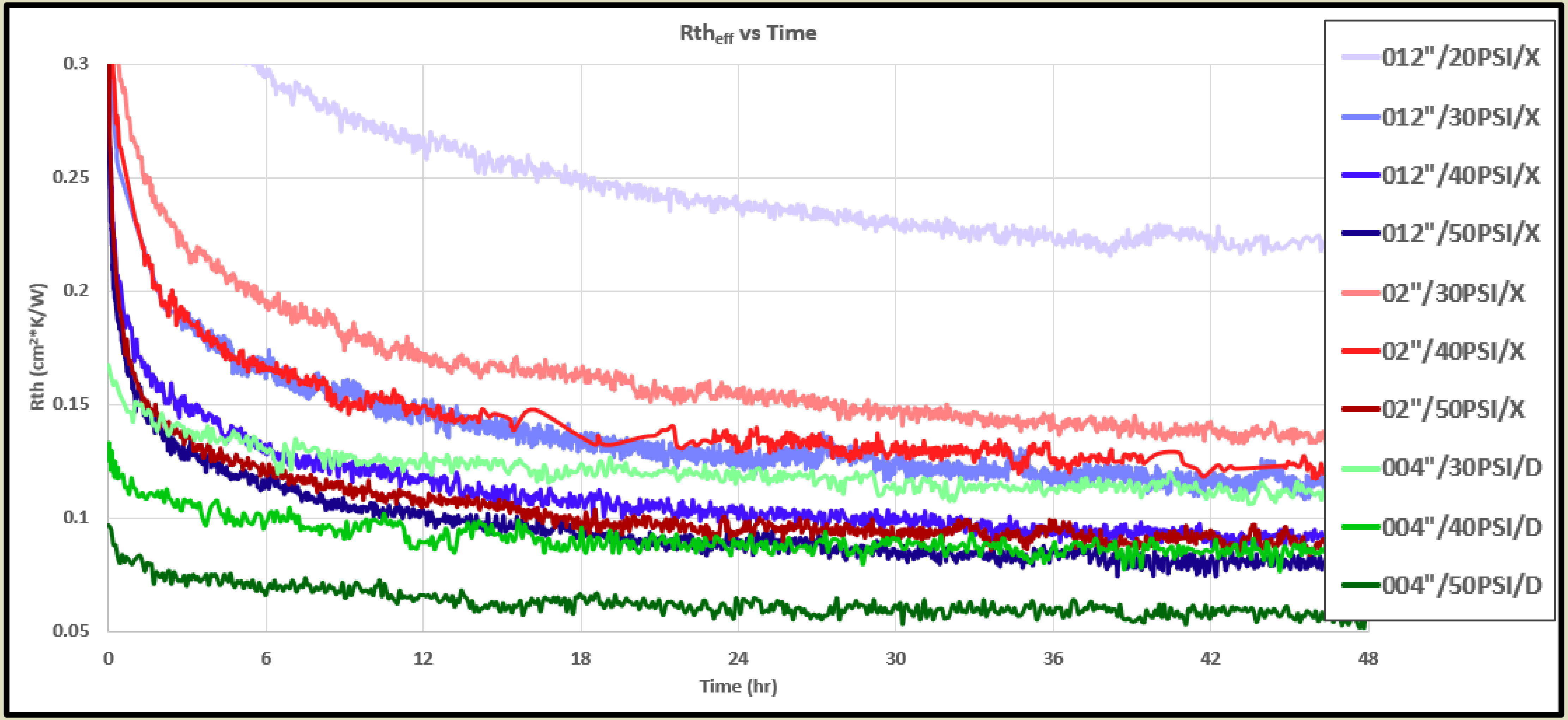
Rth_{eff} – Effect of Pattern



Rth_{eff} – Effect of Pattern



Rth_{eff} – Combined Data

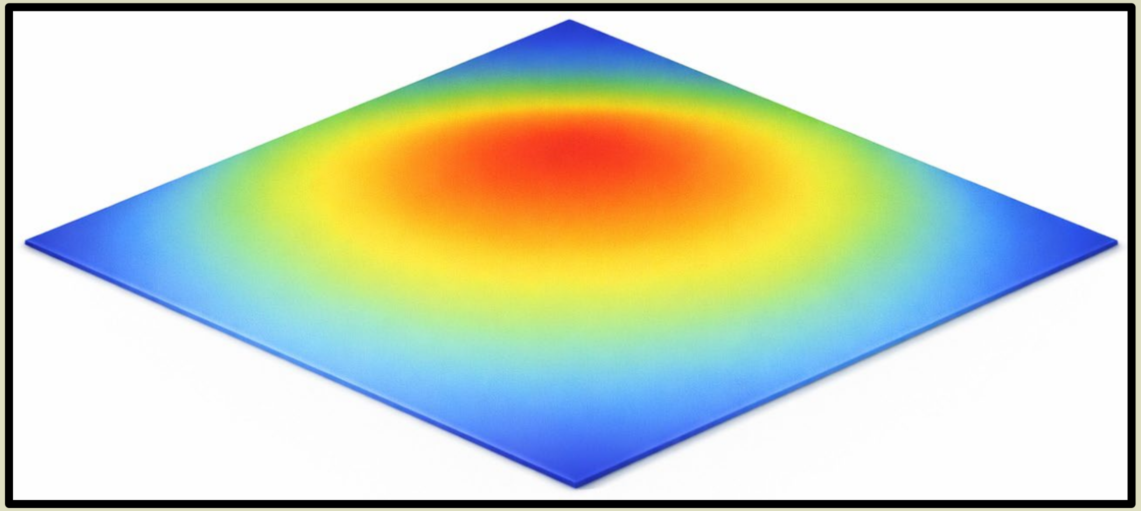


Conclusions – ASTM D5470 Data

- **Time** – substantial effect on Rth_{eff} through initial 24-48 hours
  - Decreasing interfacial resistance near time of installation
- **Pressure** – significant impact on Rth_{eff}
  - Lower interfacial resistance
- **Thickness** – low-moderate effect on Rth_{eff}
  - Marginalized by high thermal conductivity
- **Pattern** – moderate effect on Rth_{eff} near time of installation
  - Impact on long-term Rth_{eff}: application-dependent

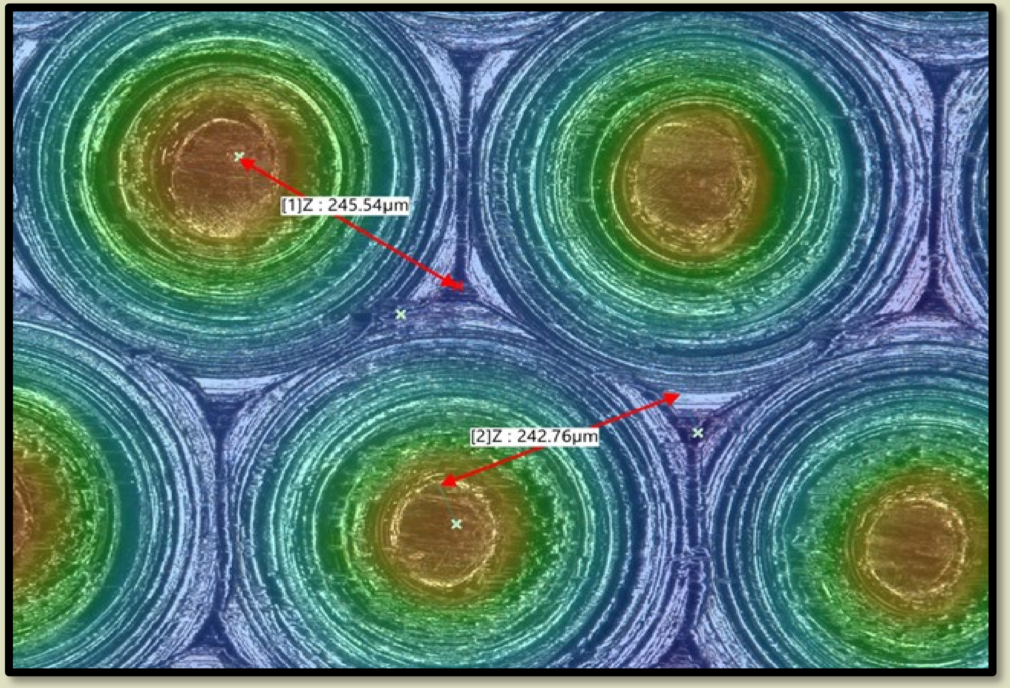
Compressible Metal TIM Considerations

- Maximum pressure
- Distribution of pressure
  - Non-coplanarity
  - Pattern selection
- Mechanism of pressure
  - Torque loss prevention hardware
  - Installation best practices
    - Washer orientation
    - Torqueing process

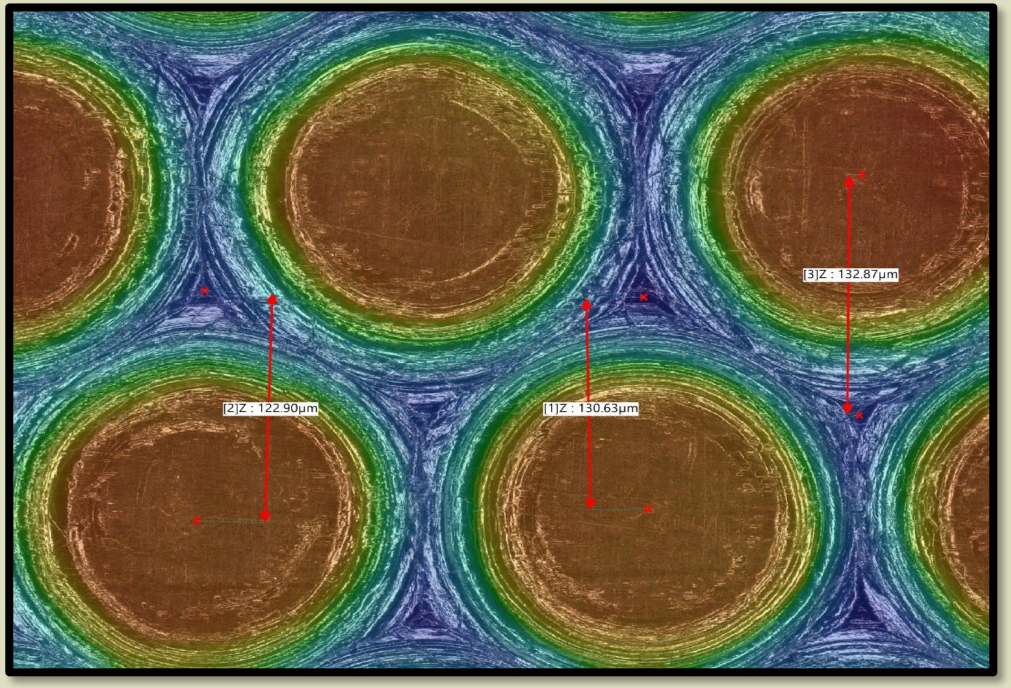


Compression Analysis

99.99% Indium Pattern “X” peak height measurement

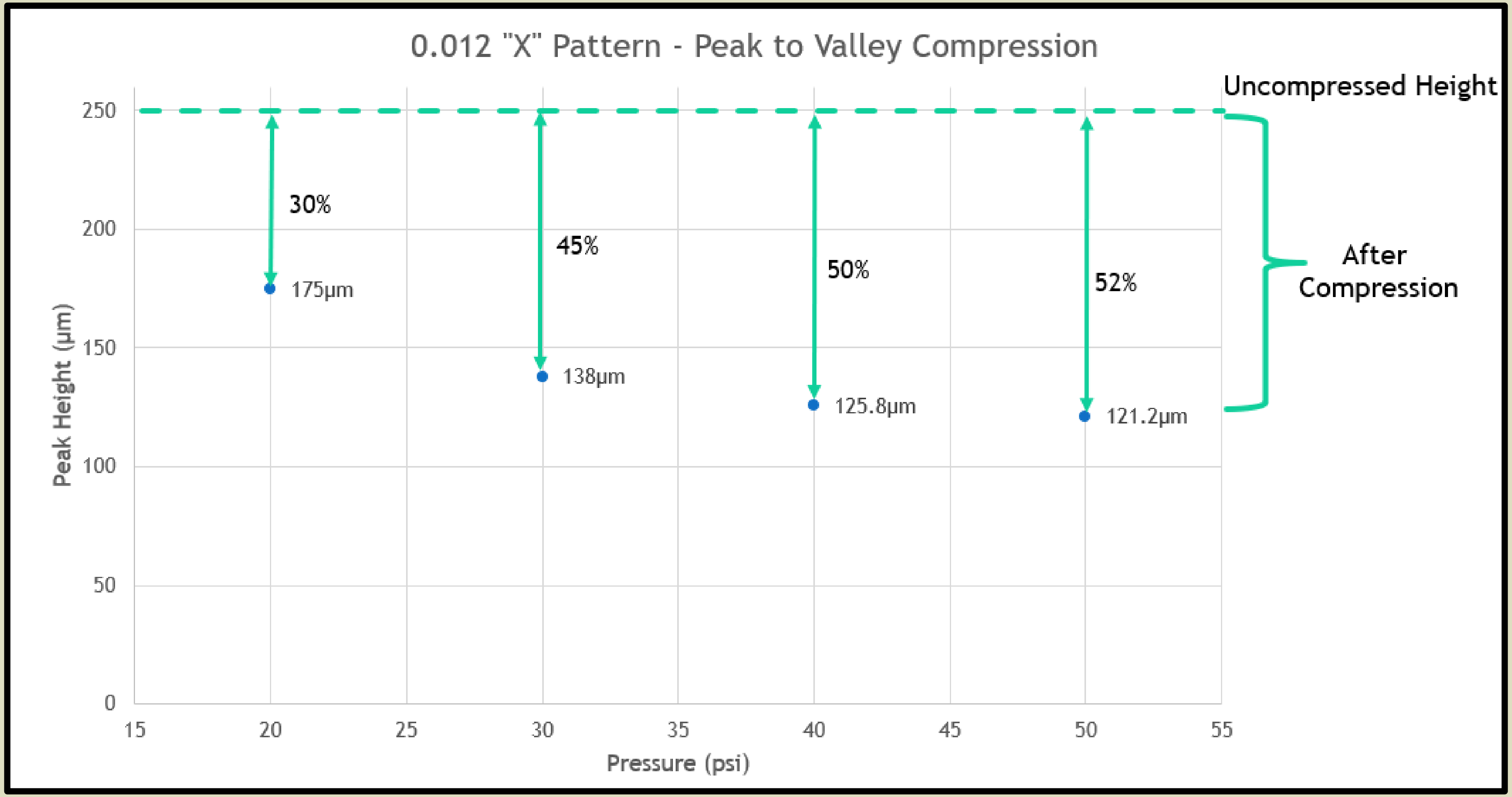


Before Compression



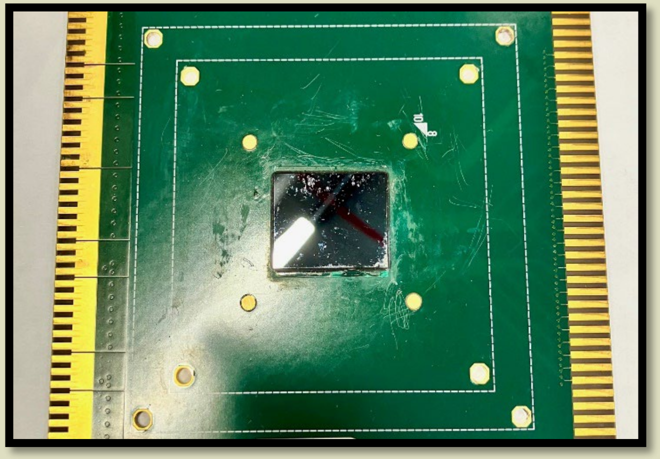
72 hours @ 40PSI, 85℃

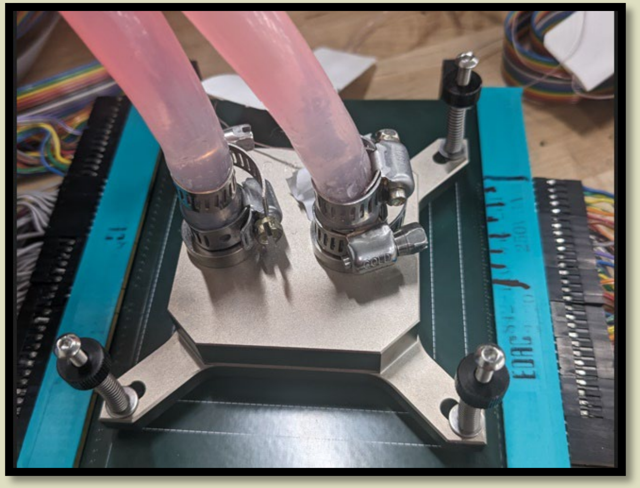
Compression Analysis

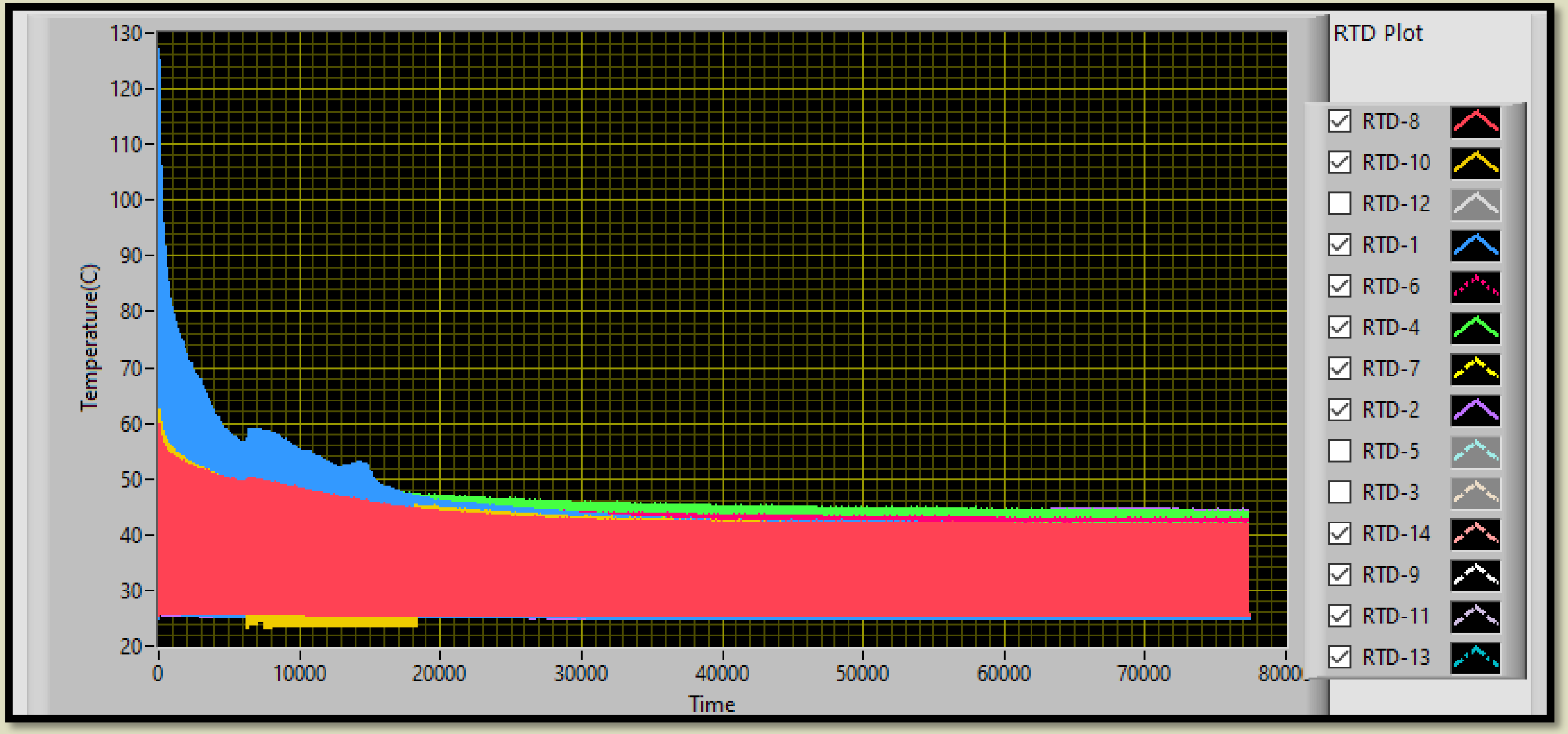


Future Work

- Correlation of ASTM D5470 data with power cycling TTV performance







Contributions/Acknowledgements

[1] Nanotest GmbH. (2025). *TIMA®5 – Thermal Interface Material Analyzer (slide deck)* [PDF]. https://nanotest.eu/fileadmin/downloads/presentations/Nanotest_TIMA5.pdf

[2] E. Skiljan, R. Mayberry, K. Aserian, J. Hertline. (2025). Compressible Metal Thermal Interface Material (TIM) for Power Electronic Module to Heat-sink Attach. *GEA Apex Expo 2026.*

[3] M. Lazić, B. Jarrett, R. McDonough, C. Burt. (2024). Solving Warping Issues with Novel Metal Compressible TIM. *TestConX 2025.*