Holden

9 October 2017

The General Manager
Consumer Product Safety Branch
Australian Competition and Consumer Commission
GPO Box 3131
CANBERRA ACT 2601

By email: takata@accc.gov.au

Dear Sirs,

ACCC Proposed Recall Notice: Motor vehicles with specified Takata airbag inflators and specified salvaged Takata airbag inflators ("Proposed Recall Notice")

GM Holden Ltd shares the ACCC's focus on consumer safety and appreciates the opportunity to present its case ahead of the ACCC's recommendation to the Minister on the Proposed Recall Notice. Terms defined in the Proposed Recall Notice have the same meanings when used in this letter.

Summary of Holden submission to the Proposed Recall Notice

General Motors Company, including GM Holden Ltd (**Holden**) (together, **GM**), is committed to safety.

In the case of Takata, GM, having instituted an investigation of Takata inflators over three years ago, has not identified a current safety defect globally, including Australia, and continues investigations to ensure that Takata airbags in GM products meet performance specifications for the long term.[1] Specifically:

- Not all Takata airbag inflators are the same. Even inflators from the same "family" can have significant differences that impact long-term performance in the field.
- GM has been actively investigating the performance of non-desiccated PSAN Takata inflators (SDI and PSDI-5) used in GM vehicles, including Holden vehicles, (**Takata inflators in GM vehicles**) since 2014, including analysis of field returns, ballistic testing and artificial aging of Takata inflators.
- Among other design differences, Takata inflators in GM vehicles use a tablet form of propellant, as distinct from other inflators with a 'batwing' form of propellant that have suffered ruptures.
- GM has significant technical data and analysis supporting the fact that Takata inflators in GM vehicles are currently safe.
- There have been no reported energetic deployments (also known as inflator rupture) in GM engineered products reported globally.

[1] GM's product safety evaluation process has undergone extensive change, as well as review and evaluation by US regulators, over the past three years. Given the scrutiny and the company's focus on innovative, data-driven analytics, and continuous improvement, GM has set a new standard for safety evaluation in the automotive industry. We welcome the opportunity to present to you on GM's Safety and Field Investigation process should you wish.

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- Takata inflators in GM vehicles are performing as designed, and will continue to do so while a detailed GM technical investigation into the long-term performance of Takata airbags is completed in March 2018.
- In North America, GM filed a petition for inconsequentiality with NHTSA covering certain GM full size trucks and SUVs that utilized Takata passenger airbag inflators. Through this petition, GM is seeking a determination that the inflators in these vehicles do not pose an unreasonable risk to safety. This petition and GM's related pleadings describe, in detail, the differences in inflator design and vehicle environment/integration that explain why the inflators in these vehicles perform differently on a long-term basis than other Takata inflators utilized by other OEMs. In November 2016 NHTSA supported GM's petition to defer the Takata 'Equipment Recall' launch on the GM full size trucks and SUVs subject to the inconsequentiality petition while GM investigates the long-term performance of the subject inflators (please see Attachment 1 – GM Petition and Attachment 2 – NHTSA Approval of Petition).
- Holden has extensively consulted with the Department of Infrastructure and Regional Development (**DIRD**) which has understood Holden's decision to defer a voluntary recall decision until completion of that GM long term investigation into subject inflators (please see Attachment 3 – DIRD Confirmation of Delay).
- GM has confirmed that a supply of inflators to support a mandatory recall of Holden products within the timeframe requested by the ACCC is not available.

Holden requests that the ACCC allow time for GM's final testing to be completed before mandating a recall that includes Takata inflators in GM vehicles, as there is no indication that use of the Takata inflators in GM vehicles will or may cause injury to any person. In keeping with its commitment to safety, if the results of the testing show any safety issue, GM will immediately take all steps to enact a voluntary recall of the affected products at that time.

1. Safety of Takata inflators in GM vehicles

No Holden product contains an Alpha Inflator. GM and Holden believe that the Takata inflators in GM vehicles are safe, for the following reasons:

1.1 Design Features and Manufacturing Quality of Takata inflators in GM vehicles

The SDI and PSDI-5 inflators used by GM are GM unique and different from inflators with demonstrated problems used by other OEMs. Particular design features of Takata inflators in GM vehicles include propellant shape and size, tablet design, thickness of steel case and propellant mass to vent ratio.

When compared to other inflators manufactured by Takata and used in other OEMs' vehicles, Takata inflators in GM vehicles have design features which reduce moisture ingress and also make the propellant more resistant to, and protected from, the effects of moisture ingress. As a result, the Takata inflators in GM vehicles do not have the same level of propellant degradation as higher risk Takata inflators used in other OEMs' vehicles.

Additionally, GM adopted the use of Takata inflators at a later point in time than other OEMs and when certain, earlier manufacturing quality issues had been addressed by Takata. This, coupled with location of manufacturing of the Takata inflators in GM vehicles in plants in Europe which have consistent environmental and quality control processes, further adds to the robustness of the Takata inflators in GM vehicles.

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For further detail, we refer you to Attachment 4 - Technical Detail, which explains in detail why these design features mean the Takata inflators in GM vehicles are different from Takata inflators used in other OEM vehicles, and pose less safety risk to consumers.

1.2 GM and Holden investigations

GM has undertaken a detailed investigation into the current and long term performance of Takata inflators in GM vehicles. Test results confirm that these inflators are performing as designed in the field. Below is a summary of information detailed in Attachment 4. Please refer to Attachment 4 for further information.

<u>(a) Statistical Study</u>:

There have been approximately 9.3 million GM vehicles built globally with GM variants of Takata inflators (including SDI and PSDI-5). All involve tablet forms of the PSAN propellant. Using a conservative deployment rate for accidents of 0.4% per year, this would mean there would be more than 260,000 driver-side airbag deployments in this population since the first usage of these inflators in 2005. There have been 0 ruptures for this population reported from the field.

<u>(b) Field Returns Analysis</u>:

To date, GM has tested 636 samples with an average age of 10.5 years. Analysis of field returns confirms no significant propellant degradation is occurring. Ballistic testing and 'live dissection' of field returns from High Ambient Humidity (**HAH**) regions of the US have also shown no ruptures when tested. When dissected, these inflators show normal propellant density and no anomalies.

<u>(c) Artificial aging field return inflators</u>:

Field returned inflators are being cycled to simulate up to 30 years of exposure to an extreme HAH environment. To date, no abnormal deployments have occurred in more than 35 aged inflator tests.

In addition to the above, GM is currently undertaking a test program to confirm the long-term performance of Takata driver-side airbag inflators used in GM vehicles.

GM expects to continue field return analysis and artificial aging and will complete all investigative work in March 2018. GM will share results with involved regulators, including the ACCC and DIRD, following completion.

2. Takata inflators in GM vehicles – recalls in other markets

The ACCC would be aware that GM has undertaken a recall of Takata non-desiccated ammonium nitrate (PSAN) inflators in certain markets, specifically, in North America and China. Holden notes the following in relation to these markets:

2.1 North America

As part of a consent order with NHTSA, since January 2016, Takata has filed a series of 'Equipment Recall' (**ER**) "defect information reports" for non-desiccated PSAN inflators manufactured by Takata in the North American market. Following the initial tranche of ER

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filings, GM recalled the SAAB 9-3 and Saturn Astra fitted with PSDI-5 inflators in January 2016, albeit without any evidence of any incidents (whether in the field or in ballistic testing) of ruptures in these specific inflators, which utilize certain GM-specific designs. At that time GM's investigation into these specific inflators was not yet sufficiently advanced to contend with or refute the basis for the Takata ERs.

GM is also executing the recall of the Pontiac Vibe in North America, based on recall filings made by Toyota for the Vibe and the Toyota Matrix (the Vibe's sister model). Neither this vehicle nor derivatives were sold in Australia.

Notably, GM is not currently executing a recall in North America for the GMT900 Light Duty family of vehicles which utilise a Takata passenger inflator subject to Takata ERs filed in May 2016 and January 2017. Instead, GM filed a "Petition for Inconsequentiality and Request for Deferral of Determination" for these vehicles, asking that NHTSA rule that the inflators in these vehicles do not pose an unreasonable risk to safety given the differences in inflator design, manufacturing, and vehicle integration in these products. Based on the analysis and investigation GM has conducted to date, as described in GM's pleadings with NTHSA, these inflators show a marked improvement to other Takata non-desiccated PSAN inflators and a significantly reduced[2] risk of rupture despite simulated and actual long-term exposure to high heat and humidity environments. In November 2016, the initial Request for Deferral of Determination was approved by NHTSA. Please see Attachment 2 for a copy of the approval. GM submitted an update as to the results of its ongoing investigation in August 2017 and awaits the further reply of NHTSA. It is Holden's belief that further testing for the vehicles sold in the Australian market will provide similar results.

2.2 China

The Chinese regulator, AQSIQ, requested GM and other vehicle manufacturers submit remediation plans for Takata airbags that use PSAN as a propellant. This resulted in a request by the Chinese regulator for a proactive recall of GM and other OEM vehicles with Takata airbags. In GM's view, this regulator recall decision was not based upon identification of a potential risk to customer safety and did not consider technical facts available to the regulator at the time of decision.

3. Proposed Recall Notice – summary of practicalities of compliance

GM does not presently believe that there is a safety issue with any vehicle supplied by Holden with a Takata inflator and therefore does not believe that a recall of its products is required. If at any time, GM determines there is a risk that the Takata inflators used in GM vehicles will or may cause injury to any person, we will act.

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[2] As described in GM's filings with NHTSA, despite long-term artificial aging of the inflators in these GMT900 vehicles simulating decades of exposure to high heat and humidity, test deployments have not resulted in a single rupture in these inflators.

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3.1. Availability of replacement parts (Schedule 1- Recall Timetable)

Holden will be unable to meet the timetable set out in Schedule 1 to the Proposed Recall Notice owing to a global shortage of suitable GM validated replacement parts.

Holden has confirmed that there are two plants that are producing alternate replacement inflators suitable for most products in the GM population considered by the Proposed Recall Notice. These two plants are currently running at full capacity for the immediate future, and have no capacity for Holden inflators at this time.

To meet the replacement requirements of the Proposed Recall Notice, Holden will need to validate and then source alternate replacement parts and negotiate supply volumes. Investigations into this have begun, but finalization of specifications, orders and manufacturing time is required to confirm recall execution timing. Holden could only begin to rework vehicles as validated parts become available for each model.

If the Proposed Recall Notice is converted to a mandatory recall, Holden's communications with its customers will have to include a statement to the effect that replacement parts are not currently available but that Holden will advise its customers as soon as such parts become available.

3.2 Prescribed Communications (clause 6(b)(iii) and Schedule 2, Part A (1)(b) and Part B (2)(b))

In Holden's view, the proposed statement to be communicated to consumers and affixed to the windscreen and engine bay is factually incorrect and significantly overstates the risk posed by Takata inflators in GM vehicles. Holden submits that the prescribed wording is misleading about its products and will cause undue alarm to its customers in circumstances where no safety issue has been identified.

Holden further submits that the express prohibition on presenting factual information about its vehicles, namely, that there have been zero reported safety incidents with Takata inflators in GM vehicles will cause further, unnecessary alarm to consumers.

3.3 Impact on Dealers and other second-hand vendors

The impact of the terms of a mandatory recall, proposed in the Proposed Recall Notice, on the sale of new and second hand vehicles with Affected Takata Airbag Inflators will be substantial.

The impact on Dealerships should not be underestimated. Specifically, the inability of Dealers to sell second hand vehicles the subject of a safety recall will inevitably cause major financial ramifications for Dealers and other second-hand vendors.

Further, Holden notes that the proposed terms of the recall (including, but not limited to, the requirement for notices to be affixed to the windscreens of vehicles) will undoubtedly impact the ability of private vehicle sellers to sell their second-hand vehicles.

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3.4 Salvage yards (clause 9)

Holden notes the significant administrative difficulty associated with identifying Spare Parts not connected to a Vehicle's VIN. Moreover, Holden does not sell to, nor have any control over, the conduct of the business of independent, third party salvage yard operators or internet vendors, nor of private parties who may transact with such parties. Holden submits that a more effective method by which Spare Parts may be salvaged would be for the Government to implement legislation barring the second-hand sale of vehicle safety equipment, including Spare Parts.

3.5 Estimated costs of recall

Holden notes the ACCC's invitation to make submissions on the estimated costs of compliance with the Proposed Recall Notice. Holden is not in a position to make such a submission at this time, however, notes that the financial impact, both direct and indirect would be significant.

On current estimates, Holden has approximately 330,000 vehicles that may be affected by the proposed recall. As we have noted above, at 3.1, Holden does not have suitable replacement parts and is not likely to have these parts for some time. Compliance with certain elements of the Proposed Recall Notice, including the requirement to provide alternative transportation until parts are replaced, will be at significant cost.

Conclusion

GM is serious about the safety of our vehicles and will voluntarily execute a safety recall should any evidence identify a risk to consumer safety.

GM continues to investigate the long term performance of the inflators to confirm that they will continue to operate safely for consumers in Australia and other countries. There are no known inflator ruptures in GM designed and manufactured vehicles sold globally. GM has confirmed that Takata inflators in GM vehicles will continue to operate correctly through GM's investigation and beyond. GM will provide regular updates to the ACCC on the ongoing results of these investigations.

Holden requests that the ACCC consider following the approach adopted by NHTSA, by allowing time for the completion of the GM testing program and excluding Takata inflators in GM vehicles from the scope of any mandatory recall.

Yours sincerely

Mark Bernhard
Chairman & Managing Director
GM Holden Ltd

cc: Jeffrey Massimilla, Vice President for Global Vehicle Safety and Product Cybersecurity, GM
Brett Vivian, Executive Director, Engineering, GM Holden Ltd

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UNITED STATES DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

In re:

EA15-001
Air Bag Inflator Rupture

GENERAL MOTORS LLC'S PETITION FOR INCONSEQUENTIALITY AND REQUEST FOR DEFERRAL OF DETERMINATION REGARDING CERTAIN GMT900 VEHICLES EQUIPPED WITH TAKATA "SPI YP" AND "PSPI-L YD" PASSENGER INFLATORS SUBJECT TO JANUARY 2017 TAKATA EQUIPMENT DIR FILINGS

General Motors LLC ("**GM**") hereby petitions the National Highway Traffic Safety Administration ("**NHTSA**") under 49 U.S.C. §§ 30118(d), 30120(h) and 49 C.F.R. part 556 with respect to the Takata "SPI YP" and "PSPI-L YD" model front-passenger airbag inflators installed as original equipment in the GM vehicles covered by Takata's equipment defect information reports ("**DIRs**") filed on January 3, 2017, and requests that NHTSA provide GM until August 31, 2017 to complete its engineering analysis and inflator-aging studies before making a determination on this Petition. In support of this request, GM relies on the engineering testing and analysis summarized below, as well as the information that GM has provided to the Agency during periodic briefings on the status of its investigation and in connection with its November 15, 2016 Petition for Inconsequentiality, as more specifically described below.

I. Introduction

As required by the Amendment to November 3, 2015 Consent Order between NHTSA and TK Holdings Inc. (the "**Amendment**"), Takata filed several equipment DIRs in May 2016 that covered, among other inflators, SPI[1] and PSPI-L[2] model airbag inflators without chemical drying agents not yet under recall that Takata sold to multiple OEMs.[3] These DIRs included the "SPI YP" and "PSPI-L YD" model front-passenger airbag inflators (the "**May DIR GMT900 Inflators**") not yet under recall that were installed as original equipment in the following GMT900[4] vehicles (collectively, the "**May DIR GMT900 Vehicles**"):

(i) 2007-2011 model year GMT900 vehicles that had ever been registered in the region defined by NHTSA as Zone A; and

(ii) 2007-2008 model year GMT900 vehicles that had ever been registered in the region defined by NHTSA as Zone B.

Takata filed the May 2016 equipment DIRs without any evidence of any incidents, whether in the field or in ballistic testing, of rupture in a SPI YP and PSPI-L YD model inflator, which utilize GM-specific designs and are contained in unique vehicle environments.

Following Takata's May DIR filings, after consultations with NHTSA, GM filed two DIRs on May 27, 2016 (updated as of June 13, 2016) that covered the May DIR GMT900 Vehicles. GM's DIRs provide, in part, that "[a]fter reviewing the available information, data, and analysis, GM believes that the vehicles it manufactured with these inflators do not contain a present defect which poses an unreasonable risk to motor vehicle safety," but that GM would conduct a recall of

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[1] SPI means "Smokeless Passenger Inflator."

[2] PSPI means "Programmable Smokeless Passenger Inflator."

[3] NHTSA required Takata to take this action because NHTSA determined that these Takata inflators may contain a latent defect—propellant degradation caused by long-term exposure to humidity and temperature cycling—that can cause the inflator to rupture during deployment.

[4] The GMT900 is a specific vehicle platform that forms the structural foundation for a variety of GM trucks and sport utility vehicles, including the Chevrolet Silverado 1500, GMC Sierra 1500, Chevrolet Silverado 2500/3500, GMC Sierra 2500/3500, Chevrolet Tahoe, Chevrolet Suburban, Chevrolet Avalanche, GMC Yukon, GMC Yukon XL, Cadillac Escalade, Cadillac Escalade ESV, and Cadillac Escalade EXT.

these vehicles "unless GM is able to prove to NHTSA's satisfaction that the inflators in its vehicles do not pose an unreasonable risk to safety."

On November 15, 2016, GM filed its Petition for Inconsequentiality and Request for Deferral of Determination Regarding Certain GMT900 Vehicles Equipped with Takata "SPI YP" and "PSPI-L YD" Passenger Inflators under 49 U.S.C. §§ 30118(d), 30120(h) and 49 C.F.R. part 556 (the "**First Petition**"). In the First Petition, GM argued that the equipment defect determined to exist by Takata in the May DIR GMT900 Inflators is inconsequential as it relates to motor vehicle safety in the May DIR GMT900 Vehicles. First Petition at 1. GM further requested that NHTSA defer a decision on the First Petition until August 31, 2017, which would permit GM to complete its testing and engineering analysis on the long-term safety of SPI YP and PSPI-L YD inflators in GMT900 vehicles. *Id.* at 3-4.

In support of its request for deferral, GM argued that the inflators in the May DIR GMT900 Vehicles are currently performing as designed, and would likely continue to perform as designed for a number of years, as evidenced by available field data, ballistic testing of field and aged parts, and stress-strength interference analysis. *Id.* at 13-17. GM further argued that, because GM's engineers and suppliers have been working on redesigned replacement inflators to be ready in the event that the inflators in the May DIR GMT900 Vehicles must be replaced, granting GM's deferral would not delay GM's efforts to engineer and validate replacement inflators as an available remedy for the May DIR GMT900 Vehicles, should that remedy ultimately be required. *Id.* at 17-18. On November 28, 2016, NHTSA granted GM's deferral request. *See* General Motors LLC, Receipt of Petition for Inconsequentiality and Decision Granting Request To File Out of Time and Request for Deferral of Determination, 81 Fed. Reg. 85681 (Nov. 28, 2016).

GM now requests similar treatment for the Takata SPI YP and PSPI-L YD inflators covered by the latest round of Takata equipment DIRs, which Takata filed on January 3, 2017 (the "**January DIR GMT900 Inflators**"). These inflators were installed as original equipment in the following GMT900 Vehicles (the "**January DIR GMT900 Vehicles**"):

GM Zone A Population	**GM Zone B Population**	**GM Zone C Population**
2012 GMT900 vehicles	2009 GMT900 vehicles	2007 – 2008 GMT900 vehicles

The facts and arguments contained in the First Petition, which remain largely unchanged since GM's November filing, support the deferral requested in this Petition with greater force. Compared to the May DIR GMT900 Inflators, the January DIR GMT900 Inflators are: (i) in newer vehicles, in the case of the Zone A and Zone B populations; or (ii) located in the lowest risk Zone C region (none of the May DIR GMT900 Vehicles were in Zone C). The January DIR GMT900 Inflators have therefore been exposed to significantly less humidity and temperature cycling than the May DIR GMT900 Inflators, and are in lower Priority Groups under the recently issued Third Amendment to the Coordinated Remedy Order. Granting GM's requested deferral is consistent with and supported by NHTSA's findings of fact in its decision on GM's First Petition; will provide GM and Orbital ATK sufficient time to complete the long-term GMT900 inflator aging study; and will allow the Agency to render a single decision on both GM petitions in light of the results of that study. Deferring a determination, moreover, will not delay GM's remedy program, if required, as the earliest Sufficient Supply & Remedy Launch Deadline for any of the vehicles covered by this Petition is December 31, 2017.

II. Background

A. GM's investigation and transparency with NHTSA with respect to its investigation

In November 2014, GM began proactively investigating Takata inflators in GMT900 vehicles. GM began this investigation in light of the Takata inflator recalls conducted by other automakers. Although Honda had experienced inflator ruptures in its vehicles and initiated limited recalls relating to Takata inflators before 2014,[5] recalls relating to Takata inflators in high-humidity regions began expanding in the latter half of 2014 to nine other OEMs, including GM (for GM-badged vehicles that were not manufactured by GM, the Pontiac Vibe (Toyota Matrix) and the Saab 9-2X (Subaru Impreza) vehicles).

Whether viewed in the context of voluntary OEM product-safety investigations generally or with respect to the Takata recalls specifically, GM's investigation—now two years in length—is extraordinary in its scope, duration, and scientific rigor. To GM's knowledge, no other OEM has expended more engineering resources to the task of understanding the root causes of inflator rupture or to estimating the long-term performance of the different Takata airbag inflator variants used in their vehicles.

In the process of this unique investigation, GM has provided NHTSA personnel with consistent, detailed information regarding GM's investigation. Since November 2014, and in addition to attending industry-wide technical meetings as part of the OEM Independent Testing Coalition, GM has been in regular communication with NHTSA regarding the status of its own investigation, updated NHTSA on new analysis and field data, responded to NHTSA inquiries,

[5] In June 2014, GM conducted a safety recall (NHTSA Recall 14V-372) relating to front driver Takata airbag inflators in certain 2013–2014 model year Chevrolet Cruze vehicles. However, this recall related to a Takata manufacturing issue (incorrectly installed baffles) and was not humidity-related.

and regularly provided in-person technical briefings to NHTSA engineers and lawyers. A listing of the various meetings and discussions follows.

- November 25, 2014. GM shares its preliminary, internal investigation plan for GMT900 vehicles with NHTSA, including GM's proposal to seek GMT900 passenger airbag inflators proactively from the field to understand the effect of the environment (vehicle and external) and humidity on these Takata inflators over time.

- January 23, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation. GM's initial presentations to NHTSA in the beginning of 2015 include, among other things, GM's preliminary analyses of Takata's CT scan measurements of propellant wafers in SPI/PSPI-L inflators returned from the field.

- February 13, 2015. GM conducts a telephonic conference with NHTSA to brief NHTSA on GM's Takata investigation and testing plans.

- March 25, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation. GM's presentation includes, among other things, GM's initial analysis of data supplied by Takata and other OEMs on the performance of Takata inflators in other vehicles, which indicates marked differences between the observed propellant degradation in SPI/PSPI-L inflators recovered from GMT900 vehicles (as measured by CT scanning) and the observed propellant degradation in inflators recovered from other vehicles.

- May 14, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- May 22, 2015. GM conducts a telephonic conference with NHTSA staff to review the status of GM's investigation.

- July 23, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- August 27, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- September 14, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- October 15, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- November 19, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>November 24, 2015</u>. GM conducts a telephonic conference to provide the November 19th briefing to certain NHTSA personnel that were unable to attend the in-person meeting on November 19.

- <u>December 17, 2015</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation, including Orbital ATK ("**Orbital**") testing and analysis and information on recent field part returns.

- <u>January 7, 2016</u>. GM conducts a telephonic conference to update NHTSA on the Orbital testing plan.

- <u>January 21, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>February 18, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>March 17, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>April 6, 2016</u>. GM conducts a telephonic conference to update NHTSA on data generated by returned field parts from GMT900 vehicles.

- <u>April 14, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>April 26, 2016</u>. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

- <u>May 10, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office and provide a comprehensive technical briefing on the status of GM's investigation. GM's presentation included, among other things, the results from Takata's CT scanning and ballistic testing on inflators returned from GMT900 vehicles in Zone A regions, which indicated that the inflators were performing safely and as designed.

- <u>May 12, 2016</u>. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

- <u>May 18, 2016</u>. GM conducts a telephonic conference to solicit feedback from NHTSA on the testing discussed during the May 10 technical briefing.

- <u>June 16, 2016</u>. Following the filing of GM's Preliminary DIRs on May 27, 2016 (see below), GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- <u>July 28, 2016</u>. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of Orbital's short-term testing and GM's inflator aging study.

- August 16, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of Orbital's short-term testing and GM's inflator aging study.

- September 1, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to provide a detailed technical briefing to ODI on GM's investigation and the initial results of Orbital's short-term testing. GM's investigation includes updated CT scanning and ballistic testing results, along with the results of GM's recently completed inflator aging study. This meeting also provides NHTSA with an overview of GM's petition for deferral, which is filed on September 2.

- September 13, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- October 4, 2016. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

- October 13, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

- November 1, 2016. GM meets with NHTSA in GM's Detroit office to update NHTSA on the status of GM's investigation.

- December 6, 2016. GM meets with NHTSA in GM's Detroit office to update NHTSA on the status of GM's investigation.

Going forward, moreover, GM will continue to provide monthly updates to NHTSA regarding the status of its investigation, as required by the terms of the November 25, 2016 order granting the deferral request in GM's First Petition. *See* General Motors LLC, Receipt of Petition for Inconsequentiality and Decision Granting Request To File Out of Time and Request for Deferral of Determination, 81 Fed. Reg. 85681 (Nov. 28, 2016).

B. GM's January 2017 DIRs

On January 10, 2017, following Takata's filing of its January DIRs under the Amendment, GM filed two DIRs covering the January DIR GMT900 Vehicles. As it stated in its earlier May 2016 filings, GM's January 2017 DIRs state that:

> After reviewing the available information, data, and analysis, GM believes that the vehicles it manufactured with these inflators do not contain a present defect which poses an unreasonable risk to motor vehicle safety. Given that GM has not determined that a safety

> defect exists, GM is filing this Preliminary DIR in light of NHTSA's Amended Consent Order directing that, "[t]he filing of DIRs by Takata will trigger the vehicle manufacturers' obligations to file DIRs," the Coordinated Remedy Order. (See CRO ¶ 46), and NHTSA regulations. See 49 C.F.R. Part 573. We are not aware of any cases of inflator ruptures in any passenger airbag inflators in our vehicles worldwide.
>
> Contemporaneously with the filing of this DIR, GM is filing with NHTSA a Petition for Inconsequentiality and Request for Deferral of Determination with respect to the subject vehicles. GM will conduct a recall of its airbag inflators covered by the January 2017 Takata DIRs in the event that GM is unable to prove to NHTSA's satisfaction that the inflators in its vehicles do not pose an unreasonable risk to safety and NHTSA denies GM's Petition for Inconsequentiality and Request for Deferral of Determination.

As stated in GM's January 2017 DIRs, GM has not determined that a defect that poses an unreasonable risk to safety exists in the January DIR GMT900 Vehicles. Nothing in this Petition or in the act of filing this Petition is an admission, implied or otherwise, that such a safety defect exists.

III. Discussion

A. Basis for Petition (49 U.S.C. § 30118(d) and § 30120(h); 49 C.F.R. Part 556.4(b)(5))

To petition for an exemption under sections 30118(d) and 30120(h) of the Safety Act, NHTSA's regulations require the manufacturer to file a DIR pursuant to 49 C.F.R. part 573. 49 C.F.R. § 556.4(c). If the manufacturer has not itself made a determination that a defect exists, this DIR does "not constitute a concession by the manufacturer of, nor will it be considered relevant to, the existence of a defect related to motor vehicle safety or a nonconformity." *Id.*

GM has not determined that a defect that poses an unreasonable risk to safety exists in the January DIR GMT900 Vehicles, and this Petition does not constitute a concession by GM of the existence of a defect in the January DIR GMT900 Vehicles, as permitted by 49 C.F.R. § 556.4(c). GM continues to study the performance of these inflators in the field and GM is continuing its engineering analysis of the specific and unique factors that influence inflator performance in GMT900 Vehicles. GM's analysis currently shows that even the oldest of these vehicles will continue to perform as designed for years into the future, even in the highest heat and humidity regions of Zone A. When its engineering analysis and inflator aging studies are completed in August of 2017, moreover, GM will be able to submit a fulsome record to NHTSA showing how the specific characteristics of these vehicles, along with the unique nature of the SPI YP and PSPI-L YD variants, affect the long term service life of the inflators after exposure to conditions of high absolute humidity.

As in the case of defect determinations under the Safety Act generally, the particular application and use of the defective component is relevant to—and, in this case, determinative of—whether the component poses a safety risk within a certain population of vehicles. As the D.C. Circuit held in the landmark case defining OEM obligations under the Safety Act, "[i]t is possible that the same component may contain a defect in performance relating to motor vehicle safety in one class of vehicle or use but not in another." *United States v. General Motors Corporation*, 518 U.S. 420, 439 n.88 (D.C. Cir. 1975) ("*Wheels*"); *see also Ctr. For Auto Safety, Inc. v. NHTSA*, 342 F. Supp. 2d 1, 14 (D.D.C. 2004), *aff'd sub nom.*, 452 F.3d 798 (D.C. Cir. 2006) ("[U]sage is clearly relevant to a determination of whether a vehicle contains a safety-related defect."). Consistent with the *Wheels* case, as discussed more fully below, the SPI "YP" and PSPI-L "YD" variants that GM used in the GMT900 platform are not used by any other original equipment manufacturer and have unique design features, which, together with the unique in-vehicle environment in the GMT900 vehicles, positively influences the performance of these inflators in the field over time compared to other inflator and vehicle variants.

B. Blomquist Expert Report and vehicle-specific differences

The Amendment was accompanied by an expert report prepared by Dr. Harold R. Blomquist (the "**Blomquist Report**"). Citing to three separate expert reports prepared by Fraunhofer Gesellschaft (retained by Takata), Exponent (retained by Honda), and Orbital ATK (retained by the OEM Independent Testing Coalition, of which GM is a member), the Blomquist Report concludes that the cause of ruptures in Takata PSAN inflators is inflator-propellant damage caused by long-term moisture intrusion and temperature cycling. Blomquist Report ¶ 17.

While the root cause of rupture is widely accepted, the "exposure time needed to sufficiently degrade the propellant to the point that an inflator poses an unreasonable risk to occupant safety" is not completely understood. *See id.* at ¶¶ 30-31. In his report, Dr. Blomquist expressly noted that "vehicle platform differences" could impact the rate of propellant degradation from vehicle to vehicle. *Id.* at ¶ 30 (stating that "further research is needed to validate" whether Exponent's "model inputs . . . correctly simulate real world performance degradation").

These vehicle platform differences, Dr. Blomquist explained, were potentially significant variables. Additional testing could "demonstrate that inflators in certain vehicle platforms, models, or configurations take a longer time to present an increased [rupture] risk . . . ." *Id.* at ¶ 30 n.12; *see also id.* at ¶ 18(a) (stating that "vehicle platform . . . can affect in-vehicle temperature and humidity near the inflator"); Amendment at ¶ 6 (stating that Takata's "own testing and analysis" supports the conclusion that manufacturing variations, vehicle make/model, and the specific type of inflator at issue "considerably" impact the "potential for propellant degradation and the expected rate of degradation").

C. GM's study and investigation of Takata inflators in GMT900 vehicles

During its investigation, GM has extensively analyzed the ballistic performance of the SPI YP and PSPI-L YD variants that GM used in the GMT900 platform, which—crucially—have a

GM-specific design and are contained in a unique vehicle environment. Although other OEMs used Takata SPI and PSPI-L model inflators, Takata produced several different variants of these models, each with different design characteristics. The SPI YP and PSPI-L YD variants that GM used in the GMT900 platform are not used by any other original equipment manufacturer and have multiple unique design advantages, including greater vent-area-to-propellant-mass ratios, steel (as opposed to aluminum) end caps, and thinner propellant wafers, which influence burn rates and internal ballistic dynamics.

The physical environment in GMT900 vehicles, moreover, better protects the front-passenger inflator from the extreme temperature cycling that can cause inflator rupture. GMT900 vehicles, which are light trucks and SUVs, have larger interior volumes than smaller passenger cars, and are equipped with solar-absorbing windshields and side glass, all of which significantly reduce interior vehicle temperatures. GM believes, given its present understanding, that these inflator-design and vehicle-environment factors help explain why, as discussed more fully below, inflators recovered from the GMT900 vehicles continue to perform as designed in the field and have not ruptured in ballistic testing, even after significant real-world and laboratory exposure to temperature cycling and humidity.

To supplement its internal analysis, GM has retained Orbital to conduct a long-term aging study that will estimate the service-life expectancy of GMT900 inflators. Orbital needs until approximately August 2017 to complete this study. As more fully described below, the current results of this investigation support the conclusion that the inflators in the January DIR GMT900 Vehicles are currently performing as designed in the field, and that even the Zone A vehicles in the field will continue to perform as designed for at least the next 8.5 years, even after exposure to some of the highest heat and highest humidity environments found in Zone A. This is five years longer than the oldest Zone A May DIR GMT900 Vehicles subject to the First Petition. GM believes this estimate of 8.5 years will only grow as GM's inflator aging studies continue and inflators continue to be conditioned and tested to show their performance over extended periods of time.

D. Field data and GM's internal testing and analysis demonstrates that the Takata SPI YP and PSPI-L YD variants in GMT900 vehicles are currently performing as designed.

1. An estimated 55,000 Takata passenger airbag inflators have deployed in GMT900 vehicles without a single reported rupture

As part of its Safety and Field Investigations process, GM actively monitors vehicle-performance data for evidence of potential safety issues, including incidents of inflator rupture. This dataset includes customer complaints, GM Technical Assistance Center logs, warranty claims, legal claims, field investigations, and NHTSA VOQs. Although these sources do not track airbag deployments in the field, it is possible to estimate field deployments using accident rate and severity information published by NHTSA (NASS). Using this method, GM estimates that over 55,000 PSPI-L and SPI inflators have deployed in GMT900 vehicles since model year 2007, the first model year that GMT900 vehicles utilized these inflators. GM is not aware of a single confirmed rupture report involving a Takata SPI YP or PSPI-L YD inflator in a GMT900 vehicle.

2. GM has analyzed and safely deployed approximately 1,600 Takata SPI YP and PSPI-L YD inflators from the oldest affected GMT900 vehicle population in the highest-risk region

The results from GM's ballistic testing is consistent with the field data. Since November 2014, GM has sent PSPI-L YD and SPI YP inflators from GMT900 vehicles in the field to Takata for ballistic testing and analysis. To date, Takata has ballistic tested 1624 such inflators, and all deployed safely and as designed; none of the inflators ruptured or demonstrated elevated deployment pressure or other signs of abnormal deployment.[6] And these tests are just the beginning. GM will be testing and deploying more inflators going forward as part of its test plans, both internally and with Orbital.

These deployed inflators included a significant number of GMT900 inflators that, according to the Blomquist Report, are at the highest risk of rupture. *See* Blomquist Report ¶ 17. The vast majority of these inflators—1169 PSPI-L YD and 392 SPI YP inflators—came from Zone A GMT900 vehicles recovered from 2007-2008 model year vehicles, which are the oldest population of GMT900 vehicles in the field with Takata passenger airbag inflators.

3. GM artificially aged and ballistic tested Takata SPI YP and PSPI-L YD inflators from the oldest GMT900 vehicle population in the highest-risk region—and all deployed normally

In addition to ballistic tests of unaltered field parts, GM has also conducted ballistic tests on laboratory aged parts to study the future performance of GMT900 SPI YP and PSPI-L YD inflators after additional aging in Zone A states. To conduct these tests, GM artificially aged 12 inflators—6 SPI YP and 6 PSPI-L YD—recovered from 2007-2008 model year GMT900 vehicles in Florida. These inflators had an average of 7.7 years (for the SPI inflators) and 7.8 years (for the PSPI-L inflators) of field exposure.

To further age the parts, GM subjected the 12 returned field parts to continuous temperature cycling in a temperature/humidity chamber. To simulate the temperatures inside a GMT900 vehicle in a Zone A state, GM left a GMT900 vehicle outside in Miami, Florida—facing south, exposed to direct sunlight, during the hottest part of the year—and collected temperature and humidity measurements from sensors placed directly on the inflator housing inside. GM replicated

[6] On information and belief, Takata has provided NHTSA with the data associated with these ballistic tests. For this reason, GM has not submitted this data with its Petition. GM can provide this data on request.

the temperature and humidity conditions that GM observed inside the Miami test vehicle in the temperature/humidity chamber, and continuously exposed the test parts to these conditions on four-hour cycles for 58 straight days. GM estimates that this cycling added the equivalent of seven additional years of Zone A temperature and humidity exposure to the test parts.

GM then sent the parts to Takata for analysis and ballistic testing. Despite having significant real-world temperature and humidity exposure and an additional 7 years of simulated Zone A aging from the temperature/humidity chamber, these inflators did not rupture during testing, or even demonstrate elevated deployment pressure or other signs of abnormal deployment. The results from these tests are attached as **Exhibit A**.

Based on these studies, GM believes that the January DIR GMT900 Vehicles in Zone A will continue to perform as designed for at least 14.5 years of exposure in the field. Given that the oldest of the January DIR GMT900 Vehicles in Zone A would be approximately six years old at present, GM believes even these oldest vehicles would continue to be safe for at least another 8.5 years, even assuming that these vehicles were exposed to some of the highest heat and highest humidity environments found in Zone A. The January DIR GMT900 Vehicles in Zone B and C, although comparatively older than the Zone A vehicles, have not been exposed to these temperature and humidity conditions, and can be expected to perform safely for much longer.

Further, GM's tests have not ceased. GM continues to age inflators and GM will continue to test and deploy inflators, both with the help of Orbital, and separately.

4. Stress-strength interference analysis suggests that the propellant in older GMT900 inflators from Zone A has not degraded to a sufficient degree to create a rupture risk

In addition to the ballistic testing described above, Takata has CT scanned 1578 PSPI-L and SPI inflators recovered from 2007-2008 model year GMT900 vehicles to measure the outside diameter of the inflator's propellant wafers—a key correlate of propellant degradation. *See*

Blomquist Report ¶ 18.b (stating that propellant degradation leads to density changes that "manifes[t] as increased diameter"). Like the inflators collected for purposes of ballistic testing, almost all of these inflators—1516—were collected from GMT900 vehicles in the Zone A region. Again, this will continue and this sample size will only grow larger. To estimate risk of rupture in these vehicles, GM engineers used an analysis technique called stress-strength interference. In this context, stress-strength interference involves plotting two curves on a graph: (i) the normal distribution of wafer diameters from scanned field inflators (the "**Field Parts Curve**"); and (ii) the normal distribution of wafer diameters in inflators that have ruptured, or energetically deployed, during ballistic testing (the "**Energetic Deployment Curve**"). If these curves overlap, the amount of overlap represents the probability of rupture in a particular group of inflators.

GM's stress-strength interference analysis is attached as **Exhibit B** and **Exhibit C.** Exhibit B contains the model for PSPI-L inflators recovered from 2007-2008 model year GMT900 vehicles in Zone A. Exhibit C contains the model for SPI inflators recovered from 2007-2008 model year GMT900 vehicles in Zone A. Because no inflators from GMT900 vehicles have ruptured, there is no understood Energetic Deployment Curve for GMT900 inflators; in the absence of such data, GM created the Energetic Deployment Curves in its analysis using data from ballistic tests conducted by Takata on inflators recovered from other vehicles that have experienced ruptures during testing.[7] GM believes that this approach is, if anything, conservative, particularly as applied to the January DIR GMT900 Inflators, which have been exposed to less environmental humidity and temperature cycling than the parts GM used to create the Field Parts Curves. Additionally, GM has presented evidence to NHTSA that the SPI YP and PSPI-L YD inflators in

[7] Takata provided these measurements to GM with the identifying names of other OEMs removed. On information and belief, Takata has already provided NHTSA with these CT scan measurements. For this reason, GM has not submitted this data with its Petition. GM can provide this data on request.

the GMT900 have design advantages that that will make these unique variants more resistant to rupture compared to other inflators based on ballistic testing, ballistic modeling, and propellant-wafer density measurements performed by Orbital (further analysis on this issue is ongoing). Once this testing is complete, the Energetic Deployment Curves in the attached charts could shift to the right, indicating additional reduction in overall rupture risk.

IV. Request for relief

GM requests that, before making a determination on this Petition, NHTSA provide GM until August 31, 2017 to complete its engineering analysis and inflator aging studies. Given that GM's analysis demonstrates that the inflators in Zone A January DIR GMT900 Vehicles will continue to perform as designed for at least another 8.5 years even in high heat and high absolute humidity environments, this request for additional time is reasonable and well-supported by the engineering analysis to date. It is also logically consistent with NHTSA's deferral decision on GM's First Petition, and would permit NHTSA to reach a single determination on both Petitions in September 2017, after Orbital has completed its long-term aging study.

Providing GM this additional time, moreover, will not delay GM's efforts to engineer and validate replacement inflators as an available remedy for the GMT900 vehicles, should that remedy ultimately be required. As NHTSA is aware, GM's engineers and GM's suppliers have been working on re-designed replacement inflators to be ready in the event that the inflators in these vehicles must be replaced. GM's current belief is that a validated engineering solution should be ready by June 30, 2017 (barring unforeseen setbacks).

As noted above, GM's investigation is ongoing. GM has retained Orbital to study and evaluate the specific SPI YP and PSPI-L YD variants that GM used in the GMT900 vehicles, and to test the effect of different inflator design variables—wafer thickness, vent area, moisture dynamics, and others—in the GMT900 platform's unique thermal environment. Attached as

Exhibit D are Statements of Work agreed upon between GM and Orbital that describe, in detail, the work Orbital has been contracted to perform for GM. Orbital has been conducting this study since May 2016, and expects to complete this study in August 2017. To date, GM believes that Orbital's work has not demonstrated that an unreasonable risk to safety exists in any GMT900 vehicles. To the contrary, GM believes that Orbital's results, which have been shared with NHTSA in the various meetings described in Section II.A above, support the contention that the January DIR GMT900 Vehicles do not pose an unreasonable risk to safety at this time and will not pose an unreasonable risk, if at all, for at least 8.5 years for the vehicles in the highest heat and humidity regions of Zone A. To be clear, GM is committed to continuing the Orbital study and to sharing the results of GM's internal analysis and Orbital's study with NHTSA going forward. GM plans to continue its monthly updates with NHTSA during this process. Once the engineering analysis and inflator aging studies are complete, GM intends to supplement and amend this Petition to provide a full record upon which NHTSA can make its determination. However, at present, GM is simply asking for more time.

V. Conclusion

Based on current field and ballistic-testing data and the analyses described herein, which indicate that the January DIR GMT900 Inflators are currently performing as designed, GM requests that NHTSA exempt GM from the notification and remedy requirements of the Safety Act with respect to GM's January 2017 DIRs until at least August 31, 2017. It is GM's belief that once its engineering analysis and inflator aging studies are complete, GM will be able to supplement and amend this Petition and the First Petition, providing a full record of its investigation and have the data available to make a determination on the GMT900 vehicles covered by these petitions. However, at this time, GM is only requesting that NHTSA grant GM until August 31, 2017 to complete this analysis and submit the results to NHTSA.

GM believes the available field data and engineering analysis supports a threshold showing that the January DIR GMT900 Inflators are currently performing as designed in the field and that a deferral of a ruling on this Petition until August 31, 2017, as with the First Petition, does not pose an unreasonable risk to safety. More specifically, the field reports, ballistic testing, and stress-strength modeling along with GM's consistent and timely updates to NHTSA on the investigation as it proceeds support the request for deferral. Further, because GM's engineers and GM's suppliers have been working on redesigned replacement inflators to be ready in the event that the inflators in these vehicles must be replaced, providing GM this additional time will not delay GM's efforts to engineer and validate replacement inflators as an available remedy for the January DIR GMT900 Vehicles, should that remedy ultimately be required.

Respectfully submitted,

GENERAL MOTORS LLC

Jeffrey M. Boyer
Vice President, Global Vehicle Safety

Exhibit List

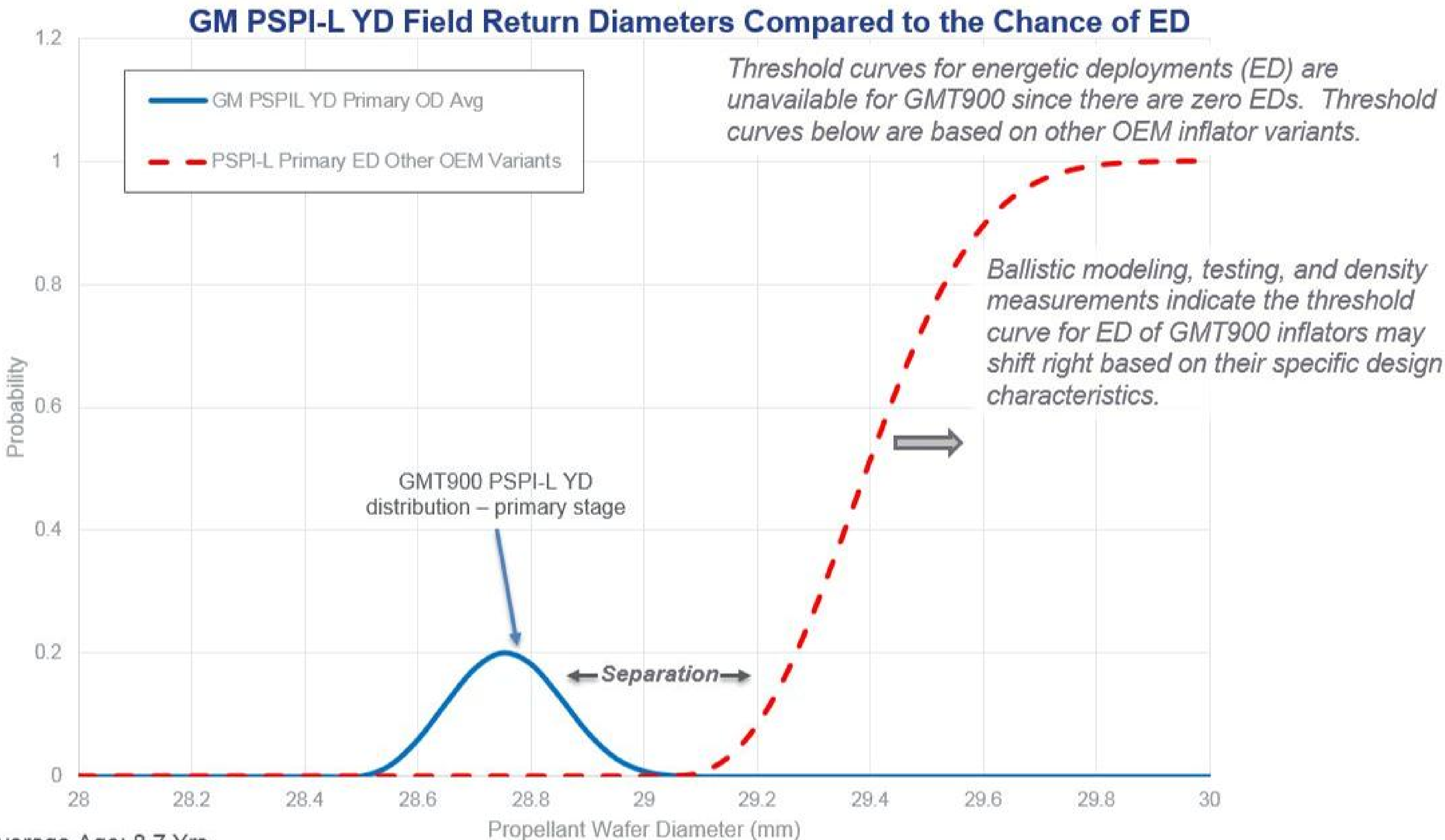
Exhibit A:	Ballistic test data – Laboratory aged field parts
Exhibit B:	Stress-strength interference analysis for PSPI-L inflators installed in 2007-2008 GMT900 vehicles (Updated)
Exhibit C:	Stress-strength interference analysis for SPI inflators installed in 2007-2008 GMT900 vehicles (Updated)
Exhibit D:	Orbital ATK SOWs

EXHIBIT A

Exhibit A submitted separately in native format

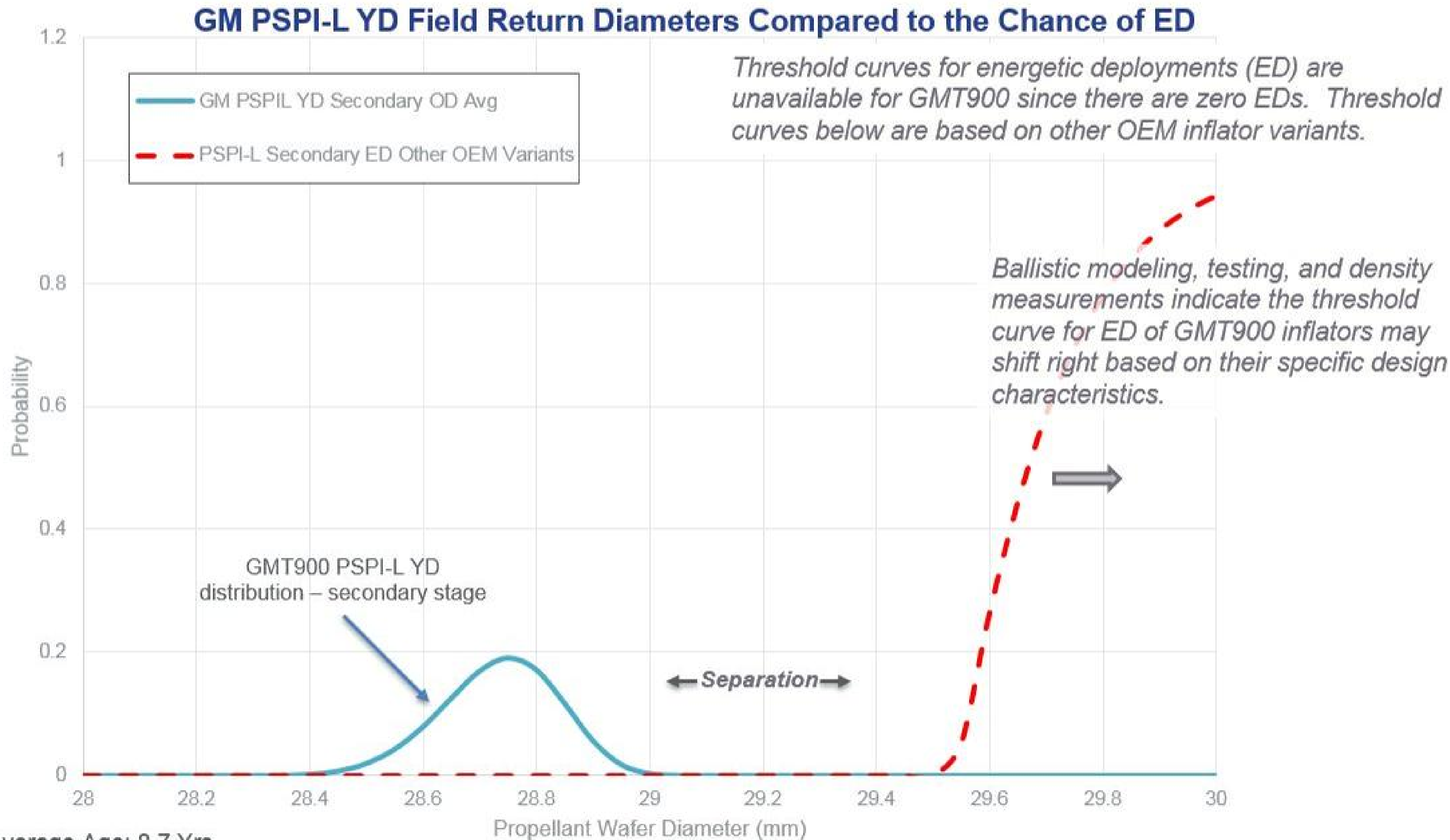
EXHIBIT B

GMT900 PAB INFLATORS – CURRENT FIELD PERFORMANCE



Average Age: 8.7 Yrs

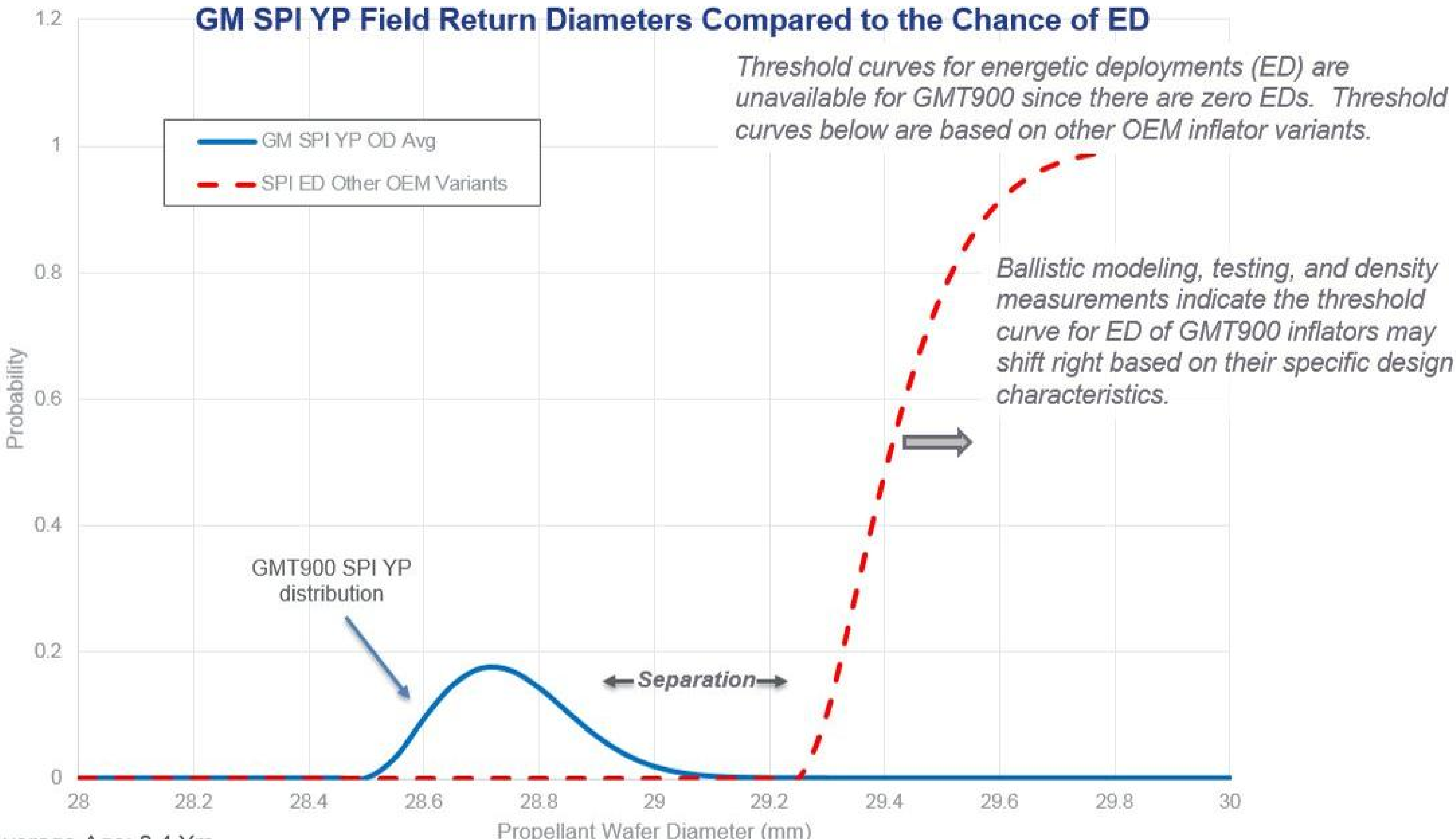
GMT900 PAB INFLATORS – CURRENT FIELD PERFORMANCE



Average Age: 8.7 Yrs

EXHIBIT C

GMT900 PAB INFLATORS – CURRENT FIELD PERFORMANCE



Average Age: 8.4 Yrs

EXHIBIT D

STATEMENT OF WORK	Passenger Airbag Testing

AUTHOR:	[redacted]	BUYER:	[redacted]
PHONE:	[redacted]	PHONE:	[redacted]
DEPARTMENT:	Internal Investigations	UPDATE DATE:	**6/15/16**
SUBMIT DATE:	6/8/16	PURCHASE ORDER #:	**<purchase order issued to supplier for development work>**
REVIEWED FOR EXPORT COMPLIANCE BY:	[redacted]	EXPORT COMPLIANCE CLASSIFICATION:	**EAR99**

PROJECT TITLE:

Passenger Airbag Testing & Analysis for GMT900 Field Returns

PURPOSE:

Review of GM High Absolute Humidity (HAH) passenger airbag field returns for indications of elevated risk on the oldest parts GM has in the field.

TASKS AND RESPONSIBILITIES:

RASIC Roles & Responsibilities

LEGEND: **G**= General Motors Engineering **S**= Supplier

R= Responsible, **A**= Approval **S**= Support, **I**= Inform, **C**= Consult

WHAT \ ROLES	R	A	S	I	C
Test Plan & DOE Matrix	S	G			
Program Management	S		G		G
Acquire Inflators	G				
Testing & Analysis	S			S	G
Final Test Report & Data	S			G	

DELIVERABLES:

Deliverable	Req'd By Date	Submit To GM
Program Plan	With Quote	Buyer
Bill of Materials	With Quote	Buyer
DOE Matrix	With Quote	Buyer
Report Out Meetings	Every Week	[redacted]
Final Report	8/15/2016	

PROJECT TIMING:

Overall Timing: 6-8 weeks

TECHNICAL SPECIFICATION:

Definition:

1. Scanning Electron Microscope (SEM) per LTP-3320-1496
2. Closed Bomb (Burn Rate) per LTP-1026
3. Crush Strength per LTP-0599
4. Inflator Types: SPI-YP (GMT900 HD), PSPI-L YD (GMT900 LD)
    a. Inflators acquired by GM though field returns and virgin inflators direct from production
5. Inflator Types: PSPI-L FD and SPI AJ
    a. Field returns and virgin inflators located at Orbital ATK.

Project Scope:

<u>Testing</u>

A DOE will be created to test the performance of new baseline and aged field returned inflators. The DOE will contain inflators selected by age, location and wafer size.

1. **Heavy Weight Inflator Testing**
    a. Between 10-40 of each type of inflator to be tested (PSPI-L YD & PSPI-L FD)
    b. The selected inflators will be dissected and disassembled according to the DOE parameters.
    c. The heavyweight test fixtures for PSPI-L (existing) will be used for obtaining ballistic data and combustion pressures for all the DOE tests.
2. **Leak Rate Testing**
    a. Approximately 6 of each type of inflator (3 virgin and 3 field) to be tested
        i. PSPI-L YD and SPI YP
        ii. PSPI-L FD and SPI AJ
    b. Inflators will be placed into moisture barrier bags containing D2O and sealed. The inflators will be temperature cycled between 20C and 50, 60 & 70C for several days. Gas samples will be extracted from the inflators and measured for D2O content by GCMS. A relative leak rate will be determined for each inflator.
    c. A transducer will be mounted on each inflator to measure the internal pressure. The inflators will be temperature cycled between 20C and 50, 60 & 70C and held. The pressure will increase due to the temperature change and the decay will be monitored. A relative leak rate will be determined for each inflator.
3. **Moisture Dynamics**
    a. **Glass Jar Ambient Temperature Moisture Competition:** Moisture levels in 2004 in the presence 3110 as a function of 2004/3110 weight ratio and total water content in the system will be assessed. Known weights of water will be added to pre-dried 2004 and 3110 into separate pre-weighed vials. The vials will be uncapped and placed into a sealed jar or Parr bomb and allowed to equilibrate. Each vial will be weighed to determine the moisture content. Data will provide plausible total inflator moisture levels in inflator systems where 2004 is desiccated by AI-cup 3110, closure 3110 or 3110 from both sources. Tests will be designed to mimic mean or high percentile moisture levels reported in the MEAF for 3110.
    b. **High Temperature Moisture Competition:** Enhance resolution of the “X curve” in a sealed system: determine if loss of 3110 desiccant capacity relative to 2004 is abrupt or gradual as a function of increasing temperature. Known weights of water will be added to pre-dried 2004 and 3110 into separate pre-weighed vials. The vials will be uncapped and placed into a Parr bomb and allowed to equilibrate at the target temperature. The Parr bomb will be cooled to room temperature and the vials will be weighed to determine the amount of moisture in each constituent. Emphasis will be to gather multiple readings for selected water levels in the temperature range between 40-70°C.
    c. **Moisture Pump Simulation:** Utilizing the best data available for equilibrium levels of moisture between head space, 3110 and 2004, rates of moisture accumulation or loss within an inflator as a function of leak rate and diurnal cycling at specified sets of hot/cold

temperatures and external absolute humidity will be estimated. Model outputs will be used in selecting moisture levels to be added to inflators for controlled environmental aging.

4. **Wafer Dissection and Testing**
   a. Test propellants from selected inflators based on age, location and wafer size. The tests will be used as an aid in differentiating GM inflator aging from other OEM inflator aging characteristics. Tests to be conducted include:
      i. Karl Fisher moisture on 2004 wafers (Polytron)
      ii. Gravimetric moisture on 3110 tablets
      iii. SEM of 2004 wafer surfaces
      iv. Envelope density of 2004 wafers and 3110 tablets (Geopyc)
      v. Closed Bomb (Burn Rate)
      vi. Crush Strength
5. **O-ring Aging**
   a. Test O-rings from selected inflators based on age, location and wafer size. The tests will be used as an aid in differentiating GM inflator aging from other OEM inflator aging characteristics. Tests to be conducted include:
      i. Shore A
      ii. Photo microscopy
      iii. THF extraction weight loss

<u>Modeling and Analysis</u>

1. **Inflator Design Comparisons**
   a. Complete a part-by-part comparison of PSPI-L FD to PSPI-L JD to PSPI-L YD and SPI – AA/AJ to SPI- DH to SPI – YP (build on Inflator design comparisons done during the ITC Root Cause investigation.)
   b. Identify design similarities, differences and determine if these differences can affect leak rate, pressure capability, operating pressure, and sensitivity to operating pressure changes.
   c. Compare design differences to failure rate differences to the MEAF.
   d. Summarize and document information.
2. **Platform Comparisons**
   a. Take OEM platform data on Temperature and humidity for diurnal cycles.
      i. Platforms will include Corolla, Vibe, Sentra, and GM LT.
   b. Compare this data to failure rate differences in the MEAF, and to OATK Leak rate and Moisture Dynamic testing.
   c. Summarize and document information.
3. **MEAF Review**
   a. Obtain and upload latest version of the MEAF.
   b. Identify failure rate differences by Inflator type/prefix and platform. Identify other differences that could also affect failure rate.
      i. Compare Corolla HAH failure rates to other types/prefixes/platforms.
      ii. Compare groupings of like-inflators based on similar design characteristics, and like-platforms based on similar temperature/humidity profiles.
      iii. Identify threshold diameter based on type/prefix and platform (not all PSPI-L have the same threshold diameter).
      iv. Relate inflator design differences and platform differences to threshold diameter differences.
   c. Summarize and document information.
4. **Ballistic Modeling**
   a. Develop ballistic models for PSPI-L YD, SPI-YP, SPI-AJ/AA, and SPI-DH.
   b. Anchor to ballistic and quench test data from Takata and OATK.
   c. Exercise models to determine differences in peak pressure, available propellant after peak pressure, and sensitivity to runaway pressure given an anomaly.
   d. Compare model differences to failure rate differences in the MEAF.
   e. Summarize and document information.

STATEMENT OF WORK	Takata Airbag Inflator Durability Testing

AUTHOR:	[redacted]	BUYER:	[redacted]
PHONE:	[redacted]	PHONE:	[redacted]
DEPARTMENT:	Internal Investigations	UPDATE DATE:	**4/15/16**
SUBMIT DATE:	2/2/16	PURCHASE ORDER #:	**<purchase order issued to supplier for development work>**
REVIEWED FOR EXPORT COMPLIANCE BY:	[redacted]	EXPORT COMPLIANCE CLASSIFICATION:	**EAR99**

PROJECT TITLE:

Takata Airbag Inflator Durability Testing

PURPOSE:

Determine how temperature and thermal cycling (long term exposure to high absolute humidity conditions) of inflators affects ballistic deployment.

TASKS AND RESPONSIBILITIES:

RASIC Roles & Responsibilities

LEGEND: **G**= General Motors Engineering **S**= Supplier

R= Responsible, **A**= Approval
S= Support, **I**= Inform, **C**= Consult

WHAT \ ROLES	R	A	S	I	C
Test Plan & Aging Matrix	S	G			
Program Management	S		G		G
Acquire Inflators	G				
Testing & Analysis	S			S	G
Final Test Report & Data	S			G	

DELIVERABLES:

Deliverable	Req'd By Date	Submit To GM
Program Plan	With Quote	Buyer
Bill of Materials	With Quote	Buyer
Aging Matrix	With Quote	Buyer
Status Update	Every Week	[redacted]
Report Out Meetings	Every Month	Schedule Meeting
Live Dissection Analysis Rpt s	Every 1.5 Months	[redacted]i
Ballistic Tank Test Data	Every 3 Months	[redacted] .
Final Report	7/1/2017	[redacted]

PROJECT TIMING:

Overall Timing: 16 Months (GM reserves the right to cease the testing at any time, for any reason, and will only be responsible for work completed as of the date the project was discontinued.)

- Inflator Build: 2 months
- Moisture Equilibrium Study: 1 month (in parallel with Thermal Aging Study)
- Thermal Cycle Aging Study: 10 months
  - 280 Cycles (5 Years) – Jul 2016
  - 560 Cycles (10 Years) – Sep 2016
  - 840 Cycles (15 Years) – Oct 2016
  - 1120 Cycles (20 Years) – Nov 2016
  - 1400 Cycles (25 Years) – Jan 2017
  - 1680 Cycles (30 Years) – March 2017
- Testing and analysis on final samples, report preparation: 4 months

TECHNICAL SPECIFICATION:

Definition:

1. SAE/USCAR 24-2 (April 2013) – Inflator Technical Requirements and Validation
2. CT Scan of inflator - Volumax Cat Scan Specifications
3. Live Dissection
   a. Weigh and measure outer diameter and inner diameter on all 2004 wafers
   b. Weigh and measure height and outer diameter on all 3110 and 2004 tablets (5 each)
   c. Measure Moisture Content
      i. 3110 tablets in closures: SPI, PSPI-L primary and secondary
      ii. One wafer: SPI, PSPI-L primary and secondary
   d. Crush Strength per LTP-0599
      i. Four wafers from SPI
      ii. Three wafers from PSPI-L primary and one from secondary
   e. Scanning Electron Microscope (SEM) per LTP-3320-1496
   f. Closed Bomb (Burn Rate) per LTP-1026
4. Post Aging Analysis
   a. CT Scan of inflator per Volumax Cat Scan Specifications
   b. Ballistic Tank Test at 23°C per SAE J2238 Airbag Inflator Ballistic Tank Test Procedure
      i. Pressure time curve from each chamber
      ii. Inspect inflators for structural anomalies
5. Inflator Types: SPI-YP (GMT900 HD), PSPI-L YD (GMT900 LD) and PSPI-L FD (Pontiac Vibe)
   a. Inflators to be acquired from Takata

Project Scope:

1. Inflator Build

- Total Moisture Content – add water to achieve the targeted total moisture content accounting for the latent moisture in the as built condition.
- Percentages use the weight of main propellant mass convention.
- Proposed total moisture content
  - Baseline – As Built
  - Mid – 0.15% primary chamber, 0.45% secondary chamber
    - Primary to compare to highest moisture from GMT900 parts (0.12%)
  - High – 0.30% primary chamber, 0.70% secondary chamber
    - Primary to compare to 95%ile moisture from returned competitor parts (0.24%)
- Confirmation - Measure the amount of moisture in the 2004 and 3110 propellant in inflators for each moisture level as built (Baseline, Mid and High).

2. Moisture Equilibrium Study

- Determine minimum cycle times (ambient to hot and hot to ambient) to bring inflators to an equilibrium condition for 3 different temperature cycles on the PSPI-L YD inflator:
  - Target hot temperatures:
    - 50°C (max inflator temp in regions outside HAH area)
    - 60°C (max inflator temp observed in GMT900 in HAH area)
    - 70°C (max inflator temp of some competitor vehicles in HAH area)
  - Target ambient temperature: 23°C

3. Thermal Cycle Aging Study

- Time Zero CT Scan on inflators – 5 for each inflator type and condition (45 inflators).
- Maintain Control Samples for each inflator type at 23°C and 70°C for each moisture level while the rest of the inflators undergo the various temperature cycles.
  - 3 Initial Live Dissection
  - 5 Initial Ballistic Tank Tests

  - 3 Final Live Dissection for each 23°C and 70°C
  - 5 Final Ballistic Tank Tests 23°C and 70°C
- Conduct accelerated aging on each inflator type at 3 specified moisture levels (Baseline, Mid and High) to 1680 cycles (approximately 30 years) or whenever GM decides to halt aging process.
  - Control the humidity inside the thermal cycling chamber to a mutually agreed upon level during cycling.
  - Start with a 4 hour cycle time (2 hours at hot, 2 hours at ambient)
  - Reduce cycle time following the outcome of the moisture equilibrium study if necessary.
  - If results of moisture equilibrium study indicate a cycle time longer than four hours, consult GM for determination whether project should continue.
- Complete the following analysis at each interval for each inflator type at the 50°C and 60°C temperature cycles for the baseline moisture level:
  - 280 cycles (5 years)
    - 1 live dissection
  - 560 cycles (10 years)
    - 1 live dissection and 2 post aging analysis
  - 840 cycles (15 years)
    - 1 live dissection
  - 1120 cycles (20 years)
    - 1 live dissection and 2 post aging analysis
  - 1400 cycles (25 years)
    - 1 live dissection
  - 1680 cycles (30 years)
    - 1 live dissection and 2 post aging analysis
- Complete the following analysis at each interval for each inflator type at each temperature cycle for the mid and high moisture levels and for the baseline moisture level at the 70°C temperature cycle:
  - 280 cycles (5 years)
    - 1 live dissection
  - 560 cycles (10 years)
    - 1 live dissection and 7 post aging analysis
  - 840 cycles (15 years)
    - 1 live dissection
  - 1120 cycles (20 years)
    - 1 live dissection and 7 post aging analysis
  - 1400 cycles (25 years)
    - 1 live dissection
  - 1680 cycles (30 years)
    - 1 live dissection and 7 post aging analysis

Inflator Matrix:

	PSPI-L FD			PSPI-L YD			SPI YP			
	As Built	0.12%	0.24%	As Built	0.12%	0.24%	As Built	0.12%	0.24%	Total
Control Samples @ 23°C	16	16	16	16	16	16	16	16	16	144
Control Samples @ 70°C	8	8	8	8	8	8	8	8	8	72
Moisture Equilibrium	0	0	0	12	12	12	0	0	0	36
Thermal Cycle Aging @ 50°C	12	27	27	12	27	27	12	27	27	198
Thermal Cycle Aging @ 60°C	12	27	27	12	27	27	12	27	27	198
Thermal Cycle Aging @ 70°C	27	27	27	27	27	27	27	27	27	243
Total	75	105	105	87	117	117	75	105	105	891

The Chief Counsel, Paul Hemmersbaugh, signed the following notice on November 22, 2016 and it has been submitted for publication in the Federal Register. While we have taken steps to ensure the accuracy of this internet version of the notice, it is not the official version of the notice. Please refer to the official version in a forthcoming Federal Register publication, which will appear on the Government Printing Office's FDSys website (www.gpo.gov/fdsys/search/home.action) and on Regulations.gov (http://www.regulations.gov) in Docket No. NHTSA-2016-0124. Once the official version of this document is published in the Federal Register, this version will be removed from the internet and replaced with a link to the official version.

UNITED STATES DEPARTMENT OF TRANSPORTATION

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

[DOCKET NO. NHTSA-2016-0124; Notice 1]

General Motors LLC, Receipt of Petition for Inconsequentiality and Decision Granting Request to File Out of Time and Request for Deferral of Determination

AGENCY: National Highway Traffic Safety Administration (NHTSA), Department of Transportation.

ACTION: Notice of receipt of petition and decision granting partial relief.

SUMMARY: On May 16, 2016, TK Holdings Inc. (Takata) filed a defect information report (DIR), in which it determined that a defect existed in certain passenger-side air bag inflators that it manufactured, including passenger inflators that it supplied to General Motors, LLC (GM) for use in certain GMT900 vehicles. GM has petitioned the Agency for a decision that, because of differences in inflator design and vehicle integration, the equipment defect determined to exist by Takata is inconsequential as it relates to motor vehicle safety in the GMT900 vehicles, and that GM should therefore be relieved of its notification and remedy obligations.

DATES: The closing date for comments is September 14, 2017.

ADDRESSES: Interested persons are invited to submit written data, views, and arguments regarding this petition for inconsequentiality. Comments must refer to the docket and notice number cited in the title of this notice and be submitted by one of the following methods:

- Internet: Go to *http://www.regulations.gov* and follow the online instructions for submitting comments.
- Mail: Docket Management Facility, M–30, U.S. Department of Transportation, 1200 New Jersey Avenue SE, West Building, Room W12–140, Washington, DC 20590.
- Hand Delivery or Courier: U.S. Department of Transportation, 1200 New Jersey Avenue SE, West Building, Room W12–140, Washington, DC 20590 between 9 a.m. and 5 p.m. Eastern Time, Monday through Friday, except Federal holidays.
- Facsimile: (202) 493-2251.

You may call the Docket at (202) 366-9324.

Note that all comments received will be posted without change to http://www.regulations.gov, including any personal information provided. Thus, submitting such information makes it public. You may wish to read the Privacy Act notice, which can be viewed by clicking on the "Privacy and Security Notice" link in the footer of http://www.regulations.gov. DOT's complete Privacy Act Statement is available for review in the Federal Register published on April 11, 2000 (65 FR 19477–78).

The petition, supporting materials, and all comments received before the close of business on the closing date indicated above will be filed in the docket and will be considered. Comments and supporting materials received after the closing date will also be filed and will be considered to the extent possible. When the petition is granted or denied, notice of the decision will also be published in the Federal Register pursuant to the authority indicated at the end of this notice.

FOR FURTHER INFORMATION CONTACT:

For legal issues: Elizabeth Mykytiuk, Office of the Chief Counsel, NCC-100, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, D.C. 20590 (telephone: (202) 366-5263).

For general information regarding NHTSA's investigation into Takata air bag inflator ruptures and the related recalls: http://www.safercar.gov/rs/takata/index.html.

SUPPLEMENTAL INFORMATION:

I. Background.

On May 4, 2016, NHTSA issued, and Takata agreed to, an Amendment to the November 3, 2015 Consent Order (the "Amendment"), under which Takata is bound to declare a defect in all frontal driver and passenger air bag inflators that contain a phase-stabilized ammonium nitrate (PSAN)-based propellant and do not contain a moisture-absorbing desiccant. Such defect declarations will be made on a rolling basis. *See* Amendment at ¶ 14. Takata timely submitted the first scheduled equipment DIRs on May 16, 2016. *See* Recall Nos. 16E-042, 16E-043, and 16E-044. Those DIRs included non-desiccated passenger inflators, designated as types SPI YP and PSPI-L YD, that were installed as original equipment on certain motor vehicles manufactured by GM (the "covered passenger inflators"), as well as other non-desiccated passenger inflators installed as original equipment on motor vehicles manufactured by a number of other automakers, which are not at issue here.

The Takata filing triggered GM's obligation to file a DIR for the affected GM vehicles. *See* 49 C.F.R. Part 573; Amendment at ¶ 16; November 3, 2015 Coordinated Remedy Order at ¶ 46.[1] GM ultimately submitted two DIRs on May 27, 2016. *See* Recall Nos. 16V-381 (for

[1] Under 49 C.F.R. § 573.5(a), a vehicle manufacturer is responsible for any safety-related defect determined to exist in any item of original equipment. *See also* 49 U.S.C. § 30102(b)(1)(C).

vehicles in Zone A) and 16V-383 (for vehicles in Zone B). In an attachment to the DIRs, GM stated that it had not determined the existence of a safety defect, and it referred to the recalls as "preliminary."[2] The attachment further indicated that, even though GM had not made an independent defect determination, the company was nonetheless filing a DIR in response to Takata's defect determination. *See* Recall Nos. 16V-381 and 16V-383. GM stated that it "expect[s] to provide NHTSA with additional test data, analysis or other relevant and appropriate evidence in support of our belief that our vehicles do not pose an unreasonable risk to safety." *See id*. GM also stated that it "will conduct a recall of its airbag inflators covered by the May 2016 Takata DIRs, unless GM is able to prove to NHTSA's satisfaction that the inflators in its vehicles do not pose an unreasonable risk to safety." *Id*.

On November 15, 2016, GM petitioned the Agency, under 49 U.S.C. §§ 30118(d), 30120(h) and 49 C.F.R. Part 556, for a decision that, because of differences in inflator design and vehicle integration, the equipment defect determined to exist by Takata is inconsequential as it relates to motor vehicle safety in the GMT900 vehicles. *See* GM's Petition for Inconsequentiality and Request for Deferral of Determination Regarding Certain GMT900 Vehicles Equipped with Takata "SPI YP" and "PSPI-L YD" Passenger Inflators (the "Petition"). GM's Petition concluded that because the putative defect is inconsequential in the GMT900 vehicles, the company should be relieved of notification and remedy obligations for Takata inflators in those GM vehicles. *See* Petition at p. 18. GM further requested that NHTSA defer its decision on the petition until GM is able to complete its testing and engineering analysis in August 2017. *See id*.

II. Request to Accept Late Filing.

[2] Neither the Safety Act nor NHTSA regulations define or use the term "preliminary recall."

As an initial matter, GM requests that NHTSA, in its enforcement discretion, accept and consider the Petition even though it was filed outside the regulatory filing deadline. *See* Petition at p. 5 n.5. GM's Petition was filed with the Agency on November 15, 2016. Under 49 C.F.R. § 556.4(c), inconsequentiality petitions usually must be filed within 30 days of the relevant defect determination. Because Takata made a defect determination concerning the covered passenger inflators on May 16, 2016, GM's Petition should have been filed by June 15, 2016.

GM has requested that NHTSA waive the 30-day filing requirement in light of GM's transparency with the Agency, including communications occurring before and contemporaneous with the May 2016 DIR filings. *See* Petition at p. 5 n.5. While such transparency alone would not support a waiver of the filing deadline, the Agency has considered the totality of the facts and circumstances presented here in deciding to grant the waiver.

First, allowing GM's Petition to be filed outside the regulatory deadline is not inconsistent with the purpose of such deadline, which is to prevent a manufacturer from unduly delaying the remedy of defects. *See* 42 FR 7146. Here, GM's delay in filing the Petition will not have any impact on the availability of a remedy. GM has indicated that it has been working diligently on a potential remedy and has stated it intends to have a validated, alternative remedy available by June 30, 2017, should it become necessary. *See* Petition at p. 17. This length of time between DIR submission and remedy is not unusual in the context of the Takata recalls, and it is consistent with the lower relative rupture risk of the covered passenger inflators and the time needed to develop, validate, and ensure the safety of an alternative remedy part. Therefore, some elapsed time between the DIR and the availability of the remedy is inevitable, regardless of the timing of GM's Petition. NHTSA has determined that the availability of the remedy for GM's

May 2016 DIRs would be essentially the same whether this Petition was filed in June or November.

Second, GM has been proactively investigating Takata inflators in GMT900 vehicles since November 2014. *See* Petition at pp. 4-5. GM believes that it has now obtained data through its investigation that supports an inconsequentiality finding, and that it will be able to prove that the covered passenger inflators do not present an unreasonable risk to safety once that investigation concludes in August 2017. *See* Petition at p. 18. Given that GM's ongoing investigation pre-dates the May 2016 DIR filings, the Agency concludes that the company is acting in good faith in filing this Petition, even though it filed the Petition beyond the deadline.[3]

Finally, GM communicated its intent to file such a petition in the attachment to its May 2016 DIRs when it stated, "GM will conduct a recall of its airbag inflators covered by the May 2016 Takata DIRs, unless GM is able to prove to NHTSA's satisfaction that the inflators in its vehicles do not pose an unreasonable risk to safety." *See* Recall Nos. 16V-381 and 16V-383. This statement is consistent with the purpose of 49 U.S.C. § 30118(d) and 49 C.F.R. Part 556, which is to enable vehicle manufacturers to petition NHTSA for an exemption from the Safety Act's notice and remedy requirements when a defect is determined to be inconsequential to motor vehicle safety. Because NHTSA, the public, and other stakeholders were on notice (since at least May 2016) of GM's intention to attempt to prove the safety of the covered passenger inflators, thereby avoiding any notice and remedy obligation, there is no prejudice to the public caused by GM filing the Petition after the standard deadline.

For the foregoing reasons, NHTSA will grant GM's request and accept the filing of its Petition outside of the 30-day deadline. NHTSA is granting this extraordinary relief because of

[3] If it appeared that a manufacturer had filed such a petition in an attempt to toll its notification and remedy obligations while it began a new investigation, the Agency would not waive the 30-day deadline.

the unique circumstances surrounding the Takata recall and the particular facts and circumstances of this case. This decision should not be considered precedent in any other case. The Agency will continue to enforce the 30-day filing deadline for inconsequentiality petitions, including any others that may be filed by GM in connection with future Takata recalls.

III. Class of Motor Vehicles Involved.

GM's Petition involves certain "GMT900" vehicles that contain the covered passenger inflators (designated as inflator types "SPI YP" and "PSPI-L YD").[4] GMT900 is a GM-specific vehicle platform that forms the structural foundation for a variety of GM trucks and sport utility vehicles, including: Chevrolet Silverado 1500, GMC Sierra 1500, Chevrolet Silverado 2500/3500, GMC Sierra 2500/3500, Chevrolet Tahoe, Chevrolet Suburban, Chevrolet Avalanche, GMC Yukon, GMC Yukon XL, Cadillac Escalade, Cadillac Escalade ESV, and Cadillac Escalade EXT. The GM DIRs included the following GMT900 vehicles:

- In Zone A, model year 2007-2011 GMT900 vehicles. Zone A comprises the following states and U.S. territories: Alabama, California, Florida, Georgia, Hawaii, Louisiana, Mississippi, South Carolina, Texas, Puerto Rico, American Samoa, Guam, the Northern Mariana Islands (Saipan), and the U.S. Virgin Islands. *See* Amendment at ¶ 7.a.
- In Zone B, certain model year 2007-2008 GMT900 vehicles. Zone B comprises the following states: Arizona, Arkansas, Delaware, District of Columbia, Illinois, Indiana, Kansas, Kentucky, Maryland, Missouri, Nebraska, Nevada, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Pennsylvania, Tennessee,

[4] GM previously filed, and ultimately withdrew, a petition to defer the recall of certain newer GMT900 vehicles that will be included in Takata's next set of DIRs, scheduled to be submitted on December 31, 2016. *See* 81 FR 64575. This Petition does not include or address that population of vehicles. *See* Petition at pp. 8-9.

Virginia, and West Virginia. *See* Amendment at ¶ 7.b.[5]

IV. Summary of GM's Petition.

According to the Petition, GM's engineering analysis supports the conclusion that the covered passenger inflators in the subject GMT900 vehicles are currently performing as designed, and will likely continue to perform as designed for a number of years - i.e., that the covered passenger inflators, as integrated into the GMT900 vehicles, do not present an unreasonable risk to safety. *See* Petition at p. 3

As an initial matter, GM notes in its Petition that Takata submitted the May 16, 2016 equipment DIRs without evidence of any incidents of inflator rupture in the SPI YP or PSPI-L YD variants that are used only in GMT900 vehicles. Petition at p. 2. GM has been studying the long-term performance of the covered passenger inflators and has conducted an analysis of the ballistic performance of the covered passenger inflators. *See* Petition at pp. 11-12. Based upon this analysis, GM asserts that the covered passenger inflators are not currently at risk of rupture. According to the Petition, GM's position is based upon the following: an estimated 52,000 Takata passenger inflator deployments in GMT900 vehicles without a rupture; ballistic tests of 1,418 covered passenger inflators without a rupture or sign of abnormal deployment; test deployment of 12 inflators artificially exposed to additional humidity and temperature cycling without a rupture or sign of abnormal deployment; and analysis, through stress-strength interference, indicating that the propellant in older covered passenger inflators has not degraded to a sufficient extent to create rupture risk. *See* Petition at p. 4.

[5] Takata also filed an equipment DIR covering non-desiccated passenger inflators in Zone C that were manufactured between January 1, 2003 and December 31, 2004. *See* Recall No. 16E-044. Because GM did not use the covered passenger inflators in its GMT900 vehicles prior to model year 2007, there were no GMT900 vehicles in Zone C affected by Takata's DIR. Zone C comprises the following states: Alaska, Colorado, Connecticut, Idaho, Iowa, Maine, Massachusetts, Michigan, Minnesota, Montana, New Hampshire, New York, North Dakota, Oregon, Rhode Island, South Dakota, Utah, Vermont, Washington, Wisconsin, and Wyoming. *See* Amendment at ¶ 7.c.

GM further states that the covered passenger inflators are not used by any other original equipment manufacturer and that those inflators have a number of unique design features that influence burn rates and internal ballistic dynamics, including greater vent-area-to-propellant-mass ratios, steel end caps, and thinner propellant wafers. *See* Petition at p. 12. In addition, GM states that the physical environment of the GMT900 vehicles better protects the covered passenger inflators from temperature cycling that can cause rupture. *Id*. More specifically, GM notes that the GMT900 vehicles have larger interior volumes than smaller passenger cars, and are equipped with solar-absorbing windshields and side glass. *Id*. To support the effect such differences may have on the safety of the covered passenger inflators, GM cites NHTSA's expert Dr. Harold R. Blomquist, who stated in his expert report that vehicle platform differences may play a role in the relative risk of rupture. *See* Petition at p. 11 (citing Amendment, Exhibit A at ¶¶ 30-31).

Finally, GM states its belief that the covered passenger inflators will not present a risk of rupture in the longer term. To supplement its internal analysis, GM has retained a third-party expert, Orbital ATK, to conduct a long-term aging study that will estimate the service life expectancy of the covered passenger inflators in the GMT900 vehicles. *See* Petition at p. 12. GM has asked Orbital ATK to test the effect of different inflator design variables - i.e., wafer thickness, vent area, moisture dynamics, and others - in the GMT900 platform's unique thermal environment. *See* Petition at pp. 17-18. GM anticipates that this study will be complete in August 2017. *Id*.

V. Request to Defer Decision on Petition.

GM implicitly acknowledges that its data, information, and views are not yet sufficient for the Agency to grant its inconsequentiality petition. Given the status of GM's engineering analysis and the results of testing conducted to date, and in order to fully-analyze the performance of these inflators over the long-term, the company has requested that NHTSA allow GM until August 31, 2017 to complete its engineering analysis and inflator aging studies. *See* Petition at pp. 17-18. Ordinarily, under 49 C.F.R. § 556.4(b)(5), an inconsequentiality petition must set forth all data, views, and arguments supporting that petition. In this case, GM states that further probative data (e.g., further aging testing and analysis) is forthcoming, but necessarily will take more time to develop. Therefore, some of the evidence GM intends to present cannot yet be set forth in the Petition. Accordingly, GM requests that the Agency defer its decision on the Petition until such data can be developed.

GM asserts that it has made a threshold showing that its inflators are safe in the short term or, at a minimum, will not present an unreasonable risk to safety during the period that the Petition is pending. *See* Petition at p. 3. GM further asserts that because its engineers and suppliers have been working on re-designed replacement inflators to be ready in the event that the inflators in these vehicles must be replaced, providing GM the additional time it requests will not delay GM's efforts to develop and validate replacement inflators as an available remedy for the Subject GMT900 Vehicles, should that remedy ultimately be required. *Id*.

The Agency acknowledges that GM has produced probative evidence to support its inconsequentiality claim. The testing and data collected by GM to date - while not yet sufficient - tends to support GM's Petition, at least with respect to the short-term safety of the covered passenger inflators. Based upon the data GM has developed and presented to date, NHTSA believes that in the coming months this evidence could ultimately grow and develop to support GM's position with respect to the long-term safety of the covered passenger inflators. Presently, however, the evidence GM has presented is not yet sufficient to prove (by a preponderance of the evidence) their long-term safety. Based upon the evidence and analysis GM has presented to date, and its plan to develop and analyze additional data, NHTSA agrees that GM's request for additional time is reasonable and supported by the testing and data collected to date.

Moreover, although a pending inconsequentiality petition tolls GM's obligation to provide a remedy, NHTSA does not believe consumers will be significantly impacted by the requested deferral. As explained above, GM has been working toward an alternative remedy in the event it should become necessary, and expects that remedy to be available in June 2017. The length of the requested deferral is through August 2017. Therefore, if NHTSA ultimately were to deny this Petition at the conclusion of GM's engineering analysis, no significant delay in the availability of remedy parts would result.

For these reasons, NHTSA will grant the requested relief, and allow GM an opportunity to provide more evidence and a fuller record upon which the Agency can make its determination. Subject to the conditions that follow, GM shall have until August 31, 2017 to present all data, views, and arguments supporting this Petition, including additional analysis and testing results, through a supplement or amendment, which shall be published in the docket. GM shall be required to provide NHTSA with monthly updates on GM's engineering analysis, Orbital ATK's study, and any other data, analysis, or test results GM develops in its effort to support its inconsequentiality claim. In addition, GM shall provide the Agency with a non-confidential summary of each update that will be made available through the public docket. During this time, any interested person may also submit written data, views, and arguments regarding this Petition. Following the conclusion of the requested deferral - i.e., August 31, 2017, NHTSA will make a decision whether to grant or deny the Petition after considering all available information.

NHTSA reserves the right to deny this Petition at any time prior to August 31, 2017, in the event necessary to mitigate an unreasonable risk to safety within the meaning of the Safety Act, based upon, *inter alia*, future field ruptures, ballistic testing failures that are not related to artificial aging tests, or other relevant facts or circumstances.

Accordingly, NHTSA hereby gives notice of its receipt of GM's Petition for Inconsequentiality and Request for Deferral of Determination Regarding Certain GMT900 Vehicles Equipped with Takata "SPI YP" and "PSPI-L YD" Passenger Inflators. And it is hereby ORDERED that:

1. GM's request to file an inconsequentiality petition for DIRs 16V-381 and 16V-383 beyond the 30-day deadline is GRANTED;
2. The period for public comment on GM's Petition shall run from the publication of this decision through September 14, 2017;
3. GM's request for a deferral of the Agency's decision so that it may have additional time to present evidence and analysis in support of this Petition is GRANTED, and GM's time for the development and presentation of further evidence, data, and information is extended to August 31, 2017;
4. GM shall provide NHTSA with monthly updates on its engineering analysis, Orbital ATK's study, and any other data, analysis, or test results the company develops in its effort to support this Petition, and GM shall provide the Agency with a non-confidential summary of each update that will be added to the public docket; and
5. NHTSA retains the right to rule on the Petition at any time before August 31, 2017 (i.e., to either deny or grant the Petition) should additional evidence, facts, or circumstances - in NHTSA's sole judgment and discretion - warrant such a decision.

Authority: 49 U.S.C. 30101, *et seq*., 30118, 30120(h), 30162, 30166(b)(1), 30166(g)(1); delegation of authority at 49 C.F.R. 1.95(a); 49 C.F.R. Parts 556, 573, 577.

Issued:

Paul A. Hemmersbaugh
Chief Counsel

Billing Code: 4910-59-P

[redacted]

[EXTERNAL] RE: Summary of GM Holden/DoIRD discussion on Saab Airbag inflators 23June2016 [SEC=UNCLASSIFIED]

11/05/2016

Retention Policy Inbox 60 days (60 days) Expires Expiration Suspended 10/11/2016

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Action Items

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[redacted]

My apologies for the delay in getting back to you on this.

As discussed, we have executive agreement for there to be a delay in making a decision on whether to recall vehicles fitted with Takata airbags manfacutrued in the Freiburg plant until further testing has been completed.

However, we have no agreement for a delay on a decision for other types of non-desiccated Takata airbags.

Can you please provide further details about the airbags fitted to the models you mention below.

Thank you for your help.

[redacted]

Vehicle Safety Standards
Department of Infrastructure and Regional Development
GPO Box 594
CANBERRA ACT 2601
[redacted]
www.infrastructure.gov.au

Australian Government
Department of Infrastructure and Regional Development

GM TECHNICAL SUBMISSION TO ACCC

Takata Non-Desiccated Frontal Airbag Inflators
October 2017

GENERAL MOTORS

TOPICS

GM CURRENT TAKATA STATUS

All Takata non-desiccated frontal airbag inflators have been improperly grouped together as having a potential design defect associated with the Phase Stabilized Ammonium Nitrate (PSAN) propellant. However, not all inflator designs perform the same and different inflators further perform differently in different vehicles.

GM's investigation shows that different types of Takata non-desiccated PSAN frontal airbag inflators perform very differently depending on the inflator design, the shape and size of the propellant and the vehicle environment into which the inflator is installed.

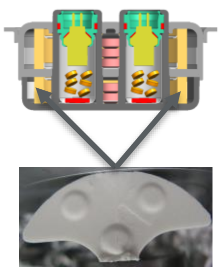
In the case of the SDI and PSDI-5 driver airbag inflators built with non-desiccated PSAN tablets, the failure rate in ballistic testing of field returns is extremely low. The failure rate is significantly higher for driver airbag inflators built with batwing-shaped wafers and passenger airbag inflators built with thick wafers.

GM's investigation shows that the SDI and PSDI-5 inflators installed in GM vehicles are currently performing as designed and show no indication of a design defect. Further, there are no known inflator ruptures in GM designed and manufactured vehicles sold globally. GM continues to investigate the long term performance of the inflators to determine if they will continue to operate safely for consumers in Australia and other countries.

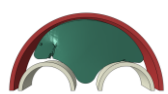
TAKATA NON-DESICCATED PSAN INFLATOR TYPES

DRIVER AIRBAG INFLATORS

Batwing Inflators
PSDI, PSDI-4, PSDI-4k

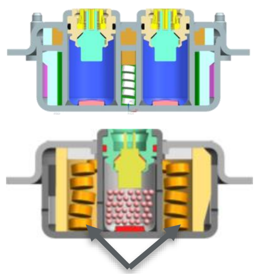


PSAN Batwings



Highest risk inflators associated with majority of fatalities and injuries
NOT USED IN GM VEHICLES

Tablet Inflators
PSDI-5, SDI

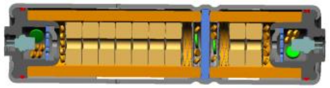


PSAN

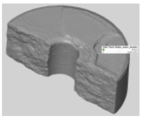
Extremely low failure rate inconsistent with design defect
DRIVER AIRBAG INFLATORS USED IN GM VEHICLES

FRONT PASSENGER AIRBAG INFLATORS

Thick Wafer Inflators
Example: PSPI-L FD

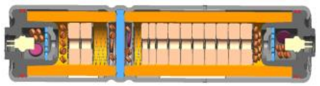


Thick Wafers

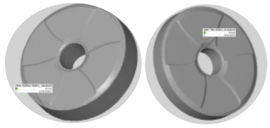


Highest failure rates in ballistic testing
NOT USED IN GM VEHICLES

GM Specific Inflators
w/ Thinner Wafers
PSPI-L YD, SPI YP



Medium & Thin Wafers



No known energetic deployments in GMT900
PASSENGER AIRBAG INFLATORS USED IN GM VEHICLES

P=Programmable, S=Smokeless, D=Driver, P=Passenger, I=Inflator

TESTING OF FIELD RETURNS

PSDI-5 FIELD RETURN TESTING

GM has requested Takata test GM PSDI-5 XK and PSDI-5 ZY used on the Saturn Astra and SAAB 9-3/9-5 respectively. The parts to be tested are the oldest parts available for these 2 vehicles from HAH (Zone A) regions. These inflator were manufactured by Takata in their Freiberg facility.

As of 27SE2017 there have been:

Vehicle	Ballistic Tests	Live Dissections	Total	Average Age
Saturn	114	4	118	9.7 Yrs
SAAB	502	128	630	10.7 Yrs

Additionally there have been 23 returned SDI inflators deployed as part of special testing.

All deployments were nominal

ORBITAL ATK STUDY

GENERAL MOTORS

Driver Airbag Program Overview

Investigation Scope

- Objective:
  - Utilize test methodologies for driver side inflators fielded by GM that have been successfully applied to determine root cause and distinguish relative susceptibility to energetic disassembly between driver and other inflator types.
- Testing included:
  - Tank testing
  - Heavy weight testing
  - Dissections and disassembles of PSDI-5 and SDI inflators. Testing included:
    - Moisture analysis of propellants (2004, 3110, AI-1)
    - Diameter and Density (2004 and 3110 tablets)
    - Color of AI-1
    - Scanning Electron Microscopy (SEM)
    - X-ray Micro Computed Tomography (Micro CT)
    - Crush Strength
    - Burn Rate (closed bomb) of 2004 and AI-1
    - O-ring testing
- Analysis Included
  - Design Comparisons of PSDI-4 vs. PSDI-5 XK/ZY vs. ZA and SDI DC vs. VL
  - Detailed engineering design comparison to other inflators
  - Ballistic Modeling of PSDI-5 XK/ZY vs. ZA and SDI DC vs. VL

Driver Airbag Inflator Overview

Inflators used in Driver Airbag Testing

- 128 PSDI-5 and 109 SDI inflators were obtained. 89 of the oldest inflators from the most severe environments were down-selected for testing. The 44 selected GM provided inflators were 6 to 12 years old and the 45 non-GM parts were 12 to 15 years old as outlined below:

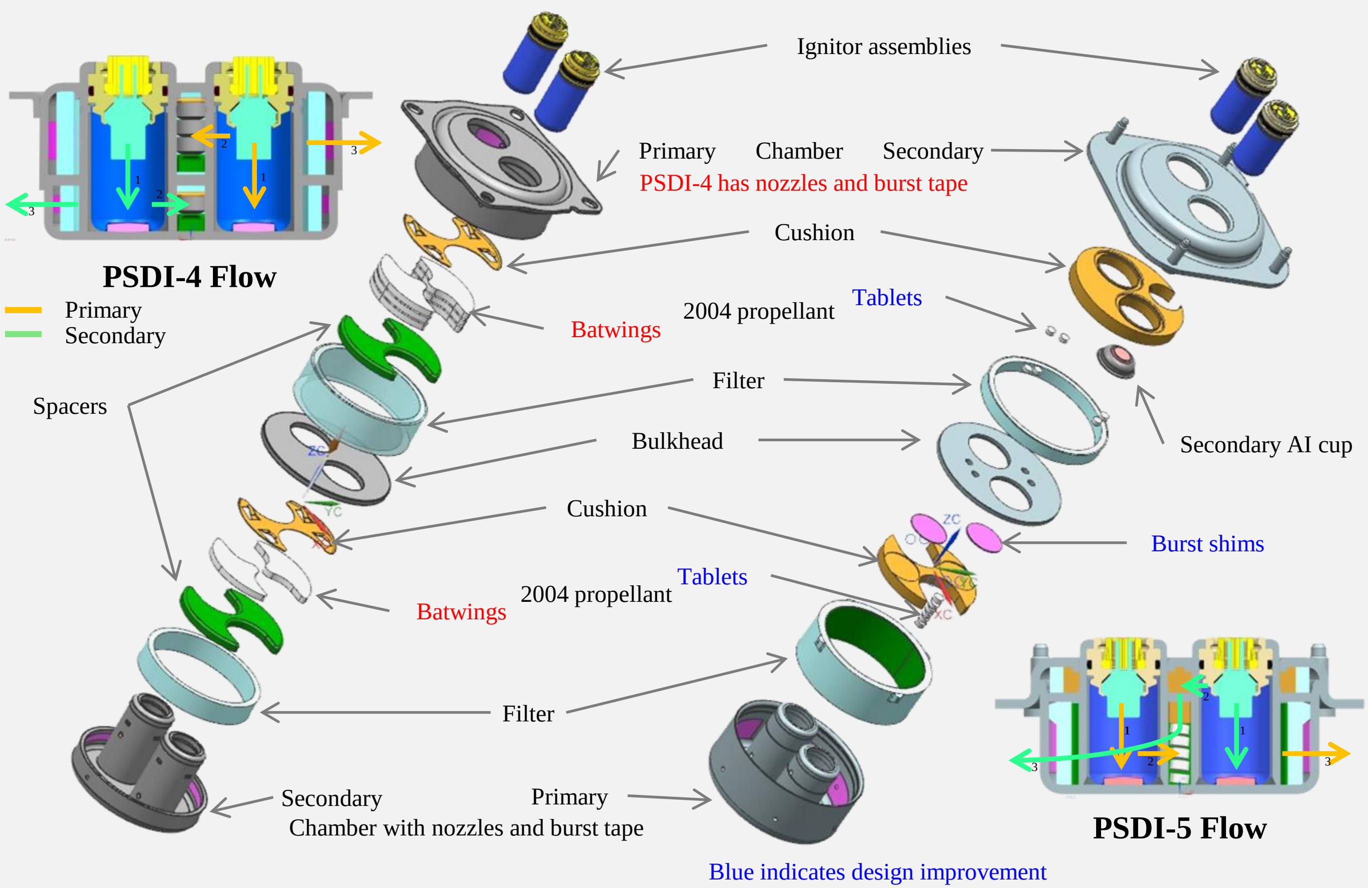
	Inflator	Inflator Age	Quantity	Location	Tests Conducted
GM	PSDI-5 ZY / XK	7-12 Years	12	TW, ES, IT	Heavy Weight
GM	PSDI-5 XK	Virgin	17	N/A	4 Heavy Weight / 10 Tank Test / 3 Dissected
GM	PSDI-5 ZY / XK	6-11 Years	6	Formosa, S. Europe	Dissection / Propellant Tests
GM	SDI VL, TH	3-8 Years	6	Brazil, India, No Info	Dissection / Propellant Tests
GM	SDI VL	Virgin	3	N/A	Dissection / Propellant Tests

	Inflator	Inflator Age	Quantity	Location	Tests Conducted
Other OEM	PSDI-5 ZA	12-15 Years	22	FL, PR	Heavy Weight
Other OEM	PSDI-5 ZA	N/A Virgin	8	N/A	5 Heavy Weight / 3 Dissected
Other OEM	PSDI-5 ZA	12 Years	6	PR	Dissection / Propellant Tests
Other OEM	SDI DC	12 Years	6	FL	Dissection / Propellant Tests
Other OEM	SDI DC	Virgin	3	N/A	Dissection / Propellant Tests

DAB Conclusions

- Tablet based driver airbag inflators are less susceptible to ED than bat wing inflators or wafer passenger inflators.
  - Density (batwing-large wafer-medium wafer-small wafer- tablet)
  - Reduced susceptibility of tablets to fracture compared to other configurations
- Tablet propellants are not showing the same degradation as similarly aged as batwings or passenger airbag wafer propellants
  - OD Growth
  - Density Change
  - Burn Rate Change / Variability
- Extensive testing has shown that the tablet based driver's inflators are not showing new or other aging mechanisms
  - Ballistic testing
  - SEM examination
  - CT scanning
  - Burning rate
  - Moisture content
  - Crush strength
  - O-ring aging
  - Statistical analysis of field return data collected by Takata
  - Detailed engineering design comparison to other inflators

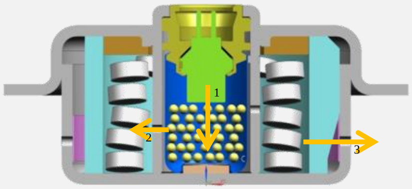
PSDI-4 vs PSDI-5 & SDI Comparison



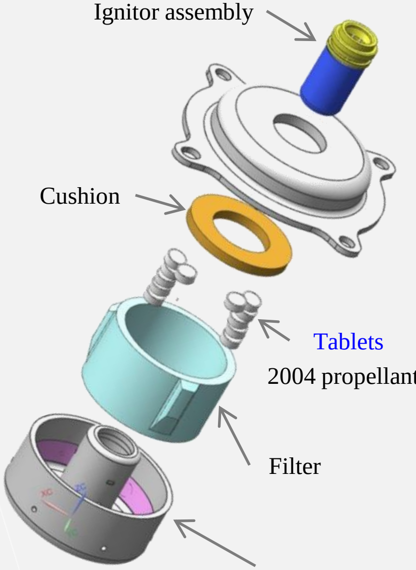
PSDI-4 vs PSDI-5 & SDI Comparison

- **Positive changes from PSDI-4 to PSDI-5 & SDI**
  - Moved from batwings to tablets, moved from 3110 tablets to 3110 granules in the igniter assemblies – both are more robust and reduce variability
  - Reduced the number of components – reduces failure mechanisms and assembly error potentials
  - Welding and hardware interfaces have noticeable improvements – PSDI-4 created a weak link where all three parts (primary chamber, bulkhead, and secondary chamber) came together at the same joint region with a single close-out weld. PSDI-5 and SDI have an extended lip which is welded forming a more stable joint.

- **Neutral changes**
  - No change in heritage seal system design (O-ring seal) between tube-to-igniter closure joint or squib to initiator closure (gasket seal) joint – potential leak paths



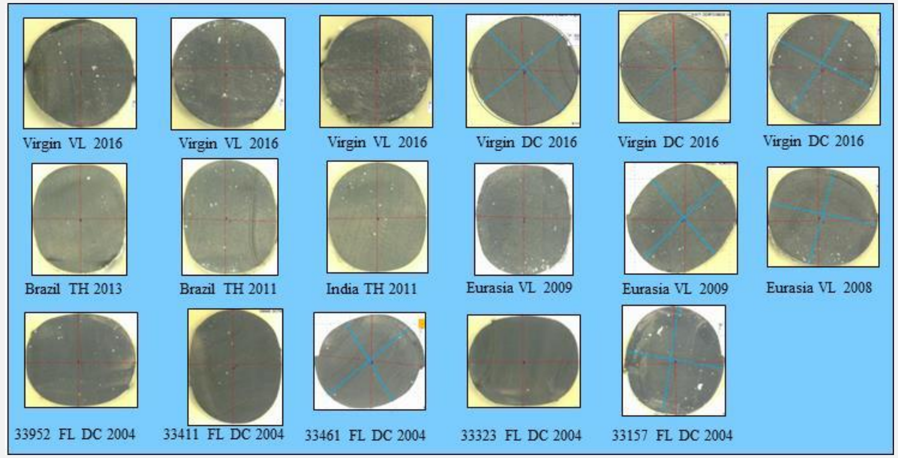
SDI Flow

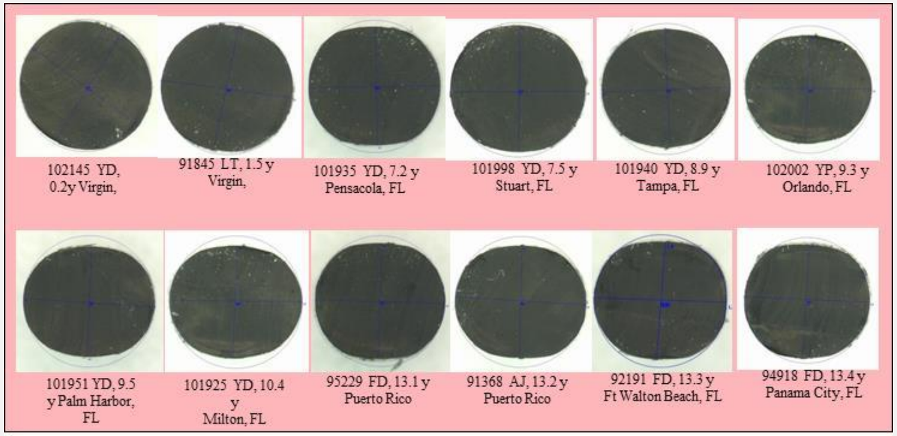


Blue indicates design improvement

Environmental Seal O Rings

- **Objective:** Testing was conducted to determine if moisture ingress through O-rings is a primary leak path as a function of age..
- **Results:** Older **driver inflator** environmental seal O-rings have significant compression set /loss of resiliency. Some O-rings were installed twisted in the O-ring groove. Similar results were observed for **passenger inflator** environmental seal O rings
- **Conclusions:** Loss of O-ring resiliency with age parallels similar trends in moisture ingress and tablet or wafer damage. Some studies suggest moisture ingress rates increase with inflator age.

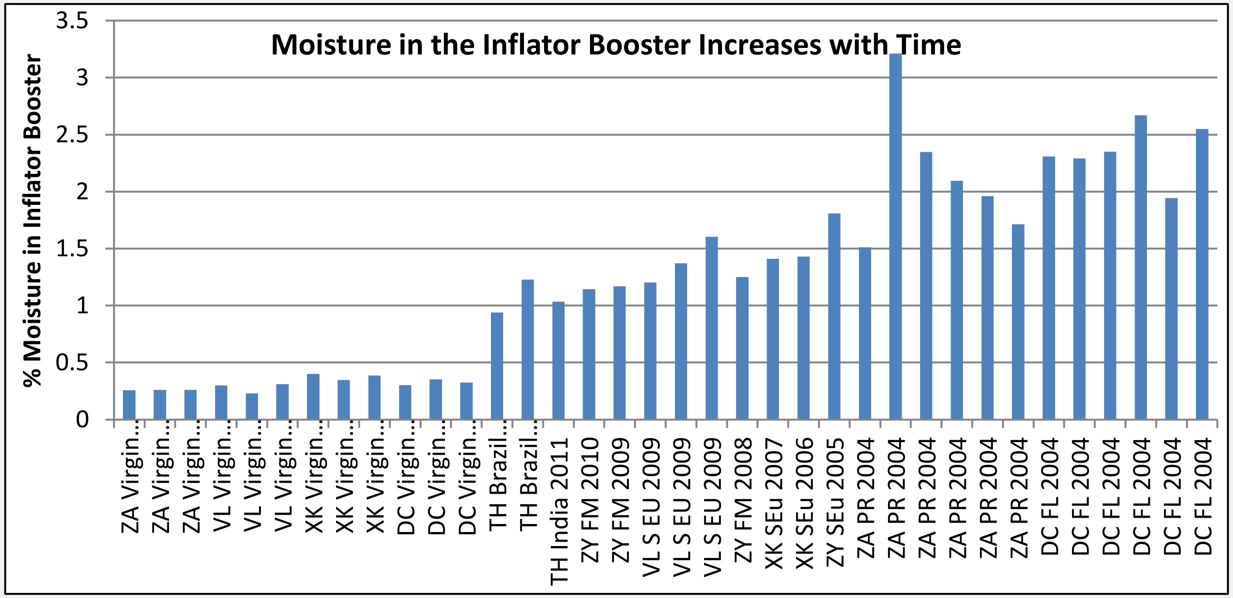




Photomicrographs were taken at 200X of the cross section of a cut O-ring. The photomicrograph size was normalized along the O-ring's radial axis

Booster Moisture Content

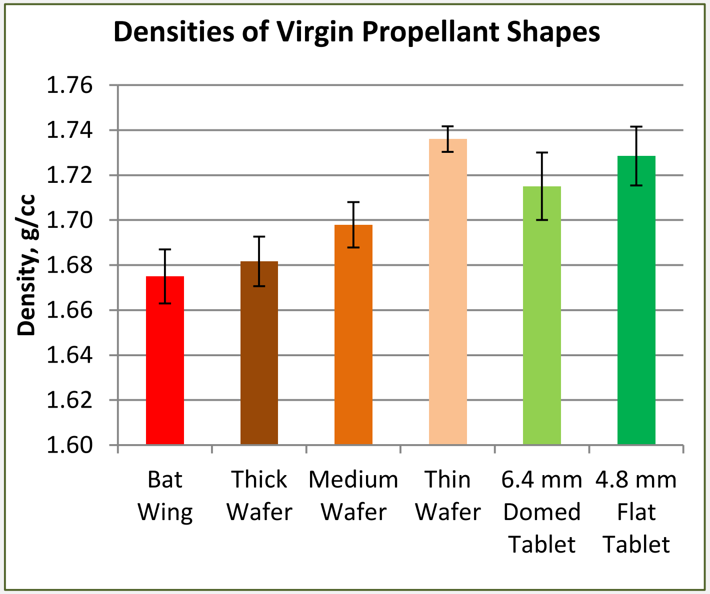
- **Objective:** Testing was conducted to determine the moisture quantity inside of the virgin and field returned inflators. Moisture content in booster was determined by weight loss after drying a sample for ~18 hours at 100°C.
- **Results:** The amount of moisture in each inflator increases as the inflator service life increases. The amount of moisture in inflators parallels loss in propellant density.
- **Conclusions:** The amount of moisture found in inflators increases with age.

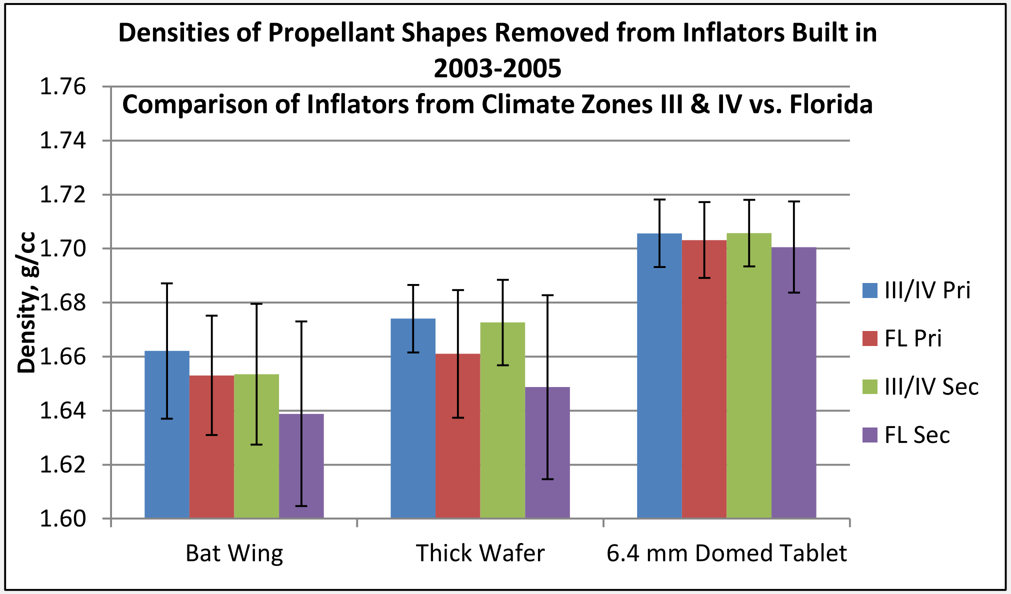


DAB Summary

Propellant Pressed to Lower Densities is More Susceptible to Aging

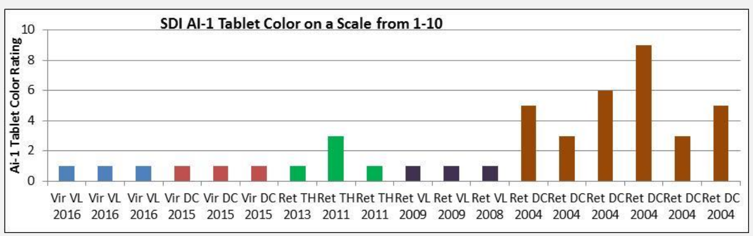
- Tablet based driver airbag inflators are less susceptible to ED than bat wing inflators or passenger inflators.
  - Ruptures of inflators from 2000-2002 were attributed to propellant pressed randomly to lower densities
    - After 2002, tighter controls on propellant density were augmented
    - The inflator rupture rate decreased
  - The propellant tablets in driver side inflators are pressed to higher densities than thicker wafers or bat wings (left graph)
- Tablets are not showing the same extent of degradation as similarly aged batwings or passenger inflator wafers
  - This is especially true in hot and humid climates like the State of Florida, United States (right graph)

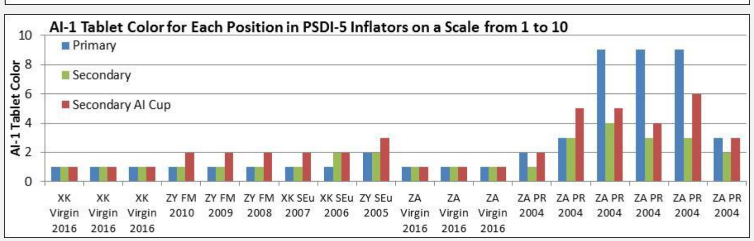




Inflator Disassembly

- **Objective:** While disassembling inflators make visual and physical observations on the condition of 2004, 3110, and AI-1 propellant.
- **Results:** Propellant removed from both virgin and aged driver side inflators looked similar. In older inflators, the AI-1 tablet is often darker, but the 2004 and 3110 propellants are visually unaffected. Passenger airbag 2004 wafers show much more visual degradation than driver airbag 2004 tablets.
- **Conclusions:** Driver airbag 2004 tablets show less visual degradation than passenger airbag 2004 wafers.





- **Top Left**: Secondary 2004 tablets and AI-1 tablet from a virgin PSDI-5 ZA.
- **Top Right**: Secondary 2004 tablets and the AI-1 tablet from a PSDI-5 ZA from Italy, made in 2006. Note that the 2004 tablets look very similar to the virgin propellant.
- **Left**: 2004 wafers from the secondary chamber of a PSPI-L FD from Florida, made in 2003. The wafers are chipped, show screen imprints, and are almost flush against each other which indicates the fins have flattened.

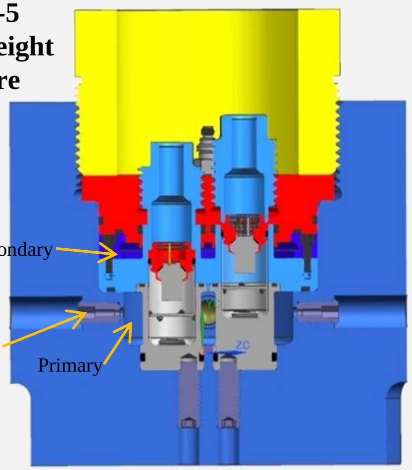
PSDI-5 Heavyweight Testing

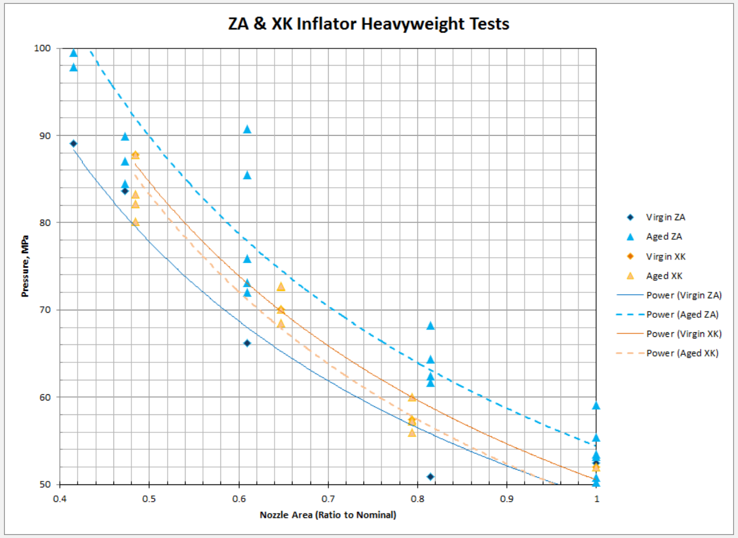
Objective: Testing was conducted in a heavy weight fixture to obtain inflator pressure time traces with virgin and field returned PSDI-5 inflators. Inflators were tested at reduced vent sizes to determine sensitivity to pressure anomalies.

Results: Combustion pressure increases as vent area decreases. The data was used to anchor the ballistic model pertaining to inflator performance vs. vent area. Both new and aged inflators showed similar responses without runaway conditions.

Conclusions: PSDI-5 inflators did not experience runaway conditions with >50% vent are reductions. Field returned inflators (aged propellant) showed similar pressure trace shapes. Aged XK inflators (GM) showed no increase in pressure from virgin samples. Aged ZA inflators increased slightly.

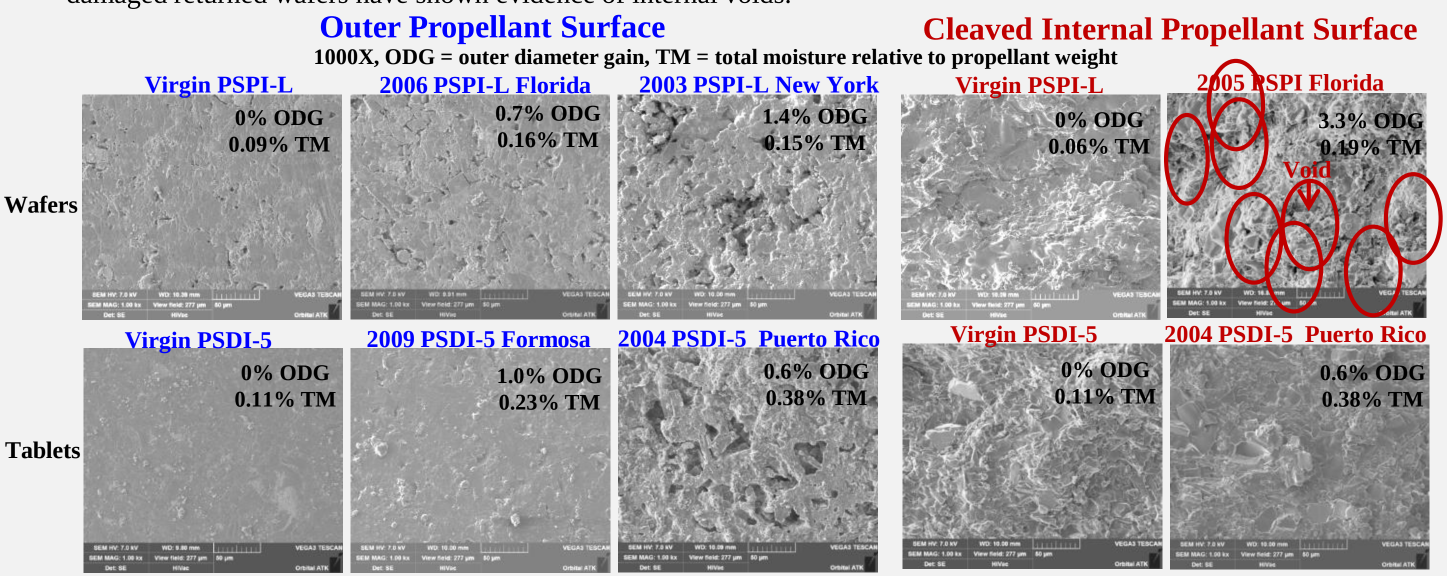
PSDI-5 Heavyweight Fixture





Scanning Electron Microscopy

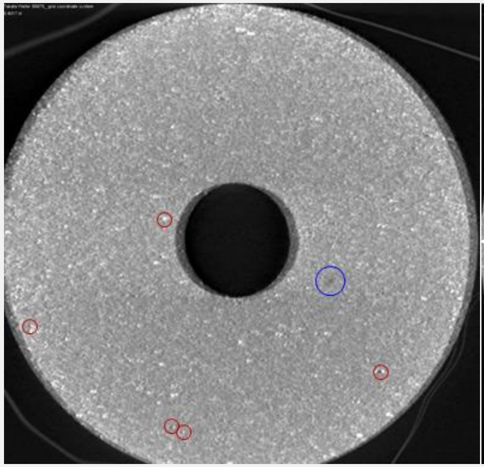
- **Objective:** Testing was conducted to determine propellant damage (voids and surface changes) as a function of age. A TESCAN VEGA-3 microscope was used to document the internal and external surface appearance of wafers. Samples were gold coated using a Denton Vacuum Desk V Sputter Coater to enhance conductivity prior to examination. Selected magnifications were obtained between 32X-2000X at both a surface and an internal surface.
- **Results:** Photomicrographs of the tablets generally showed signs of good health on the surface and internally. Only a few driver side inflators returned from HAH regions had tablets that showed evidence of surface pitting. Tablets exhibiting surface pitting had higher levels of moisture adsorbed in the 3110 and 2004 propellants.
- **Conclusions:** Although surface pitting has been observed on both returned tablet and wafer surfaces, only severely damaged returned wafers have shown evidence of internal voids.



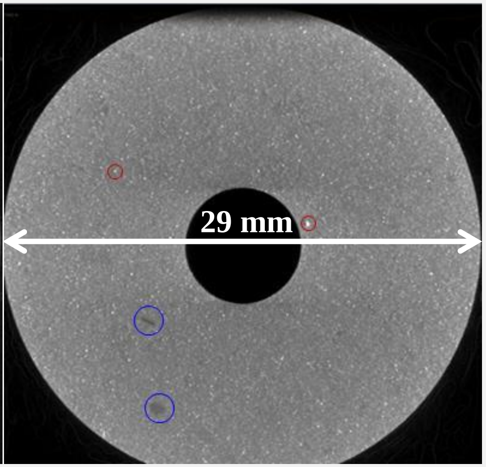
X-ray Micro Computed Tomography
(Micro-CT Scan)

- **Objective: X-ray Micro Computed Tomography (Micro-CT Scan):** Testing was conducted to look at voids and high density inclusions.
- **Results: Larger voids** often found in wafers were not observed in driver airbag tablets. However, **smaller voids** typically found near high density inclusions were observed. With one exception, the number of small voids from returned inflators were similar to virgin tablets.
- **Conclusions:** Tablets are pressed more efficiently than thicker wafers. **Larger voids** in wafers may have started as low density areas in virgin wafers. The **smaller voids** often become more apparent in the micro CT as propellant damage progresses.

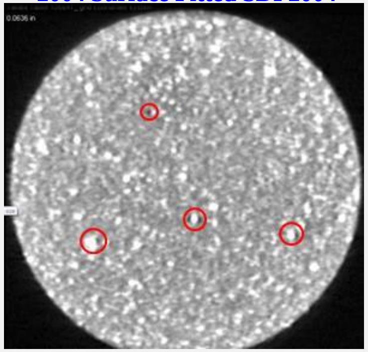
Virgin PSPI-L



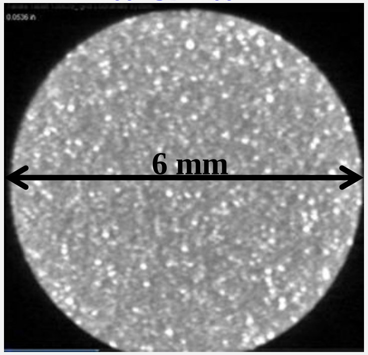
2003 PSPI-L New York



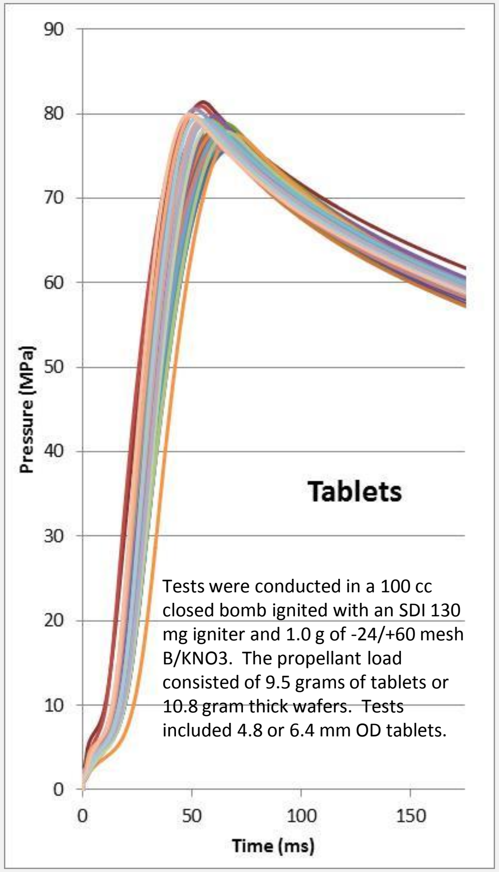
2004 Surface Pitted SDI 2004

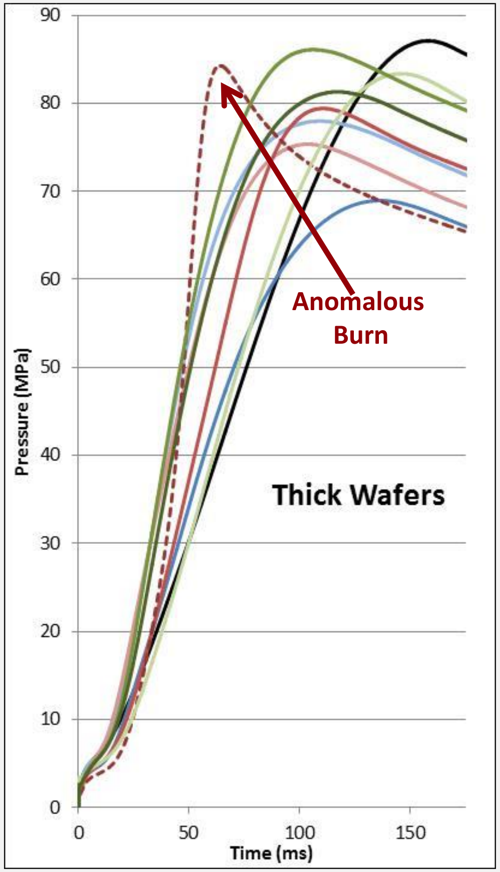


2004 SDI 2004



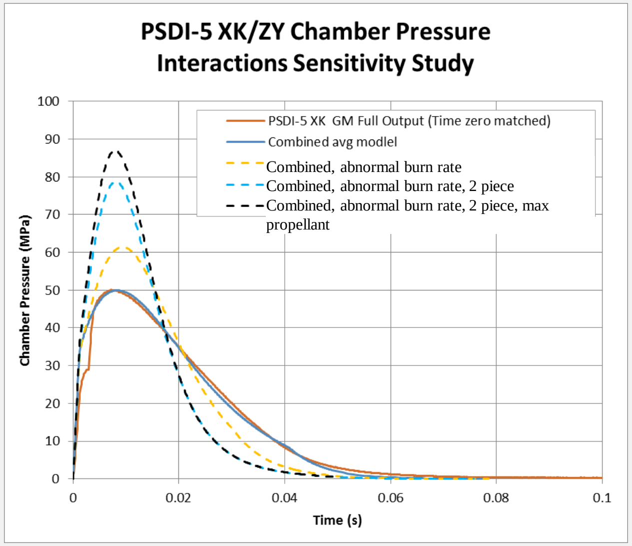
- **Objective:** Testing was conducted to determine if aged and virgin propellants exhibited changes in burn rate and to provide inputs to the ballistic model.
- **Results:** Rise rates for tablets are faster than wafers. No anomalous pressure traces were observed for tablets, even those from year 2004 inflators that were returned from HAH regions. Under the same test conditions, anomalous behavior was observed for thick, lower density wafers from inflators scientifically aged under conditions that caused inflator rupture.
- **Conclusions:** Tablets from 12 year returned inflators showed no discernable change in burn rate.

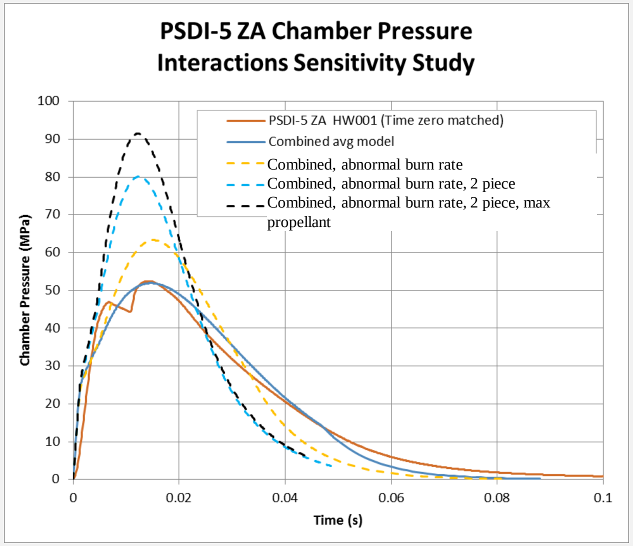




Ballistic Modeling

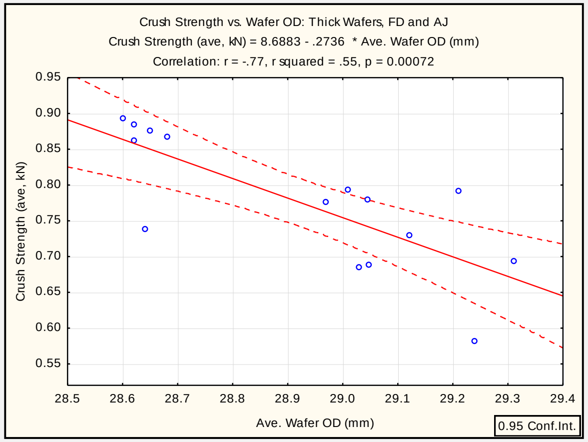
- **Objective:** Ballistic modeling was conducted with data from tank and heavy weight testing with Orbital ATK propellant grain design and internal ballistics software. This study investigated inflator performance to variations in several key performance characteristics.
- **Results:** Propellant configuration differences including break-up, propellant loading, and burn rate influenced the shape of the pressure vs time curve and the duration of burn.
- **Conclusions:** Ballistic analysis indicates the PSDI-5 design would require a stack-up of all tablets breaking into two pieces, the maximum allowed propellant weight, and degraded (abnormal) propellant burn rate to achieve ED pressures (>100MPa)

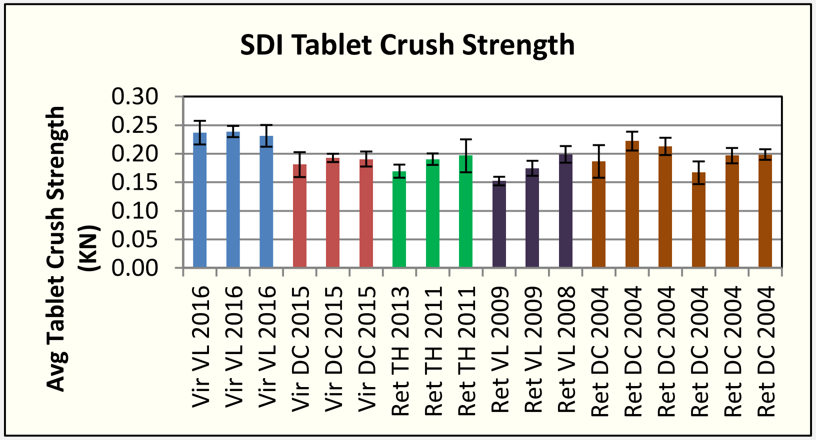


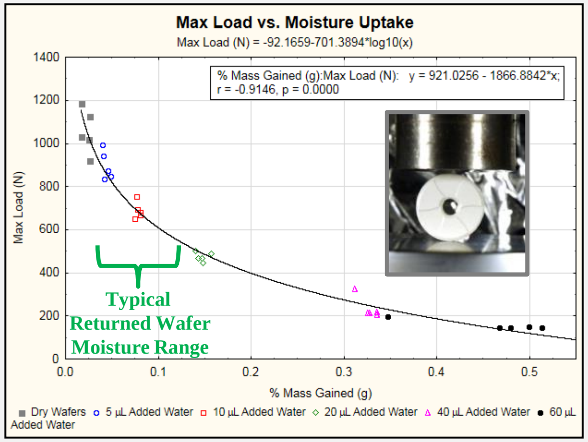


Propellant Crush Strength

- **Objective:** Crush strength was conducted to determine if the propellant mechanical strength degraded as a function of age.
- **Results:** Data did not trend with inflator moisture content or tablet OD although such trends have been observed for thick wafers.
- **Conclusions:** Several variables effect the mechanical strength of tablets. Tablet crush strength did not correlate with OD growth or with density.







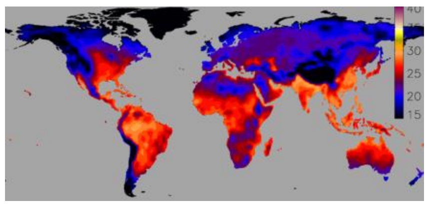
GM ACCELERATED AGING

GENERAL MOTORS

STATUS OF GM ACCELERATED AGING OF INFLATORS

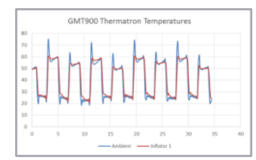
Environmental Testing Background

Field return parts collected from the hot humid areas of various countries are being artificially aged by subjecting the inflators to environmental cycling representative of the highest vehicle temperature and humidity conditions measured in S. China. Inflators will then be deployed and analyzed.



Acquire oldest field returns from global HAH regions available

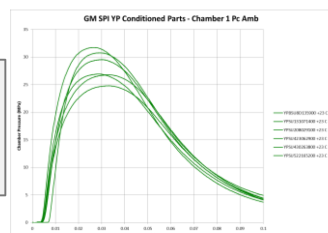
Age >207 inflators in environmental chambers



Temperature profiles of the environmental chamber are based on vehicle testing in S. China after comparison on data collected from S. ROK, N. Australia, and S. US

Induce additional environmental aging on the parts to generate a total of 30 or more years of simulated or actual HAH field exposure

Measure pressure generated during deployment on 207 samples



STATUS OF GM ACCELERATED AGING OF INFLATORS

GM has collected parts globally for testing and analysis.

- 135 returned DAB parts have been put into environmental chambers for accelerated aging.
- 163 new parts have also been put into the environmental chambers

Source of the Returns

Target Samples	Inflator Type	Thermal Test Cycles	Virgin Parts	Returned Parts*	Source of Returned Parts						
					Korea	Taiwan	India	Australia	Brazil	Europe	China
69	SDI	1920	58	48	6		9	11	21	1	
69	PSPI-5	1920	50	19		14				5	
35	SDI	750	19	20	20						
35	PSPI-5	750	35	0							
30	SDI	1920	0	30							30**

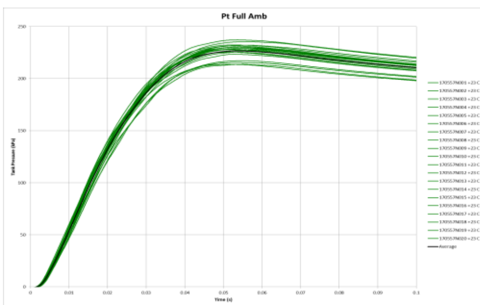
* An additional 12 SDIs and 1 PSDI-5 6yo field returns from Brazil and Australia were added March 2017 added to the environmental chamber and will be removed from test in March 2018, however they will have accumulated only about 1484 Cycles by that time.

* * These parts are being tested by GM China and will not complete aging until ~Nov 2017

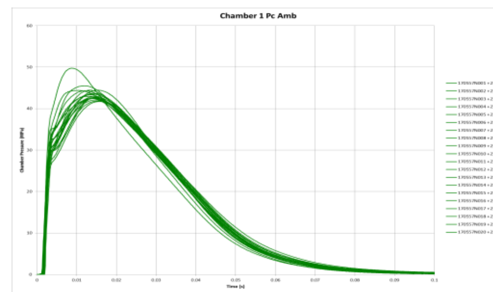
The removal of parts from test is periodic from May 2017 to March 2018 since the returned parts were put on test as they were received.

STATUS OF GM ACCELERATED AGING OF INFLATORS – DEPLOYMENT RESULTS

- 20 inflators originally from S. Korea, with 5 to 6 years field exposure have been tested. The inflators had an additional ~600 environmental cycles of exposure in the environmental chamber to simulate a total of approximately 25 years of exposure to the Korean environment.
- 5 PSDI-5 returned from Southern Europe, with 11 years field exposure have been tested. The inflators had an additional 1064 thermal cycles added for a total exposure of about 30 yrs of HAH exposure.
- 16 SDI inflators with 750 cycles were ballistically tested.



Tank testing indicates all normal deployment pressures on the return parts with additional environmental chamber aging.



Internal inflator pressure also are in the normal range. Peak pressures above 60 MPa are considered high pressure deployments. The threshold for ED is about 90 MPa .

- **All deployments were nominal.**

COMPARISON TO OTHER OEM TEST RESULT

TESTING OF DRIVER INFLATORS FROM US HIGH HUMIDITY REGIONS

All Driver Airbag Tested

- Takata has deployed about 38,465 driver inflators returned from all OEMs with 189 ruptures for a rate of .49% (AUG2017).
- If this rupture rate applied to the GM SDI and PSPI-L inflators, the chance that:
  - 636 Laboratory tests being conducted without failure would be about:
    $(.995)^{661}$ = 4.3% - unlikely
  - 260,000 field deployment occurring without a known failure is about:
    $(.995)^{260000}$ ~ 0 - essentially impossible

This would indicate the GM inflator does belong in the population of Takata driver airbags tested.

Judging GM inflators with this population may be considered an unfair comparison since the majority of EDs have occur on design that use the “batwing” design and that are older than the GM products.

Age	No ED	ED	Total Tests
0	26		26
1	17		17
2	2		2
3	118		118
4	109		109
5	410		410
6	349		349
7	571		571
8	3854	5	3859
9	6540	9	6549
10	8477	7	8484
11	10953	8	10961
12	4880	12	4892
13	1044	12	1056
14	612	15	627
15	314	119	433
17		2	2

Ballistic Test Result for All Driver Inflators Returned from HAH Regions in the US from other OEMs. There are no EDs on GM products

ED	Tests	Rate
189	38465	0.49%

TESTING OF DRIVER INFLATORS FROM US HIGH HUMIDITY REGIONS

11-12 Year Age Tablet Based Driver Airbag Tested

- Segmenting the population to only include inflators from a similar age and family of tablet based designs reduces the rupture rate from the overall .49% rate to .08% for the non GM inflators.
- If this rupture rate applied to the GM SDI and PSPI-L inflators, the chance of the estimated 53,700 field deployment for this population occurring without a known failure is:

$(.9992)^{53700} = 2.2 \times 10^{-19}$ essentially impossible

Comparing the GM products to the rupture rate of a comparative design with the population of the similar age also indicates it is highly unlikely that the GM inflators are similar to the other OEM designs. It should be noted that all the laboratory test failures occurred on a single non-GM model.

This calculation can not be made specific for Australia because the population is too young.

All Non HAH Tablet						GM
Age	No ED	ED	Total Tests	GM Lab Tests	GM Volume	Australia Volume
0	4		4		330,576	17,747
1					470,380	25,630
3	2		2		527,961	31,789
4	5		5		491,292	43,286
5	9		9		481,003	44,093
6	260		260	4	519,142	42,162
7	166		166	16	475,326	46,406
8	468		468	1	511,361	31,879
9	1091		1091	87	706,371	15,150
10	3237		3237	285	764,381	19,963
11	7188	1	7189	242	769,470	20,935
12	3958	8	3966	1	398,139	10,386
13	504	1	505		0	0
14	2		2		0	0

Segmenting out this population

Ballistic Test Result for Tablet Based Driver Inflators Returned form HAH Regions in the US. There are no EDs on GM products.

ED	Tests	Rate
9	11155	0.081%

SUMMARY & NEXT STEPS

GM continues to monitor field reports in Europe and around the globe. There are no ruptures of non-desiccated ammonium nitrate inflators installed in GM engineered vehicles including those sold globally.

Extensive testing of parts returned globally has shown there is no significant change in GM inflators. All ballistic tests have been nominal.

GM has collected inflator temperature and humidity data from vehicles located in the hottest, most humid area of China. GM is used this data, and data collected in Korea, Australia, and the US to artificially age inflators and understand their long term performance. GM anticipates completing this work by March 2018.

GM will continue regular communication with ACCC/DIRD to share investigation results.

GM PRESENTATION TO ACCC

Takata Non-Desiccated Frontal Airbag Inflators

9th October 2017

GENERAL MOTORS

GM DRIVER AIRBAG – TAKATA OVERVIEW

Background

- NHTSA, Takata, Honda, Toyota focused on "Why are the inflators rupturing?"
- Heat, humidity and time can degrade ammonium nitrate propellant, however…
- Driver inflator issue is primarily due to early batwing design, challenges with making the wafer
- NHTSA made early conclusions that have evolved in time

How does GM know we are safe today?

- Why are we not rupturing? Hired OATK to help determine this.
- Investigation started three years ago focused on many things including design, manufacturing differences
- Field returns and ballistic testing demonstrating safe performance
- Crash statistics estimate more than 260,000 safe Driver airbag deployments in GM vehicles since 2005
- NHTSA granted GM's request to not recall the GMT900 vehicles and provided a year deferment to perform our inflator conditioning study. Harry Blomquist continues to support NHTSA in our monthly reviews and was supportive in the deferral.

How does GM know we will be safe in the future?

- Extensive and abusive conditioning study by GM and OATK to look into the future and understand our service life
- Committed to conduct continued field part return to study part behavior in the future

Next steps

- Conditioning study to be completed March 2018, willing to return to share results with ACCC
- Utilizing Cornerstone approach, statistical experts, to understand probability of safety risk
- Continued daily effort to look for potential field ruptures and investigate for understanding
- GM will act quickly to address this if at any point the results indicate a safety risk

TAKATA INFLATOR IN GM PRODUCTS- TECHNICAL OVERVIEW

Compared with other types of Takata inflators, the Takata inflators used in GM vehicles Inflators have characteristics which reduce moisture ingress and also make the propellant more resistant to, and protected from, the effects of environmental conditions.

These design features include:

1. Propellant shape and size. Takata inflators used in GM vehicles utilize propellant tablets, not the older 'Batwing' design. Tablets are:
   a. Manufactured with consistently higher density
   b. Demonstrated to have less density change over time based on field return analysis
   c. Not failing in the field.

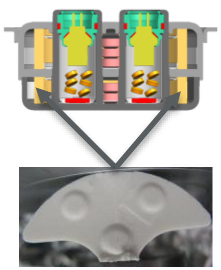
2. The GM dual stage (PSDI-5) driver-side airbag inflator has a lower propellant mass to vent area ratio than other OEMs' Takata inflators. This reduces the pressures in the inflator during deployment, reducing the risk to occupants.

3. The PSDI-5 and SDI driver-side airbag inflator has a thicker section steel case which increases the safety factor in the case of pressure build up within the inflator.

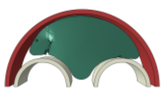
TAKATA NON-DESICCATED PSAN PROPELLANT

DRIVER AIRBAG INFLATORS

Batwing Inflators PSDI, PSDI-4, PSDI-4k

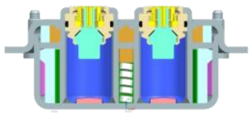


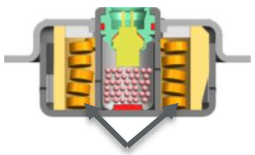
PSAN Batwings



Highest risk inflators associated with majority of fatalities and injuries
NOT USED IN GM VEHICLES

Tablet Inflators PSDI-5, SDI





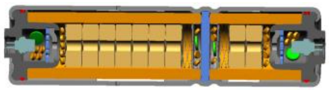
PSAN

Extremely low failure rate inconsistent with design defect
DRIVER AIRBAG INFLATORS USED IN GM VEHICLES

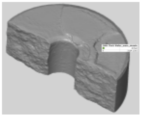
Inflators used in Holden vehicles

FRONT PASSENGER AIRBAG INFLATORS

Thick Wafer Inflators Example: PSPI-L FD

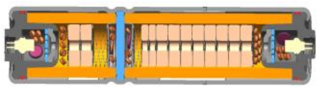


Thick Wafers

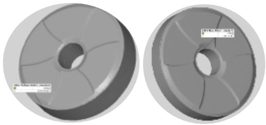


Highest failure rates in ballistic testing
NOT USED IN GM VEHICLES

GM Specific Inflators w/ Thinner Wafers PSPI-L YD, SPI YP



Medium & Thin Wafers



No known energetic deployments in GMT900
PASSENGER AIRBAG INFLATORS USED IN GM VEHICLES

P=Programmable, S=Smokeless, D=Driver, P=Passenger, I=Inflator

Other relevant characteristics are:

4. Implementation timing: GM adopted both desiccated and non-desiccated Takata inflators later than other OEMs. GM airbag experience contributed to Takata improvements prior to implementation in GM vehicles.

- Design: GM did not use the earlier ‘Batwing’ design which has documented issues with propellant manufacturability.
- Manufacturing: GM started using Takata products after documented initial propellant manufacturing quality issues were addressed. These manufacturing quality issues resulted in field events in other OEMs’ vehicles.

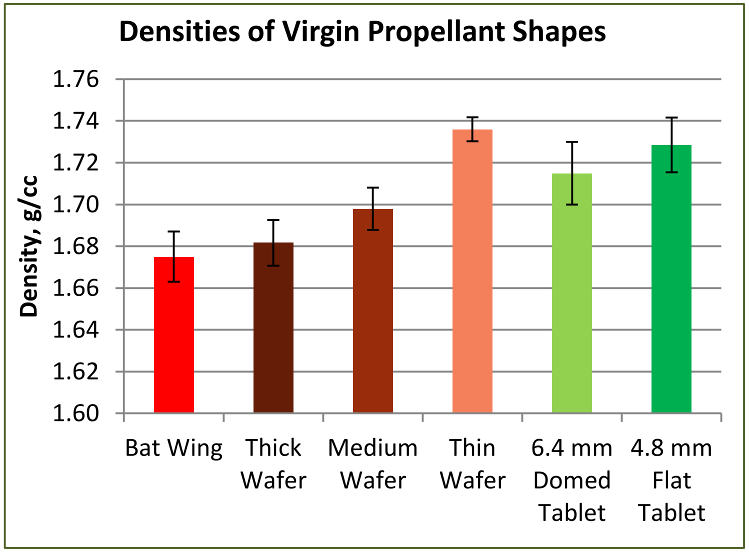
5. Manufacturing location – The non-desiccated Takata inflators used in GM vehicles are sourced from plants in Europe that have consistent environmental and quality control processes. This results in:

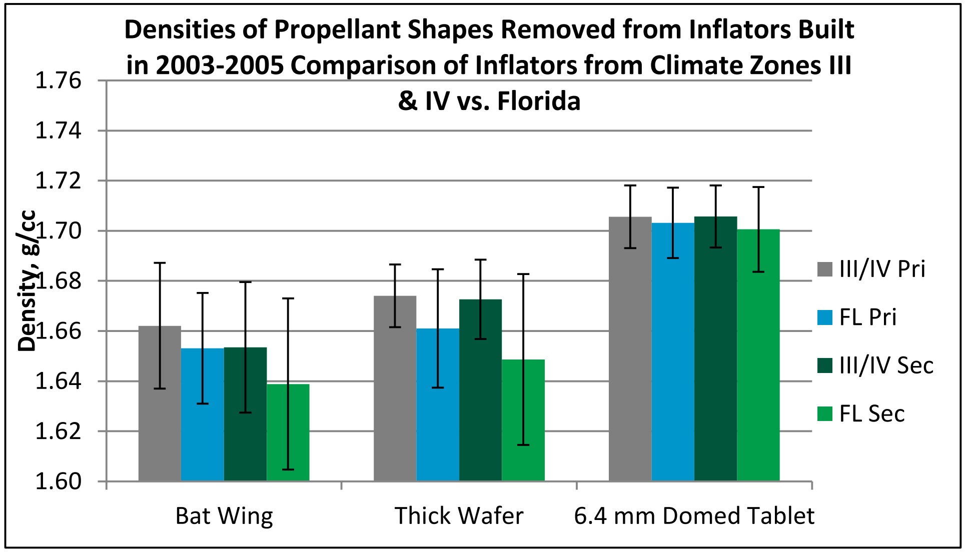
- Proper welding and welding inspection
- Reduced likelihood of incorrect inflator assembly
- Components installed in the right order
- The correct amount of components installed – specifically the main propellant, booster propellant and the autoignition tablets.
- Reduction in the “as built” moisture levels
- Reduction in the long term leak rate

DRIVER AIRBAG TEST STATUS – FIELD RETURN ANALYSIS

Detailed Analysis of Field Returns

- GM contracted Orbital ATK, experts in the field of propellant aging, to analyze GM DAB and PAB inflators and compare them to other non GM inflators.
- The GM DAB parts were returned from global locations
- Results:
  - OATK conducted extensive testing including: Moisture analysis of propellants (2004, 3110, AI-1), Diameter and Density (2004 and 3110 tablets), Color of AI-1, Scanning Electron Microscopy (SEM), X-ray Micro Computed Tomography (Micro CT), Crush Strength, Burn Rate (closed bomb) of 2004 and AI-1, O-ring testing
  - No significant propellant degradation was detected. The types of the PSDI-5 and SDI inflators in GM vehicles are performing as designed and do not have the same level of propellant degradation as high risk inflators in other OEM vehicles.



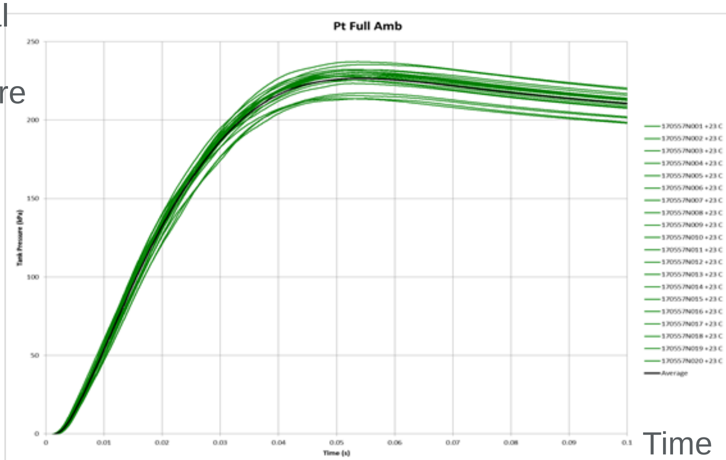


DRIVER AIRBAG TEST STATUS - BALLISTIC TESTING

Ballistic Testing and Live Dissection of Field Returns

- Testing of inflators returned from the HAH regions of the US.
  - Average age of the parts tested is 10.5 years.
- Status:
  - 616 Samples have deployed. All deployments were nominal and without indication of degraded propellant.
  - 132 Samples have been dissected with no anomalies found
    - The density of 1.71 g/cc within the specification of a new part.

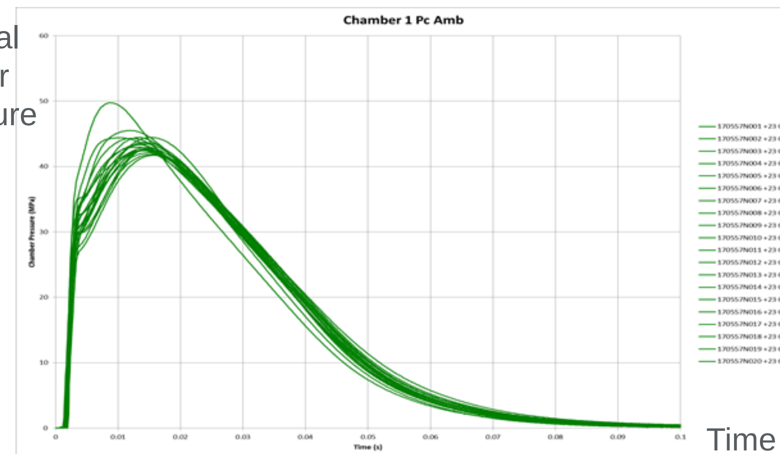
Internal inflator pressure



Time

Tank testing indicates all normal deployment pressures on the return parts with additional environmental chamber aging.

Internal inflator pressure



Time

Internal inflator pressure also are in the normal range. Peak pressures above 60 MPa are considered high pressure deployments. The threshold for ED is about 90 MPa .

DRIVER AIRBAG TEST STATUS – FIELD PERFORMANCE

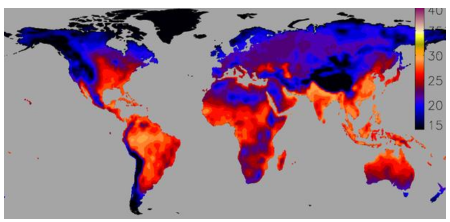
Field Performance

- There have been approximately 9.3 million GM vehicles built globally with the GM variants of the SDI and PSDI-5 Takata inflators.
- Status:
  - Using a conservative deployment rate for accidents of 0.4% per year, this would mean there would be more than 260,000 DAB deployments in this population since the first usage in 2005 of these inflators.
  - There have been 0 reported ruptures for this population.

DRIVER AIRBAG TEST STATUS - ACCELERATED AGING

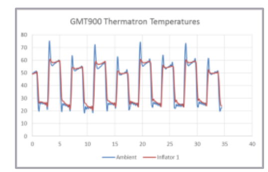
Environmental Testing Background

Field return parts collected from the hot humid areas of various countries are being artificially aged by subjecting the inflators to environmental cycling representative of the highest vehicle temperature and humidity conditions measured in S. China. Inflators will then be deployed and analyzed.



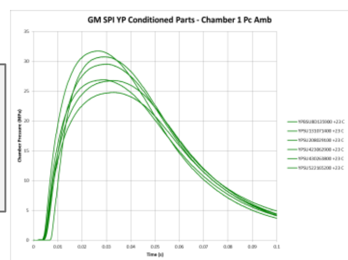
Acquire oldest field returns from global HAH regions available

Age >207 inflators in environmental chambers



Temperature profiles of the environmental chamber are based on vehicle testing in S. China after comparison on data collected from S. ROK, N. Australia, and S. US

Measure pressure generated during deployment on 207 samples



Induce additional environmental aging on the parts to generate a total of 30 or more years of simulated or actual HAH field exposure

DRIVER AIRBAG TEST STATUS - ACCELERATED AGING

Artificial Aging of New and Field Return Inflators

- New and returned parts cycled in an environmental chamber to simulate 30 years of exposure to a Southern China environment with 1680, 70C peak, temperature cycles.
  - It is estimated that approximately 1430 cycles would be equivalent to 30 years exposure in Cairns, QLD.
  - The peak inflator temperature recorded in Cairns QLD on GM Holden vehicles was 66C.

Target Samples	Inflator Type	Thermal Test Cycles	Virgin Parts	Returned Parts*	Source of Returned Parts						
					Korea	Taiwan	India	Australia	Brazil	Europe	China
69	SDI	1960	58	48	6		9	11	21	1	
69	PSDI-5	1960	50	19		14				5	
35	SDI	750	19	20	20						
35	PSDI-5	750	35	0							
30	SDI	1960	0	30							30**

* An additional 12 SDIs and 1 PSDI-5 6yo field returns from Brazil and Australia were added March 2017 added to the environmental chamber and will be removed from test in March 2018, however they will have accumulated only about 1484 Cycles by that time.

* * These parts are being tested by GM China and will not complete aging until ~Nov 2017

- Status:
  - What has been completed
    - 16 virgin parts and 20 parts returned from Korea tested at ~ 750 cycles
    - 5 parts returned from S. Europe tested at ~1680 Cycles.
    - All deployments were nominal and without indication of degraded propellant.
    - 38 additional parts cycled to 750 are awaiting ballistic testing.
  - What will be completed
    - 23 parts have been returned from Northern Australia are being artificially aged to 30 to 35 years of HAH exposure, along with the remaining samples from the rest of the world
  - There has been a decision to increase future tests to 1960 cycles or 35 years to be equivalent to GM PAB testing and ITC testing, targeted completion is now **March 2018.**

SUMMARY

- Inflators in GM vehicles, both in the field and in laboratory deployments, continue to deploy safely and as intended.
- GM's investigation shows that the SDI and PSDI-5 inflators installed in GM vehicles are currently performing as designed and show no indication of a design defect.
- We are continuing testing of these inflators. Completion of the testing is March 2018.
- We will continue update ACCC on the test status.
- If at any point in time GM determines there is an unreasonable risk to customer safety, **we will act**.

GMT900* INVESTIGATION
TAKATA FRONT PASSENGER AIRBAG INFLATORS

August 23, 2017

*The GMT900 is used to designate our full size Pick Up and Utilities architecture. The Heavy Duty vehicles use GM unique inflators, SPI-YP, and the Light Duty vehicles also use GM unique inflators, PSPI-L YD. The inflators are manufactured by Takata and contain non-desiccated ammonium nitrate as their propellant.

GENERAL MOTORS

GENERAL MOTORS

GM'S COMMITMENT TO SAFETY

General Motors has demonstrated its commitment to vehicle safety in a myriad of ways. At GM safety and quality are foundational commitments, never compromised

- If there is a safety issue, we act: From 2014 through 2016 GM has conducted 140 safety recalls
- When safety is at issue we act because our customers are at the center of everything we do
- We continue to support NHTSA and appreciate the meeting today. We share with NHTSA a strong commitment to customer safety

GMT900 INVESTIGATION
TAKATA FRONT PASSENGER AIRBAG INFLATORS

GENERAL MOTORS

INTRODUCTION

GM has filed two petitions with NHTSA, dated November 15, 2016 and January 10, 2017, requesting a determination that the risk posed by Takata inflators in certain GMT900 vehicles is inconsequential as it relates to motor vehicle safety. NHTSA has consolidated these two petitions to be decided together and has entered an interim order deferring its decision on these petitions until August 31, 2017 to allow GM time to complete its ongoing testing and engineering analysis related to the inflators in GMT900 vehicles.

GM submitted these petitions based on evidence that GMT900 Takata inflators are operating safely and would continue to do so for years into the future. The evidence was generated through GM's ongoing investigation. GM began this investigation in November 2014 and has regularly and consistently shared findings with NHTSA throughout. This includes deep dive reviews in May 2016, September 2016, April 2017 as well as monthly updates in accordance with NHTSA's deferral order starting in September 2016 through the present.

INTRODUCTION

GM completed all investigation work as originally planned:

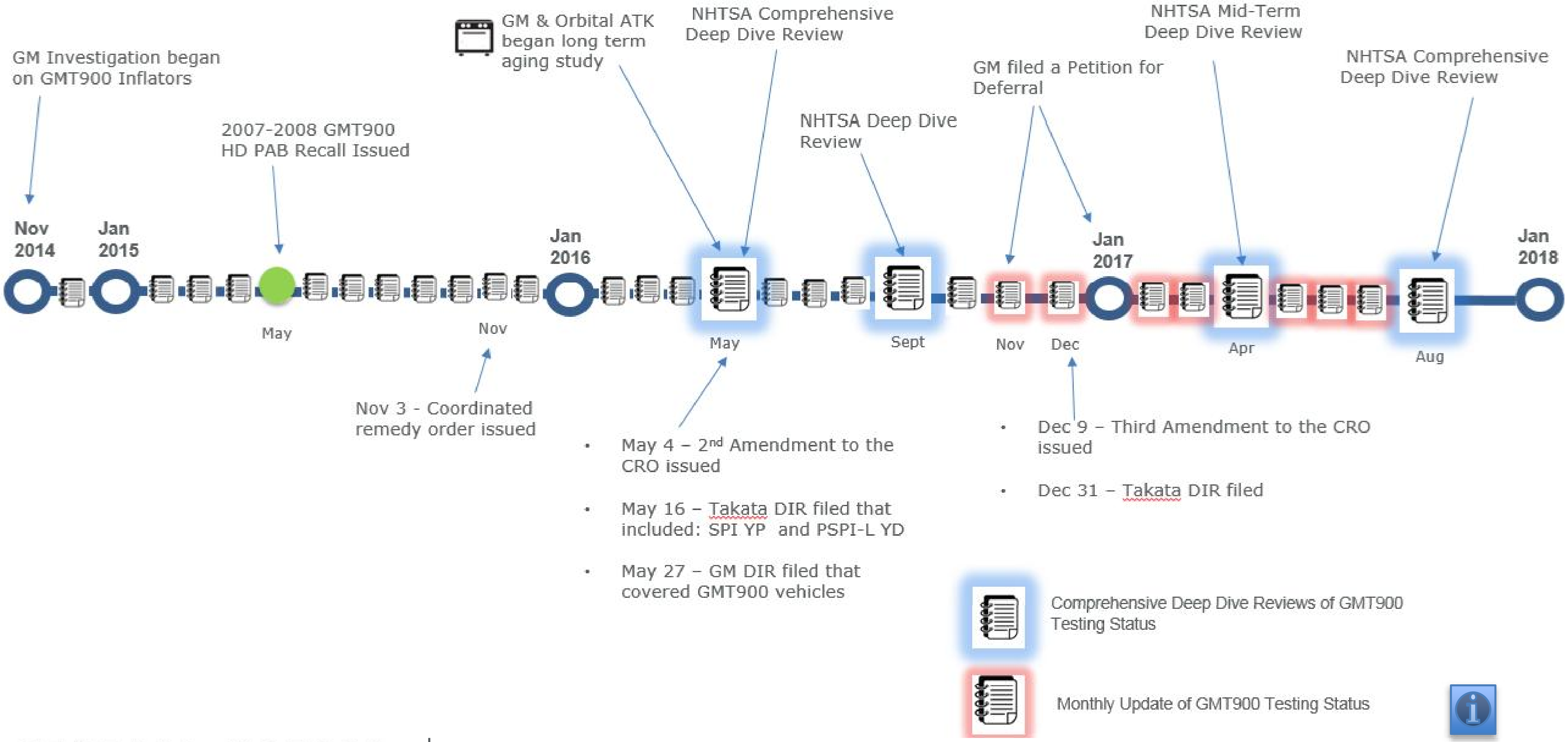
- Analysis of field crashes indicating more than 60,000 deployments of GMT900 Takata airbag inflators
- Ballistic testing of over 4000 GMT900 inflators returned from the oldest GMT900 model years mainly from the highest risk areas of the country (Zone A)
- Exhaustive testing and analysis of field return parts from both the GMT900 and competitor vehicles
- An accelerated aging study simulating 30 years of exposure in Southern Florida at extreme temperatures and moisture levels on both GMT900 inflators and a different inflator type that has had failures both in the field and in ballistic testing

Today, GM is presenting a comprehensive review of its investigation into GMT900 Takata inflators. GM believes that the evidence being presented fully supports the relief requested in the petitions. However, we also believe it would be beneficial to continue our testing and analysis. Therefore, if NHTSA is not prepared to grant the petitions at this time, GM is requesting that NHTSA extend its deferral before making a determination on GM's petitions from August 31, 2017 to March 31, 2018 to include additional work such as:

- Continued cycling of GMT900 Takata inflators beyond 30 years exposure in Southern Florida to provide greater insight into long term performance
- Development of a predictive model to help quantify the service life of GMT900 Takata inflators

BACKGROUND - TIMELINE

GM began its investigation of the GMT900 Takata inflators in November 2014 and has held, including today, 40 reviews and meetings with NHTSA to communicate findings and inform the agency of next steps. The following timeline summarizes some of the more significant activities during this period. A link is also included to a backup slide that provides a comprehensive list of the meetings.

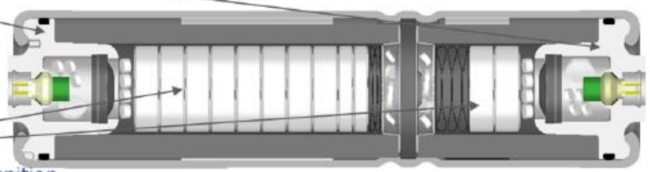


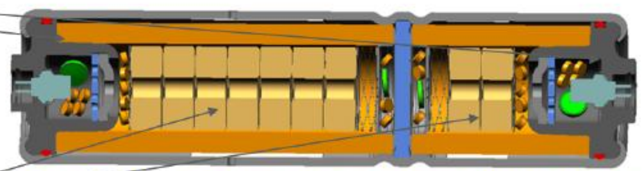
Comprehensive List

BACKGROUND – GMT900 UNIQUE CHARACTERISTICS – INFLATOR DESIGN

In the numerous reviews with NHTSA, GM presented evidence that the Takata inflators installed in the GMT900 as well as the vehicle environment itself have unique characteristics that make it less susceptible to inflator rupture from long term exposure to conditions of high heat and humidity. This is the reason that the GMT900 inflators continue to perform safely compared to different Takata inflators used in other OEM vehicles that have known issues in the field and in ballistic testing.

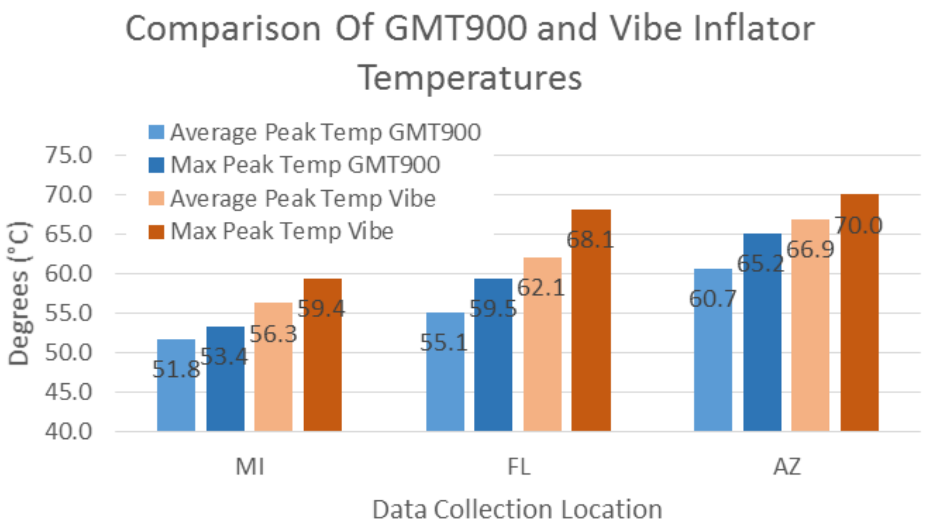
The following graphic summarizes the differences between the PSPI-L YD inflator installed in GMT900 Light Duty vehicles and PSPI-L FD installed in the Pontiac Vibe and other OEM vehicles. As GM contended, these two inflator variants, both from the PSPI-L family, have proven to have significantly different long term performance characteristics.

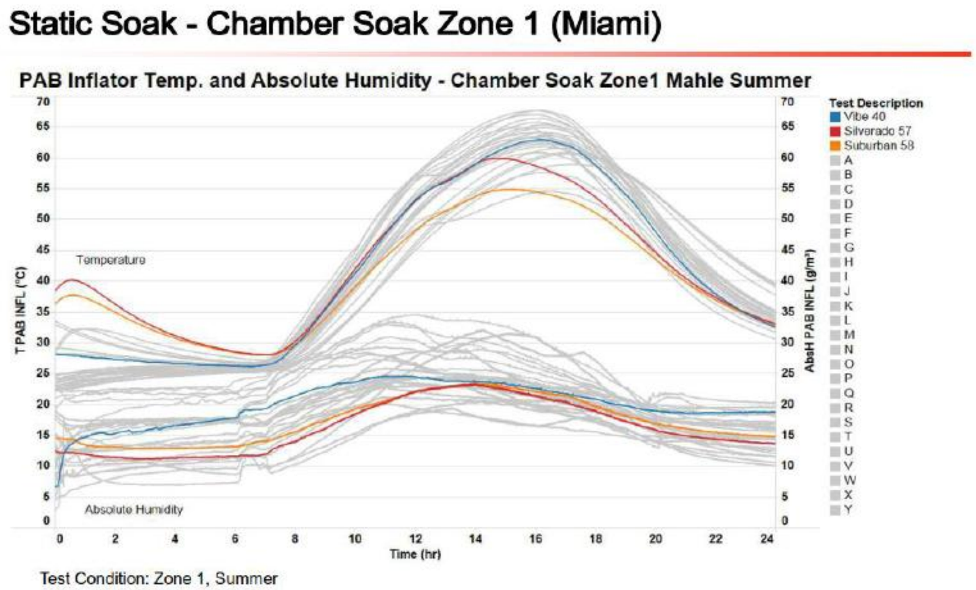




BACKGROUND – GMT900 UNIQUE CHARACTERISTICS – VEHICLE ENVIRONMENT

GM also presented evidence that characteristics such as vehicle size and standard solar absorbing windshields and side glass result in significantly lower inflator temperatures in the GMT900 during daily cycling than other vehicles with known issues. Peak inflator temperatures during diurnal cycling has been shown to be a significant root cause element of propellant degradation due to long term exposure to conditions of high heat and humidity. The following graphs summarize measurements made by GM in three different field locations, Michigan, Florida and Arizona and a similar laboratory study conducted by Takata simulating diurnal cycling in Miami on numerous vehicle models.





BACKGROUND – GM'S EXTENSIVE INVESTIGATION

GM and Orbital ATK used multiple state of the art analysis and testing methods to conduct this investigation.

Long term aging studies

Analysis of Field part return

Analysis of Field Data

- Dissection of Aged Parts
- Heavy Weight Testing
- Propellant Stack Height
- Thermal aging tests VEC
- Thermal aging tests OATK
- Moisture Dynamics
- Crush strength tests
- Propellant Density
- Quench Testing
- Gas Diffusion Through Wafer
- Field Deployment Investigation
- Burn rate tests
- Vehicle Design Comparisons
- SEM of Internal Surface
- AI Tablet Analysis
- Ballistic Testing
- Ballistic modeling
- Crash data statistics
- Crimp Diameter
- SEM of External Surface
- CT Scan Analysis
- Dissection of Field Returns
- Field Environment Measurement
- MEAF review
- O-ring tests
- Leak Tests
- Micro CT analysis
- Envelope density tests
- Inflator design comparisons
- Moisture Tests

FINDINGS – ACCIDENT DATA AND FIELD RETURNS

No known inflator ruptures in GMT900 field accidents

Based on field crash statistics, GMT900 vehicles have been involved in over 60,000 accidents in which the Takata airbag inflator would have deployed. Even with such a large number of field deployments, there are no known reports of inflator ruptures from any of these field incidents. This includes over 45,000 deployments of the 2007-2012 vehicles with inflators recalled by Takata as required by their Consent Order and which are the subject of GM petitions.

No inflator ruptures in ballistic testing of field return inflators

GM has collected and Takata has conducted ballistic tests on over 4,100 GMT900 Takata inflators collected from the oldest vehicles mainly from Zone A states. There have been no inflator ruptures, energetic deployments or abnormally high-pressure deployments in any of the ballistic tests.

FINDINGS – ACCIDENT DATA AND FIELD RETURNS

Summary of GMT900 Field Data and Field Returns as of 21Aug2017

	GMT900 LD PSPI-L YD	GMT900 HD SPI YP	GMT900 Total	Ruptures
Estimated Total U.S. PAB Field Deployments	>35.8K	>24.9K	>60.7K	0*
Estimated U.S. PAB Field Deployments (Petition Vehicles**)	>24.8K	>20.8K	>45.7K	0*
Ballistic Tests – All Zones	1617	2559	4176	0
Ballistic Tests – Zone A Returns	1595	2209	3800	0
Average Age of Tested Parts	8.6 Yrs	9.5 Yrs	9.1 Yrs	N/A
Oldest Returned Part	11.5 Yrs	10.7 Yrs	11.5 Yrs	N/A

No ruptures or characteristic pressure traces of abnormal deployment in any GMT900 ballistic tests

**Based on available sources of field data*
***Petition Vehicles: 2007-2012 MY GMT900 vehicles as specified in Amended Takata Consent Order, Paragraph 14*

FINDINGS – LONG TERM AGING STUDY

GM has conducted extensive accelerated aging studies on GMT900 Takata inflators simulating up to 30 years of exposure in Southern Florida so far.

For this study, inflators were specially manufactured with measured amounts of moisture added to each chamber of the inflator.

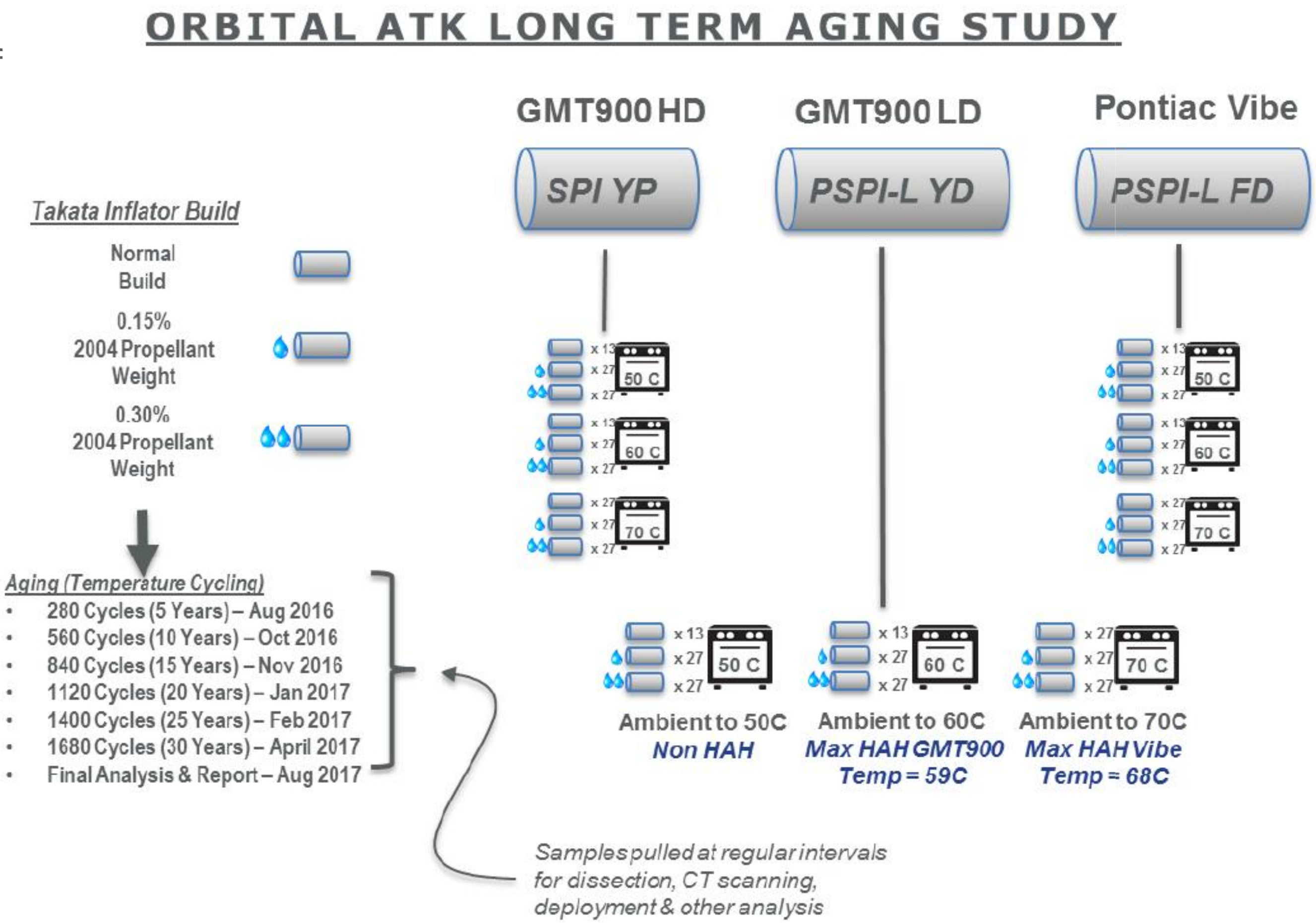
The **test parameters** were intentionally selected to **exceed GMT900 field relevant temperature and moisture measurements in an effort to induce failures**. GMT900 field measurements are as follows:

Temperature
GMT900 Peak Temp 59C

Primary Chamber Moisture
GMT900 Average Moisture .13%

Secondary Chamber Moisture*
GMT900 Ave Moisture .18%

Each cycle is 2 hours at the high temperature followed by 2 hours at 20C



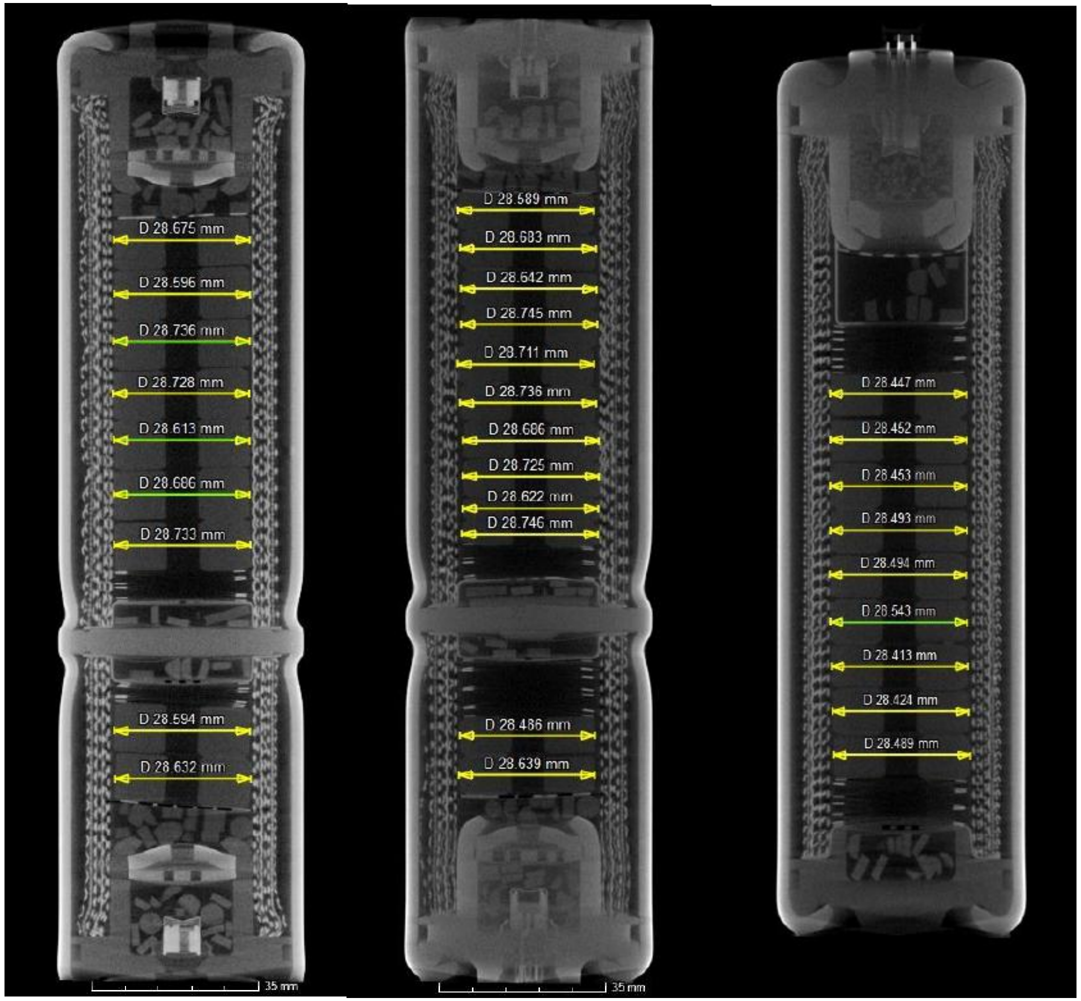
* Secondary Moisture:
.45% and .70% were used
The test moisture content was not chosen on based on the analysis of GMT900 parts, it was chosen to determine the effects of very high levels of moisture found on some other non GM returns.

FINDINGS – LONG TERM AGING STUDY

The inflators included in the long term aging study use non-desiccated Phase Stabilized Ammonium Nitrate (PSAN) as their main propellant in the form of wafers and tablets. Over time with repeated temperature cycling the propellant may degrade. This degradation may be accelerated by the presence of moisture.

It has been found from both field returns and ballistic testing that the outer diameter (OD) of the wafers can be used as a metric of the propellant degradation for the wafers.

Example of CT Scans of Inflators



PSPI-L FD
Pontiac Vibe/Other OEM

PSPI-L YD
GMT900 Light Duty

SPI YP
GMT900 Heavy Duty

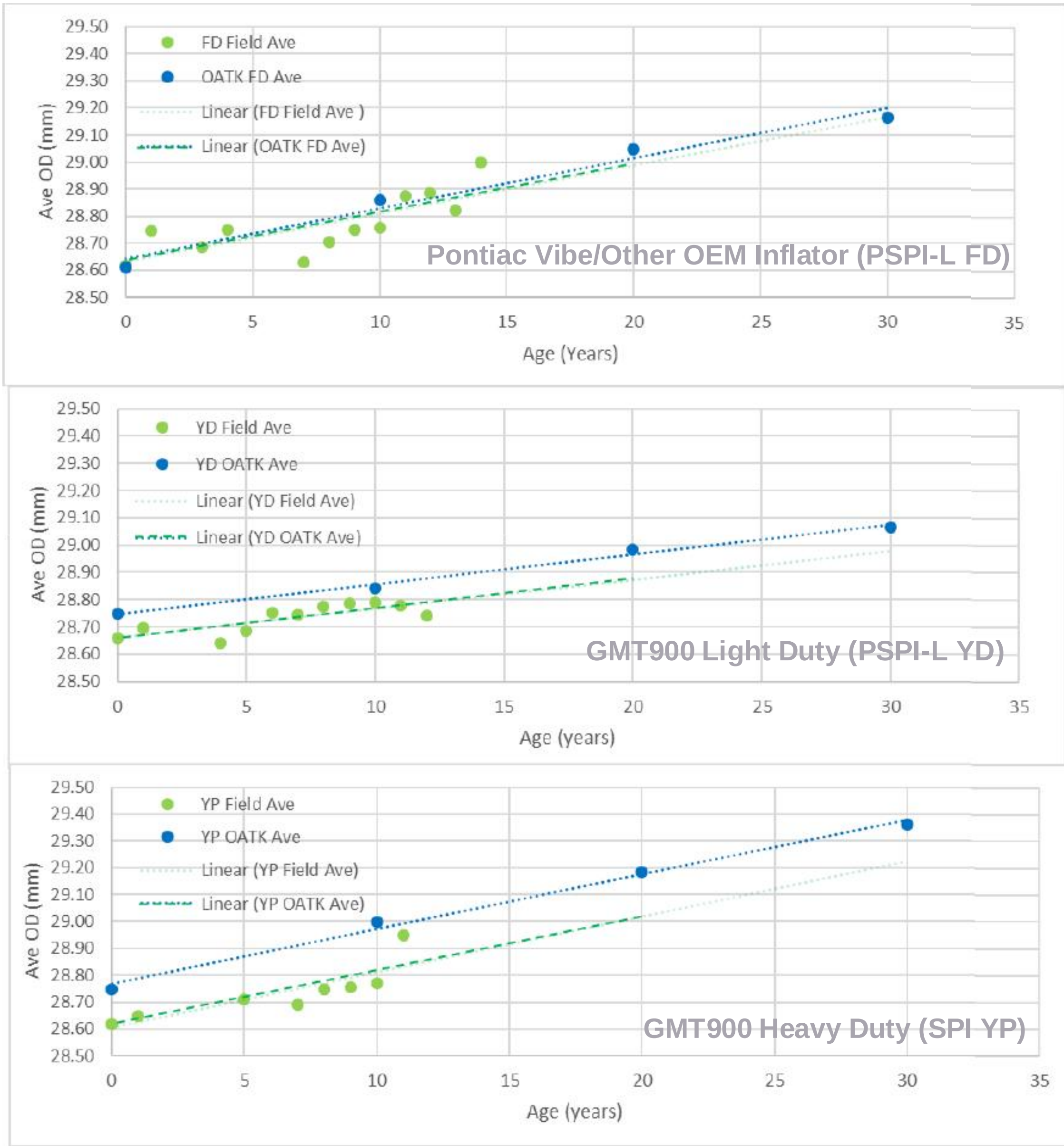
Wafer Diameter Measurement

- The SPI is a single stage inflator and the PSPI-L are dual stage inflators
- The GMT900 designs uses more but thinner propellant wafers in comparison to the PSPI-L FD used in the Pontiac Vibe and several other non GM vehicles
- Using CT scans, the OD can be measured without the dissection of the inflator – allowing the inflator to later be ballistically tested.
- The wafer diameter gets larger when exposed to temperature cycles and moisture, this has been found to correlate to abnormal deployments.
- The increase in OD changes the volume of the propellant wafer and typically generates a decrease in density. Lower density is associated with higher rates of gas generation.

FINDINGS – LONG TERM AGING STUDY

The long term aging study generated propellant growth at a rate consistent with parts recovered from the field. Total growth on the GMT900 inflators is well beyond the oldest field return parts and has exceeded the point where ruptures would be expected on Takata inflators from other OEM vehicles.

Comparison of Wafer Growth - Long Term Aging Study and Zone A Field Returns



The charts at the right show excellent correlation of wafer growth rate over time between inflators returned from the field compared to inflators from the Orbital ATK long term aging study. Wafer growth is measured by an increase in the outside diameter (OD).

- Using 56 cycles/year in the long term aging study generates rates of OD growth similar field data as indicated by parallel best fit lines for all 3 inflators
- Each inflator has its own rate of OD change, and it is approximately the same for both field and test measurements
- **The OATK accelerated aging test reasonably approximates OD growth and the data trends of the field returns for all three inflators.**

FINDINGS – LONG TERM AGING STUDY

As the long term aging study progressed, Orbital ATK pulled a predetermined number of inflators after every 280 cycles for testing and analysis.

- At 280 (5 Years), 840 (15 Years) and 1400 (25 Years) cycles: One inflator from each unique set of test conditions was dissected and analyzed
- At 560 (10 Years), 1120 (20 Years) and 1680 (30 Years) cycles:
  - One inflator from each unique set of test conditions was dissected and analyzed
  - Additional inflators were CT scanned and subjected to ballistic tests

The **PSPI-L FD inflator used in the Pontiac Vibe and other OEM vehicles** showed indications of propellant growth and degradation putting it at risk of rupture as early as 560 to 840 cycles (10 - 15 years). **Multiple inflator ruptures and abnormal high pressure deployments were observed in ballistic testing starting at 1120 cycles and increased after 1680 cycles, including a rupture on an inflator cycled to a maximum temperature of 60 C.**

Unlike the PSPI-L FD inflator, the **GMT900 inflators** used in Light Duty vehicles (PSPI-L YD) and Heavy Duty vehicles (SPI YP) **all deployed safely with no instances of inflator rupture or even abnormally high pressure deployments**.

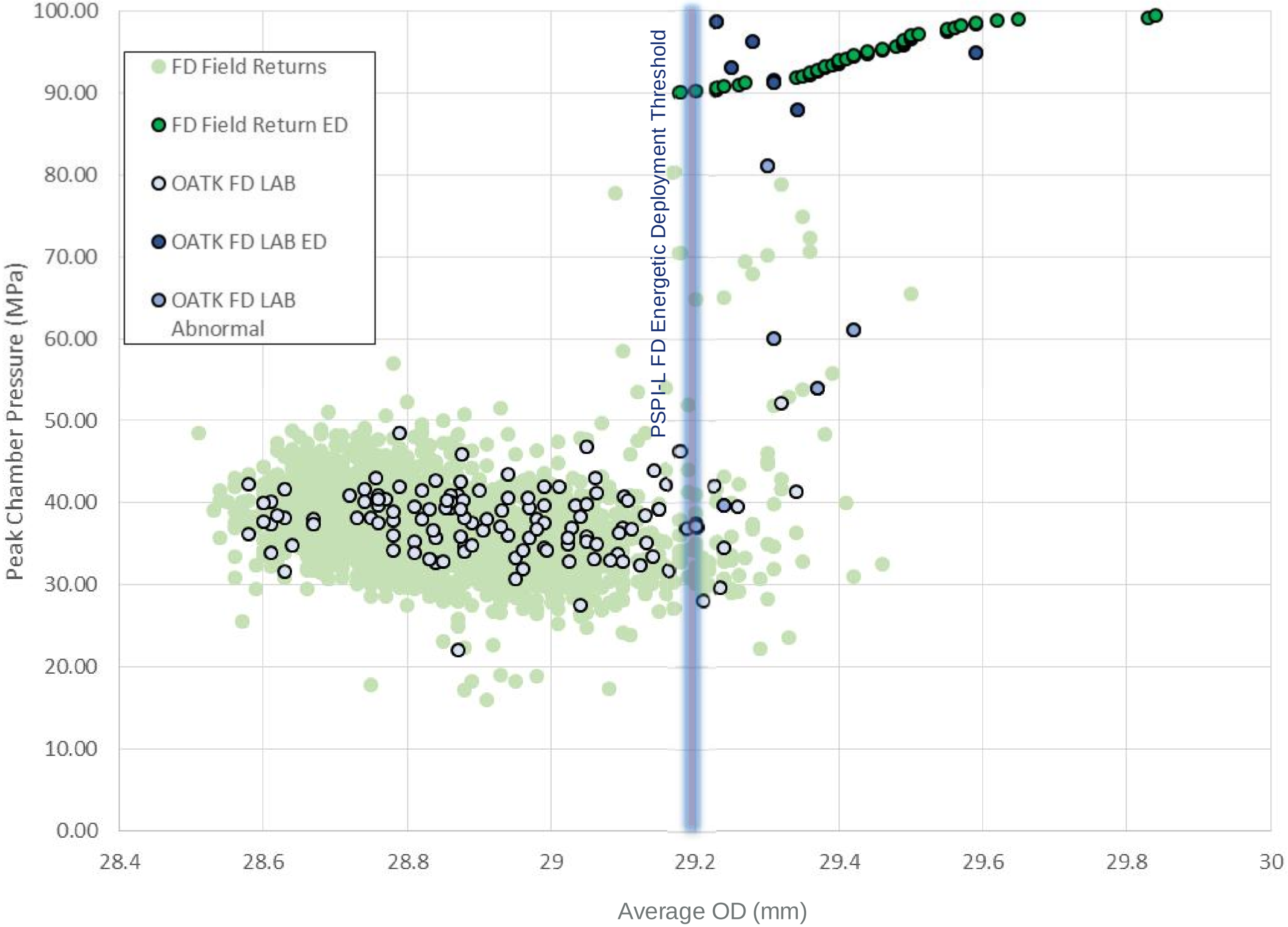
The graphs on the following slides compare ballistic test results of field return parts to ballistic test results from the long term aging study…

FINDINGS – LONG TERM AGING STUDY

The chart at the right shows peak inflator pressure from ballistic testing against propellant growth as indicated by wafer outside diameter (OD) measurements. Results are shown from both inflators returned from the field and inflators that were part of the Orbital ATK long term aging study

- PSPI-L FD field returns are from the Pontiac Vibe as well as other OEM vehicles
- There is a slight downward trend in pressure with increasing OD in both data sets
- The initial Energetic Deployment (ED) occurred at an OD of about 29.2 mm for both the OATK artificially aged parts and the field returns

Ballistic Test Results of Pontiac Vibe/Other OEM (PSPI-L FD) Inflator



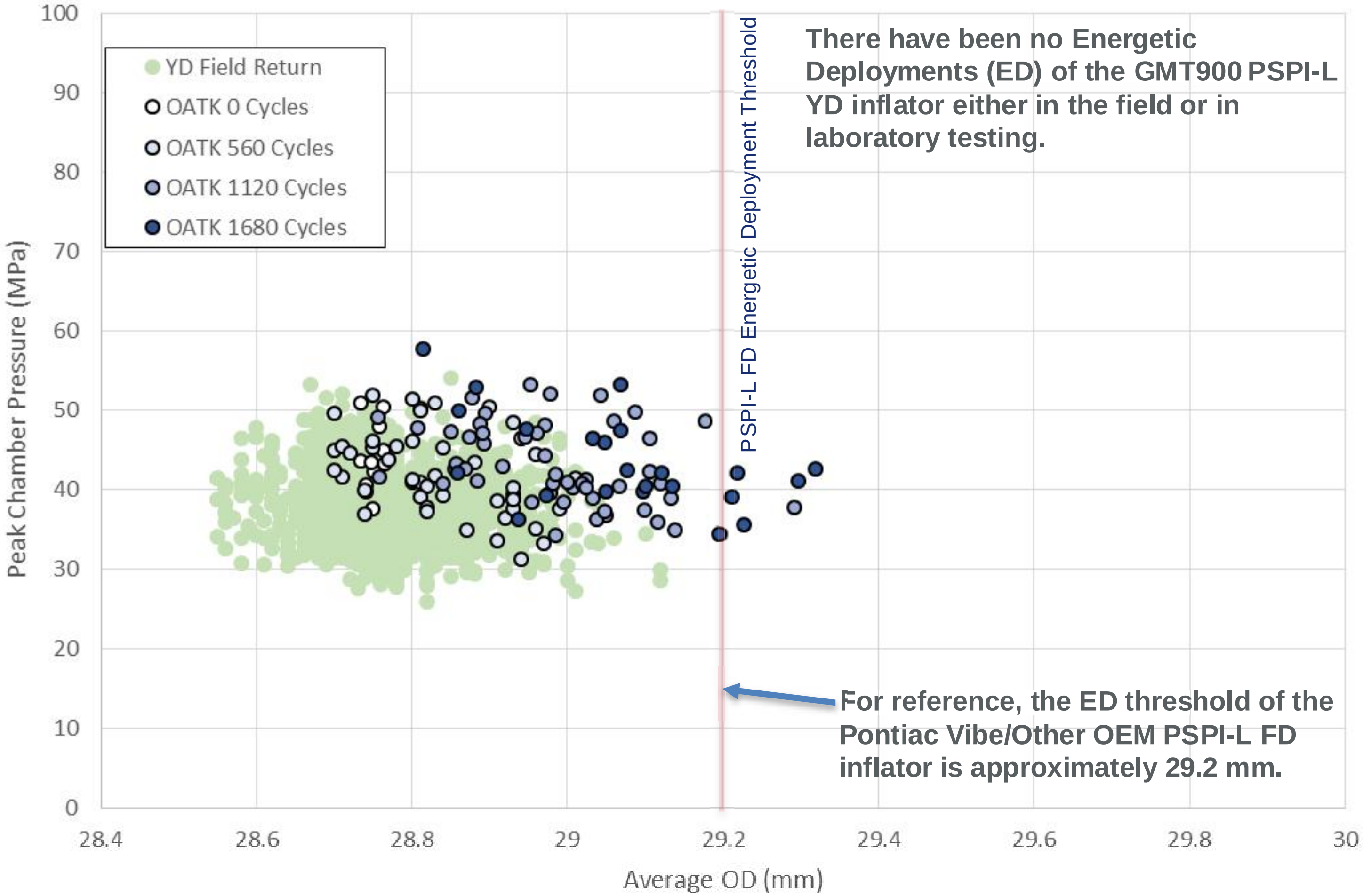
Note: The field EDs were assigned sequential pressure values from 90 to 100 MPa since peak pressure values were inaccurate prior to ED.

FINDINGS – LONG TERM AGING STUDY

The chart at the right shows peak inflator pressure from ballistic testing against propellant growth as indicated by wafer outside diameter (OD) measurements. Results are shown from both inflators returned from the field in Zone A and inflators that were part of the Orbital ATK long term aging study

- There is a slight downward trend in pressure with increasing OD in both field and aged data
- OD of the OATK artificially aged parts exceed the largest measured field return OD and the initial threshold for Energetic Deployment (ED) for the Vibe inflator.
- **There were no ED or abnormal pressure traces for the GMT900 LD inflator**

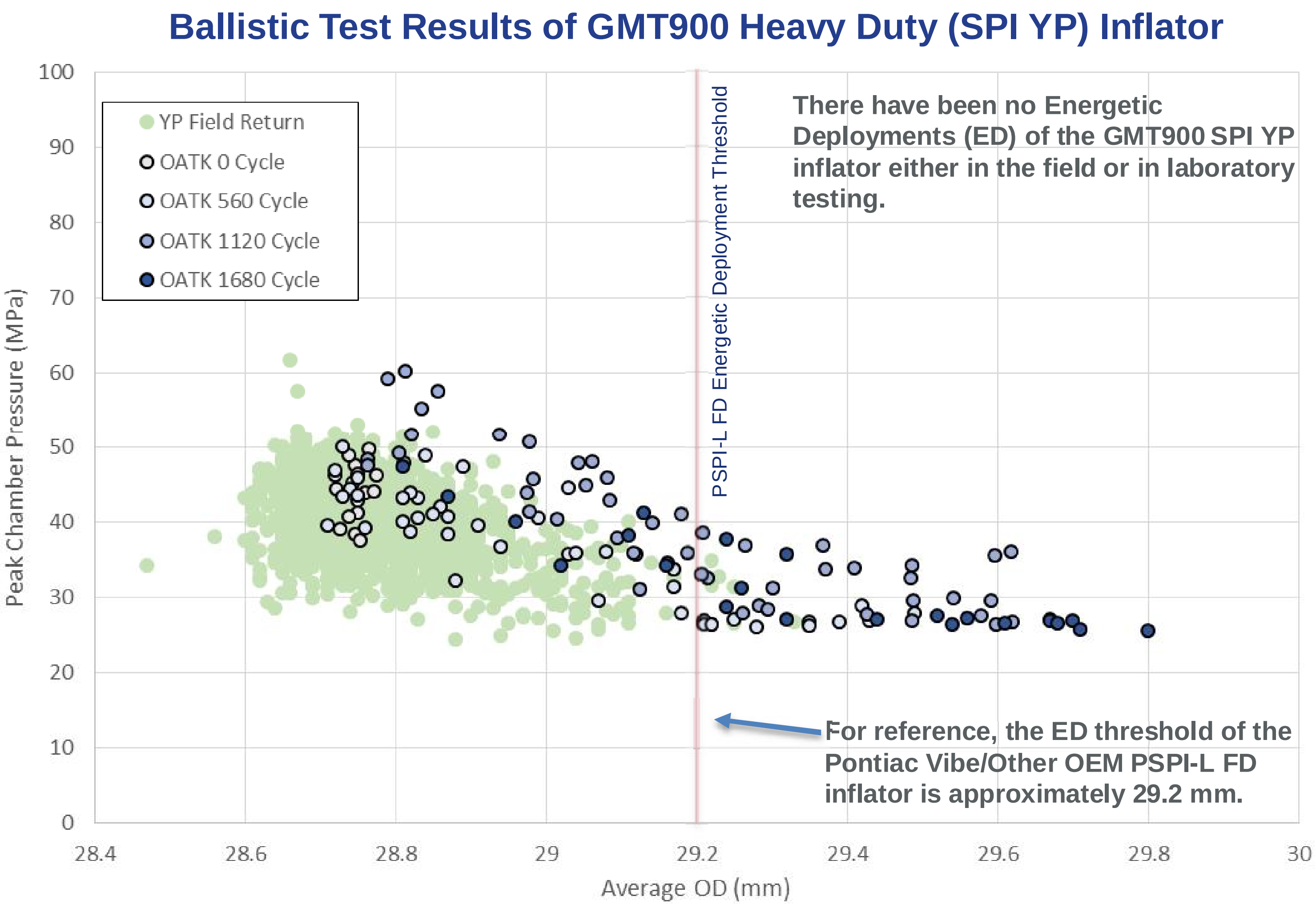
Ballistic Test Results of GMT900 Light Duty (PSPI-L YD) Inflator



FINDINGS – LONG TERM AGING STUDY

The chart at the right shows peak inflator pressure from ballistic testing against propellant growth as indicated by wafer outside diameter (OD) measurements. Results are shown from both inflators returned from the field in Zone A and inflators that were part of the Orbital ATK long term aging study

- There is a downward trend in pressure with increasing OD in both field and aged data
- OD of the OATK artificially aged parts exceed the largest measured field return OD and the initial threshold for ED for the Vibe inflator
- **There were no ED or abnormal pressure traces for the GMT900 HD inflator**



FINDINGS - RISK ASSESSMENT

Short Term Risk Assessment: No identified risk

- The Orbital ATK aging study generated propellant degradation in test parts that far exceeds the likely degradation of any inflators currently in the field. All of these inflators have deployed safely and none deployed with higher-than-normal pressure traces that can be a precursor to Energetic Deployment (ED).
- The amount of propellant degradation that will take place in field components from today through March 2018 will likely be small—i.e., almost immeasurable.
- According to all available testing data, this degradation will have no impact on the ballistic performance of the inflators.

Long Term Risk Assessment: No identified risk through 30 years of testing

- The Orbital ATK aging process was designed to induce severe propellant degradation with an intent to cause EDs and abnormal deployments.
- While it did cause the propellant in the GMT900 inflators to degrade, this degradation occurred slowly, and—crucially—did not generate an ED, an abnormal deployment, or even the higher-than-normal pressure traces that can be a precursor to an ED.
- Modeling and component testing of the GMT900 inflators has shown that its unique design features make it more robustness to the higher gas generation rates of degraded propellant compared to other Takata inflators.

STATISTICAL ASSESSMENT BASED ON RESULTS OF GM INVESTIGATION

CORNERSTONE RESEARCH
ECONOMIC AND FINANCIAL CONSULTING AND EXPERT TESTIMONY

Statistical Assessment of Energetic Deployment Risk among GMT900 Inflators

Professor Arnold Barnett
MIT

August 16, 2017

GENERAL MOTORS

ASSIGNMENT AND SCOPE OF WORK

- What can be learned from the available data about the likelihood of GMT900 inflators experiencing an energetic deployment ("ED")?
- Data from several distinct sources speak to that question:
  - OATK Long-Term Aging Study ("Lab Study")
  - Field-returned inflators ("Field Returned")
  - Actual crash and deployment estimates ("Field Crashes")

MY EXPERIENCE IN TRANSPORTATION SAFETY

- George Eastman Professor of Management Science and Professor of Statistics, Sloan School of Management, Massachusetts Institute of Technology
- Extensive safety- and risk assessment-related experience
  - Principal investigator on safety-related research projects
    - "Assessing and Expanding the Set of Air Safety Risk Indicators" (FAA grants, 1990 and 1992); "World Airline Safety" (FAA grant, 1997); "North Runway Safety Study" (LAX, 2008-2010)
  - Published extensively about safety in peer-reviewed journals
  - Teach courses on risk analysis and on transportation
    - "The Airline Industry"; "Data, models, and decisions"; "Engineering Probability and Statistics"; "Logistics and Transportation Planning"
  - Consultant on transportation safety to numerous organizations
    - US Transportation Security Administration, Federal Aviation Administration, 16 US airlines, Association of American Railroads, Los Angeles World Airports, Amsterdam Schiphol airport
  - Recipient of awards for safety research
    - 1996 President's Award from the Institute for Operations Research and the Management Sciences
    - 2002 President's Citation from Flight Safety Foundation for "truly outstanding service on behalf of safety"

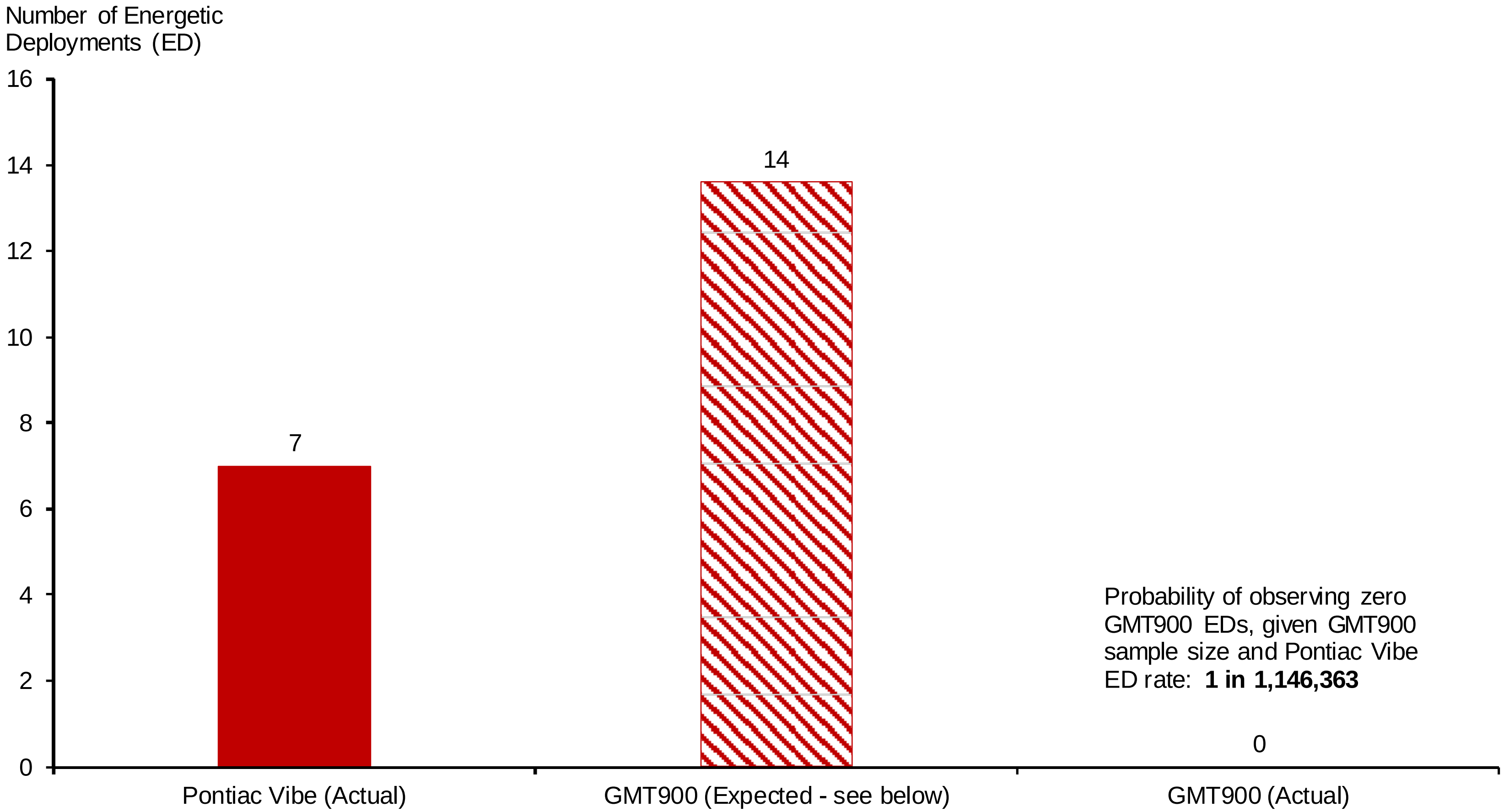
THREE INDEPENDENT SOURCES OF DATA

- Lab Study Samples
  - Simulation of long-term aging at temperature and humidity conditions comparable to a warm Miami, FL summer for **700+ inflators**
  - Included **control group** of Pontiac Vibe inflators
  - Aged inflators up to a simulated **30 years—**so far
  - Study appears to have effectively degraded inflators as aging would have:
    - Achieved high wafer outer diameter levels
    - Observed 7 Pontiac Vibe inflator EDs
- Field Returned Samples
  - Data on **250,000+ inflators** ages 0-16 years from dealers in hot and humid climates (Southeast US) and elsewhere that were sent to Takata for deployment and CT scanning
  - Included inflators from many anonymous OEMs and many inflator types
- Deployment Experience Based on Actual Crashes
  - Estimated deployments on the road based on total light truck and SUV registrations, crash rates, and vehicle attrition rates

OATK AGING STUDY ("LAB STUDY")

- Provides valuable information to supplement what can be learned from the field-returned and field-crashes samples.
- Allows one to test inflators at levels of degradation **not actually observed** in the field.
- Realistic:
  - The **rate of degradation** (as measured by average primary wafer outer diameter) as a function of simulated age is similar to the rate observed in the field returned inflators as a function of actual age.
  - EDs among Pontiac Vibe inflators **increased sharply** at higher ages, as would be expected if the aging process were accurately simulated.

OATK AGING STUDY RESULTS:
PONTIAC VIBE ED RATE APPLIED TO GMT900 INFLATORS
VS. MEASURED GMT900 ED RATE OF ZERO



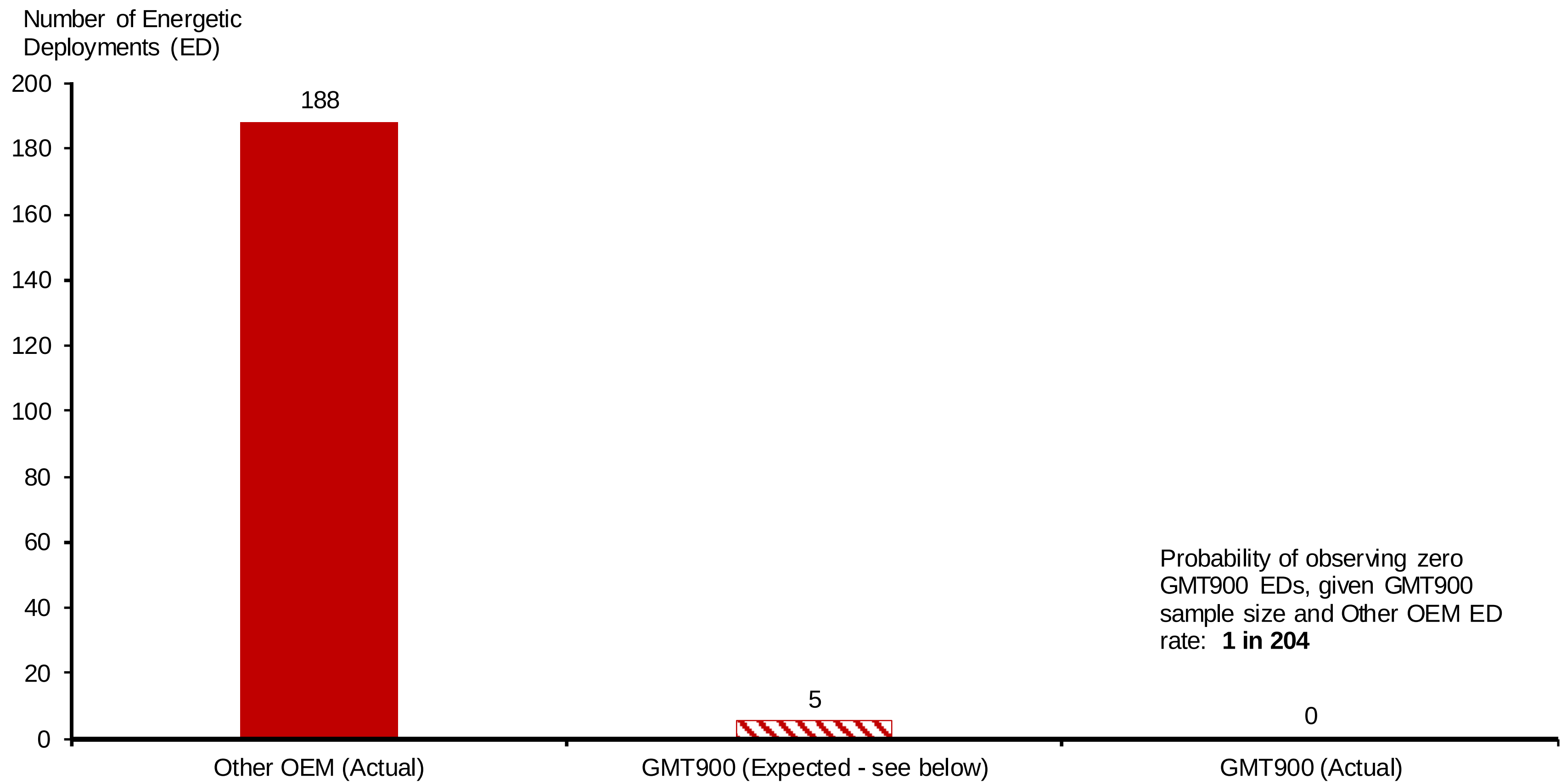
Source: OATK Aging Study Results

Note:

[1] The number of expected GMT900 energetic deployments is calculated by applying the observed energetic deployment rate in the laboratory for the Pontiac Vibe (4.96% = 7/141) to the sample size of the GMT900 inflators in the laboratory (274). The probability of observing zero energetic deployments of GMT900 inflators in the laboratory, given the GMT900 laboratory sample size (274) and the Pontiac Vibe energetic deployment rate (4.96%), is calculated as: $(1-(7/141))^{274}$ = 0.0000872%, which is equivalent to 1 in 1,146,363, rounded to the nearest whole number.

GE

FIELD RETURNED RESULTS:
OTHER OEM ED RATE APPLIED TO GMT900 INFLATORS VS. MEASURED GMT900 ED RATE OF ZERO

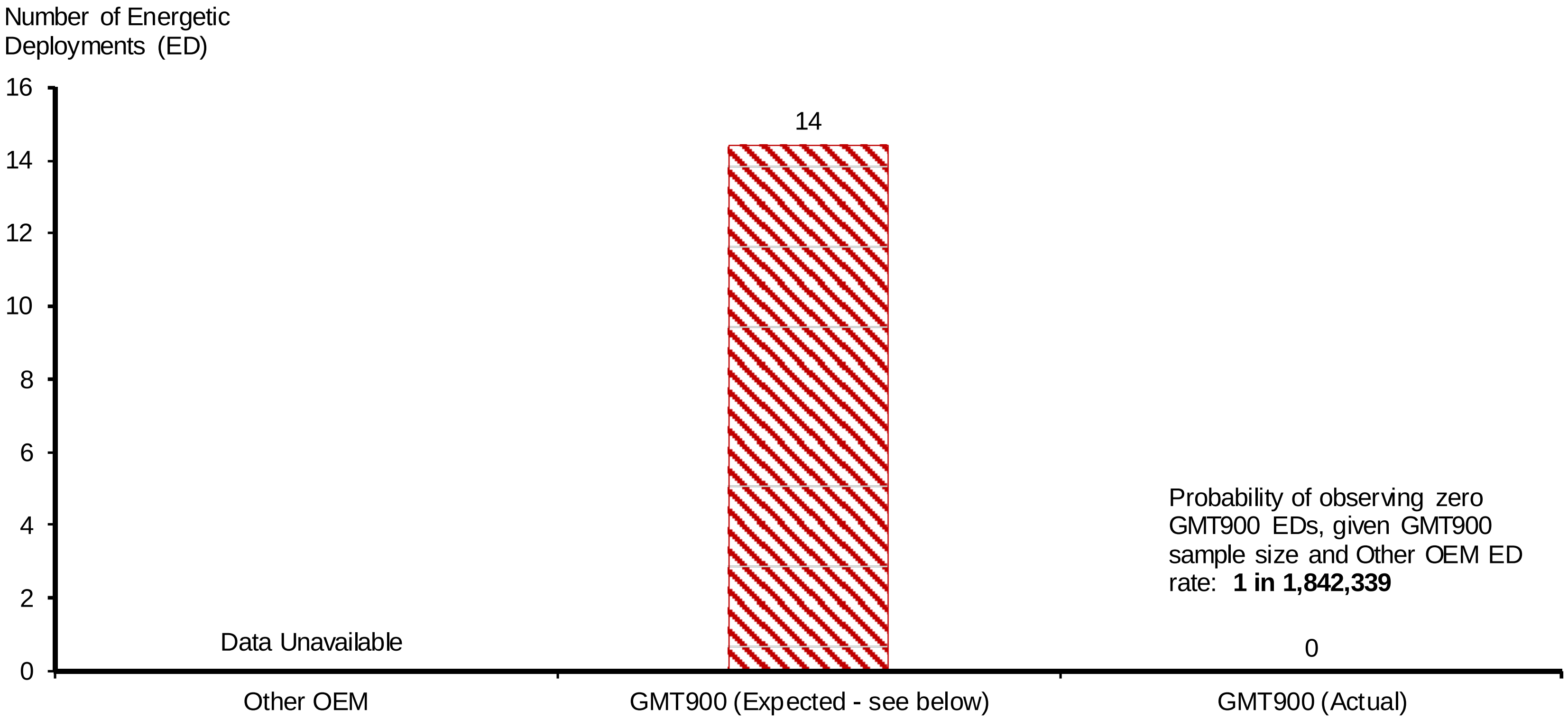


Source: Anonymized MEAF Data, as of 7/31/17 for GMT900 inflators and 3/18/17 for other inflators

Note:
[1] The number of expected GMT900 energetic deployments is calculated by applying the observed energetic deployment rate among inflators in the field-returns data that are (1) from non-GM OEMs, (2) of inflator type "SPI" or "PSPI-L", and (3) 8–10 years old (0.31% = 188/60,682), to the sample size of GMT900 inflators in the field-returns data that are also 8–10 years old (1,714). The probability of observing zero energetic deployments of GMT900 inflators in this sample, given the GMT900 sample size (1,714) and the other OEM energetic deployment rate (0.31%), is calculated as: $(1-(188/60{,}682))^{1{,}714}$ = 0.49%, which is equivalent to 1 in 204, rounded to the nearest whole number.

G E

FIELD CRASHES RESULTS:
OTHER OEM ED RATE APPLIED TO GMT900 INFLATORS VS. MEASURED GMT900 ED RATE OF ZERO



Source: GM Estimates of Vehicles in Service; Anonymized MEAF Data, as of 7/31/17 for GMT900 inflators and 3/18/17 for other inflators

Note:
[1] Data on the number of non-GM vehicles with a Takata inflator are currently unavailable to GM.
[2] The number of GMT900 energetic deployments is estimated by applying the observed energetic deployment rate among inflators in the field-returns data that are (1) from non-GM OEMs, (2) of inflator type "SPI" or "PSPI-L", and (3) 8–10 years old (0.31% = 188/60,682), to the estimated number of GMT900 deployments on the road among inflators that are 8–10 years old, according to GM (4,649). The probability of observing zero energetic deployments of GMT900 inflators in this sample, given the GMT900 sample size (4,649), is calculated as: $(1-(188/60,682))^{4,649}$ = 0.00005428%, which is equivalent to 1 in 1,842,339, rounded to the nearest whole number.

G E

COMBINED RESULTS

- If the GMT900 had the same ED risk as the other vehicles considered, the probability of observing zero EDs across all three independent sources is **vanishingly small**:

Lab		Field Returned		Field Crashes		Combined
1 in 1,146,363	x	1 in 204	x	1 in 1,842,339	=	1 in 430,973,817,921,320
						or
						0.000000000000232%

1 in 430 trillion

GENERAL MOTORS

SOME CONCLUDING THOUGHTS

- The absence of EDs among GMT900 inflators is **potent evidence** of low risk, and is not somehow less persuasive because no EDs were observed.
- If additional certainty is needed on the risk of ED in GMT900 inflators, additional time for more testing would be warranted. **But the evidence up to this time has been extensive, and it could not be better.**

CORNERSTONE RESEARCH

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GENERAL MOTORS

GMT900 INVESTIGATION – SUMMARY OF RESULTS

GMT900 INVESTIGATION – SUMMARY OF RESULTS

The GMT900 inflators utilize a unique design with features that, along with the GMT900 vehicle environment, make them more resilient to heat/humidity induced rupture risk compared to other Takata inflators in other vehicles.

All available data supports the conclusion that the GMT900 inflators are uniquely resilient against heat/humidity induced rupture risk:

Orbital ATK Aging Study

- An accelerated aging study **simulating 30 years of exposure** at extreme temperatures and moistures levels
- This study **induced ruptures and abnormal deployments in inflators used in Pontiac Vibes and other OEM vehicles**
- **None of the GMT900 inflators ruptured**, abnormally deployed, or displayed the warning signs associated with a possible future rupture, **despite identical aging conditions**

Field Incident Analysis

- Analysis of field crashes indicating more than 60,000 deployments of GMT900 Takata airbag inflators **without a reported ru**pture

Returned Parts Analysis

- Successful ballistic testing of over 4000 GMT900 inflators returned from the oldest GMT900 model years mainly from the highest risk areas of the country (Zone A) **without a rupture or high-pressure deployment**

TECHNICAL PRESENTATION

GMT900 INVESTIGATION
TAKATA FRONT PASSENGER AIRBAG INFLATORS
TECHNICAL PRESENTATION

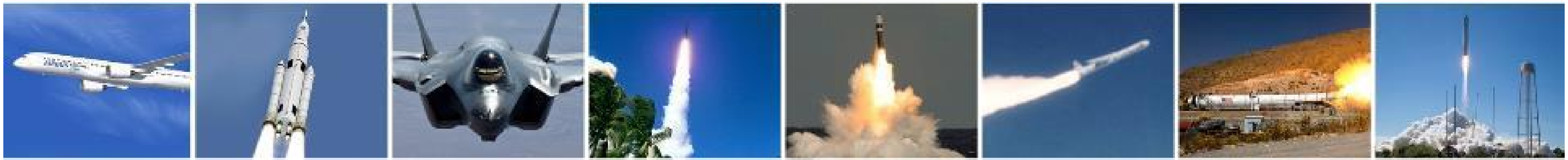
GENERAL MOTORS

ORBITAL ATK AGING STUDY

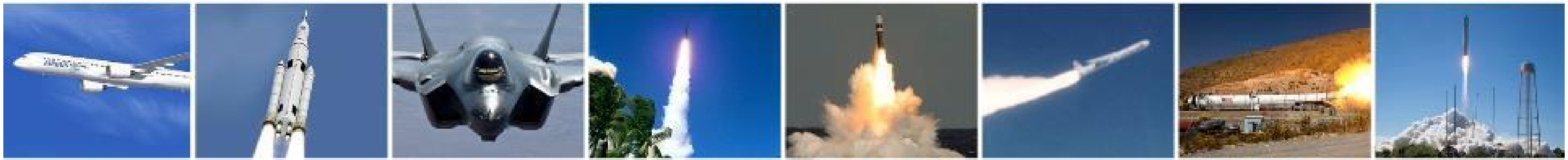
Scientific Aging Study with General Motors

Briefing to NHTSA

23 August 2017



Aging Study and Overview



GMT-900 Investigation – Aging Matrix

Orbital ATK

ORBITAL ATK LONG TERM AGING STUDY

Takata Inflator Build

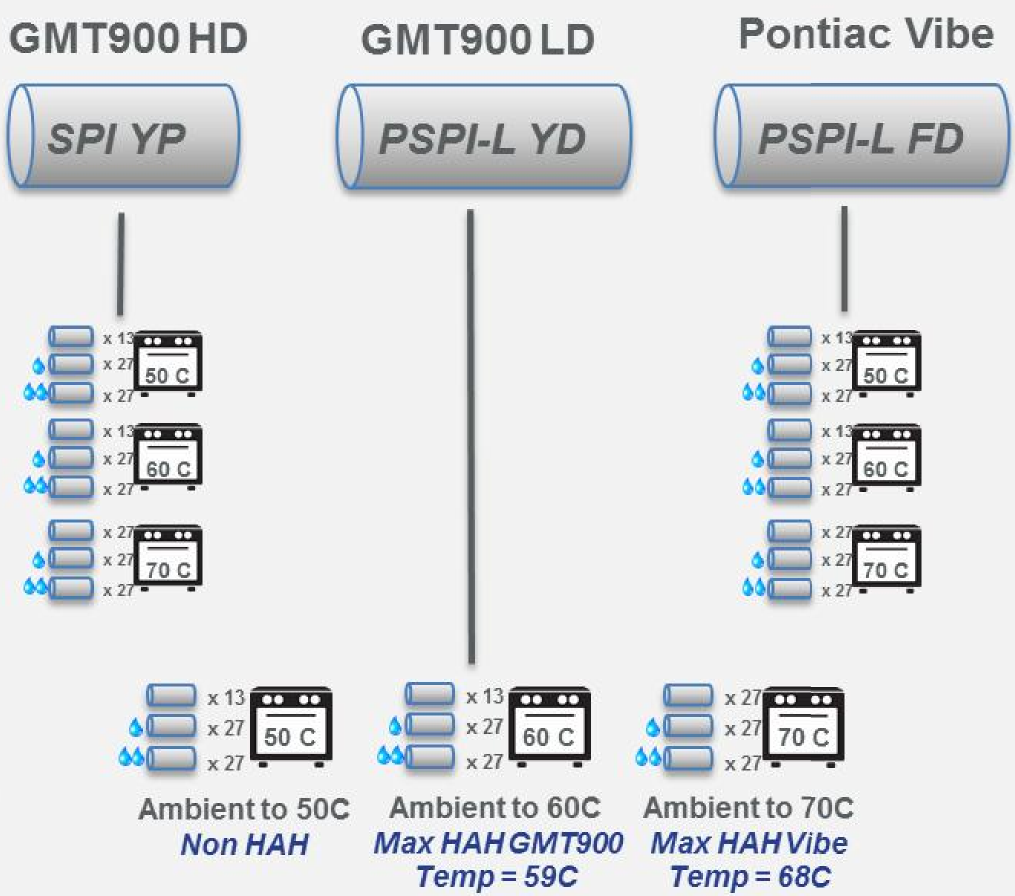
Normal Build

0.15% 2004 Propellant Weight

0.30% 2004 Propellant Weight

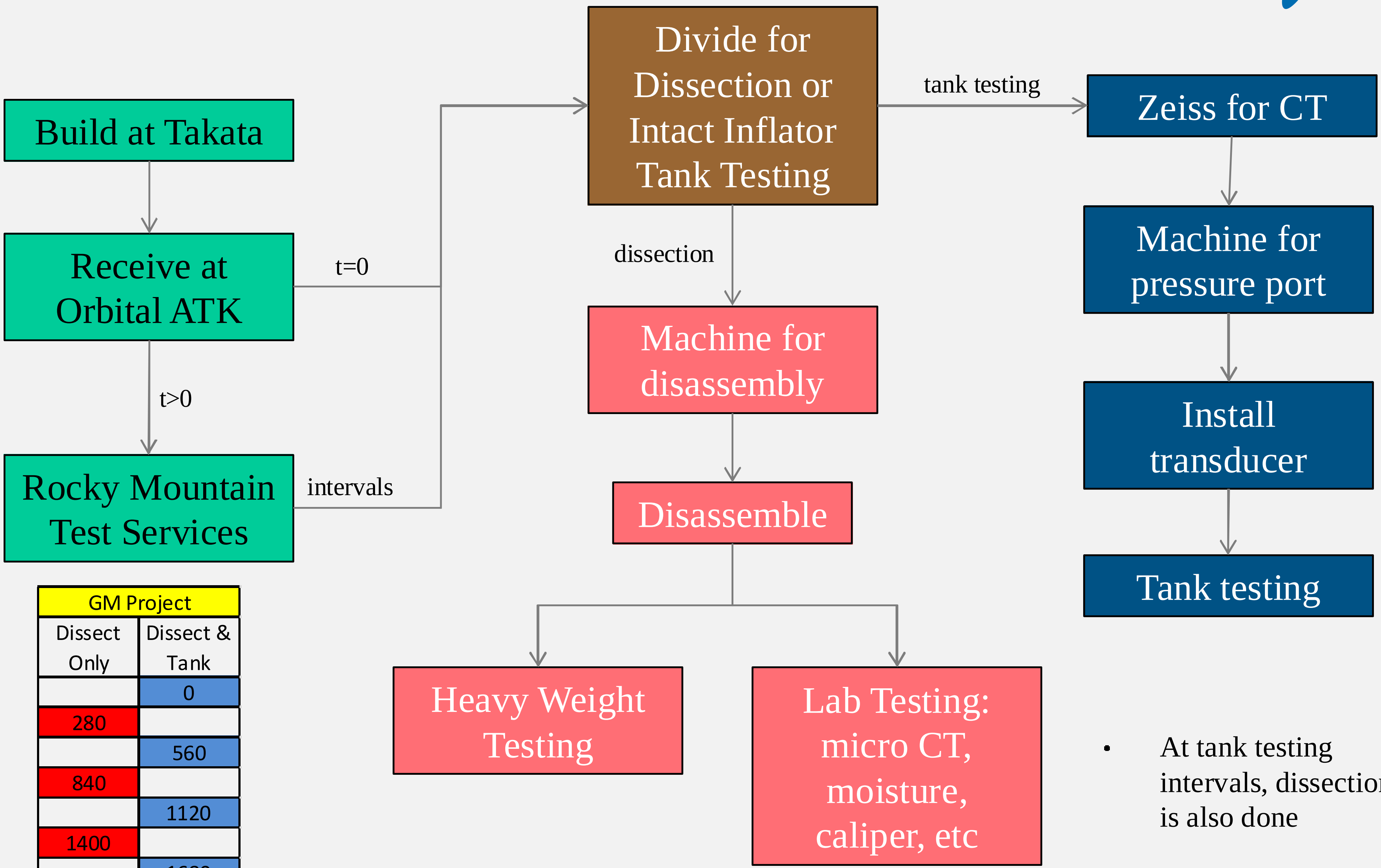
Aging (Temperature Cycling)

- 280 Cycles (5 Years) – Aug 2016
- 560 Cycles (10 Years) – Oct 2016
- 840 Cycles (15 Years) – Nov 2016
- 1120 Cycles (20 Years) – Jan 2017
- 1400 Cycles (25 Years) – Feb 2017
- 1680 Cycles (30 Years) – April 2017
- Final Report – Aug 2017



Samples pulled at regular intervals for dissection, CT scanning, deployment & other analysis

Parts Flow Summary



GM Project	
Dissect Only	Dissect & Tank
	0
280	
	560
840	
	1120
1400	
	1680

- At tank testing intervals, dissection is also done

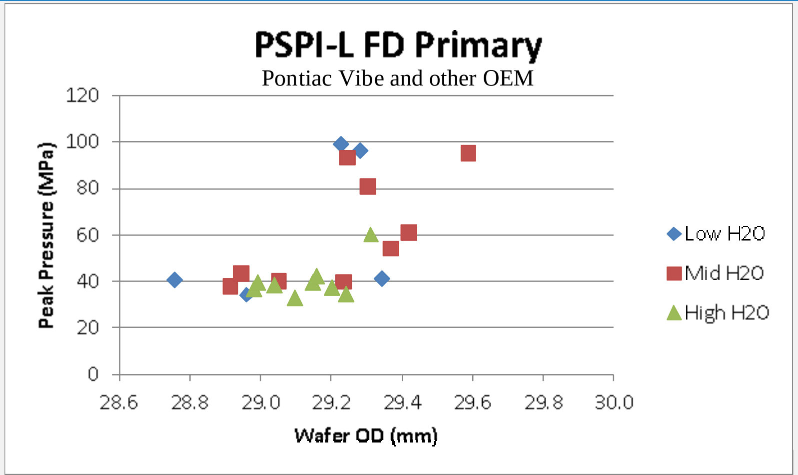
GM Project – Tech Overview

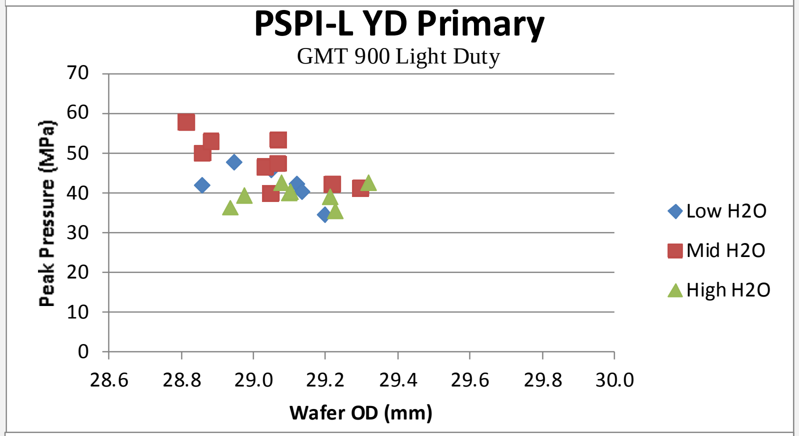
Technical Effort	Brief Description	Summary	Location
Wafer OD and Density	Change in wafers under scientific aging	Higher temperature and higher moisture results in faster growth	Page 46, Backup 101
Inflator Ballistic Tank Testing	Characterize aged inflators using industry standard tank test	Matched field return results in every aspect including t/P trace for ED events	Page 51, Backup 123
Ballistic Closed Bomb testing	Validate ballistic characteristics of aged wafers	ED prone wafer ballistics consistent with that ED behavior	Page 66, Backup 138
Inflator Ballistic Modeling and Analysis	Model all sytems to explain ballistic results	Coherent narrative on inflator differences connecting to ED	Page 78, Backup 163
Statistical Analysis of Field Data	Review of "MEAF" in conjunction with vehicle field exposure studies	Same inflator in different vehicles shows quite different response. Different vehicles achieve different temperatures under same environmental conditions	**Backup 170**
Moisture in Inflators for Scientific Aging	Testing dissected inflators at time zero and each aging cycle for moisture content for all energetics	Data confirmed that total moisture was not changing significantly (no leakage, very little if any moisture from decomposition of energetic materials)	**Backup 184**
Moisture in Virgin and Field Return Inflators	Compare moisture levels in virgin inflators with field returns	Trends as expected with field returns showing more moisture. AI-1 weight loss is low.	**Backup 182**
Moisture Dynamics Inside Inflators	Develop understanding of how moisture moves between energetic formulations	Moisture moves in and out of 2004 and 3110 easily. Will migrate over time to bentonite in 3110 which is a desiccant. Level of moisture for maximum transfer is sub-saturation of bentonite in 2004 plus 3110.	**Backup 187**
Inflator crimp diameter	Examine manufacturing and design for leakage to allow ingress of excess moisture	Specification ranges allow for significant differences in crimp that can lead to low squeeze on o-rings.	**Backup 190**
O-ring analysis and aging	Examine virgin and aged o-rings for damage that could result in increased leakage over time	O-ring aging reults in slow and modest reduction in capability. Field return o-rings show evidence of a wide range of compressions consistent with crimp/squeeze data.	**Backup 192**
CT Measurements of Inflators	Measure every wafer OD and stack height in inflators	Saw early distortion of wafers near water addition. Did not distort further. Stack height showed fusion of wafers especially in SPI-YP (dual spring)	**Backup 205**
Quench Testing	Interrupt combustion process immediately after ignition to examine fracturing of wafers	Larger wafers do not break up as much. Aged break up lower than initial. Wafers nearest closure break up more.	**Backup 215**
Wafer Crush Strength	Examine whether wafer strength degrades sufficiently over time to explain failures	Wafer strength is more affected by moisture content than aging. Change appears insufficient to explain failures.	**Backup 231**
SEM of Propellant	Obeserve propellant surfaces under extreme magnification for changes during aging.	More highly aged propellant shows significant signs of degradation. Higher moisture affects significantly.	**Backup 234**
Micro CT of Propellant	Look for porosity in propellant bulk	Signs of increased porosity due to very small pores in aged samples.	**Backup 290**
Gas Diffusion through Propellant	Searching for method to directly measure porosity and permeability	Diffusion is reduced on exposure to moisture in propellants and generally increases in aged samples.	**Backup 299**
Infaltor Leak Testing	Attempt to determine leakage rate that can give insight into moisture ingress.	Leakage occurs through every opening in the inflator. Reported rates vary widely and are difficult to measure. In field returns with greater than average moisture, amount cannot be rationalized by diffusion through the o-ring.	**Backup 301**
AI-1 Tablet Testing	Evaluate hypotheses that AI-1 color is an indicator of pending ED or is a source of water inside inflator	AI-1 tablets exposed to moisture in YD inflator exhibited the largest color change. Weight loss was minor and not a signficant contributor to moisture in inflators.	**Backup 305**

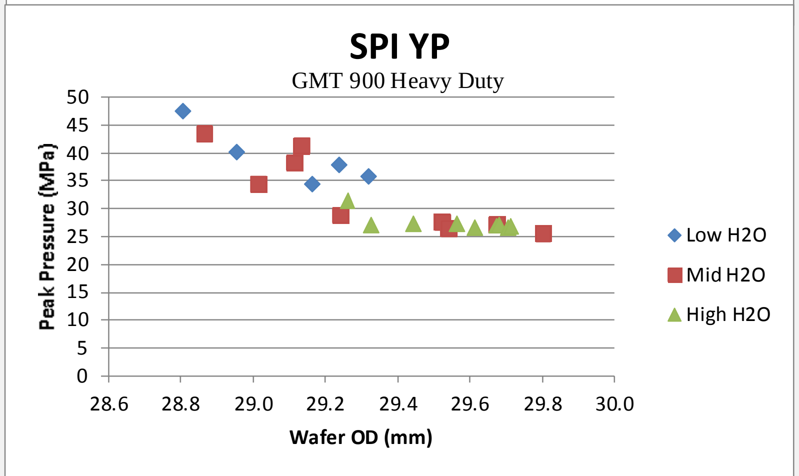
- Full scope of proposed work has been accomplished
- Summary of all work will be included in back-up charts provided to NHTSA
- Scope provides an in-depth study and analysis of every aspect of the subject inflators and their aging characteristics
- Sample size in number of items (inflators/motors) is large compared to typical aging matrices we execute; detail in analysis and testing is similar

- Summary of findings and full scope of work
    - Items highlighted in blue are in main briefing
    - All others in back-up to the presentation

Most Significant Findings

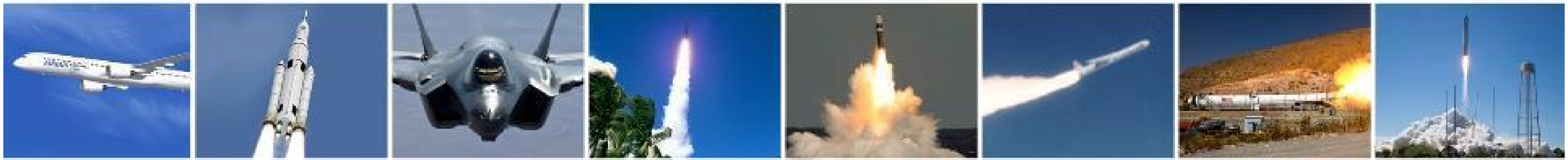






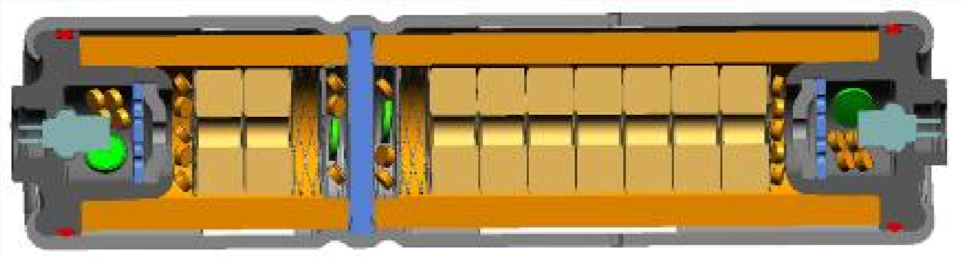
- Scientific aging study is providing desired insight into subject inflator similarities and differences
  - As prepared inflators verified to match desired state for the scientific aging study
  - Multiple methods of test and analysis show consistent results providing confidence in experimental methods and data gathered
- The three subject inflator models are responding differently to the conditions of scientific aging
  - Temperature then moisture are primary drivers
  - FD showing greatest propensity to ED
  - Data correlates well with field returns
  - Technical explanations for differences is reasonable
- The predicted service life of these inflators
  - Data can support service life model input parameters
  - Direct extrapolation matches field return data
- Longer aging will add to strength of data
  - Finding where YD and YP begin to have ED or extending out non-ED will increase confidence in conclusion on relative robustness of inflators

Design Comparisons

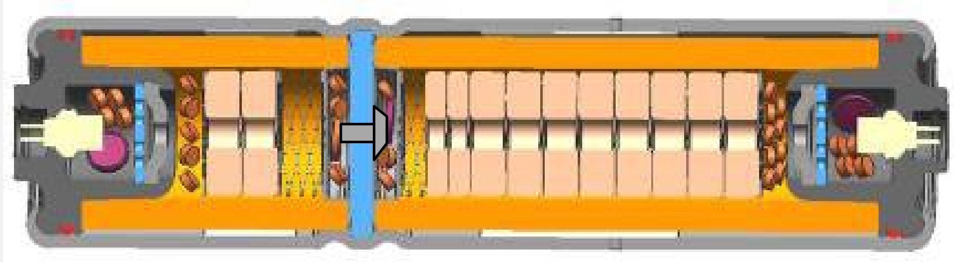


PSPI-L Summary Comparison

FD – Vibe and Other OEM



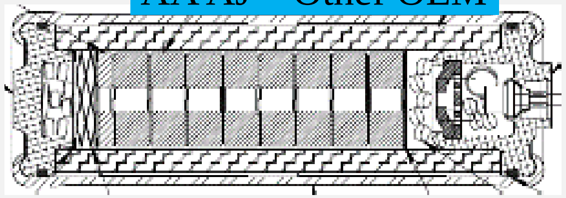
YD – GMT900 Lt Duty



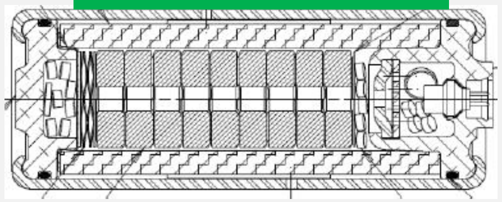
- **Structural Capability**: Equivalent burst capability
  - YD steel closure is stronger than FD aluminum closure
- **Sealing System:** Slight improvement
  - Same crimp OD
  - Same O-ring drawing
  - YD steel closure has less CTE difference; minor improvement
  - YD burst tape thickness increase from 0.20mm to 0.25mm; greater resistance to manufacturing flaws and handling damage
- **Igniter**: Ballistic equivalent
- **Ballistics**
  - Same propellants
  - Same AI assemblies
  - YD goes away from 10.8 gram wafers on both primary and secondary. This will affect breakup on ignition, and resulting surface area vs web.
  - YD Primary has 8x2.4mm vents vs 6x2.57 mm vents for FD. More vents better distributes heat to filter pack, and is better tolerates blockage of an individual vent.
  - YD Secondary has 2 x2.4mm vents vs 4x2.35 mm vents for FD. Fewer vents concentrates heat to filter pack, and is less tolerant of individual vent blockage.
  - YD has 4 layer vs 5 layer FD filter pack. Comparable ballistics.

SPI Summary Comparison

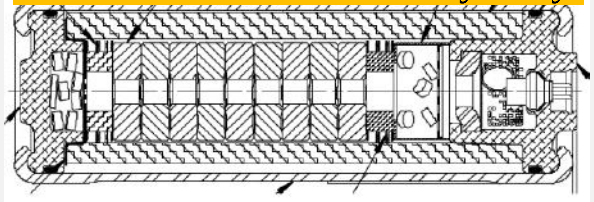
AA AJ – Other OEM



MG DH – Other OEM



YP Rev H – GMT900 Hvy Duty

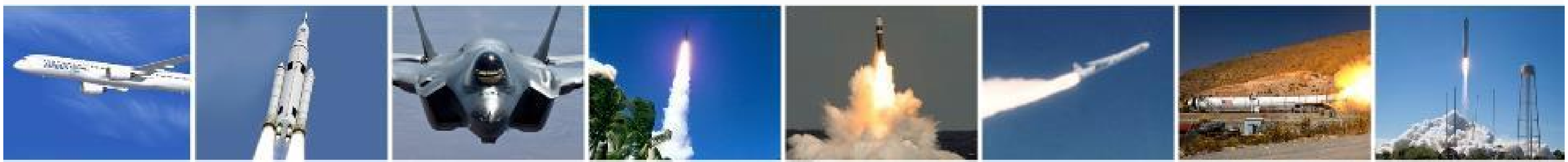


- YP is most similar to MG/DH
- Primary difference is ignition train/wafer support

- **Structural Capability**: same
- **Sealing System**: Comparable
  - Same crimp OD
  - Same O-ring drawing
  - Comparable shim tape thickness
- **Igniter**: YP has revised ignition train and wafer support
- **Ballistics**
  - Same propellants
  - Comparable AI assemblies
  - YP same wafers as MG/DH
  - YP vent area is comparable to MG/DH
  - Comparable screen packs

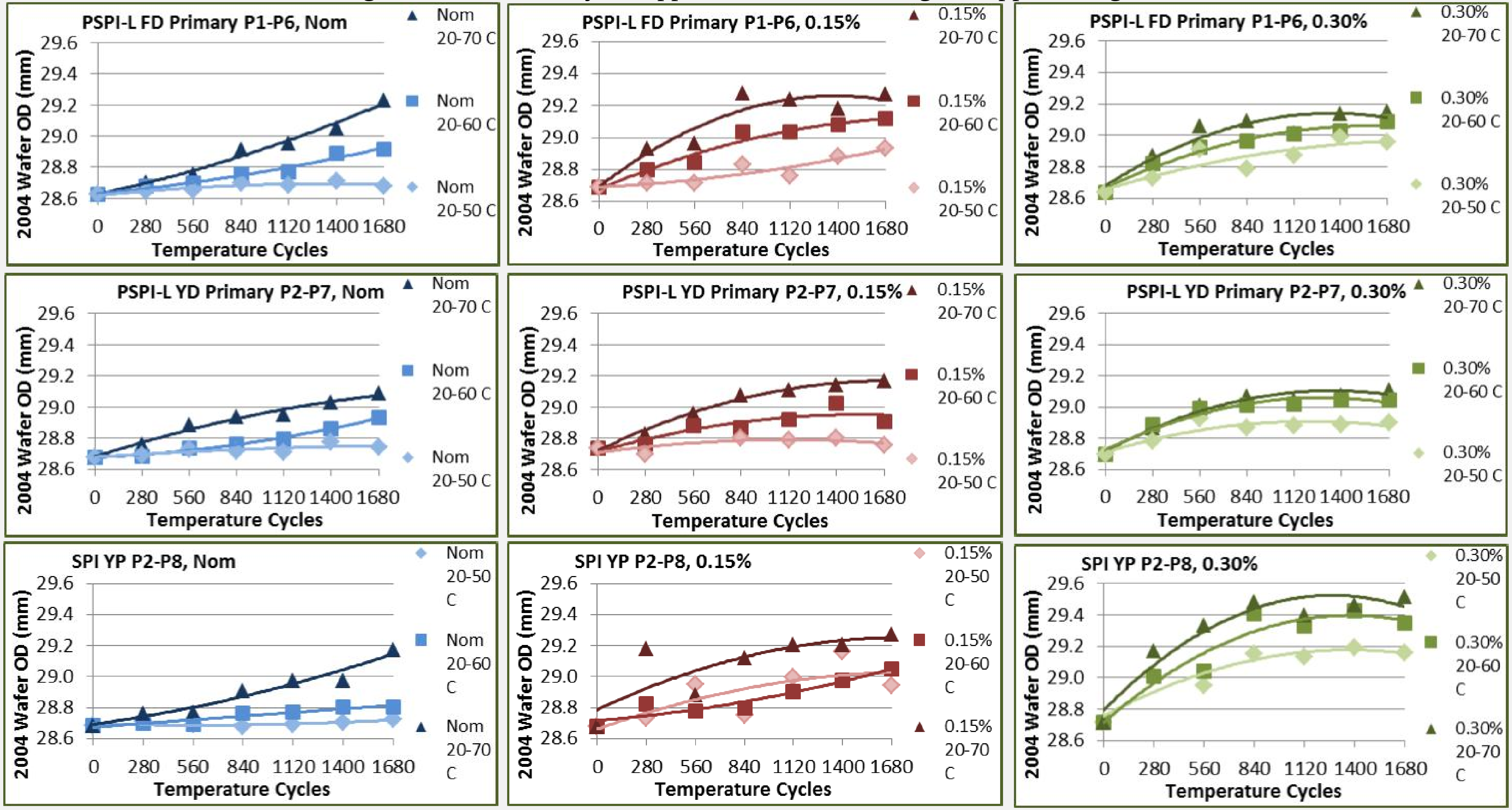
Comparison to PSPI-L Primary
- 9 medium wafers
- Retaining springs at both ends
- Vent area = 42.47 mm^2
- FD vent area = 31.25 mm^2
- YD vent area = 36.19 mm^2

Wafer Growth under Aging Conditions



Primary Chamber Wafer OD Caliper Measurements

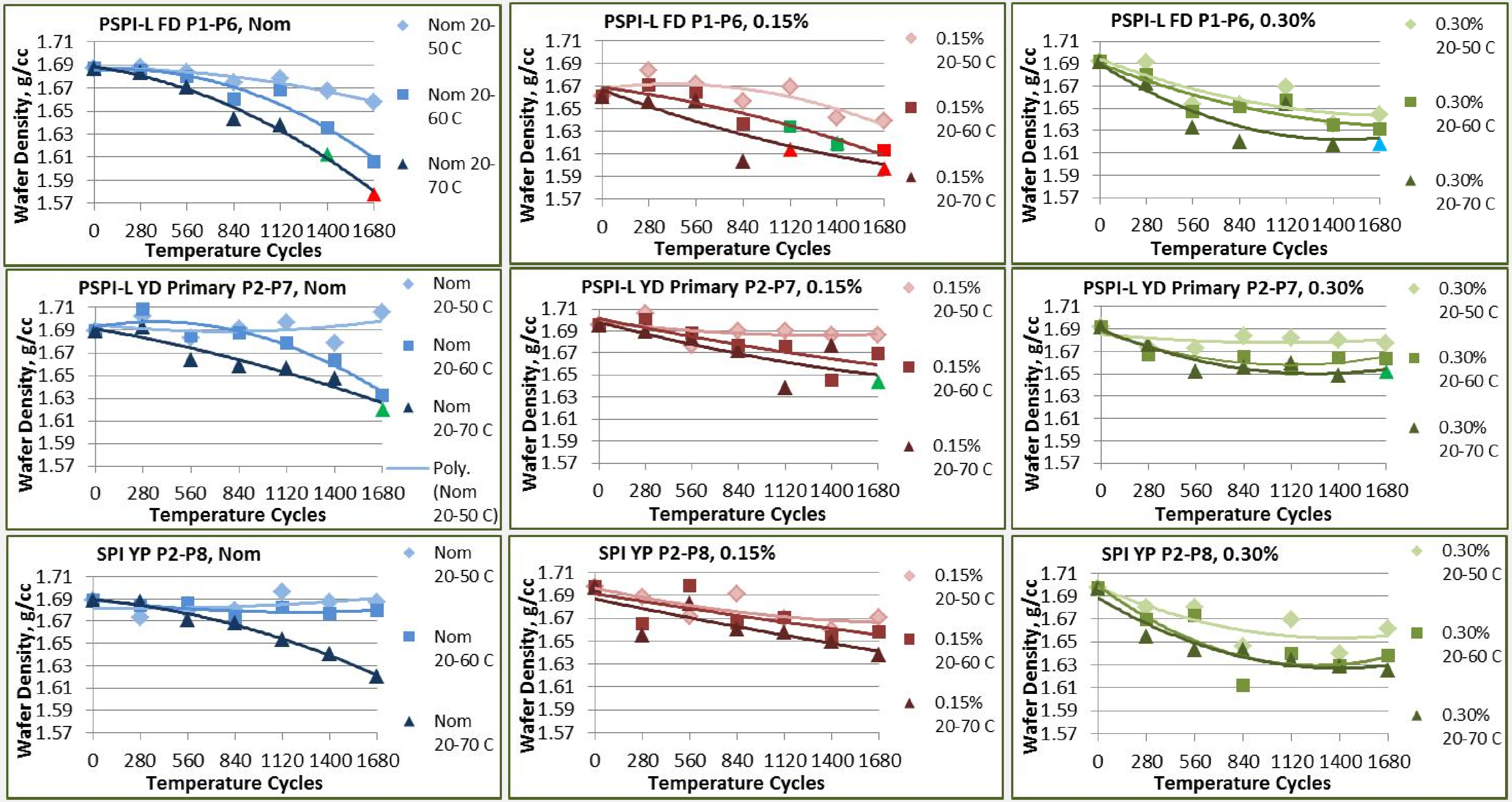
- FD (Vibe and other OEM) and YP (GM Hvy duty) outer diameters are larger than the corresponding YD (GM Lt Duty)
  - YP 0.30% outer diameters are the largest – density does not follow – appears to be compression related
- Growth of wafers with added moisture appear to be slowing down in growth
  - Nominal wafer OD growth at 20-70 C cycle, appears to be accelerating and approaching moisture added values



ED
Near ED
CB Abnormal Burn

Primary Chamber Wafer Caliper Density

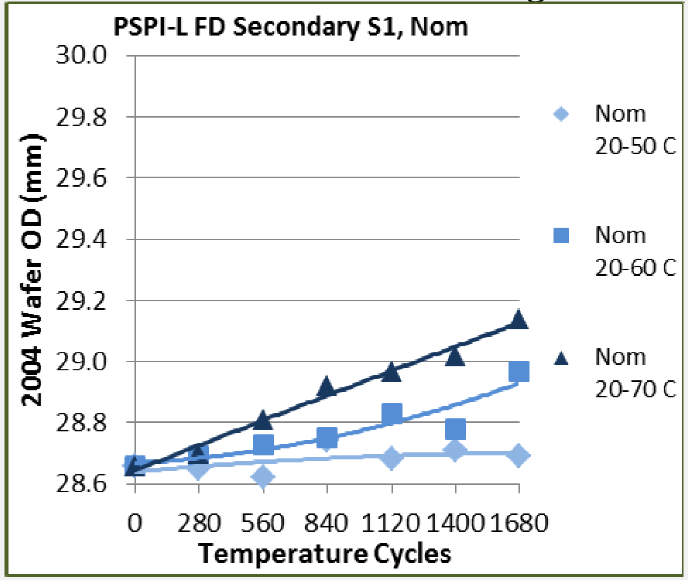
- FD nominal and mid 20-70 C densities are the lowest - EDs at 1680 cycles are occurring with these inflators
- FD and YP 0.30% densities are lower that the corresponding YD. YP OD's were greater than FD, densities are similar.
- Decrease in density at higher moisture levels is slowing down
  - Decrease in nominal wafer density, especially 20-70 C cycles, appears to be accelerating

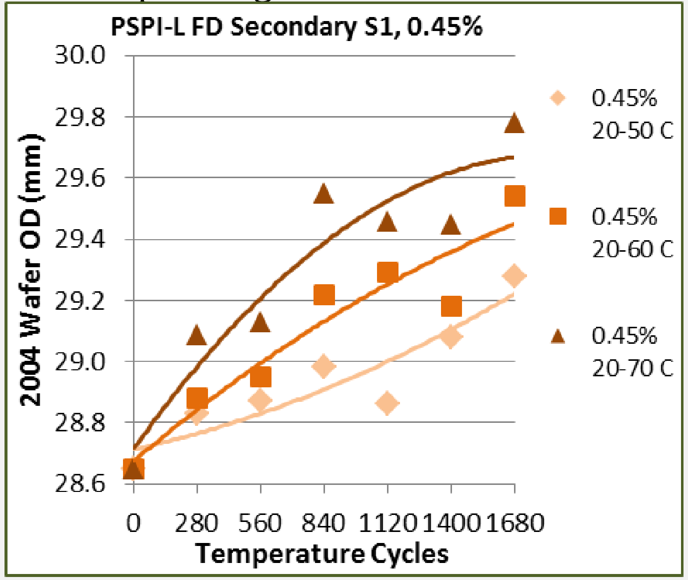


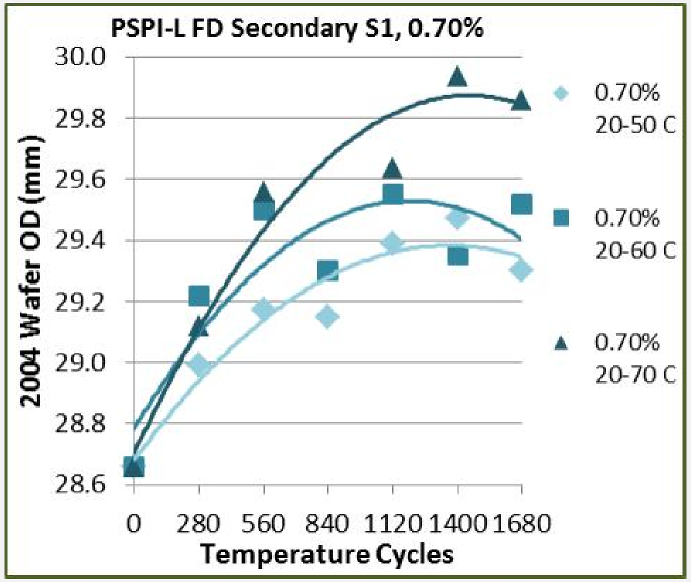
PSPI-L FD & YD Secondary Chamber Caliper Measurements

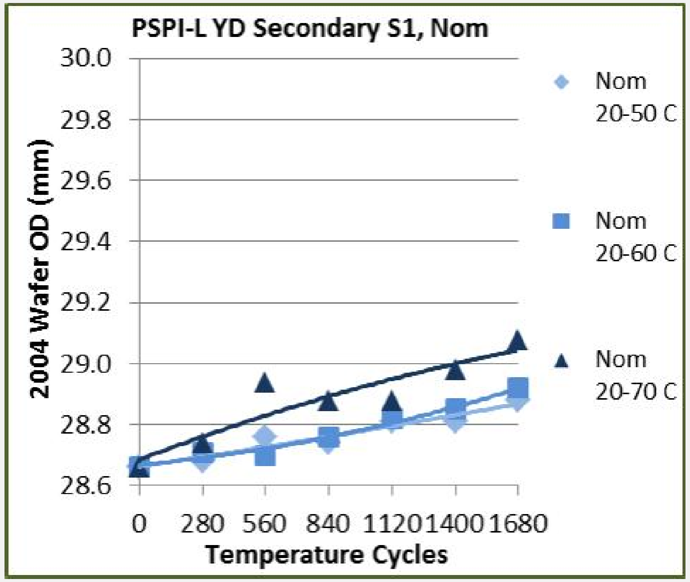
Orbital ATK

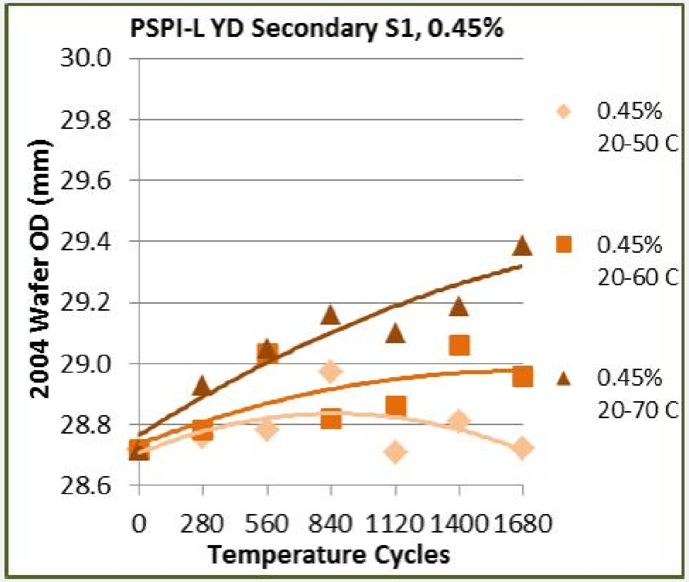
- Growth in secondary FD and YD nominal wafer OD is less than in the primary chamber
    - Mid and high moisture wafers are increasing in OD at a greater rate than the nominal in the secondary chamber
- FD outer diameters are larger than the corresponding YD

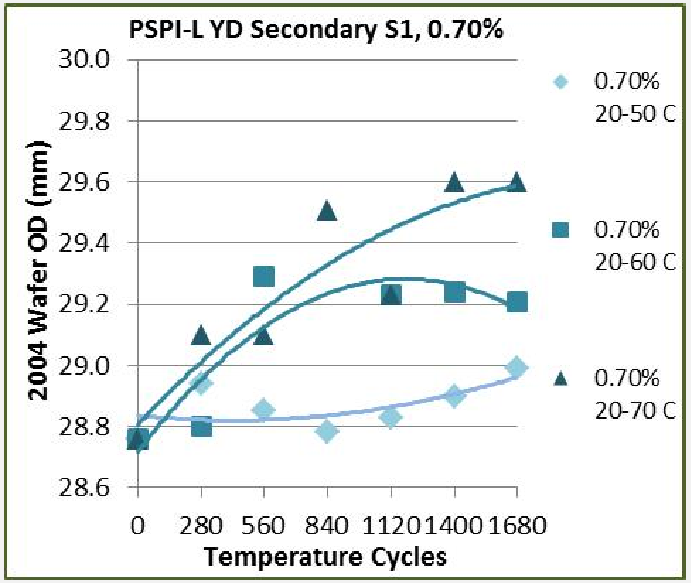








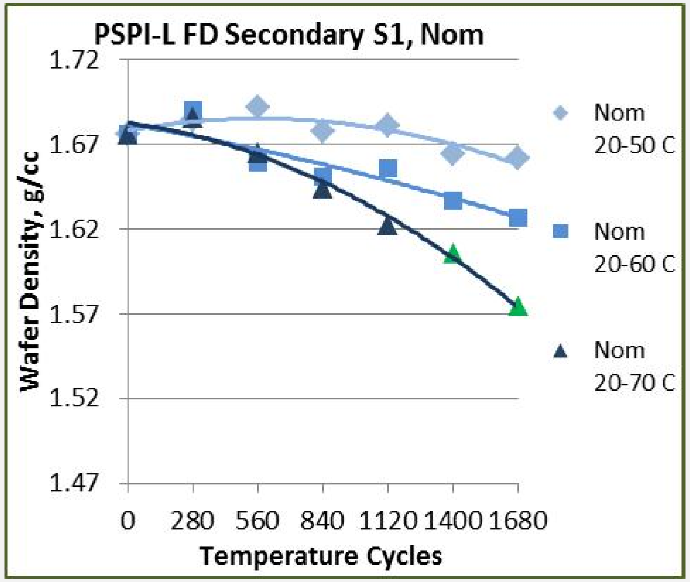


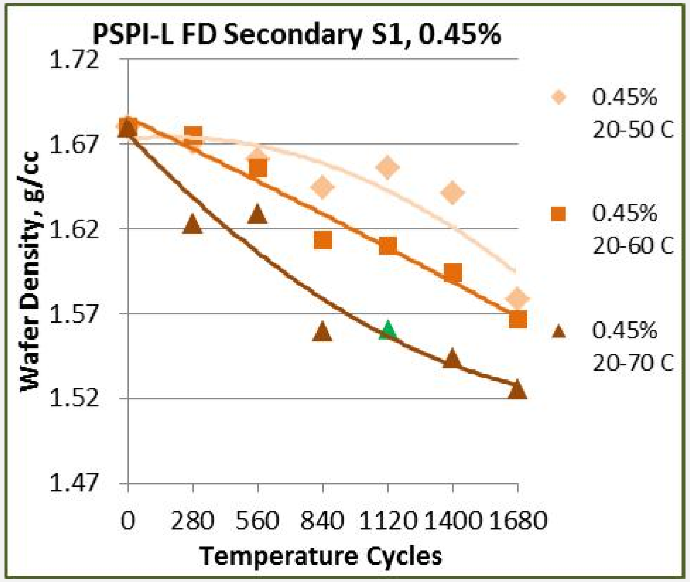


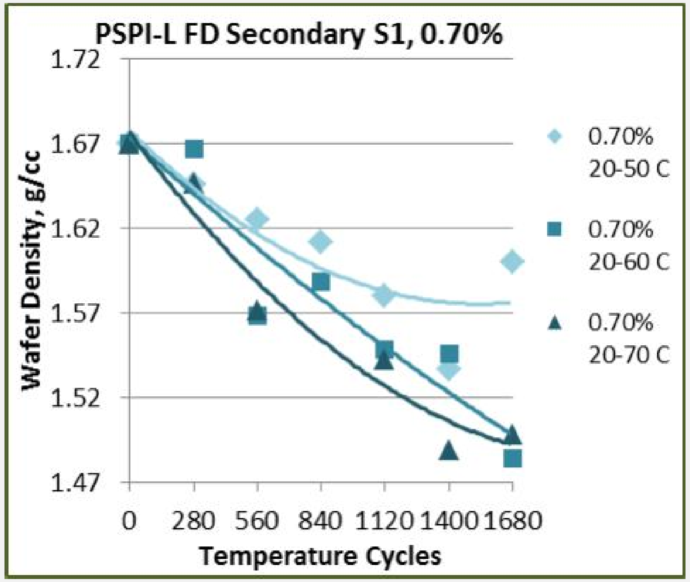
PSPI-L FD & YD Secondary Chamber Caliper Density

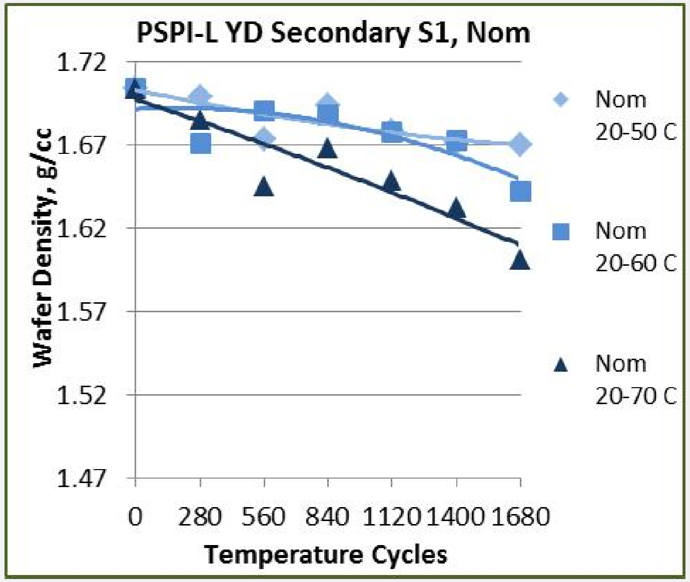
CB Abnormal Burn

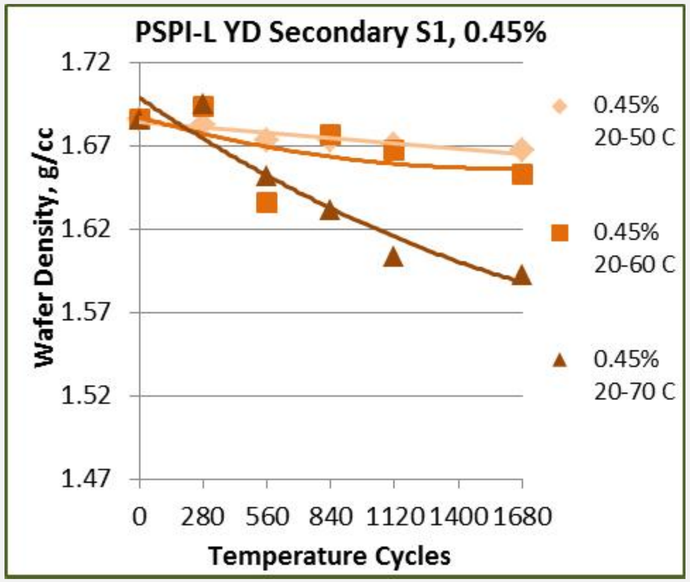
- Decrease in secondary FD and YD nominal wafer density comparable to that in the primary chamber
  - ➢ Mid and high moisture wafers are loosing density at a greater rate than the nominal in the secondary chamber
- FD densities are lower than the corresponding YD

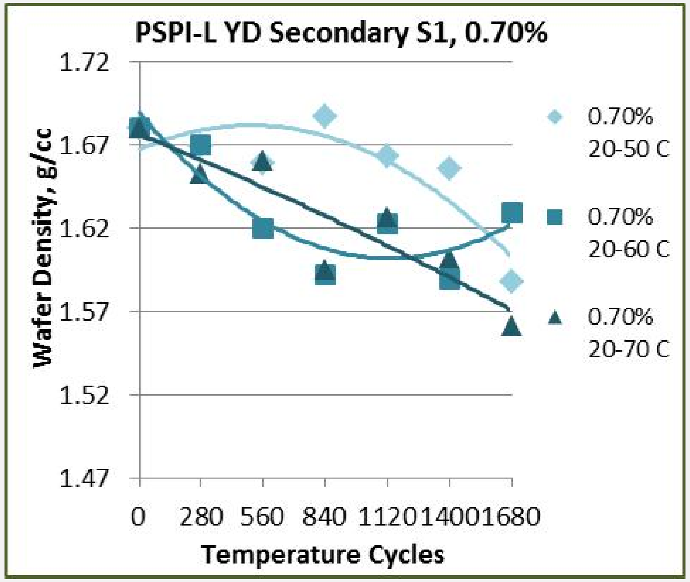




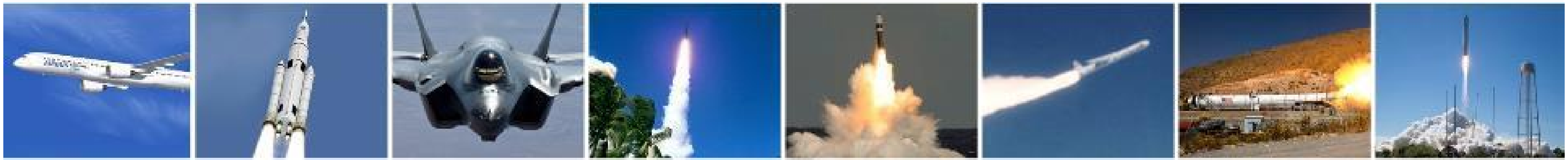








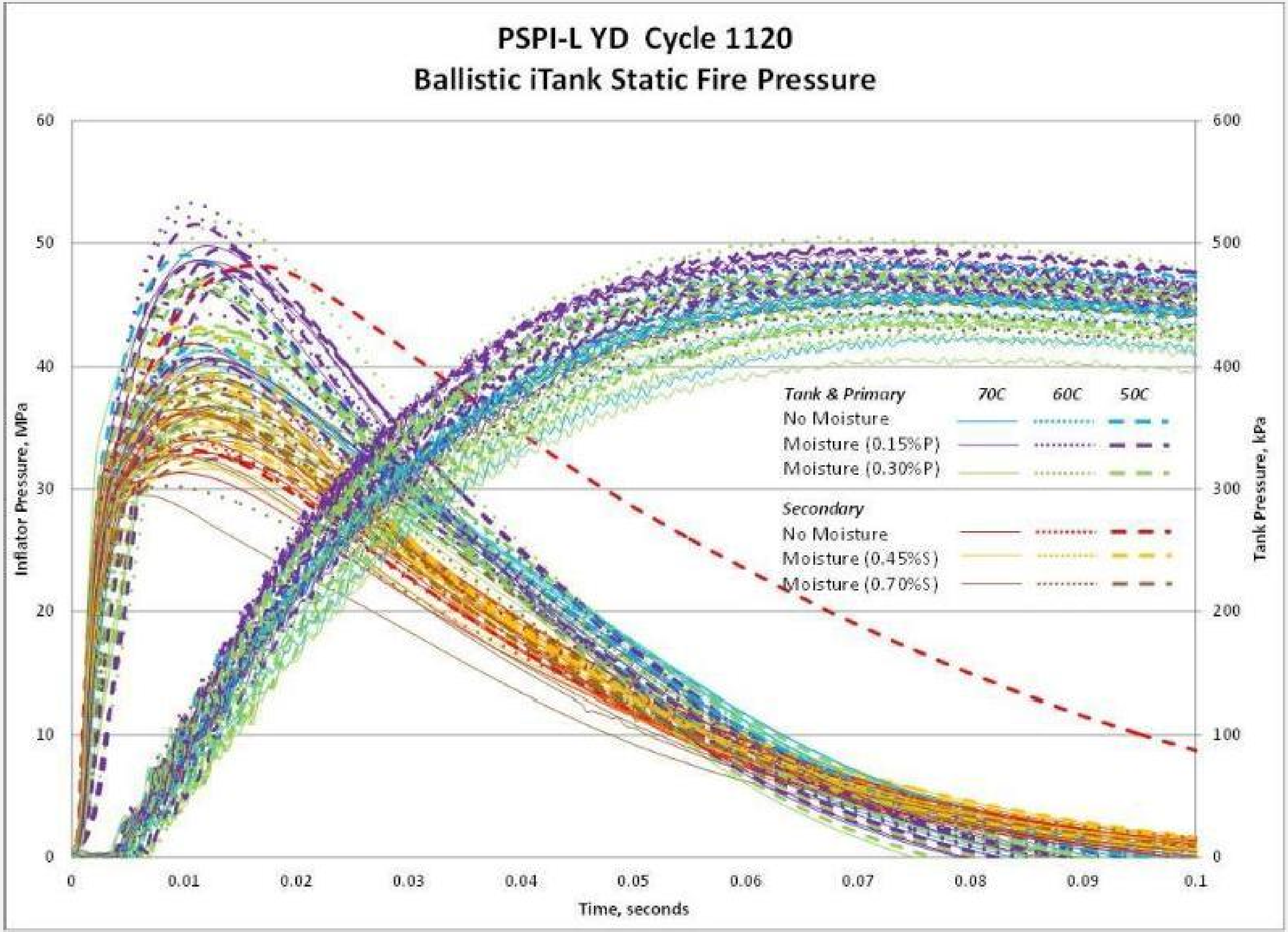
Ballistic Testing in Standard Tank



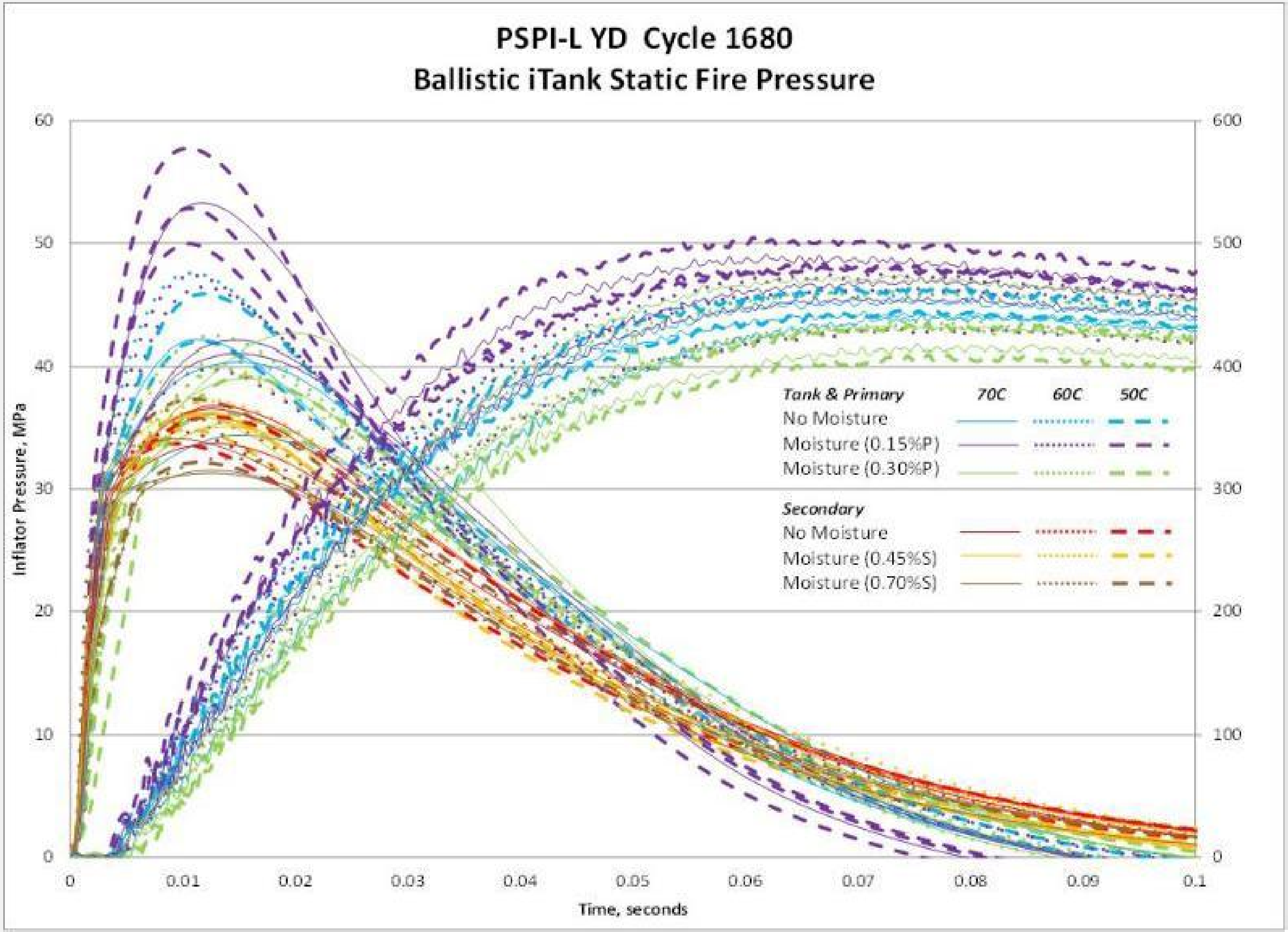
GM Tank Testing

- Status
  - All PSPI-L YD (GM Lt Duty) 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are starting to show higher performance over the 1140 cycle results
    - Highest combustion pressures come from mid moisture levels
    - Lowest performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is now equivalent for all three moisture levels and the general trend of reduced combustion pressure with larger wafer OD is seen for the mid and low moisture levels
    - This trend is not apparent in the secondary chamber, also wafer growth at the high moisture level outpaces the lower moisture levels

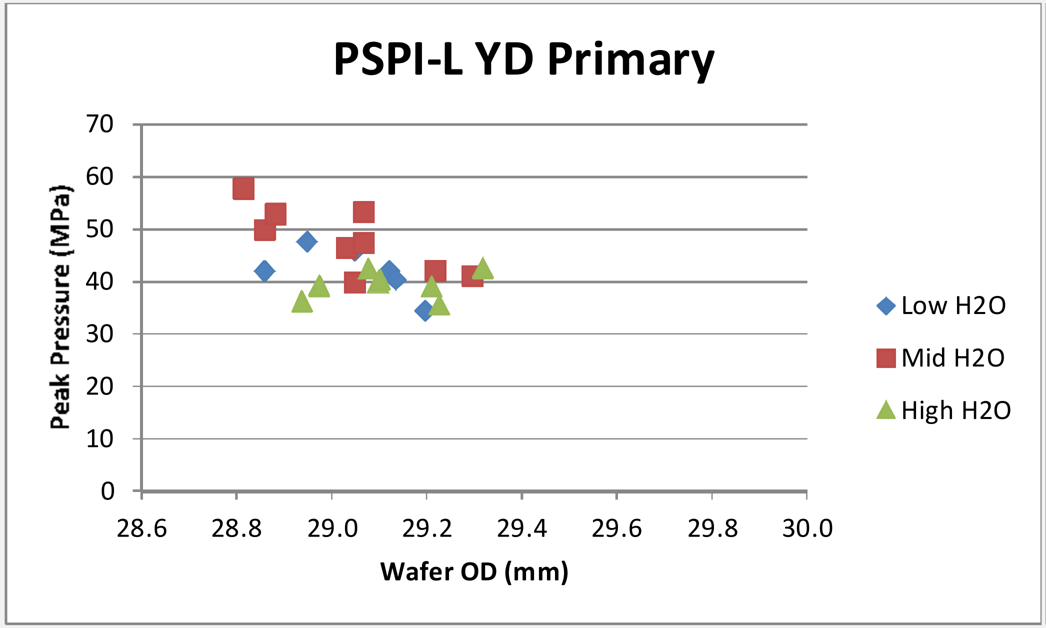
GM Tank Testing Cycle 1120

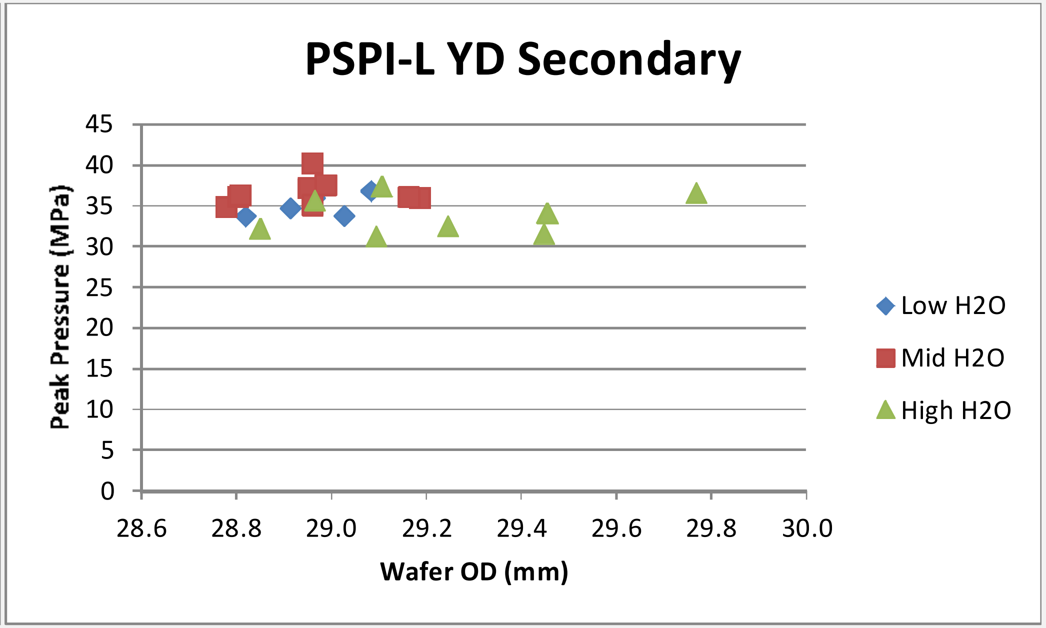


GM Tank Testing Cycle 1680



GM Tank Testing Cycle 1680

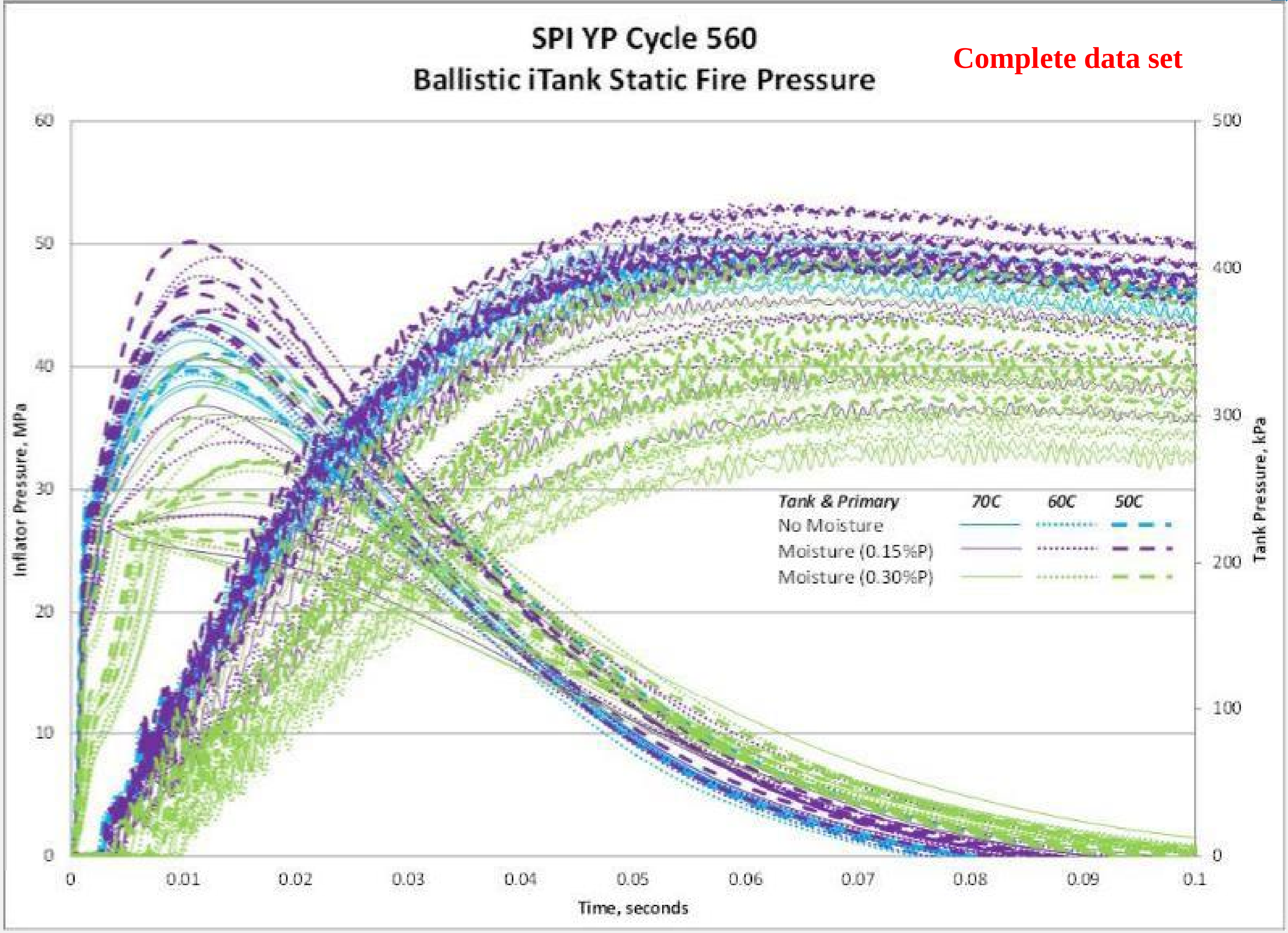




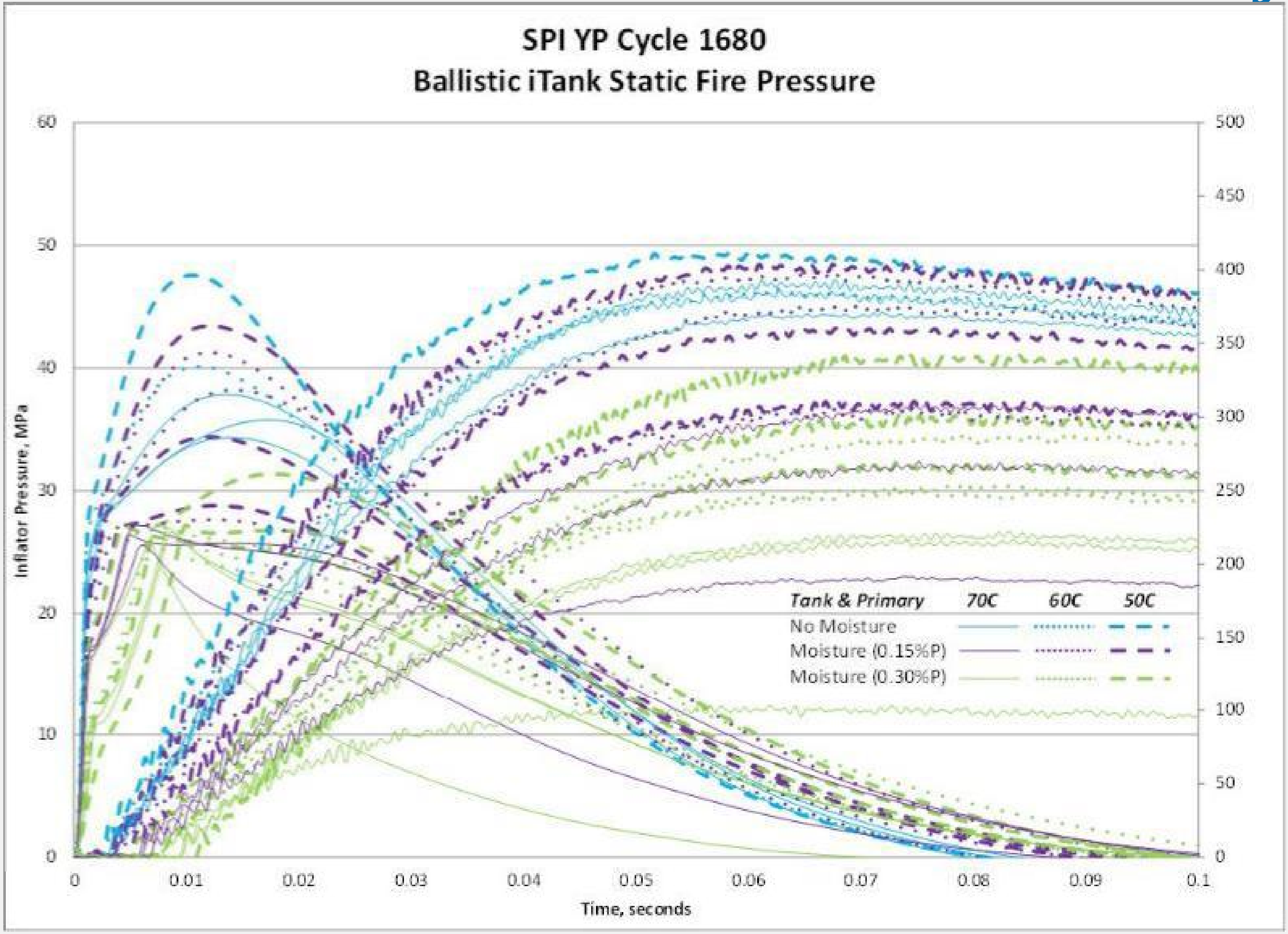
GM Tank Testing

- Status
  - All SPI YP (GM Heavy Duty) 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are showing lower performance than the 560 cycle results (used 560 due to correction issues with 1120)
    - Highest combustion pressures come from nominal and mid moisture levels 50°C
    - Lowest performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is similar for all mid and high moisture levels, lower for nominal
    - The trend of reduced combustion pressure with larger wafer OD is very apparent in this inflator

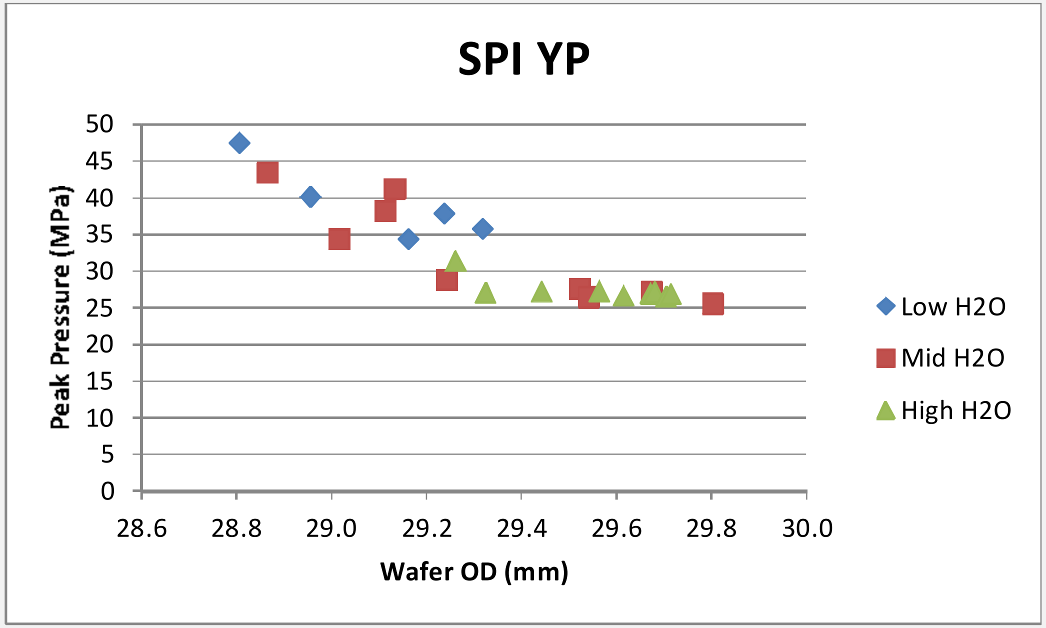
GM Tank Testing Cycle 560



GM Tank Testing Cycle 1680



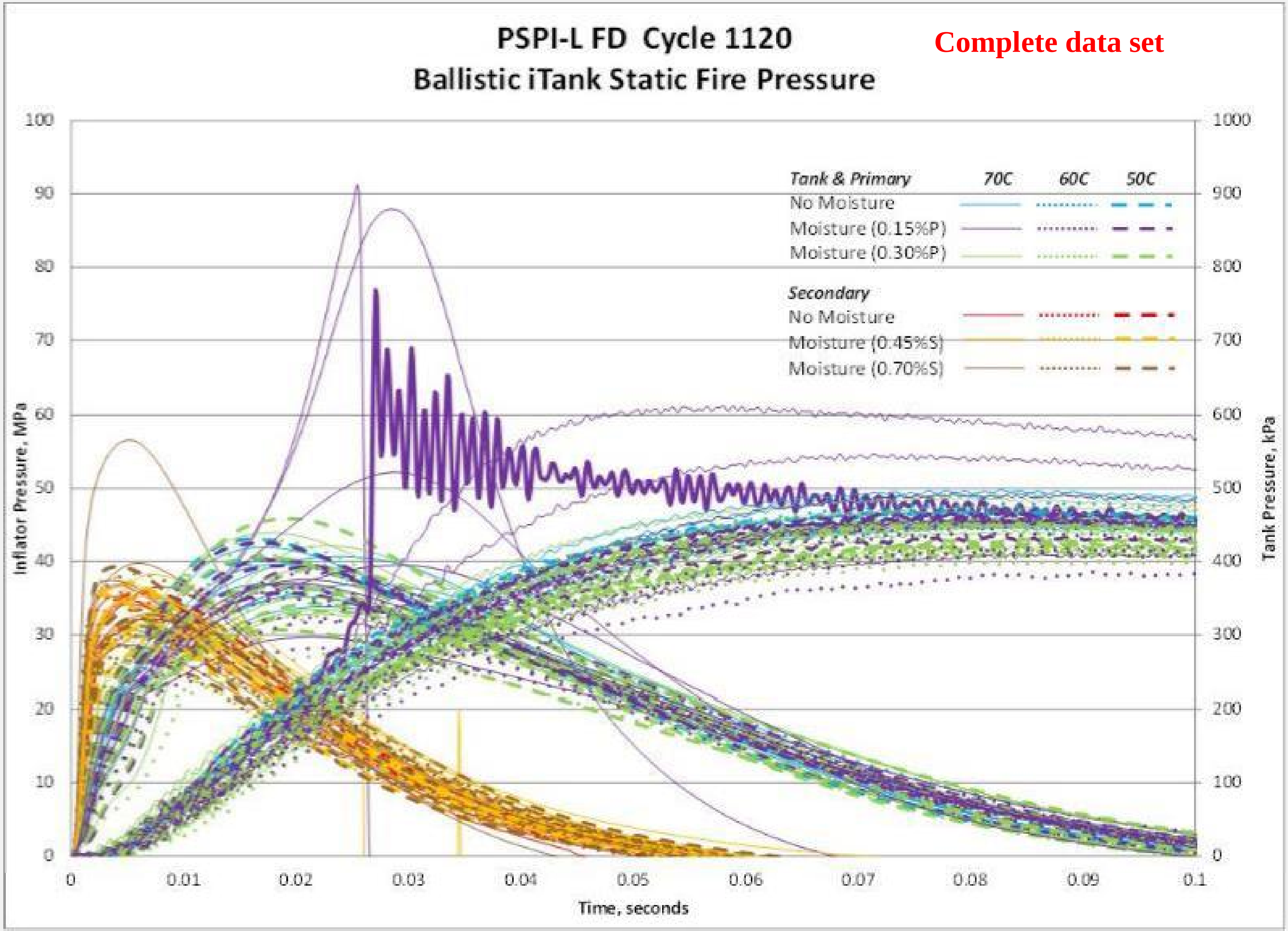
GM Tank Testing Cycle 1680



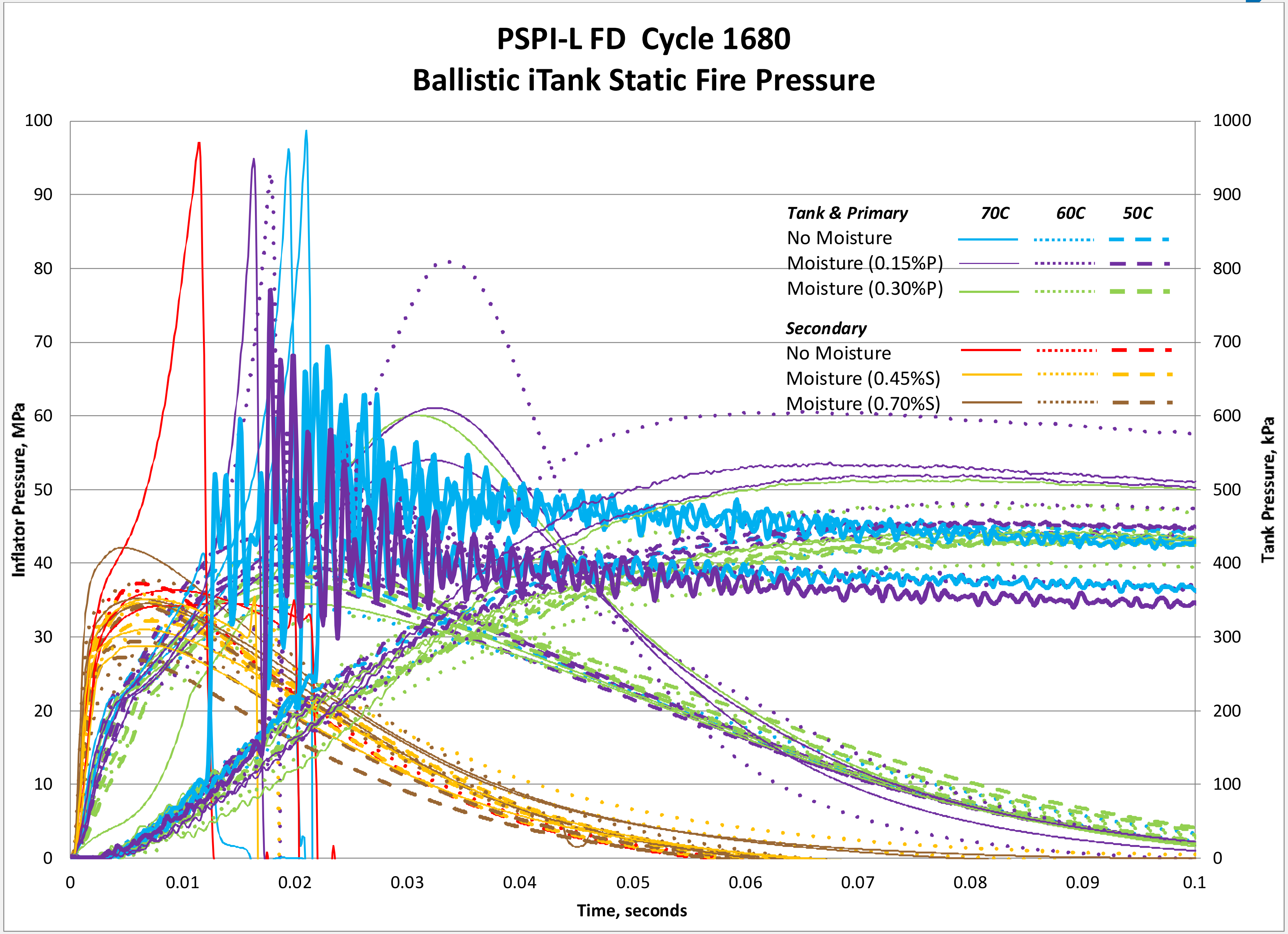
GM Tank Testing

- Status
  - All PSPI-L FD (Vibe and other OEM) 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are moving into higher probabilities of ED events (5 ED & 5 abnormal ED type behavior events so far)
    - Abnormal behavior including ED's are now occurring at high temperature nominal moisture levels and high/mid temperature mid moisture levels all in the primary chamber, only one abnormal curve at high moisture level
    - Marginally lower performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is trending higher at mid moisture levels and the trend of reduced combustion pressure with larger wafer OD is not seen, an ED threshold OD is ~29.2mm
    - The secondary chamber has reached an ED threshold OD of 29.4mm only for nominal moistures, also wafer growth at the high moisture level outpaces the lower moisture levels
    - Abnormal ED type behavior curves have slower start and higher time to peak

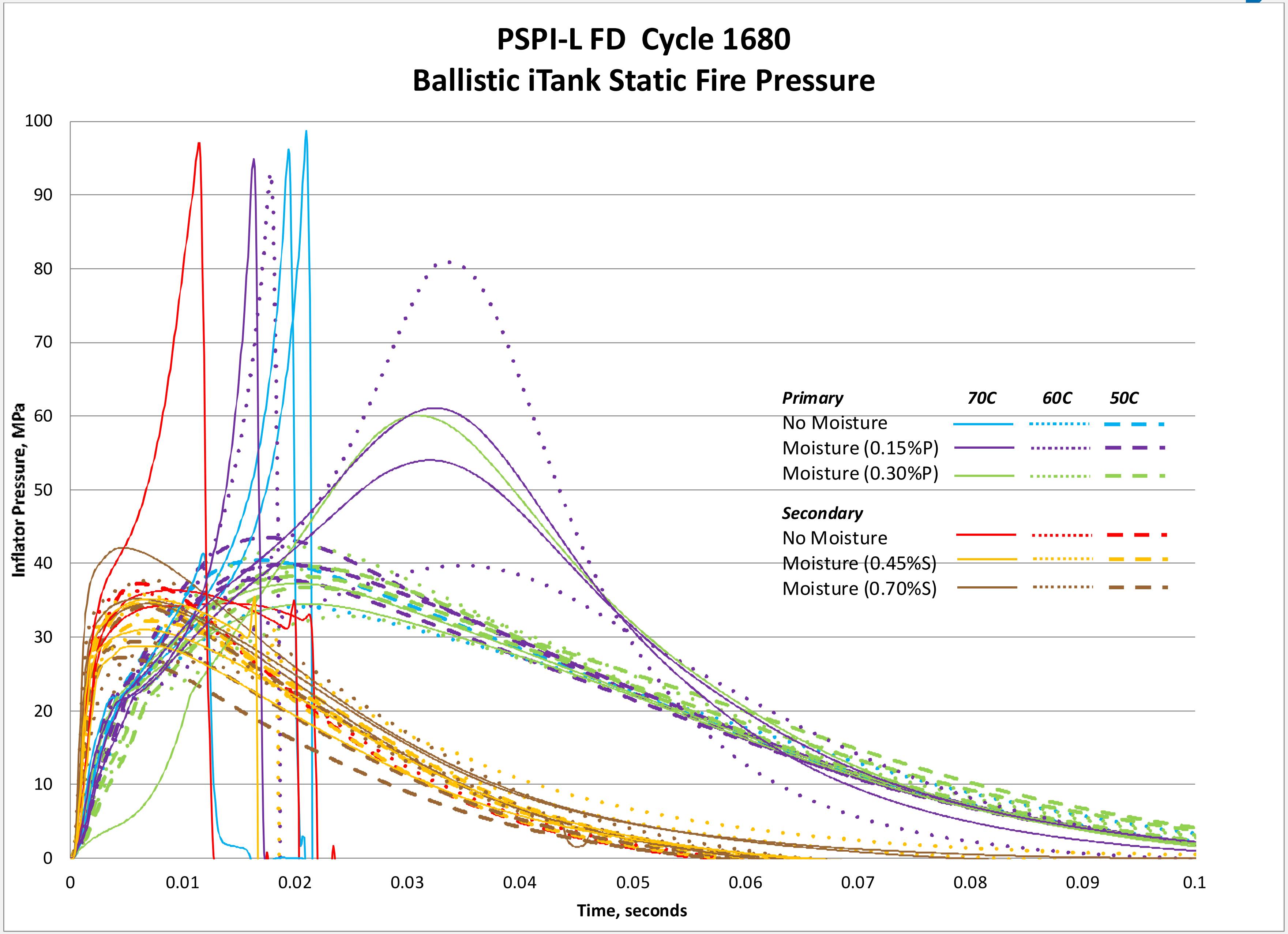
GM Tank Testing Cycle 1120



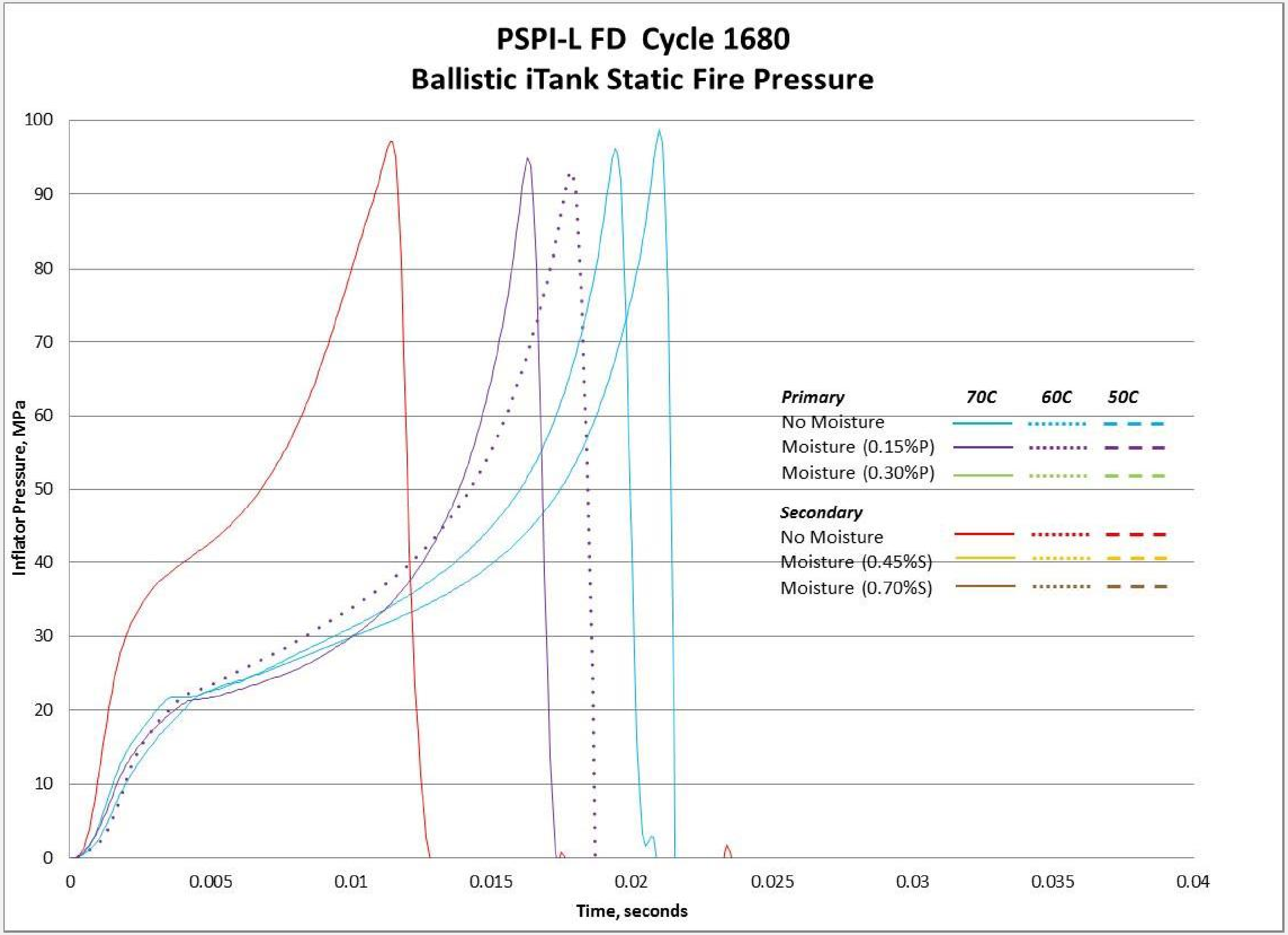
GM Tank Testing Cycle 1680



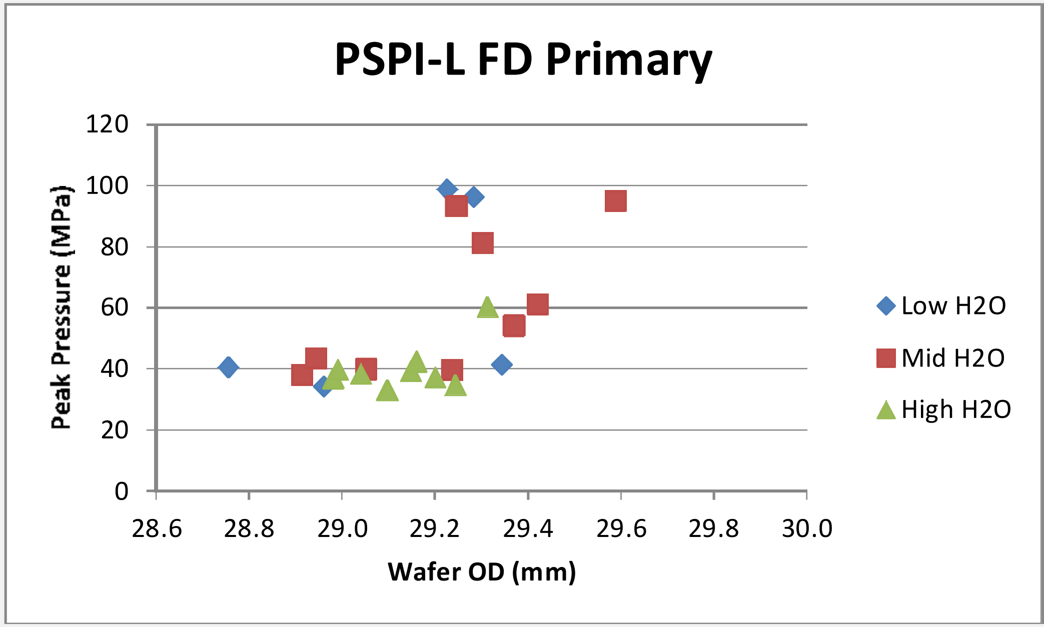
GM Tank Testing Cycle 1680

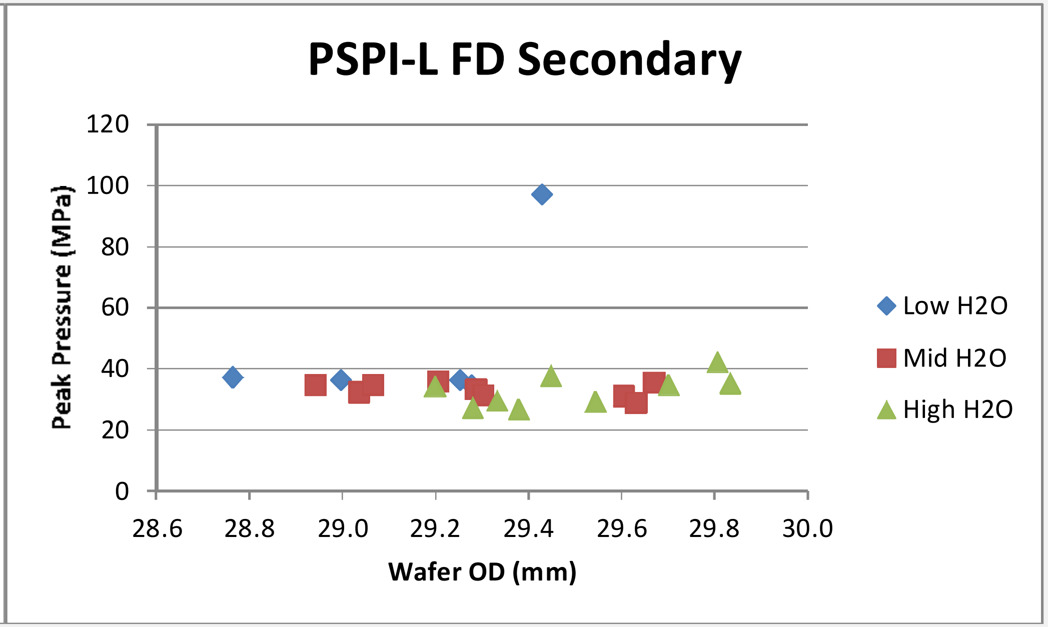


GM Tank Testing Cycle 1680

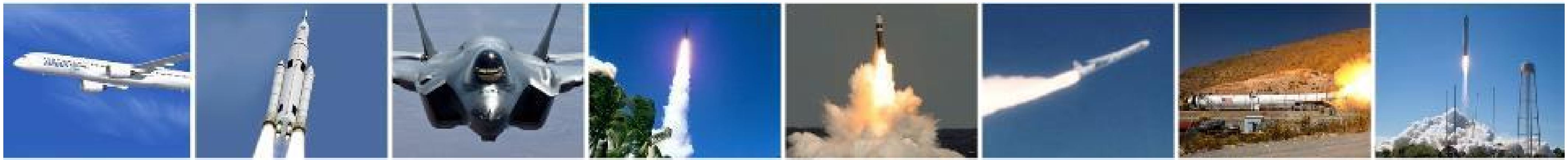


GM Tank Testing Cycle 1680

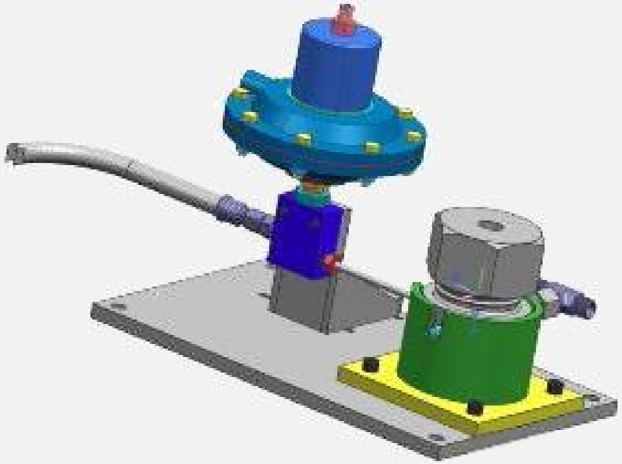




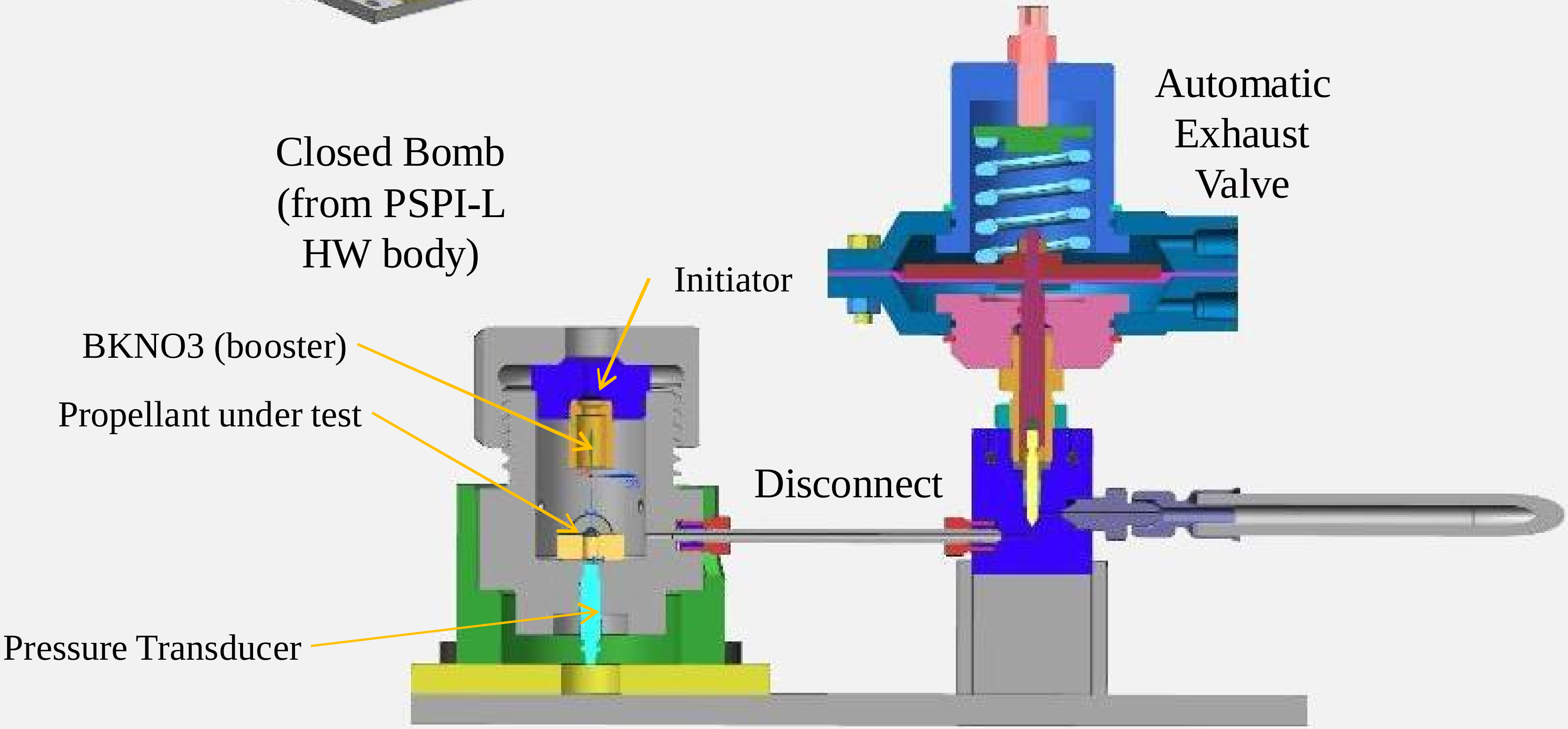
Closed Bomb Burn Rate and Vivacity



Closed Bomb

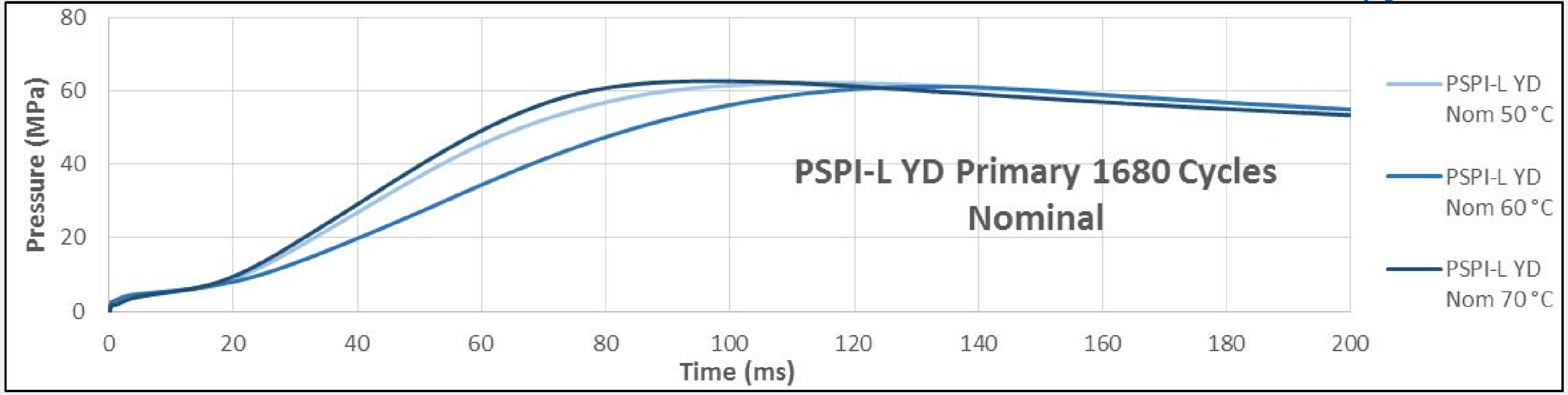


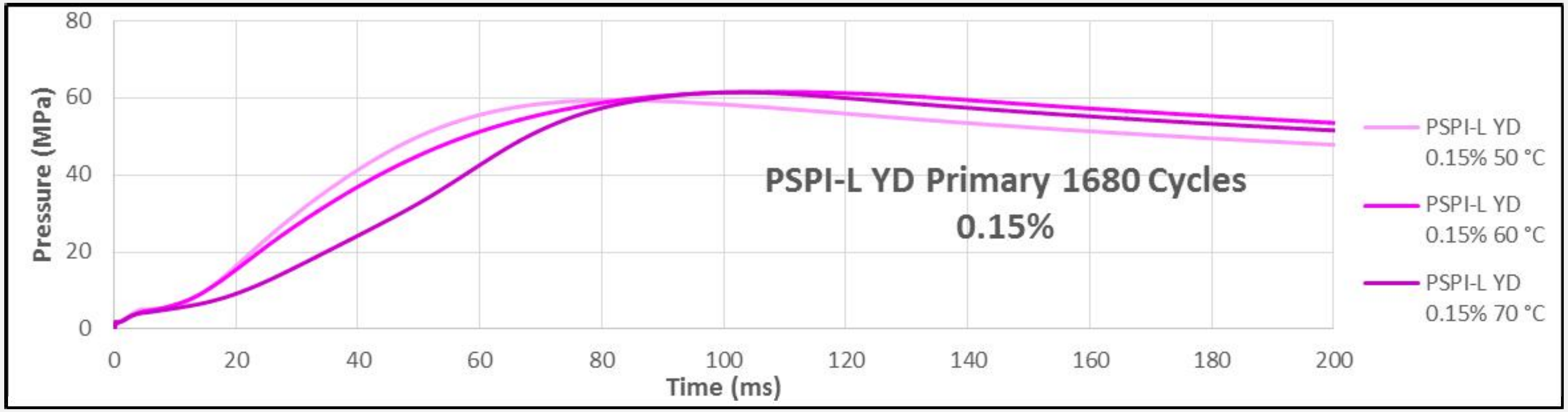
- Design Capability
  - Allows testing of all propellant types (wafers, tablets, main & booster)
  - Propellant weights up to full large wafer (10.8g) capacity
  - Up to 15,000 psi (103 MPa)
  - Piezoelectric pressure transducers
- Ignition System
  - Uses standard automotive initiators
  - Varying amount and types of booster material will be used to ensure uniform ignition – BKNO3 is the typical booster material

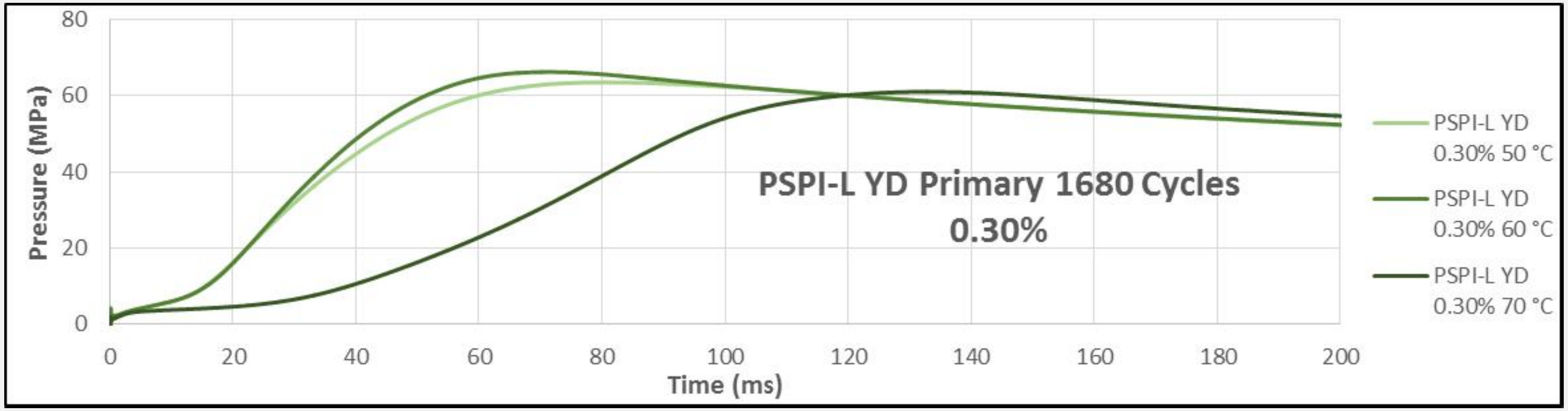


Closed Bomb Burn Rate (1680)
PSPI-L YD, Primary

- Modest slope breaks are observed:
  - 0.15% 20-70C
  - 0.30% 20-70C
- GM Light Duty



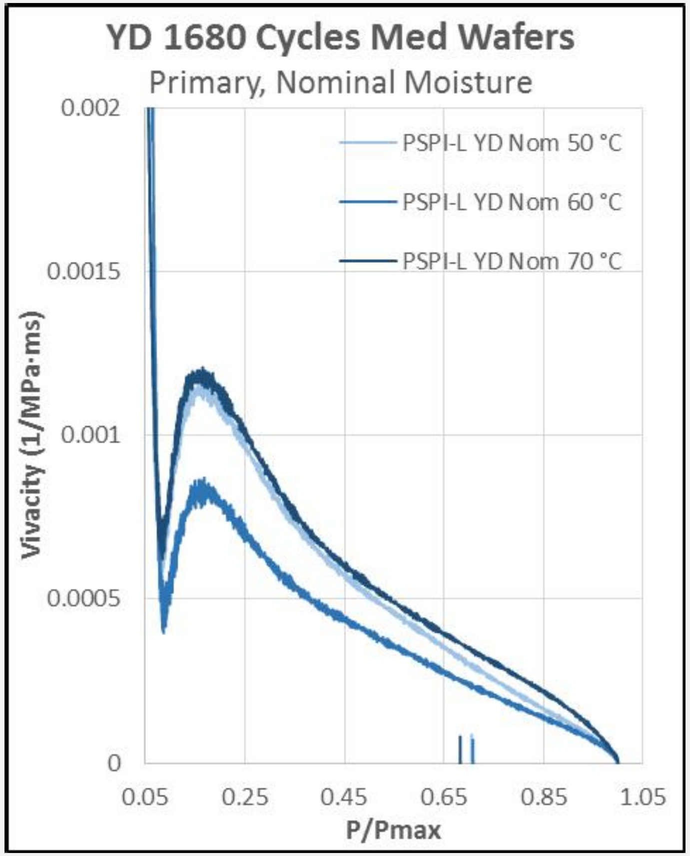


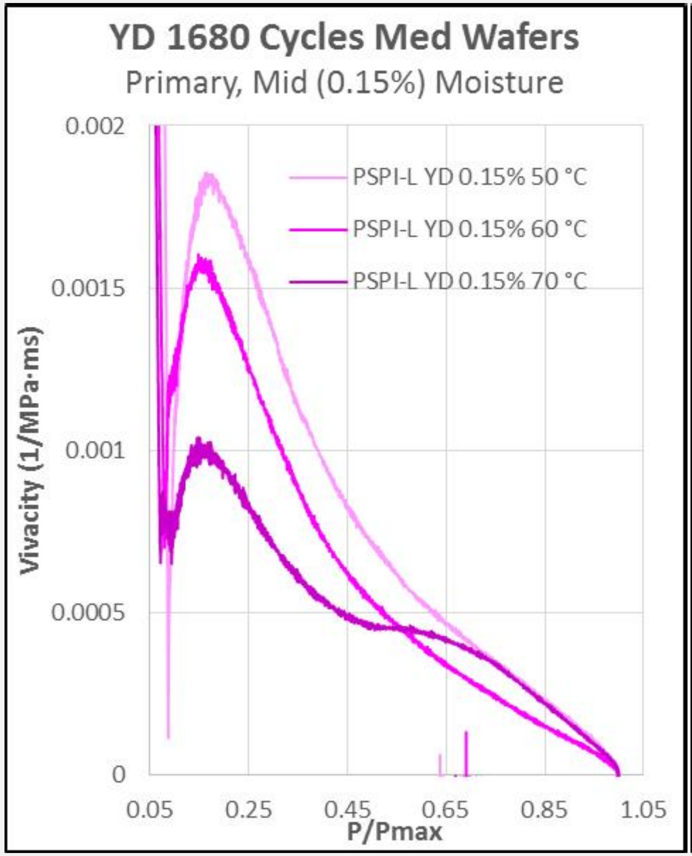


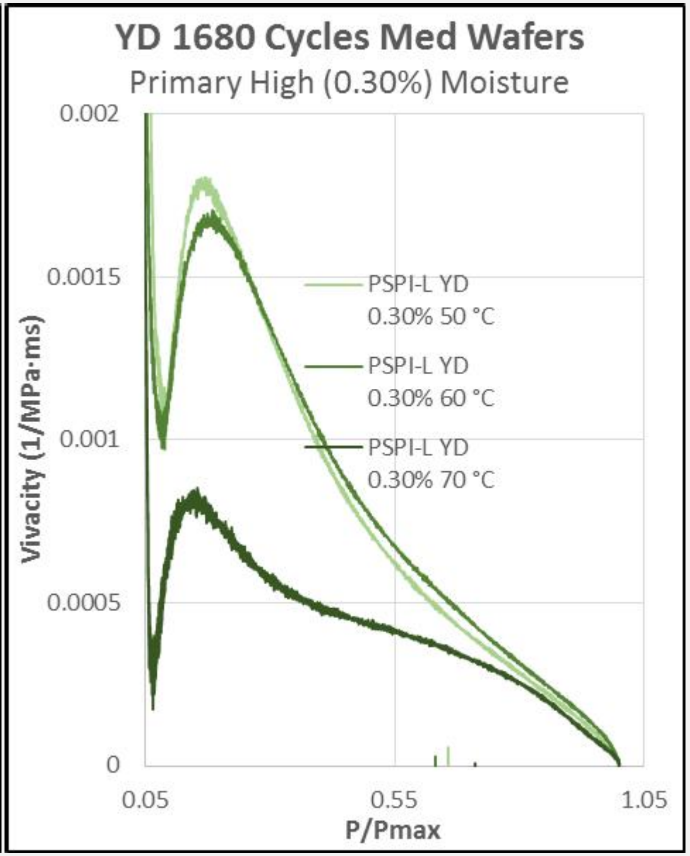
Closed Bomb Burn Rate (1680)

PSPI-L YD Vivacity Plots, Primary

- Abnormal burn behavior late into the burn is observed for all moisture conditions at 20-70C:
  - Most pronounced: 0.15% 20-70C
  - Gradual but significant: 0.30% 20-70C
  - Subtle: Nominal 20-70C

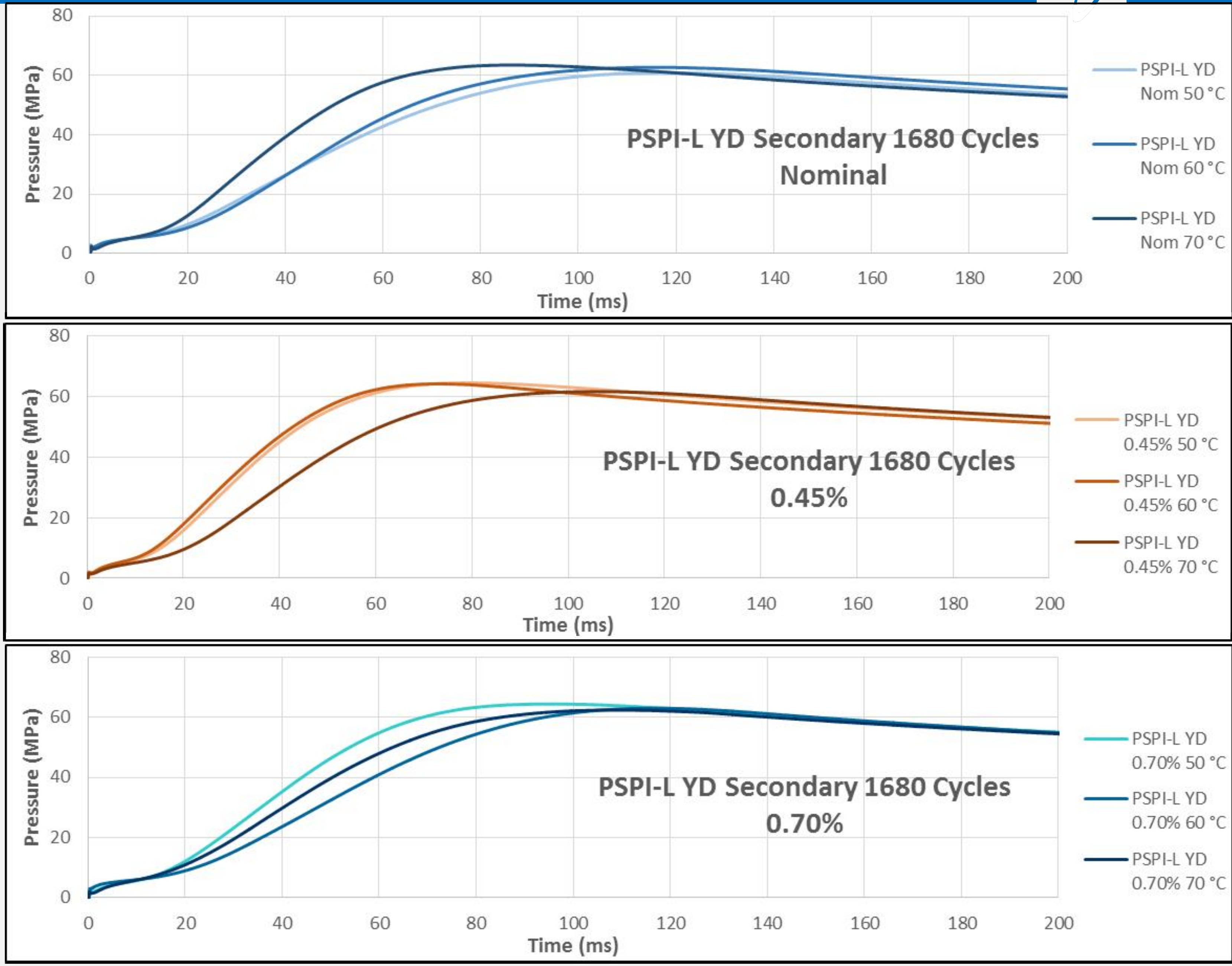






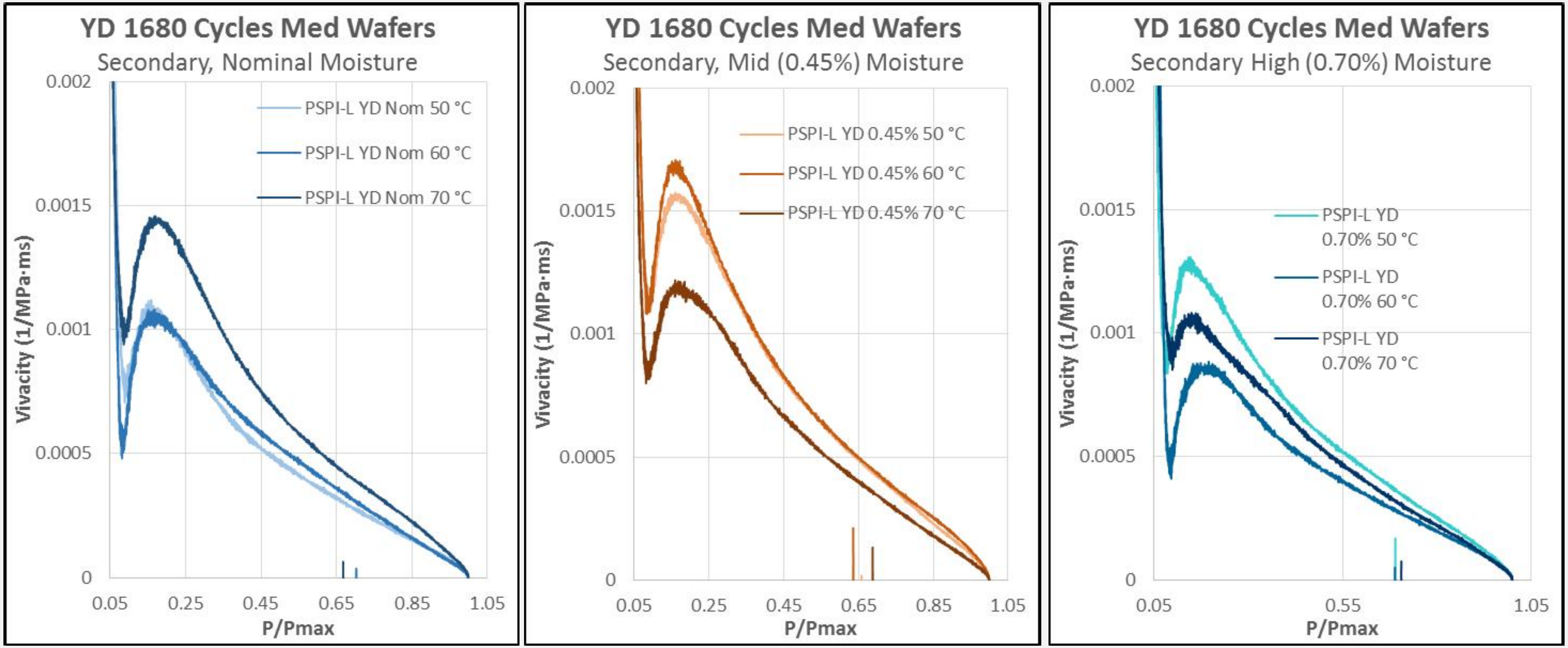
Closed Bomb Burn Rate (1680)
PSPI-L YD, Secondary

- No slope breaks observed



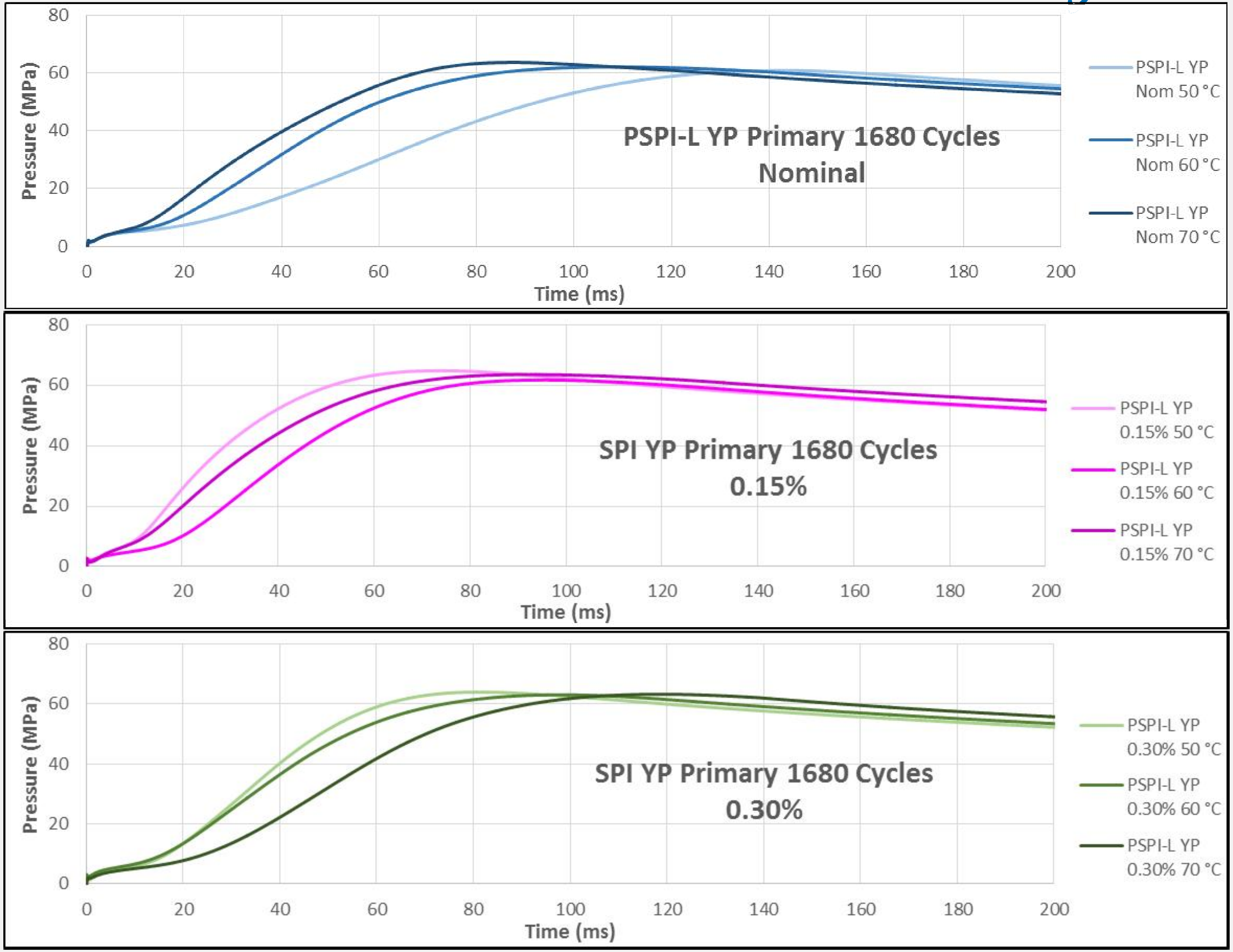
Closed Bomb Burn Rate (1680)
PSPI-L YD Vivacity Plots, Secondary

- No abnormal burn behavior
- Initial mass flow for 0.70% moisture wafers is lower than nominal and 0.45% inflators



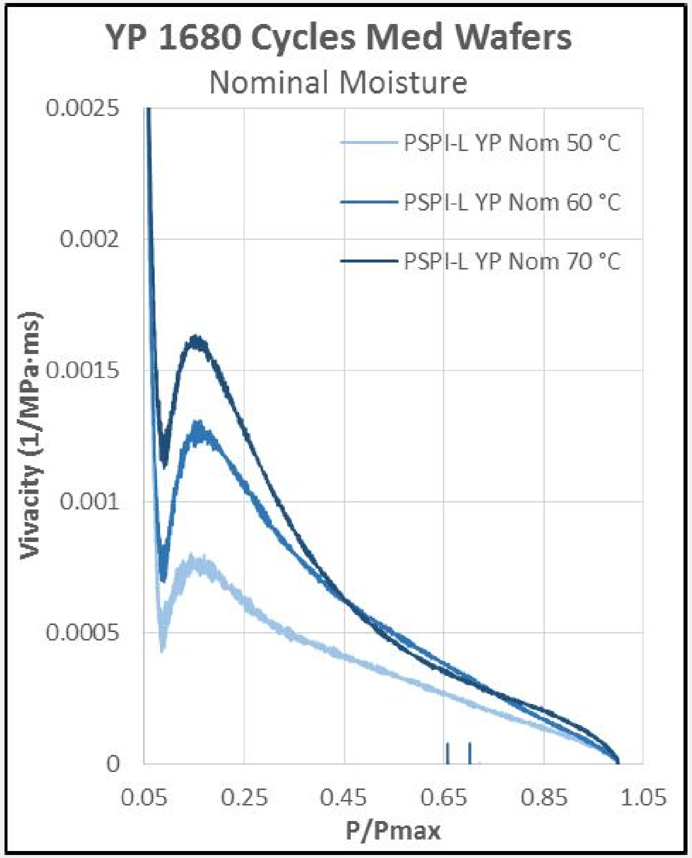
Closed Bomb Burn Rate (1680)
SPI YP

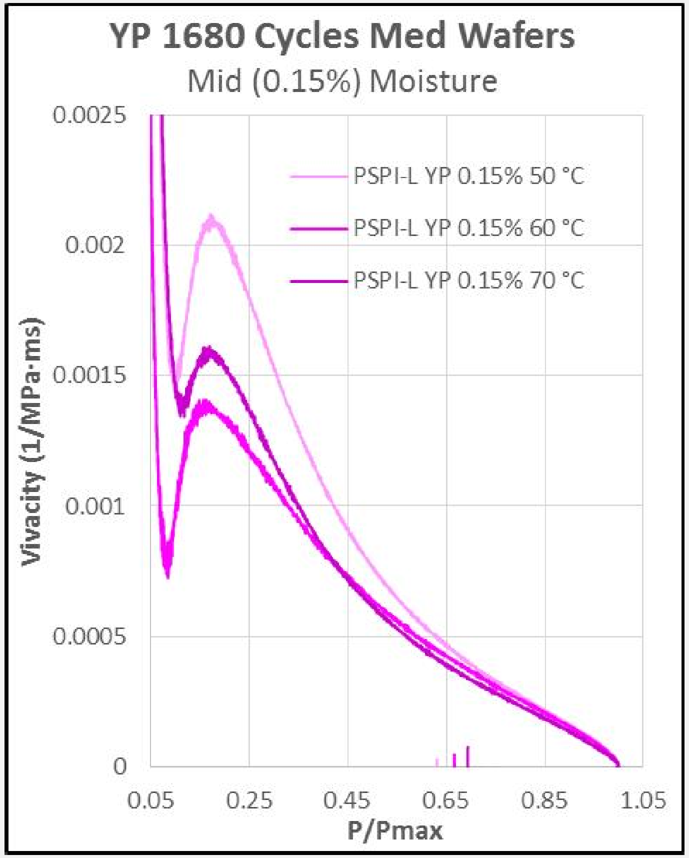
- No obvious abnormal burning observed
- GM Heavy Duty

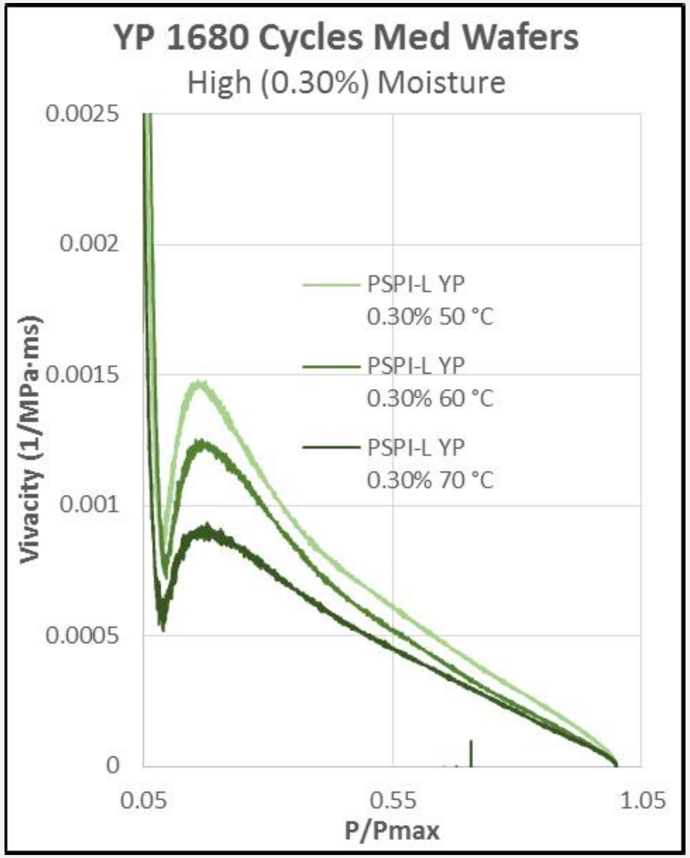


Closed Bomb Burn Rate (1680)
SPI YP Vivacity Plots

- Slight hint of abnormal burn behavior is observed for Nominal 20-70 C late in burn
- Initial mass flow for 0.15% moisture wafers is higher than for nominal and 0.30% counterparts



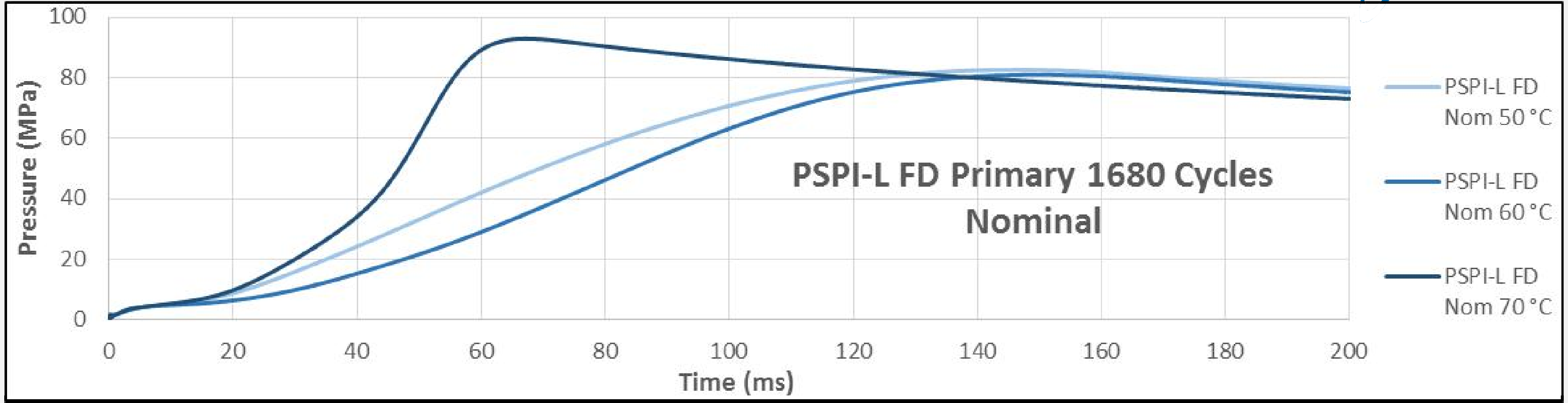


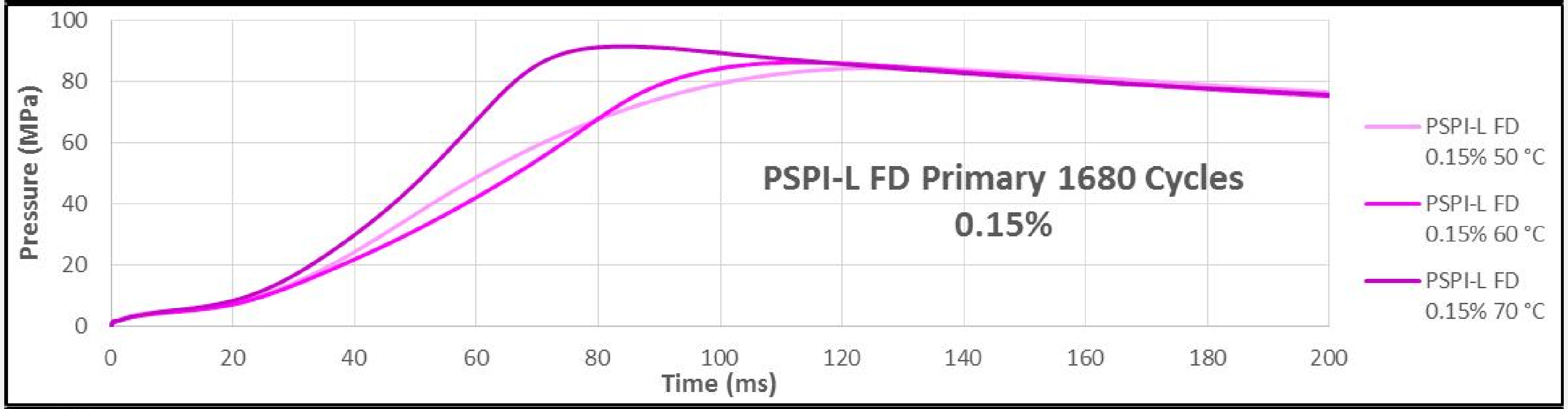


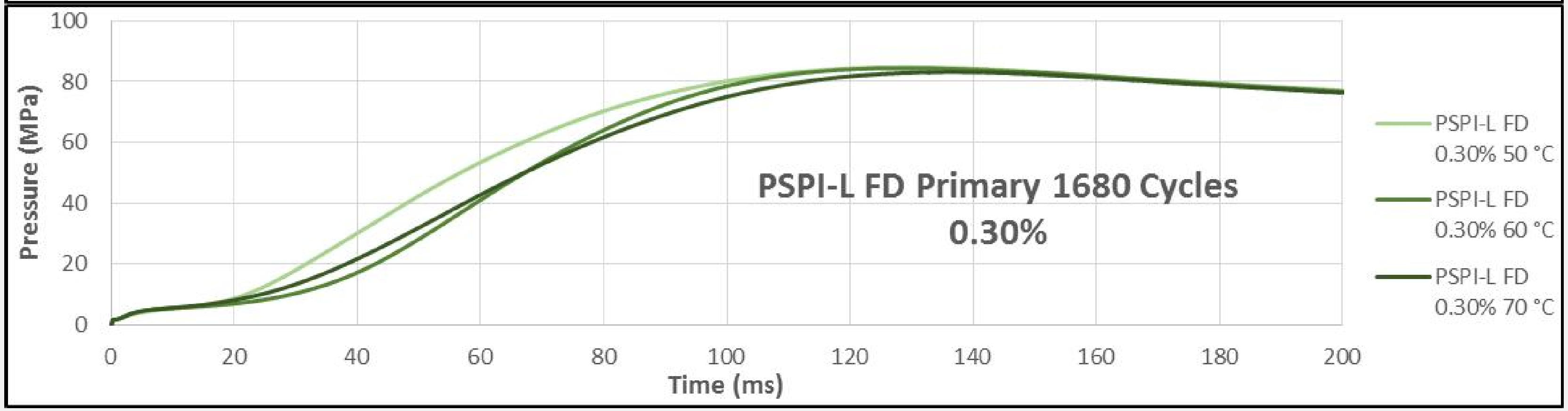
Closed Bomb Burn Rate (1680)
PSPI-L FD, Primary

- Slope breaks are observed:
  - Largest: Nominal 20-70C
  - Next Largest: 0.15% 20-70C
  - Smallest: 0.15% 20-60C

- Vibe and other OEM

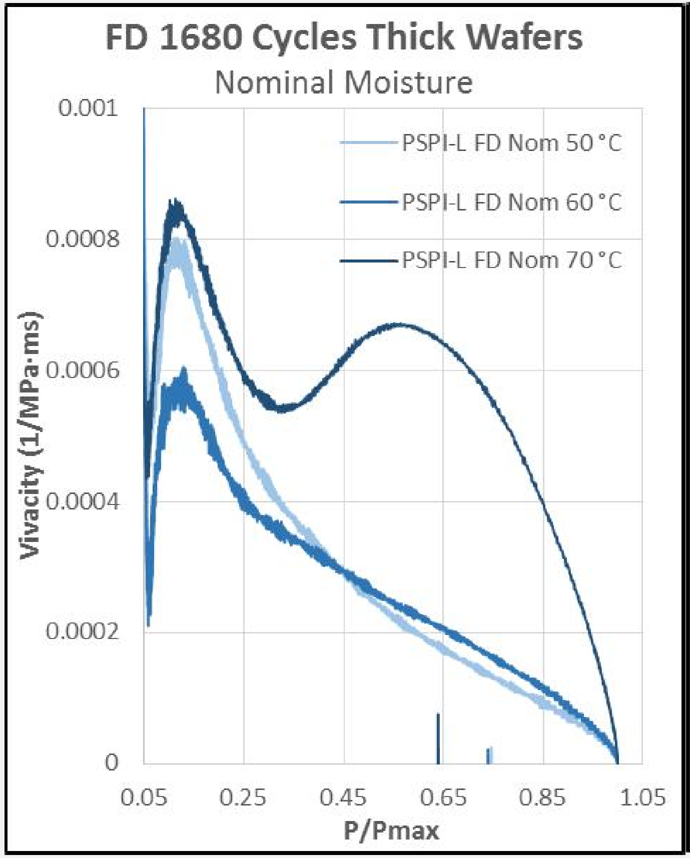


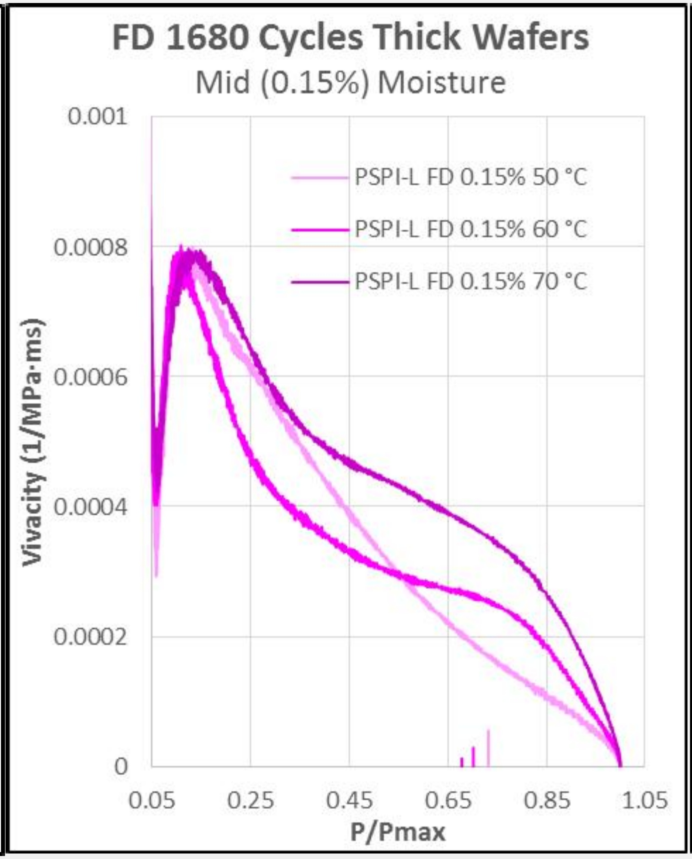


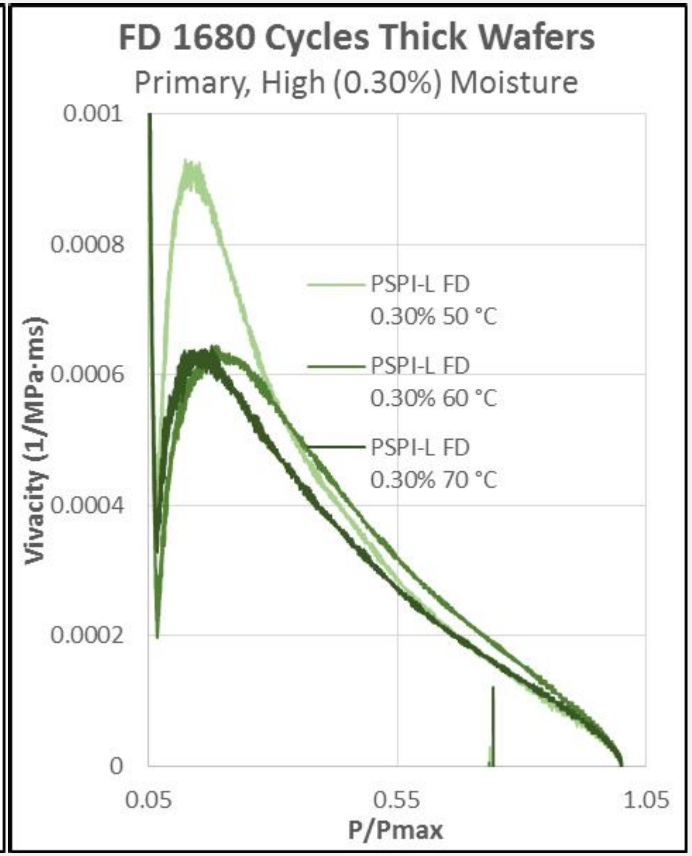


Closed Bomb Burn Rate (1680)
PSPI-L FD Vivacity Plots, Primary

- Abnormal burn behavior is observed:
  - Most pronounced: Nominal 20-70C
  - Somewhat pronounced: 0.15% 20-70C
  - Late in the burn: 0.15% 20-60C
  - Subtle: Nominal 20-60C

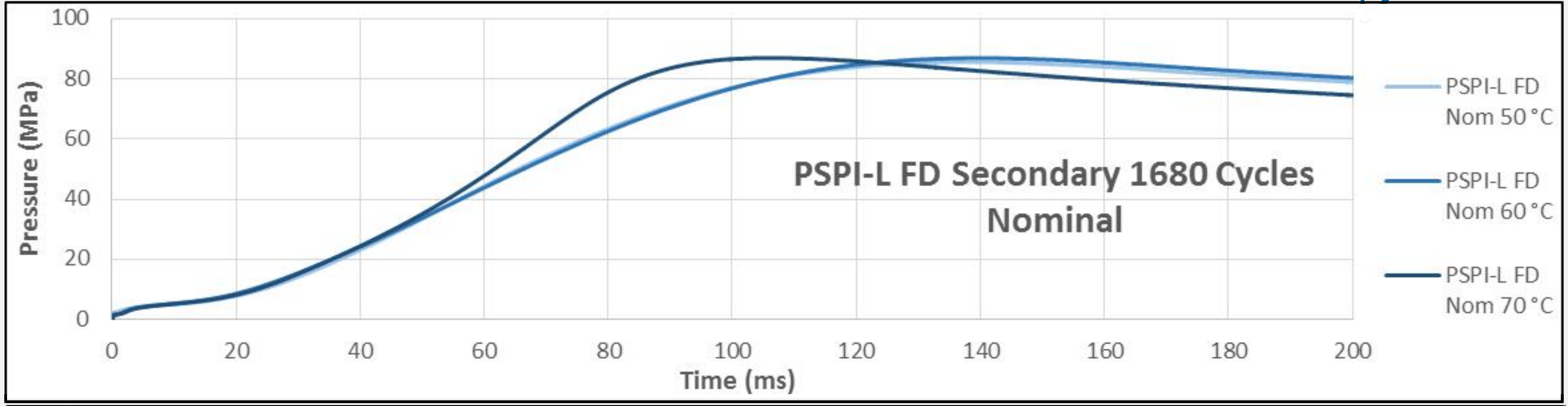


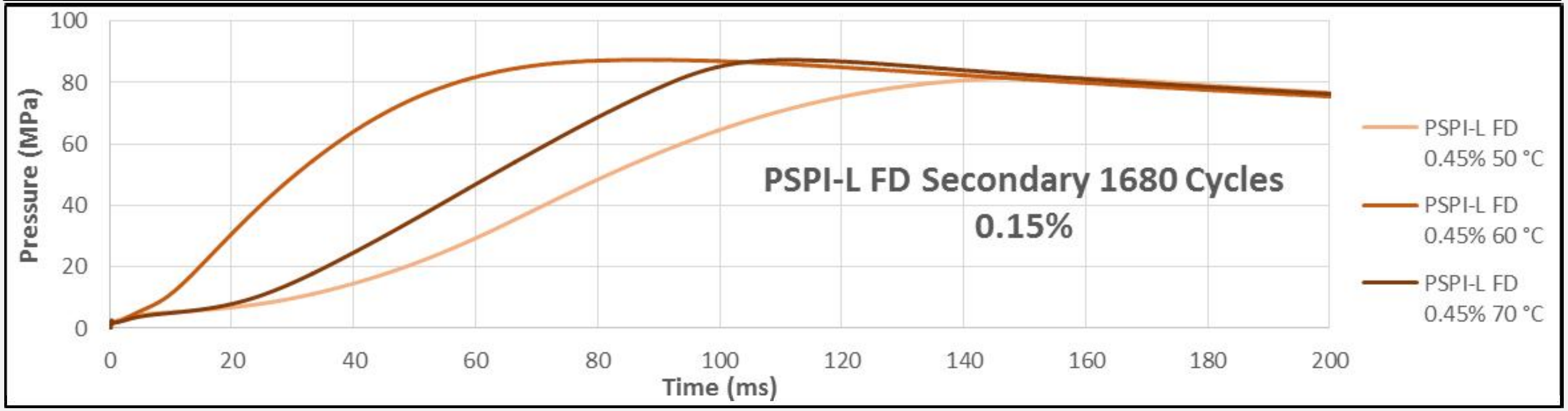


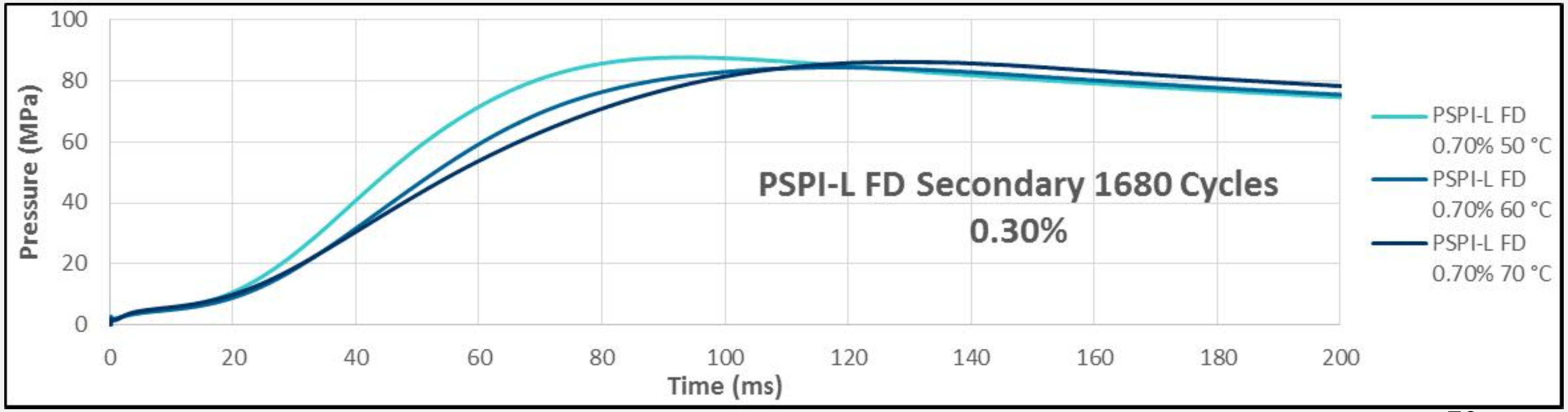


Closed Bomb Burn Rate (1680)
PSPI-L FD, Secondary

- Slope break for Nominal 20-70 C
- 0.45% 20-60 C has a very fast rise rate for FD wafers

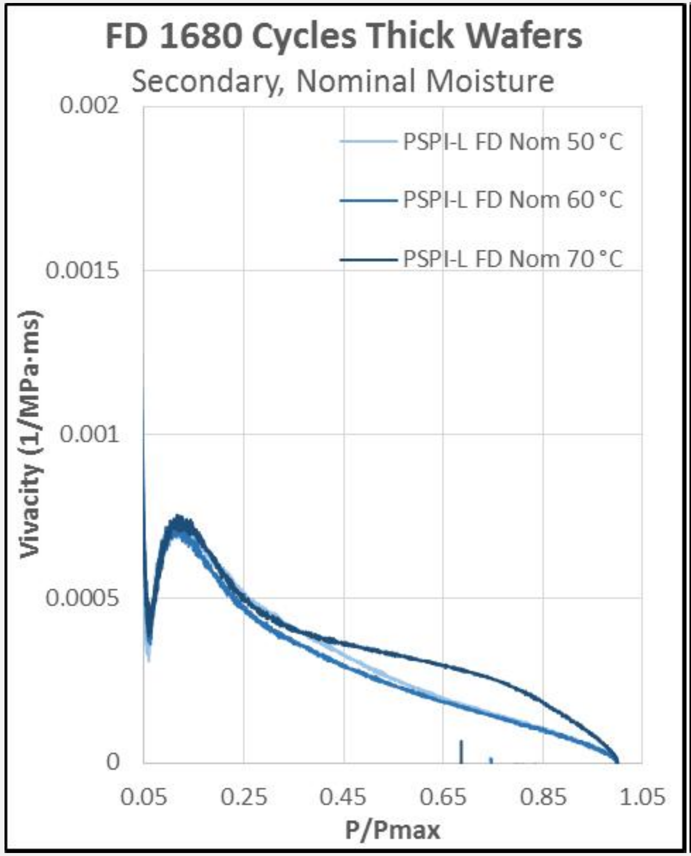


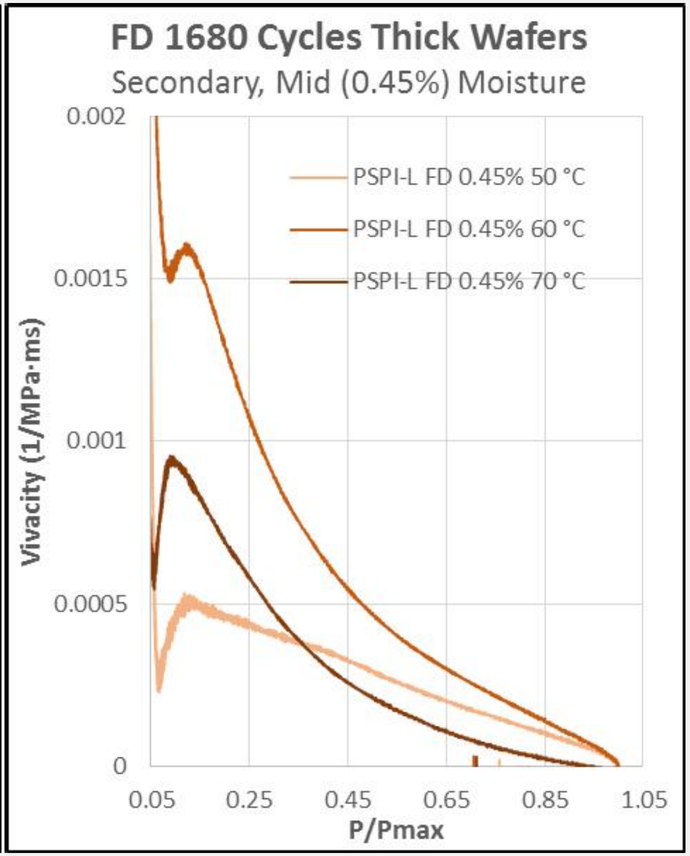


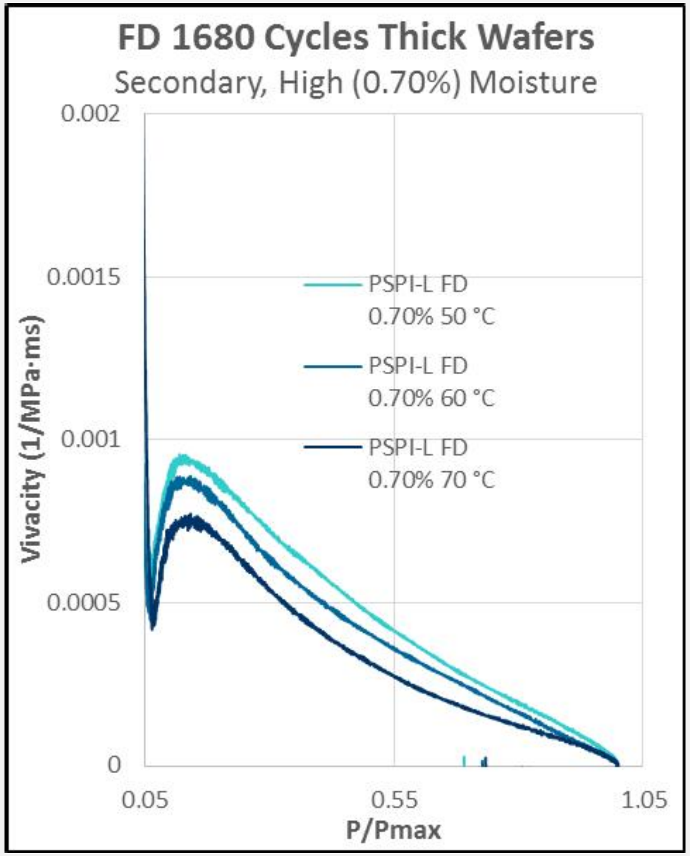


Closed Bomb Burn Rate (1680)
PSPI-L FD Vivacity Plots, Secondary

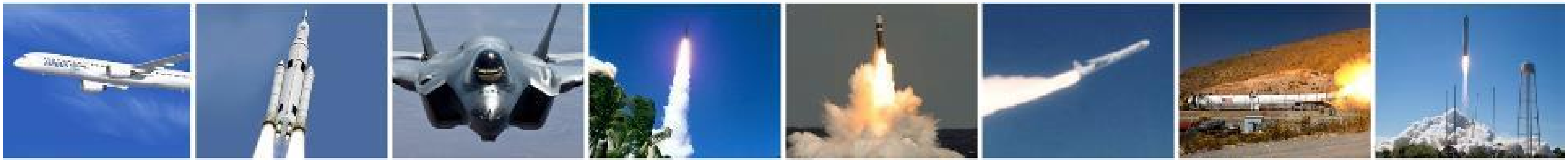
- Abnormal burn behavior is observed for Nominal 20-70 C
- Initial mass flow for 0.45% 20-60 C is very large for thick wafers







Ballistic Modeling and Evaluation of Design Differences

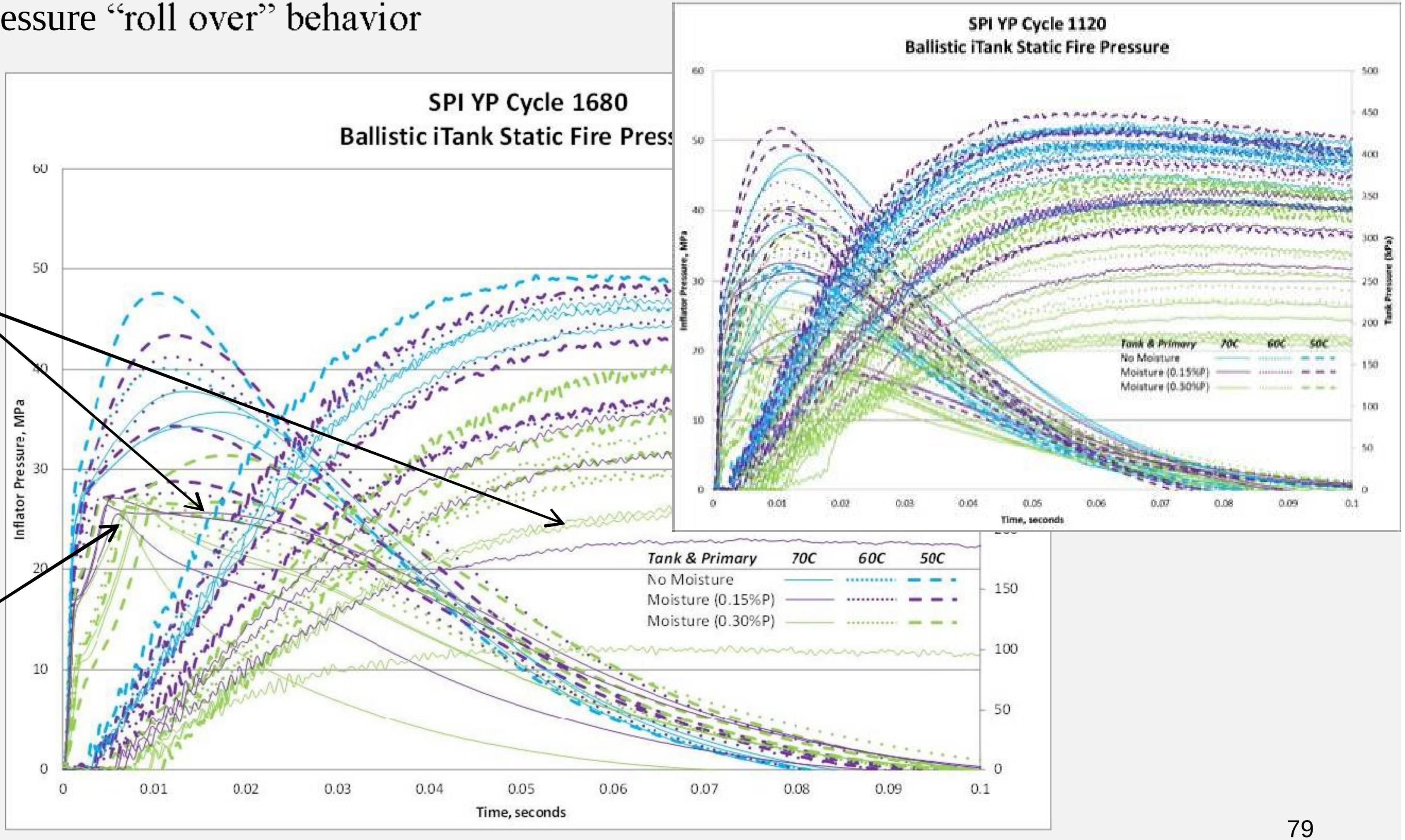


Summary

- Previously reported on FD (Vibe) and YD (Lt Duty) ballistic differences
  - Medium wafers in YD exhibit improved ballistics towards ED
- SPI-YP (Hvy Duty) inflator models were developed to investigate the observed performance characteristics from the GM tank testing and correlate to FD and YD findings
    - Some aged wafers exhibit lower pressure levels, reduced pressure integral, and low pressure "roll over" behavior

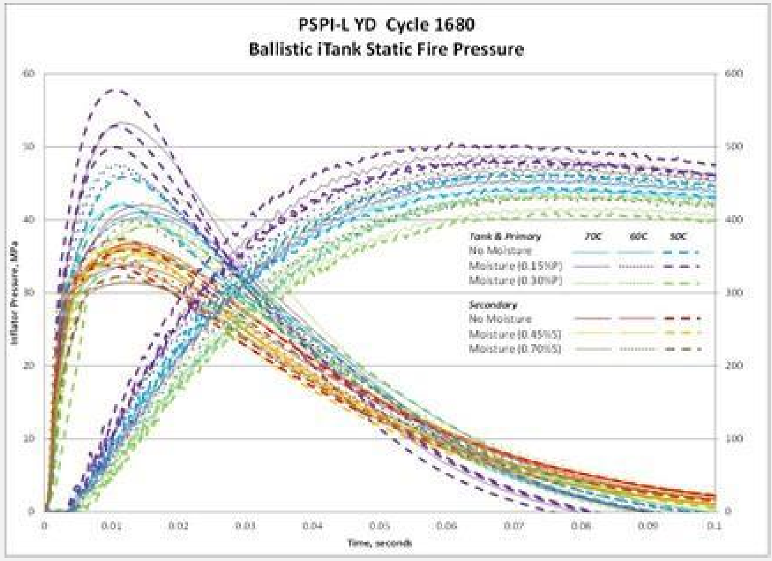
Reduced pressure level and integral

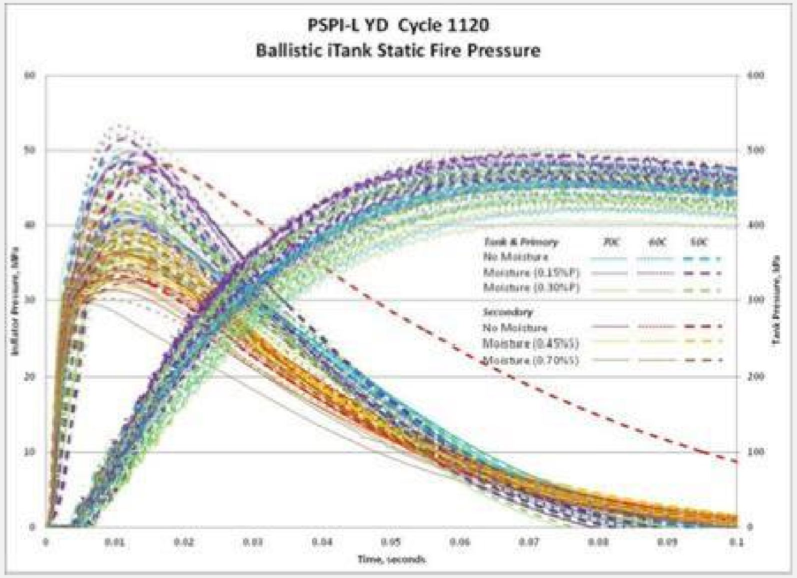
Low pressure "roll-over"

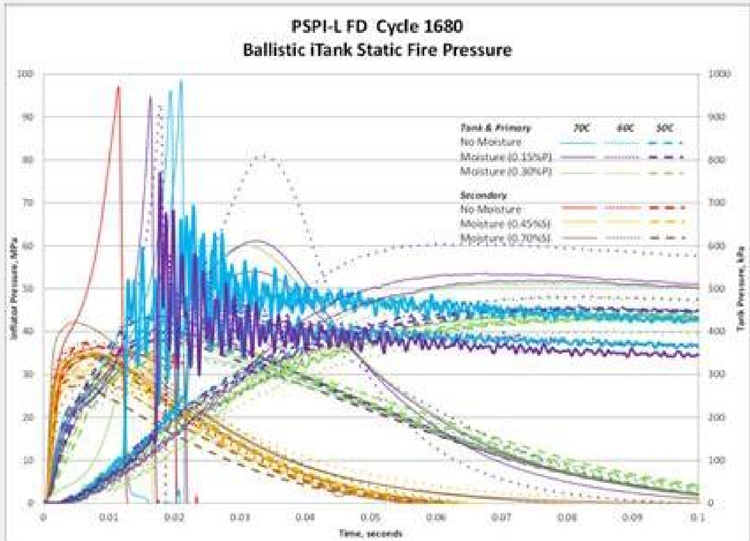


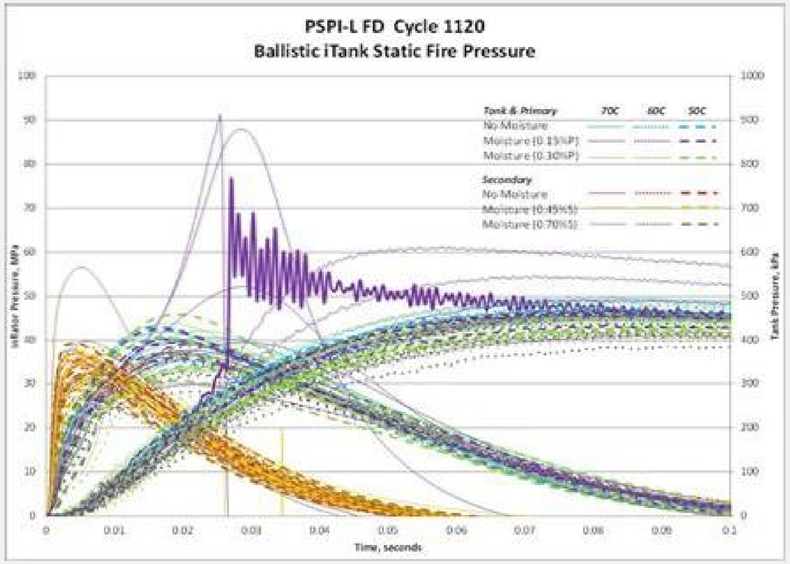
PSPI-L FD and YD Observations

The behavior appears to be more prevalent in SPI YP HW testing than in PSPI-L YD or FD inflators



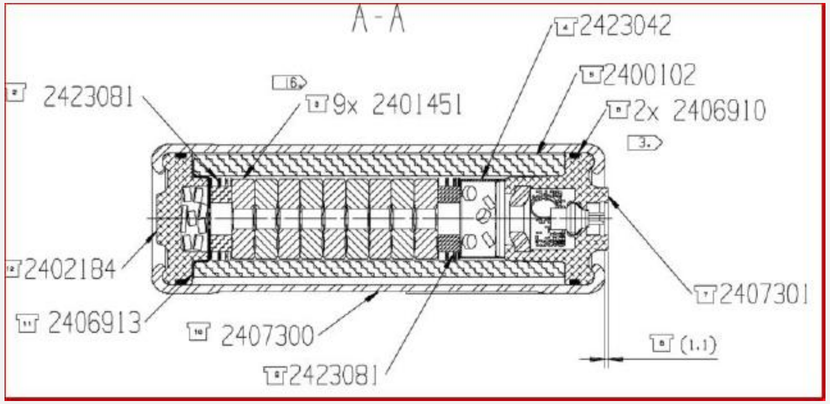






Design Differences

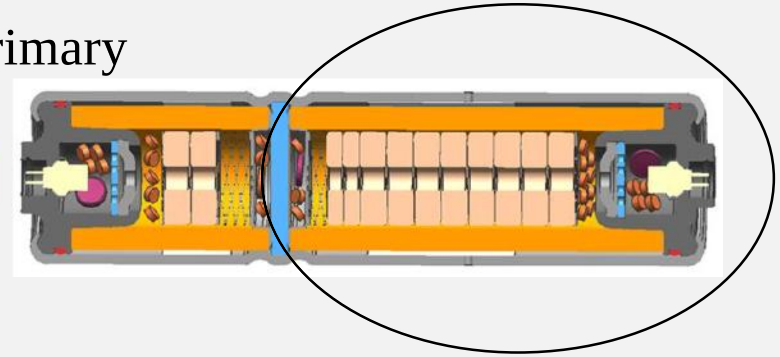
SPI-YP



9 medium wafers
Vent area = 42.47 mm^2
Retaining springs at both ends

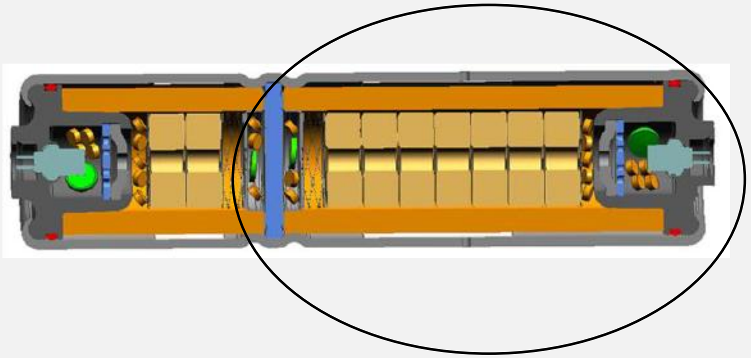
PSPI-L Primary

YD



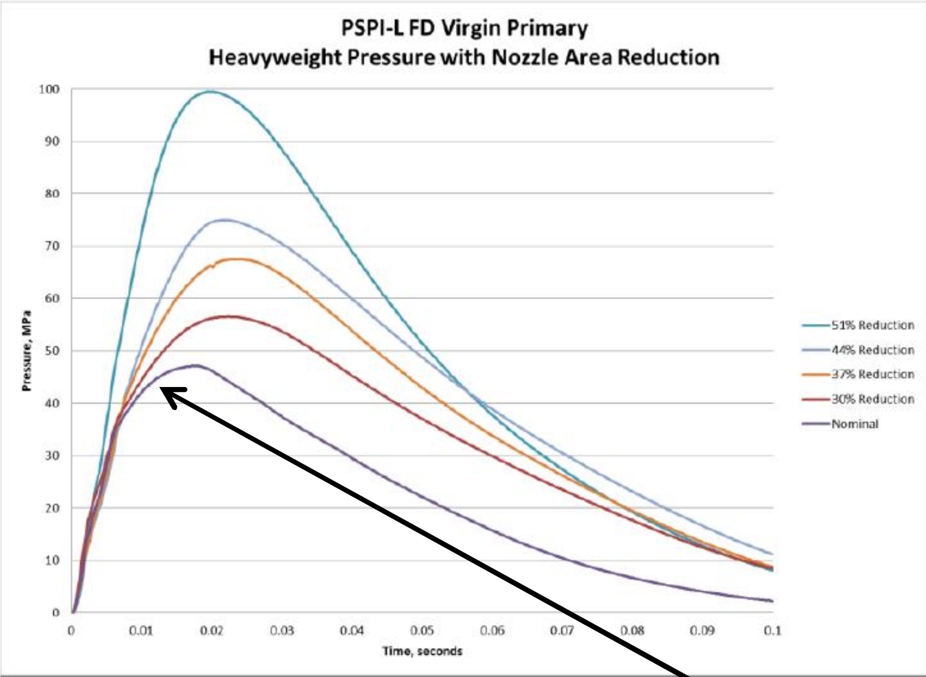
8 medium, 2 thin wafers
Vent area = 36.19 mm^2

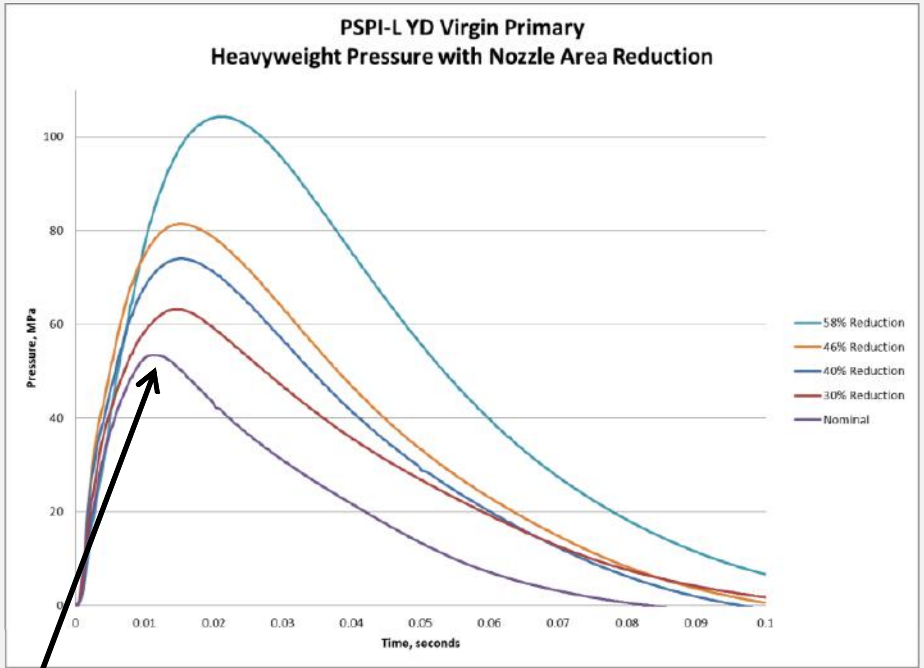
FD



7 thick wafers
Vent area = 31.25 mm^2

FD and YD Heavyweight Testing Comparison

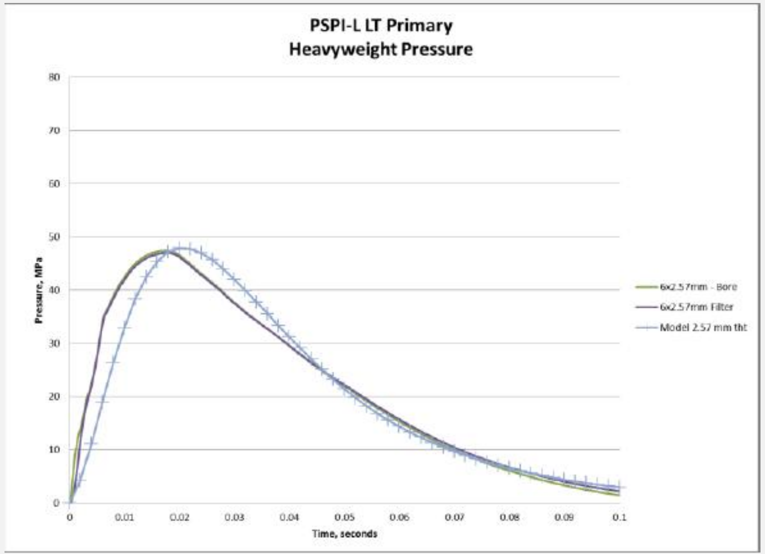


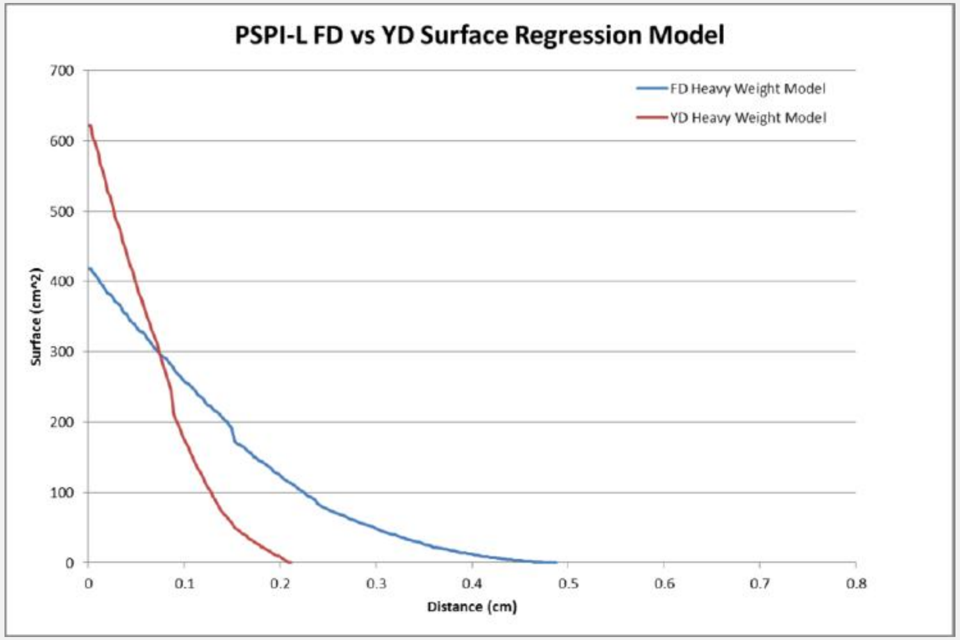


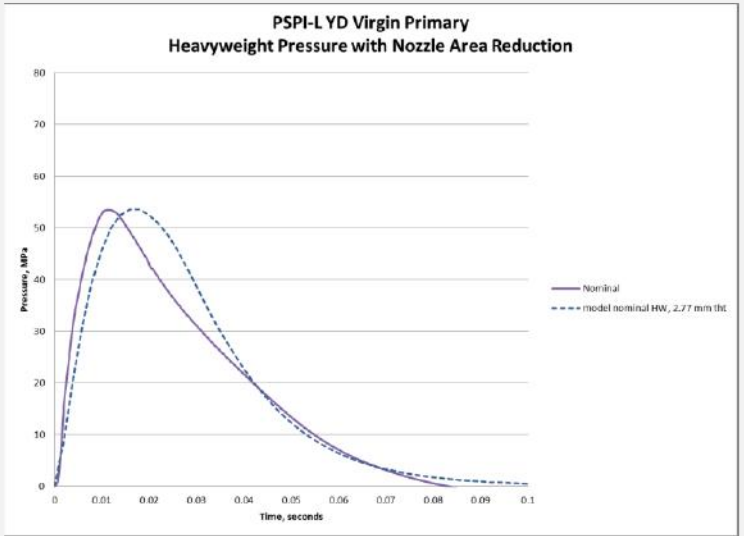
Nominal YD pressures are higher and peak earlier than FD

FD (LT) vs. YD Heavy Weight Modeling

- Pressure Integral matched
- Distributed surface area breakup required to match pressure vs time shape
- YD requires more break-up than FD

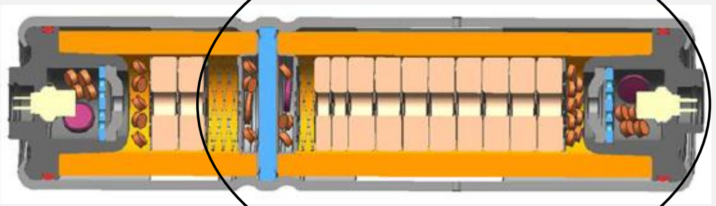




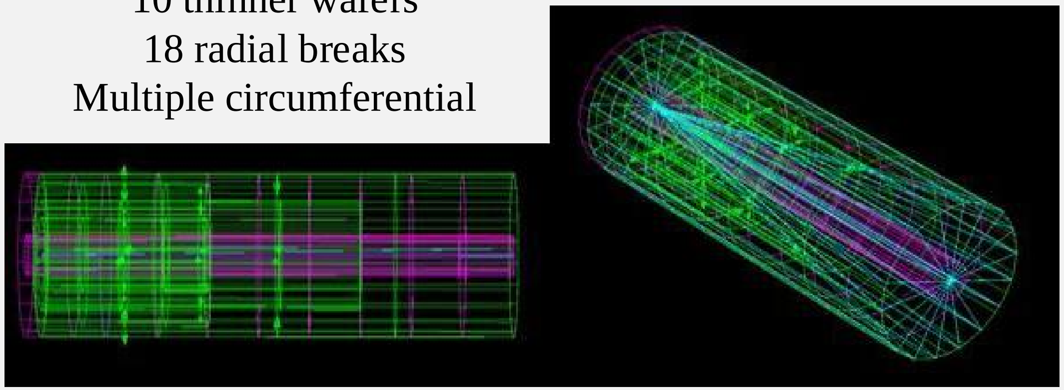


Surface Regression Model Comparison

YD

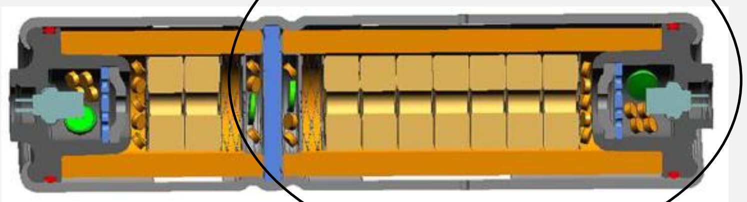


10 thinner wafers
18 radial breaks
Multiple circumferential

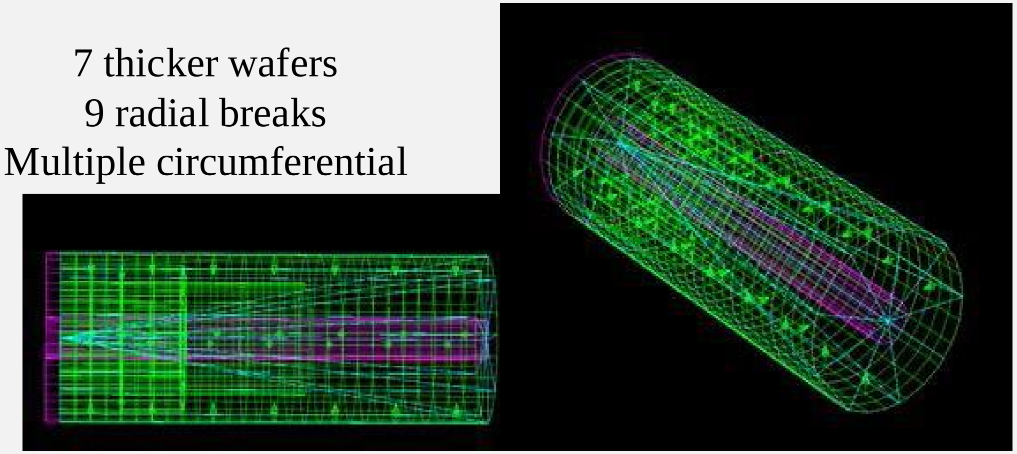


YD Thickness	Primary Wafers	Breakup		
8.4 mm	8	wafers	pieces per wafer	total pieces
		2	72	144
		3	36	108
		3	18	54
5.36 mm	2	2	72	144
			Total	450

FD



7 thicker wafers
9 radial breaks
Multiple circumferential



FD Thickness	Primary Wafers	Breakup		
11 mm	7	wafers	pieces per wafer	total pieces
		2	36	72
		2	18	36
		3	9	27
			Total	135

- Ballistic modeling investigated the PSPI-L FD (LT) and PSPI-L YD inflator configurations
  - 3D propellant surface regression and ballistic performance models were developed for each configuration
  - The models were anchored to measured test data for each configuration collected as part of the heavyweight testing effort.
- Initial observation:
  - The YD configuration requires greater breakup of the wafers than the FD configuration to create the best match to the measured data.

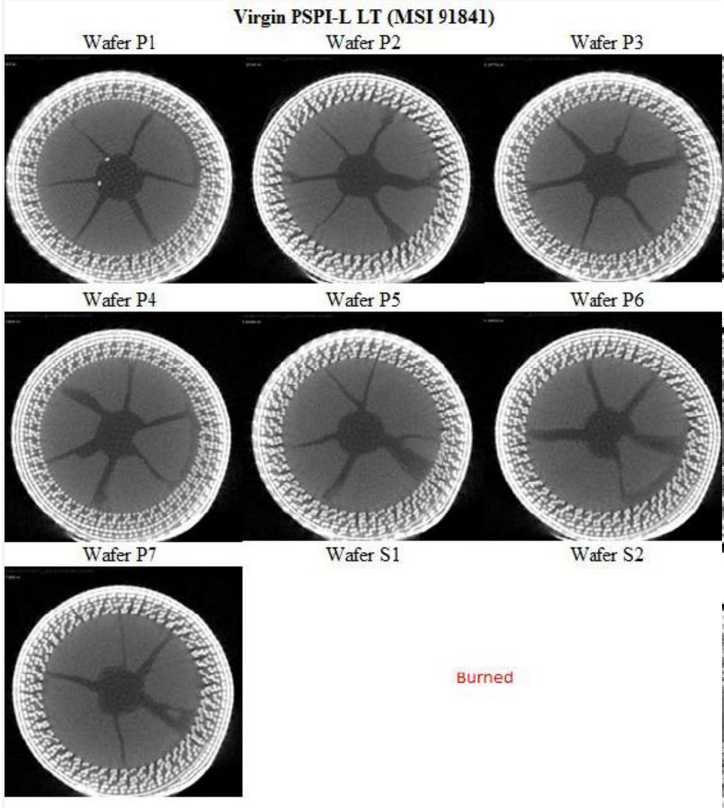
Observed Quench Data

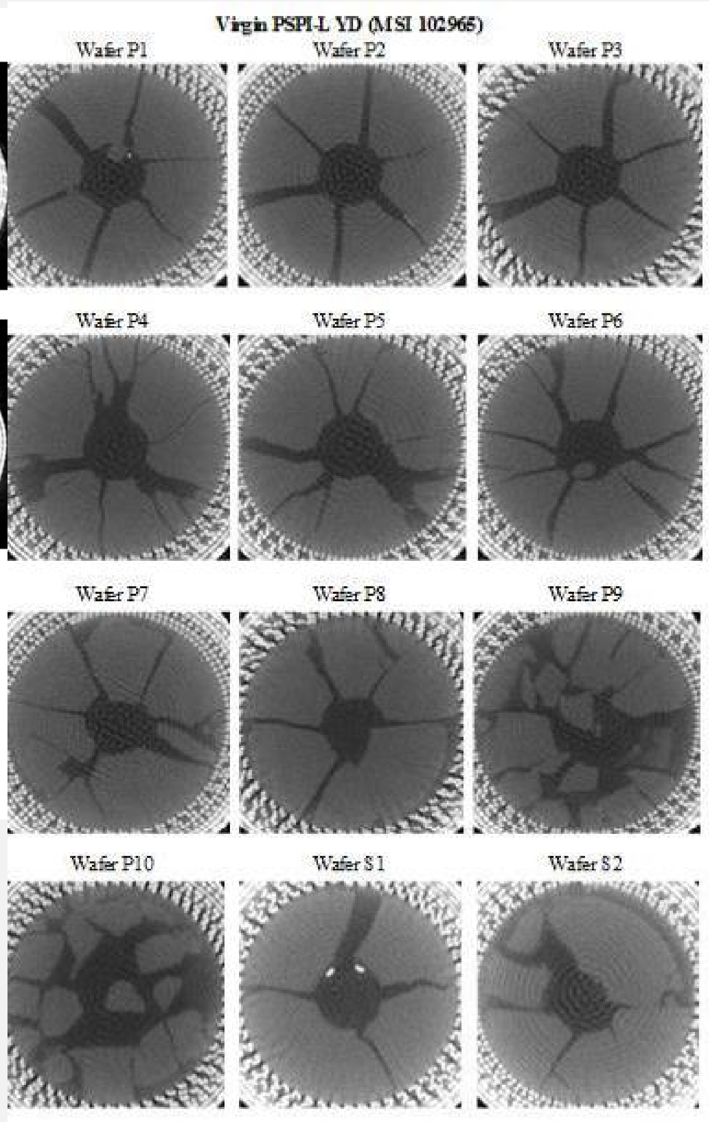
Observed quench data and ballistic model results appear consistent

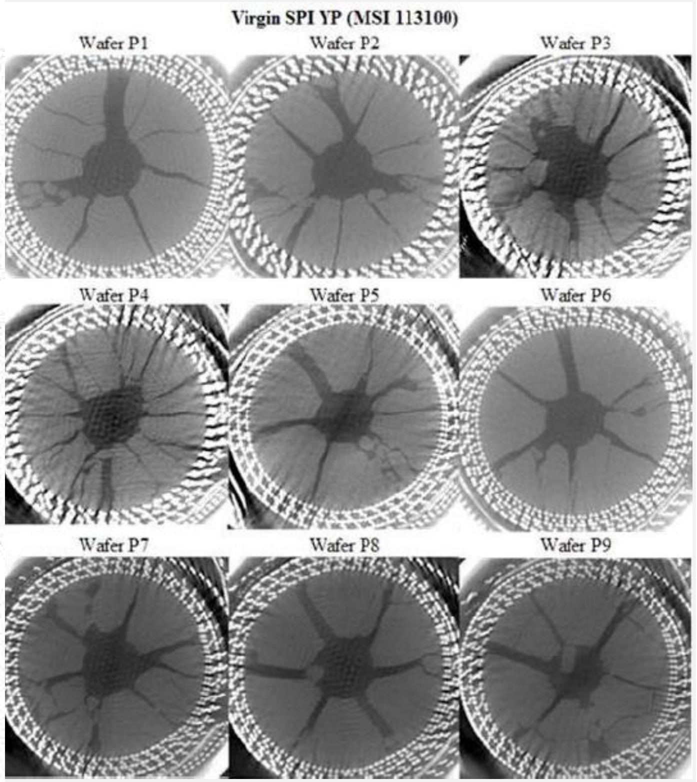
- Wide variety of break-up configurations
- Large number of fractures on some wafers, fewer on others
- Variety of sizes of resulting wafer pieces
- YD breaks up more than FD
- YP more similar to YD than FD
- Aged wafers break up less than virgin.

Quench Test Results: Comparison of Virgin Inflators

- The break-up in wafers closest to the igniter in the PSPI-L inflators is very similar, but as you move away from the igniter there is more break-up in the medium wafers of the YD.
- The thin wafers in the PSPI-L YD, P9 and P10, and the medium wafers in SPI YP break-up the most out of all 3 types

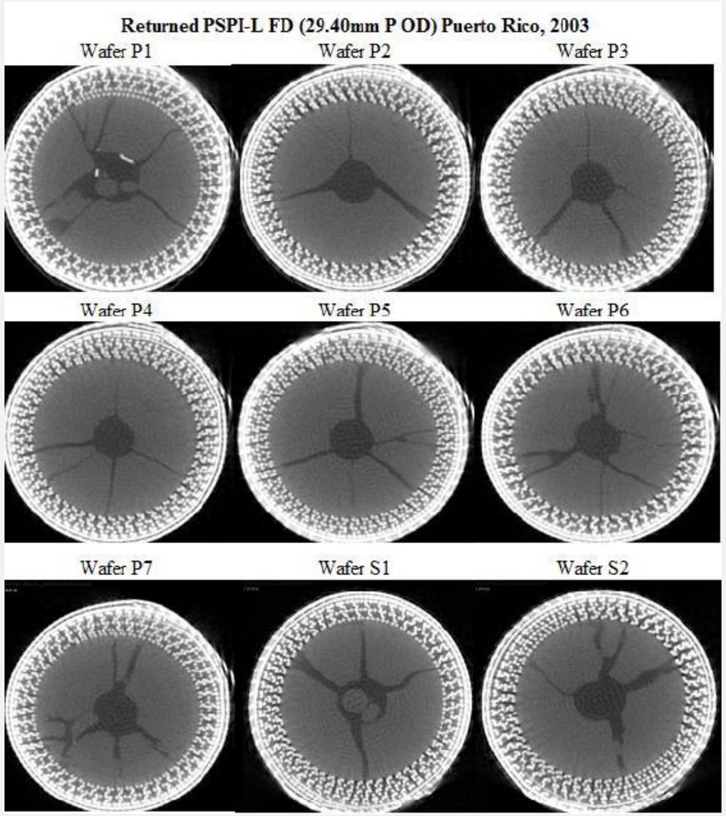


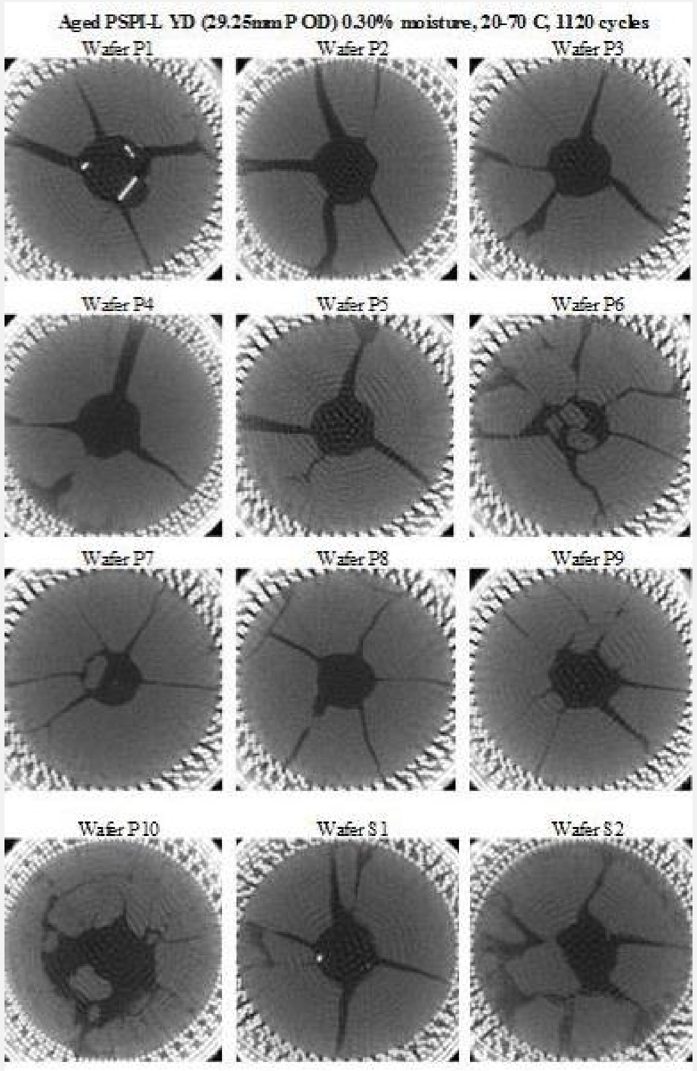


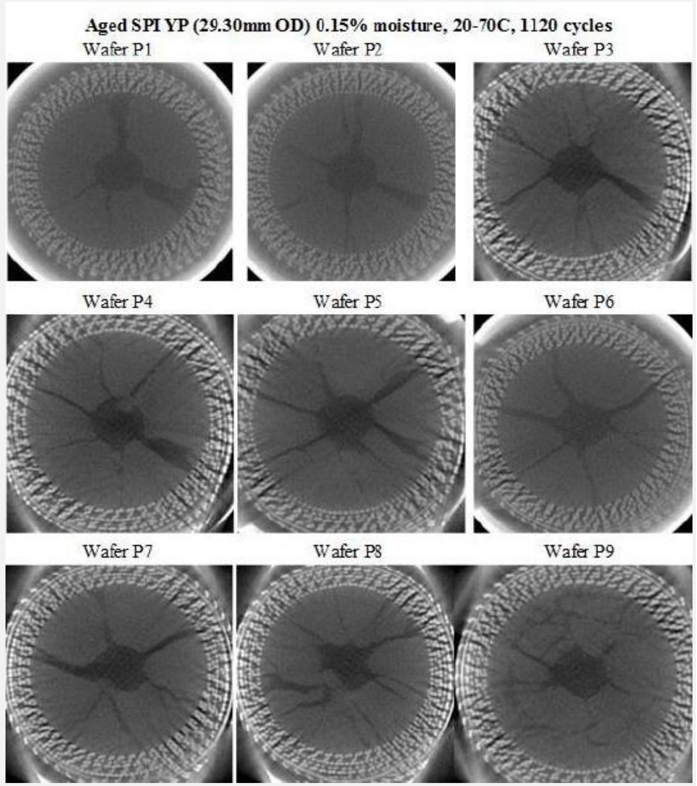


Quench Test Results: Comparison of Aged Inflators

- The larger wafers show less break-up in all three inflator types
- SPI YP inflators still show more break-up than the other two

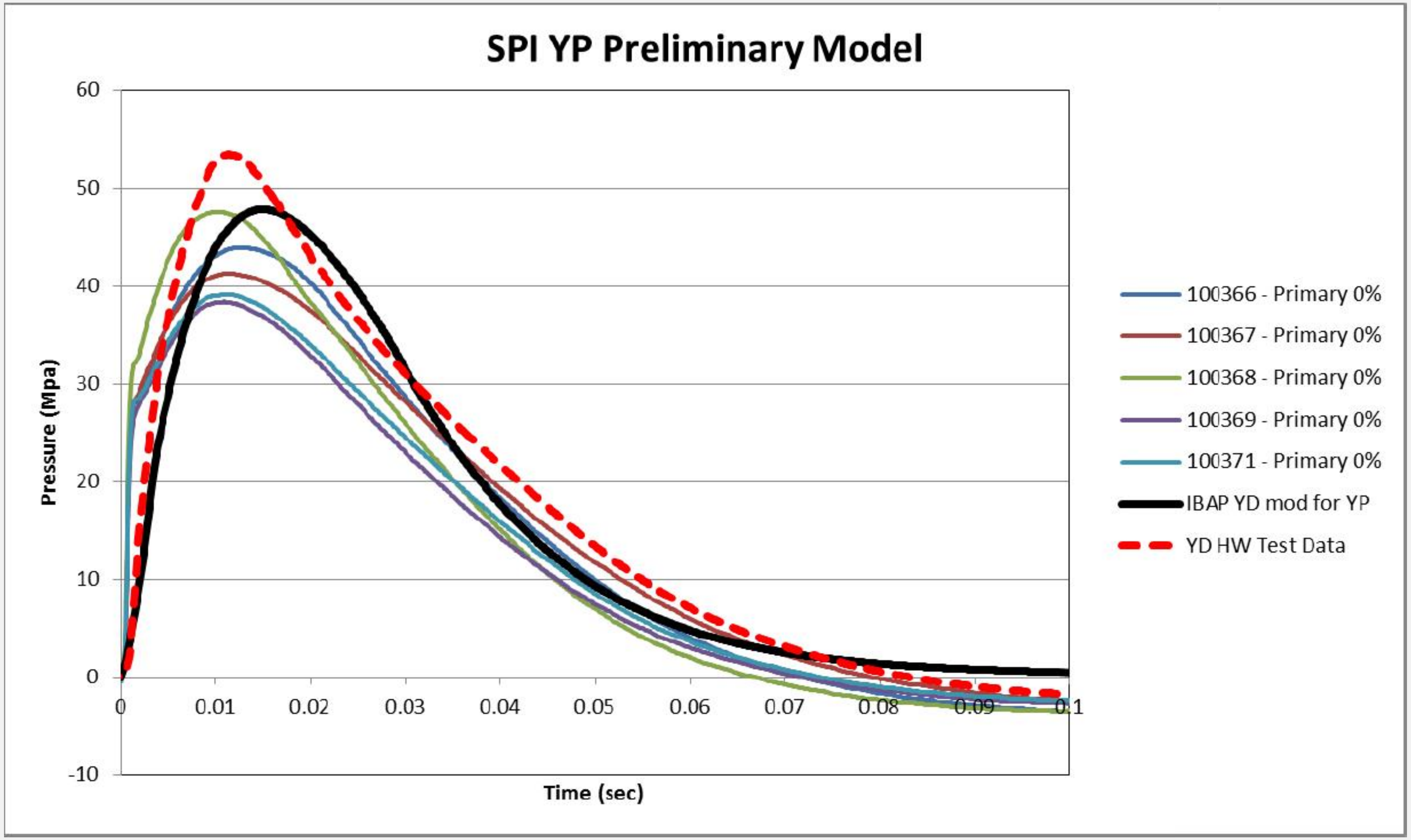






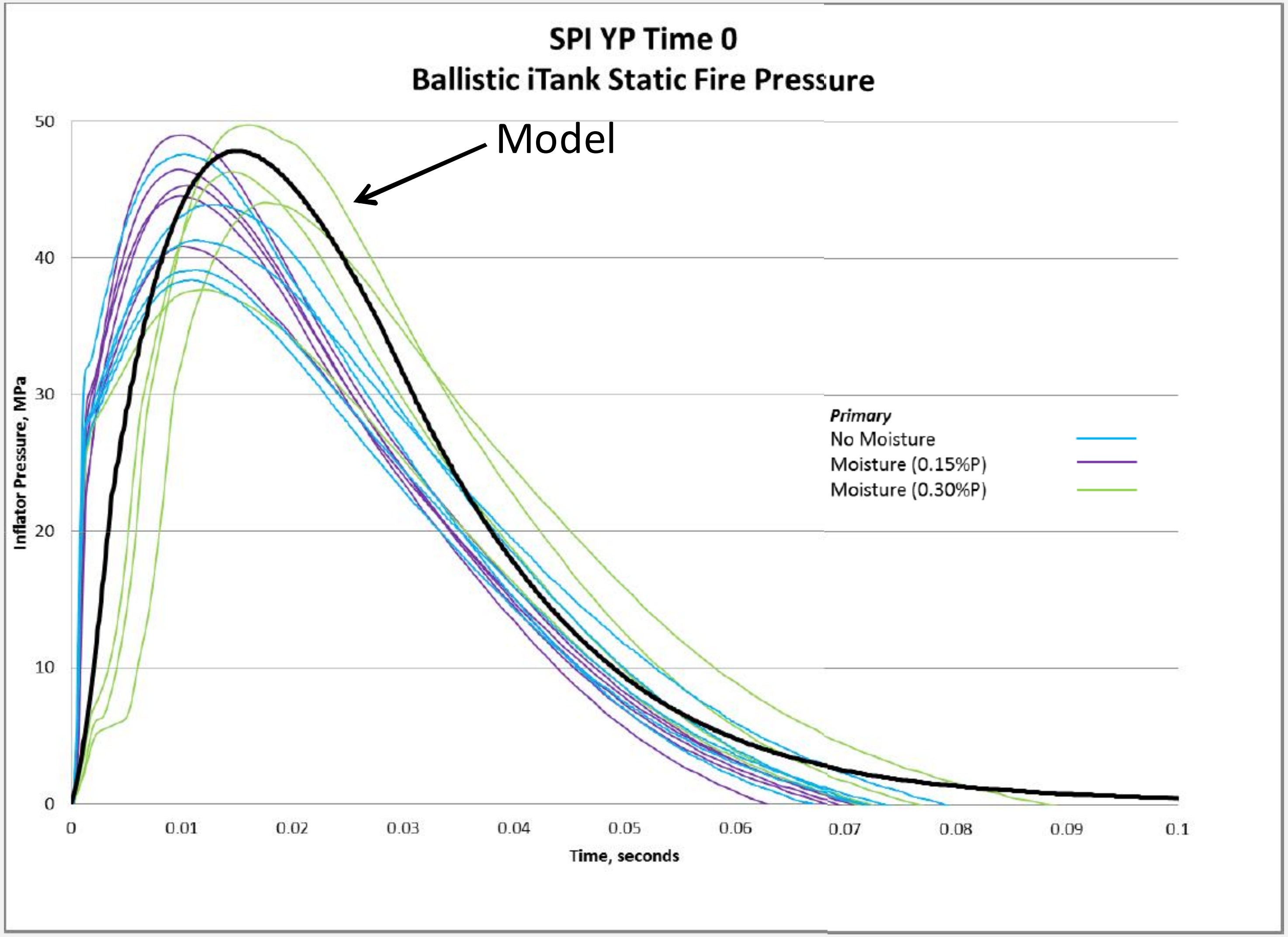
SPI YP Ballistic Modeling

- PSPI-L YD Model used as basis due to similarity
- Adjusted model for YP vent area and propellant mass.
- Assumed PSPI-L YD wafer break-up and burning surface area as starting point
- YP prediction is lower than YD model and similar to measured YP HW data



Observed Tank Test Aging Data

SPI YP model similar to measured data
Ignition rise is somewhat slower
Measured data seems to have a gage drift later in the test (heat affected?)



SPI YP Wafer Break-up Sensitivity Study

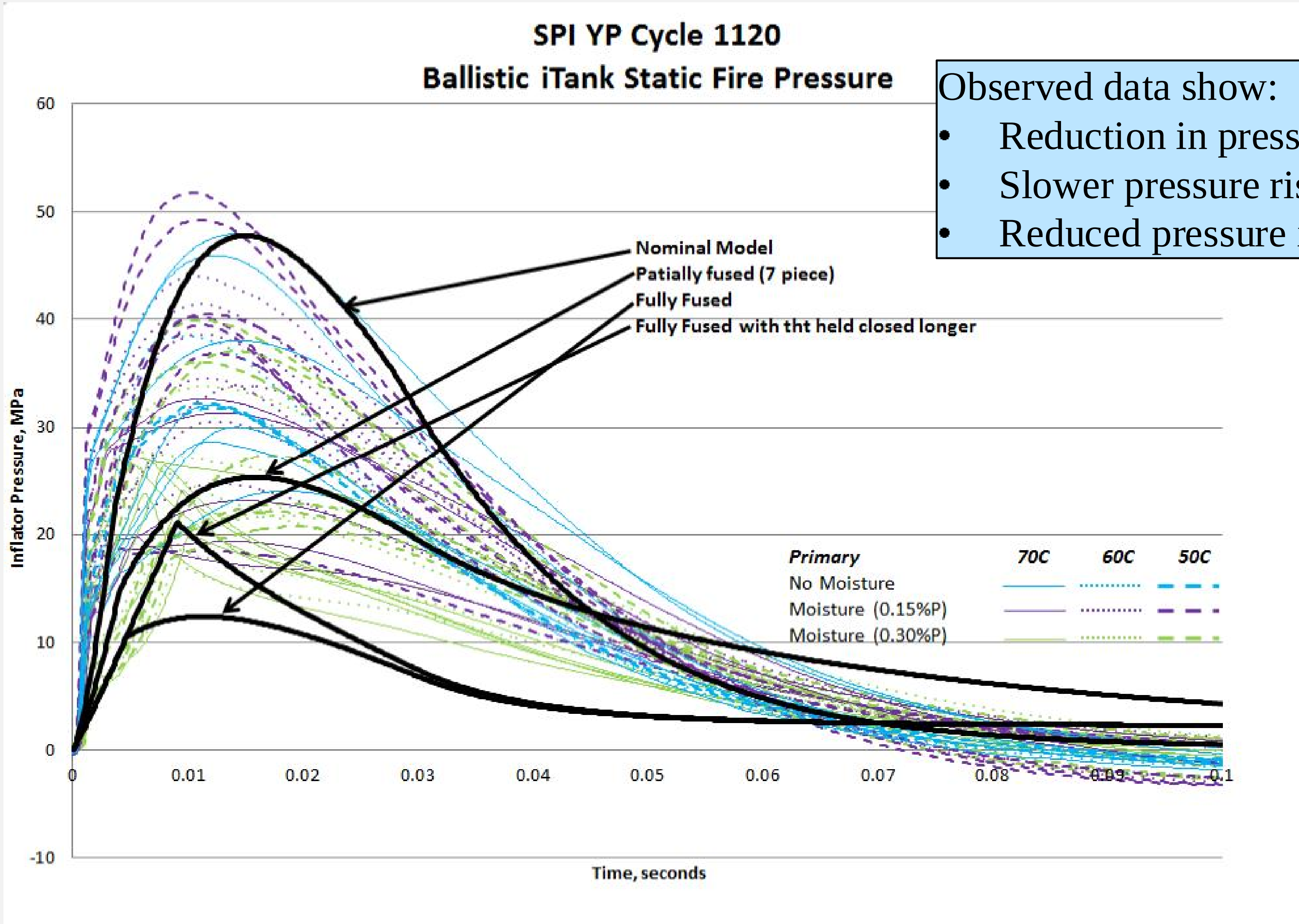
Orbital ATK

Assume reduced break-up occurs as wafers age

- Wafer grows into screen
- Two springs in YP exert compression on wafers from both ends
- Wafers fuse together to various extents over time
- Effect of vent opening at low break-up on “roll-over” behavior

Note: quench data results show break-up of YP wafers for tested aged inflators

Reduced Wafer Break-up Modeling



Observed data show:

- Reduction in pressure level
- Slower pressure rise
- Reduced pressure integral

Summary of Ballistic Modeling

- Ballistic models were developed to investigate the observed performance behavior of SPI YP inflators in the heavy weight test apparatus.
  - Models were anchored to nominal performance data and compared to PSPI-L FD and YD models and heavy weight test results
  - Some aged SPI YP inflator tests exhibited lower pressures, lower pressure integrals, and a low pressure “roll-over” behavior.
  - These characteristics were less prevalent on PSPI-L YD and FD inflator tests

- Wafer break-up sensitivity was investigated.
  - Results showed that reduced break-up results in predicted performance similar to that observed in the SPI YP heavyweight tests
  - Vent opening can play important roll in the low pressure “roll-over” characteristics.

- Ballistic stability favors systems with more surface area early in combustion
  - Less ability to generate higher effective surface area burning later
  - Ballistic advantage is sufficiently large to compensate for propellant degradation (density) to a significant degree

Study Conclusions and Recommendations

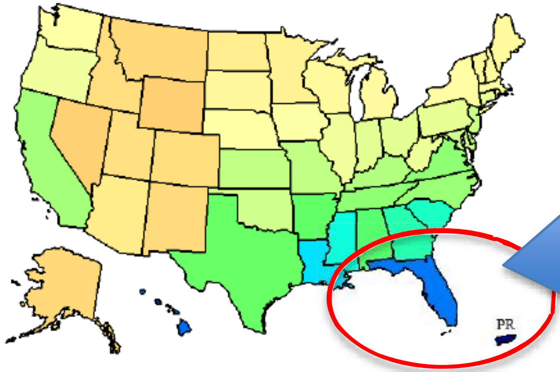
- Consistent data provides confidence
  - Consistent data validates design of the scientific study and execution of both experiments and testing
  - Data matches field returns in every aspect
  - Data aligns internally and externally well providing high confidence in trends and allows conclusions to be drawn with confidence
- Key differences are materially significant
  - Temperature is the largest driving factor in wafer growth
    - Inflators that experience lower peak temperatures will show reduced effects of aging
  - Moisture is required for faster growth of wafers
    - Higher moisture accelerates rate of damage at all temperatures
  - Vehicles show differences in both temperature and humidity with them tracking each other (higher temperature correlates with higher humidity in vehicles)
  - Large wafer FD is most susceptible to aging that results in higher probability of an ED
  - Inflators with small wafers exhibit a reduced propensity to high pressure events due to inherent ballistic advantages
    - Even when density reduction is similar
    - This may also suggest an advantage for tablet based systems

- Recommendation
  - A further 280 cycles will increase the understanding of how large the improvement is for the inflators used in the GM-900 compared to those used in the Vibe and other vehicles

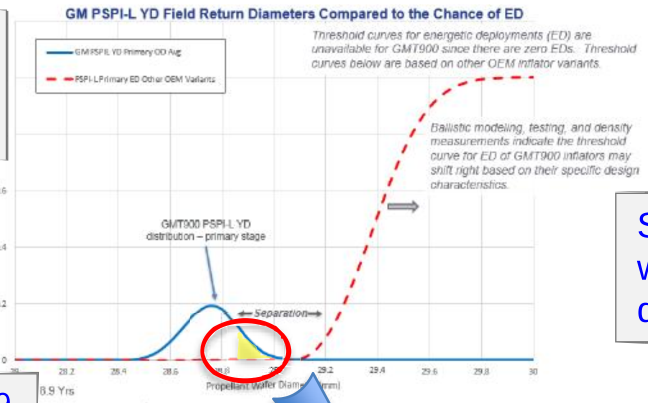
GM ACCELERATED AGING

ARTIFICIAL AGING GM -BACKGROUND

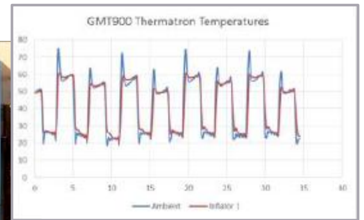
For GMT900 GM environmental testing was intended to quickly assess the near term robustness of the GMT 900 over the summer of 2016. The remaining parts are being used to determine the ED threshold for GM inflators.



Acquire oldest field returns from HAH regions

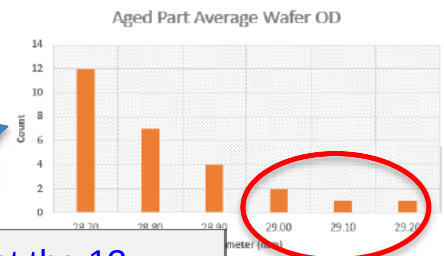


Select the parts with the most degradation

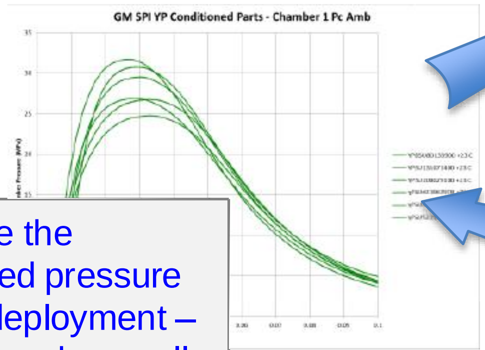


Temperature profile based on vehicle testing in HAH region

Induce additional environmental aging on the part



Select the 12 parts with the most degradation

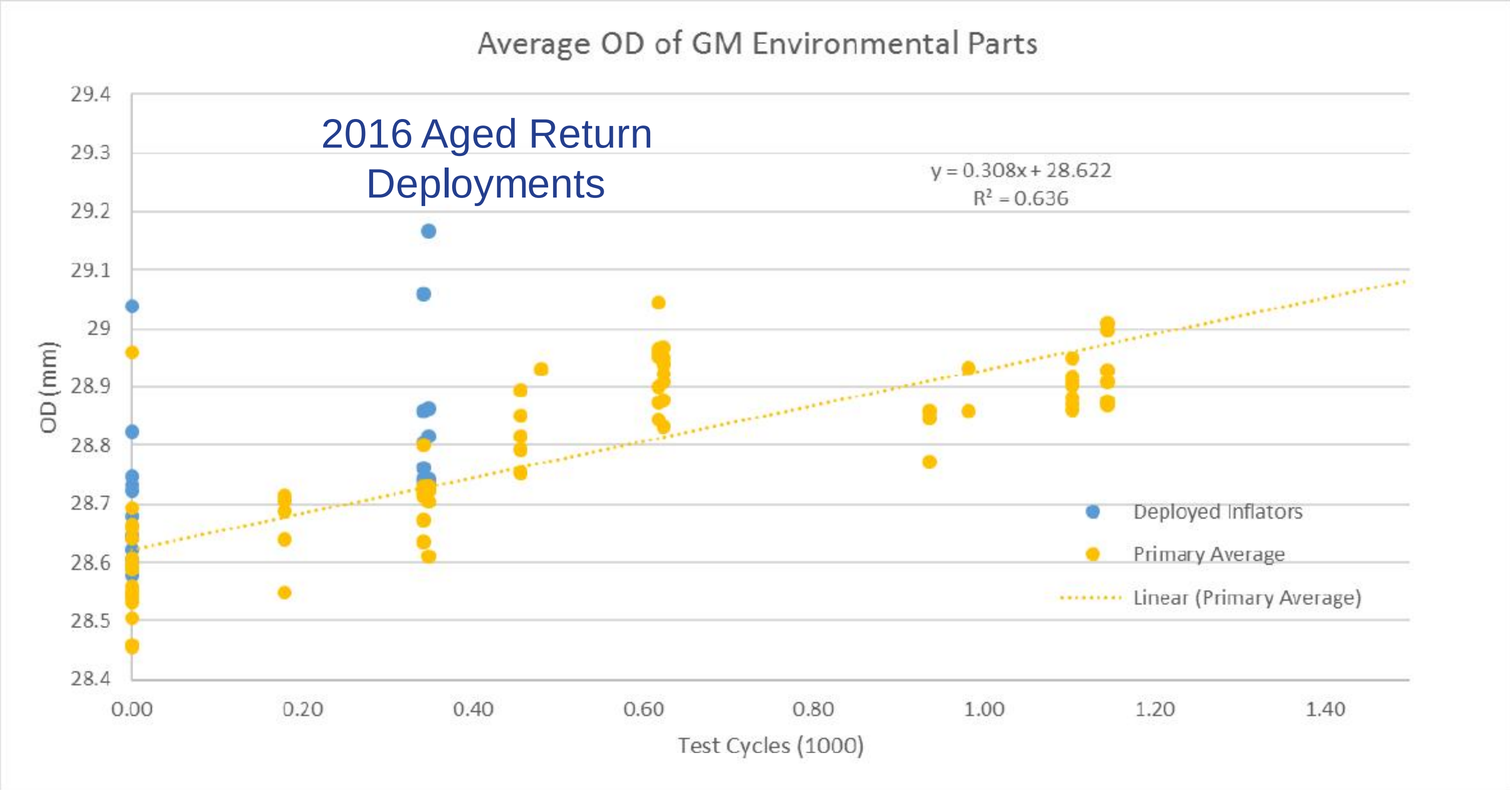


Measure the generated pressure during deployment – all deployed normally

Cycle the remaining 19 parts and deploy @ 29.2 to 29.6mm

GENERAL MOTORS

GM ENVIRONMENTAL TESTING



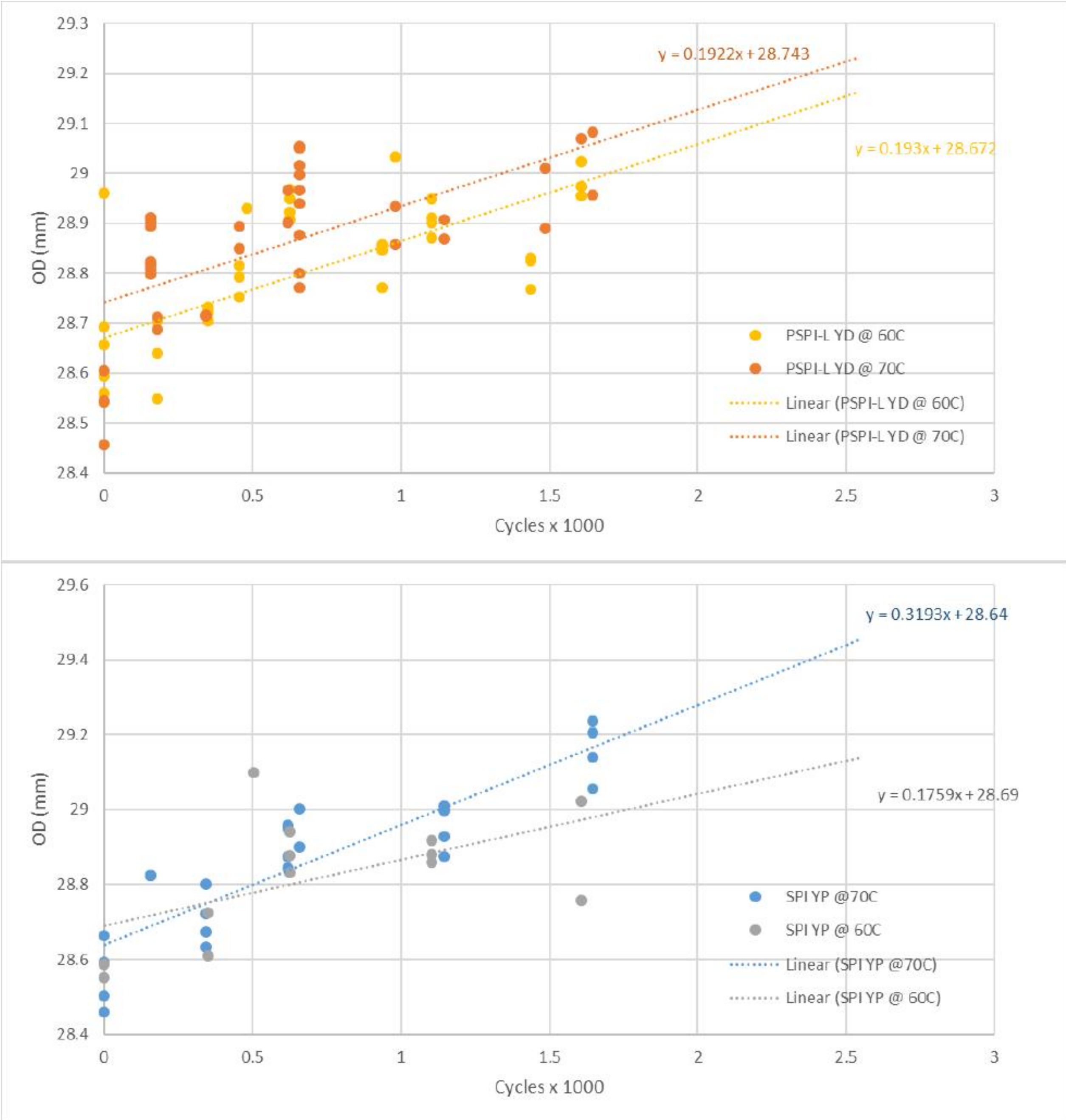
GM environmental testing took a different approach than OATK

- Started with MY07 GMT900 parts that had been in the field ~8 yrs that were selected for large diameters
- No additional water was added; the parts are being cycled in a HAH environment (25-40 g/cm3)
- The temperature profile is based on Miami temperature measurements on the Vibe and GMT900
- During AUG2016 the **largest OD parts for each inflator type and temperature profile were deployed and they deployed normally**.
- The **remaining parts were put back into the environmental chamber** to continue cycling.

GM ENVIRONMENTAL TESTING

Current status of GM environmental testing:

- After initial OD growth the rate of change has slowed
- As of 10AUG2017 the largest OD of parts are 29.08 mm and 29.23 for the YD and YP
- Though these are large ODs compared to field returns they are smaller than 81 OATK aged samples that have already been deployed successfully – it would be redundant to OATK testing to deploy these lower OD parts.
- Planned additional 5 months would results in part comparable to OATK 1680 cycle parts



BACKUP

GM COMMUNICATION TO NHTSA ON STATUS OF GMT900 INVESTIGATION

November 25, 2014. GM shares its preliminary, internal investigation plan for GMT900 vehicles with NHTSA, including GM's proposal to seek GMT900 passenger airbag inflators proactively from the field to understand the effect of the environment (vehicle and external) and humidity on these Takata inflators over time.

January 23, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation. GM's initial presentations to NHTSA in the beginning of 2015 include, among other things, GM's preliminary analyses of Takata's CT scan measurements of propellant wafers in SPI/PSPI-L inflators returned from the field.

February 13, 2015. GM conducts a telephonic conference with NHTSA to brief NHTSA on GM's Takata investigation and testing plans.

March 25, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation. GM's presentation includes, among other things, GM's initial analysis of data supplied by Takata and other OEMs on the performance of Takata inflators in other vehicles, which indicates marked differences between the observed propellant degradation in SPI/PSPI-L inflators recovered from GMT900 vehicles (as measured by CT scanning) and the observed propellant degradation in inflators recovered from other vehicles.

May 14, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

May 22, 2015. GM conducts a telephonic conference with NHTSA staff to review the status of GM's investigation.

July 23, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

August 27, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

September 14, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

October 15, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

November 19, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

November 24, 2015. GM conducts a telephonic conference to provide the November 19th briefing to certain NHTSA personnel that were unable to attend the in-person meeting on November 19.

December 17, 2015. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation, including Orbital ATK ("**Orbital**") testing and analysis and information on recent field part returns.

January 7, 2016. GM conducts a telephonic conference to update NHTSA on the Orbital testing plan.

January 21, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

February 18, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

March 17, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

April 6, 2016. GM conducts a telephonic conference to update NHTSA on data generated by returned field parts from GMT900 vehicles.

April 14, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

April 26, 2016. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

May 10, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office and provide a comprehensive technical briefing on the status of GM's investigation. GM's presentation included, among other things, the results from Takata's CT scanning and ballistic testing on inflators returned from GMT900 vehicles in Zone A regions, which indicated that the inflators were performing safely and as designed.

Orbital is a leading engineering firm with recognized global expertise in propulsion systems.

May 12, 2016. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

May 18, 2016. GM conducts a telephonic conference to solicit feedback from NHTSA on the testing discussed during the May 10 technical briefing.

June 16, 2016. Following the filing of GM's Preliminary DIRs on May 27, 2016 (see below), GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

July 28, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of Orbital's short-term testing and GM's inflator aging study.

August 16, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of Orbital's short-term testing and GM's inflator aging study.

September 1, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to provide a detailed technical briefing to ODI on GM's investigation and the initial results of Orbital's short-term testing. GM's investigation includes updated CT scanning and ballistic testing results, along with the results of GM's recently completed inflator aging study. This meeting also provides NHTSA with an overview of GM's petition for deferral, which is filed on September 2.

September 13, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

October 4, 2016. GM conducts a telephonic conference to update NHTSA on the status of GM's investigation.

October 13, 2016. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

November 1, 2016. GM meets with NHTSA in GM's Detroit office to update NHTSA on the status of GM's investigation.

January 11, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

February 21, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

March 15, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

April 5, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to provide a detailed technical briefing to the ODI on GM's investigation and the results of Orbital mid-term testing. GM's investigation includes updated CT scanning and ballistic testing results, along with the results of GM's recently completed inflator aging study.

May 9,2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

June 21, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

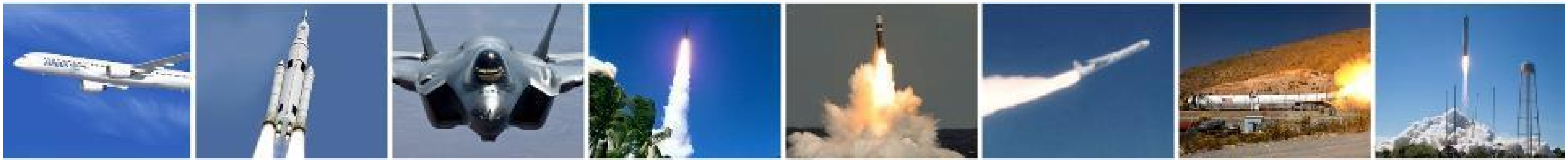
July 20, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

August 16, 2017. GM meets with NHTSA in NHTSA's Washington, D.C. office to update NHTSA on the status of GM's investigation.

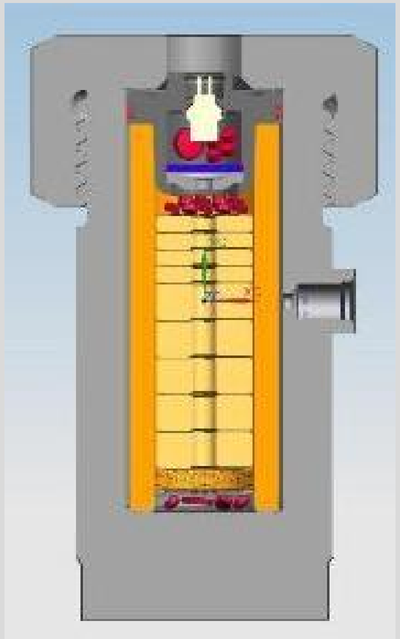
Back Up Data

Briefing to NHTSA

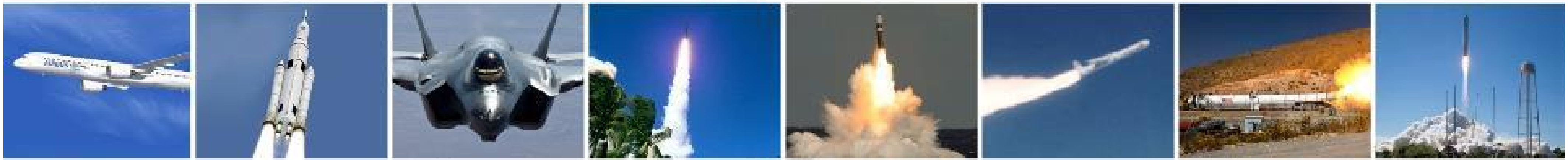
23 August 2017



0-1680 Wafer Health Analysis

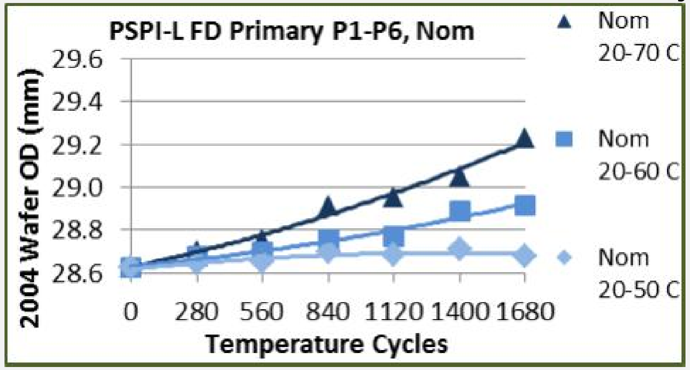


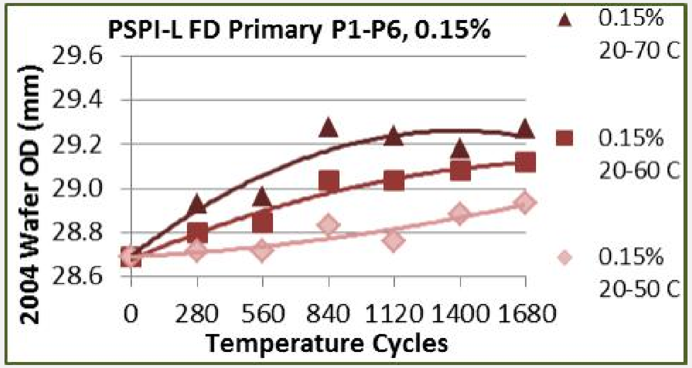
Discussion

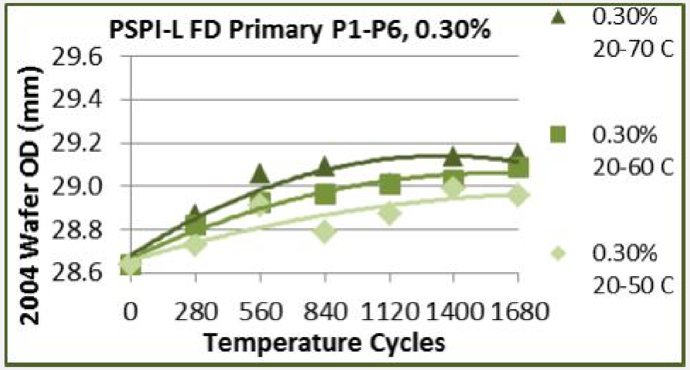


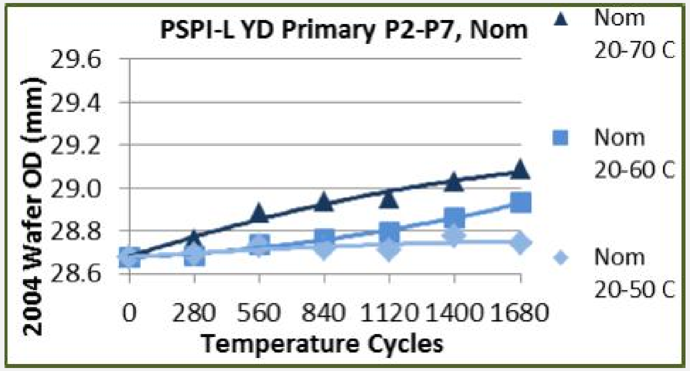
Primary Chamber Wafer OD Caliper Measurements

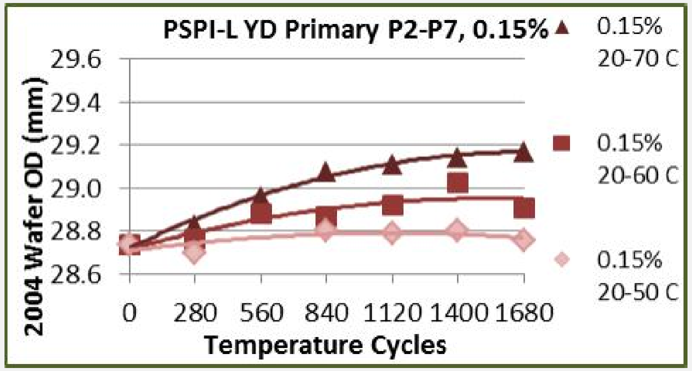
- Nominal wafer OD growth, especially 20-70 C cycles, appears to be accelerating at extended cycles
  - Growth at higher moisture levels is slowing down
- FD and YP outer diameters are larger than the corresponding YD
  - YP 0.30% outer diameters are by far the largest

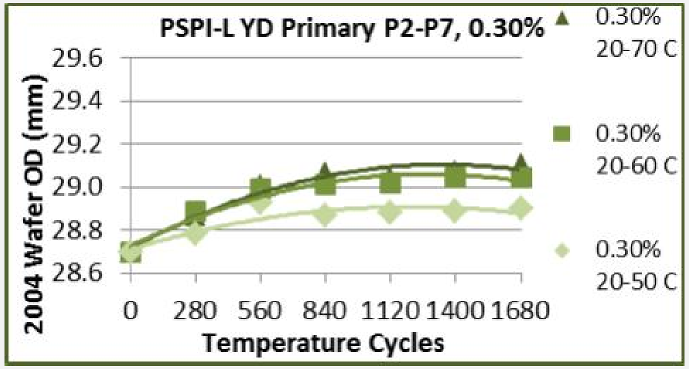


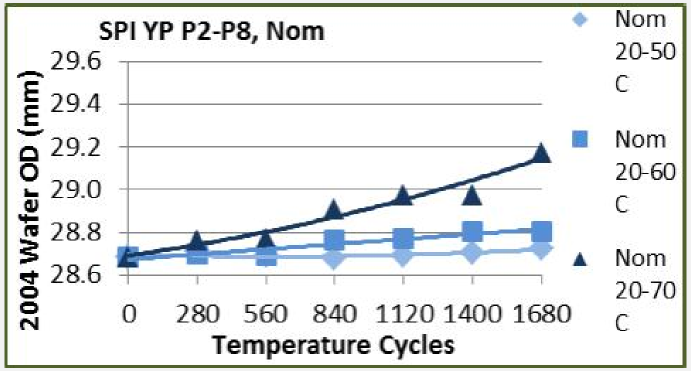


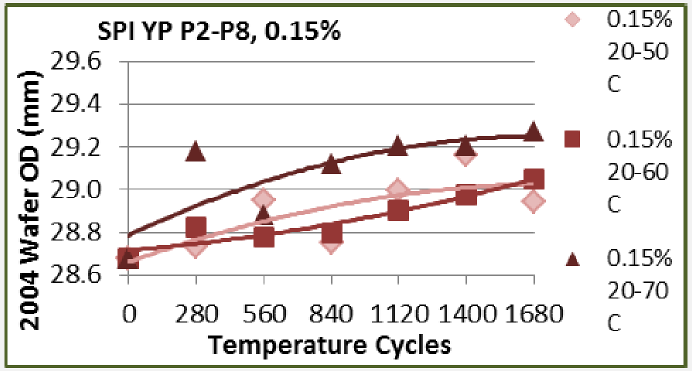


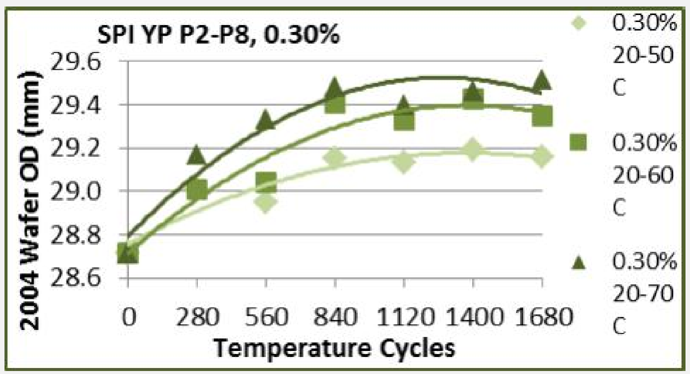








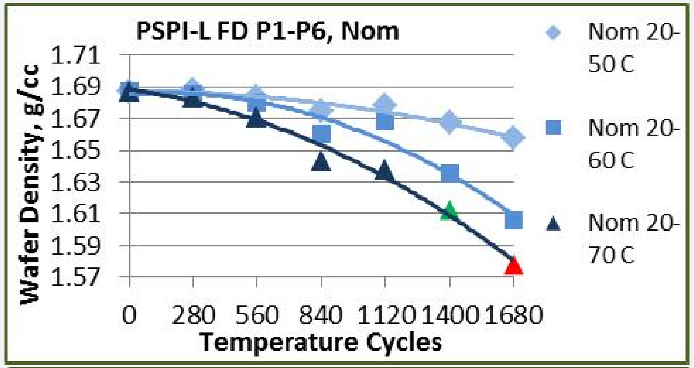


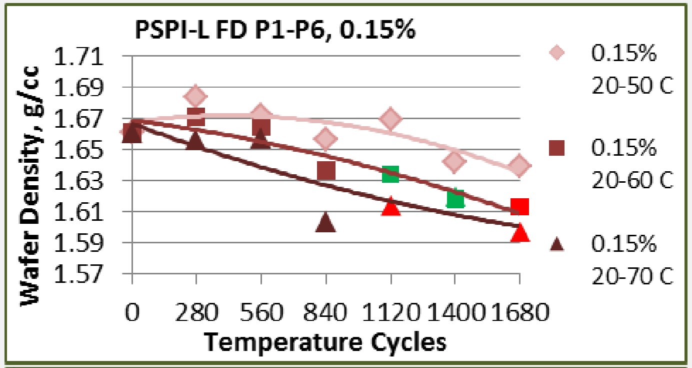


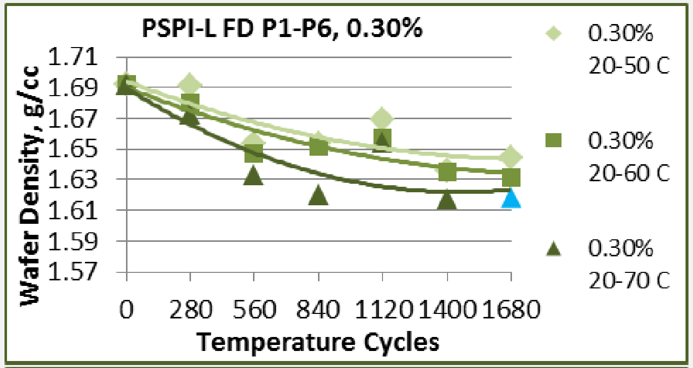
ED
Near ED
CB Abnormal Burn

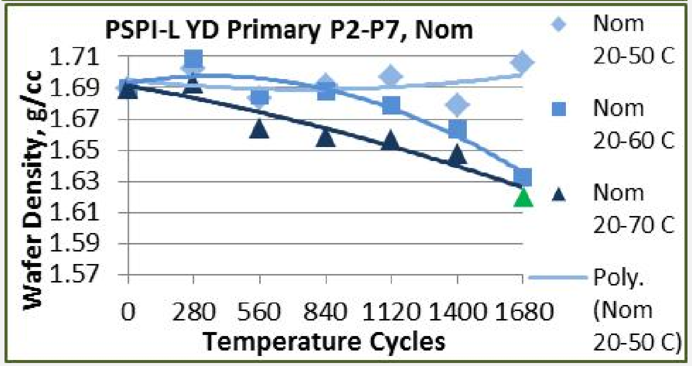
Primary Chamber Wafer Caliper Density

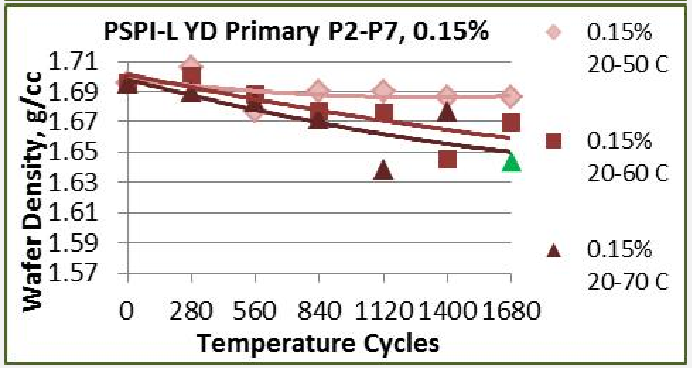
- Decrease in nominal wafer density, especially 20-70 C cycles, appears to be accelerating at extended cycles
  - ➢ Decrease in density at higher moisture levels is slowing down
- FD nominal and mid 20-70 C densities are the lowest-the conditions where EDs at 1680 cycles are occurring
- FD and YP 0.30% densities are lower that the corresponding YD. YP OD's were greater than FD, densities are similar.

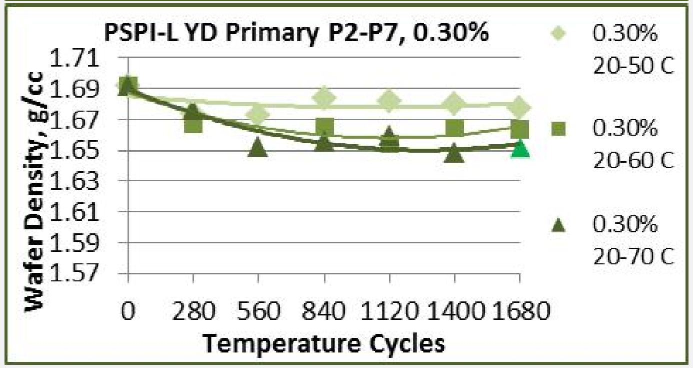


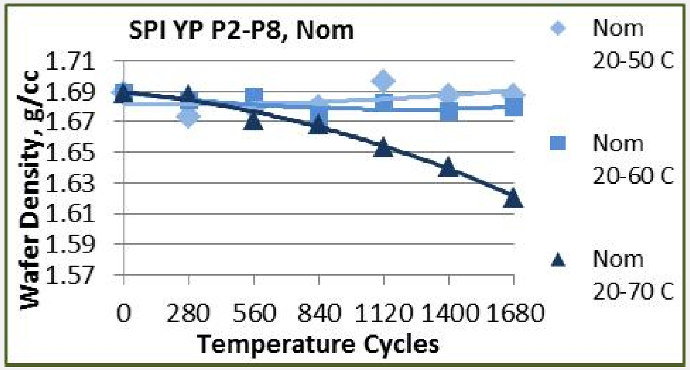


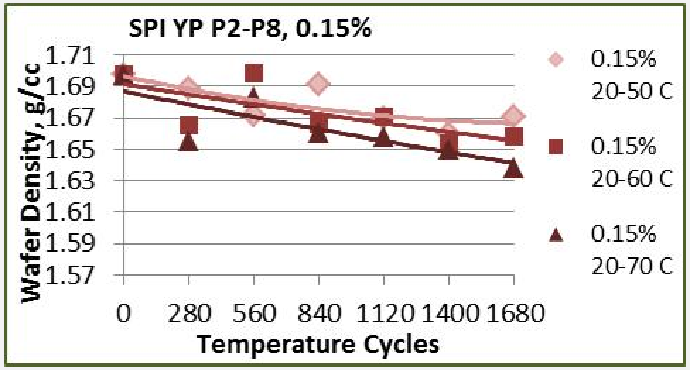


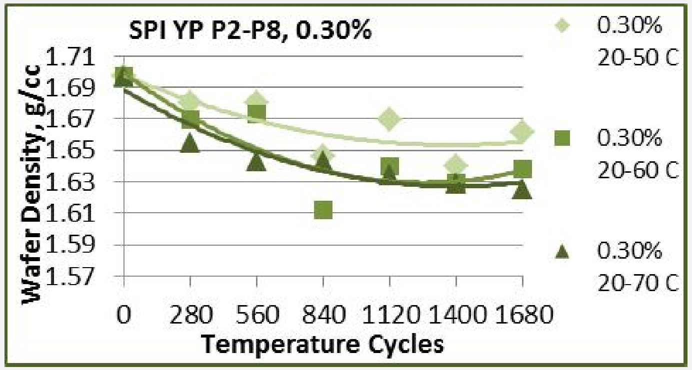










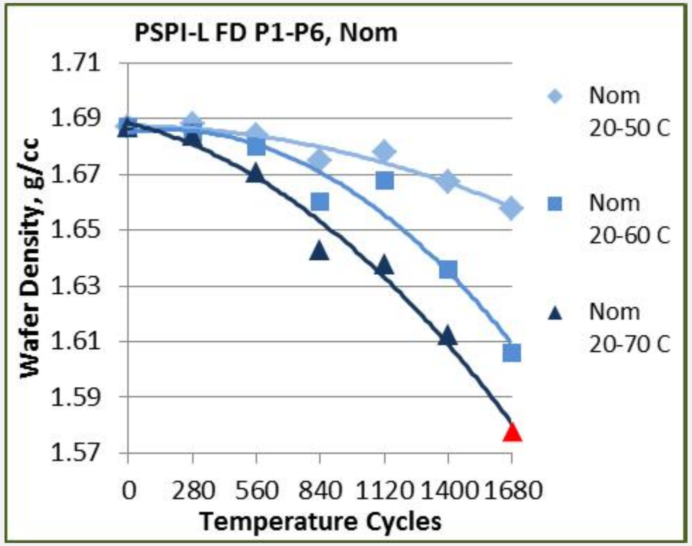


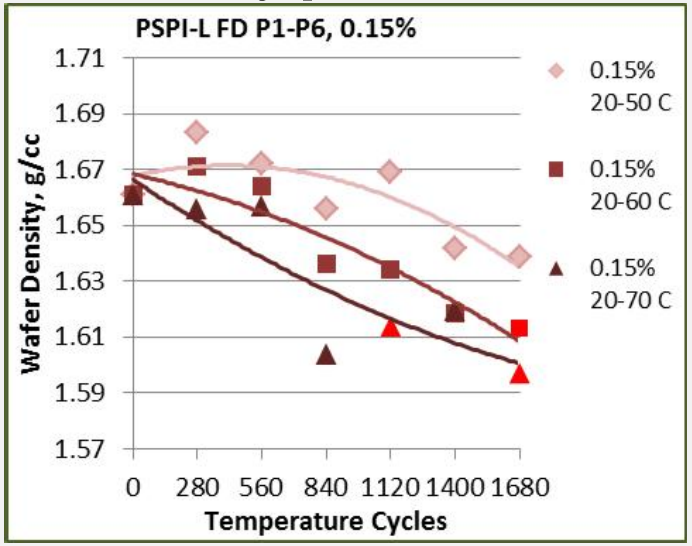
Comparison of PSPI-L FD ICAM Stack Height and Primary Chamber Caliper Density

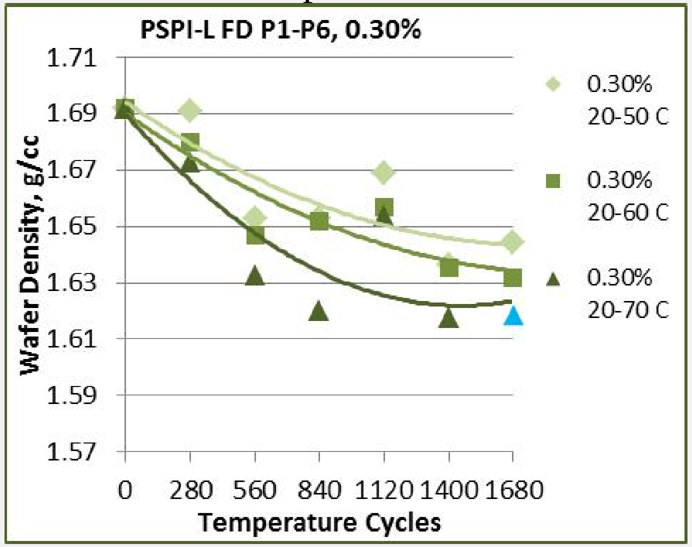
ED

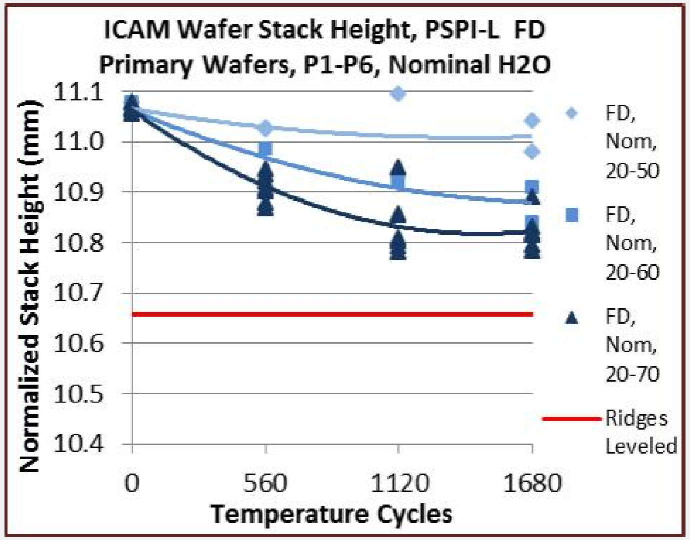
Near ED

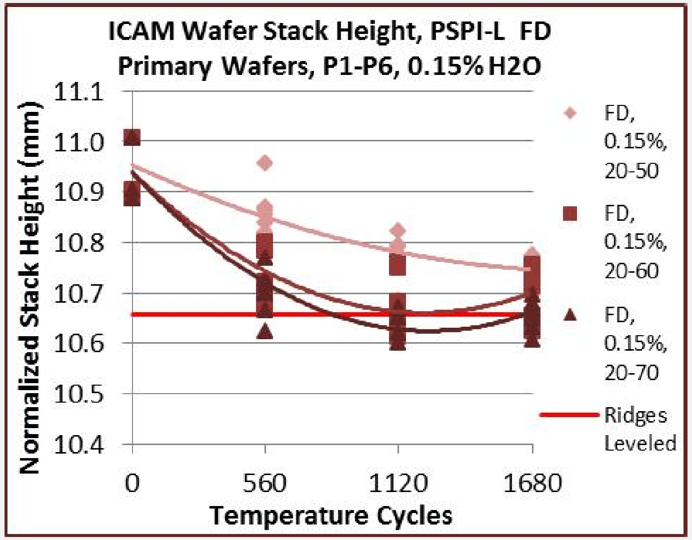
- 0.30% chambers: Rate of wafer damage decreases significantly when stack height reaches 10.66 mm, ≈840 cycles
  - At a stack height of 10.66 mm, no ingress/egress of moisture through wafer tops and bottoms can occur
    - Further wafer damage will occur mainly near the ID and OD
- Nominal chambers: Ingress/egress through wafer tops and bottoms is viable through 1680 cycles
- 0.15% chambers: 20-50C follows the nominal damage pattern whereas 20-70 follows the 0.30% pattern

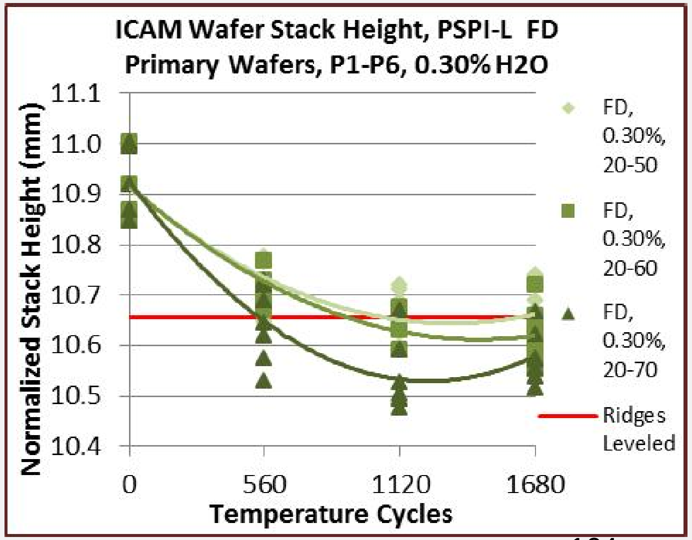






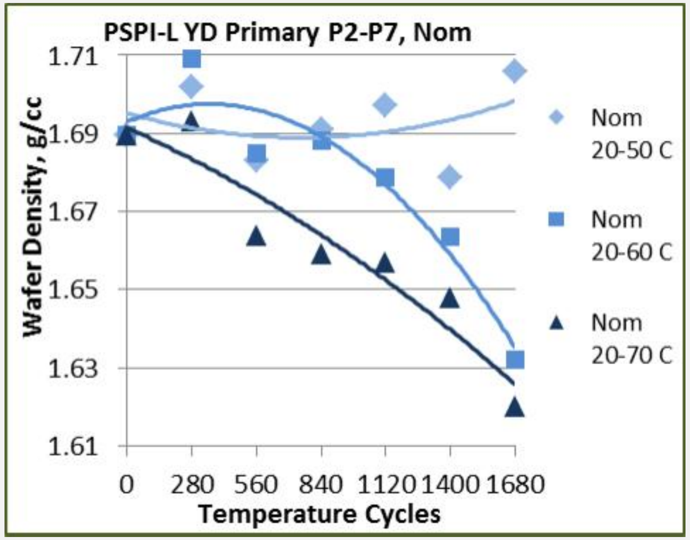


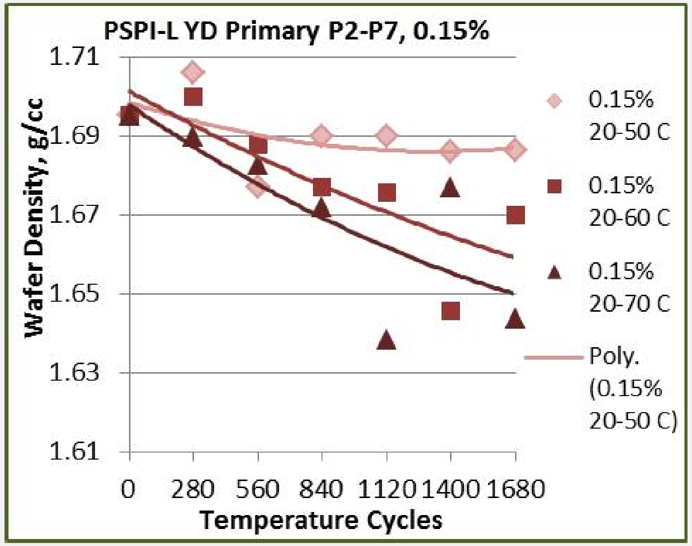


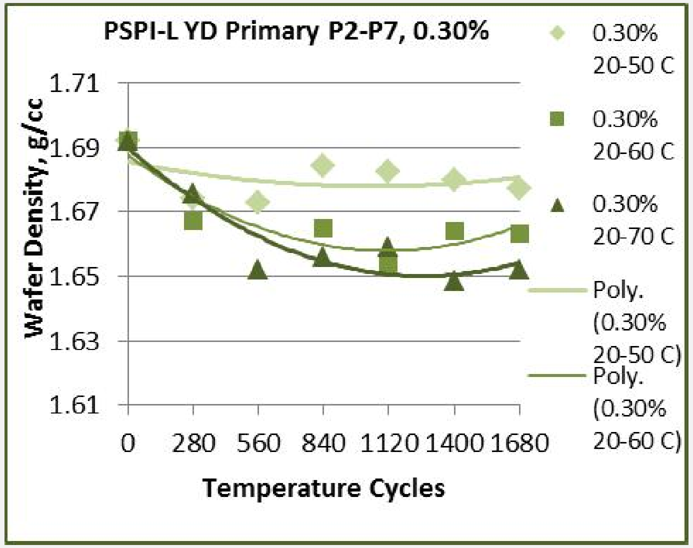


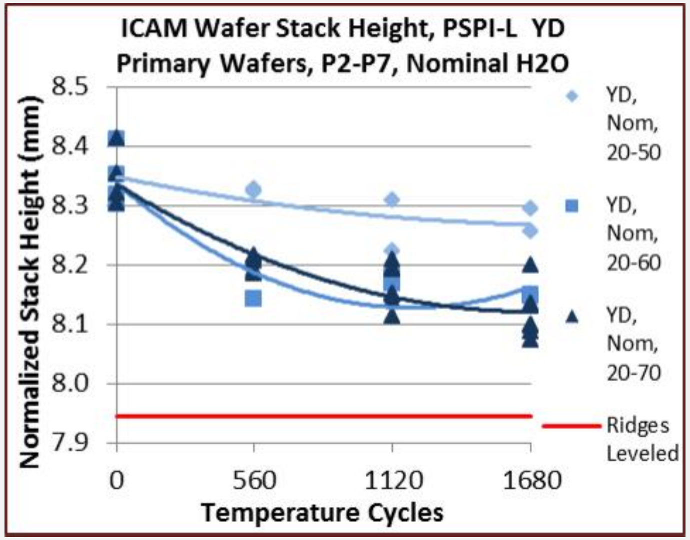
Comparison of PSPI-L YD ICAM Stack Height and Primary Chamber Caliper Density

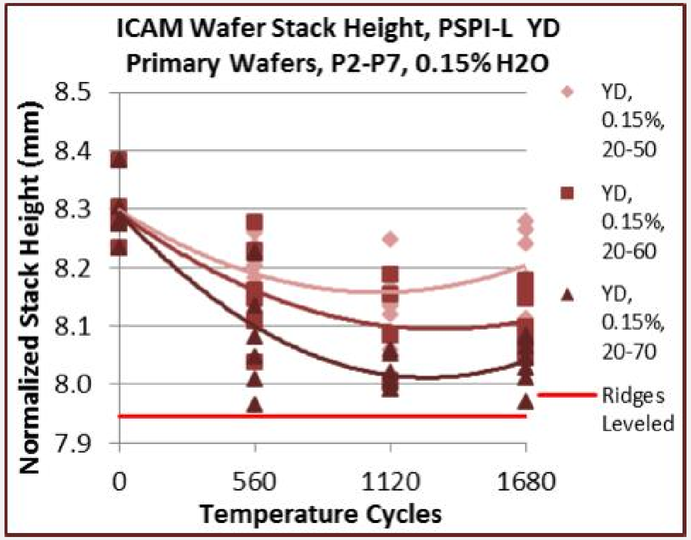
- Minimal wafer damage in moisture levels of 20-50C primary chambers
- 0.30% chambers: Wafer damage rate decreases at ≈840 cycles at stack height where wafer ridges are flattened, 7.94 mm
- Nominal chambers: Ingress/egress through wafer tops and bottoms is viable through 1680 cycles
- 0.15% chambers: Broad range of stack heights and significant scatter in density data

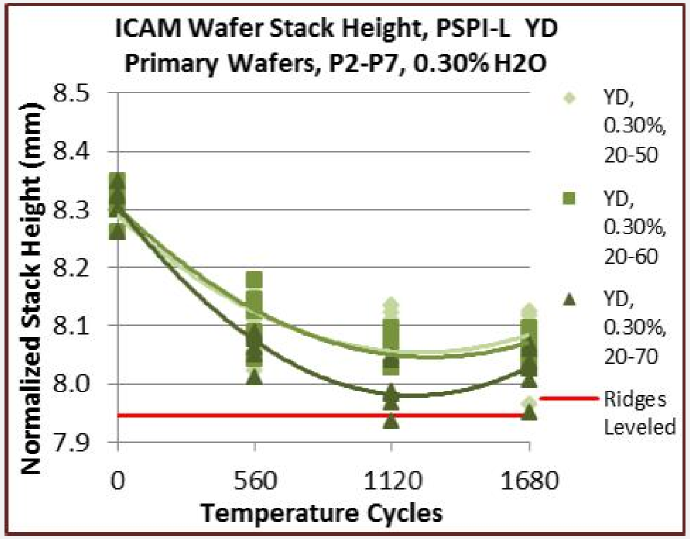






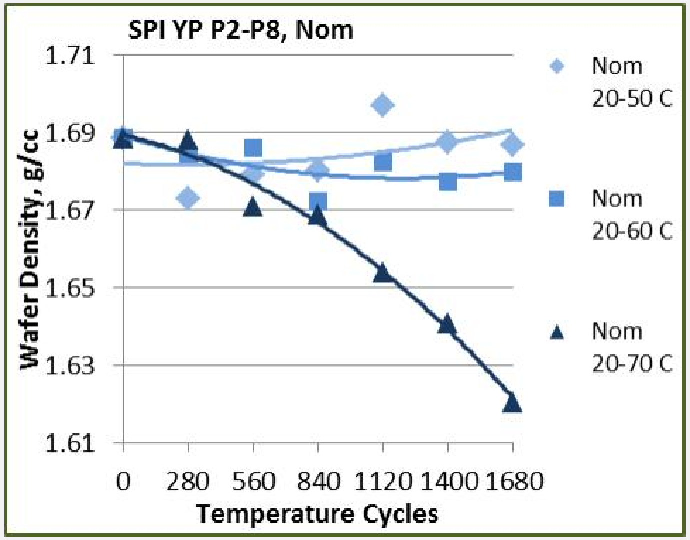


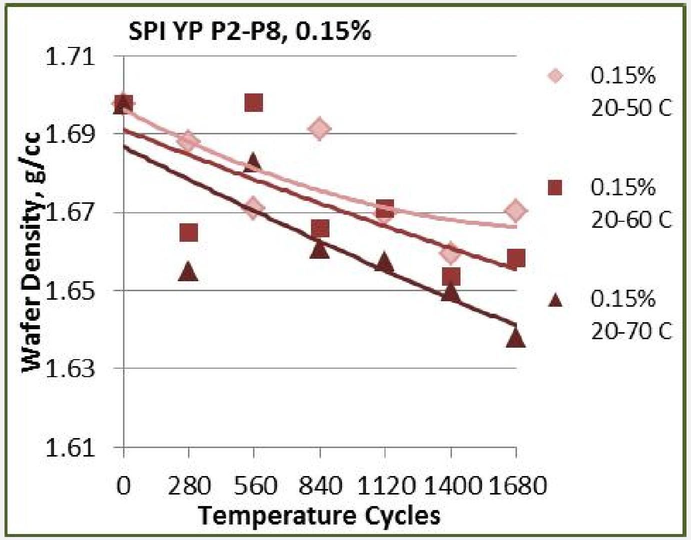


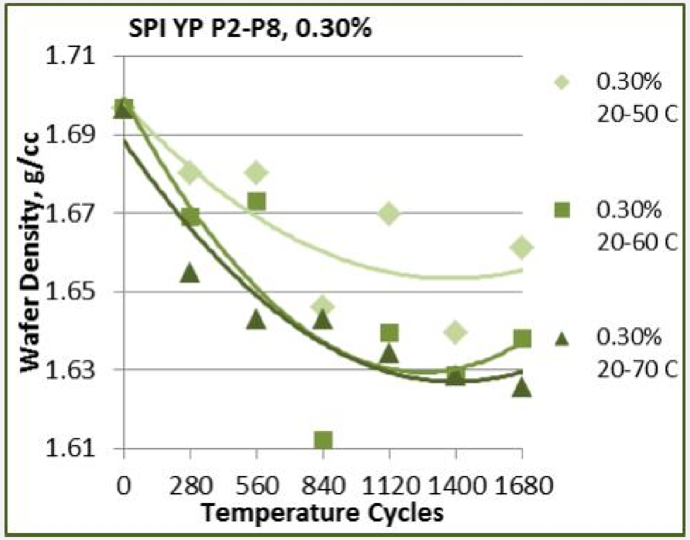


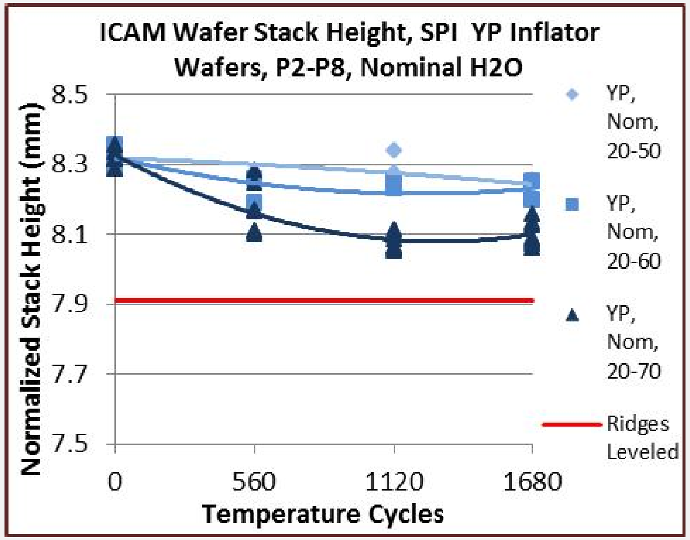
Comparison of SPI YP ICAM Stack Height and Primary Chamber Caliper Density

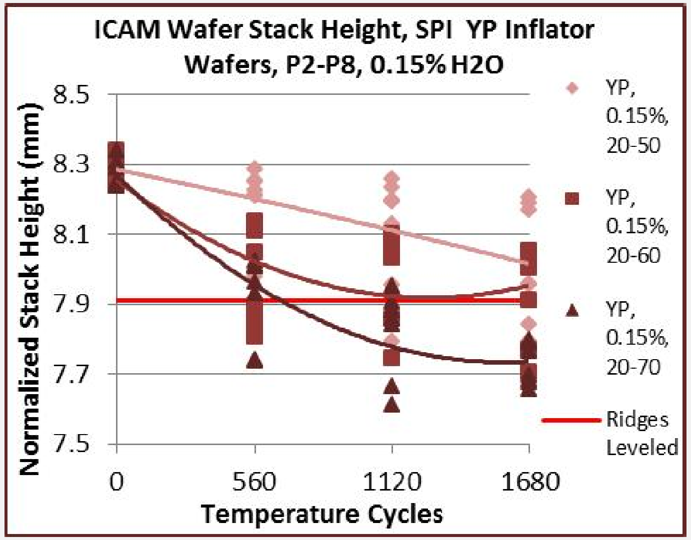
- 0.30% chambers: Rate of wafer damage decreases significantly when stack height passes 7.9 mm, ≈560 cycles
  - ➢ When stack height reaches 7.9 mm, no ingress/egress of moisture through wafer tops and bottoms can occur
    - – Further wafer damage will occur mainly near the ID and OD
- Nominal chambers: Ingress/egress through wafer tops and bottoms is viable through 1680 cycles
- For 0.15% and 0.30% chambers, stack heights are significantly less than 7.9 mm: Wafer OD values overestimate damage

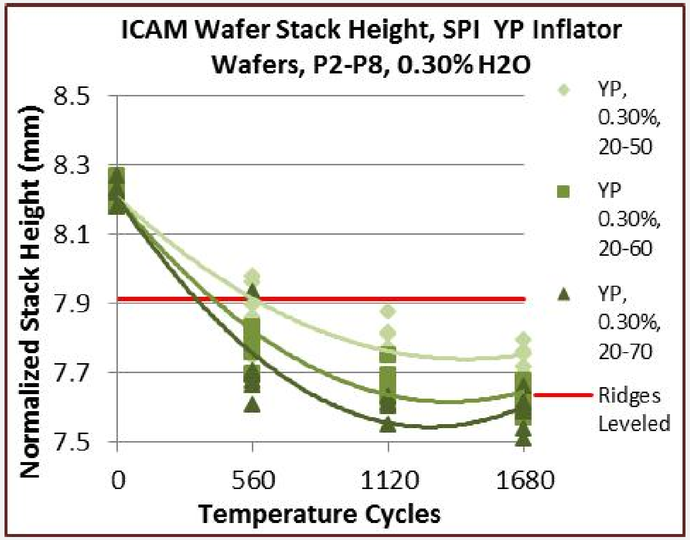






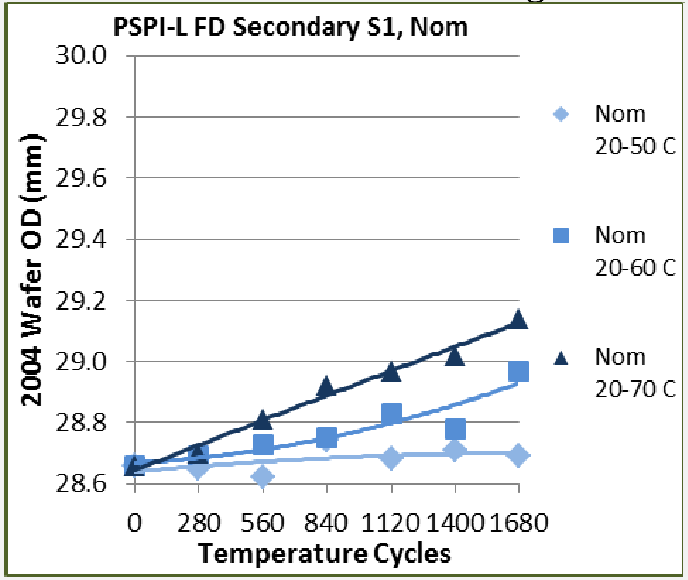


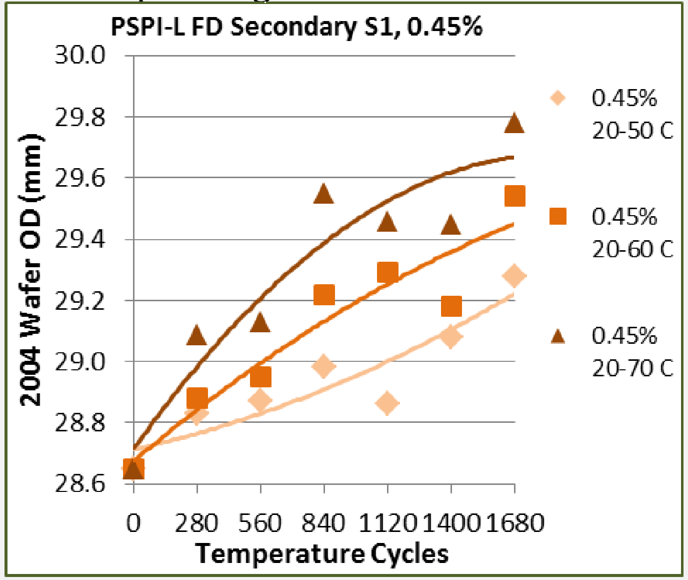


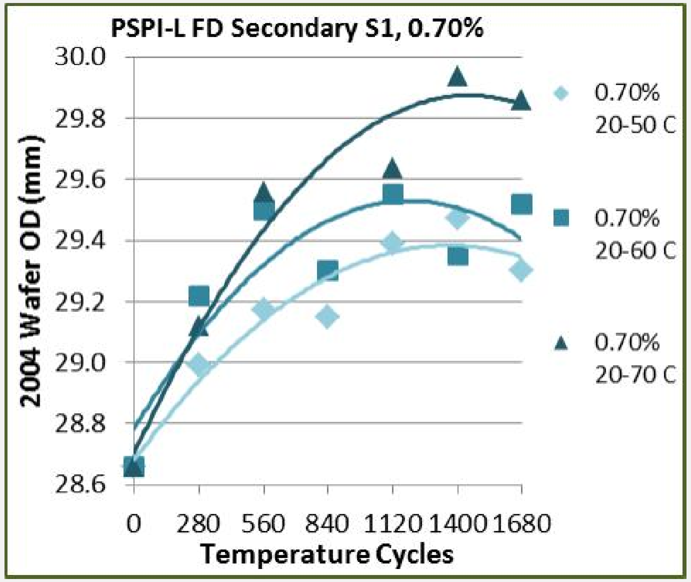


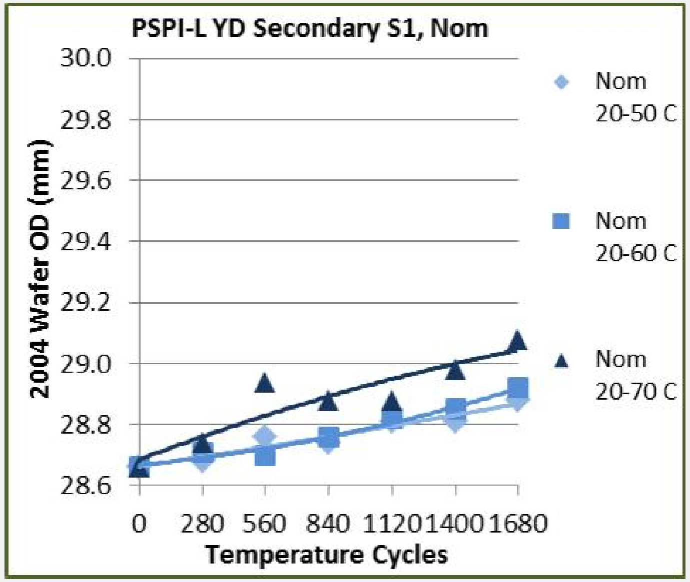
PSPI-L FD & YD Secondary Chamber Caliper Measurements

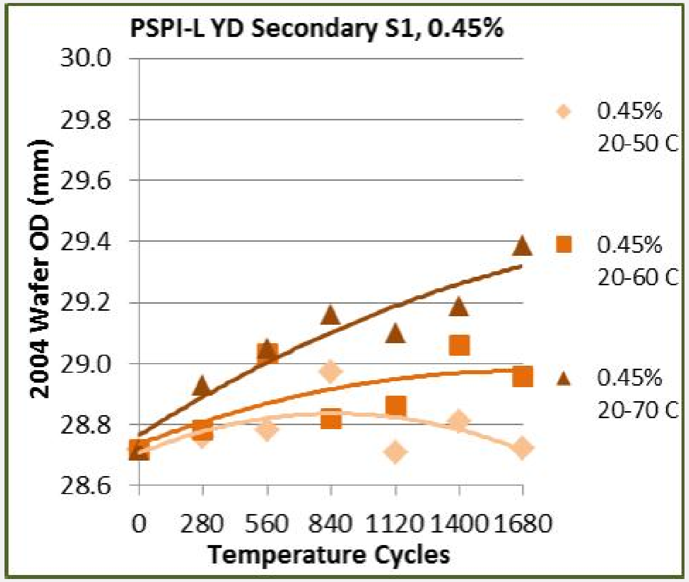
- Growth in secondary FD and YD nominal wafer OD is slightly less than in the primary chamber
  - Mid and high moisture wafers are increasing in OD at a greater rate than the nominal in the secondary chamber
- FD outer diameters are larger than the corresponding YD

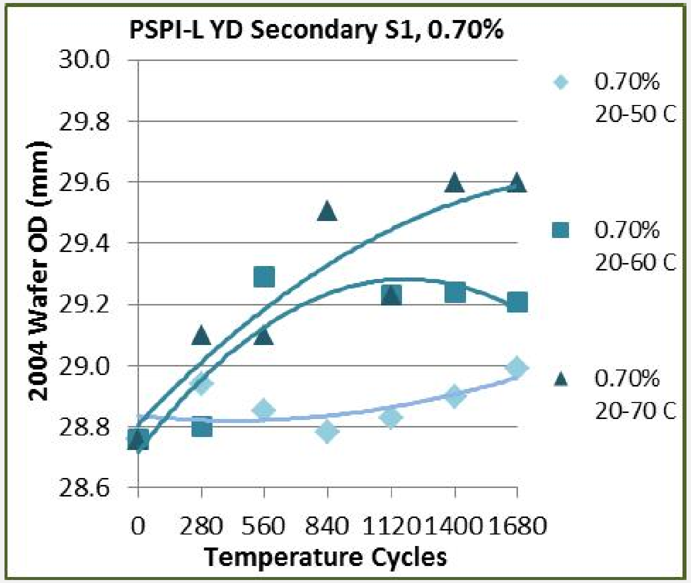








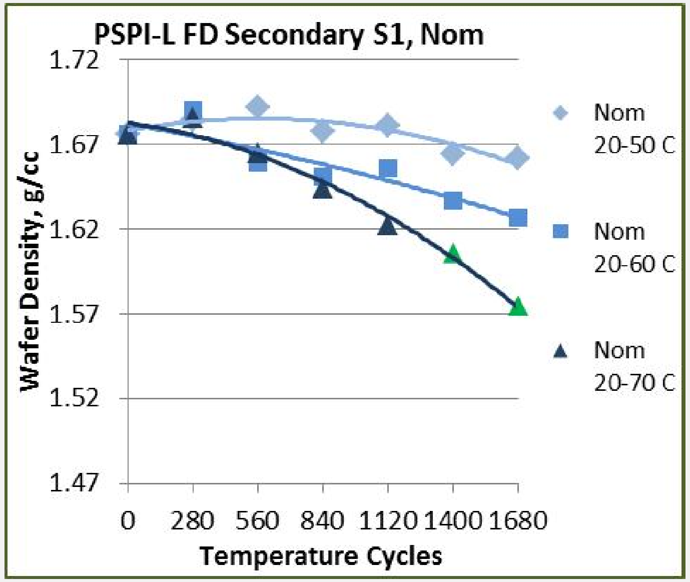


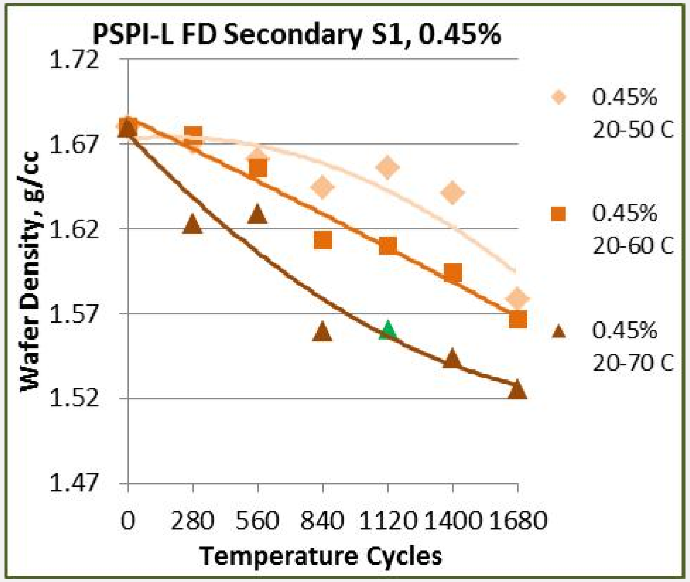


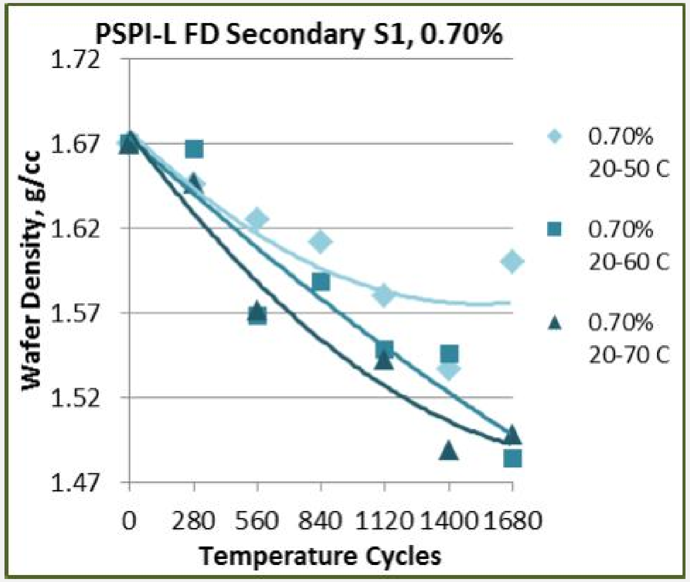
PSPI-L FD & YD Secondary Chamber Caliper Density

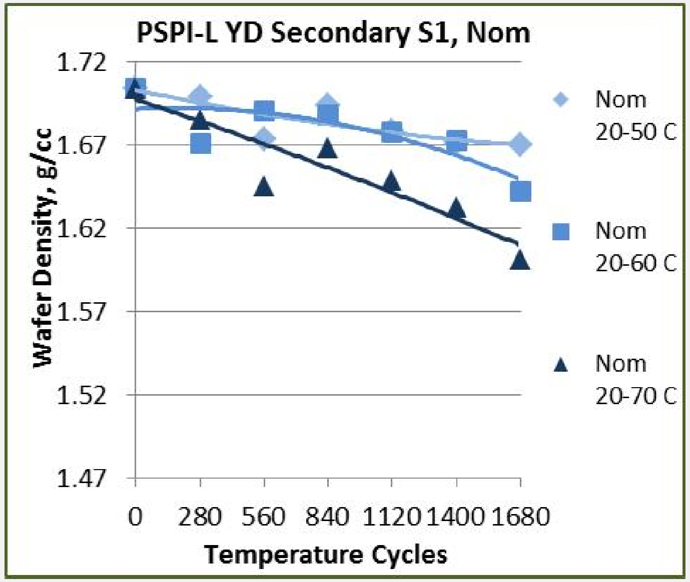
CB Abnormal Burn

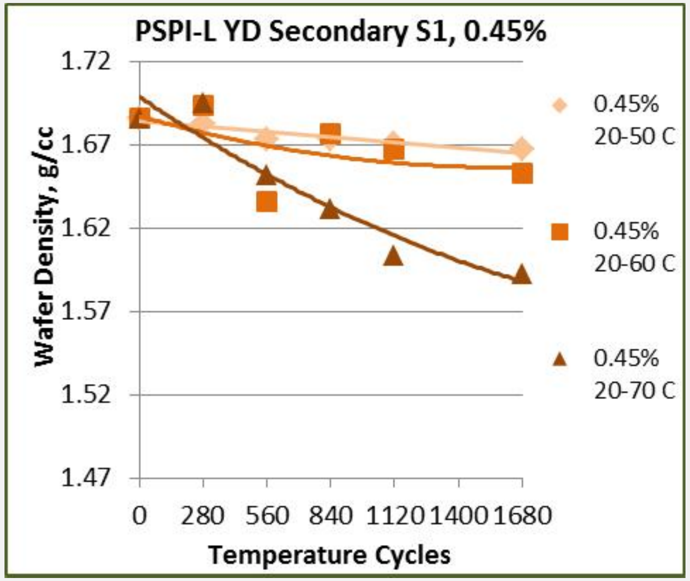
- Decrease in secondary FD and YD nominal wafer density comparable to that in the primary chamber
  - ➢ Mid and high moisture wafers are loosing density at a greater rate than the nominal in the secondary chamber
- FD densities are lower than the corresponding YD

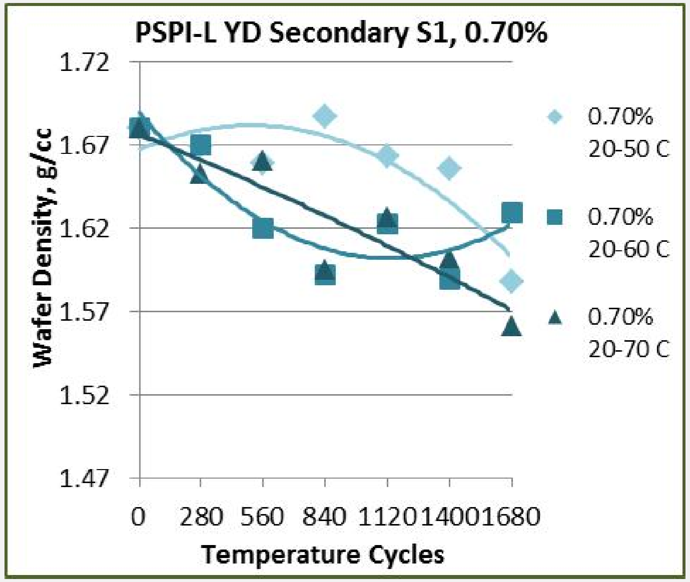






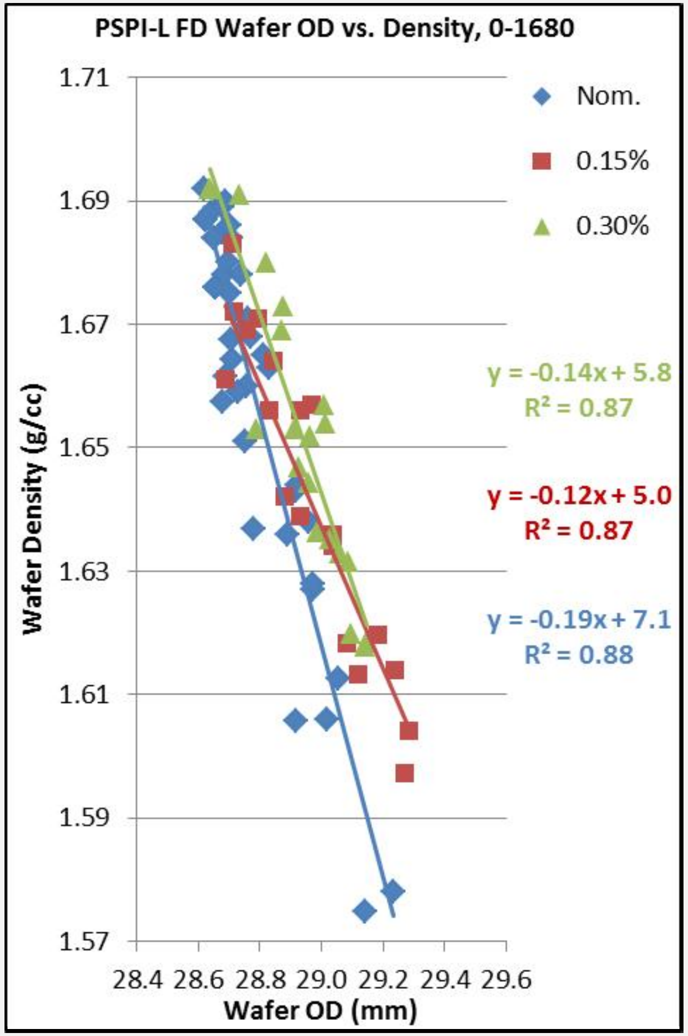


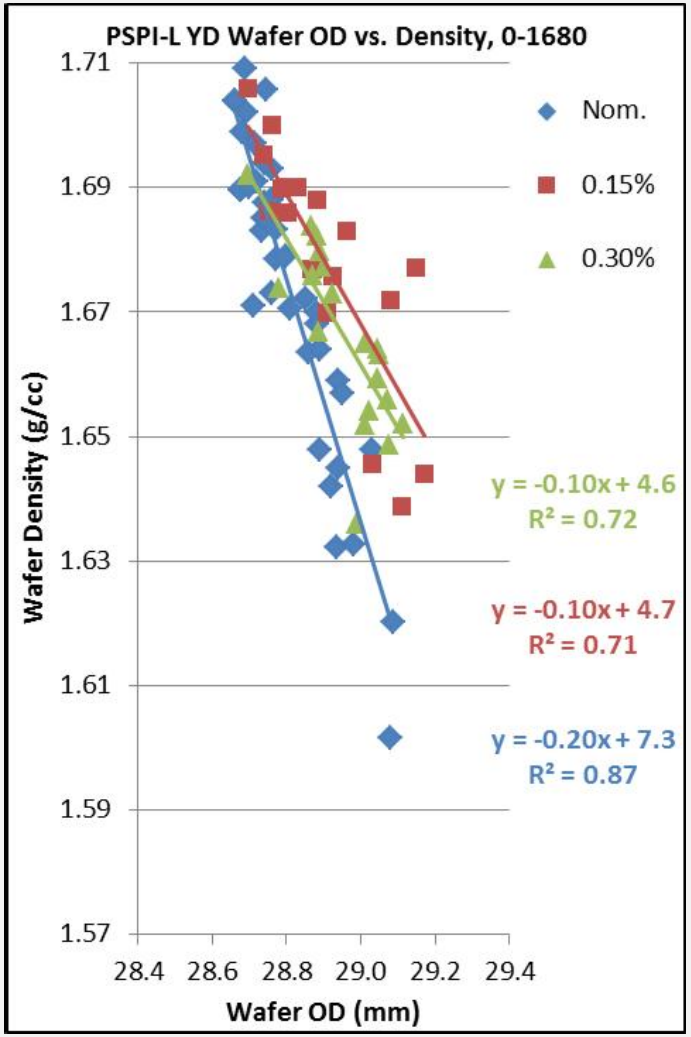


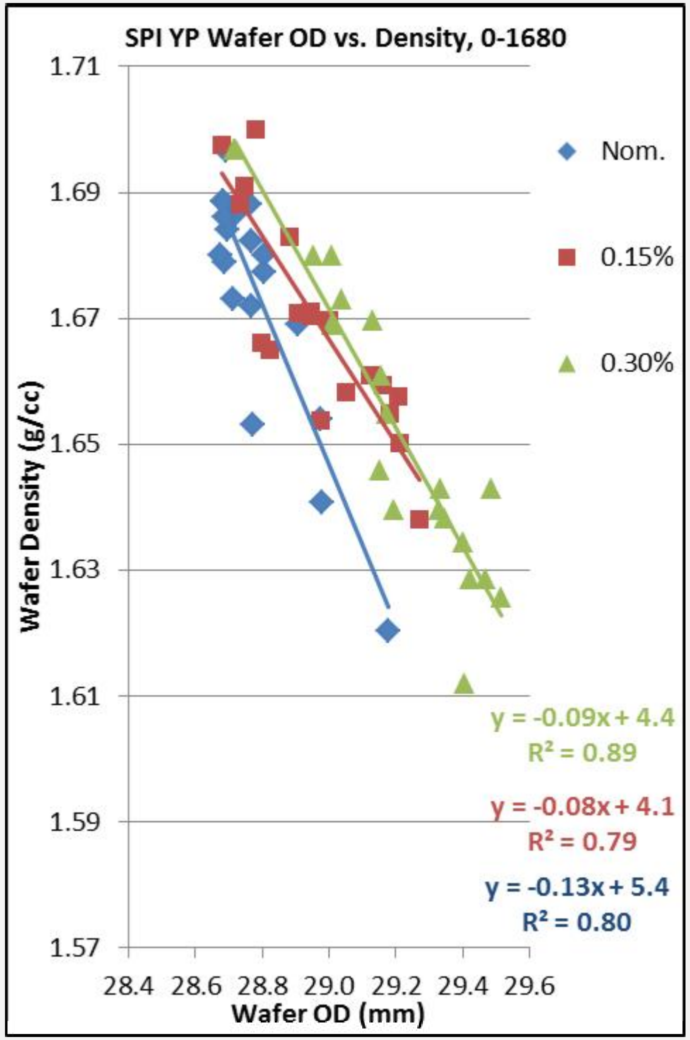


Caliper OD vs. Density: Nominal, 0.15% and 0.30%

- In all cases, nominal OD vs. density data are diverging from mid and high moisture
  - For a given density, nominal wafers have a smaller OD
  - The difference may be due to pancaking of the wafers by the springs at mid and high moisture
    - Slopes for dual spring, extremely pancaked YPs are smaller than the FD and YDs
  - Possibly, pore growth occurs primarily on the OD of mid and high moisture wafers once void space between wafers has been eliminated

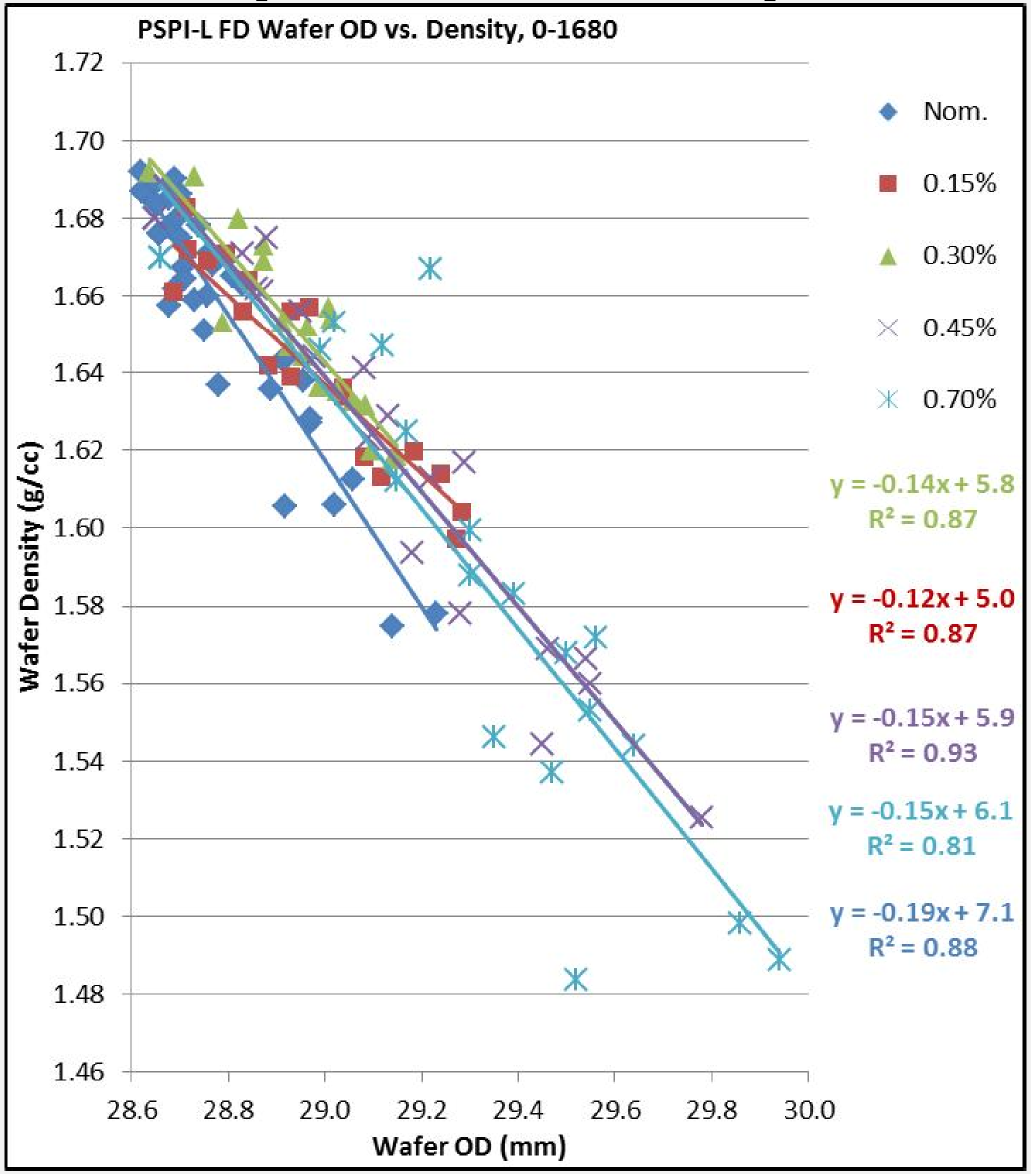


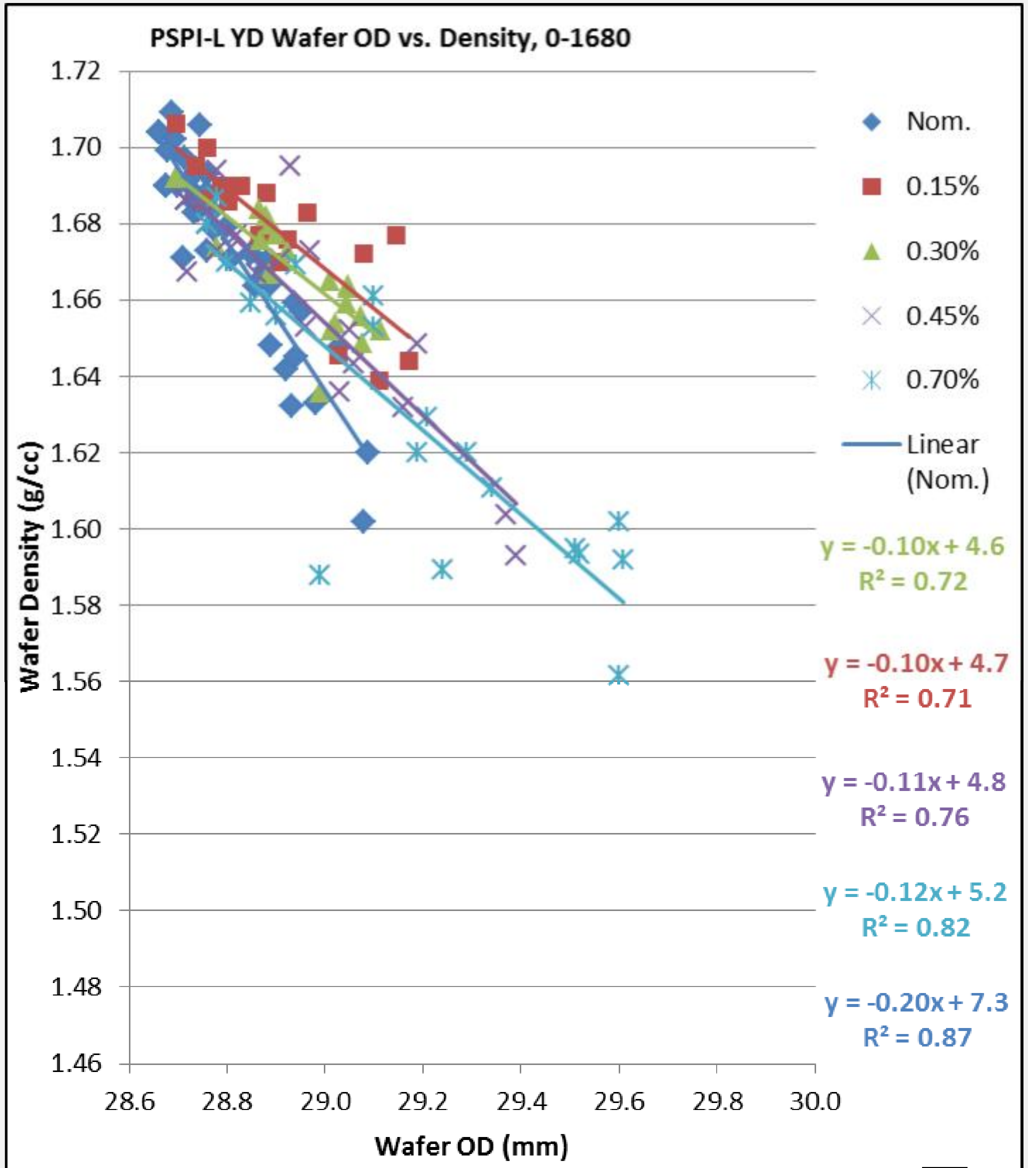




Caliper OD vs. Density: FD and YD with 0.45% and 0.70%

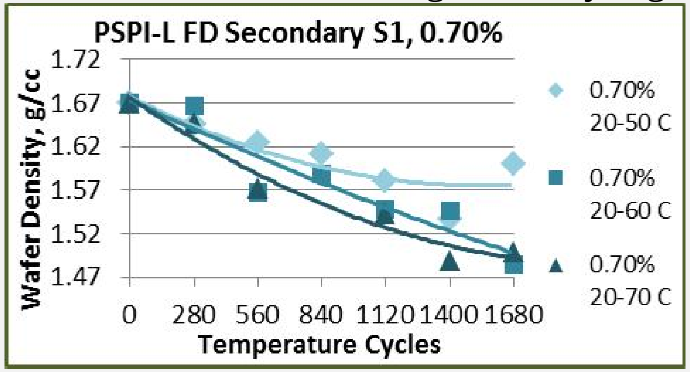
- Secondary mid and high moisture OD vs. density data trend with their primary counterparts
  - Slopes are lower than the slope for nominal primary/secondary data

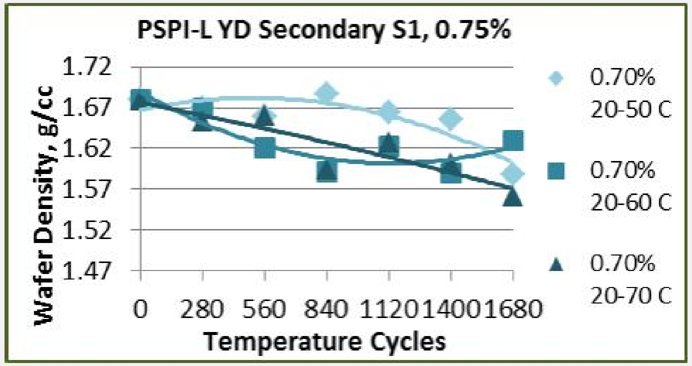




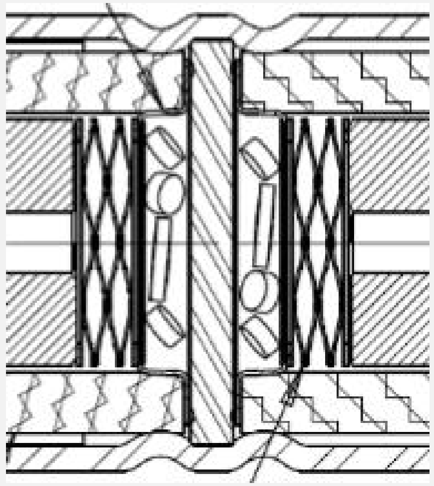
Secondary Chamber PSPI-L FD & YD 0.70% Moisture Wafer Damage

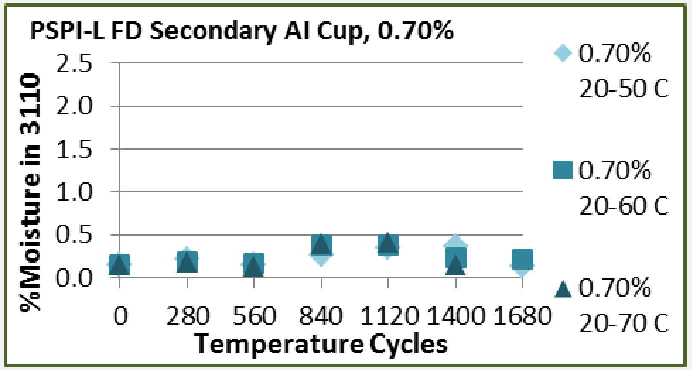
- Wafer damage is significantly less in YD, 0.70% moisture, secondary chambers than the corresponding FD
  - ➢ An anvil (highlighted in red) is added to the YD bulkhead to conduct heat to the AI-1 tablet
    - This compromises the AI-cup seal allowing its 3110 to desiccate the 2004 in the main chamber
      - Significantly higher moisture and darker AI-1 tablet color in YD substantiate this.

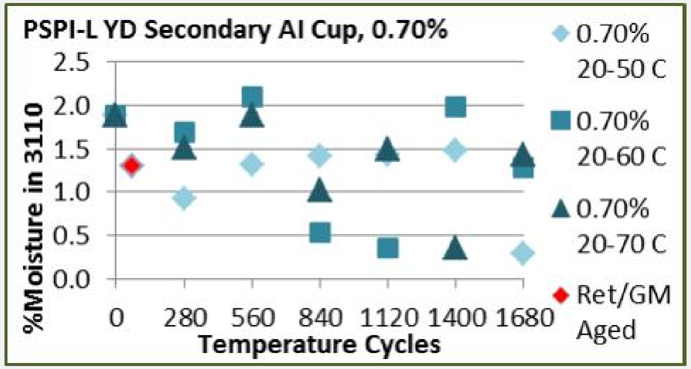


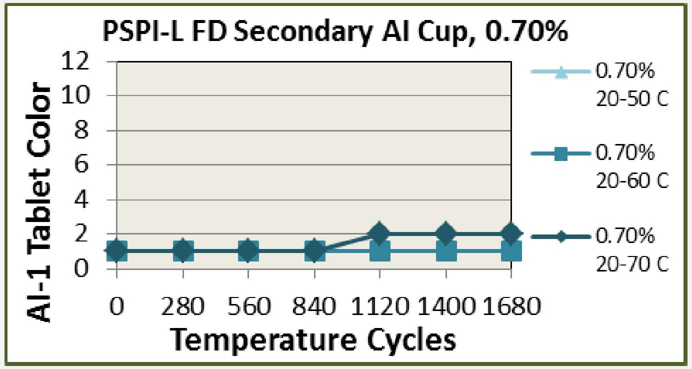


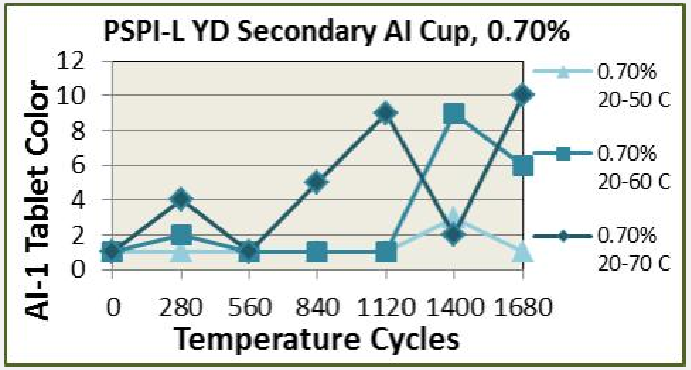
PSPI-L FD Bulkhead



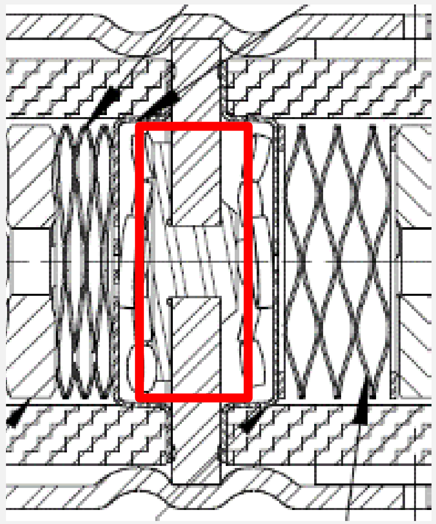






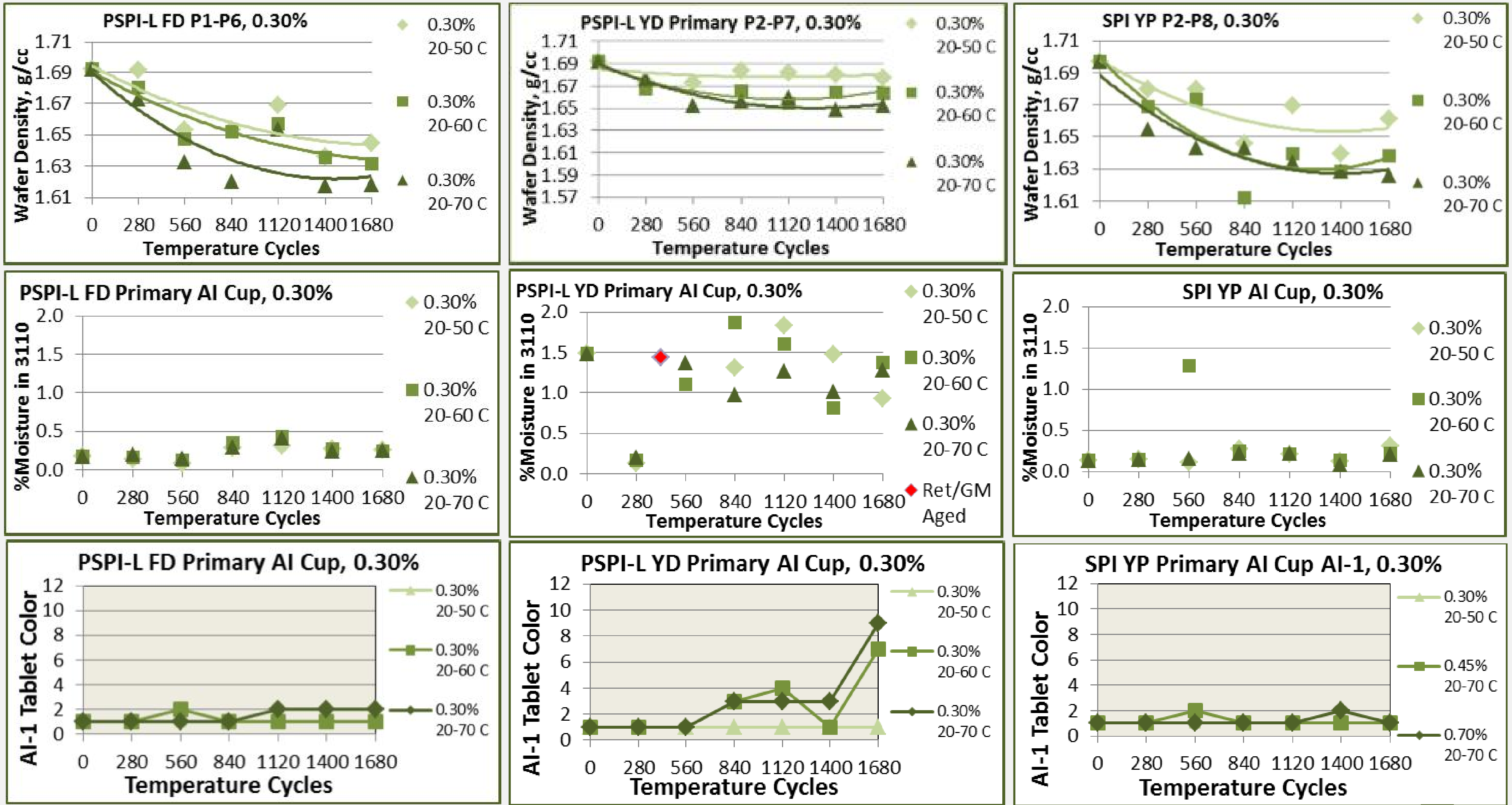


PSPI-L YD Bulkhead



Primary Chamber
0.30% Moisture Wafer Damage

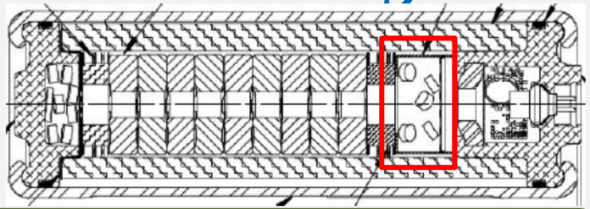
- Similar trend as in secondary chamber
  - In most cases, SPI YP Al-cups are well sealed as they are in FD

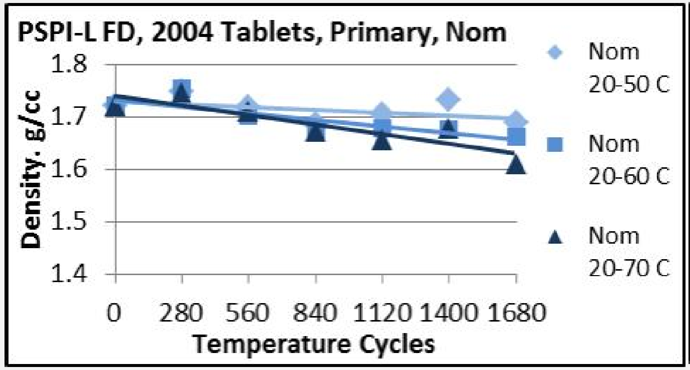


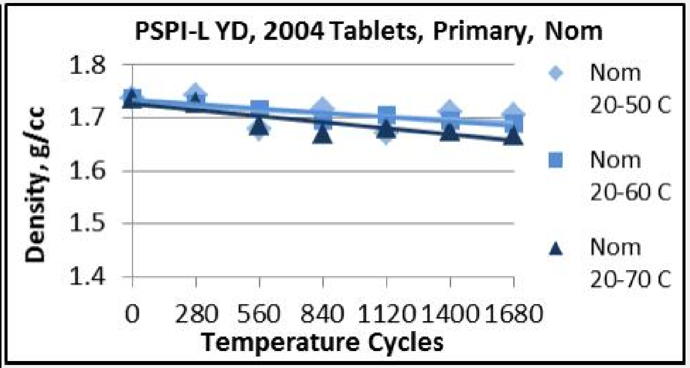
Primary Chamber 2004 Tablet Density

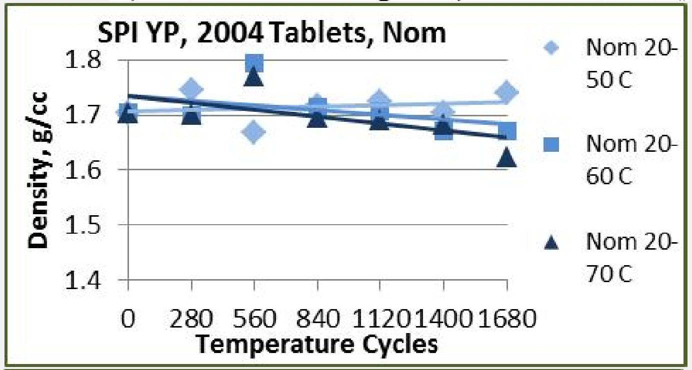
- The SPI YP 2004 tablets are sealed in a cup (in red)
  - ➢ Said tablets experience less damage at 0.15% and 0.30% than those from FD and YD

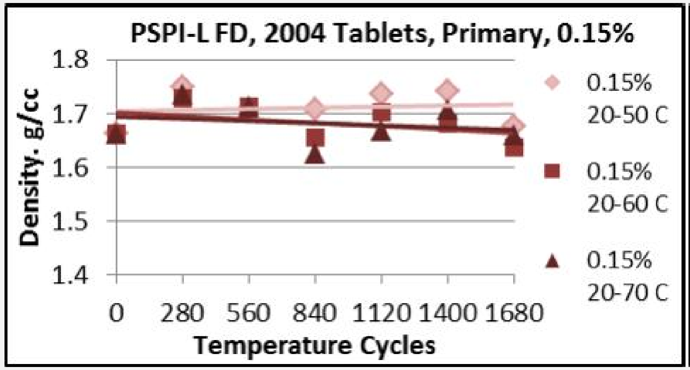
SPI YP

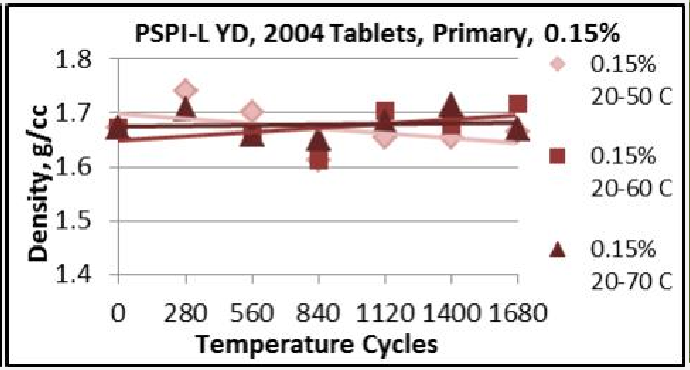


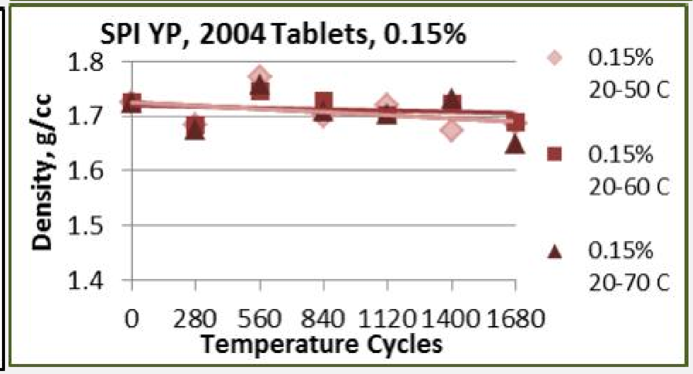


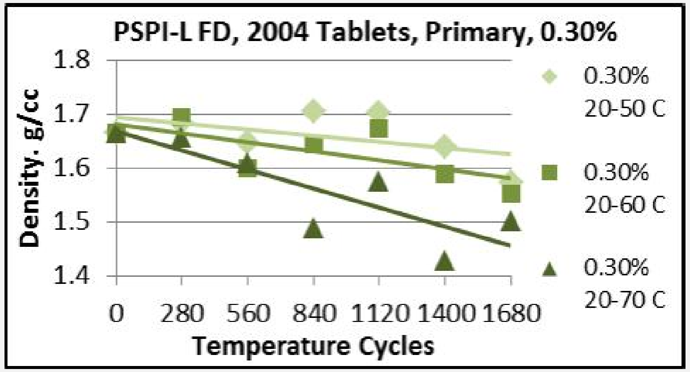


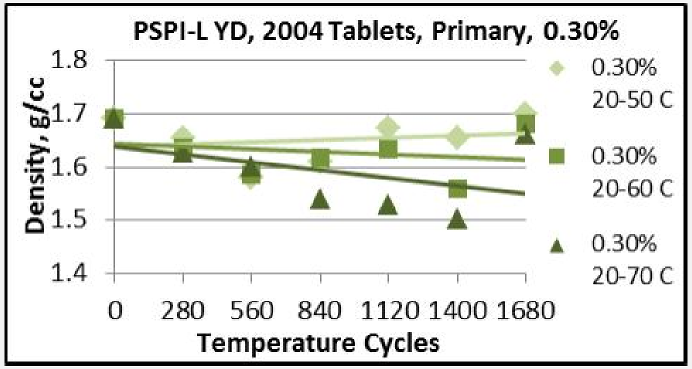


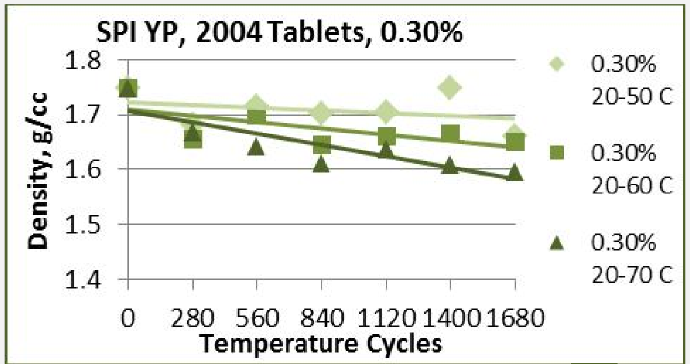




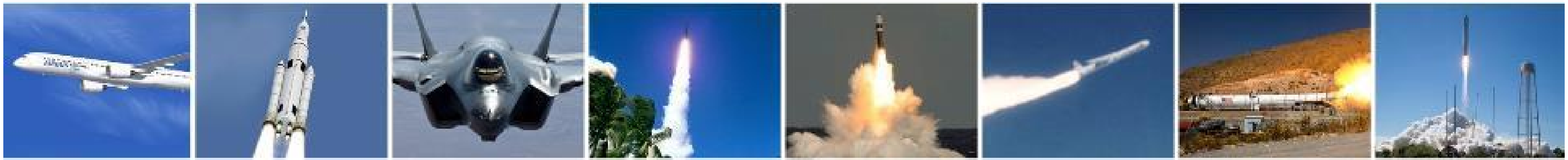






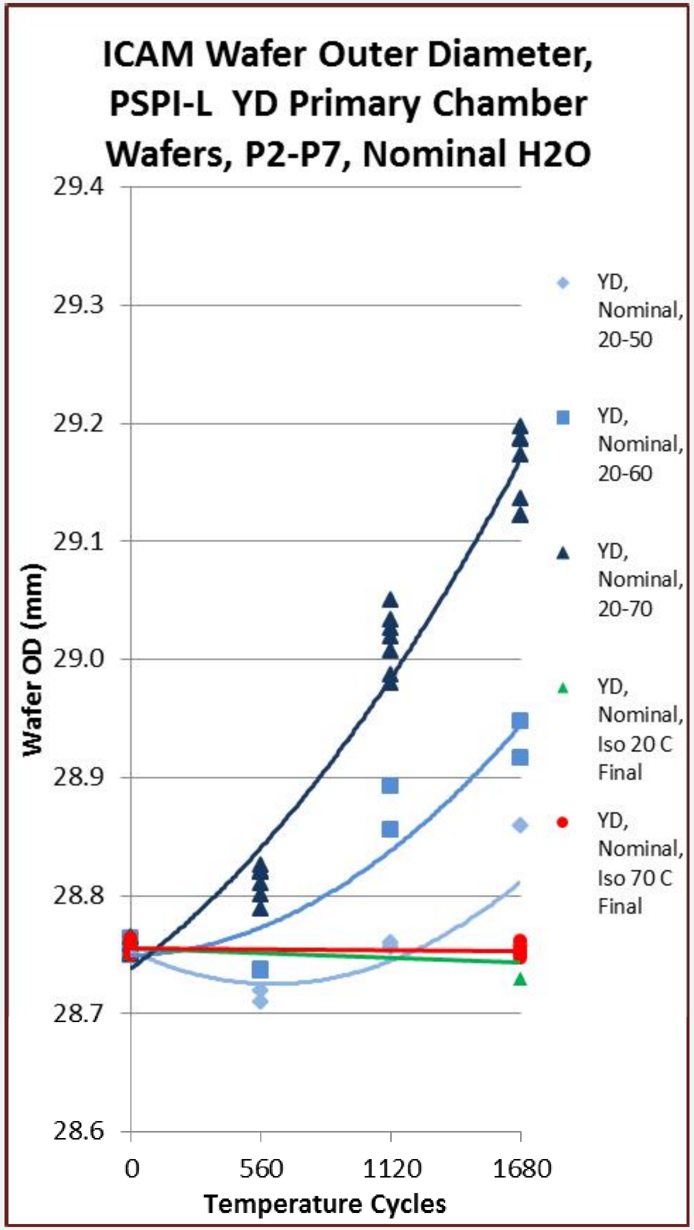


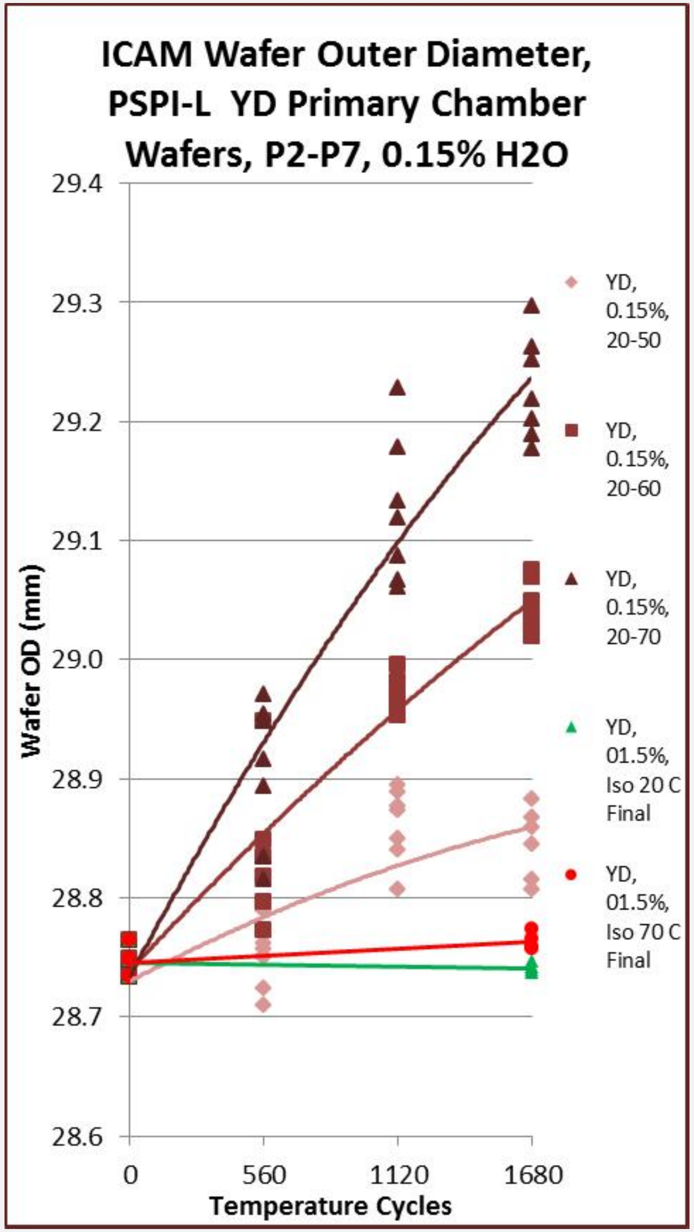
Test OD's

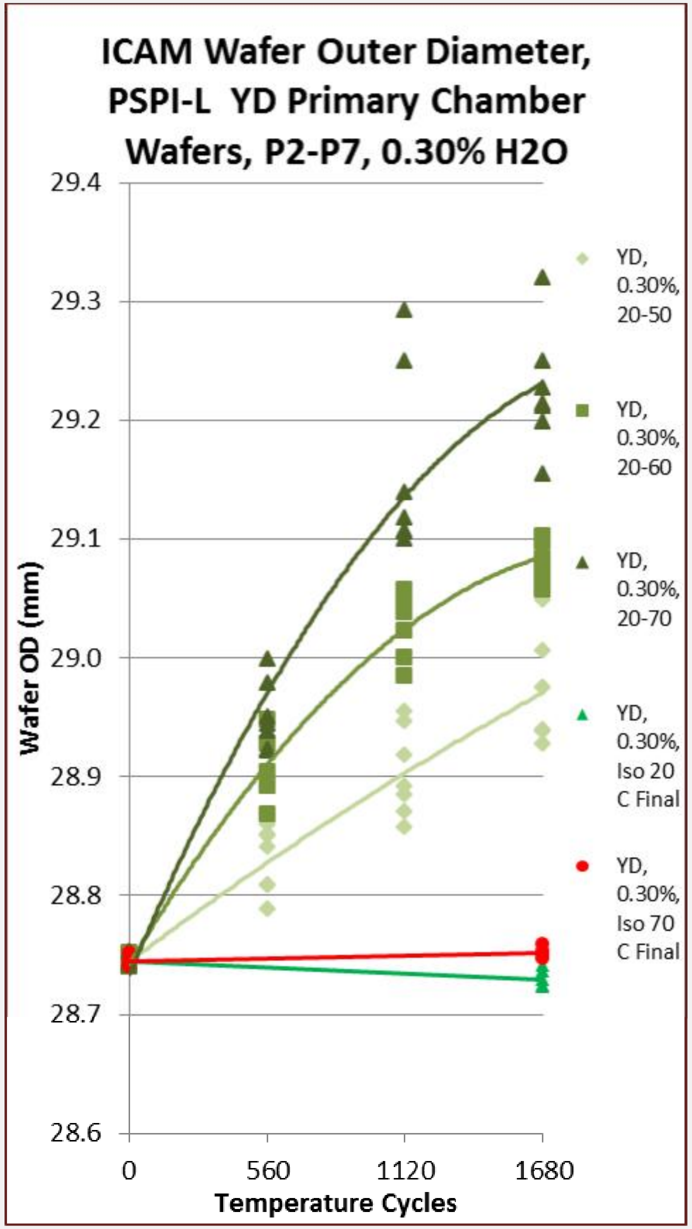


PSPI-L YD with Constant 20 C and 70 C Data
ICAM Wafer OD, Primary Chamber

- Minimal change in wafer outer diameter for the inflators held at constant temperature

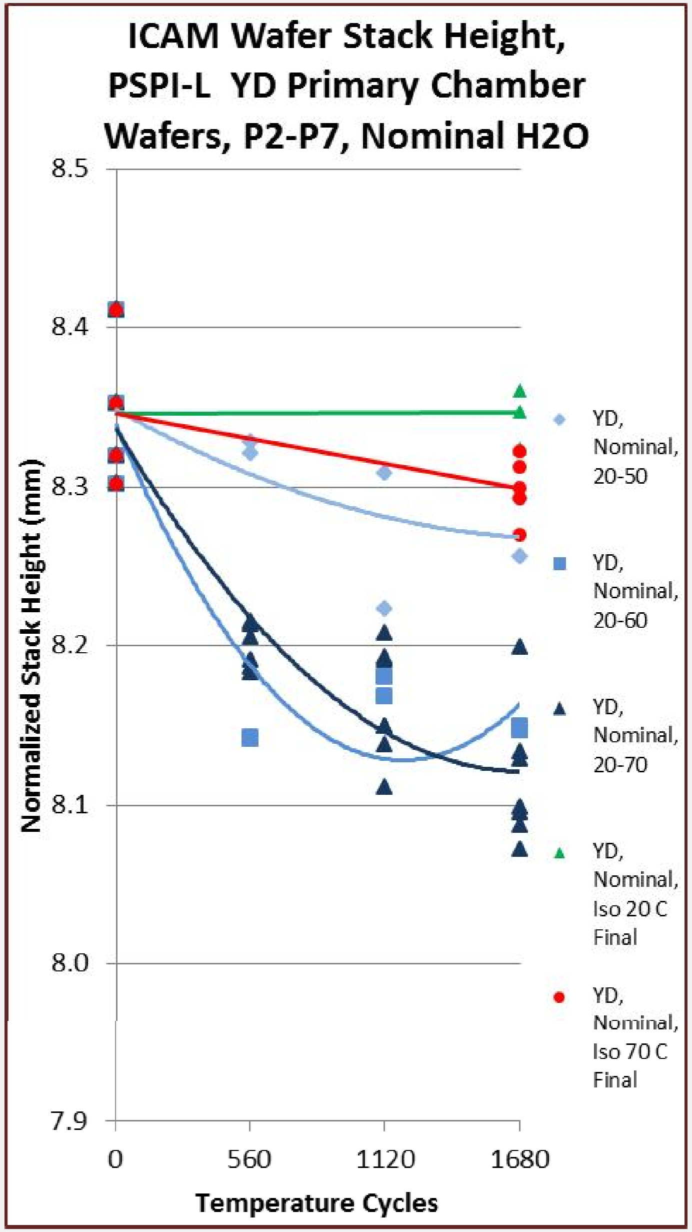


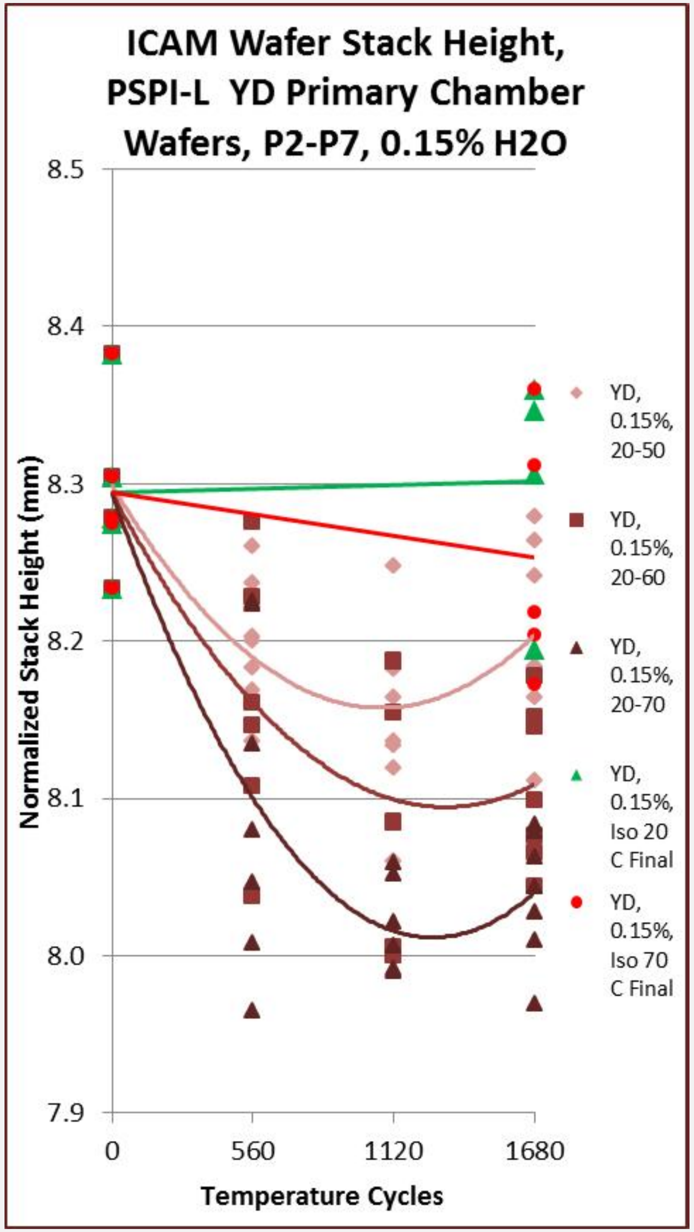


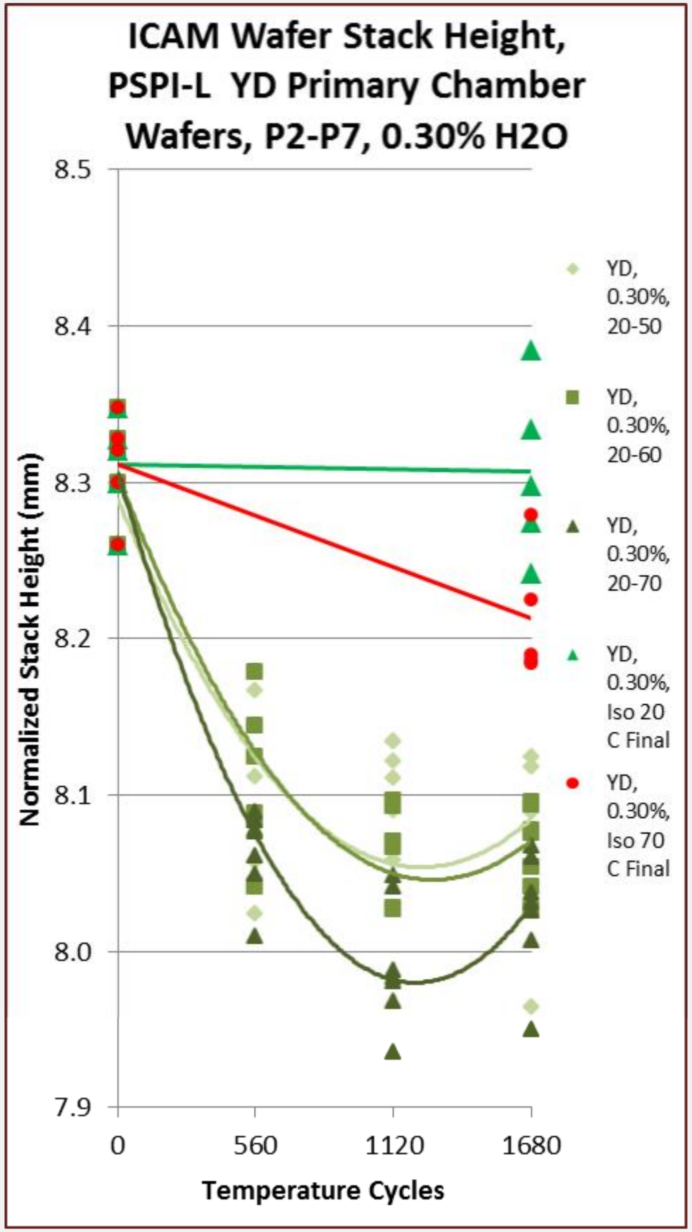


PSPI-L YD with Constant 20 C and 70 C Data
ICAM Wafer Stack Height, Primary Chamber

- Stack height compression is less for inflators held at constant temperature
  - Compression is greater for inflators held at 70 C

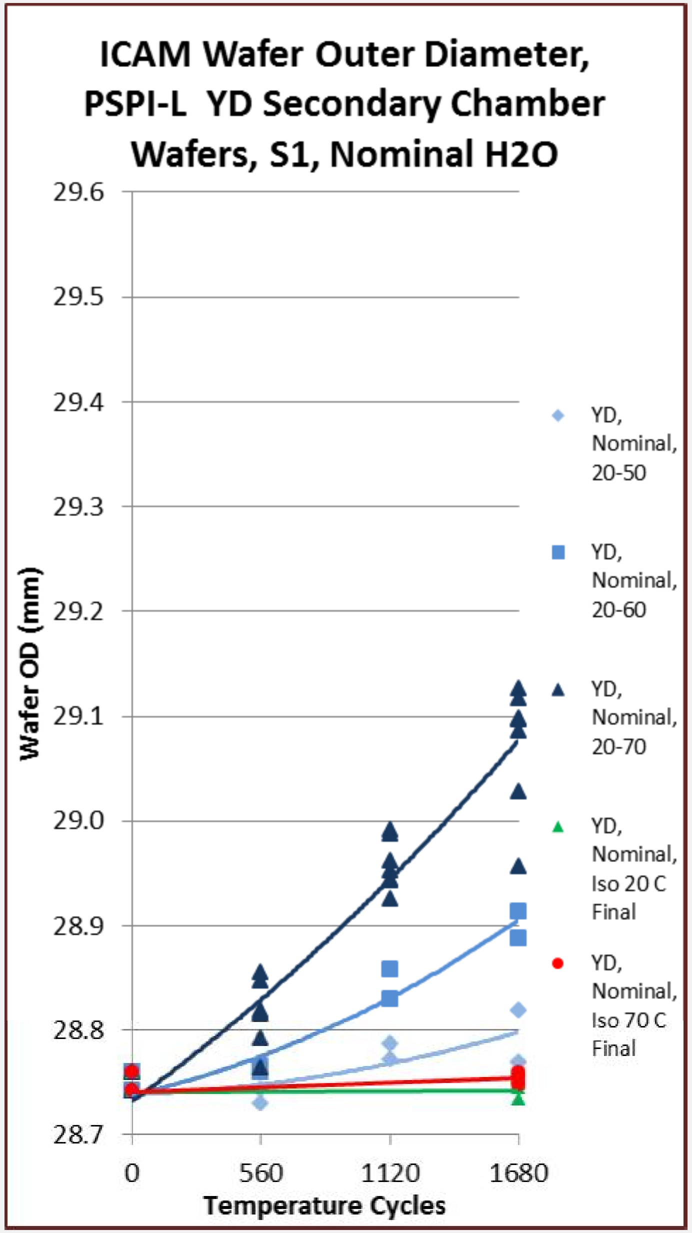


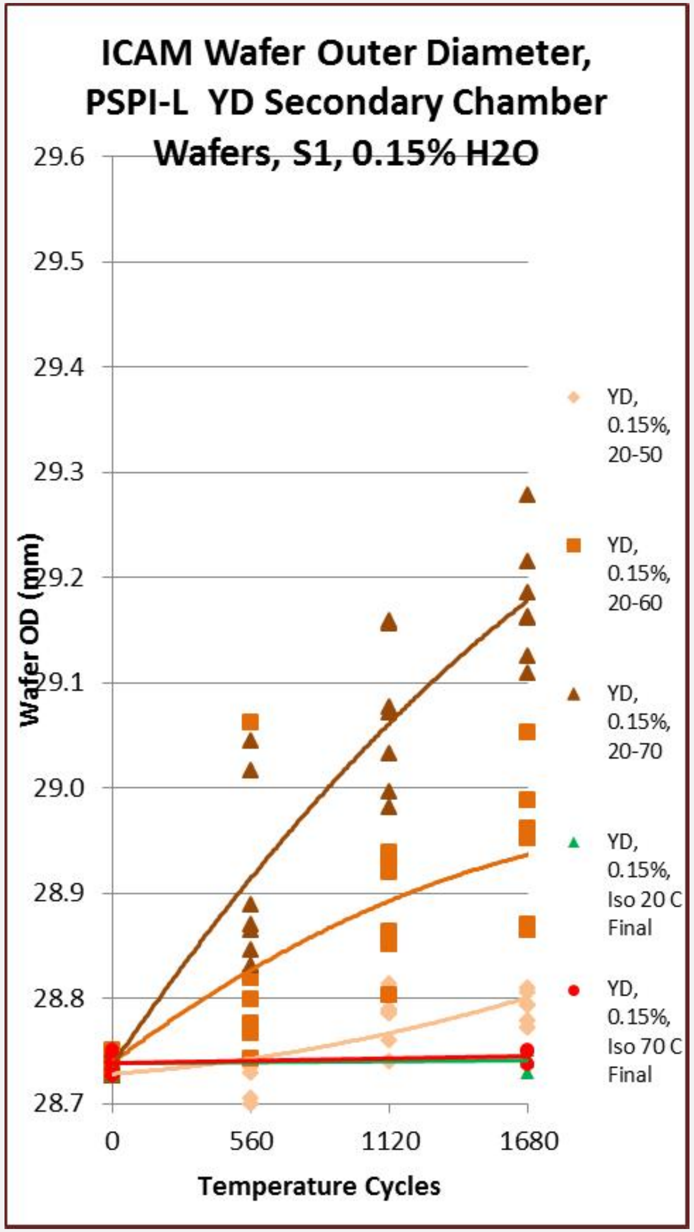


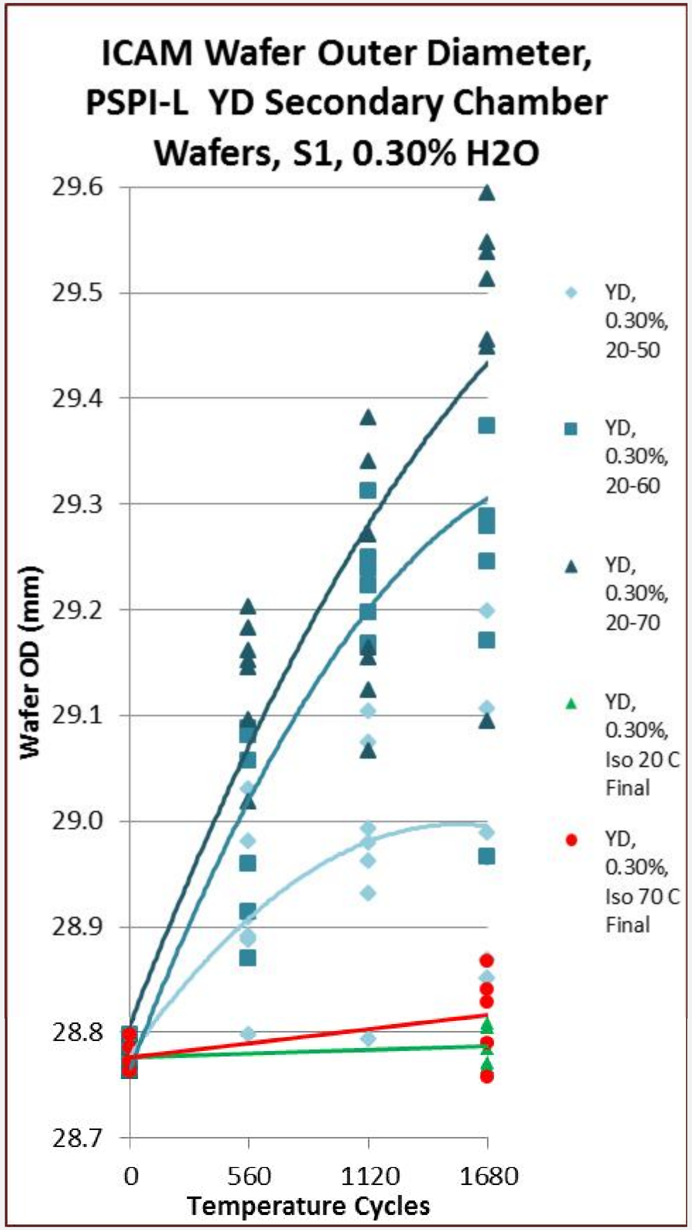


PSPI-L YD with Constant 20 C and 70 C Data
ICAM Wafer OD, Secondary Chamber

- Minimal change in wafer outer diameter for the inflators held at constant temperature

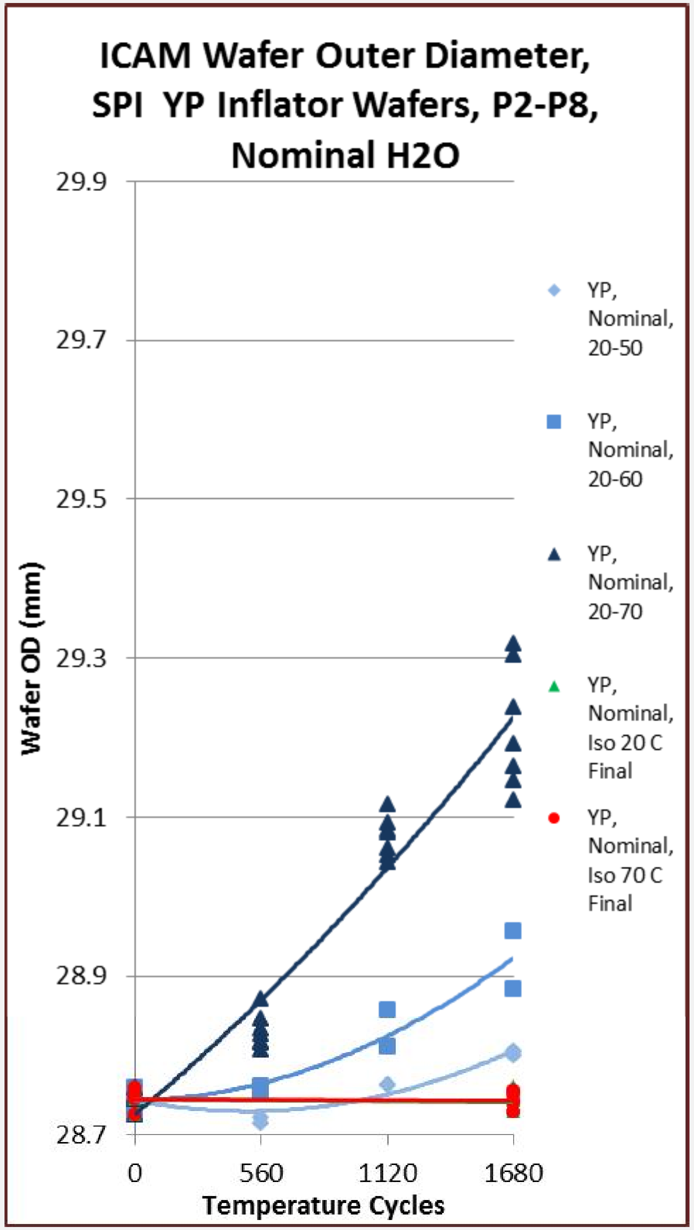


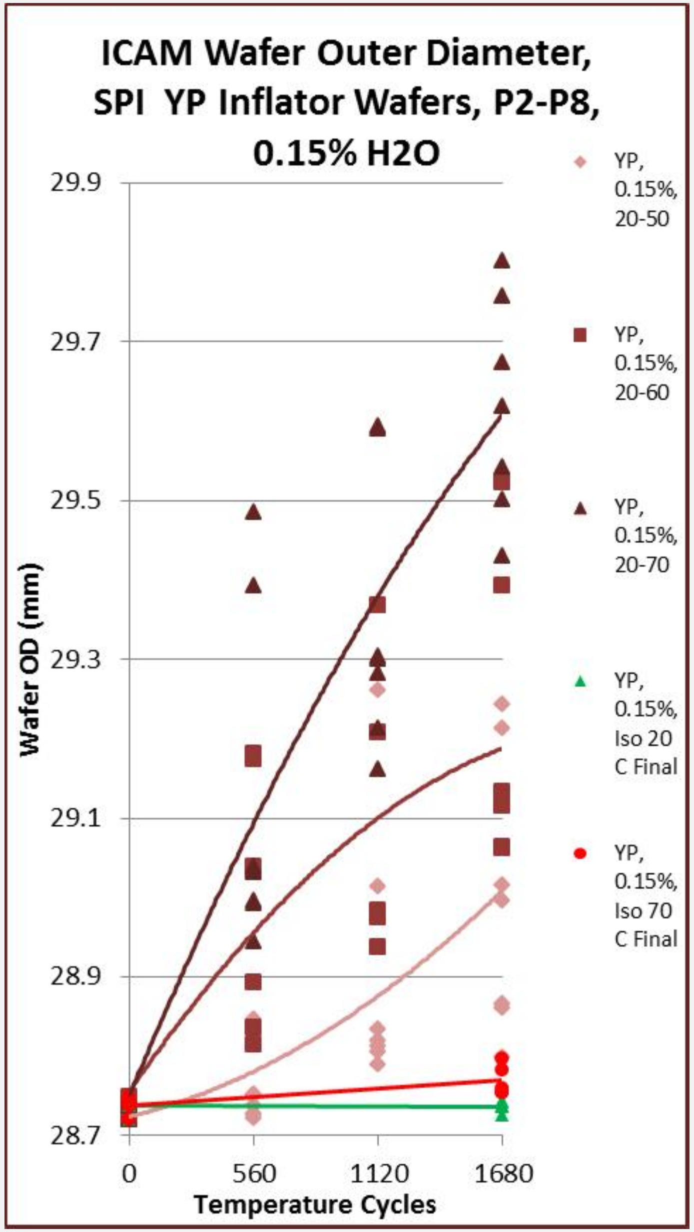


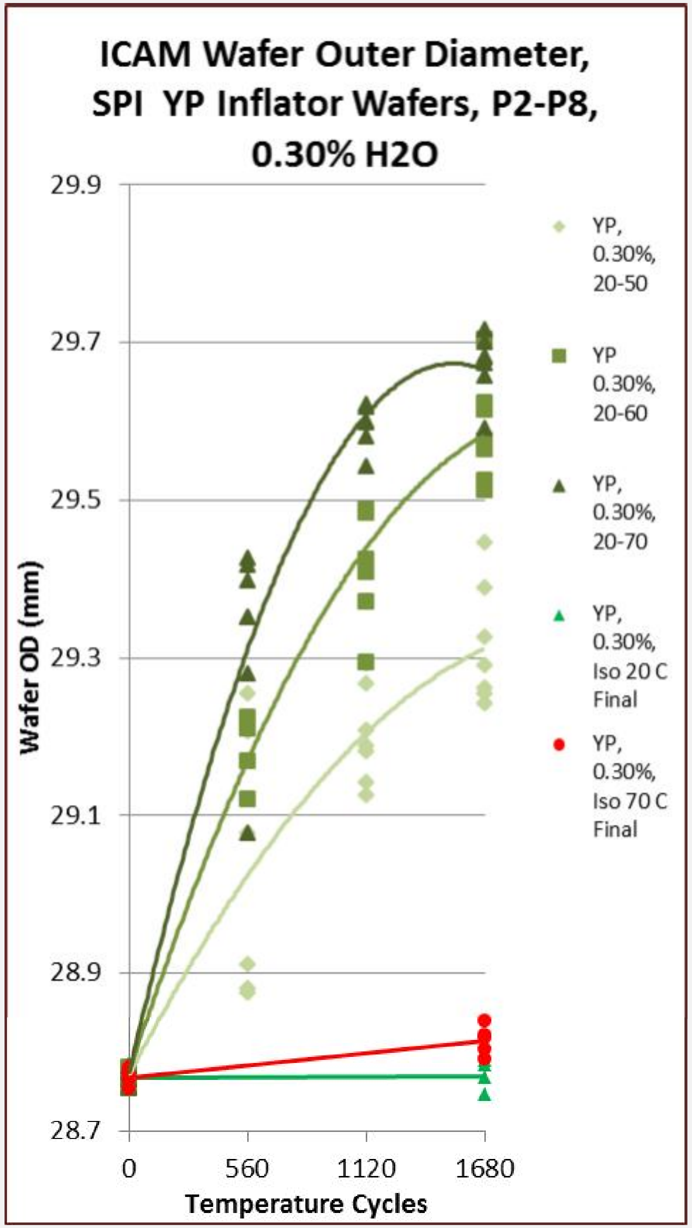


SPI YP with Constant 20 C and 70 C Data
ICAM Wafer OD, Primary Chamber

- Minimal change in wafer outer diameter for the inflators held at constant temperature

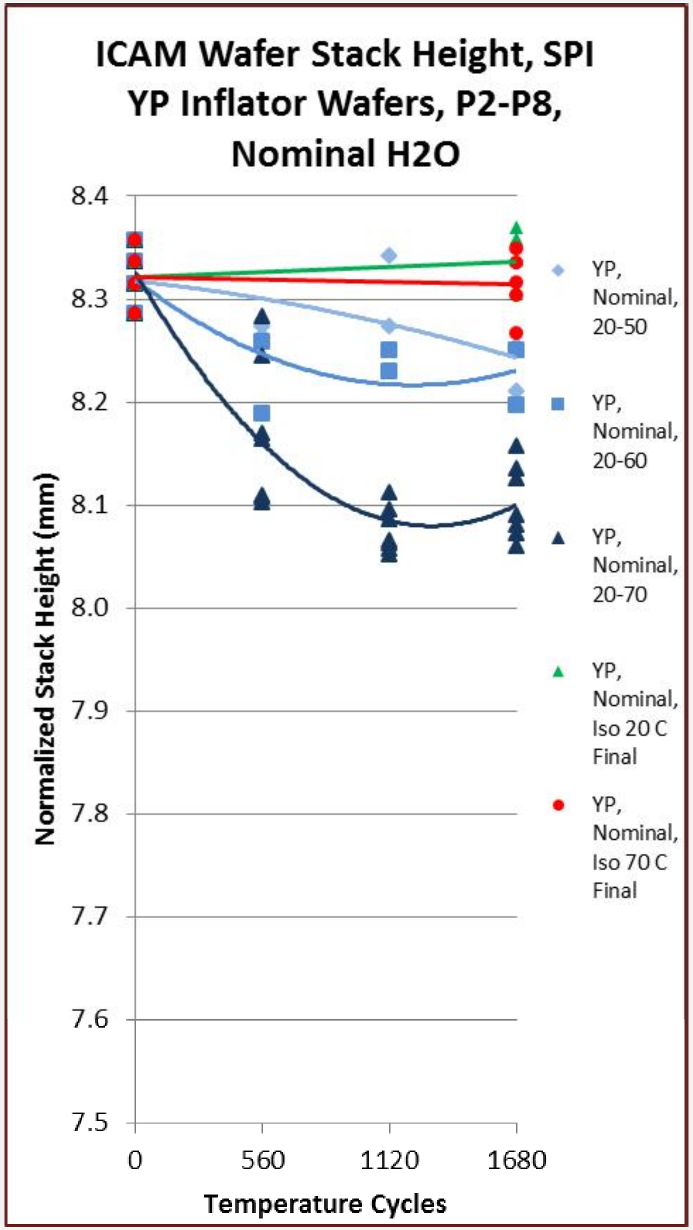


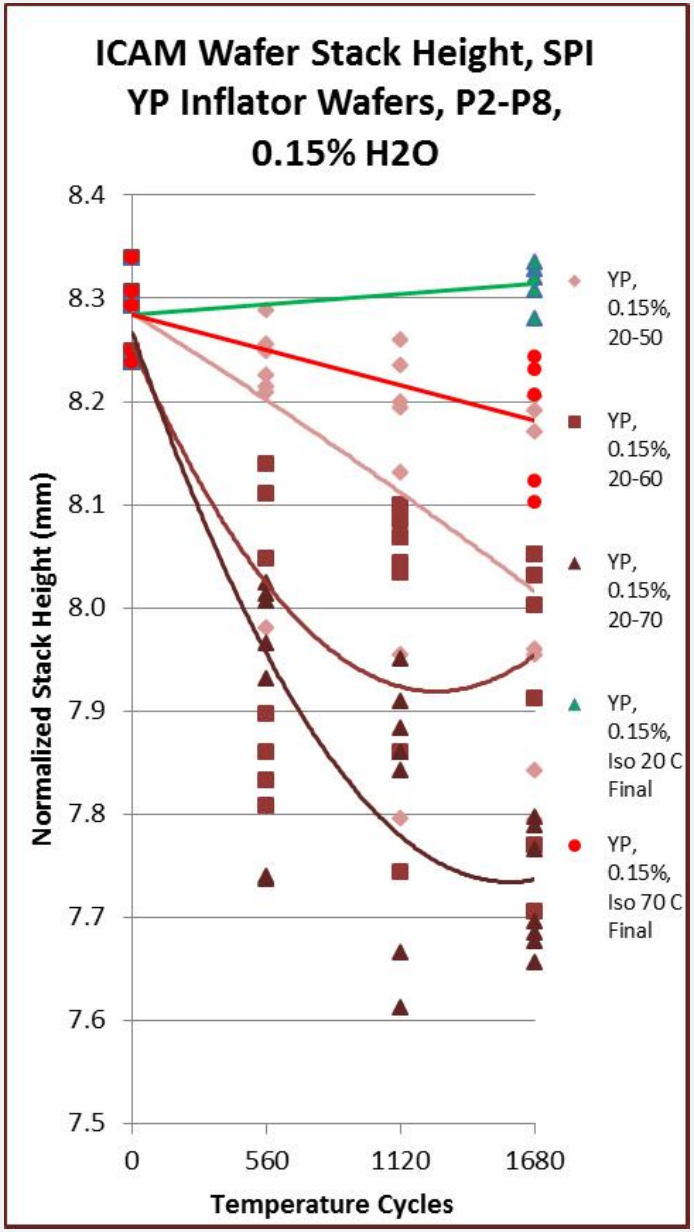


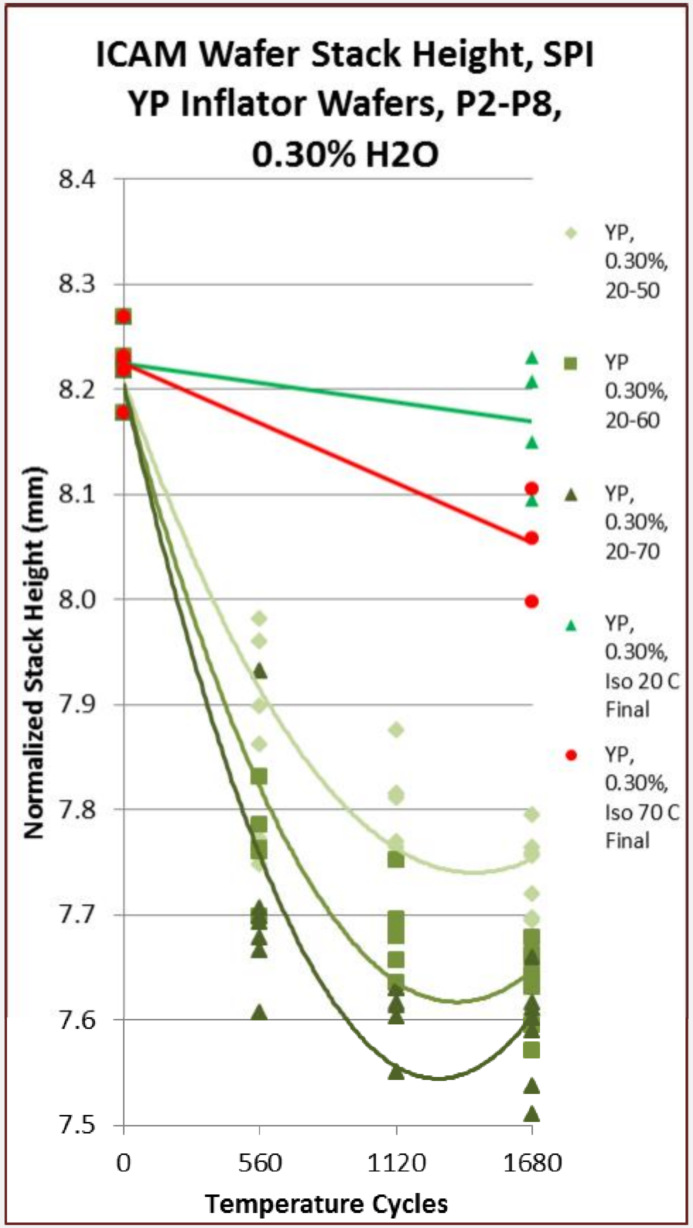


SPI YP with Constant 20 C and 70 C Data
ICAM Wafer Stack Height, Primary Chamber

- Stack height compression is less for inflators held at constant temperature
  - Compression is greater for inflators held at 70 C



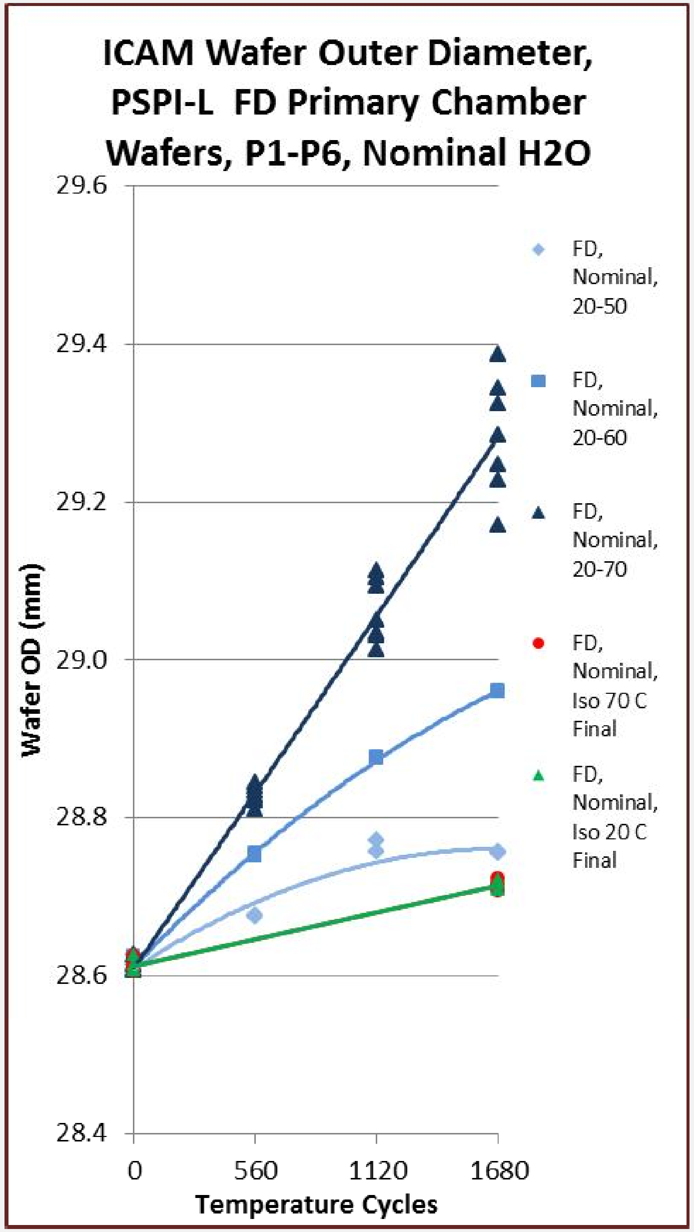


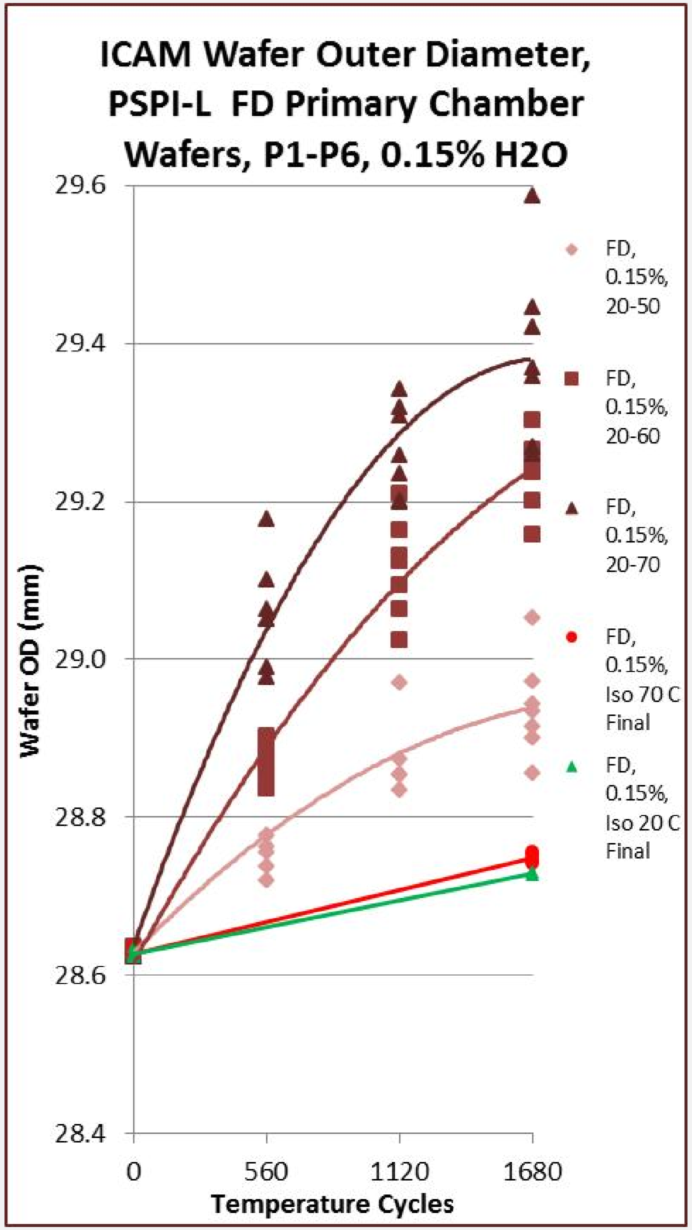


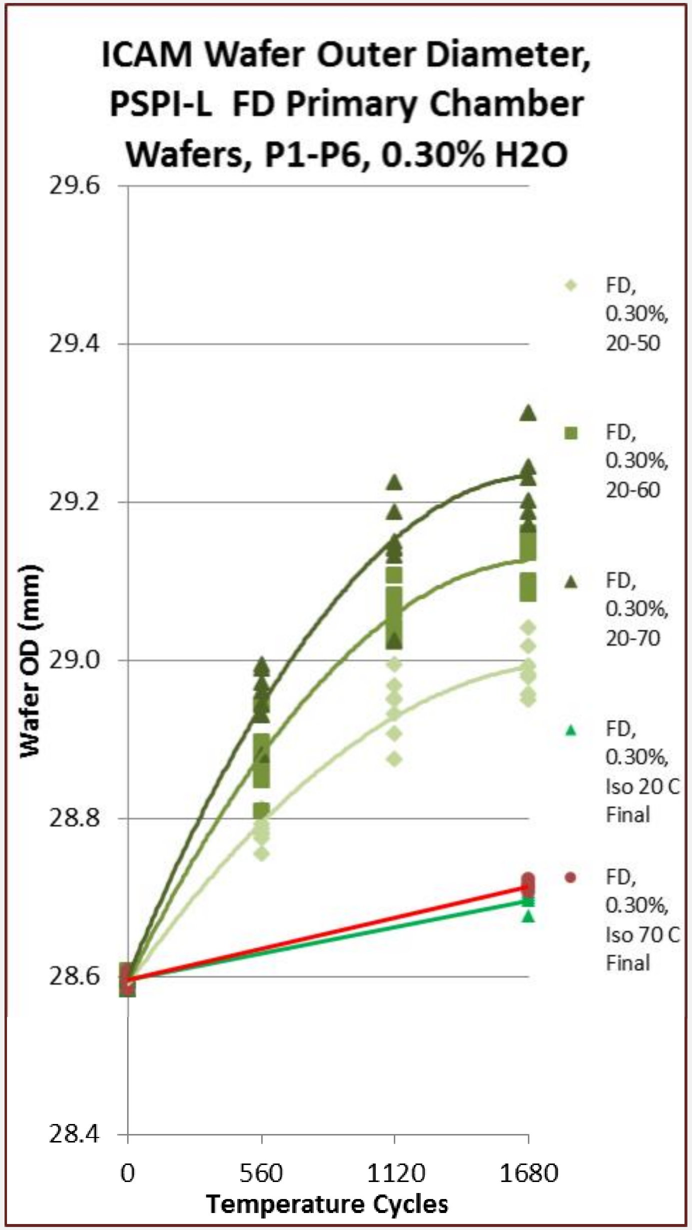
PSPI-L FD with Constant 20 C and 70 C Data

ICAM Wafer OD, Primary Chamber

- Minimal change in wafer outer diameter for the inflators held at constant temperature

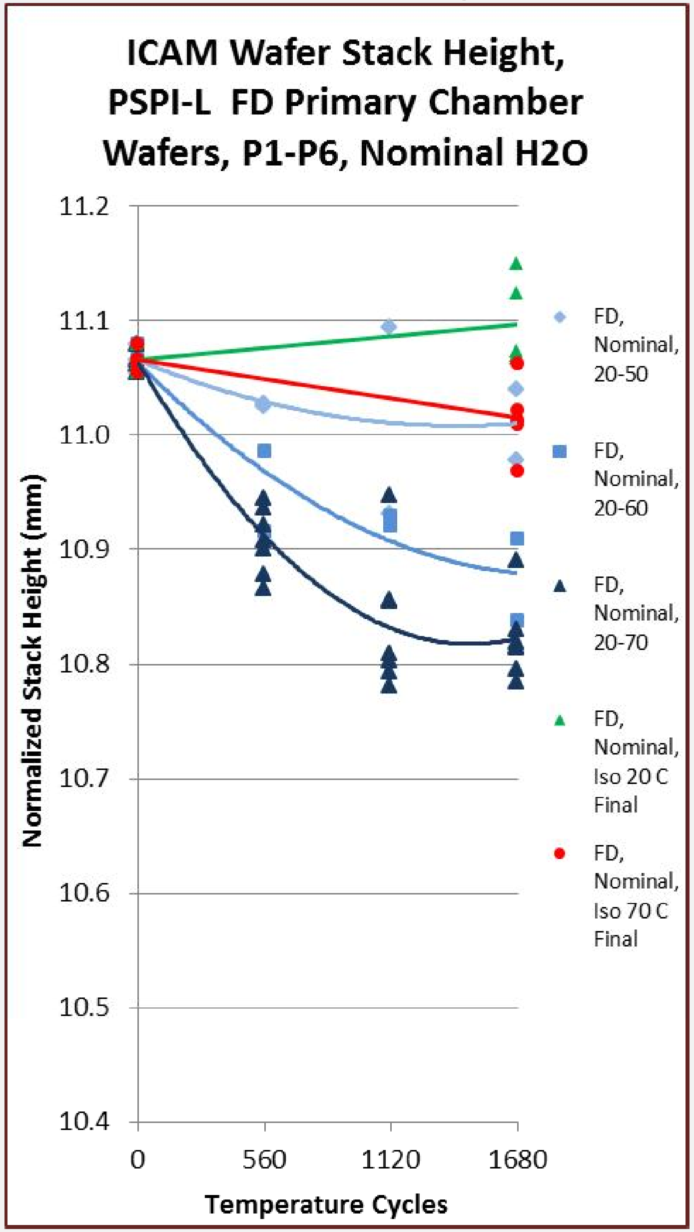


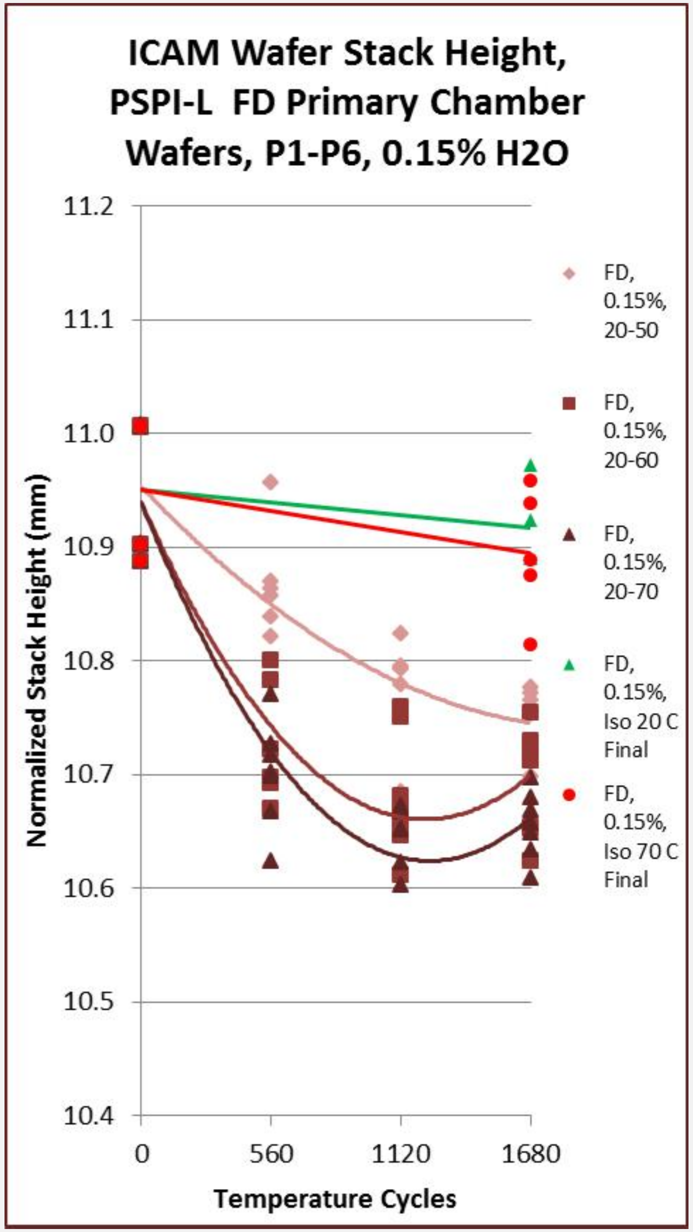


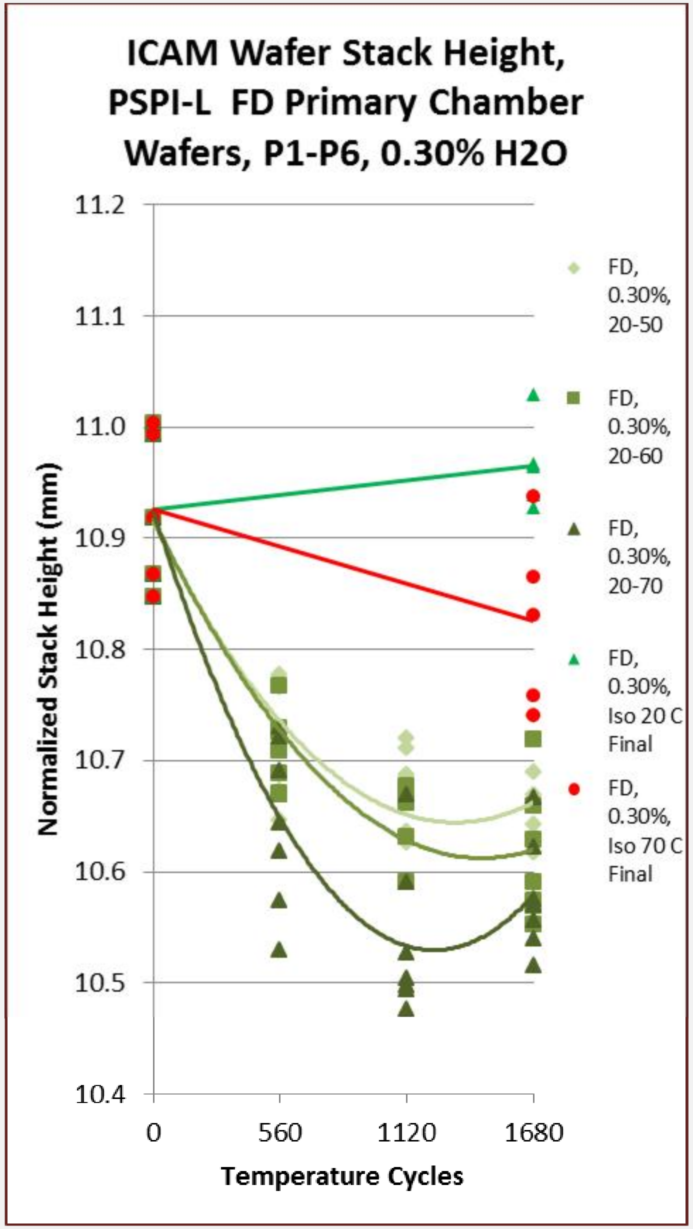


PSPI-L FD with Constant 20 C and 70 C Data
ICAM Wafer Stack Height, Primary Chamber

- Stack height compression is less for inflators held at constant temperature
  - Compression is greater for inflators held at 70 C



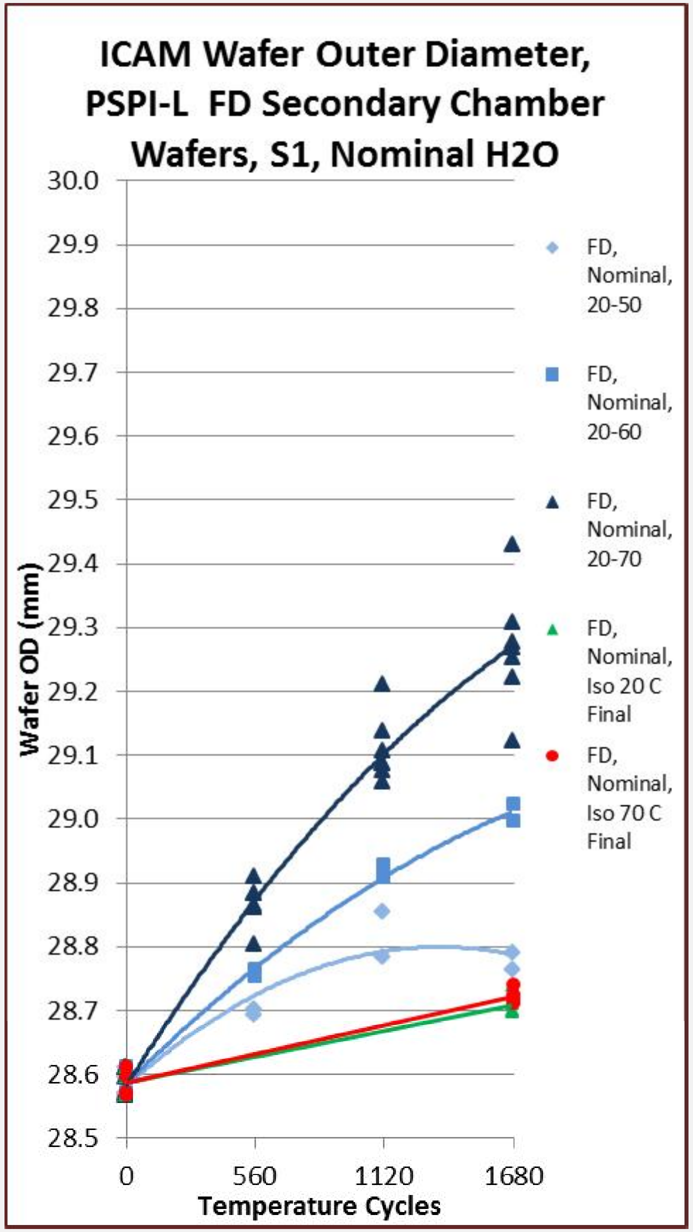


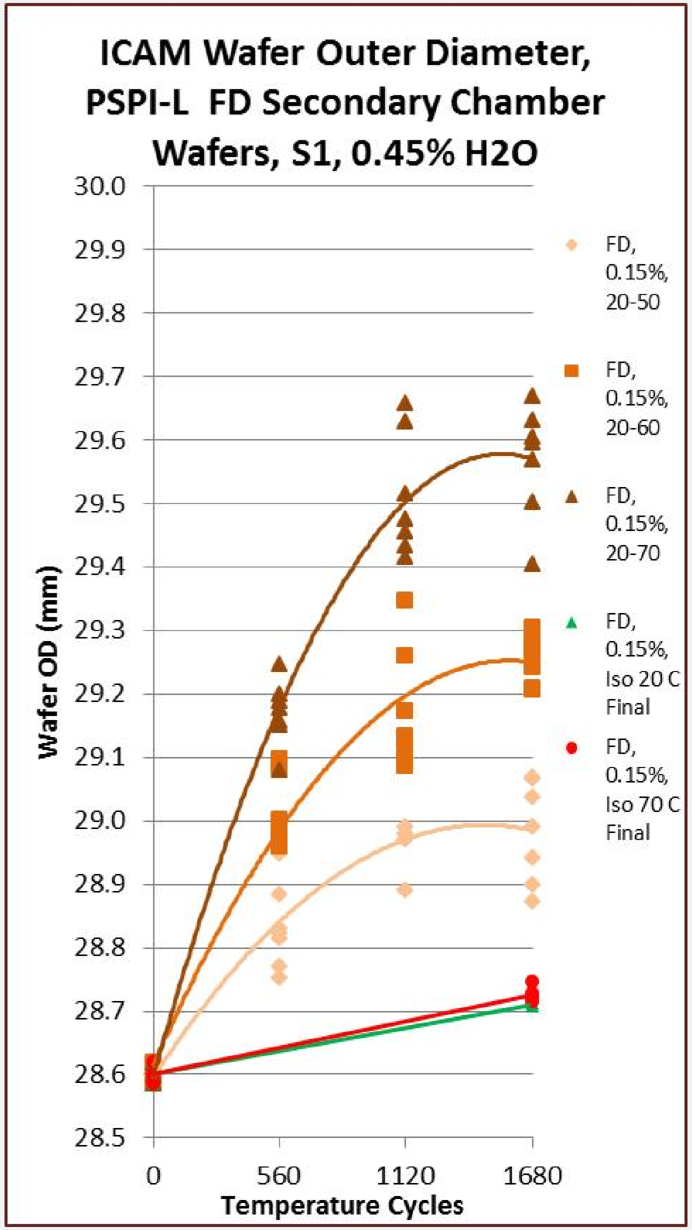


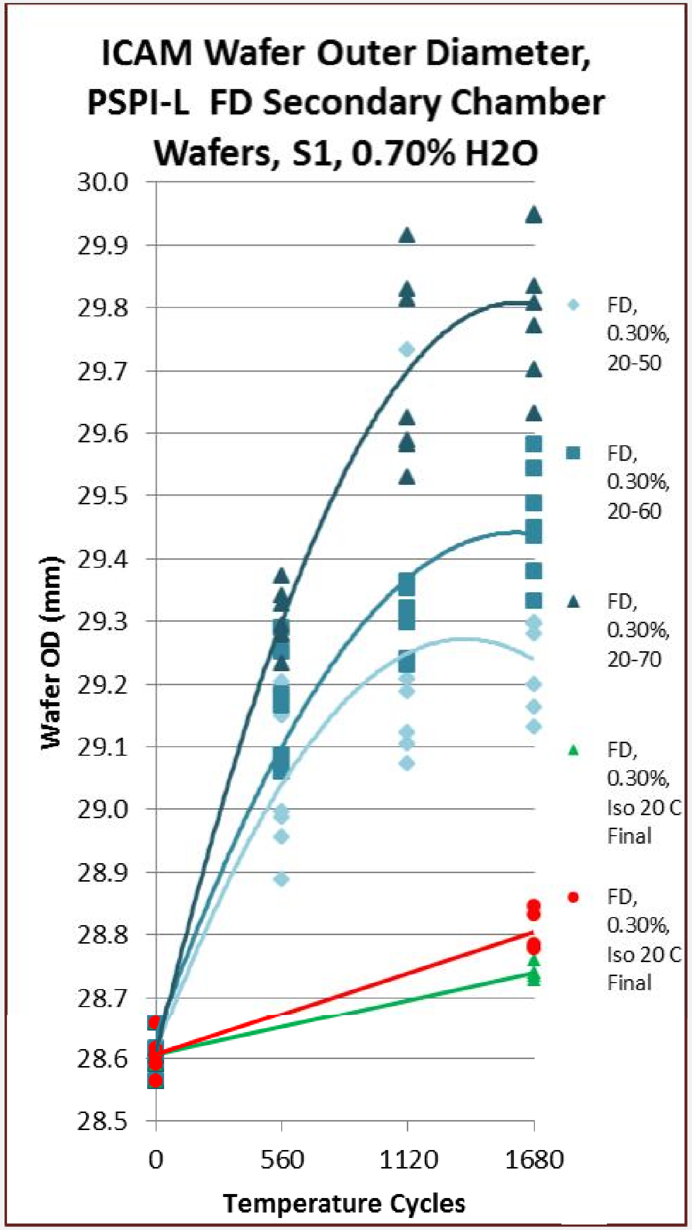
PSPI-L FD with Constant 20 C and 70 C Data

ICAM Wafer OD, Secondary Chamber

- Minimal change in wafer outer diameter for the inflators held at constant temperature

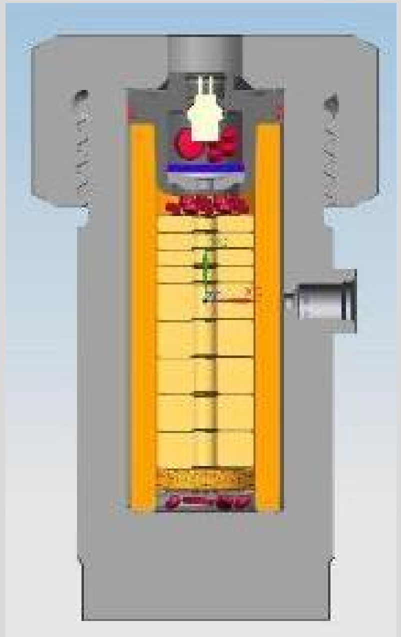


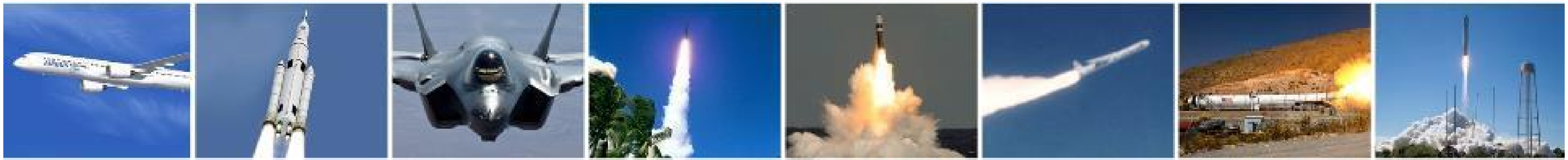




1680 Tank Testing

Discussion

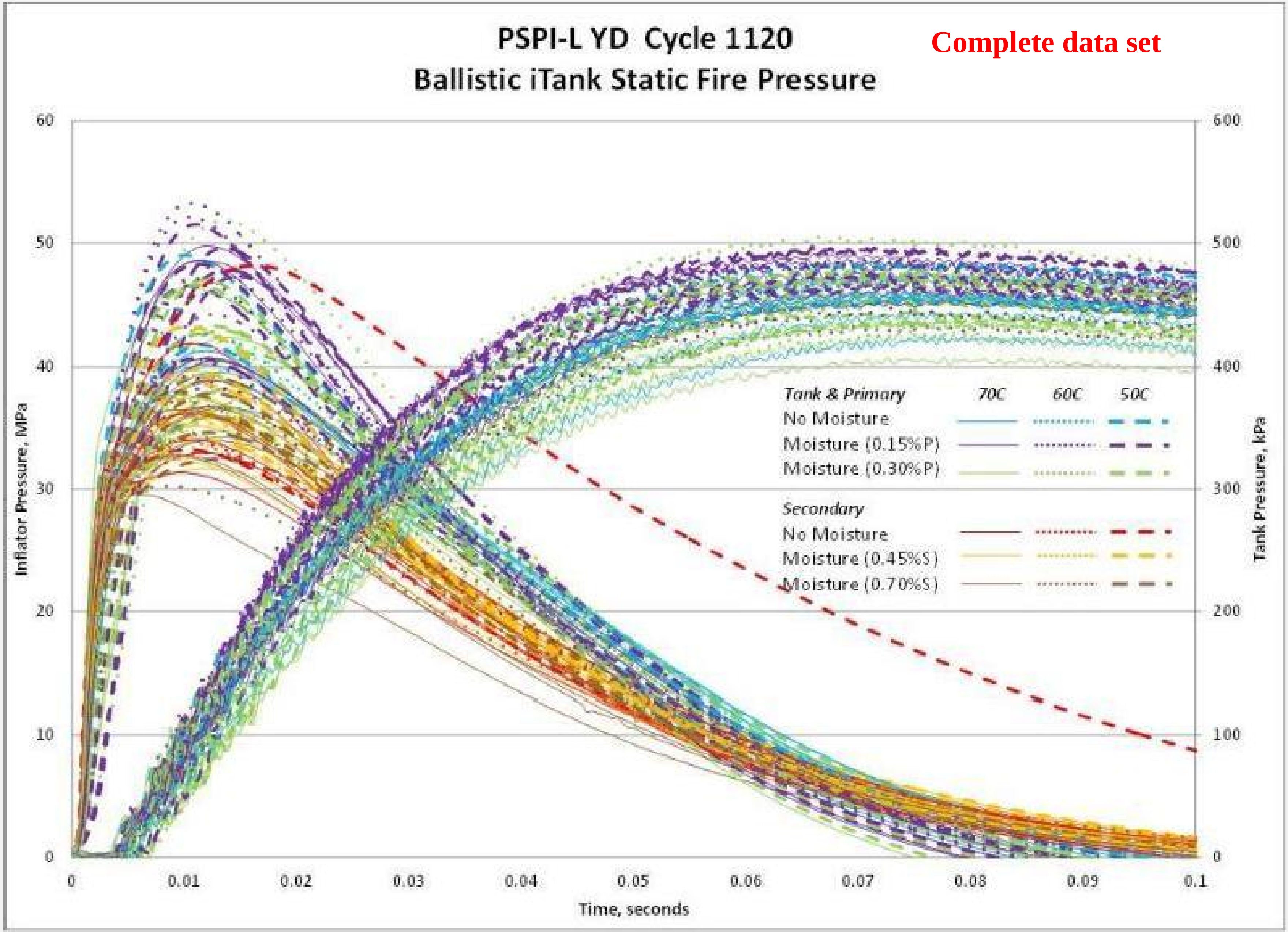




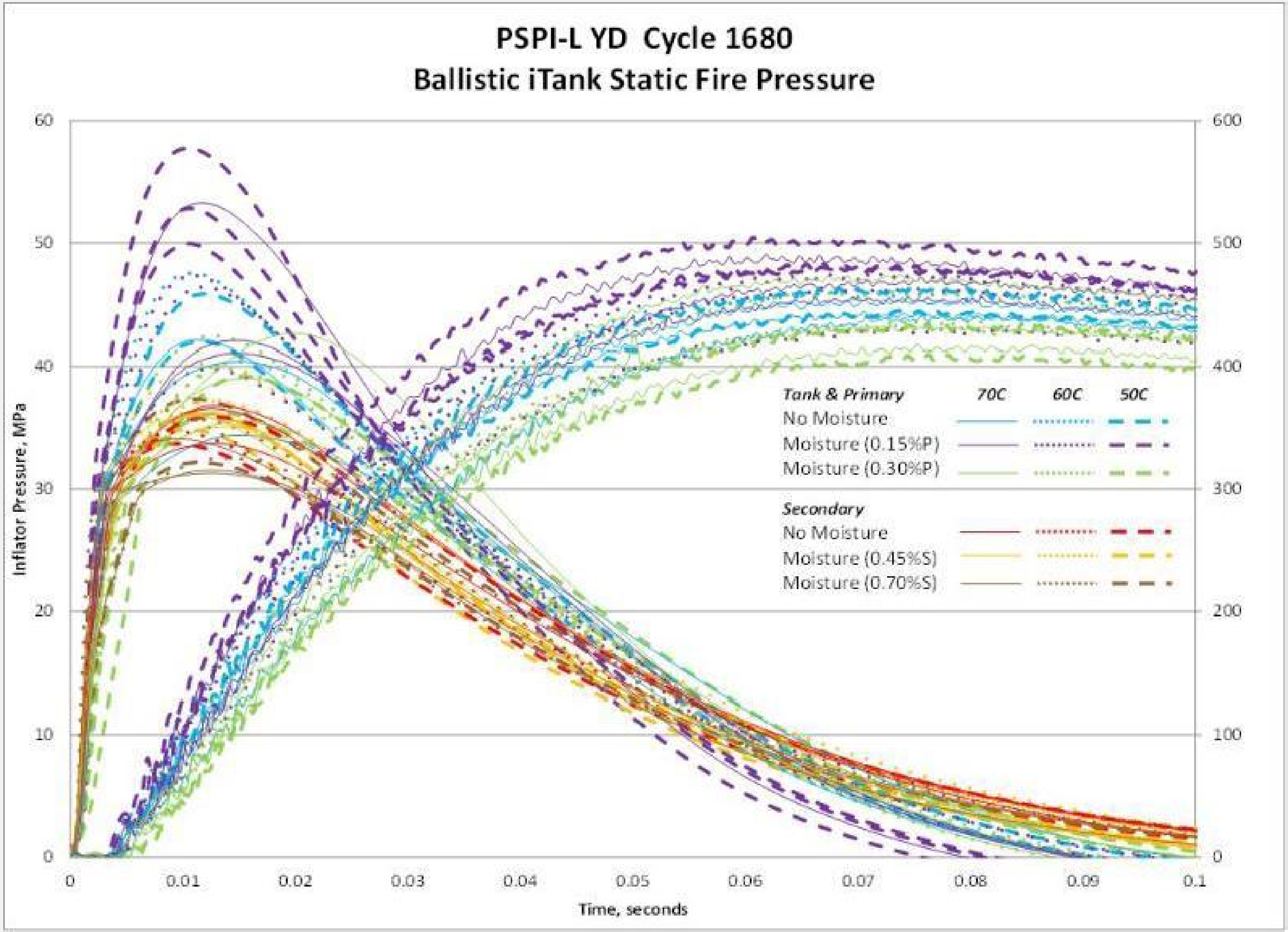
GM Tank Testing

- Status
  - All PSPI-L YD 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are starting to show higher performance over the 1140 cycle results
    - Highest combustion pressures come from mid moisture levels
    - Lowest performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is now equivalent for all three moisture levels and the general trend of reduced combustion pressure with larger wafer OD is seen for the mid and low moisture levels
    - This trend is not apparent in the secondary chamber, also wafer growth at the high moisture level outpaces the lower moisture levels

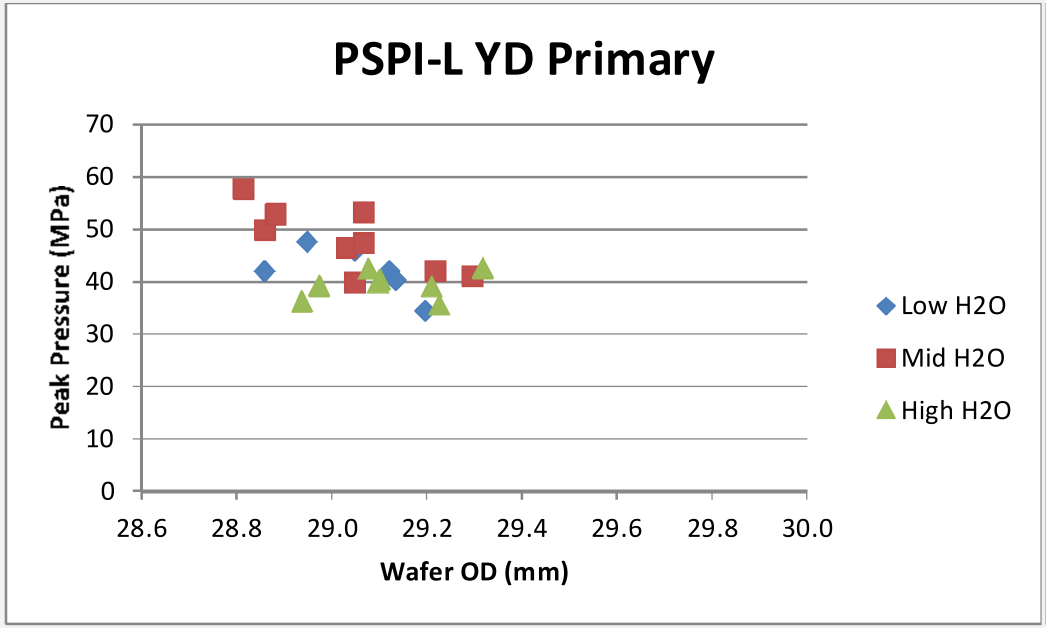
GM Tank Testing Cycle 1120

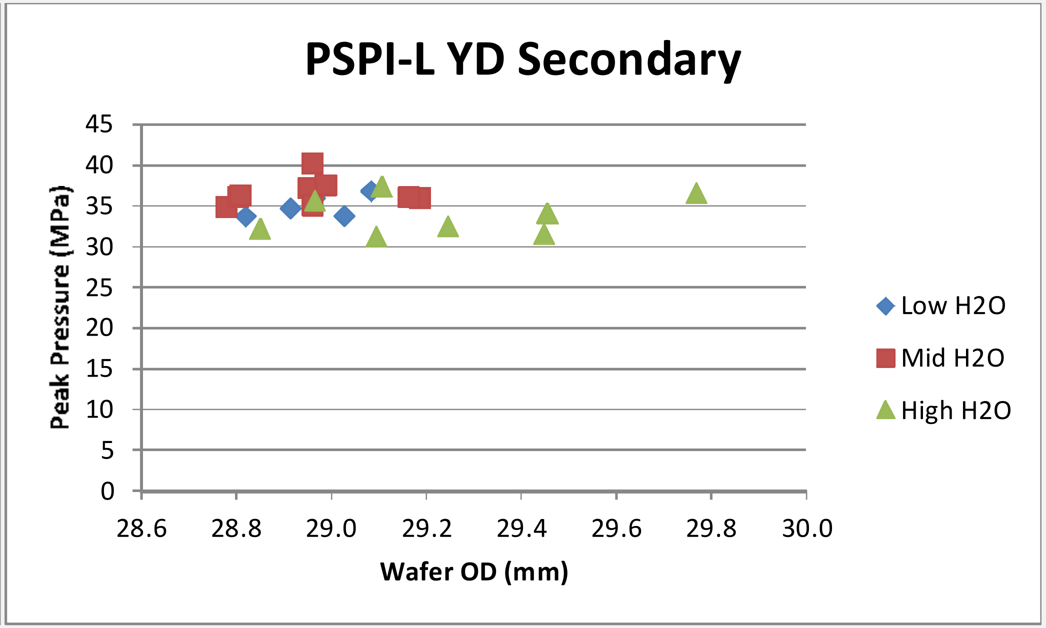


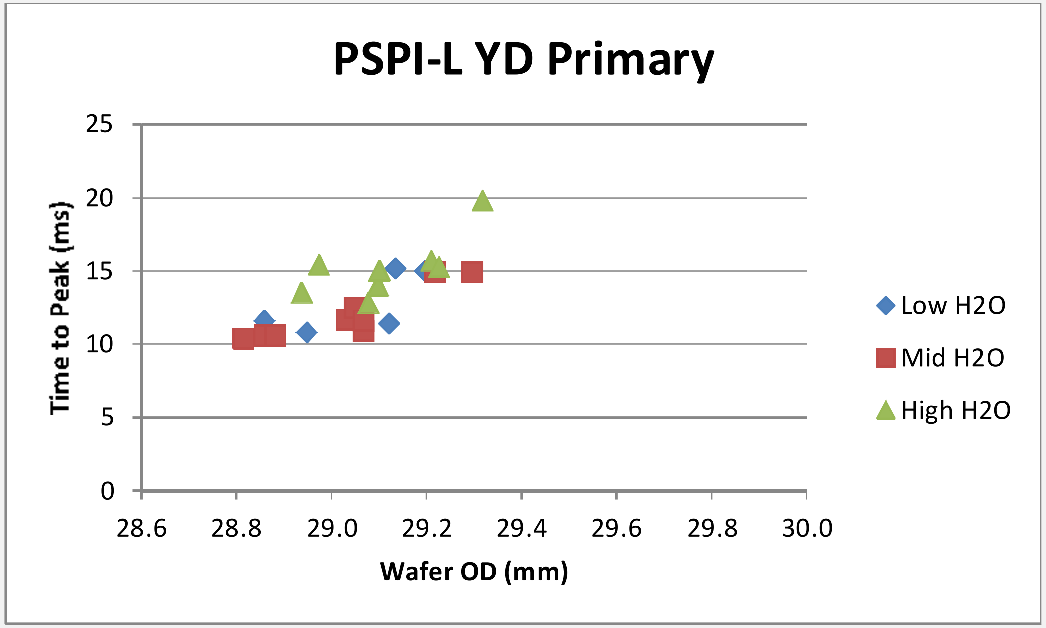
GM Tank Testing Cycle 1680

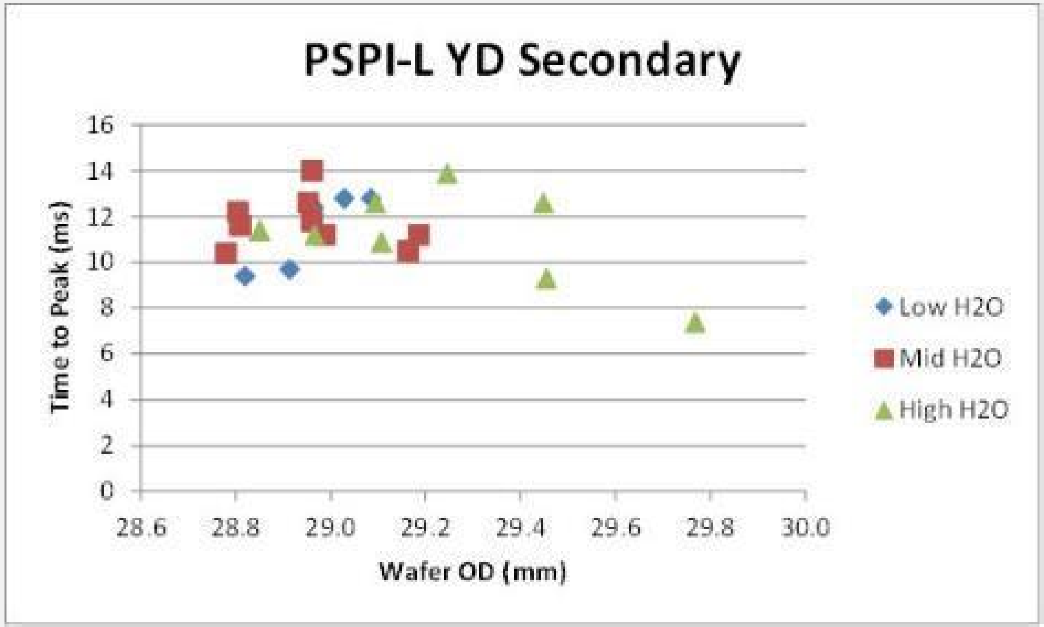


GM Tank Testing Cycle 1680





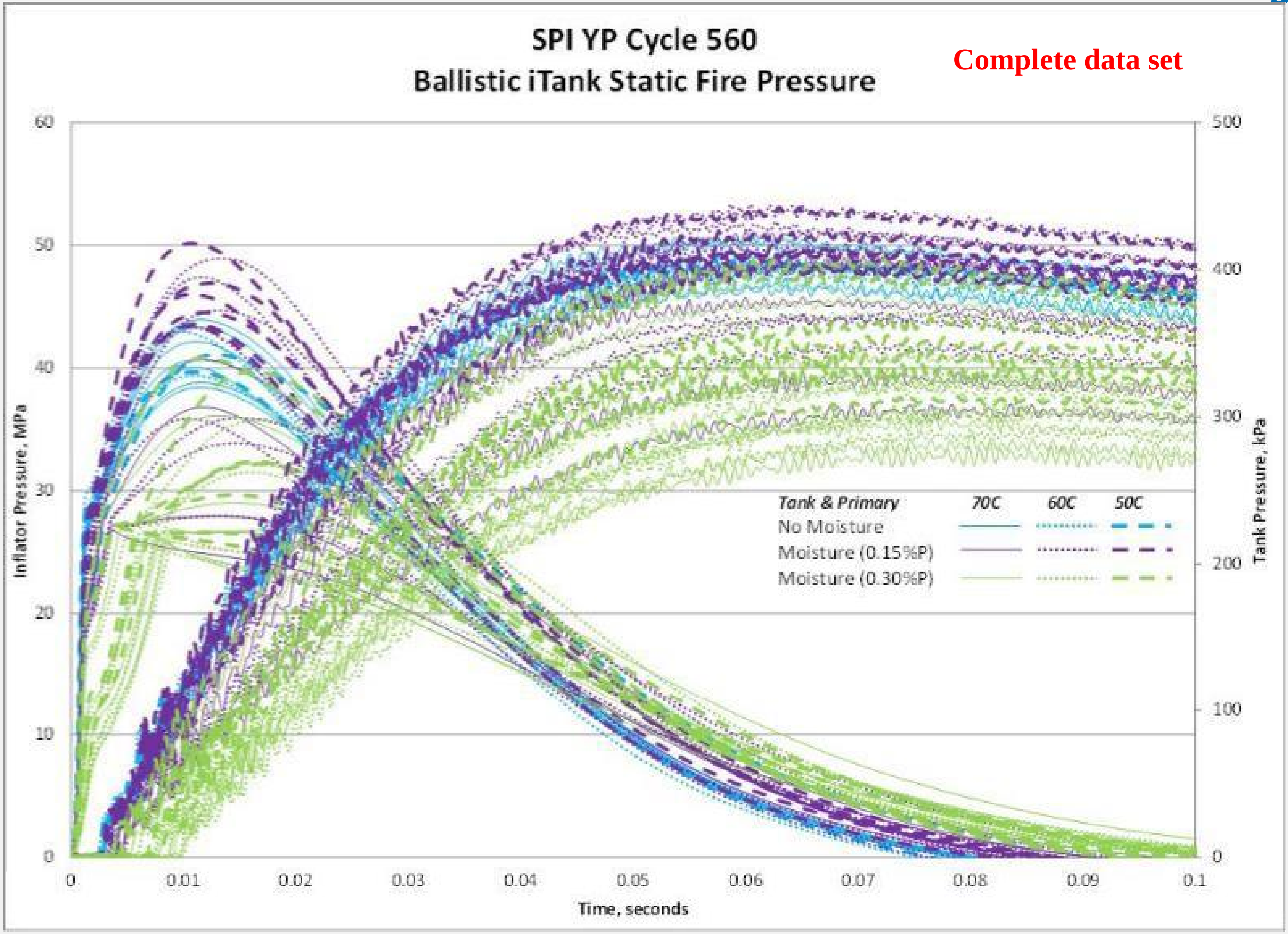




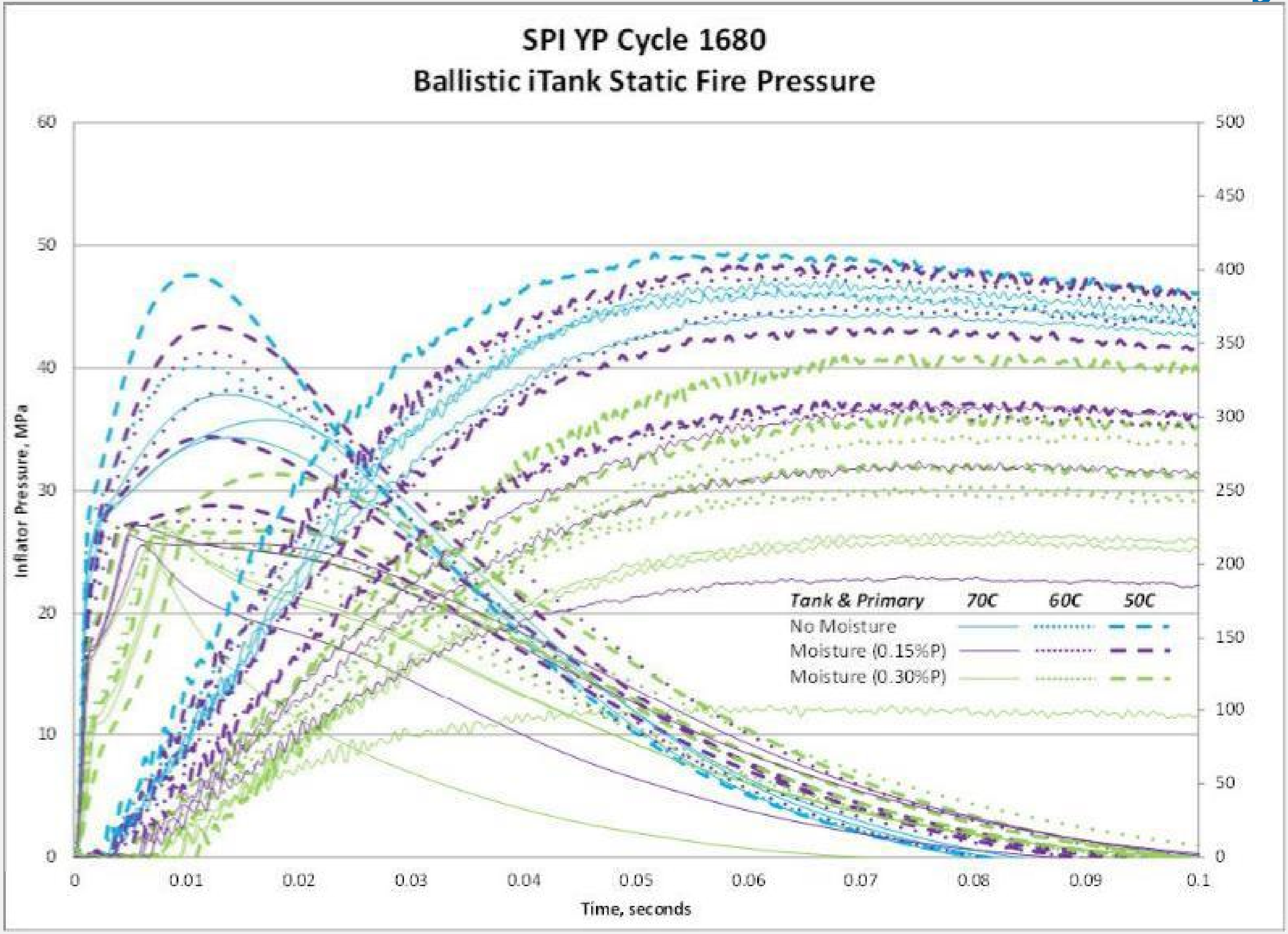
GM Tank Testing

- Status
  - All SPI YP 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are showing lower performance than the 560 cycle results (used 560 due to correction issues with 1120)
    - Highest combustion pressures come from nominal and mid moisture levels 50°C
    - Lowest performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is similar for all mid and high moisture levels, lower for nominal
    - The trend of reduced combustion pressure with larger wafer OD is very apparent in this inflator

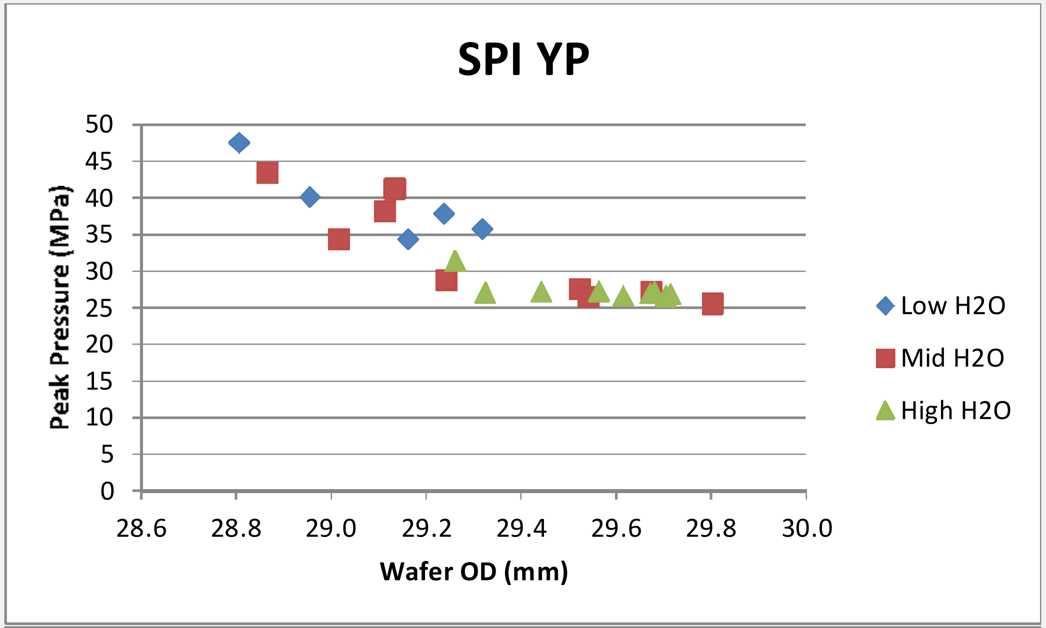
GM Tank Testing Cycle 560

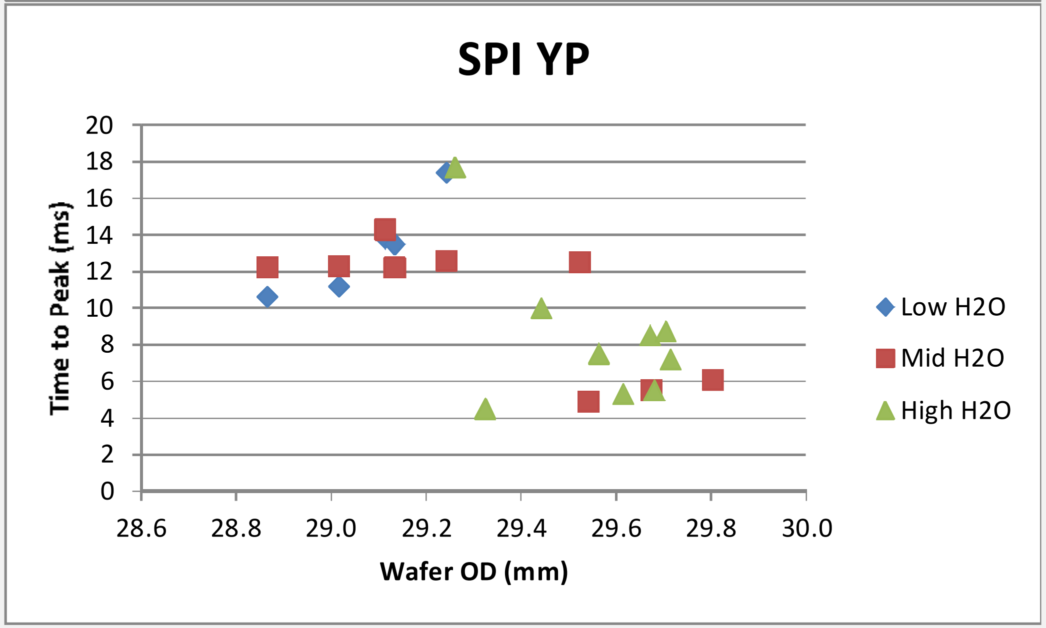


GM Tank Testing Cycle 1680



GM Tank Testing Cycle 1680

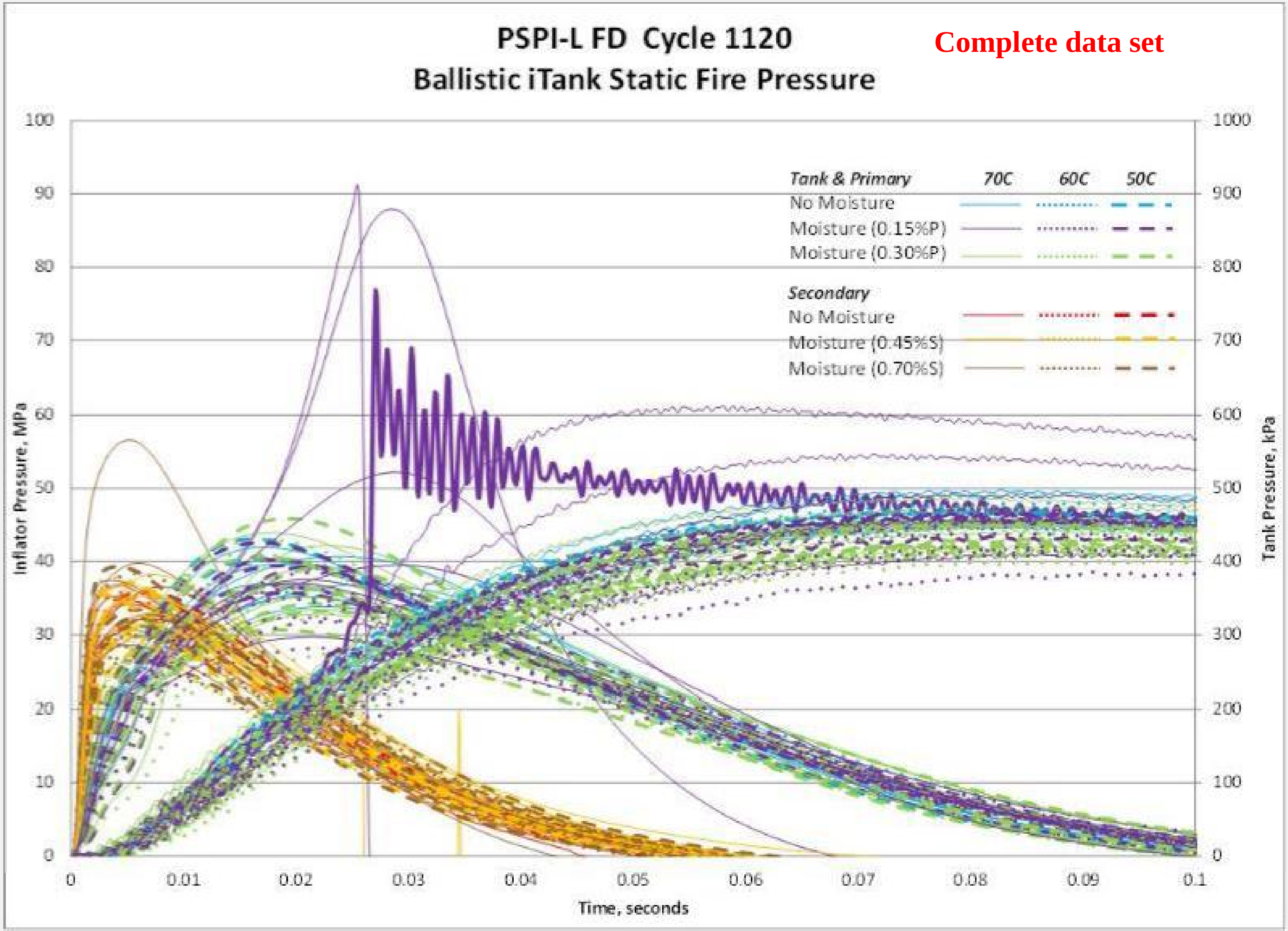




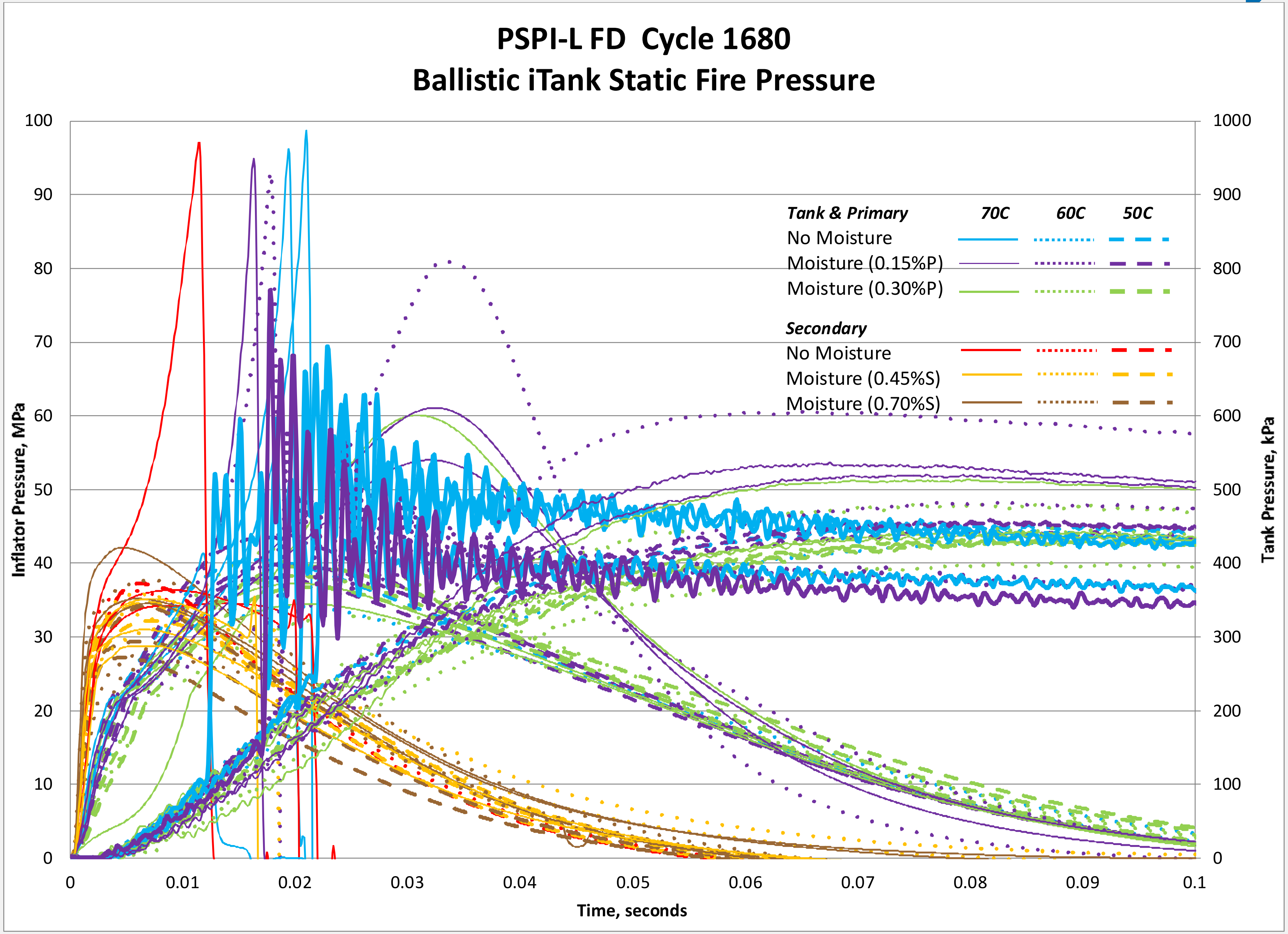
GM Tank Testing

- Status
  - All PSPI-L FD 1680 cycle tests completed
  - Plotted the 23 shots
    - Inflators are moving into higher probabilities of ED events (5 ED & 5 abnormal ED type behavior events so far)
    - Abnormal behavior including ED's are now occurring at high temperature nominal moisture levels and high/mid temperature mid moisture levels all in the primary chamber, only one abnormal curve at high moisture level
    - Marginally lower performance comes from the high moisture levels
  - Plots of Peak Pressure and Time to Peak vs. wafer size (as measured by CT scan) for tested inflators have been updated to show moisture effects
    - Wafer growth for the primary chamber is trending higher at mid moisture levels and the trend of reduced combustion pressure with larger wafer OD is not seen, an ED threshold OD is ~29.2mm
    - The secondary chamber has reached an ED threshold OD of 29.4mm only for nominal moistures, also wafer growth at the high moisture level outpaces the lower moisture levels
    - Abnormal ED type behavior curves have slower start and higher time to peak

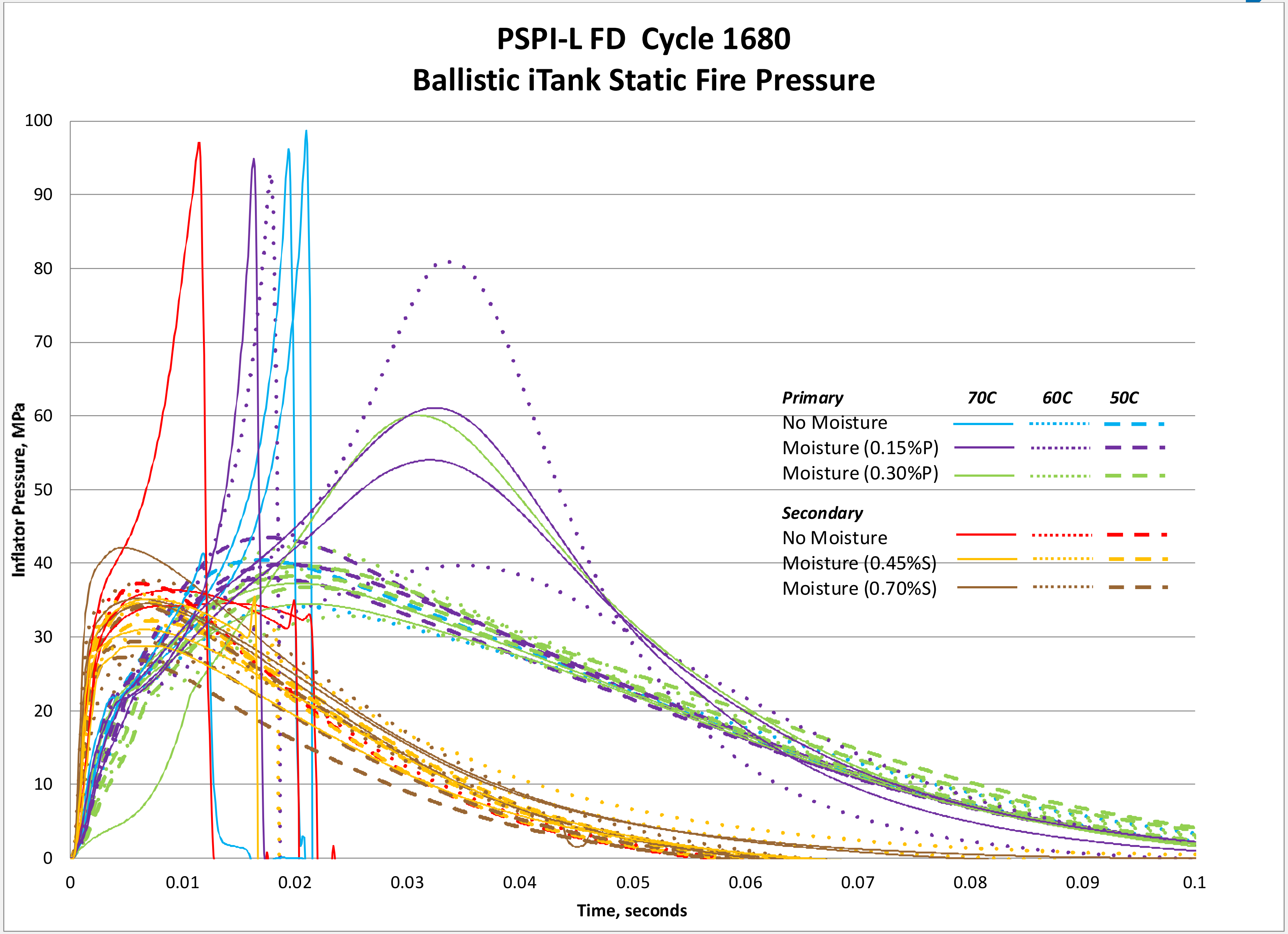
GM Tank Testing Cycle 1120



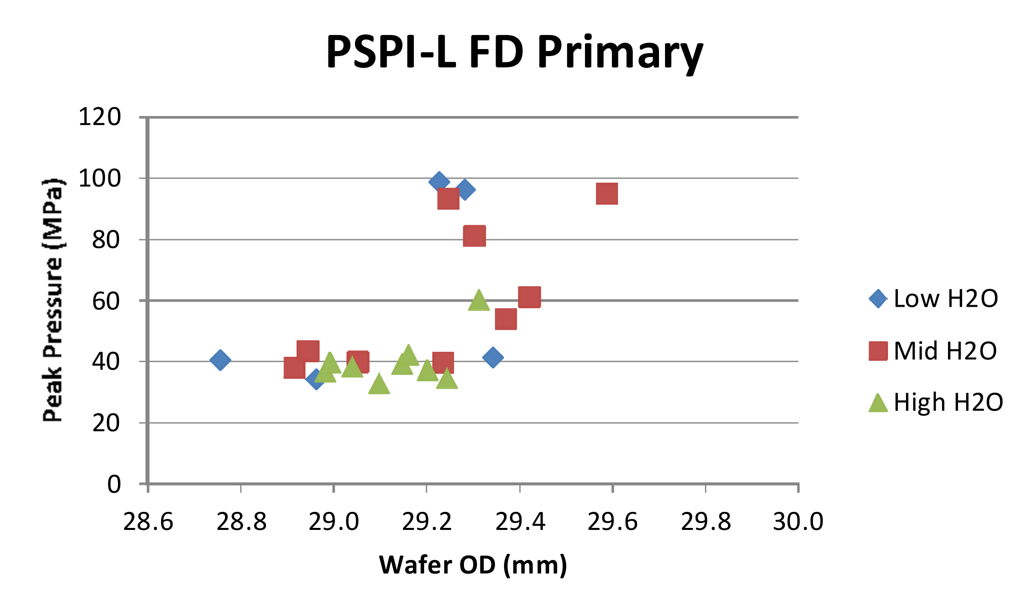
GM Tank Testing Cycle 1680

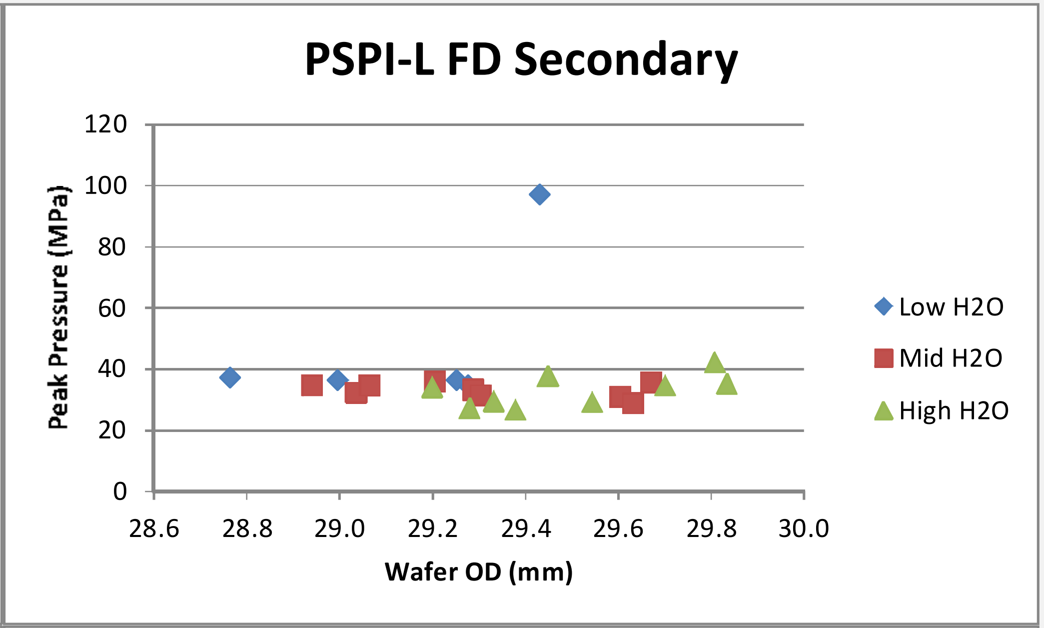


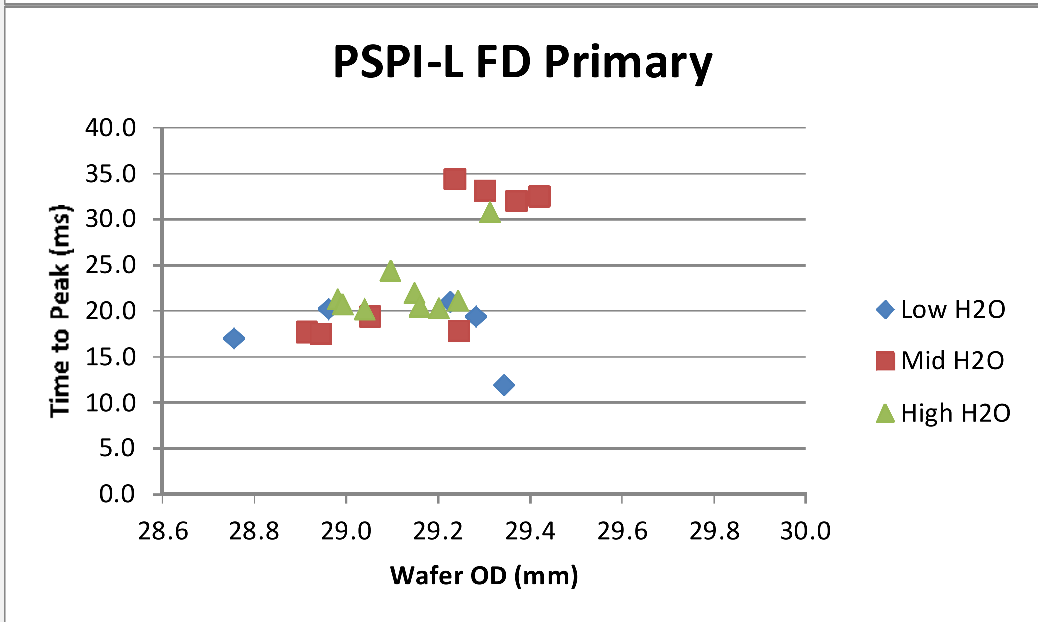
GM Tank Testing Cycle 1680

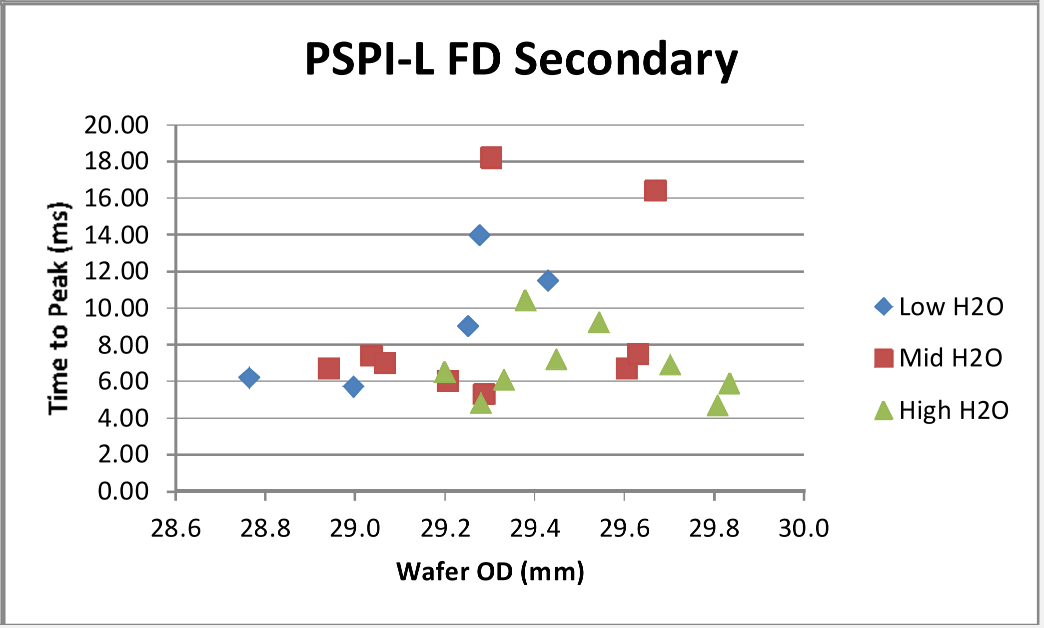


GM Tank Testing Cycle 1680







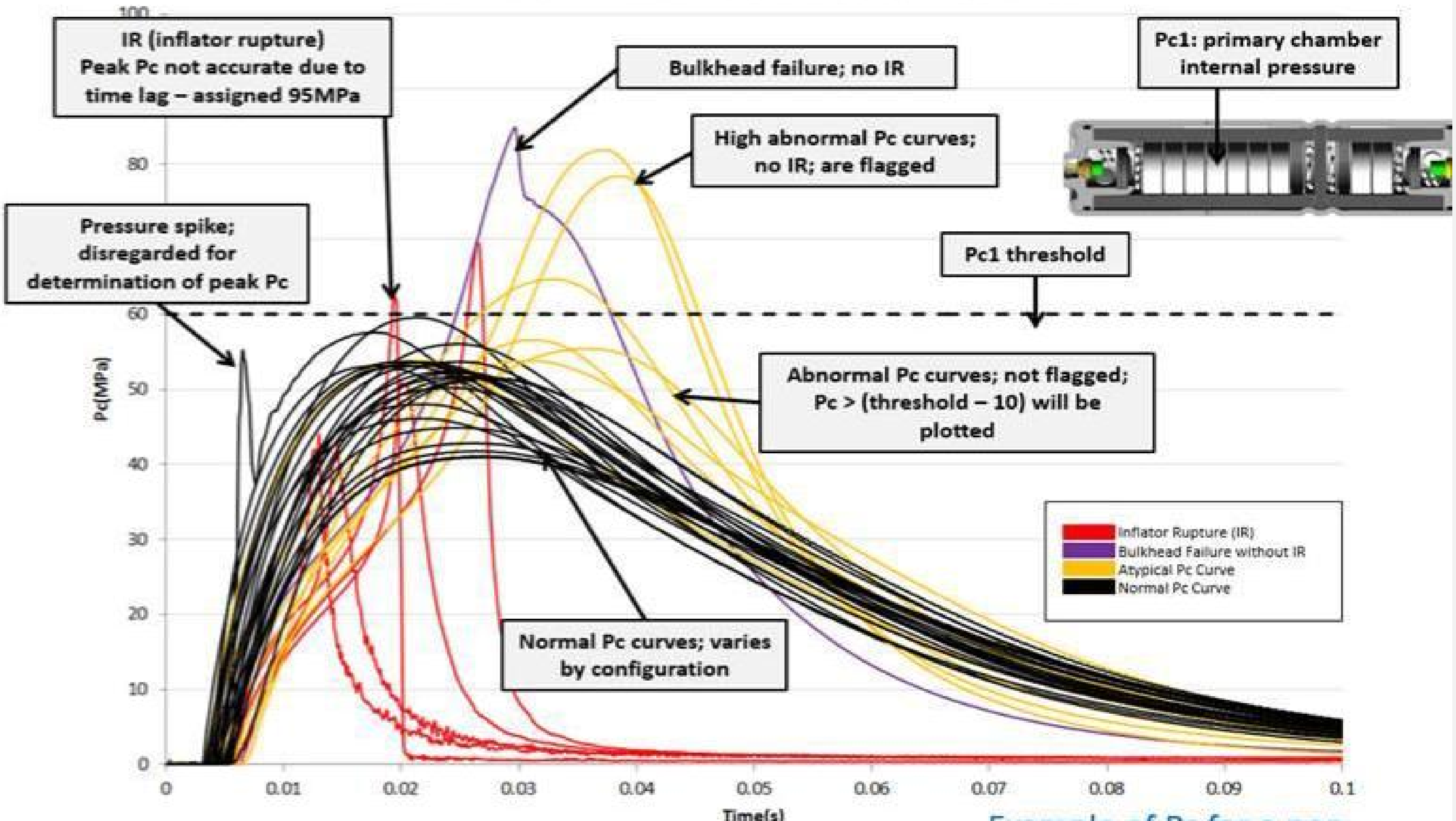


Orbital ATK

TAKATA

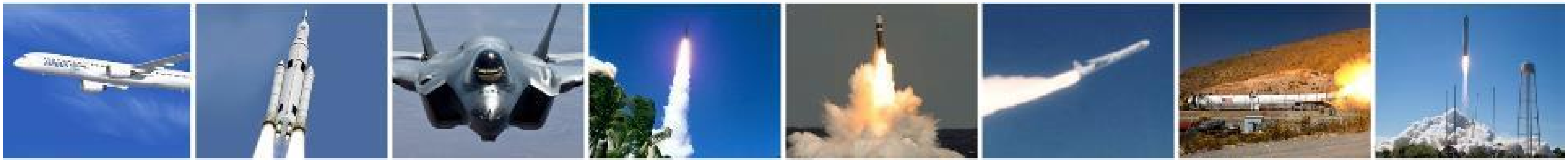
PSPI-L Threshold Pc1

PSPI-L Primary Chamber Pressure (Pc1) Example

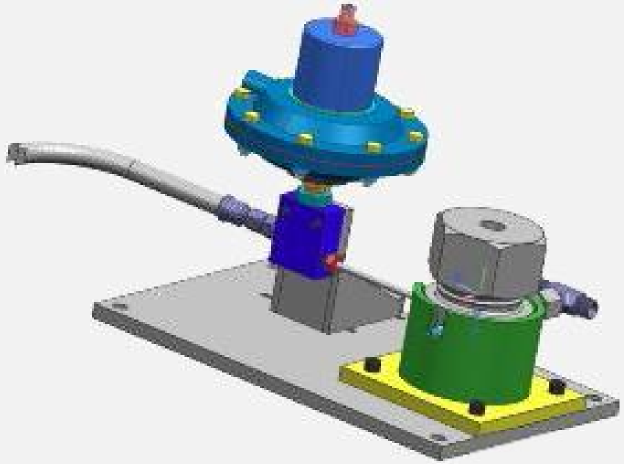


Example of Pc for a non-

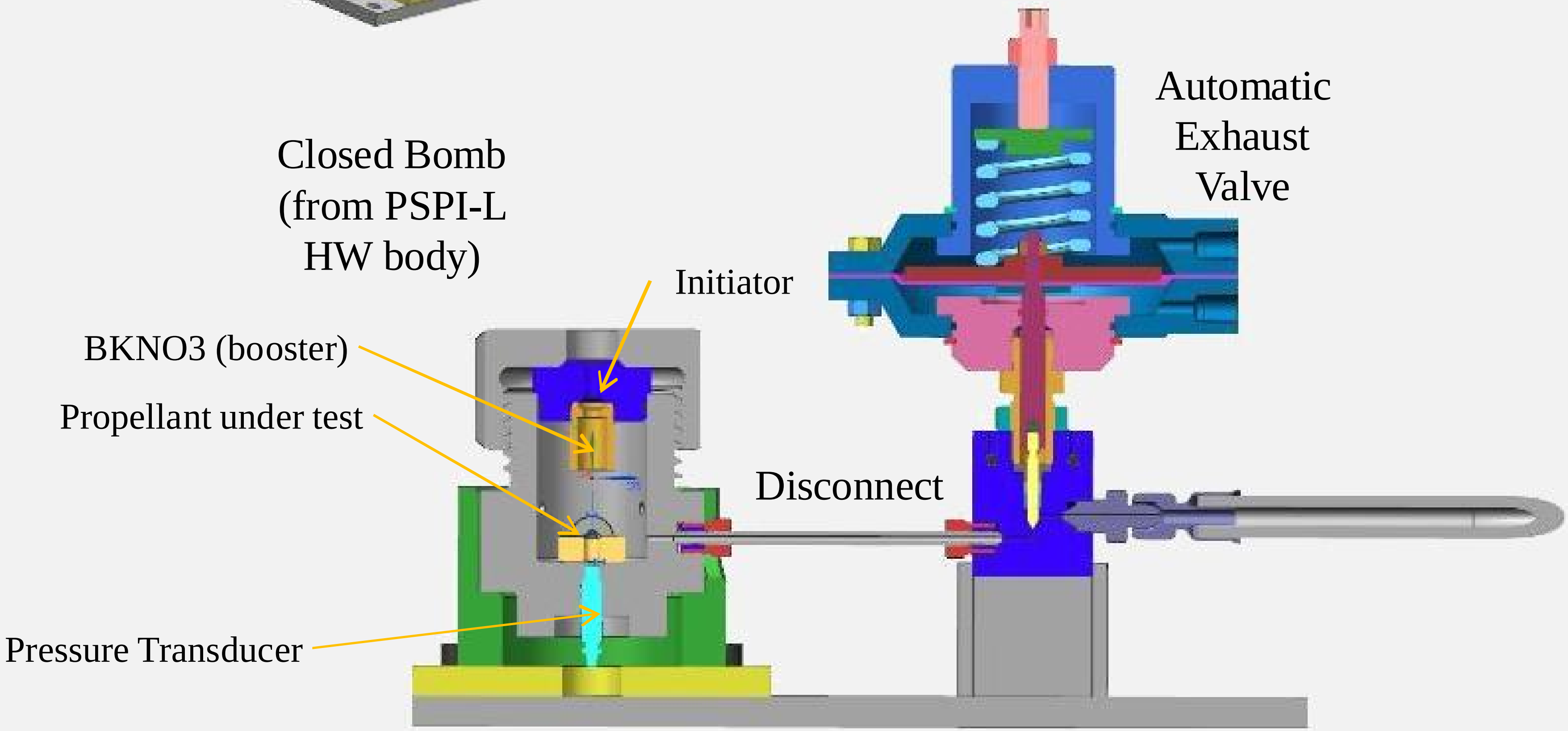
Burn Rate and Vivacity 1680



Closed Bomb

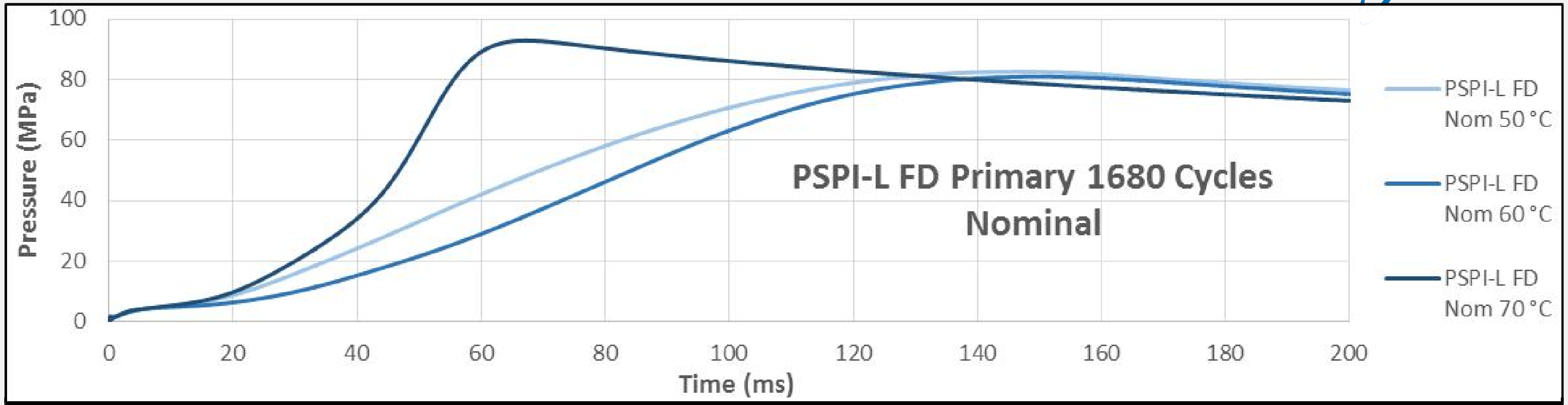


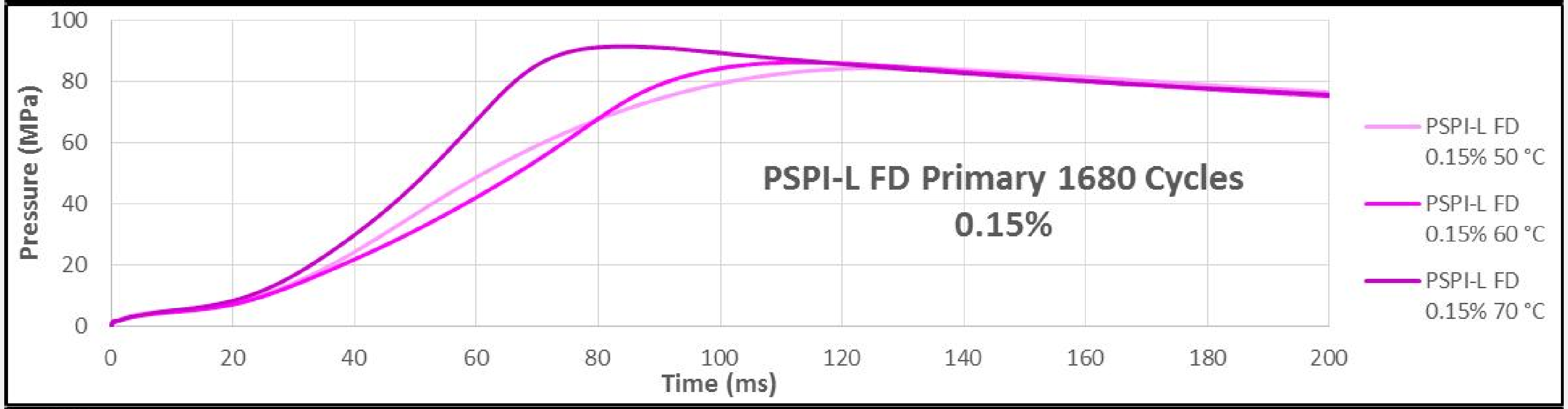
- Design Capability
  - Allows testing of all propellant types (wafers, tablets, main & booster)
  - Propellant weights up to full large wafer (10.8g) capacity
  - Up to 15,000 psi (103 MPa)
  - Piezoelectric pressure transducers
- Ignition System
  - Uses standard automotive initiators
  - Varying amount and types of booster material will be used to ensure uniform ignition – BKNO3 is the typical booster material

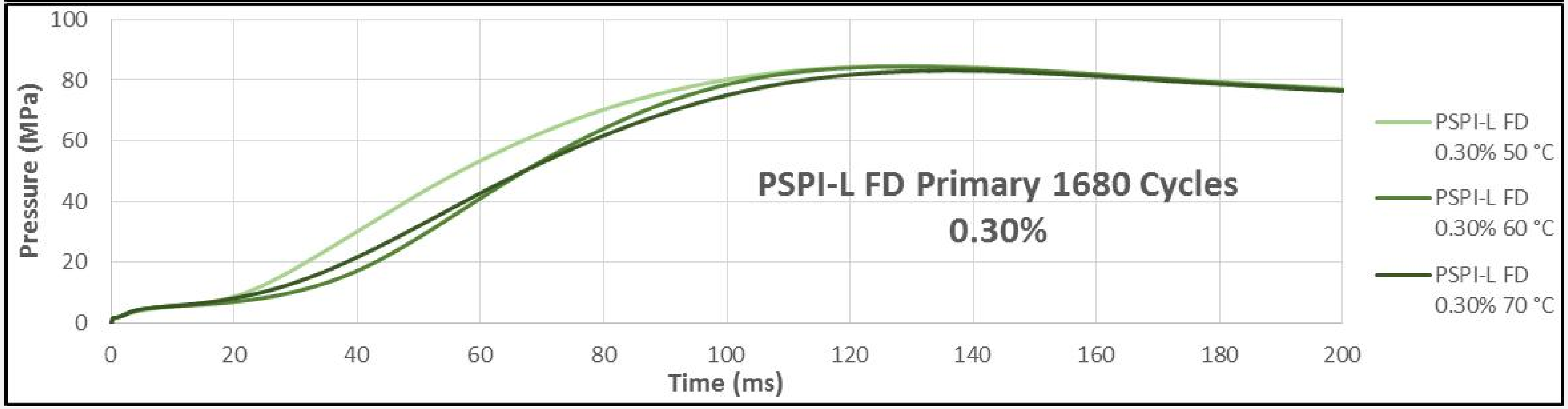


Closed Bomb Burn Rate (1680)
PSPI-L FD, Primary

- Slope breaks are observed:
  - Largest: Nominal 20-70C
  - Next Largest: 0.15% 20-70C
  - Smallest: 0.15% 20-60C



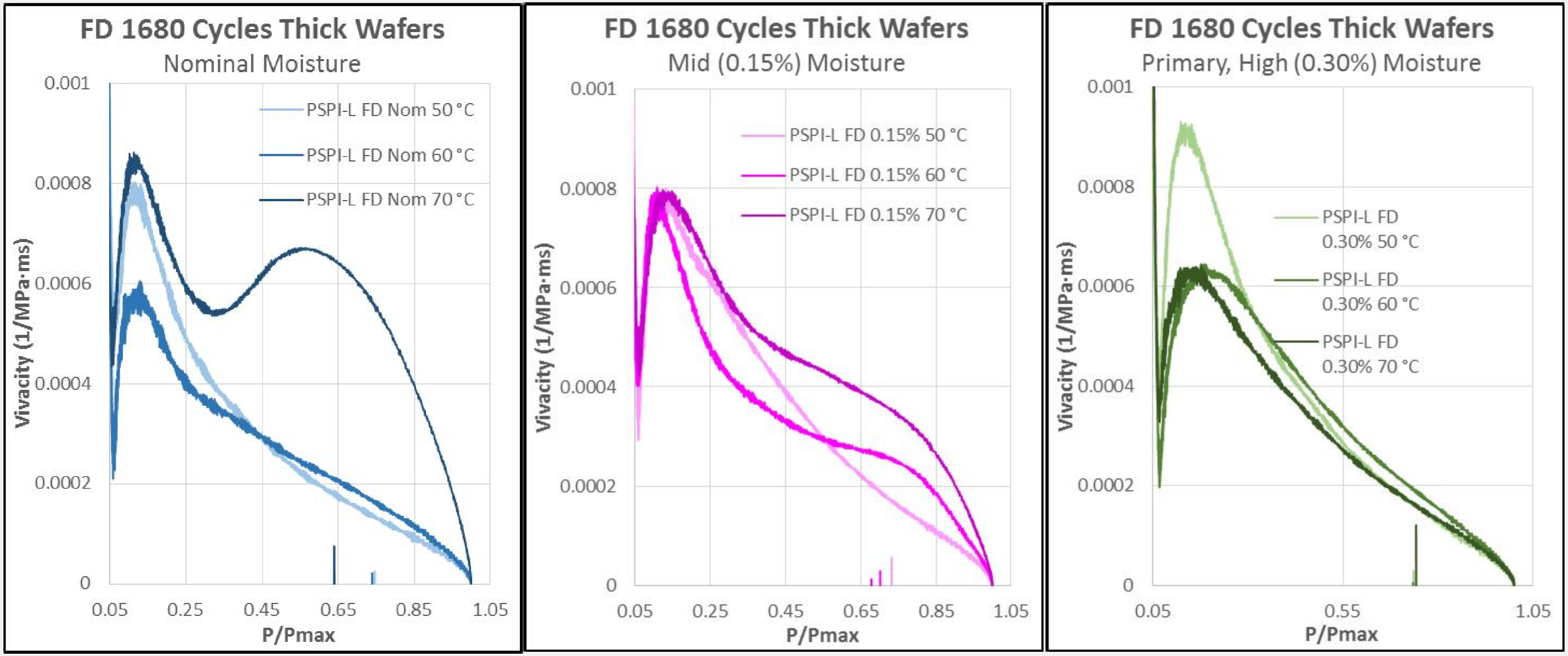




Closed Bomb Burn Rate (1680)

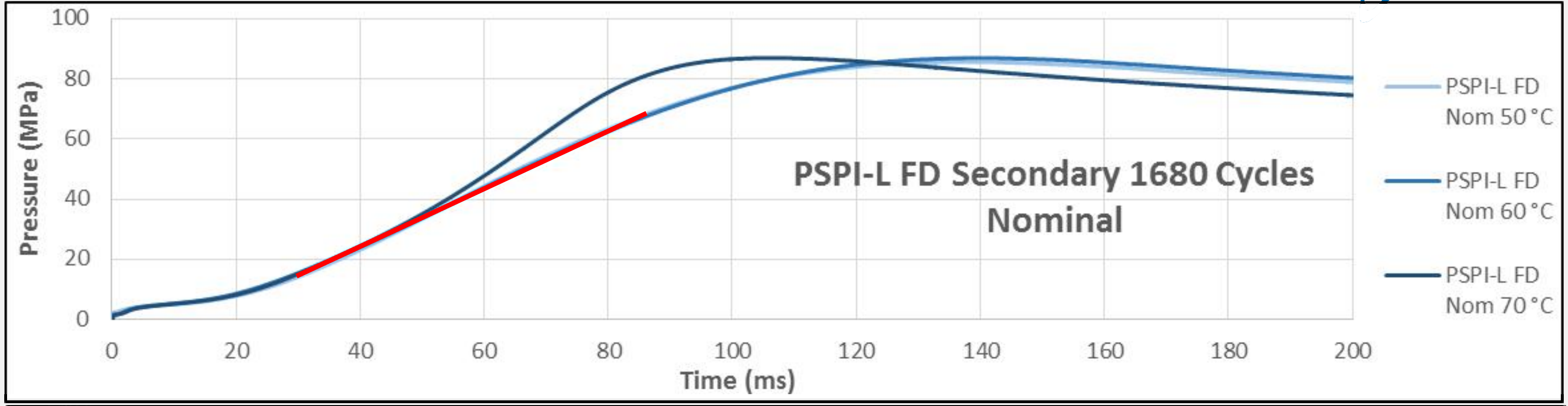
PSPI-L FD Vivacity Plots, Primary

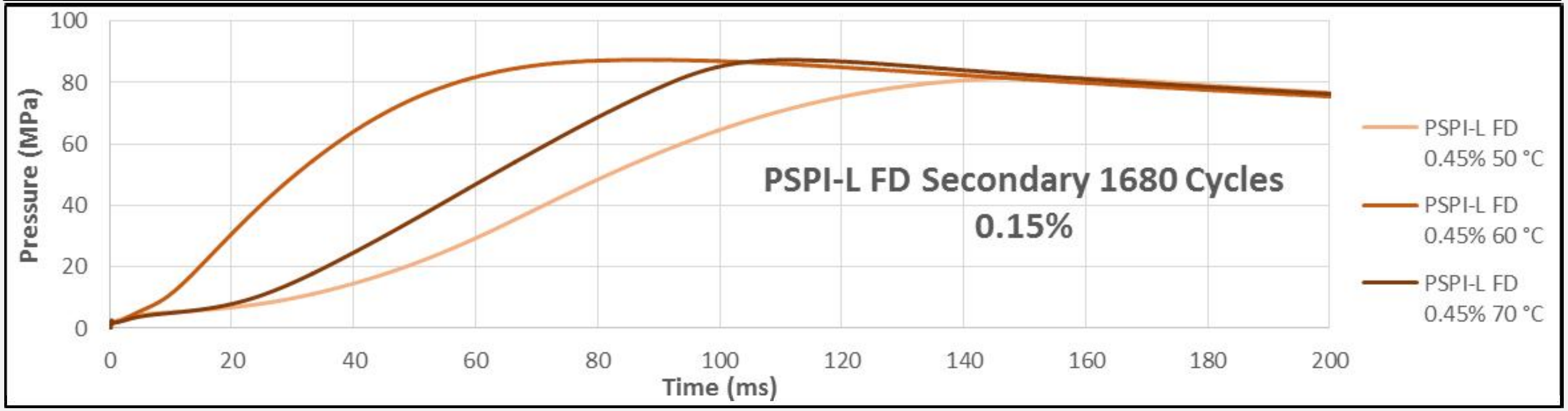
- Abnormal burn behavior is observed:
  - Most pronounced: Nominal 20-70C
  - Somewhat pronounced: 0.15% 20-70C
  - Late in the burn: 0.15% 20-60C
  - Subtle: Nominal 20-60C

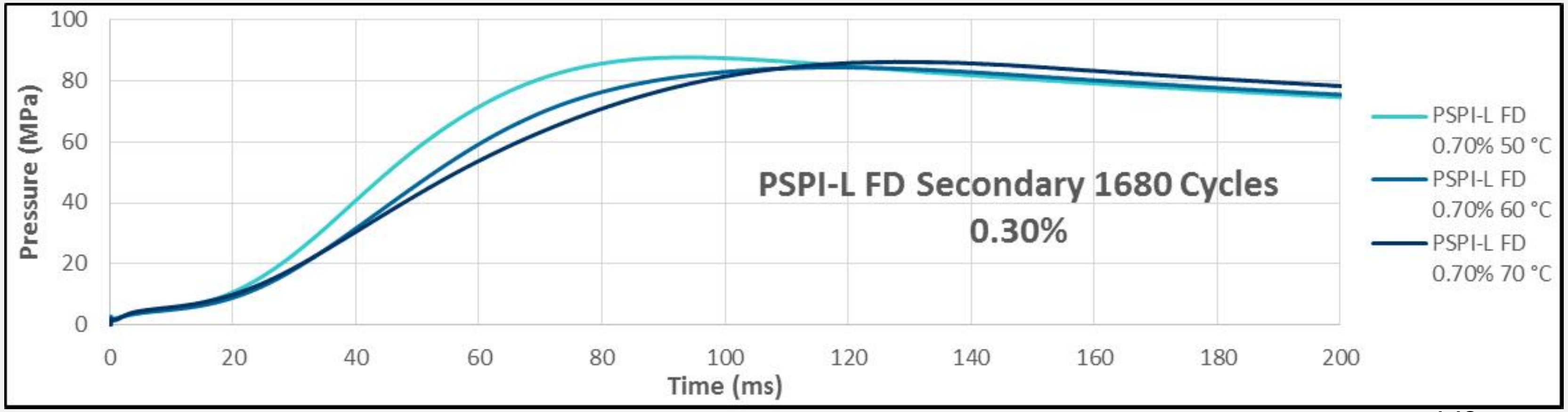


Closed Bomb Burn Rate (1680)
PSPI-L FD, Secondary

- Slope break for Nominal 20-70 C
- 0.45% 20-60 C has a very fast rise rate for FD wafers



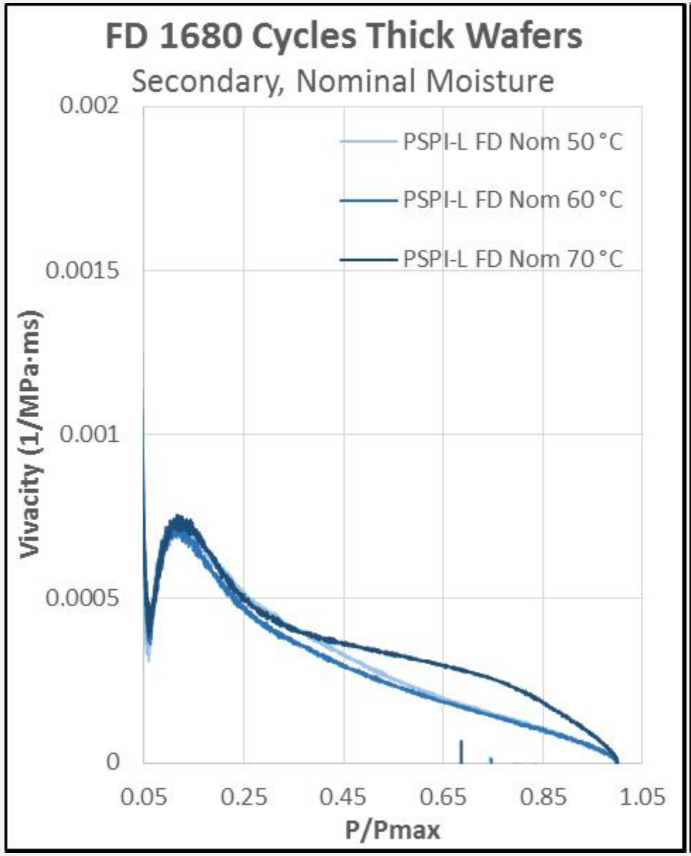


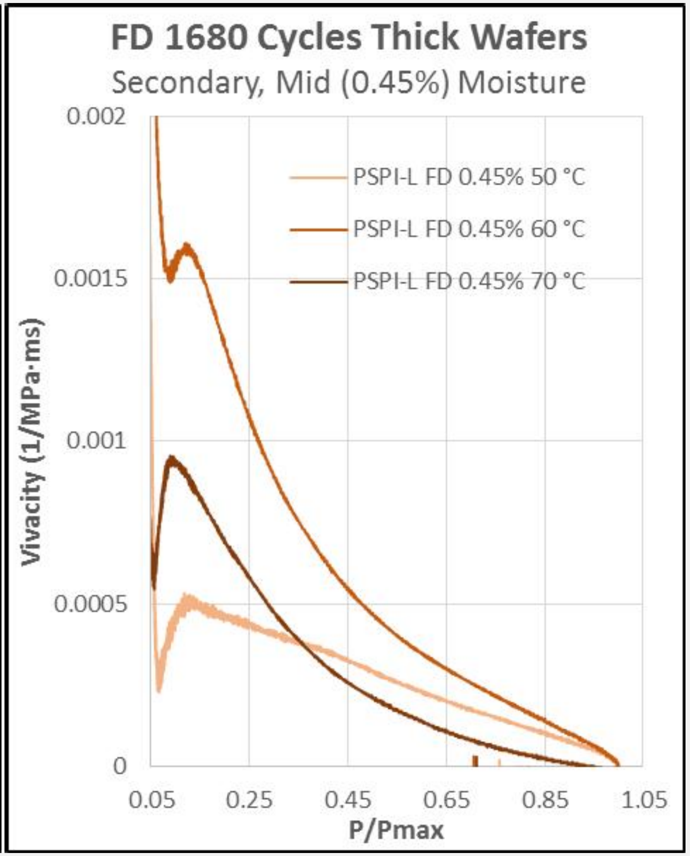


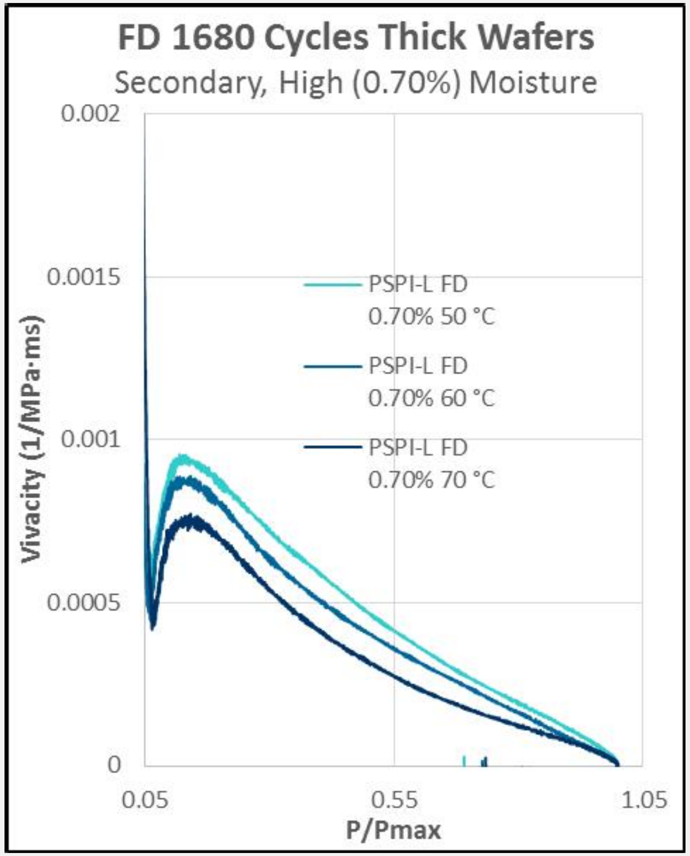
Closed Bomb Burn Rate (1680)

PSPI-L FD Vivacity Plots, Secondary

- Abnormal burn behavior is observed for Nominal 20-70 C
- Initial mass flow for 0.45% 20-60 C is very large for thick wafers

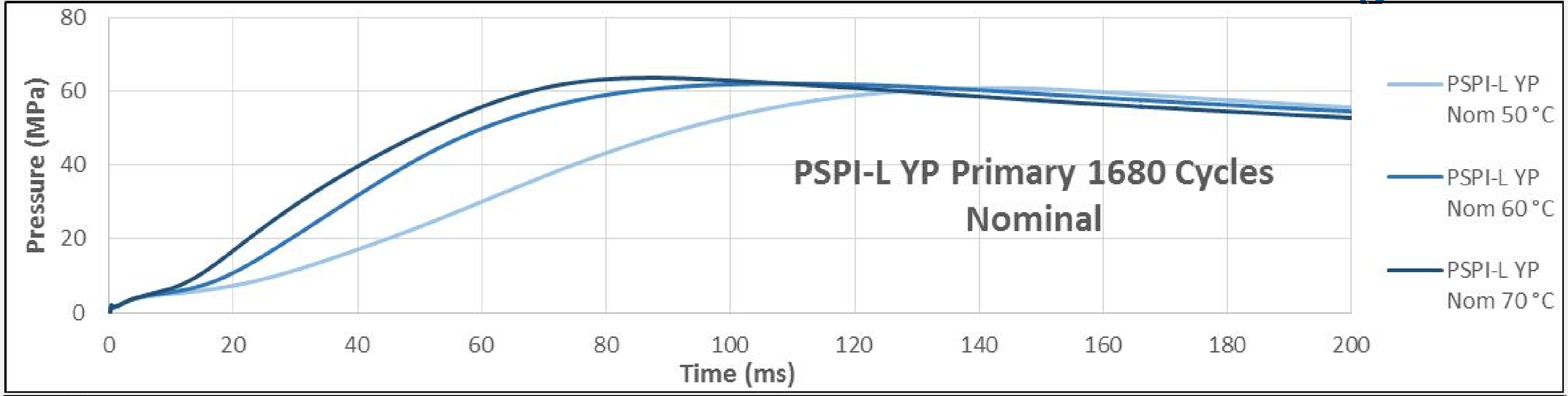


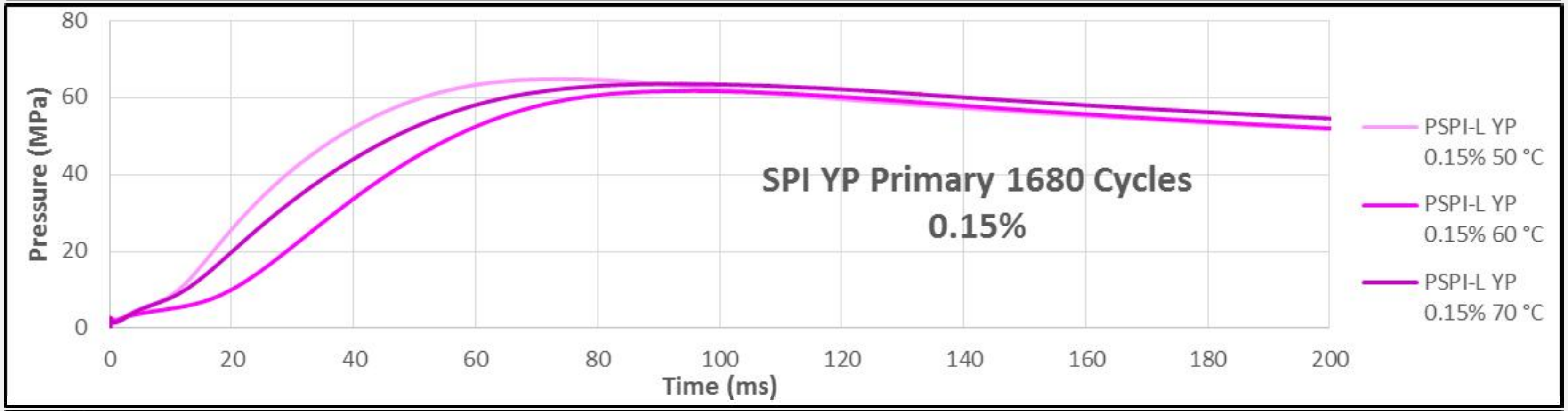


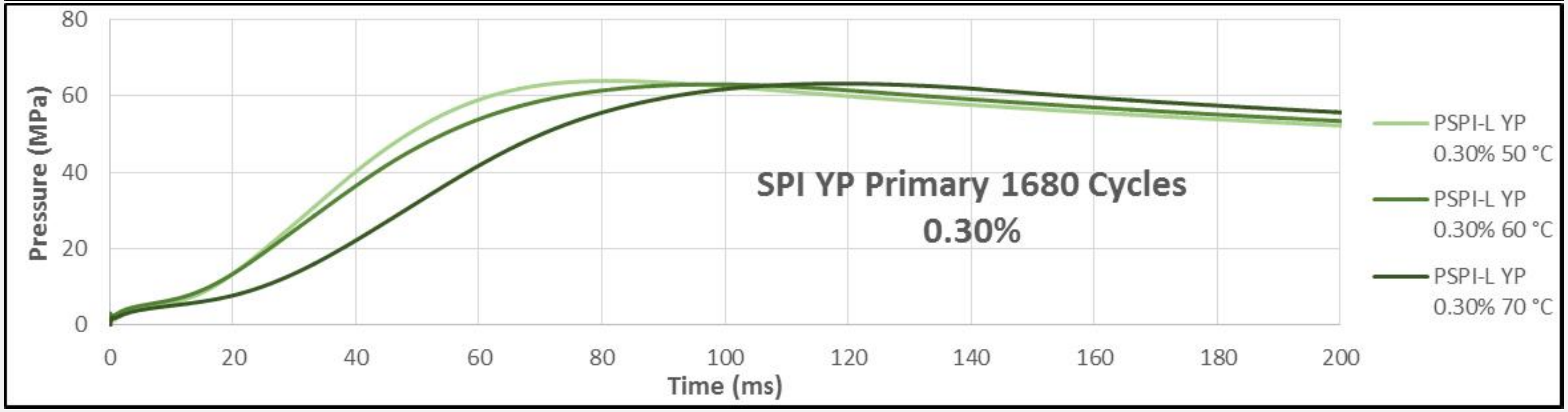


Closed Bomb Burn Rate (1680)
SPI YP

- No obvious abnormal burning observed

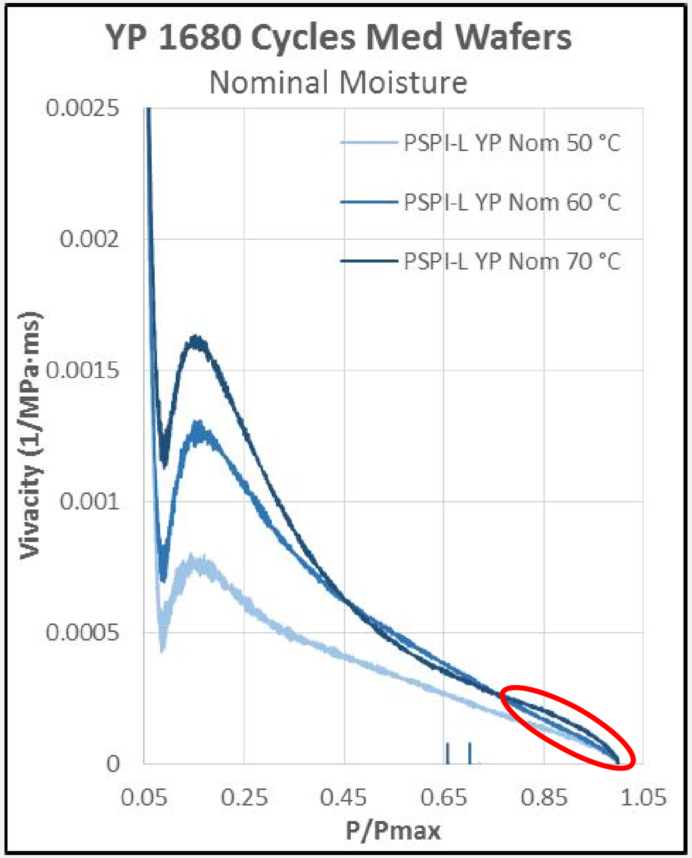


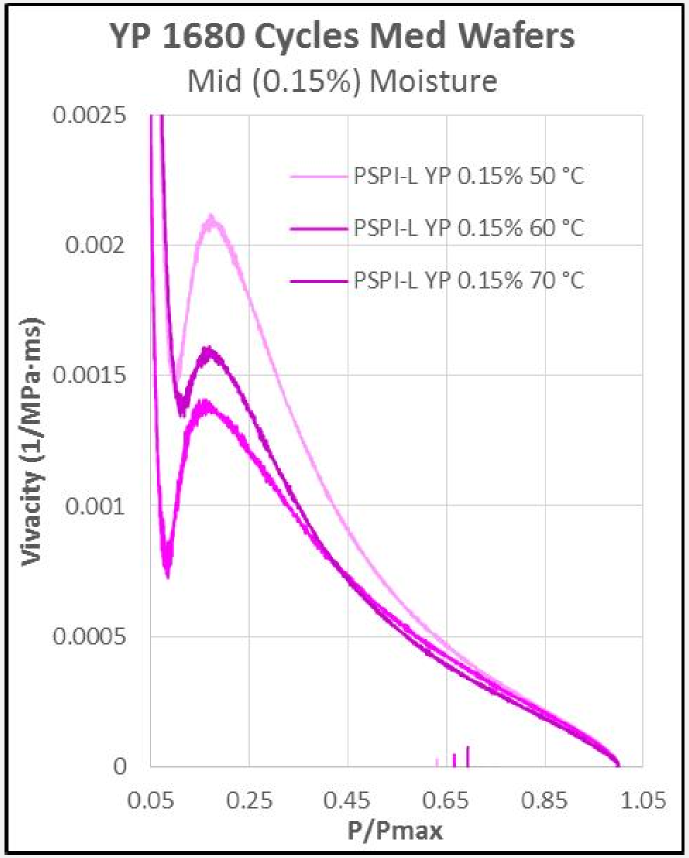


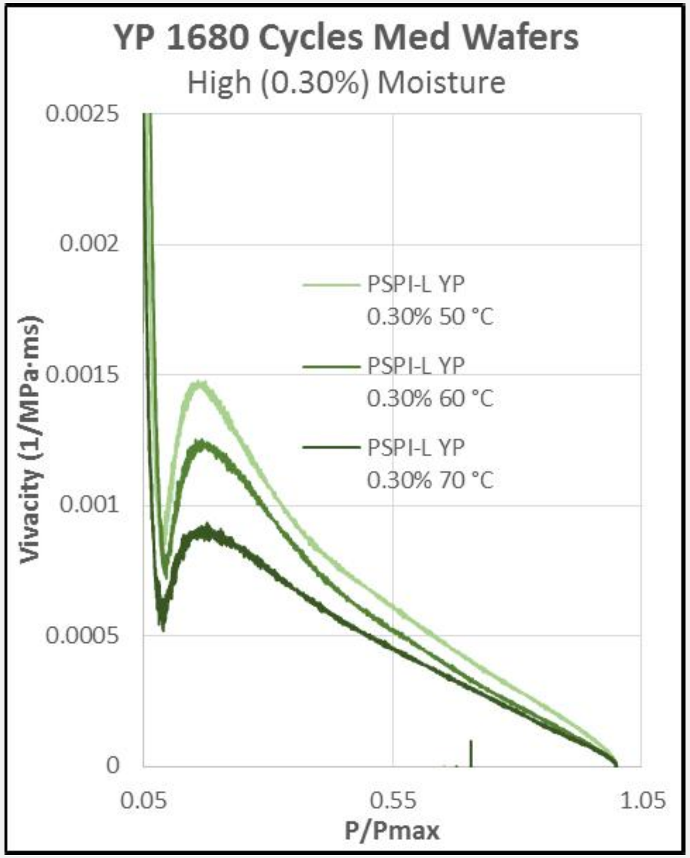


Closed Bomb Burn Rate (1120)
SPI YP Vivacity Plots

- Slight hint of abnormal burn behavior is observed for Nominal 20-70 C late in burn
- Initial mass flow for 0.15% moisture wafers is higher than for nominal and 0.30% counterparts

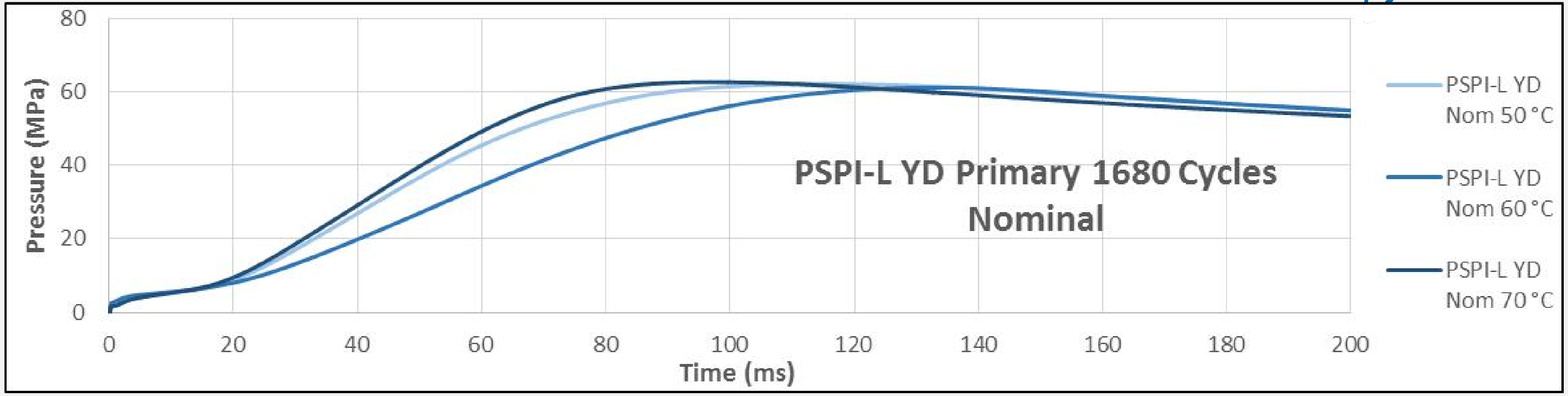


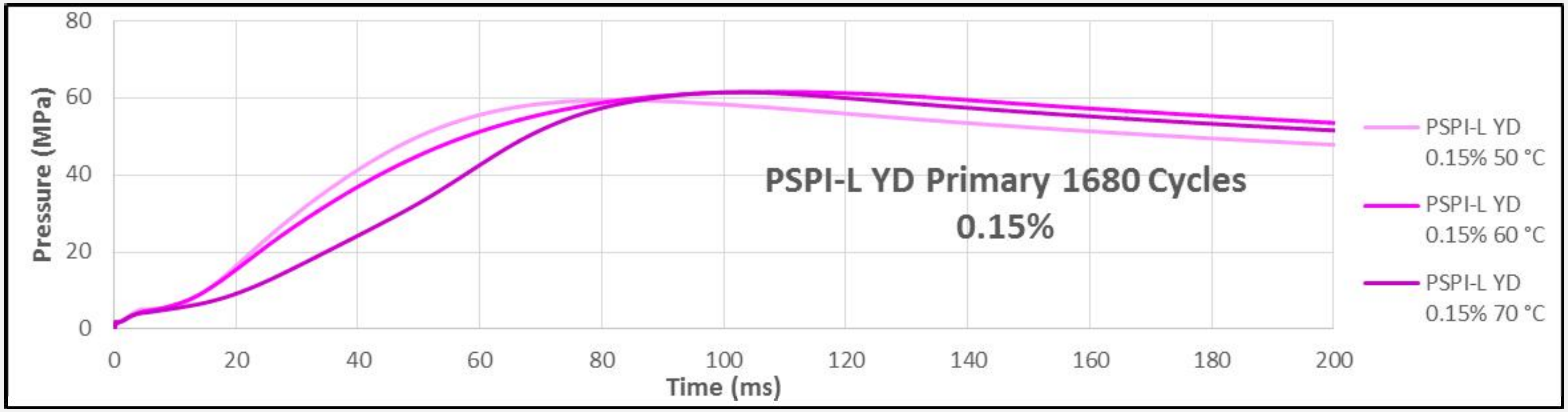


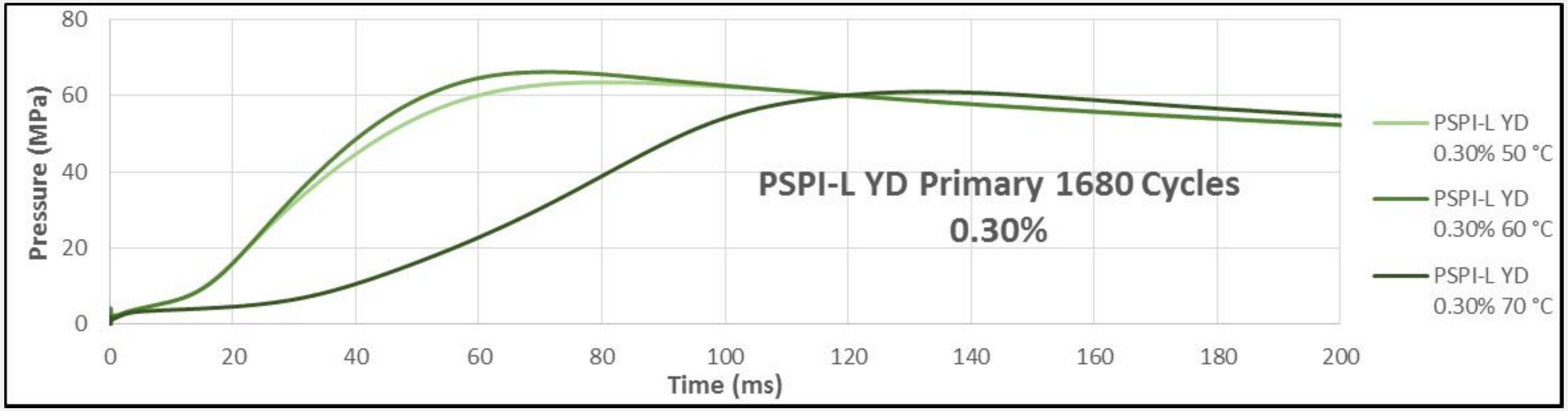


Closed Bomb Burn Rate (1680)
PSPI-L YD, Primary

- Modest slope breaks are observed:
  - 0.15% 20-70C
  - 0.30% 20-70C

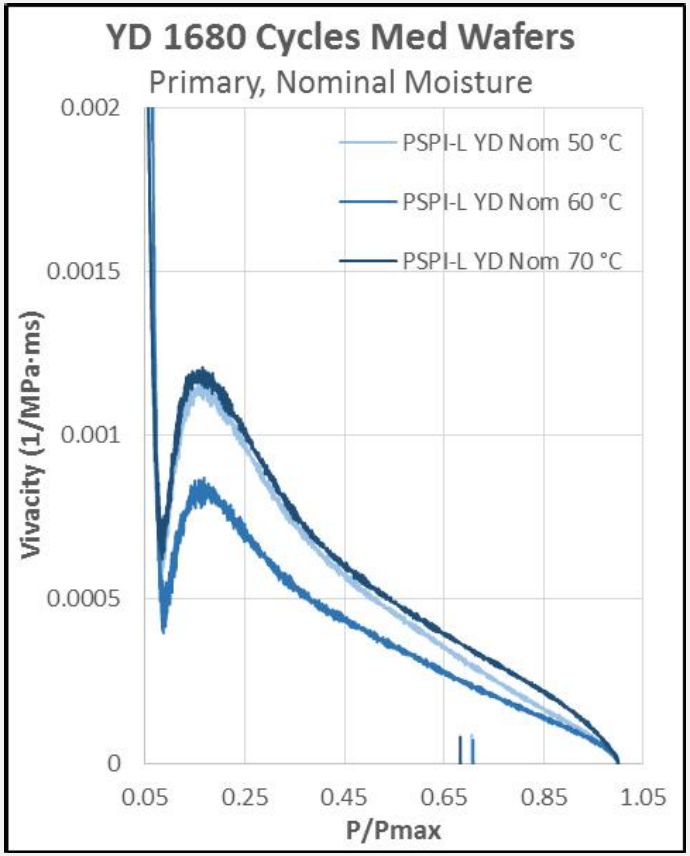


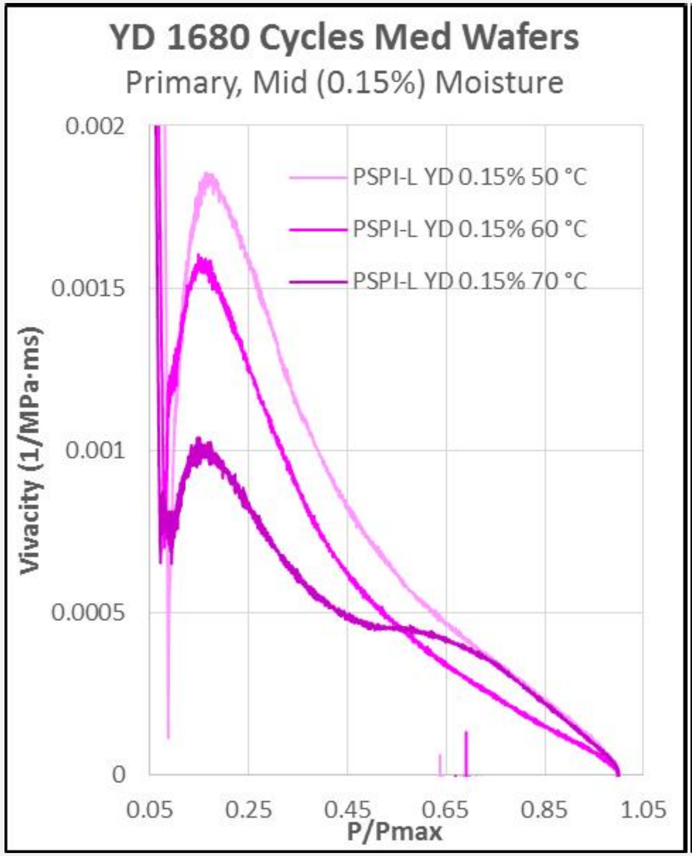


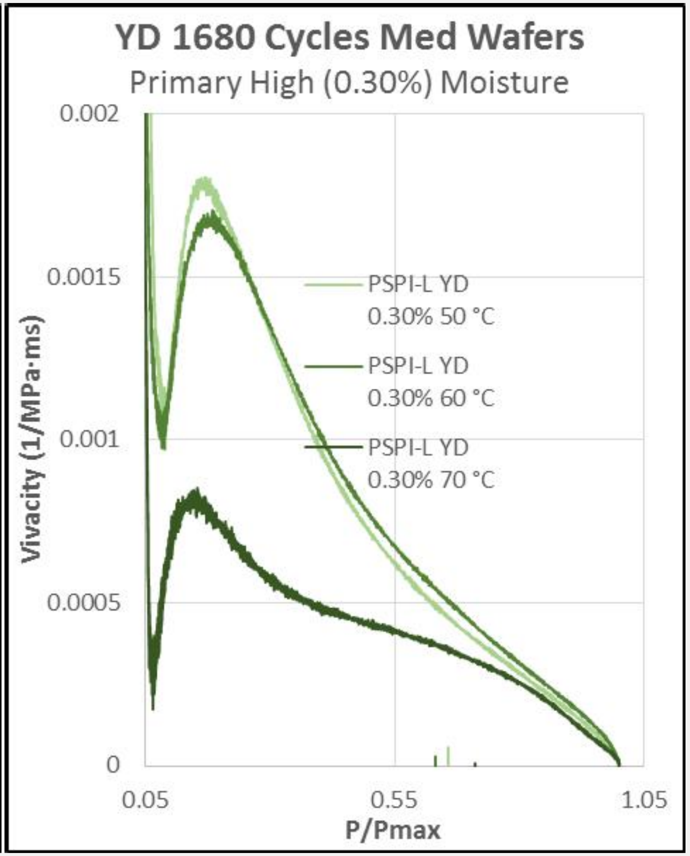


Closed Bomb Burn Rate (1120)
PSPI-L YD Vivacity Plots, Primary

- Abnormal burn behavior late into the burn is observed for all moisture conditions at 20-70C:
  - Most pronounced: 0.15% 20-70C
  - Gradual but significant: 0.30% 20-70C
  - Subtle: Nominal 20-70C

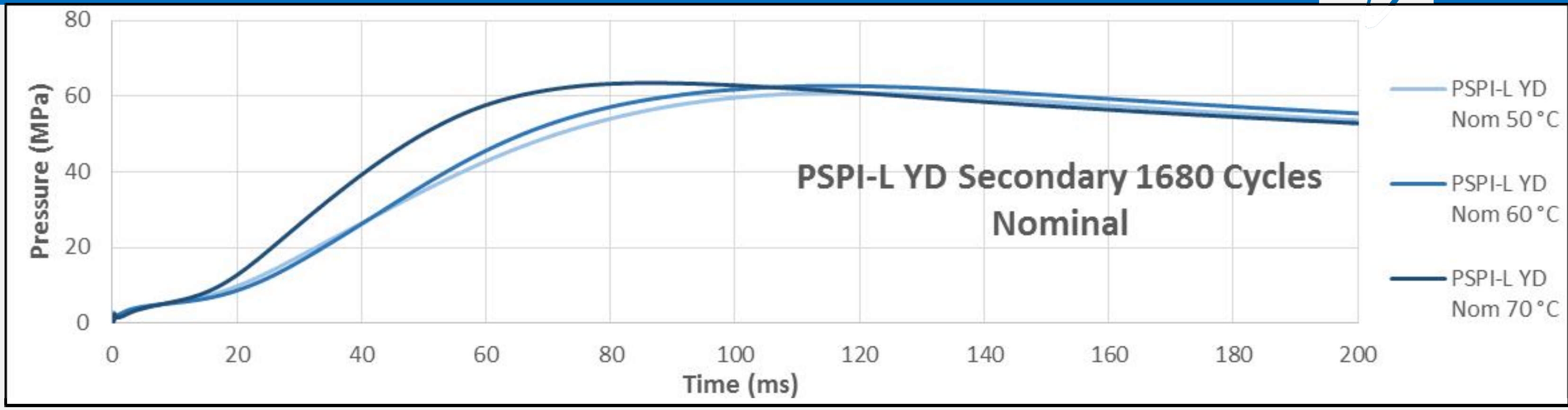


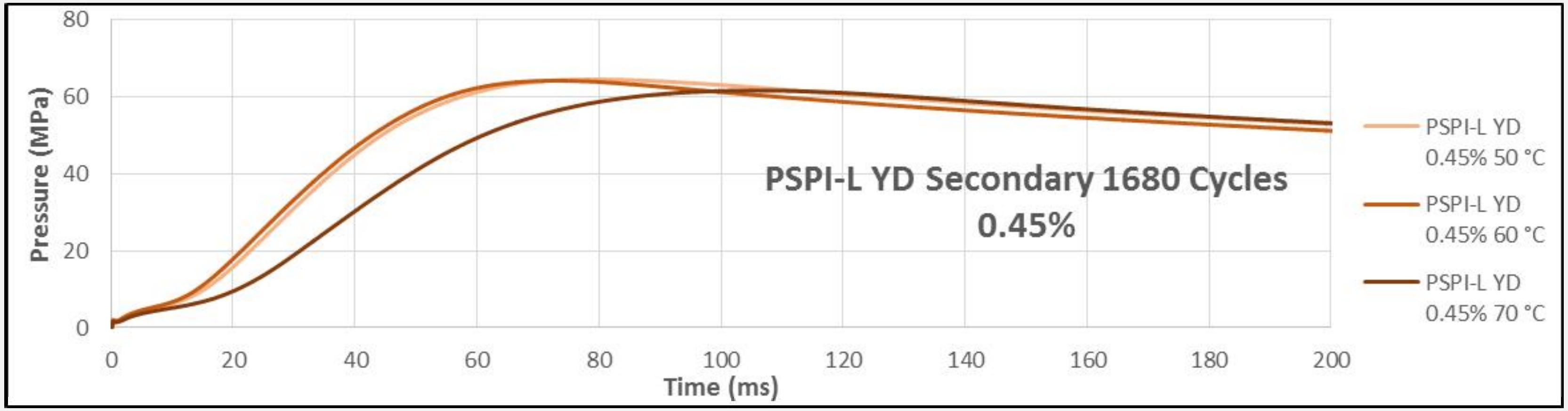


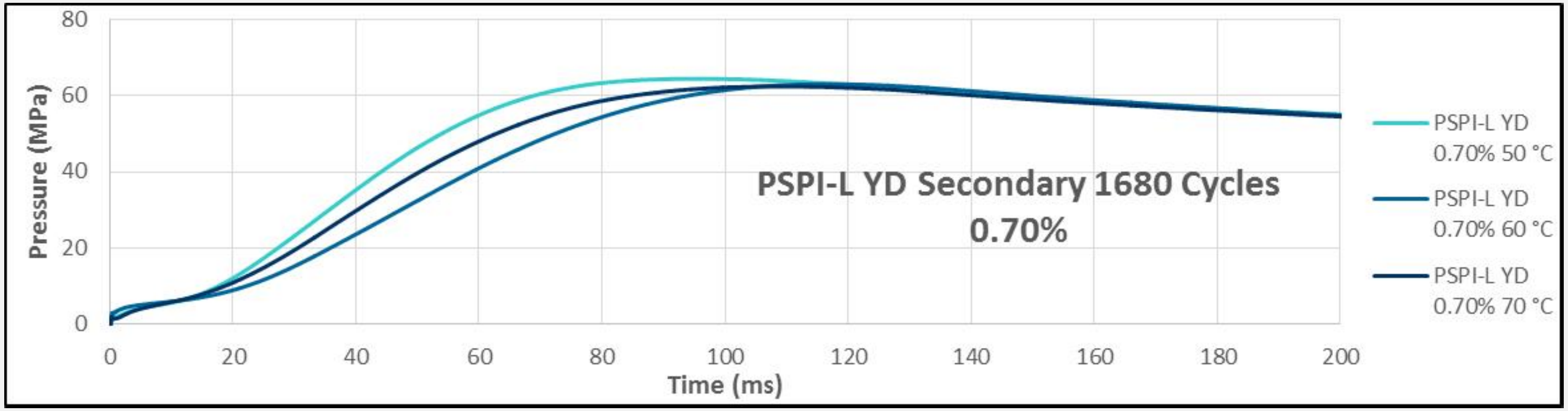


Closed Bomb Burn Rate (1680)
PSPI-L YD, Secondary

- No slope breaks observed



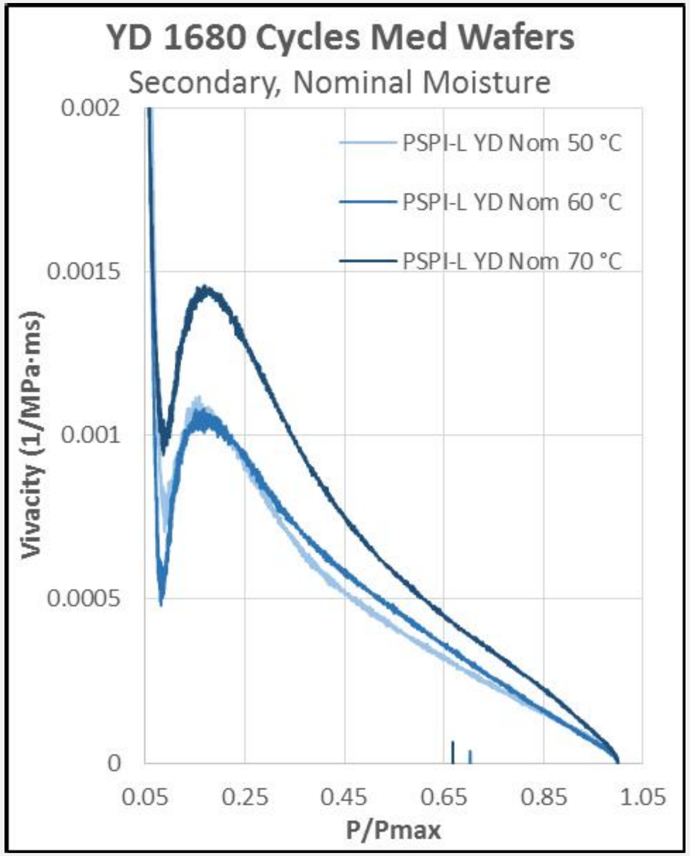


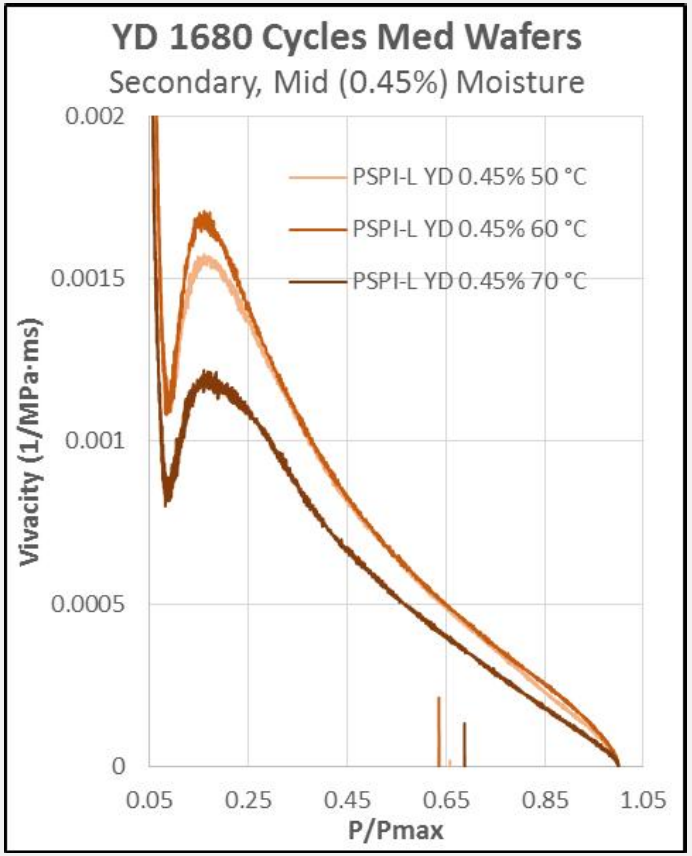


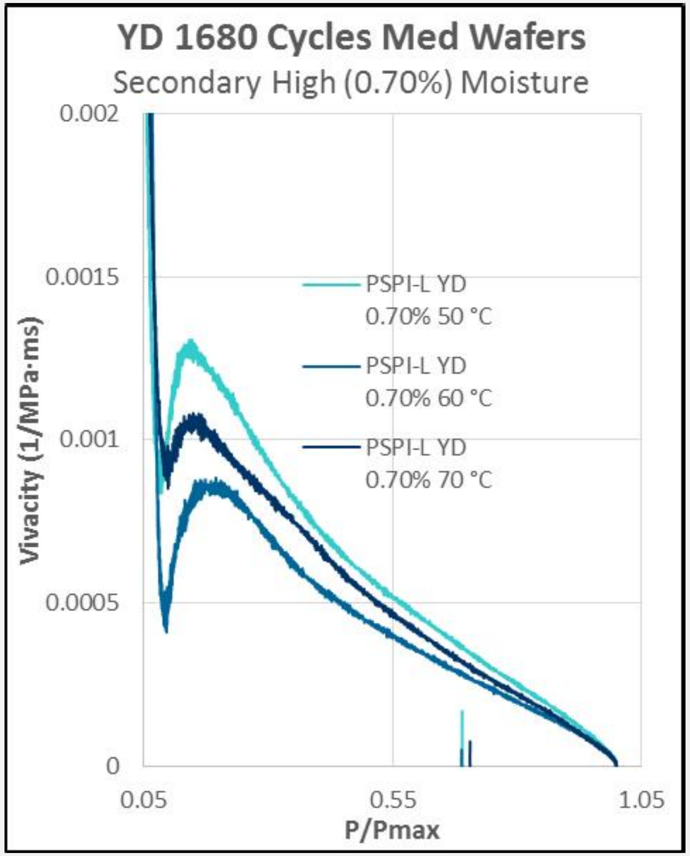
Closed Bomb Burn Rate (1120)

PSPI-L YD Vivacity Plots, Secondary

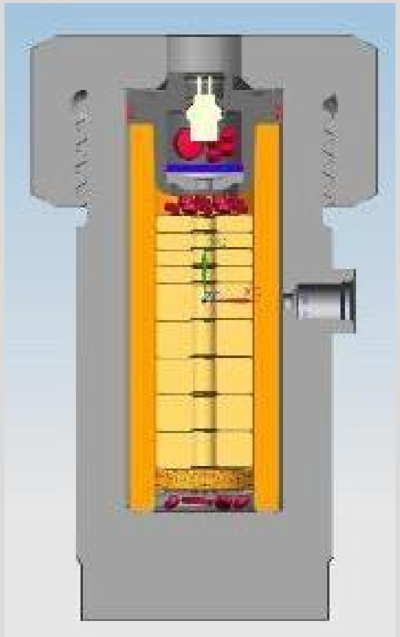
- No abnormal burn behavior
- Initial mass flow for 0.70% moisture wafers is lower than nominal and 0.45% inflators



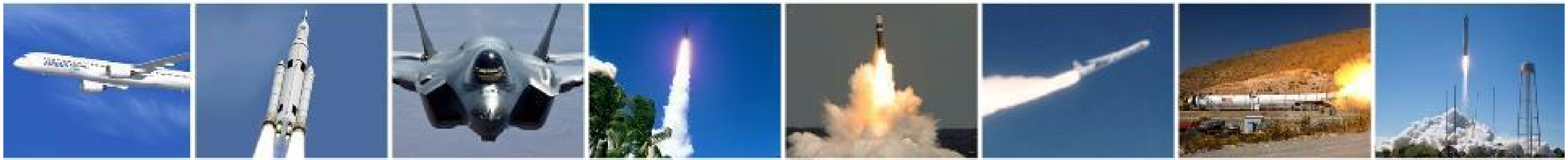




Closed Bomb Burn Rate at 1120 cycles

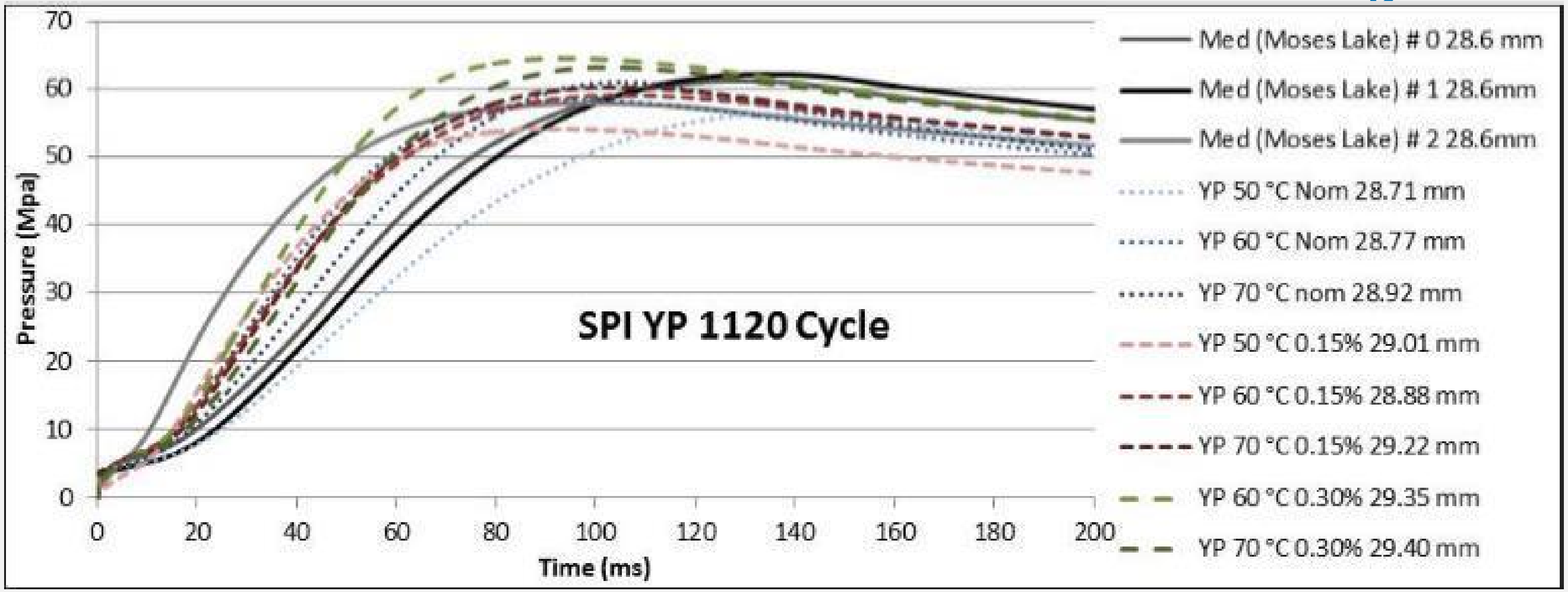


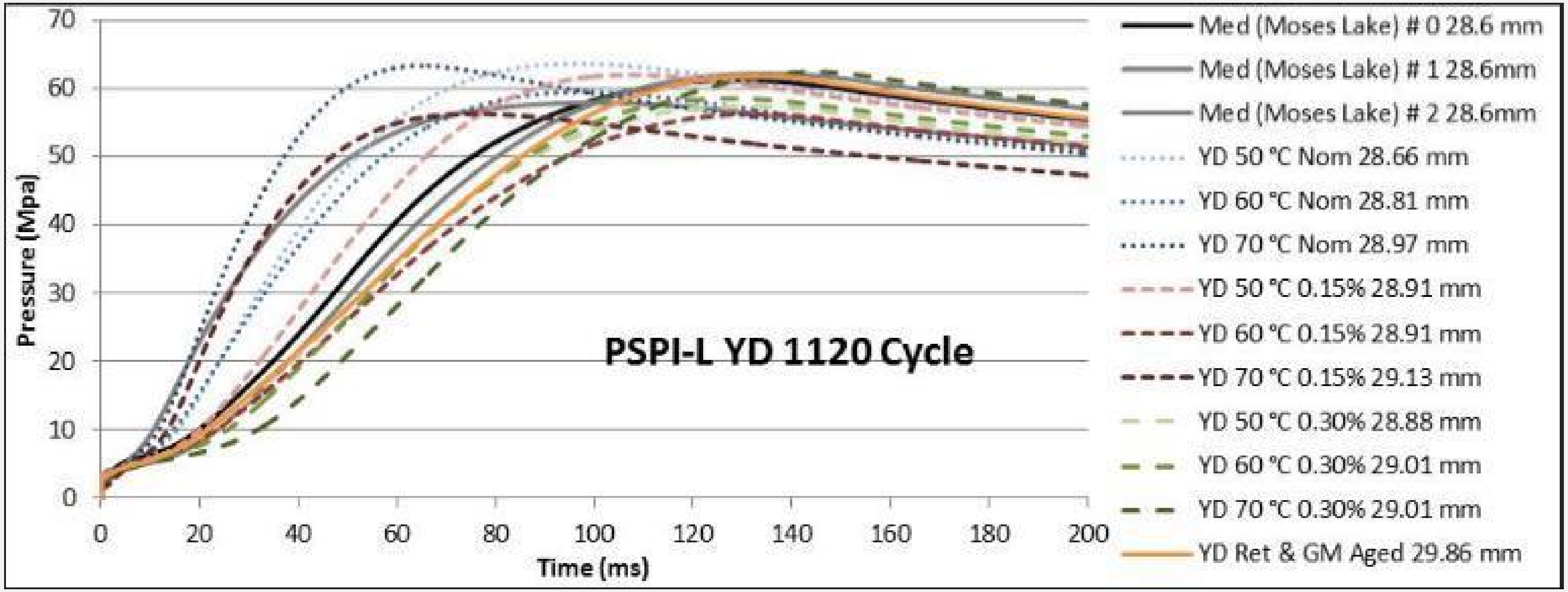
Discussion



Closed Bomb Burn Rate (1120)
SPI YP/PSPI-L YD

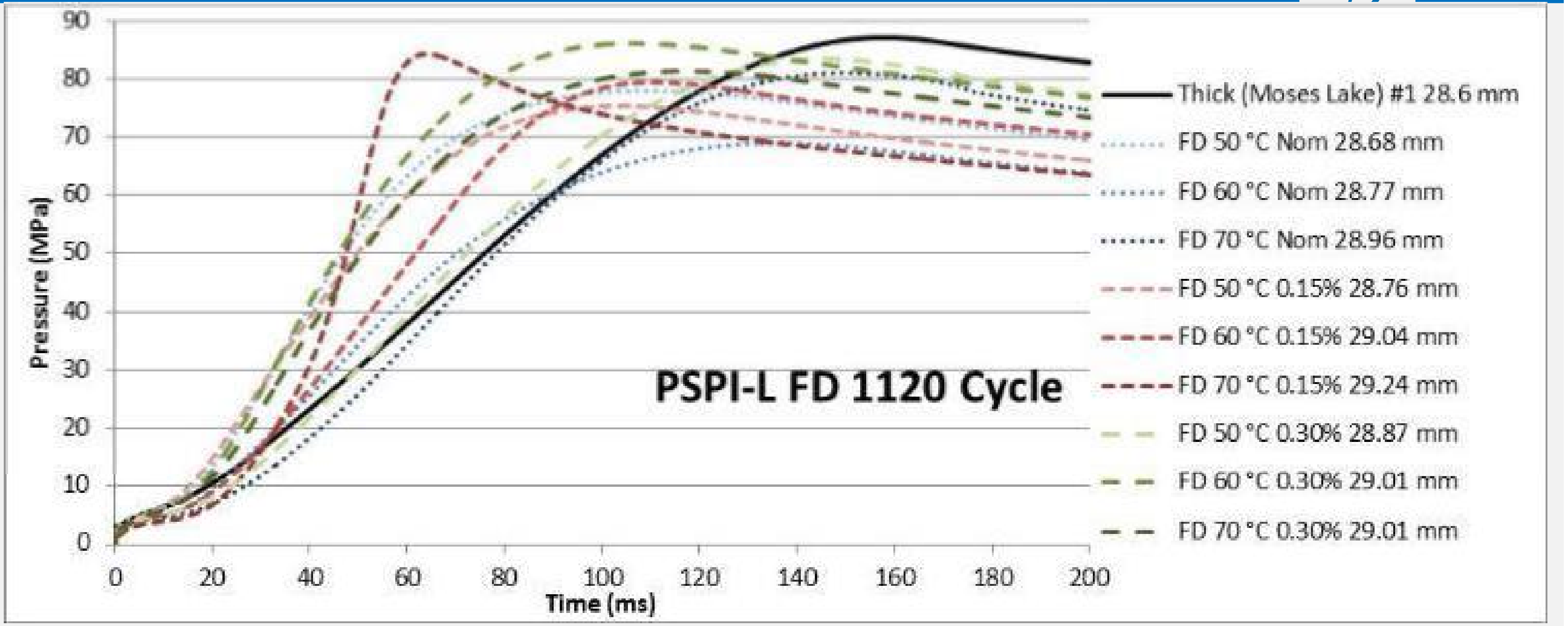
- For YP, some of the fastest rise times are from inflators with 0.30% H_2O
- For YD, the opposite is true
- YP high moisture wafers have significantly higher diameters

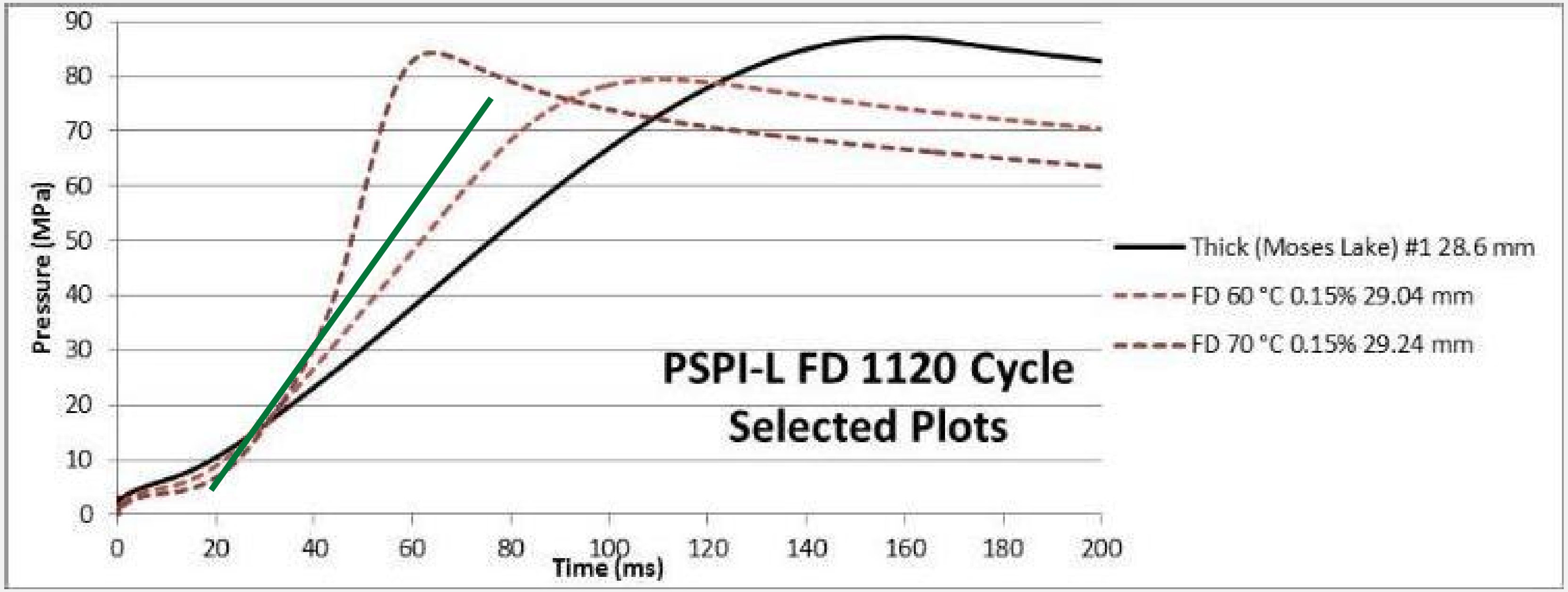




Closed Bomb Burn Rate (1120)
PSPI-L FD

- Some of the slowest rise times are for wafers with nominal moisture
- Fastest rise time is for the mid moisture, 20-70 C wafer
  - Its very fast rise time is due in part to a positive change in slope at about 30 Mpa
  - Green line on bottom plot added to show slope change

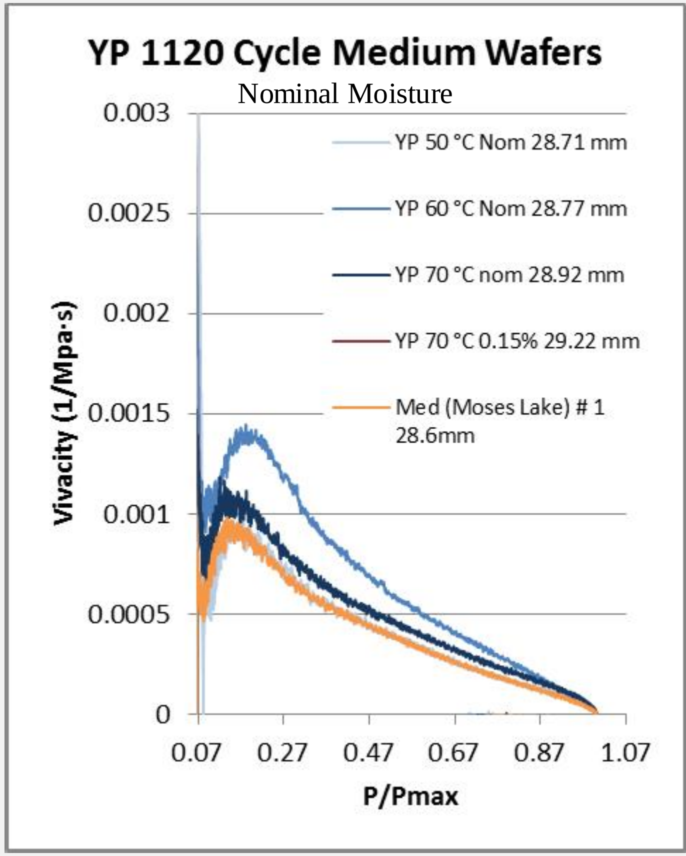


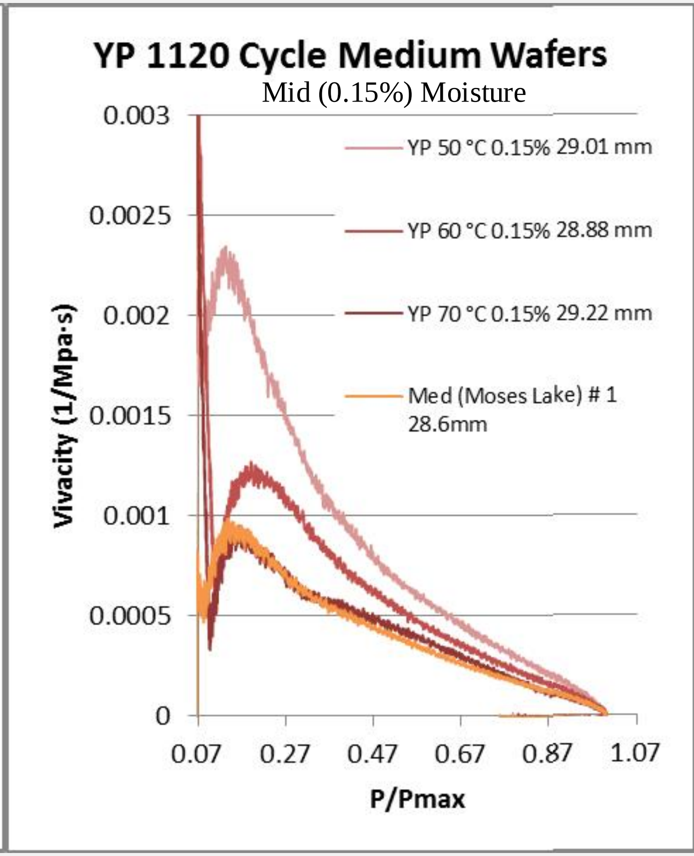


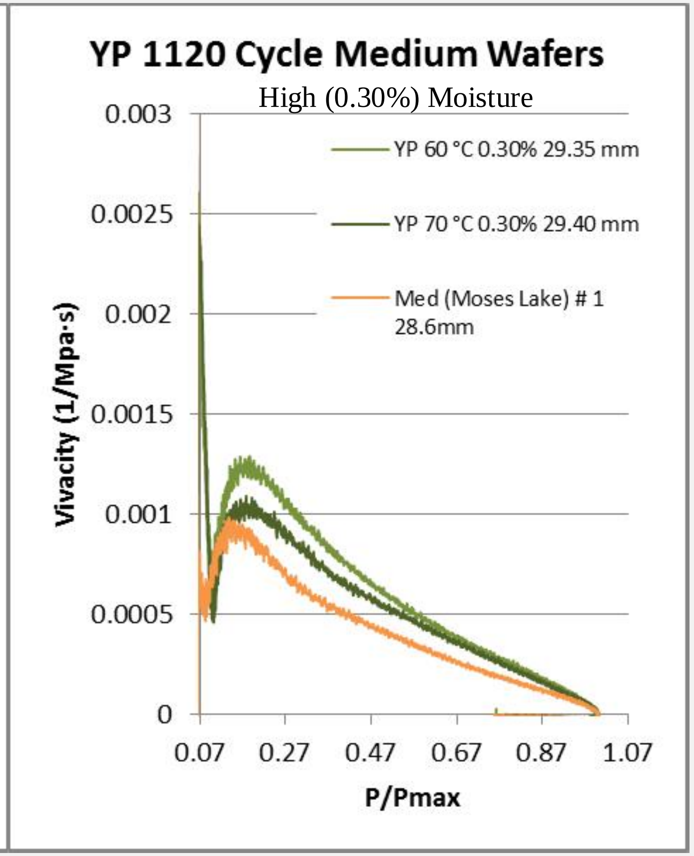
Closed Bomb Burn Rate (1120)

SPI YP Vivacity Plots

- Plots show changes in surface area as a function of the fraction of the total wafer burn
  - Highest surface area during the burn is due to combustion of granular B/KNO_3 igniter
    - 0.8 grams in the ignition closure and 0.5 grams in a cup underneath the wafer
  - Significant differences between tests in the first quarter of the total burn
    - Possible initial surface area differences: wafer surface pitting, break up of floating wafer
- Greatest deviations in mid moisture samples (center plot) followed by nominal moisture
- Samples cycled between 20-70C best mimic virgin wafer behavior
- Tests are slated on dried wafers from the mid and high moisture inflators



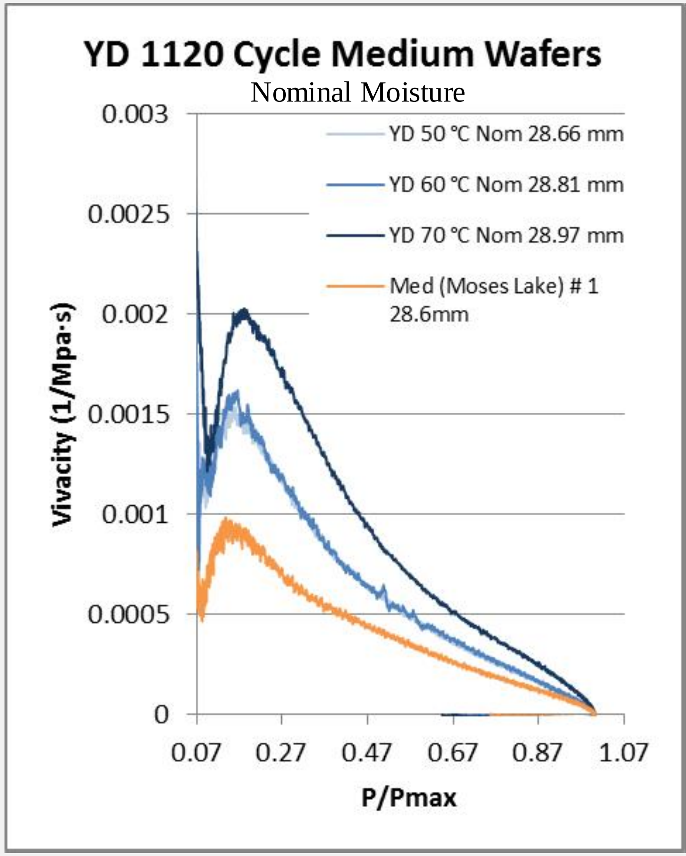


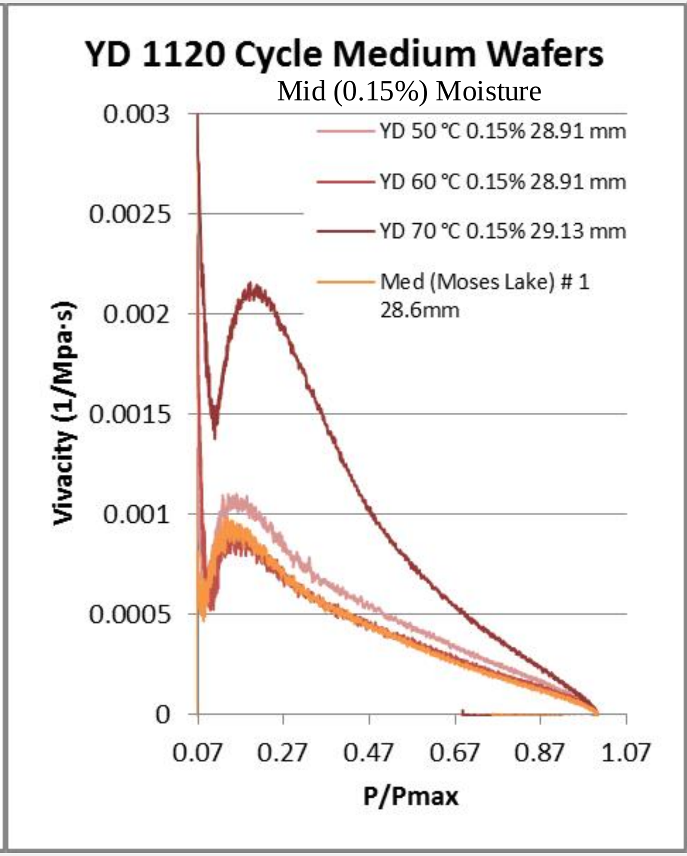


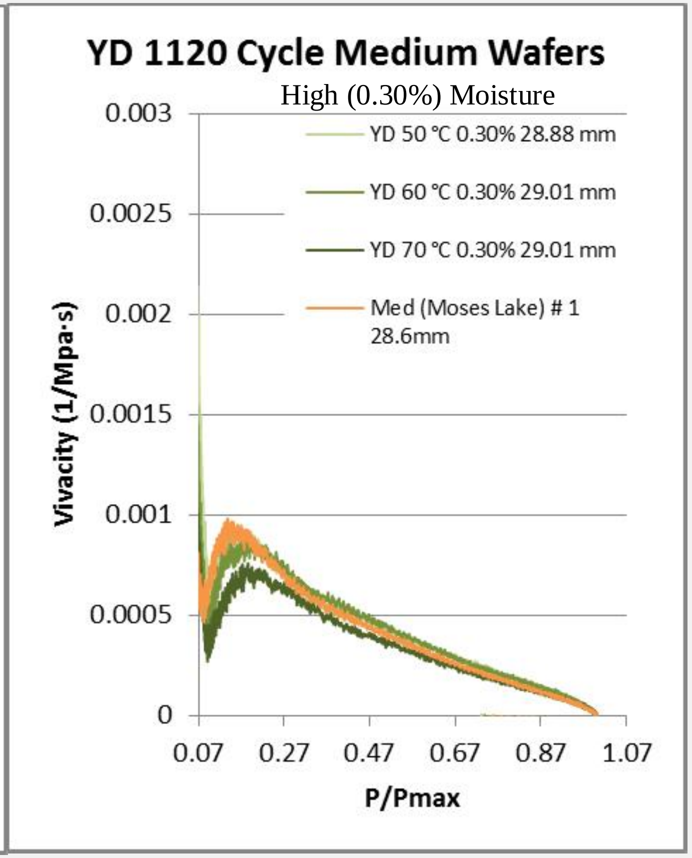
Closed Bomb Burn Rate (1120)

PSPI-L YD Vivacity Plots

- Greatest deviations from virgin vivacity at nominal and mid moistures
- As opposed to YP, wafers cycled 20-70 C have the largest deviations



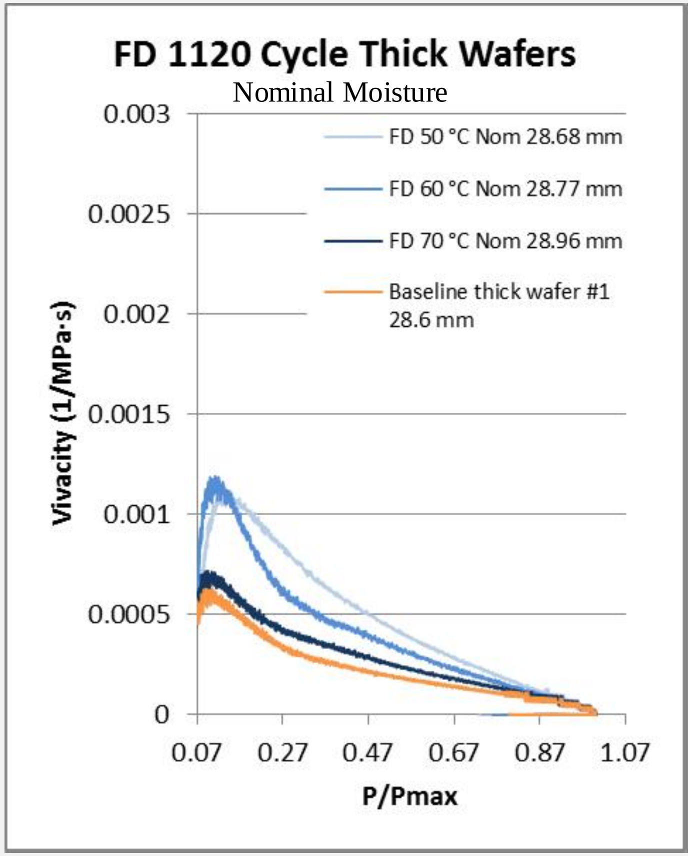


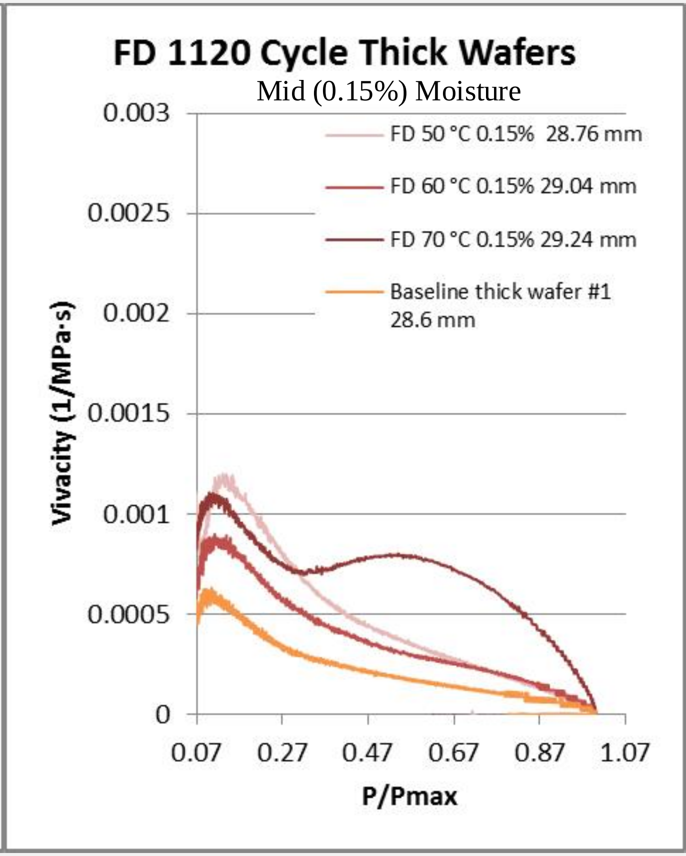


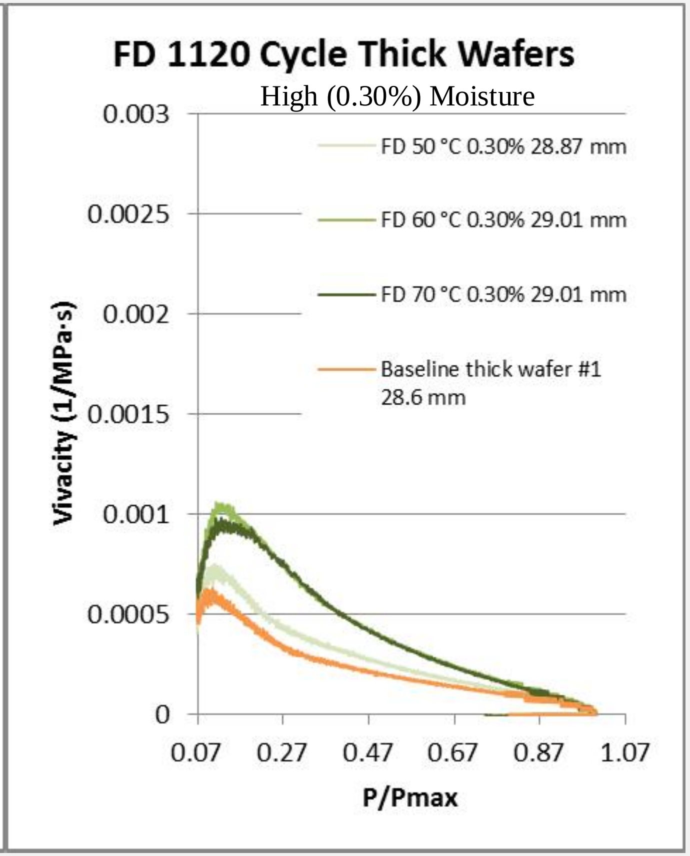
Closed Bomb Burn Rate (1120)

PSPI-L FD Vivacity Plots

- Virgin vivacity patterns for these thick wafers are slightly different than for the SPI YP and PSPI-L YD medium wafer counterparts
  - Peak in the early propellant base deviation occurs earlier in the burn, about 10-13% vs. 15-20% for medium wafers
  - Peak vivacities tend to be lower and more consistent
- An additional positive deviation in vivacity peaks at 55% of burn completion for the 0.15% moisture, 20-70 C test.
  - Corresponds to a deflection in the P vs. T trace
  - This is the inflator type that exhibited the ED and near ED in inflator tank tests
  - The vivacity of the 0.15% moisture 20-60 C test almost plateaus in the same burn regime

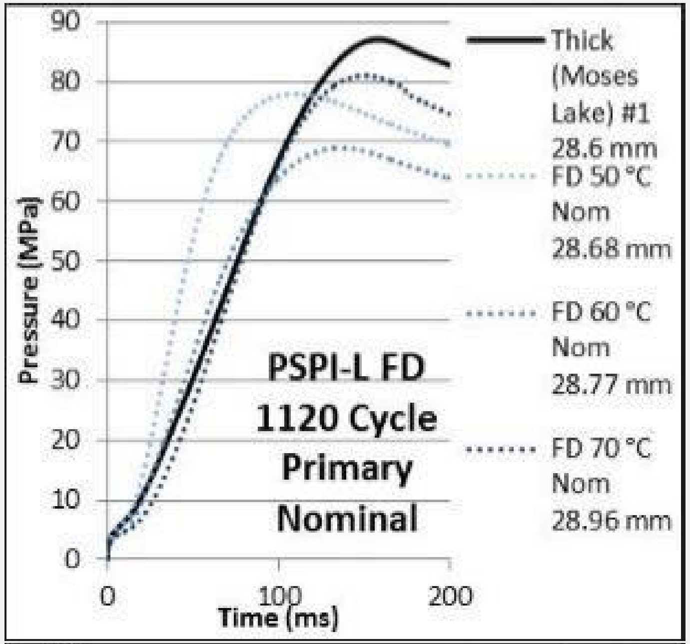


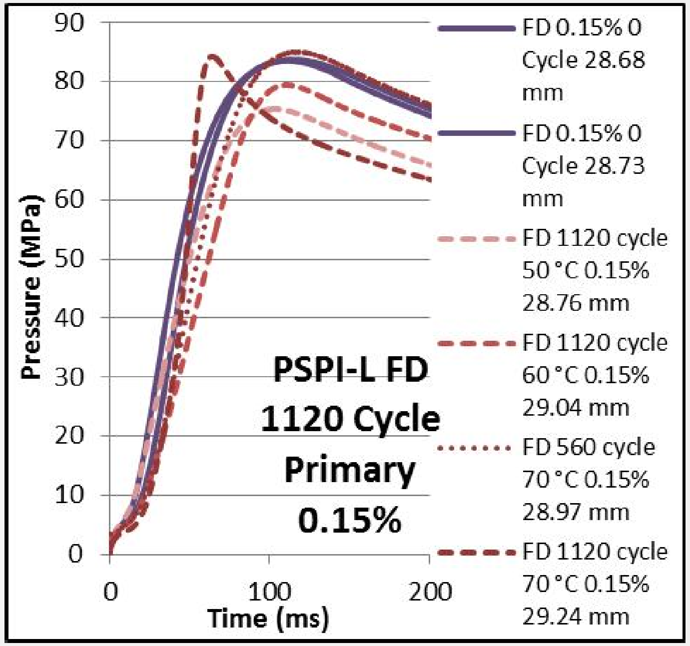


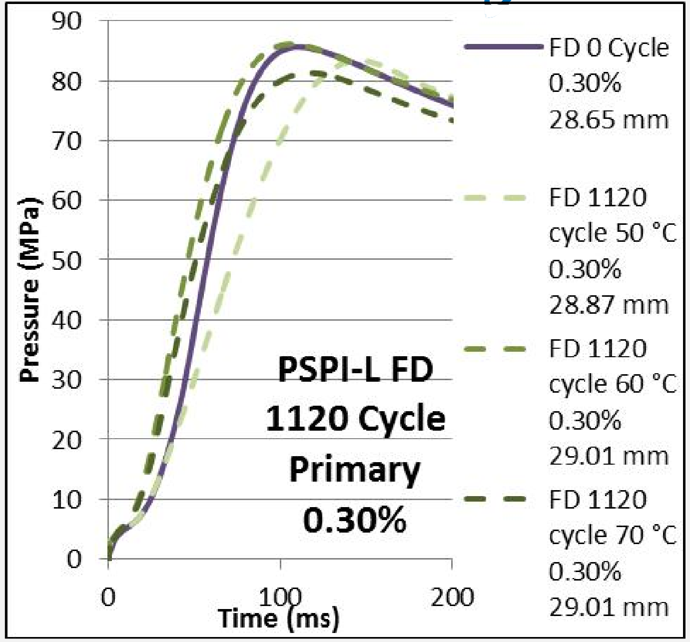


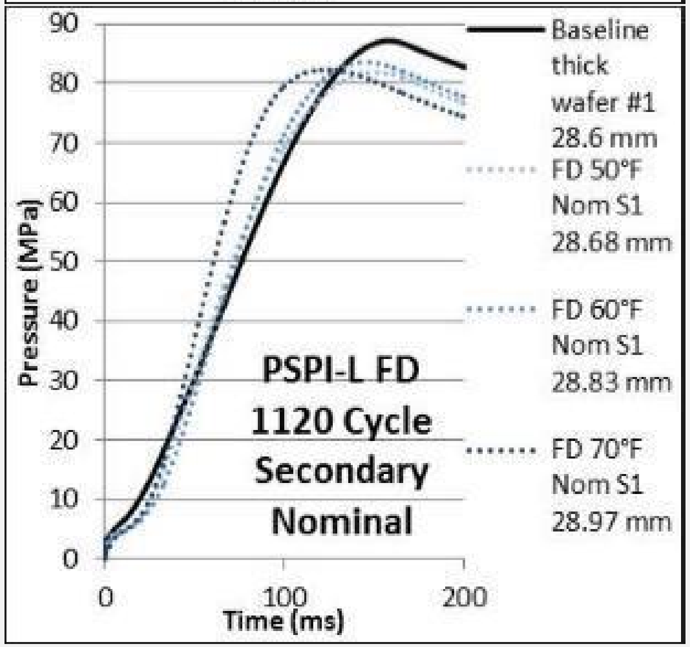
Closed Bomb Burn Rate (1120)

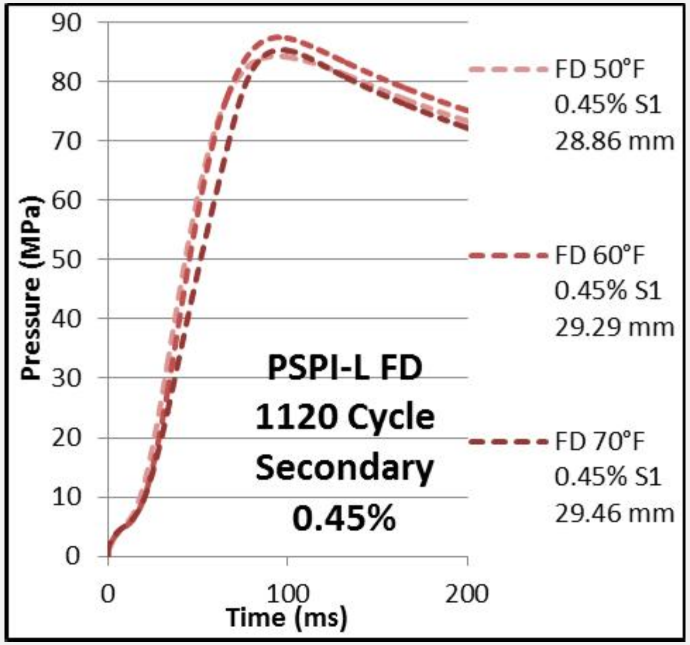
FD Pressure vs. Time Traces

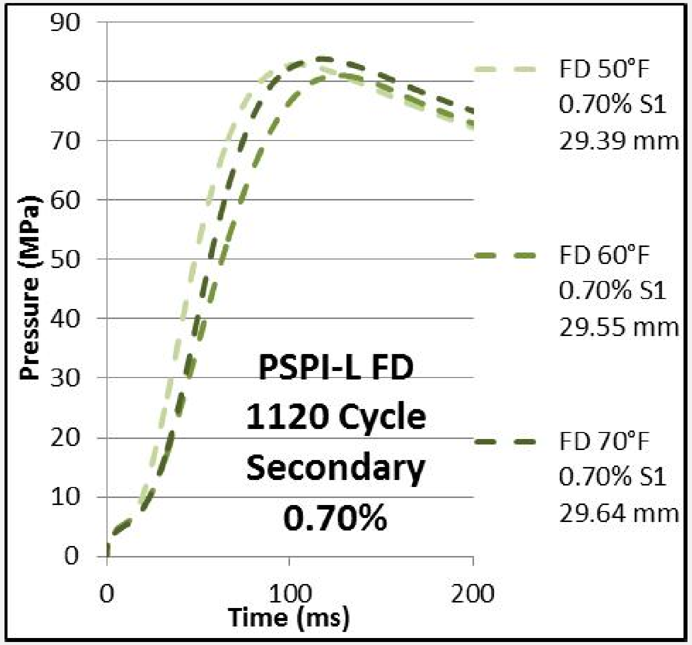




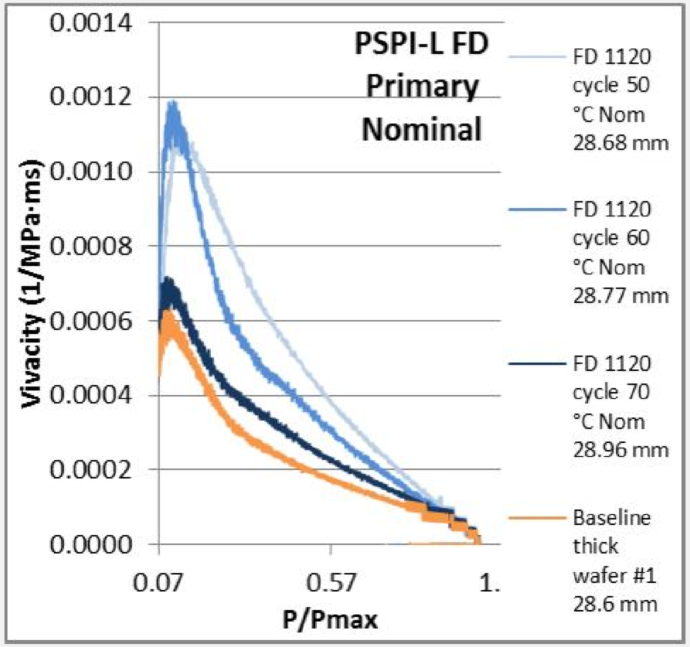


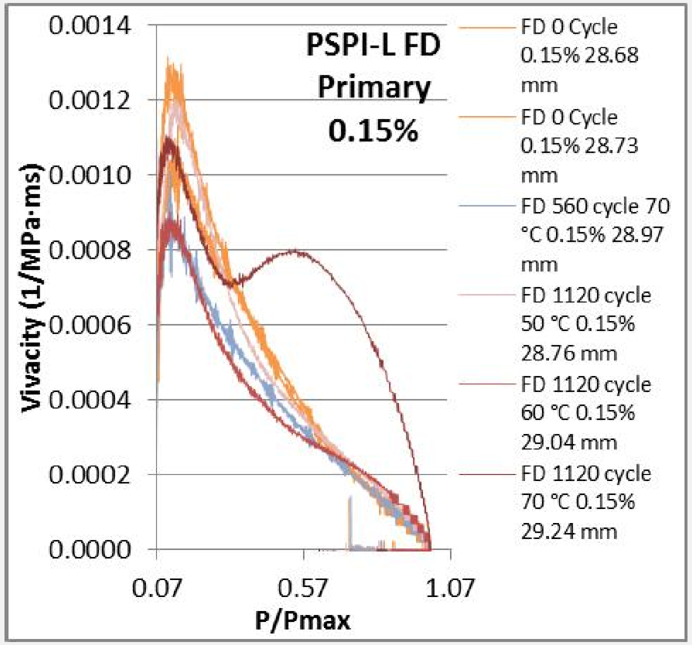


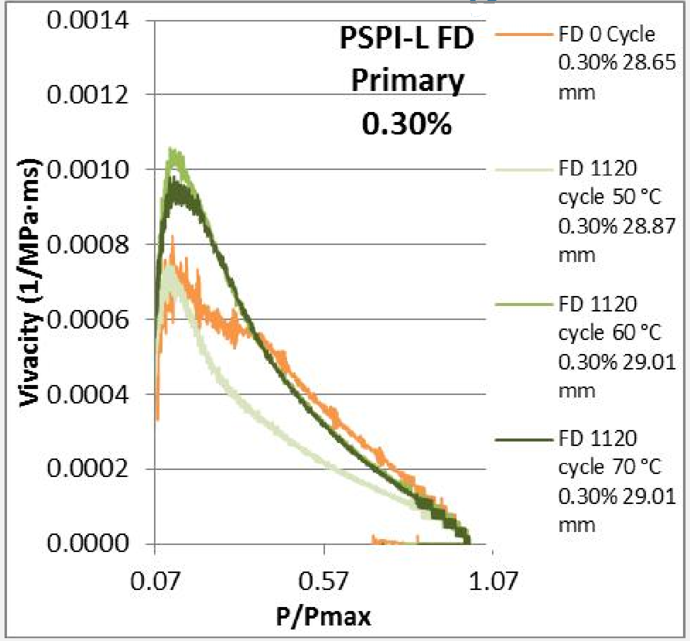


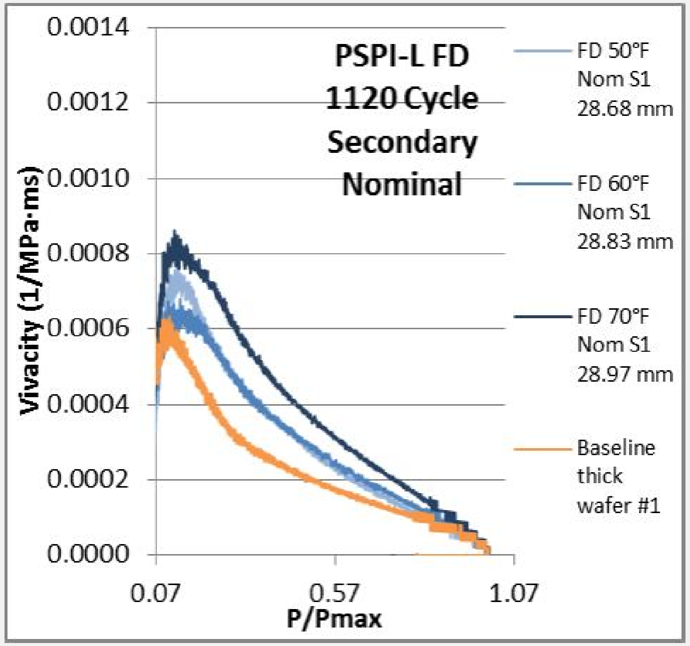


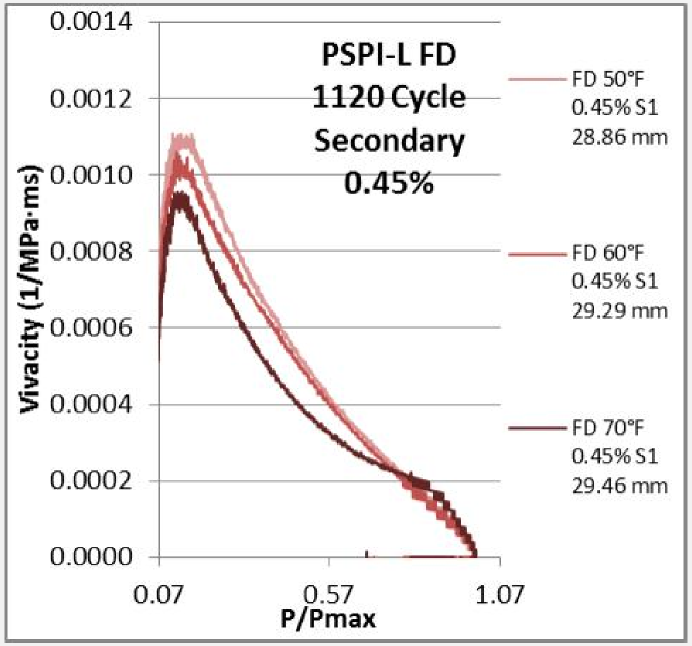
Closed Bomb Burn Rate (1120)
FD Vivacity Plots

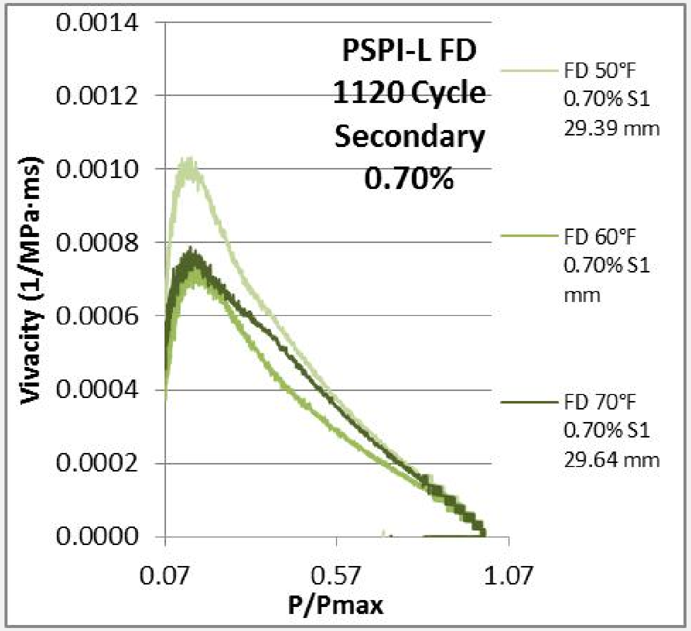








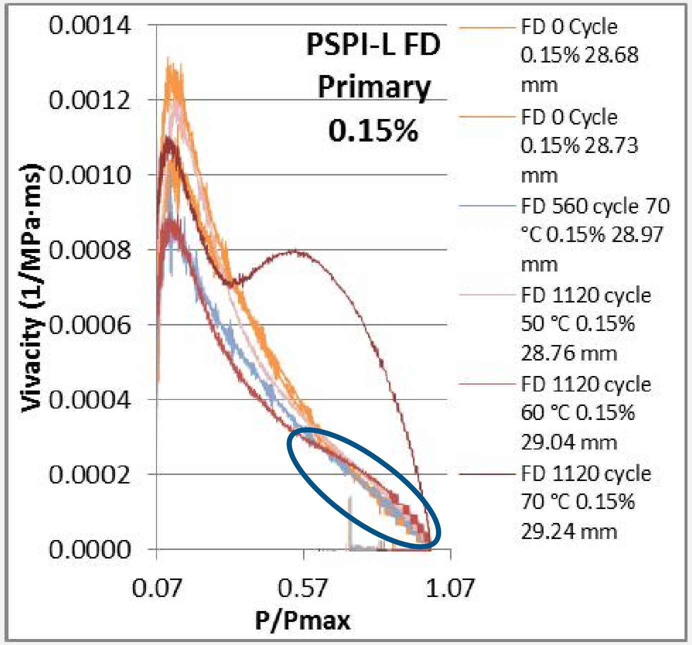


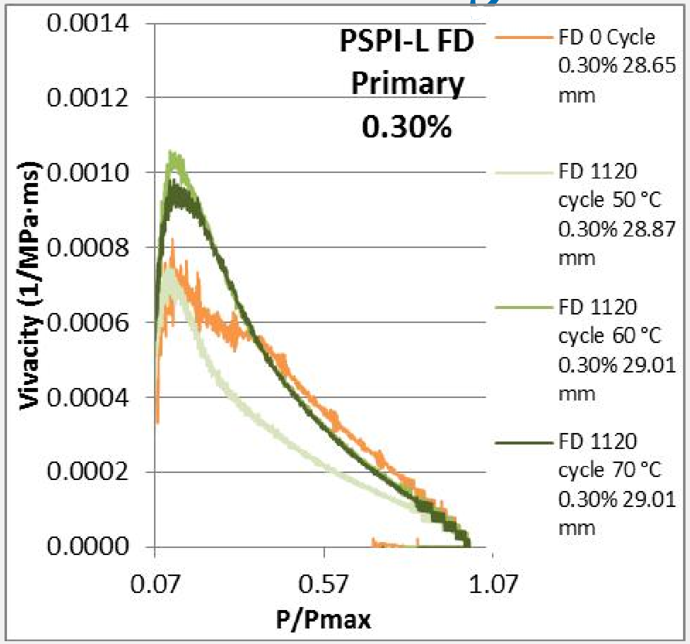


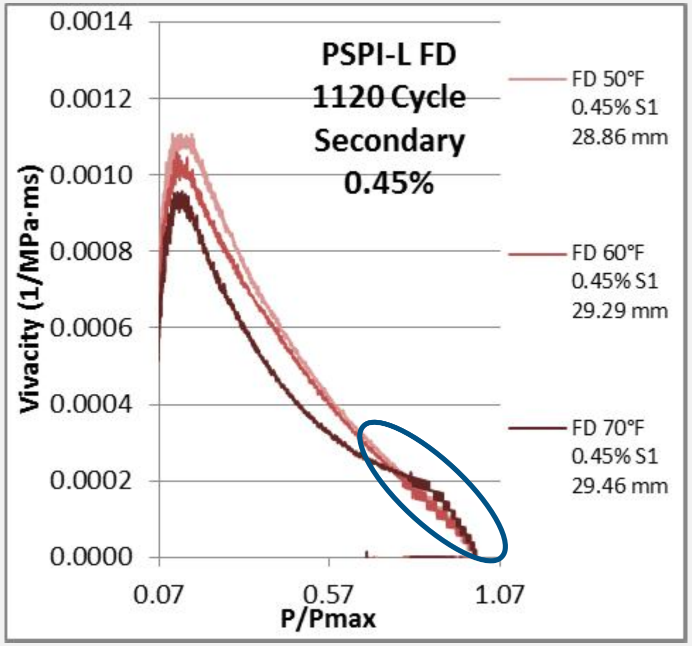
Closed Bomb Burn Rate (1120)

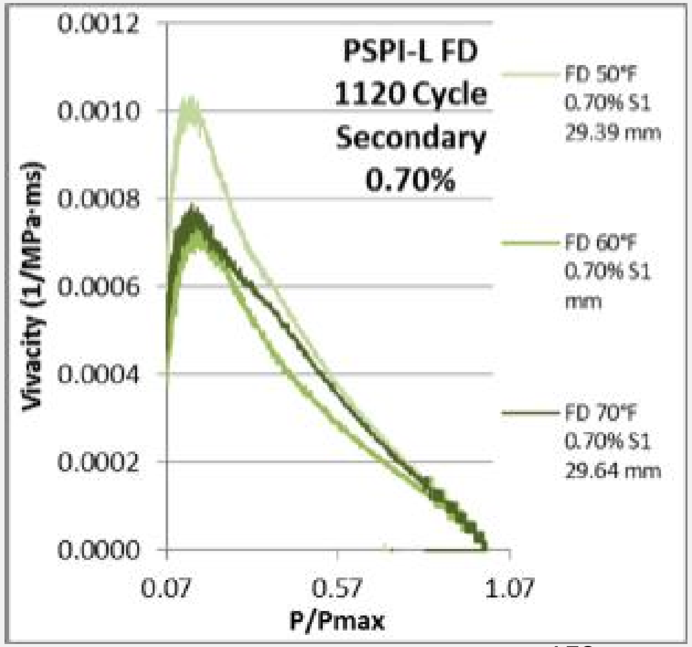
FD Vivacity Plots

- Obvious abnormal burn behavior for primary, 1120 cycle 0.15%, 20-70 C.
- Hints of abnormal behavior for other higher temperature and moisture aging conditions
  - Primary, 1120 cycle 0.15%, 20-60 C
  - Secondary, 1120 cycle 0.45%, 20-70 C
- The vivacity plot for 560 cycle 0.15%, 20-70 C (blue trace) is normal







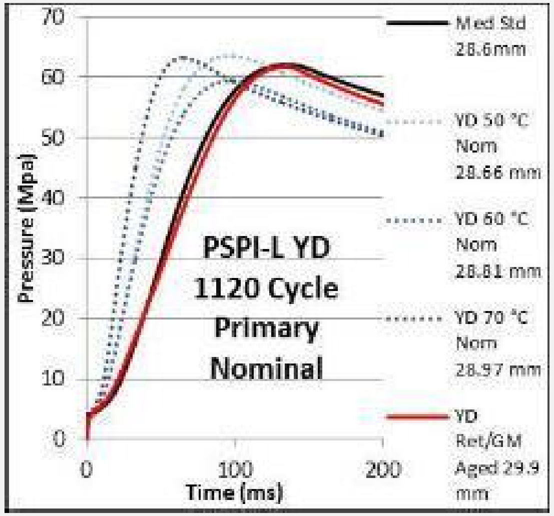


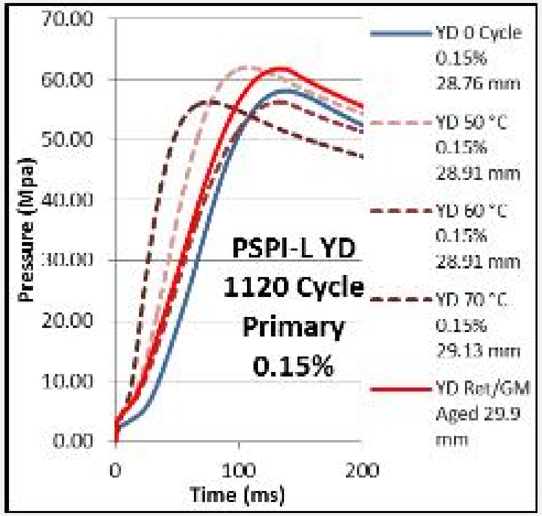
Closed Bomb Burn Rate (1120)

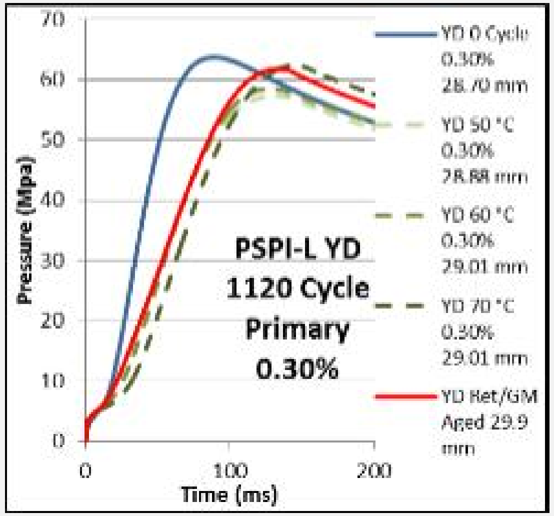
YD Pressure vs. Time Traces

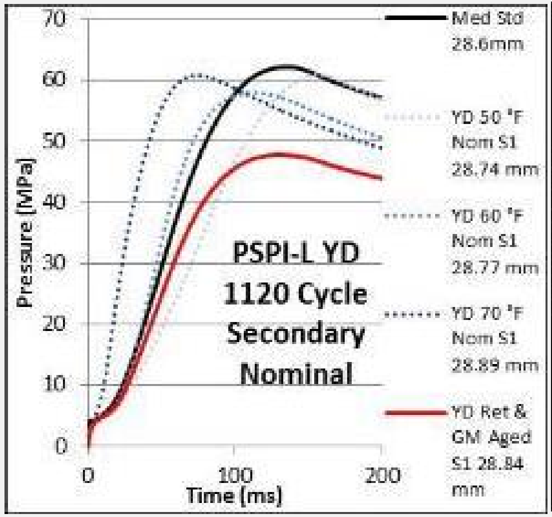
- Rise rates are typically fastest for nominal and mid moistures at 20-70 C
  - ➢ All three cycle temperatures for secondary, 0.45% moisture are fast
- Rise times, both primary and secondary, for “Returned & GM Aged” wafers are on the slow end of tests thus far

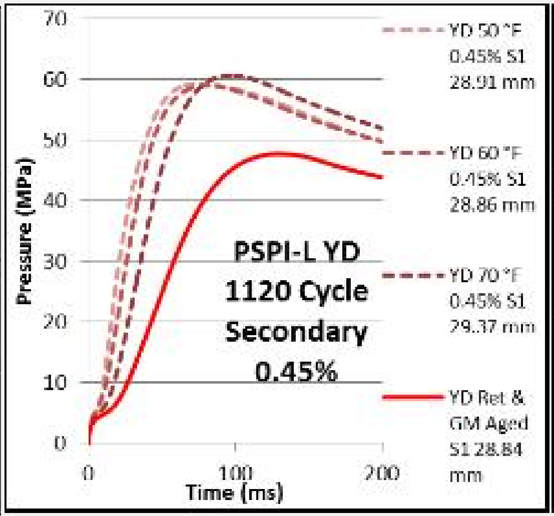
- Low maximum pressures may be due to lack of grease protecting the transducer from thermal shock
  - ➢ Secondary “Returned and GM Aged”
  - ➢ Secondary 0.70% moisture tests

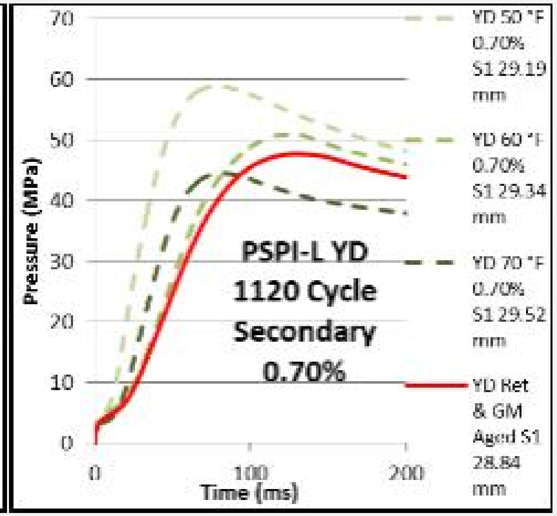








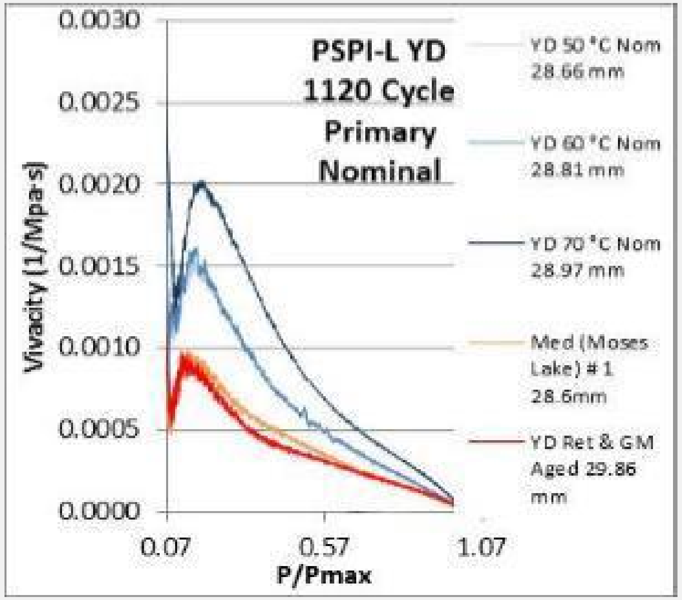


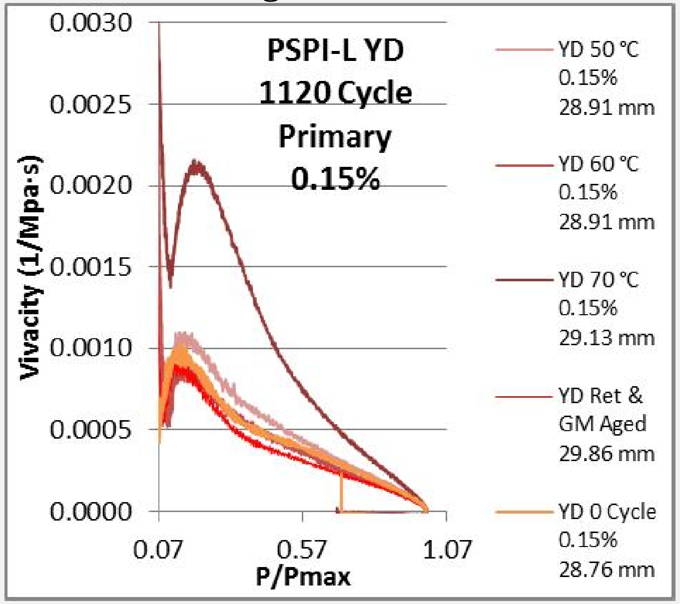


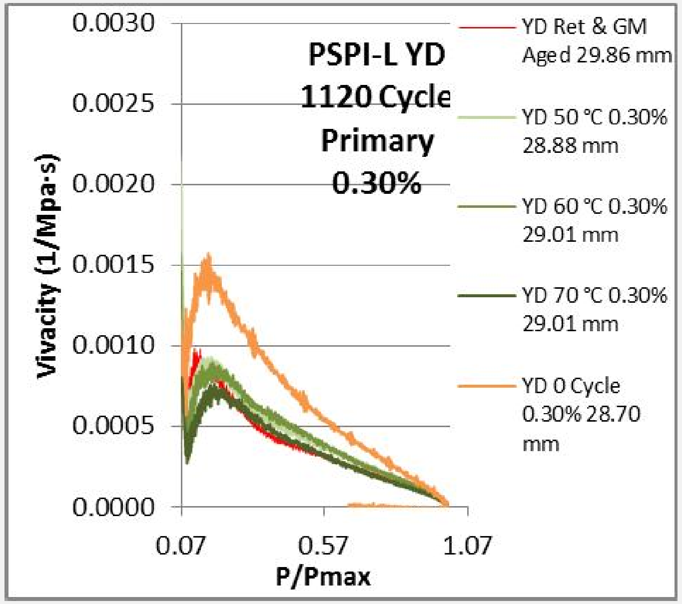
Closed Bomb Burn Rate (1120)

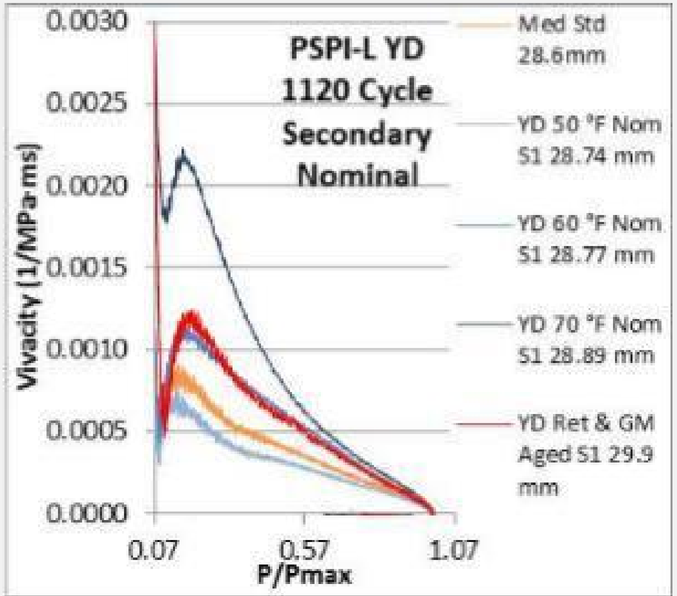
YD Vivacity Plots

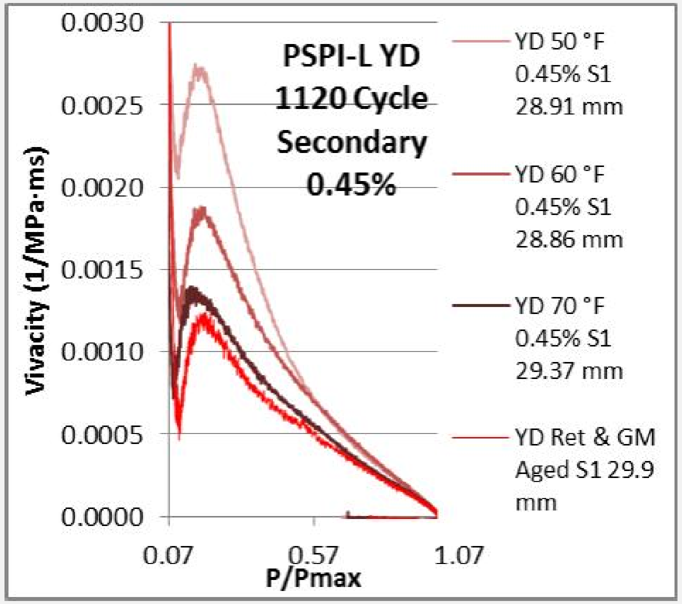
- No hint of abnormal burn behavior is observed for these medium wafers
  - Hints were observed for thick HAH wafers aged under the same conditions

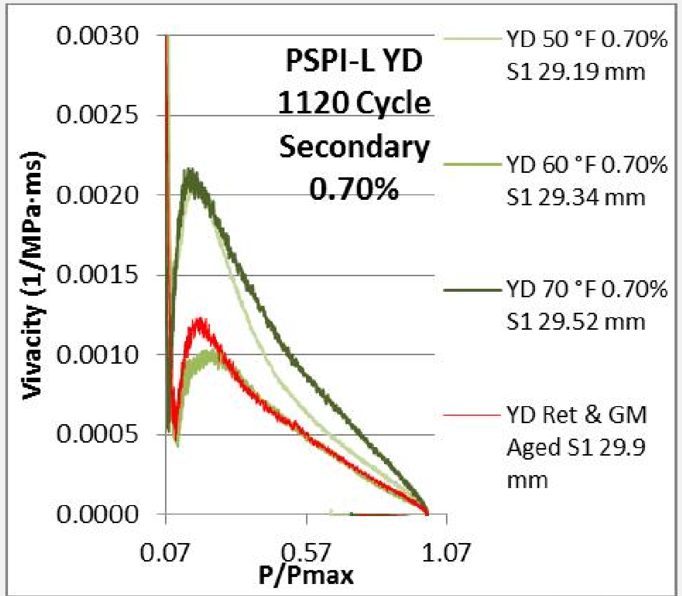








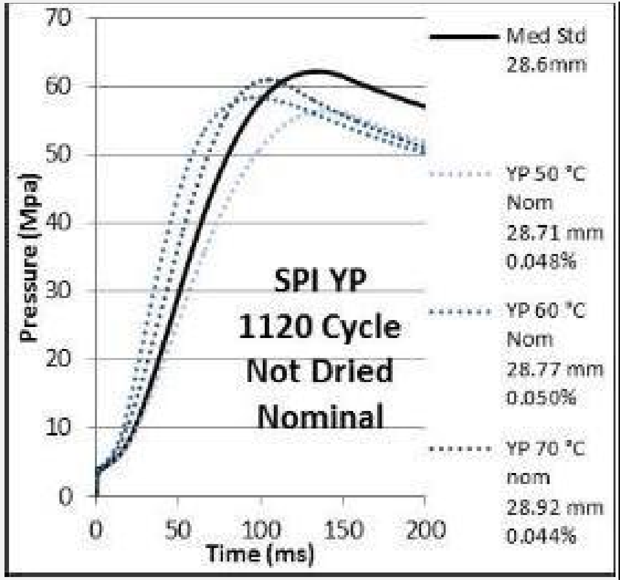


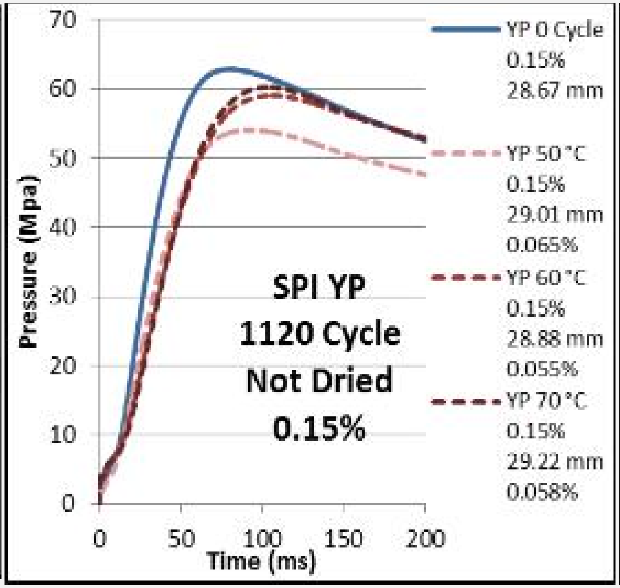


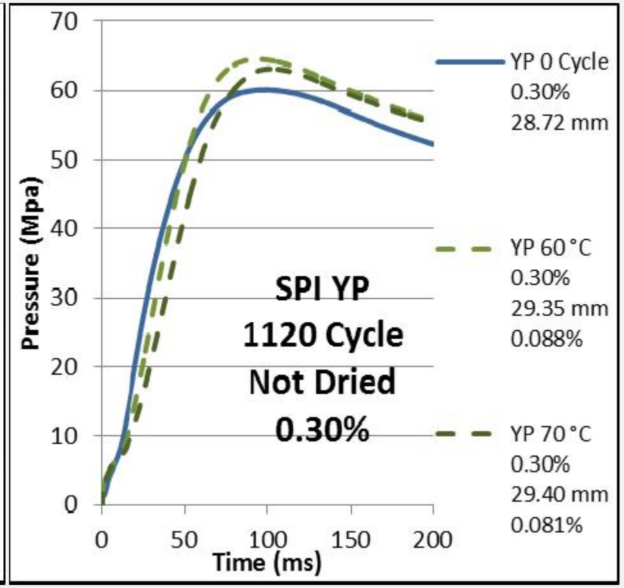
Closed Bomb Burn Rate (1120)

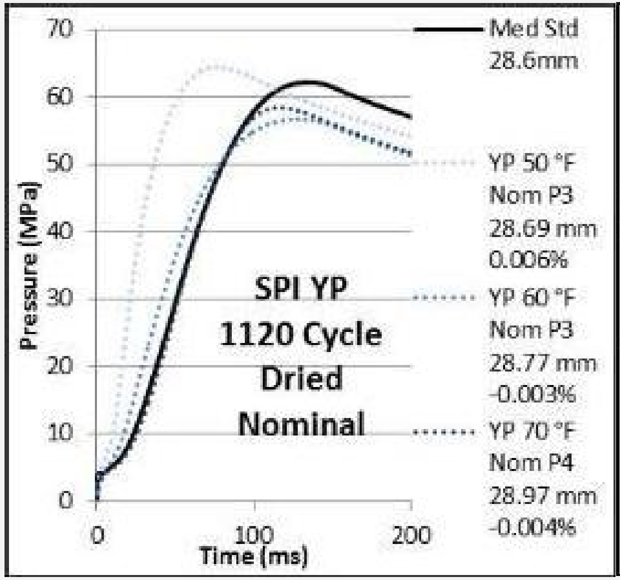
YP Pressure vs. Time Traces-As Received vs. Dried

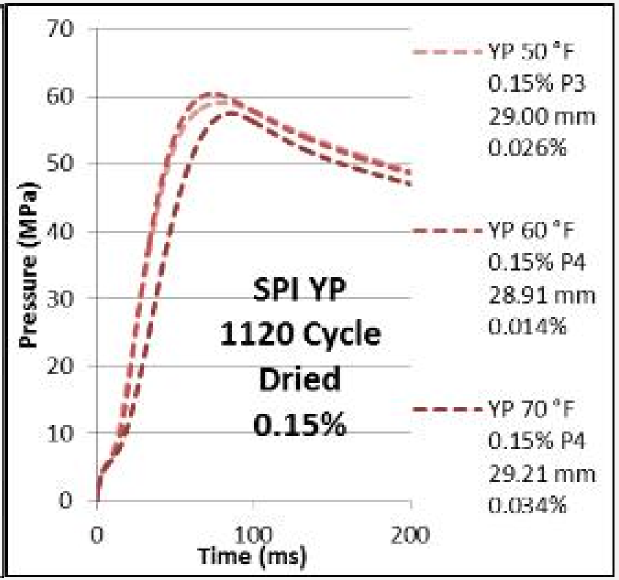
- No consistent changes in rise rate with drying except mid moisture
  - **Wet: 1.00 ± 0.04 MPa/msec   Dried: 1.33 ± 0.21 MPa/msec**

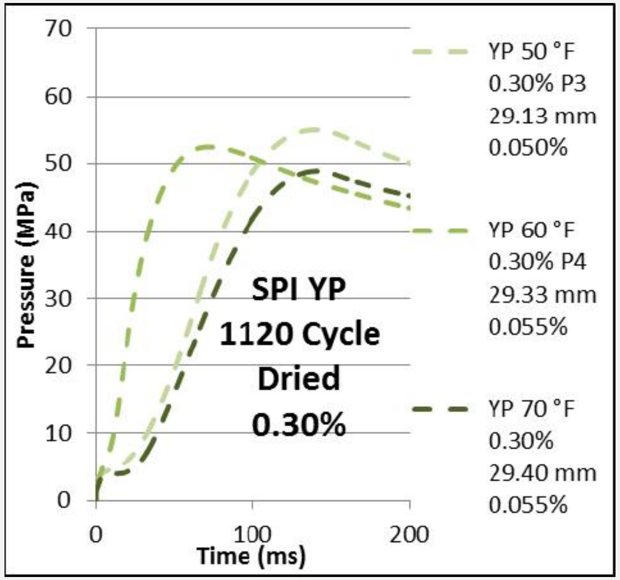










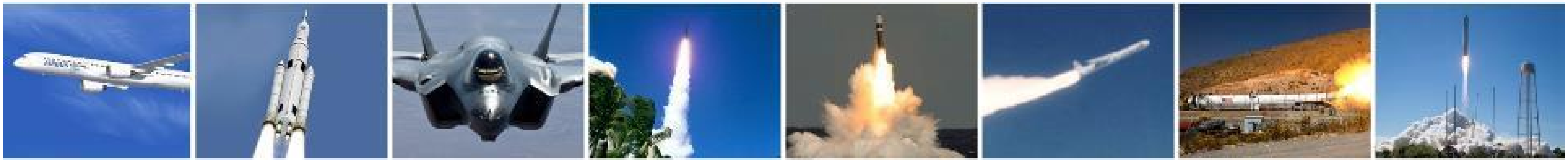


Low maximum pressures for Secondary 0.70% tests may be due to lack of grease protecting the transducer from thermal shock

Closed Bomb Burn Rate (1120)
Vivacity Plot Summary

- Vivacity peaks in the range of 10-20% of total burn
  - High moisture and PSPI-L FD tests tend to deviate less from baseline
    - This may suggest deviations are due to ignition promoted wafer breakup
      - Medium wafers tend to fracture more readily
      - Wafers with higher moisture are less brittle
  - No obvious trend relative to maximum cycling temperature
- Changes in slope near mid burn appear to be more indicative of the wafer condition that caused inflator ED
  - This propensity was very obvious for PSPI-L FD with 0.15% moisture after 1120 cycles from 20-70 C.
    - SEM and micro CT data should be taken on wafers from the same inflator
  - A subtle indication of this behavior observed for the 20-60 C sample.
- Will continue analysis
  - Start SPI tests on dried wafers
  - Start PSPI-L FD and PSPI-L YD secondary wafer tests

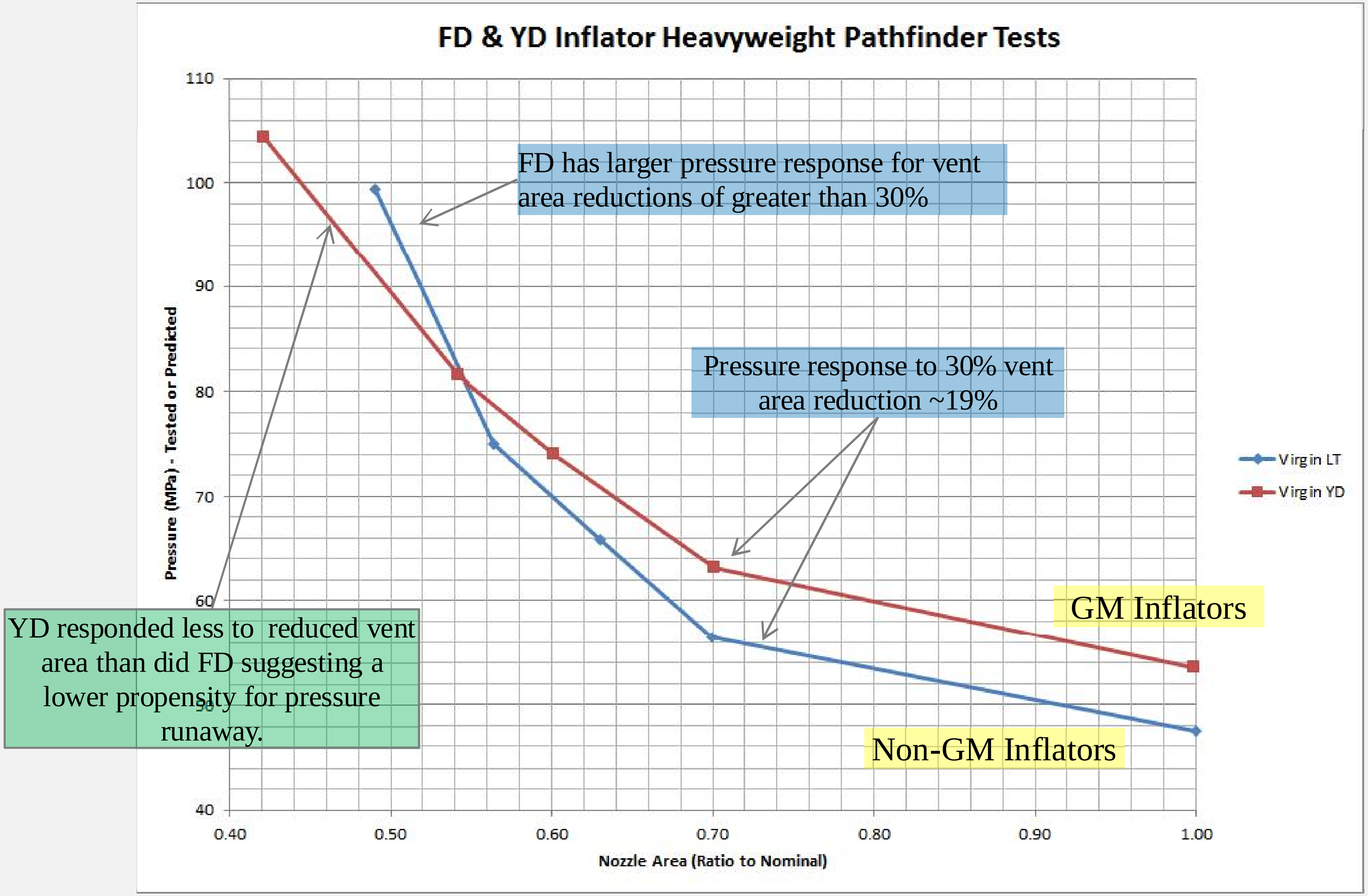
Heavy Weight Testing and Ballistic Modeling



Heavy Weight Vent Area DOE Construction

- A multi-factor full DOE matrix was constructed examining PSPI-L FD and YD inflators of various ages and wafer sizes
  - PSPI-L YD (GM) inflators consisted of two groups:
    - Virgin
    - 8 year old field returns with mid size OD wafers
  - PSPI-L FD (non-GM) inflators consisted of three groups:
    - Virgin
    - 13 year old field returns with mid size OD wafers (match YD, 28.3-28.8 mm)
    - 13 year old field returns with large OD wafers (29.1mm +/- 0.1 mm)
- The DOE was designed to fire these inflators in heavyweight hardware utilizing various vent sizes to artificially increase combustion pressure
  - Five vent sizes were varied from nominal for each inflator type and then reduced to provide a range of pressure up to ~100 MPa (this is greater than the inflator design)
  - Fifty-five inflators were fired in the DOE matrix
- The purpose of the DOE was to determine the response of each type of inflator type to both wafer size and combustion pressure
  - Can inflators be pushed into ED behavior with high pressure?
  - Is there a threshold response to wafer size or a gradual behavior change?

Vent Area DOE Virgin Heavy Weight Data

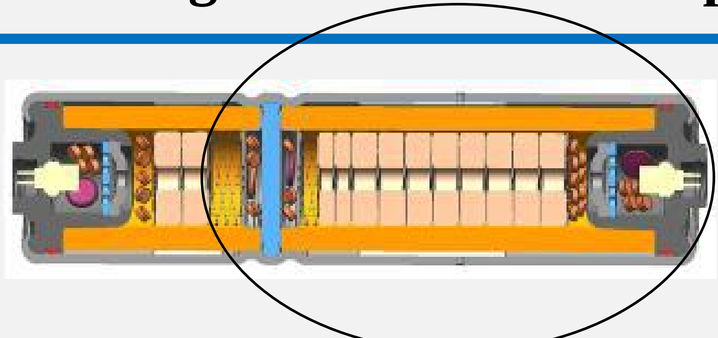


Vent Area DOE Summary and Observations

- FD and YD inflators show statistically difference response to nozzle area reduction testing
  - ➢ The pressure response to nozzle area reduction is lower than initial modeling predictions for both FD and YD inflators
  - ➢ FD inflators have a much higher pressure response above 30% nozzle area reduction
  - ➢ YD inflator has lower response showing lesser tendency towards pressure run away
  - ➢ Inflator responses to pressure change is extremely important in determining runaway scenarios
- ED's have only occurred for wafer OD > ~28.95 mm even when combustion pressures are pushed to high levels, no YD tests went to ED
  - Consistent with other measurements that wafers must grow to a threshold size
  - The wafer OD thresholds for ED do tend to decrease as nozzle areas are reduced
- Data validates information from field return data on threshold wafer diameter for ED

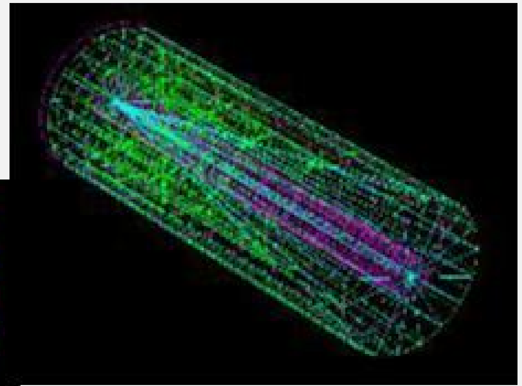
Modeling to Compare to DOE Experiments:
Surface Regression Model Comparison

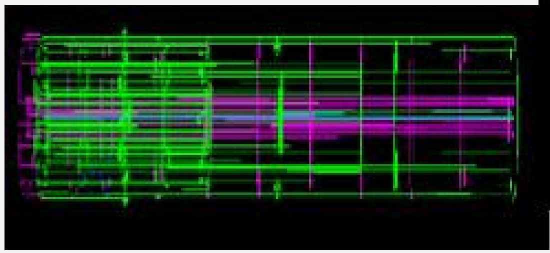
YD



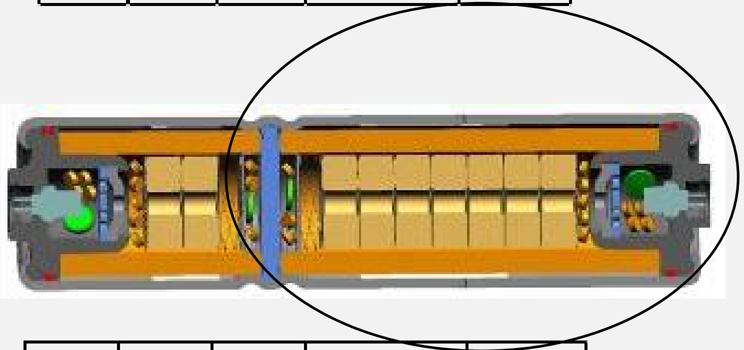
YD	Primary			
Thickness	Wafers	Breakup		
8.4 mm	8	wafers	pieces per wafer	total pieces
		2	72	144
		3	36	108
		3	18	54
5.36 mm	2	2	72	144
			Total	450

10 thinner wafers
18 radial breaks
Multiple circumferential



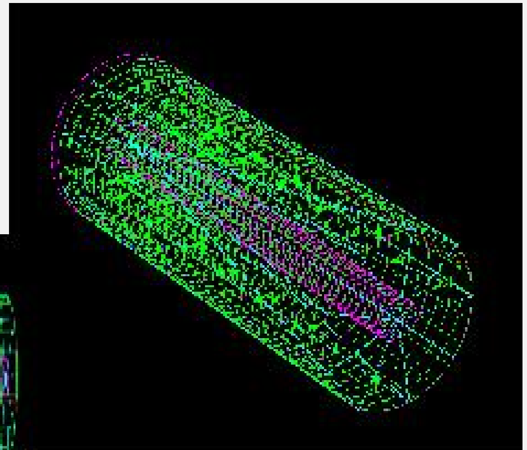


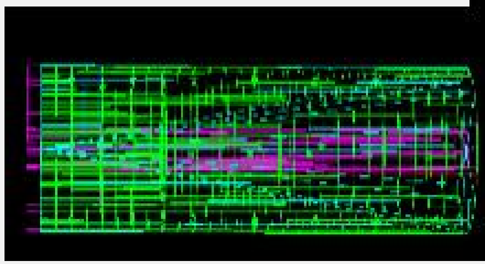
FD



FD	Primary			
Thickness	Wafers	Breakup		
11 mm	7	wafers	pieces per wafer	total pieces
		2	36	72
		2	18	36
		3	9	27
			Total	135

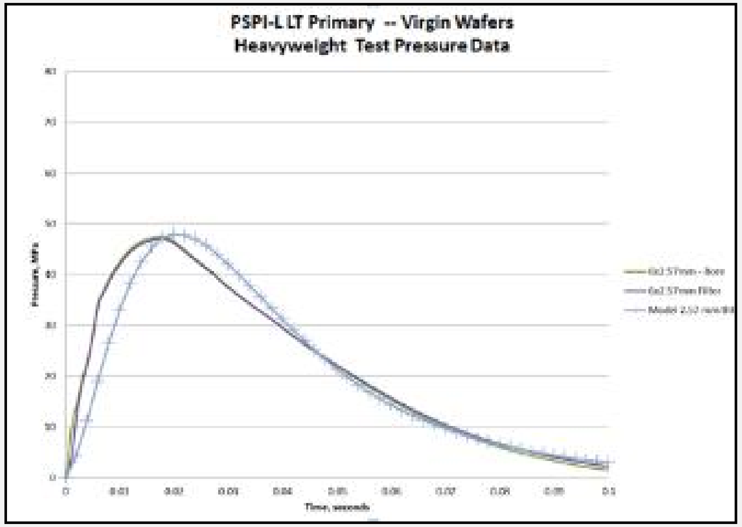
7 thicker wafers
9 radial breaks
Multiple circumferential

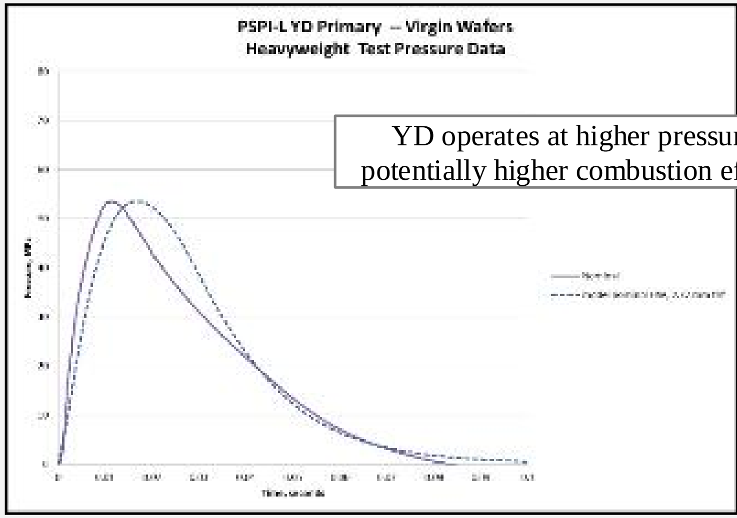




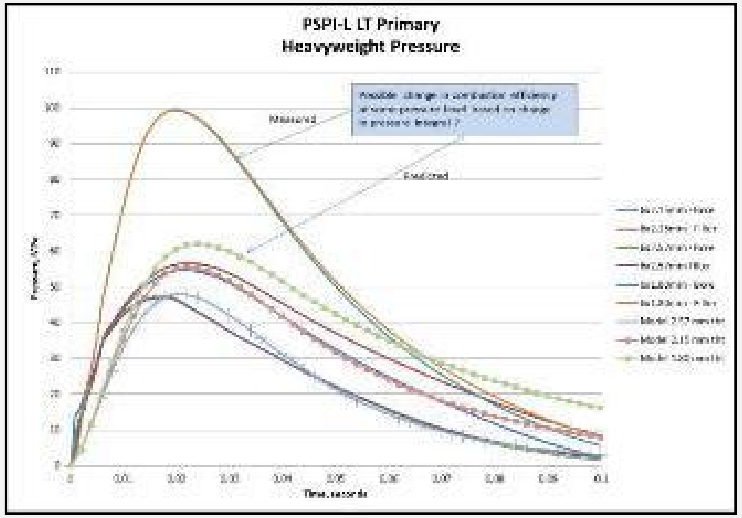
- Ballistic modeling investigated the PSPI-L FD (LT) and PSPI-L YD inflator configurations
  - 3D propellant surface regression and ballistic performance models were developed for each configuration
  - The models were anchored to measured test data for each configuration collected as part of the heavyweight testing effort.
- Initial observation:
  - The YD configuration requires greater breakup of the wafers than the FD configuration to create the best match to the measured data.

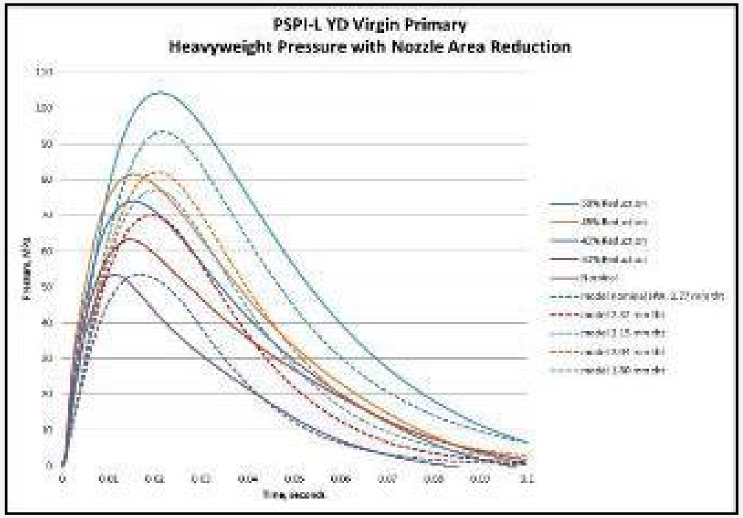
Ballistics Models for FD/LT and YD





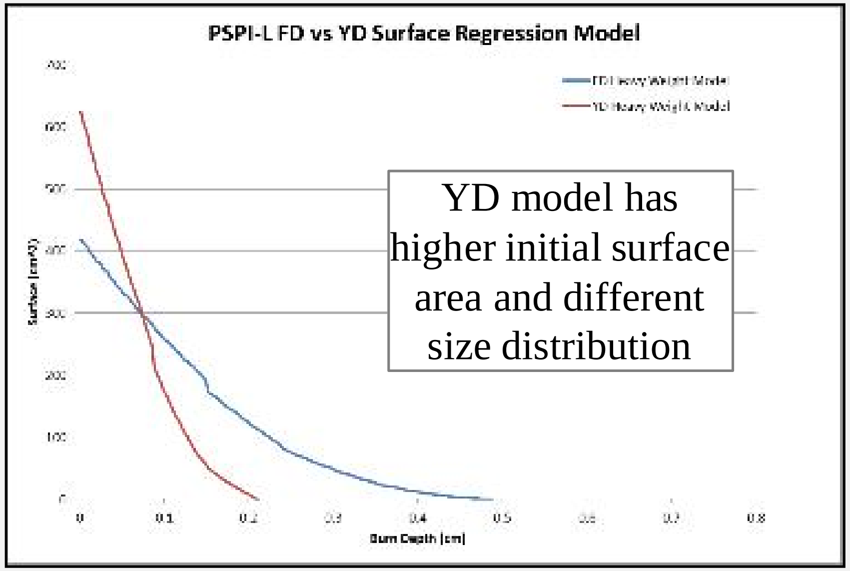
YD operates at higher pressure and potentially higher combustion efficiency



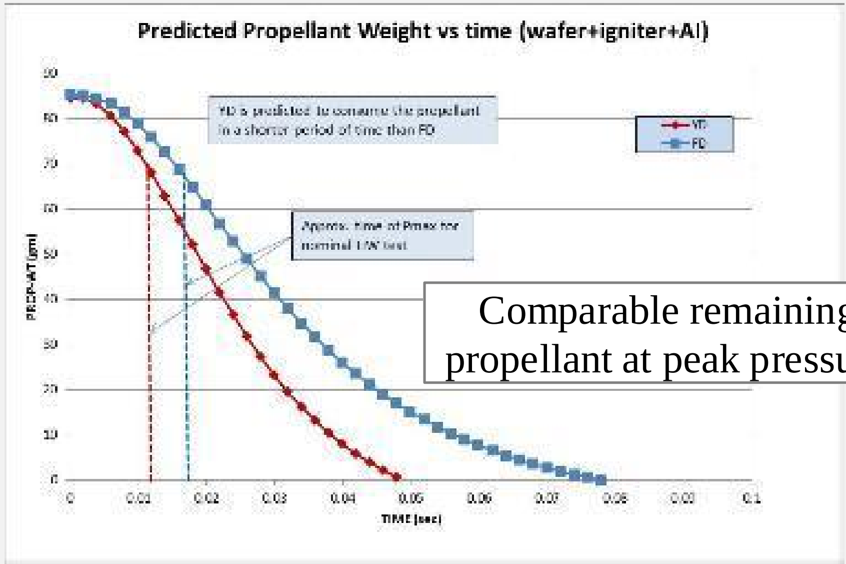


- The YD configuration is designed to operate at a somewhat higher pressure level than the FD configuration. This may have some significance if the combustion efficiency of the propellant is a function of pressure.
- This is supported by the observed pressure responses of the YD vs FD configurations tested in the heavyweight test apparatus with varying vent areas. Varying the vent areas was done to drive increases in pressure level.

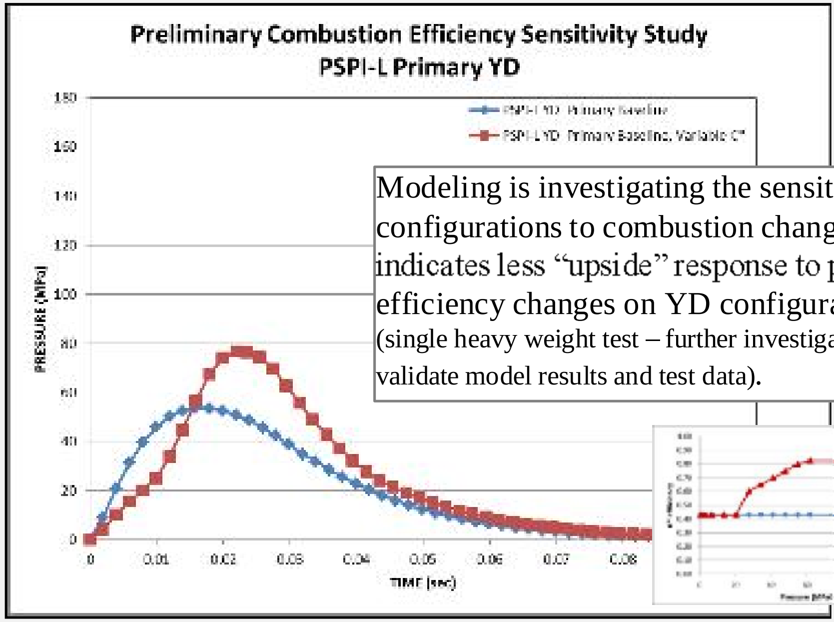
FD/LT Appears More Sensitive to Vent Area Change



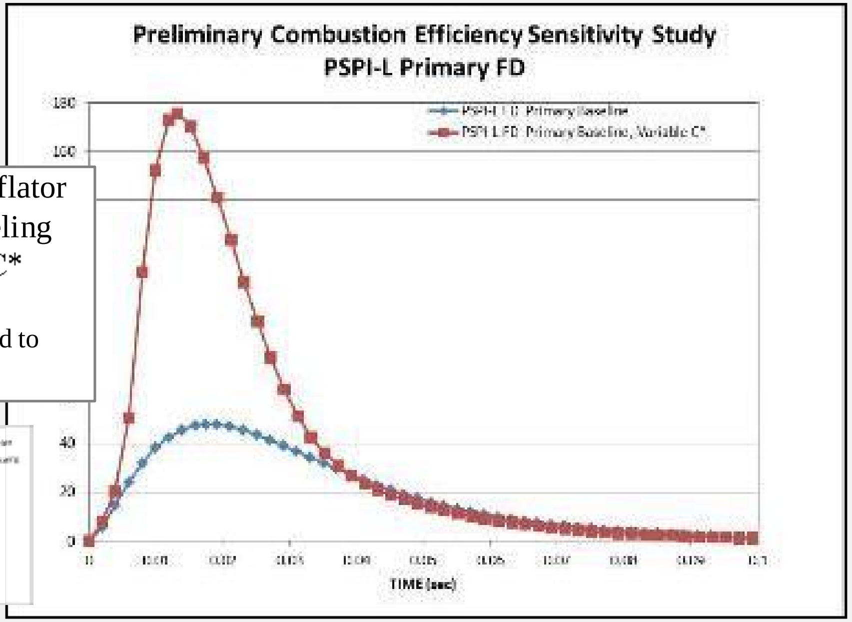
YD model has higher initial surface area and different size distribution



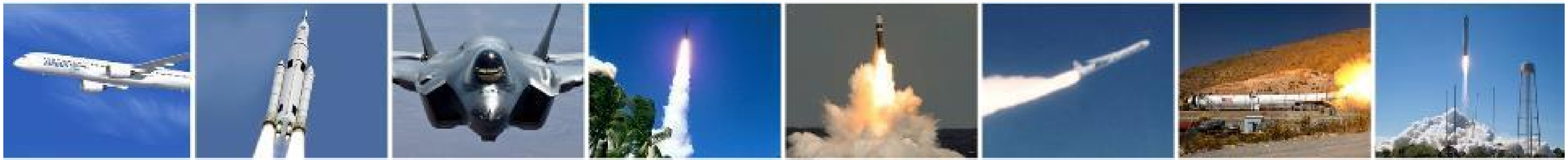
Comparable remaining propellant at peak pressure



Modeling is investigating the sensitivity of inflator configurations to combustion changes. Modeling indicates less "upside" response to potential C* efficiency changes on YD configuration.
(single heavy weight test – further investigation required to validate model results and test data).



Statistical Analysis of Field Data

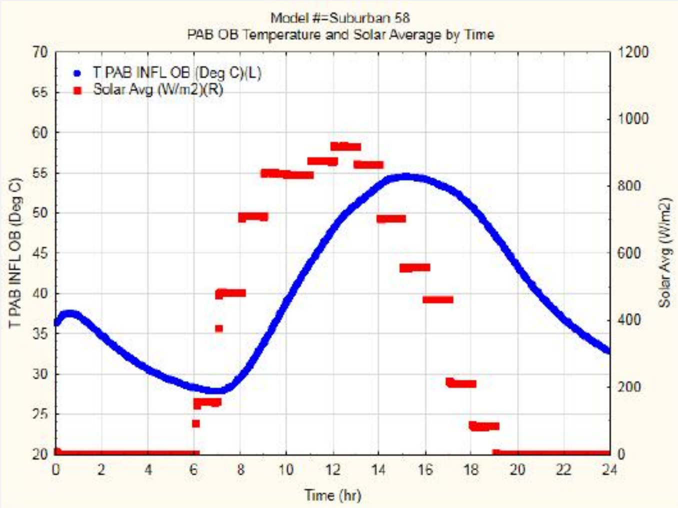


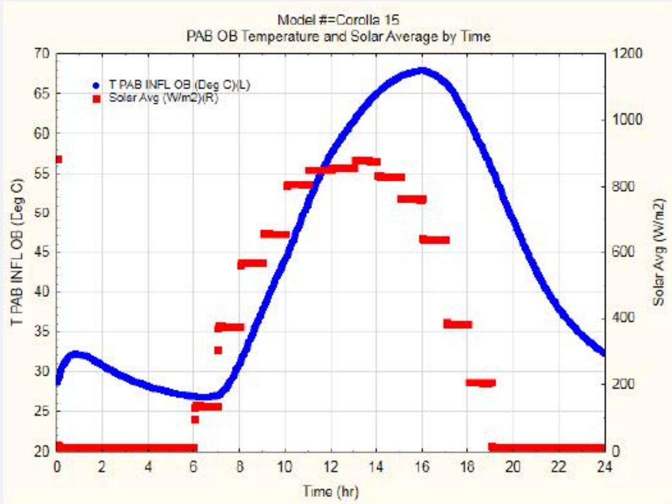
Review of Data

- Several vehicles were exposed in a lab setting to environmental conditions designed to simulate a Florida summer day
  - 3 Series (3), Accord (5), Civic, Corolla (3), CRV, Lancer, Legacy, Matrix, Mazda 6, Ranger (Sentra (3), Silverado, Suburban, and GM Vibe were tested
    - Most had data recorded for 24 hours
  - Vehicles identified as 3 Series–23, Accord-17, Corolla-13, Corolla-14, Corolla-15, Legacy-38, Matrix-45, and GM Vibe-40 had data recorded for multiple days (2 or 3)
    - Chose Passenger Air Bag (PAB) Outboard (OB) temperature
- No information on age, model, color, etc. of the platforms
- Summary of Environmental testing:
  - Statistically significant differences in temperatures for different platforms.
  - Larger vehicle consistently exhibit lower temperatures
  - Gmt900 family has maximum temperatures near 55°C under conditions that some other vehicles exhibit higher temperatures
    - Maximum temperature range matches range of interest in other experiments especially moisture transport experiments
- Review of relevant statistical data from MEAF
  - Detailed examination of PSPI-L and SPI inflators in data base
  - Following charts present several views of the critical data
    - Age of inflator versus Maximum Pressure in test firing
      - PSPI-L FD and JD (other OEMs)
      - SPI AJ (other OEMs) and SPI YP (GM)
    - Age of inflator versus wafer outside diameter
      - SPI AJ (other OEMs) and SPI YP (GM)
  - Data shows distinct platform dependence
    - Larger platforms show lower ED rates
    - Gmt900 is younger than other platforms
    - Gmt900 shows no ED to date
    - Other larger vehicle have several more years with very low or zero failure rates

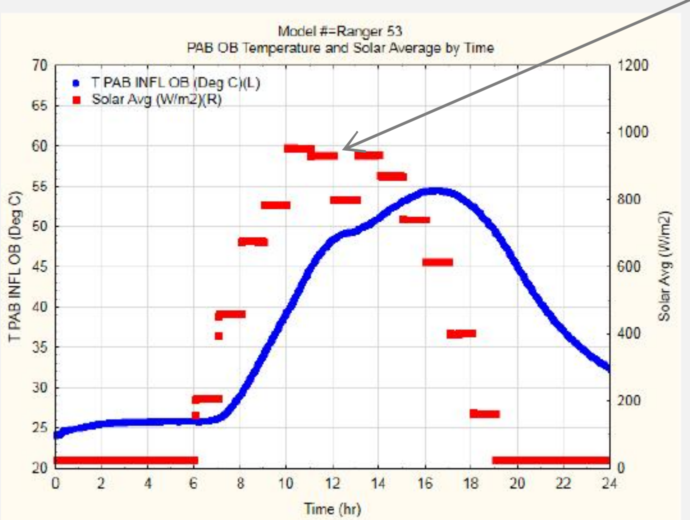
Data from: Vehicle Environmental Testing Project Report by Atlas Consulting Solutions (14-Mar-2016)

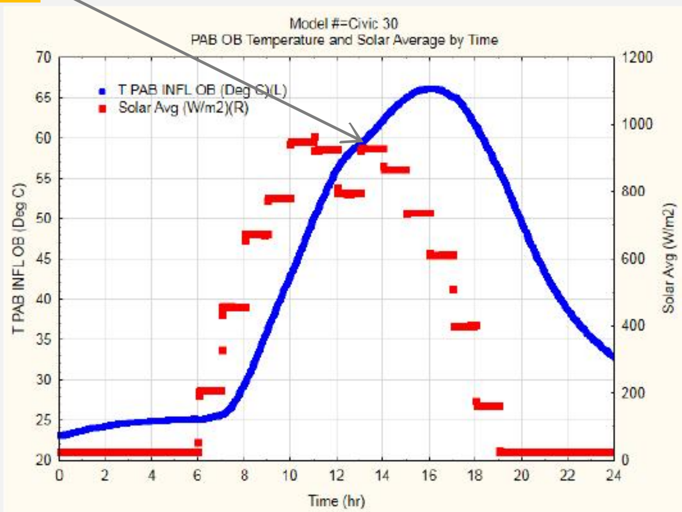
Two Profiles were used. Dip and no Dip.
Same Input Shows Different Responses





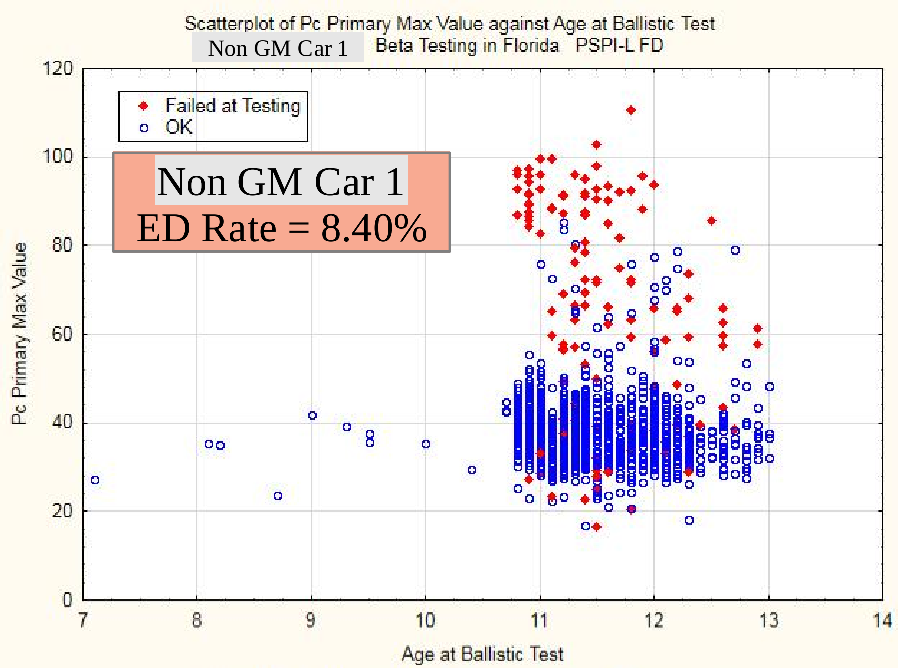
DIP

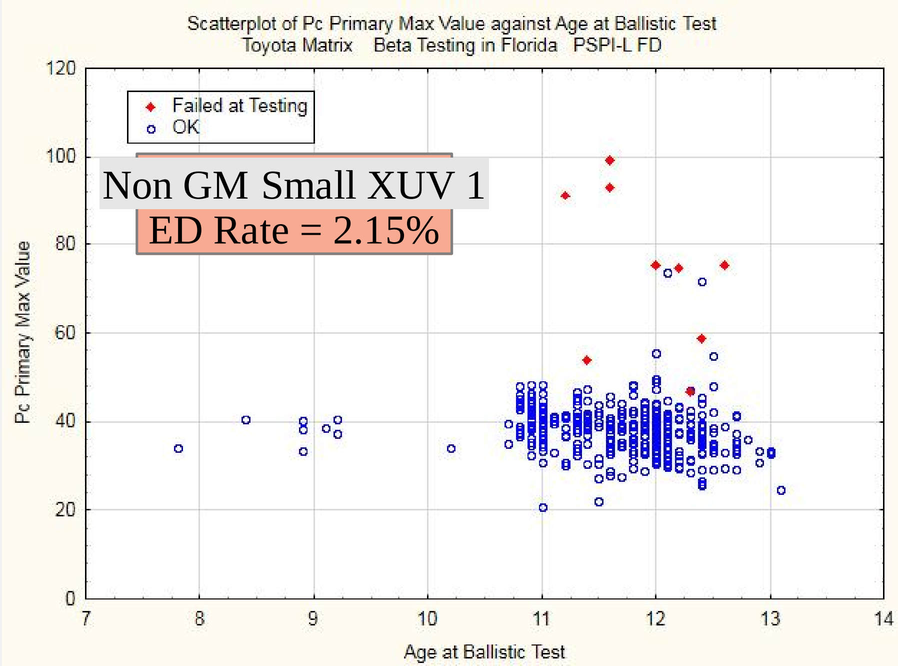


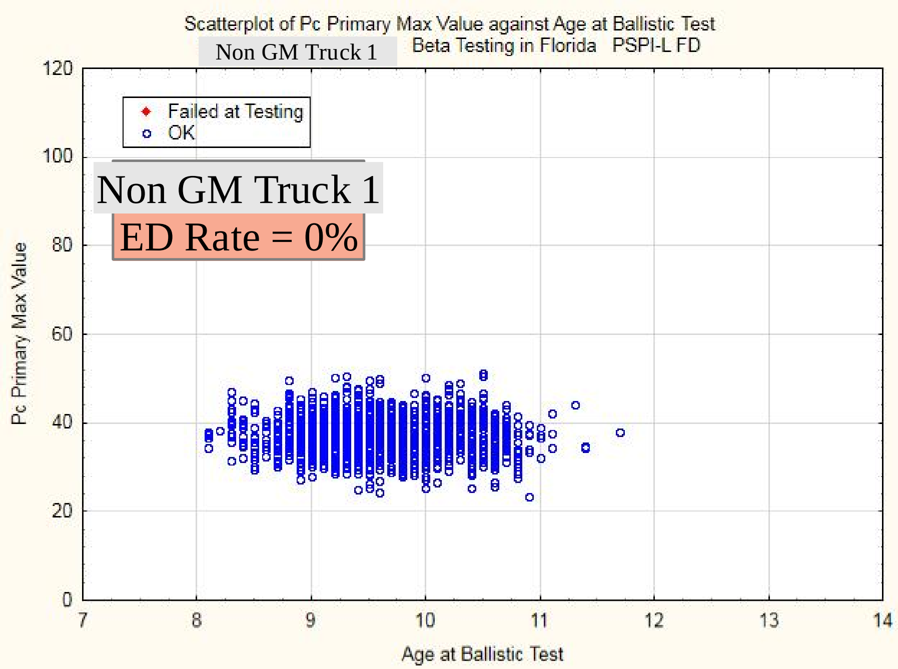


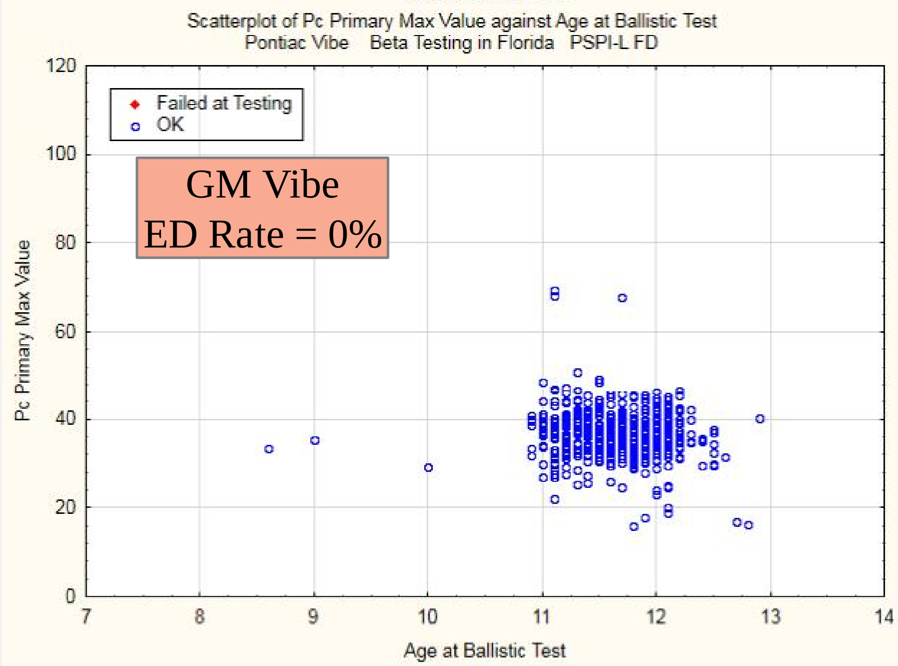
- Representative data from field environmental experiments
- Similar solar flux results in different max temperatures based on different platforms
- Gmt900 is consistently at low range of observed temperatures

PSPI-L FD/Florida: Same Inflator, Same Zone, Different Outcomes with Different Platforms

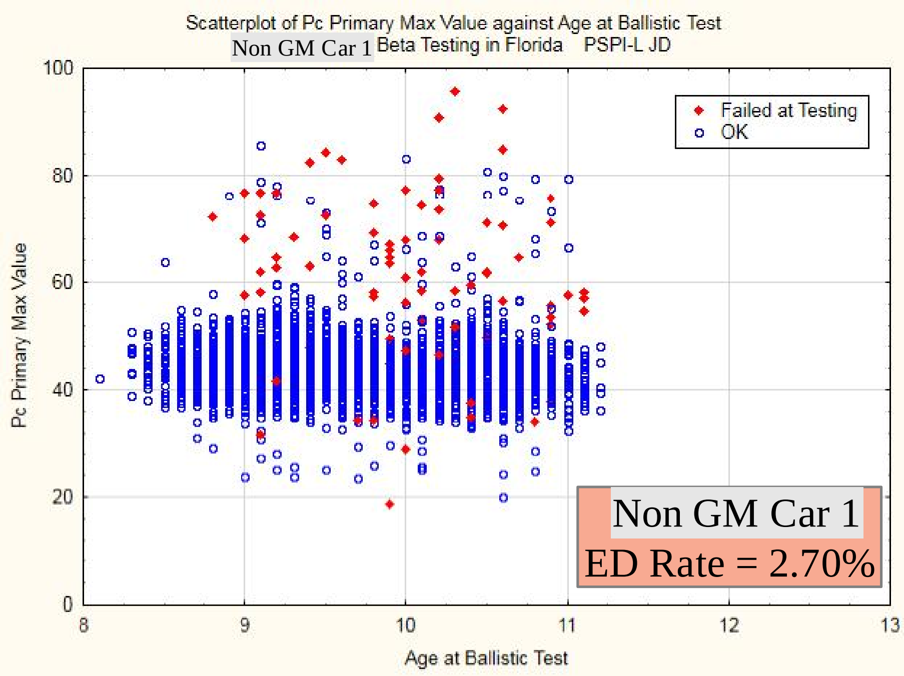


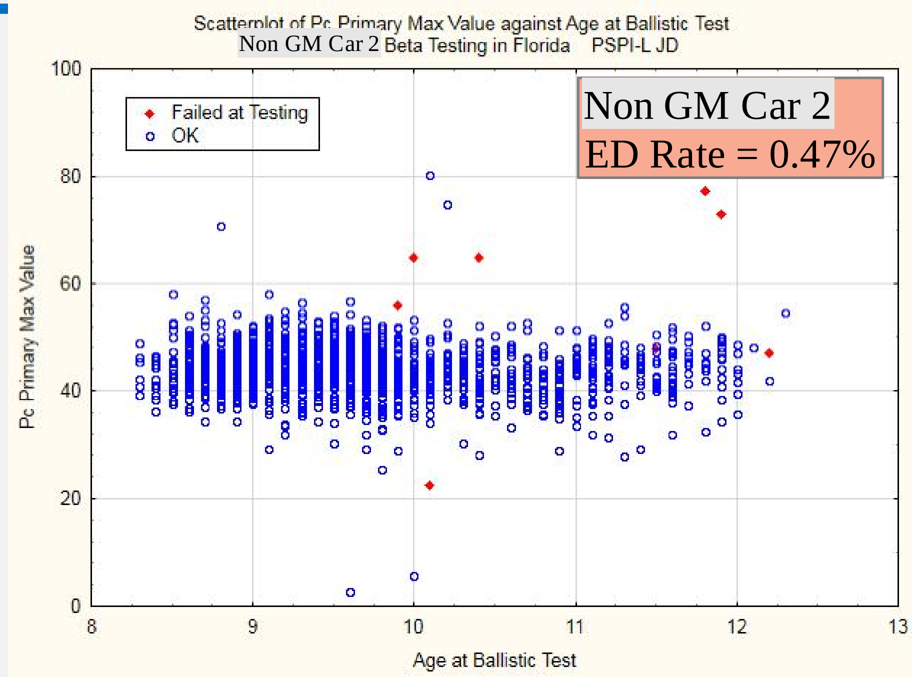


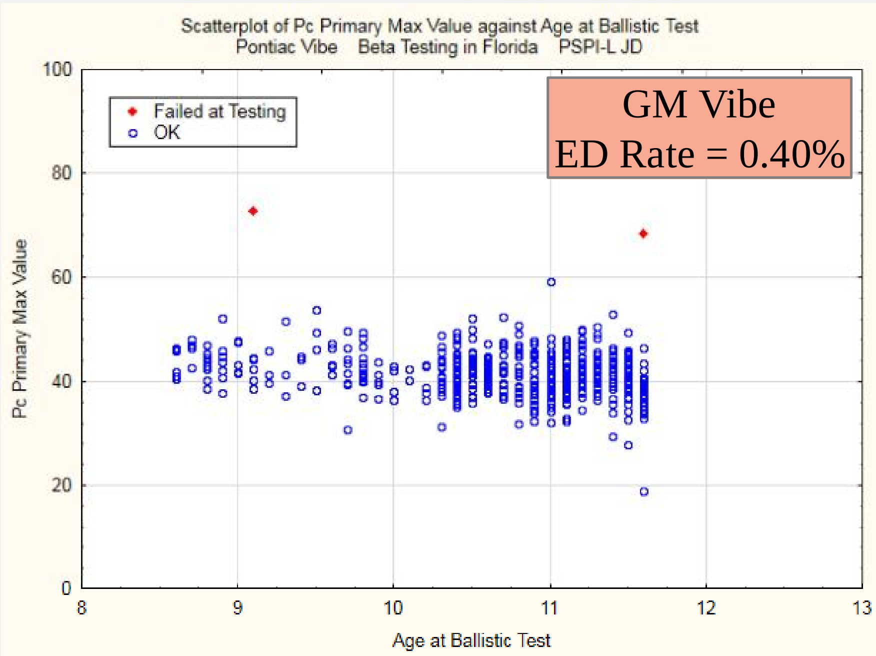


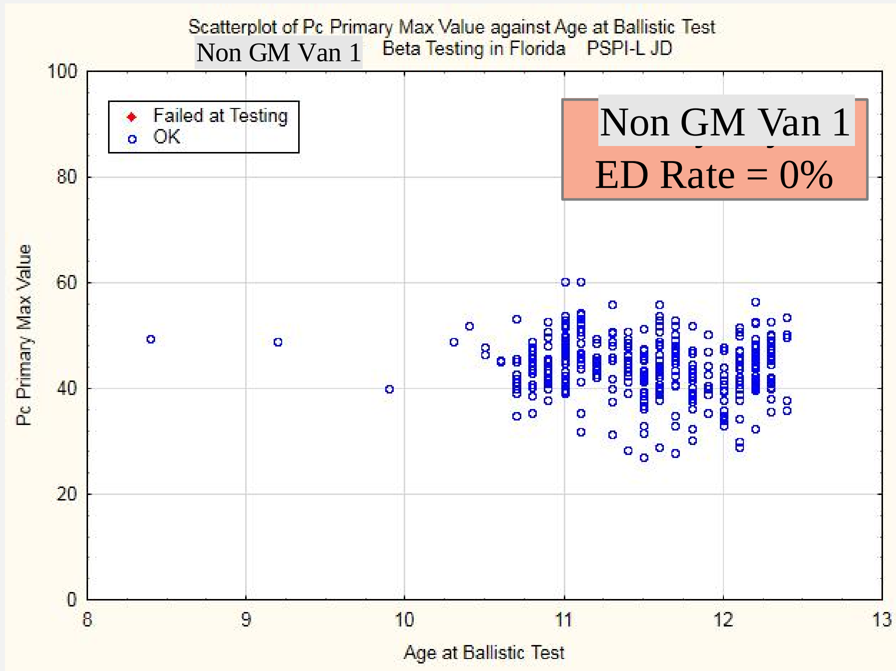


PSPI-L JD/Florida: Same Inflator, Same Zone, Different Outcomes with Different Platforms

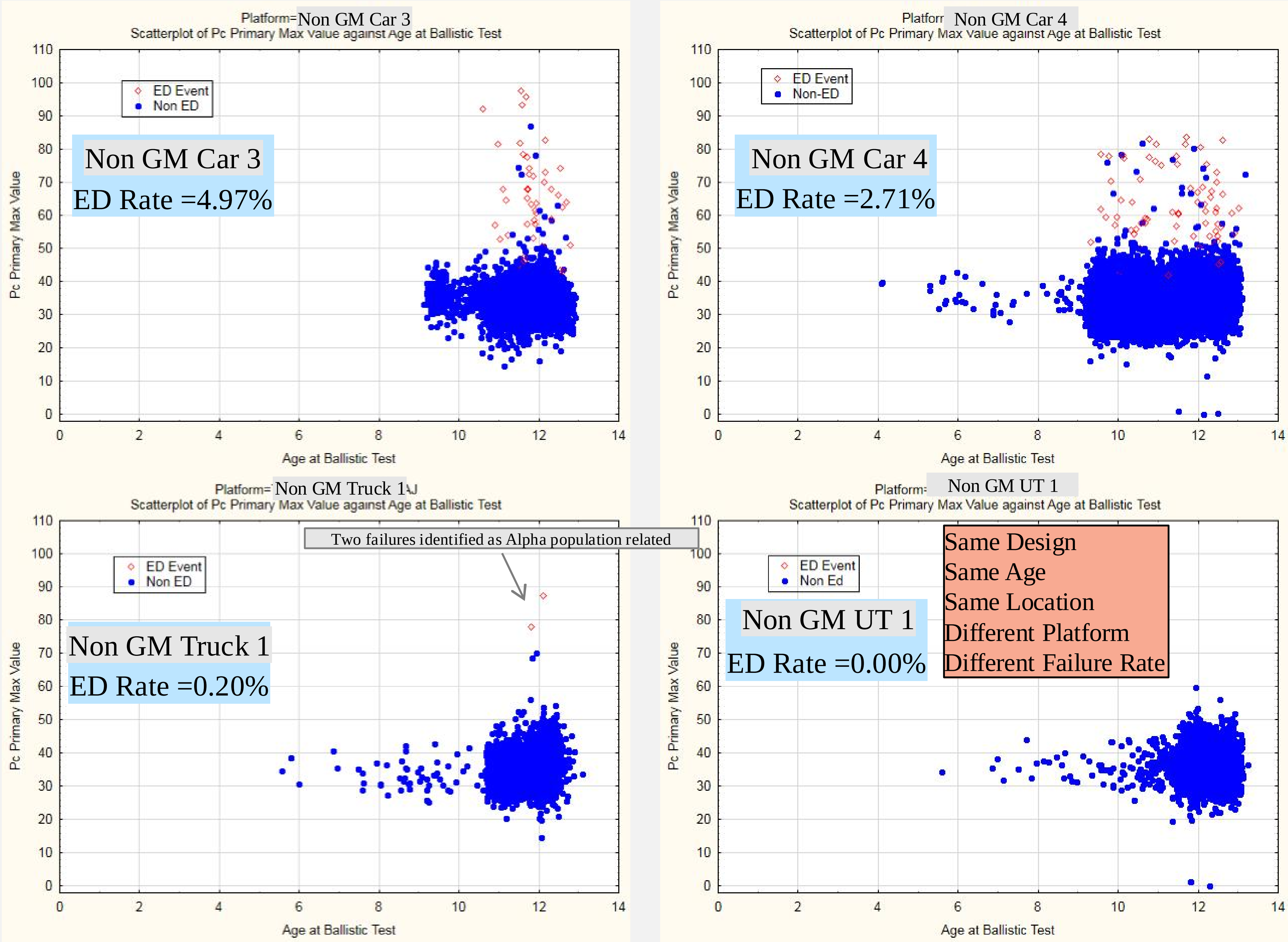




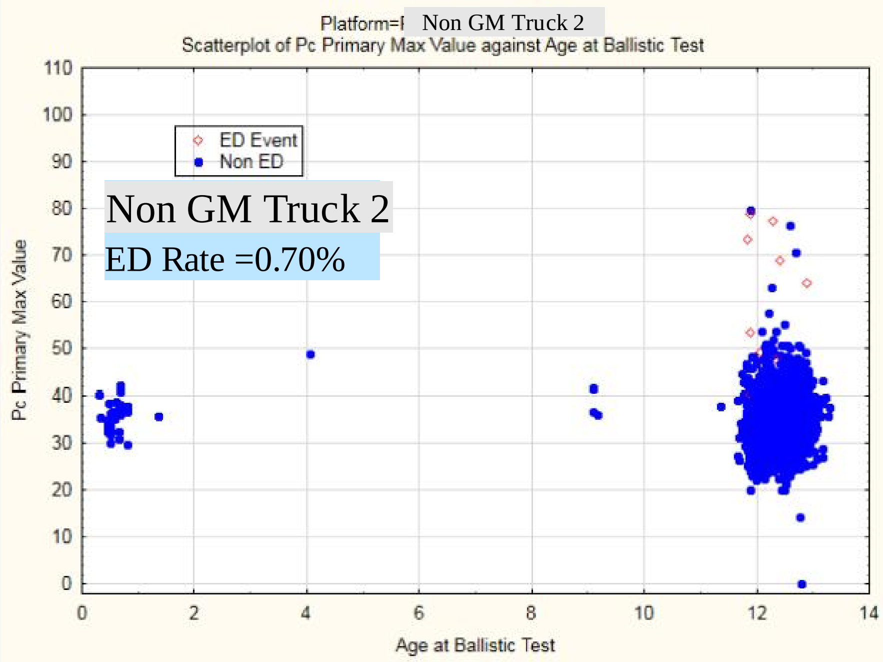


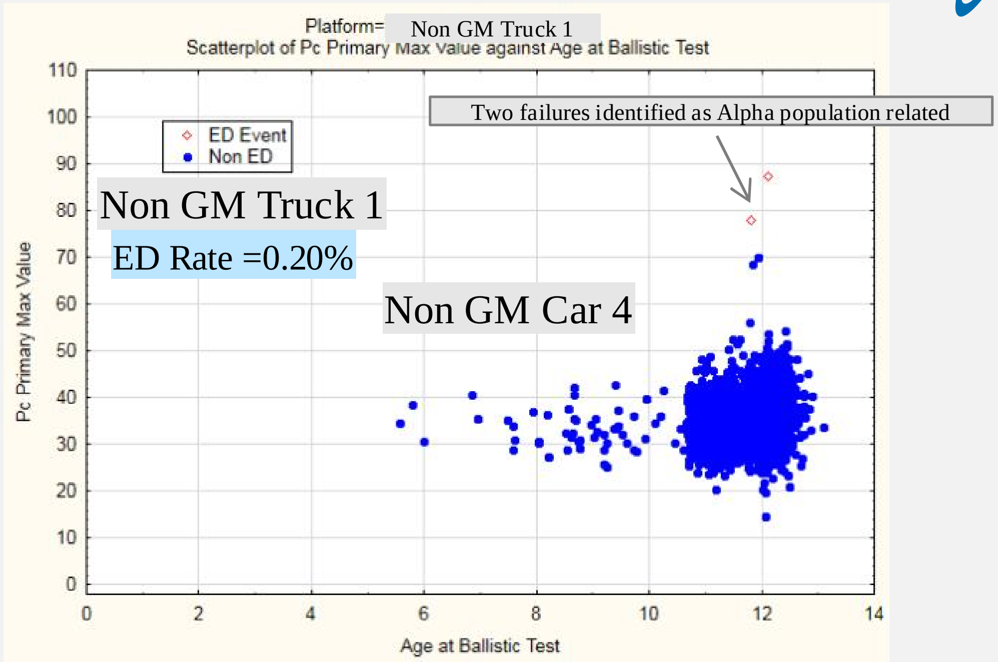


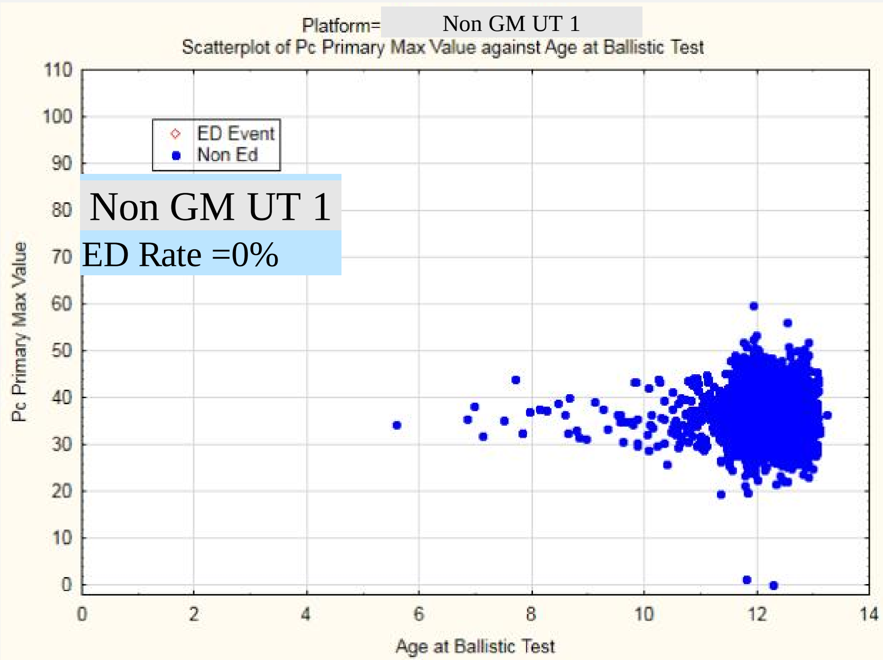
SPI AJ: Same Inflator, Same Zone, Different Outcomes with Different Platforms

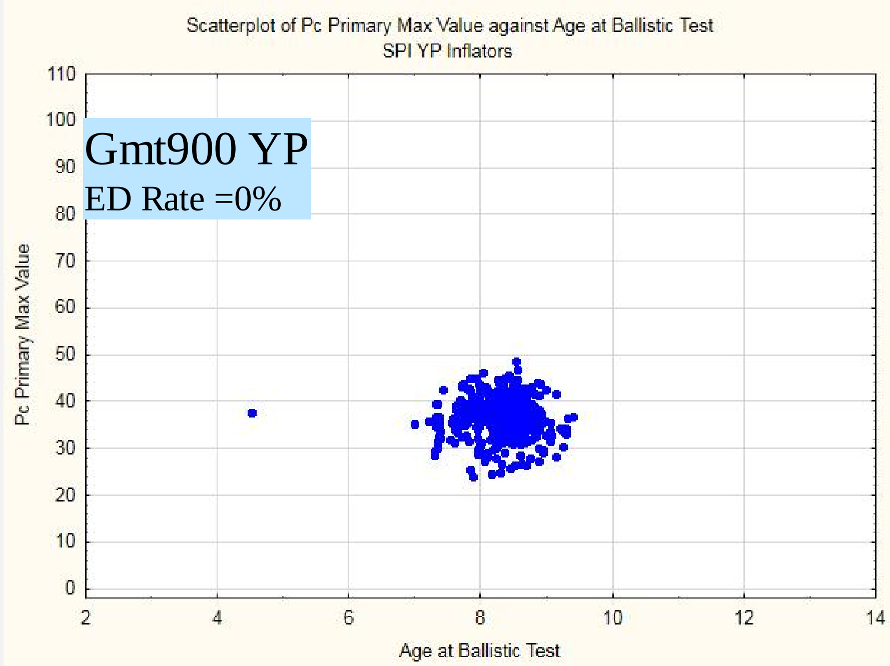


SPI AJ & YP: Same Zone, Different Outcomes;
Platforms with few or no ED's



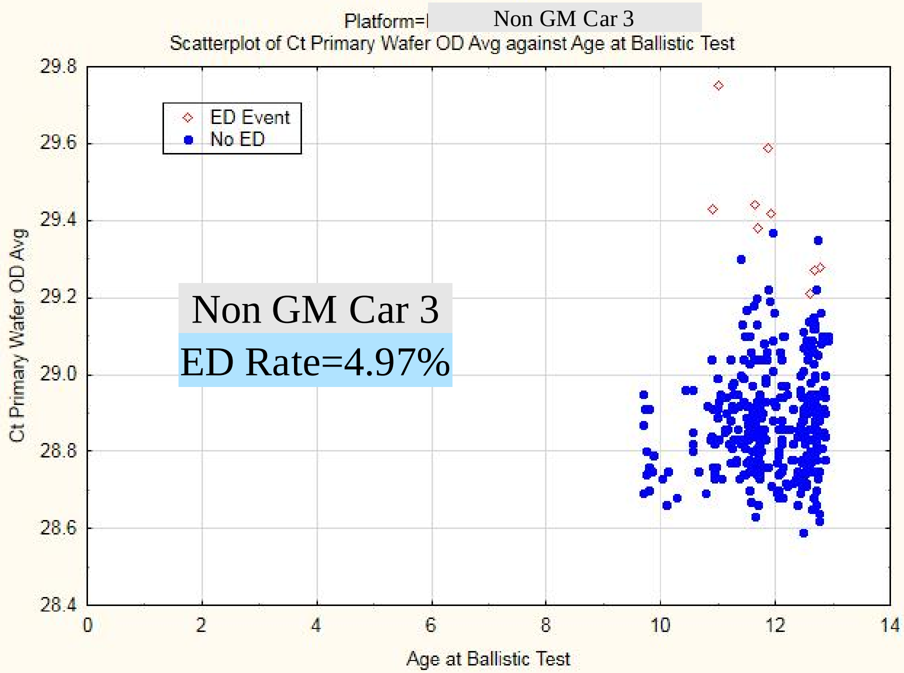


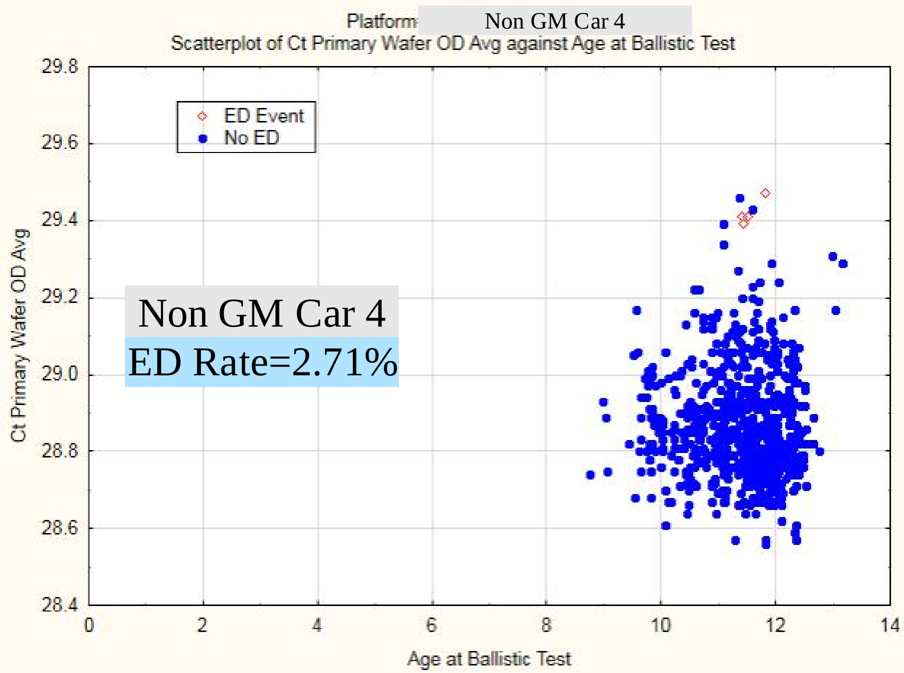


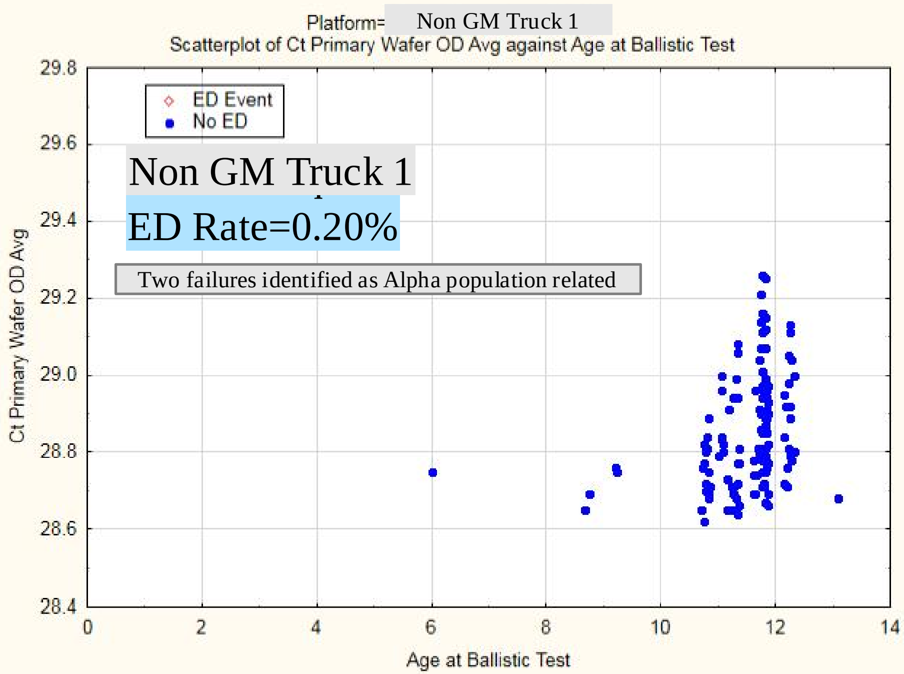


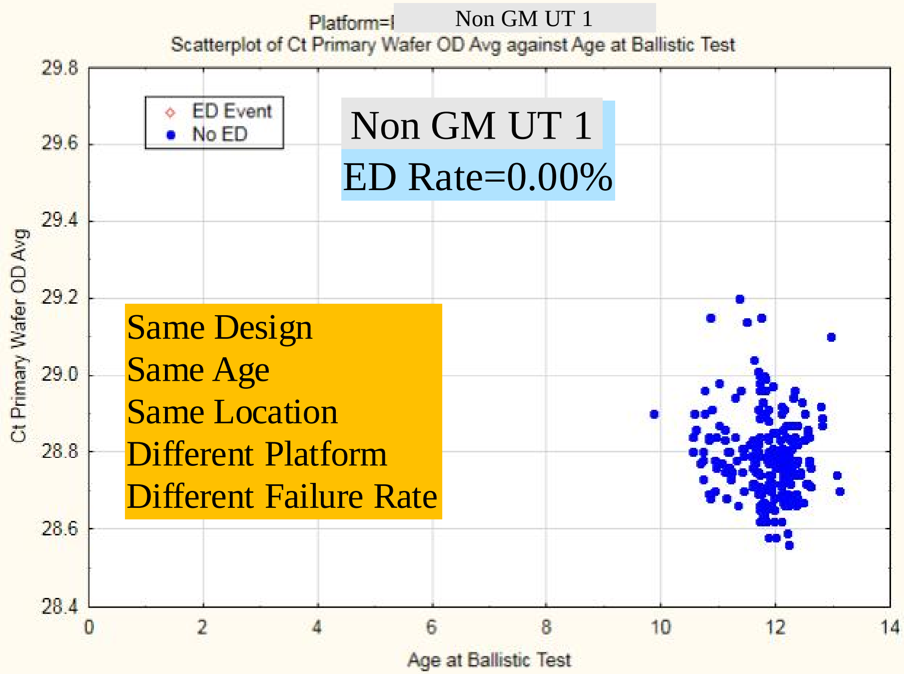
SPI AJ: Wafer Diameters: Same Inflator, Same Zone, Different Outcomes with Different Platforms

Limited data here on diameter change with time for a given platform



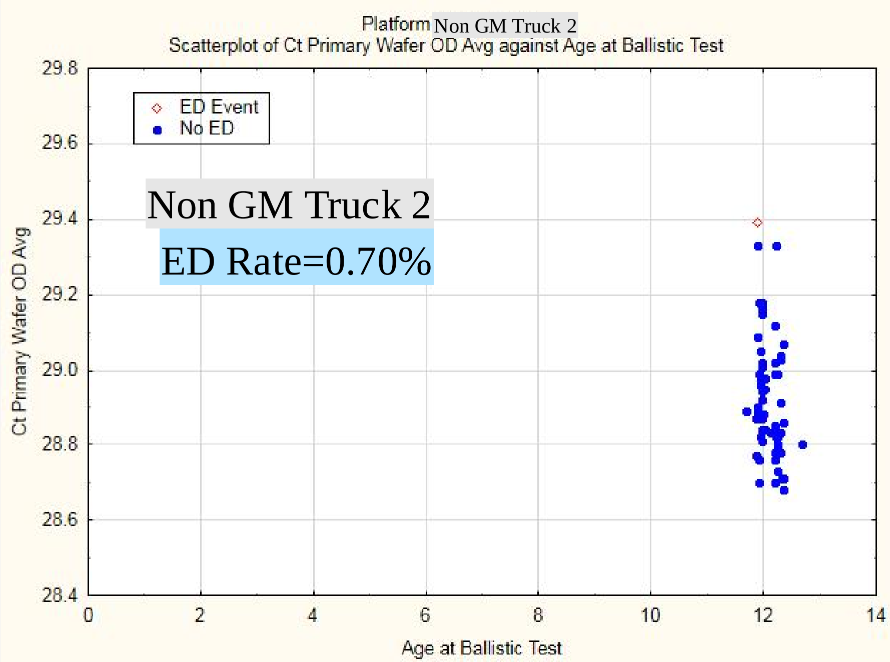


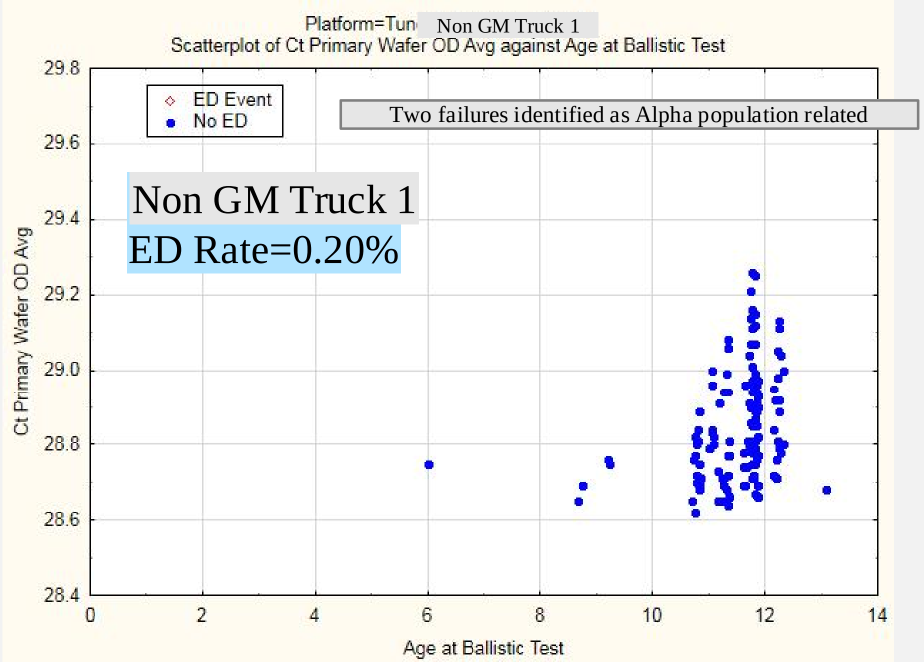


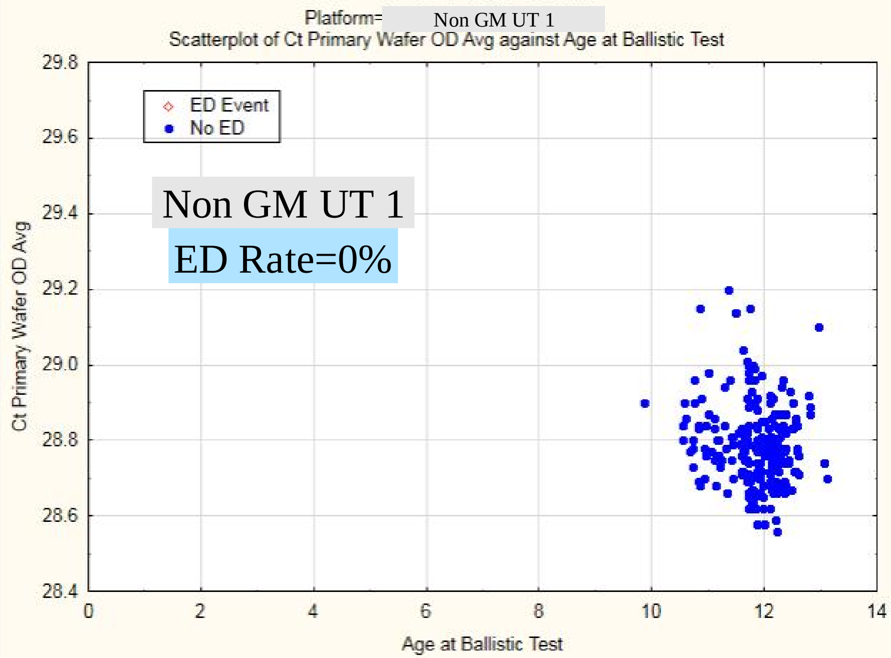


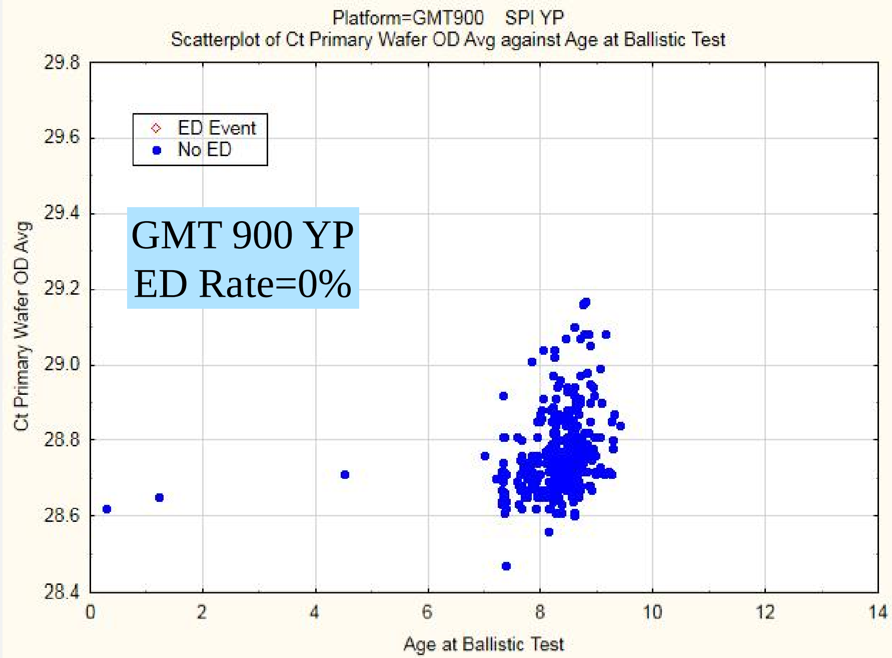
SPI AJ & YP – Wafer Diameter, Same Zone, Different Outcomes, Platforms with limited failures

Again: limited data on diameter change with time



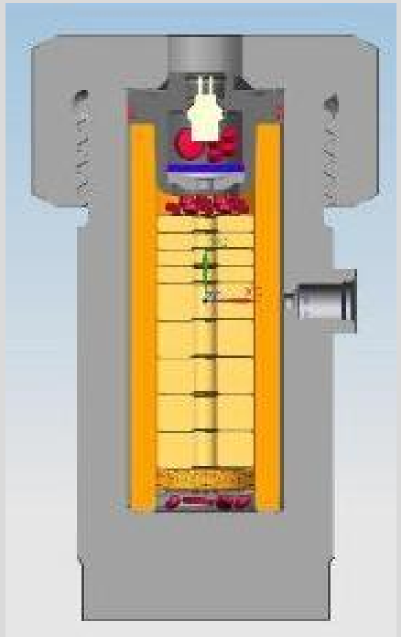




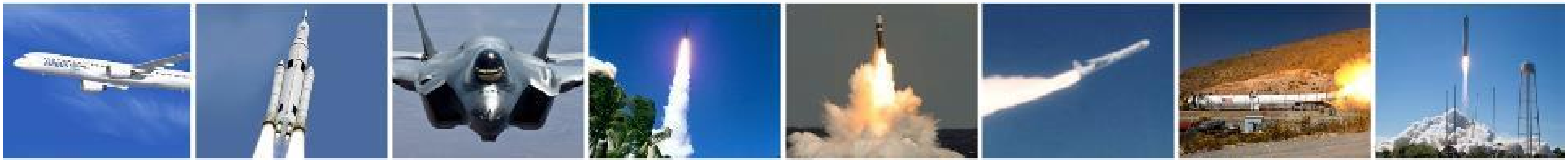


Orbital ATK

Total Inflator Moisture

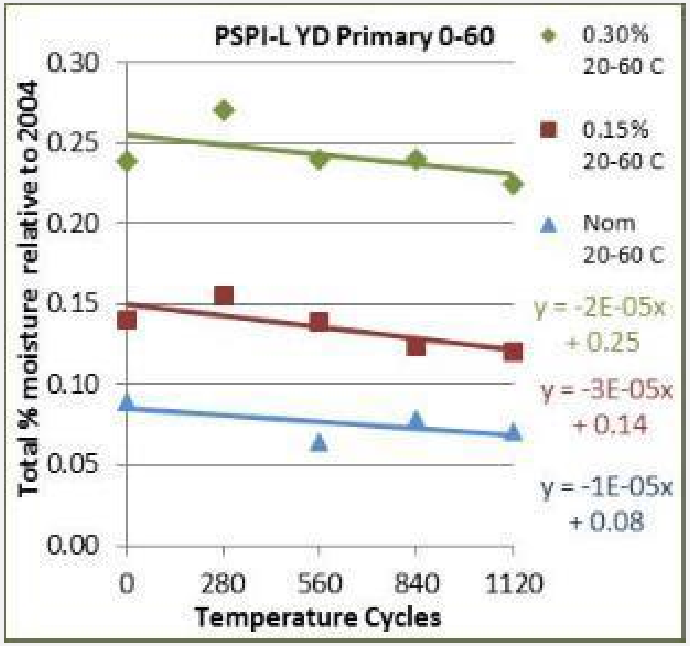


Discussion



Total Inflator Moisture (1680)
Introduction

- Data are available from 0-1680 cycles for PSPI-L FD and for PSPI-L YD and SPI YP for 0-1120 cycles to allow observation of trends, if any, in net gain or loss of moisture in the inflators as they are cycled.
  - Rest of data will be available in near future
- Data are summarized in graphs such as the one below:

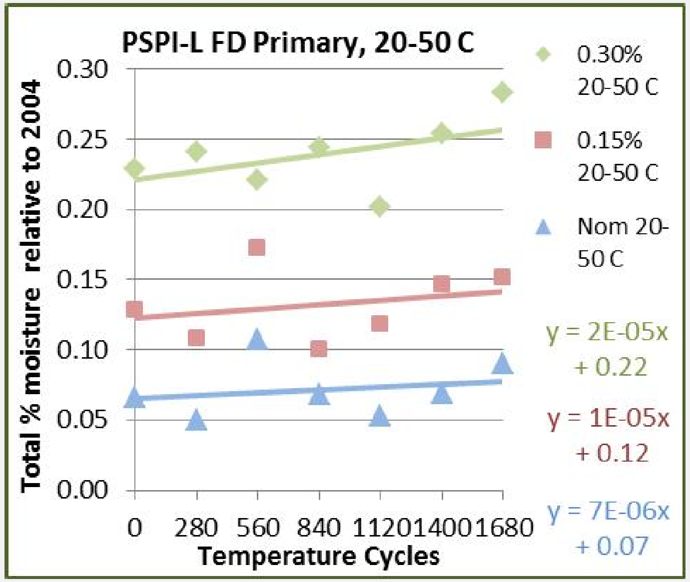


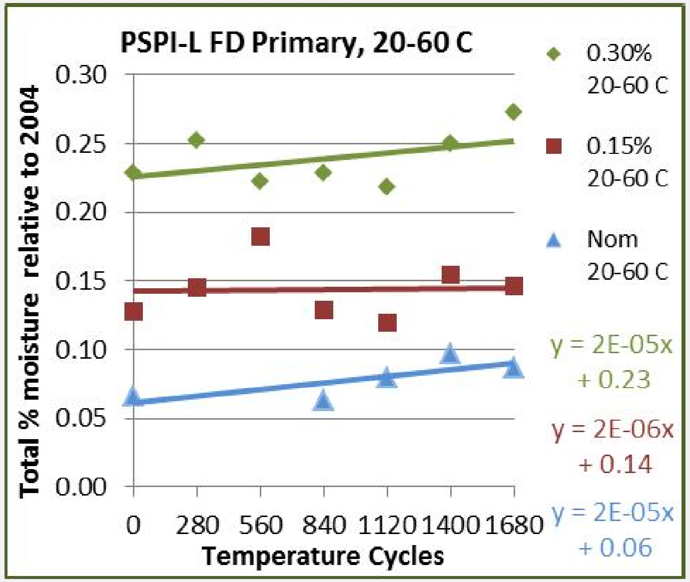
- A trend line is fitted to each set of data points
  - Negative slopes are indicative of a net loss of moisture from that inflator chamber type and aging condition
    - Positive slopes are indicative of a net gain
  - The intercepts provide an estimate of time zero moisture as analyzed in each inflator chamber type/aging condition
    - 3110 moisture was obtained via 18 hour weight loss at 100 C
    - 2004 moisture was obtained via the Karl Fischer method on a wafer from the chamber
  - Each data point represents results from a single inflator
    - Abnormal results from a given inflator chamber will skew slope values significantly

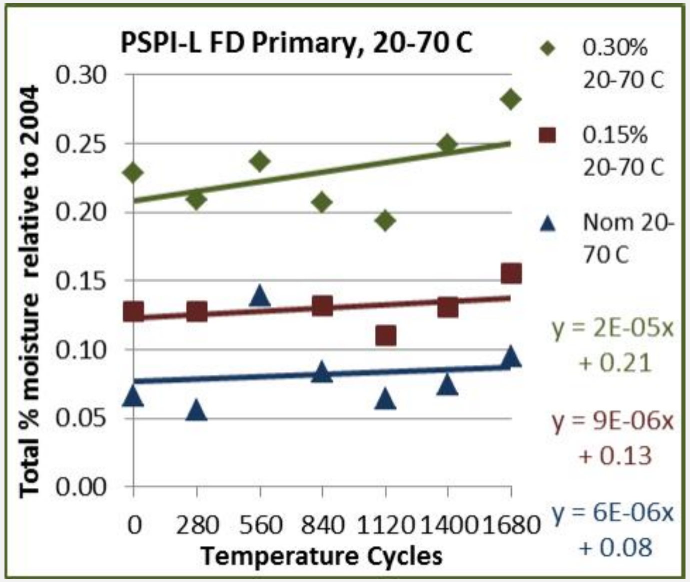
Total Inflator Moisture (1680)

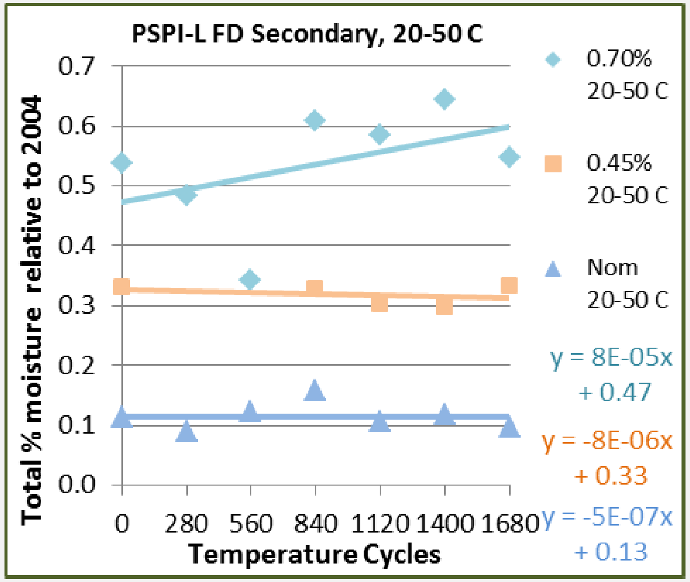
FD Inflators

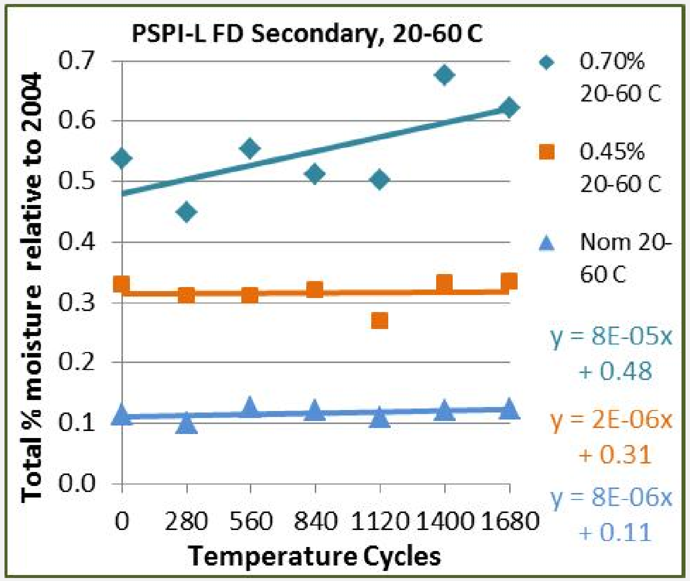
- Moistures below targets: mid P (0.15%), high P (0.30%), mid S (0.45%) and high S (0.70%)
- No loss in moisture through 1680 cycles:
  - 1400 and 1680 slightly higher due to higher ambient RH during disassembly and test preparation

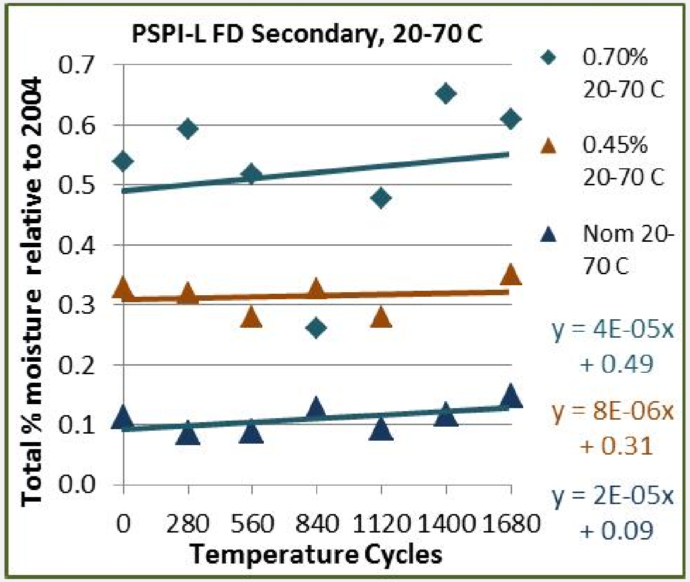








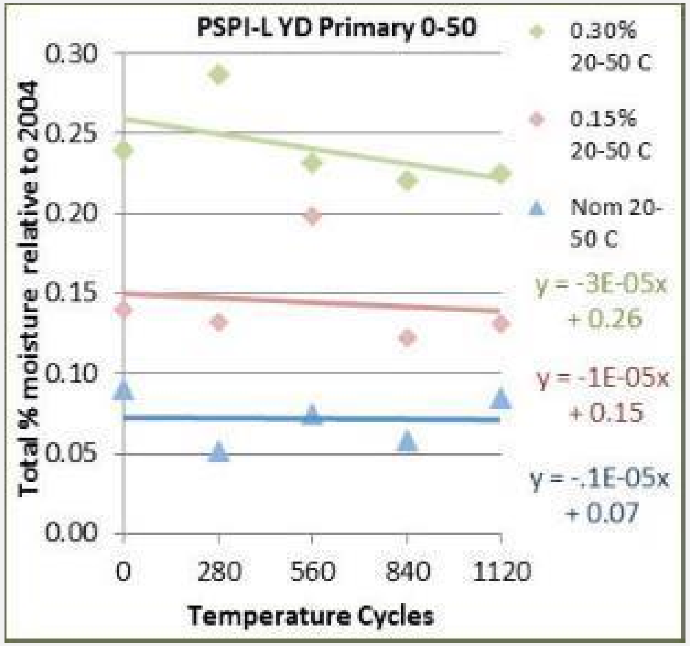


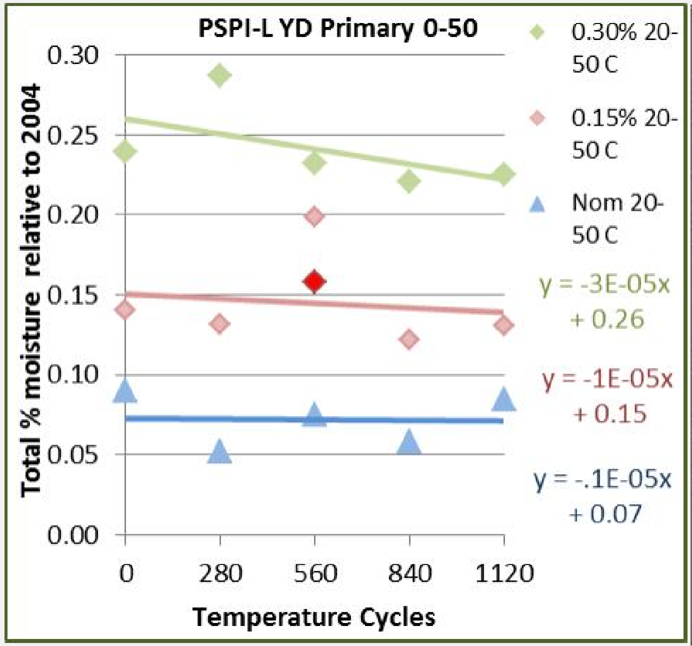


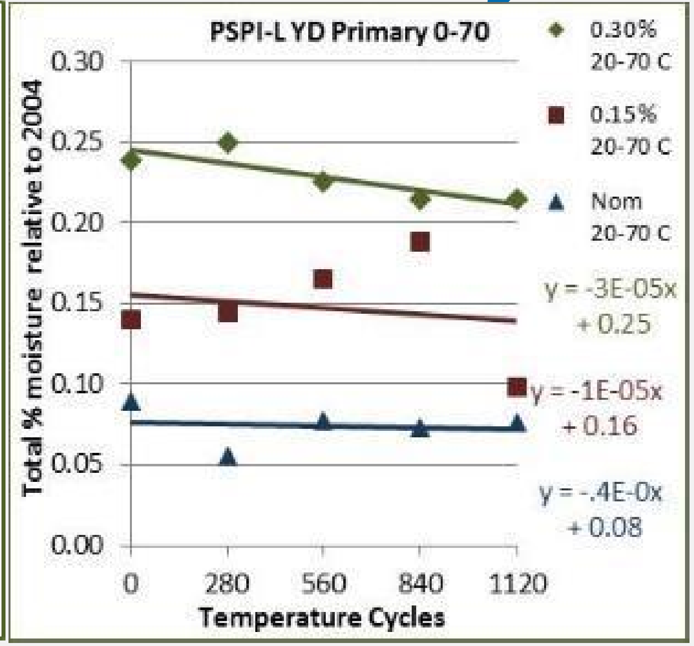
Total Inflator Moisture (1120)

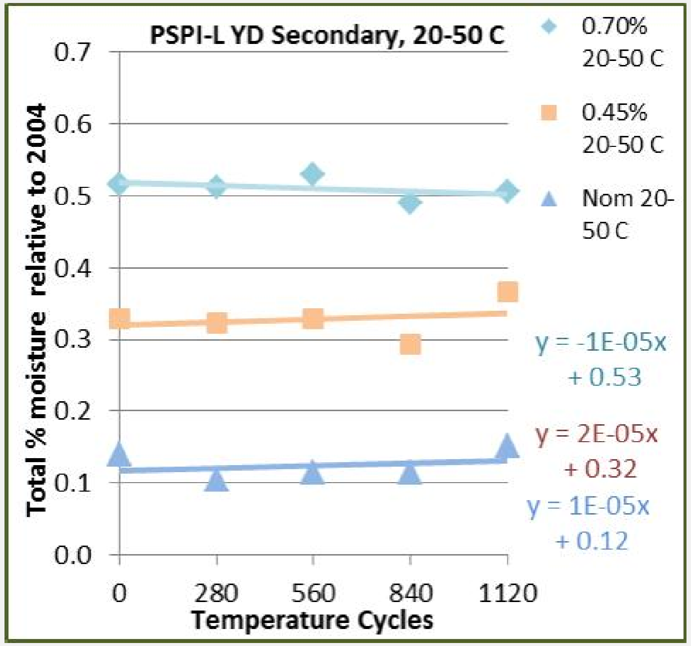
YD Inflators

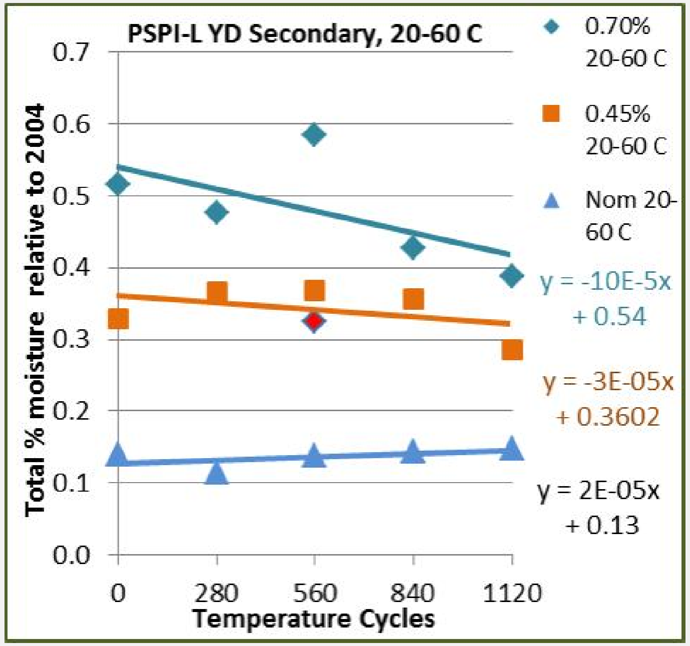
Returned YD inflator further aged by GM

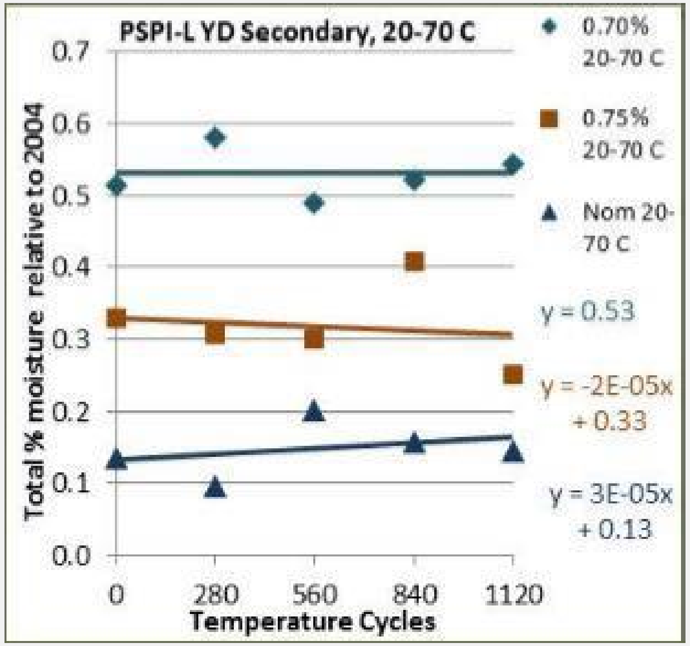






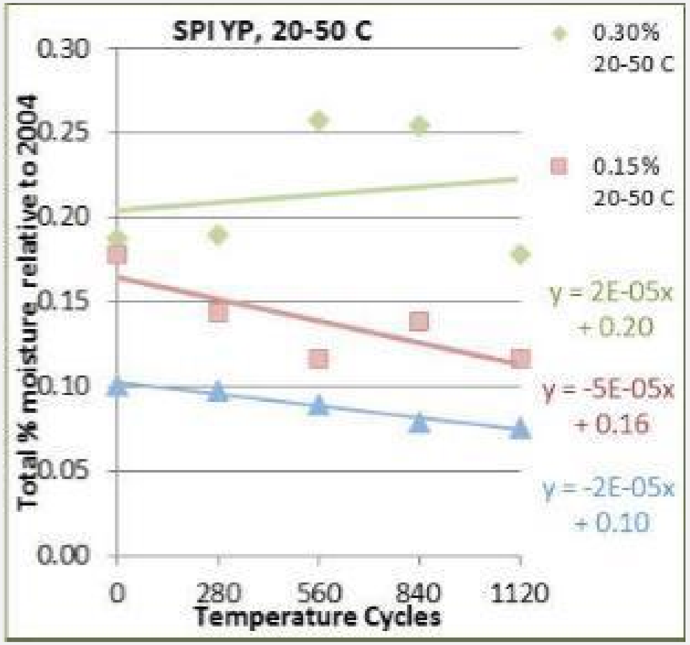


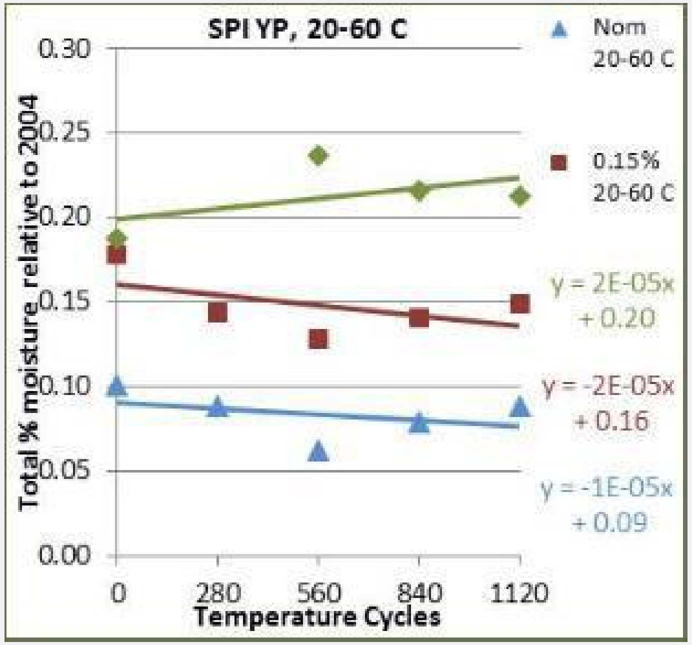


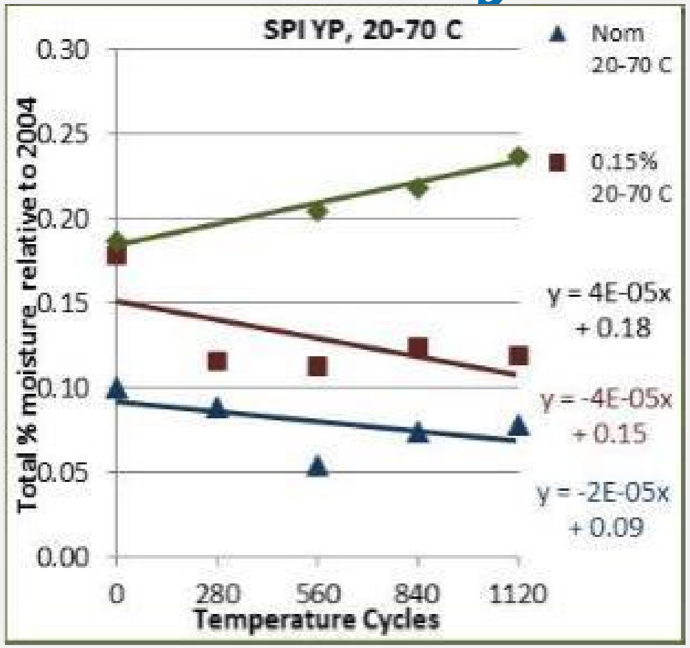


Total Inflator Moisture (1120)

YP Inflators and Data Summary

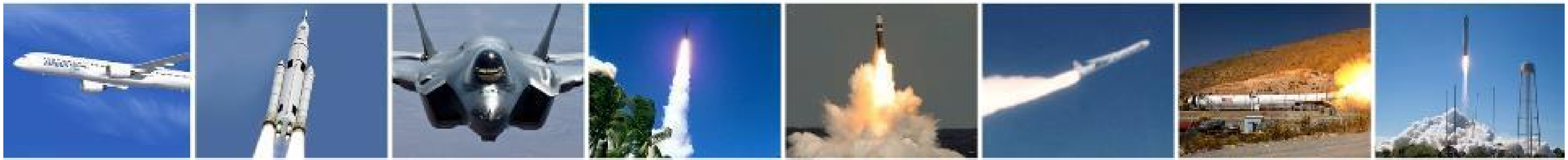






- Intercepts-Total Analyzed Moisture
  - Nominal Inflators-Values for secondary chambers are higher than primary
    - Consistent with higher 3110/2004 ratio in the secondary
  - Moisture Added Inflators
    - Values for mid moisture primary chambers are close to the targeted 0.15%
    - Values for all other chambers are significantly lower than target values
- Slopes-Moisture Loss or Gain During Cycling
  - PSPI-L FD and YD
    - Moisture Added Inflators-Gradual loss in moisture with increasing cycle time is typical
    - Nominal Inflators-Very slight gain in moisture is typical
  - SPI YP
    - Slopes for moisture added inflators may be skewed by abnormal zero time values
    - Decreasing nominal values may indicate gradual intrusion of moisture into the YP 2004 tablet cup
- Values for the Returned YP that was aged further by GM tend to be close to mid moisture inflators

Moisture Content



2004 Wafer Moisture Content

Wafer Thickness	Wafer Type	Pri/ Sec	Wafer Age (yr)		Wafer OD (mm)		Karl Fischer (%)	
			Avg	Stdev	Avg	Stdev	Avg	Stdev
Thick	FD virgin	pri	0.3	0.0	28.61	0.01	0.051	0.010
		sec			28.66	0.02	0.067	0.010
	FD returned	pri	13.3	0.2	29.04	0.01	0.099	0.015
	AJ returned	pri	13.2	0.0	29.11	0.14	0.190	0.042
Medium	YD virgin	pri	0.3	0.0	28.67	0.02	0.062	0.010
		sec			28.66	0.01	0.056	0.004
	YD returned	pri	9.6	0.7	28.75	0.10	0.088	0.008
	YP returned	pri	9.2	0.2	28.87	0.14	0.120	0.033

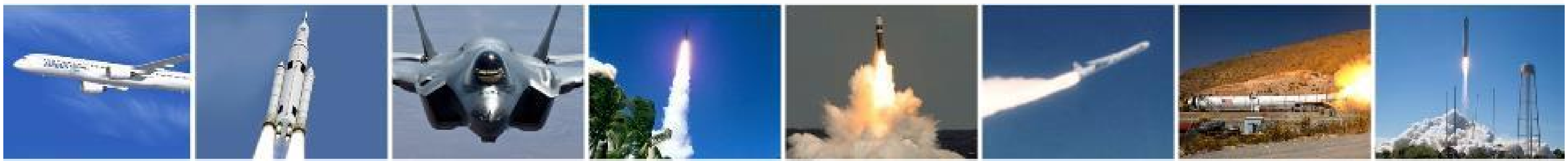
- Virgin Moistures are expected levels with values elevated for the returned propellants.
  - Slightly more moisture present in returned other OEM FDs and AJs than the younger GM inflator model YDs and YPs
  - Significantly more moisture in returned SPIs (AJ and YP) than PSPI-Ls (FD and YD)
    - The SPIs have two O-ring seals per chamber as opposed to one in the PSPI-Ls
    - Should check the MEAF to see if this trend holds for a large population of inflators from similar platforms

2004 Wafer/3110 Tablet Moisture Content

Wafer Thickness	Wafer Type	Pri/ Sec	Wafer Age (yr)		Wafer OD (mm)		Karl Fischer (%)		3110 Moisture Closure (% of 3110)		AI-1 Color Closure	AI-1 Weight Closure (g)		AI-1 Density Closure (g)		3110 Moisture AI Cup (% of 3110)		AI-1 Color AI Cup	AI-1 Weight AI Cup (g)		AI-1 Density AI Cup (g)	
			Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev		Avg	Stdev	Avg	Stdev	Avg	Stdev		Avg	Stdev	Avg	Stdev
Thick	FD virgin	pri	0.3	0.0	28.61	0.01	0.051	0.010	0.20	0.02	1	0.286	0.005	1.99	0.03	0.22	0.06	1	0.283	0.006	2.00	0.01
		sec			28.66	0.02	0.067	0.010	0.24	0.04	1	0.289	0.001	1.99	0.02	0.22	0.04	1	0.284	0.006	1.99	0.01
	FD returned	pri	13.3	0.2	29.04	0.01	0.099	0.015	1.43	0.47	5	0.273	0.010	1.89	0.06	0.99	0.41	3	0.273	0.015	1.92	0.06
		sec			29.18	0.15	0.093	0.024	1.21	0.10	6	0.270	0.009	1.91	0.07	0.57	0.11	3	0.278	0.007	1.84	0.05
	AJ returned	pri	13.2	0.0	29.11	0.14	0.190	0.042	3.13	0.47	9	0.268	0.007	1.74	0.05	---	---	---	---	---	---	---
Medium	YD virgin	pri	0.3	0.0	28.67	0.02	0.062	0.010	---	---	---	---	---	---	---	0.48	0.30	1	0.276	0.018	1.92	0.15
		sec			28.66	0.01	0.056	0.004	---	---	---	0.283	NA	2.00	NA	0.23	0.01	1	0.285	0.005	2.00	0.02
	YD returned	pri	9.6	0.7	28.75	0.10	0.088	0.008	1.09	0.15	2	0.283	0.005	1.97	0.05	1.29	0.20	1	0.273	0.009	1.95	0.03
		sec			28.75	0.10	0.077	0.016	0.60	0.32	1	0.279	0.001	1.93	0.02	0.74	0.29	1	0.277	0.001	1.94	0.01
	YP returned	pri	9.2	0.2	28.87	0.14	0.120	0.033	---	---	2	0.278	0.003	1.94	0.02	---	---	---	---	---	---	---

- 2004 wafer and available 3110 tablet data trend well with each other
  - Returned FDs and AJs show higher moisture contents than the younger GM YDs
- Weight loss in AI-1 is small in all cases
  - AI-1 likely not a significant source of moisture due to decomposition in these inflators

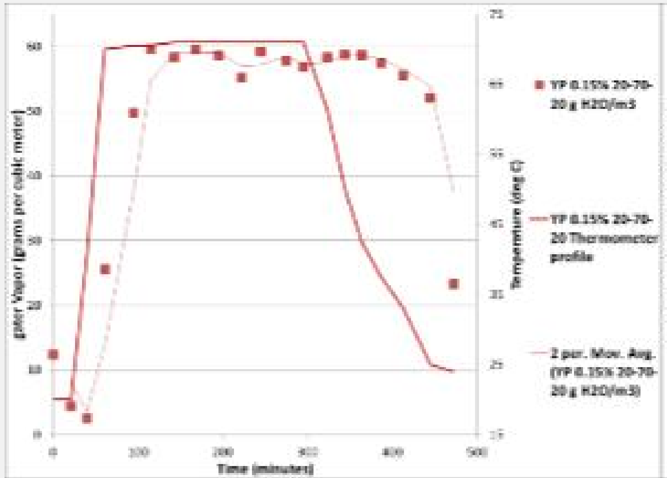
Moisture Dynamics

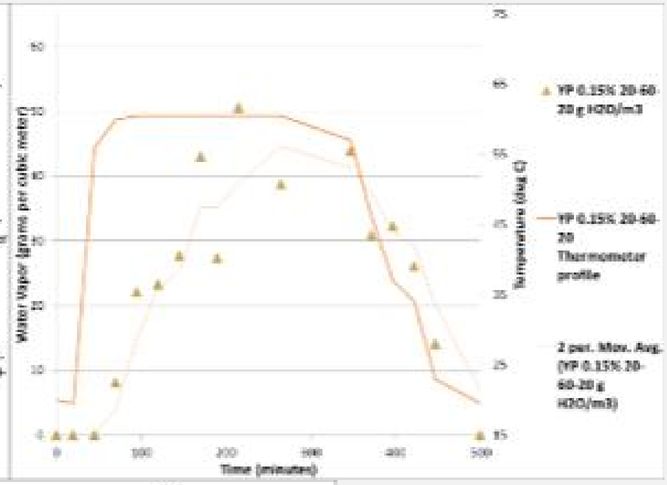


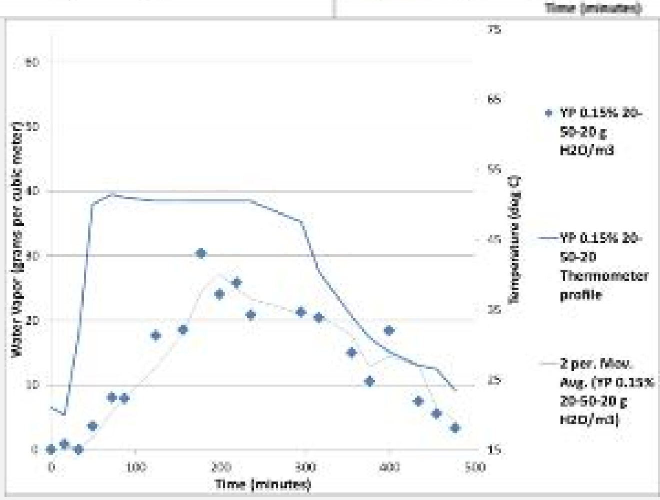
Moisture Diffusion, Inflators via Gas Chromatography

Water Vapor Behavior as a Function of Maximum Cycle Temperature

- Slight increase in peak water vapor levels between 20-50 and 20-60 cycles
- Great increase in peak water vapor levels between 20-60 and 20-70 cycles
  - **Significantly larger amount of water vapor movement for the 20-70 cycle**







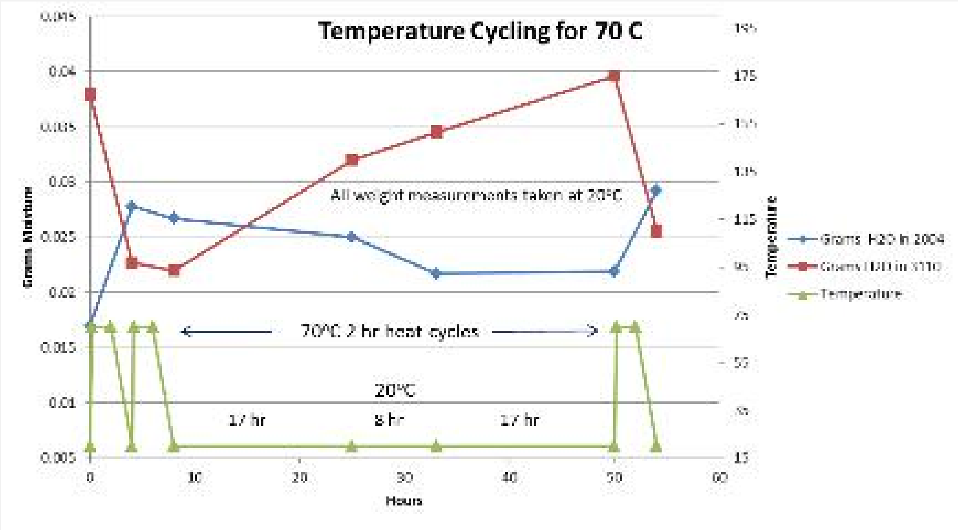
Moisture equilibration time in SPI YP inflators is not very dependent on peak temperature in a heat cycle

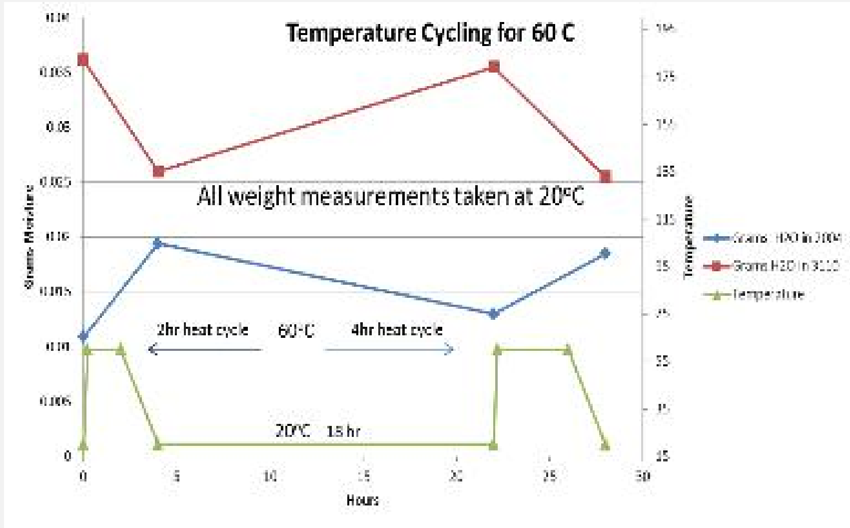
Target Water (%)	Heat Cycle	Time to Peak H2O Vapor (hr)	Time to Min H2O Vapor (hr)
0.15%	20-50-20	3.1	3.0
0.15%	20-60-20	4.1	3.9
0.15%	20-70-20	3.4	3.0

- Data suggest moisture transport is much less pronounced below 60°C. Moisture transport is the primary mechanism of density reduction (grain growth) identified by all investigators.

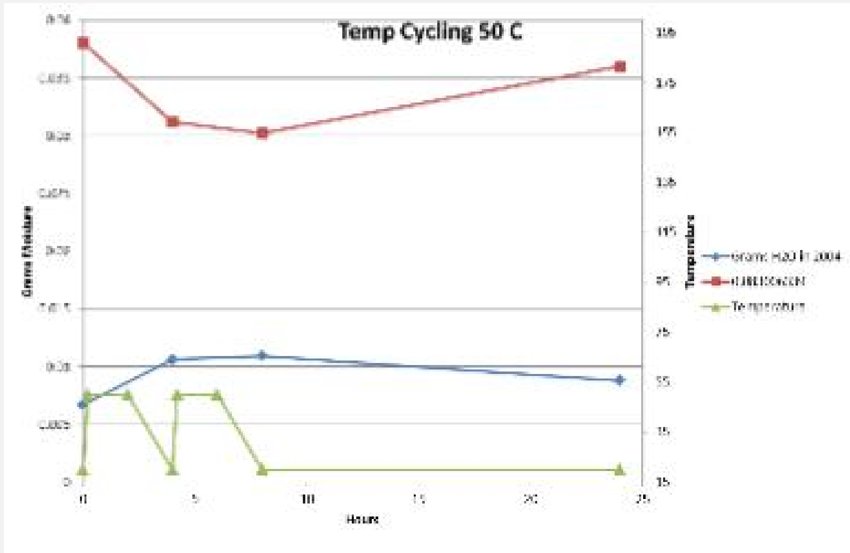
HAH Task 3: Parr Bomb Moisture Dynamics
3110/2004 Temperature Cycling

Significant increase in the amount of moisture transferred from 3110 to 2004 and back to 3110 in 20-70-20 cycles

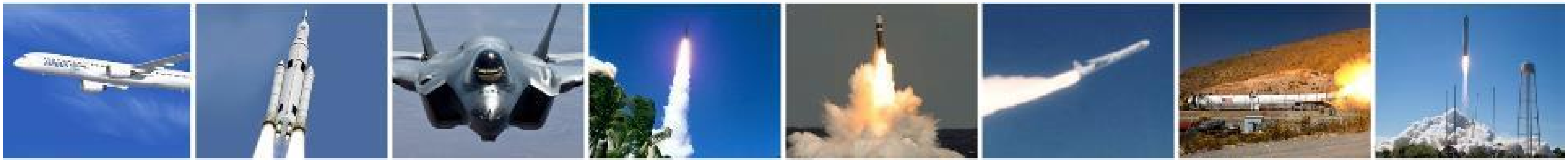




- Data shown with weight of moisture rather than percentage in formulations to illustrate quantity of moisture that moves
  - Starting percentages are 2.4% for 3110 and 0.15% for 2004
  - Weight is 1.6g of 3110 and 10.6g of 2004
  - Moisture introduced externally and allowed to equilibrate
- Significantly more moisture transfer at 70^{o}C than 60^{o}C, less transfer at 50^{o}C (40%, 28%, 18% out of 3110)
- Takes significant time at cool temp to fully reverse process



Crimp Data



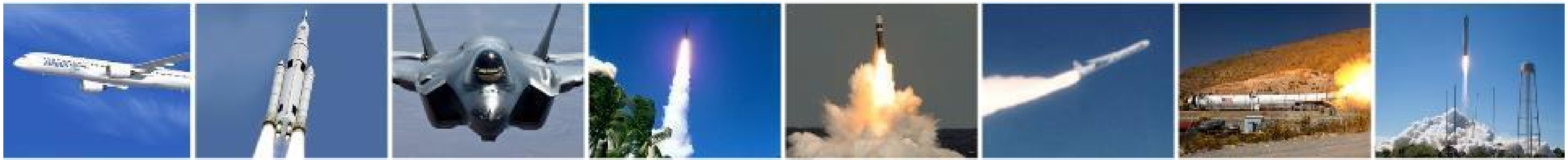
PSPI-L Crimp Outer Diameter

PSPI-L Crimp Outer Diameters (hand measured)

Prefix	Age	Count	Average	Stdev	Max	Min
FD/JD	Returned	593	52.60	0.12	52.79	52.16
YD	Returned	30	52.31	0.13	52.66	52.09
LT/LU	virgin	76	52.42	0.08	52.51	52.27
YD	virgin	10	52.22	0.05	52.28	52.15

- PSPI-L FD and JD inflators built circa 13 years ago have larger crimp ODs than YDs (GM inflators) built circa 7 years ago
- Virgin inflators tend to have lower and tighter controlled crimp ODs

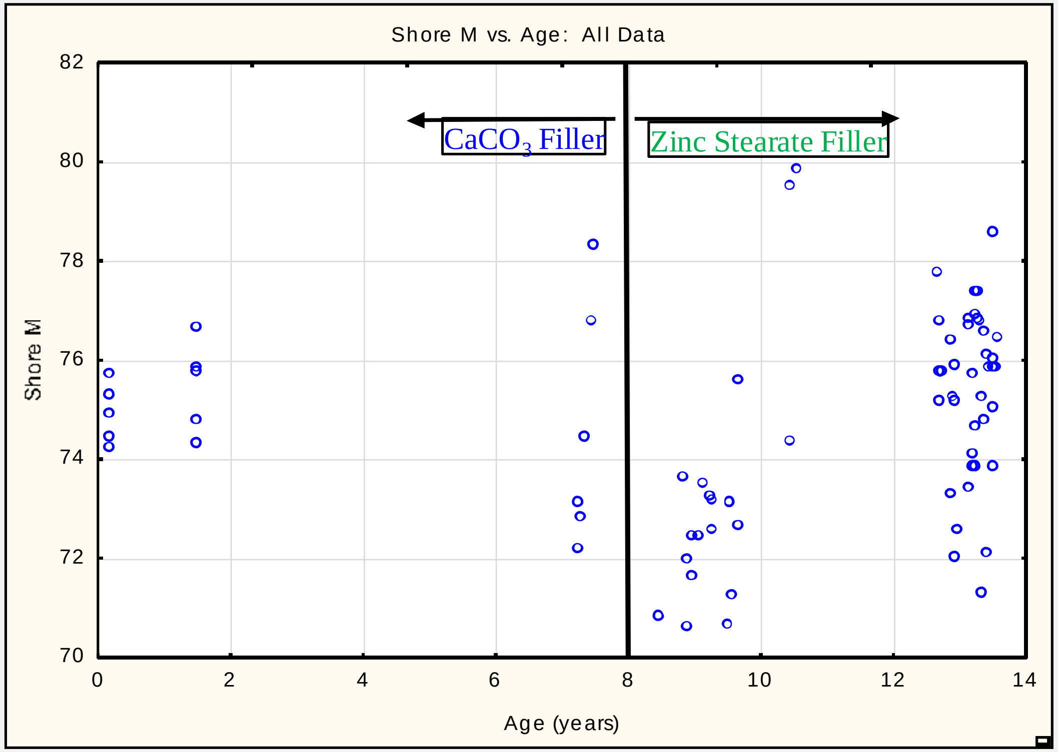
O-ring Testing

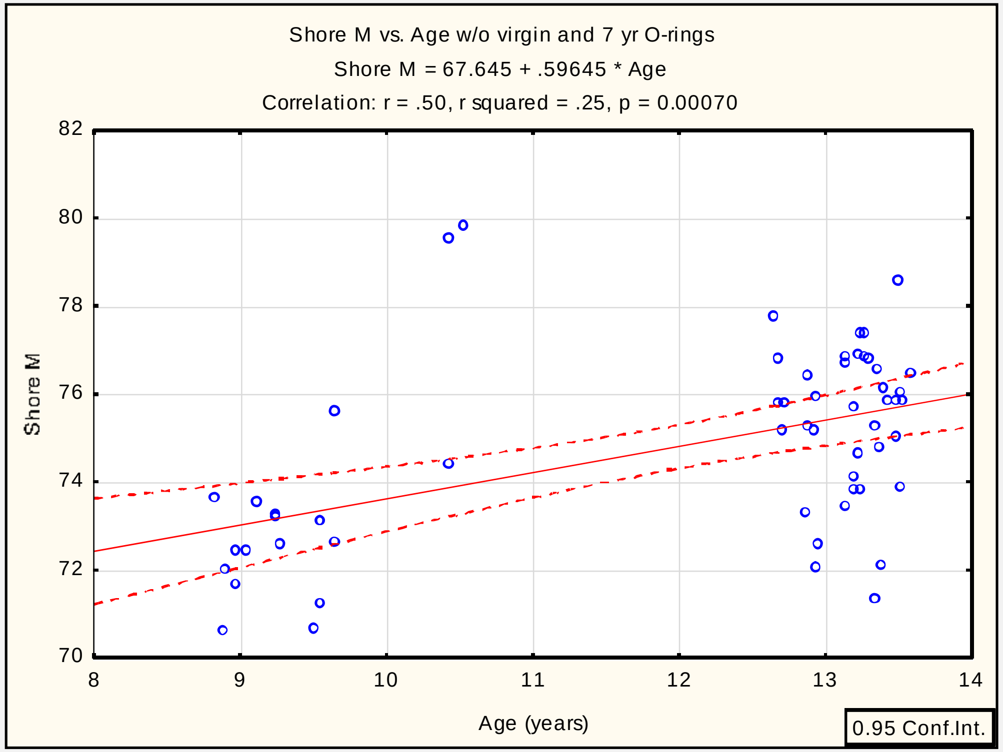


O ring Shore M Hardness vs. Age

- EPDM O rings newer than 8 years are compounded differently: May effect hardness
- The older AJ and FDs have O rings that are generally harder than those from YD and YPs
- A technical expert suggests all O-rings measured have acceptable hardness

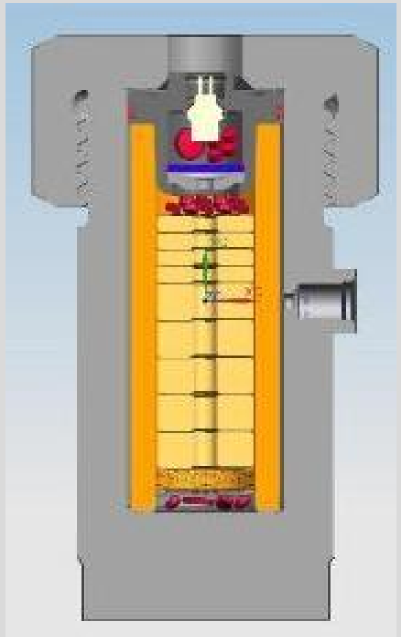
Type	Count	Ave Age (yr)	Shore M Avg	Shore M Med	Shore M Std Dev	Shore M Max	Shore M Min
LT (virgin)	5	1.5	75.5	75.8	0.9	76.7	74.3
FD (virgin)	5	0.2	74.9	74.9	0.6	75.7	74.3
YD (7 yr)	6	7.3	74.6	73.8	2.4	78.3	72.2
YD (>7yr)	15	9.4	73.6	73.1	2.8	79.9	70.6
YP (returned)	5	9.2	72.4	72.6	1.1	73.5	70.7
AJ (returned)	3	13.2	75.2	74.7	1.4	76.9	74.1
FD (returned)	33	13.2	75.4	75.9	1.7	78.6	71.3





GM PAB HAH, O-Ring Analysis

O-ring Cross Sections



Discussion







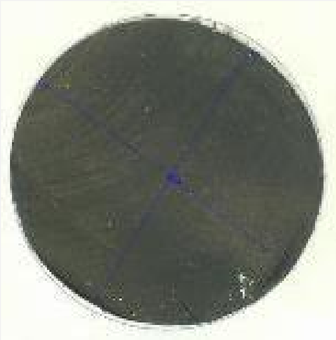

Introduction

- The GM PAB O-ring analysis focused on Shore M hardness
- As part of Phase III test methodology improvement efforts, O-ring cross sections of 12 GM PAB O-rings cross sections were analyzed via photomicrographs
  - The goal was to determine if the O-rings acquired a thermal set with age
    - O-rings contract more at cold than the corresponding metal of the O-ring notch
      - If the O-rings acquire a thermal set, leakage around the O-rings at cold temperatures is enhanced
        - Negative pressure during cold portions of diurnal cycles will pull moisture into the inflator
- Further CT data of inflators was analyzed to better determine the extent of O-ring squeeze in passenger inflators from both returned and virgin inflators
  - The greater the O-ring squeeze, the lower the propensity for moisture diffusion through the O-ring
- The data to be presented in the following section was reviewed internally and suggestions for DAB O-ring analyses were provided

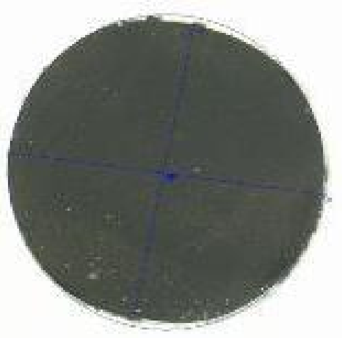
O-Ring Cross Section Analysis

Photomicrographs

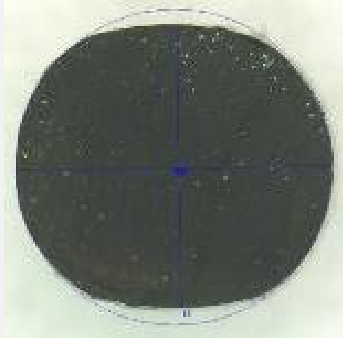
- O-ring descriptions in red font contain calcium carbonate filler whereas black fonts contain zinc stearate
- Y-axis heights are a function of both O-ring age and maximum crimp diameter
  - For example, 13 year O-rings have similar y-axis heights as 7-9 year O-rings but much larger crimp diameters



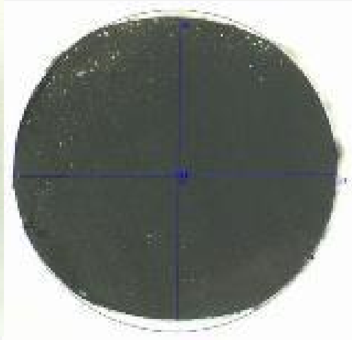
102145 YD, 0.2 y
Crimp-52.16 mm
Y-axis-2.54 mm
Virgin,
Monclova



91845 LT, 1.5 y
Crimp-52.29 mm
Bore ID-47.50 mm
Y-axis-2.51 mm
Virgin,
Monclova



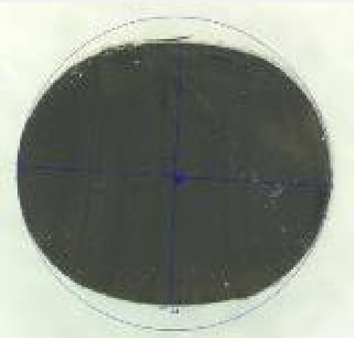
101935 YD, 7.2 y
Crimp-52.38 mm
Y-axis-2.36 mm
GM Yukon
Pensacola, FL



101998 YD, 7.5 y
Crimp-52.44 mm
Y-axis-2.45 mm
GM Silverado,
Stuart, FL

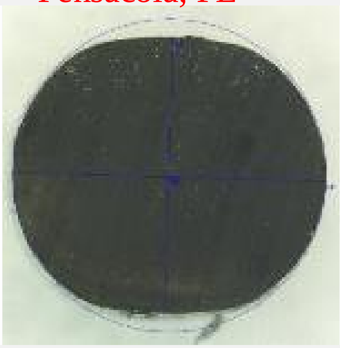
101940 YD, 8.9 y
Crimp-52.33 mm
Y-axis-2.40 mm
GM Escalade,
Tampa, FL

102002 YP, 9.3 y
Crimp-unknown
Y-axis-2.28 mm
GM Silverado,
Orlando, FL



101951 YD, 9.5 y
Crimp-unknown
Y-axis-2.30 mm
GM Yukon XL,
Palm Harbor, FL

101925 YD, 10.4 y
Crimp-unknown
Y-axis-2.27 mm
GM Yukon
Milton, FL



95229 FD, 13.1 y
Crimp-52.81 mm
Y-axis-2.38 mm
Non GM Car 1
Puerto Rico

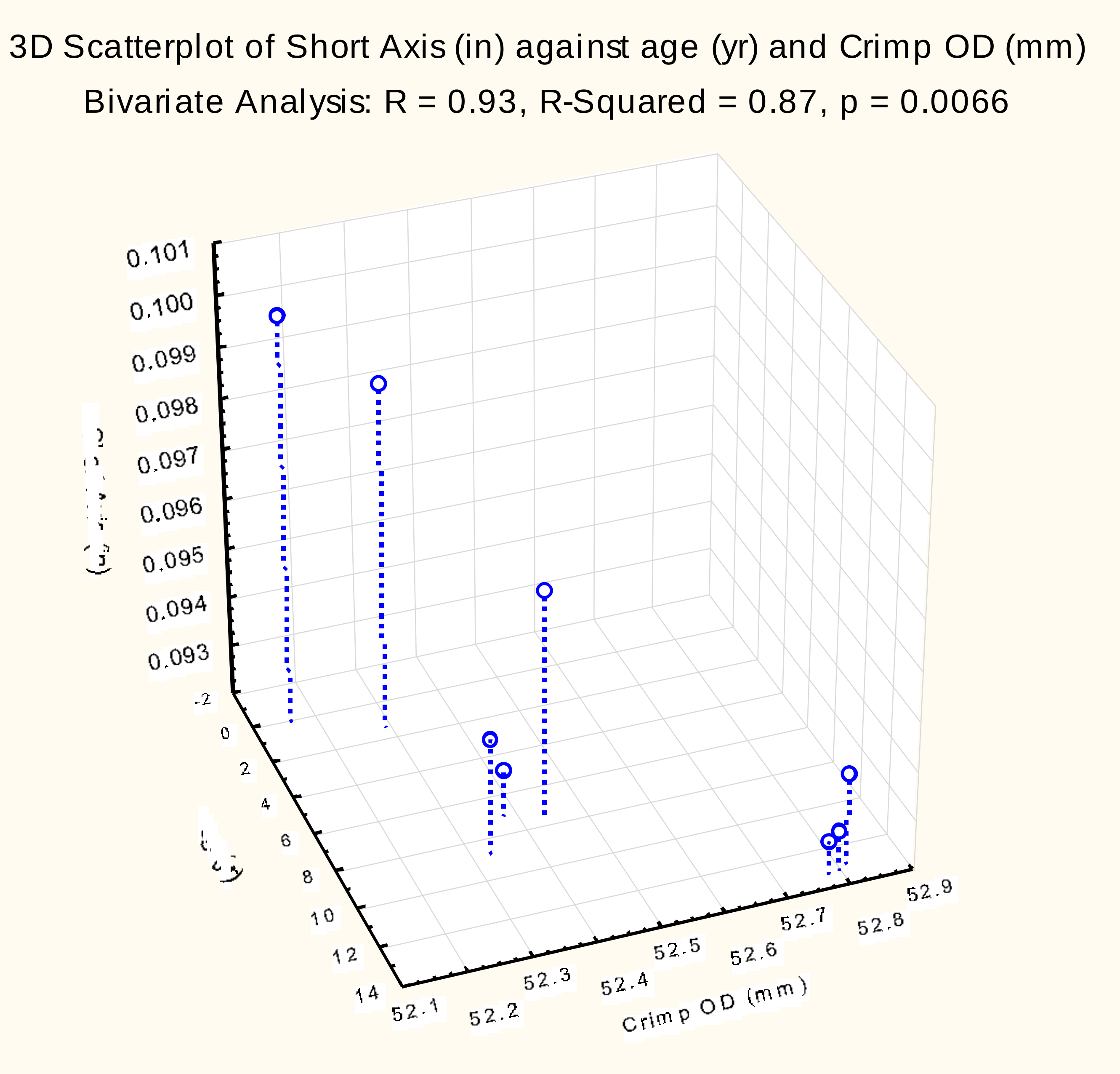
91368 AJ, 13.2 y
Crimp-unknown
Y-axis-2.34 mm
Non GM Car 3
Puerto Rico

92191 FD, 13.3 y
Crimp-52.80 mm
Bore ID-47.65 mm
Y-axis-2.36 mm
Non GM Car 1
Ft Walton Beach, FL

94918 FD, 13.4 y
Crimp-52.78 mm
Bore ID-47.66 mm
Y-axis-2.35 mm
Non GM Car 1
Panama City, FL

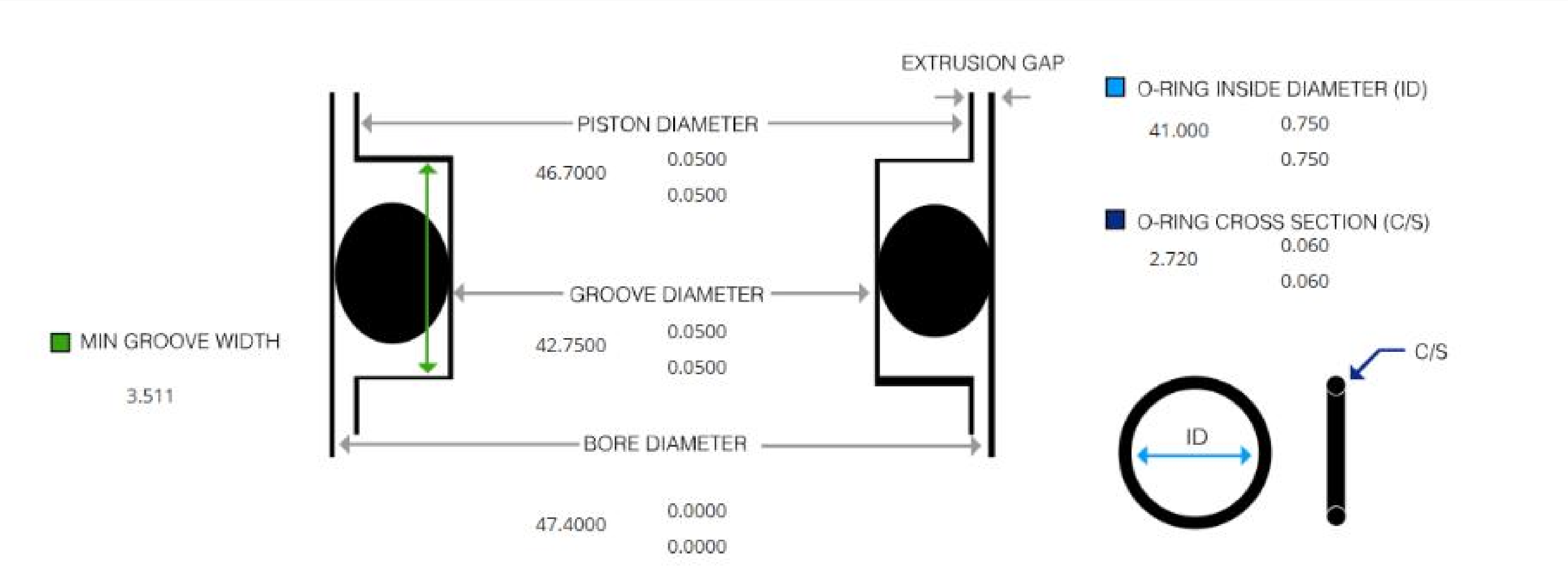
O-Ring Cross Section Analysis
Statistical Analysis

- O-ring y-axis height is in direction of the crimp
  - Trends with both O-ring age and Crimp OD
- O-ring x-axis width has no such correlation.
- Driver airbag O-ring analysis will focus on O-ring cross section instead of Shore M analysis

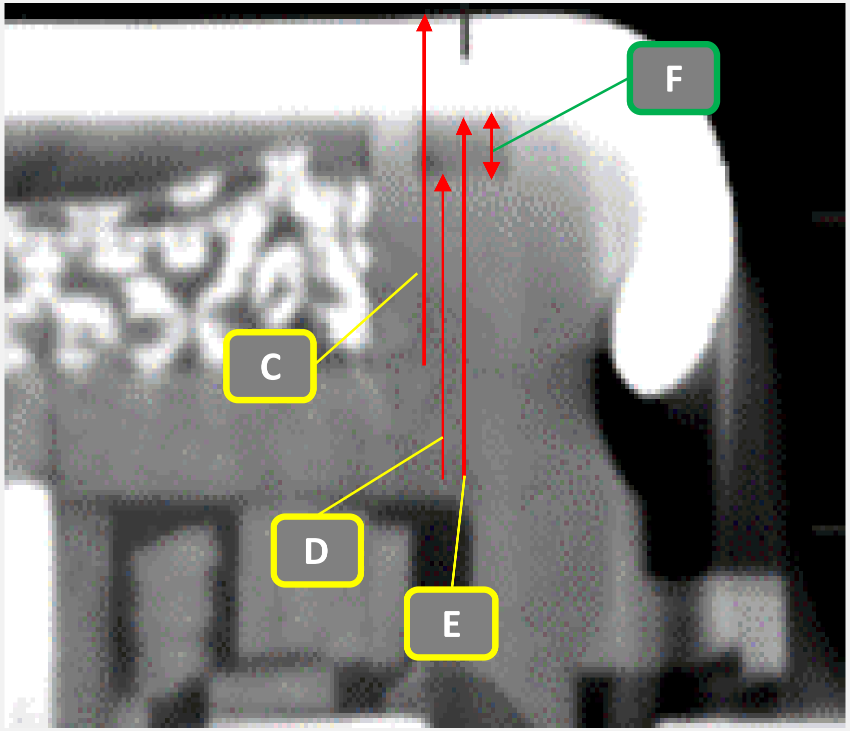


Bore Diameter Definition

- Passenger inflator case "bore diameter" is a measure of O-ring squeeze
  - Similar to Maximum Crimp OD
- In the GM DAB program, O-ring cross section, inflator bore diameter and groove height will be measured and the results analyzed



O-ring Related ICAM Analysis Measurements

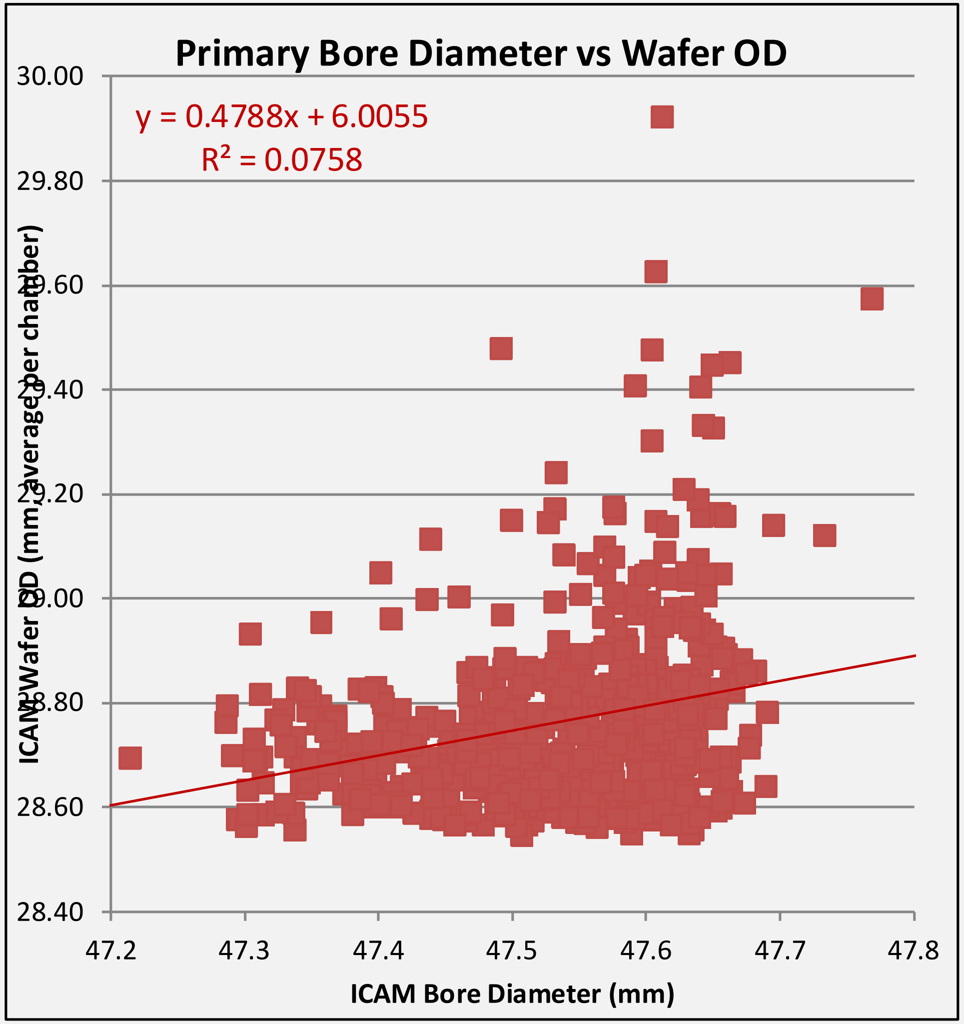


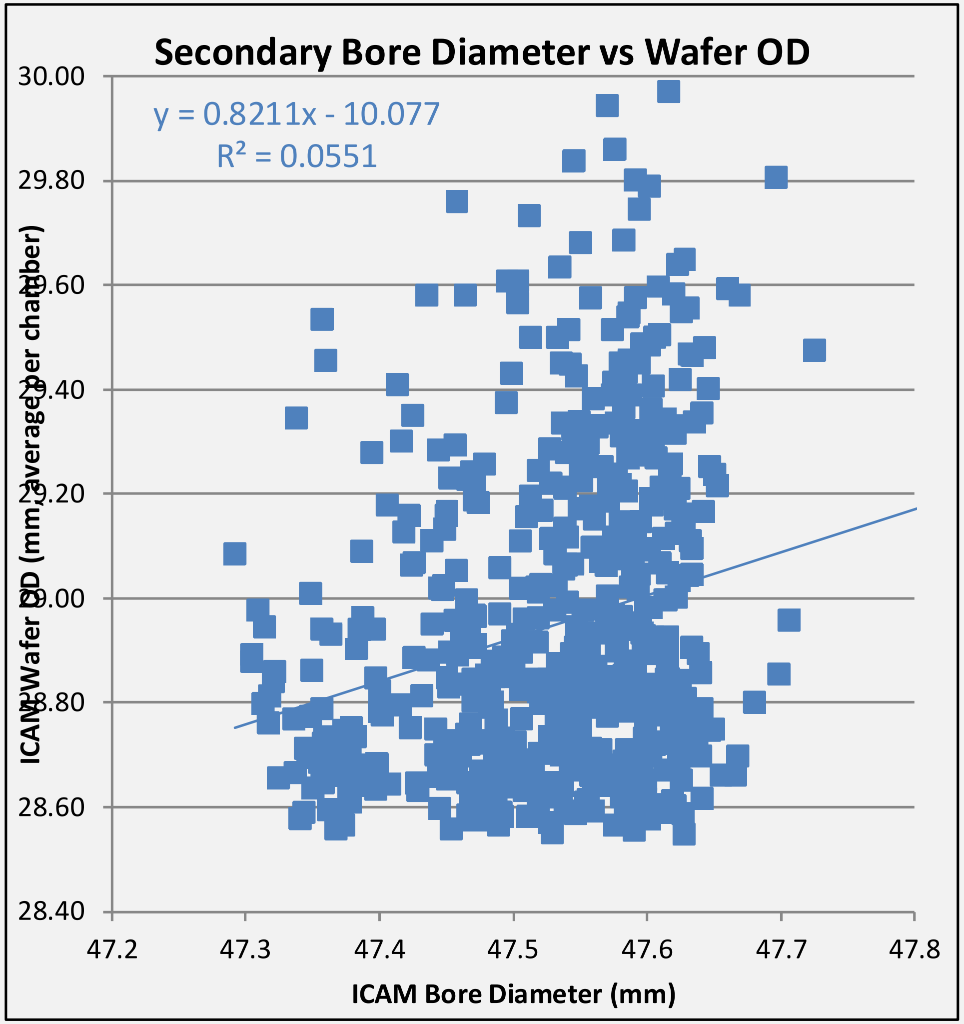
C	Case_Pri_oRingNotch_outDiam	Circle fitted to ALL thetas
E	Case_Pri_oRingNotch_innDiam	Circle fitted to ALL thetas
D	Oring_Pri_endPlate_innDiam	Circle fitted to ALL thetas
F	Oring_Pri_notchSpaceMax Oring_Pri_notchSpaceMed Oring_Pri_notchSpace95th	Measured independently at EACH theta, then output the MED (50^{th}), 95^{th}, MAX (100^{th}) percentile of those independent measures

- Bore diameter (Measurement E) is a measurement determined as part of the ICAM CT analysis of passenger inflators
- Over 580 PSPI-L inflators were CT scanned and ICAM analyzed as part of Phase I/II
  - Any correlations between wafer health and bore diameter can be investigated

Plots of Wafer OD vs Bore Diameter

- Similar correlations of Bore Diameter with Wafer OD
  - ➢ Shows that leakage due to poor O-ring sealing contributes to wafer damage with age
  - ➢ Low correlation coefficients suggest other factors also contribute, e.g., climate, other leak paths





Squeeze Analyses, PSPI-L Inflators

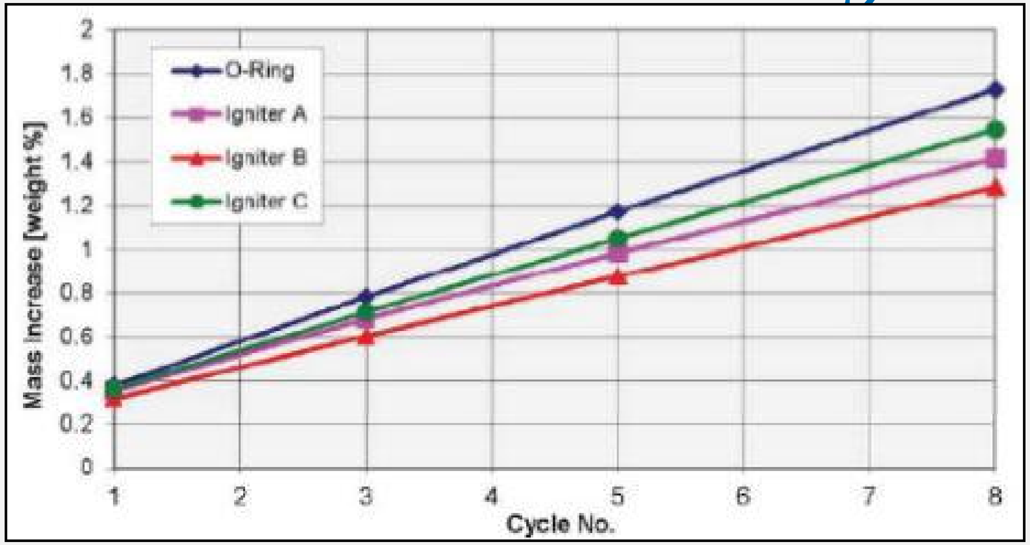
- Selected inflator populations were examined for extent of O-ring squeeze
  - Extent of O-ring squeeze is less in the older population of inflators, circa 2003
    - Greater O-ring squeeze will minimize diffusion of water vapor through the O-ring
    - If the O-ring has acquired a permanent O-ring set, leakage of moisture around the O-ring at cold portion of the diurnal cycle may still occur

Population ID	Percentile	Bore Diameter (mm)	% Squeeze (minimum)*	% Squeeze (average)*	% Squeeze (maximum)*
1162 ea PSPI-L FD and JD primary and secondary closures (returns except 62)	5th	47.35	7	12.65	18.3
	50th	47.55	3.1	8.85	14.6
	95th	47.65	1.1	6.95	12.8
62 ea PSPI-L LT and LU primary and secondary closures (virgin)	5th	47.37	6.6	12.25	17.9
	50th	47.48	4.5	10.2	15.9
	95th	47.52	3.7	9.45	15.2
340 ea SPI YP, PSPI-L FD & YD primary and secondary closures (virgin), produced on Armada Prototype Line	5th	47.18	10.3	15.85	21.4
	50th	47.26	8.8	14.35	19.9
	95th	47.31	7.8	13.4	19.0

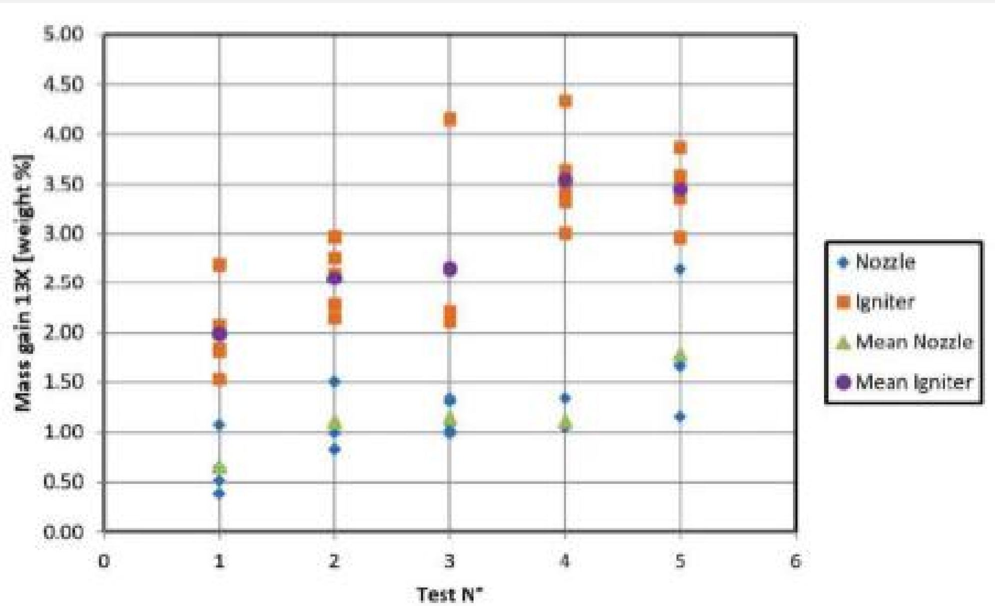
*With compensation for stretch

Fraunhofer Inflator Leak Path Test Summary

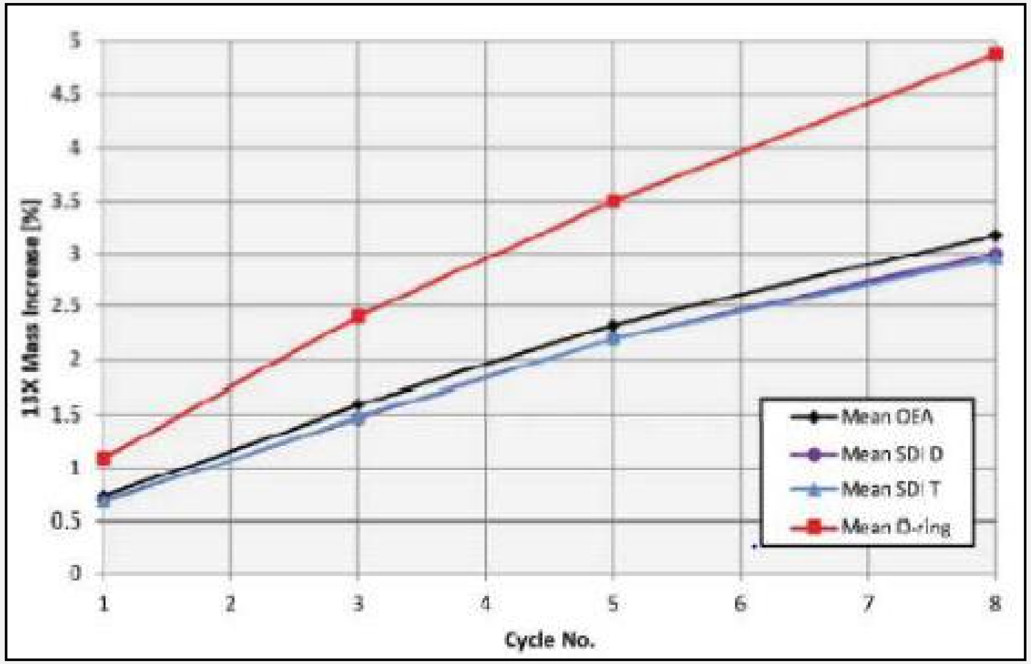
- Leak path test data suggest that leakage can occur around the igniter O-ring as well as around the closure O-ring
  - Leakage is 2-2.5 times faster for returned O-ring based seals
    - Change in rate greatest for Closure O-ring seal
- Data show leakage via tape seals over nozzles but rates appear to be slower.



13X (3 g) mass increase as a function of diurnal cycles-seals from virgin inflators



Moisture ingress rates comparing igniter to tape seal leak paths

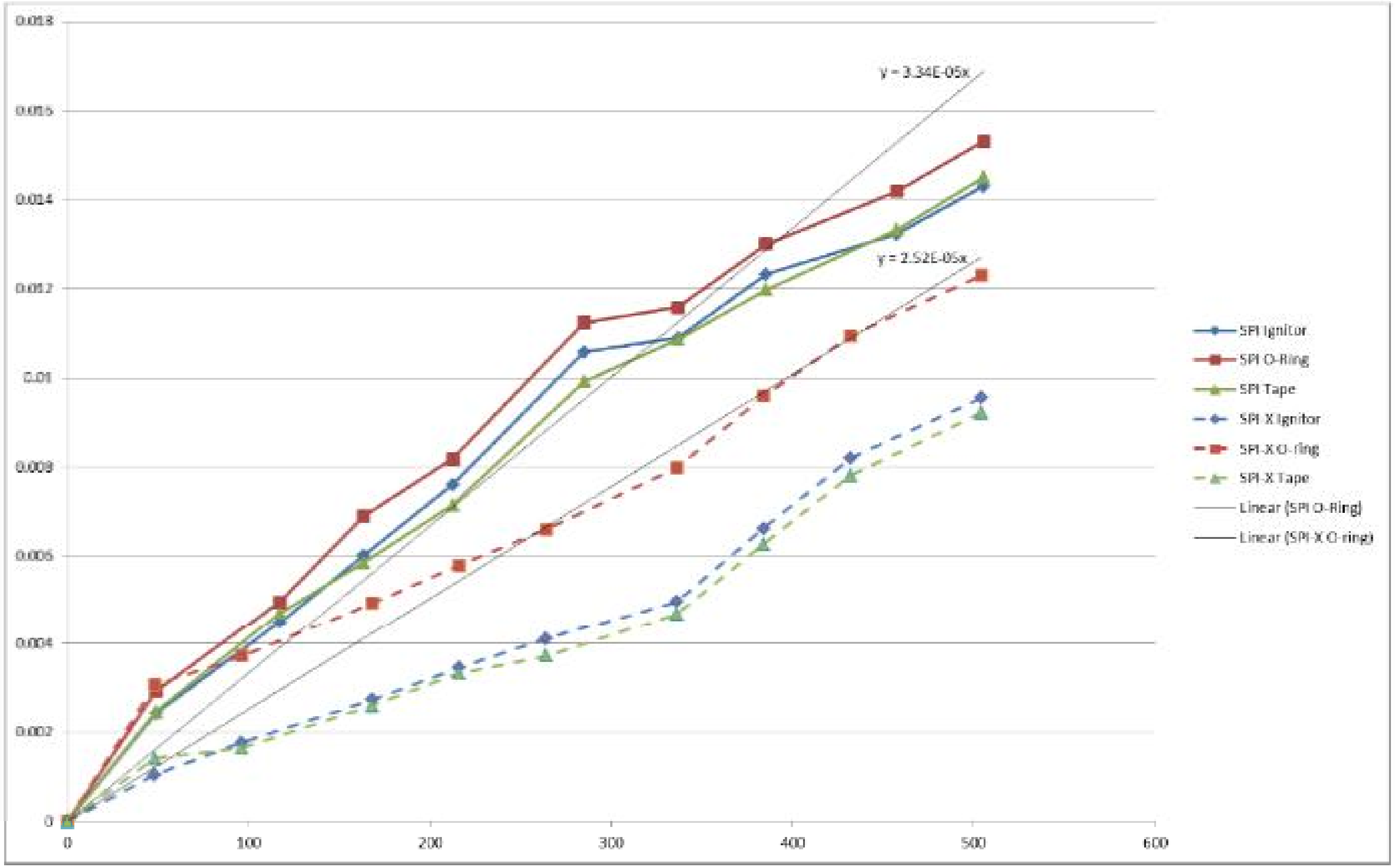


13X (3 g) mass increase as a function of diurnal cycles-seals from returned inflators

Takata Leak Test Results

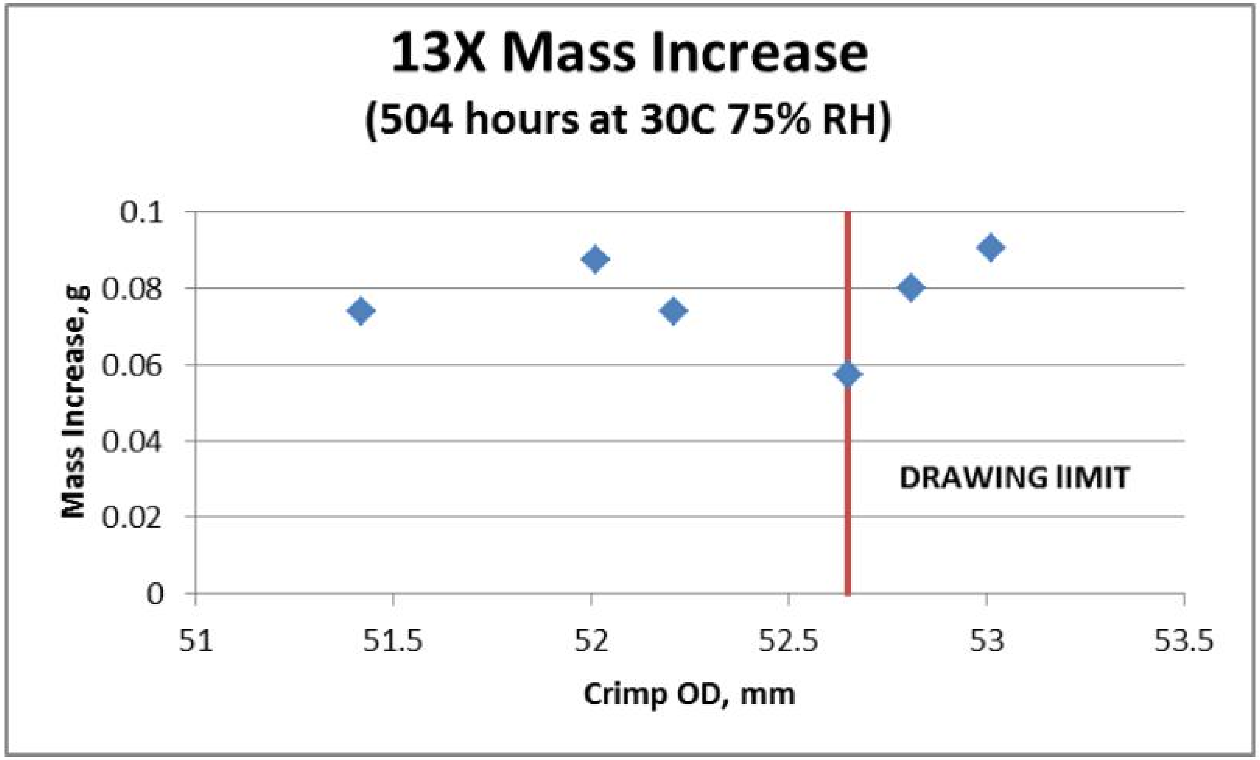
- Takata leak test results suggest that all three leak paths are viable, not just the closure O-ring

- Using a consistent test set-up and external environment (30C 75% RH), the SPI-X analog transferred significantly less water into the test device than the SPI analog

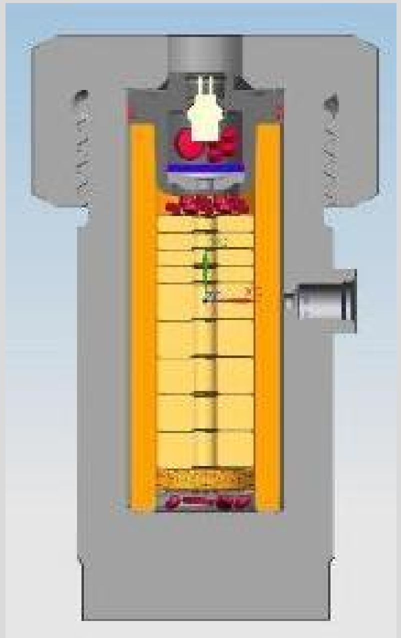


Impact of Passenger Crimp Diameter

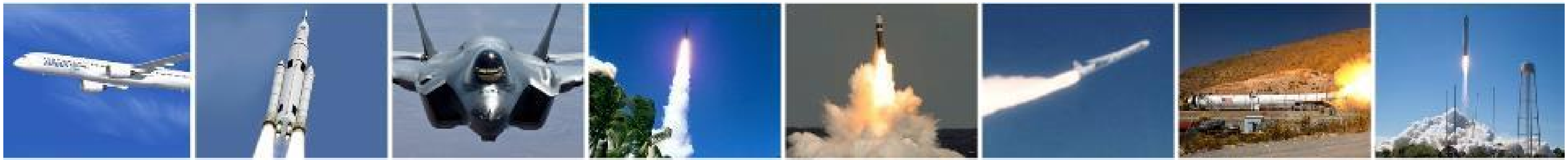
- The chart below shows the total 13X moisture gain in the test devices.
- The results show no increase in moisture ingress with increasing diameter.



1680 CT Scanning Results

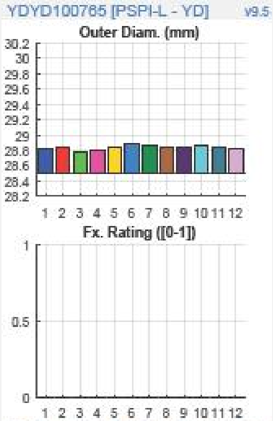


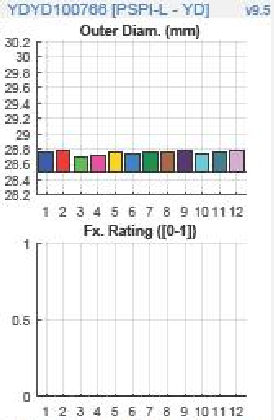
Discussion



YD 1680 Cycle Nominal Moisture

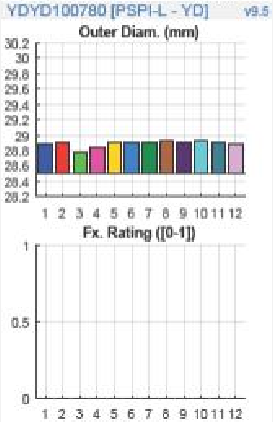
Nominal 20-50 C

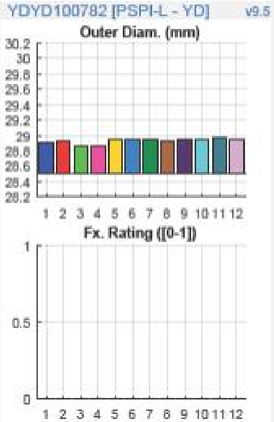




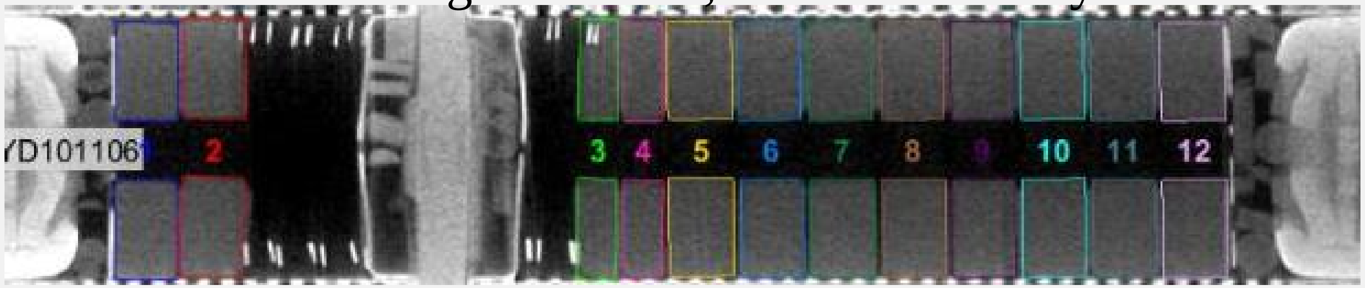
100766 Nominal Moisture, 1680 20-50 C Cycles

Nominal 20-60 C

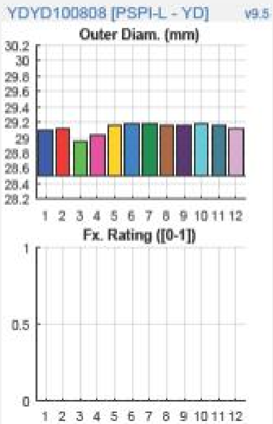


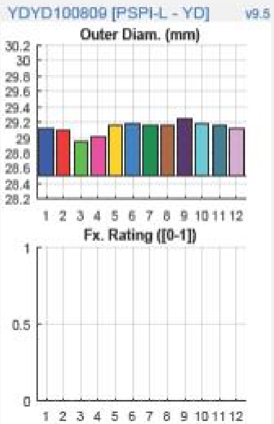


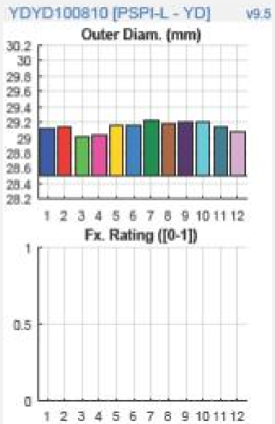
101106 High Moisture, 1680 20-70 C Cycles

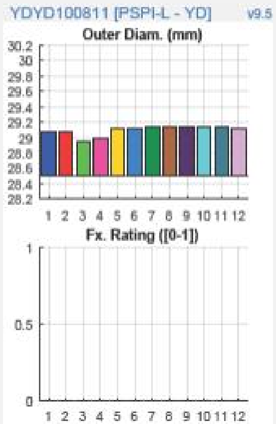


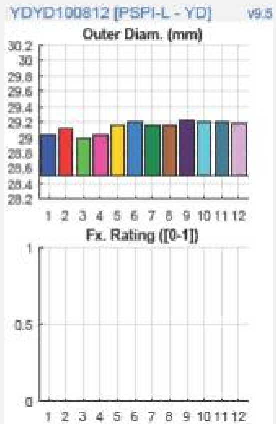
Nominal 20-70 C

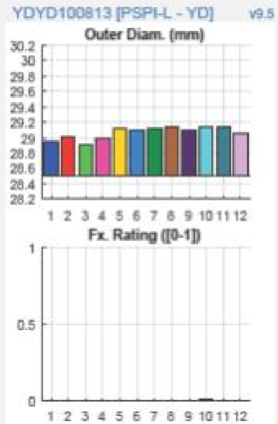


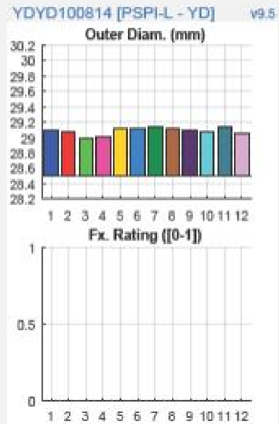






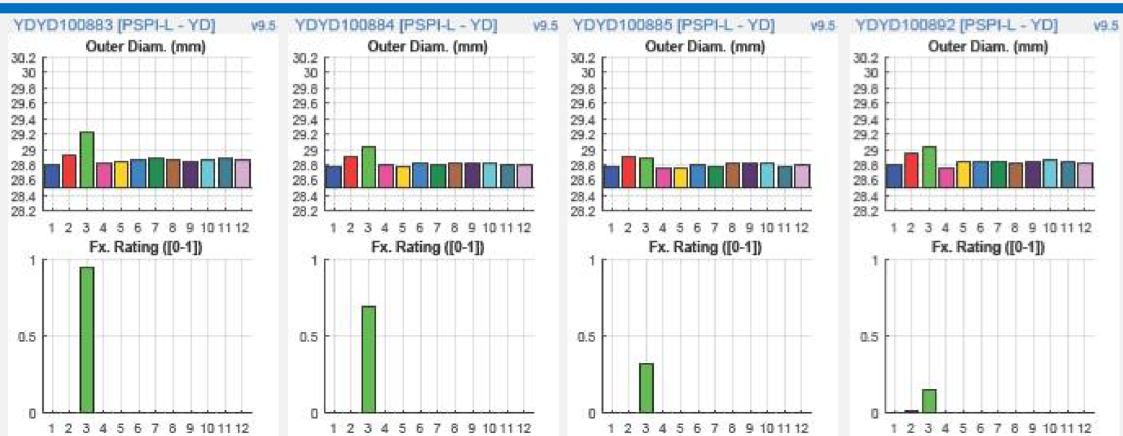




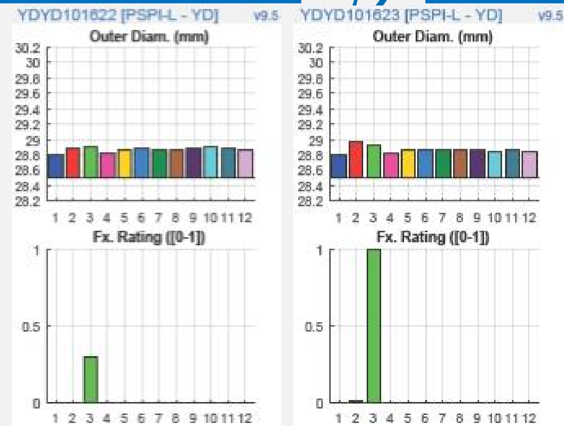


YD 1680 Cycle Mid Moisture

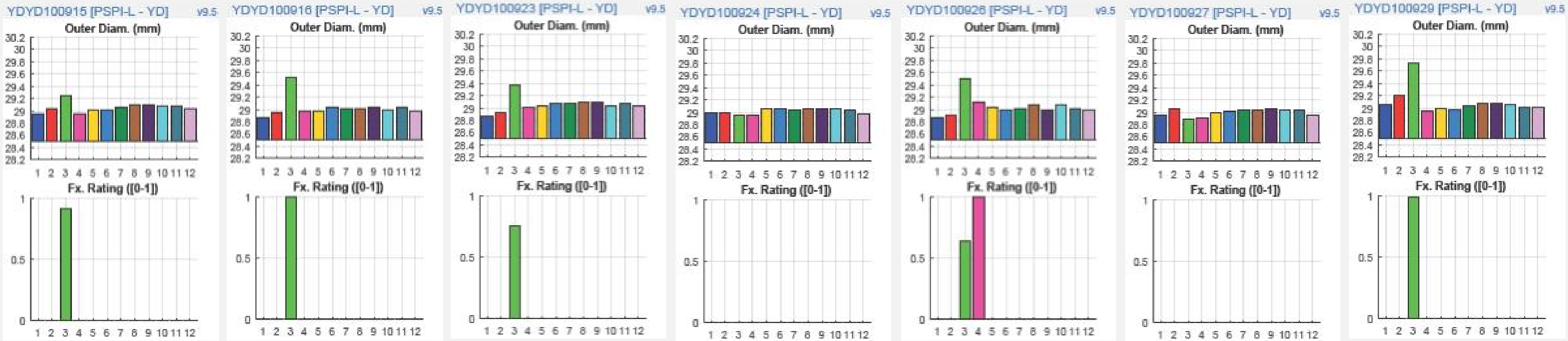
Mid
20-50 C



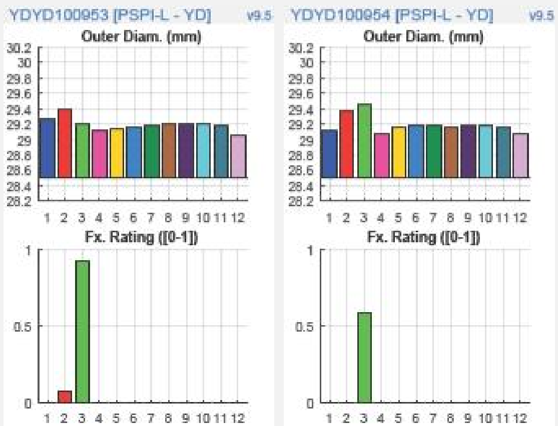
No ICAM data for YD100894



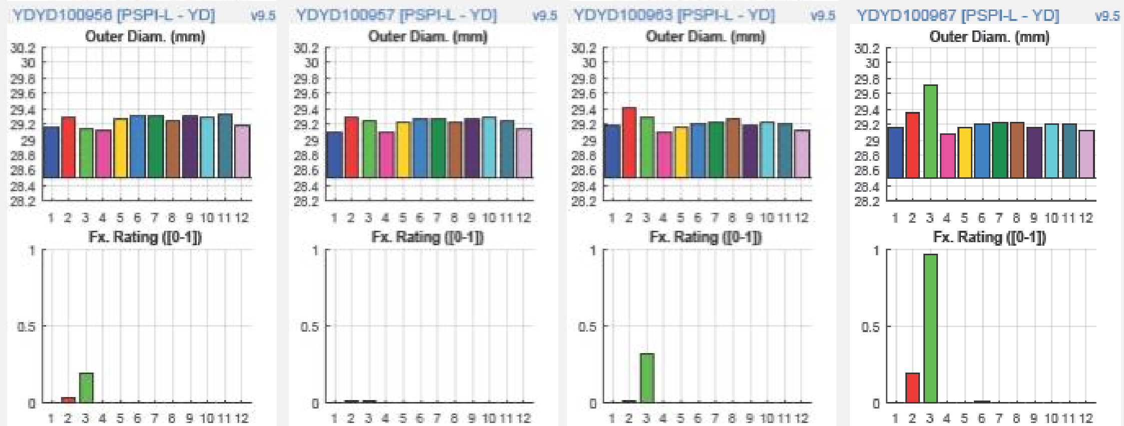
Mid
20-60 C



Mid
20-70 C

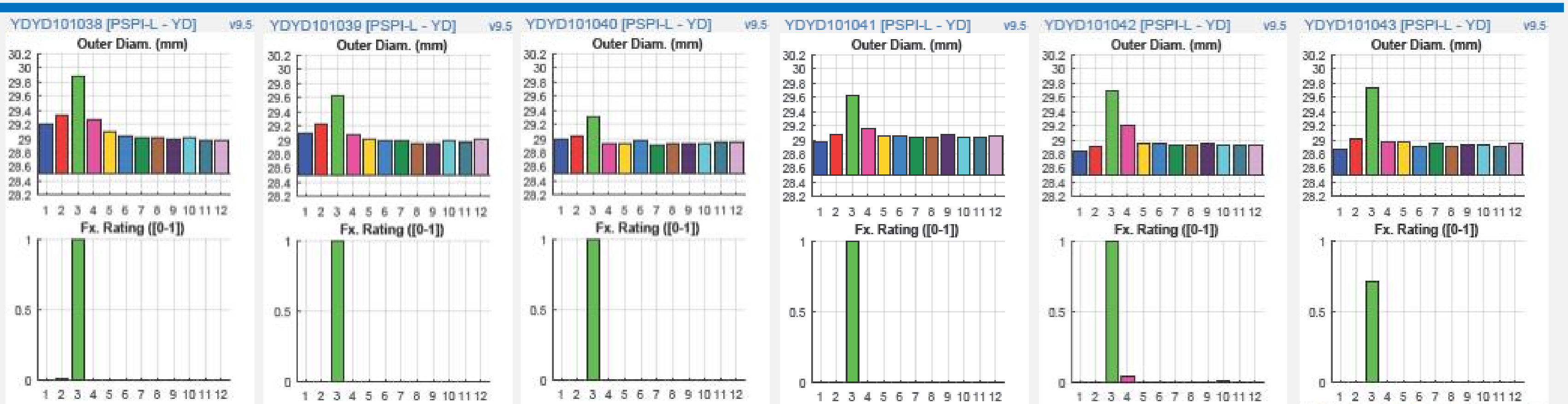


No ICAM data for YD100955



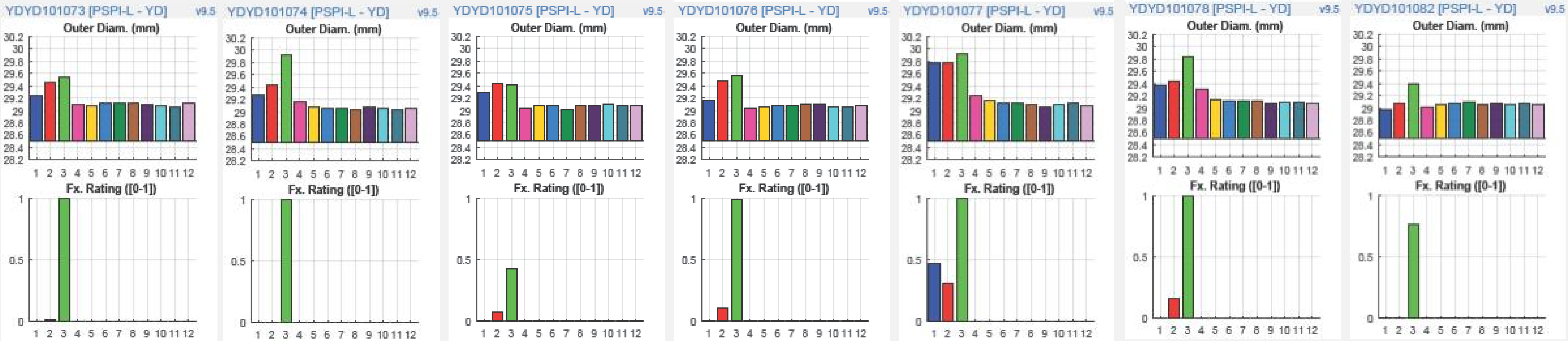
YD 1680 Cycle High Moisture

High
20-50 C

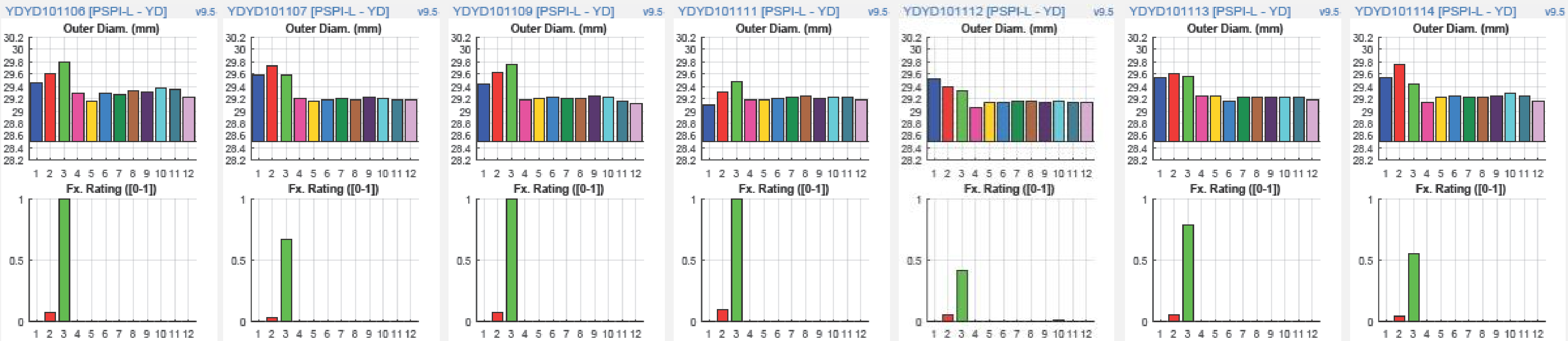


No ICAM data for YD101044

High
20-60 C

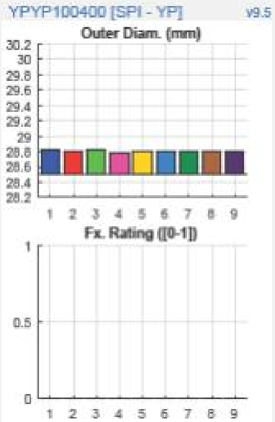


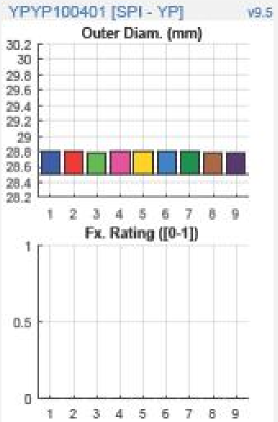
High
20-70 C



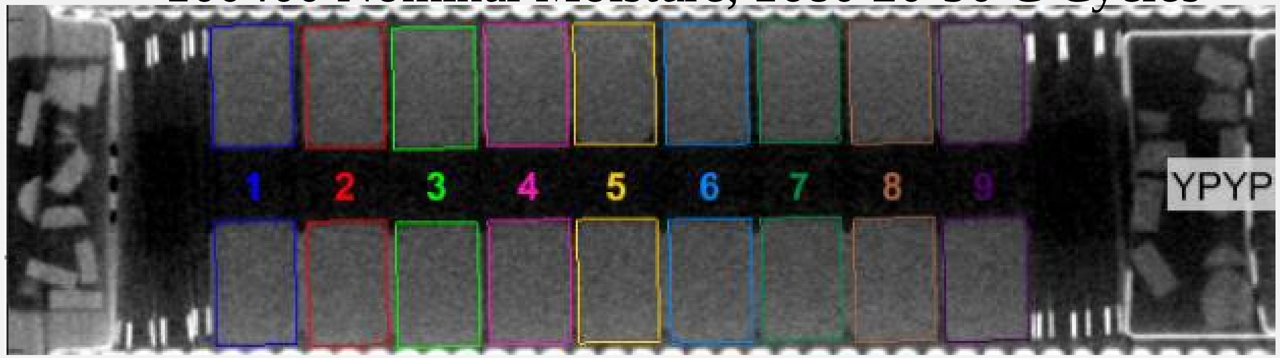
YP 1680 Cycle Nominal Moisture

Nominal 20-50 C

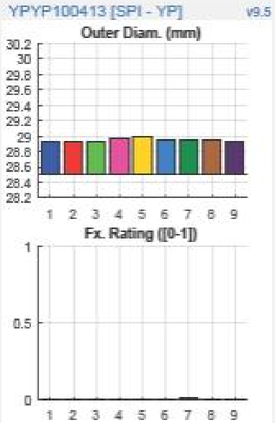


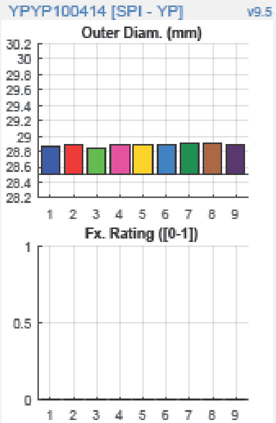


100400 Nominal Moisture, 1680 20-50 C Cycles

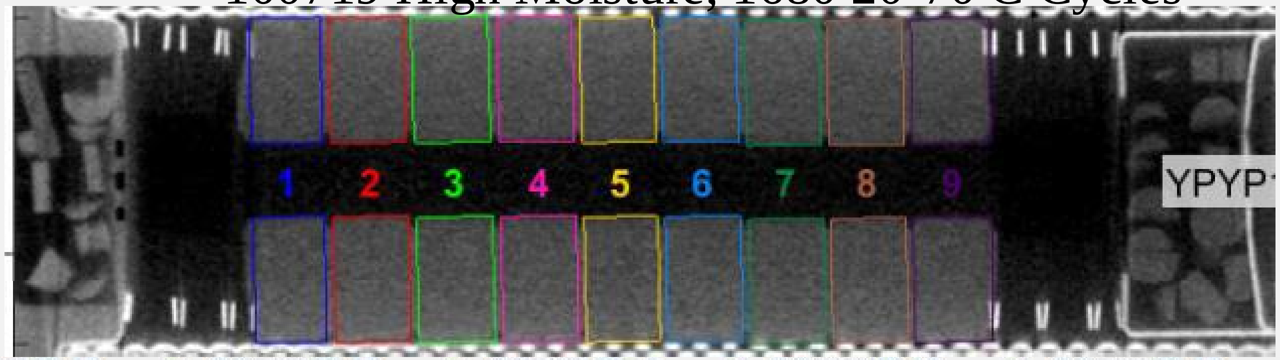


Nominal 20-60 C

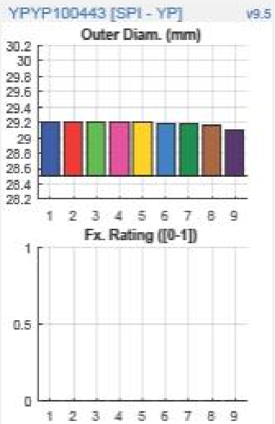


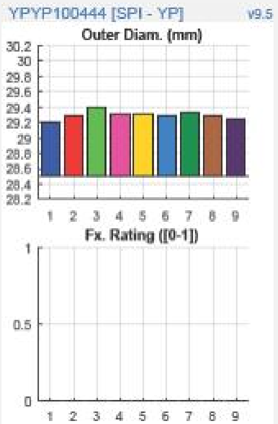


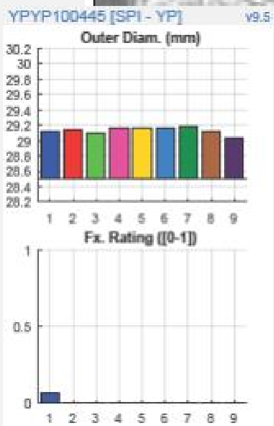
100719 High Moisture, 1680 20-70 C Cycles

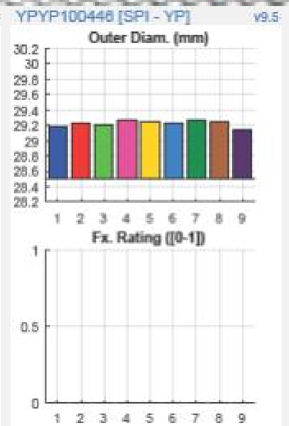


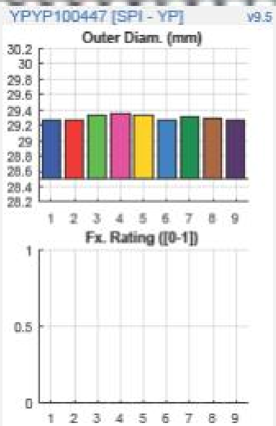
Nominal 20-70 C

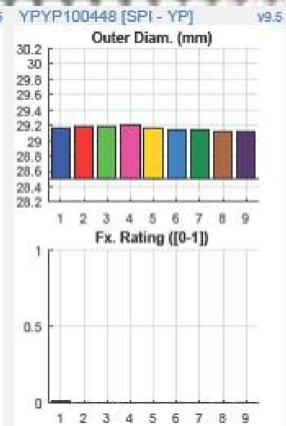


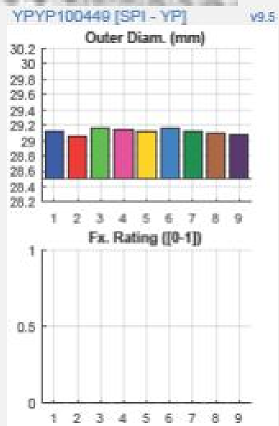






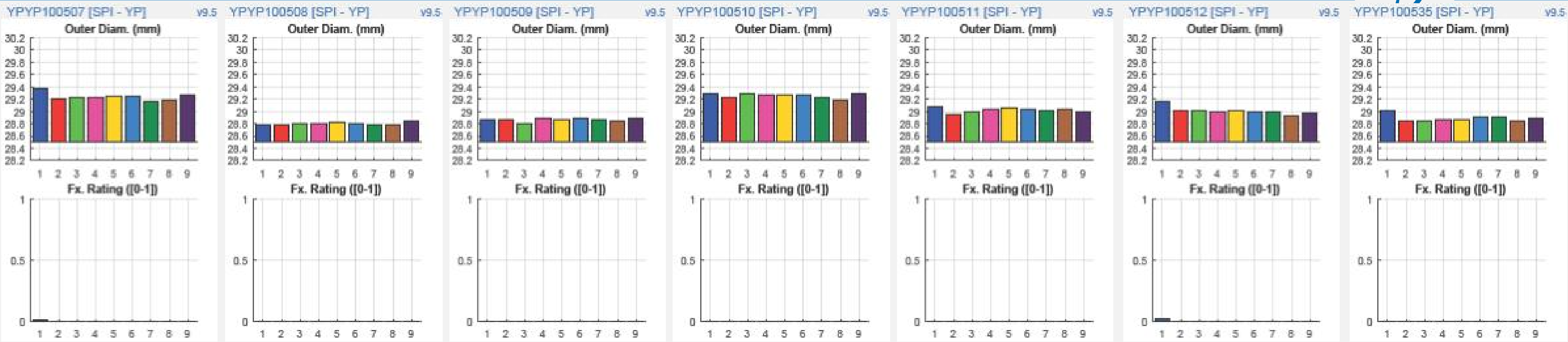




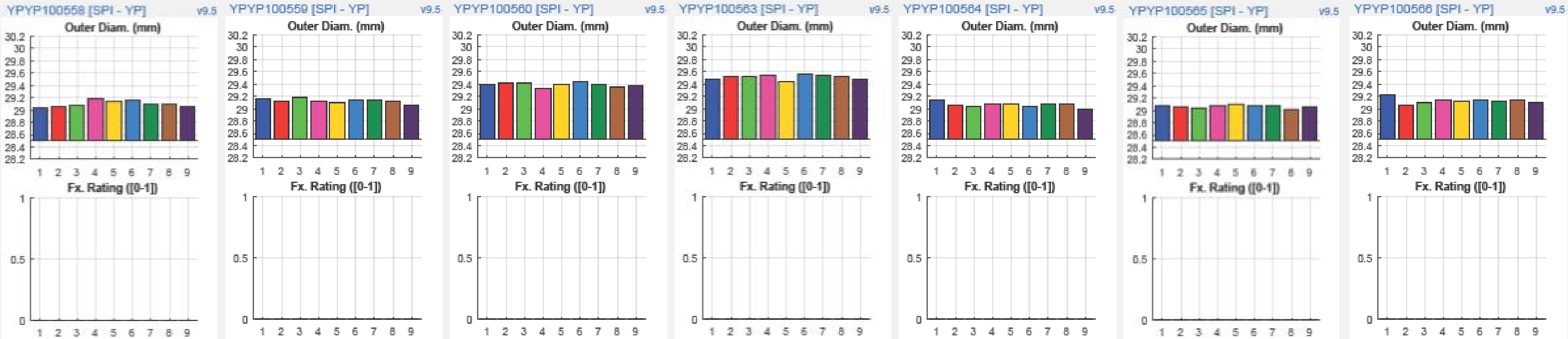


YP 1680 Cycle Mid Moisture

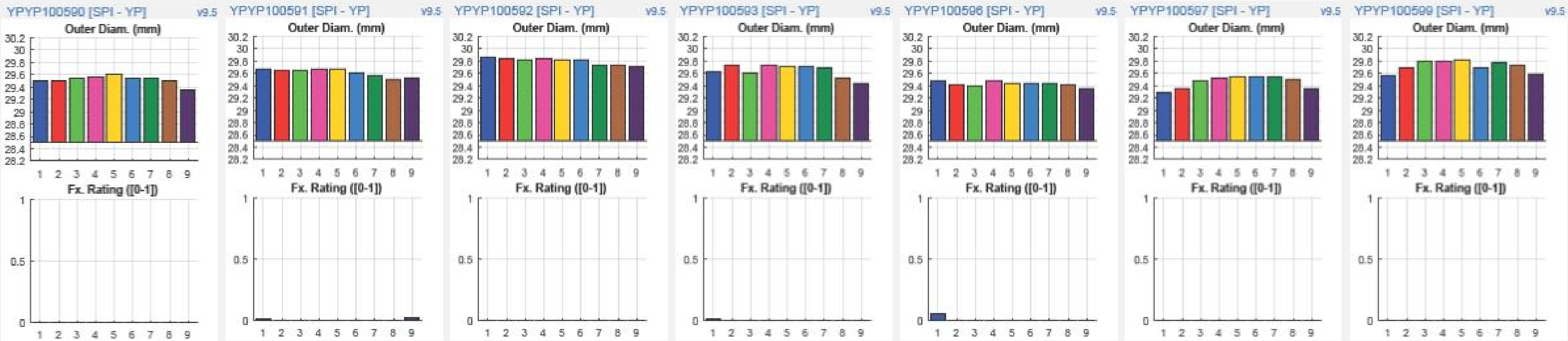
Mid
20-50 C



Mid
20-60 C



Mid
20-70 C

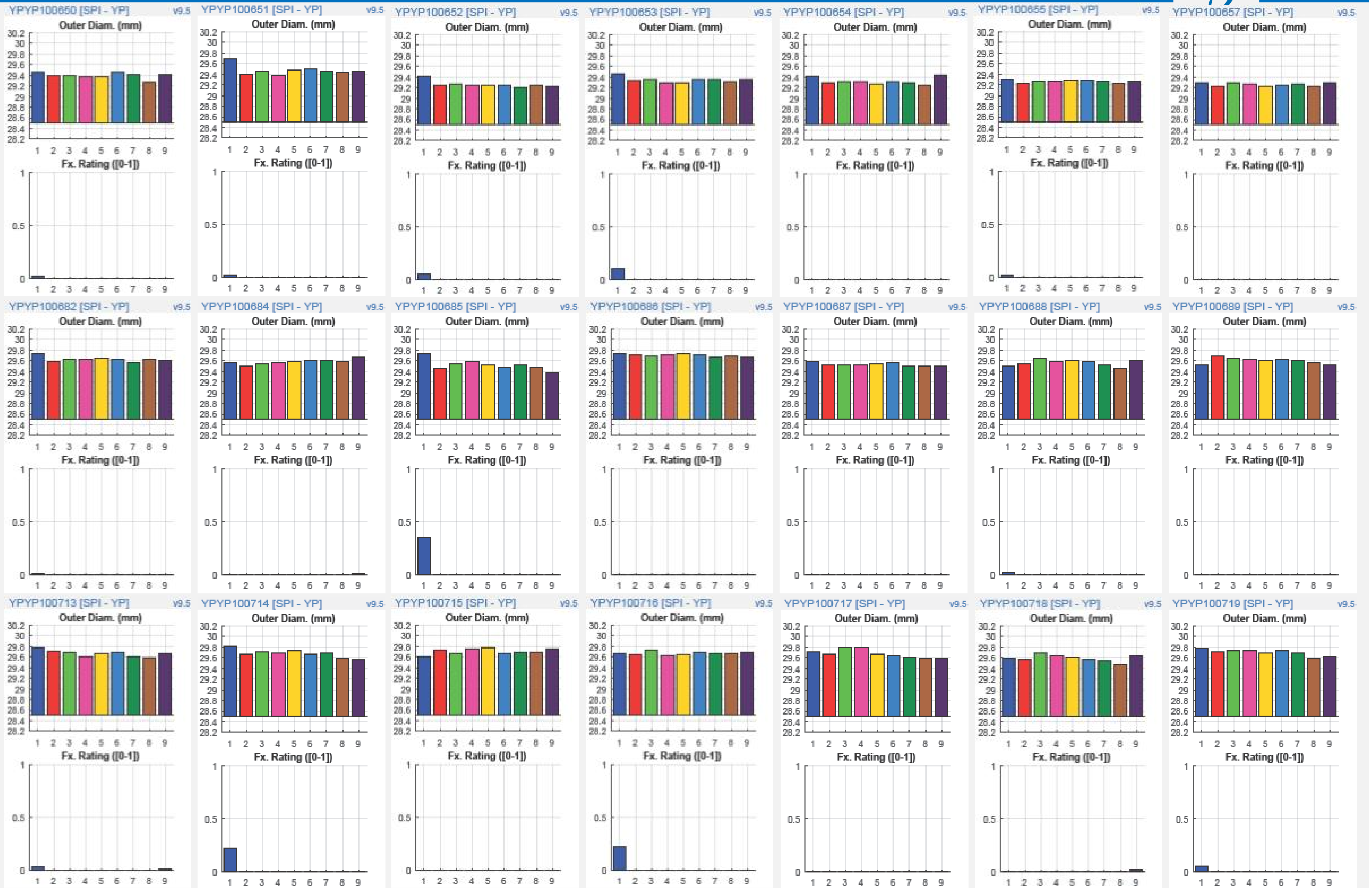


YP 1680 Cycle High Moisture

High
20-50 C

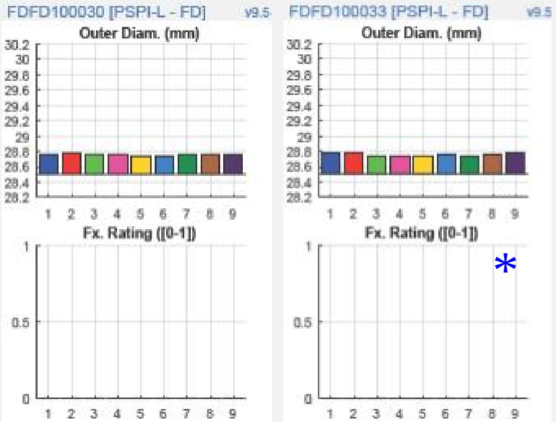
High
20-60 C

High
20-70 C

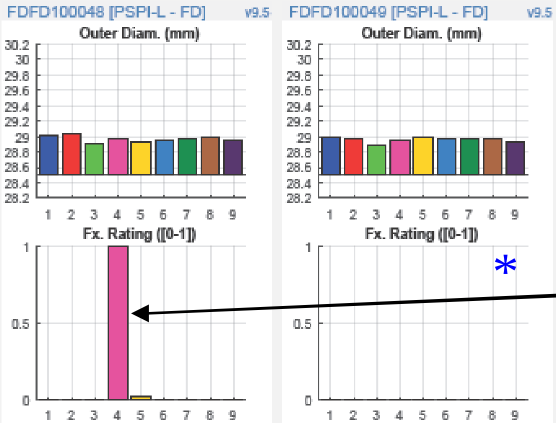


FD 1680 Cycle Nominal Moisture

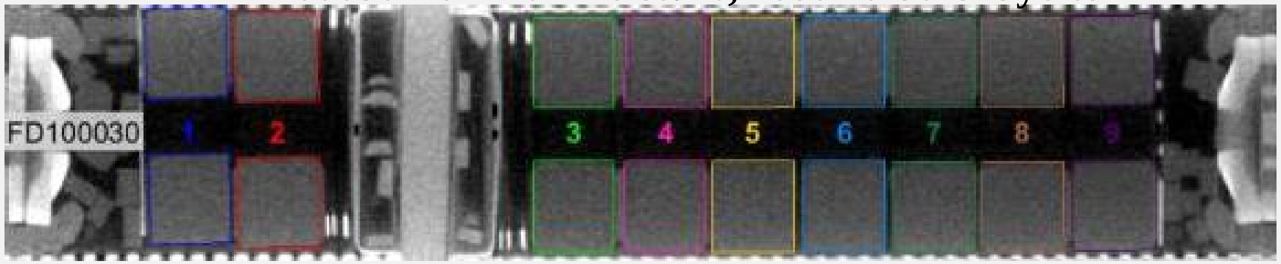
Nominal
20-50 C



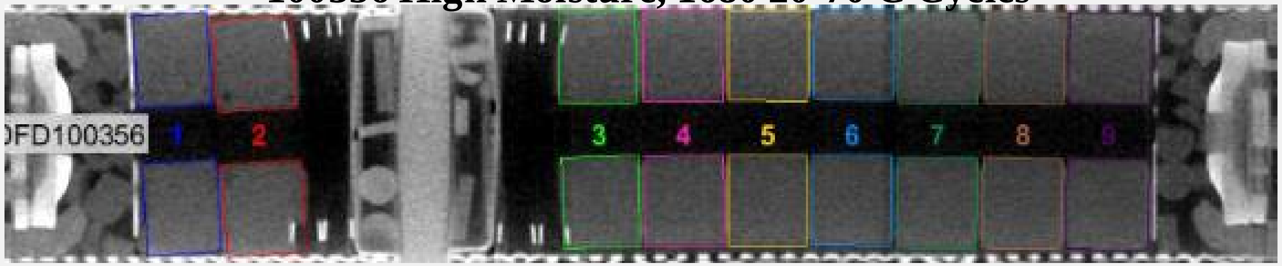
Nominal
20-60 C



100030 Nominal Moisture, 1680 20-50 C Cycles

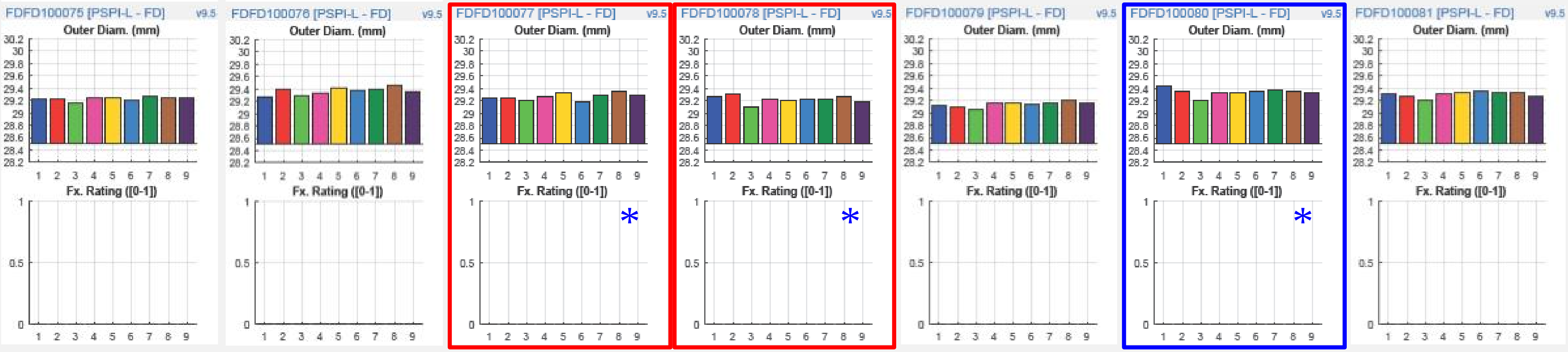


100356 High Moisture, 1680 20-70 C Cycles



* Designates tested inflators

Nominal
20-70 C



FD 1680 Cycle Mid Moisture

Mid
20-50 C

Mid
20-60 C

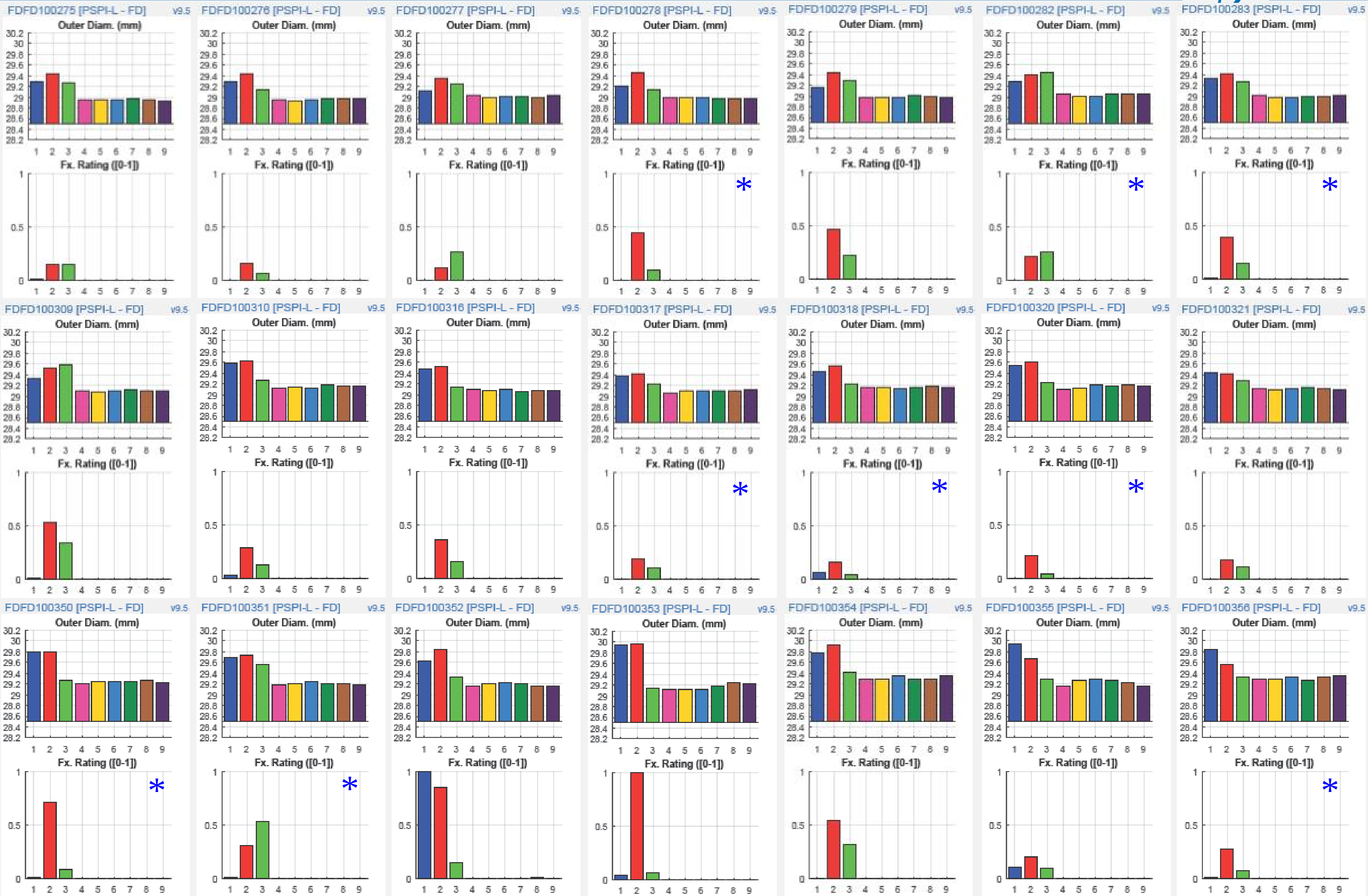
Mid
20-70 C

FD 1680 Cycle High Moisture

High
20-50 C

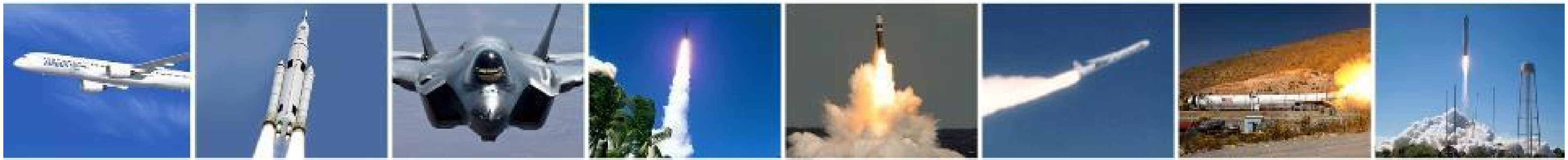
High
20-60 C

High
20-70 C



Quench Testing

Discussion



GM Quench Test Scope of Work / Status

- Quench testing of 8 SPI YP and 8 PSPI-L YD inflators
  - ➢ Contains a mix of virgin inflators, field aged inflators, and artificially aged inflators
  - ➢ All inflators have been fired.
  - ➢ Micro CT scanning of all inflators is complete and analyzed
- Design comparisons between units that have been quench tested:

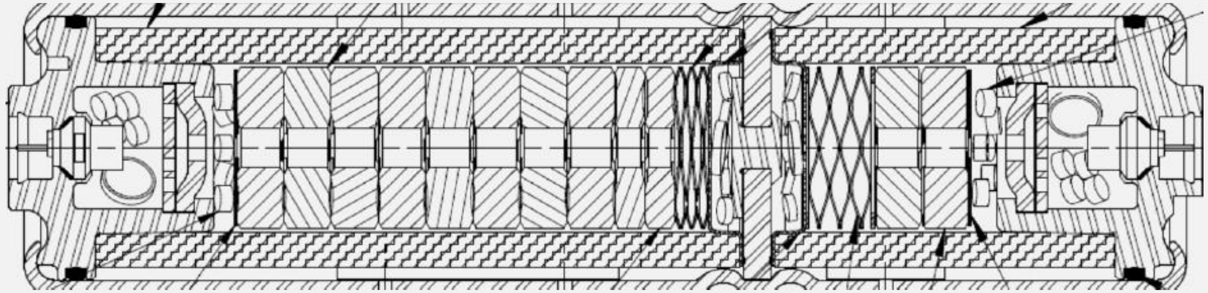
Inflator Type	Primary Chamber Wafers	Secondary Chamber Wafers
PSPI-L FD*	7 thick wafers	2 thick
PSPI-L YD	8 medium, 2 thin	2 medium
SPI YP	9 medium	N/A

* Quench testing of PSPI-L LT/FD inflators was completed on the ITC bridge program

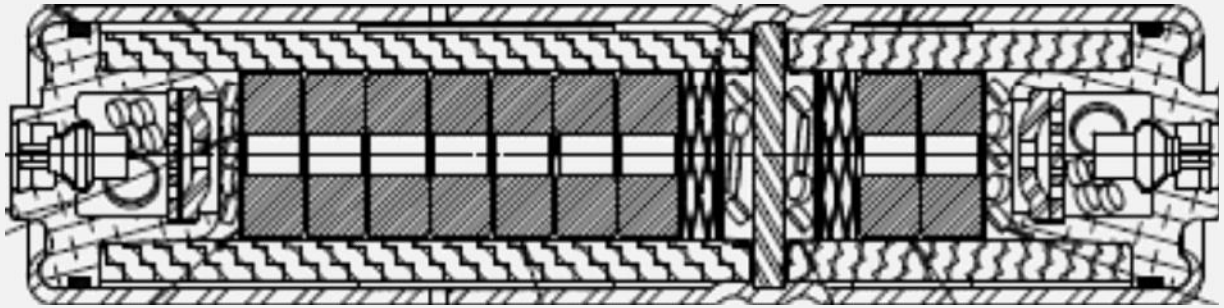
GM Quench Test Status

Numbering P1 . . . P10 S2 . . . S1

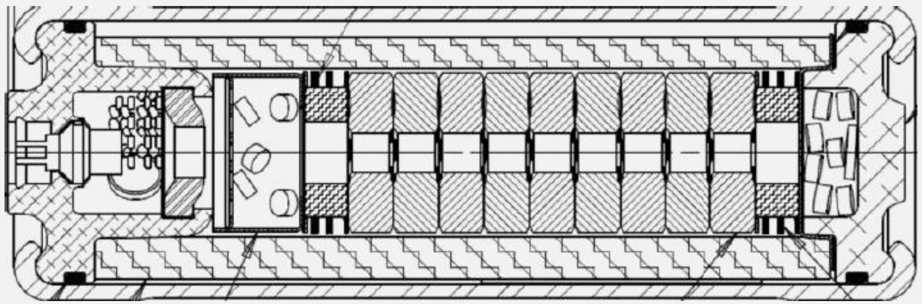
PSPI-L YD



PSPI-L FD / LT

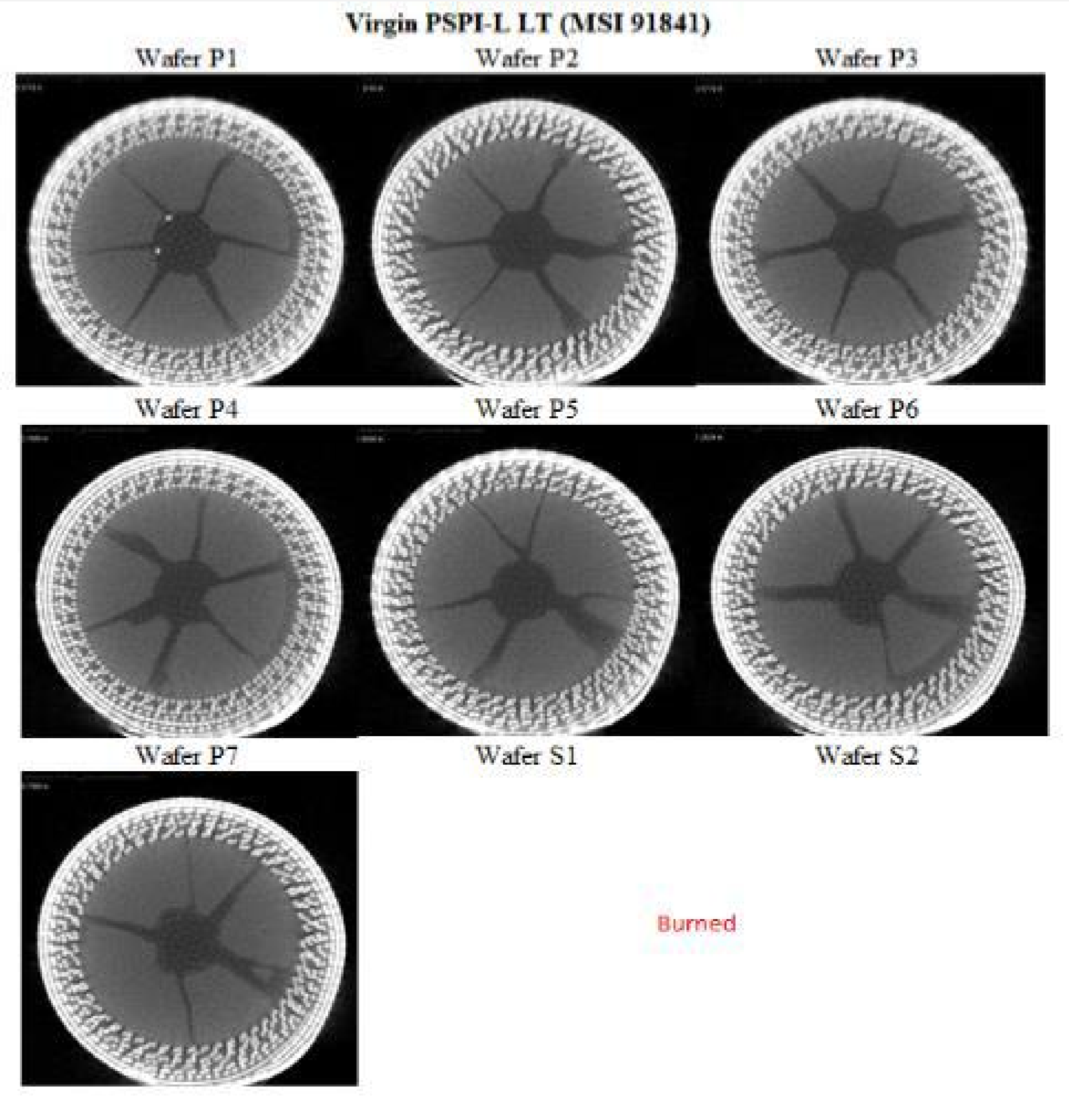


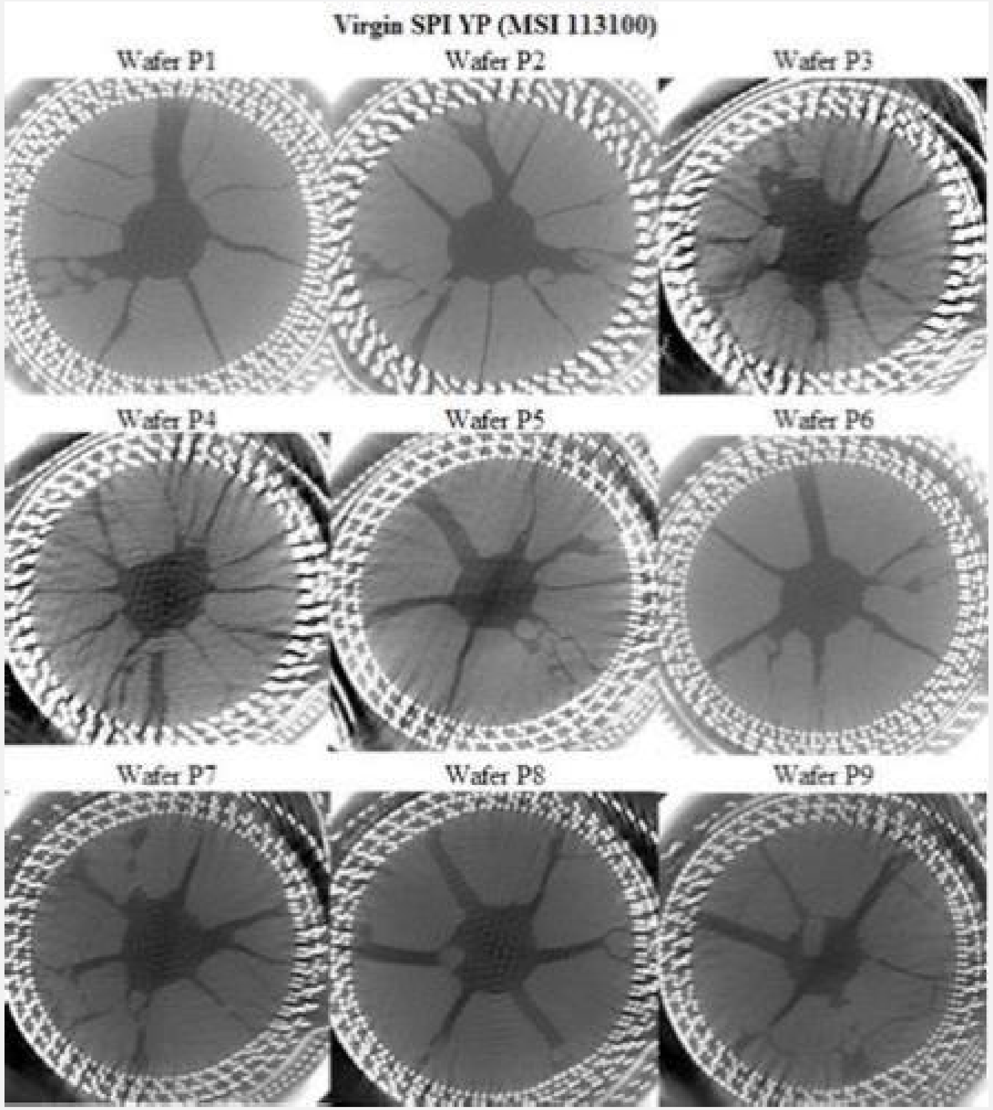
SPI YP



Quench Test Results, Virgin SPI vs PSPI-L LT

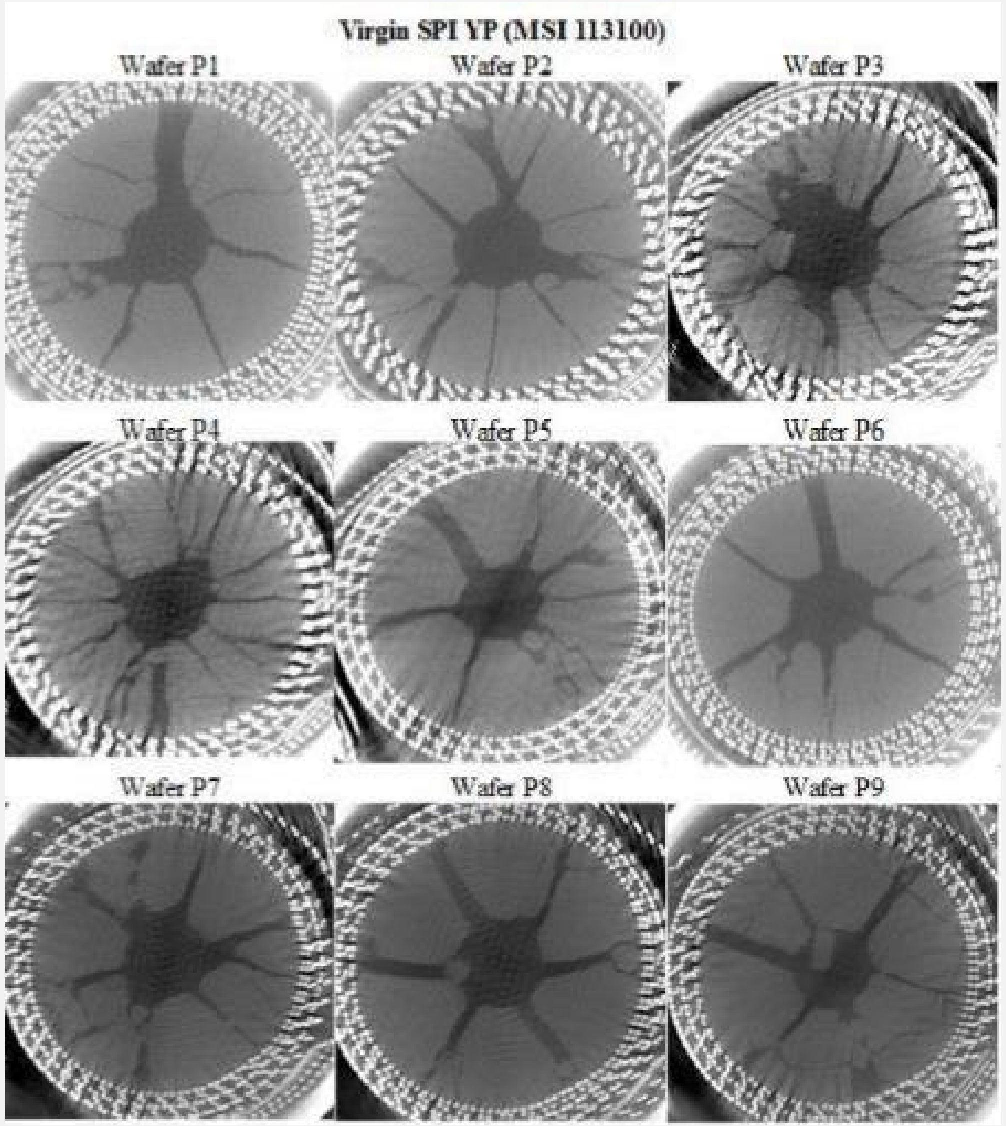
- The break-up pattern in each looks similar, but there is significantly more break-up with medium wafers

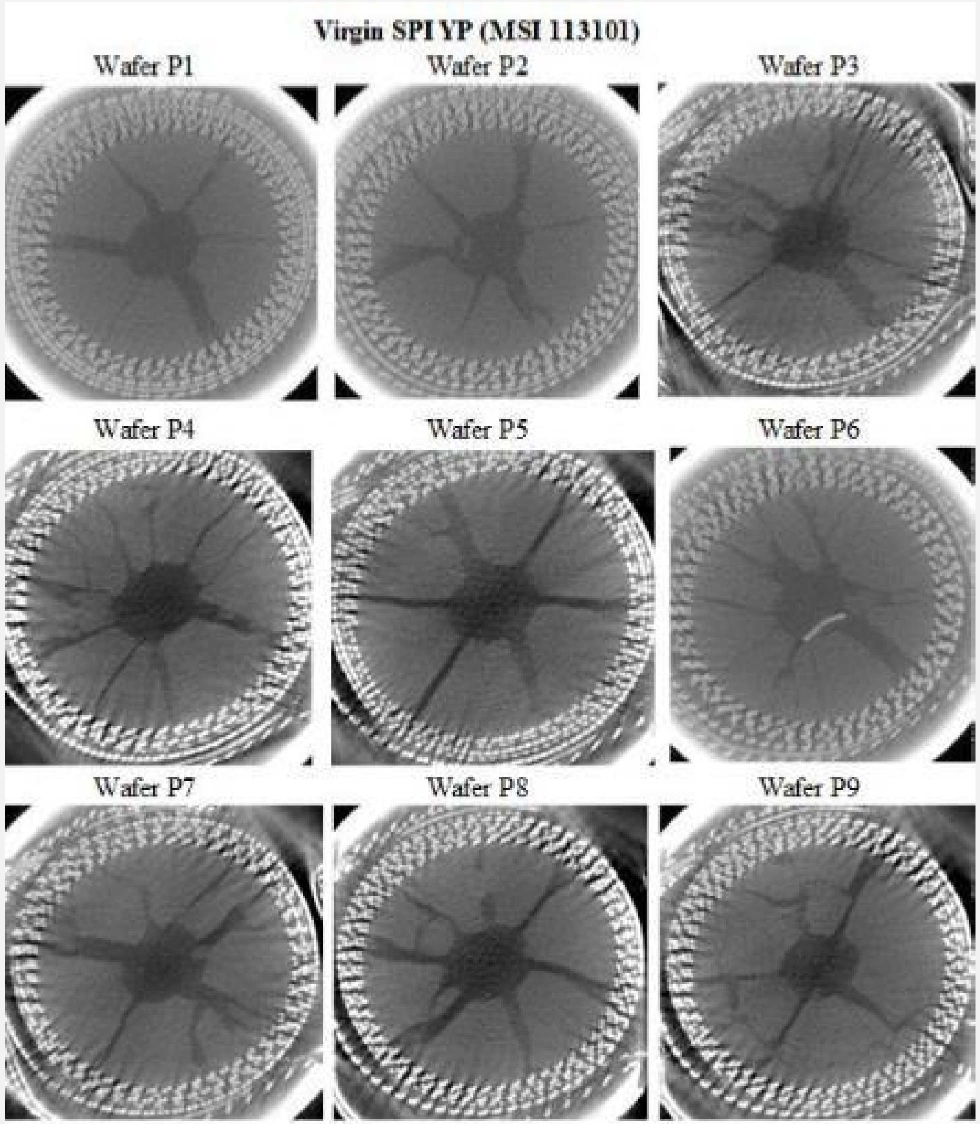




Quench Test Results, Virgin SPI YP

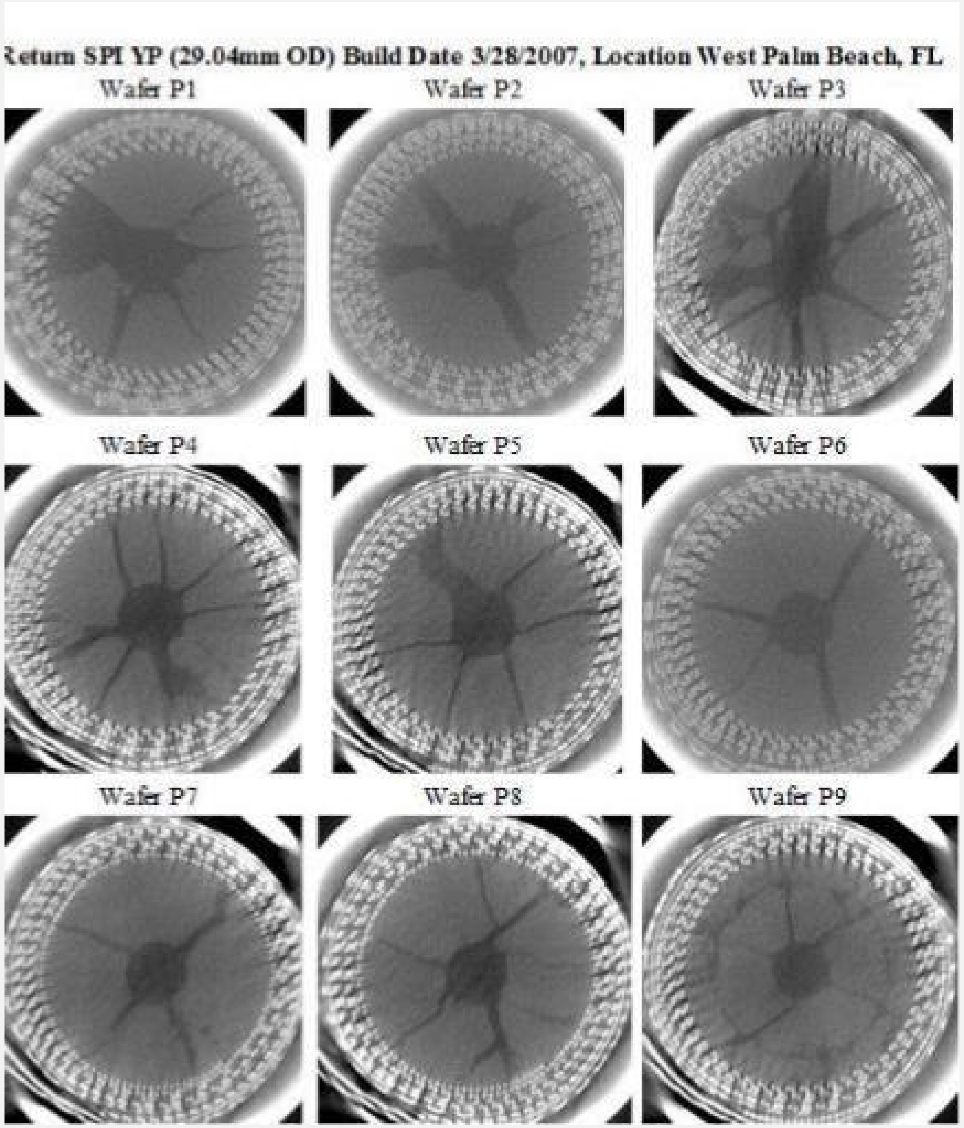
- The break-up pattern in both virgin inflators looks similar, validates technique

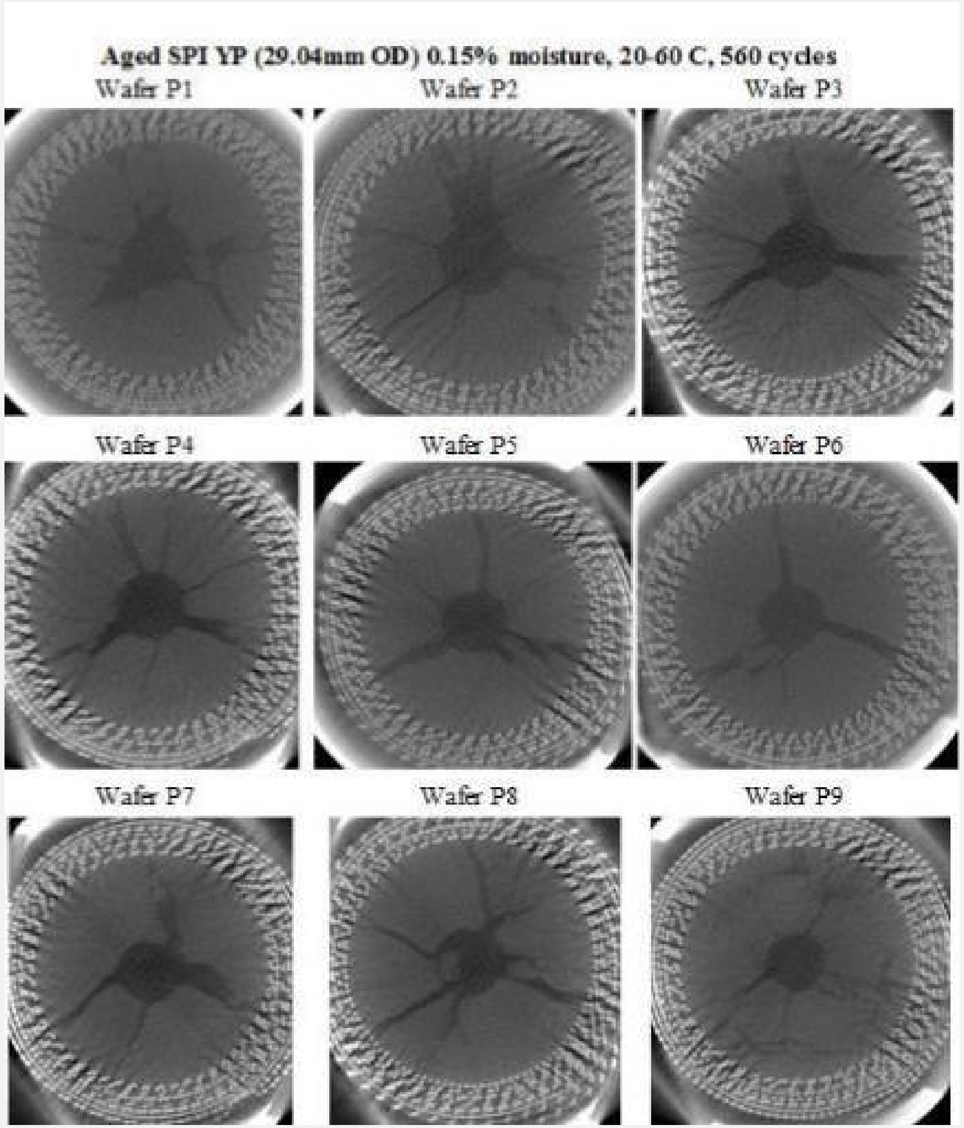




Quench Test Results, Aged vs Returned SPI YP

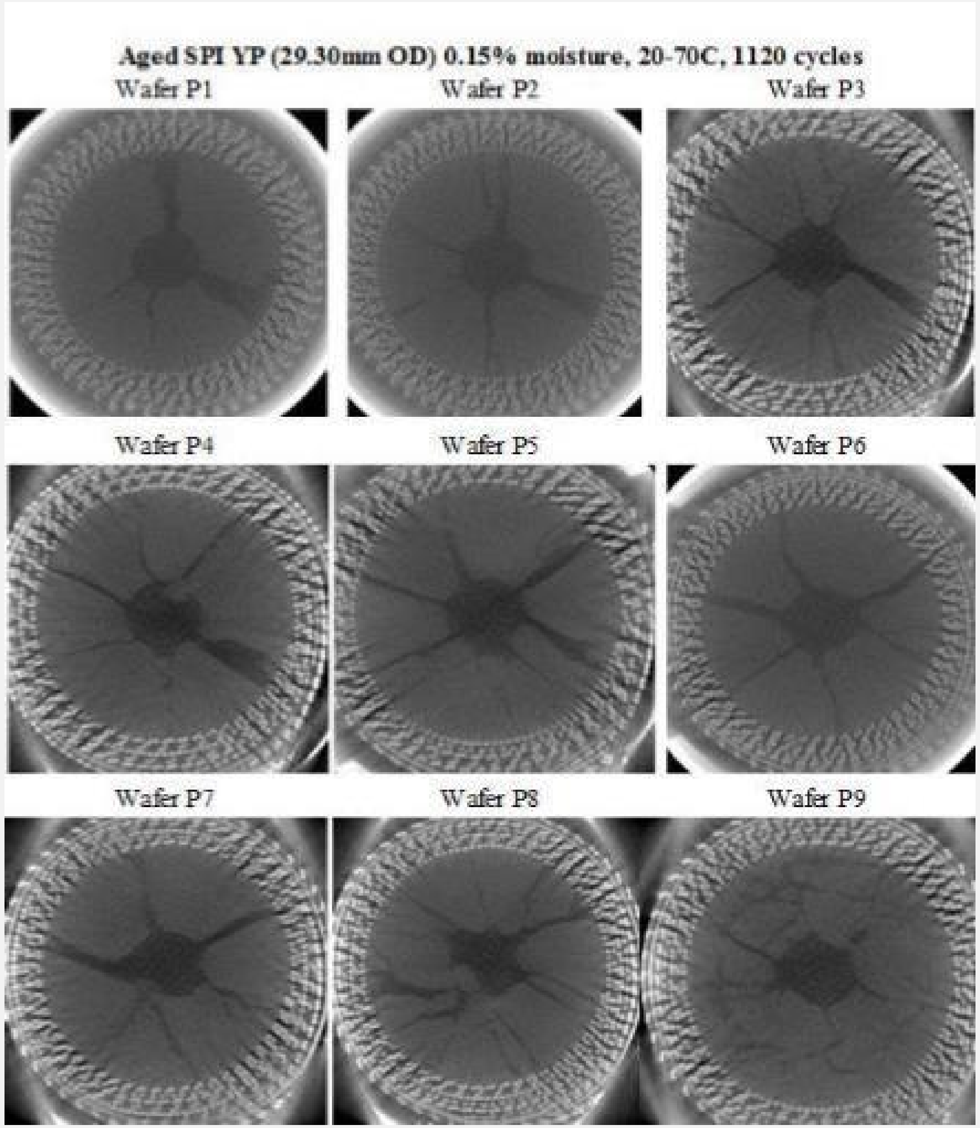
- The break-up pattern in both aged vs returned of the same wafer size looks similar

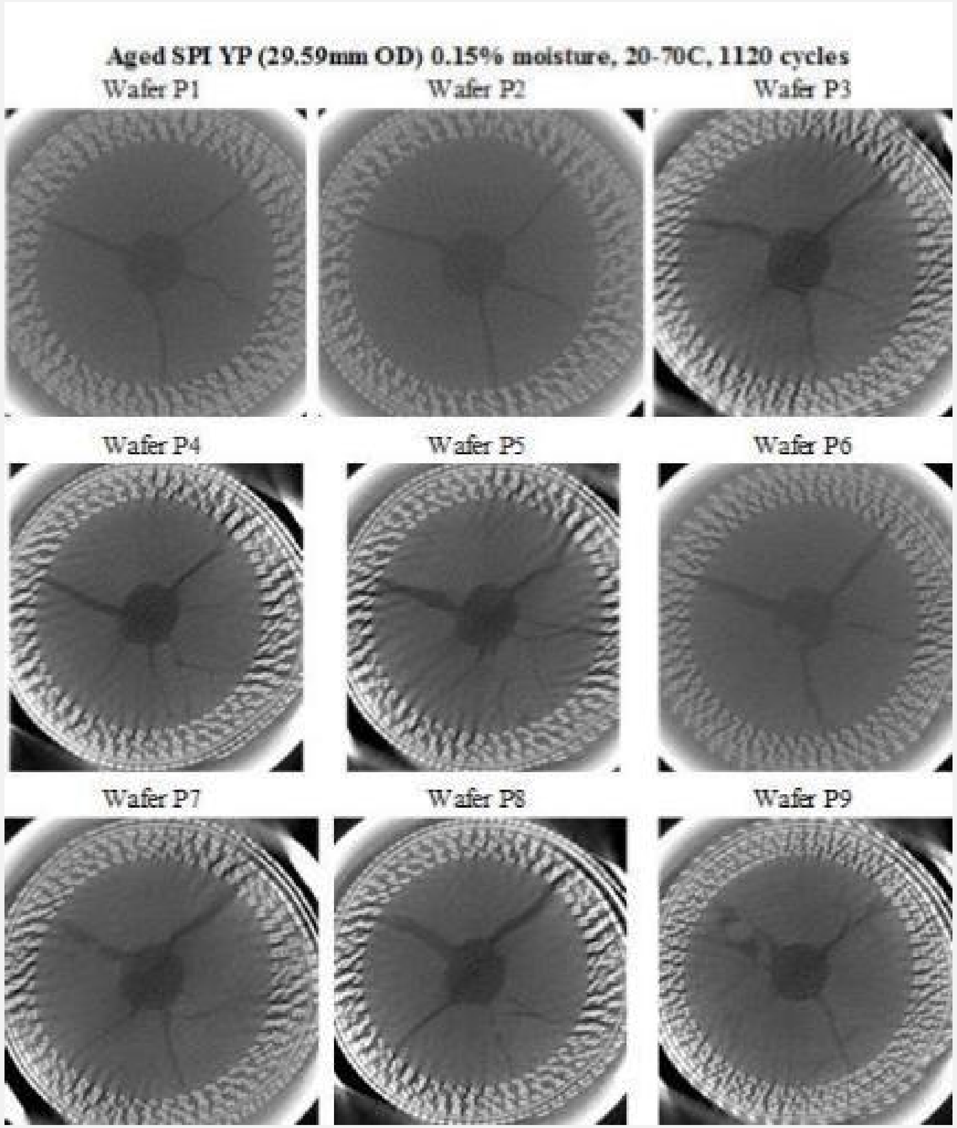




Quench Test Results, Aged Large OD Wafers YP

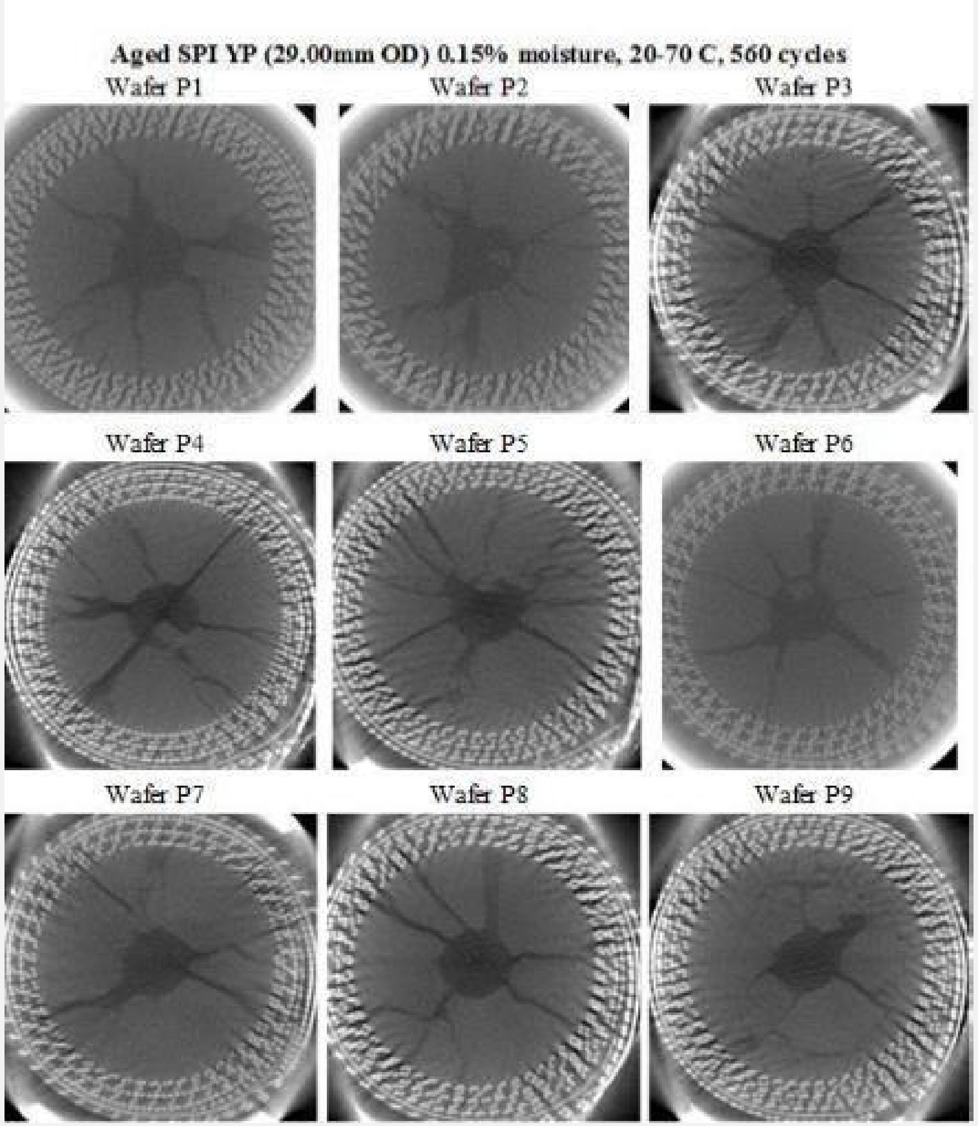
- The break-up pattern in the largest wafer inflators looks similar, possibly less breakup than smaller OD wafers

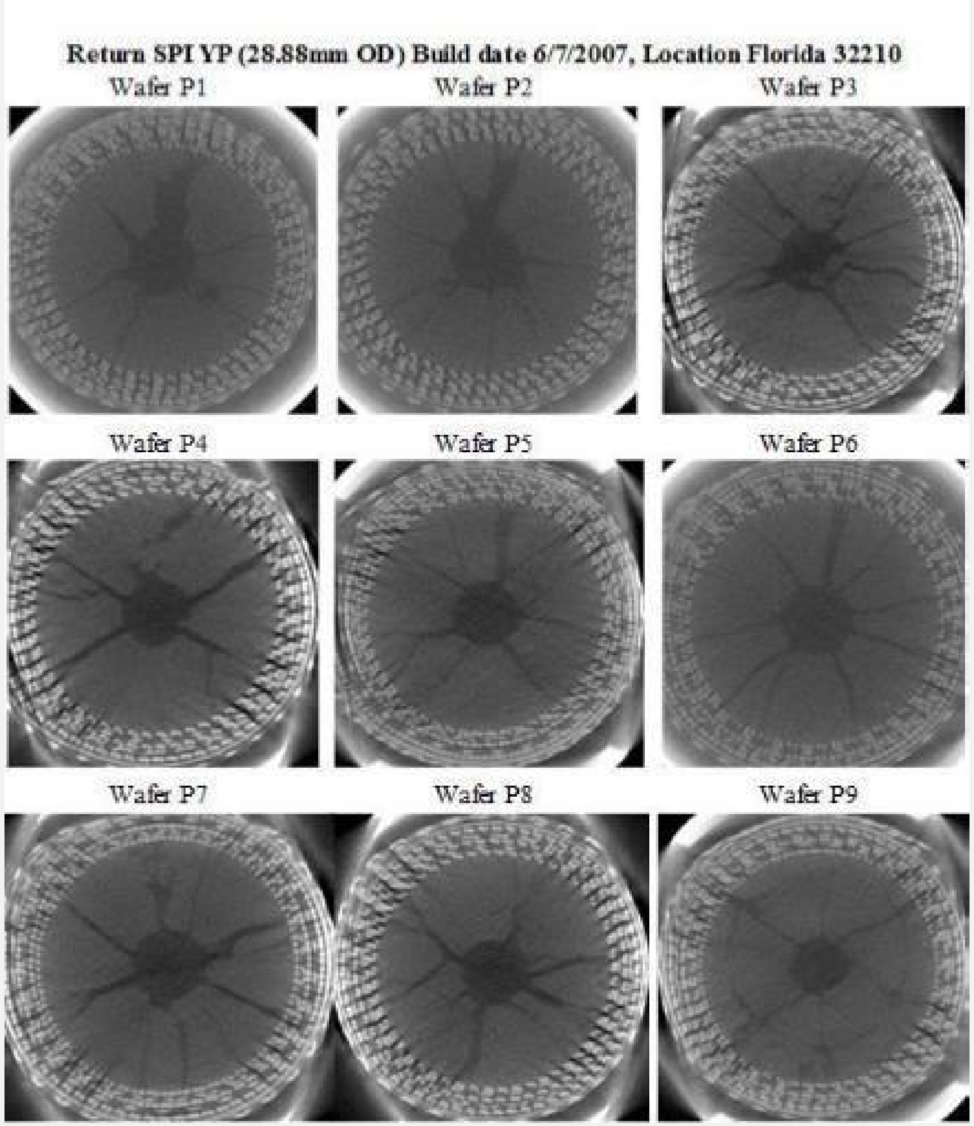




Quench Test Results, Mid Aged vs Returned

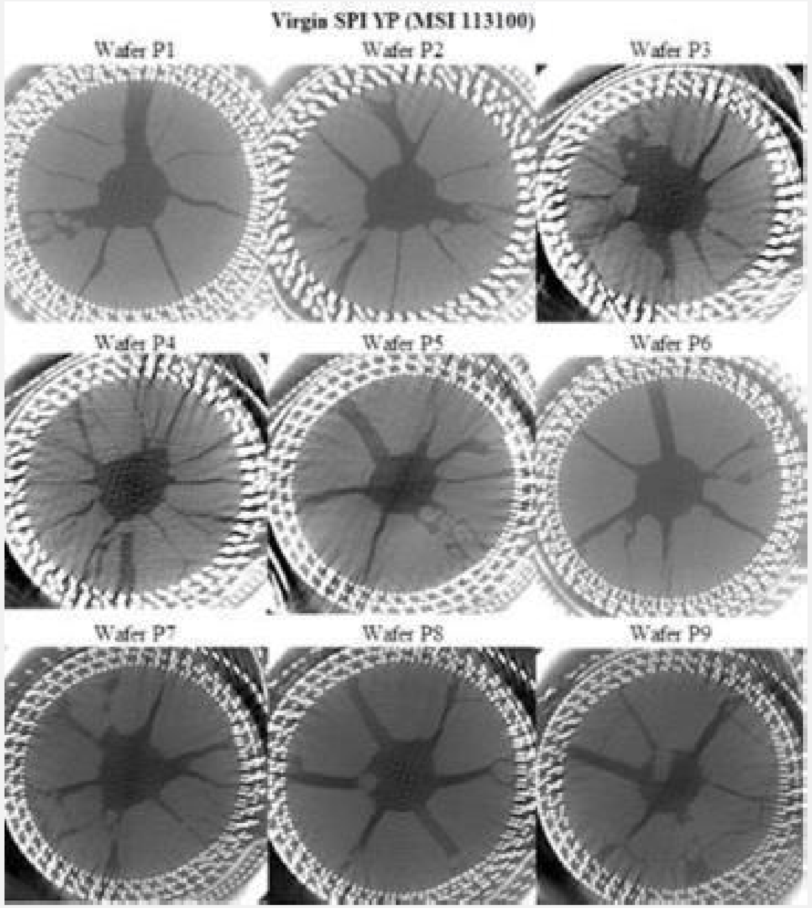
- The break-up pattern in aged vs returned inflators with small wafer sizes also looks similar

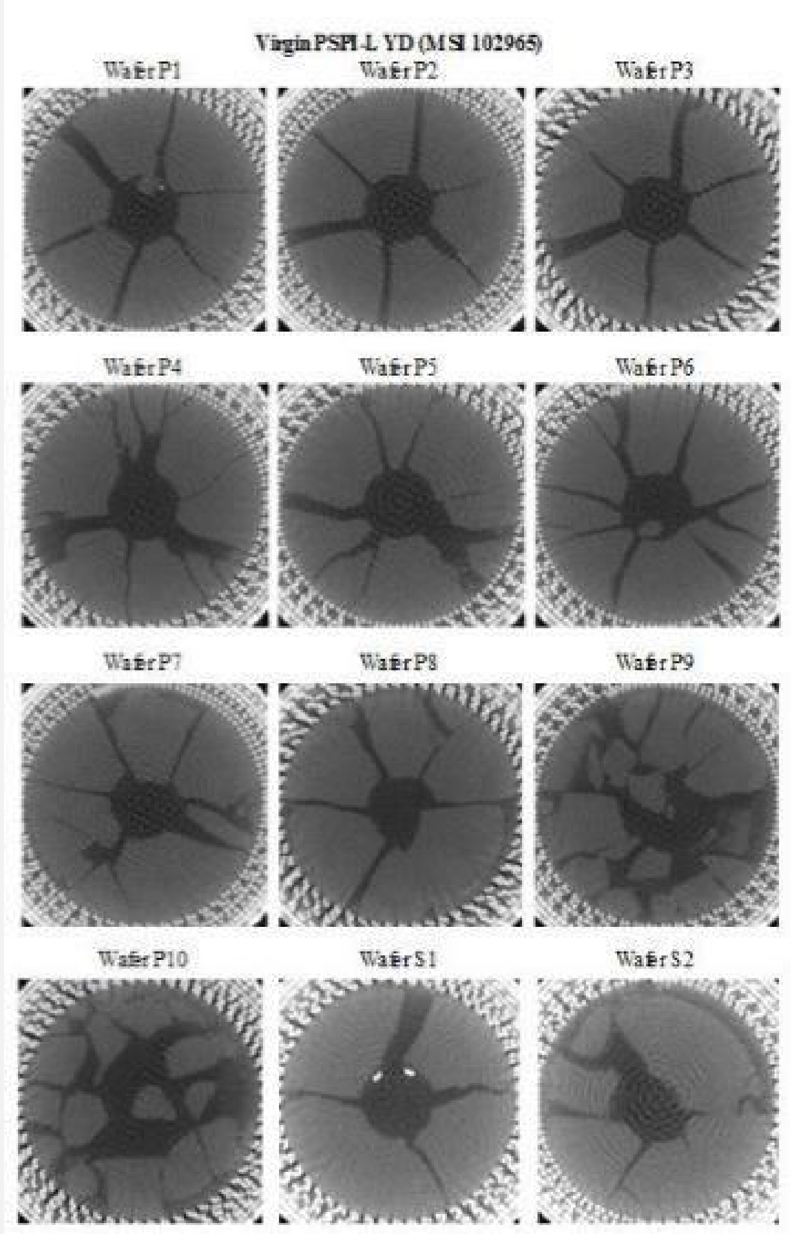




Quench Test Results, Virgin SPI YP vs PSPI-L YD

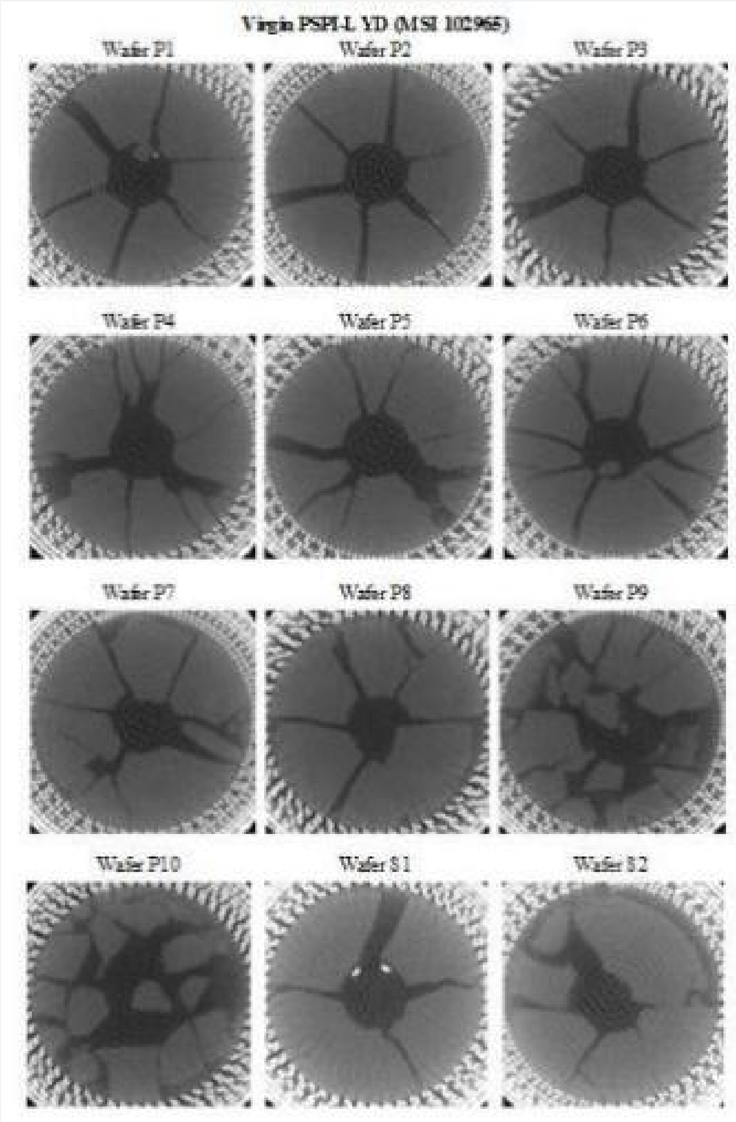
- Overall SPI has more breakup, exception is the two thin wafers, P9 & P10, in the PSPI-L YD

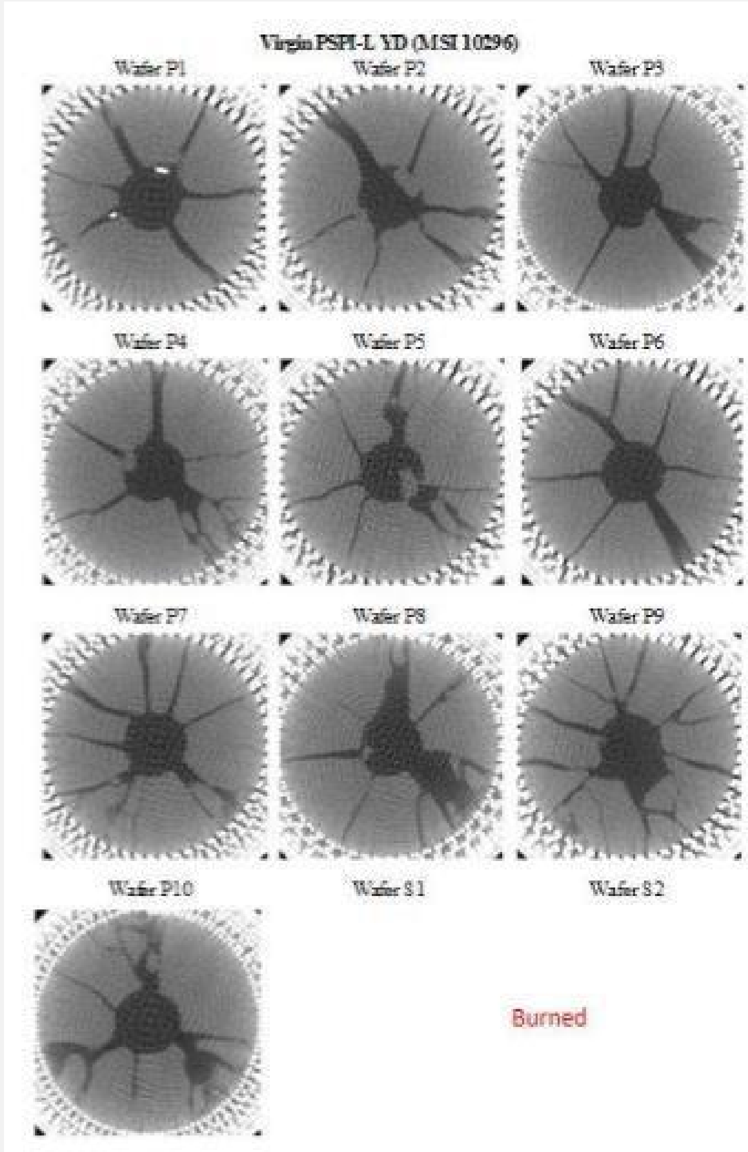




Quench Test Results, Virgin PSPI-L YD

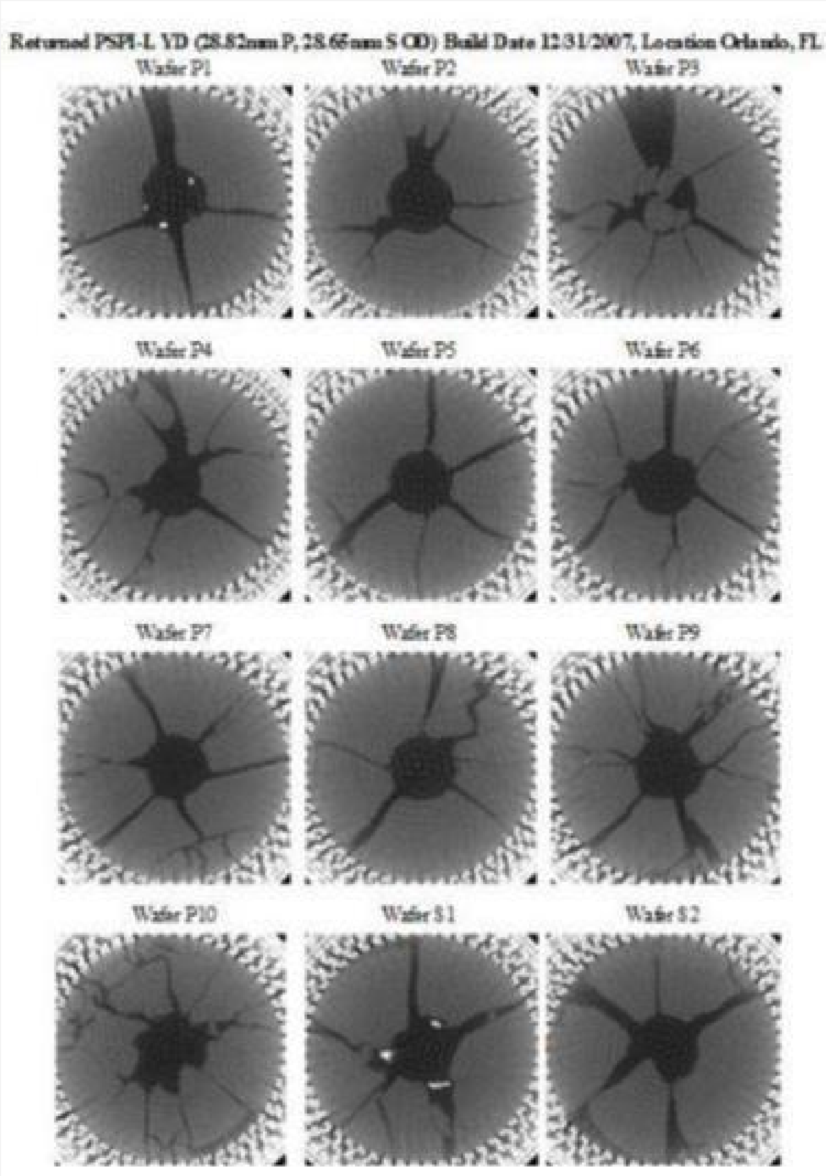
- The break-up pattern in both virgin inflator looks similar but slightly less breakup of P9 & P10 in the second inflator. The secondary also burned on the second inflator.

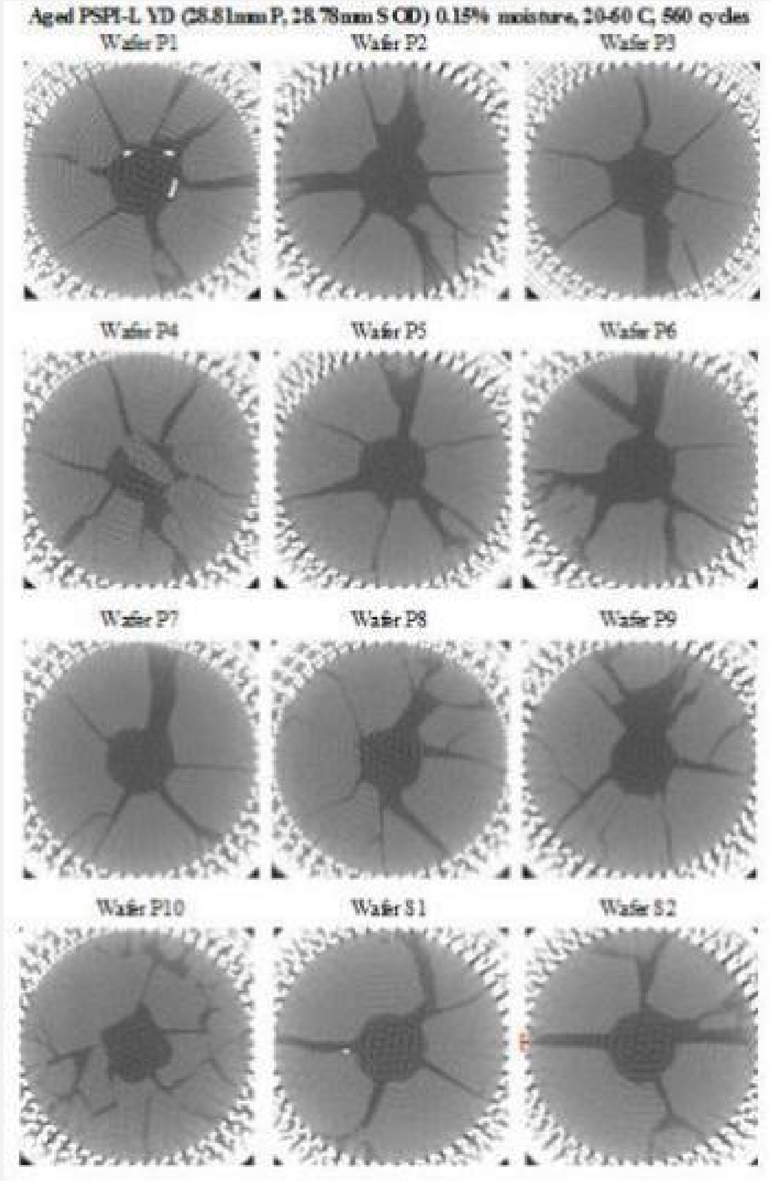




Quench Test Results, Aged vs Returned YD

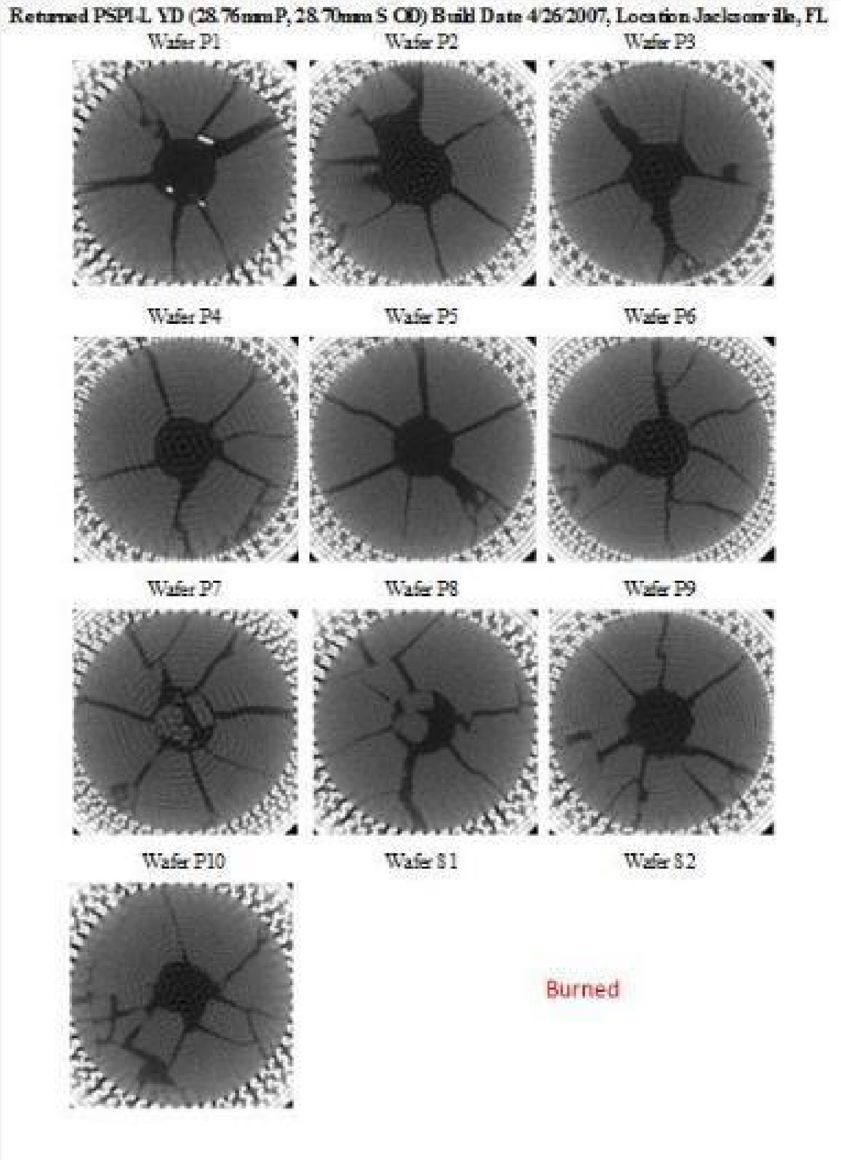
- The break-up pattern in both aged vs returned of the same wafer size looks similar

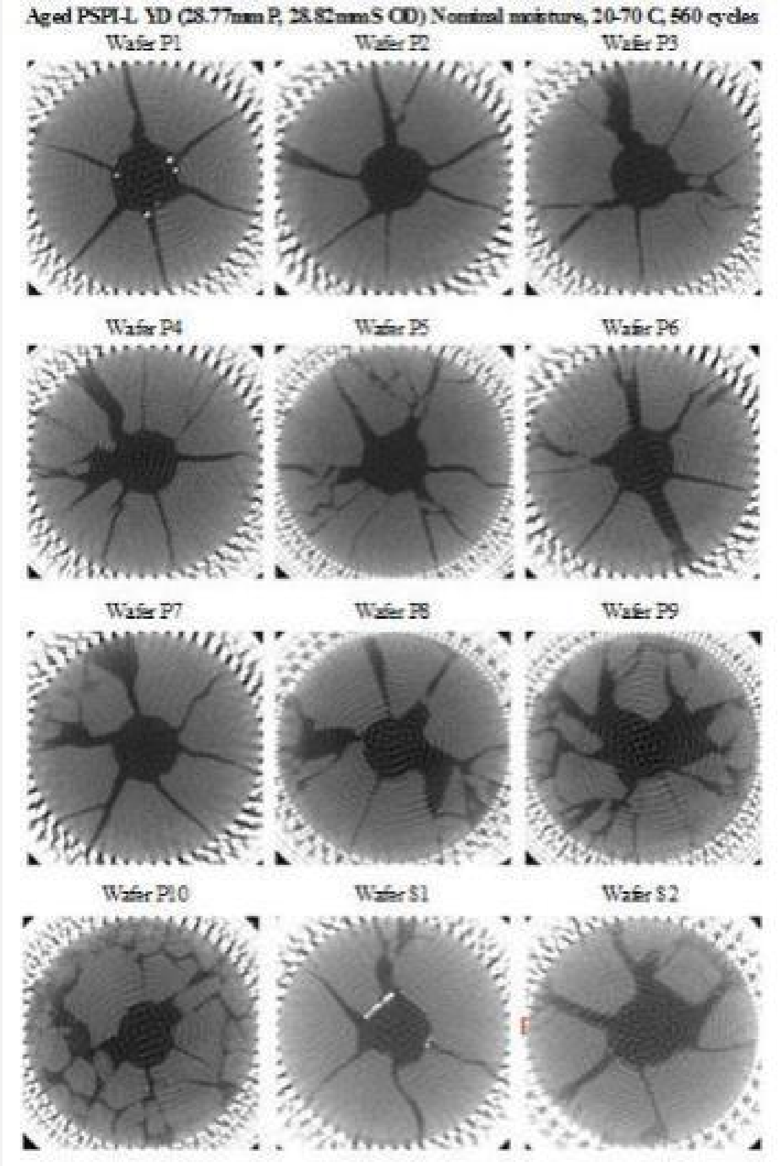




Quench Test Results, Aged vs Returned YD

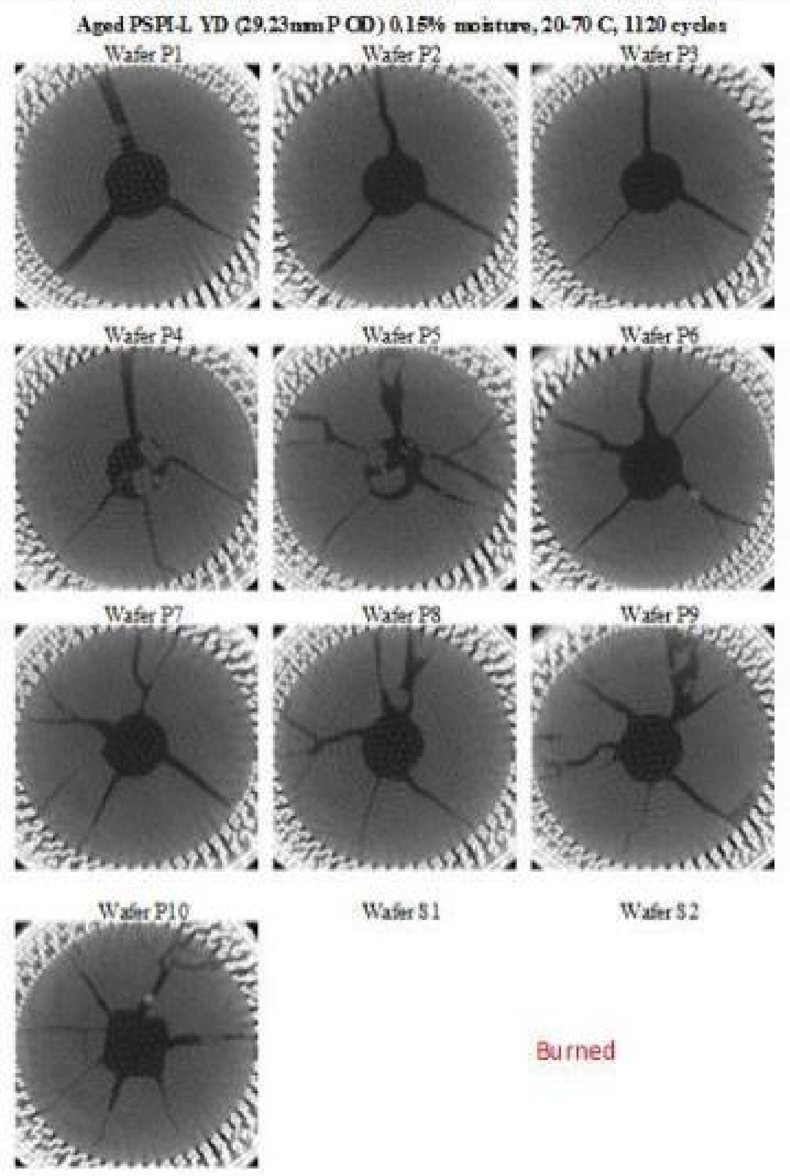
- In this case the aged inflator looks to have slightly more breakup overall, but the secondary burned on the returned inflator

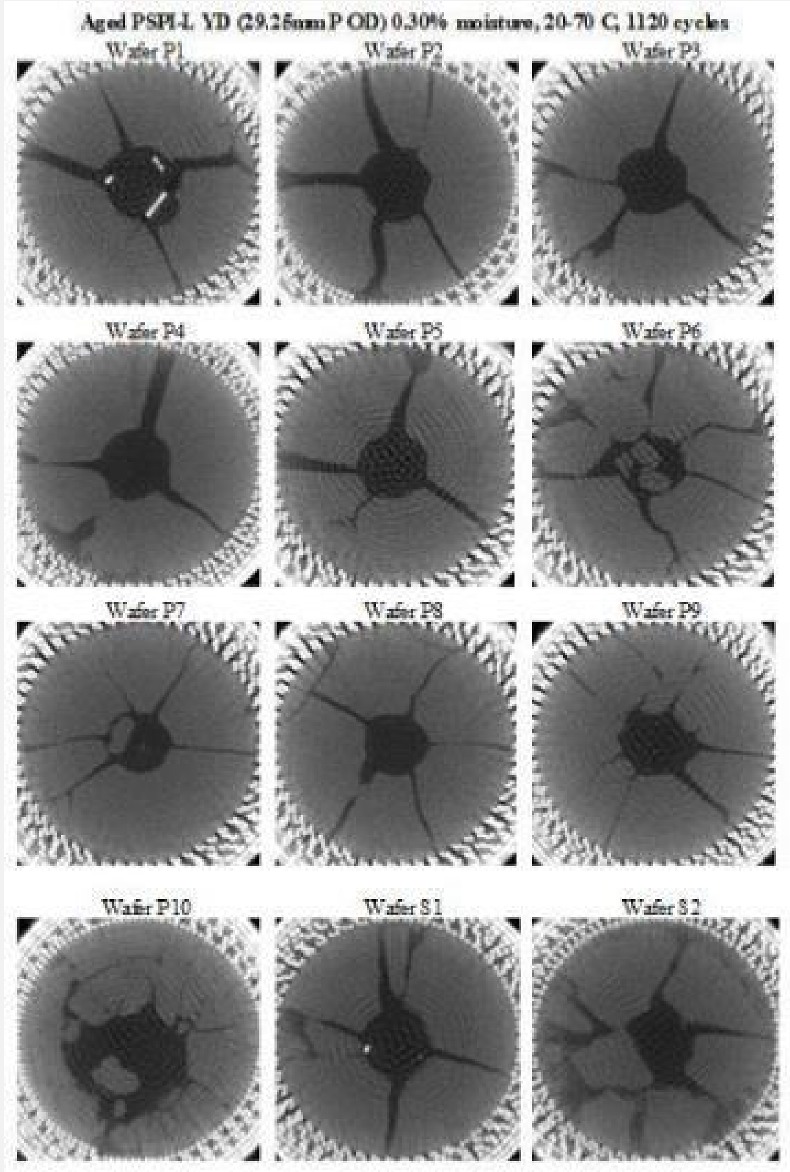




Quench Test Results, Aged Large OD Wafers YD

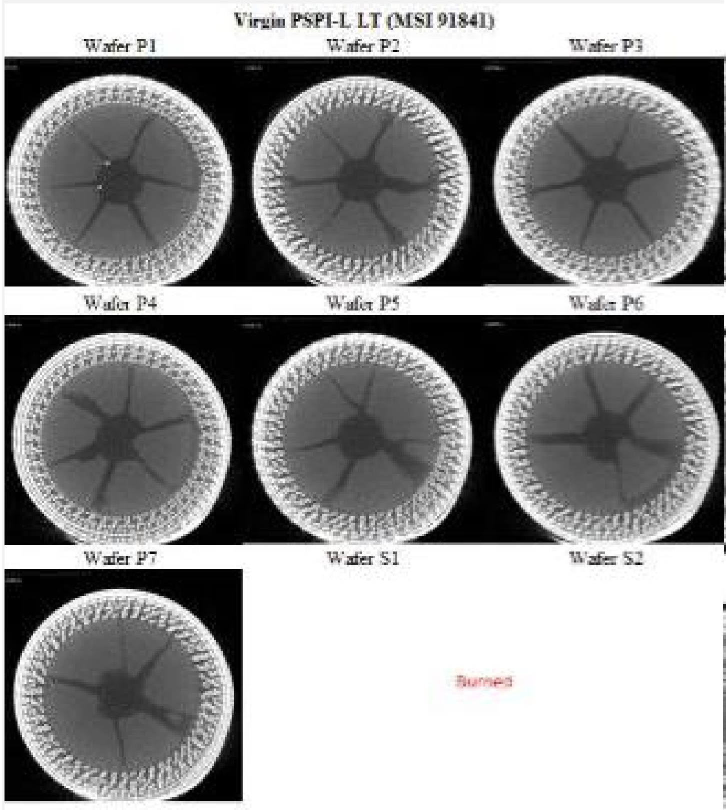
- The break-up pattern in the largest wafer inflators looks similar, slightly more breakup in the aged inflator. Also looks like there is less breakup than in smaller OD wafers

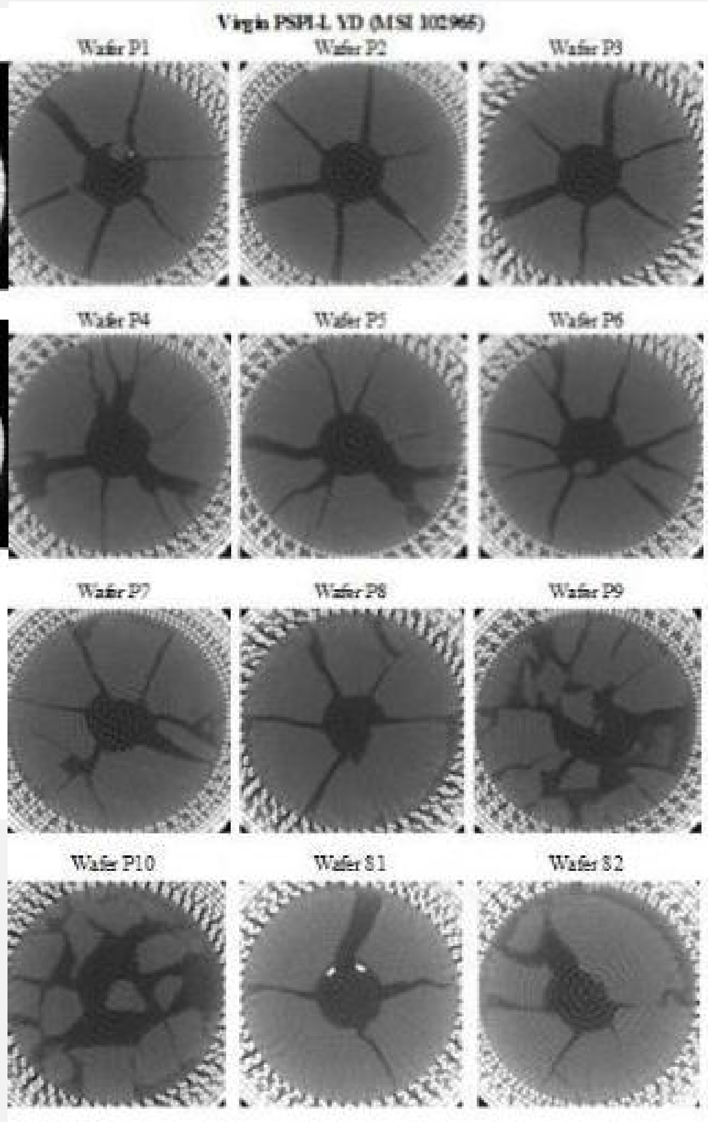


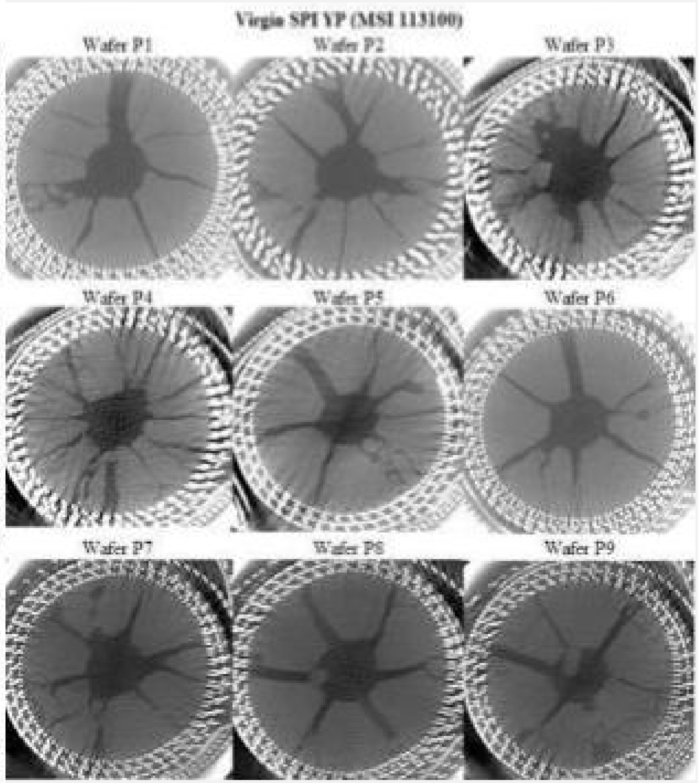


Quench Test Results: Comparison of Virgin Inflators

- The break-up in wafers closest to the igniter in the PSPI-L inflators is very similar, but as you move away from the igniter there is more break-up in the medium wafers of the YD.
- The thin wafers in the PSPI-L YD, P9 and P10, and the medium wafers in SPI YP break-up the most out of all 3 types

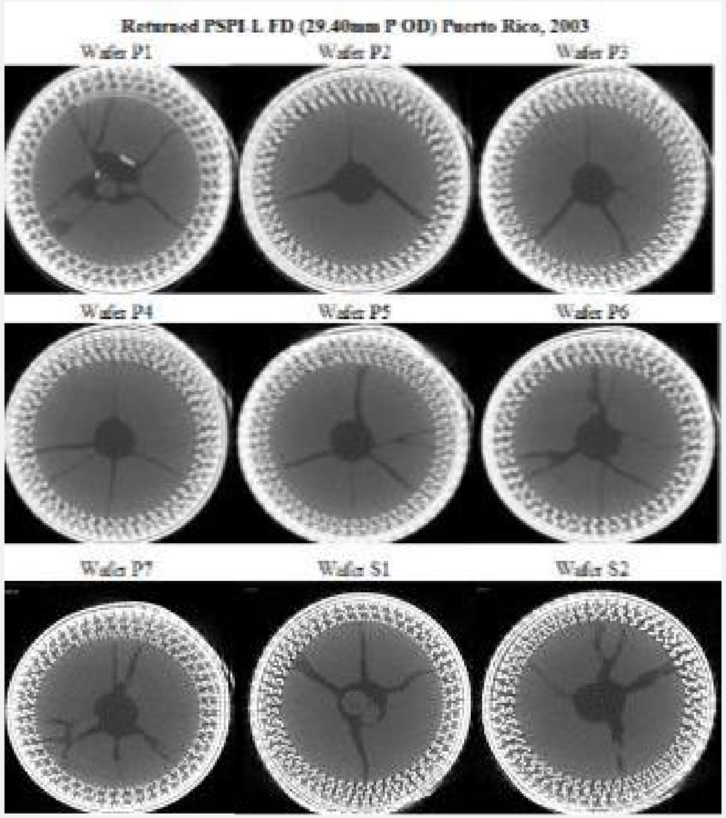


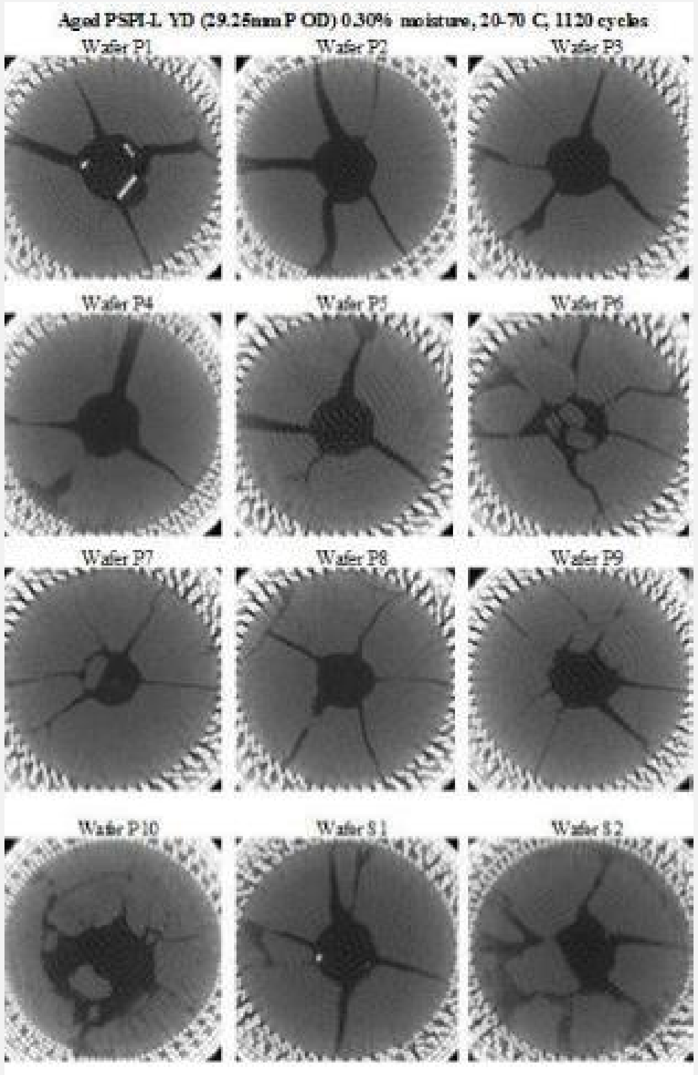


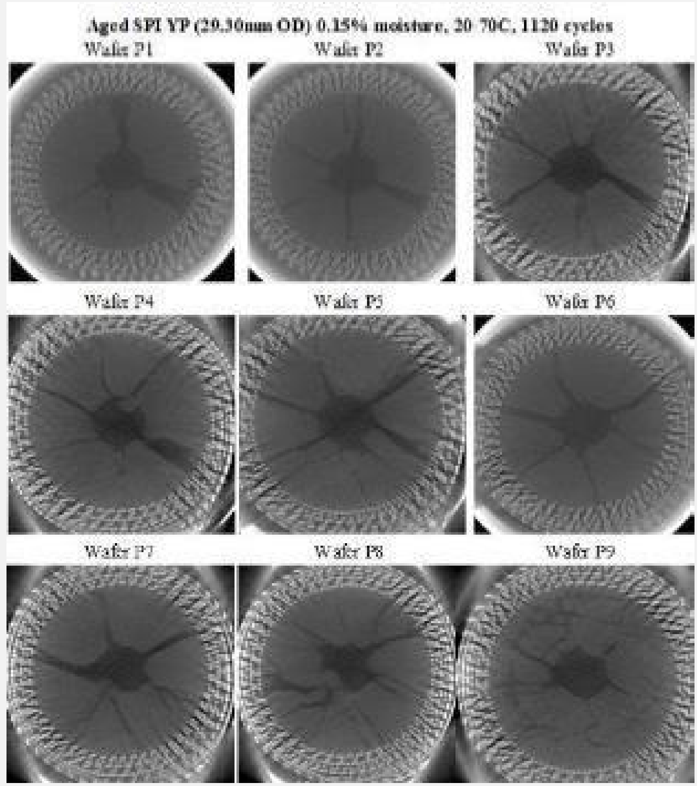


Quench Test Results: Comparison of Aged Inflators

- The larger wafers show less break-up in all three inflator types
- SPI YP inflators still show more break-up than the other two



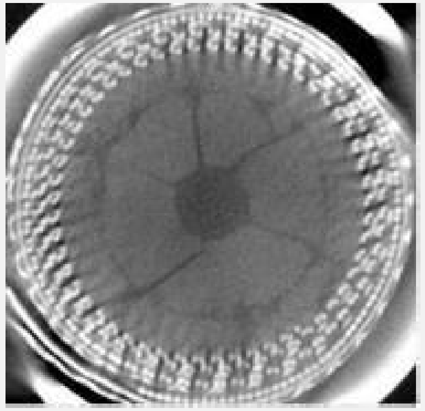




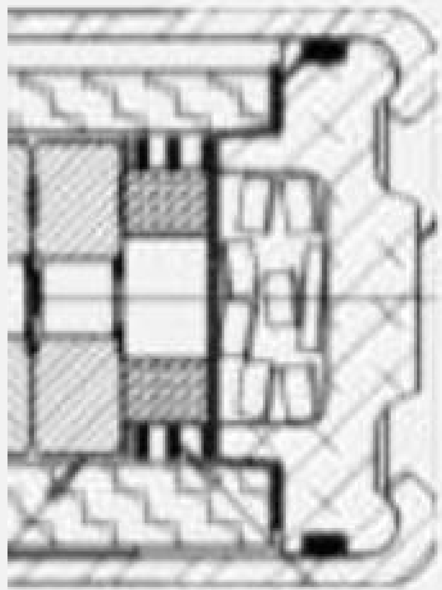
GM Quench Test Observations

- For SPI YP in general and subjectively;
  - Wafers P3, P4 and P9 tend to breakup most
  - P9 breaks in a interesting manner (next to AI cup) with a circular break a few mm away from the OD and a spider pattern from ID to OD
  - Wafer thickness vs. break-up under assessment

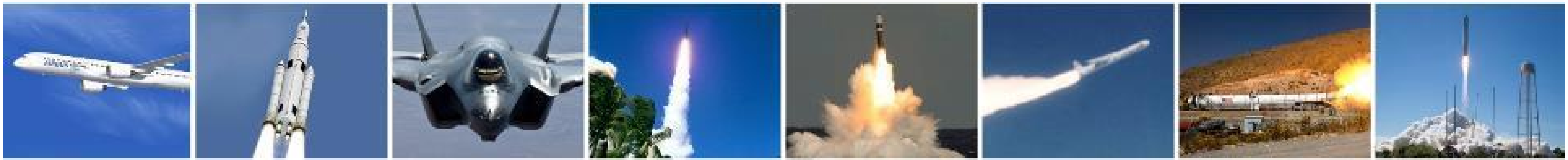
P9



- For PSPI-L YD in general and subjectively;
  - Wafers P9 and P10 tend to breakup most (thin wafers), but these are also the wafers closest to the AI cup



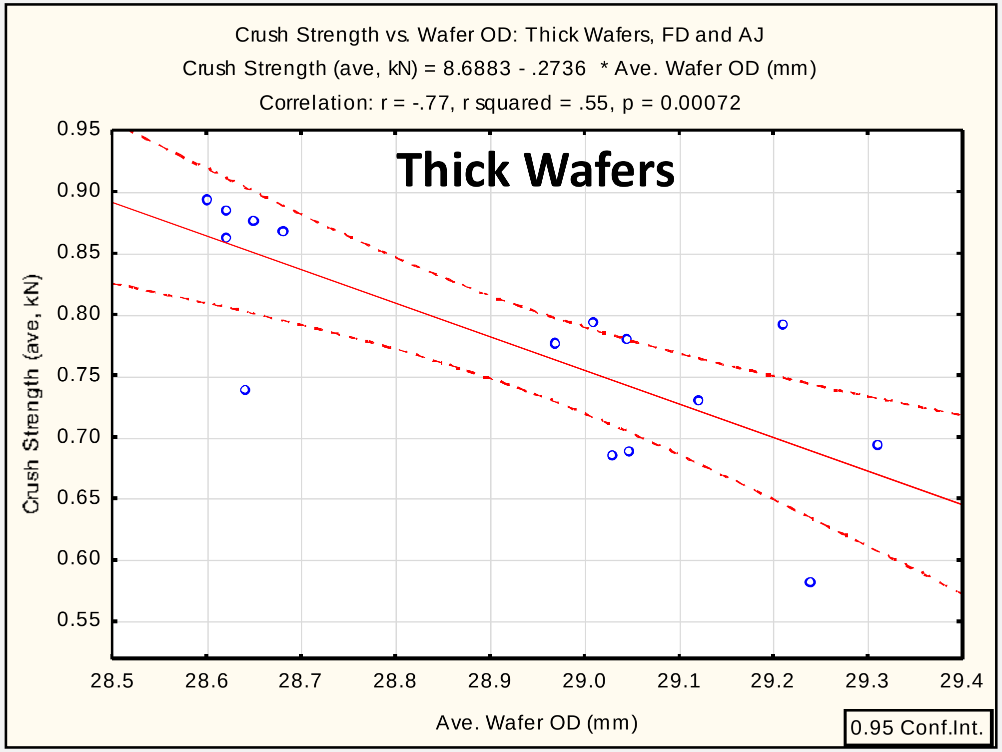
Crush Strength Analysis

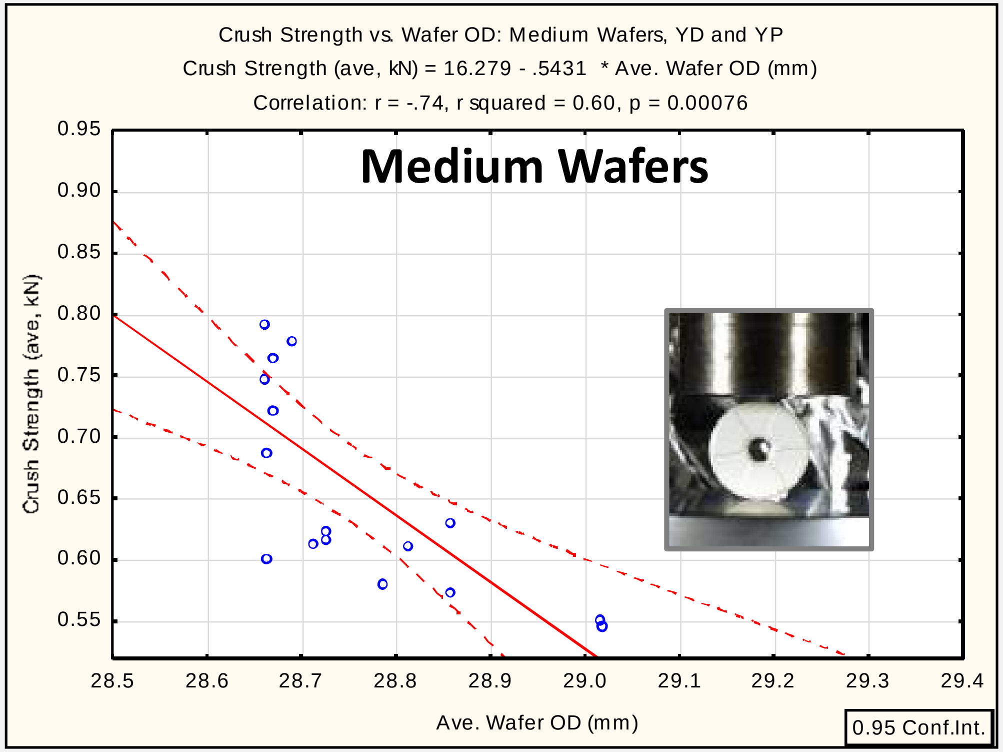


HAH PAB Crush Strength Analysis

- Thicker wafers are harder to crush
- Wafer growth is less for medium (0.4%) than thick (1.7%)
- However, wafer mechanical strength loss is greater for medium (21%) than thick (15%) even though the latter are older.
  - Abnormalities produced with age causing mechanical weakening tend to be nearer the surface than the center of a wafer
  - Medium wafers have more "surface" and less "center"

Wafer Thickness	Wafer Type	Pri/ Sec	Wafer Age (yr)		Wafer OD (mm)		Crush Strength (kN)	
			Avg	Stdev	Avg	Stdev	Avg	Stdev
Thick	FD virgin	pri	0.3	0.0	28.61	0.01	0.88	0.02
		sec			28.66	0.02	0.83	0.08
	FD returned	pri	13.3	0.2	29.04	0.01	0.72	0.05
	AJ returned	pri	13.2	0.0	29.11	0.14	0.70	0.10
Medium	YD virgin	pri	0.3	0.0	28.67	0.02	0.76	0.04
		sec			28.66	0.01	0.77	0.02
	YD returned	pri	9.6	0.7	28.75	0.10	0.63	0.06
	YP returned	pri	9.2	0.2	28.87	0.14	0.58	0.03





0-1680 Cycle Primary Chamber

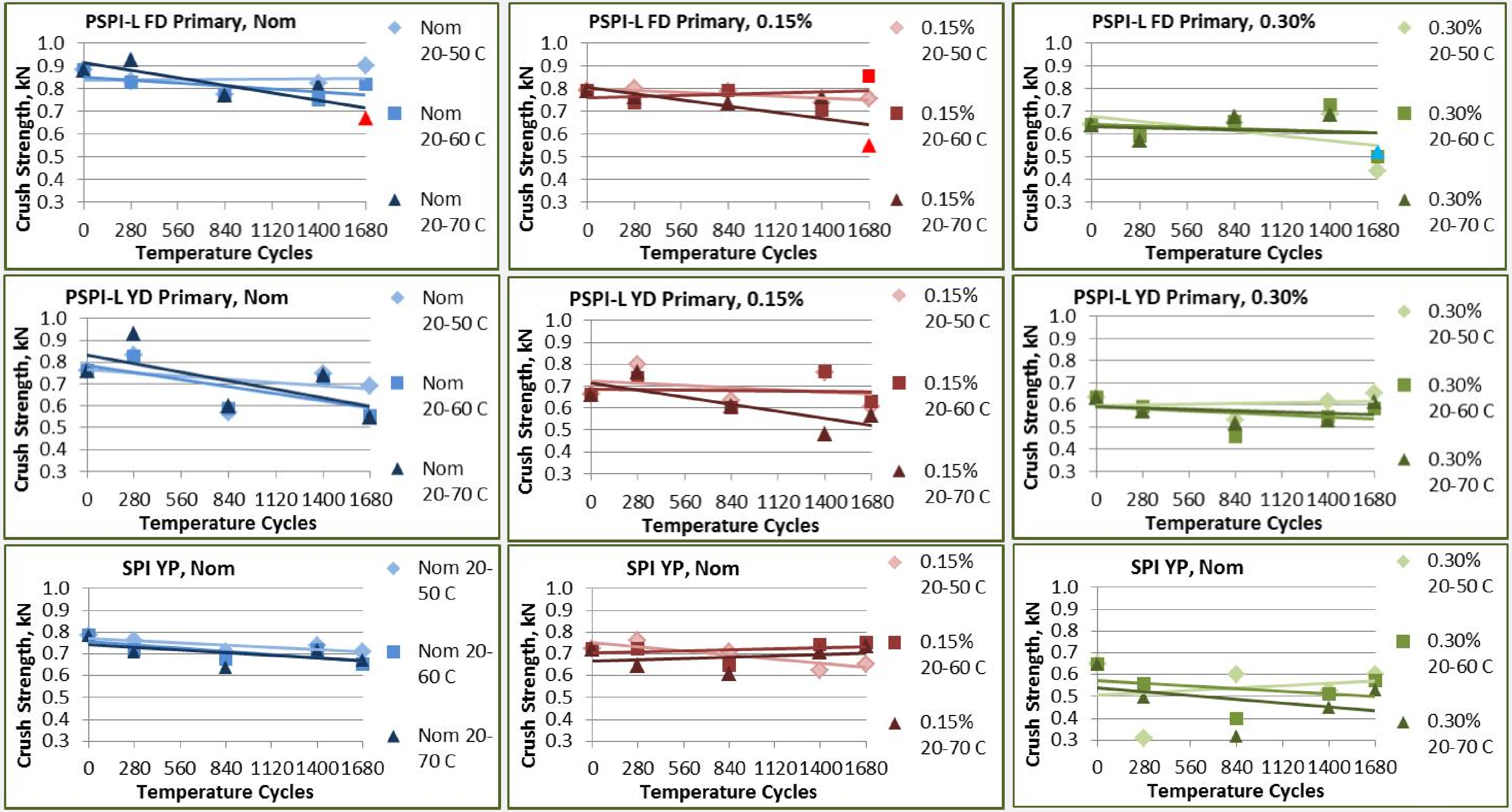
Radial Wafer Crush Strength at 0.05 mm/s

ED

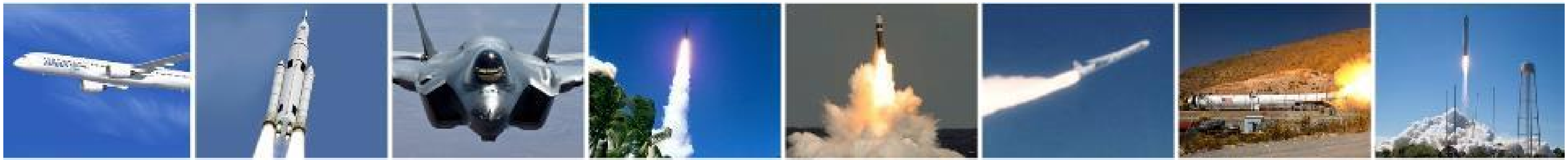
Near ED

Orbital ATK

- General trends: Thick FD > Med YD & YP; Moisture: Nom > Mid >High
- No definitive trend for most mid and high moisture inflators
- Trending to lower crush strength with increasing cycles: Nominal inflators, FD and YD 20-70C



Scanning Electron Microscope (SEM)



SEM Summary
(Photomicrographs Follow)

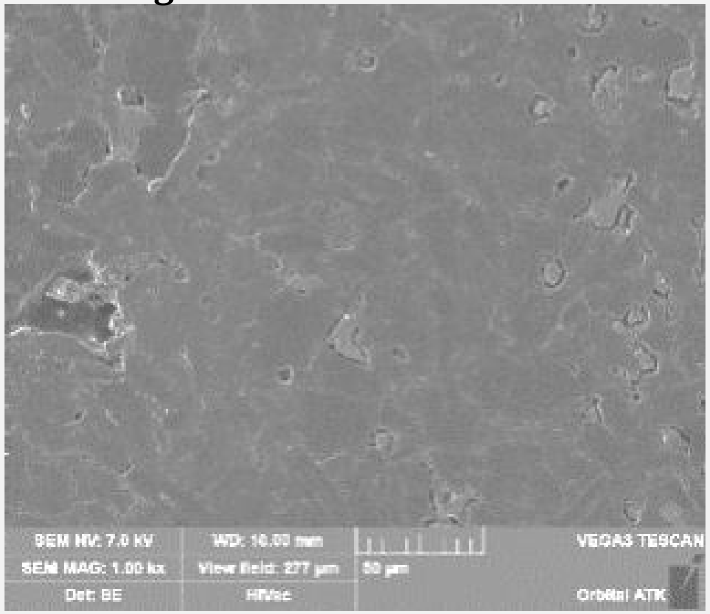
- Same set of samples examined as in other tests
  - GM PSPI-L YD and SPI YP inflators and other OEM PSPI-L FD and SPI AJ inflators
  - All samples removed from inflators without other modification
  - External (radial) surface examined directly
  - Internal surfaces exposed by fracturing full wafers
- Radial Surfaces-Returned AJ and especially Returned FD exhibit extensive surface pitting
  - Virgin YD has a rougher surface finish than Virgin FD, Returned YP and YD
  - YD and YP returned wafers have surface finishes similar to virgin wafers
- Internal Surfaces-No obvious differences
  - May have fractured along defects or perhaps did not fracture where defects are
  - Returned AJ SEMs indicate extra internal porosity seen in other very large OD wafers
- SEM contributes to consistent conclusions from multiple techniques
  - Disassembled inflator observations, density, mechanical properties, moisture dynamics consistent in showing less severely aged samples from GM inflators

PSPI-L FD Samples Show Significant Aging

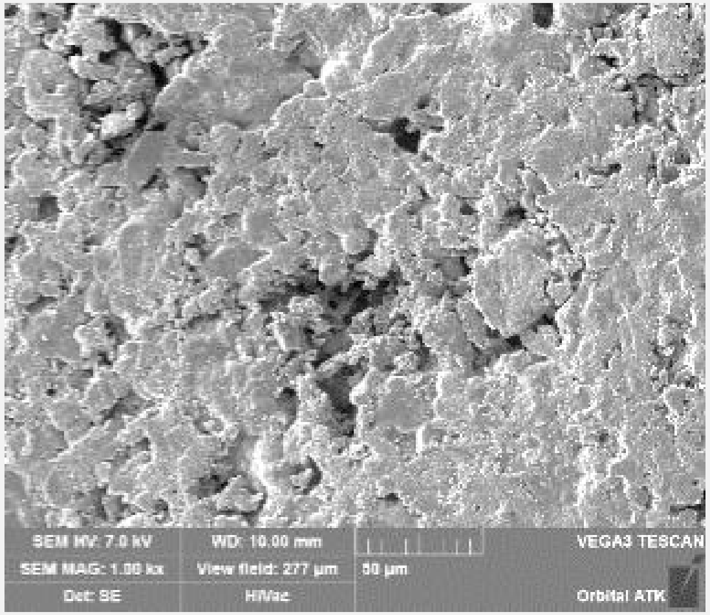
1000X Magnification-
Radial Surface

- Note significant differences in virgin versus returned samples for this inflator prefix
- Results consistent for several samples and visible at all magnifications
- Virgin surface similar for PSPI-L FD (this page) and PSPI-L YD (next page)
- Aged surfaces show marked differences from virgin samples

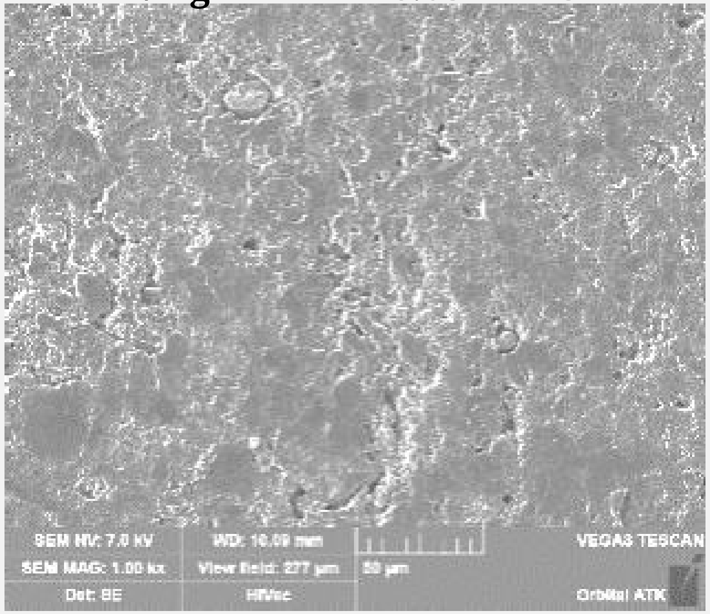
Virgin FD #1 28.65 mm OD



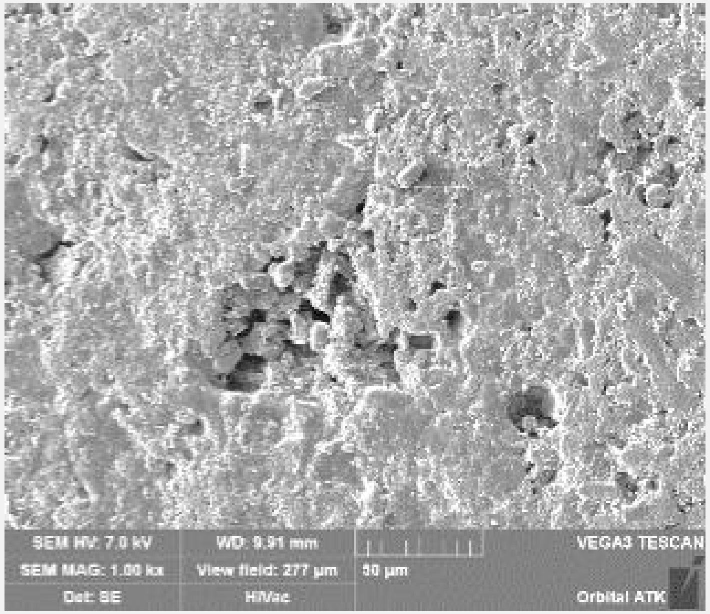
Returned FD #1 29.05 mm



Virgin FD #2 28.65 mm OD



Returned FD #2 29.05 mm

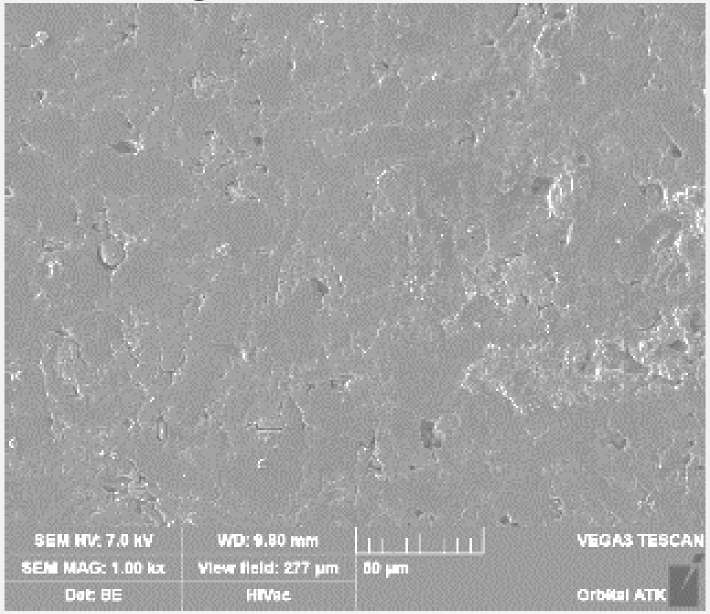


PSPI-L YD Do Not Show Significant Aging

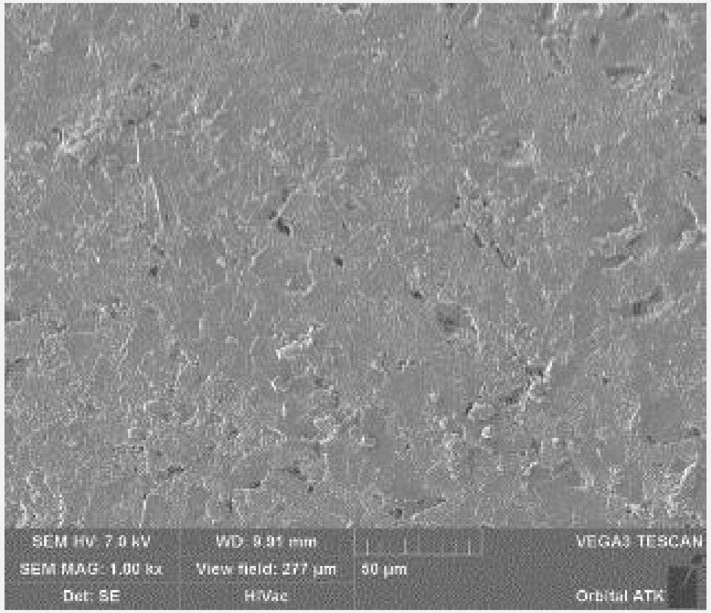
1000X Magnification-
Radial Surface

- Note general similarity between virgin and returned samples for this inflator prefix
- Results consistent for several samples and visible at all magnifications
- Virgin surface similar for PSPI-L FD (previous page) and PSPI-L YD (this page)
- Aged surfaces show marked differences with PSPI-L YD showing markedly less aging effects

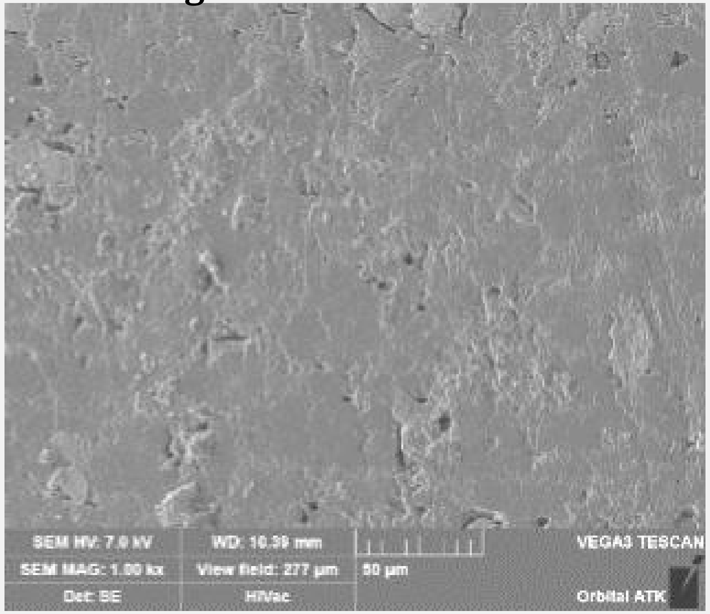
Virgin YD #1 28.67 mm



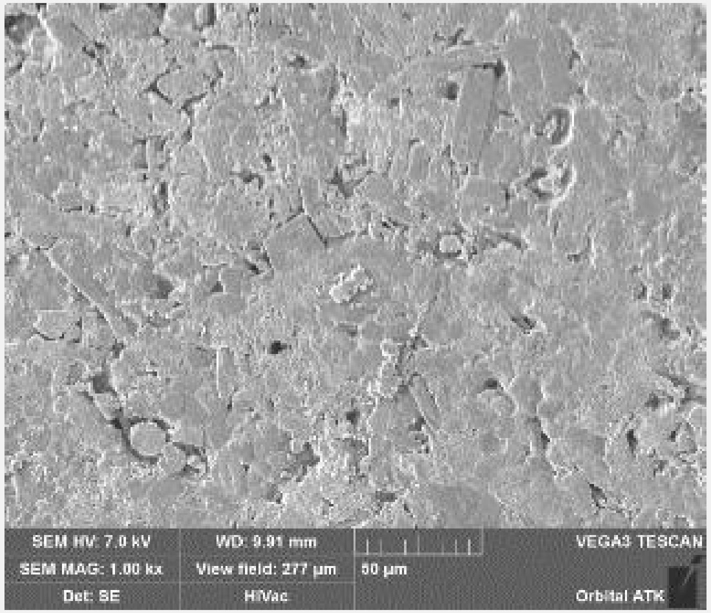
Returned YD #1 28.86 mm



Virgin YD #2 28.69 mm



Returned YD #2 28.86 mm



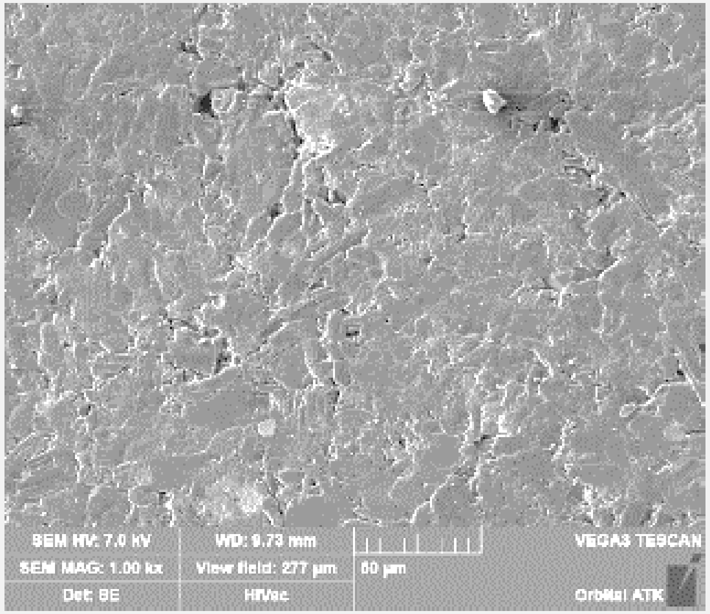
SPI AJ & YP Returned Inflators Show Differences in Aged Samples

Orbital ATK

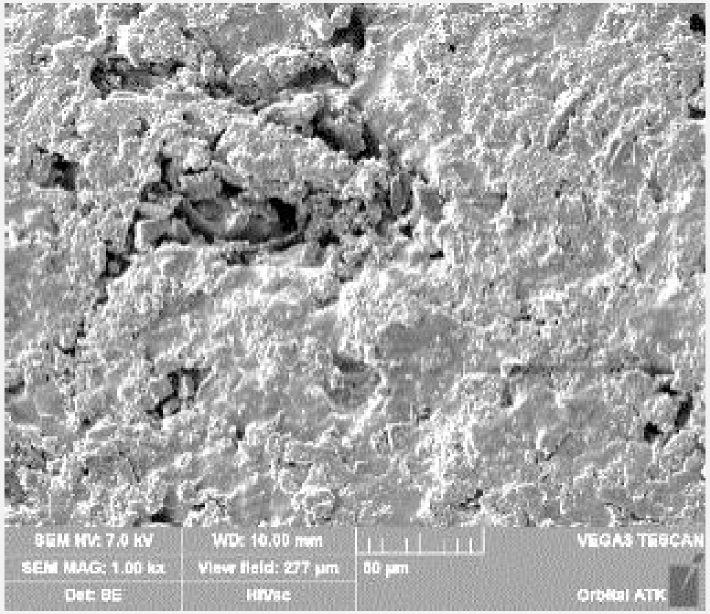
1000X Magnification-Radial Surface

- Virgin samples similar (not shown)
- Results consistent for several samples and visible at all magnifications
- Returned GM SPI YP surface similar to virgin materials (compare to previous pages)
- Surface of returned SPI AJ from other OEM shows significant aging effects

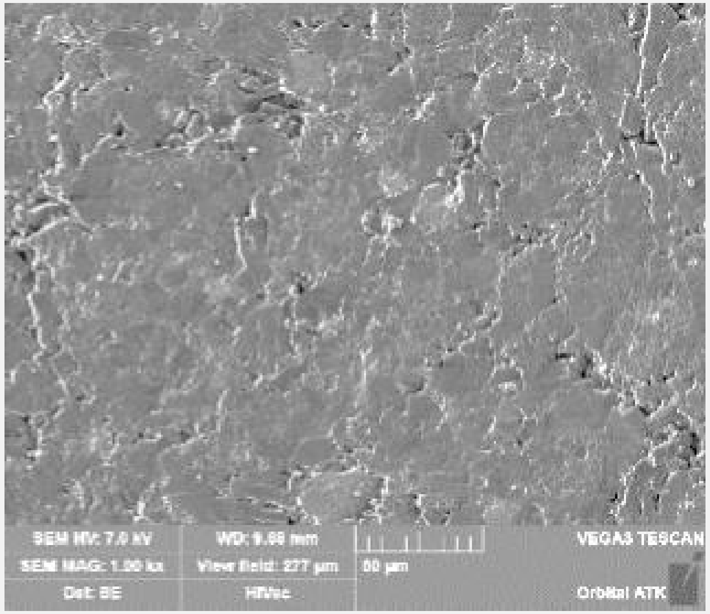
Returned YP #1 29.02 mm



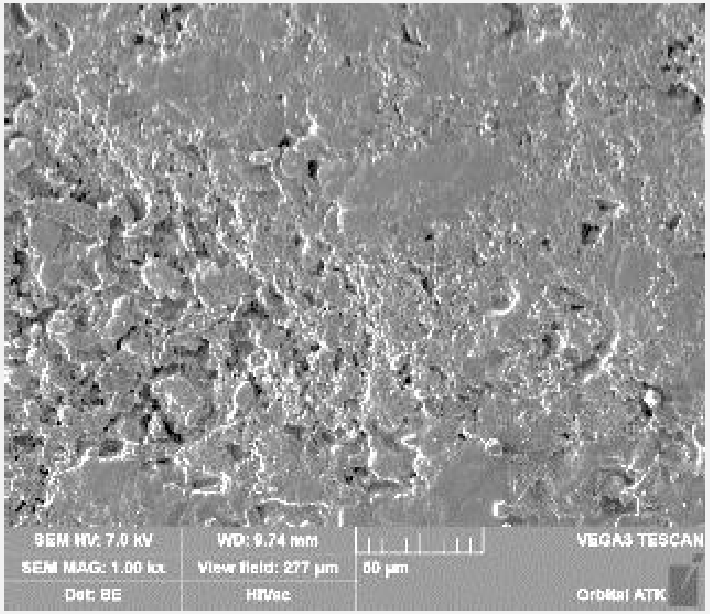
Returned AJ #1 29.24 mm



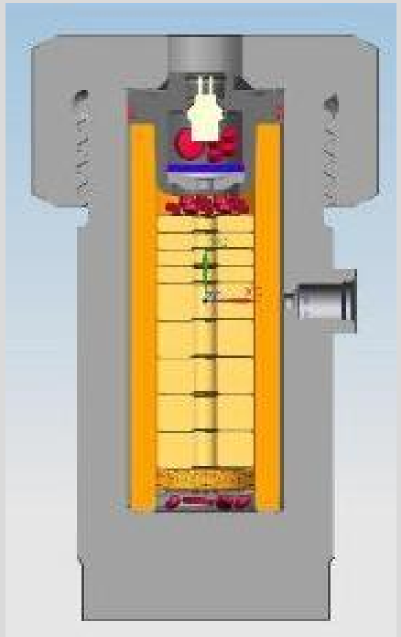
Returned YP #2 29.02 mm



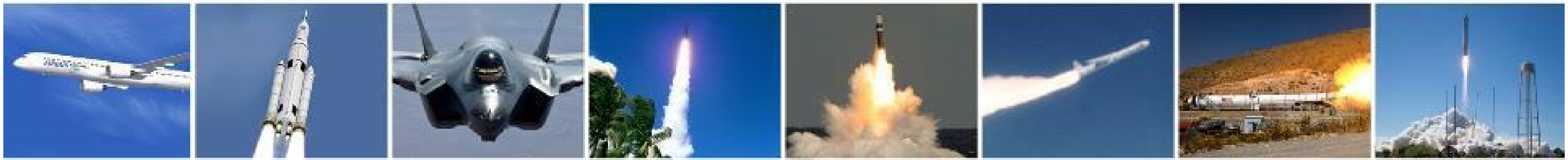
Returned AJ #2 29.24 mm



SEM and Micro CT (1120)



Discussion



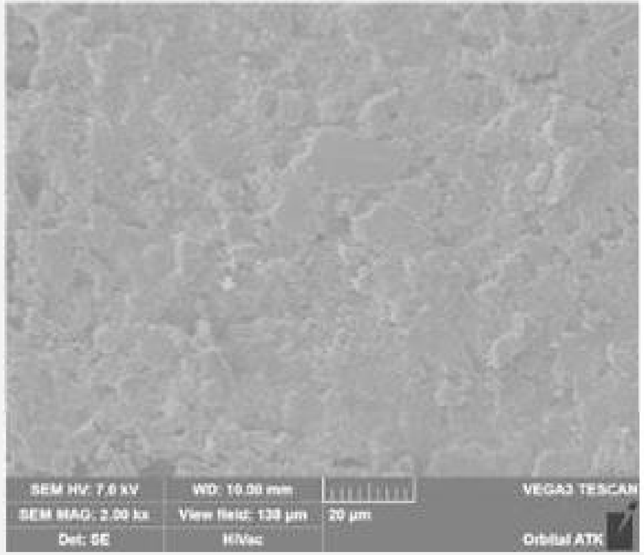
SEM 0-840 Cycle
Review of SEM approaches

- Look at same moisture condition, 20 C-50 C, 20 C-60 C and 20 C-70 C
  - PSPI-L YD (0.15% moisture)

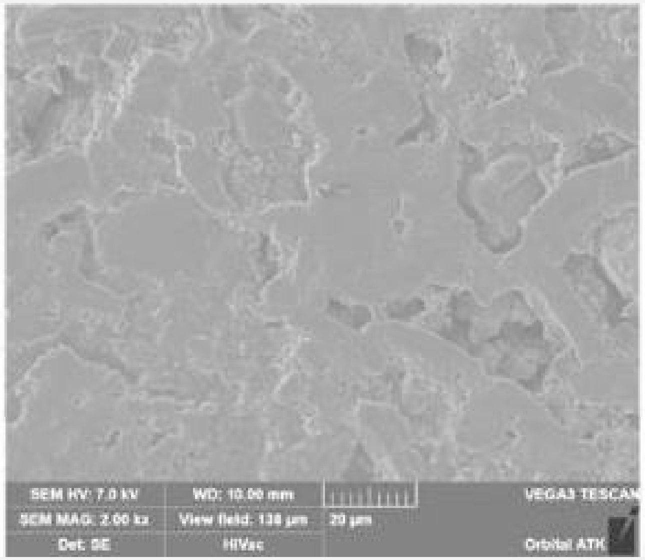
PSPI-L YD Primary, 840 Cycles, 0.15% H2O

Tests as Function of Maximum Cycling Temperature
2000X Magnification-External Surface

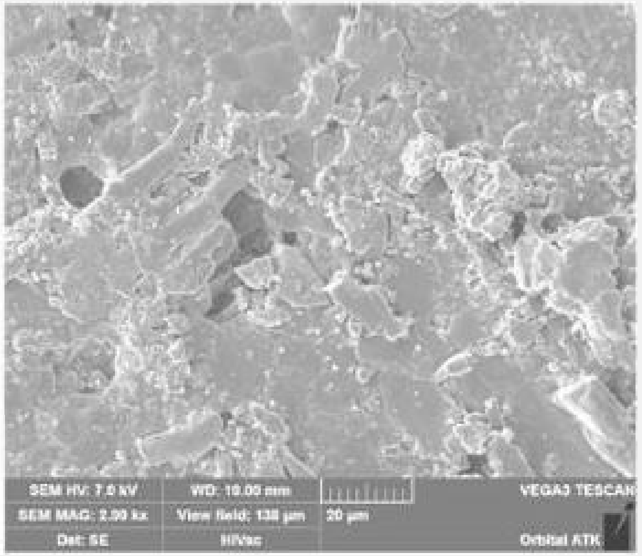
PSPI-L YD Primary P3 #2 (100871)
20 C-50 C



PSPI-L YD Primary P3 #2 (100904)
20 C-60 C



PSPI-L YD Primary P3 #2 (100940)
20 C-70 C



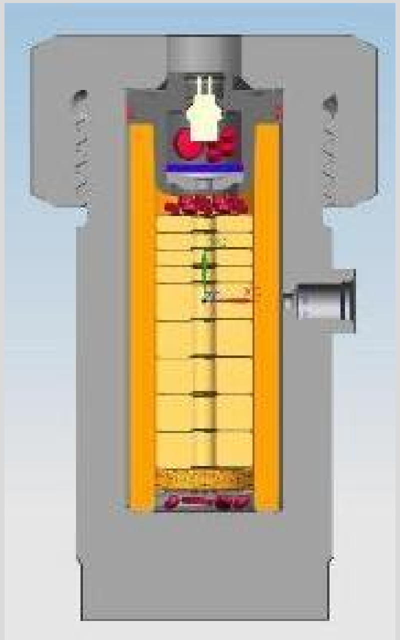
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100871	PSPI-L	YD	Primary	P3	840	50	0.15%	0.052	28.80	1.690
100904	PSPI-L	YD	Primary	P3	840	60	0.15%	0.047	28.87	1.677
100940	PSPI-L	YD	Primary	P3	840	70	0.15%	0.085	29.08	1.672

- Greatest surface porosity observed in the sample aged from 20 C-70 C

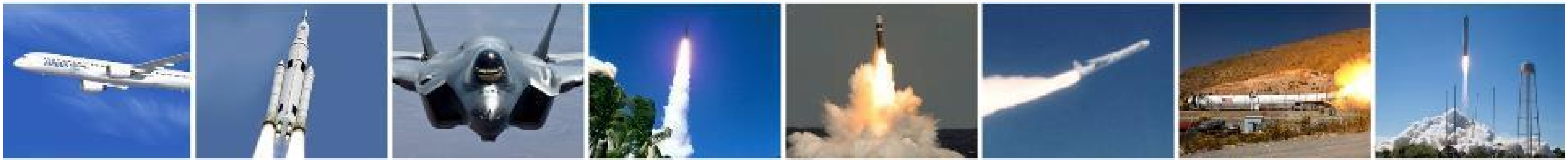
SEM/Micro CT 1120 Cycle
Proposals

- SEM
  - Follow a particular aging condition through each cycle
    - Add 1120 cycle to 0-840 SPI YP 0.30% 20 C-70 C series
  - Look at same moisture condition, 20 C-50 C, 20 C-60 C and 20 C-70 C
    - PSPI-L YD (0.15% moisture)
    - PSPI-L FD (0.15% moisture)
    - SPY YP (0.15% Moisture)
  - Returned YP Inflator that was GM Aged
- Micro CT
  - Look at same moisture condition, 20 C-50 C, 20 C-60 C and 20 C-70 C
    - PSPI-L YD (0.15% moisture): 20 C to 60 C only
    - PSPI-L FD (0.15% moisture): All three maximum temperatures
    - SPY YP (0.15% Moisture): 20 C to 60 C only
  - Use pore analysis software for data analysis

SEM Analysis (0-1120 Cycle)
SPI YP Primary,
0.30% Moisture
20 C -70 C



Discussion

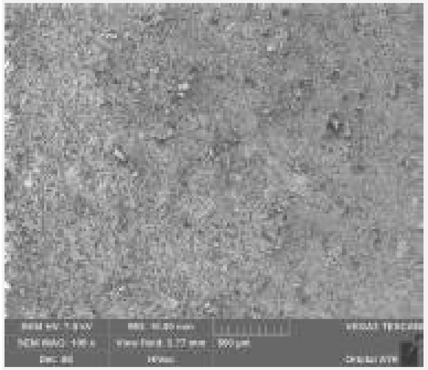


SEM 0-1120 Cycle-Constant Moisture and Temperature

100X Magnification-External Surface: YP 0.30% total moisture, 20-70 C

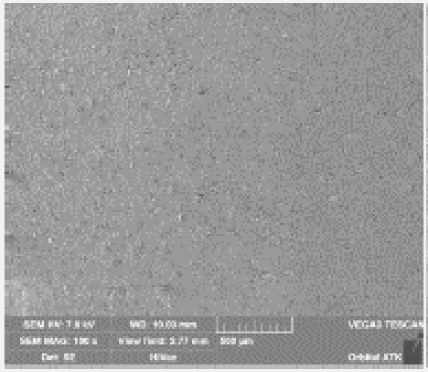
Orbital ATK

Zero Time YP #1 P3
0.3% H20 (100606)



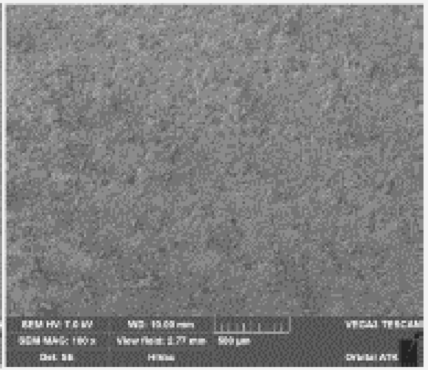
0.123% H20, 28.72 mm

280 Cycle YP #1 P3
0.3% H2O 70 C (100690)



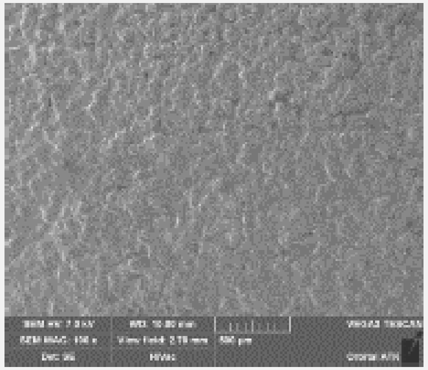
0.091% H20, 29.17 mm

560 Cycle YP #1 P5
0.3% H2O 70 C (100691)



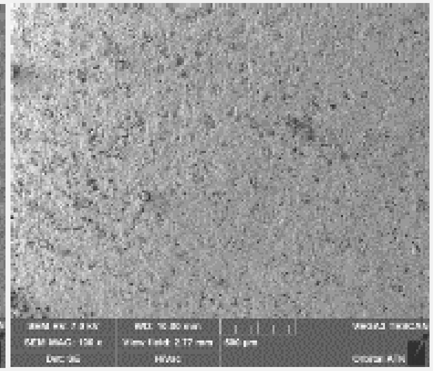
0.132% H20, 29.33 mm

840 Cycle YP #1 P3
0.3% H2O 70 C (100700)



0.181% H20, 29.49 mm

1120 Cycle YP #1 P5
0.3% H2O 70 C (100701)



0.081% H20, 29.40 mm

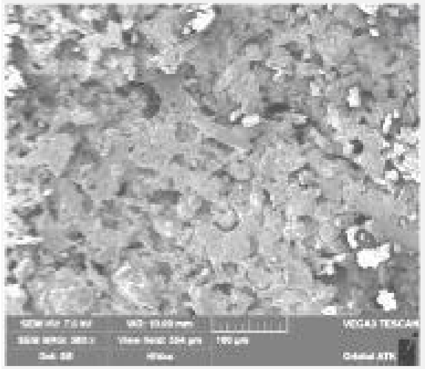
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp deg-C	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Crush Strength (ksi)
100606	SPI	YP	Primary	P3	0	NA	0.30%	0.123	28.72	0.609
100690	SPI	YP	Primary	P3	280	70	0.30%	0.091	29.17	0.498
100691	SPI	YP	Primary	P5	560	70	0.30%	0.132	29.33	
100700	SPI	YP	Primary	P3	840	70	0.30%	0.181	29.49	0.328
100701	SPI	YP	Primary	P5	1120	70	0.30%	0.081	29.40	

- Surface roughness appears to be a function of moisture content of the 2004 wafer
  - Lowest moisture 280 and 1120 cycle are rather smooth
    - Pitting is deeper in 1120 cycle
  - Mid moisture 0 and 560 cycle surfaces have a jagged, rough surface topography
  - Abnormally high moisture 840 cycle have a topography smoothed by moisture effects

SEM 0-1120 Cycle-Constant Moisture and Temperature

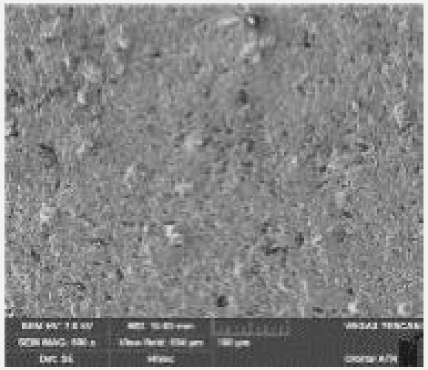
500X Magnification-External Surface: YP 0.30% total moisture, 20-70 C

Zero Time YP #1 P3
0.3% H20 (100606)



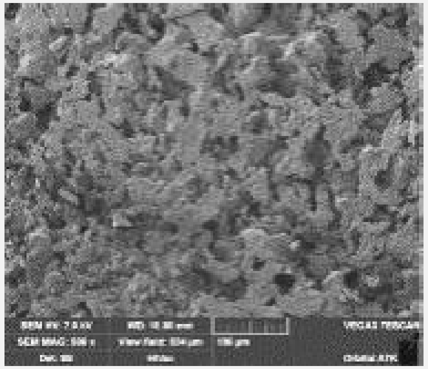
0.123% H20, 28.72 mm

280 Cycle YP #1 P3
0.3% H2O 70 C (100690)



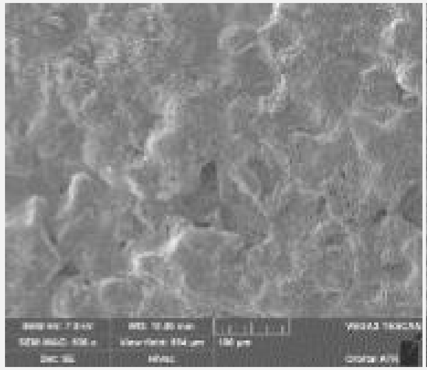
0.091% H20, 29.17 mm

560 Cycle YP #1 P5
0.3% H2O 70 C (100691)



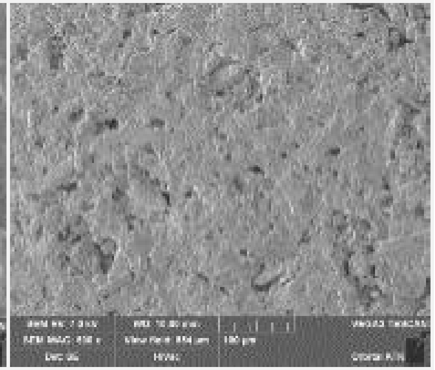
0.132% H20, 29.33 mm

840 Cycle YP #1 P3
0.3% H2O 70 C (100700)



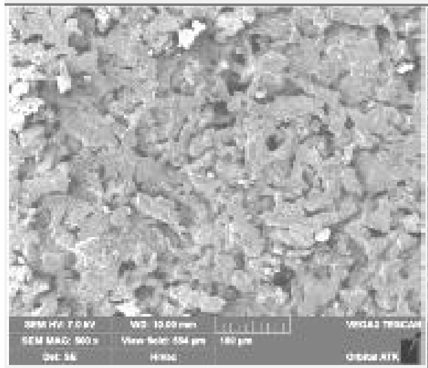
0.181% H20, 29.49 mm

1120 Cycle YP #1 P5
0.3% H2O 70 C (100701)



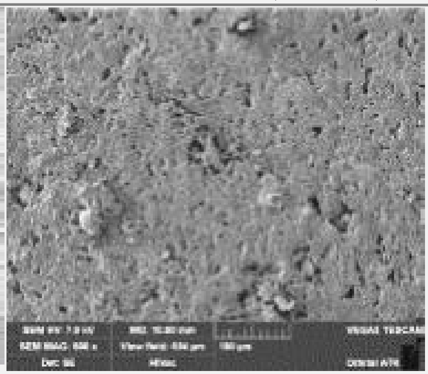
0.081% H20, 29.40 mm

Zero Time YP #2 P3
0.3% H20 (100606)



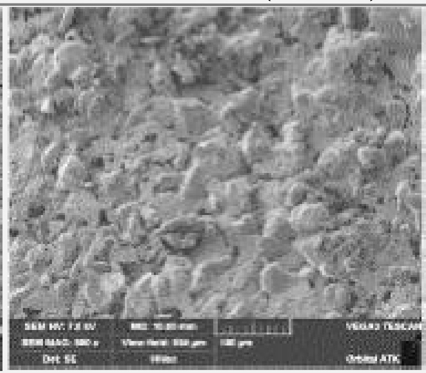
0.123% H20, 28.72 mm

280 Cycle YP #2 P3
0.3% H2O 70 C (100690)



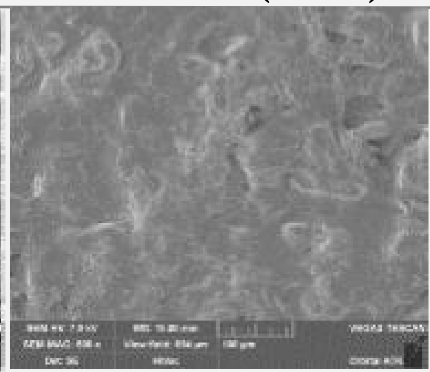
0.091% H20, 29.17 mm

560 Cycle YP #2 P5
0.3% H2O 70 C (100691)



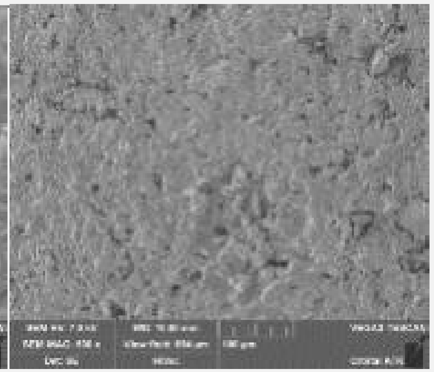
0.132% H20, 29.33 mm

840 Cycle YP #2 P3
0.3% H2O 70 C (100700)



0.181% H20, 29.49 mm

1120 Cycle YP #2 P5
0.3% H2O 70 C (100701)



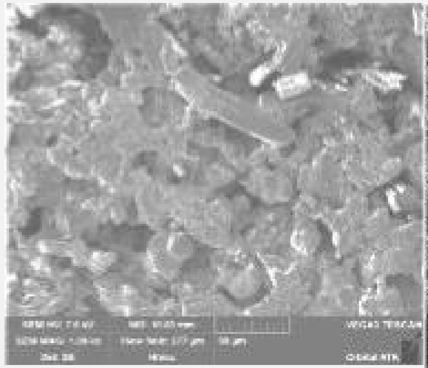
0.081% H20, 29.40 mm

- Perhaps, the sharp surfaces on an eroded 2004 wafer surface such as in 560 cycle #1 gradually smooth out in progression such as 560 cycle #1, 560 cycle #2 and 840 cycle #1

SEM 0-1120 Cycle-Constant Moisture and Temperature

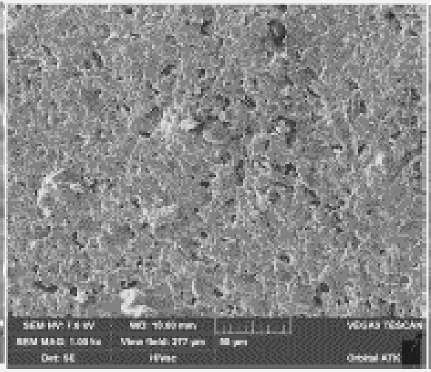
1000X Magnification-External Surface: YP 0.30% total moisture, 20-70 C

Zero Time YP #1 P3
0.3% H20 (100606)



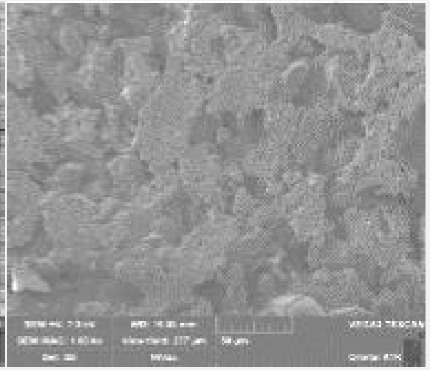
0.123% H20, 28.72 mm

280 Cycle YP #1 P3
0.3% H2O 70 C (100690)



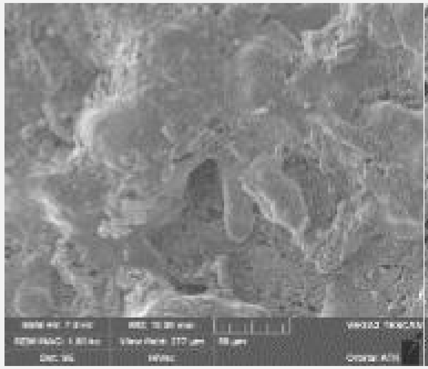
0.091% H20, 29.17 mm

560 Cycle YP #1 P5
0.3% H2O 70 C (100691)



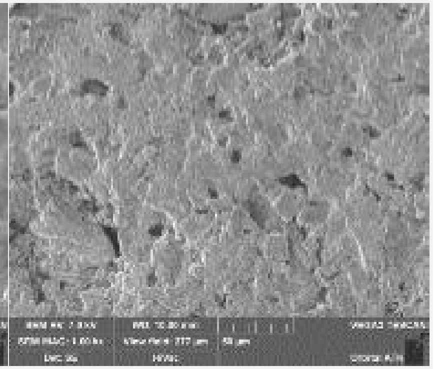
0.132% H20, 29.33 mm

840 Cycle YP #1 P3
0.3% H2O 70 C (100700)



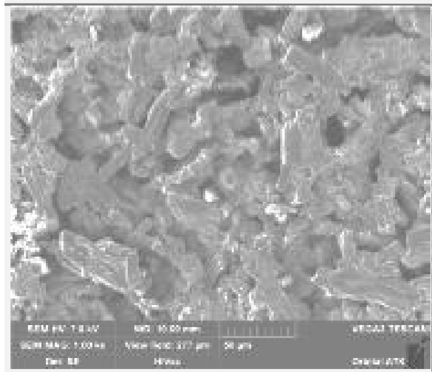
0.181% H20, 29.49 mm

1120 Cycle YP #1 P5
0.3% H2O 70 C (100701)



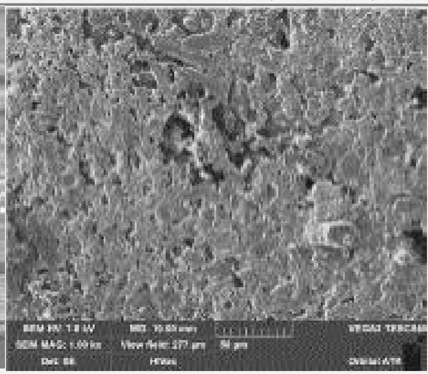
0.081% H20, 29.40 mm

Zero Time YP #2 P3
0.3% H20 (100606)



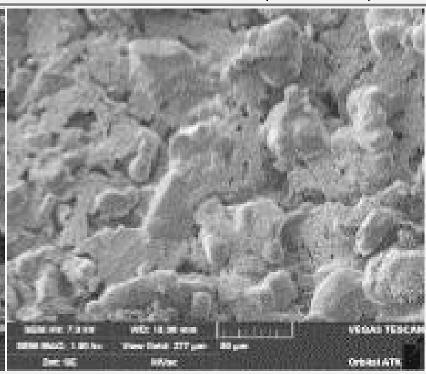
0.123% H20, 28.72 mm

280 Cycle YP #2 P3
0.3% H2O 70 C (100690)



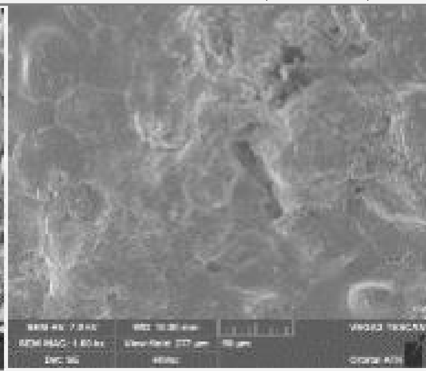
0.091% H20, 29.17 mm

560 Cycle YP #2 P5
0.3% H2O 70 C (100691)



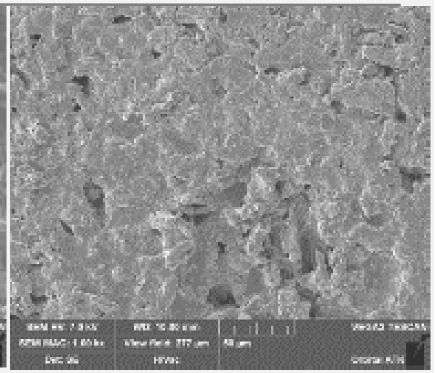
0.132% H20, 29.33 mm

840 Cycle YP #2 P3
0.3% H2O 70 C (100700)



0.181% H20, 29.49 mm

1120 Cycle YP #2 P5
0.3% H2O 70 C (100701)



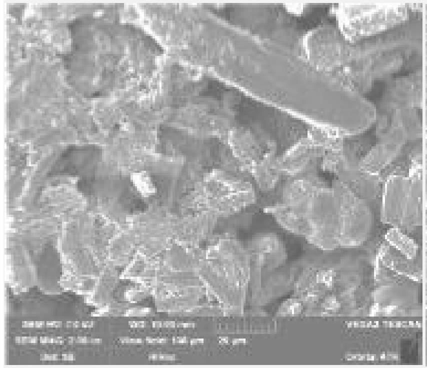
0.081% H20, 29.40 mm

- Surface erosion and topography are dependent on wafer moisture content
  - Could effect wafer ignitability and combustion pressure rise rate

SEM 0-1120 Cycle-Constant Moisture and Temperature

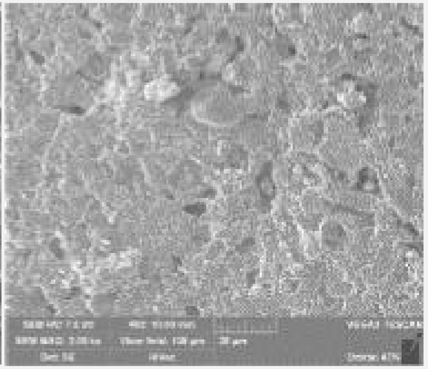
2000X Magnification-External Surface: YP 0.30% total moisture, 20-70 C

Zero Time YP #1 P3
0.3% H20 (100606)



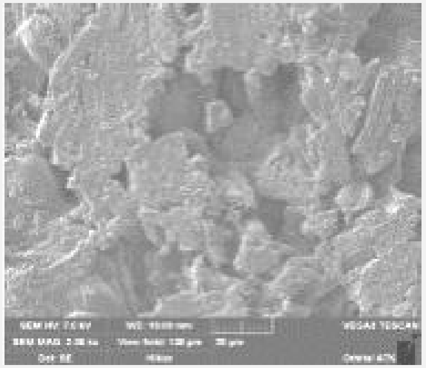
0.123% H20, 28.72 mm

280 Cycle YP #1 P3
0.3% H2O 70 C (100690)



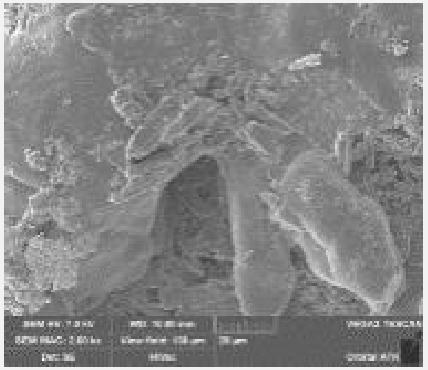
0.091% H20, 29.17 mm

560 Cycle YP #1 P5
0.3% H2O 70 C (100691)



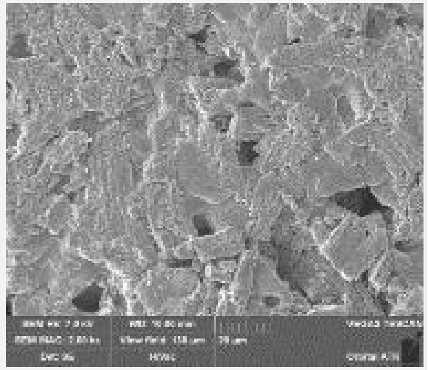
0.132% H20, 29.33 mm

840 Cycle YP #1 P3
0.3% H2O 70 C (100700)



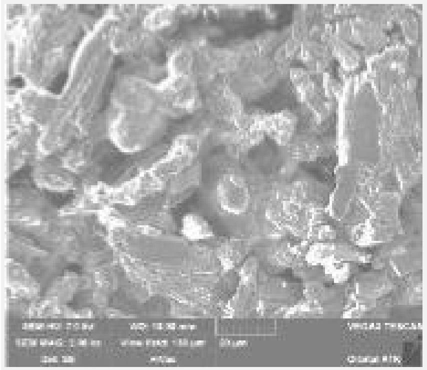
0.181% H20, 29.49 mm

1120 Cycle YP #1 P5
0.3% H2O 70 C (100701)



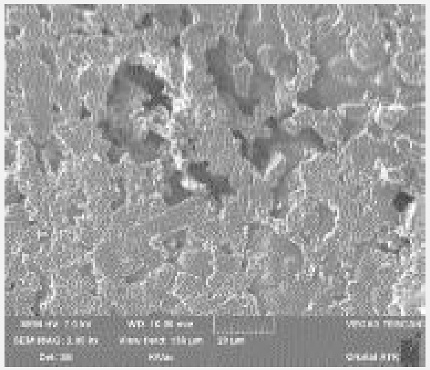
0.081% H20, 29.40 mm

Zero Time YP #2 P3
0.3% H20 (100606)



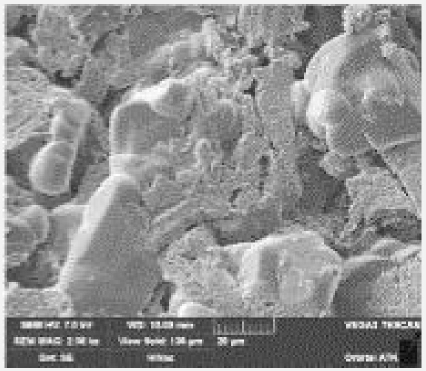
0.123% H20, 28.72 mm

280 Cycle YP #2 P3
0.3% H2O 70 C (100690)



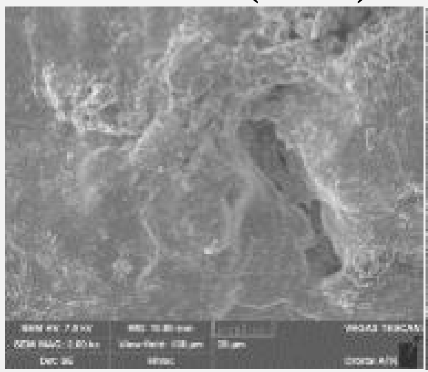
0.091% H20, 29.17 mm

560 Cycle YP #2 P5
0.3% H2O 70 C (100691)



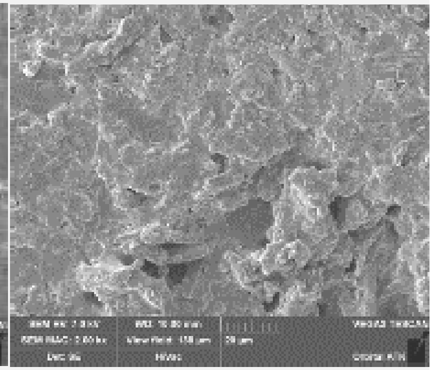
0.132% H20, 29.33 mm

840 Cycle YP #2 P3
0.3% H2O 70 C (100700)



0.181% H20, 29.49 mm

1120 Cycle YP #2 P5
0.3% H2O 70 C (100701)



0.081% H20, 29.40 mm

- 1120 has deep surface pores

SEM 0-1120 Cycle-Constant Moisture and Temperature

100X Magnification-Internal Surface: YP 0.30% total moisture, 20-70 C

- Nothing definitive was gained from the internal surfaces of this series

SEM/Micro CT 1120 Cycle
Proposals

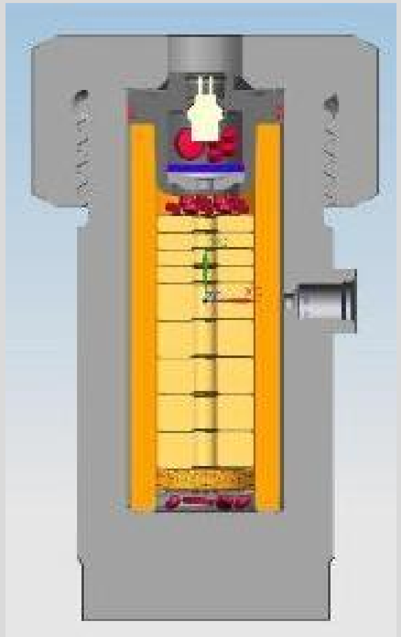
- SEM
  - Follow a particular aging condition through each cycle
    - Add 1120 cycle to 0-840 SPI YP 0.30% 20 C-70 C series
    - Separate presentation
  - Look at same moisture condition, 20 C-50 C, 20 C-60 C and 20 C-70 C
    - PSPI-L YD (0.15% moisture)
    - PSPI-L FD (0.15% moisture)
    - SPY YP (0.15% Moisture)
  - Returned YP Inflator that was GM Aged

1120 Cycle SEM

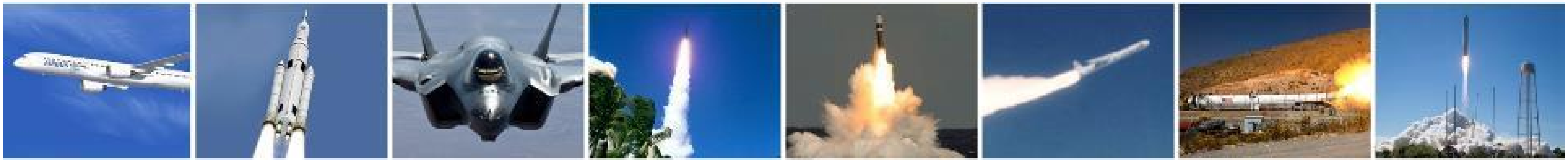
Comparison of Samples at 0.15% Moisture

Varying Maximum Cycle Temperature,

SPI YP:	**20-50 C, 20-60 C, 20-70 C**
PSPI-L FD:	**20-50 C, 20-60 C, 20-70 C**
PSPI-L YD:	**20-50 C, 20-60 C, 20-70 C**

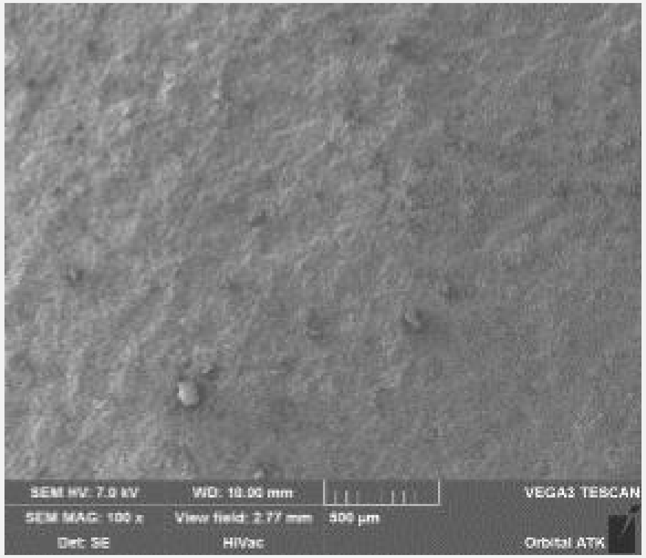


Discussion



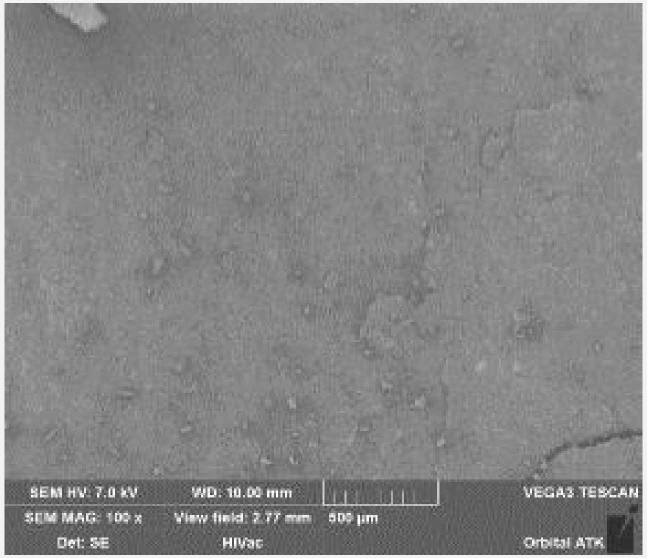
100X Magnification-Internal Surface
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

SPI YP Primary P5 #1 (100497)



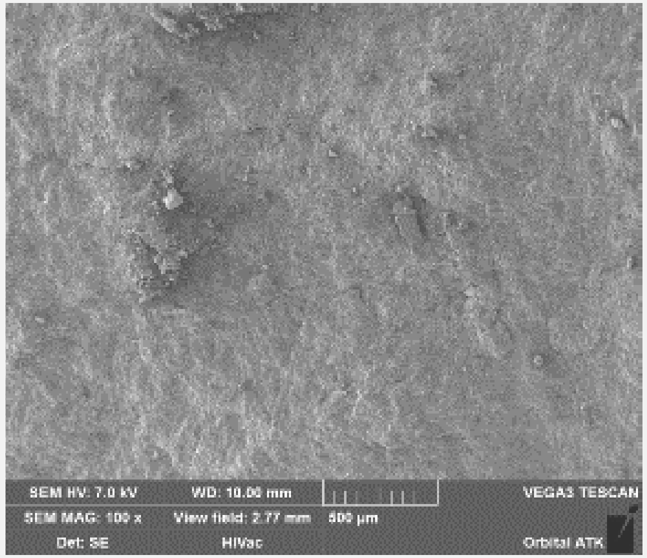
1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

SPI YP Primary P5 #1 (100547)



1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #1 (100580)



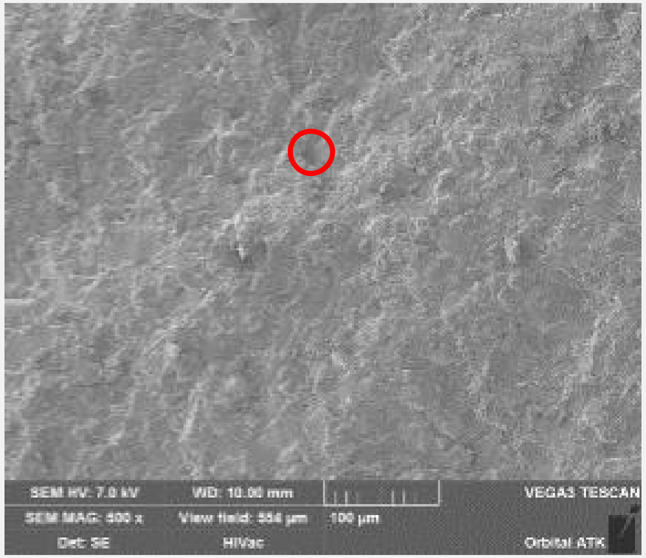
1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100497	SPI	YP	Primary	P5	1120	50	0.15%	0.065	29.00	1.670
100547	SPI	YP	Primary	P5	1120	60	0.15%	0.055	28.91	1.671
100580	SPI	YP	Primary	P5	1120	70	0.15%	0.058	29.21	1.658

- Some micro pores observed in the 20-70 C sample
  - Best observed at 500X and 1000X magnification

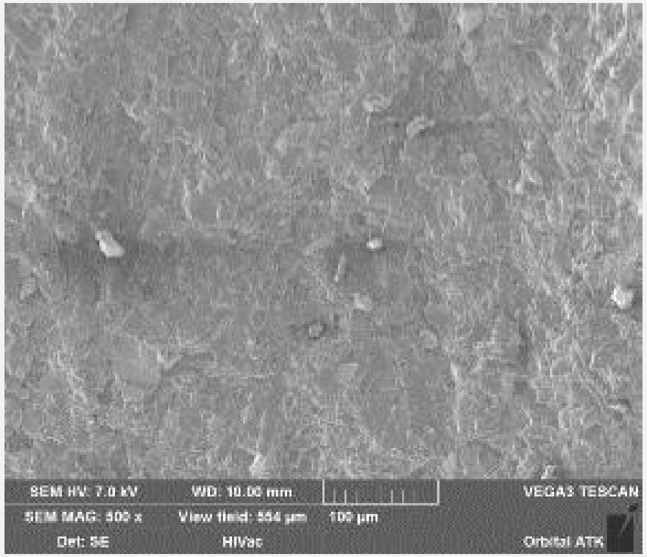
500X Magnification-Internal Surface
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

SPI YP Primary P5 #1 (100497)



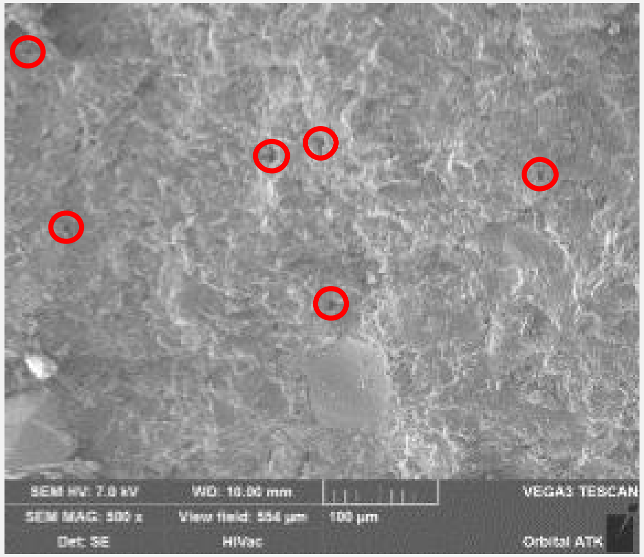
1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

SPI YP Primary P5 #1 (100547)



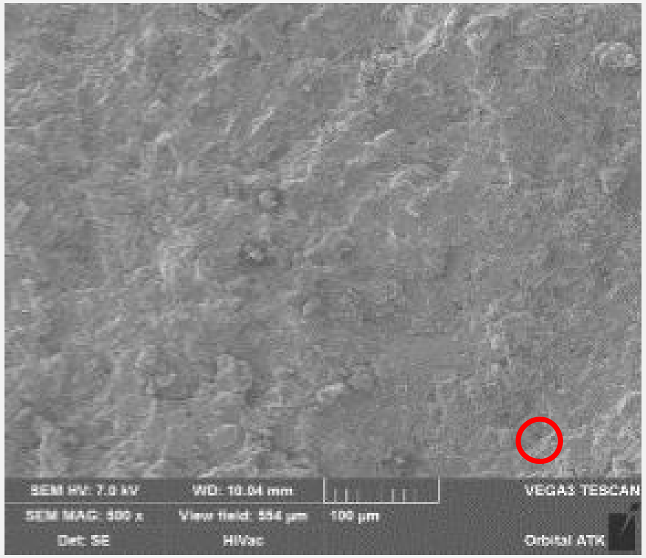
1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #1 (100580)

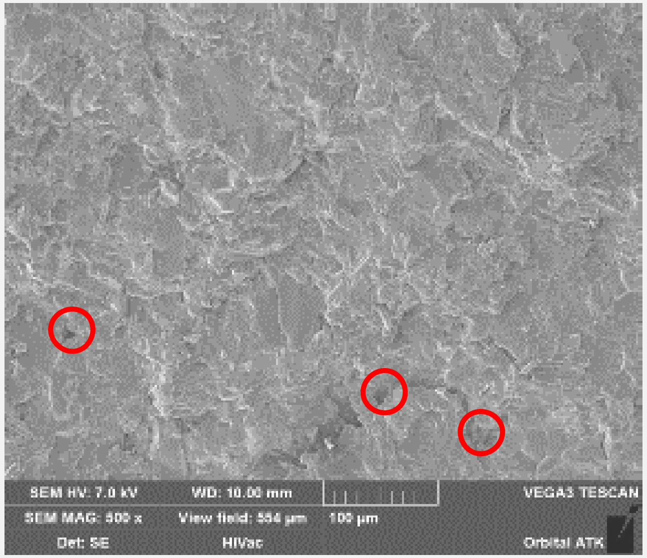


1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

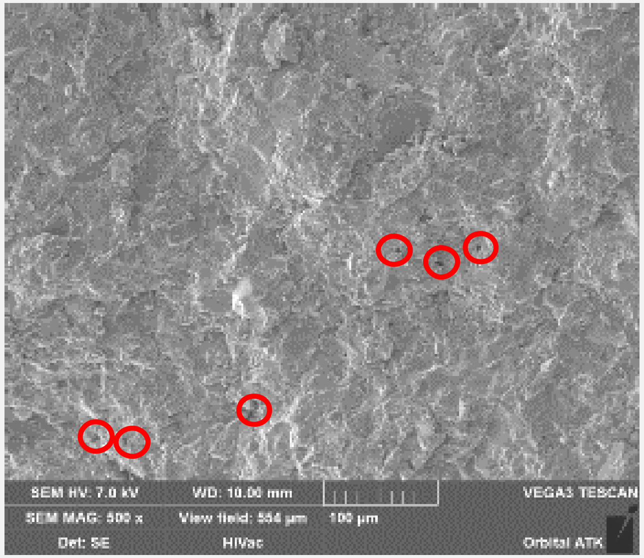
SPI YP Primary P5 #2 (100497)



SPI YP Primary P5 #2 (100547)

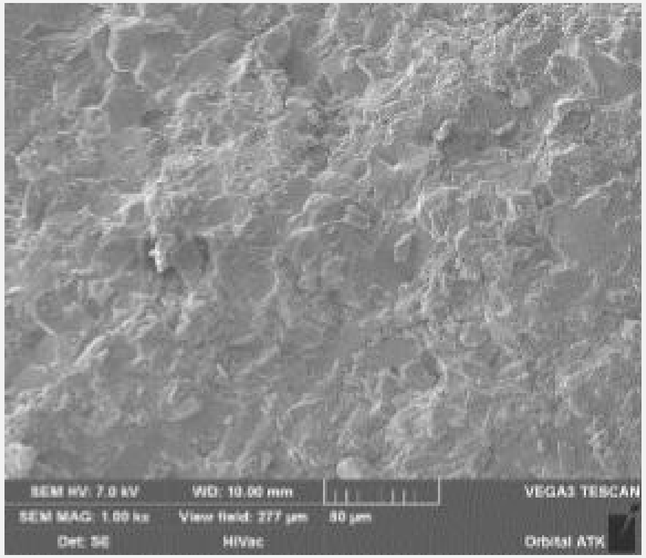


SPI YP Primary P5 #2 (100580)



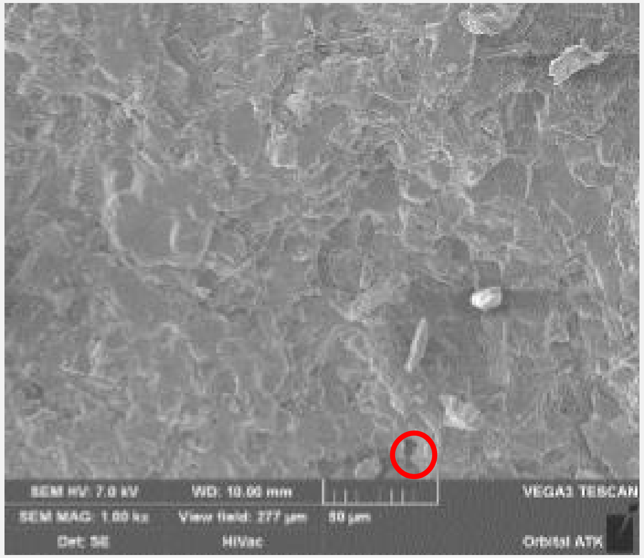
1000X Magnification-Internal Surface
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

SPI YP Primary P5 #1 (100497)



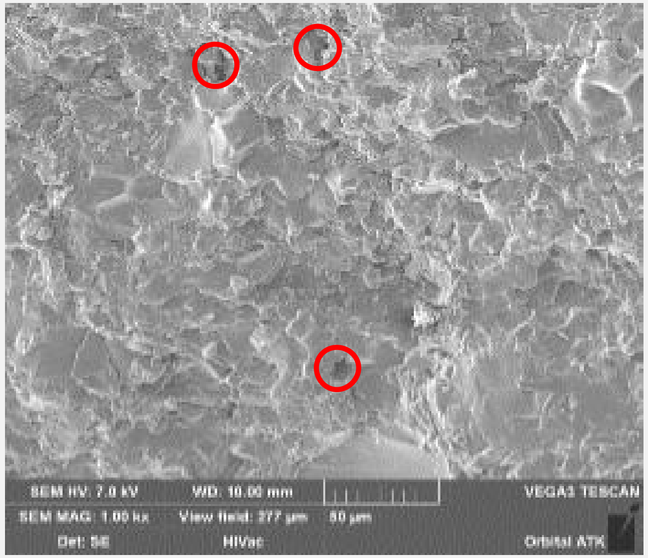
1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

SPI YP Primary P5 #1 (100547)



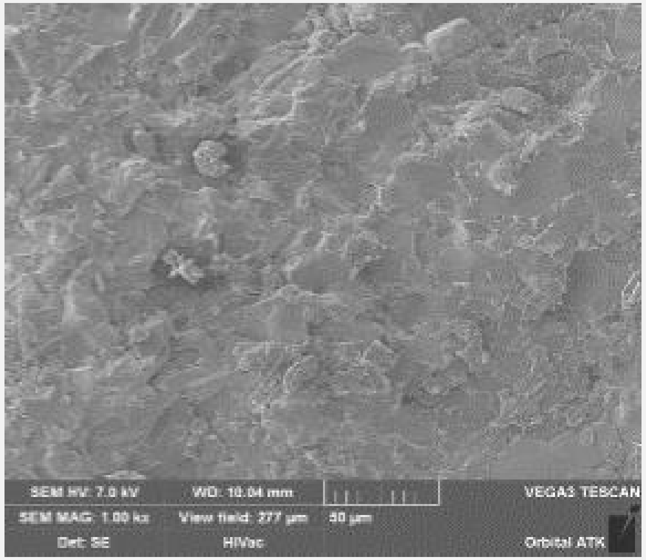
1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #1 (100580)

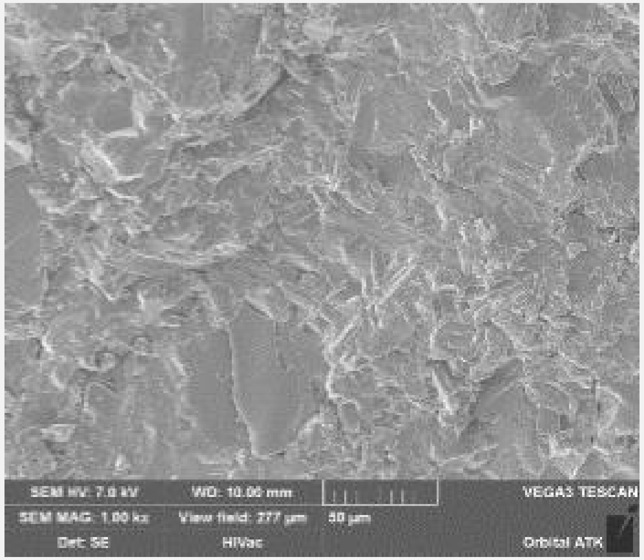


1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

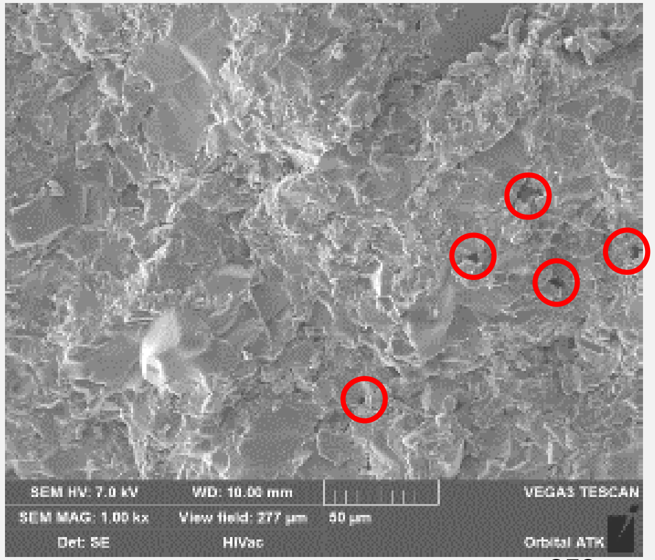
SPI YP Primary P5 #2 (100497)



SPI YP Primary P5 #2 (100547)



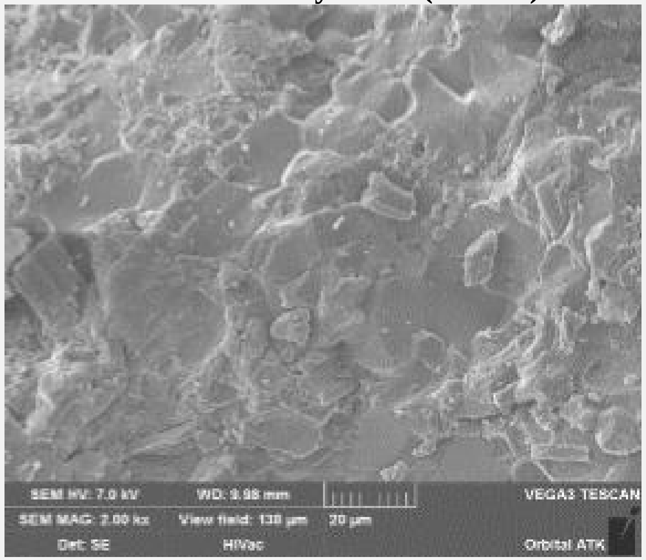
SPI YP Primary P5 #2 (100580)



2000X Magnification-Internal Surface

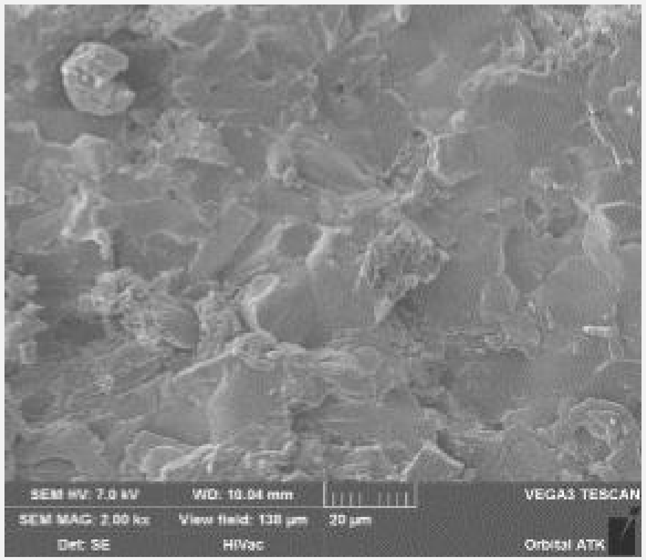
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

SPI YP Primary P5 #1 (100497)

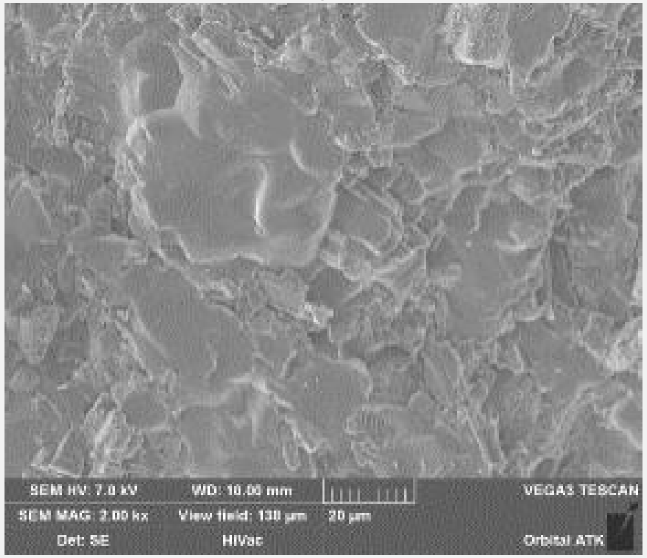


1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

SPI YP Primary P5 #2 (100497)

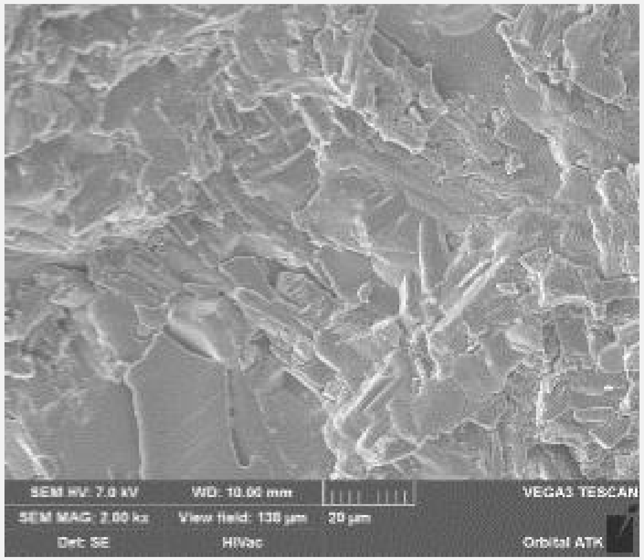


SPI YP Primary P5 #1 (100547)

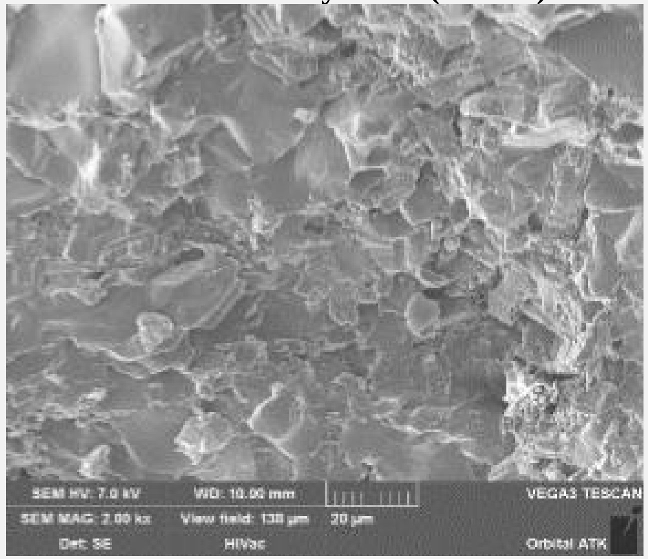


1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #2 (100547)

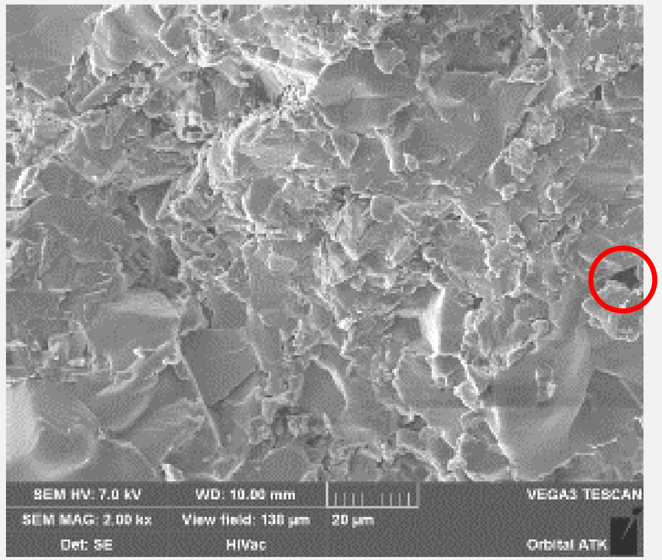


SPI YP Primary P5 #1 (100580)



1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

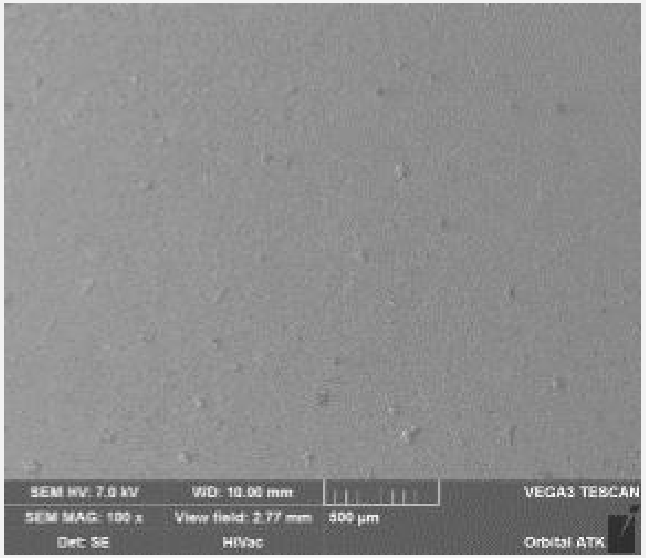
SPI YP Primary P5 #2 (100580)



100X Magnification-External Surface

SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

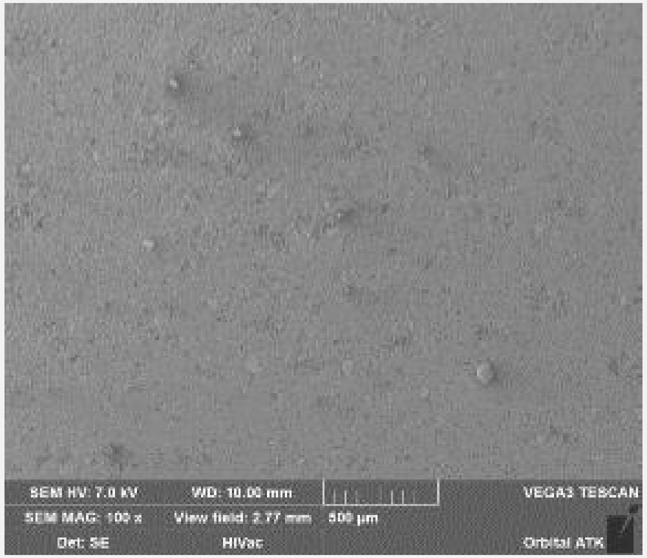
SPI YP Primary P5 #1 (100497)



1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

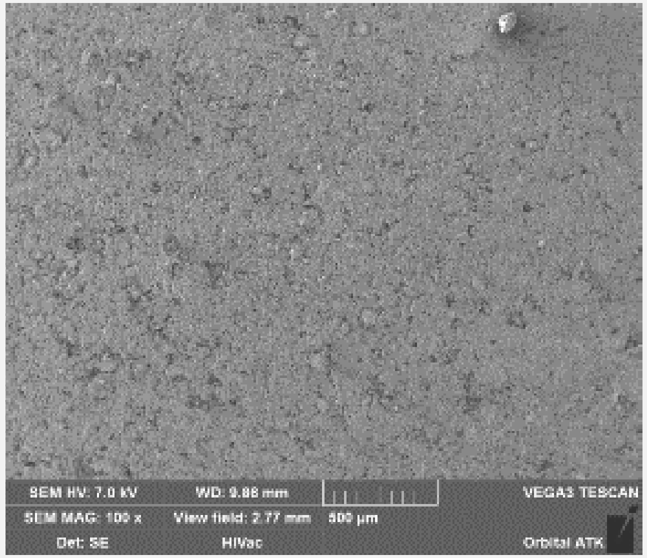
SPI YP Primary P5 #1 (100547)



1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #1 (100580)



1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

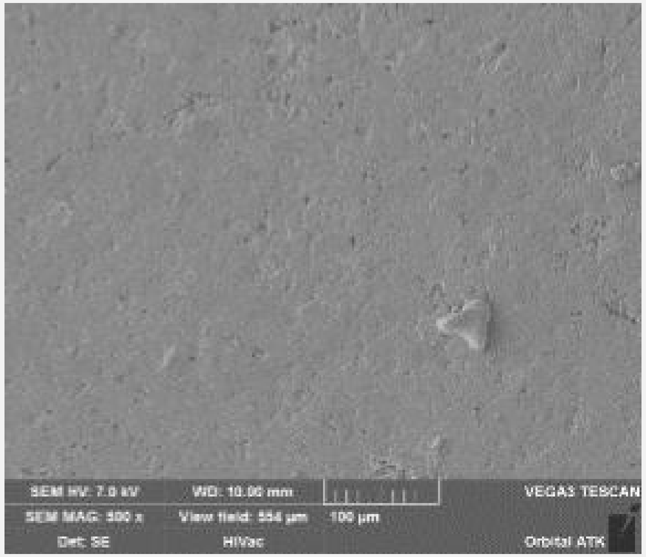
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100497	SPI	YP	Primary	P5	1120	50	0.15%	0.065	29.00	1.670
100547	SPI	YP	Primary	P5	1120	60	0.15%	0.055	28.91	1.671
100580	SPI	YP	Primary	P5	1120	70	0.15%	0.058	29.21	1.658

- Surface roughness for 20-50 C and 20-60 C are similar
  - More pronounced pitting on the 20-60 C sample surface at higher magnification
- Significant surface erosion on the 20-70 C sample surface is observed

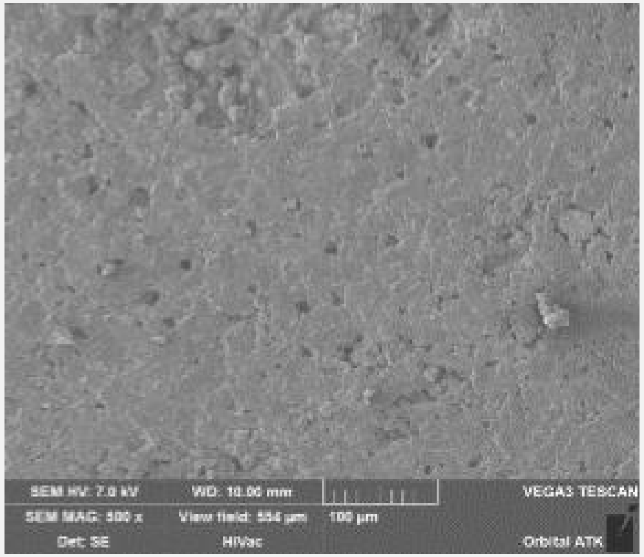
500X Magnification-External Surface
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

Orbital ATK

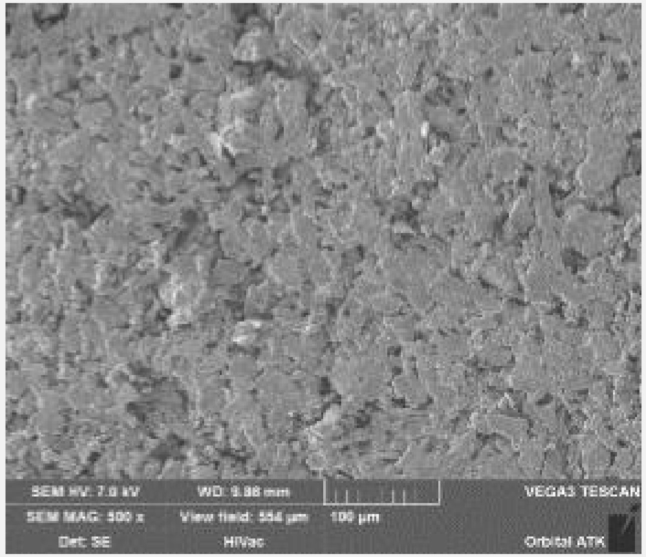
SPI YP Primary P5 #1 (100497)



SPI YP Primary P5 #1 (100547)



SPI YP Primary P5 #1 (100580)

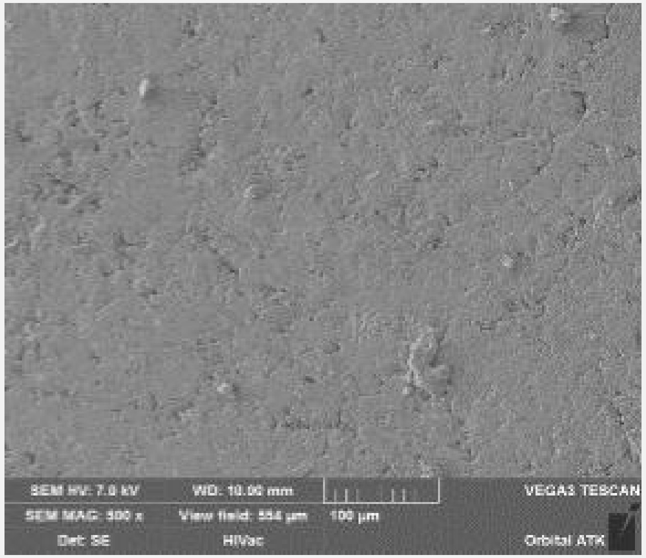


1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

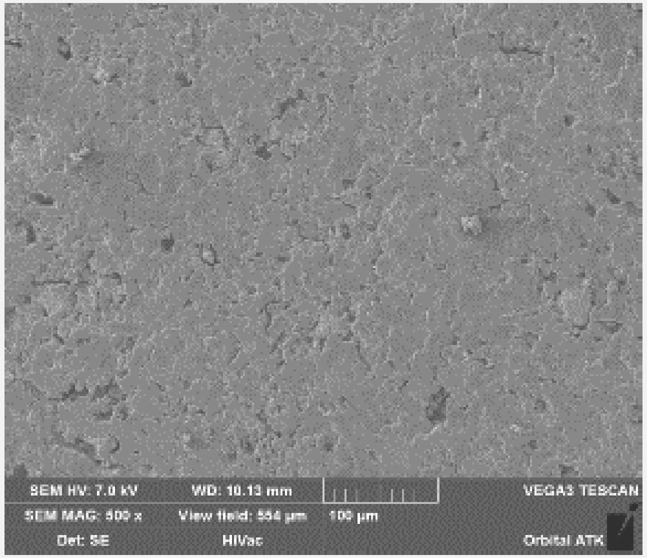
1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

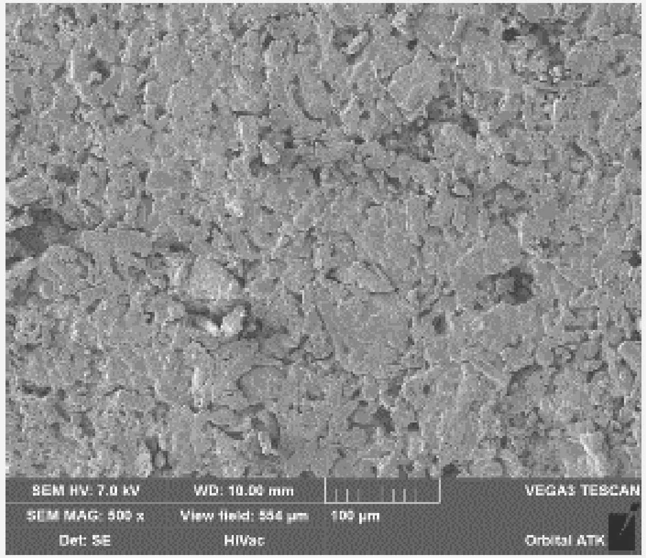
SPI YP Primary P5 #2 (100497)



SPI YP Primary P5 #2 (100547)



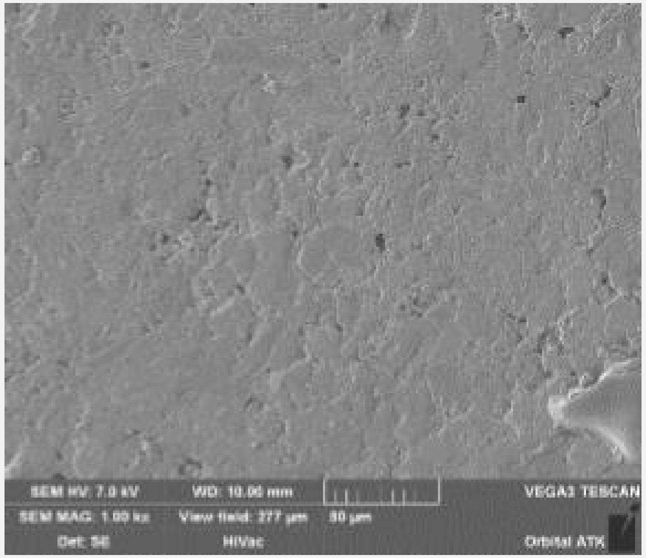
SPI YP Primary P5 #2 (100580)



1000X Magnification-External Surface

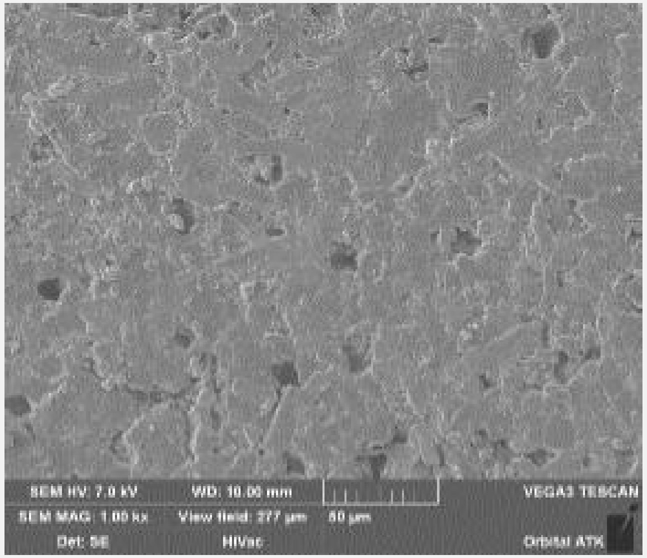
SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

SPI YP Primary P5 #1 (100497)



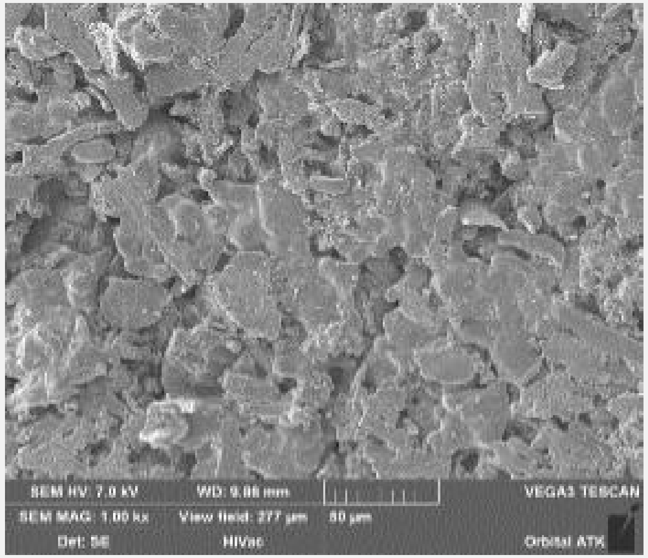
1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

SPI YP Primary P5 #1 (100547)



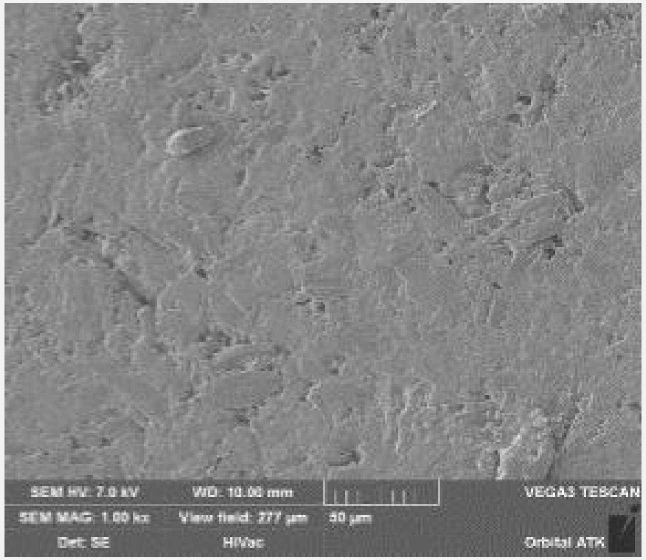
1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

SPI YP Primary P5 #1 (100580)

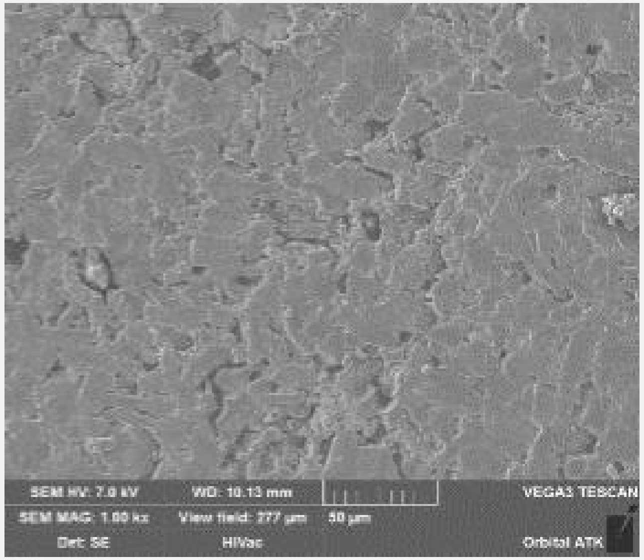


1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

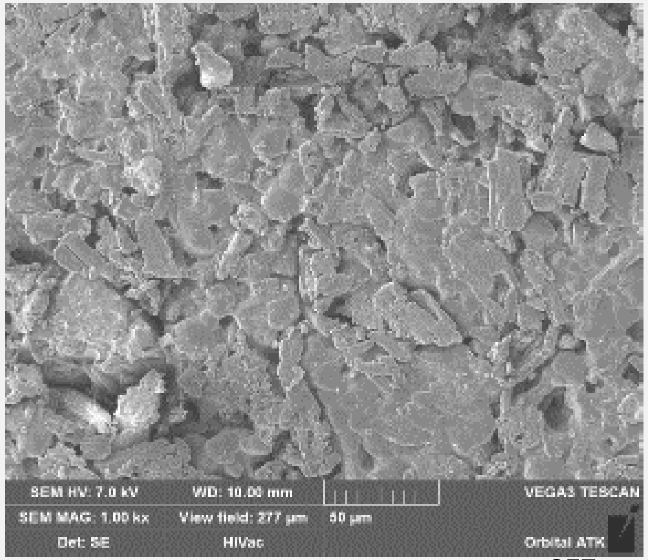
SPI YP Primary P5 #2 (100497)



SPI YP Primary P5 #2 (100547)



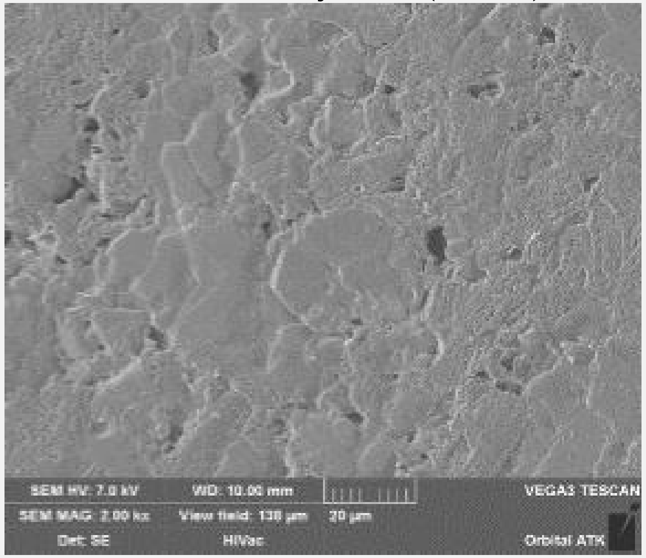
SPI YP Primary P5 #2 (100580)



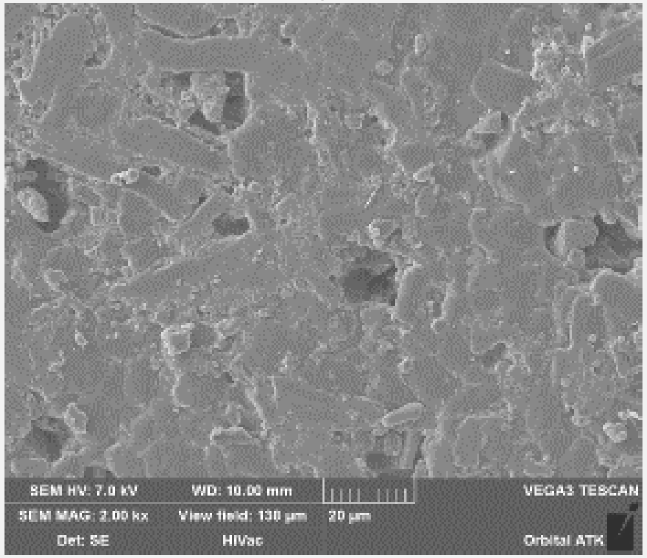
2000X Magnification-External Surface

SPI YP, Primary, 0.15% Moisture Varying Max Cycle Temp

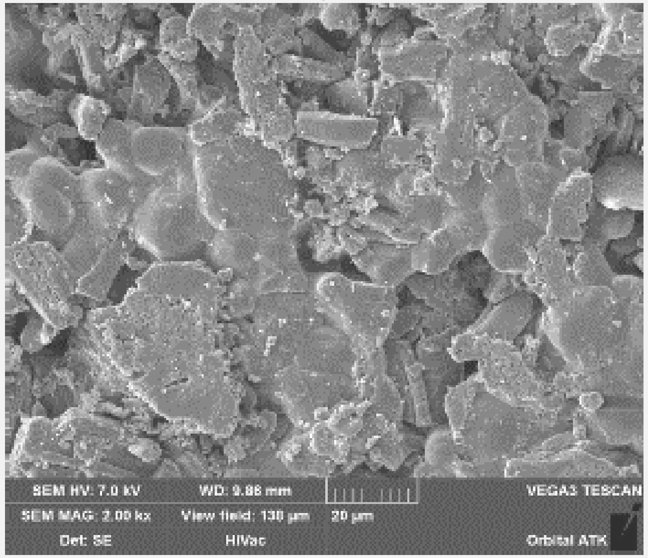
SPI YP Primary P5 #1 (100497)



SPI YP Primary P5 #1 (100547)



SPI YP Primary P5 #1 (100580)

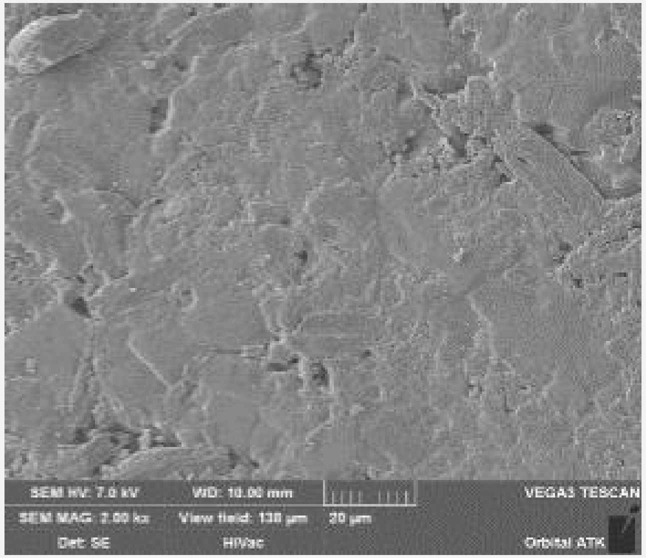


1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

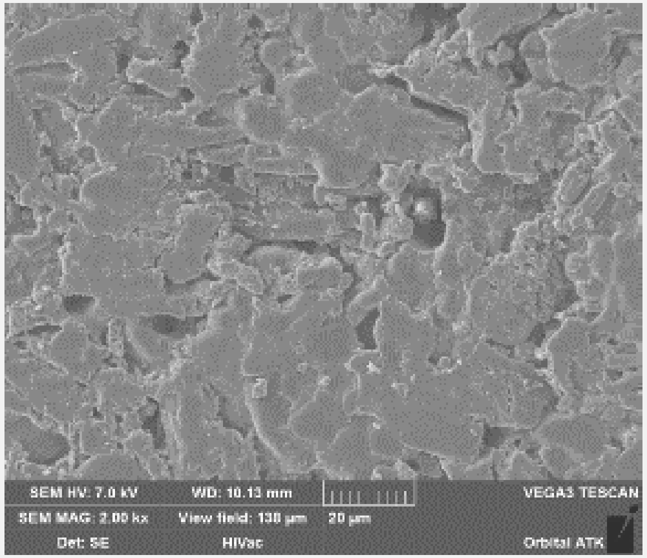
1120 cycle, 20-60 C, 0.055% H20, 28.91 mm

1120 Cycle 20-70 C, 0.058% H20, 29.21 mm

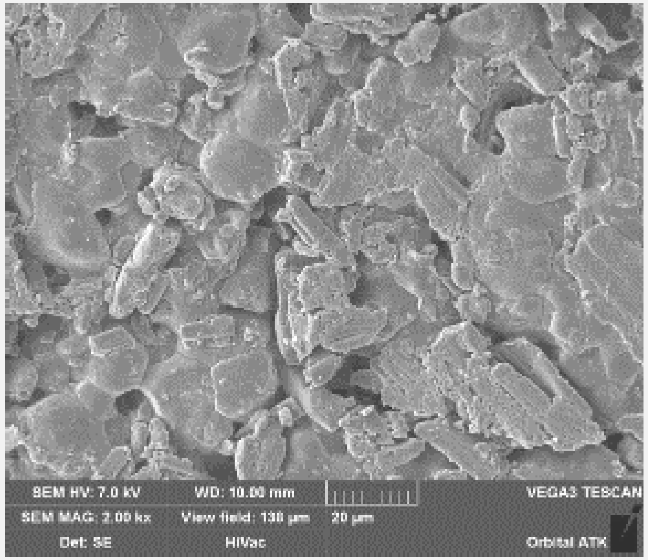
SPI YP Primary P5 #2 (100497)



SPI YP Primary P5 #2 (100547)



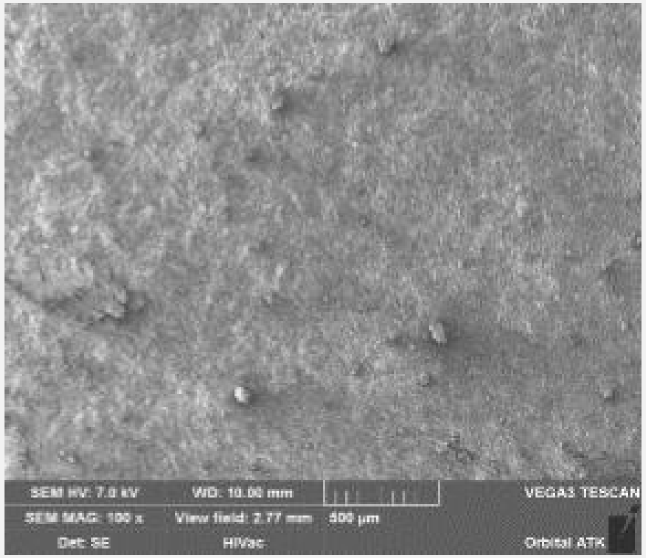
SPI YP Primary P5 #2 (100580)



100X Magnification-Internal Surface

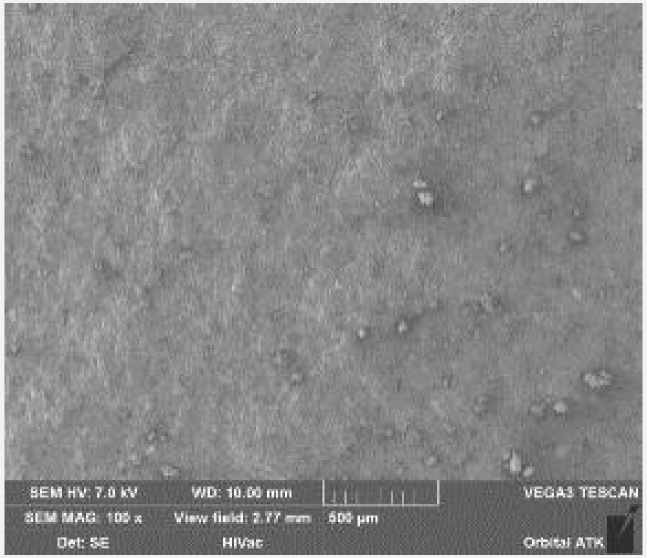
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



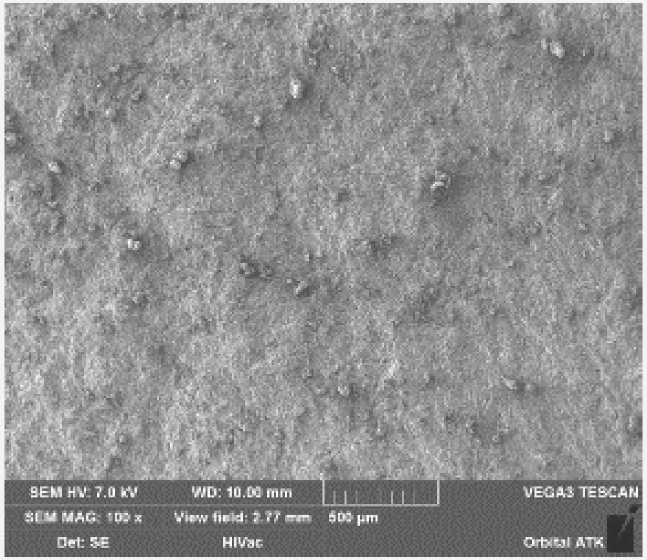
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)



1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

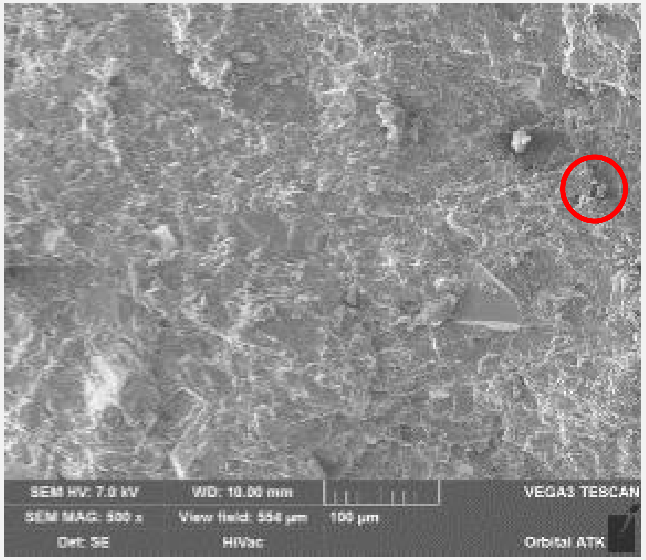
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100133	PSPI-L	FD	Primary	P4	1120	50	0.15%	0.053	28.76	1.669
100170	PSPI-L	FD	Primary	P4	1120	60	0.15%	0.055	29.04	1.634
100201	PSPI-L	FD	Primary	P4	1120	70	0.15%	0.064	29.24	1.614

- Some cracks or voids can be seen, especially around grains.
  - More prevalent in the 20-60 C and 20-70 C samples
    - These were from inflators that exhibited abnormal burn

500X Magnification-Internal Surface

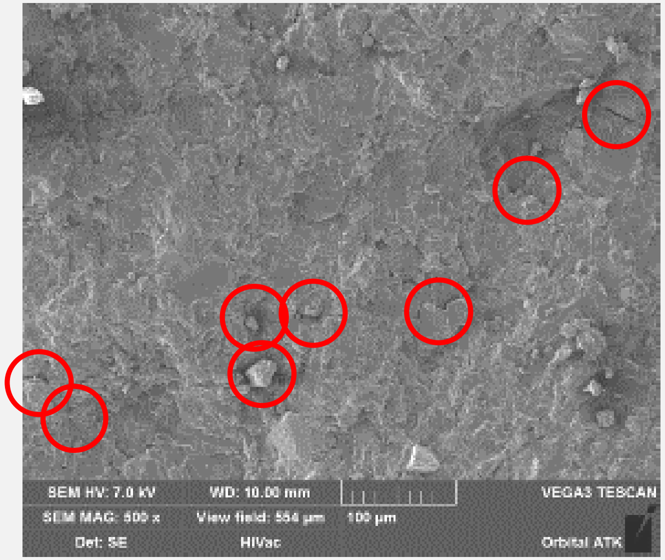
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



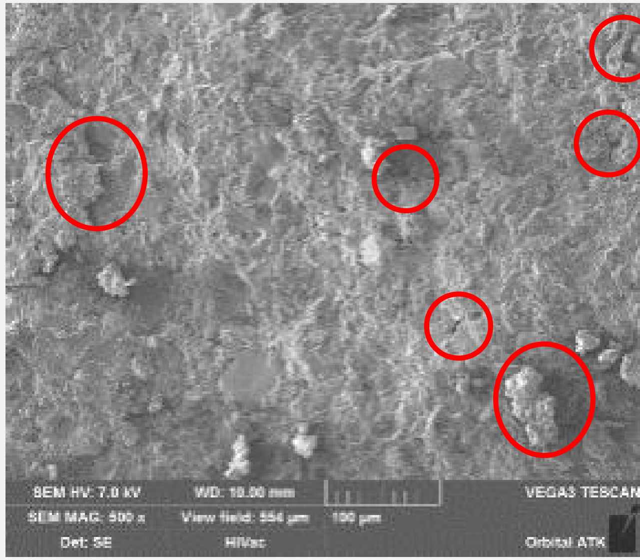
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



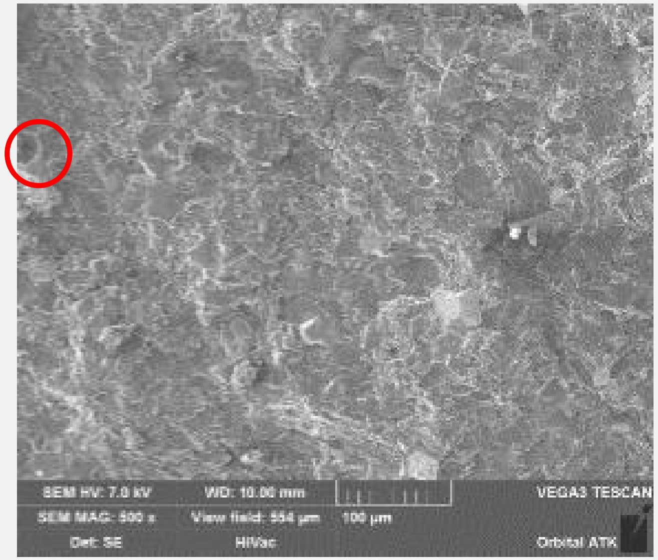
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

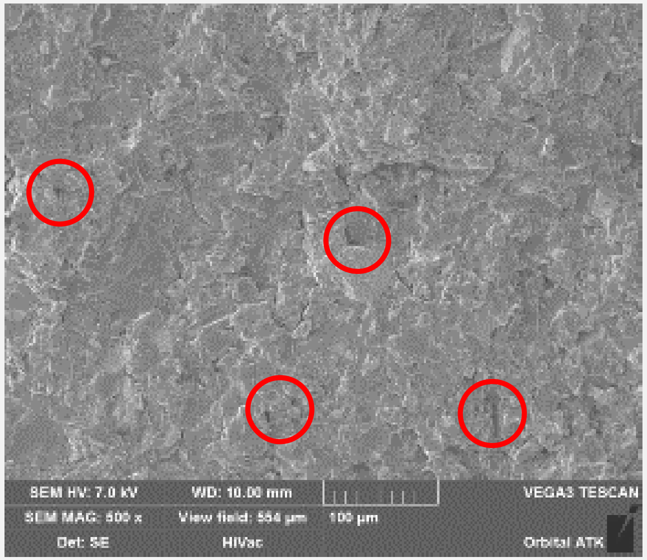


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

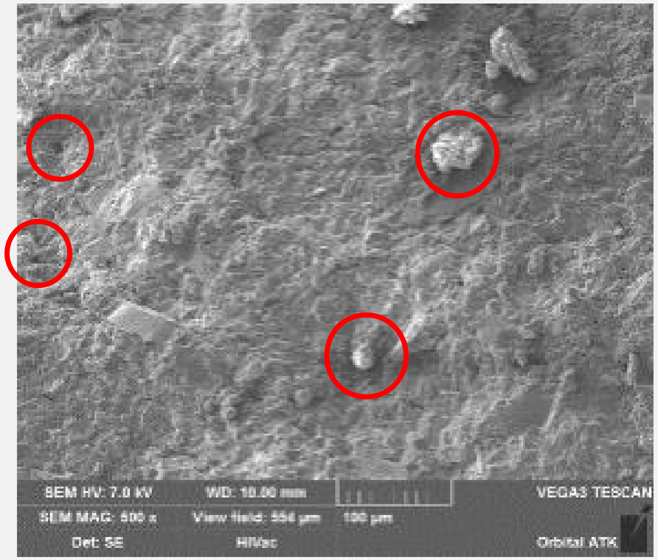
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)



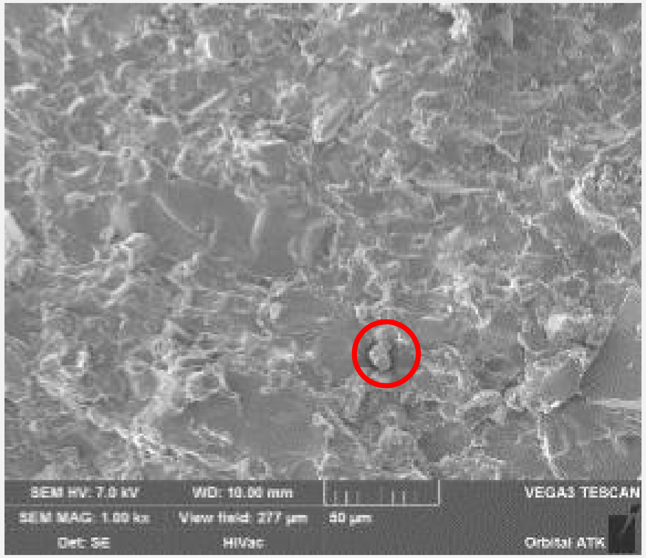
PSPI-L FD Primary P4 #2 (100201)



1000X Magnification-Internal Surface

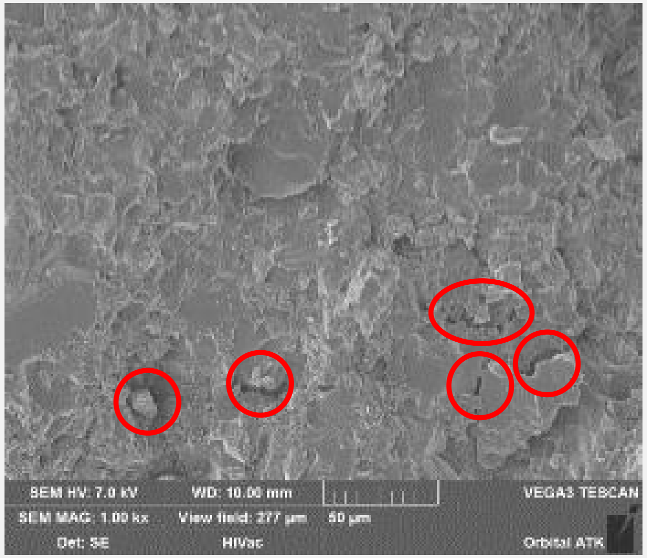
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



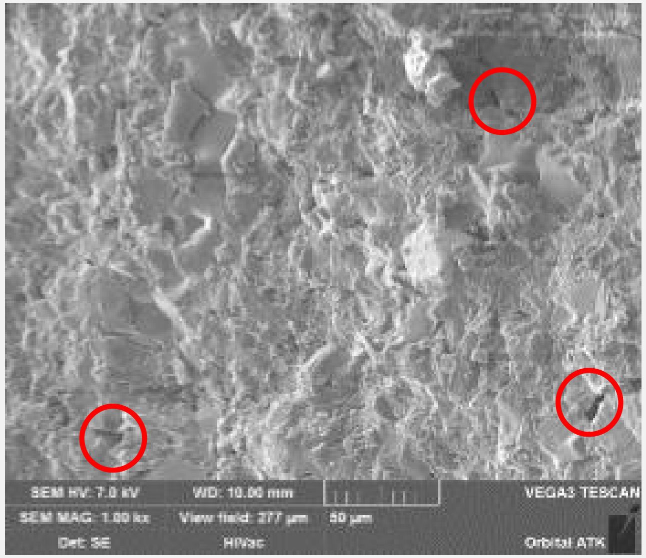
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



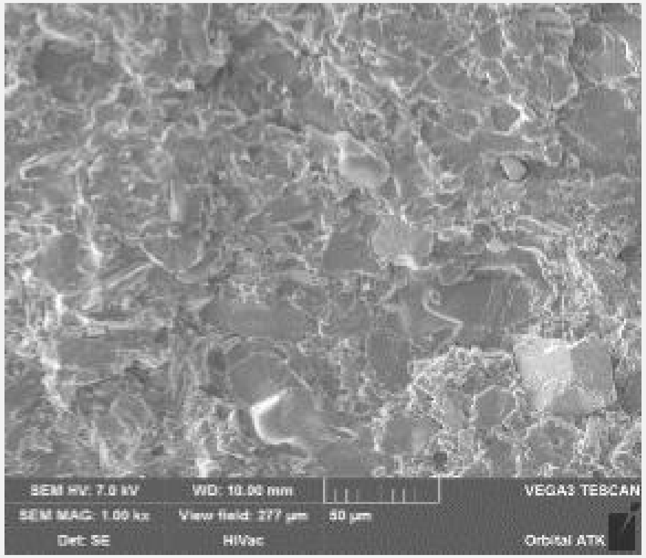
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

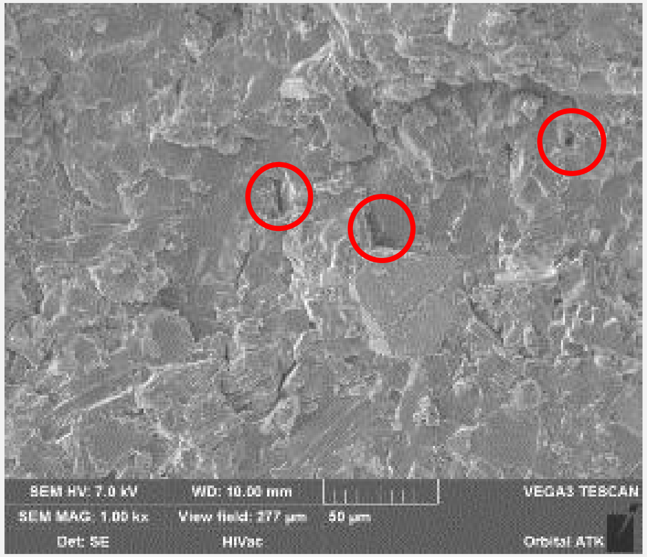


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

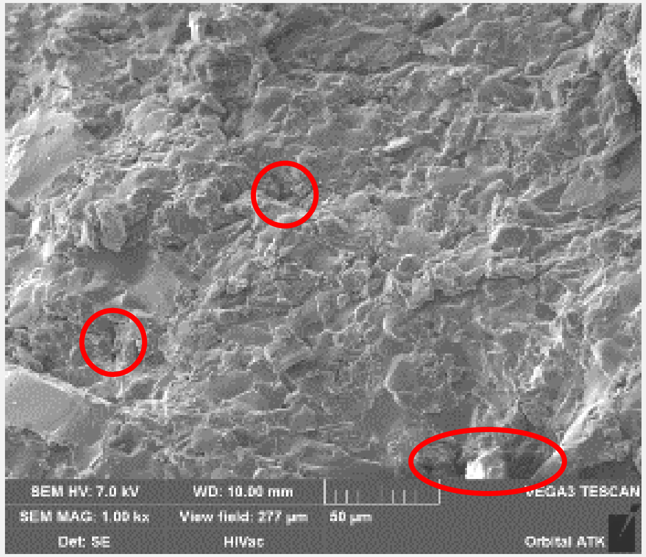
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)



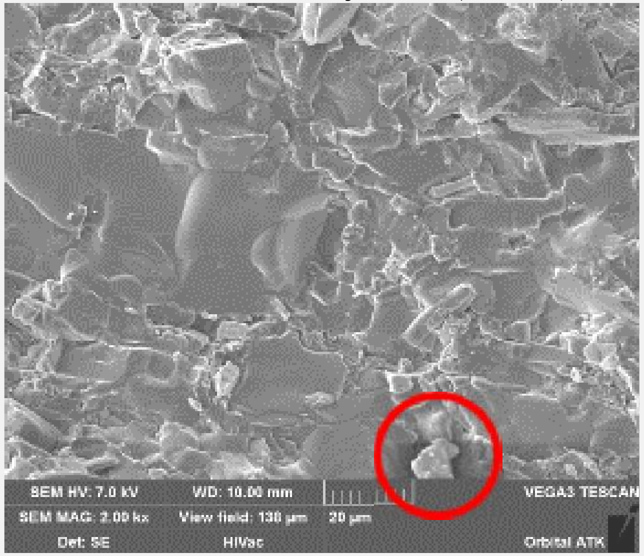
PSPI-L FD Primary P4 #2 (100201)



2000X Magnification-Internal Surface

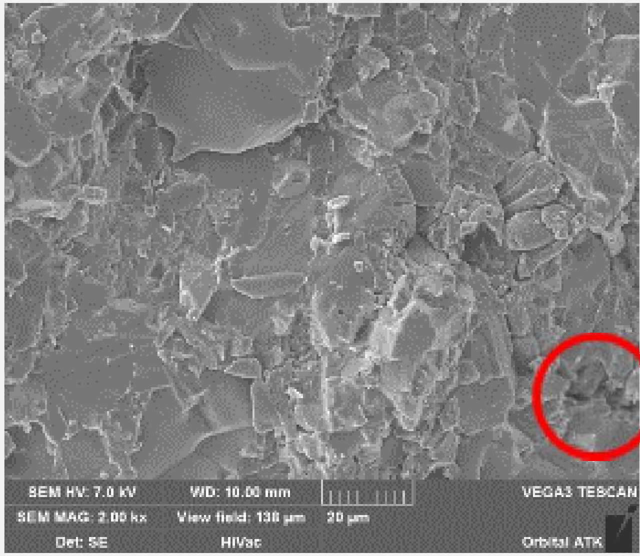
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



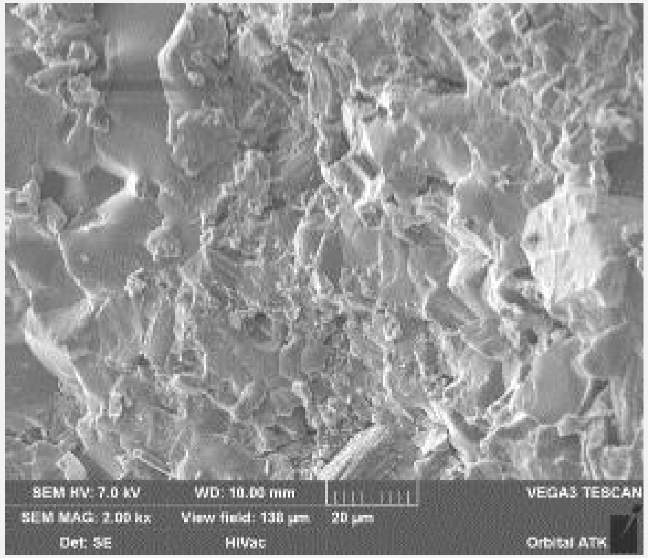
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



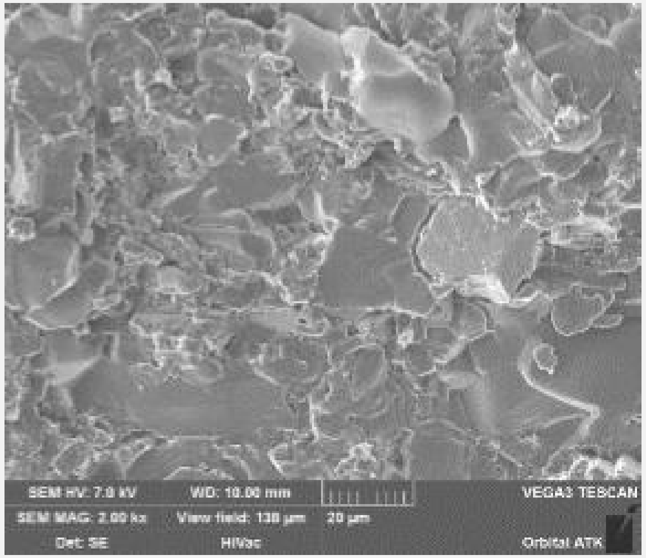
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

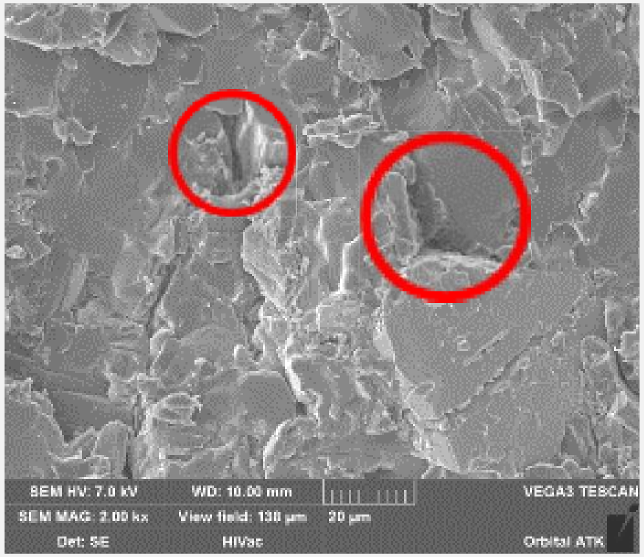


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

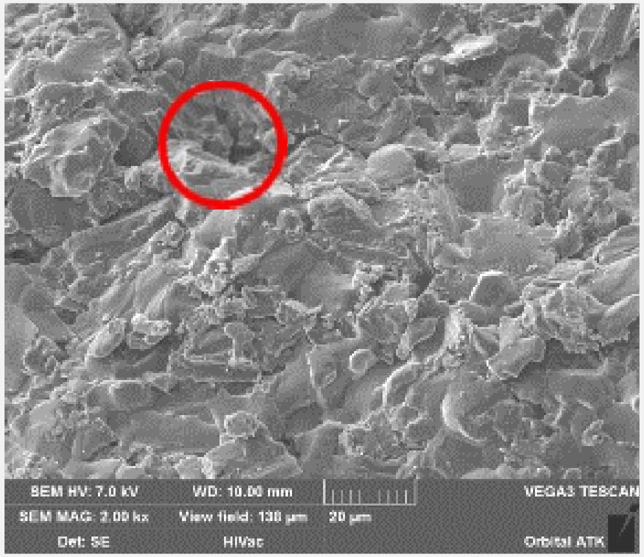
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)



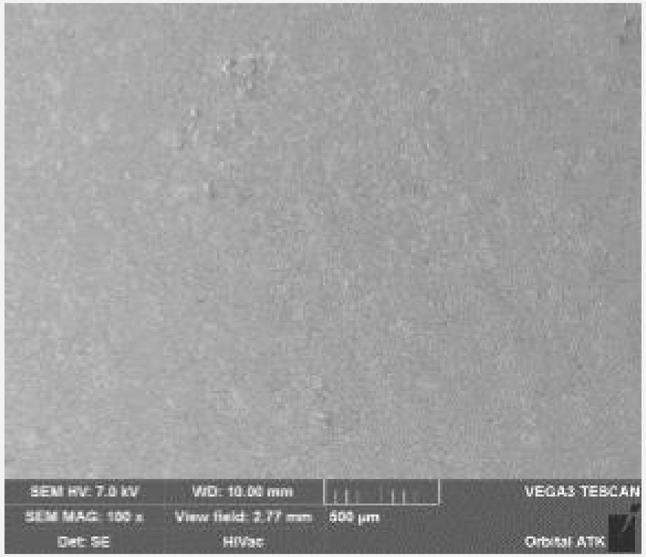
PSPI-L FD Primary P4 #2 (100201)



100X Magnification-External Surface

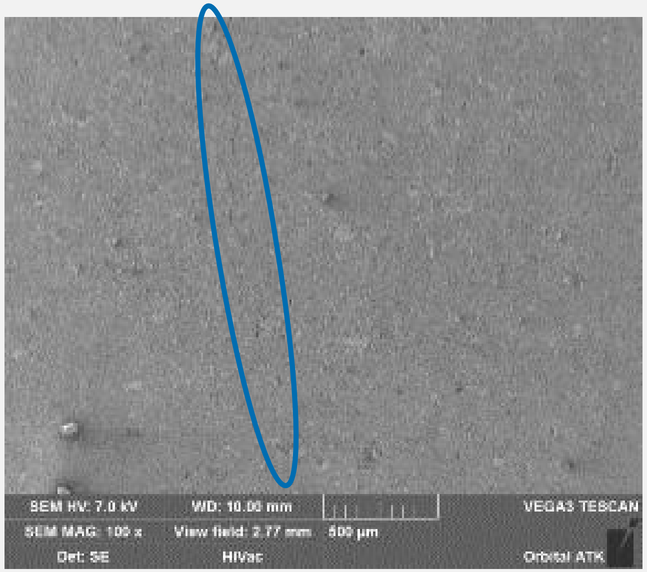
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



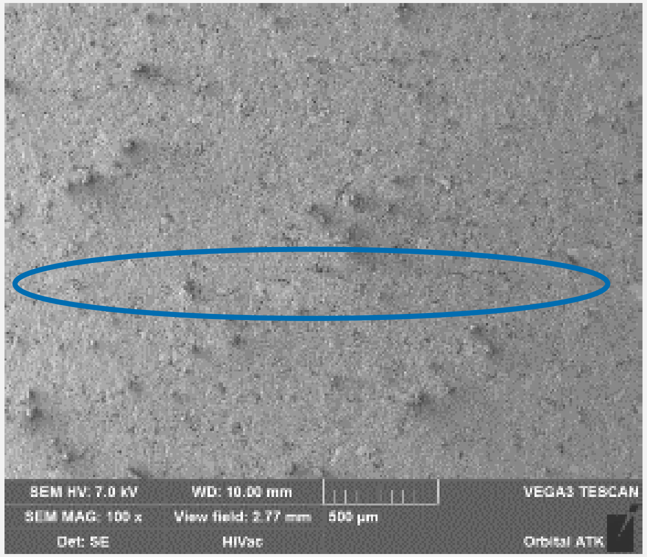
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)



1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

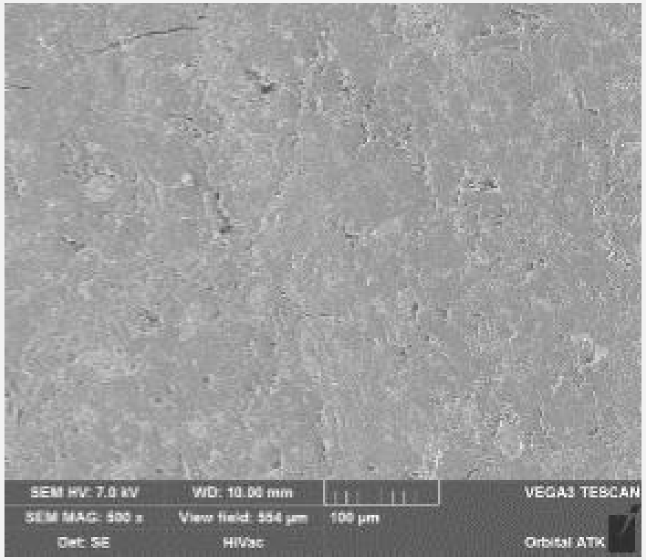
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100133	PSPI-L	FD	Primary	P4	1120	50	0.15%	0.053	28.76	1.669
100170	PSPI-L	FD	Primary	P4	1120	60	0.15%	0.055	29.04	1.634
100201	PSPI-L	FD	Primary	P4	1120	70	0.15%	0.064	29.24	1.614

- The 20-60 C and 20-70 C surface have long fissures or series of pores (see especially 100X and 500X)
  - These may have been created during sample preparation but exhibit a greater propensity for fracturing
  - 2000 X magnification shows that some pores centered in fissures are deep

500X Magnification-External Surface

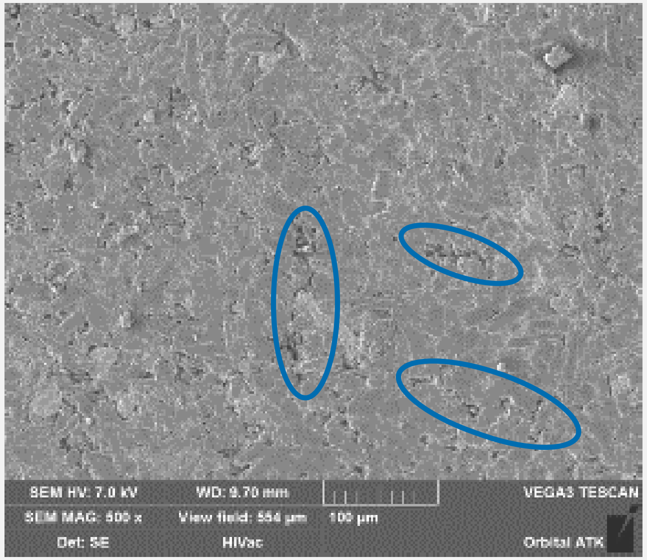
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



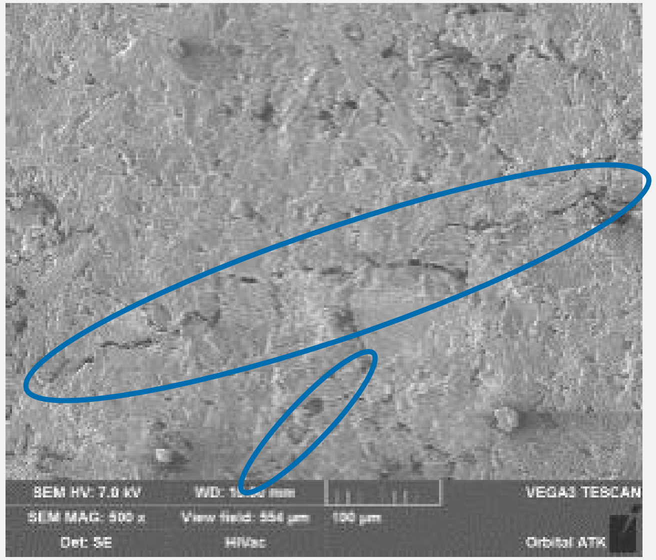
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



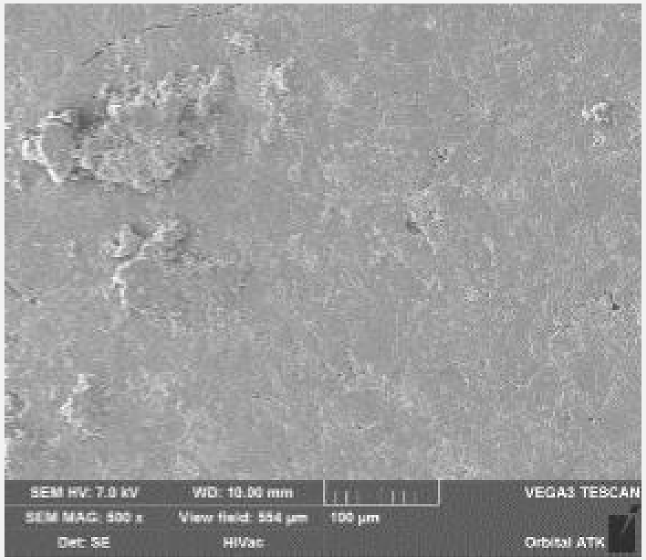
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

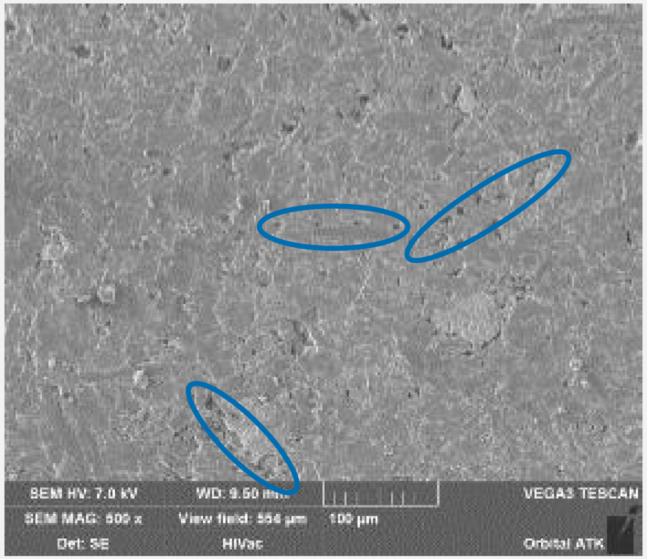


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

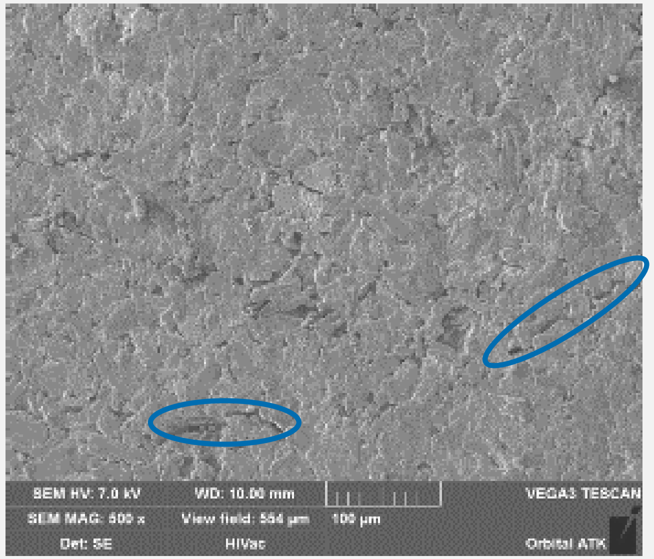
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)

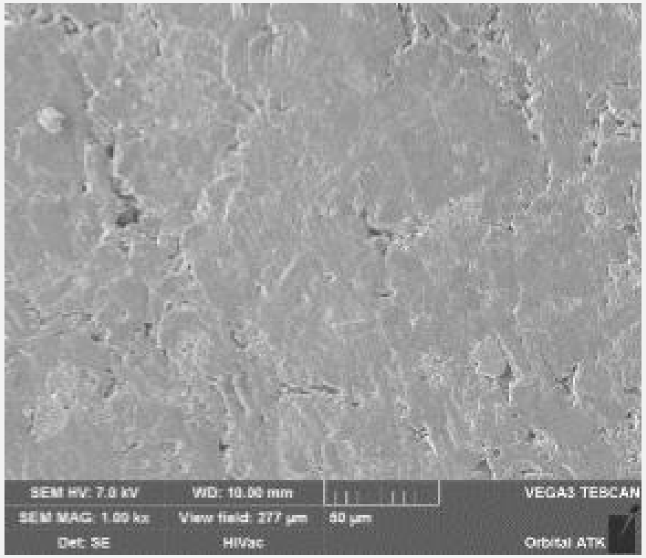


PSPI-L FD Primary P4 #2 (100201)



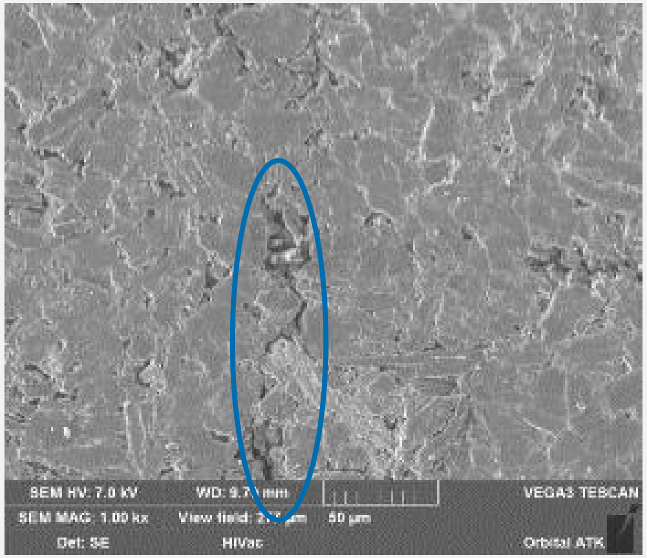
1000X Magnification-External Surface
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



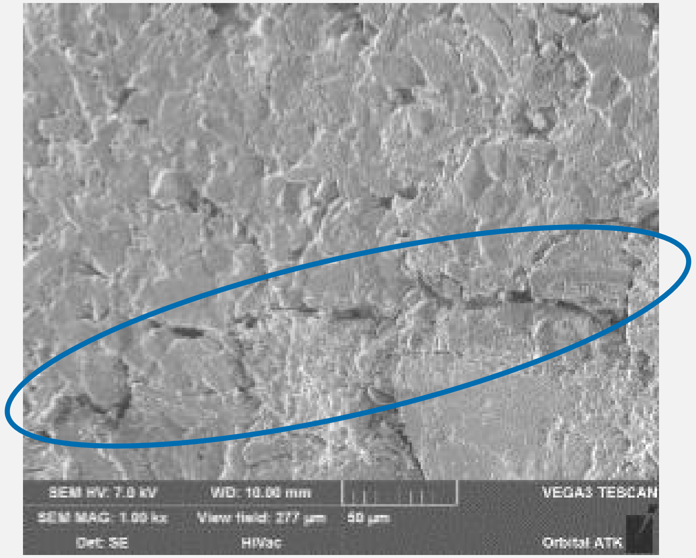
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



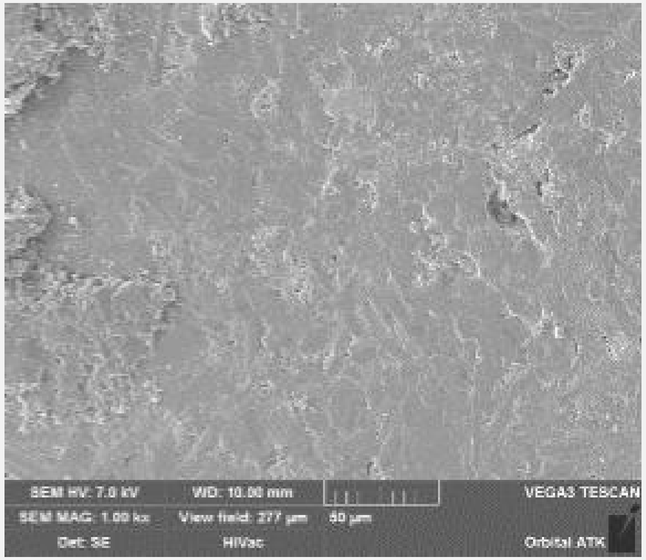
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

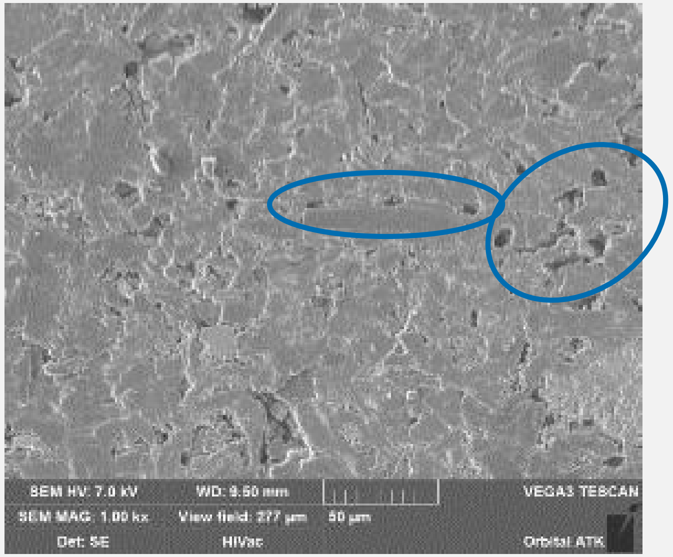


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

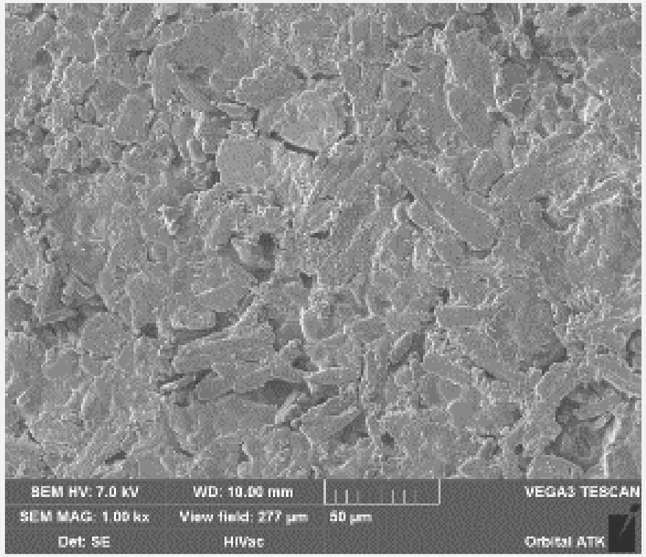
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)



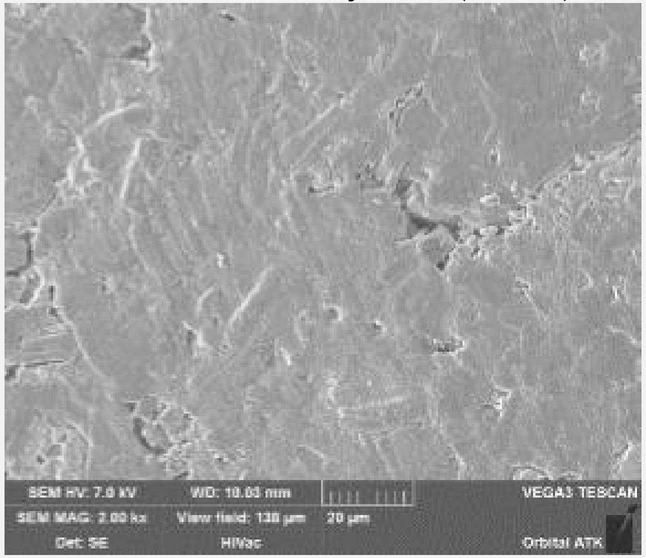
PSPI-L FD Primary P4 #2 (100201)



2000X Magnification-External Surface

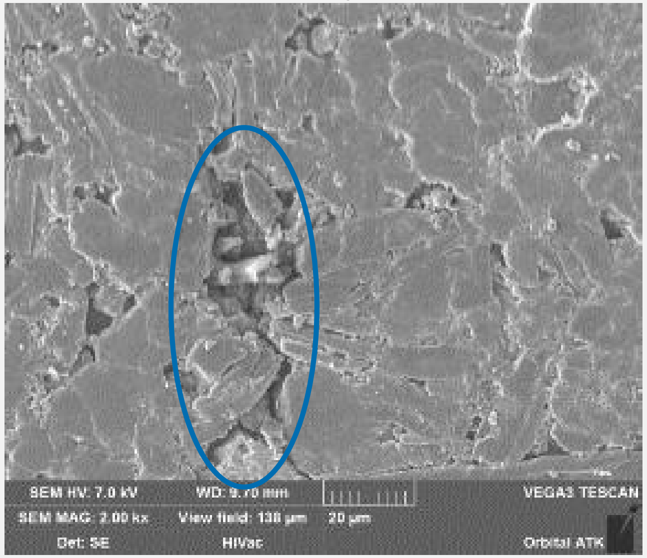
PSPI-L FD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L FD Primary P4 #1 (100133)



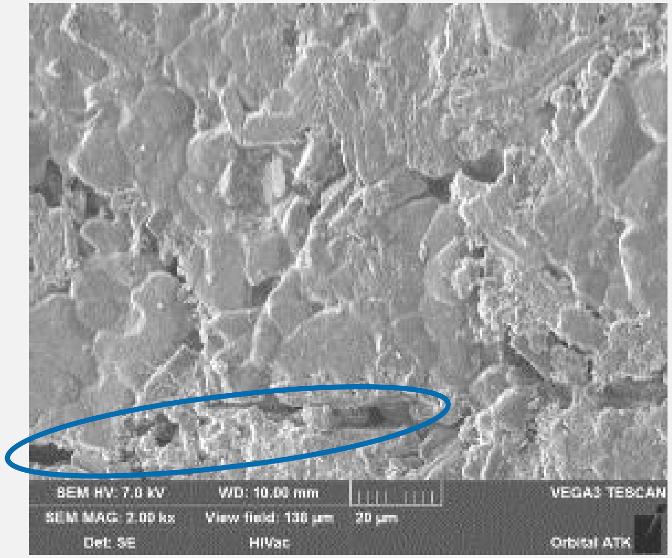
1120 Cycle, 20-50 C, 0.053% H20, 28.76 mm

PSPI-L FD Primary P4 #1 (100170)



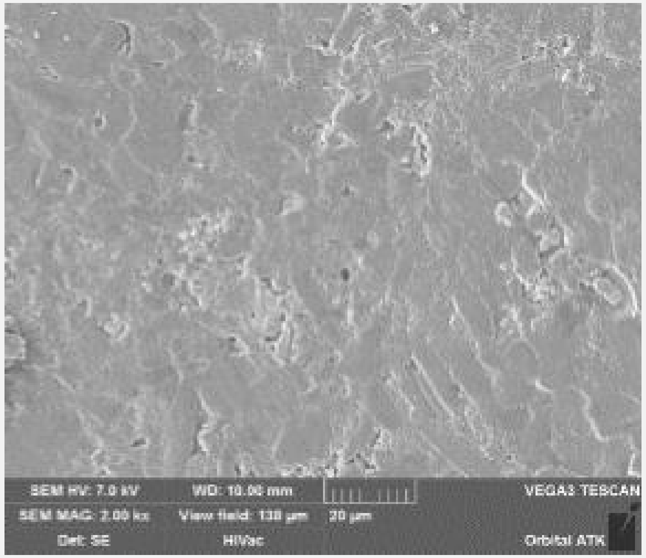
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L FD Primary P4 #1 (100201)

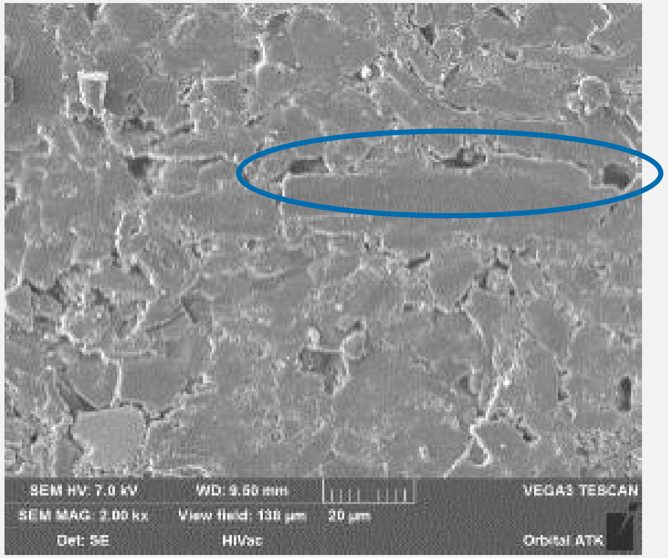


1120 Cycle 20-70 C, 0.064% H20, 29.24 mm

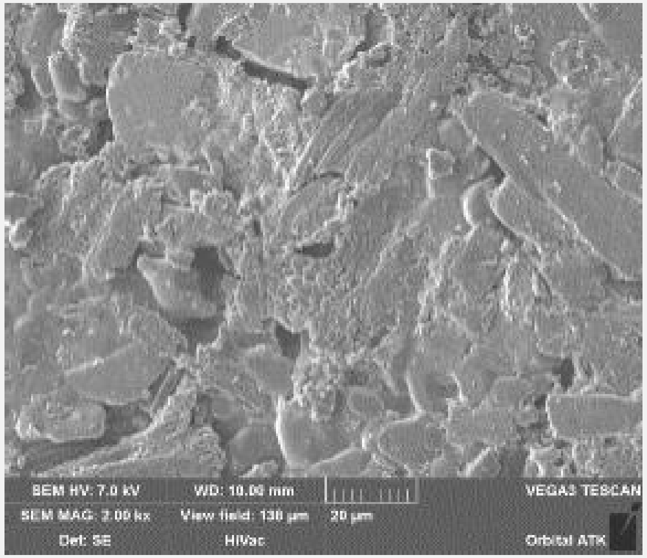
PSPI-L FD Primary P4 #2 (100133)



PSPI-L FD Primary P4 #2 (100170)



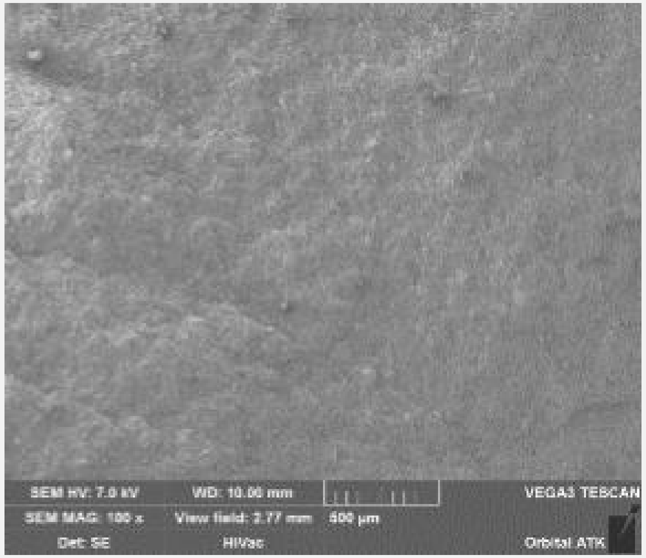
PSPI-L FD Primary P4 #2 (100201)



100X Magnification-Internal Surface

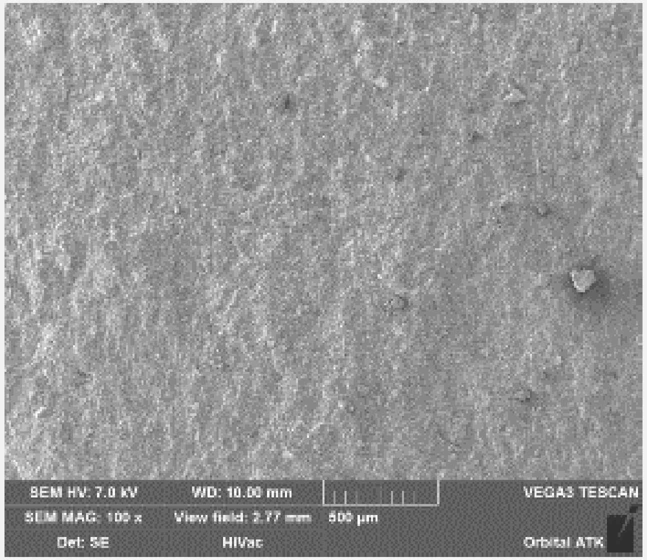
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



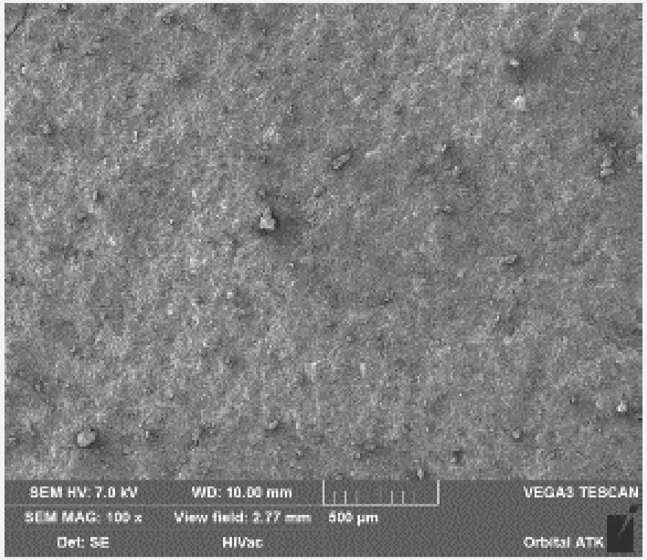
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)



1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

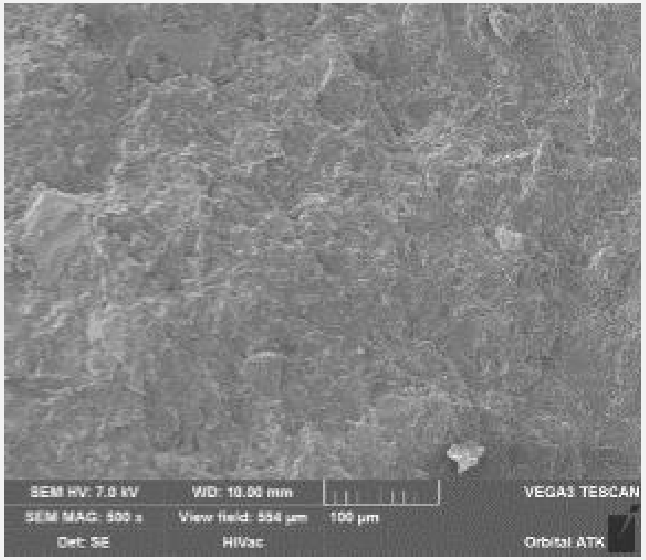
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100872	PSPI-L	YD	Primary	P4	1120	50	0.15%	0.057	28.79	1.690
100905	PSPI-L	YD	Primary	P4	1120	60	0.15%	0.046	28.92	1.676
100941	PSPI-L	YD	Primary	P4	1120	70	0.15%	0.050	29.11	1.639

- Some voids or cracks around grains can be observed

500X Magnification-Internal Surface

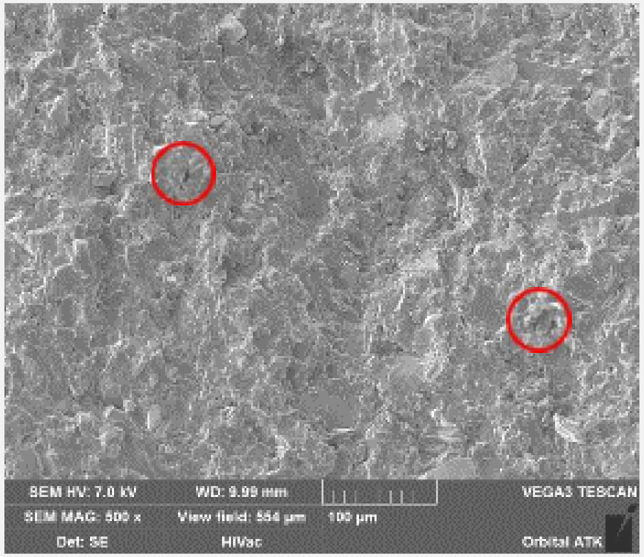
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



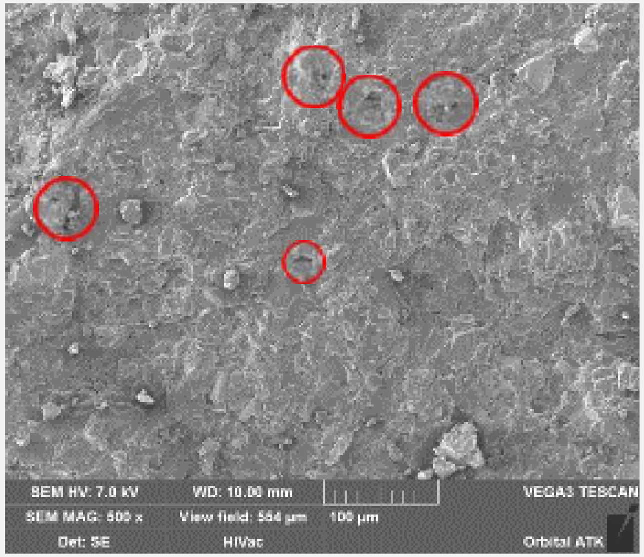
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



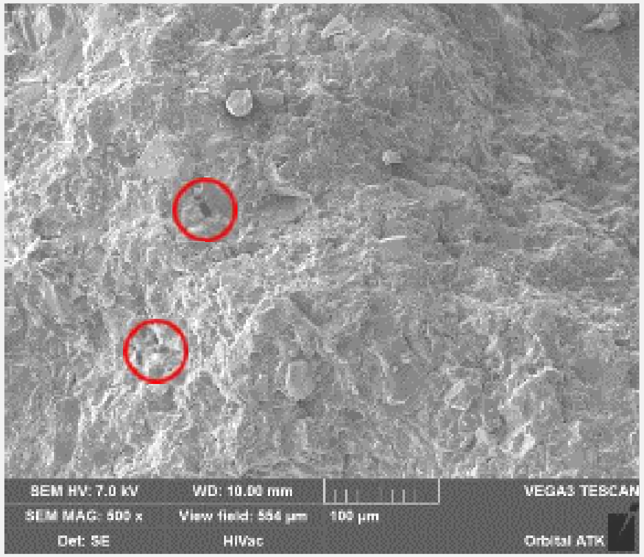
1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)

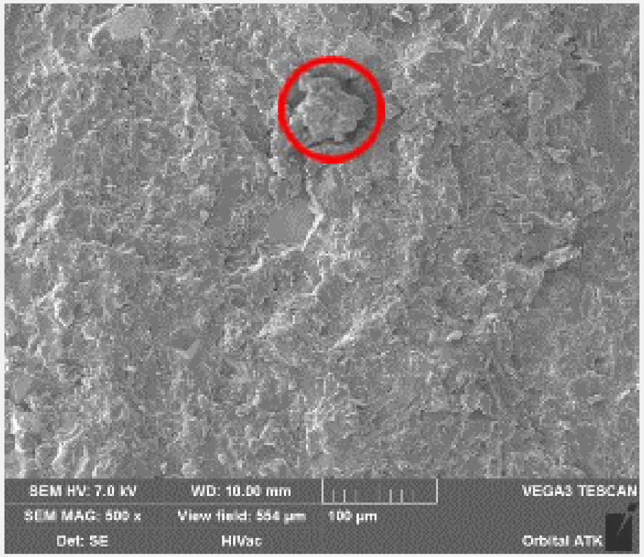


1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

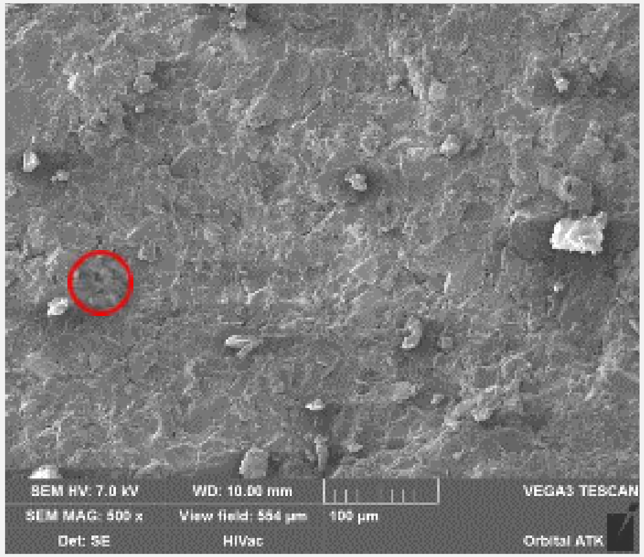
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (100905)



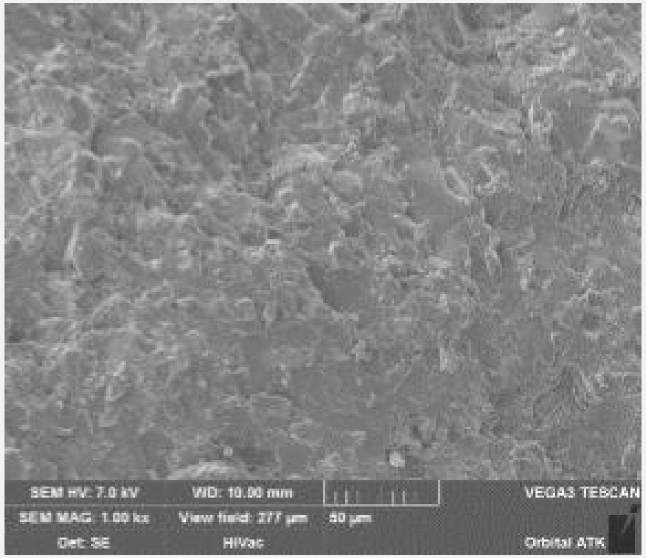
PSPI-L YD Primary P4 #2 (100941)



1000X Magnification-Internal Surface

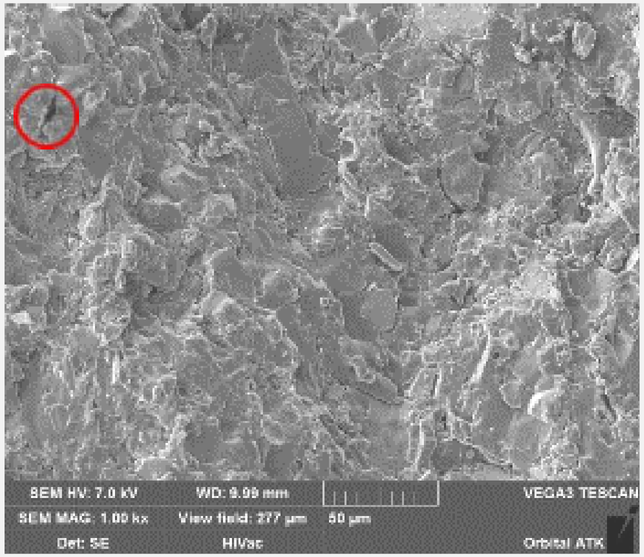
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



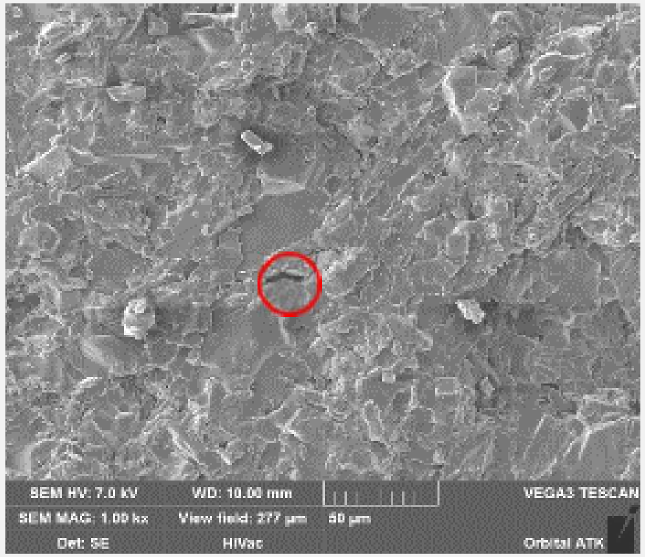
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



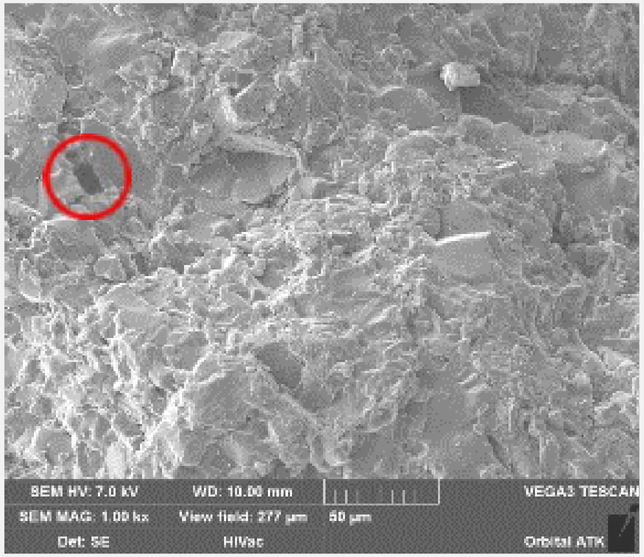
1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)

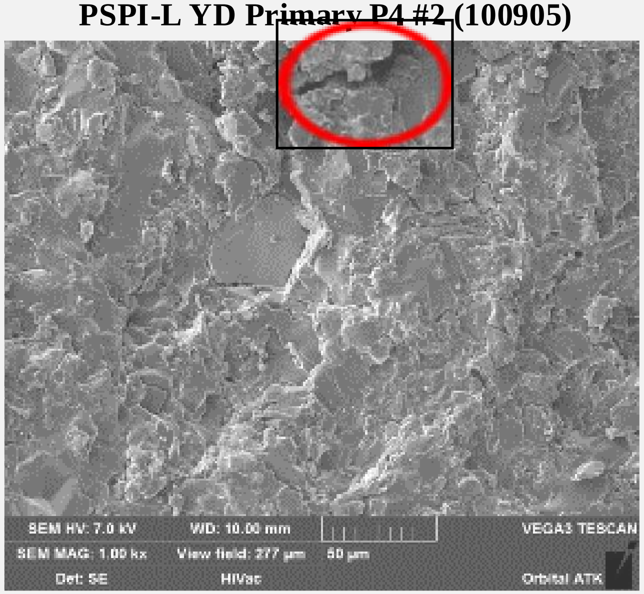


1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

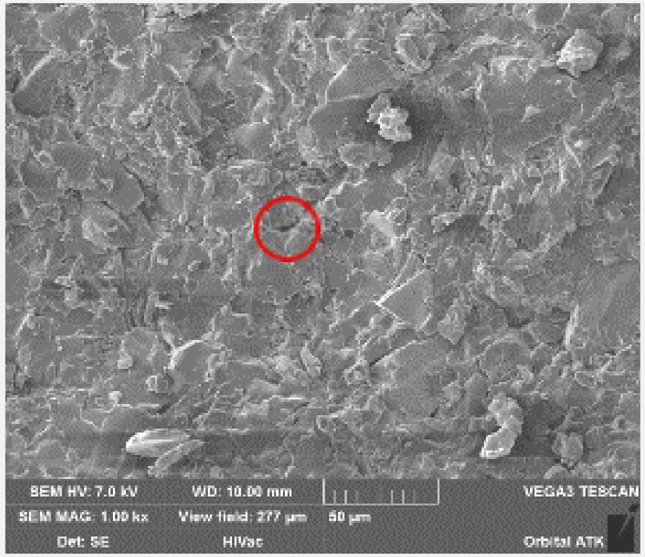
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (100905)



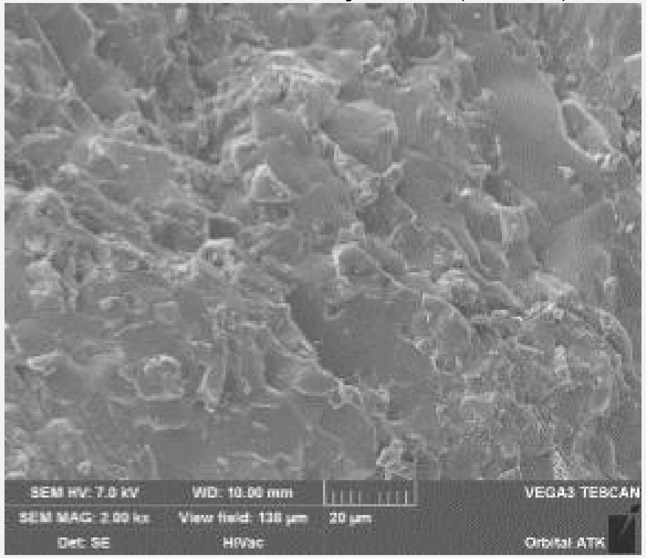
PSPI-L YD Primary P4 #2 (100941)



2000X Magnification-Internal Surface

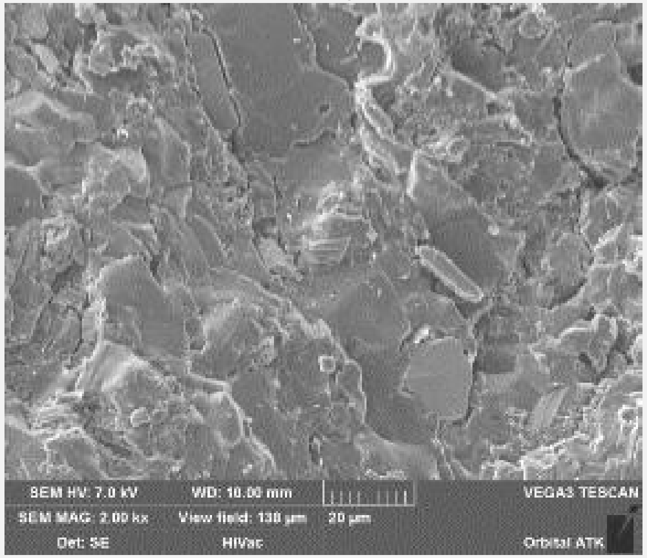
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



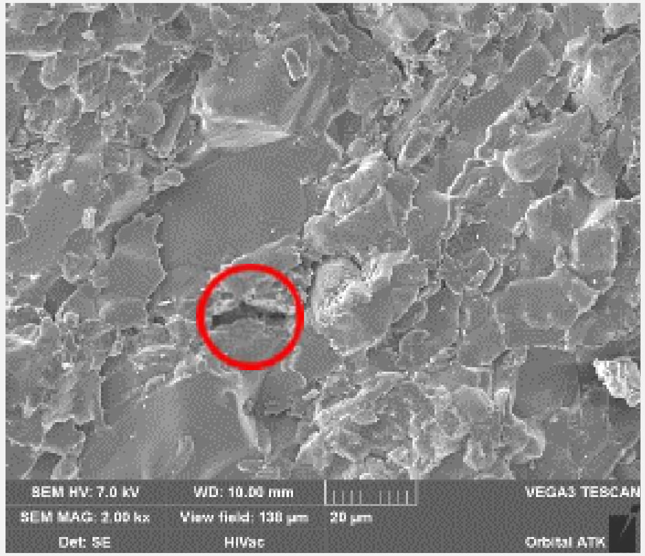
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



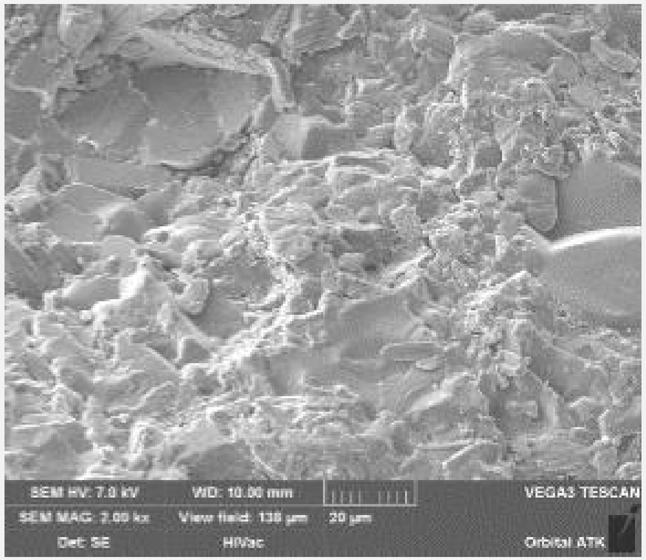
1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)

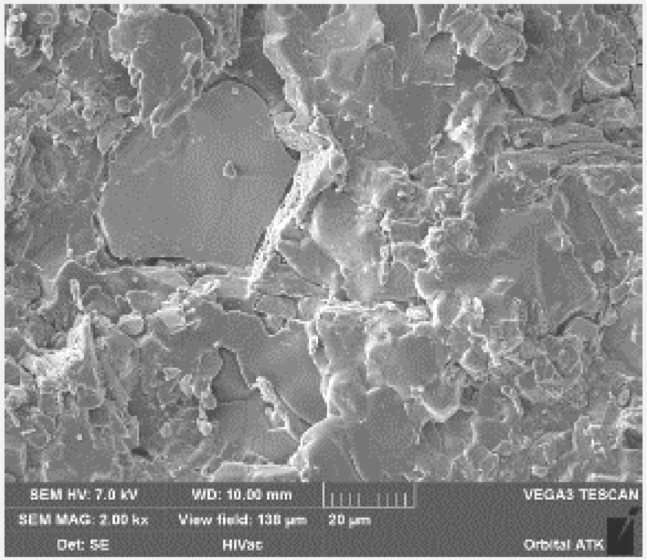


1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

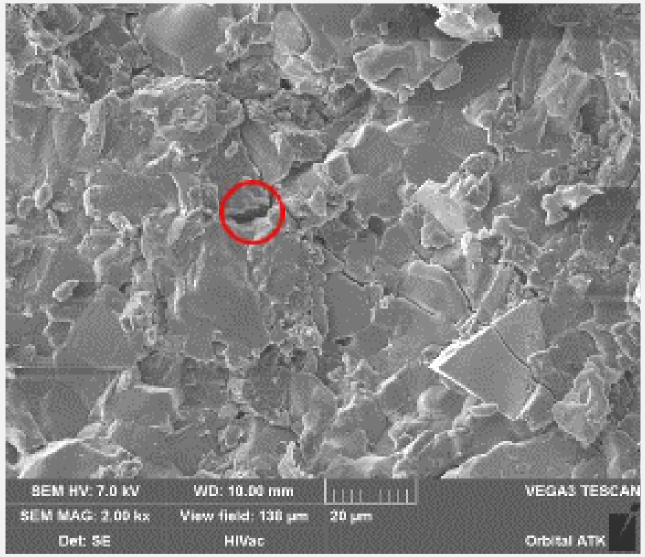
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (100905)



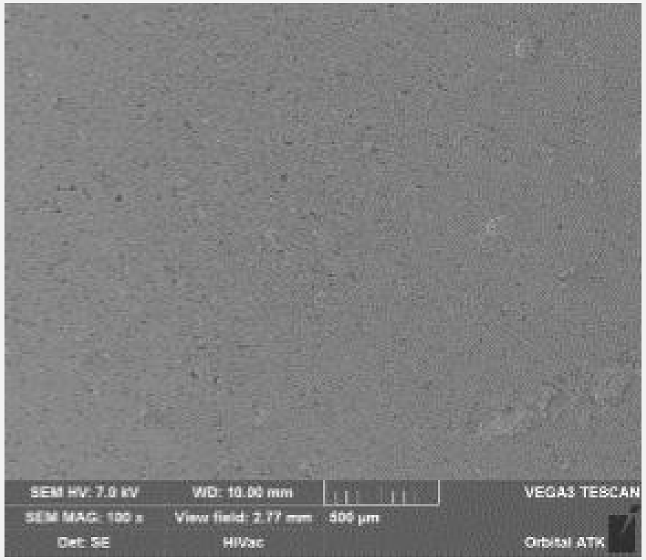
PSPI-L YD Primary P4 #2 (100941)



100X Magnification-External Surface

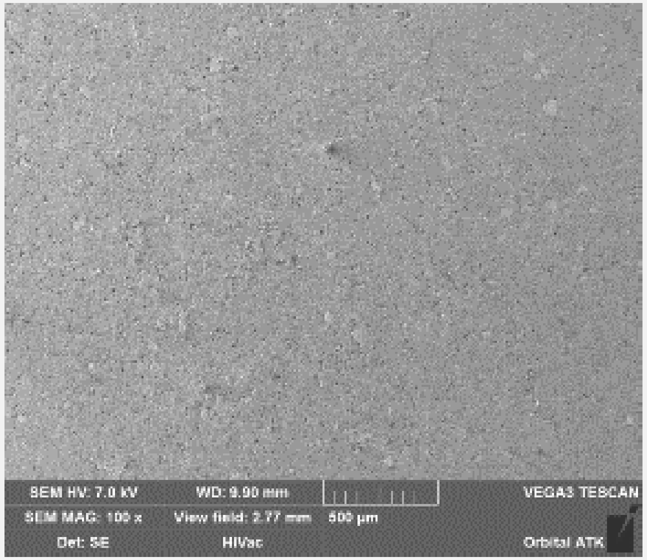
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



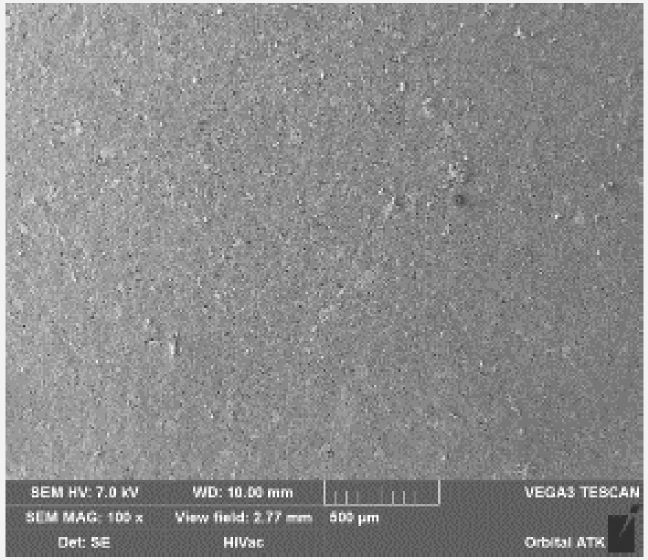
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)



1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

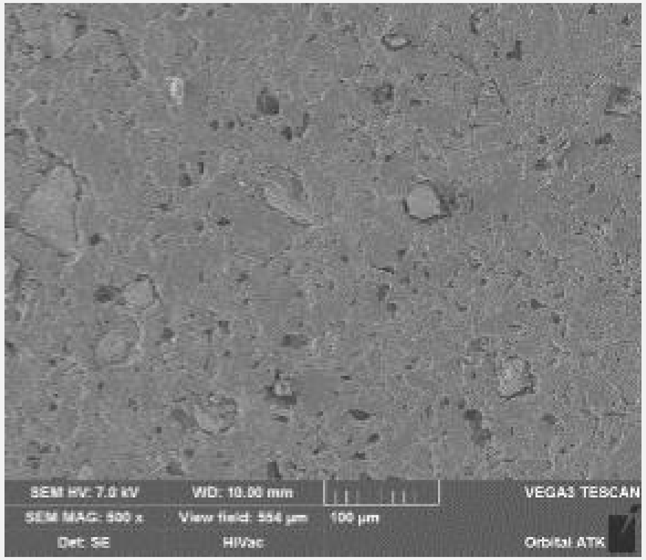
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)
100872	PSPI-L	YD	Primary	P4	1120	50	0.15%	0.057	28.79	1.690
100905	PSPI-L	YD	Primary	P4	1120	60	0.15%	0.046	28.92	1.676
100941	PSPI-L	YD	Primary	P4	1120	70	0.15%	0.050	29.11	1.639

- Only slight increases in surface pitting during the progression from 50 C, 60 C and 70 C

500X Magnification-External Surface

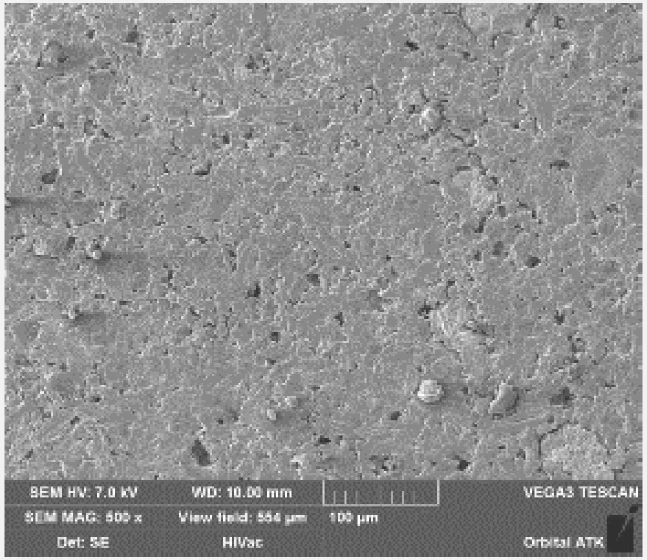
PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

PSPI-L YD Primary P4 #1 (100872)



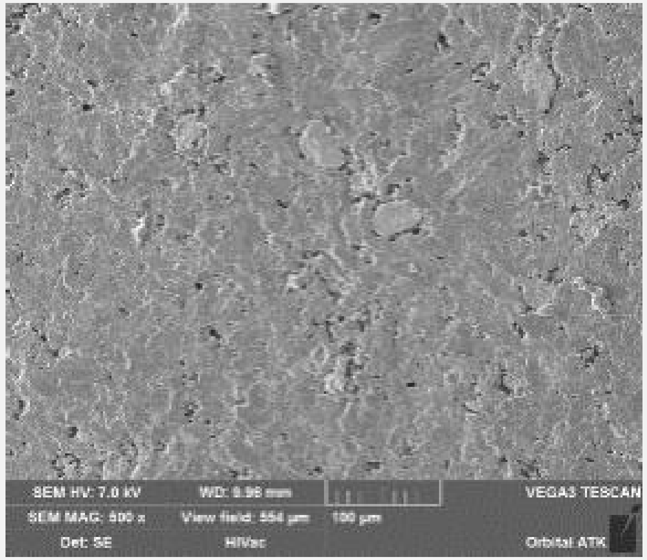
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (100905)



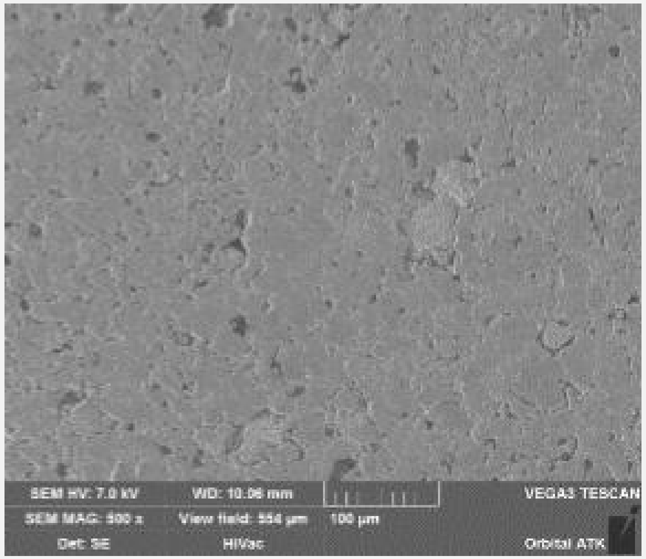
1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #1 (100941)

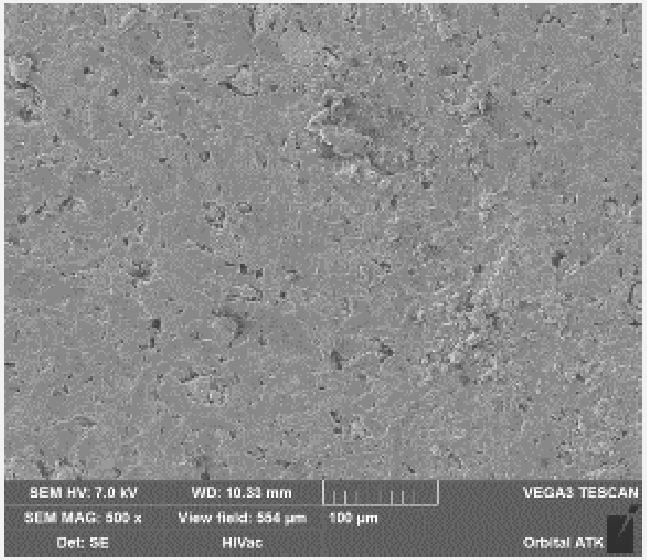


1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

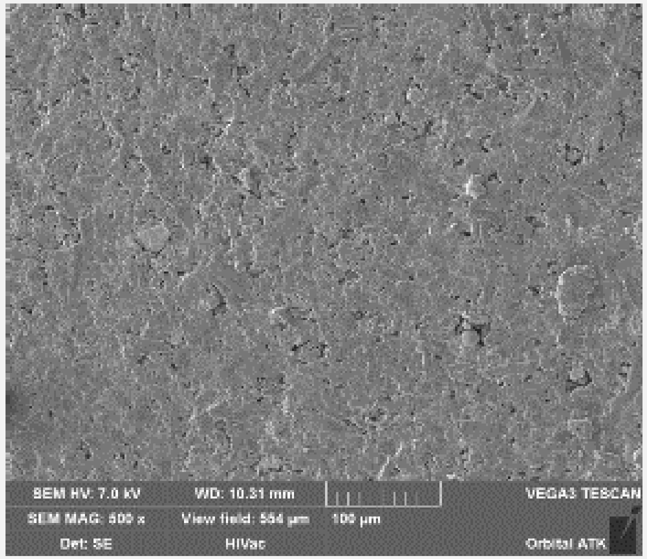
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (100905)



PSPI-L YD Primary P4 #2 (100941)

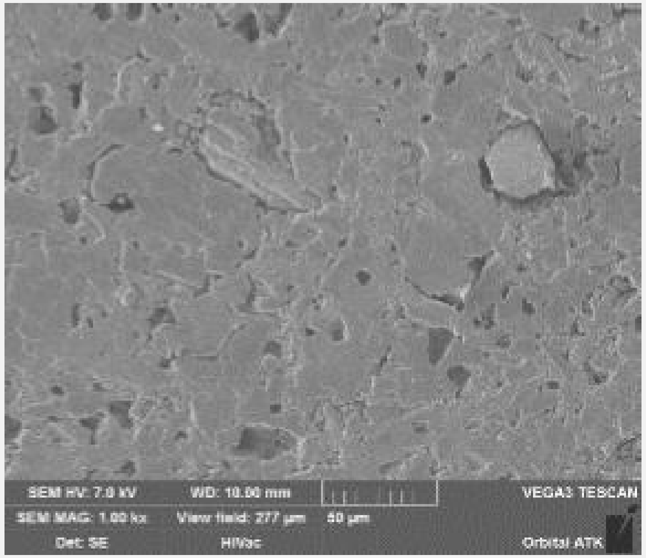


1000X Magnification-External Surface

PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

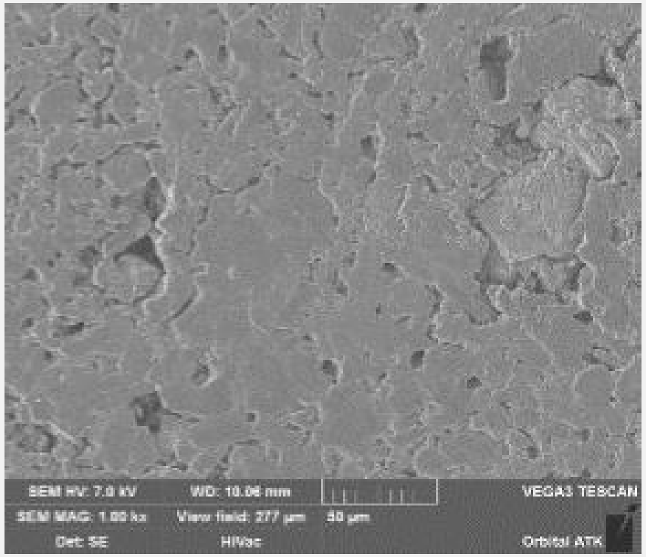
Orbital ATK

PSPI-L YD Primary P4 #1 (100872)

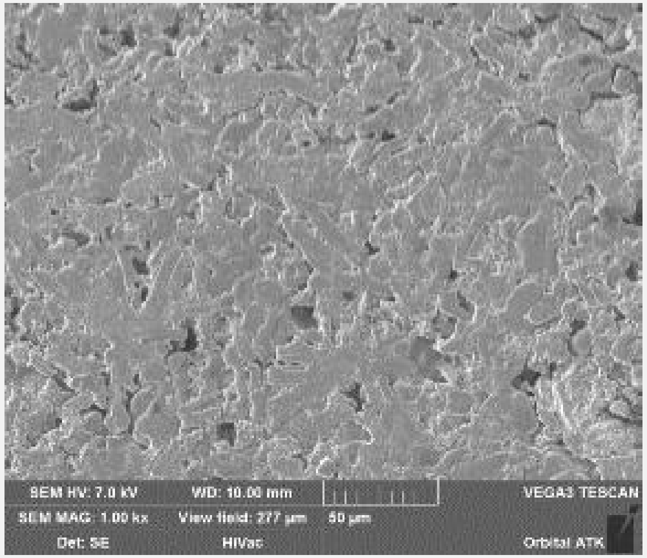


1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #2 (100872)

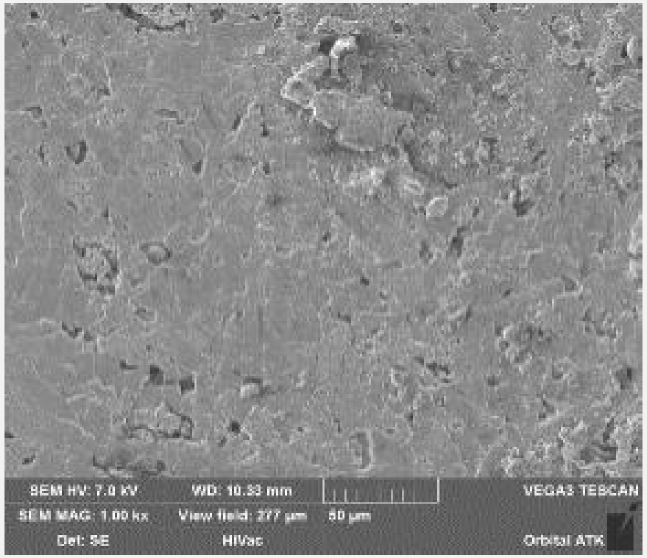


PSPI-L YD Primary P4 #1 (100905)

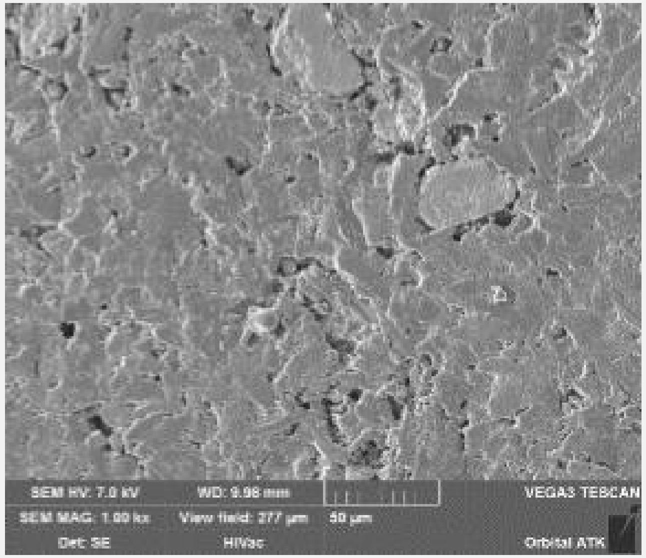


1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #2 (100905)

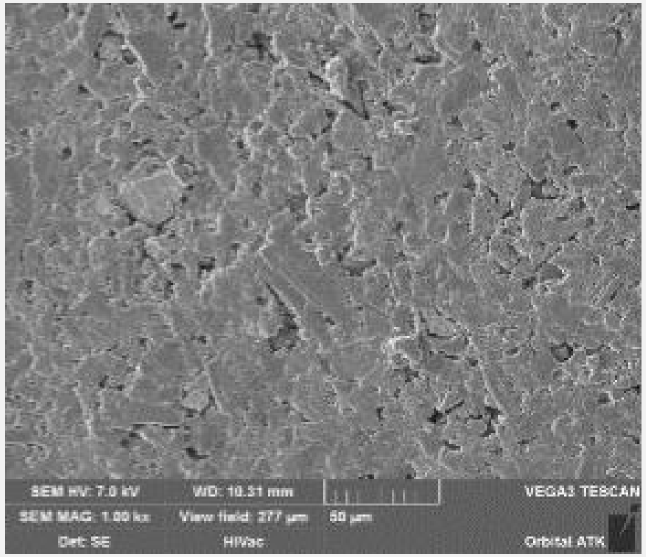


PSPI-L YD Primary P4 #1 (100941)



1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

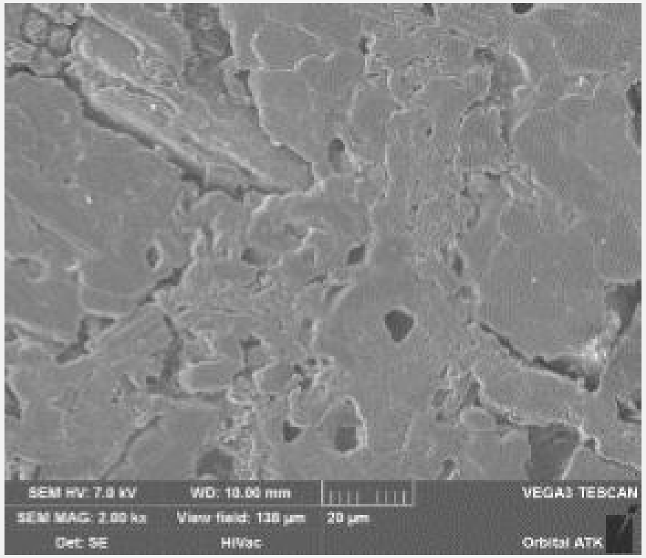
PSPI-L YD Primary P4 #2 (100941)



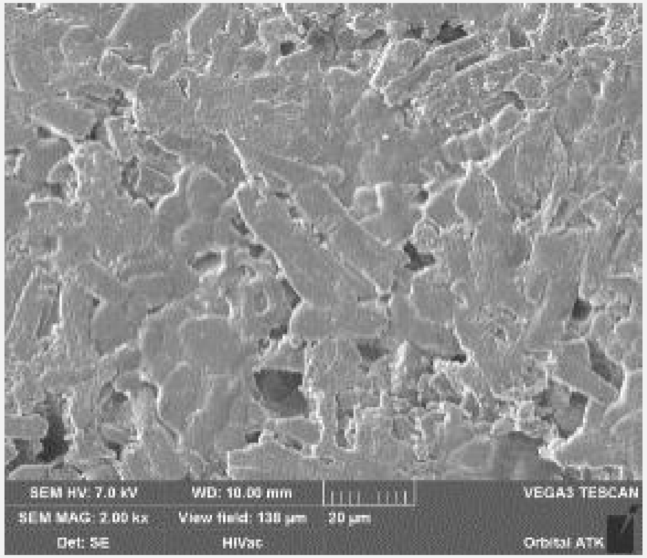
2000X Magnification-External Surface

PSPI-L YD, Primary, 0.15% Moisture Varying Max Cycle Temp

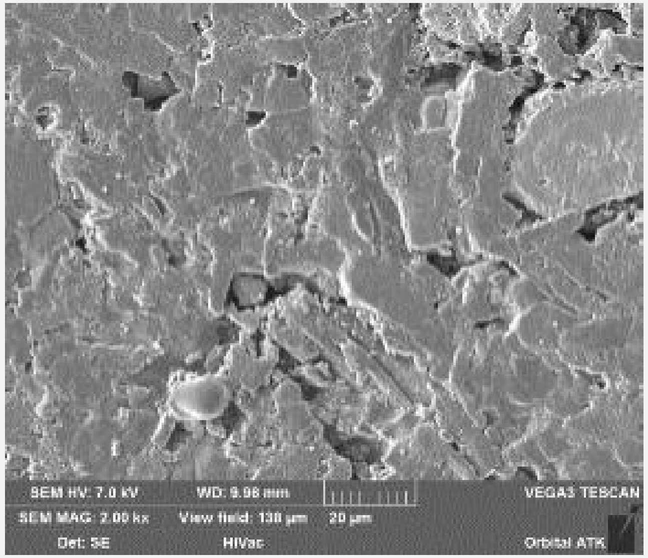
PSPI-L YD Primary P4 #1 (100872)



PSPI-L YD Primary P4 #1 (100905)



PSPI-L YD Primary P4 #1 (100941)

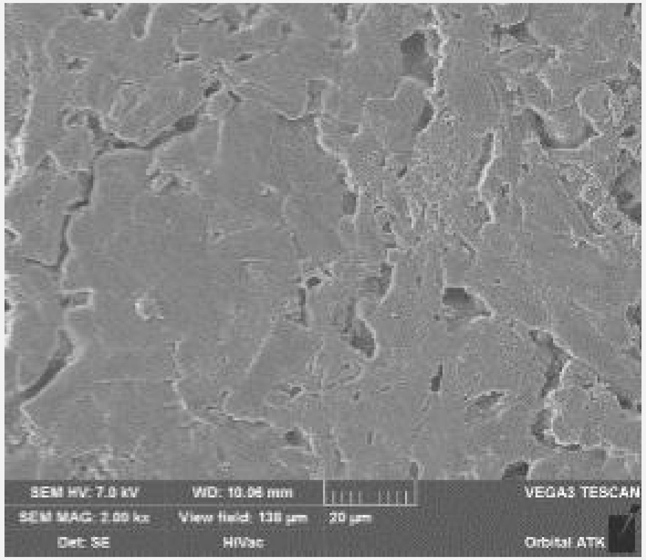


1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

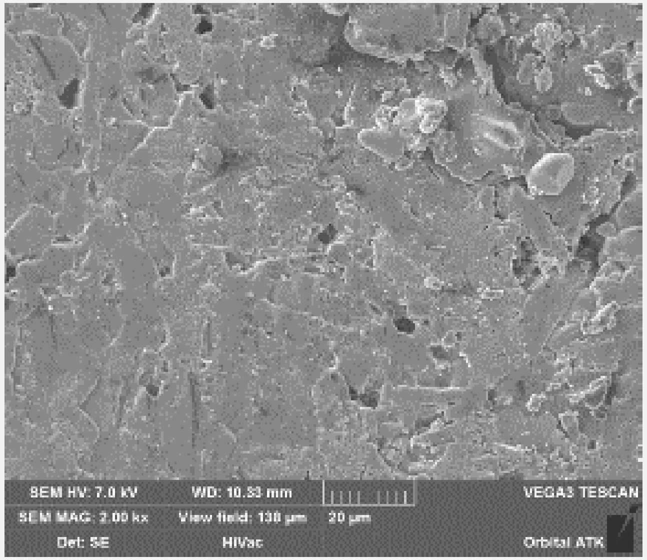
1120 cycle, 20-60 C, 0.046% H20, 28.92 mm

1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

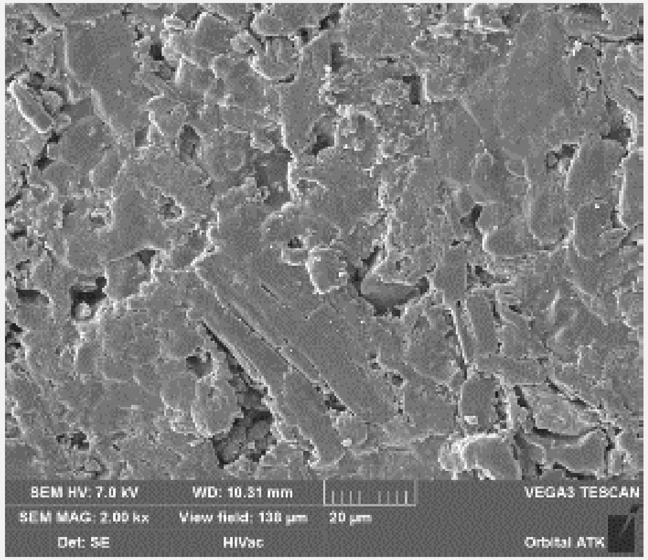
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (100905)



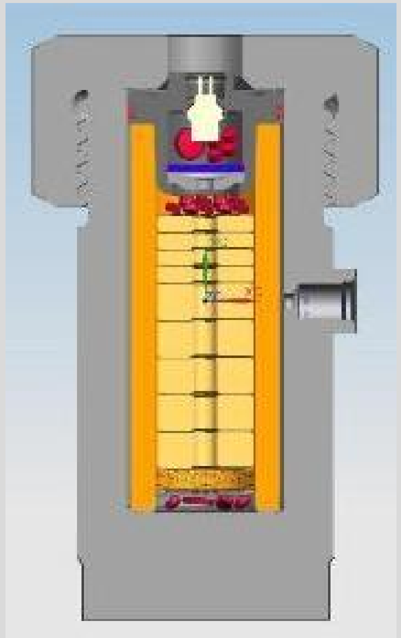
PSPI-L YD Primary P4 #2 (100941)



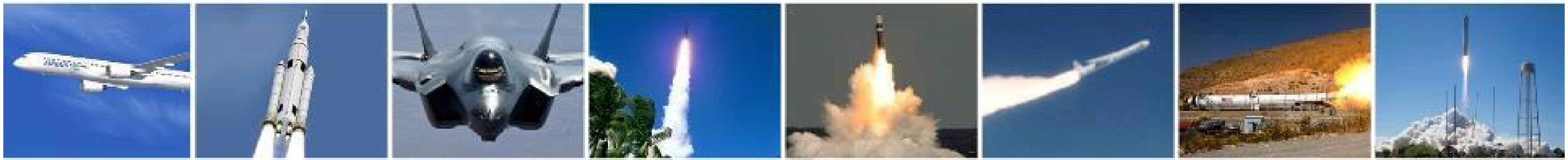
1120 Cycle SEM

Comparison of YD Samples at 0.15% Moisture with the YD returned that was aged by GM,

PSPI-L YD: 20-50 C, Ret & GM aged, 20-60 C



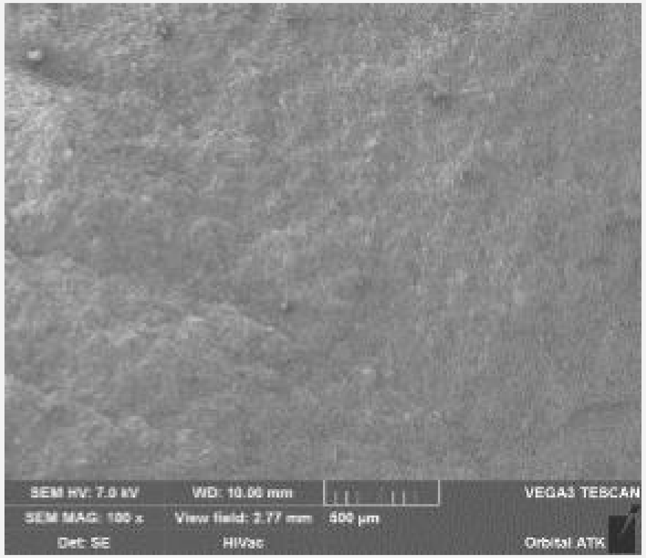
Discussion



100X Magnification-Internal Surface

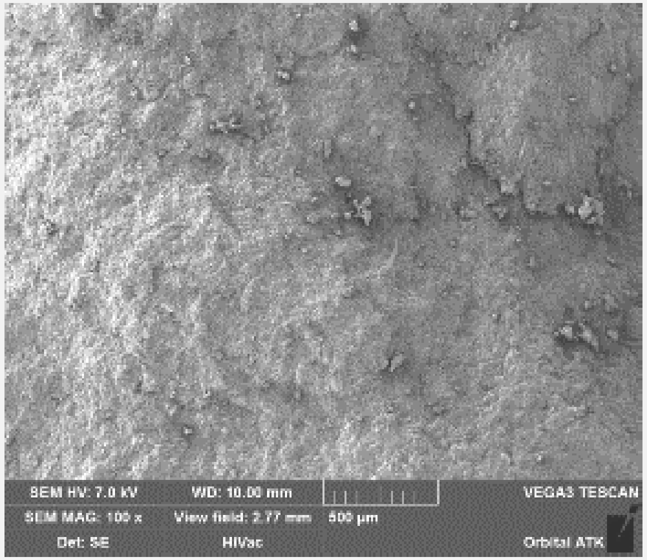
Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



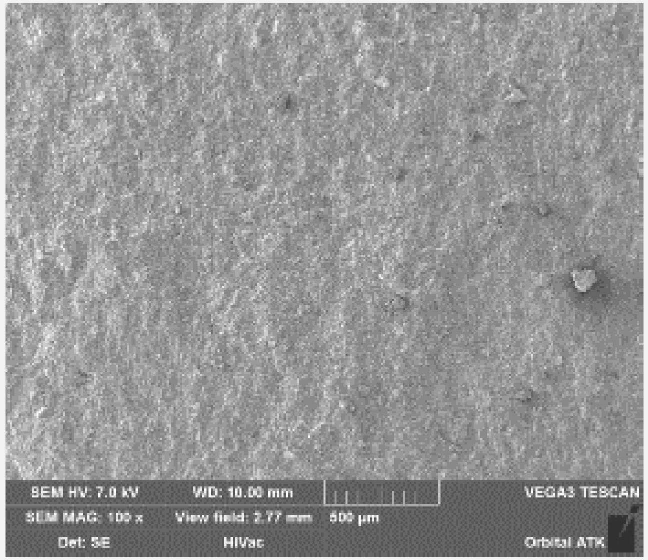
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)



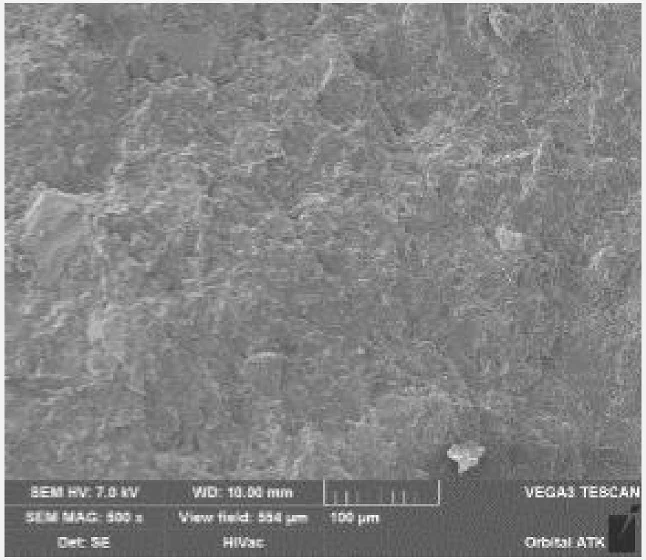
1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)	Crush Strength (ksi)
100872	PSPI-L	YD	Primary	P4	1120	50	0.15%	0.057	28.79	1.690	
100905	PSPI-L	YD	Primary	P4	1120	60	0.15%	0.046	28.92	1.676	
113189	PSPI-L	YD	Primary	P4	Ret	NA	GM Aged	0.060	28.97	1.659	

- Minimal abnormalities in the wafer from the returned inflator that was aged further at GM
  - Includes a crack seen at 500X
    - Could have arisen during sample preparation

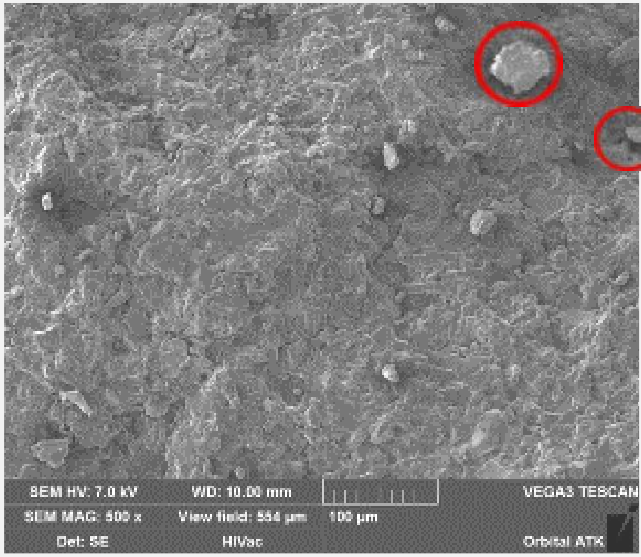
500X Magnification-Internal Surface Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



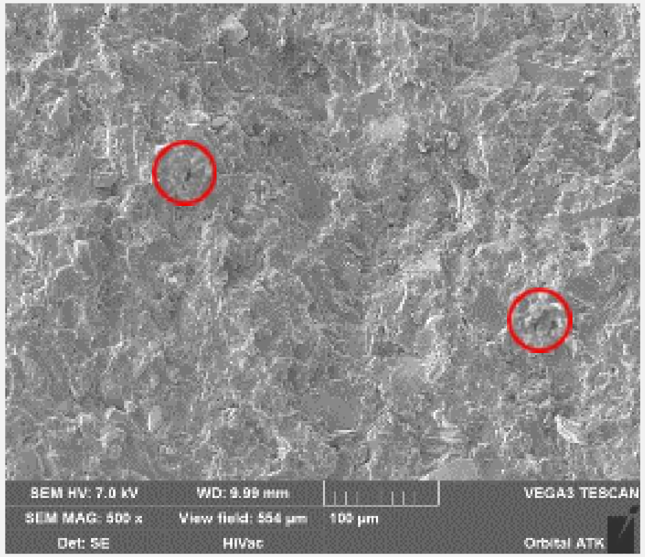
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



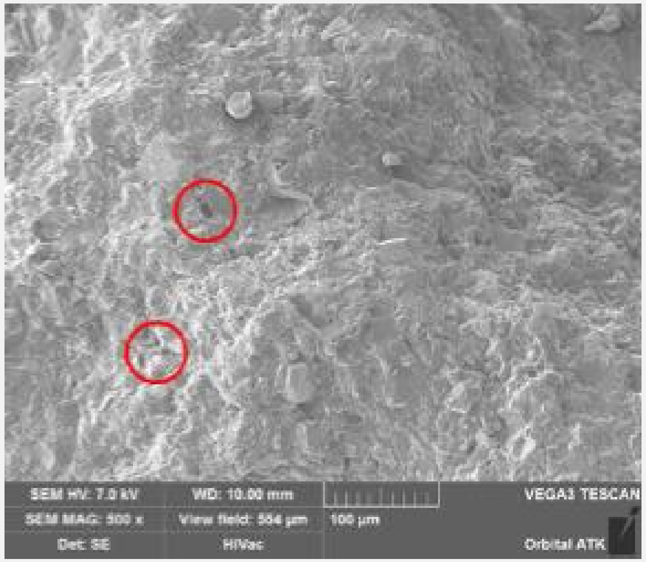
Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)



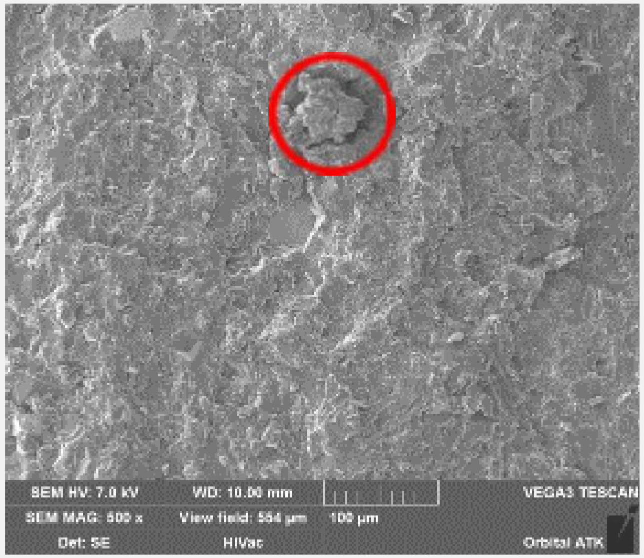
1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)

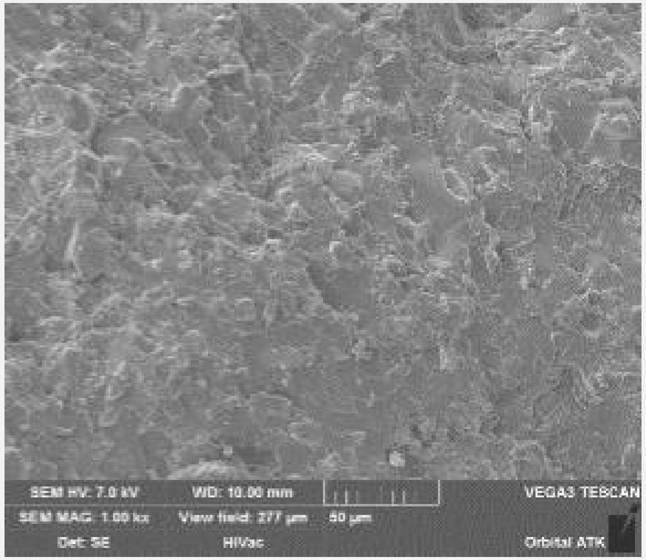
PSPI-L YD Primary P4 #2 (100905)



1000X Magnification-Internal Surface

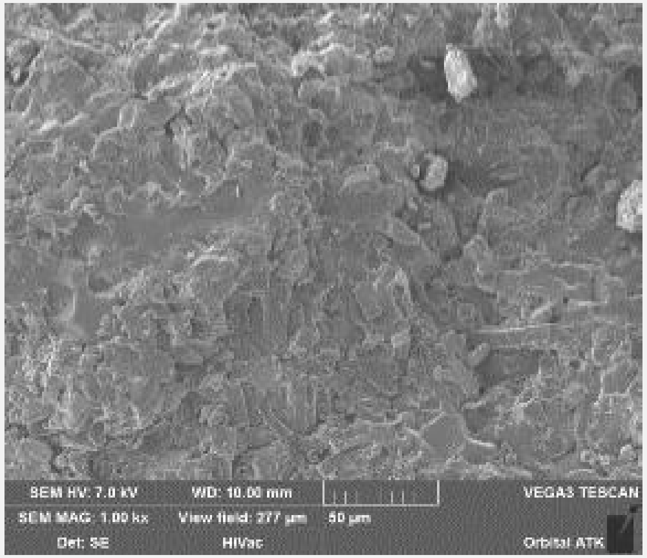
Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



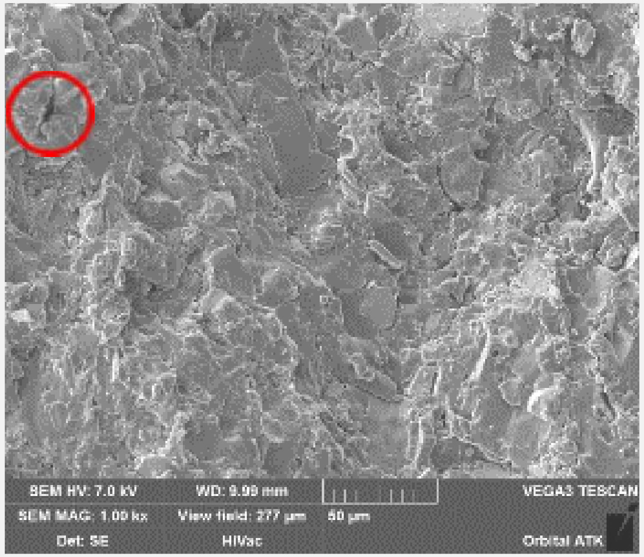
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



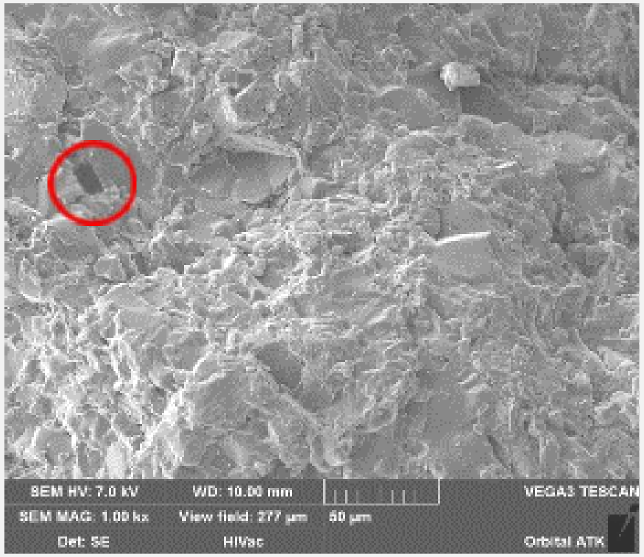
Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)

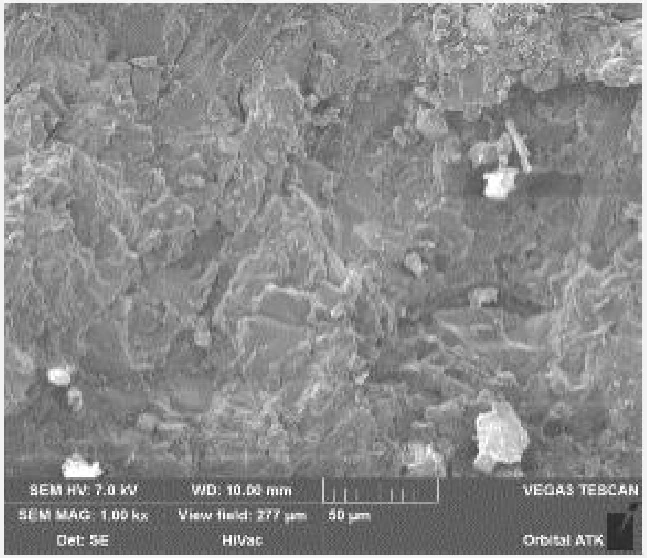


1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

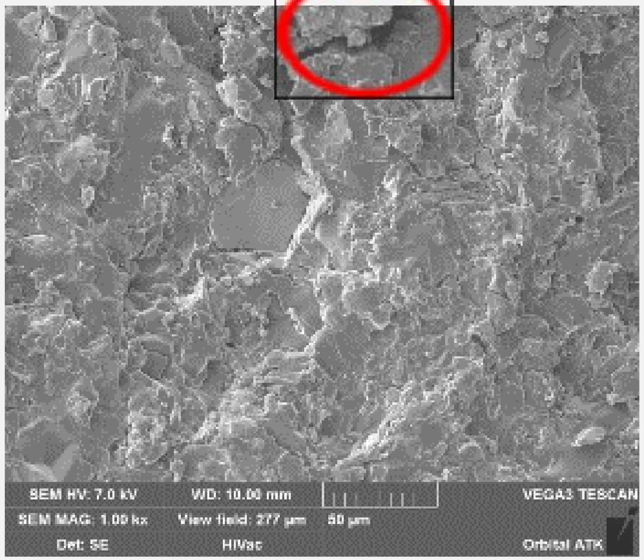
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)



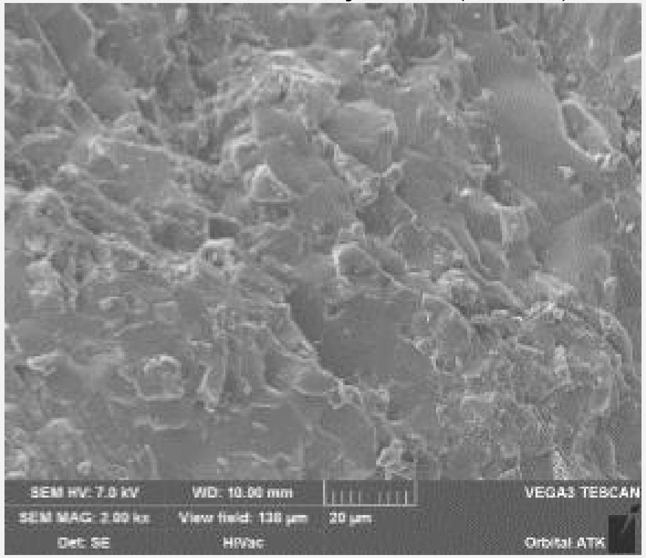
PSPI-L YD Primary P4 #2 (100905)



2000X Magnification-Internal Surface

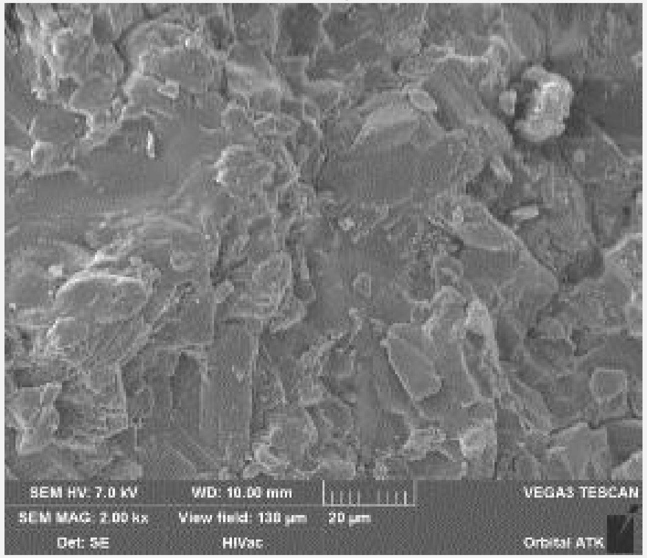
Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



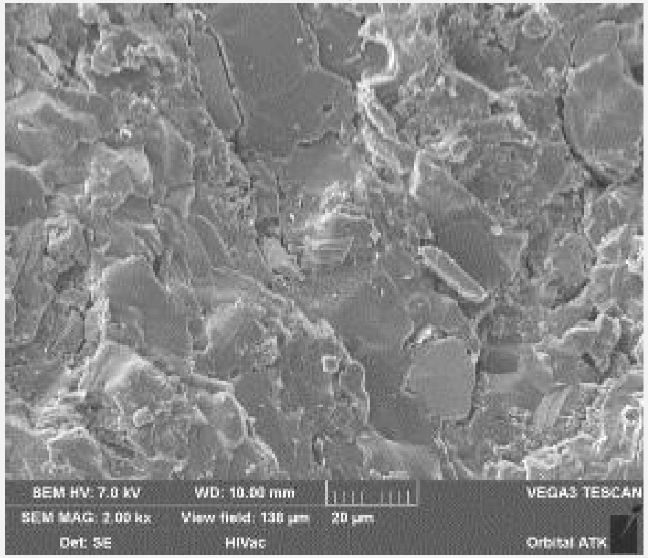
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



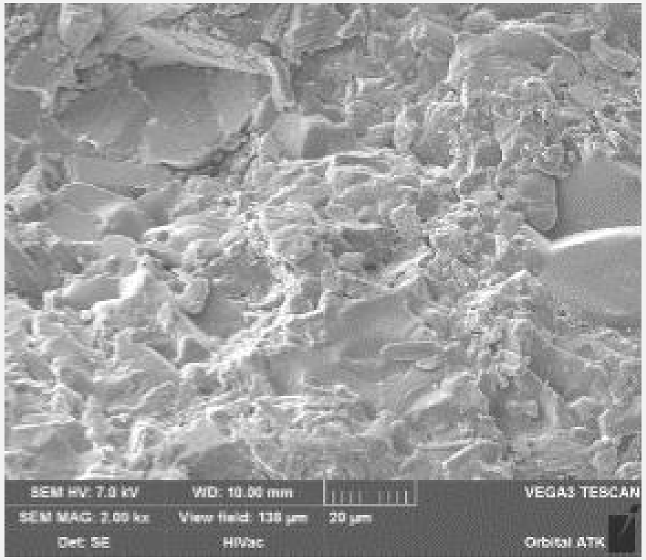
Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)

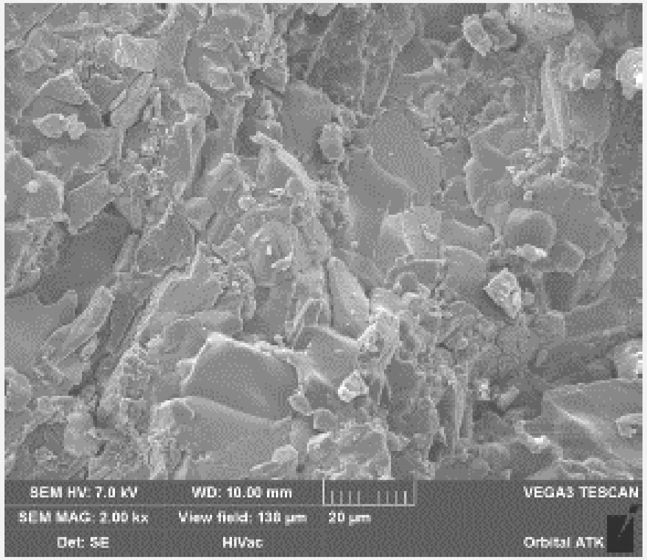


1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

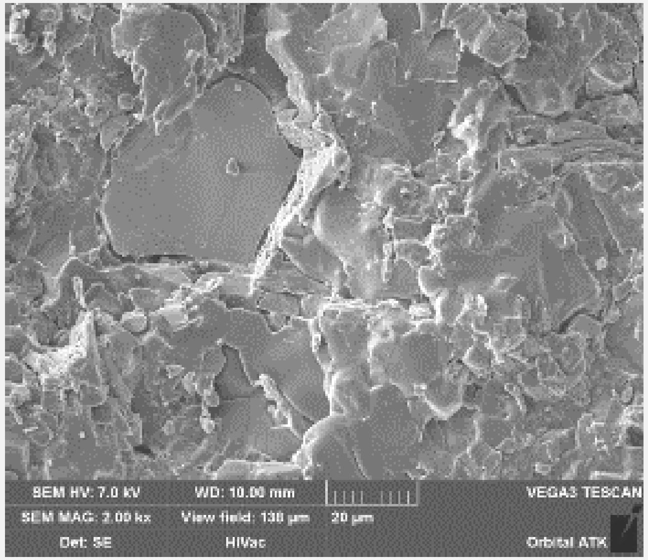
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)



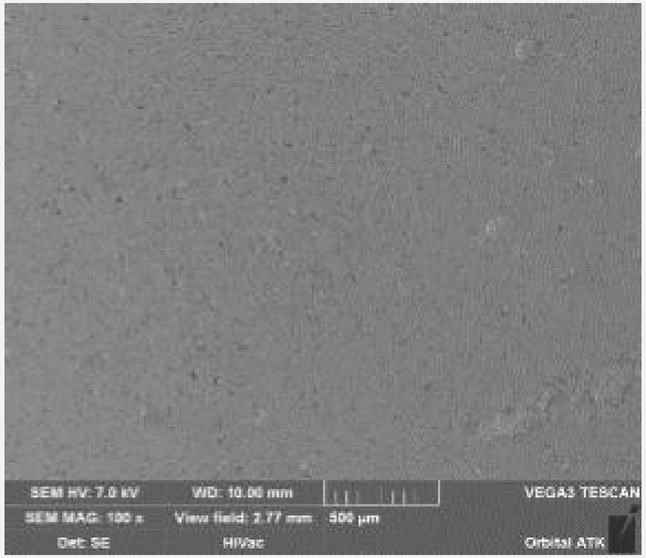
PSPI-L YD Primary P4 #2 (100905)



100X Magnification-External Surface

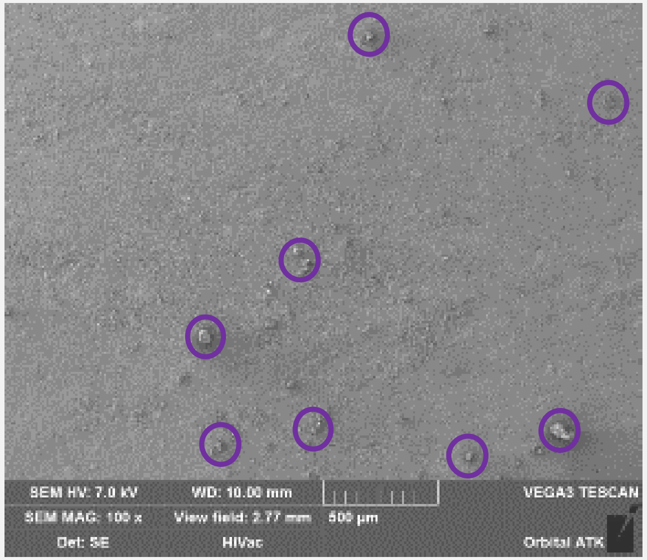
Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



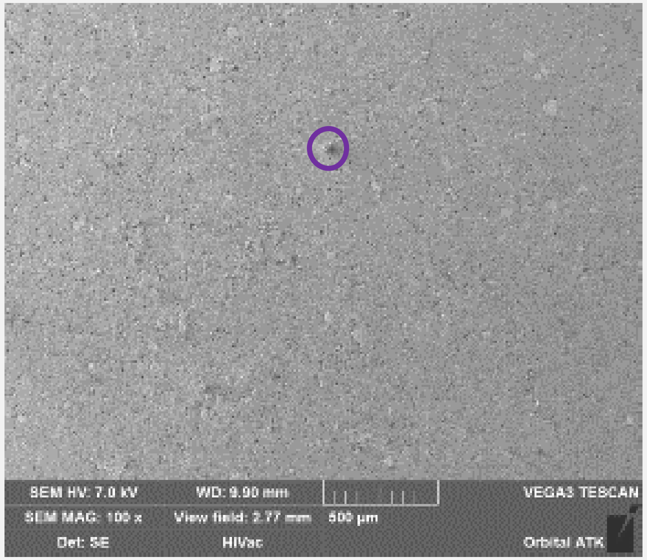
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)



1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

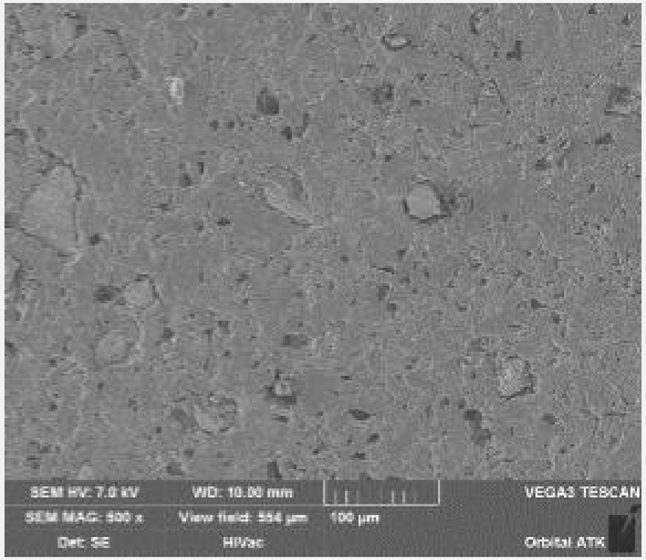
Parent MSI	Inflator Type	Prefix	Inflator Chamber	Wafer Position	Cycle	Max Cycle Temp (°C)	Total Target % Moisture	Actual Wafer % Moisture	Wafer OD (mm)	Avg Wafer Density (g/cc)	Crush Strength (ksi)
100872	PSPI-L	YD	Primary	P4	1120	50	0.15%	0.057	28.79	1.690	
100905	PSPI-L	YD	Primary	P4	1120	60	0.15%	0.046	28.92	1.676	
113189	PSPI-L	YD	Primary	P4	Ret	NA	GM Aged	0.060	28.97	1.659	

- Surface roughness of the wafer from the returned inflator aged at GM is between the 20-50 C and the 20-60 C sample
  - There appear to be crystallites that have formed on the surface of the GM and 20-60 C wafers

500X Magnification-External Surface

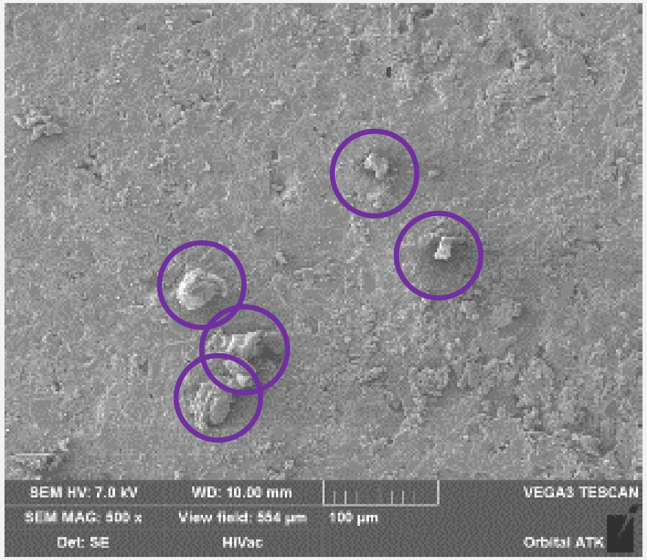
Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

PSPI-L YD Primary P4 #1 (100872)



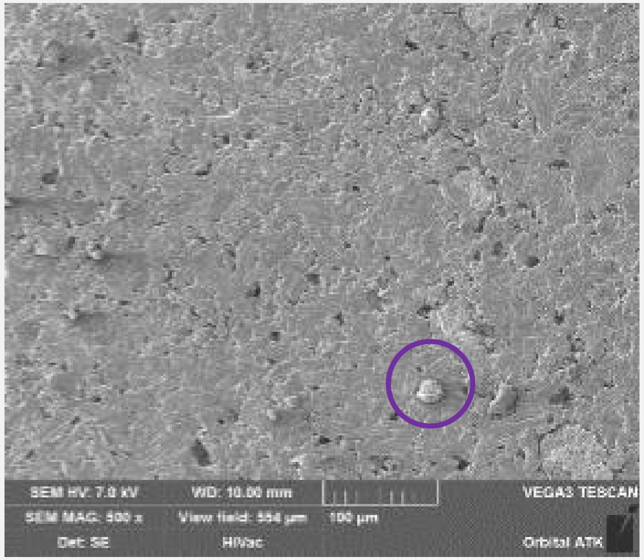
1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

PSPI-L YD Primary P4 #1 (113189)



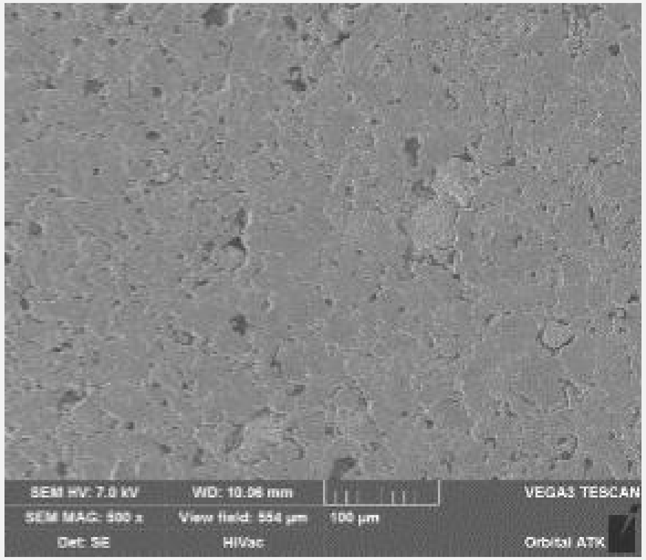
Ret & GM Aged, 0.060% H20, 28.97 mm

PSPI-L YD Primary P4 #1 (100905)

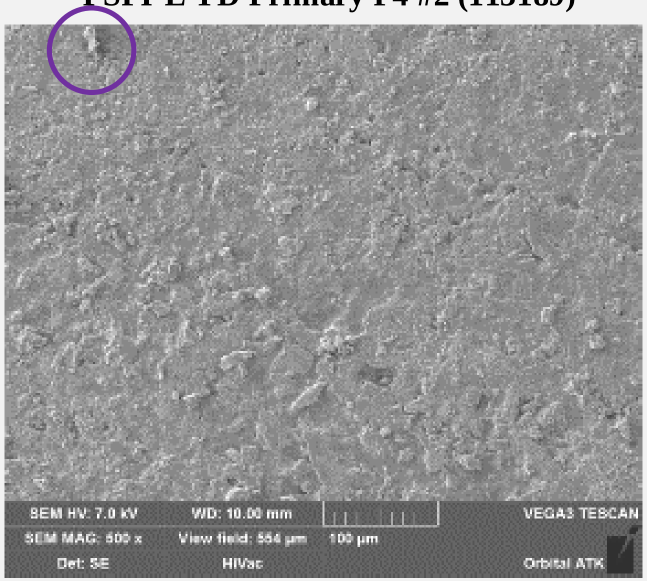


1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

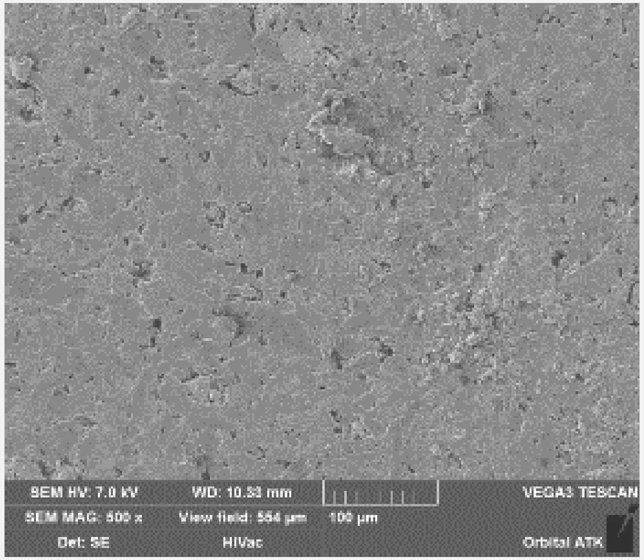
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)



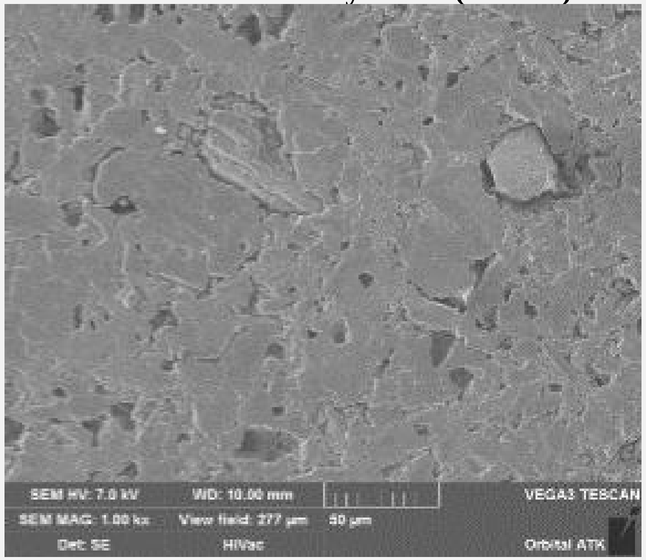
PSPI-L YD Primary P4 #2 (100905)



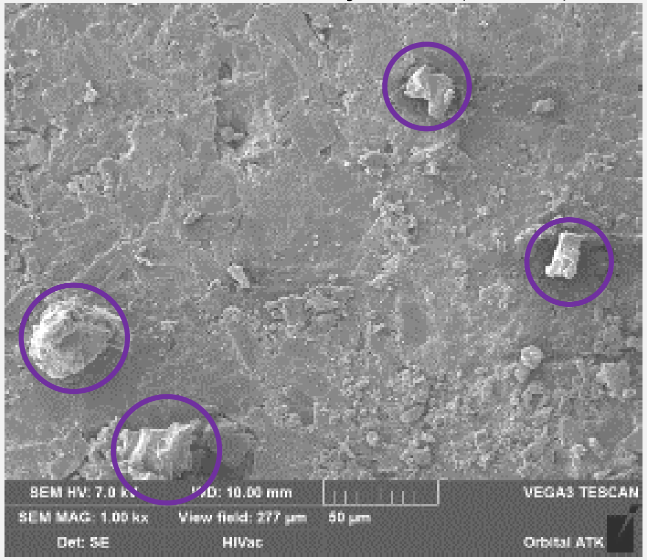
1000X Magnification-External Surface

Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

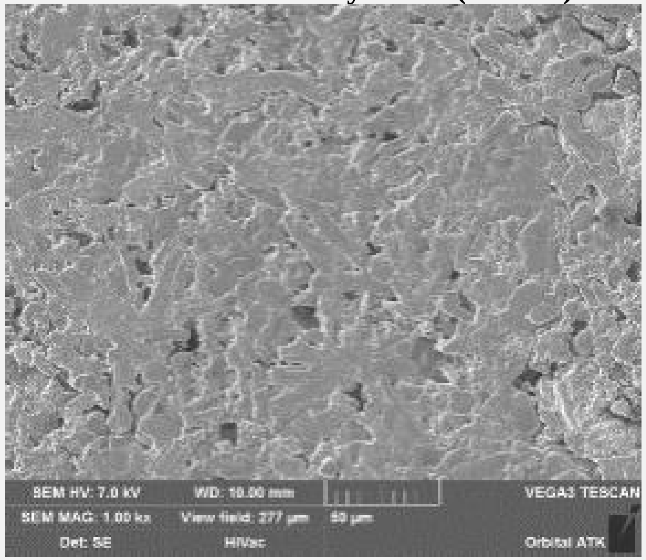
PSPI-L YD Primary P4 #1 (100872)



PSPI-L YD Primary P4 #1 (113189)



PSPI-L YD Primary P4 #1 (100905)

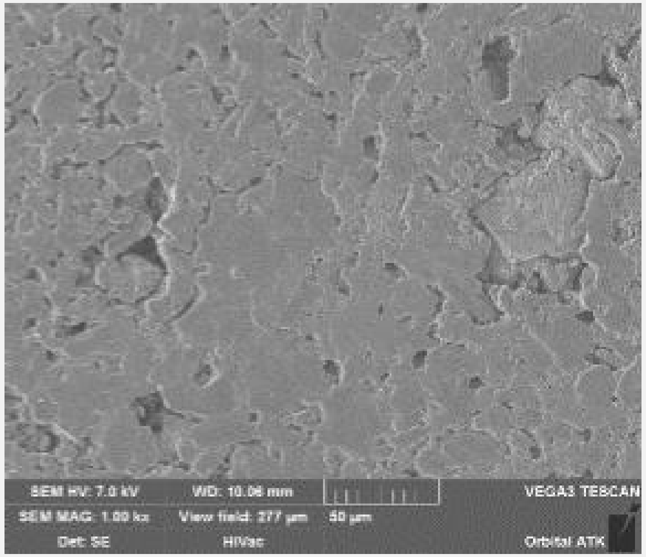


1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

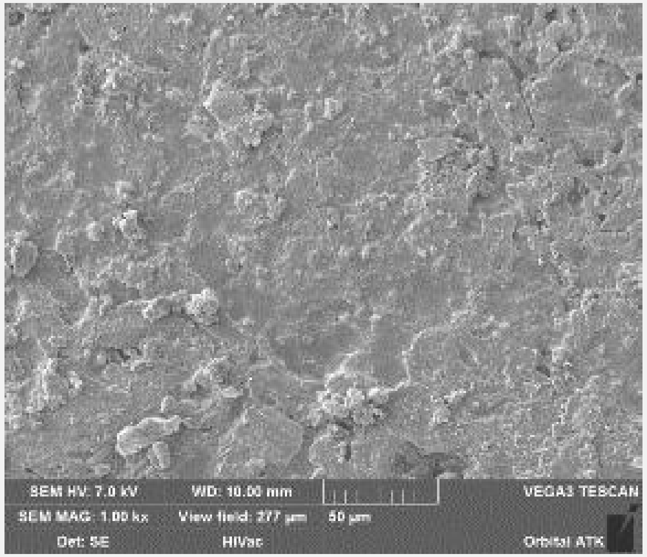
Ret & GM Aged, 0.060% H20, 28.97 mm

1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

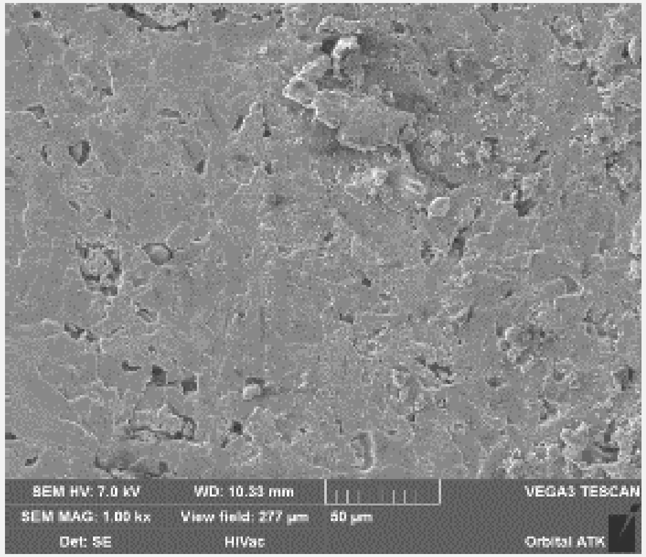
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)



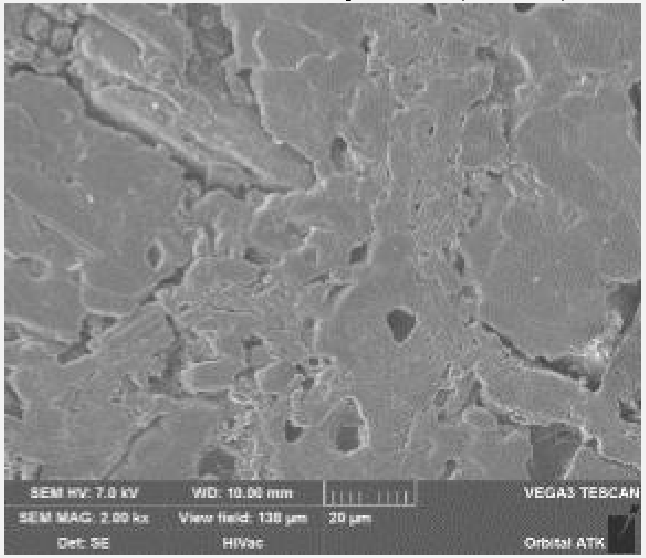
PSPI-L YD Primary P4 #2 (100905)



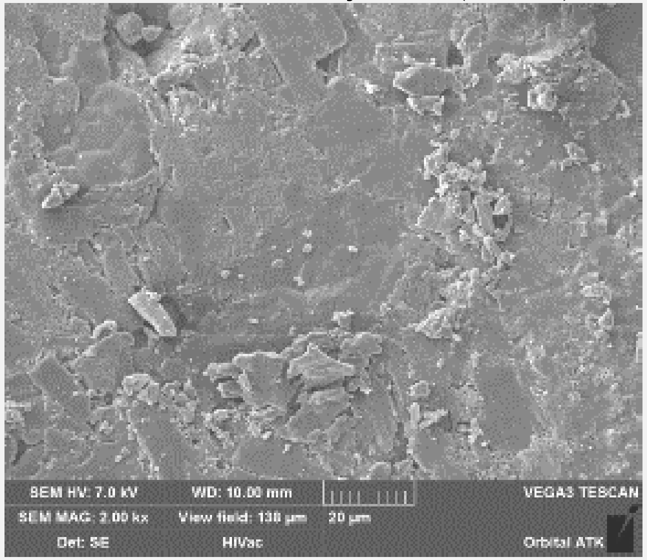
2000X Magnification-External Surface

Comparison of Returned/GM aged (center) with 1120 cycle 0.15% 20-50 C (left) and 20-60 C (right)

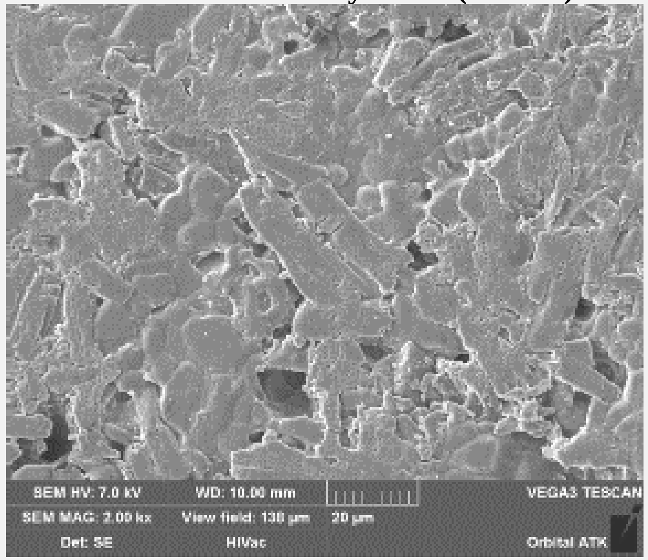
PSPI-L YD Primary P4 #1 (100872)



PSPI-L YD Primary P4 #1 (113189)



PSPI-L YD Primary P4 #1 (100905)

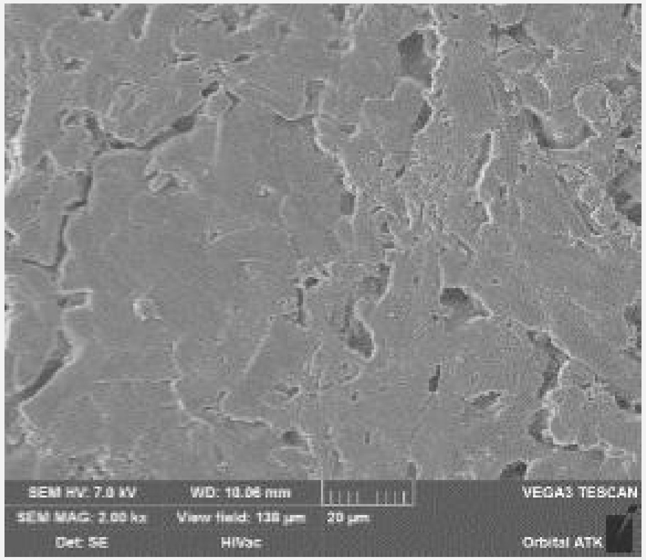


1120 Cycle, 20-50 C, 0.057% H20, 28.79 mm

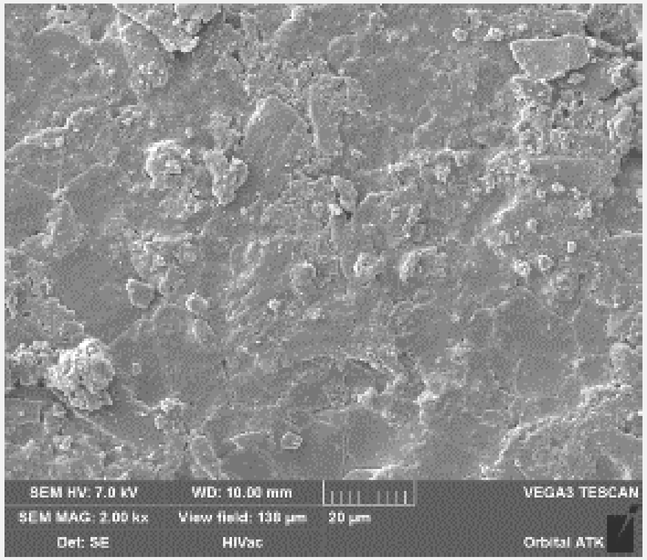
Ret & GM Aged, 0.060% H20, 28.97 mm

1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

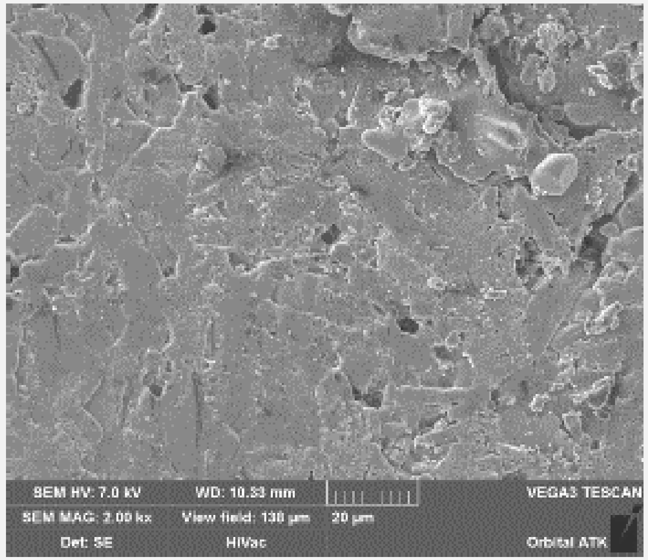
PSPI-L YD Primary P4 #2 (100872)



PSPI-L YD Primary P4 #2 (113189)



PSPI-L YD Primary P4 #2 (100905)

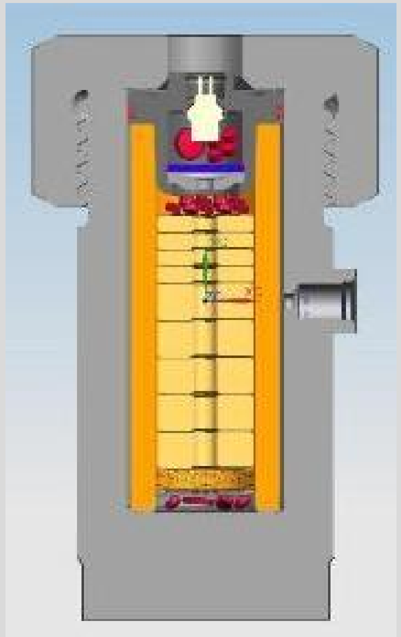


1120 Cycle External Surface SEM

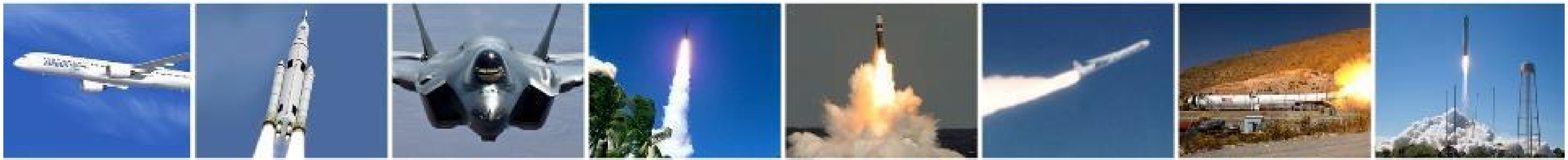
Comparison of Samples at 0.15% Moisture

Varying Inflator Type at 1000X

20-50 C: SPI YP, PSPI-L FD, PSPI-L YD
20-60 C: SPI YP, PSPI-L FD, PSPI-L YD
20-70 C: SPI YP, PSPI-L FD, PSPI-L YD



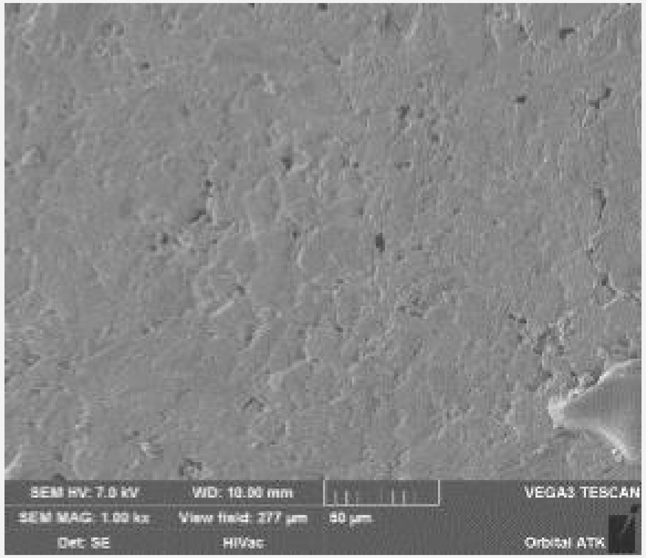
Discussion



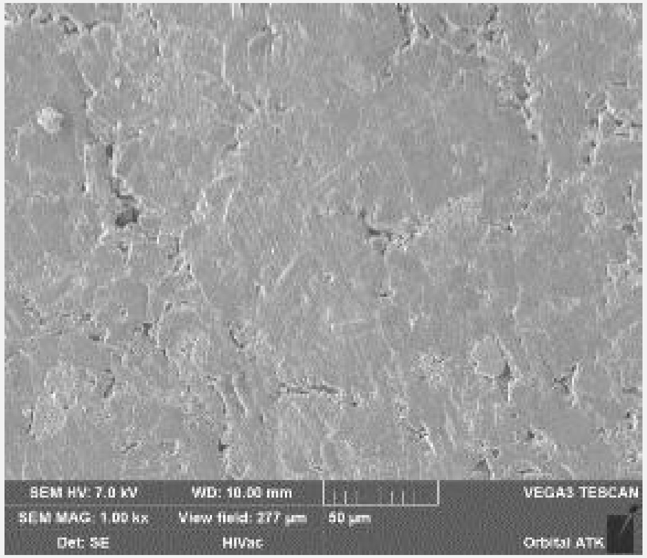
1000X Magnification-External Surface

20-50 C, 1120 Cycle, Primary, 0.15% Moisture Varying Inflator Type

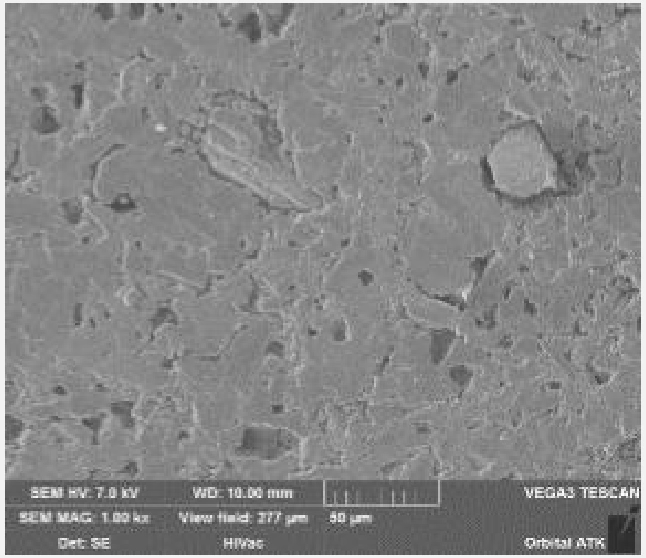
SPI YP Primary P5 #1 (100497)



PSPI-L FD Primary P4 #1 (100133)



PSPI-L YD Primary P4 #1 (100872)

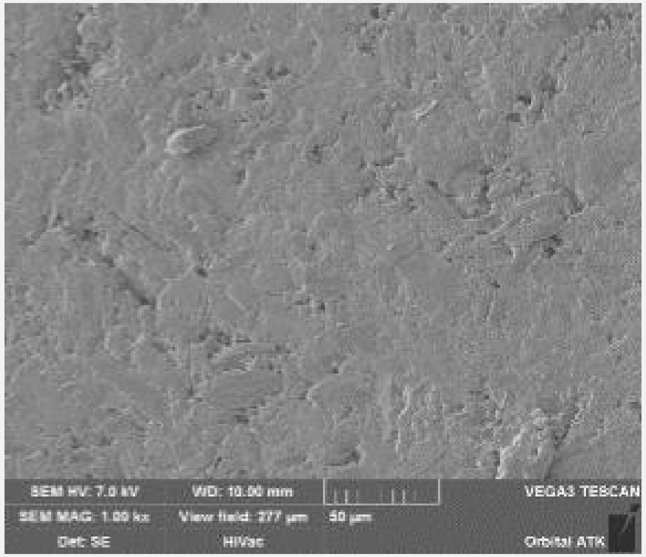


1120 Cycle, 20-50 C, 0.065% H20, 29.00 mm

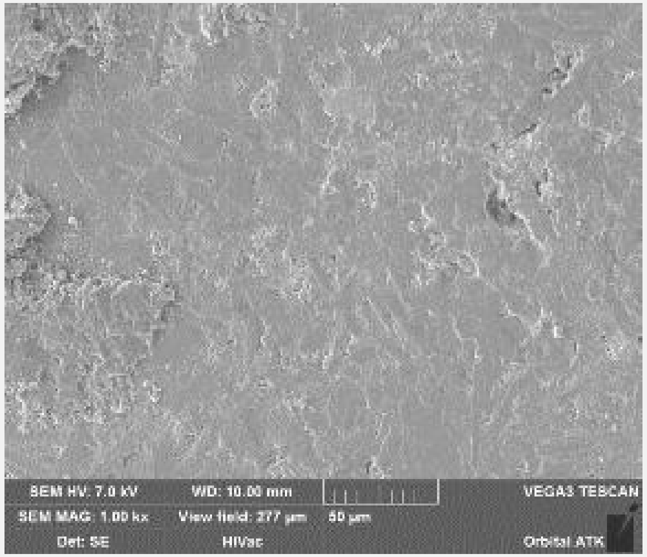
1120 cycle, 20-50 C, 0.053% H20, 28.76 mm

1120 Cycle 20-50 C, 0.057% H20, 29.79 mm

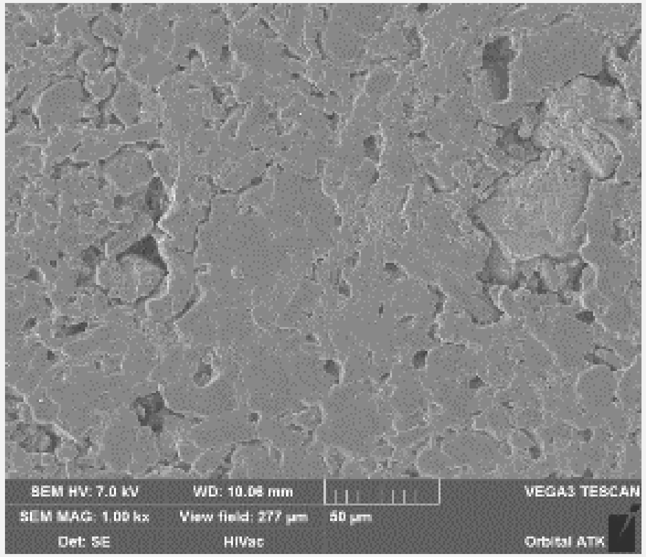
SPI YP Primary P5 #2 (100497)



PSPI-L FD Primary P4 #2 (100133)



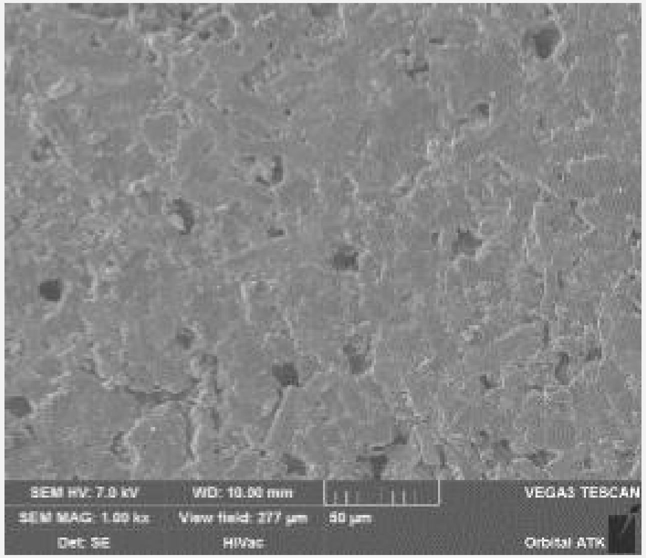
PSPI-L YD Primary P4 #2 (100872)



1000X Magnification-External Surface

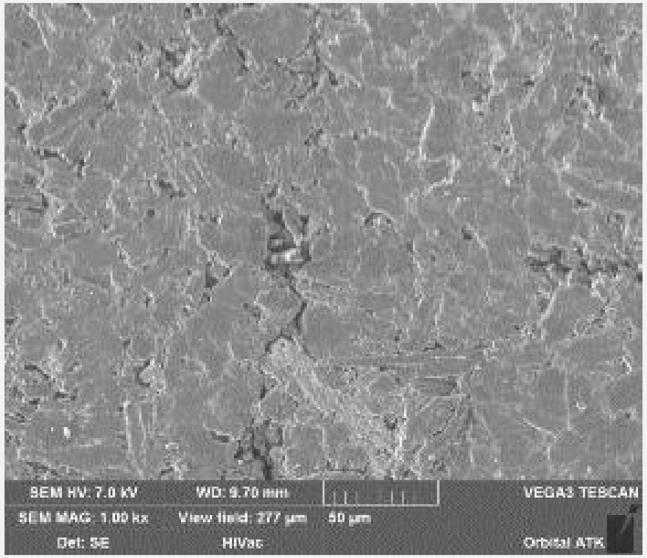
20-60 C, 1120 Cycle, Primary, 0.15% Moisture Varying Inflator Type

SPI YP Primary P5 #1 (100547)



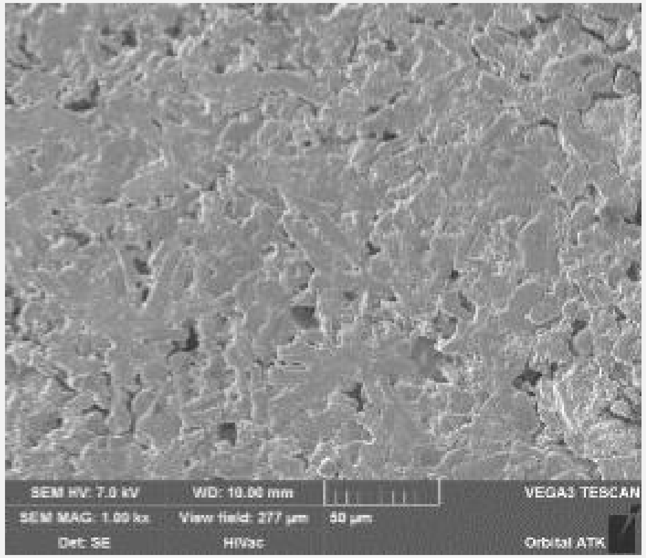
1120 Cycle, 20-60 C, 0.055% H20, 28.91 mm

PSPI-L FD Primary P4 #1 (100170)



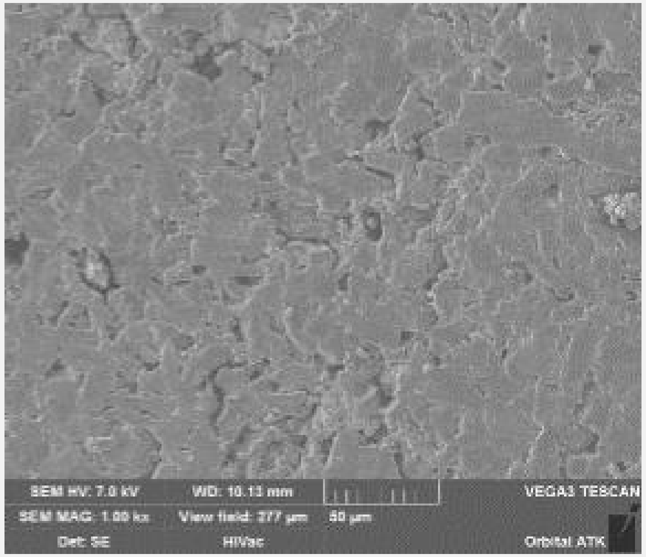
1120 cycle, 20-60 C, 0.055% H20, 29.04 mm

PSPI-L YD Primary P4 #1 (100905)

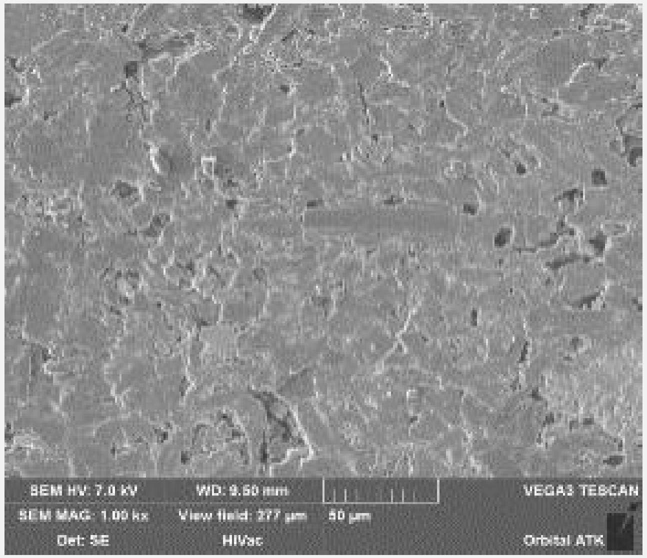


1120 Cycle 20-60 C, 0.046% H20, 28.92 mm

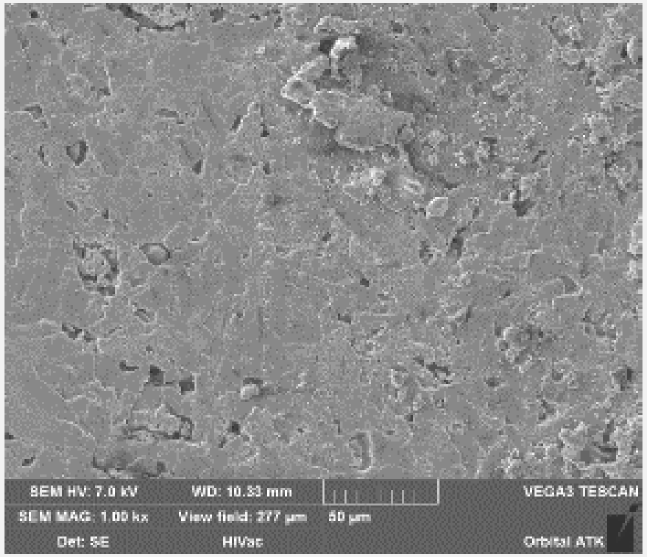
SPI YP Primary P5 #2 (100547)



PSPI-L FD Primary P4 #2 (100170)



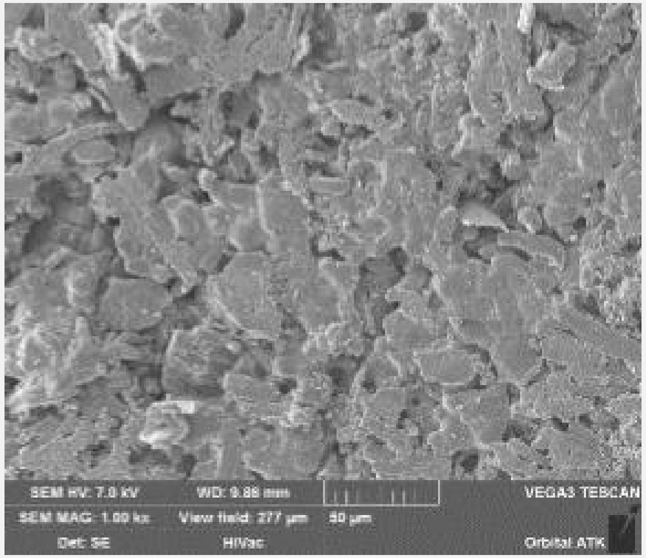
PSPI-L YD Primary P4 #2 (100905)



1000X Magnification-External Surface

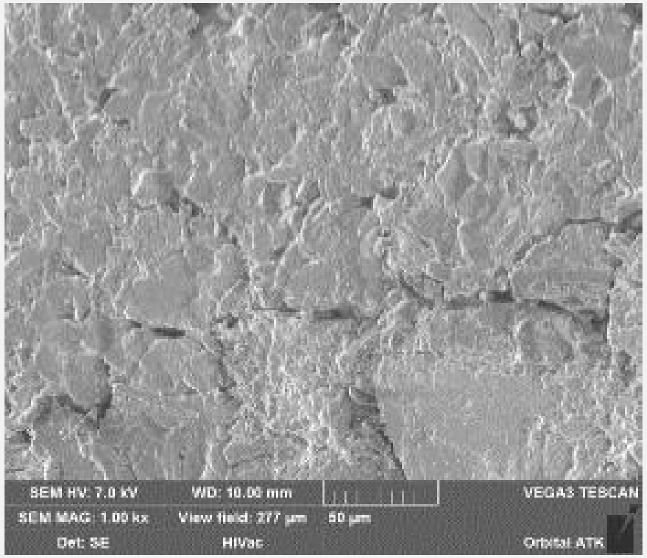
20-70 C, 1120 Cycle, Primary, 0.15% Moisture Varying Inflator Type

SPI YP Primary P5 #1 (100580)



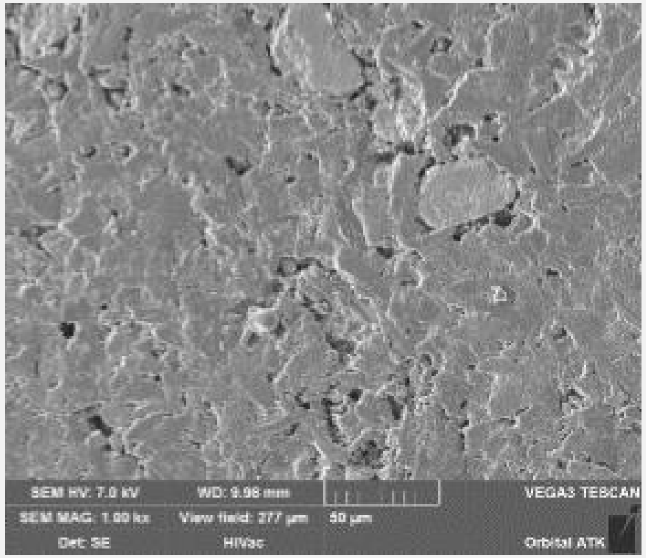
1120 Cycle, 20-70 C, 0.058% H20, 29.21 mm

PSPI-L FD Primary P4 #1 (100201)



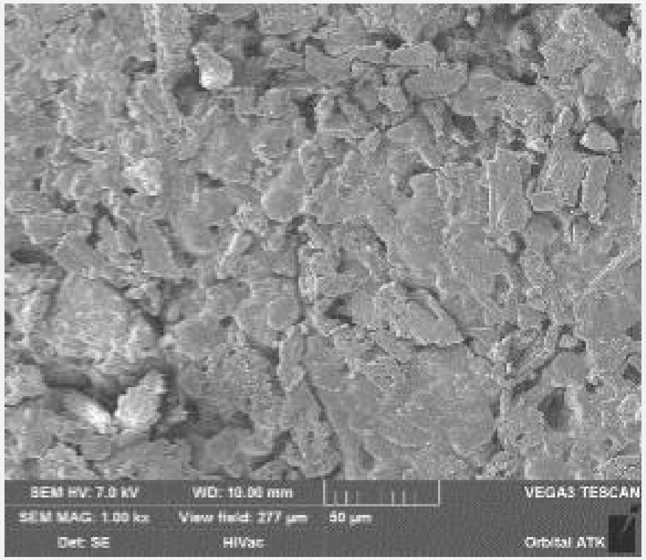
1120 cycle, 20-70 C, 0.064 H20, 29.24 mm

PSPI-L YD Primary P4 #1 (100941)

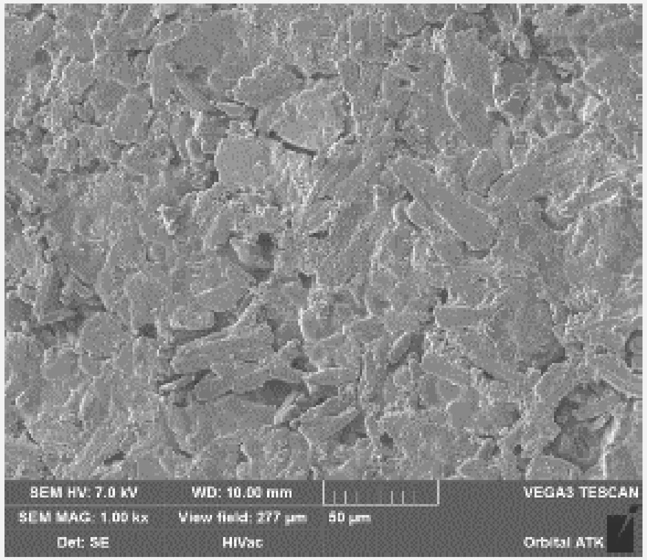


1120 Cycle 20-70 C, 0.050% H20, 29.11 mm

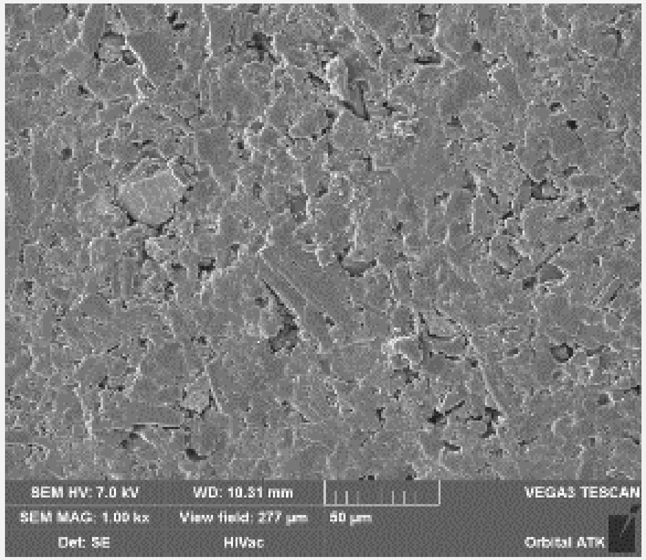
SPI YP Primary P5 #2 (100580)



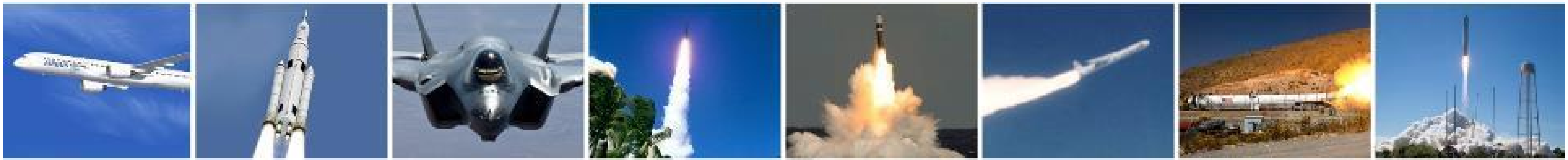
PSPI-L FD Primary P4 #2 (100201)



PSPI-L YD Primary P4 #2 (100941)



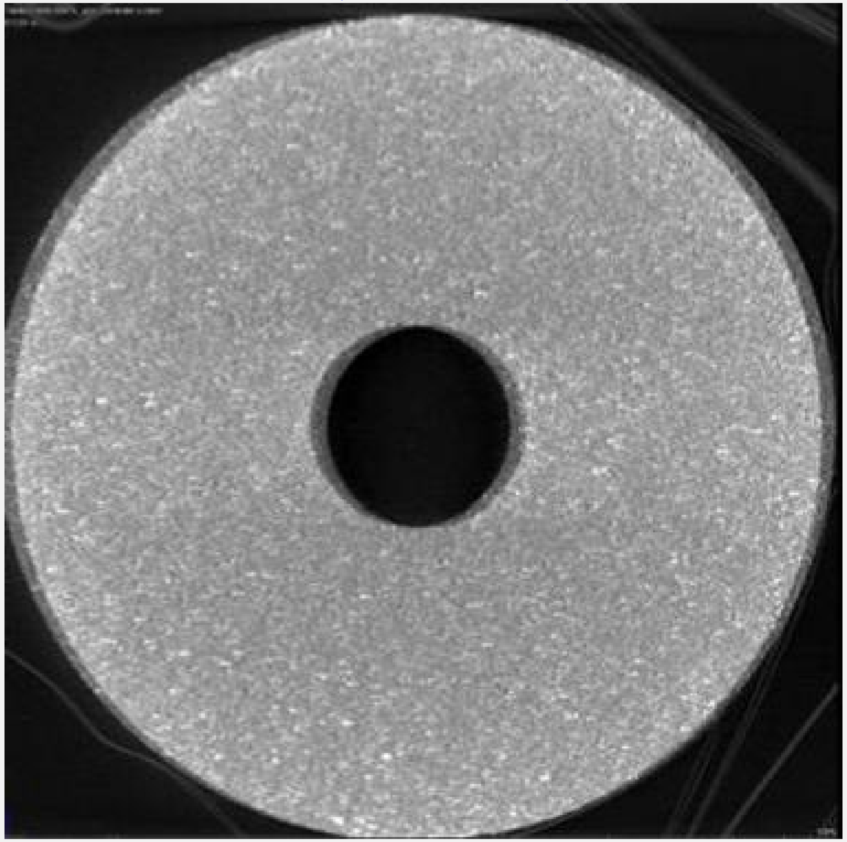
Micro-CT Scan Analysis



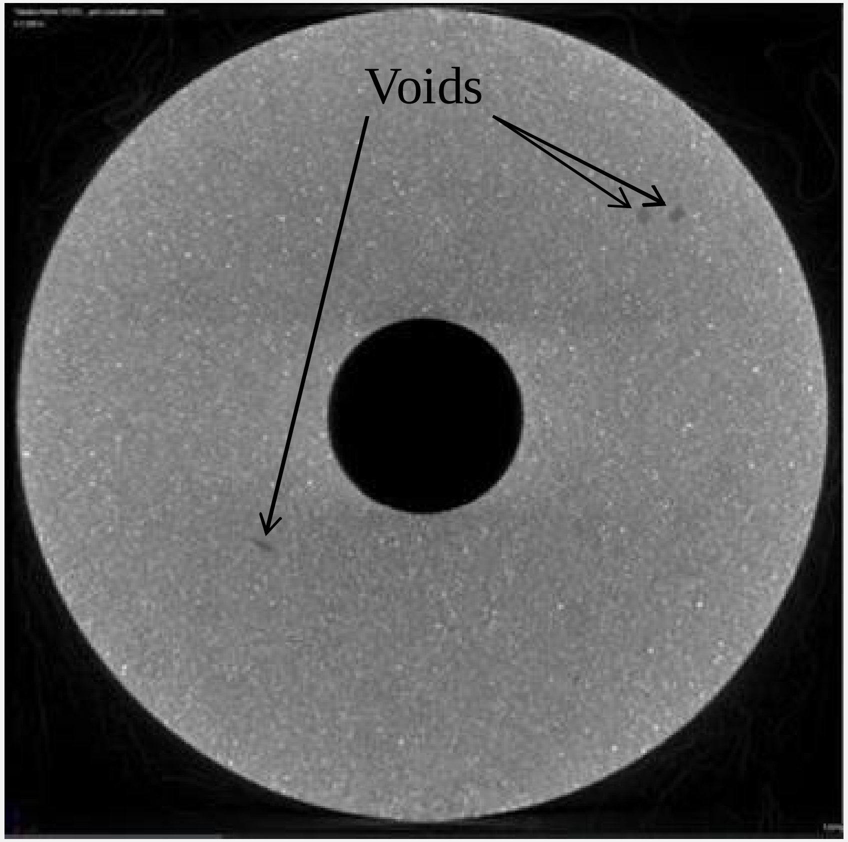
2004 Wafer Micro-CT Analysis

- Inspection of micro-computed tomography (micro-CT) scans show that observable voids increase as a function of the wafer's age and environmental history

99979 (at 11 seconds)



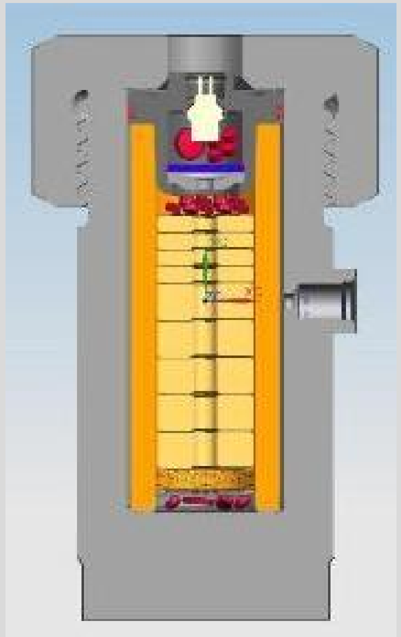
92202 (at 13 seconds)

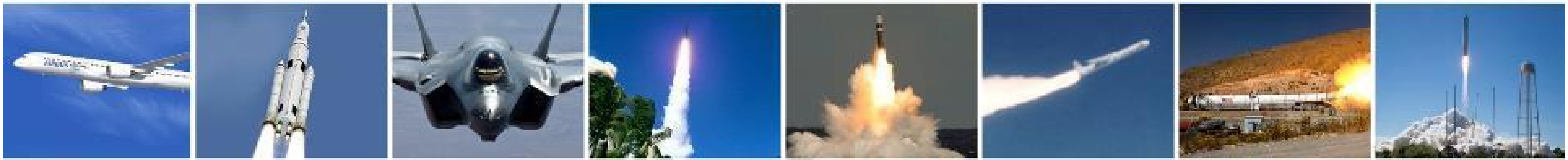


Inflator Type	Prefix	Date of Birth	Recall Address	Ave. Wafer OD in Chamber (mm)	# of voids observed	OATK ID	Serial or Vin	Wafer ID	Vehicle
PSPI-L	FD	2/14/2003	Brooklyn, NY	29.21	45	92202	FDHP2140126	P-5	Toyota Corolla
SPI	AJ	5/30/2003	Puerto Rico	29.24	56	95246	AJJP5304262	P-5	Mitsubishi Lancer
PSPI-L	YD	3/6/2006	Milton, FL	28.86	37	101925	1GKFC13J67R146862	P-5	GMC Yukon
SPI	YP	6/30/2007	West Palm Beach, FL	29.02	22	102682	YPBSU6X0486	P-5	Chevy Silverado
PSPI-L	FD	4/21/2016	NA	28.62	2	99979	160419P018	P-5	Prototype Line
PSPI-L	YD	4/28/2016	NA	28.69	3	100727	160420P011	P-5	Prototype Line

Micro CT at 560 cycles

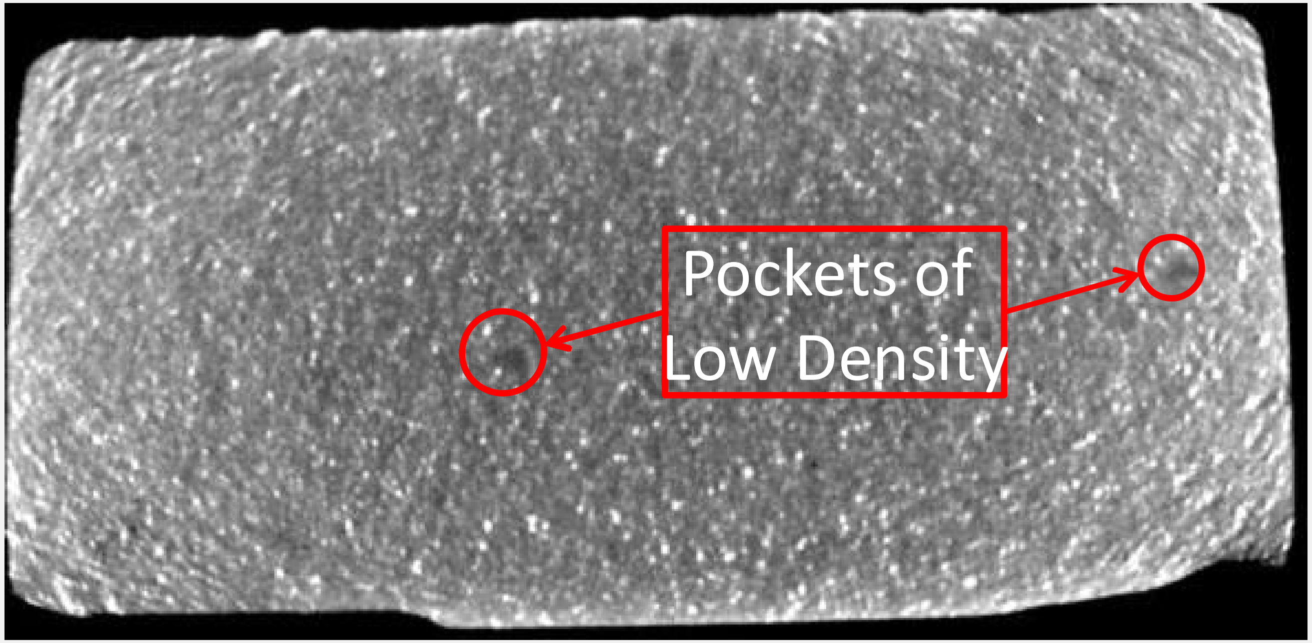
Discussion



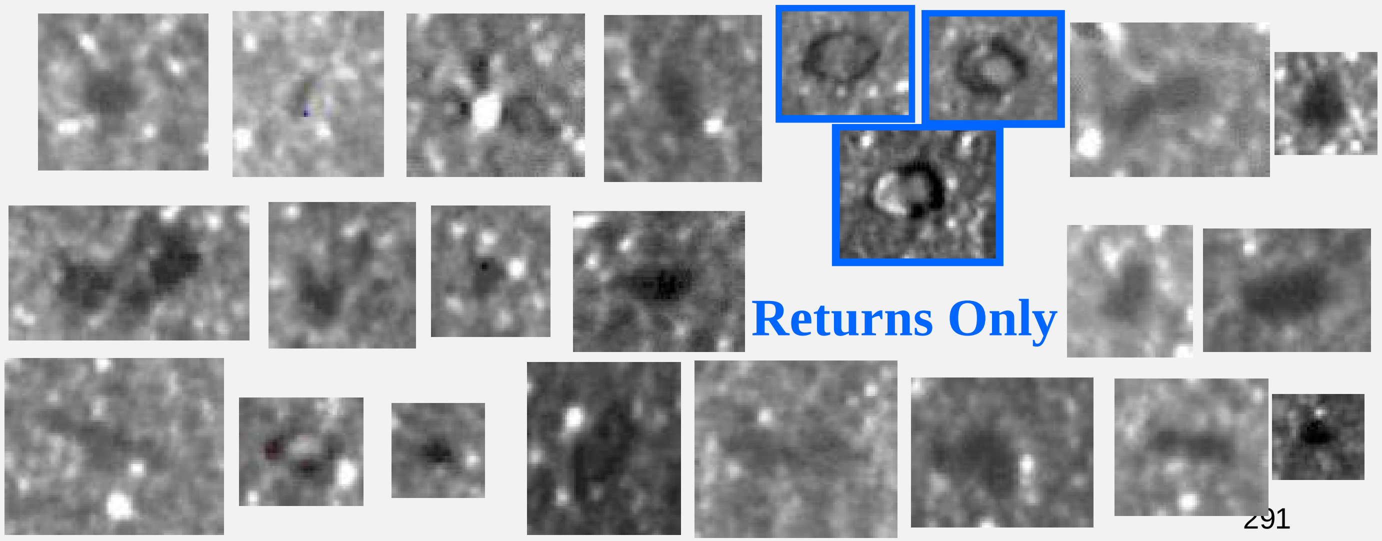


Early ITC Observation
Micro CT of Wafers: “Pockets of Low Density”
From Phase I/II Root Cause Analysis

- Documented pockets of low density were found in virgin and aged wafers
  - Volume of individual pockets: 0.007 to 0.4 mm^3
  - <u>More than twice as many in the 29.6 mm wafers.</u>
  - Total observed pocket volume/wafer:
    - Less than 1% of total expanded volume of a 29.6 mm wafer (289 mm^3)
    - Virgin: 0.3 mm^3
    - 29.6 mm: 2.4-2.5 mm^3
  - Gravlin test series observed pocket volume/wafer
    - Gravlin S-2 29.23 mm: 1.6 mm^3
    - Gravlin P-2 29.55 mm: 3.9 mm^3
- Most void space in wafers cannot be resolved by the Orbital ATK micro CT (less than 0.1 mm^3)



Other instances of low density pockets

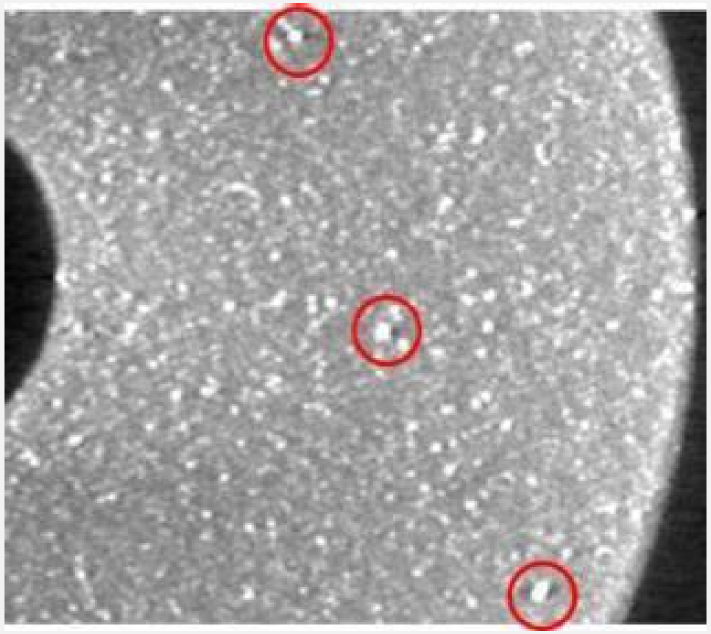


Wafer Micro CT

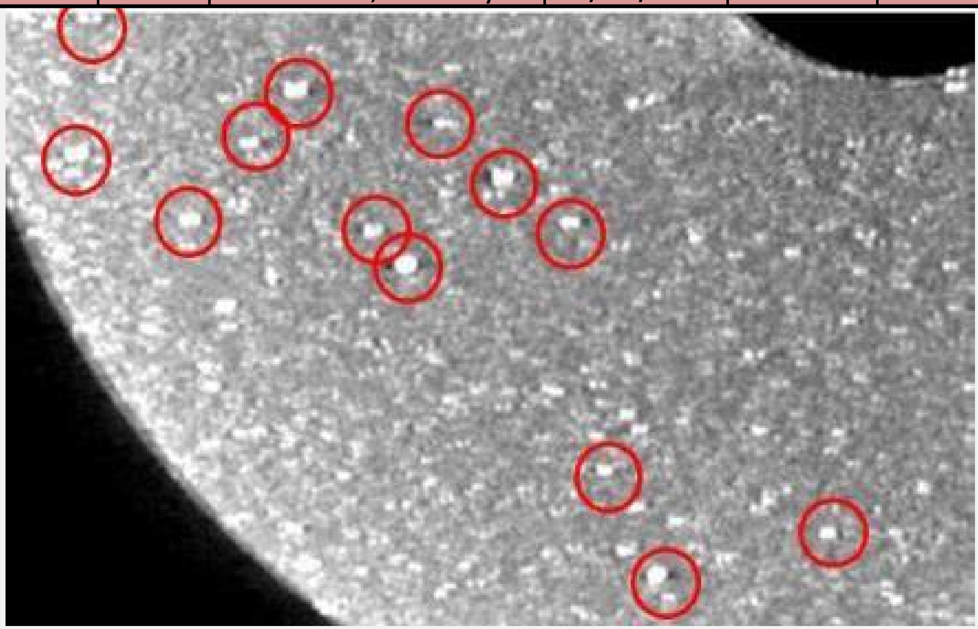
Voids Adjacent to High Density Spots, Scientifically Aged

- The number of high density (bright) spots with adjacent voids (dark spots) is lower for wafers in inflators where higher levels of moisture was added
  - High density grains in wafers are strontium nitrate (3.0 g/cc) and bentonite (2-2.7 g/cc)

Inflator Type	Prefix	Wafer ID	Vehicle or Test History	Date of Birth	Wafer Moisture (%)	# of high density spots with voids
PSPI-L	FD	S-1	nom H_2O, 560 cycle	4/21/2016	0.039	100
PSPI-L	FD	S-1	0.45% H_2O, 560 cycle	4/21/2016	0.081	155
PSPI-L	FD	S-1	0.70% H_2O, 560 cycle	4/21/2016	0.176	47
PSPI-L	YD	P-5	0.15% H_2O, time zero	4/28/2016	0.075	329
PSPI-L	YD	P-5	0.30% H_2O, time zero	4/28/2016	0.092	77
PSPI-L	YD	P-5	nom H_2O, 560 cycle	4/28/2016	0.063	330
PSPI-L	YD	P-5	0.15% H_2O, 560 cycle	4/28/2016	0.107	331
PSPI-L	YD	P-5	0.30% H_2O, 560 cycle	4/28/2016	0.123	70
PSPI-L	YD	P-5	0.30% H_2O, 1120 cycle	4/28/2016	0.102	203



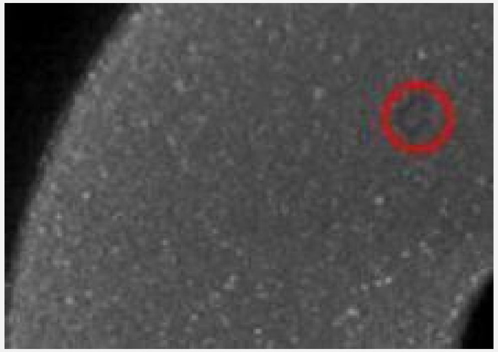
101084 PSPI-L YD, P5, 560 20-70 C Cycles 0.30% H2O



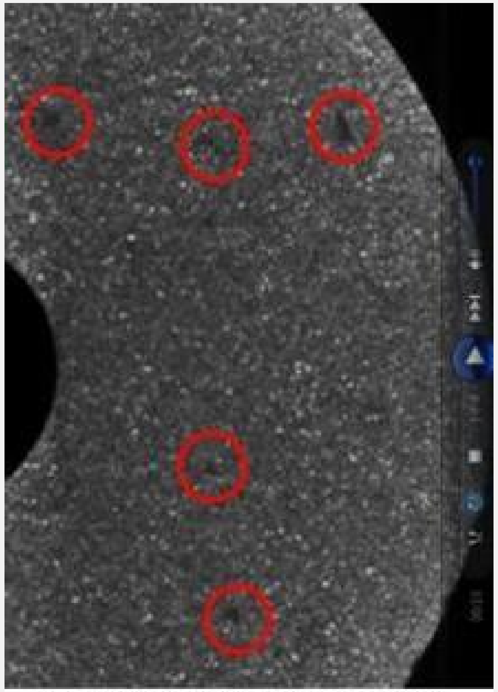
100931 PSPI-L YD, P5, 560 20-70 C Cycles 0.15% H2O

Wafer Micro CT

Void Analysis



100191 560 20-70 C Cycles 0.45% H2O S1,



95246 2003 SPI AJ P5
2003 Other OEM

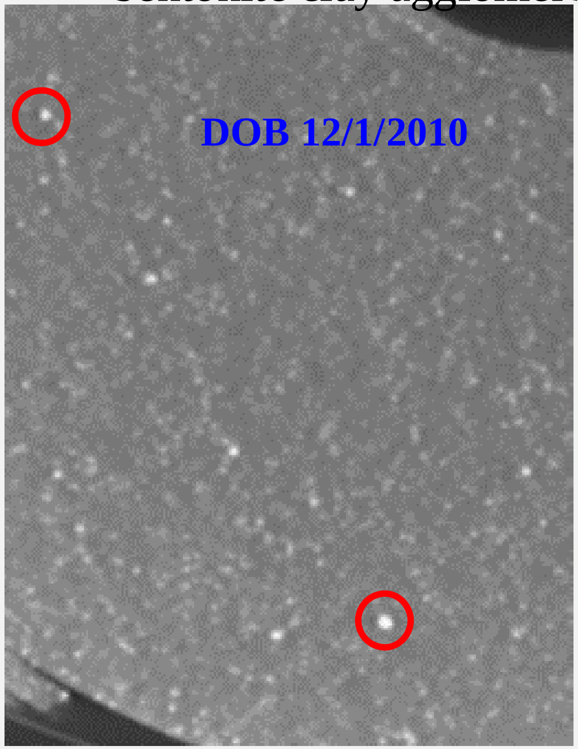
- More recently produced wafers, both returned (blue rows) and temperature cycled (**tan rows**) tend to have less micro-CT visible voids than older returned wafers
  - ➢ Returned wafer with 12/1/2010 date of birth (red font) has minimal voids
    - – Table sorted according to wafer OD

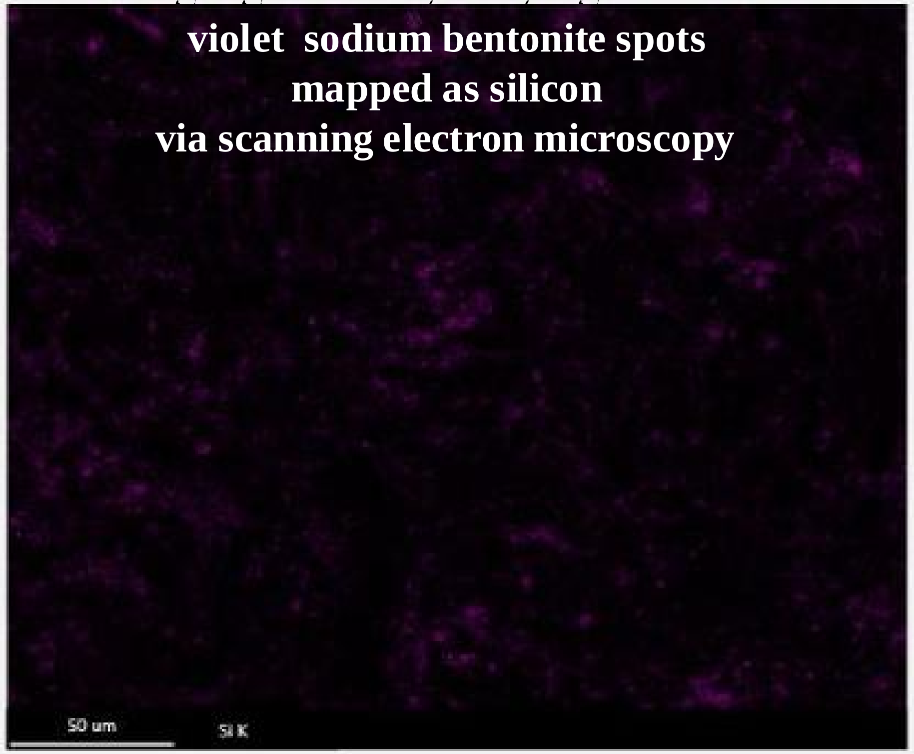
Inflator Type	Prefix	Wafer ID	Vehicle or Test History	Date of Birth	Recall Address	**Wafer OD (mm)**	**# of larger voids**
PSPI-L	FD	S-1	0.70% H2O, 560 cycle	4/21/2016	NA	**29.56**	**3**
SPI	AJ	P-5	Other OEM smaller vehicle	5/30/2003	Puerto Rico	**29.24**	**56**
PSPI-L	FD	P-5	Other OEM smaller vehicle	2/14/2003	Brooklyn, NY	**29.21**	**45**
PSPI-L	FD	S-1	0.45% H2O, 560 cycle	4/21/2016	NA	**29.13**	**9**
PSPI-L	FD	P-5	0.30% H2O, 560 cycle	4/21/2016	NA	**29.10**	**3**
PSPI-L	YD	P-5	0.30% H2O, 1120 cycle	4/28/2016	NA	**29.04**	**3**
PSPI-L	YD	P-5	0.30% H2O, 560 cycle	4/28/2016	NA	**29.03**	**3**
SPI	YP	P-5	Chevy Silverado	6/30/2007	West Palm Beach, FL	**29.02**	**22**
PSPI-L	YD	P-5	Chevy Silverado + 2798 hours 23-73 C, high humidity cycling	12/5/2007	Crestview, FL (Panhandle)	**28.98**	**50**
PSPI-L	YD	P-5	0.15% H2O, 560 cycle	4/28/2016	NA	**28.97**	**2**
PSPI-L	YD	P-5	nom H2O, 560 cycle	4/28/2016	NA	**28.92**	**2**
PSPI-L	YD	P-5	GMC Yukon	3/6/2006	Milton, FL	**28.86**	**37**
PSPI-L	FD	S-1	nom H2O, 560 cycle	4/21/2016	NA	**28.81**	**2**
PSPI-L	YD	P-5	0.30% H2O, time zero	4/28/2016	NA	**28.76**	**1**
PSPI-L	YD	P-5	GMT900	12/1/2010	Austin, TX	**28.74**	**1**
PSPI-L	YD	P-5	0.15% H2O, time zero	4/28/2016	NA	**28.71**	**3**
PSPI-L	YD	P-5	nom H2O, time zero	4/28/2016	NA	**28.69**	**3**
PSPI-L	FD	P-5	0.30% H2O, time zero	4/21/2016	NA	**28.65**	**0**
PSPI-L	FD	P-5	nom, time zero	4/21/2016	NA	**28.62**	**2**

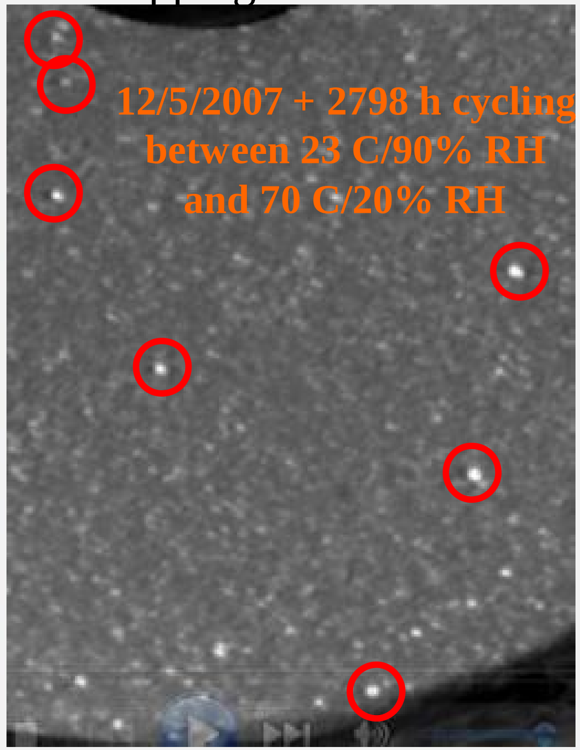
Wafer Micro CT

Voids Adjacent to High Density Spots, Returned Inflators

- Dispersion pattern of high density spots in micro CT is similar to randomly dispersed sodium bentonite clay agglomerates having significantly varying size in SEM element mapping



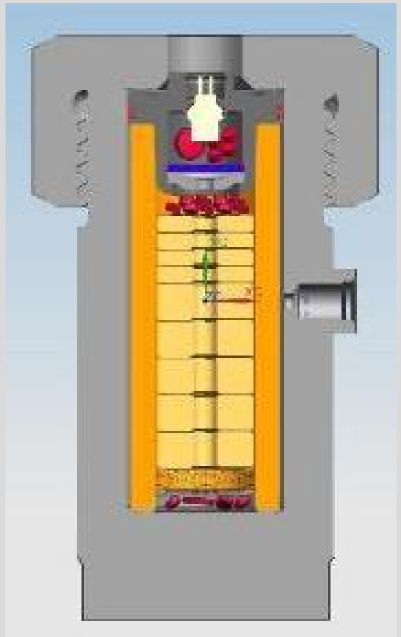




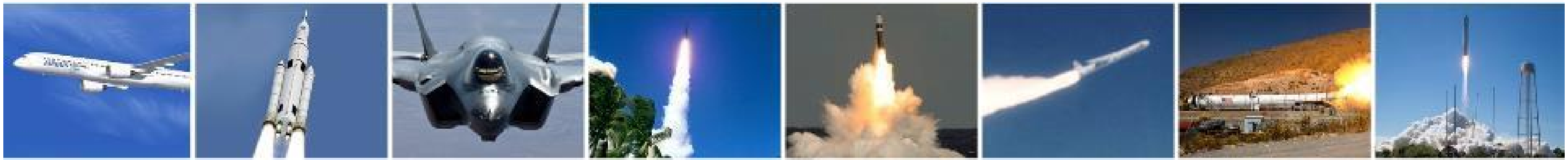
- Extended temperature cycling in a hot humid environment appears to increase the number of high density spots having adjacent voids.

Inflator Type	Prefix	Wafer ID	Vehicle and Test History	Date of Birth	Recall Address	Wafer OD (mm)	Wafer Moisture (%)	# of voids	# of high density spots with voids	Serial Number
PSPI-L	YD	P-5	GMT900, as received	12/1/2010	Austin, TX	28.74	0.056	1	63	YDBSAC10308
PSPI-L	YD	P-5	Chevy Silverado + 2798 hours 23-73 C, high humidity cycling	12/5/2007	Crestview, FL (Panhandle)	28.98	0.065	50	641	YDBLUC50109

GM DAB SDI Micro CT Analysis



Discussion



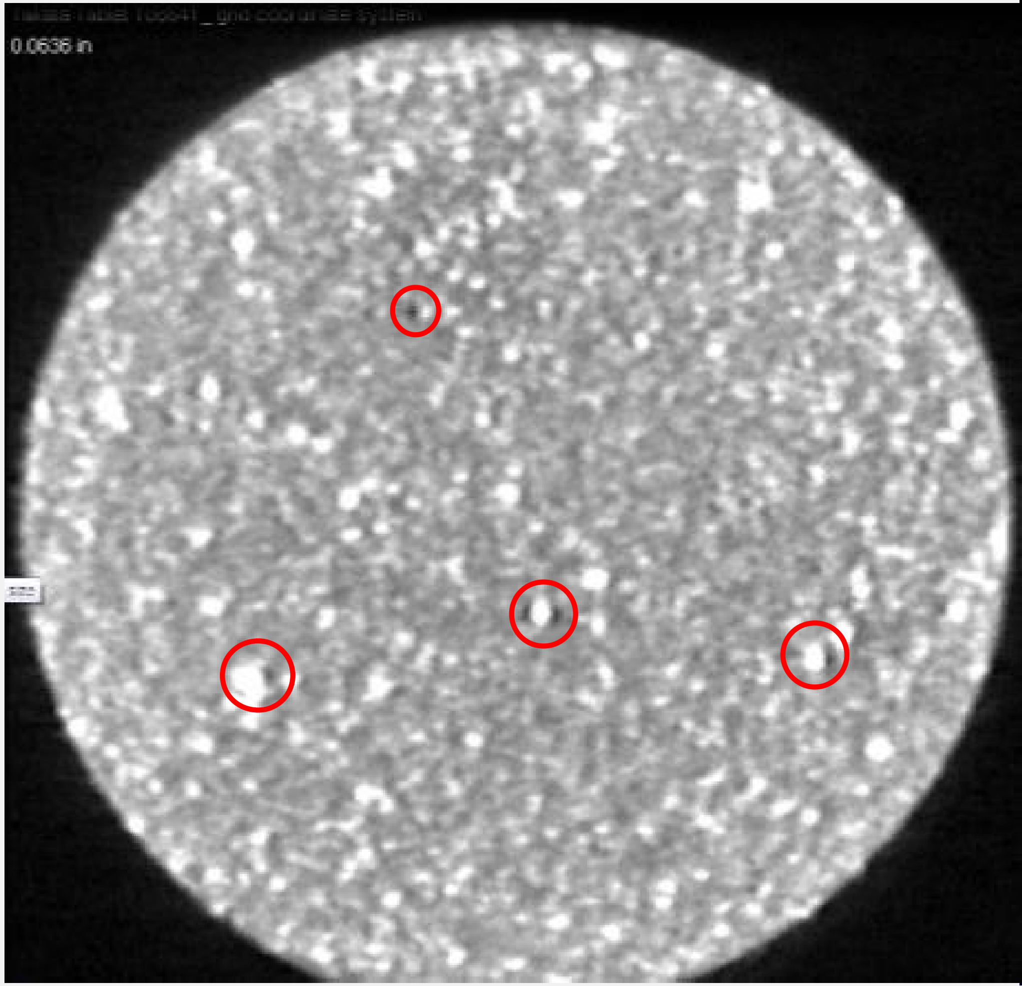
SDI Tablet Micro CT Analysis

- Selected tablets from SPI inflators were submitted for Micro CT analysis
  - ➢ A count was taken of distinctly dark low density areas near very bright spots (high density)
- A large number of voids detected by high density grains on a tablet from a 2004 SDI DC inflator returned from Sunrise, FL
  - ➢ Same inflator that had significant surface pitting
  - ➢ Of the eighteen inflators investigated:
    - Highest moisture content, both in 3110 and total moisture
    - Second lowest crush strength
    - Highest AI-1 color rating
    - Lowest O-ring elliptical area
- A large variation in tablet health can be found in inflators of the same age and region

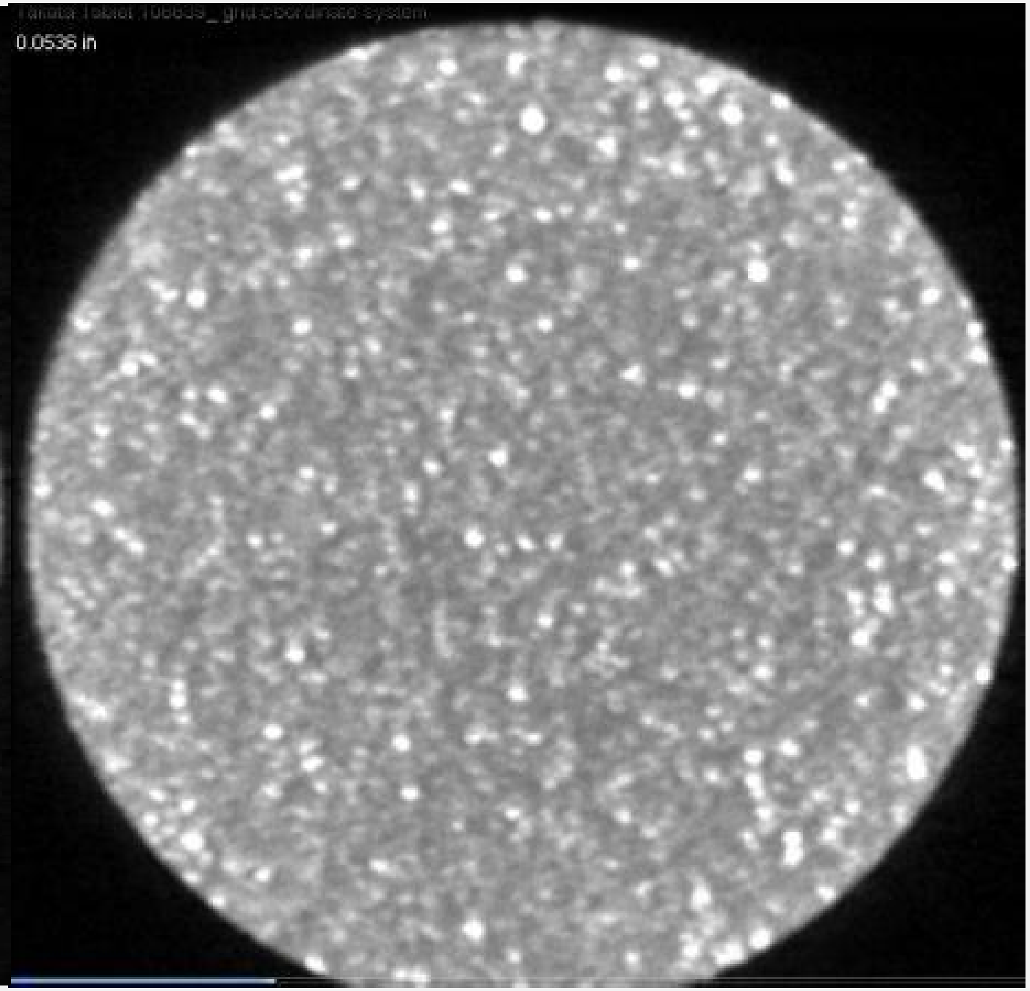
MSI #	Type	History	Age	Micro CT Voids (by high density grains)	Tablet Avg Diameter (mm)	Crush Strength Avg (KN)	%H2O in 3110	Total water (% relative to 2004)	AI-1 Tablet Color Level	Elliptical Area (sq mm)
111807	Virgin SDI VL	Virgin VL (Monclova?)	9/1/2016	16	6.358	0.239	0.23	0.067	1	2.38
111845	Returned SDI TH	India MA6JFDHDBBH017321	7/1/2011	12	6.356	0.196	1.03	0.148	1	2.33
91876	Virgin SDI DC	Virgin DC (Monclova)	2/6/2015	10	6.378	0.181	0.30	0.084	1	2.36
106641	Returned SDI DC	33323 Sunrise, E FL = Ft. Lauderdale	7/1/2004	52	6.408	0.167	2.67	0.342	9	2.12
106639	Returned SDI DC	33461 Palm Springs, E FL Coast	7/1/2004	5	6.384	0.199	2.55	0.329	5	2.20

SDI Micro CT Analysis
100X Magnification-External Surface

- Voids or lower density areas were observed near high density grains.



Returned SDI DC 2004 Sunrise, FL (106641)

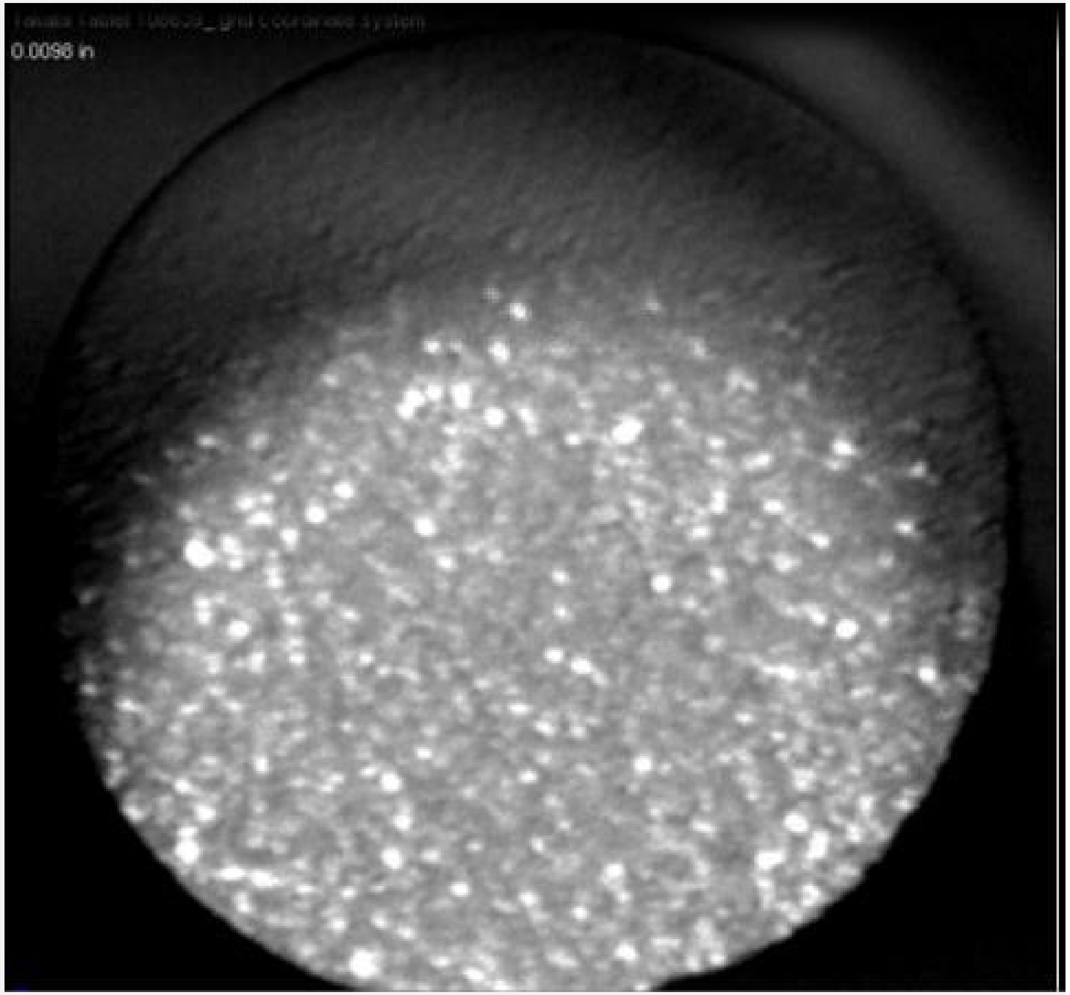


Returned SDI DC 2004 Palm Springs, FL (106639)

SDI Micro CT Analysis
100X Magnification-External Surface

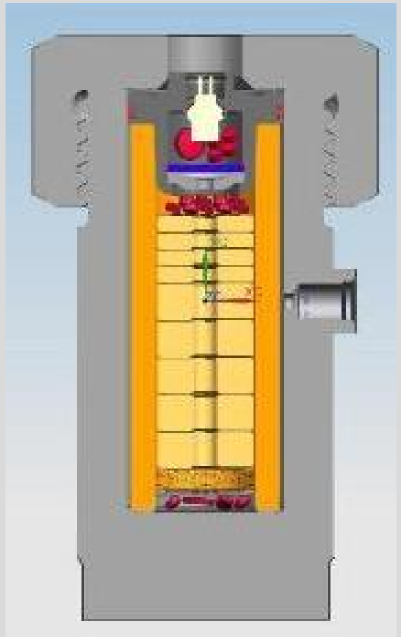
- Similar voids are found in the SEM 2004 SDI DC from Sunrise, FL are found within 0.25mm from the tablet surface
  - Same sample had significant surface pitting in the SEM

Returned SDI DC 2004 Sunrise, FL (106641)

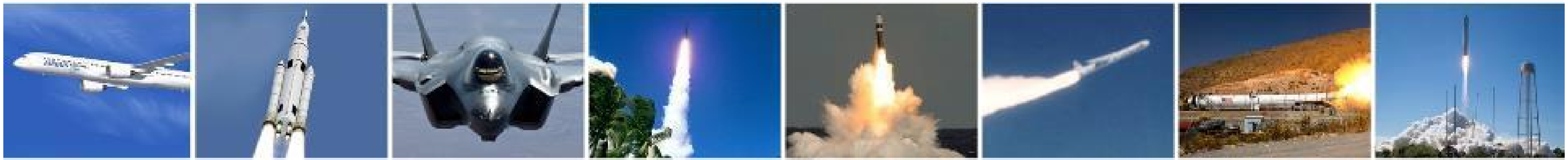


Returned SDI DC 2004 Palm Springs, FL (106639)

Propellant Diffusion

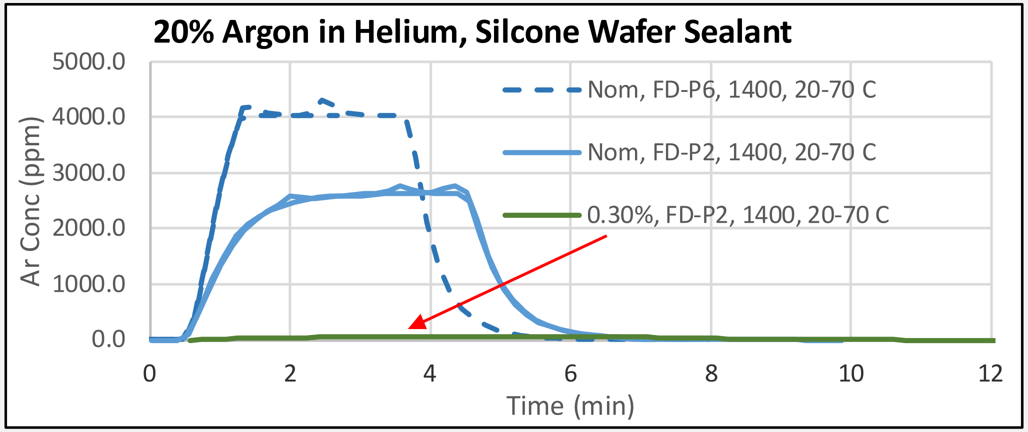


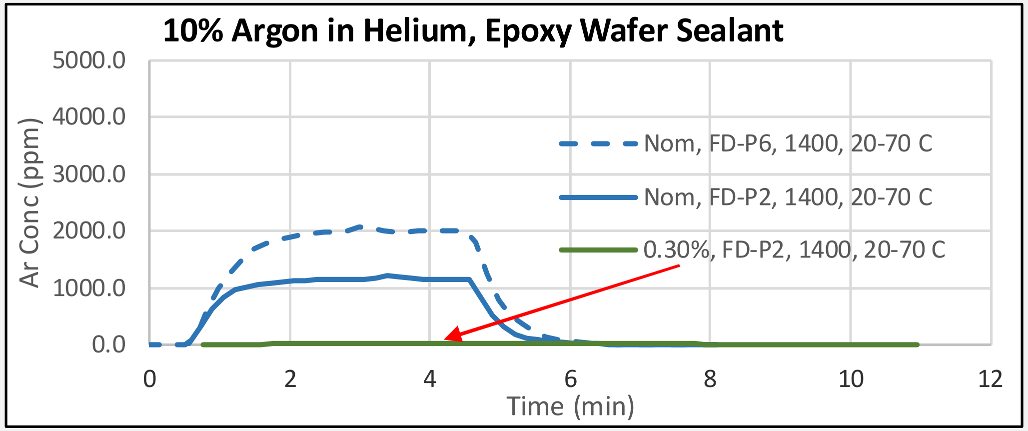
Discussion

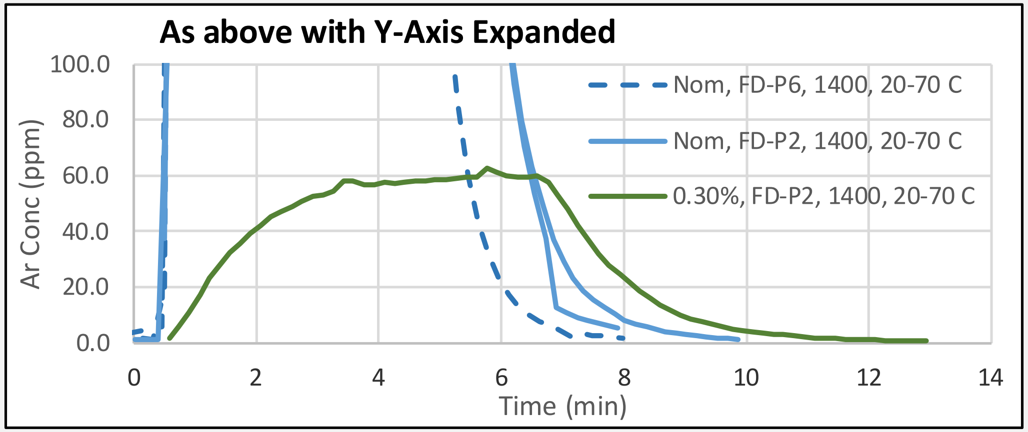


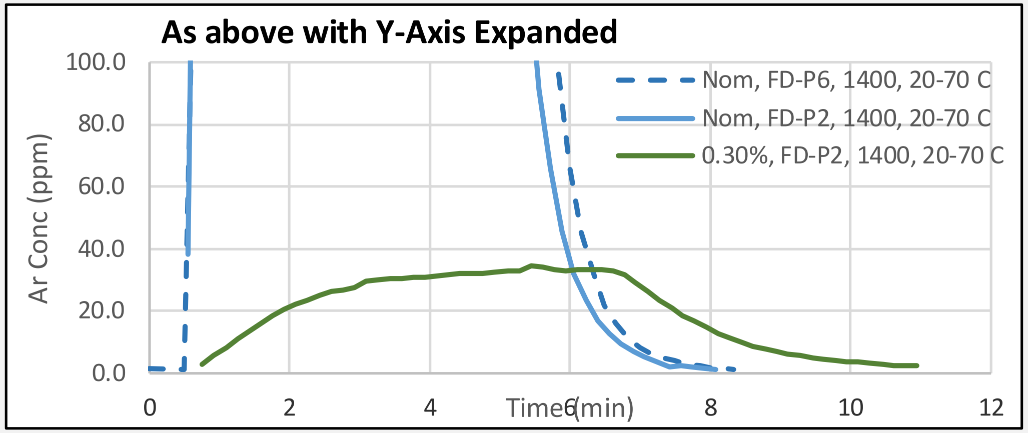
Propellant Diffusivity/Permeability
PSPI-L FD, 1400 Cycle, 20-70 C, Nominal vs. 0.30% Wafers

- **Experiment**: Diffusivity/permeability with varied % argon in Helium (20% left plots, 10% right plots)
  - ➢ Argon gas diluted in helium gas was allowed to permeate through a wafer sealed in a metal plate.
  - ➢ Mass spectrometry detects argon concentration on the other side as a function of time during step change between pure helium and argon in helium
- **Results:**
  - ➢ Nominal wafers are at least 40 times more permeable that their 0.30% counterparts after aging for 1400 20-70 C cycles
    - – The 0.30%, FD-P6, 1400, 20-70 C sample exhibited no detectable argon permeability
    - – A proportional response was observed using half the argon concentration and a more aggressive sealant
  - ➢ Large difference in permeability response (as with ED), even though densities and OD's are very similar

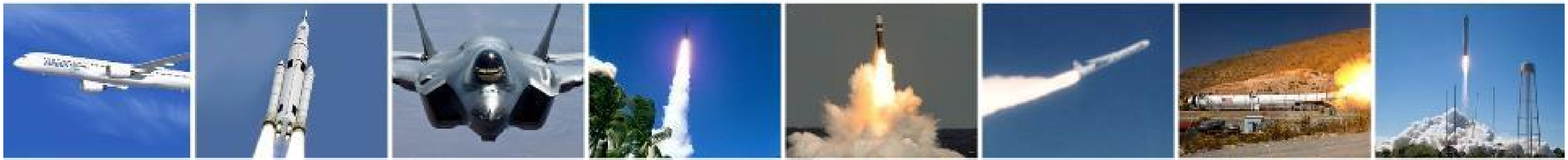






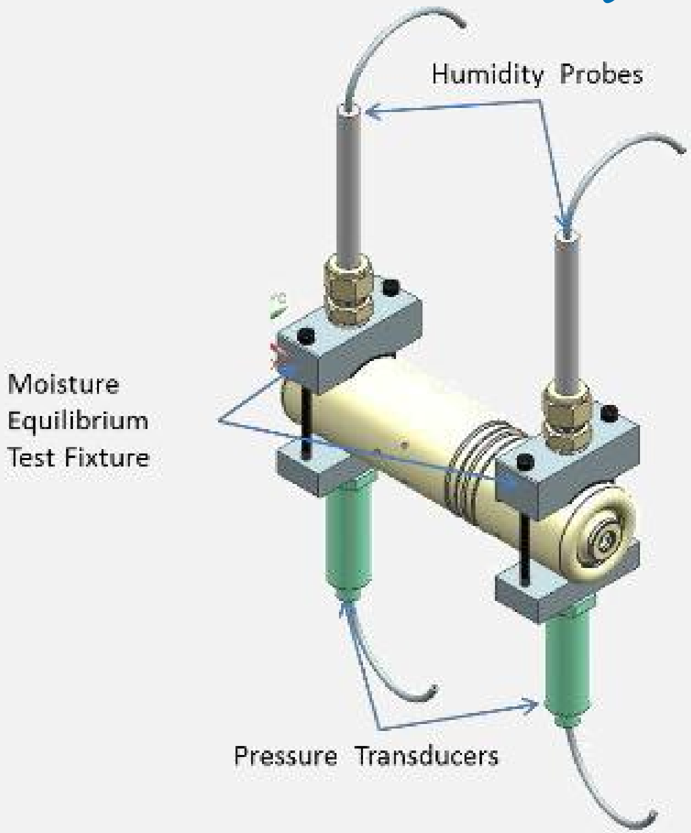


Leak Testing

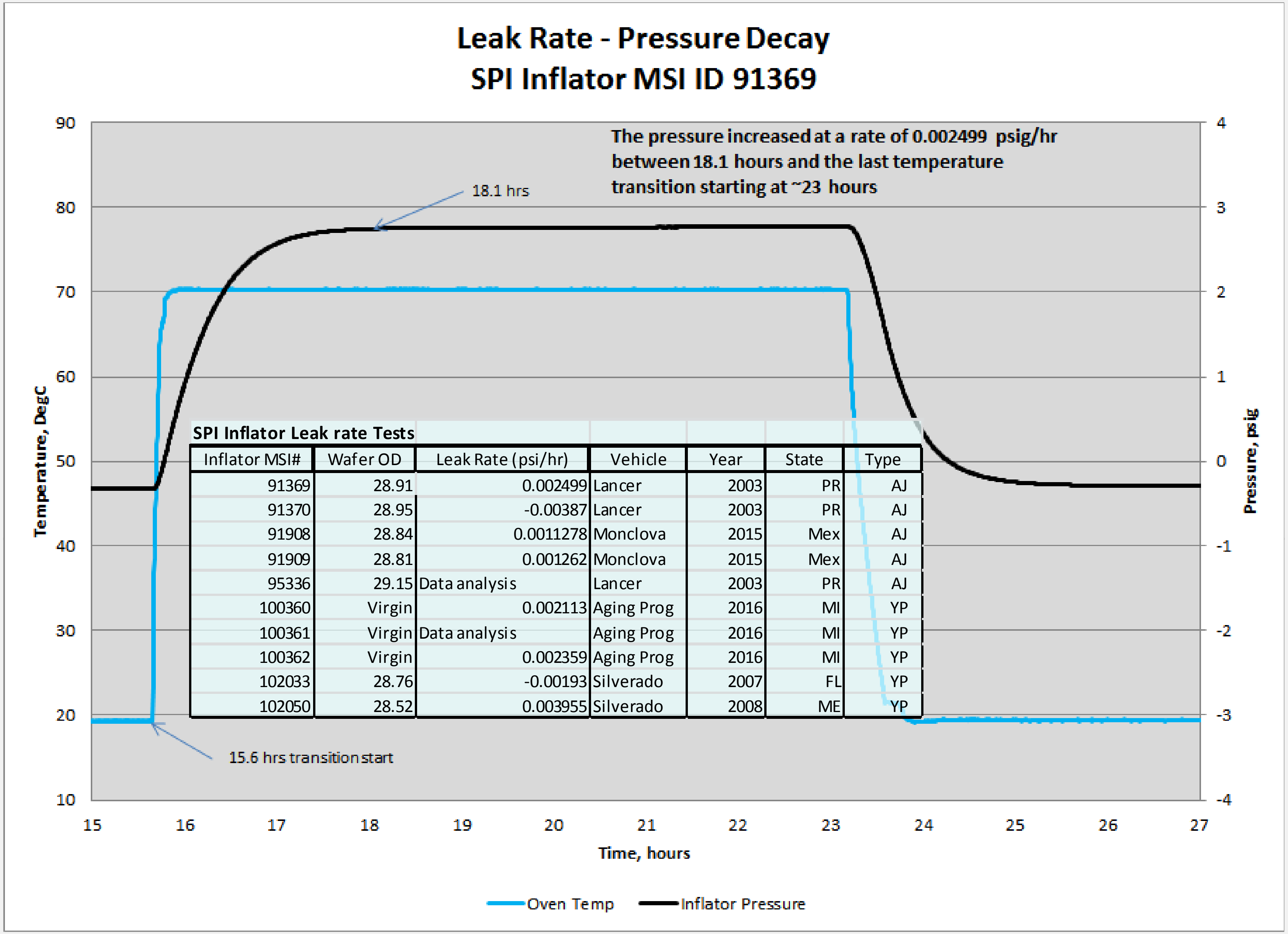


Pressure Decay Testing (updated)

- Fixtures were constructed to allow monitoring of the pressure and humidity within both chambers of a PSPI-L inflator
  - Only pressure transducers were used in this testing
  - Inflators were then temperature ramped from 20 to 70°C
  - After pressure stabilizes, the slope of the pressure trace is calculated
- We have completed 10 tests of 24 (all SPI's)
  - 12 SPI YP and 12 PSPI-L YD are to be tested
  - Eight tests have been plotted with 2 more in progress
  - Testing terminated after SPI
    - Judged that trend is established and further testing will not provide more insight



Pressure Decay Testing Data (updated)



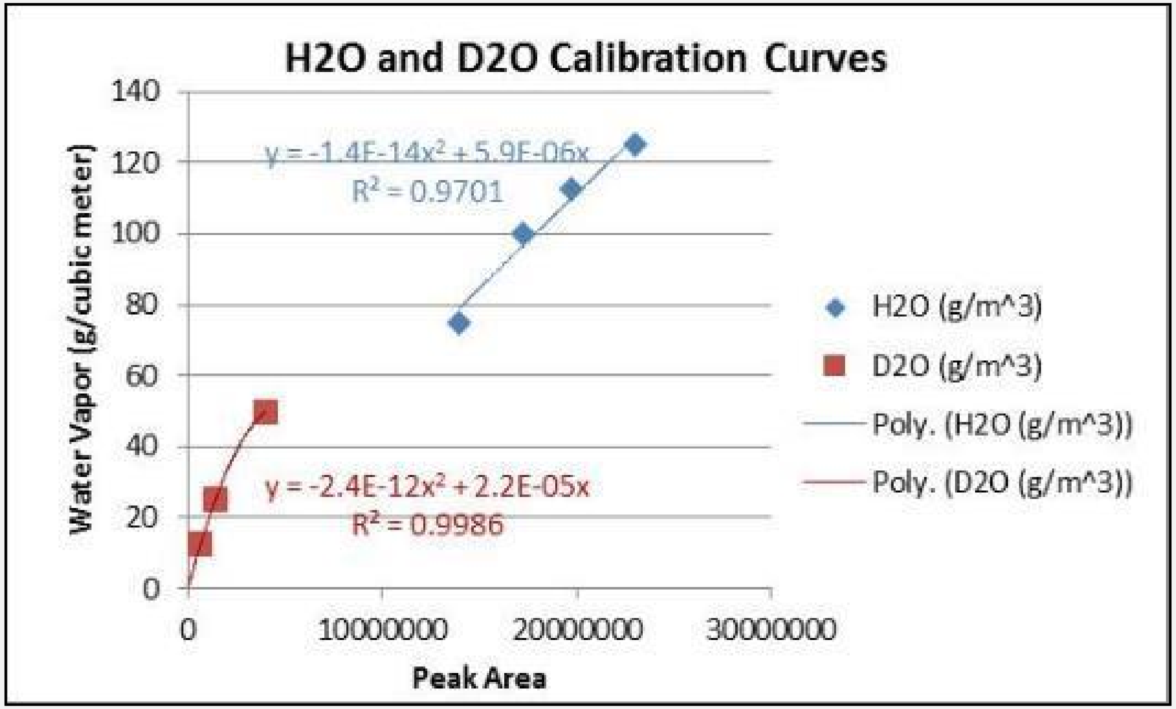
SPI Inflator Leak rate Tests

Inflator MSI#	Wafer OD	Leak Rate (psi/hr)	Vehicle	Year	State	Type
91369	28.91	0.002499	Lancer	2003	PR	AJ
91370	28.95	-0.00387	Lancer	2003	PR	AJ
91908	28.84	0.0011278	Monclova	2015	Mex	AJ
91909	28.81	0.001262	Monclova	2015	Mex	AJ
95336	29.15	Data analysis	Lancer	2003	PR	AJ
100360	Virgin	0.002113	Aging Prog	2016	MI	YP
100361	Virgin	Data analysis	Aging Prog	2016	MI	YP
100362	Virgin	0.002359	Aging Prog	2016	MI	YP
102033	28.76	-0.00193	Silverado	2007	FL	YP
102050	28.52	0.003955	Silverado	2008	ME	YP

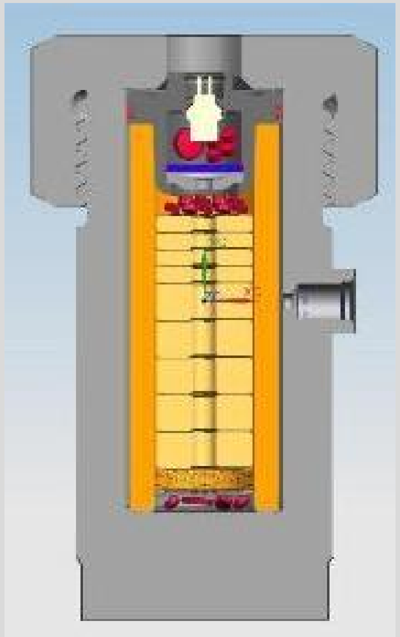
Inflator Aging in Presence of External D_2O

Experimental Design

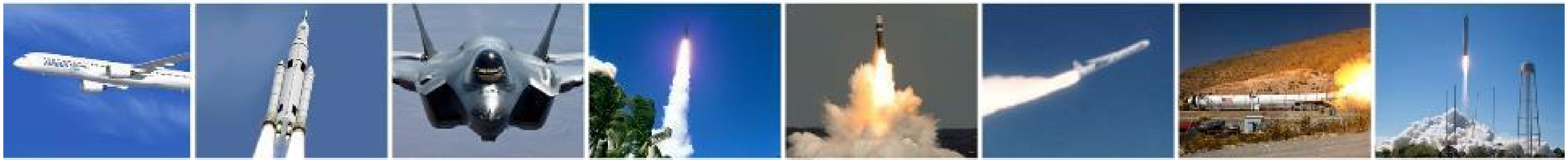
- Inflators were sealed in a moisture barrier bag with 10 grams of deuterium oxide (D2O)
- Sealed bags were subjected to four hour 20-70-20 temperature cycling
  - 8 each for 11.7 days and 16 each for 17.1 days
- Internal gas samples were collected through a vent from inflators maintained at 70 C
- Samples were analyzed by Gas Chromatography using a Mass Spectrometer as the detector (GC-MS) and H_2O and D_2O peak areas analyzed
- A calibration curve was created using samples from head space vials with known concentrations of H_2O and D_2O



AI-1 Tablet Results at 1680 cycles

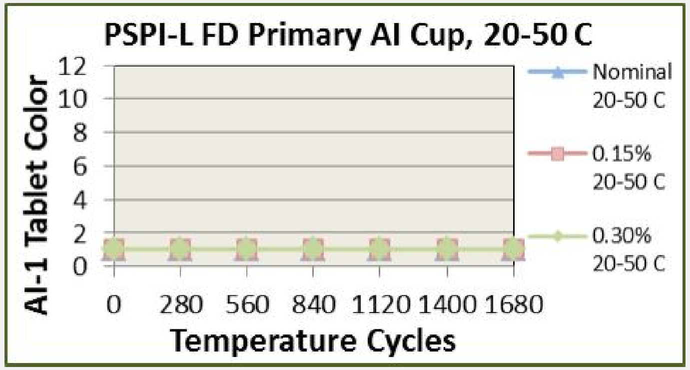


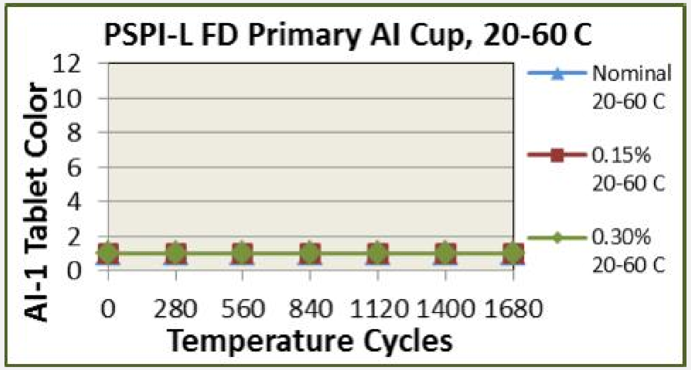
Discussion

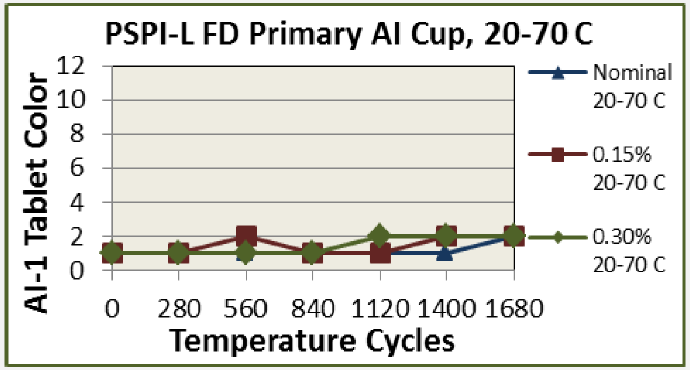


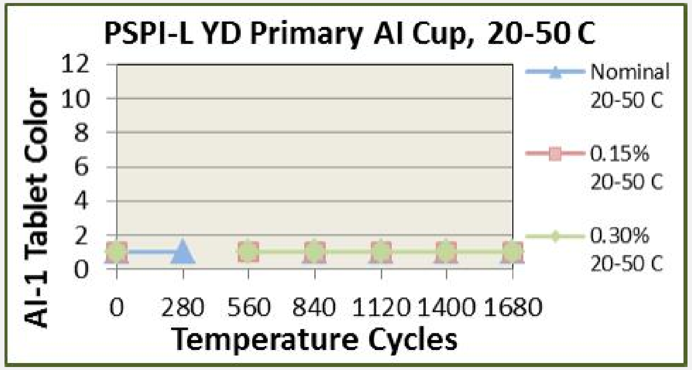
0-1680 Cycle AI Cup AI-1 Tablet Color
Primary Chamber Summary

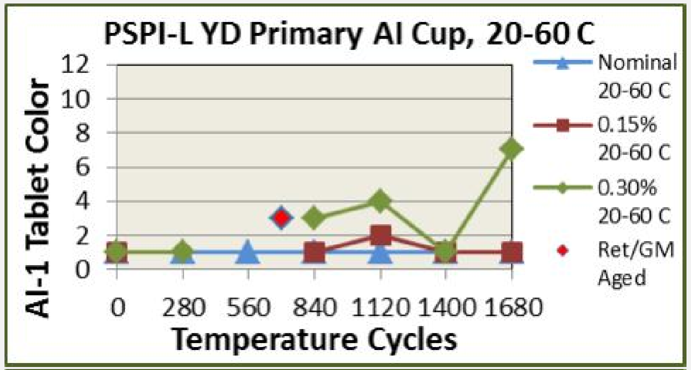
- Aging is only occurring in the YD AI cups at higher temperatures and moistures
  - YD AI cup seals are breached by an anvil in the bulkhead
  - Similar results are also seen in AI-1 tablet outer diameters

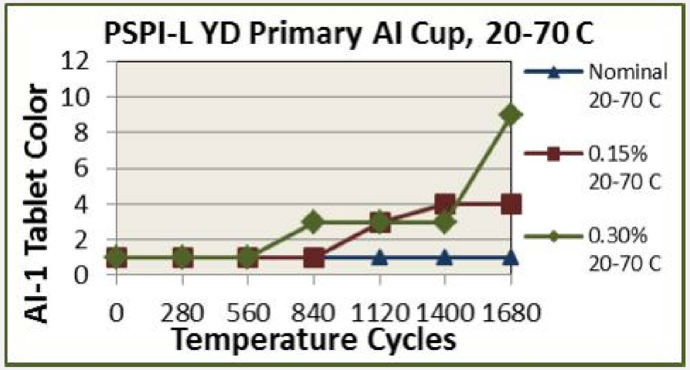


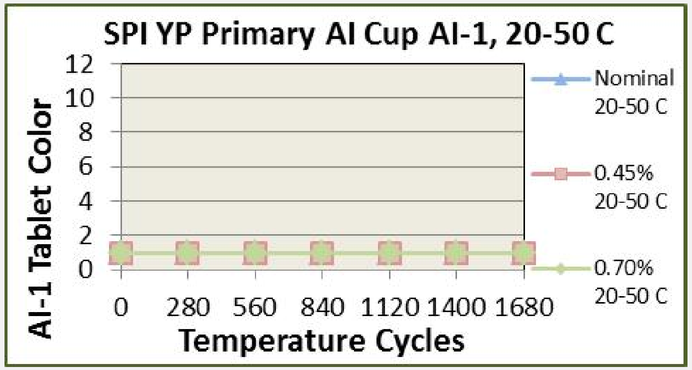


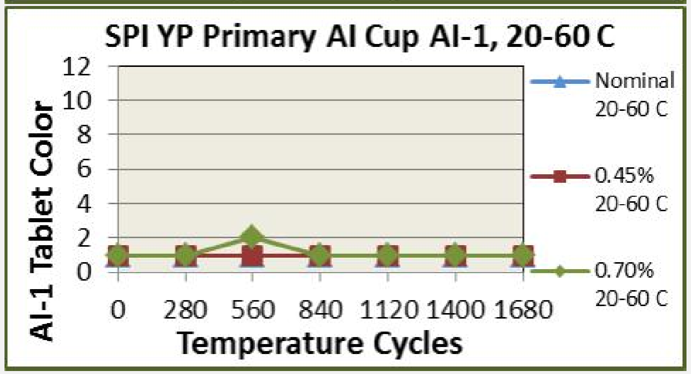


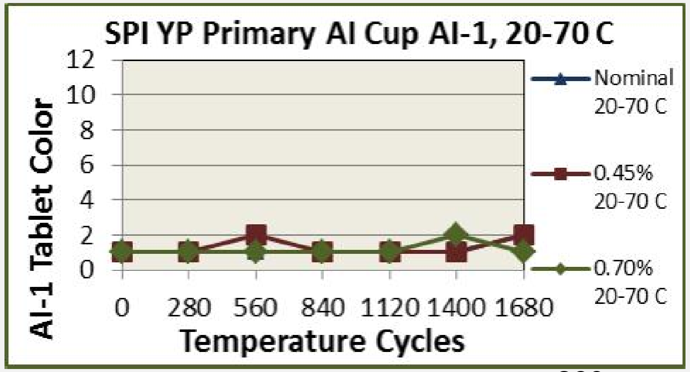




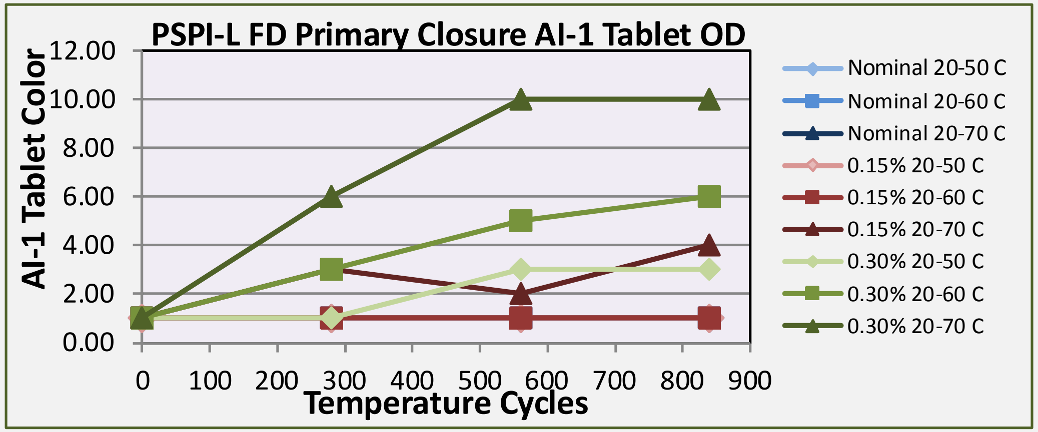


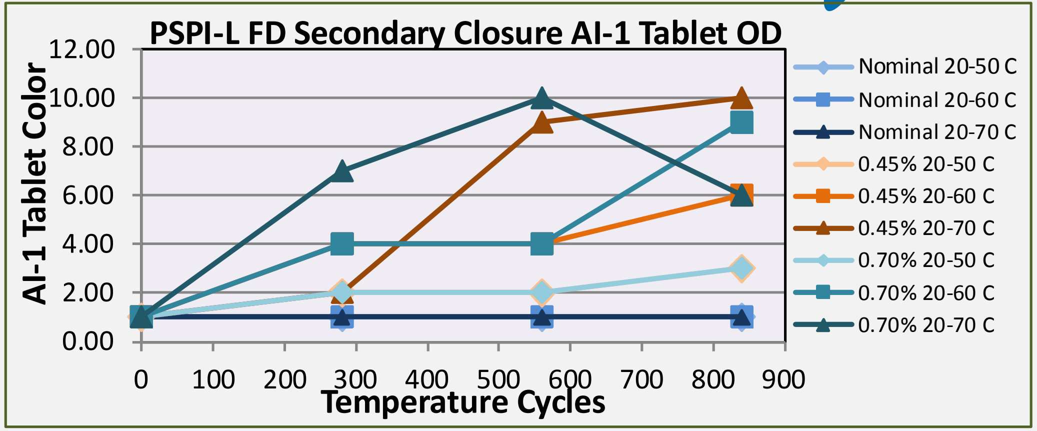


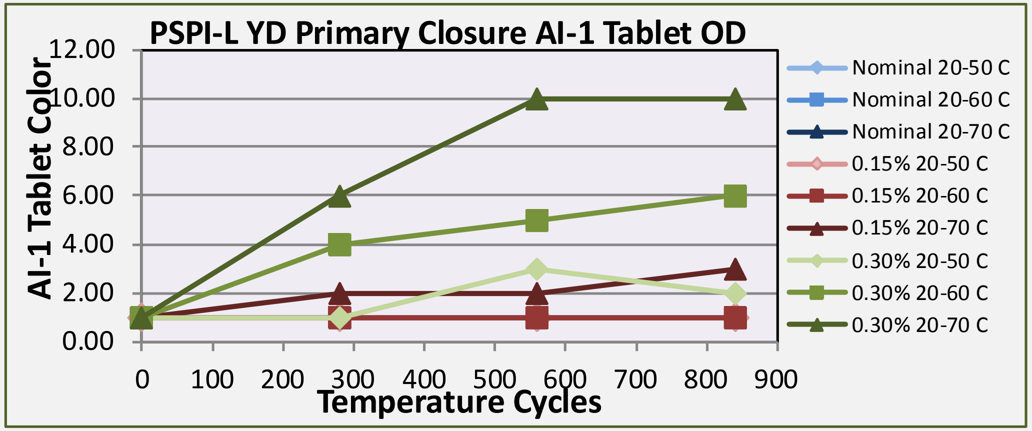


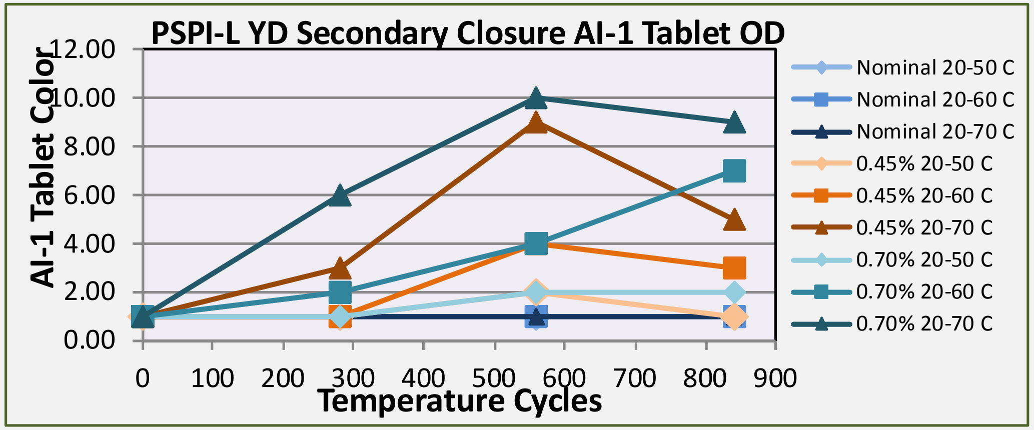


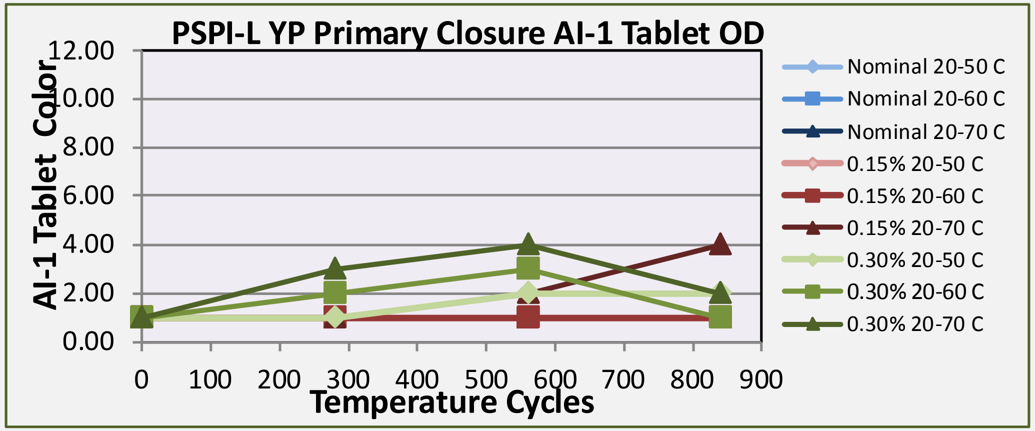
0-840 Cycle Closure AI-1 Tablet Color
Data Summary







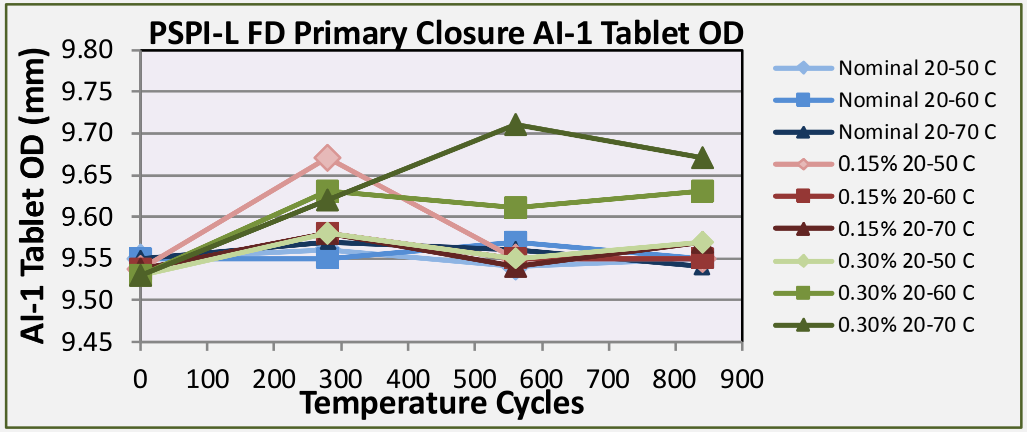


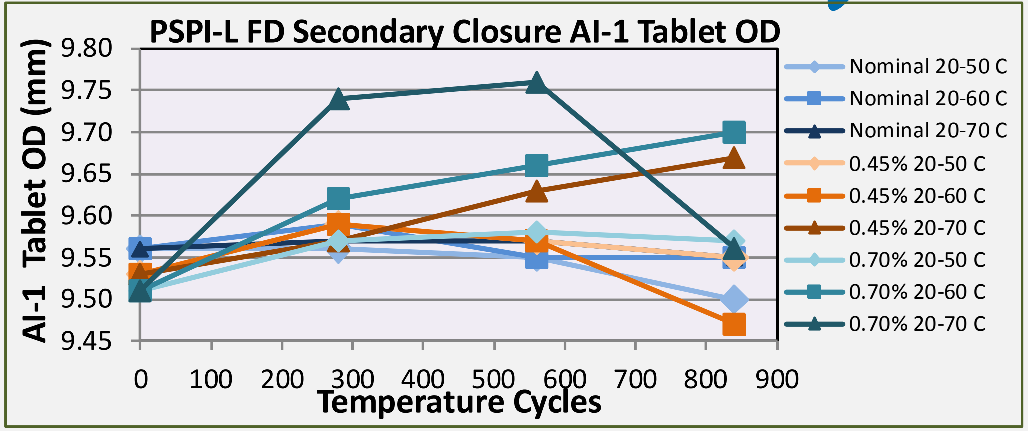


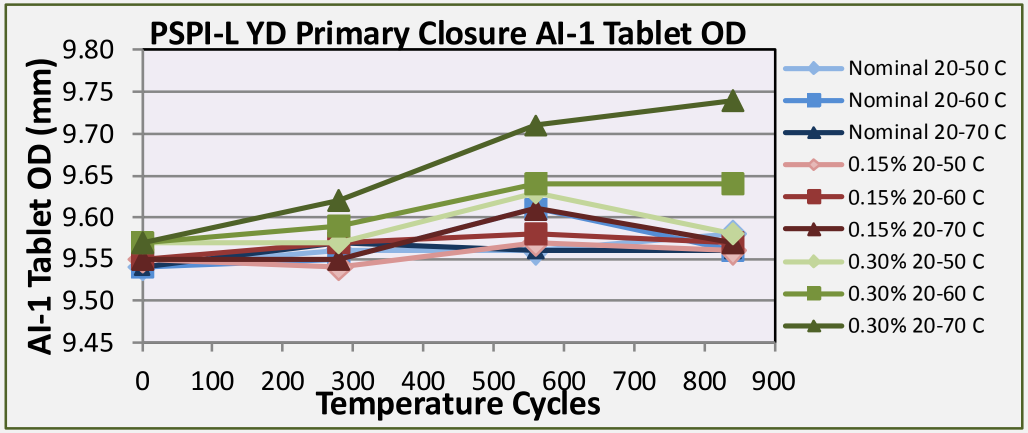
- Higher temperature/higher moisture inflators have darker AI-1 tablets including a few "nines" and "tens" for FD and YD
- YP AI-1 tablets are not as dark: highest value is a "four"
  - It is noteworthy that YP wafers have grown more than those of FD and YD

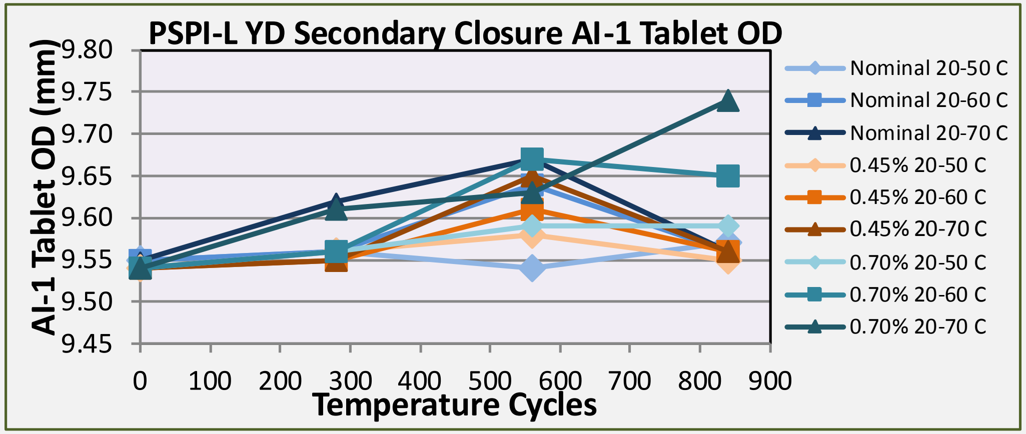
0-840 Cycle Closure AI-1 Tablet OD

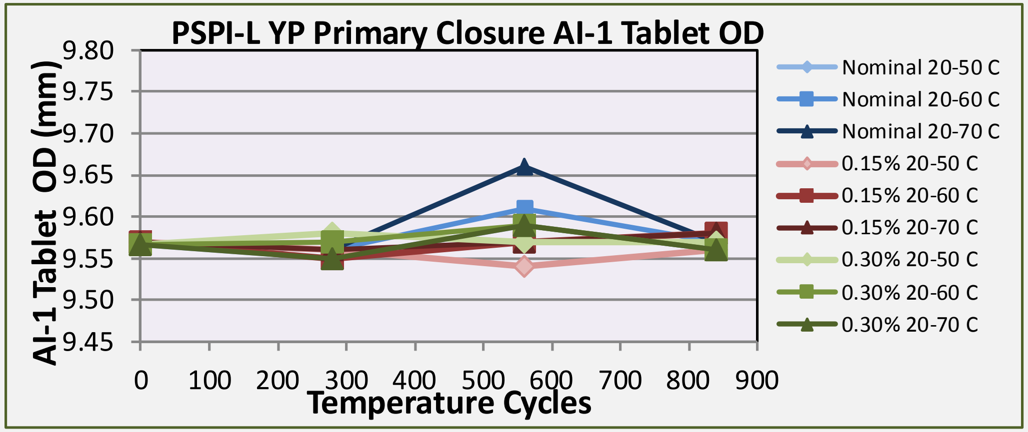
Data Summary











- In general, AI-1 tablet outer diameters in closures are increasing with temperature cycles for inflators with highest moisture and higher temperature
  - YP inflators do not follow that trend
- AI-1 tablet color trends are consistent with OD measurements
  - Color measurement has less errant scatter
  - Propose eliminating AI-1 OD measurement and reporting AI-1 color only

0-1680 Cycle Closure AI-1 Tablet Color

Data Summary

- Data are pending