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Evaluation of Foam Specifications for Use on the Proposed FMVSS No. 213 Test Bench

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16. Abstract

Child restraint systems sold in the United States must meet performance requirements specified by the National Highway Traffic Safety Administration (NHTSA) in Federal Motor Vehicle Safety Standard (FMVSS) No. 213, that include a sled test simulating a 48 kilometer per hour frontal impact. The original design of the FMVSS No. 213 test bench was based on a 1974 Chevrolet Impala bench seat. NHTSA updated some features of the bench seat in 2003 (68 FR 37620) to better represent vehicle seats of that time, and that bench is still in use today. In more recent years, NHTSA once again evaluated whether the current FMVSS No. 213 test bench, including the seat foam, needs further modification to better represent the rear seats of recent model passenger cars. The report titled, "Evaluation of Seat Foams for the FMVSS No. 213 Test Bench," released in September 2016, discusses the development of a new foam set based on the rear seats of more recent model year vehicles. NHTSA worked with a foam manufacturer, the Woodbridge Group (WB), to develop this new foam set based on a 2008 Nissan Sentra. After this collaboration, NHTSA procured 14 sets of the WB foams.

Through another NHTSA contract, foams from five manufacturers (including WB) were identified for possible use on the proposed FMVSS No. 213 test bench (Docket #NHTSA 2020-0093-0012). Foams from four of the vendors, including both "custom" and "off the shelf" foams, were selected for additional indentation force-deflection (IFD) testing, temperature and humidity studies, and dynamic sled testing. Based on the IFD and dynamic sled testing results, it was determined there are at least four manufacturers that can produce foams that meet specifications for use on the proposed FMVSS No. 213 test bench. The four foams discussed in this report were durable, and they met most, but not all the initial specifications as developed by The Woodbridge Group and NHTSA for IFD testing. However, the variations did not substantially affect the ATD responses in the dynamic sled tests, which are the outcomes of interest in FMVSS No. 213 testing. This led to the decision that a set of specifications (hereafter called "procurement specifications") would be established on which NHTSA (or its contracted test labs) could rely during the procurement process. In addition, a separate set of test specifications would be established to which NHTSA contract laboratories must certify the foams used in FMVSS No. 213 testing. The test procedure will also include requirements for soaking and storing, as well as required IFD procedure and criteria, for use of the foam during sled testing.

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Table of Contents

List of Tables

List of Figures

Executive Summary

Child restraint systems sold in the United States must meet performance requirements specified by the National Highway Traffic Safety Administration (NHTSA) in Federal Motor Vehicle Safety Standard (FMVSS) No. 213, that include a sled test simulating a 48 kilometer per hour frontal impact. The original design of the FMVSS No. 213 test bench was based on a 1974 Chevrolet Impala bench seat. NHTSA updated some features of the bench seat in 2003 (68 FR 37620) to better represent vehicle seats of that time, and that bench is still in use today. In more recent years, NHTSA evaluated whether the current FMVSS No. 213 test bench, including the seat foam, needs further modification to better represent the rear seats of recent model passenger cars. The report titled, "Evaluation of Seat Foams for the FMVSS No. 213 Test Bench," released in September 2016, discusses the development of a new foam set based on the rear seats of more recent model year vehicles. NHTSA worked with a foam manufacturer, The Woodbridge Group (WB), to develop this new foam set based on a 2008 Nissan Sentra. After this collaboration, NHTSA procured 14 sets of the WB foams.

A variety of dynamic sled tests and indentation force-deflection (IFD) tests were conducted with the WB foams to better understand the durability and responsiveness of the foams, and to establish test procedures and specifications for the foams used on the proposed FMVSS No. 213 test bench. NHTSA contracted with the National Center for Manufacturing Sciences (NCMS) who subcontracted to Calspan Corporation to find a minimum of three suppliers as viable sources for the FMVSS No. 213 test bench foam. This contract, which resulted in the 2018 "Foam Feasibility Study Final Report,"[1] identified 15 foam suppliers (including WB) that manufactured foam for a variety of uses. Foams from 5 of the 15 suppliers were identified "as meeting the requirement of the initial specifications" as specified in the contract. These suppliers included Century Foam Products, Comcast Urethane, Lear Corporation, Perfect Fit-McDonald Inc, and WB, and included both "custom" and "off the shelf" foams.

Foams from four of the vendors were selected for additional indentation force-deflection (IFD) testing, temperature and humidity studies, and dynamic sled testing. Based on the IFD and dynamic sled testing results, it was determined there are at least four manufacturers that can produce foams that meet the initial specifications provided by NHTSA and developed by The Woodbridge Group and NHTSA for use on the proposed FMVSS No. 213 test bench. Those foams include Century Foam Serial #25550, Perfect Fit-McDonald Serial #290, Lear Corporation, and WB foam. The four foams discussed in this report were durable, and they met most, but not all the initial specifications for IFD testing. However, the variations did not substantially affect the ATD responses in the dynamic sled tests, which are the outcomes of interest in FMVSS No. 213 testing.

[1] Foam Feasibility Study Final Report, June 2018; Docket #NHTSA-2020-0093-012.

This led to the decision that a set of specifications (hereafter called "procurement specifications") would be established on which NHTSA (or its contracted test labs) could rely during the procurement process. In addition, a separate set of test specifications would be established to which NHTSA contract laboratories must certify the foams used in FMVSS No. 213 testing. The test procedure will also include requirements for soaking and storing, as well as required IFD procedure and criteria, for use of the foam during sled testing.

1. Introduction

Child restraint systems (CRSs) sold in the United States must meet performance requirements specified by the National Highway Traffic Safety Administration (NHTSA) in Federal Motor Vehicle Safety Standard (FMVSS) No. 213, that include a sled test simulating a 48 kilometer per hour (30 miles per hour) frontal impact.[2] The original design of the FMVSS No. 213 test bench was based on a 1974 Chevrolet Impala bench seat. NHTSA updated some features of the bench seat in 2003[3] to better represent vehicle seats of that time and it is still in use today.

The "Moving Ahead for Progress in the 21st Century Act" (MAP21) directed NHTSA to initiate a rulemaking to amend the standard seat assembly specifications under FMVSS No. 213 to better simulate motor vehicle rear seats.[4] Specifically, research was conducted to develop a new standard seat assembly that better represents the current vehicle fleet, including stiffer seat cushion foam, a more representative seat geometry, updated lap/shoulder belts, and child restraint anchorages. NHTSA worked with a foam manufacturer, The Woodbridge Group (WB)[5] to develop this new foam set based on a 2008 Nissan Sentra.

In order to update the current bench foam, a dynamic impact test device and test procedure was developed for evaluating the force-displacement characteristics of recent model year vehicle rear seats. A pendulum impact device (PID) was used to evaluate the rear seats from 15 vehicles (model years 2006 to 2011) along with existing foams used in the current FMVSS No. 213 and the ECE R44 benches. The 2008 Nissan Sentra force-displacement response was found to be most similar to the average vehicle rear seat responses of the vehicles tested. The Nissan Sentra foam was evaluated for density, indentation force deflection (IFD), and compression force deflection (CFD) by ASTM D3574 by Woodbridge. Additional testing and analysis resulted in a final foam agreed upon by NHTSA to be used in the proposed FMVSS No. 213 test bench upgrade. The report titled, "Evaluation of Seat Foams for the FMVSS No. 213 Test Bench," released in September 2016, discusses the development of this new foam set and the initial testing NHTSA had conducted.[6]

NHTSA proposed the seat pan foam be one piece, instead of the two-piece foams that are used in the existing procedure. The WB foams were made of polyurethane and produced using molding casts. The bun, or 203-millimeter (8-inch) block, was then cut to the specified thickness of 102 millimeters (4 inches). The final result was a seat cushion foam consisting of a 102-millimeter thick piece to be used for the seat pan with the following specifications: density of 47 kilograms

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[2] 49 CFR 571.213
[3] 68 FR 37620 DOT-HS-4-00865.
[4] MAP-21 Section 31501(a).
[5] The Woodbridge Group, INC located in Troy, MI.
[6] Wietholter, K, Louden, A." Development of a Representative Seat Assembly for FMVSS 213", Sept 2016.

per cubic meter ± 10 percent, a 50 percent compression force deflection (CFD) value of 6.6 kilopascals ± 10 percent, and a 50 percent indentation force deflection (IFD) value of 440 Newtons ± 10 percent.[7] The seat back (51 millimeters (2 inches)) was cut from the same bun; therefore it has the same density. Woodbridge did not provide specifications for the 51-millimeter seat back. NHTSA developed a set of specifications for use with the seat back foam after testing the foams. These initial specifications are described in Section 3, Table 1.

The overall dimensions of the seat pan and seat back are the following: 711 millimeters (28 inches) wide by 483 millimeters (19 inches) deep, with thicknesses of 102 millimeters for the seat pan and 51 millimeters for the seat back.[8] After this collaboration and over the last few years, NHTSA has procured 14 sets of the WB foams.

2. Objectives

The objective of this study was to better understand the durability and responsiveness of various foams, and to establish test procedures and specifications for the foams used on the proposed FMVSS No. 213 test bench. To accomplish this desired objective, NHTSA's Vehicle Research and Test Center (VRTC) conducted IFD tests using a tensile test machine.[9] During the IFD tests, the specifications of the foam were analyzed by comparing the IFD values between WB foam and other manufactured foams. Multiple IFD tests were run with multiple manufacturers and foam samples to determine if foam from different sources could meet the initial specifications, and if any other factors, such as temperature, humidity, different soaking times, number of uses on each foam, etc. affected the IFD responses. VRTC also conducted dynamic sled tests using foams from multiple manufacturers to evaluate what effect, if any, the different foams have on the anthropomorphic test device (ATD) responses while testing with the proposed FMVSS No. 213 test bench. The data collected during the dynamic sled tests was analyzed and compared to results obtained during previously run sled tests at VRTC, which used only the WB foams.

3. Foam Background

3.1 The Woodbridge Group

After collaboration with WB on the development of an updated foam and associated foam specifications (hereafter called initial specifications) for use on the proposed FMVSS No. 213 test bench, NHTSA procured 14 sets of WB-supplied foam over the last several years. A variety of dynamic sled and IFD tests were conducted with the WB foams to better understand each piece of foam's durability and responsiveness. Before the dynamic sled tests were conducted, each foam piece was tested per IFD procedures, and the results were analyzed to see if the foam fell within the initial specifications listed in Table 1, which are those resulting from the 2016

[7] Woodbridge Test Report, Henry Hojnaki, 2012; NHTSA Docket # NHTSA 2013-0055.
[8] NHTSA Frontal Sled Bench Drawing Package, May 2019, Docket #NHTSA-2020-0093-004.
[9] NHTSA tested the foams at VRTC utilizing a 1000-pound load cell on the United tensile tester and 3000-pound load cell on an MTS dynamic tensile test machine series 322 with a 3.3-kip actuator.

study (for the 102-mm foam), plus specifications for the 51-millimeter foam using the 25, 50, and 65 percent IFD tests.

The densities of the foams were not verified by NHTSA/VRTC but instead were provided by Woodbridge. The IFD test is a commonly used test in the foam industry to provide stiffness characteristics. The 50 percent IFD test specifications were proposed by Woodbridge for the 102-millimeter (4-inch) seat back foam. The additional IFD tests (25 and 65 percent compression) for both the seat back and seat pan were developed by NHTSA based on initial tests with the initial foams provided by WB. According to the foam manufacturer, test facilities could perform the force deflection test on the various foam sets, but not the CFD test.[10] The current foam certification procedure for FMVSS No. 213 specifies testing the foam seat cushions at 25 percent compression, while VRTC tested the new foam sets at 25, 50, and 65 percent compressions before a sled series.

The foams were tested at the dimensions used for the sled buck for both the seat pan and seat back (as defined in Section 1.0) and were tested at the approximate center. The results from the IFD testing include the force observed after 60 seconds to compress the foam to 25 and 65 percent of its original thickness (25% and 65% IFD values, respectively) and then at 50 percent of its thickness. Additional details of the testing procedures are discussed in Section 5.2.

Table 1: Initial Specifications for 102-millimeter (4-inch) and 51-millimeter (2-inch) Foams

	Density Kg/m^3 (lb/ft^3)	**50% CFD** kPa (lb/in^2)**	**IFD* 25% N (lb) [range]**	**IFD* 50% N (lb) [range]**	**IFD* 65% N (lb) [range]**
Seat Pan (102 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	237 (53.3) ± 15% [201-273]	440 (98.9) ±10% [396-484]	725 (162.9) ±15% [616-834]
Seat Back (51 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	157 (35.3) for reference	300 (67.4) ±15% [255-345]	480 (107.9) for reference

* Indentation Force Deflection (IFD)

** Compression Force Deflection (CFD)

[10] The CFD test is a destructive test performed on a 4x4x4-inch cube which is cut from the foam piece itself; foam manufacturers would have to provide that information.

3.2 Other Foam Suppliers

NHTSA contracted with the National Center for Manufacturing Sciences (NCMS)[11] to find a minimum of three suppliers as viable foam sources for use on the proposed FMVSS No. 213 test bench. Fifteen foam suppliers (including WB) that manufactured foam for a variety of uses were identified, and five of these were able to produce foams that meet the initial specifications identified in Table 1. These suppliers included Century Foam Products, Comcast Urethane, Lear Corporation, Perfect Fit-McDonald, Inc. and WB.

Lear Corporation, WB, and Comcast Urethane foam sets were all fabricated using the molding method. The molding method process works by pouring a foam mixture into specified shaped enclosed molds where the foam reaction takes place. All three manufacturers used a custom high resilience formula for the foam to achieve the desired foam specifications outlined in Table 1. These foam sets are considered to be "custom" foams and are referred to as that throughout the report.

Century Foam Products and Perfect Fit-McDonald foam sets were produced using the slab stock method. This method pours the mix onto a conveyor with sides. There, the foam mixture reacts and expands into a slab (like bread rising), where it is then cut, stored, and cured to up to 24 hours. After the 24 hours, the foam is then cut again into the desired shape. These foam sets are both considered to be "off the shelf" foam. Instead of a custom formula, the "off the shelf" manufacturers typically offer several types of foams, each with different density and IFD responses.

From the five foams identified to meet the initial specifications, four foams were chosen for this study. Those foams include Century Foam Serial #25550, Perfect Fit-McDonald Serial #290, Lear Corporation,[12] and WB foam. Additional foam manufacturer information reported in the NHTSA contract with NCMS is included in Appendix A.

4. Foam Evaluation: Indentation Force-Deflection (IFD) Test

4.1 Foam Test Procedure Background

IFD testing is a quasi-static test to assess the stiffness of a foam sample using a circular indenter to compress the foam to a specified percent of the foam's height. While static testing is unable to represent dynamic conditions, IFD testing is a commonly used tool for comparison in the foam industry. The current FMVSS No. 213 test procedure uses the IFD test to determine if the cushion characteristics are within specification. It references the ASTM Standard D1564-71,

[11] Foam Feasibility Study Final Report, June 2018; NHTSA Docket Number; NHTSA-2020-0093-0012.

[12] The Lear foam set used for this study was slightly different than the foam that was identified in the NCMS study. NHTSA worked with Lear Corporation to fine tune the original sample to match the specifications and dimensions of the foam sets to be closer to the specifications listed in Table 1. The NCMS study resulted in a foam sample of only 15 x 15 inches, and it was stated that a new mold would need to be made in order to meet the desired dimensions. Additional discussions with the manufacturer led to them being able to manufacturer foam samples per the drawing package dimensions and closer to the initial test specifications.

which was subsequently updated to ASTM Standard D3574-11.[13] Per the current FMVSS No. 213 test procedure, to be suitable for use in compliance testing, the foam inserts shall be compressed to 25 percent of their thickness and meet the following load limits:

- 51-millimeter (2-inch) thick foam: 20.4 to 24.9 kilograms (45 to 55 lb)
- 102-millimeter (4-inch) thick foam: 9.5 to 12.2 kilograms (21 to 27 lb)[14]

For each foam procured, the respective foam manufacturer was asked to meet the initial specifications listed in Table 1 and report the IFD results. Two of the four vendors could only provide general specifications, due to Perfect Fit-McDonald, Inc and Century Foam Products being a distributor of the foams. They could not provide physical test data on the individual foam sets per the NHTSA IFD specifications but provided general sale specifications.

After the foams were received at VRTC from the manufacturer, each foam was immediately tested using a tensile test machine. Initially, the foams were tested using the test methodology based on ASTM Standard D3574-11 Test B1with some minor deviations from the standard procedure.[15] Both sizes of the foam were tested, although the ASTM Standard D3574-11 procedure specifies that the foam sample should not be smaller than 380 by 380 by 100 millimeters. The tests were conducted at both 25 and 65 percent of the thickness of each of the foam cushions. Additionally, based on discussions with The Woodbridge Group, a test conducted at 50 percent compression was added and the results were recorded for each foam. Per the standard, Test B1, Section 21, Note 6, states that the different compressions are acceptable if agreed upon between the supplier and the purchaser as an acceptable test and if it is denoted.

To further develop the IFD test procedures for use with the proposed FMVSS No. 213 test bench foam, factors including the tensile test machine type, humidity, temperature, stroke rate, and order of testing were analyzed. The final recommended IFD test procedure for the foam cushion analysis can be found in Appendix B.

4.2 Foam Testing Background

All foam sets were tested multiple times over the last several years at VRTC. Historical plots of the IFD values versus time for each foam can be found in Appendix C. All foam sets were stored on a wire shelf near an outside wall, vertically stacked no more than three sets high, in a temperature and humidity monitored lab environment area at VRTC. Per discussions with WB, it was suggested that all foams be stored in a controlled environment at all times with a nominal relative humidity of 50 percent and a temperature of approximately 22 degrees Celsius (72

[13] ASTM D3574-11 "Standard Test Methods for Flexible Cellular Materials – Slab, Bonded, and Molded Urethane Foams" – "Test B1 Indentation Force Deflection Test – Specified Deflection (IFD)".
[14] FMVSS No. 213 test procedure. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/tp-213-10_tag.pdf
[15] Deviations from the standard procedure included non-standard dimensions of test specimens; the specification states that the test needs to be on 100-millimeter thick foam. Another deviation from the ASTM standard was that the pre-flex was applied at 51 mm/min rather than 250 mm/min due to limitation from the equipment at the time.

degrees F). The lab area at VRTC was temperature controlled and the humidity was monitored, but not controlled.

Prior to 2018, only WB foams (foam sets #4-12) were used for dynamic sled testing, and multiple IFD tests were conducted. WB provided IFD results for the foams to assure the initial foam specifications were met. In 2018, two more sets of WB foams were procured (foam sets #13 and #14), along with three sets each of Century Foam serial #25550, Perfect Fit-McDonald serial #290, and Lear Corporation foam. Both WB and Lear Corporation sent IFD values from tests at their respective facilities, however, neither Perfect Fit-McDonald or Century Foam provided actual IFD test results but provided general specifications.[16] The IFD test results can be found in Appendix A.

Table 2 reports the different foam sets and numbers of uses per set for the foams procured. The number of uses includes IFD tests and dynamic sled tests for a total count. This table shows that while the foam sets were used frequently, they were proven very durable. WB foam sets #1, #2, and #3 were procured, but they were only used for initial evaluation and were not used for this study; therefore, they are not reported in this table or report.

5. Initial Analysis

5.1 IFD Analysis

Since 2014, NHTSA has tested 14 sets of the WB foam sets and has documented the IFD results. Over the last six years, the foam's IFD responses varied greatly. In some occurrences, the IFD response of the foam did not fall within the initial specification range for one or all the compression specifications (Table 1). Originally, if the foams fell out of range, they were not used for sled testing, although they continued to be used to monitor the changes in IFD responses as part of this study. In multiple cases, a majority of the foams fell back in the specified range for all compressions (25%, 50%, 65%) at a later date, allowing the foam to be used for sled testing again. The IFD values of the different WB foam sets over the six years[17] are reported in Appendix C, including the two sets used at Calspan for sled testing. It is unclear if the IFD responses fell back into specification due to aging of the foam or due to any outside factors previously mentioned.

In more recent years (2018 to current), several foam sets exceeded the specification for the 102-millimeter (4-inch) 50 percent compression, even though they had previously met the specification in prior testing. The higher IFD responses led to a study to analyze the possible "other factors" potentially affecting the foam IFD responses. This evaluation was conducted from 2017 to 2019, with initial testing occurring in July 2017, and the majority of the testing conducted from August 2018 through January 2019. Other factors that were investigated

[16] The "custom" foam manufacturers have the testing equipment in house and provided the IFD responses for an additional price, whereas the "off the shelf" foam sets chosen were supplied by distributers and could not provide the actual IFD tests on the actual foam sets purchased.
[17] IFD values recorded up to Jan 2019.

included: tensile test machine (section 5.2), order of compression testing (section 5.2), and foam procurement method including foam manufacturing process (section 5.3). Numerous tests were performed during the study, and while both thicknesses of the foam sets were tested, only the results from the tests conducted with the 102-millimeter (4-inch) foam are reported in the tables for comparison purposes.

Table 2: Foam Set Type and Number of Uses[18]

Foam Set	Procurement	Number of Uses	IFD Tests	Sled Tests
WB4	14-Aug	62	16	46
WB5	14-Aug	48	16	32
WB6	14-Aug	20	10	10
WB7	15-Jul	78	22	56
WB8	15-Jul	72	13	59
WB9	15-Aug	9	9	0
WB10	15-Aug	14	14	0
WB11	15-Aug	16	16	0
WB12	15-Aug	10	10	0
WB13	18-Mar	37	35	2
WB14	18-Mar	43	40	3
LR1	18-Mar	44	31	13
LR2	18-Mar	5	5	0
CF_25550-0	17-Jul	5	5	0
CF_25550-1	18-Mar	5	5	0
CF_25550-2	18-Mar	36	23	13
CF_25550-3	18-Mar	4	4	0
PF_290-1	18-Feb	4	4	0
PF_290-2	18-Feb	41	26	15
PF_290-3	18-Mar	4	4	0
PF_290-4	18-Mar	4	4	0

[18] The total number of uses calculated were based on the last test conducted in January 2019.

5.2 Tensile Test Machine and Testing Order Analysis

All IFD tests before June 2018 were conducted on a United tensile test machine with a 4448-Newton (1000-lb) load cell.[19] In June 2018, VRTC upgraded to a larger tensile test machine manufactured by MTS Systems Corporation (MTS).[20] This machine utilizes a 13,345-Newton (3000-lb) load cell to perform the IFD testing. The new machine also allowed for the testing to be completed at a 250 millimeters per minute pre-flex rate and could run the tests at the three compression percentages consecutively, in one test. By comparison, the United tensile test machine could run the tests at a rate of 51 millimeters per minute for the pre-flexion portion.

A small study was conducted to determine if the tensile test machine change made a difference in the resulting IFD values. At the time of this study, two test procedures with different orders of compression testing were being considered. The first procedure, Method 1, included IFD tests at 25 percent compression, promptly followed by a 65 percent compression test (with a one-minute wait time in between compressions). After waiting for a minimal time of one hour, a 50 percent compression test was performed. In the second procedure, Method 2, an alternate procedure used by WB, the three levels of compression were tested in ascending order (i.e., 25%, 50%, then 65%), with one-minute wait times in between each compression level. This procedure was developed per discussions with WB and was considered since it eliminated the hour wait time between tests, resulting in a more time efficient test procedure.

Each WB foam (#4 - #14) was tested on both the previous tensile test machine (United) and the new tensile test machine (MTS). The foams were tested using both procedures on both machines resulting in four total tests per foam sample. Table 3 reports the IFD values for the four different tests that were conducted on each 102-millimeter seat pan foam piece using the two different machines and two different test methods. For ease of reporting, only the 50 percent compression of the seat pan foam results are listed and used for the comparison described below.

The percent difference for each set of foam when tested on the MTS versus the United tensile test machine was calculated. A negative percent difference corresponds to a higher IFD value when the foam was tested on the MTS compared to the same test on the United. Percent difference was calculated as shown in equation 1, and the results are listed in Table 4.

$$\text{Percent difference} = \frac{(\text{difference between maximums})}{(\text{average of maximums})} * 100 \tag{1}$$

[19] The United tensile test machine used at VRTC was: SFN 'Smart-1' Test System (SFM-100KN) using a 1000-pound load cell (United IFI-493030).

[20] The MTS tensile test machine used at VRTC was dynamic test impactor MTS Series 322 using a 3000 lb (66-19E-03 S/N#116504A) load cell with a 3.3-kip actuator

Table 3: Comparison of IFD Values for the United and MTS Tensile Test Machine: 50 Percent Compression Results

	IFD Values (N)			
WB Foam Set Number (102-mm thickness)	United		MTS	
	Method 1 25%/65% then 50%	**Method 2 25%/50%/65%**	**Method 1 25%/65% then 50%**	**Method 2 25%/50%/65%**
4	**428**	**430**	**434**	**421**
5	**432**	**434**	**423**	**440**
6	**442**	**445**	**449**	**434**
7	**425**	**427**	**422**	**434**
8	**427**	**430**	**433**	**420**
9	**408**	**410**	**392**	**416**
10	**408**	**409**	**416**	**402**
11	**415**	**416**	**404**	**419**
12	**415**	**419**	**419**	**405**
13	**454**	**455**	**445**	**457**
14	**445**	**446**	**450**	**436**

Table 4: Percent Difference for Each Foam Set Comparing the Tensile Test Machines for 50 Percent Foam Compression

WB Foam Set No. (102-mm thickness)	Percent Difference Between United and MTS	
	Method 1 25%/65% then 50%	Method 2 25%/50%/65%
4	-1.3%	2.2%
5	2.0%	-1.4%
6	-1.5%	2.5%
7	0.7%	-1.6%
8	-1.4%	2.4%
9	4.0%	-1.4%
10	-2.0%	1.7%
11	2.6%	-0.8%
12	-0.9%	3.4%
13	2.0%	-0.5%
14	-1.1%	2.4%

The largest percent difference for the two different tensile test machines was 4.0 percent with a difference of 16 Newtons shown in the results for Foam Set #9. Since the percent differences were small and there was no trend in which machine produced the higher results, it was determined that using the different machines did not affect the IFD values of the foams. Therefore, the newer MTS machine was used for all further IFD tests at VRTC.

The results from the two methods were compared using the tests on the MTS machine. Table 5 reports the IFD values for the two different test methods for the 102-millimeter foam pieces at 50 percent compression. The calculated percent differences (Equation 1) between the two procedures are shown in Table 6. A positive percent difference corresponds to a higher IFD value when the foam was tested using Method 1 compared to Method 2.

The largest difference was -5.9 percent, with a difference of 24 Newtons for Foam Set #9. Overall, the percent differences were small, and there was not a trend for either procedure resulting in higher IFD results. Therefore, it was determined to use the more time efficient method, Method 2, for all future testing and analysis.

Table 5: MTS Test Machine Results: 50 Percent IFD Method 1 versus Method 2

WB Foam Set No. (102-mm thickness)	IFD Values (N)	
	Method 1 25%/65% then 50%	Method 2 25%/50%/65%
4	434	421
5	423	440
6	449	434
7	422	434
8	433	420
9	392	416
10	416	402
11	404	419
12	419	405
13	445	457
14	450	436

Table 6: Method 1 versus Method 2 Percent Difference Results

WB Foam Set No. (102-mm thickness)	Percent Difference Between Method 1 and Method 2
4	3.0%
5	-3.8%
6	3.3%
7	-2.7%
8	3.1%
9	-5.9%
10	3.5%
11	-3.7%
12	3.3%
13	-2.7%
14	3.2%

5.3 Non-Woodbridge Foam Manufacturers

As discussed previously, NHTSA had identified non-WB foams to evaluate using the IFD test procedures and to use in the dynamic sled test series. The foams used included two “off the shelf” foams produced by Century Foam and Perfect Fit-McDonald, and a “custom” foam manufactured by Lear Corporation. Like the WB foams, it was observed over time that some of the other foams fell in and out of the initial IFD compression specification range (per Table 1). Along with the IFD analysis study, the four different foams, which included WB, were used in a sled test series conducted in October and November of 2018. During the sled test series and subsequent IFD tests, the temperature and humidity were recorded in the VRTC bay area for use in further analysis, discussed later in this report.

In Figures 1 and 2, the IFD values from initial IFD tests performed from September of 2016 to January of 2019 are plotted for the 102-millimeter foam pieces. Figure 1 includes all the samples of the "off the shelf" foams manufactured by Century Foam and Perfect Fit-McDonald. Figure 2 includes all the samples for the "custom" foams manufactured by WB and Lear Corporation. The symbols with the imbedded asterisks (*) indicate the foams that were used for the sled test series.

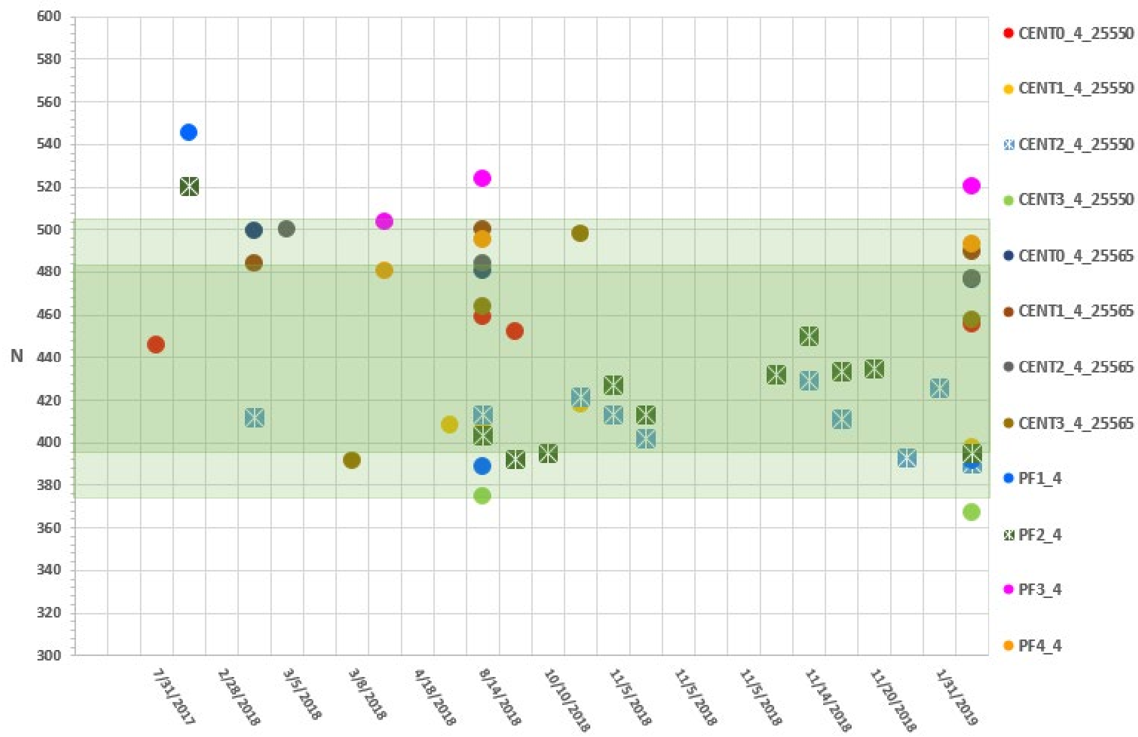


Figure 1: "Off the Shelf" Foams IFD 50% Compression Results - 102-millimeter Foams

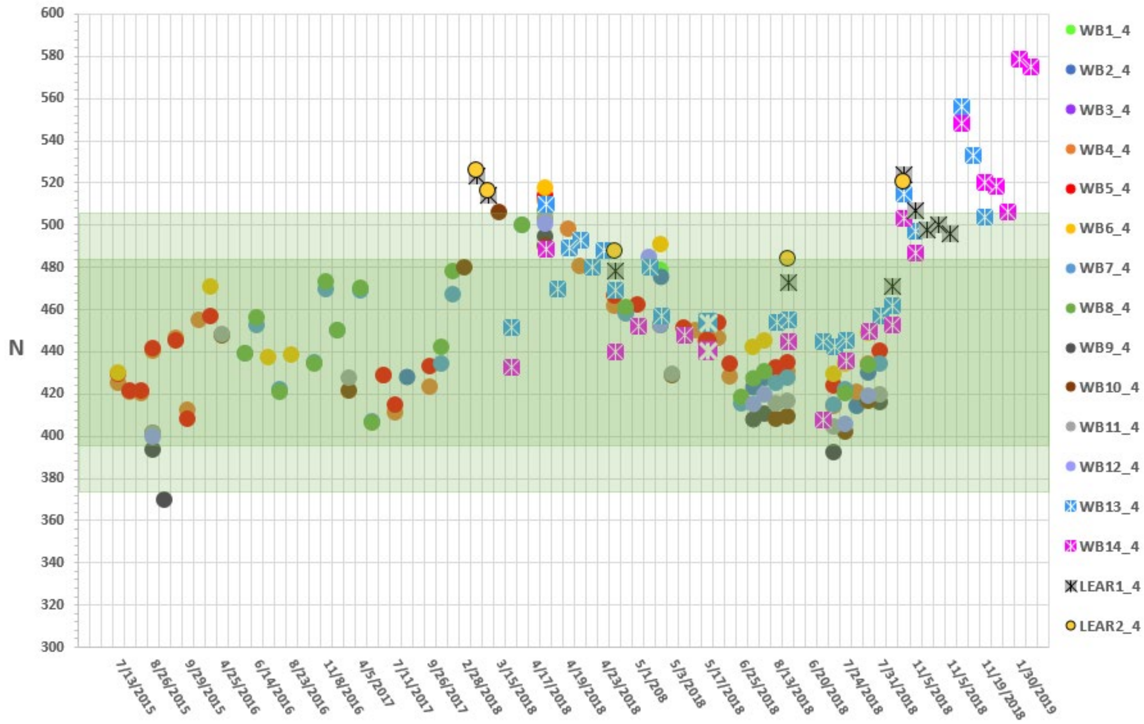


Figure 2: "Custom" Foams IFD 50% Compression Results – 102-millimeter Foams

During the test series time frame, the IFD values were analyzed and compared between "custom" foams and "off the shelf" foams. The IFD values were tested before, during, and after the sled test series.[21] During the sled test series, the foams were tested per IFD test procedures after approximately five sled uses. During the duration of the sled test series, the two "off the shelf" foams showed IFD responses that were not substantially different after being used on the sled when compared to the initial IFD test results, however, both of those foams had original IFD values at the lower range of the 50 percent compression specification[22] (Figure 1). The Lear foam was always on the higher side of the range and was usually out of the specification (Figure 2). Lear foams are shown with grey boxes with (*) or yellow circles. However, the Lear foam IFD responses were generally similar to the WB foam sets #13 and #14 (shown in blue and purple boxes with (*)).

Overall, Figures 1 and 2 illustrate the IFD variability throughout the use history of each foam sample. Looking at specific foams, such as WB14_4, Figure 2 shows the changing IFD responses from 2015 to 2019; from falling into the middle of the 50 percent compression specification, to exceeding the specification. This initial analysis did not result in the

[21] Only the 50% compression results for the 102-mm foams are shown in the body of the report. The 25% and 65% compression results for the "custom" and "off the shelf" foams along with all the 51-mm foam results can be found in Appendix D.

[22] The darker green zone in Figure 1 and subsequent figures represents the 440 N ± 10% specification listed in Table 1. The lighter green zone represents 440 N ± 15%, which will be discussed later in this report.

determination of an exact cause of why the foam sets fell out of specification during the periodic IFD testing, but it did lead to additional discussions on the foam specification range and the effects of humidity variation on the foams' IFD responses. During the sled test series, it was observed that the relative humidity and temperature could influence the foam IFD responses. This led to an additional study on relative humidity and temperature effects on the foam during storage and in testing environments.

6. Foam Specifications Analysis and Discussion

6.1 IFD Specification: Temperature and Humidity Discussion

Since 2015, VRTC has stored the foam sets in a temperature controlled (approximately 21º Celsius (70º Fahrenheit)) and humidity monitored bay, stacked vertically at a maximum of three sets high. Originally the temperature and humidity in the lab area were not closely monitored, but they likely changed with the different seasons and outside temperatures and humidity. This effect from the temperature and humidity was not identified with the earlier WB foam sets, and they were tested at random times during the year. However, starting in about 2017, all the foam sets being used for sled testing started falling out of the specification range (Table 1) (Appendix C shows the historical plots of each WB foam set). Due to this observation, from June 2018 through January 2019, the temperature and relative humidity in the VRTC lab area were recorded using a data logger.[23] During that time, the temperature ranged from 16 to 24 degrees Celsius with an average of 22 degrees Celsius. The relative humidity ranged from 1 to 77 percent with an average of 57 percent.

During the sled test series in 2018, it was observed that the potential effect of the temperature and relative humidity might have an effect on the IFD responses of other foams, in addition to the WB foam sets. The foam sets used for the sled test series were WB foam sets #13 and #14 and one set each of Lear, Century, and Perfect Fit-McDonald foams. During the duration of the sled test series, the two "off the shelf" foams showed IFD responses that were not substantially affected by the varying temperature and humidity. The Century foam set was the least affected, while in contrast, the IFD responses for the "custom" foams, WB and Lear, were affected. Over the period of the sled test series, as the humidity decreased the IFD value increased. During the sled testing period, the average temperature and relative humidity in the VRTC lab where the IFD testing was being conducted was approximately 21 degrees Celsius and 38.5 percent relative humidity.[24] During that time, the ambient lab temperature ranged from 18 to 23 degrees Celsius and the relative humidity ranged from 16 to 63 percent. The sled environment was maintained per standard test protocols, with temperatures ranging from 21 to 25 degrees Celsius and the relative humidity ranging from 10 to 80 percent.

[23] HOBO Onset Data Logger, Model MX1101. https://www.onsetcomp.com/products/data-loggers/mx1101.
[24] The HOBO Onset Data Logger has a -20 to 70-degree Celsius range and a 1 to 95 percent relative humidity range. The manufacturer specifies a measurement error of +/- 0.21 degrees Celsius and +/- 2 percent relative humidity.

NHTSA discussed this observation with The Woodbridge Group and it was recommended that the foams manufactured by WB should be stored in a controlled environment with a relative humidity of 50 percent. Woodbridge noted that all their foams were stored in a humidity-controlled room set to 50 percent relative humidity. This is not a practical application for most labs, therefore additional analysis was conducted to explore other options to determine the full effect that humidity had on the foams.

The ambient temperature and relative humidity of the lab area at VRTC in which the foams were stored were plotted versus the IFD responses of the foams. Figure 3 shows the relative humidity of the lab area over 10 months (May 2018 through February 2019) versus the IFD responses from WB foam set #14. The relative humidity is shown in the yellow on the plot. The different colored circles indicate the date on which an IFD test was conducted. In the spring and summer months the relative humidity averaged around 60 percent, whereas during the fall and winter months it dropped to approximately 30 percent, or lower. The sled test series was conducted during the months of October and November, and during that time, the relative humidity ranged from about 20 to 40 percent, with some high and low data spikes at different times. As the humidity lowered, the foams responded with higher IFD values (i.e., the foams were stiffer).

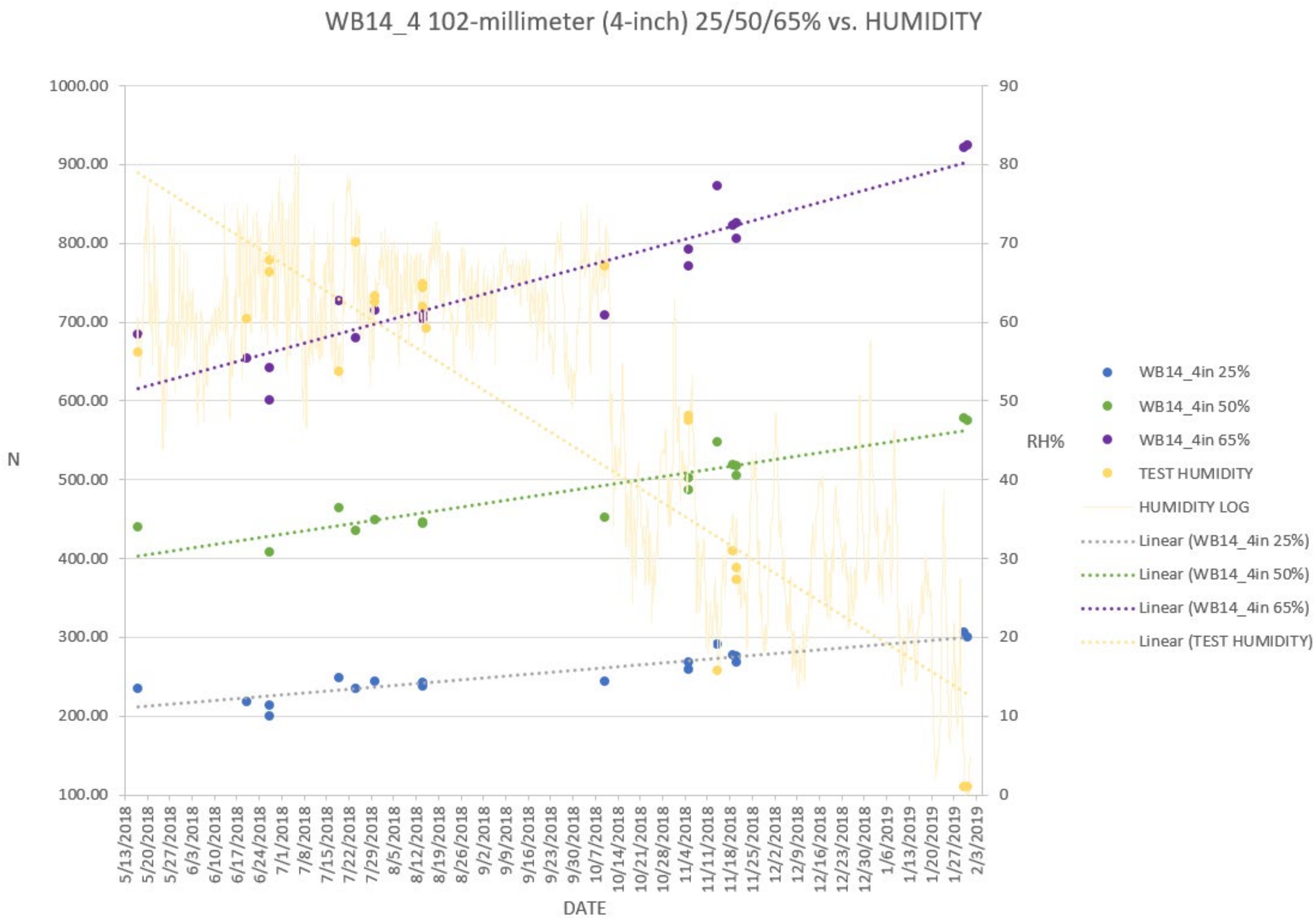


Figure 3: Relative Humidity in the VRTC Bay Versus IFD Values

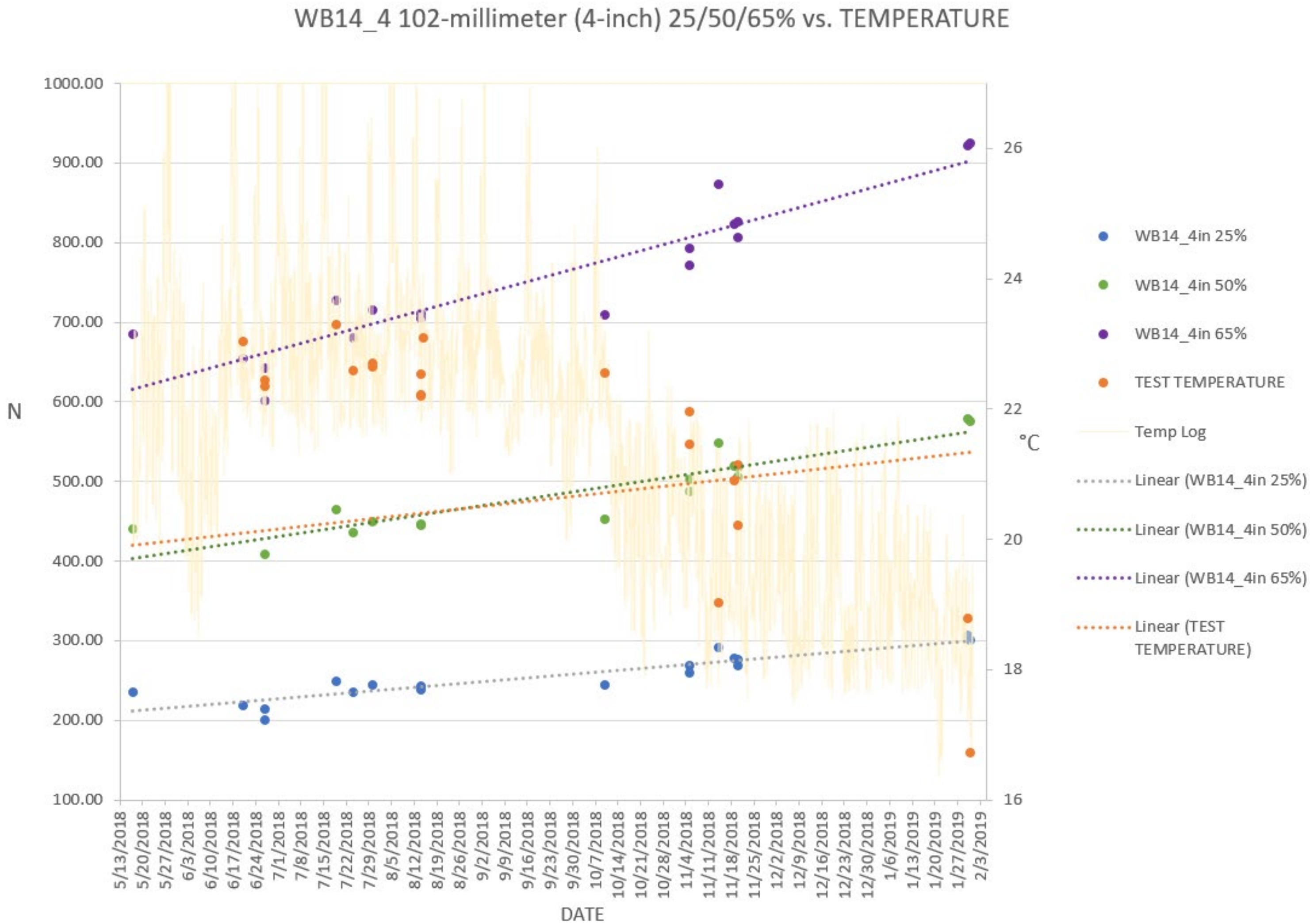


Figure 4: Temperature in the VRTC Bay Versus IFD Values

Figure 4 shows the temperature of the lab area over 10 months (May 2018 through February 2019) versus the IFD values from WB foam set #14. The temperature is shown in orange on the plot. In the spring and summer months the temperature averaged around 23 degrees Celsius, whereas during the fall and winter months it dropped to approximately 20 degrees Celsius. As the temperature dropped the IFD responses increased.

The ambient temperature range in the lab area varied by three degrees Celsius, while the relative humidity varied by 77 percent, based on the dates when the IFD tests were conducted. The IFD results from the other foams were also plotted with the temperature and humidity data (Appendix F). The other "custom" foam, Lear Corporation, had similar trends as WB #14, with WB #14 showing the largest differences. The "off the shelf" foams, Perfect Fit-McDonald and Century Foam, were also tested. Both these sets of foams showed little to no effect from the temperature and humidity change.

In addition to the IFD tests being conducted at VRTC, another NHTSA Research contract[25] with the Calspan Corporation was in place. The contract called for the test facility to procure two foam sets from The Woodbridge Group to use for a research program with testing on the proposed FMVSS No. 213 test bench. NHTSA instructed Calspan to test the foam sets as received (12/6/2018) and again during the dynamic sled test series (April through June 2019), after every five or six sled tests. They were given the specifications listed in Table 1 for reference.

Calspan stored their foam sets in a temperature and humidity-controlled room during this test series. Table 7 reports the ambient temperature (in Celsius) and relative humidity (percent) during the time of each IFD test conducted for both sets of foam (CS_WB#6 & #7).

Table 7: Calspan Tests: Humidity and Temperature of IFD Lab

	CS_WB#6 51-mm		CS_WB #6 102-mm		CS_WB #7 51-mm		CS_WB #7 102-mm	
Date	Humidity	Temp	Humidity	Temp	Humidity	Temp	Humidity	Temp
12/6/2018	48	22	51	22	42	22	43	22
4/9/2019	51	22	49	23	52	22	51	23
4/26/209	52	22	52	22	54	22	54	22
5/2/2019	54	22	51	22	53	22	54	22
5/8/2019	51	22	51	23	52	22	50	22
6/12/2019	50	22	50	22	52	22	52	22
6/13/2019	54	22	54	22	54	22	50	22
6/14/2019	48	22	50	22	52	22	54	22
6/21/2019	54	22	52	23	54	22	52	22
6/27/2019	50	22	50	23	50	22	51	22
Average	51	22	51	22	51.5	22	51	22

[25] Contract Number DTNH2214D00359L/693JJ918F000238 "FMVSS No. 213 R&R: Updated Frontal Standard Seat Assembly".

Calspan conducted the IFD tests per the procedure specified by NHTSA (Appendix B) and tested the compressions consecutively in one test (Method 2). Each IFD test conducted by Calspan resulted in IFD responses that fell within the initial specification ranges listed in Table 1 for all compressions, 25, 50, and 65 percent. Figure 5 shows the results over time of the IFD tests on the 102-millimeter (4-inch) foam sets #6 and #7 at the 50 percent compression. These foam sets were also used for a dynamic sled series. The other compression results for both foam sets can be found in Appendix E.

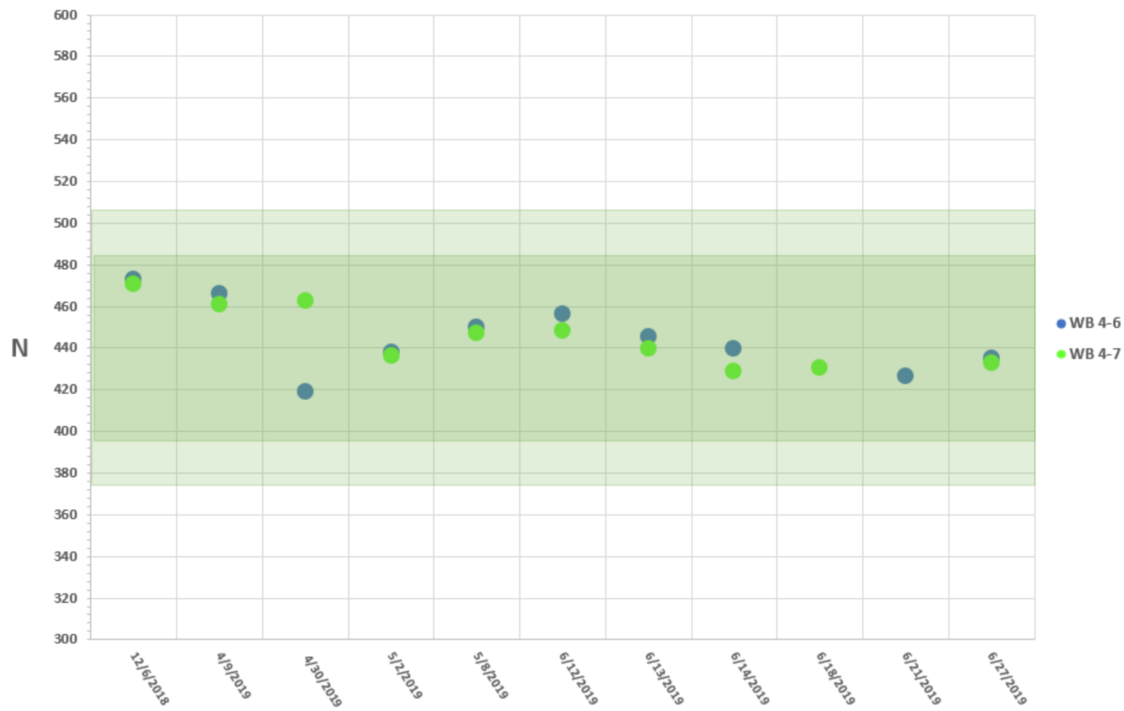


Figure 5: Calspan WB 102-Millimeter Foam Sets #6 and #7 50 Percent IFD Compression Results

Data received from Calspan showed the potential fix to the effect of temperature and humidity was to store or soak the foams in a temperature and relative humidity-controlled room, stabilizing and maintaining the IFD values within the specifications listed in Table 1.

After Calspan completed the testing requirements of the contract, the Woodbridge foam sets (CS_WB6 and CS_WB7) were sent to VRTC to be tested. This study utilized a controlled room in which the temperature and relative humidity could be monitored but not adjusted (18 degrees Celsius and 46 ± 2% relative humidity). To see what effect there was on the IFD values, the foam sets were tested at VRTC as received from Calspan (7/17/2019), after storing the foam sets in a temperature and humidity-controlled room for 24 hours (7/18/2019), and after being stored in the lab environment for four and eight days (7/23/2019 and 7/31/2019). Table 8 shows results from the 50 percent compression IFD tests for both the 102-millimeter (4-inch) foam sets. The first two rows show the results from the last tests conducted by Calspan, for reference. The IFD responses showed little variability among the different test soaks, however, none of the tests were conducted at low lab humidity levels.

Table 8: IFD Response: Calspan Foam Set #6 and #7 as Tested at VRTC with Controlled Temperature and Relative Humidity

Date	Lab Temp °C	Lab Relative Humidity Percentage	Foam Size and Number 102 mm (4-in)	Test Description Comment	50% IFD Response (N)
6/27/2019	23	50	CS_WB6_4	Last test completed at Calspan before shipping foam to VRTC	435
6/27/2019	22	51	CS_WB7_4	Last test completed at Calspan before shipping foam to VRTC	433
7/17/2019	22	73	CS_WB6_4	As received (within 1 hour of arrival)	426
7/17/2019	22	72	CS_WB7_4	As Received (within 1 hour of arrival)	427
7/18/2019	24	66	CS_WB6_4	Soaked in controlled temp/humidity room 24 HRS	433
7/18/2019	24	66	CS_WB7_4	Soaked in controlled temp/humidity room 24 HRS	427
7/23/2019	22	62	CS_WB6_4	Soaked in the lab/storage area 4 days	428
7/23/2019	22	62	CS_WB7_4	Soaked in the lab/storage area 4 days	428
7/31/2019	23	67	CS_WB6_4	Soaked in the lab/storage area 8 days	426
7/31/2019	23	66	CS_WB7_4	Soaked in the lab/storage area 8 days	426

To further investigate the relative humidity effects, VRTC fabricated an insulated box (Figure 6) that could maintain the standard conditions of 22 degrees Celsius and a 50 percent relative humidity. In addition, the box could also be adjusted as needed. The box was built to hold up to six sets of foam at one time. Within the box is an air conditioner, humidifier, and dehumidifier.

Figure 6: Temperature and Humidity Insulated Box at VRTC

To understand the effect humidity has on the foam, a small study was conducted in which six different sets of 102-millimeter (4-inch) foams were stored in the box for different lengths of time at specified humidity levels. The foam sets chosen were the WB #7 (one of the first batches of foam sets procured), WB #13 (one of the last foam sets procured), WB #14 (one of the last foam sets procured), Lear_1 (LR1), Perfect Fit-McDonald_250-2 (PF_290-2), and Century_25550_2 (CF_25550-2).

Each foam piece was tested per IFD test specifications prior to soaking them in the temperature and humidity-controlled box. Three different time durations were selected to soak the foam samples which included 4 hours, 24 hours, and 48 hours. Testing was conducted in the lab at two different humidity levels; when the lab recorded high humidity (above 60%) and low humidity (below 30%). Tables 9 and 10 show the test matrix. Note that not all the foams were tested after all the soak durations.

Table 9: Test Matrix for Foam Soak When Relative Humidity was Above 60%

	4-hour soak	24-hour soak	48-hour soak
WB #7	NA	NA	Tested
WB #13	Tested	Tested	NA
WB #14	NA	Tested	NA
Lear 1	Tested	NA	NA
PF 290-2	Tested	NA	NA
CF_ 25550-2	Tested	NA	NA

Table 10: Test Matrix for Foam Soak When Relative Humidity was Below 30%

	4-hour soak	24-hour soak	48-hour soak
WB #7	NA	NA	Tested
WB #13	Tested	Tested	Tested
WB #14	NA	Tested	Tested
Lear 1	Tested	Tested	Tested
PF 290-2	Tested	Tested	NA
CF_ 25550-2	Tested	Tested	NA

When the test bay was considered high humidity (above 60% relative humidity), soaking the foams for any duration of time had minimal effect on the IFD responses. Figure 7 plots both the 102-millimeter (4-inch) "custom" (WB #7, WB #13, WB #14, and LR1) and the "off the shelf" (CF_25550-2 and PF 209-2) foam responses at 25, 50, and 65 percent compression over the different soaking periods. The 25, 50, and 65 percent compression specification tolerance ranges (as listed in Table 1) are shaded in pink, green, and blue, respectively.

When the lab was considered at low humidity (less than 30% relative humidity), the storage box soaking times had a larger effect on the foam sets. The IFD responses are shown in the plot in Figure 8. As stated before, each of the foam sets was tested prior to the soak; four of the six foam sets were not within the specification for one or more of the compressions. For the 25 and 50 percent compressions, soaking for four hours did not bring any of the foams within specification. After the 24-hour soak, most of the foams improved but some were still not within the specification range (as listed in Table 1). The 48-hour soak produced little change from the 24-hour soak, but one foam (WB #7) came into specification for the 50 percent compression.

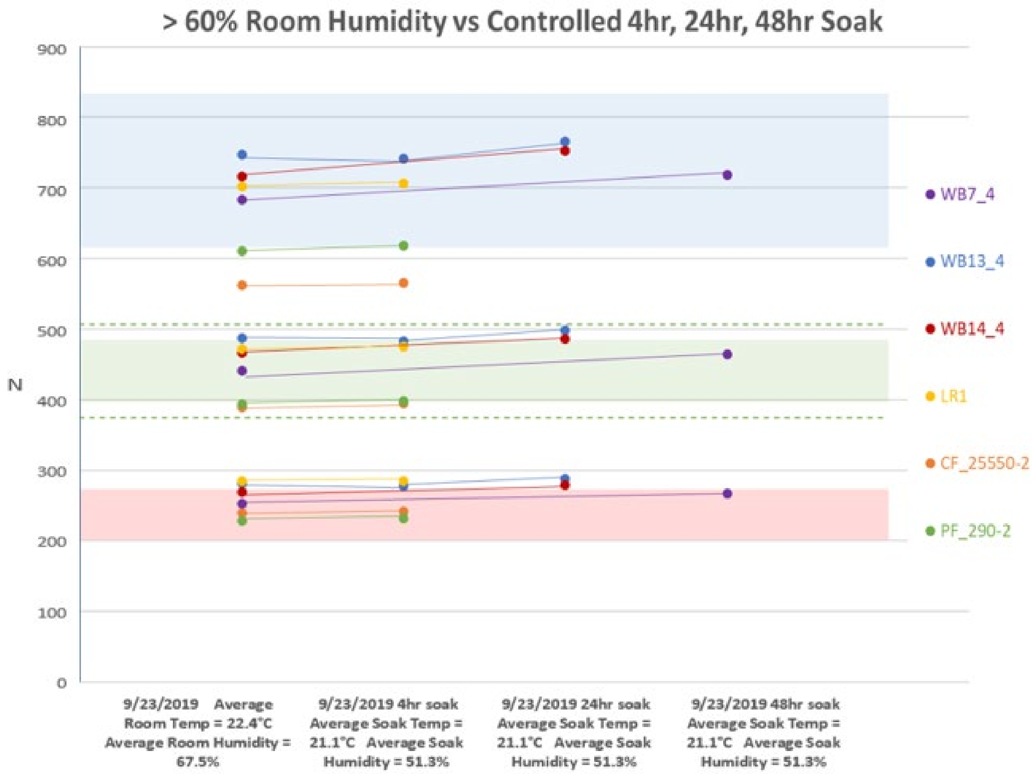


Figure 7: IFD Responses at Higher Humidity: Foams Soaked in Controlled Temperature/Humidity Box

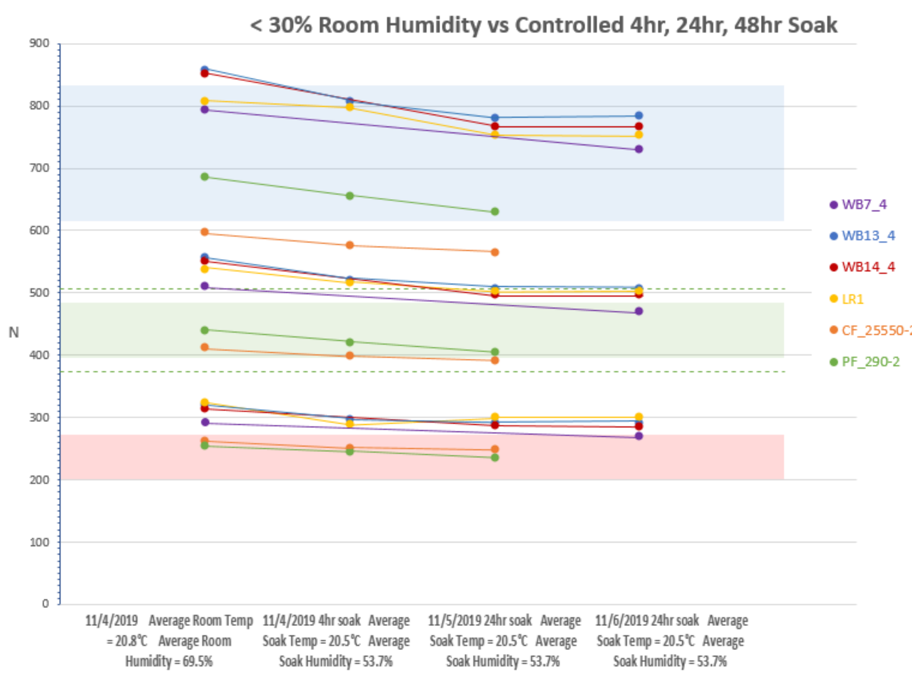


Figure 8: IFD Responses at Lower Humidity: Foams Soaked in Controlled Temperature/Humidity Box

This small study indicated that relative humidity can affect the foam IFD responses, with higher humidity resulting in lower IFD responses. Soaking the foam sets in a controlled temperature and relative humidity chamber for a minimum of 24 hours prior to testing should reduce this variability, although some of the foam sets tested still did not fall within the specification range.

6.2 IFD and Dynamic Sled Testing

The initial specifications for the foam sets are reported in Table 1. This includes an IFD value for the 50 percent compression to be 440 ± 10 percent Newtons (396 N to 484 N). The 50 percent IFD compression results of the 102-millimeter (4-inch) WB foam sets, tested at VRTC from August 2014 to August 2019, are plotted in Figure 9. The IFD results for all WB foams at all three compressions can be found in Appendix C. The IFD results were mostly within the specification until April 2018, when the foams started to exceed the upper range value of 484 Newtons. Additional testing that summer resulted in the majority of the foam sets meeting the 50 percent compression specification, which could be due to the relative humidity in the summer months being about 50 to 70 percent. As discussed previously, the foam sets started to fall out of range during the dynamic sled test series in October/November of 2018. During that time, Woodbridge foam sets #13 and #14 exceeded the foam specification values.

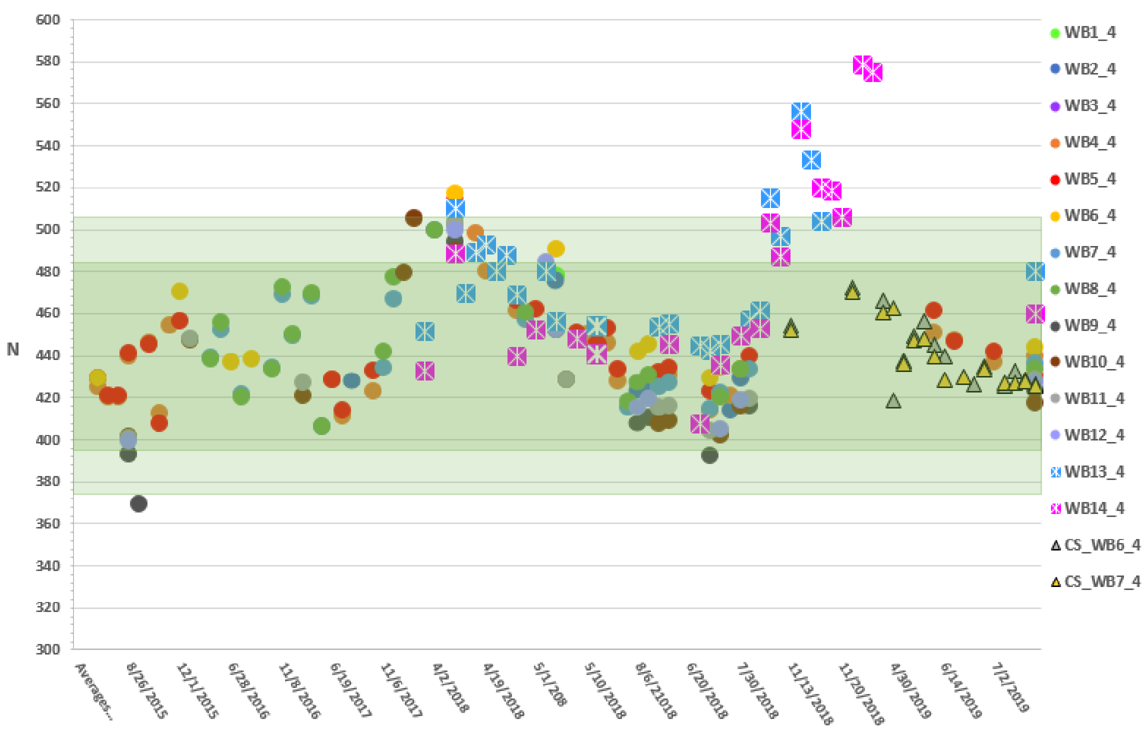


Figure 9: Woodbridge Foam Sets: IFD 50% Compression Responses Over Time

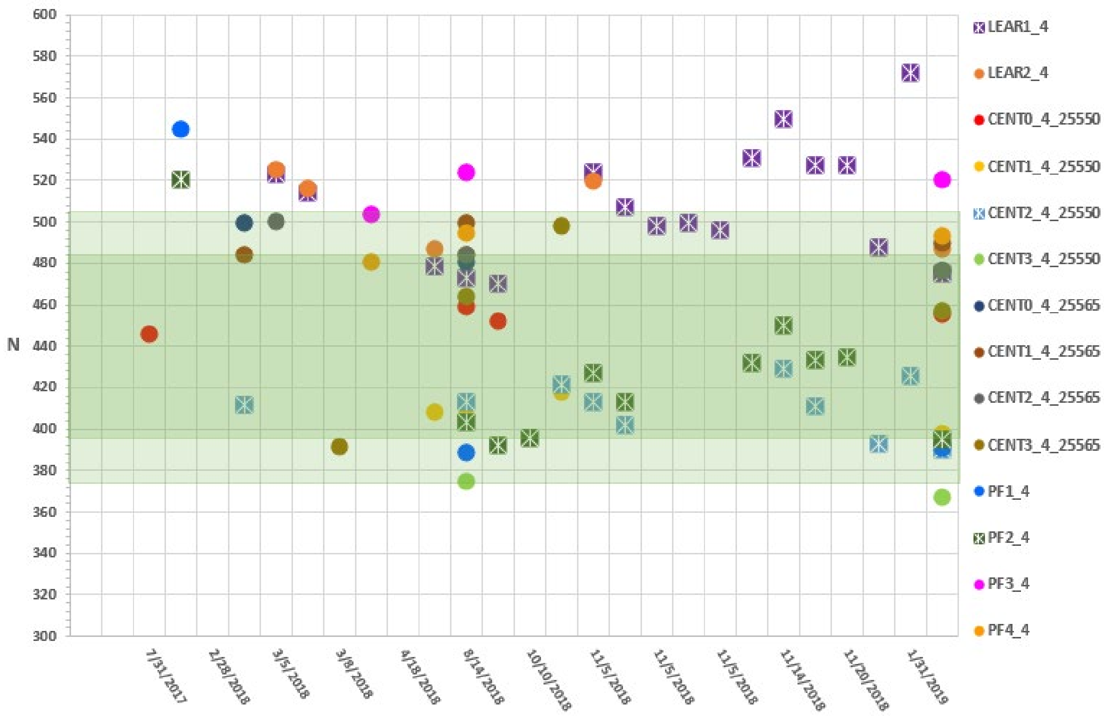


Figure 10: Other Foam Sets: IFD 50% Compression Responses Over Time

Figure 10 shows the historical IFD responses for the non-WB foams from August 2018 through January 2019. Additional results of the other manufactured foams and all compression rates can be found in Appendix D. Beginning in November 2018, the Lear Corporation foam was also consistently above the specified range (Table 1).

The dynamic sled test series in the fall of 2018 was conducted to evaluate what effect, if any, the different foams have on the anthropomorphic test device (ATD) responses while testing with the proposed FMVSS No. 213 test bench. In addition, the foam durability and repeatability were studied in this series.[26] A variety of CRSs were used along with different size ATDs. Three repeatability tests were conducted on each non-WB foam set with each ATD, and five runs used a WB foam for comparison. In addition, previous sled tests that utilized the WB foams were also used for comparisons. Between each sled test, a minimum of an hour wait time was observed to allow the foam to relax and return to its original state. After each test, the foam set and cover were inspected for any tears or cuts.

As discussed previously, two of the foam sets selected for testing (Woodbridge and Lear Corp) exceeded the IFD 50 percent specification range (see Figures 9 and 10). Injury responses between the different ATDs tested were compared to previous sled tests run in the same orientation but with foams that fell within the specification range. Minimal differences in ATD

[26] NHTSA database numbers V10740-V10785.

responses between the two sled test series were observed. Appendix G reports the testing details, injury responses, and data analysis comparisons for the dynamic sled test series.

6.3 Foam Evaluation Summary and Observations

Based on the IFD and dynamic sled test series results, it was determined there are at least four manufacturers that can produce foams for use on the proposed FMVSS No. 213 test bench: The Woodbridge Group, Lear Corporation, Century Foam, and Perfect Fit-McDonald. The four foams discussed in this report met the majority of the initial specifications listed in Table 1, and they produced similar and repeatable ATD responses in the dynamic sled testing.

Additionally, all foams were very durable for the entire series. After every sled test, each foam set (seat pan and seat back) was checked for any cuts and/or rips. This included the foam being closely inspected around the area of the metal plate on which the foam is installed and at the points of contact with the CRSs. The fabric covering the foam sets was also checked for rips and/or stretch marks after every test. The foam sets were not unwrapped after every test due to time constraints.

Both the Century Foam (CF_25550-2) and the Lear foam sets did not have any damage during the sled series. The Perfect Fit-McDonald (PF_290-2) seat back foam did not have any damage, but it was observed that the seat pan foam had some minor damage with three small tears near where the steel plate is located (Figure 11) after a series of forward facing tests was conducted. The tears ranged from 6 to 10 millimeters deep and 25 to 50 millimeters long. This was also observed on rare occurrences with the WB foam sets in previous sled test series. The foams were repaired by gluing the tears with spray adhesive. In addition, the fabric covering was not torn and proved to be durable during this series of testing.

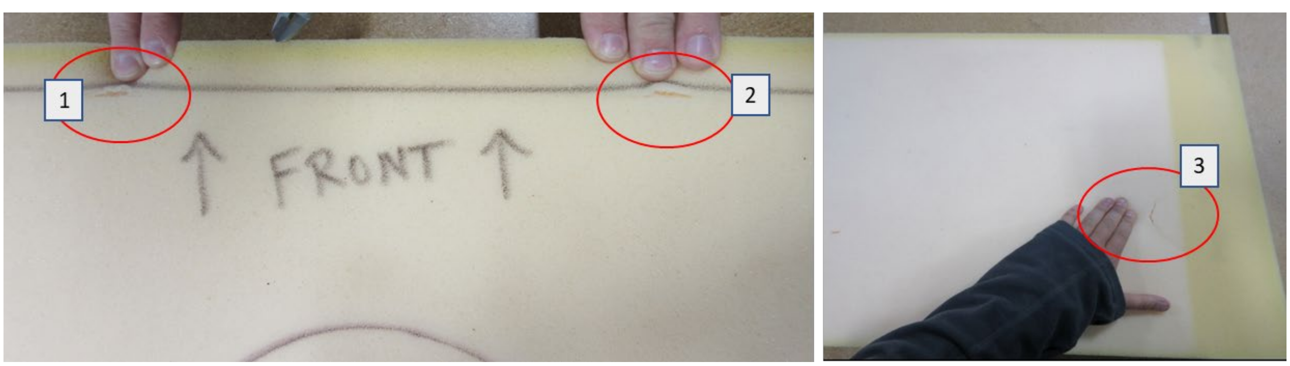


Figure 11: Perfect Fit-McDonald 290-2 Foam Damage on Seat Pan

6.4 Foam Specification Discussion

NHTSA worked with The Woodbridge Group to develop an initial set of specifications for the foam sets to be used on the proposed FMVSS No. 213 test bench, as listed in Table 1. These include specifications for the 25, 50, and 65 percent IFD tests for both the 102-millimeter (4-inch) and 51-millimeter (2-inch) foams. The testing described in this report showed that the various foams met most, but not all, of these initial specifications for the IFD testing (the density and CFD specifications were not verified). However, the variations did not substantially affect the ATD responses in the dynamic sled tests, which are the outcomes of interest in the FMVSS No. 213 testing. This led to the decision that a set of procurement specifications would be established on which foam manufacturers must certify their foams on which NHTSA (or its contracted test labs) could rely on during the procurement process. In addition, a separate set of test specifications would be established to which NHTSA's contract laboratories must certify the foams used in FMVSS No. 213 testing. The procurement specifications are listed in Table 11. As shown, the density and CFD requirements are maintained, along with the IFD 50 percent compression specification of 440 ± 10 percent Newtons for the seat pan. The 25 and 65 percent IFD compressions shall be monitored and used only for reference for the seat pan as well as the seat back.

Table 11: Procurement Specifications for Seat Pan and Seat Back Foams

	Density kg/m^3 (lb/ft^3)	**50% CFD kPa (lb/in^2)**	**IFD 25% N (lb)**	**IFD 50% N (lb)**	**IFD 65% N (lb)**
Seat Pan (102 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	237 (53.3) ± 15% For reference	440 (98.9) ±10% [396-484]	725 (162.9) ±15% For reference
Seat Back (51 mm)	47 (2.9) ±10%	6.6 (0.96) ±10%	157 (35.3) For reference	300 (67.4) ±15% [255-345]	480 (107.9) For reference

The test specifications are listed in Table 12. In laboratory testing, verification of the density and CFD responses should not be required, but the NHTSA contract laboratories should have the ability to test the foam sets following the IFD test method (Appendix B) described in this report at 25, 50, and 65 percent compressions. However, the foams will only be required to meet the finalized compression specifications according to FMVSS No. 213. Also, the tolerance on the IFD 50 percent compression specification for the 102-millimeter foam is widened to ± 15 percent, giving a range of 374 to 506 Newtons. Additionally, the test specification should specify the foam sets be soaked for a minimum of 24-hours in a humidity and temperature-controlled area prior to being tested to the IFD procedure/specifications. If the foam is not within specification after the 24-hour soak, additional testing and/or soaking of the foam set may be necessary before sled use. When the foam sets are not installed on the sled buck, the best practice will be to store them in a temperature and humidity-monitored area.

Table 12: Test Specifications for the Seat Back and Seat Pan Foams

	IFD 25% N (lb)	**IFD 50% N (lb)**	**IFD 65% N (lb)**
Seat Pan (102 mm)	237 (53.3) ± 15% For reference	440 (98.9) ±15% [374-506]	725 (162.9) ±15% For reference
Seat Back (51 mm)	157 (35.3) For reference	300 (67.4) ±15% [255-345]	480 (107.9) For reference

Appendix A: Manufacturer Information

Table A1: Manufacturer Information and Questionnaire Responses from NCMS Study

Companies	Address	City	State	Zip Code	Phone	Name	Email	Distributor / Manufacturer	Quoted a Foam(s)	Received written response from supplier	Supplier states can meet all specifications	Supplier states can meet all specifications, all specs were reported/received
Century Foam Products	1235 W. Hively Avenue	Elkhart	IN	46517	574-295-8888	Jack Bowman	jbowman@centuryfoam.com	Distributor	Yes	Yes	Yes	No
Comcast Urethane	425 Leggit Road	Marshall	MI	49068	888-732-3894	Mark Warner	mwarner@ccurethane.com	Manufacturer	Yes	Yes	Yes	No
The Foam Factory	17500 23 Mile Road	Macomb	MI	48044	586-627-3626	Linda	www.foambymail.com/contact-us	Distributor	No	No	No	No
Future Foam	2210 Parview Road	Middleton	WI	53562	608-770-2532	Jim Mulvey	jmulvey@futurefoam.com	Manufacturer	No	No	No	No
FXI Corporation	1400 N. Providence Road	Media	PA	19063	610-744-2300	Doug Karp	dkarp@fxi.com	Manufacturer	No	No	No	No
IR Specialty Foam, LLC	3500 20th Street, Suite B	Fife	WA	98424	800-426-7944	Todd Olstad	tolstad@irfoam.com	Manufacturer	No	No	No	No
Lear Corporation	21700 Telegraph Road	Southfield	MI	48033	248-447-7832	Russ Davidson	rdavidson@lear.com	Manufacturer	Yes	Yes	Yes	Yes
Ohio Foam Corporation	529 S. Kibler Street	Washington	OH	44854	419-492-2151	Peter Kesler	www.ohiofoam.com/contact	Distributor	No	No	No	No
Penn Foam	2625 Mitchell Avenue	Allentown	PA	18103	610-797-7500	Bob Fromknecht	bob@pennfoam.com	Manufacturer	No	No	No	No
Penz Products, Inc.	1320 S. Merrifield Avenue.	Mishawaka	IN	46544	574-255-4736	Roy Szymanski	rszymanski@penzproductsinc.com	Manufacturer	No	No	No	No
Perfect Fit-McDonald, Inc.	18249 Olympic Avenue South	Tukwila	WA	98188	253-220-4412	Mark Roddy	markr@perfectfit.com	Distributor	Yes	Yes	Yes	Yes
Plastomer Corporation	37819 Schoolcraft Road	Livonia	MI	48150	734-464-0700	Bill Christoferson	william.christofferson@plastomer.com	Manufacturer	No	No	No	No
Unique Molded Foam	13221 Allman Road	Concord	MI	49237	517-524-9010	Tim	N/A	Manufacturer	No	No	No	No
Wisconsin Foam Products	4601 Tompkins Drive	Madison	WI	53716	608-221-4385	Jim Olson	jim@wifoam.com	Distributor	No	No	No	No
The Woodbridge Group	1515 Equity Drive	Troy	MI	48084	248-280-6314	David Ludberg	david.ludberg@woodbridgegroup.com	Manufacturer	Yes	Yes	Yes	Yes

*Source: NCMS Foam Study, NHTSA Docket: NHTSA-2020-0093-0012

Table A2: Manufacturer Product Information Specifications Results from NCMS Study

APPENDIX E

FOAM SUPPLIER'S PRODUCT INFORMATION

Test methods are specified to ASTM Standards

Density, 50% Indentation Force Deflection (IFD) or 25/65% IFD, and 50% Compression Force Deflection (CFD)

Supplier	Name	Email	Foam Grade	Type	Density (PFC = lbs/ft^3)	Indentation Force Deflection (IFD)	Compression Force Deflection (CFD) (PSI = lbs/in^2)
National Highway Traffic Safety Administration (NHTSA) Speifications					47 kg/m^3 (2.9 pcf) ± 10% 2.9 ± 10% (2.62 - 3.19)	**25% IFD** 237 N (53.2lbs) ± 15% 53.2 ± 15% (45.2 - 61.2) **50% IFD** 440 N (98.9lbs) ± 10% 98.9 ± 10% (89.0 - 108.8) **65% IFD** 725 N (162.9lbs) ± 15% 162.9 ± 15% (138.5 - 187.3)	**50% CFD** 6.6 kPa (0.95 psi) ± 10% 0.95 ± 10% (0.86 - 1.05)
Century Foam Products	Jack Bowman	jbowman@centuryfoam.com	R-25550-000 Premier Foam	Slabstock	42.45 kg/m^3 (2.65 pcf)	@ 25%; 200.17 - 244.65 N (45.00 - 55.00 lbs) @ 50%; not reported @ 65%; not reported	Did Not Supply
Century Foam Products	Jack Bowman	jbowman@centuryfoam.com	B-25565-103 Premier Foam	Slabstock	42.45 kg/m^3 (2.65 pcf)	@ 25%; 266.89 - 311.38 N (60.00 - 70.00 lbs) @ 50%; not reported @ 65%; not reported	Did Not Supply
Century Foam Products	Jack Bowman	jbowman@centuryfoam.com	Q 41 Carpenter Foam	Slabstack	45.65 kg/m^3 (2.85 pcf)	@ 25%; 177.93 - 222.41 N (40 - 50 lbs) @ 50%; not reported @ 65%; not reported	Did Not Supply
Comcast Urethane	Mark Warner	mwarner@ccurethane.com	F 210-01 US colorless (RN 3542)	Molded	70 kg/m^3 (4.37 pcf)	Did Not Supply	Did Not Supply
Lear Corporation	Russ Davidson	rdavidson@lear.com	Lear Molded Blocks	Molded	49.98 kg/m^3 (3.12 pcf)	@ 25%; 123.57 - 204.62 N (22.78 - 46.00 lbs) @ 50%; 190.96 N (42.93 lbs) @ 65%; not reported	Did Not Supply
Perfect Fit-McDonald, Inc.	Mark Roddy	markr@perfectfit.com	H290-55S1 Foamex	Molded	48.86 kg/m^3 (3.05 pcf)	@ 25%; 222.41 - 266.89 N (50.0 - 60.0 lbs) @ 50%; not reported @ 65%; 524.89 N (118.0 lbs min)	Did Not Supply
Perfect Fit-McDonald, Inc.	Mark Roddy	markr@perfectfit.com	H270-40S1 Foamex	Molded	45.33 kg/m^3 (2.83 pcf)	@ 25%; 164.58 - 191.27 N (37.0 - 43.0 lbs) @ 50%; not reported @ 65%; 422.58 N (95.0 lbs min)	Did Not Supply
The Woodbridge Group	David Ludberg	david.ludberg@woodbridgegroup.com	Comfortech Trimvisible	Molded	47 kg/m^3 (2.93 pcf)	@ 25%; not reported @ 50%; 440 N (98.92 lbs) @ 65%; not reported	6.6 kPa (0.96 psi)

*All price quotes are for new 213 bench foam

Category	Range
Seat Pan Price / each	$13.50 - $160.00
Seat Back Price / each	$8.00 - $230.00
Cost per Set	$21.72 - $460.82
Minimum Sets	5 - 60
Mold Costs	$7,600 - $45,000

*Source: NCMS Foam Study, NHTSA Docket: NHTSA-2020-0093-0012

NHTSA Foams Used in this Study Certification Sheets

Table A3-

Table A3: Century Premier-B 25550 000 Specification Sheet

Premier Foam™

Polyurethane Foam Grade Specification

R-25550-000

Property	Requirement		Test Method
Density	2.45 - 2.65	lbs/ft³	ASTM D3574
IFD @ 25% Deflection 4"	45.00 - 55.00	lbs/50 in²	ASTM D3574
Elongation	100%	minimum	ASTM D3574
Tensile Strength	8 lbs/in²	minimum	ASTM D3574
Tear Resistance	1.00 lbs/lineal inch	minimum	ASTM D3574
Support Factor	1.80	minimum	
Color	White		
Bio-Polyol	Yes		
Smolder Resistant	Pass		TB117-2013 (smolder) / NFPA 260

Last Revision: 07/15/2014

Note: The Cal 117-2013 Smolder test is not intended to reflect performance presented by this material under actual fire conditions. This material does not contain a fire retardant additive.

Premier Foam Inc. reserves the right to alter the specifications of the above product at any time without prior notification.

Table A4: Lear Foam Data Specification Sheet

Item #	Properties	Test Method	Units	Test Results	
1	Density	ASTM D3574-08	kg/m3	35.00	50.00
2	Indention Force Deflection	ASTM D3574 Test B1 or ISO 2439 Method C	Lbf		
	original 25 % IFD, Ibf			22.78	46.00
	original 40% IFD, Ibf			33.27	65.50
	original 50% IFD, Ibf			42.93	0.00
3	Constant Force Pounding Height Loss and IFD Loss	ASTM D 3574 Test I3 Procedure B	%	2.03	2.10
				18.37	21.00
4	Hysteresis Loss	ASTM D 3574 App.X6 , Procedure A	%	22.33	24.25
5	Tensile Strength	ISO 1798	kPa	109.74	165.47
6	Tensile Elongation	ISO 1798	%	105.92	94.50
7	Tear Resistance	ASTM D624 Die C or ISO34	N/m	670.22	569.15
8	Comp Set - 50% @ 70C	ASTM D3574 D or ISO1856 A	% max	5.28	7.00
	Comp Set after steam autoclave	ASTM D3574 D procedure J2 -5 hour @120C	% max	14.00	18.50
9	CFD Loss after Steam autoclave	ASTM D 3574 D, procedure J2	%	13.73	22.50
10	Flammability	Must Comply with FMVSS 302 Test	mm/min	Pass	Pass

Table A5: Perfect Fit-McDonald Inc. Foam Data Specification Sheet

PERFECT FIT-McDONALD, INC.
18249 OLYMPIC AVE S.
TUKWILA WA 98188

Foamex

SALES SPECIFICATION
HIGH RESILIENCE (HR) POLYETHER POLYURETHANE FOAM

FOAM GRADE: **H290-55S1**
COLOR: PEACH

EFFECTIVE: 12-04-02
SUPERSEDES: 03-01-00

TEST ITEM	UNIT	RANGE	TEST METHOD
DENSITY	PCF	2.75-3.05	ASTM 3574
I.F.D. @ 4" THICK			
- 25% DEFLECTION	LBS.	50.0-60.0	ASTM 3574
- 65% DEFLECTION	LBS.	118.0 MIN.	ASTM 3574
SUPPORT FACTOR	RATIO	2.50 MIN.	
RECOVERY	%	80 MIN.	
HYSTERESIS LOSS	%	20 MAX	
CONSTANT DEFLECTION COMPRESSION SET			
- 90% DEFLECTION	%	10 MAX.	ASTM 3574
- 75% DEFLECTION	%	8 MAX.	ASTM 3574
- 50% DEFLECTION	%	3 MAX.	ASTM 3574
STEAM AUTOCLAVE AGING - COMPRESSION SET @ 50% DEFLECTION	%	N/A	ASTM 3574
DRY HEAT AGING - COMPRESSION SET @ 50% DEFLECTION	%	5 MAX.	ASTM 3574
AIR FLOW	CFM	1.0 MIN.	ASTM 1564
RESILIENCE (BALL TEST)	%	50.0 MIN.	ASTM 3574
TENSION TEST			
- TENSILE STRENGTH	PSI	20.0 MIN.	ASTM 3574
- ULTIMATE ELONGATION GRIP SEPARATION	%	100 MIN.	ASTM 3574
TEAR RESISTANCE	PLI	1.30 MIN.	ASTM 3574
STATIC FATIGUE 75%			
- I. F. D. LOSS @ 25%	%	10 MAX.	ASTM 3574
- THICKNESS LOSS @ 75% COMPRESSION	%	1 MAX.	ASTM 3574

FLAMMABILITY PERFORMANCE *	
- CALIFORNIA TECHNICAL BULLETIN 117, SEC. A, PART I	PASS
- CALIFORNIA TECHNICAL BULLETIN 117, SEC. D, PART II	PASS
- FEDERAL M.V.S.S. 302	PASS
- FAA, FAR 25.853 (B)	MEETS

* THIS FLAMMABILITY DATA IS NOT INTENDED TO REFLECT HAZARDS PRESENTED BY THIS OR ANY OTHER MATERIAL UNDER ACTUAL FIRE CONDITIONS.
NOTE: FAA , FAR 25.853 (B) MUST BE TESTED EACH RUN BY A INDEPENDENT CERTIFIED LAB TO CERTIFY FOR USE ON AIRCRAFT. THIS MATERIAL HAS BEEN TESTED AND MEETS THIS STANDARD.

The above specifications have been reviewed and approved. ______ Signature Plant Mgr Title 6-26-02 Date

Appendix B: Indention Force-Deflection (IFD) Test Procedure

1. Before the foam sets are installed and used on the frontal seat assembly, test each foam piece to measure their indentation force-deflection (IFD) characteristics.
    a. Prior to conducting the IFD test, store the foam set in a temperature and humidity-controlled chamber with a temperature range of 21.1 ± 2.8 degrees Celsius (70 ±5 degrees Fahrenheit) and a relative humidity range of 55 ±5 percent for a minimum of 24 hours.
    b. Record the temperature and relative humidity of the storage location.
2. Test each foam specimen at 25%, 50%, and 65% compression, consecutively, using ASTM Standard D3574-11 Test B1 as a guideline.
3. Test each foam sample on the side that will interact with the CRS during sled testing.
    a. Mark the foams "Top" or "Bottom" for consistency. If the foam cushion has a skin, face the skin side up (i.e., the side interacting with the CRS).
4. Use an apparatus having a flat circular indenter foot 200 +3/-0 mm (7.87 +0.12/-0 in) in diameter to deflect the specimen.
5. Ensure the apparatus is on a horizontal plate which is perforated with approximately 6.5 mm holes on approximately 20 mm centers to allow for rapid escape of air during the test.
6. Test Procedure
    a. Place the specimen on the tensile test machine.
    b. Identify the test height of the specimen by having the indenter apply a force of 4.5 N to the specimen.
    c. Pre-flex the specimen by compressing it to 75% of its test height, two times at 250 ± 25 mm/min.
        i. The indenter should completely clear the top of the specimen after each pre-flex.
    d. Rest the specimen at least 6 minutes.
    e. Compress the specimen to 25% of its test height at a rate of 50 ± 5 mm/min and hold one minute once the correct deflection is met.
    f. Record the IFD value at the end of this minute.
    g. Immediately compress the specimen to 50% of its test height at a rate of 50 ± 5 mm/min and hold one minute once the correct deflection is met.
    h. Record the IFD value at the end of this minute.
    i. Immediately compress the specimen to 65% of its test height at a rate of 50 ± 5 mm/min and hold one minute once the correct deflection is met.
    j. Record the IFD value at the end of this minute.
    k. Return the indenter to the starting position, clearing the top of the specimen.
7. IFD values of the foam must fall within the test specifications per Table B1.
    a. If the foam does not fall within test specifications after the initial 24-hour temperature and humidity-controlled soak, a minimum of 30 minutes must pass before re-testing the foam for certification.
        i. During the 30 minutes, two potential methods to help the specimen fall within the test specification could include but are not limited to the following:

1. Soak the specimen for more than the 30-minute minimum timeframe (within temperature and humidity tolerances).
2. Manually compress or knead the foam.

ii. If foam does not fall within the test specifications after step (i), re-soak the specimen for an additional 24 hours or longer within the temperature and humidity tolerances.

1. Specimen is unusable if it does not fall within the test specifications after repeating the steps detailed in step (i).

b. When the foam sets are not being used for testing, a best practice is to store them in an area with a temperature range of 20.3 ± 4.7 degrees Celsius (67.5 ± 7.5 degrees Fahrenheit) and that is humidity-monitored.

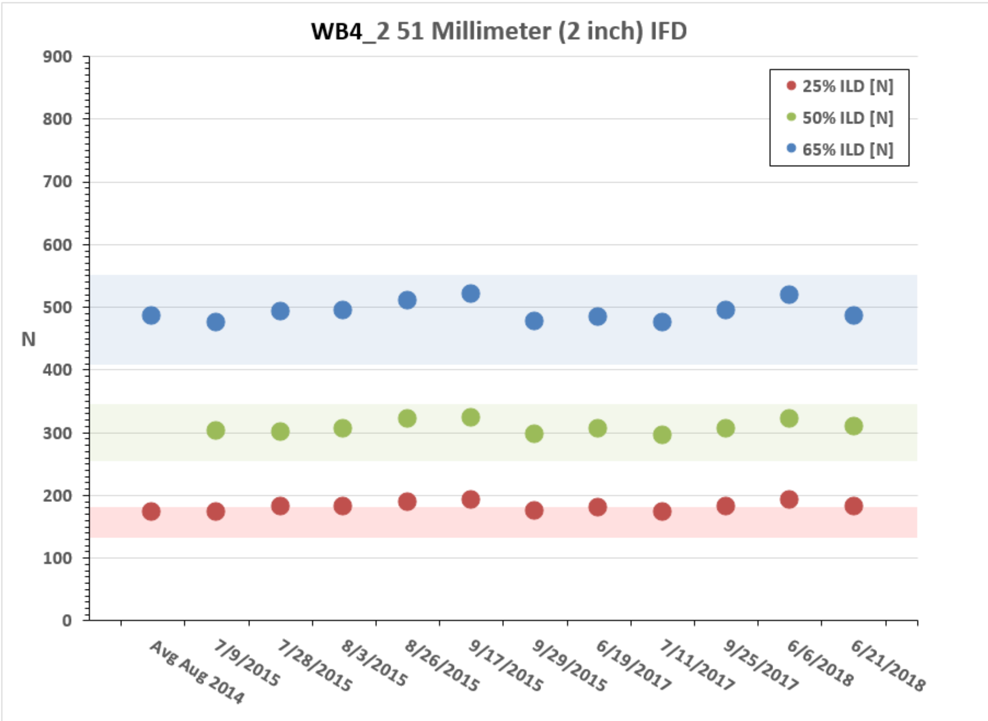
8. Record the temperature and relative humidity at the time of the test.

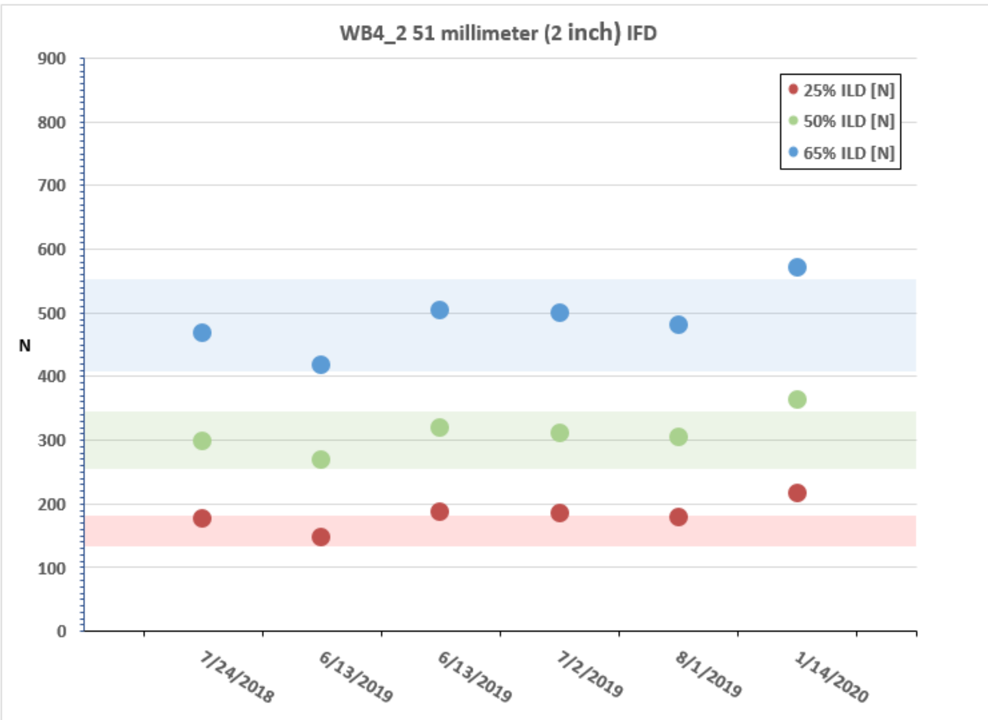
Table B1: Test Specifications for the Seat Back and Seat Pan Foams

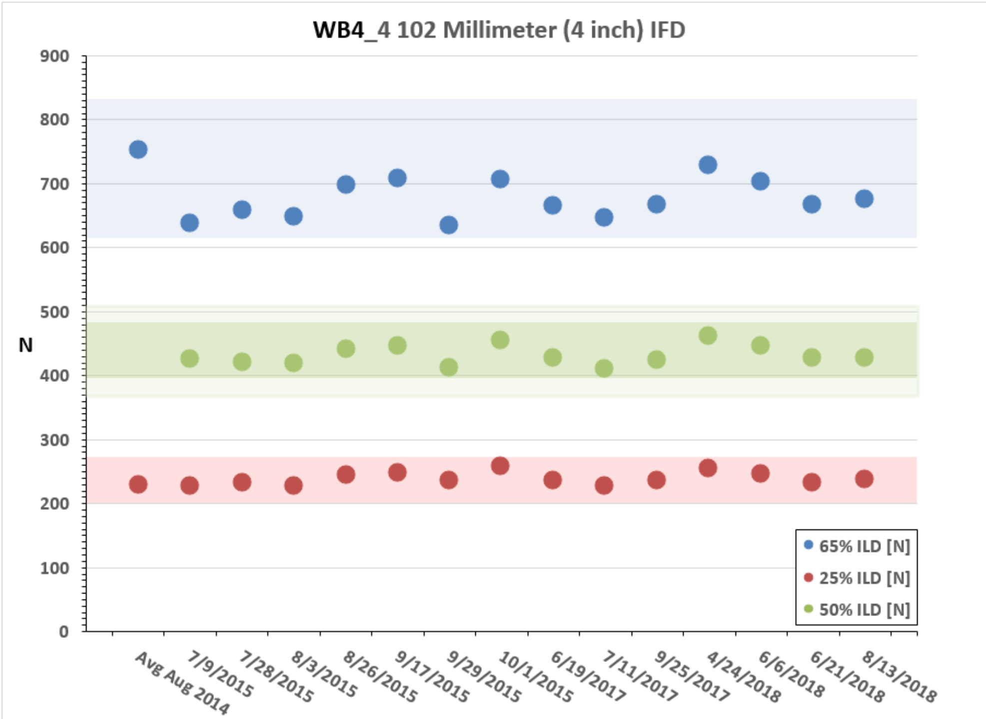
	IFD 25% N (lb) [range]	**IFD 50% N (lb) [range]**	**IFD 65% N (lb) [range]**
Seat Pan (102 mm)	237 (53.3) ±15% For reference	440 (98.9) ±15% [374-506]	725 (162.9) ±15% For reference
Seat Back (51 mm)	157 (35.3) For reference	300 (67.4) ±15% [255-345]	480 (107.9) For reference

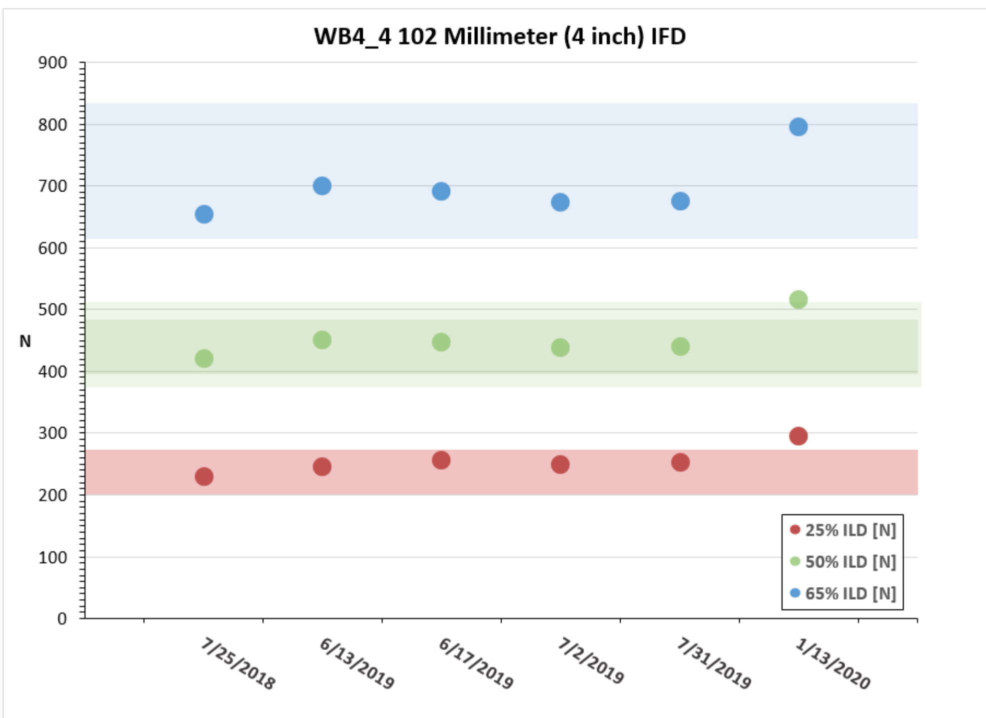
Appendix C: Foam IFD History

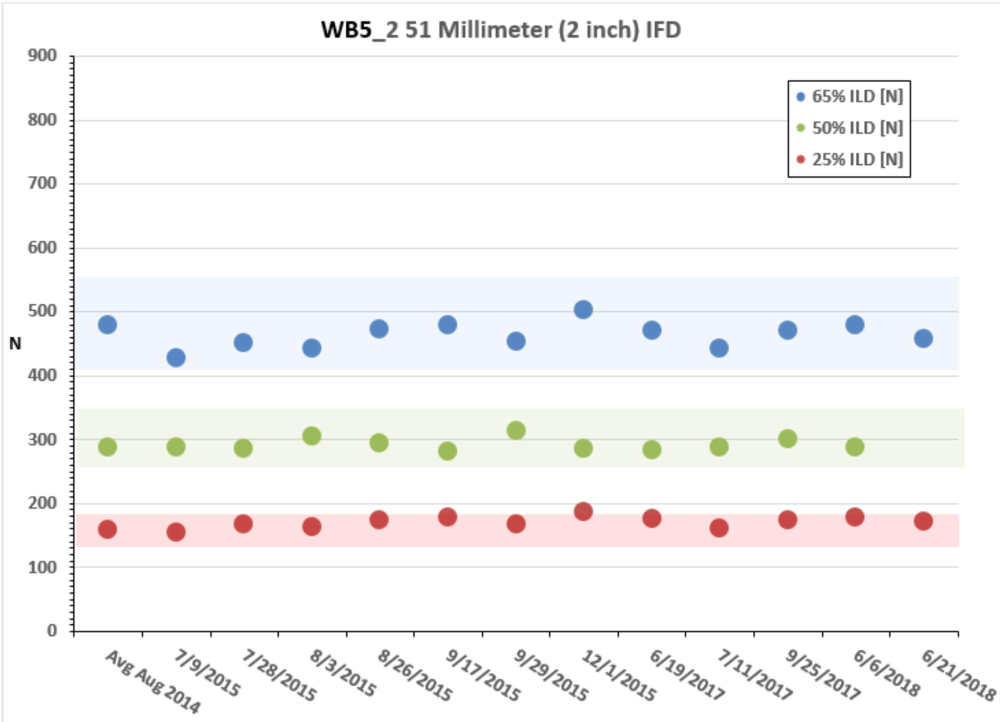
Since 2015, VRTC has tested the 51-millimeter (2-inch) and 102-millimeter (4-inch) foam sets (WB#4 through WB#14 and the WB foams received from Calspan), recording the 25%, 50%, and 65%, IFD values. This appendix contains plots showing each foam set's IFD values over this time frame.


WB4_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
0
100
200
300
400
500
600
700
800
900
Avg Aug 2014
7/9/2015
7/28/2015
8/3/2015
8/26/2015
9/17/2015
9/29/2015
6/19/2017
7/11/2017
9/25/2017
6/6/2018
6/21/2018


WB4_2 51 millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
0
100
200
300
400
500
600
700
800
900
7/24/2018
6/13/2019
6/13/2019
7/2/2019
8/1/2019
1/14/2020


WB4_4 102 Millimeter (4 inch) IFD
N
900
800
700
600
500
400
300
200
100
0
Avg Aug 2014
7/9/2015
7/28/2015
8/3/2015
8/26/2015
9/17/2015
9/29/2015
10/1/2015
6/19/2017
7/11/2017
9/25/2017
4/24/2018
6/6/2018
6/21/2018
8/13/2018
65% ILD [N]
25% ILD [N]
50% ILD [N]


WB4_4 102 Millimeter (4 inch) IFD
N
900
800
700
600
500
400
300
200
100
0
7/25/2018
6/13/2019
6/17/2019
7/2/2019
7/31/2019
1/13/2020
25% ILD [N]
50% ILD [N]
65% ILD [N]


WB5_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
Avg Aug 2014
7/9/2015
7/28/2015
8/3/2015
8/26/2015
9/17/2015
9/29/2015
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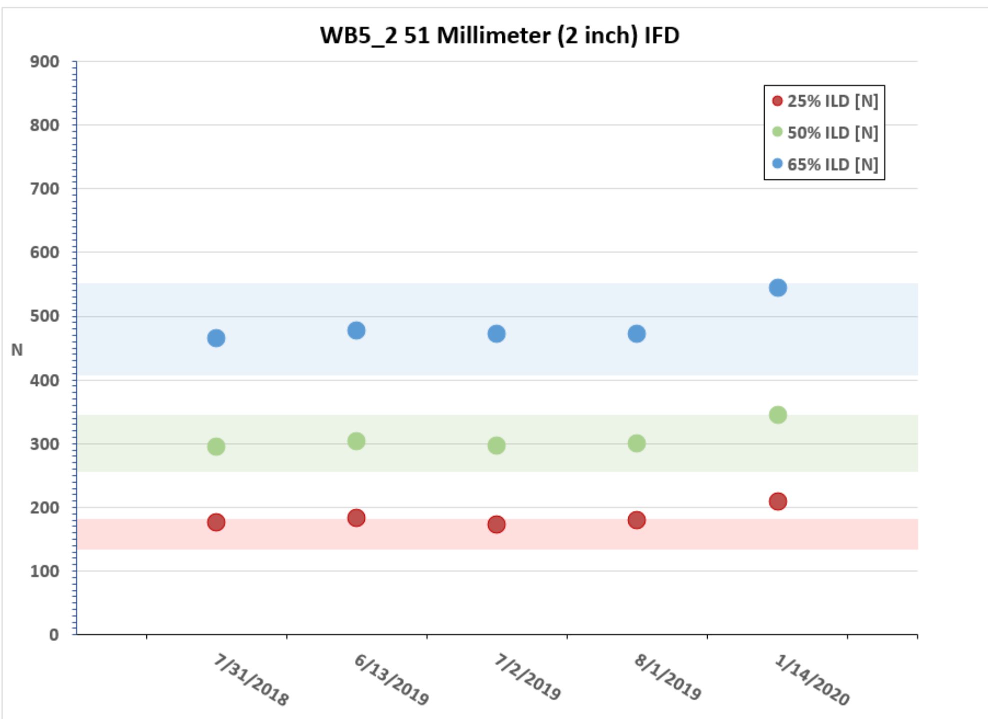
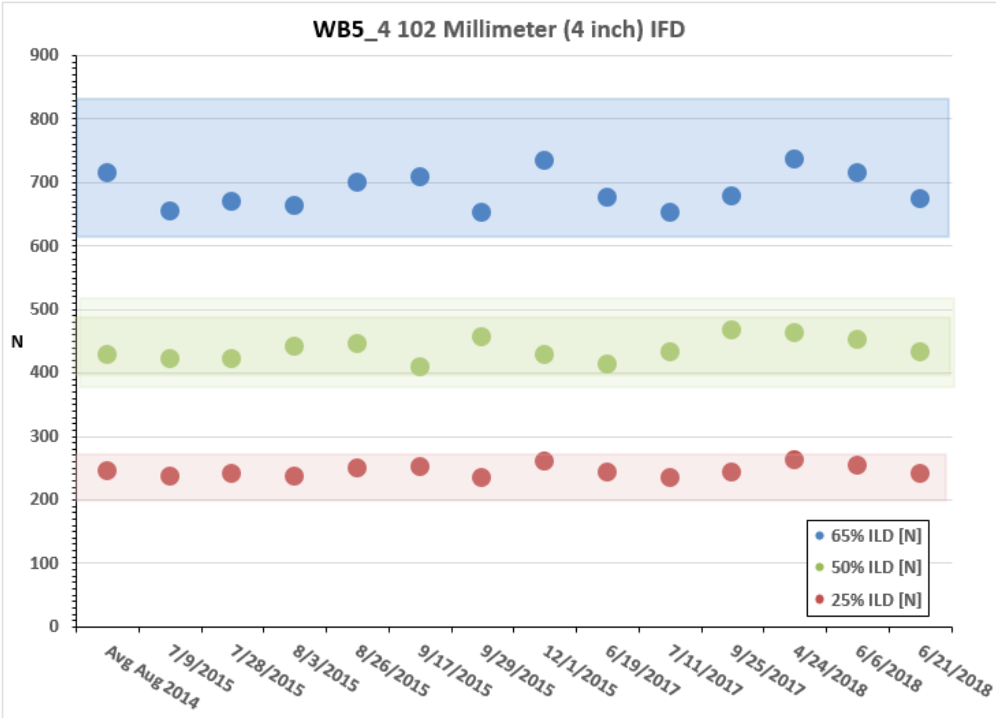
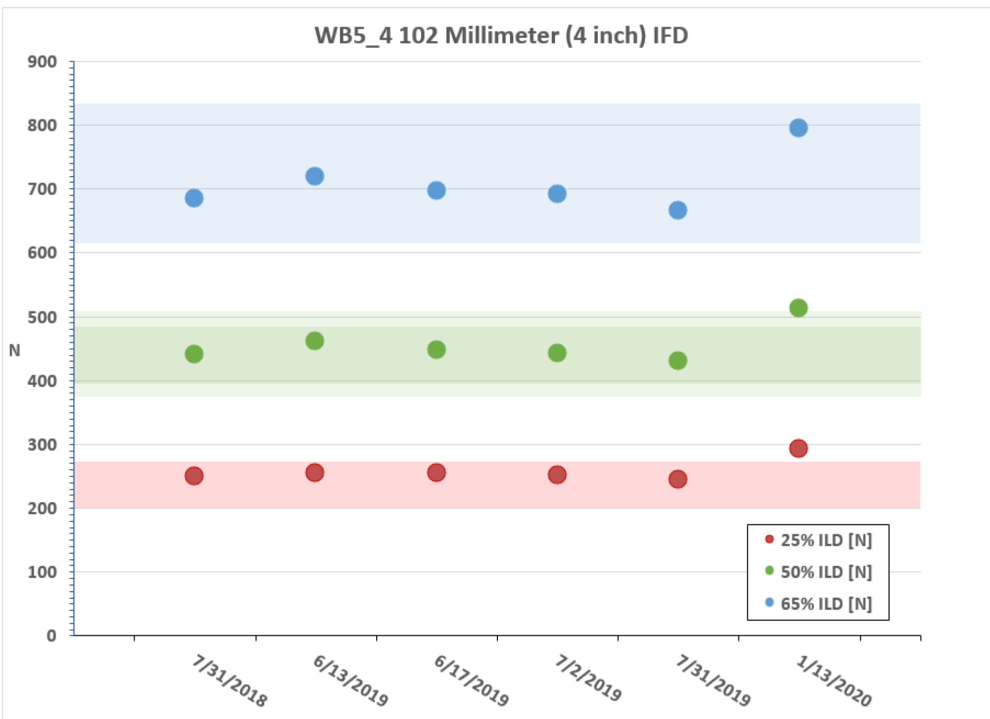
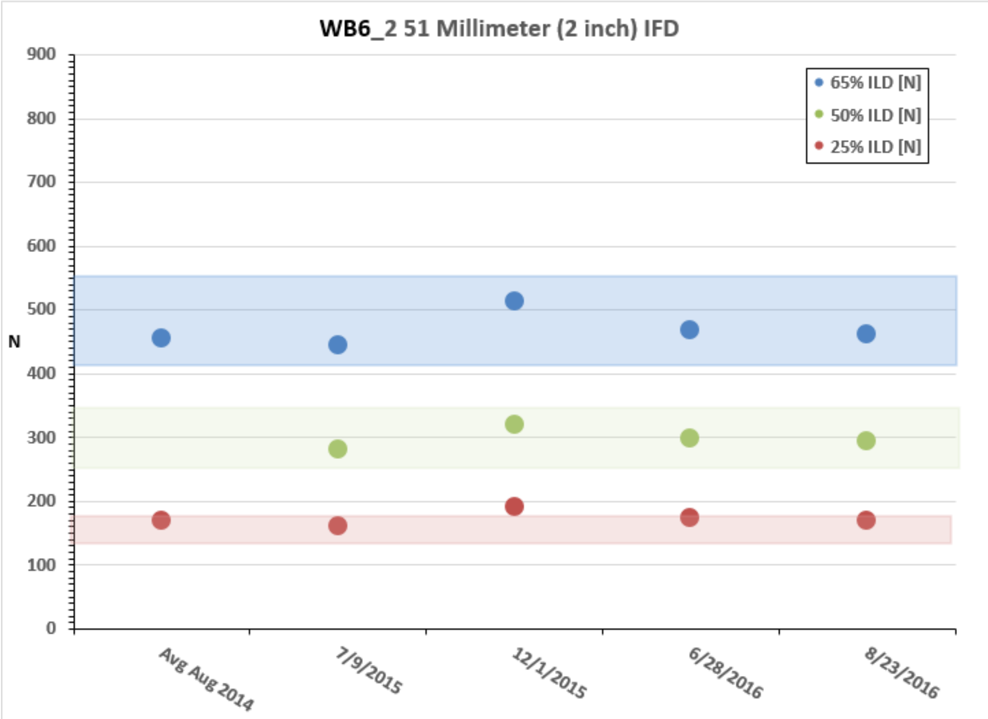
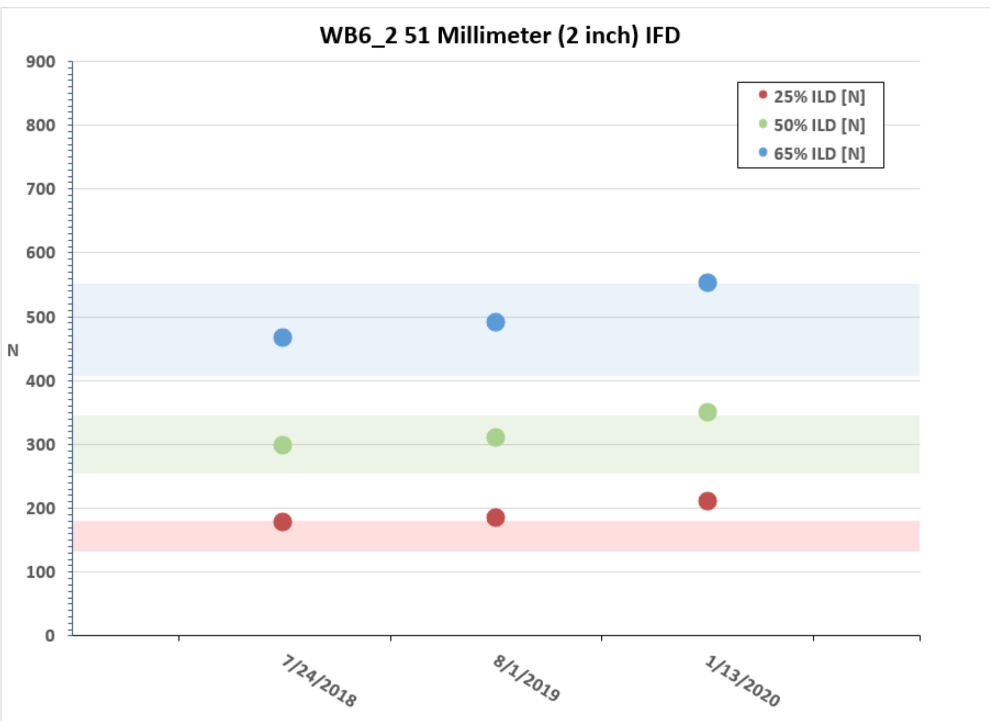
9/25/2017
6/6/2018
6/21/2018

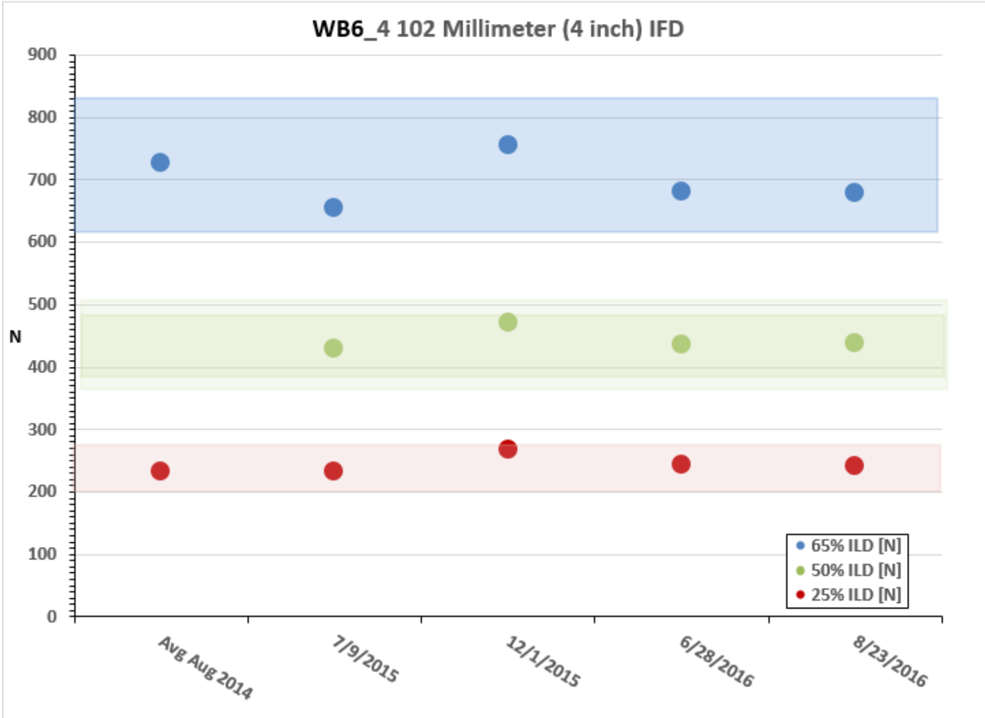

WB5_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/31/2018
6/13/2019
7/2/2019
8/1/2019
1/14/2020

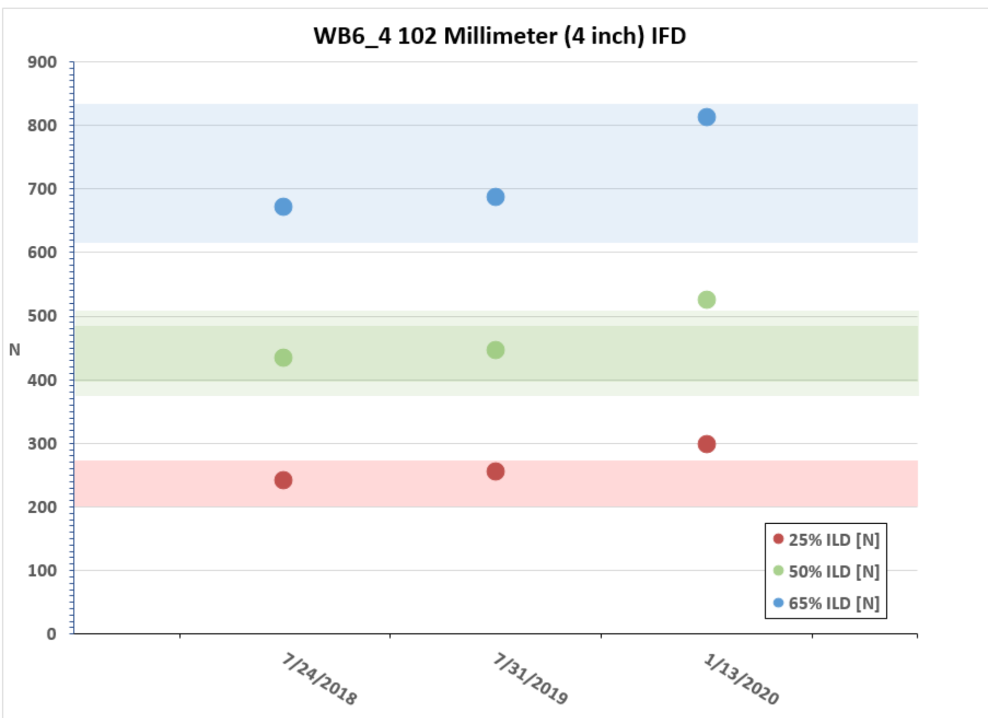

WB5_4 102 Millimeter (4 inch) IFD
N
900
800
700
600
500
400
300
200
100
0
Avg Aug 2014
7/9/2015
7/28/2015
8/3/2015
8/26/2015
9/17/2015
9/29/2015
12/1/2015
6/19/2017
7/11/2017
9/25/2017
4/24/2018
6/6/2018
6/21/2018
65% ILD [N]
50% ILD [N]
25% ILD [N]

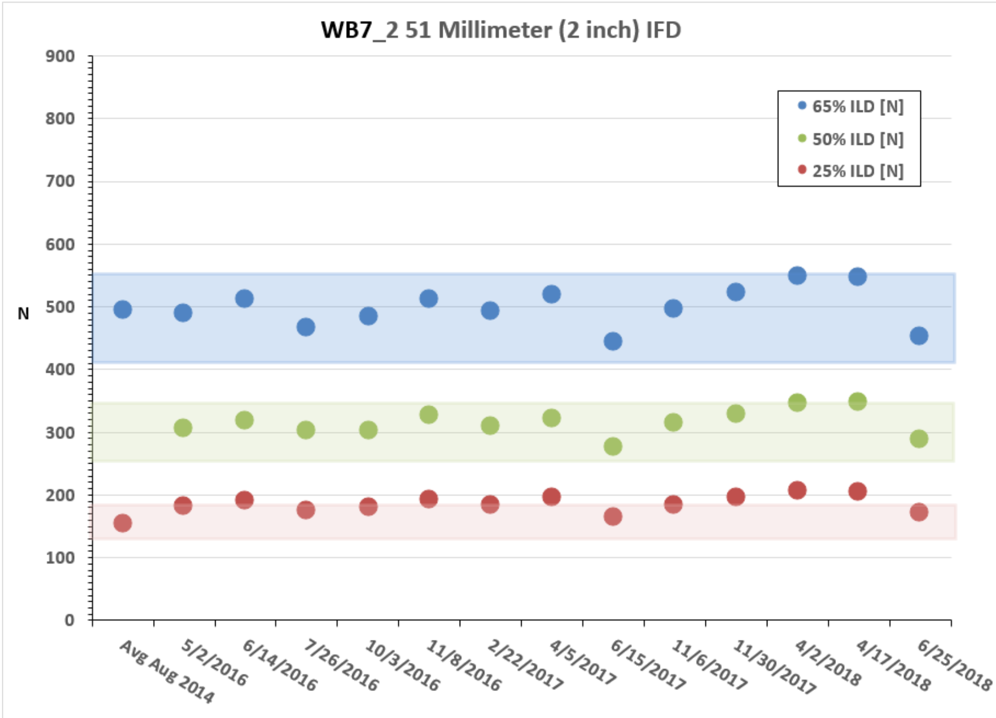

WB5_4 102 Millimeter (4 inch) IFD
N
900
800
700
600
500
400
300
200
100
0
7/31/2018
6/13/2019
6/17/2019
7/2/2019
7/31/2019
1/13/2020
25% ILD [N]
50% ILD [N]
65% ILD [N]

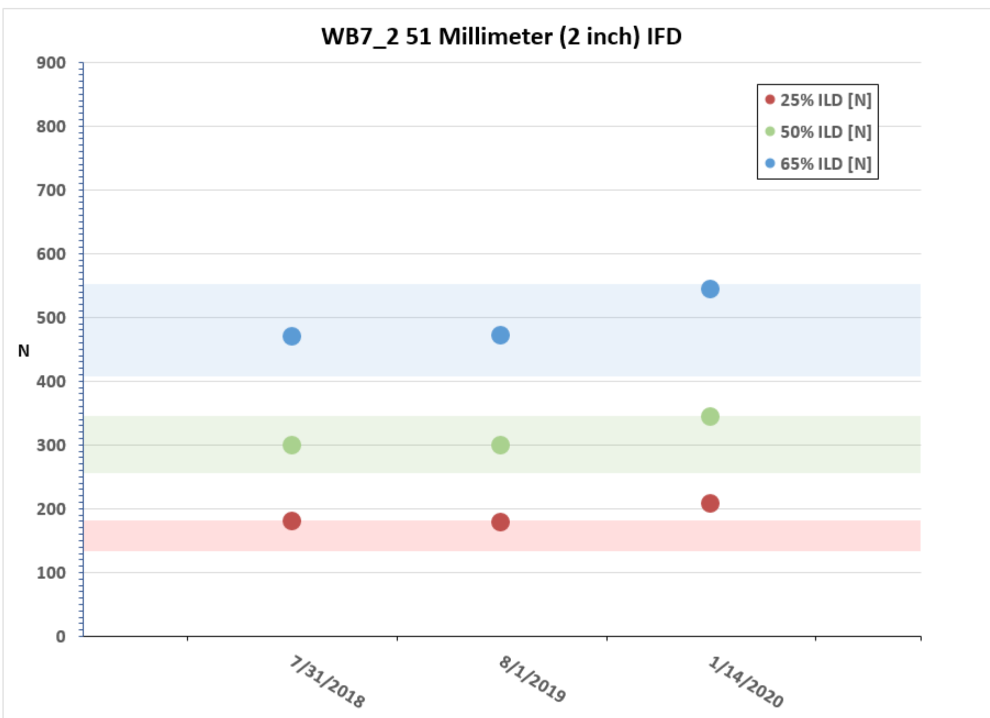

WB6_2 51 Millimeter (2 inch) IFD
65% ILD [N]
50% ILD [N]
25% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
Avg Aug 2014
7/9/2015
12/1/2015
6/28/2016
8/23/2016

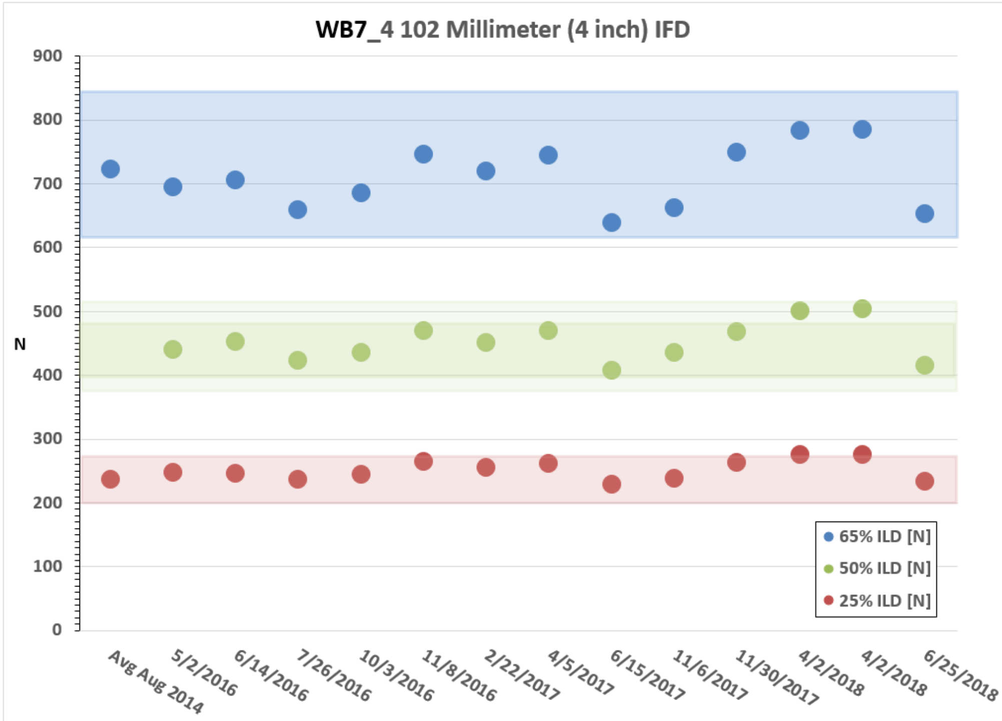

WB6_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
7/24/2018
8/1/2019
1/13/2020

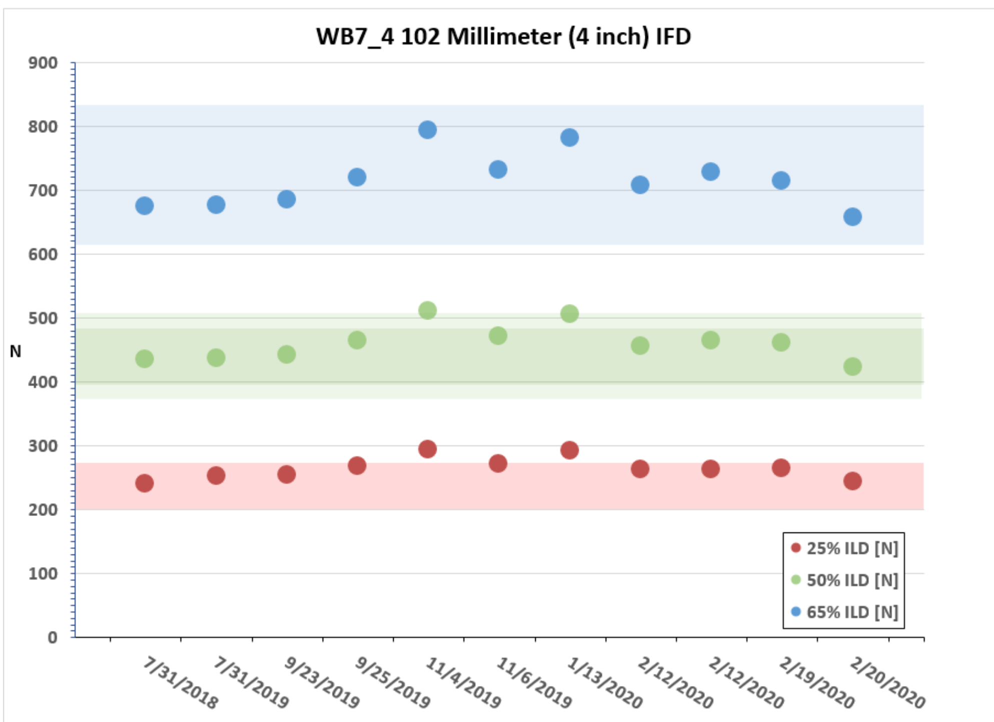

WB6_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
65% ILD [N]
50% ILD [N]
25% ILD [N]
Avg Aug 2014
7/9/2015
12/1/2015
6/28/2016
8/23/2016


WB6_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/24/2018
7/31/2019
1/13/2020


WB7_2 51 Millimeter (2 inch) IFD
65% ILD [N]
50% ILD [N]
25% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
Avg Aug 2014
5/2/2016
6/14/2016
7/26/2016
10/3/2016
11/8/2016
2/22/2017
4/5/2017
6/15/2017
11/6/2017
11/30/2017
4/2/2018
4/17/2018
6/25/2018


WB7_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
7/31/2018
8/1/2019
1/14/2020


WB7_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
65% ILD [N]
50% ILD [N]
25% ILD [N]
Avg Aug 2014
5/2/2016
6/14/2016
7/26/2016
10/3/2016
11/8/2016
2/22/2017
4/5/2017
6/15/2017
11/6/2017
11/30/2017
4/2/2018
4/2/2018
6/25/2018


WB7_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/31/2018
7/31/2019
9/23/2019
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11/4/2019
11/6/2019
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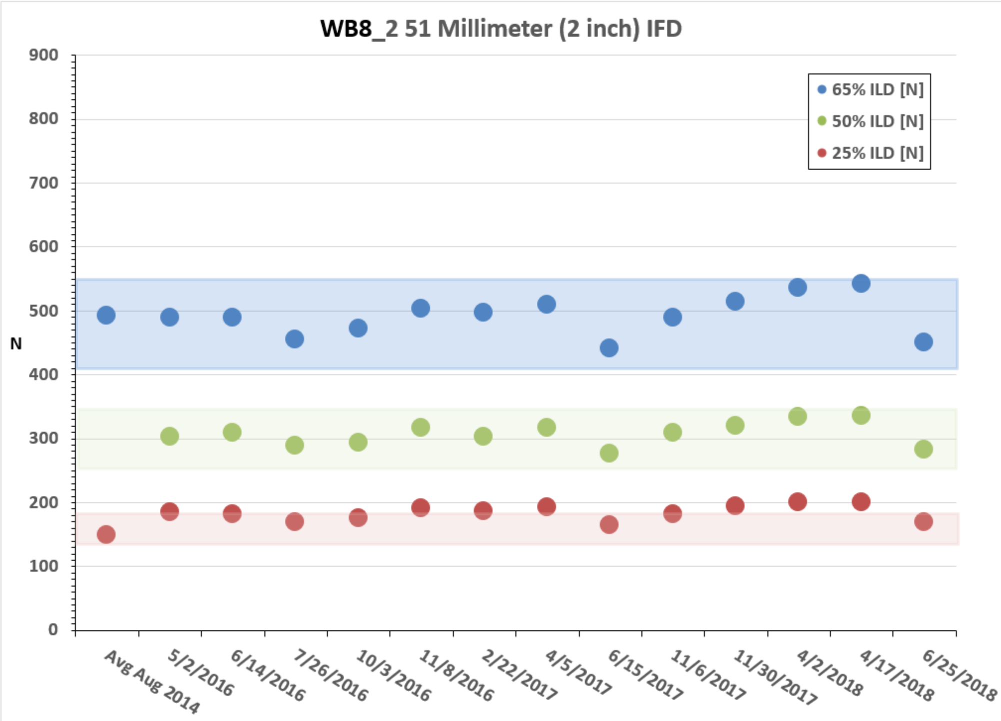
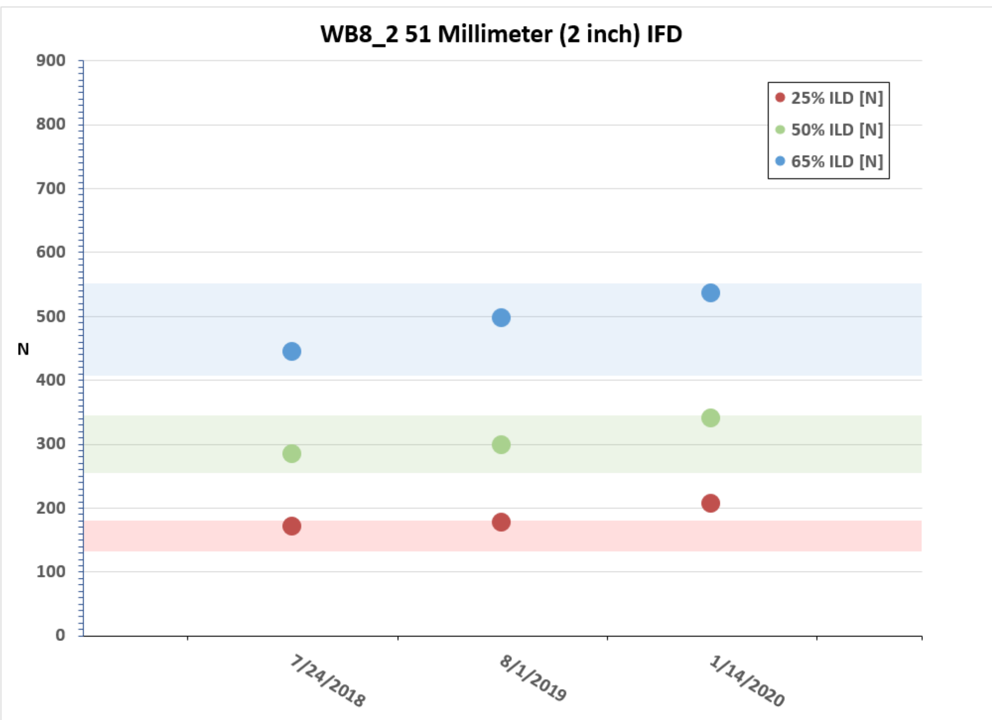
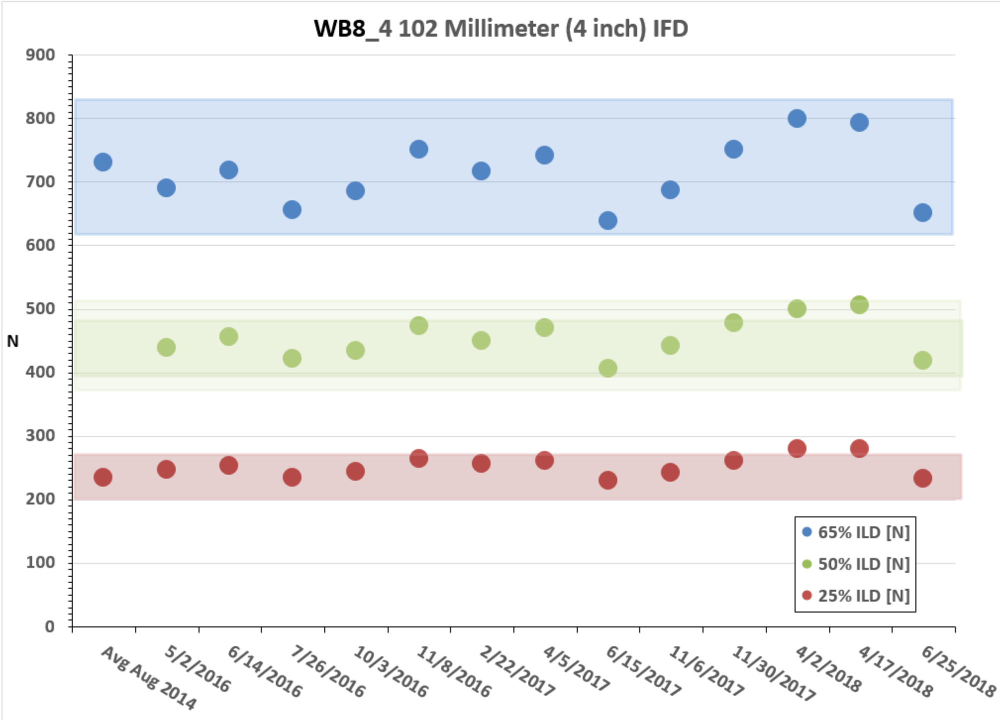
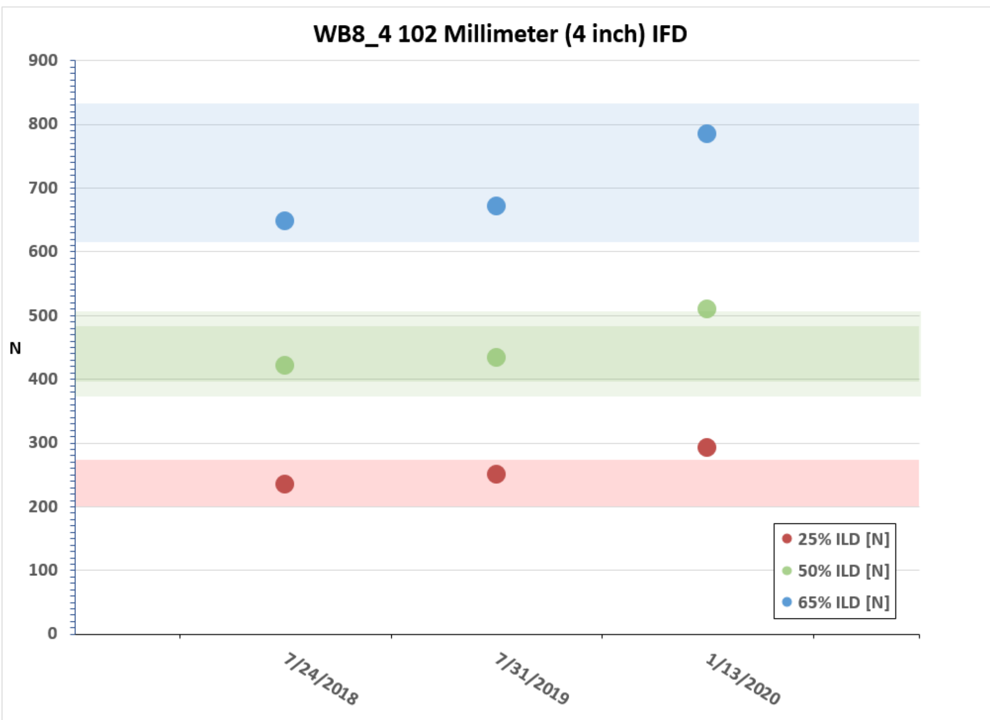
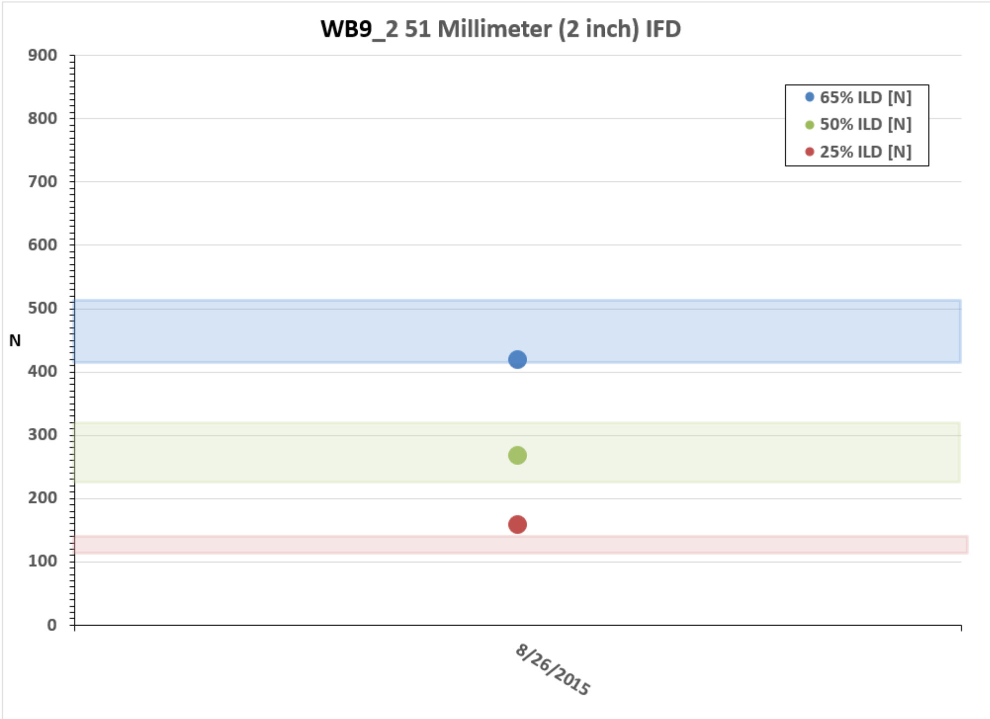
2/12/2020
2/19/2020
2/20/2020

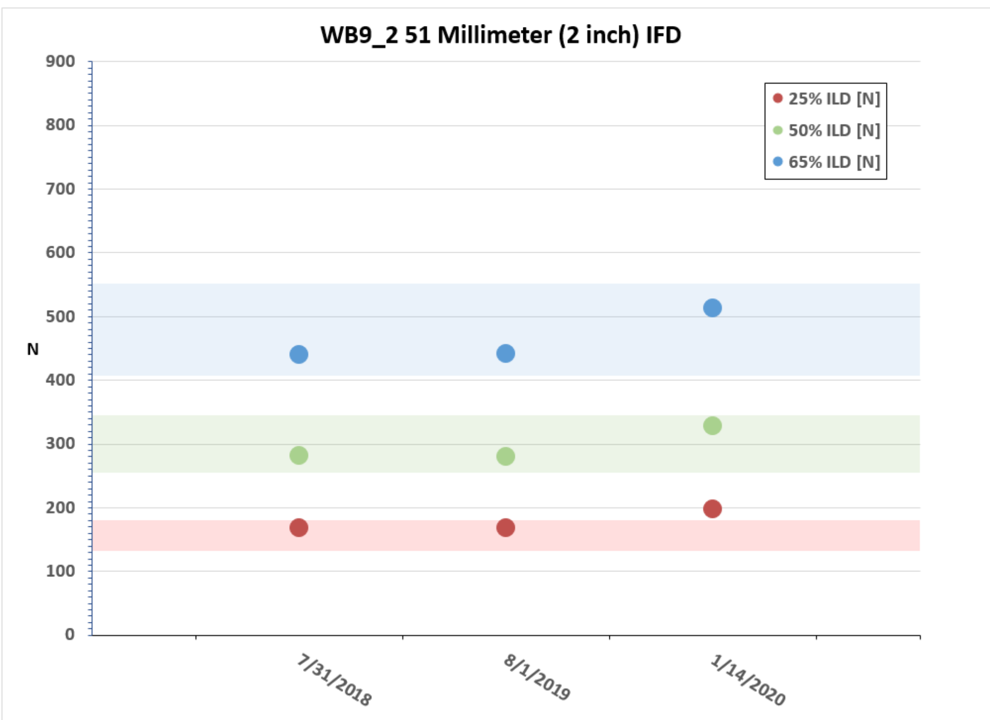

WB8_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
Avg Aug 2014
5/2/2016
6/14/2016
7/26/2016
10/3/2016
11/8/2016
2/22/2017
4/5/2017
6/15/2017
11/6/2017
11/30/2017
4/2/2018
4/17/2018
6/25/2018

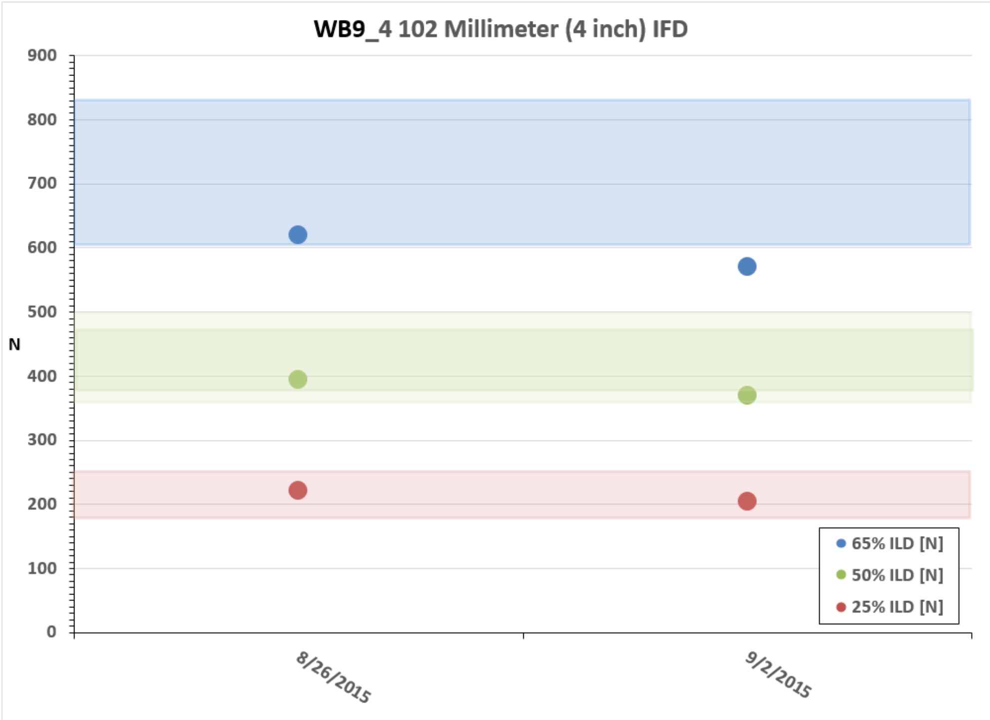

WB8_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/24/2018
8/1/2019
1/14/2020

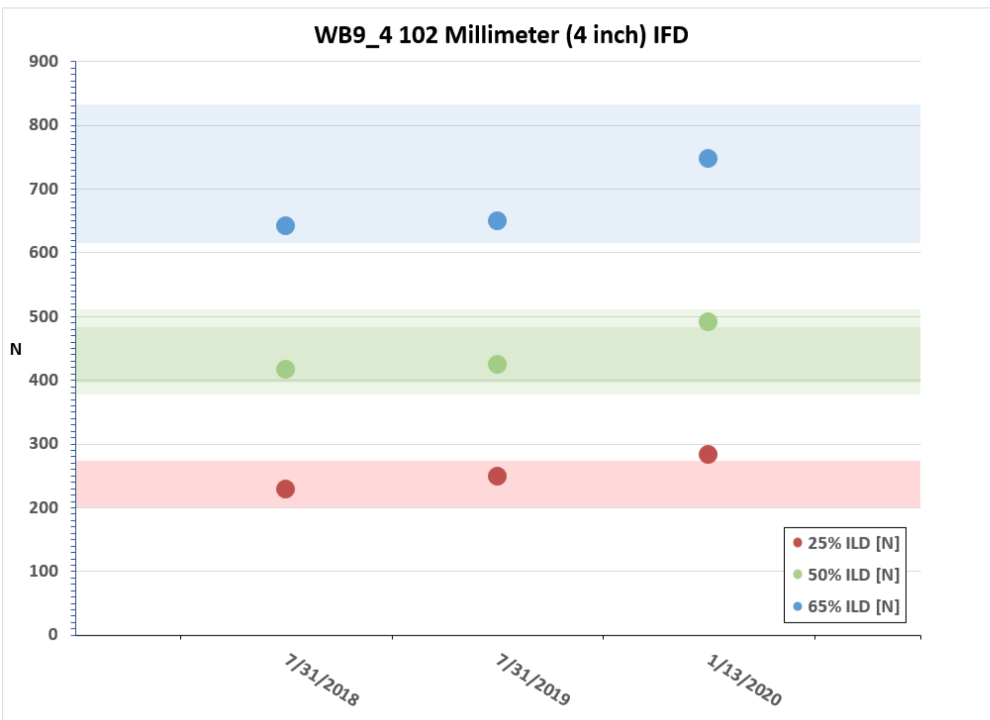

WB8_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
Avg Aug 2014
5/2/2016
6/14/2016
7/26/2016
10/3/2016
11/8/2016
2/22/2017
4/5/2017
6/15/2017
11/6/2017
11/30/2017
4/2/2018
4/17/2018
6/25/2018

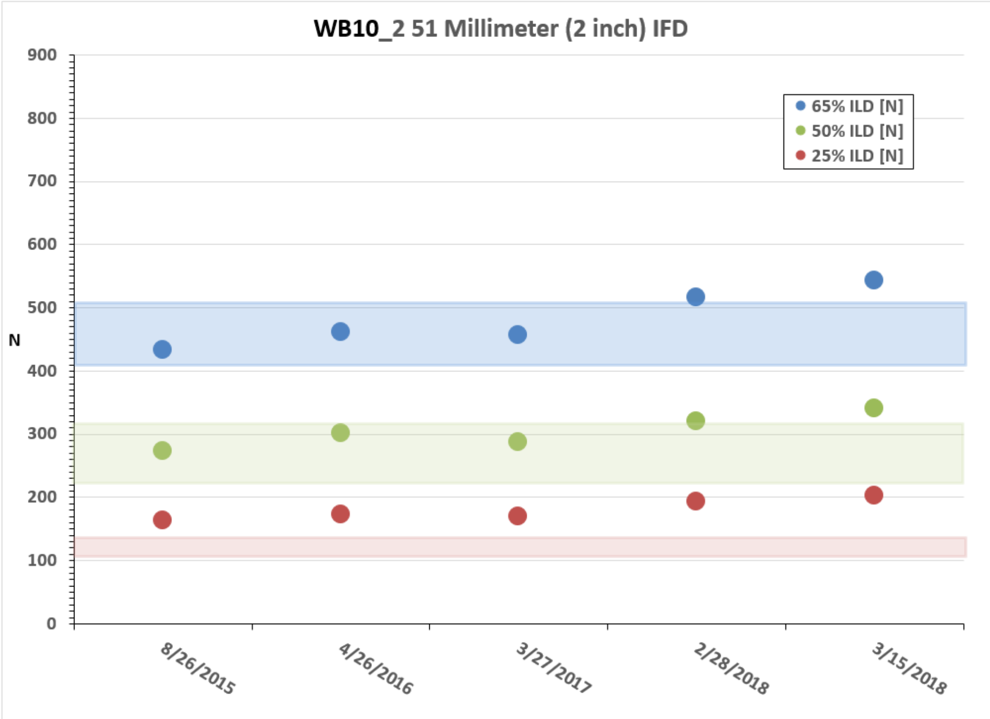

WB8_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/24/2018
7/31/2019
1/13/2020

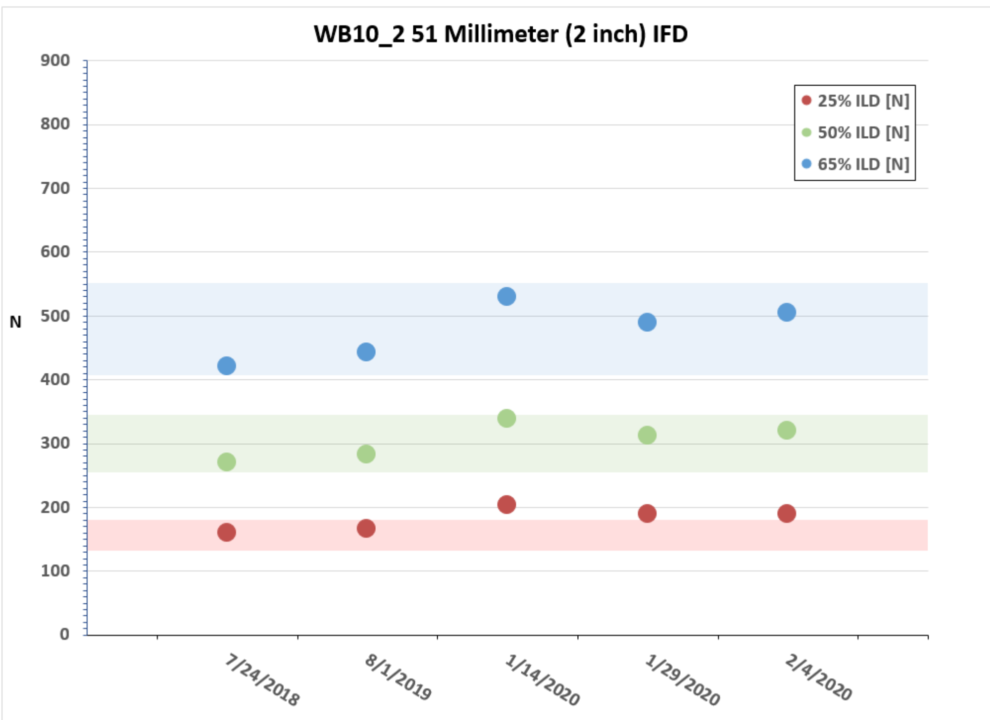

WB9_2 51 Millimeter (2 inch) IFD
65% ILD [N]
50% ILD [N]
25% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
8/26/2015

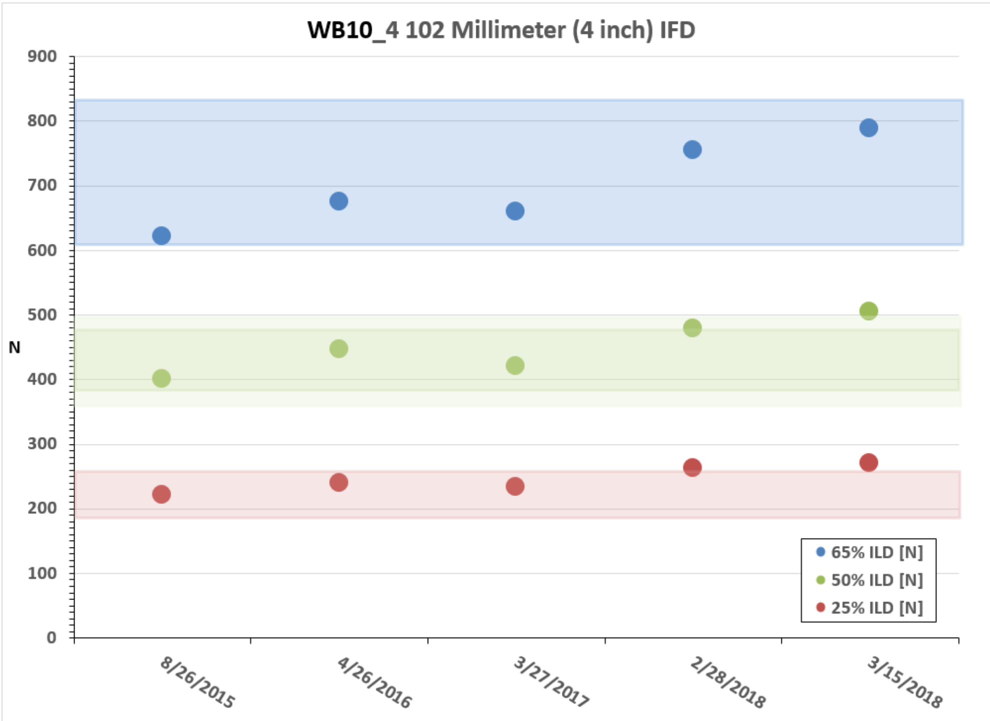

WB9_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
7/31/2018
8/1/2019
1/14/2020

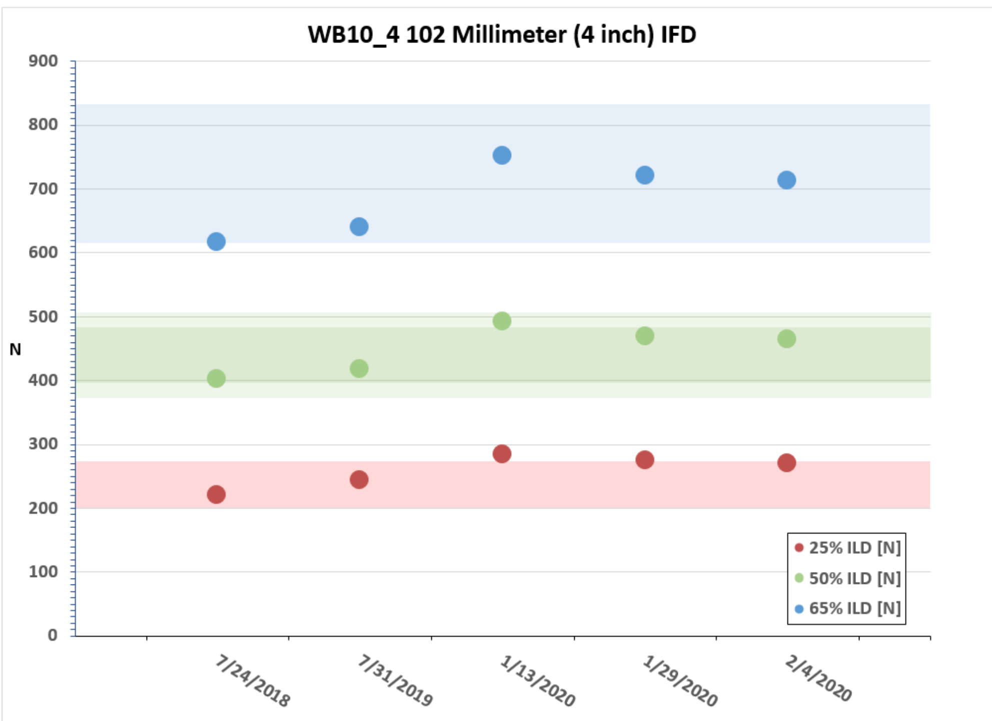

WB9_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
8/26/2015
9/2/2015
65% ILD [N]
50% ILD [N]
25% ILD [N]

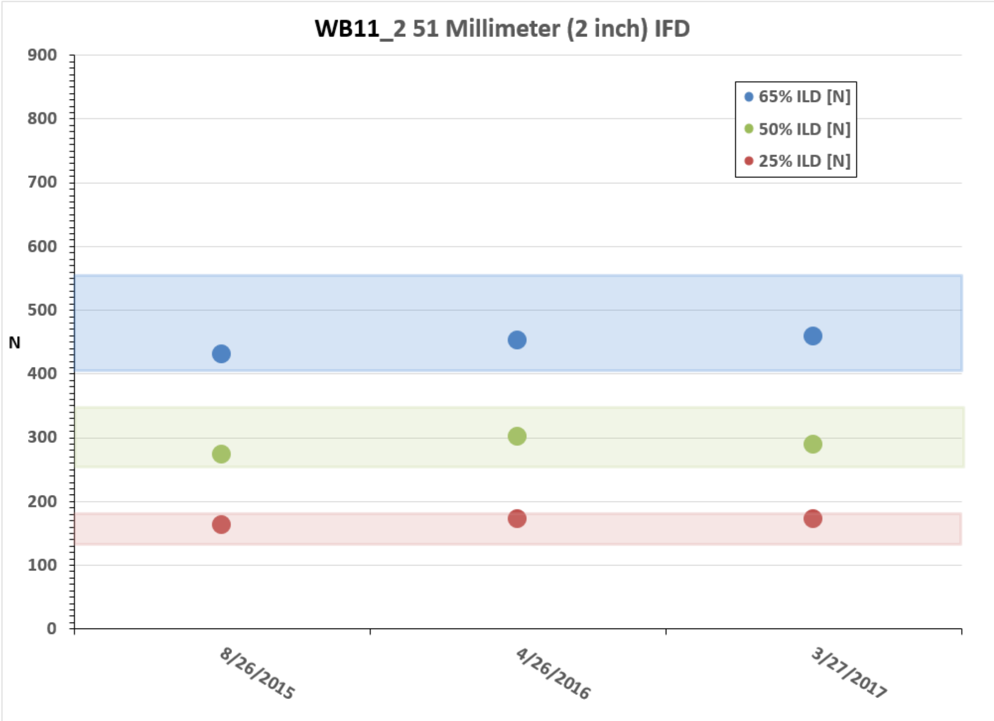

WB9_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
7/31/2018
7/31/2019
1/13/2020
25% ILD [N]
50% ILD [N]
65% ILD [N]


WB10_2 51 Millimeter (2 inch) IFD
65% ILD [N]
50% ILD [N]
25% ILD [N]
N
0
100
200
300
400
500
600
700
800
900
8/26/2015
4/26/2016
3/27/2017
2/28/2018
3/15/2018

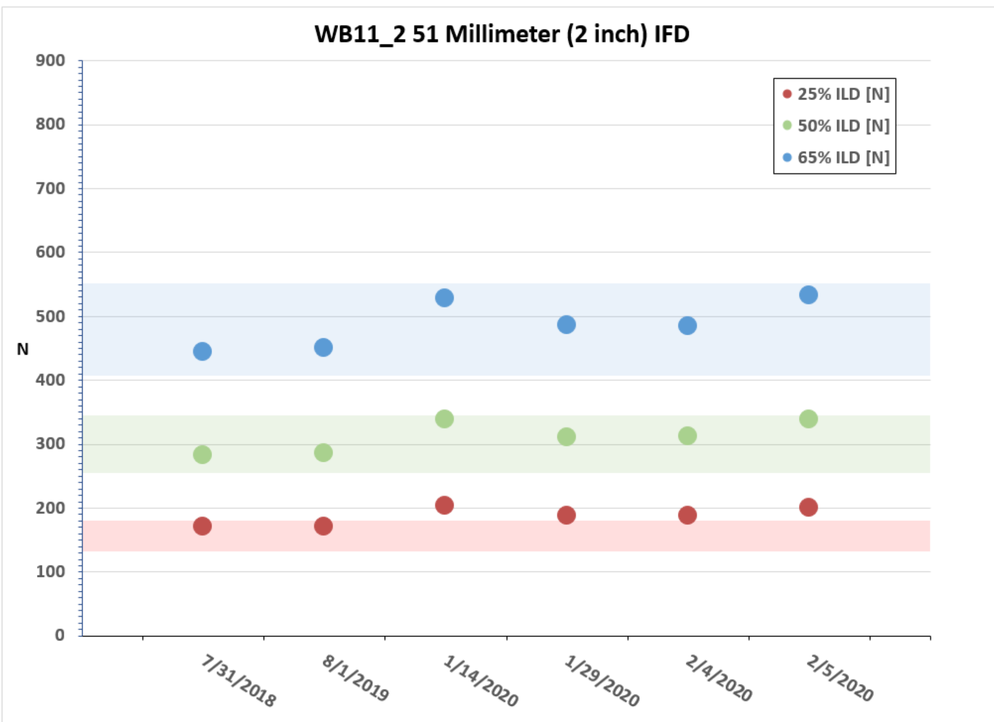

WB10_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
0
100
200
300
400
500
600
700
800
900
7/24/2018
8/1/2019
1/14/2020
1/29/2020
2/4/2020


WB10_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
8/26/2015
4/26/2016
3/27/2017
2/28/2018
3/15/2018
65% ILD [N]
50% ILD [N]
25% ILD [N]

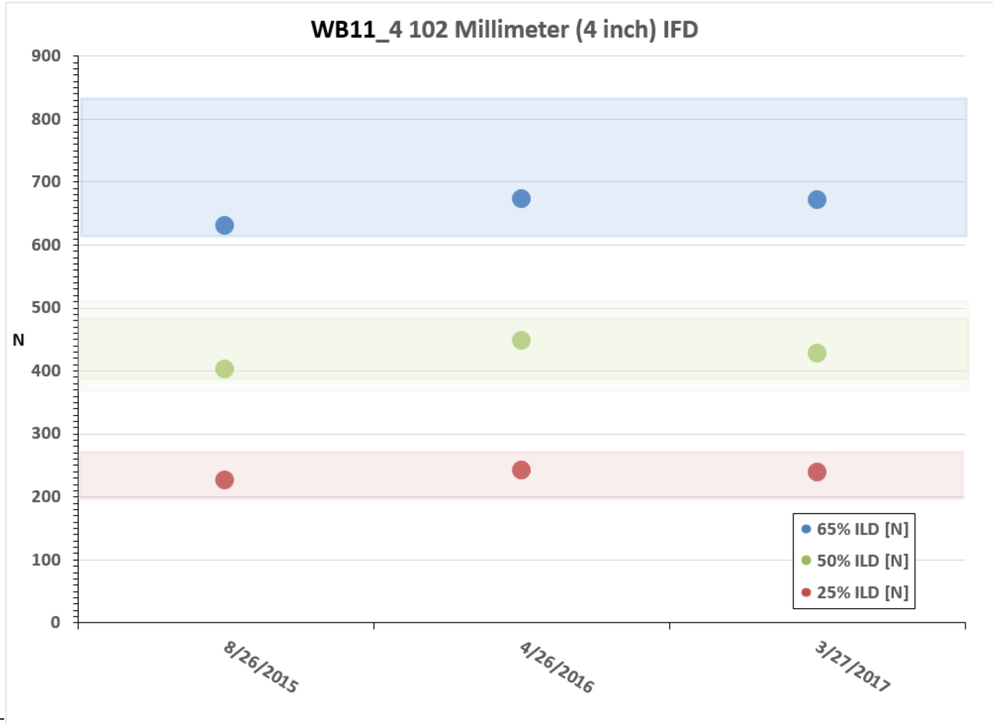

WB10_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
7/24/2018
7/31/2019
1/13/2020
1/29/2020
2/4/2020
25% ILD [N]
50% ILD [N]
65% ILD [N]

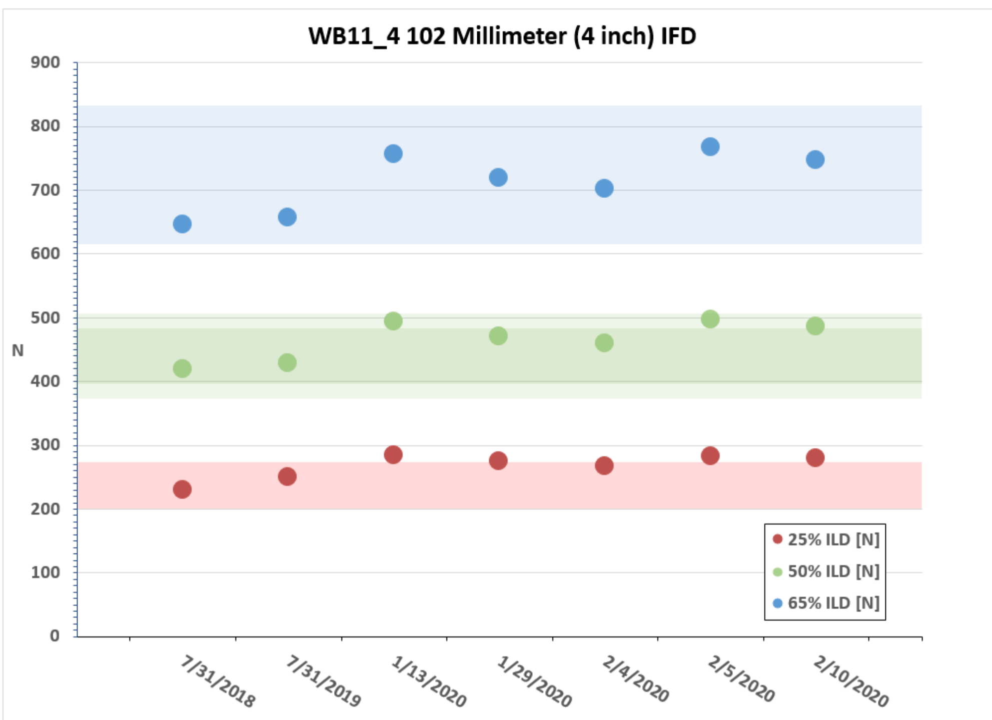


WB11_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
8/26/2015
4/26/2016
3/27/2017

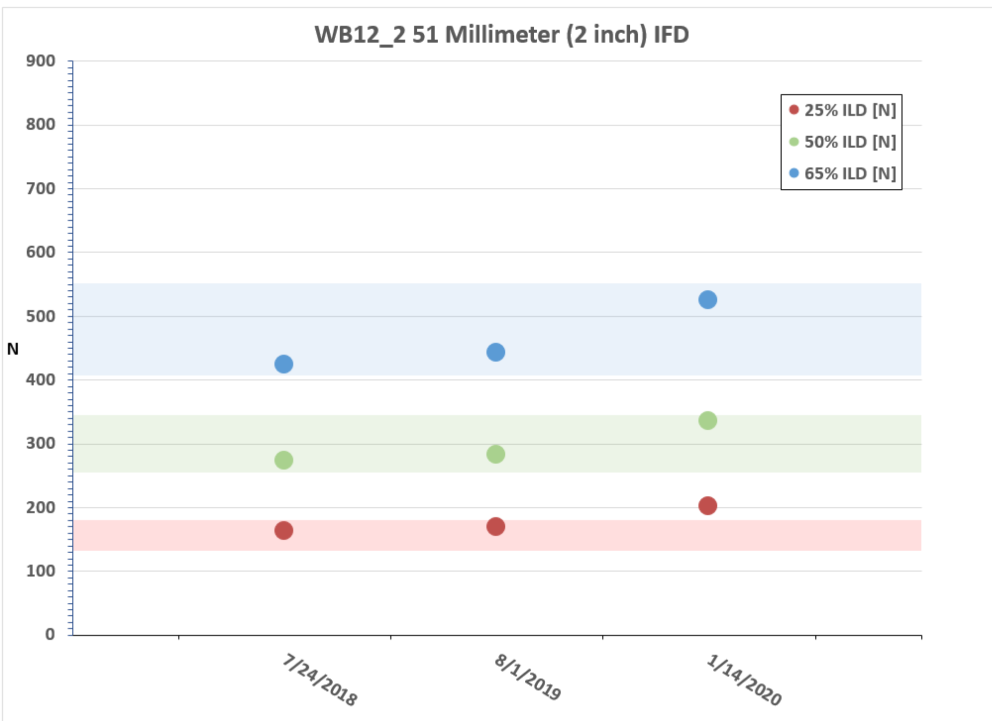


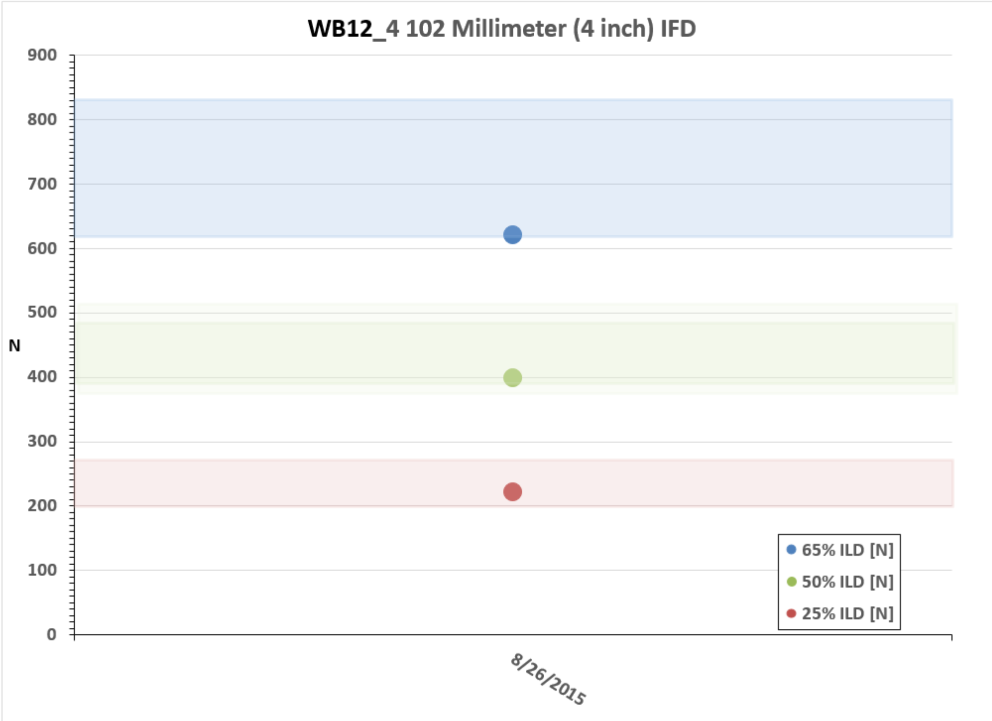
WB11_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/31/2018
8/1/2019
1/14/2020
1/29/2020
2/4/2020
2/5/2020

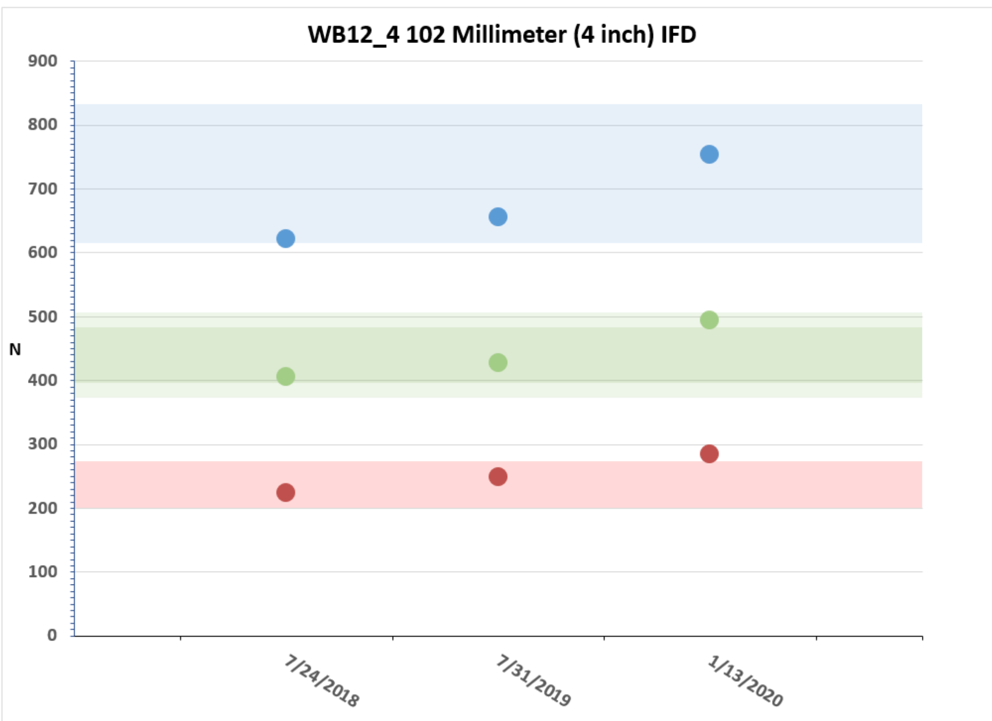

WB11_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
8/26/2015
4/26/2016
3/27/2017

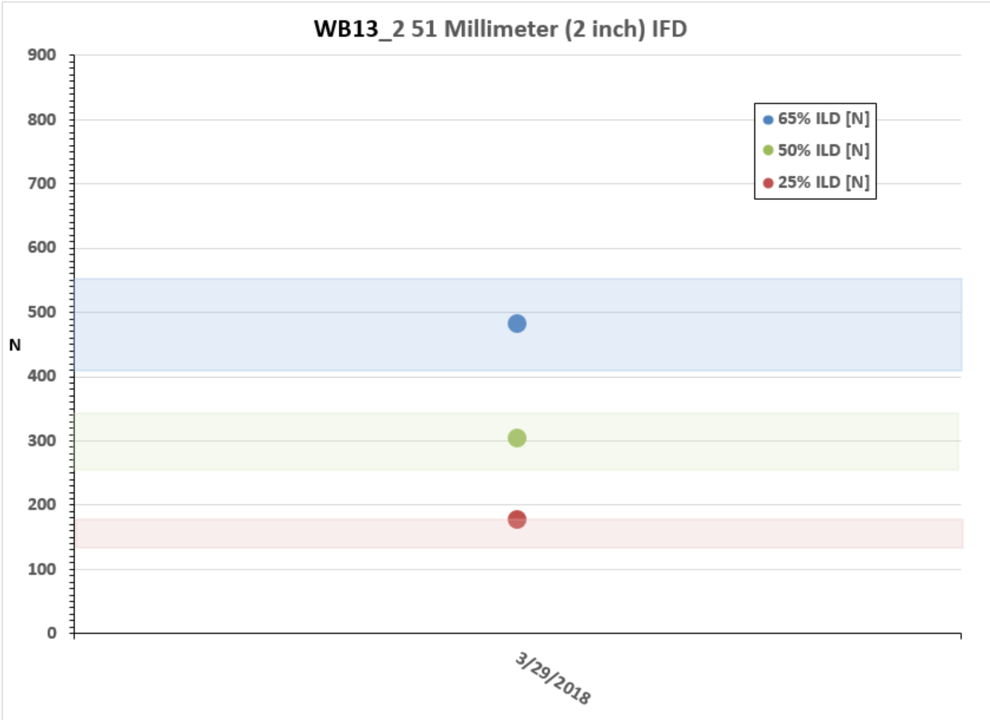

WB11_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/31/2018
7/31/2019
1/13/2020
1/29/2020
2/4/2020
2/5/2020
2/10/2020


WB12_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
8/26/2015

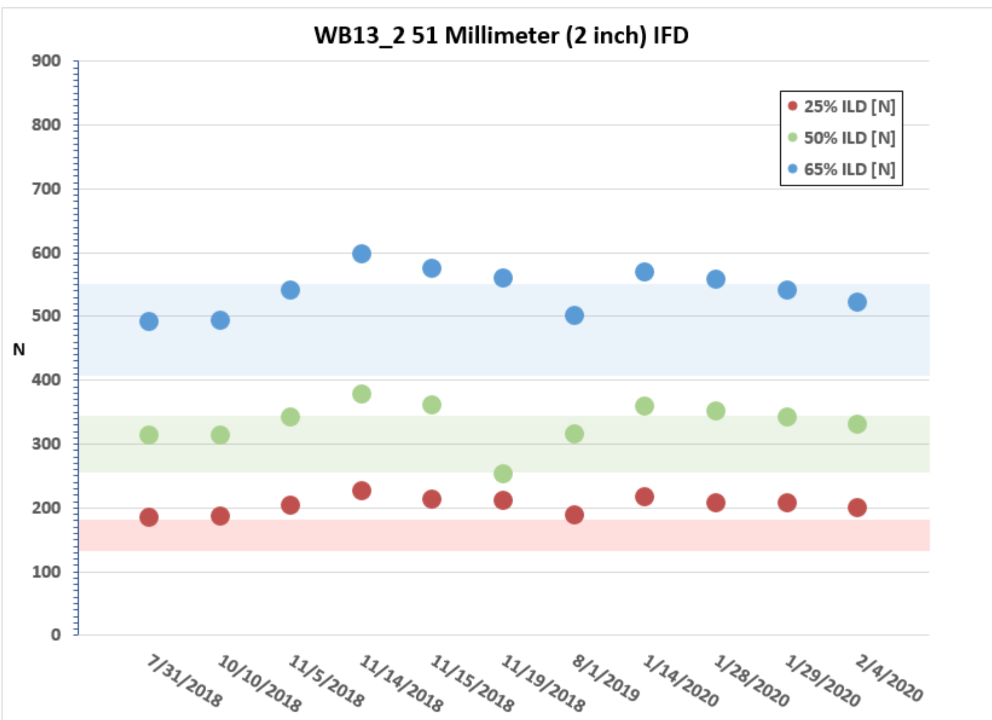

WB12_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/24/2018
8/1/2019
1/14/2020


WB12_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
8/26/2015

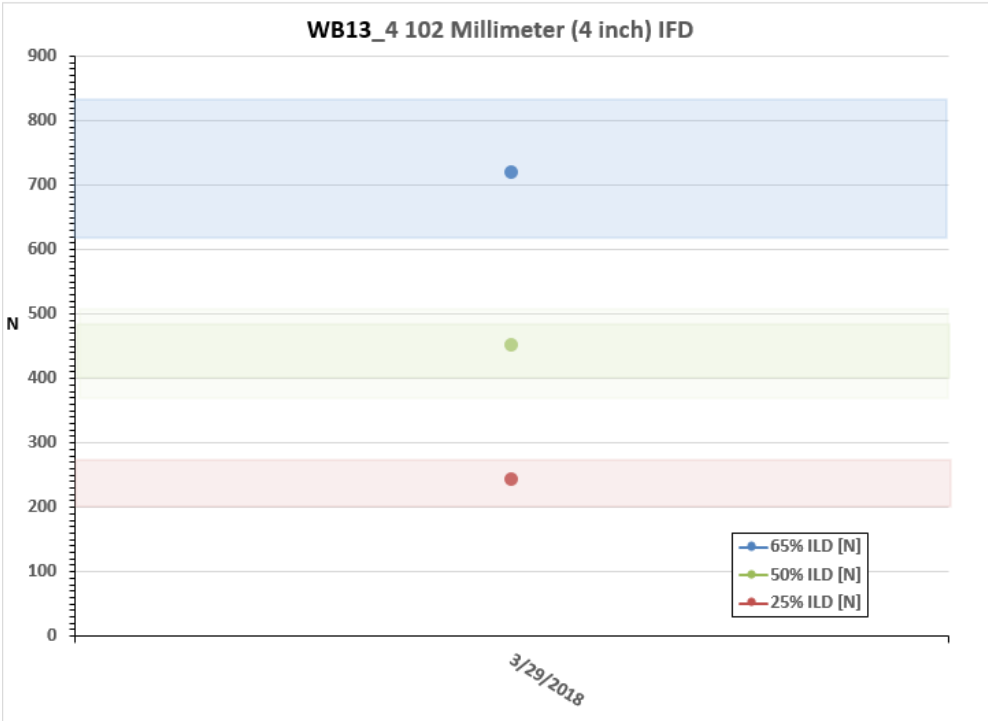

WB12_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
7/24/2018
7/31/2019
1/13/2020



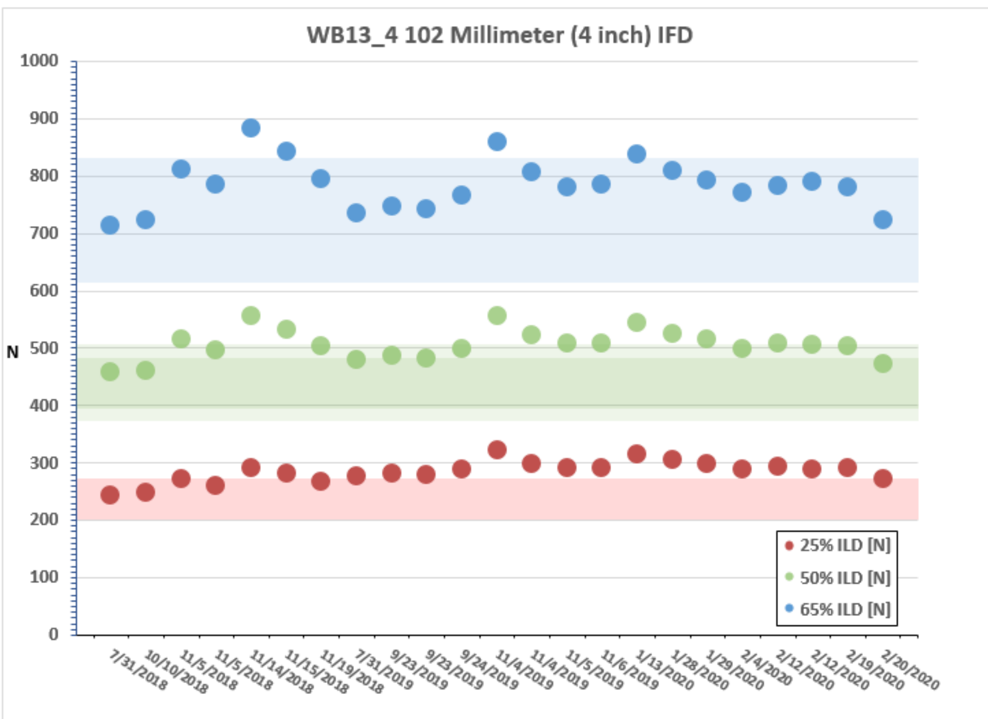
WB13_2 51 Millimeter (2 inch) IFD
65% ILD [N]
50% ILD [N]
25% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
3/29/2018



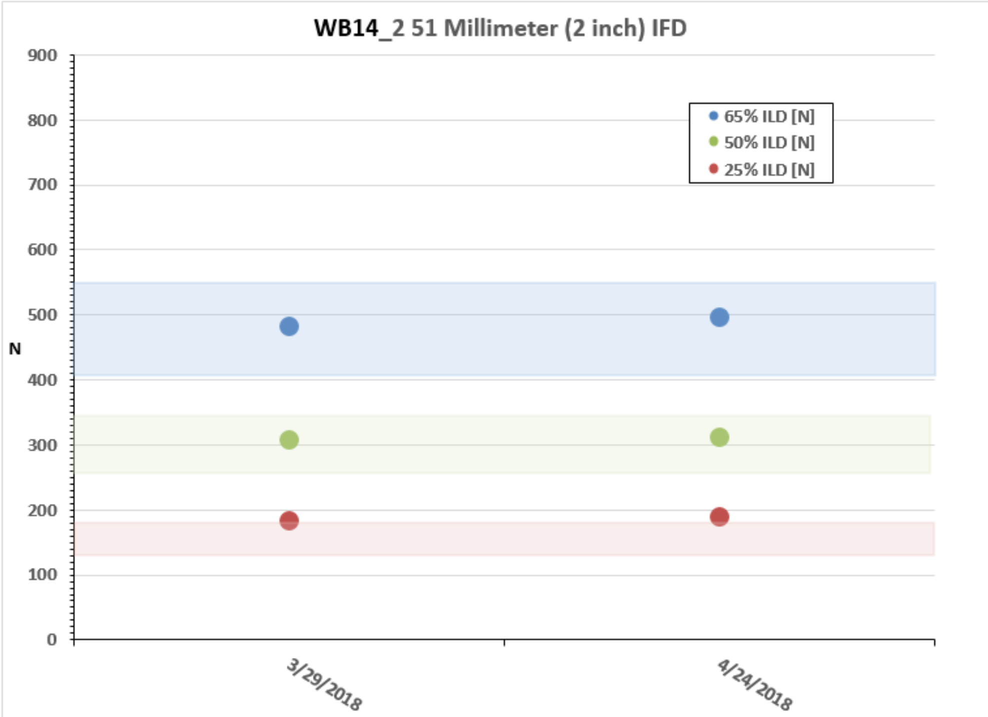
WB13_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
7/31/2018
10/10/2018
11/5/2018
11/14/2018
11/15/2018
11/19/2018
8/1/2019
1/14/2020
1/28/2020
1/29/2020
2/4/2020

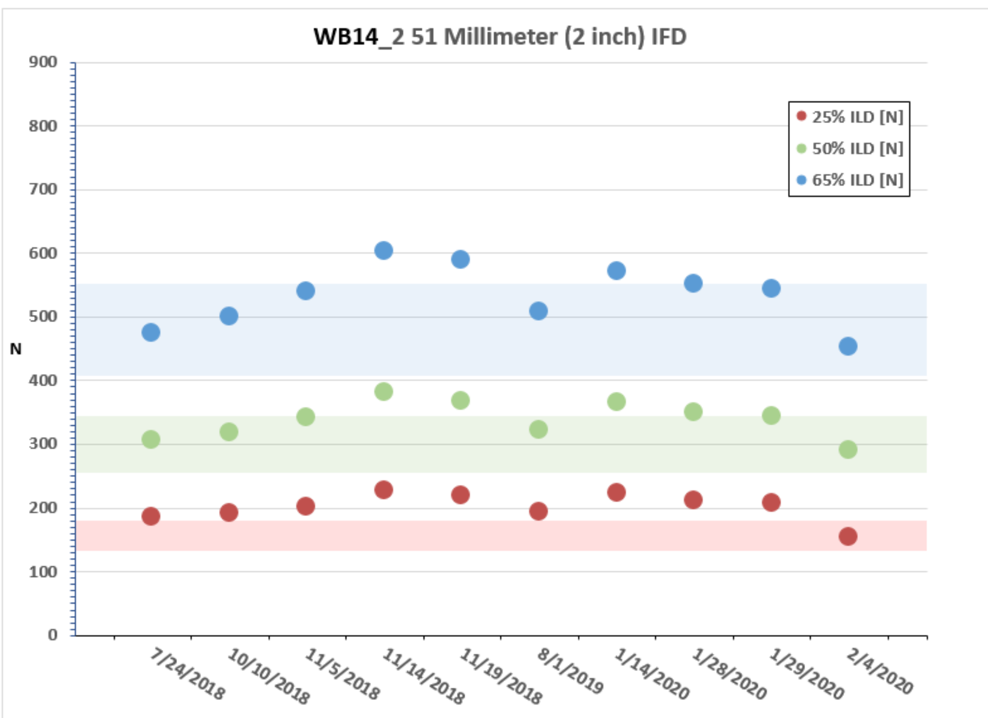


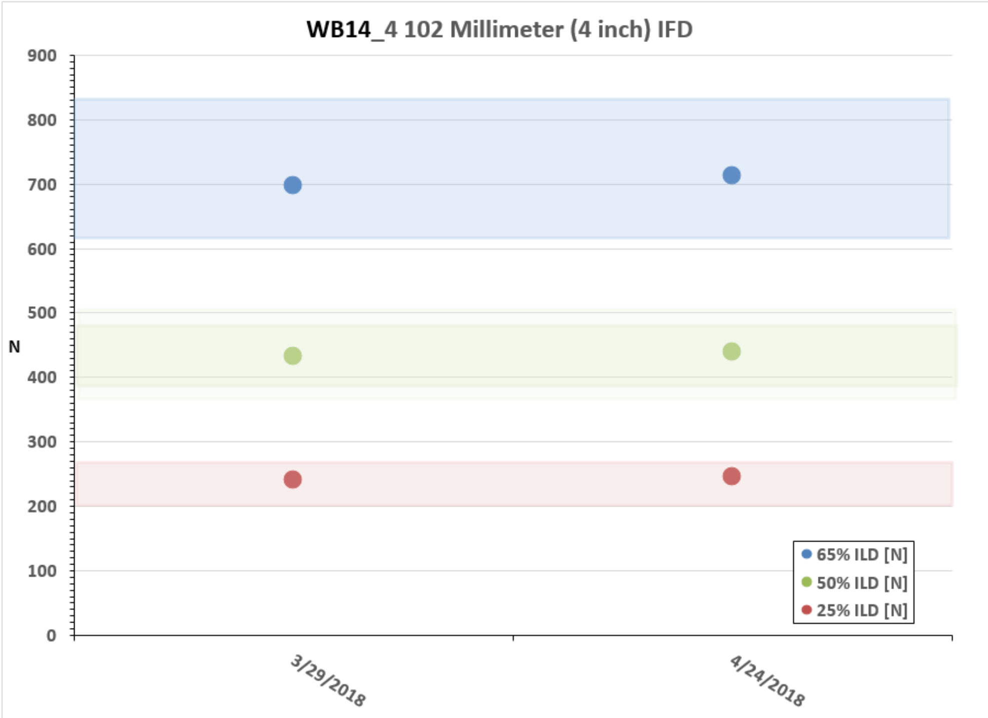
WB13_4 102 Millimeter (4 inch) IFD
N
0
100
200
300
400
500
600
700
800
900
65% ILD [N]
50% ILD [N]
25% ILD [N]
3/29/2018

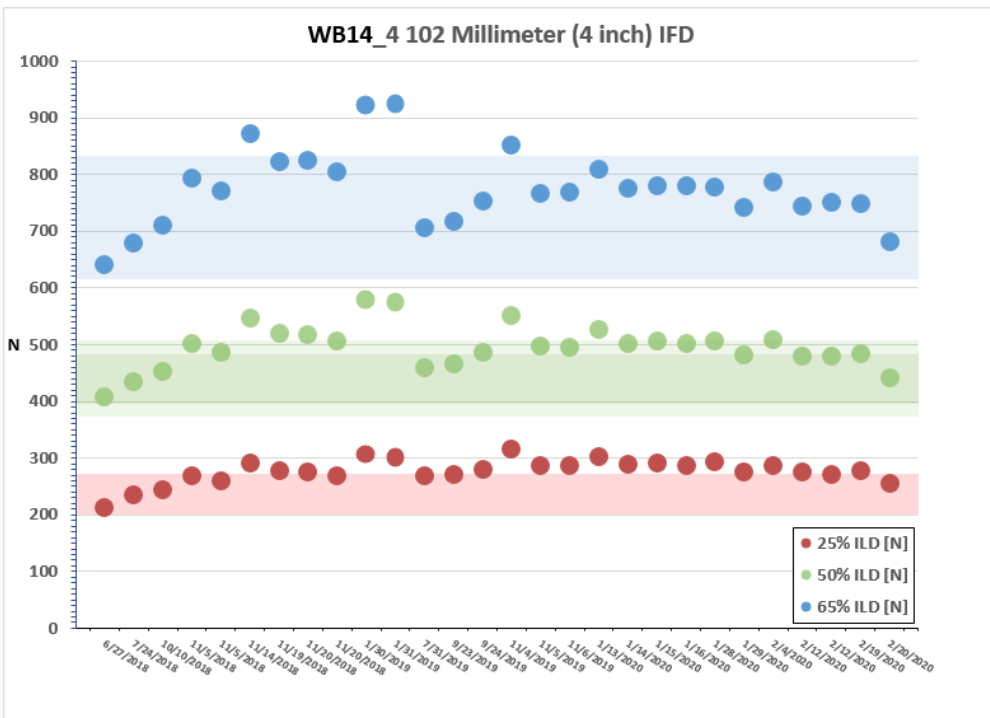


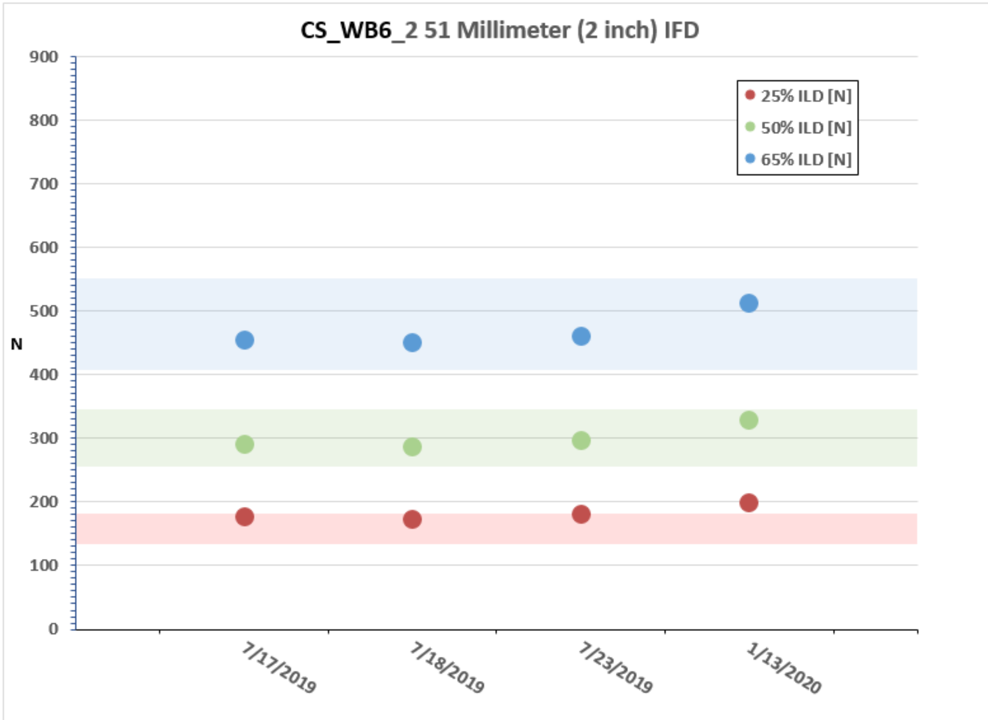
WB13_4 102 Millimeter (4 inch) IFD
N
0
100
200
300
400
500
600
700
800
900
1000
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/31/2018
10/10/2018
11/5/2018
11/5/2018
11/14/2018
11/15/2018
11/19/2018
7/31/2019
9/23/2019
9/23/2019
9/24/2019
11/4/2019
11/4/2019
11/5/2019
11/6/2019
1/13/2020
1/28/2020
1/29/2020
2/4/2020
2/12/2020
2/12/2020
2/19/2020
2/20/2020

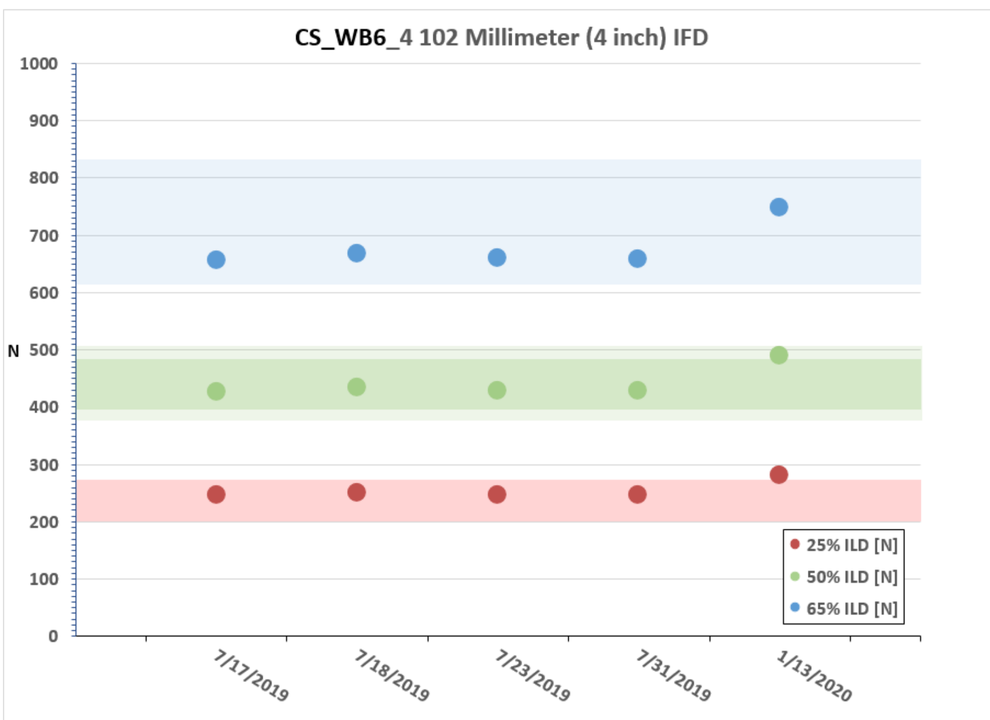

WB14_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
65% ILD [N]
50% ILD [N]
25% ILD [N]
3/29/2018
4/24/2018

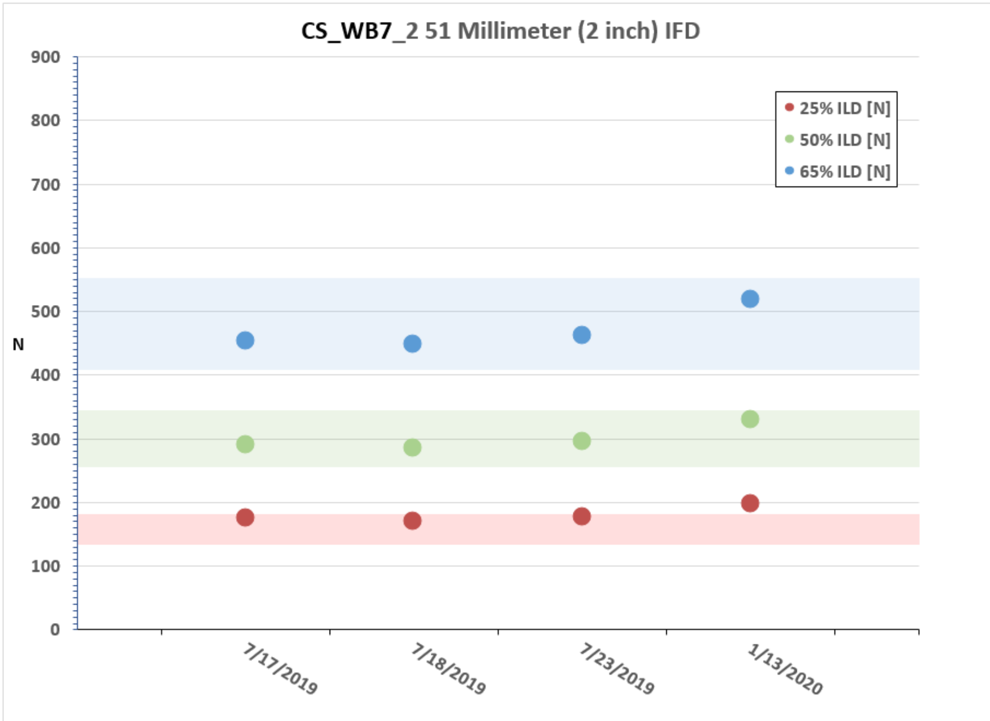

WB14_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/24/2018
10/10/2018
11/5/2018
11/14/2018
11/19/2018
8/1/2019
1/14/2020
1/28/2020
1/29/2020
2/4/2020

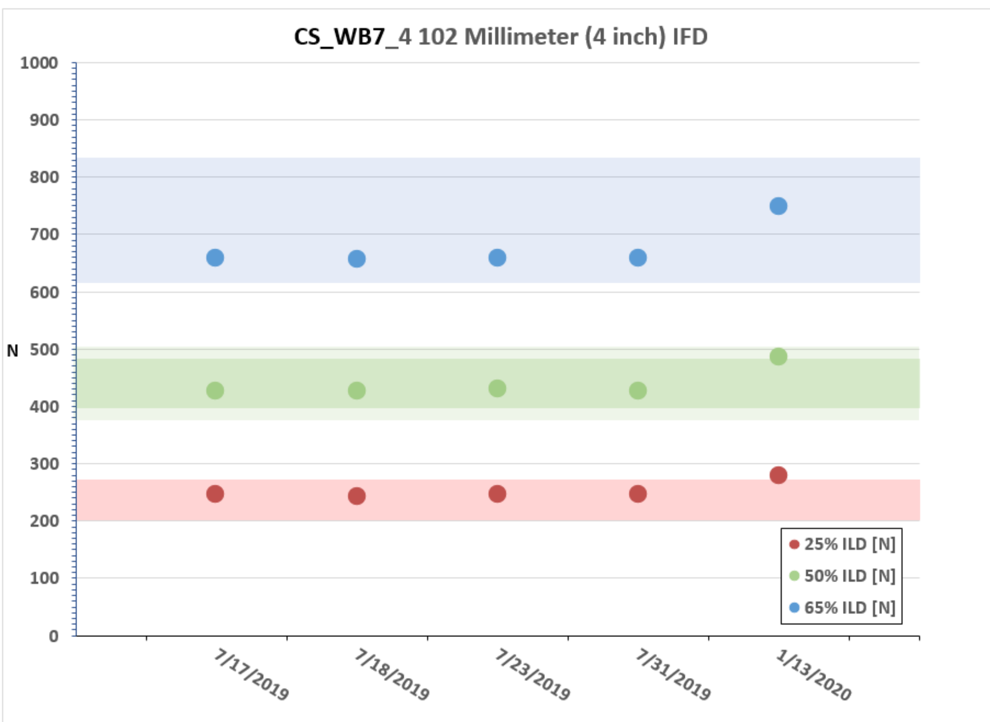

WB14_4 102 Millimeter (4 inch) IFD
900
800
700
600
500
N
400
300
200
100
0
65% ILD [N]
50% ILD [N]
25% ILD [N]
3/29/2018
4/24/2018


WB14_4 102 Millimeter (4 inch) IFD
1000
900
800
700
600
N 500
400
300
200
100
0
25% ILD [N]
50% ILD [N]
65% ILD [N]
6/27/2018
7/24/2018
10/10/2018
11/5/2018
11/5/2018
11/14/2018
11/19/2018
11/20/2018
11/20/2018
1/30/2019
1/31/2019
7/31/2019
9/23/2019
9/24/2019
11/4/2019
11/5/2019
11/6/2019
1/13/2020
1/14/2020
1/15/2020
1/16/2020
1/28/2020
1/29/2020
2/4/2020
2/12/2020
2/12/2020
2/19/2020
2/20/2020


CS_WB6_2 51 Millimeter (2 inch) IFD
25% ILD [N]
50% ILD [N]
65% ILD [N]
N
900
800
700
600
500
400
300
200
100
0
7/17/2019
7/18/2019
7/23/2019
1/13/2020


CS_WB6_4 102 Millimeter (4 inch) IFD
N
1000
900
800
700
600
500
400
300
200
100
0
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/17/2019
7/18/2019
7/23/2019
7/31/2019
1/13/2020


CS_WB7_2 51 Millimeter (2 inch) IFD
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/17/2019
7/18/2019
7/23/2019
1/13/2020


CS_WB7_4 102 Millimeter (4 inch) IFD
1000
900
800
700
600
500
400
300
200
100
0
N
25% ILD [N]
50% ILD [N]
65% ILD [N]
7/17/2019
7/18/2019
7/23/2019
7/31/2019
1/13/2020

Figures C1 through C6 show the 25%, 50%, and 65% compression IFD values from 2014 through 2019 for the WB seat pan (102-millimeter (4-inch)) and seat back (51-millimeter (2-inch)) foams.

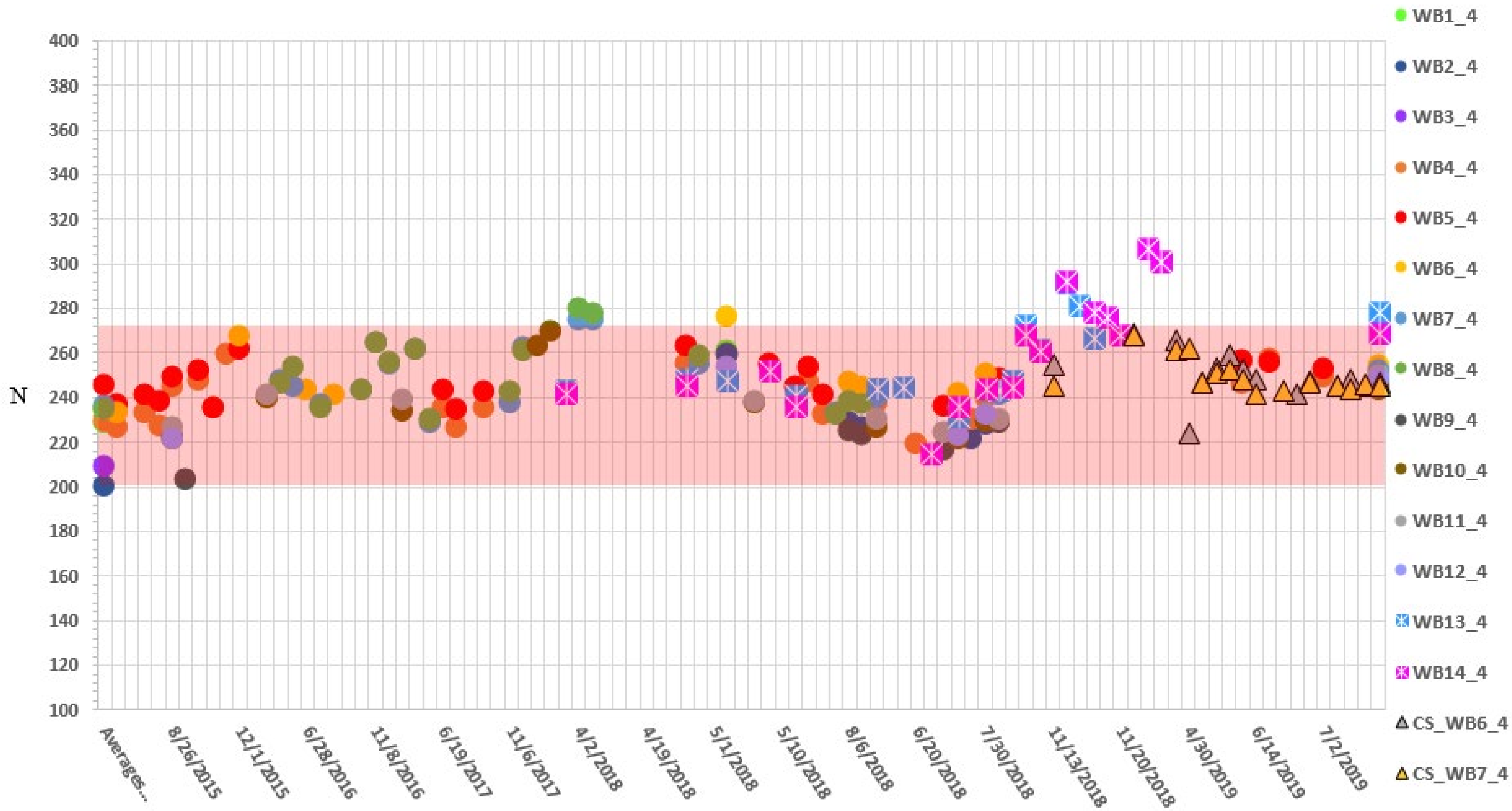


Figure C1: 25% Compression IFD Values for WB Seat Pan 102-millimeter (4-inch) Foams from 2014 to 2019

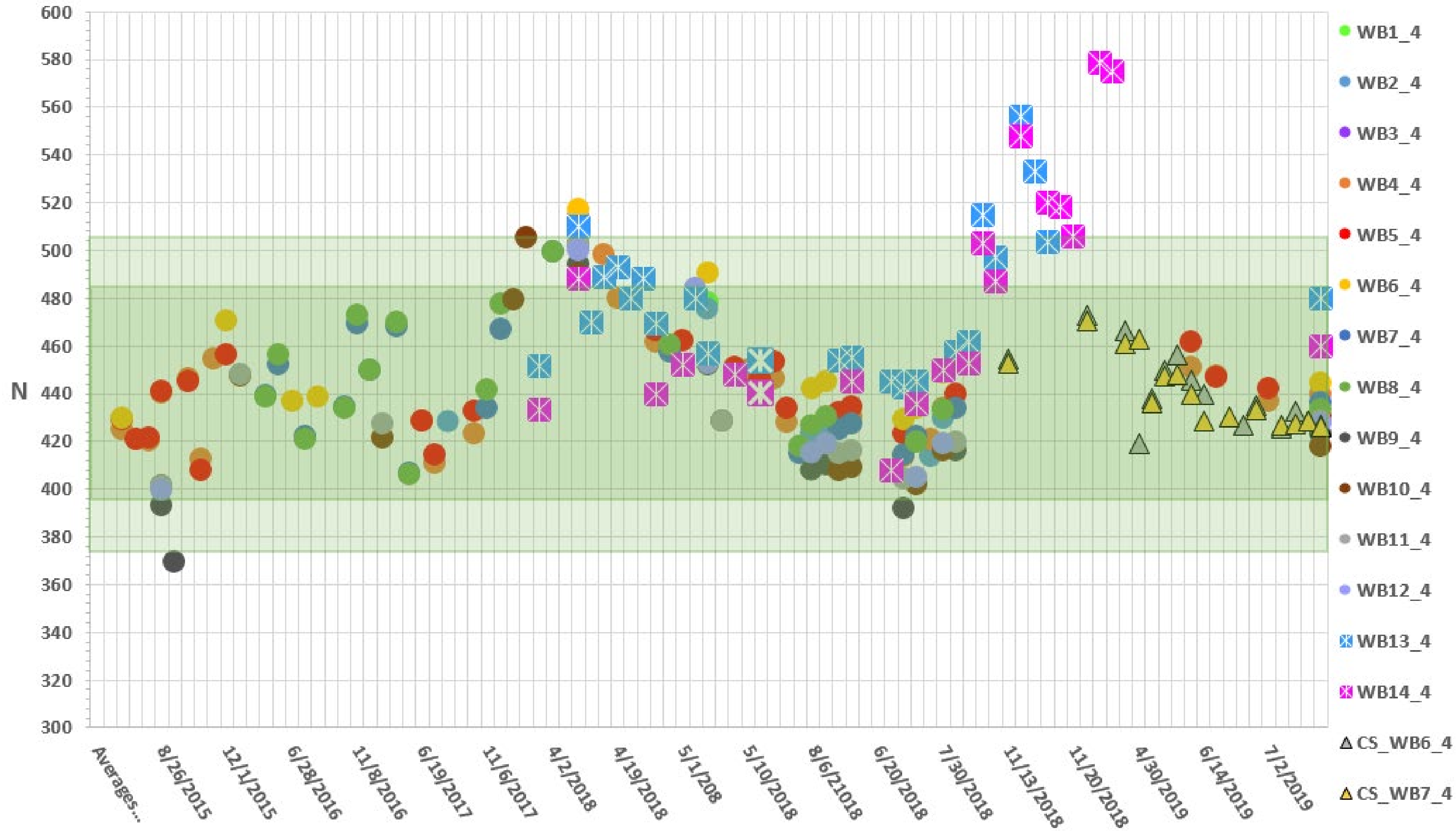


Figure C2: 50% Compression IFD Values for WB Seat Pan 102-millimeter (4-inch) Foams from 2014 to 2019

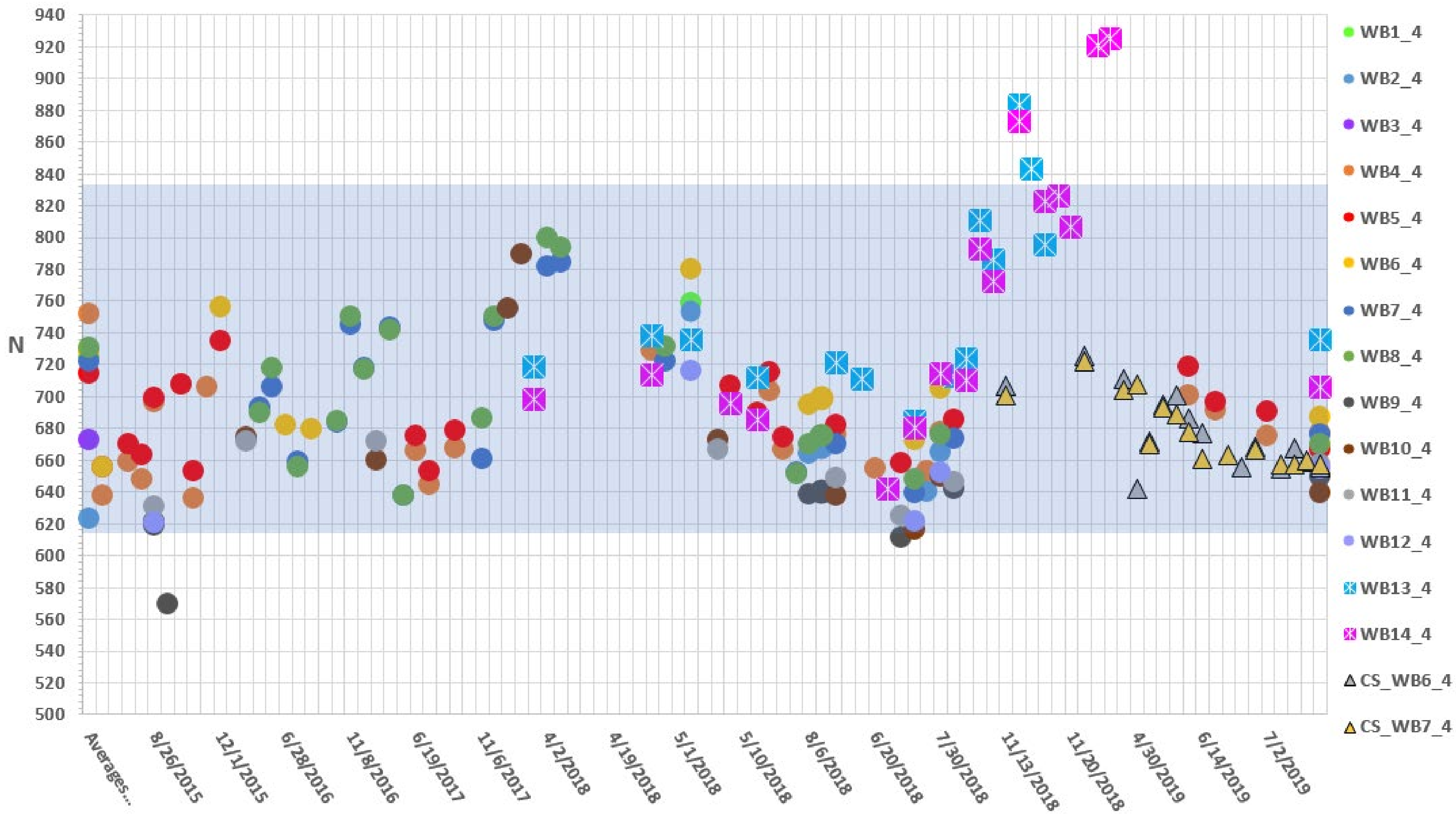


Figure C3: 65% Compression IFD Values for WB Seat Pan 102-millimeter (4-inch) Foams from 2014 to 2019

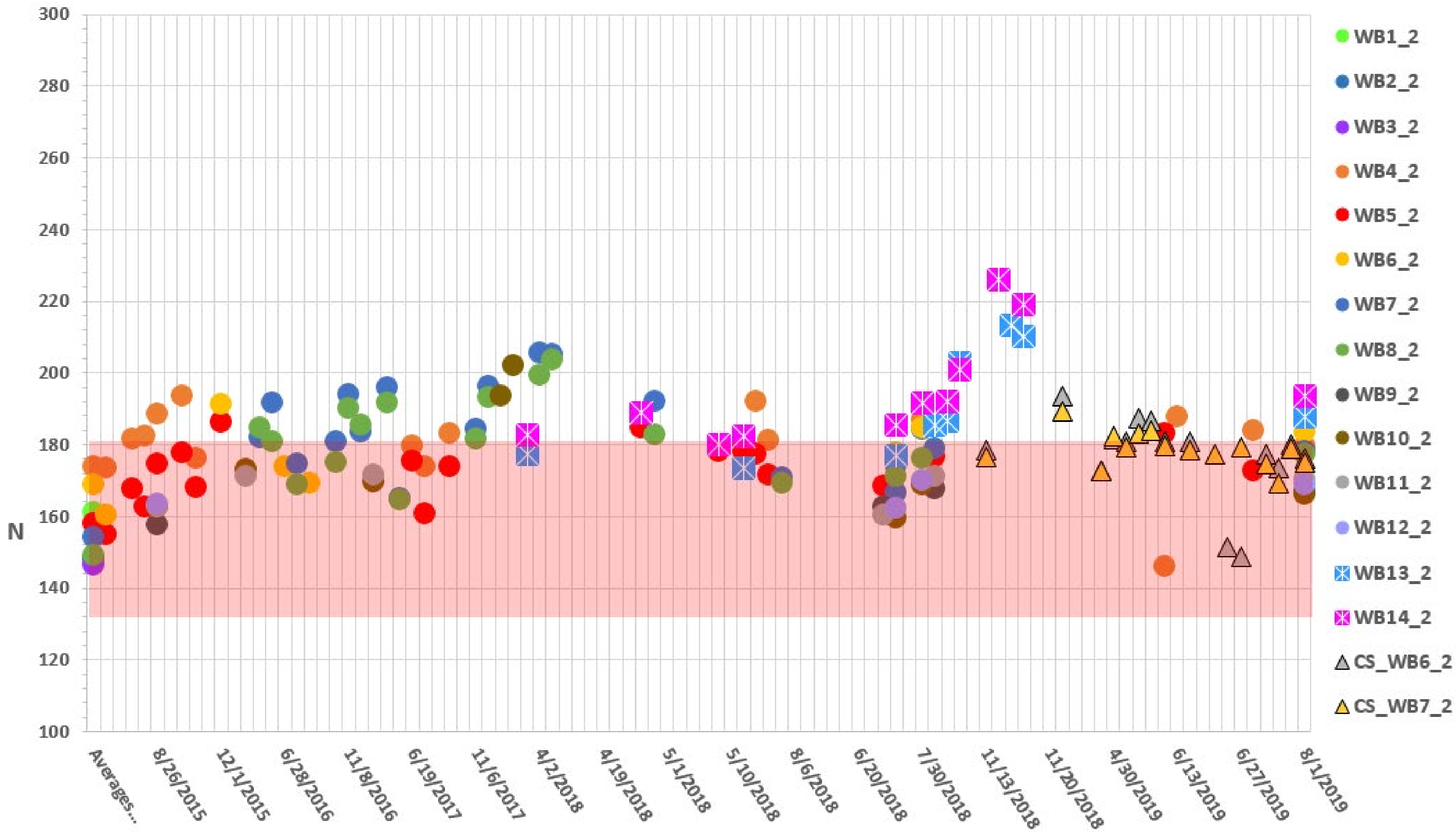


Figure C4: 25% Compression IFD Values for WB Seat Pan 51-millimeter (2-inch) Foams from 2014 to 2019

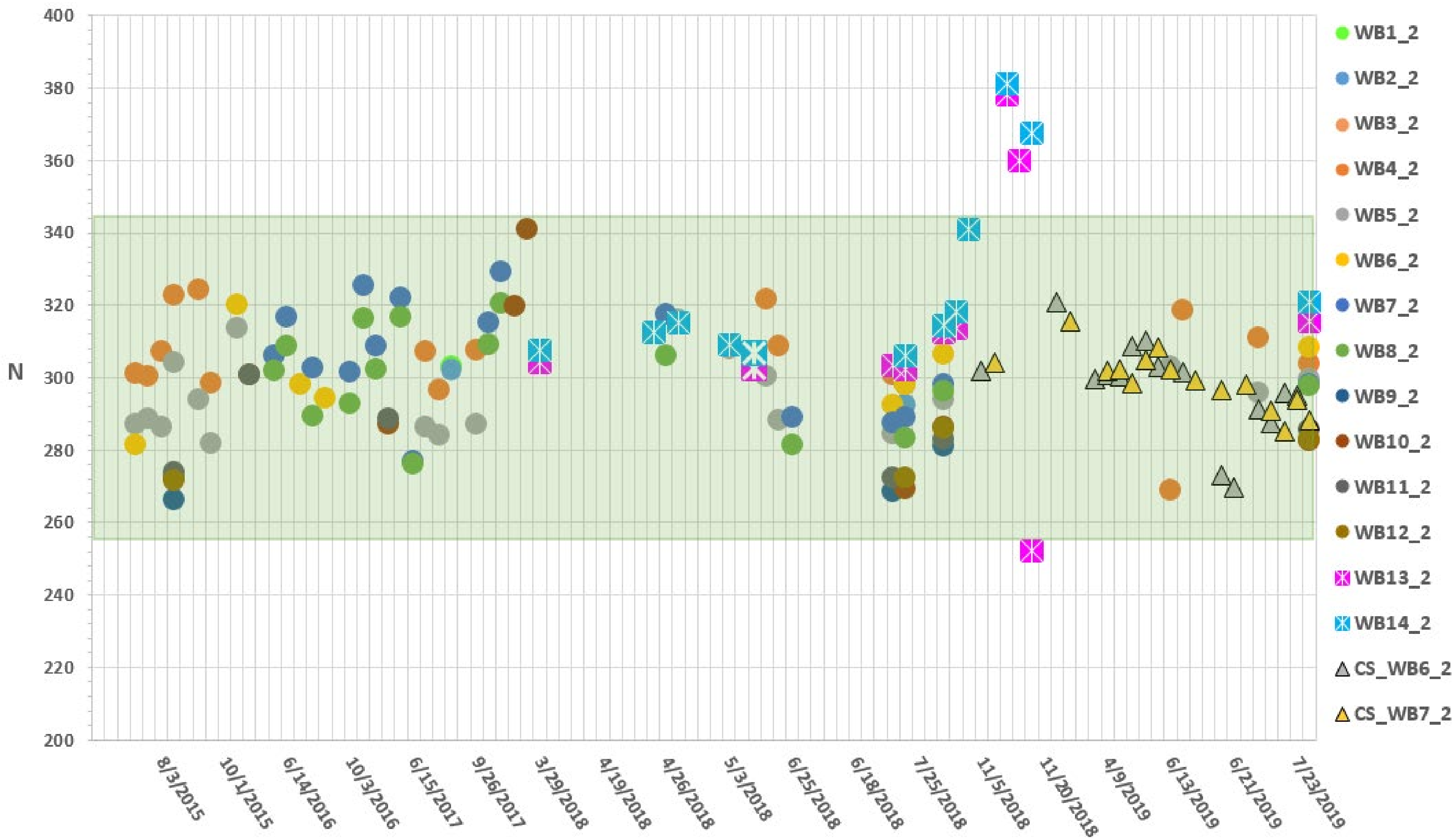


Figure C5: 50% Compression IFD Values for WB Seat Pan 51-millimeter (2-inch) Foams from 2014 to 2019

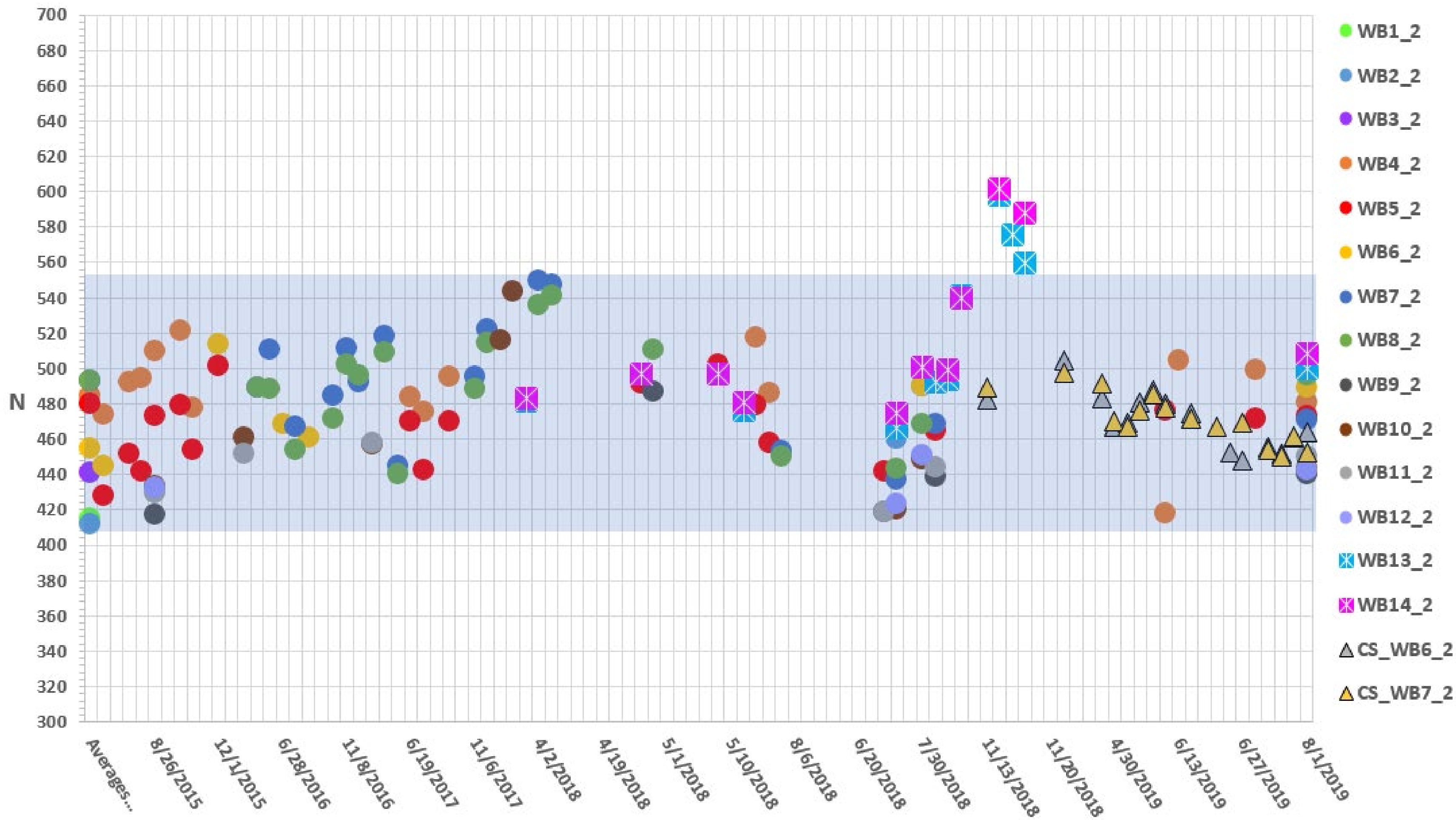


Figure C6: 65% Compression IFD Values for WB Seat Pan 51-millimeter (2-inch) Foams from 2014 to 2019

Appendix D: "Custom" vs. "Off the Shelf" Foams - 25%, 50%, and 65% Compression IFD Values

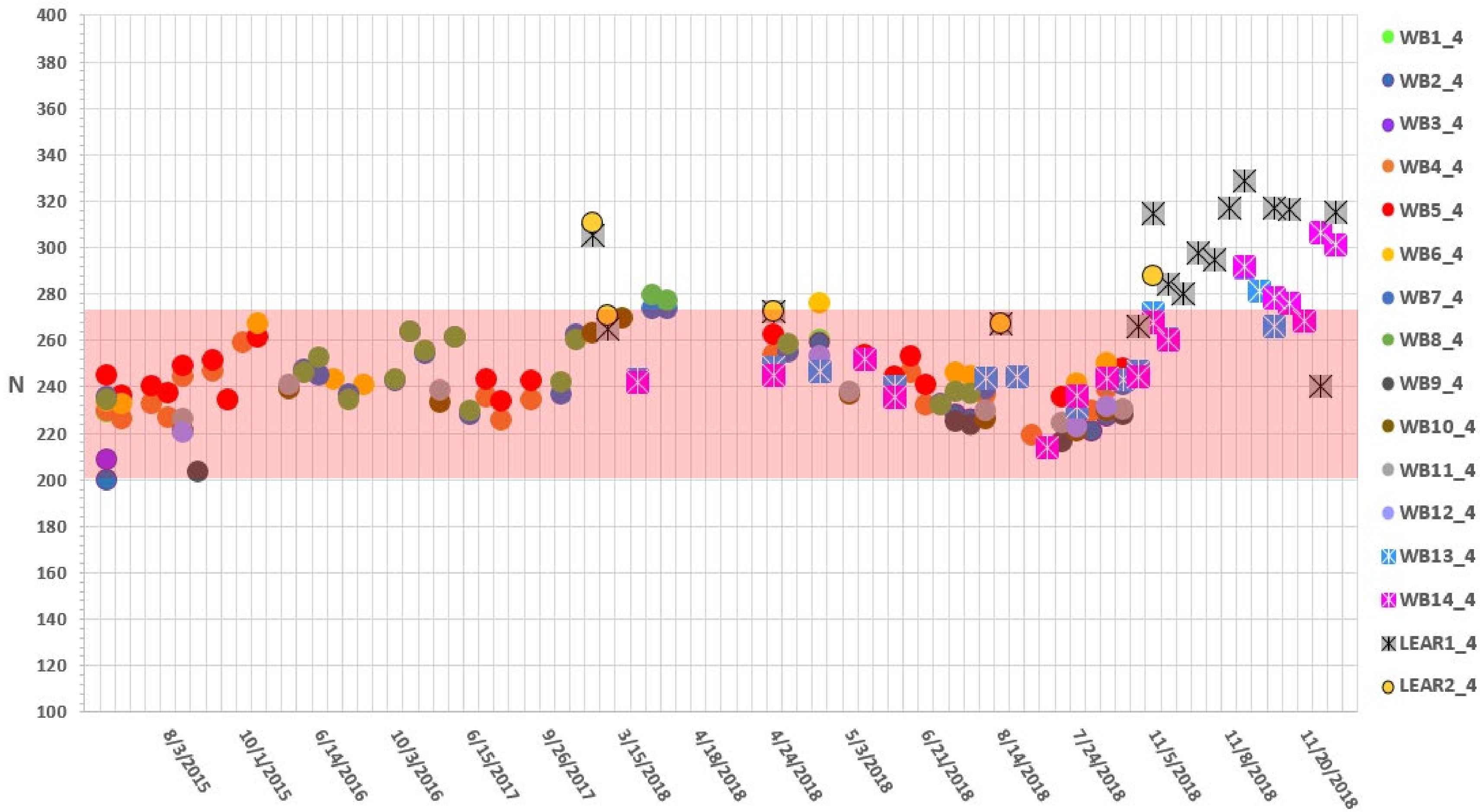


Figure D1: 25% Compression IFD Values for "Custom" Foams Seat Pan 102 millimeters (4 inches)

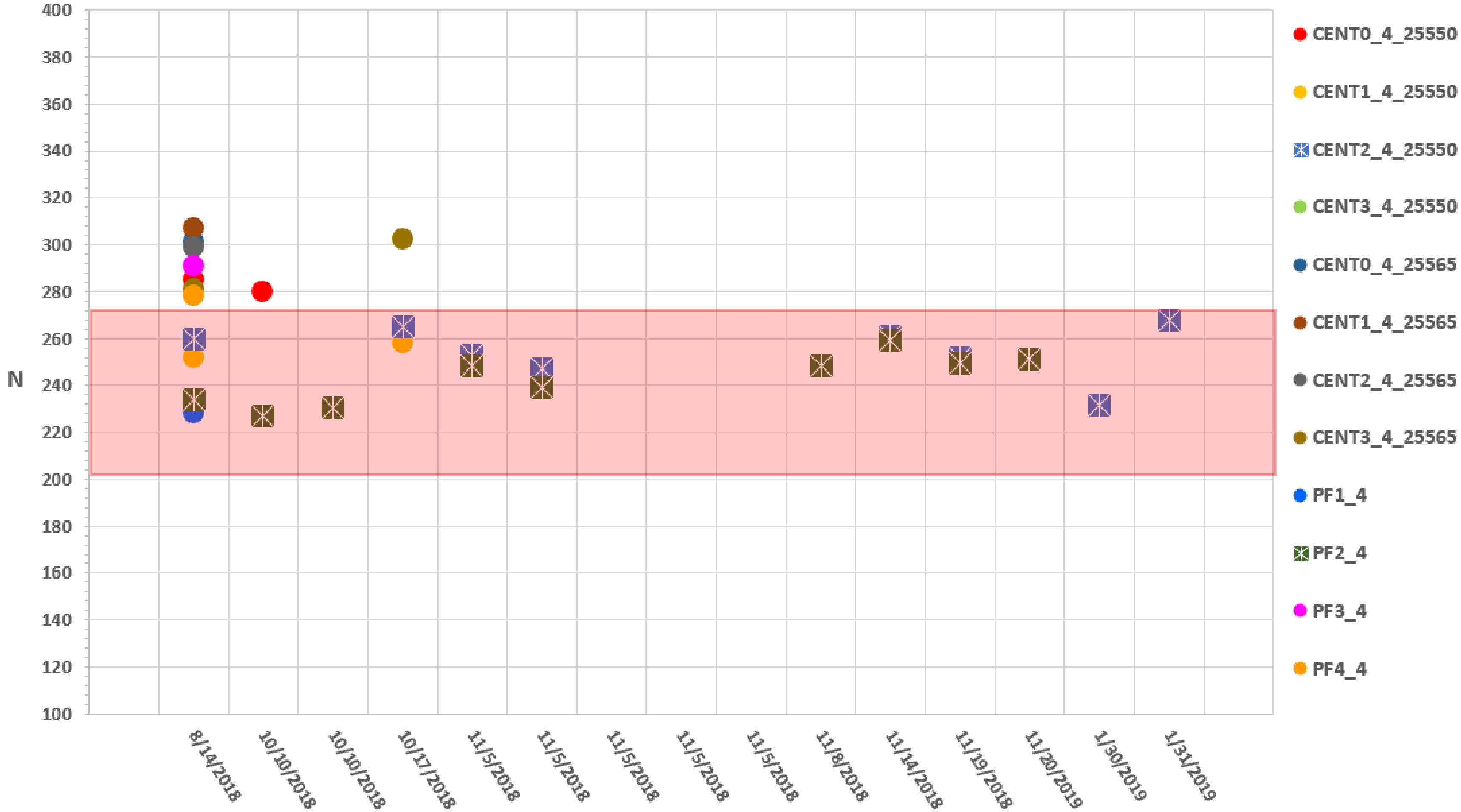


Figure D2: 25% Compression IFD Values for "Off the Shelf" Foams Seat Pan 102 millimeters (4 inches)

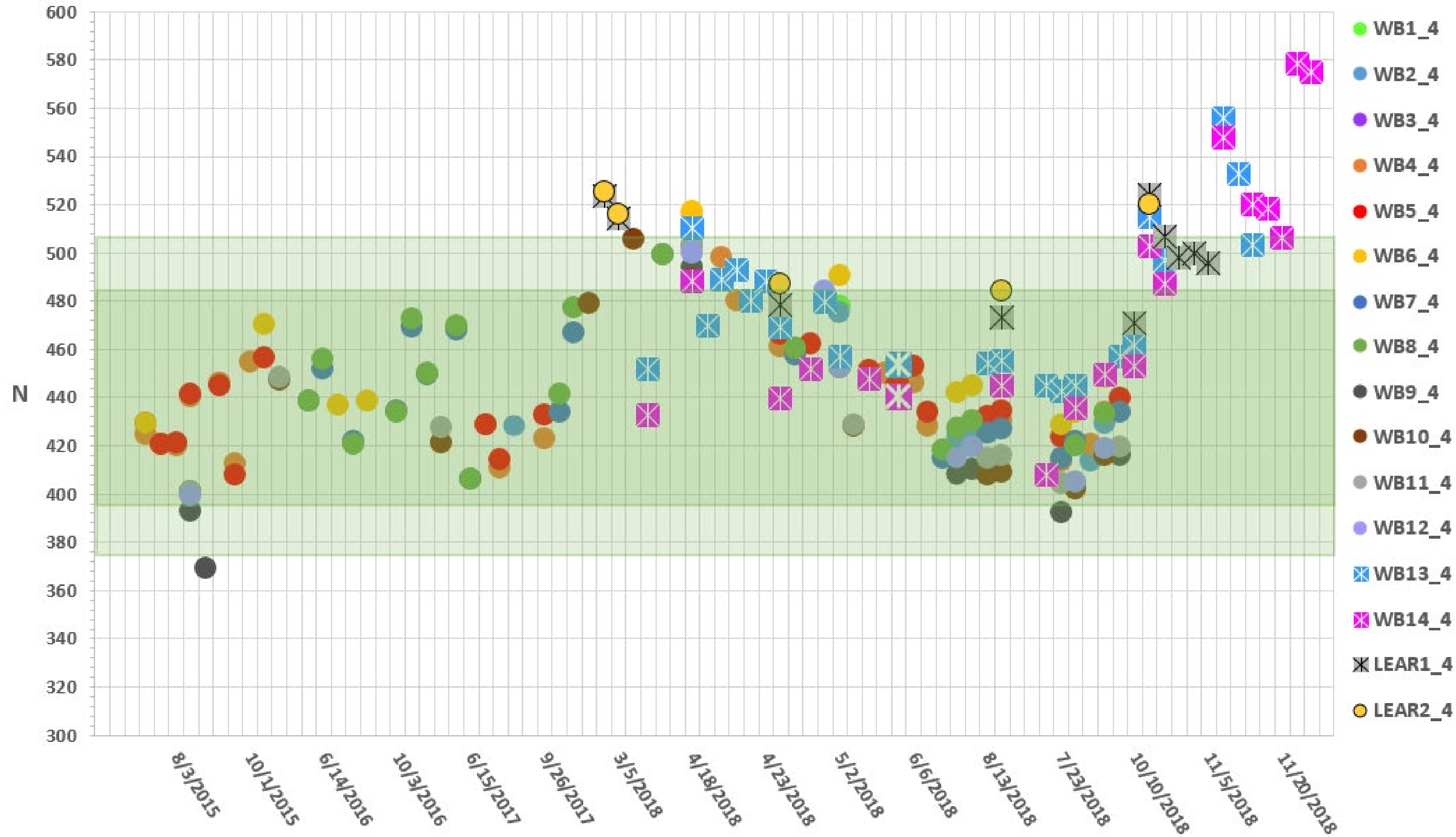


Figure D3: 50% Compression IFD Values for “Custom” Foams Seat Pan 102 millimeters (4 inches)

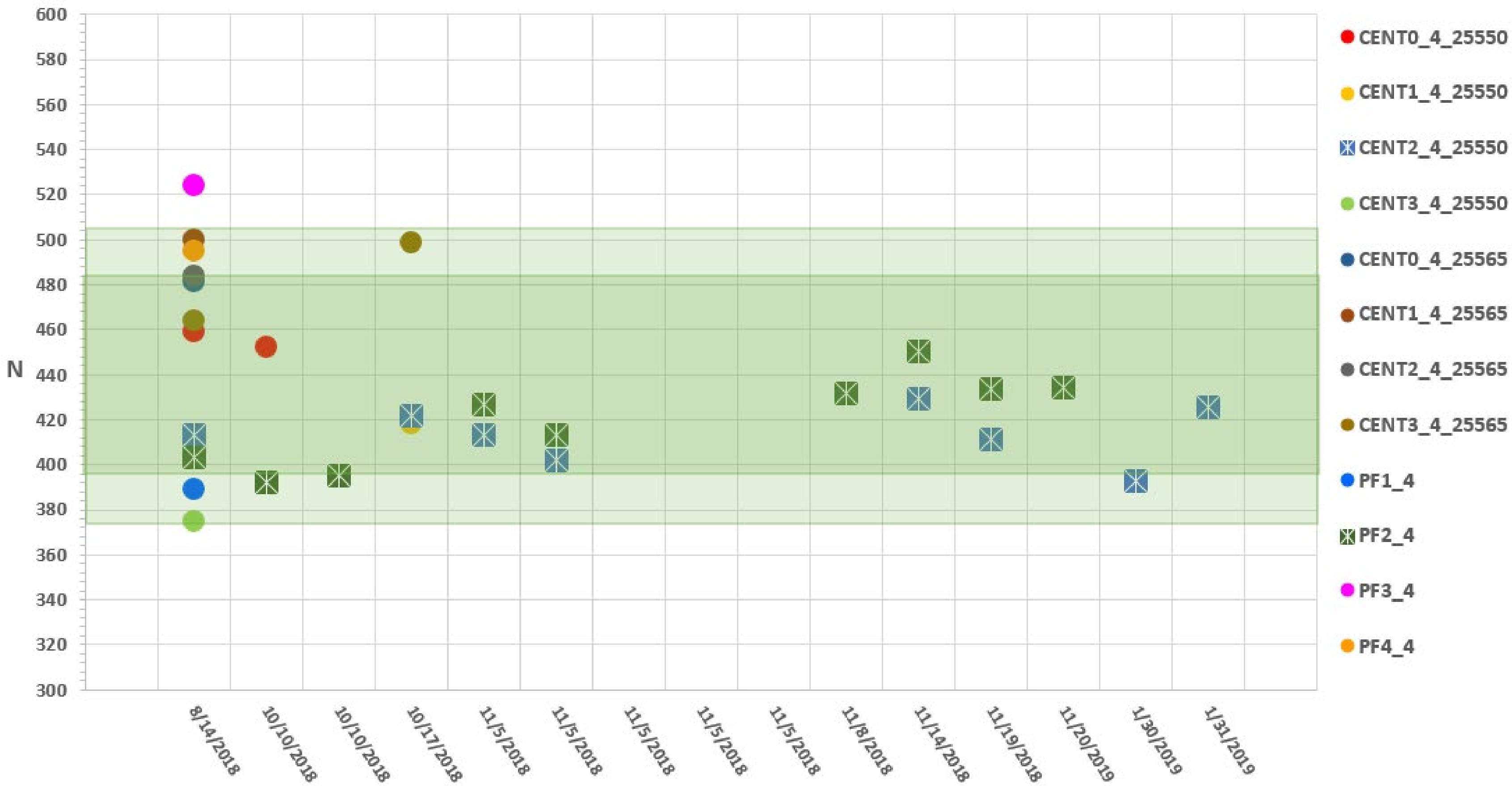


Figure D4: 50% Compression IFD Values for “Off the Shelf” Foams Seat Pan 102 millimeters (4 inches)

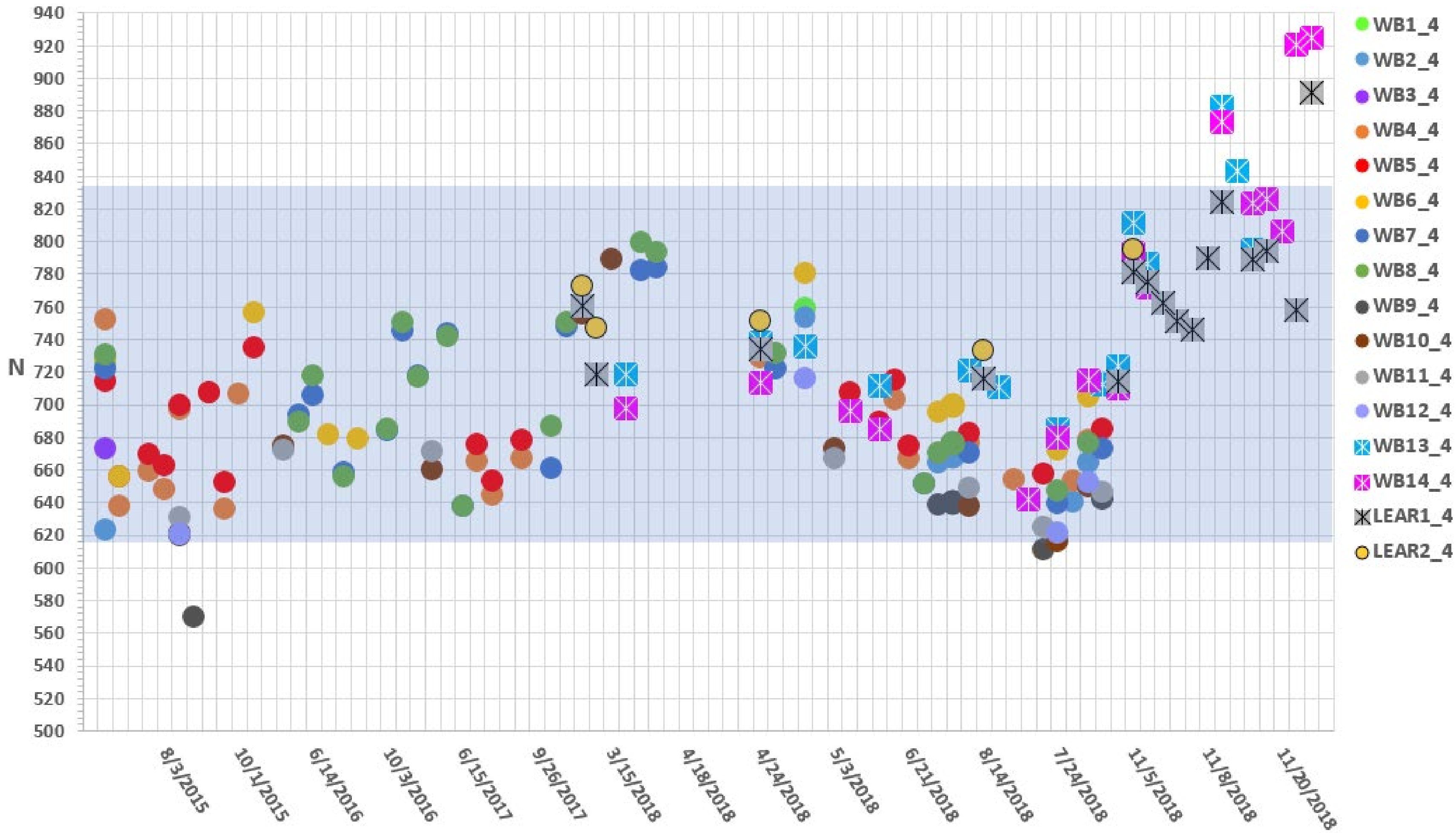


Figure D5: 65% Compression IFD Values for “Custom” Foams Seat Pan 102 millimeters (4 inches)

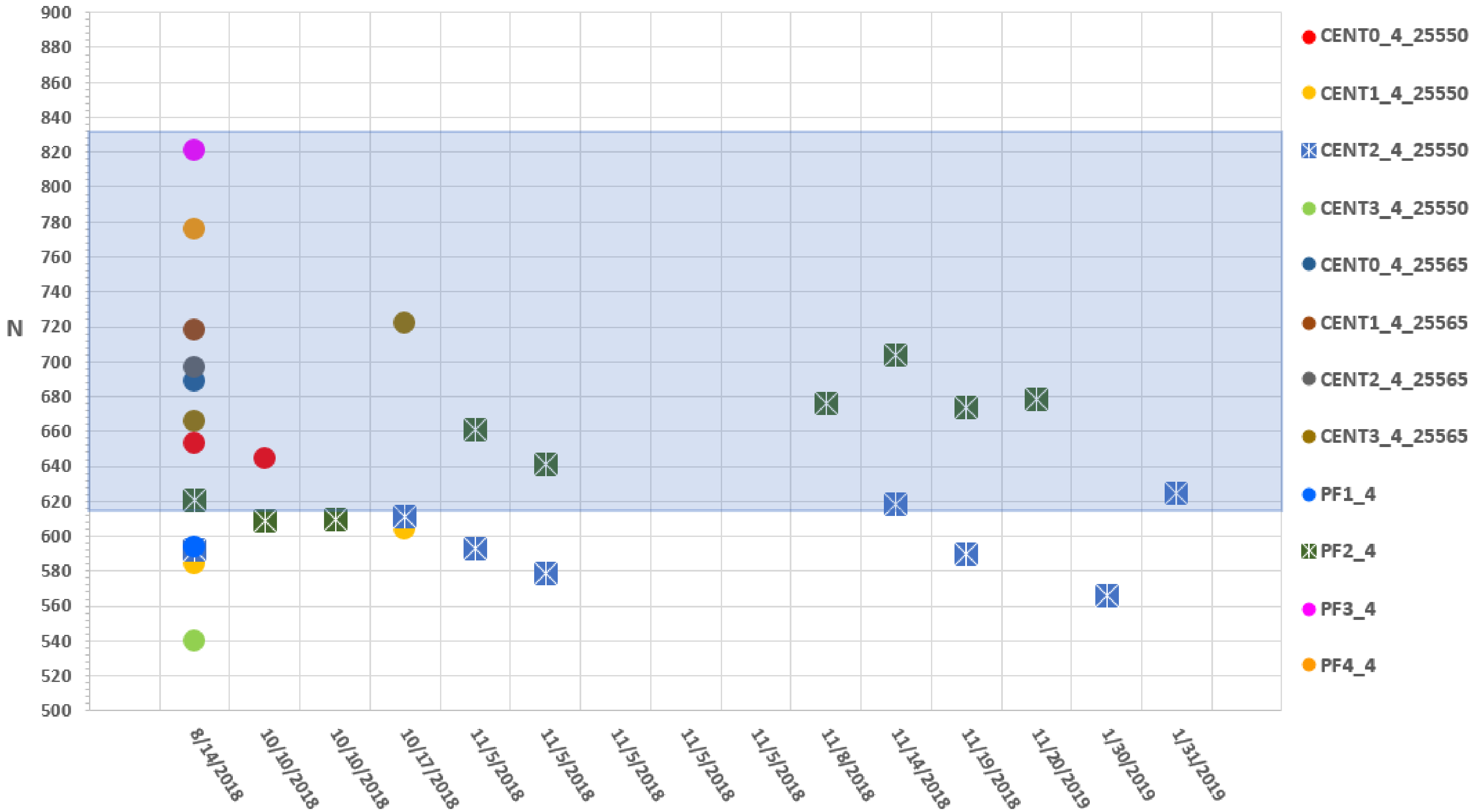


Figure D6: 65% Compression IFD Values for “Off the Shelf” Foams Seat Pan 102 millimeters (4 inches)

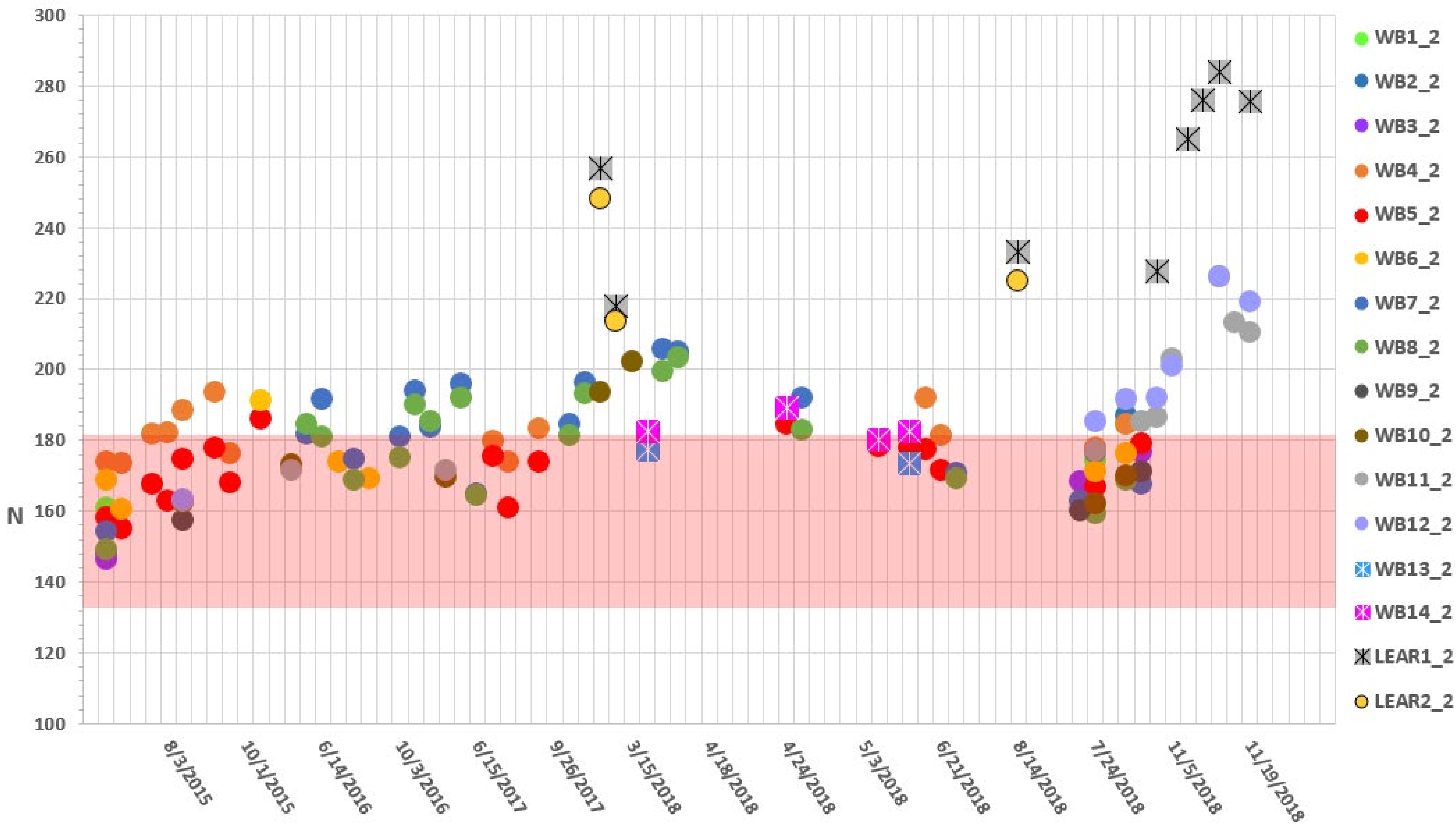


Figure D7: 25% Compression IFD Values for “Custom” Foams Seat Pan 51 millimeters (2 inches)

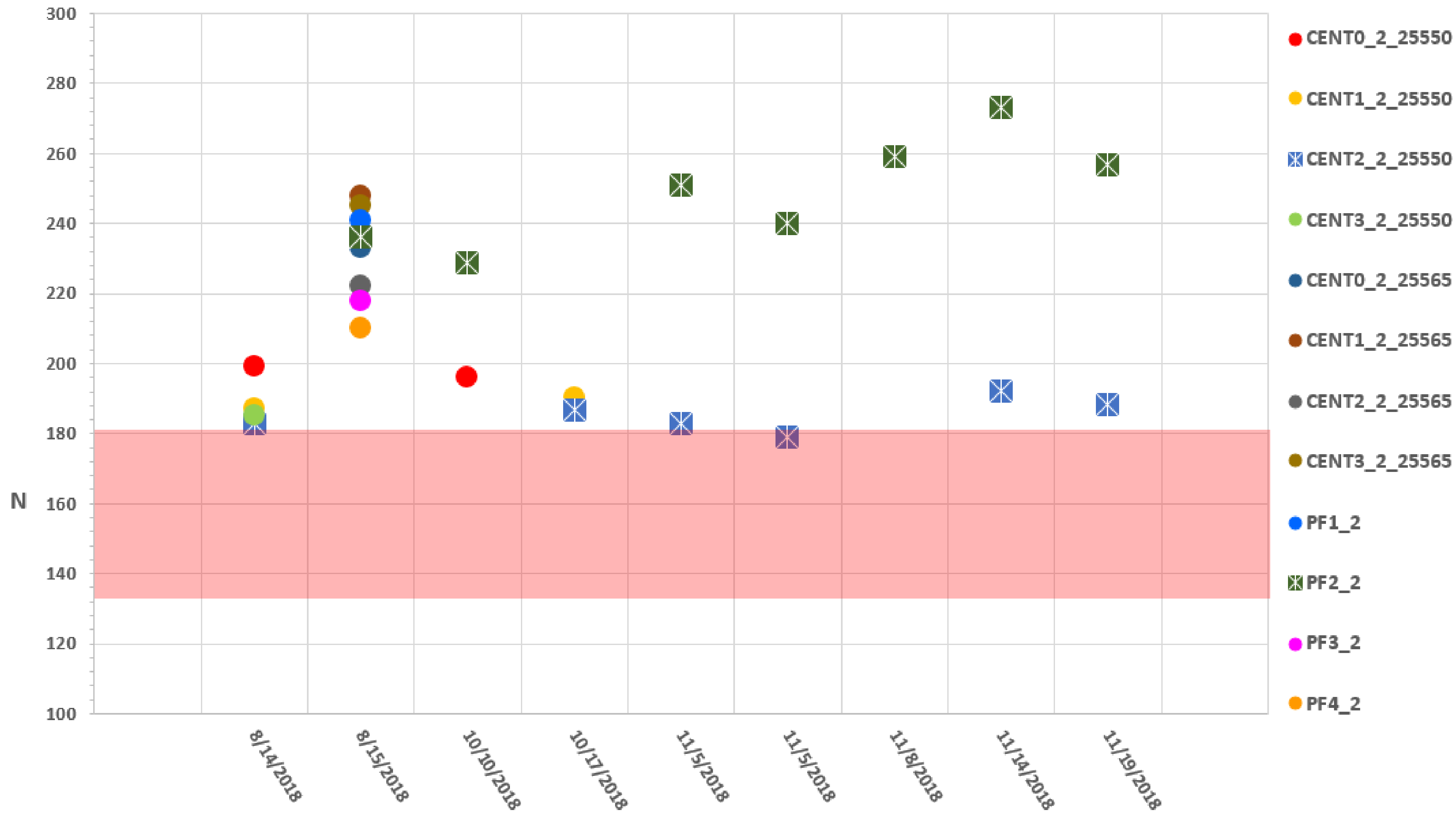


Figure D8: 25% Compression IFD Values for “Off the Shelf” Foams Seat Pan 51 millimeters (2 inches)

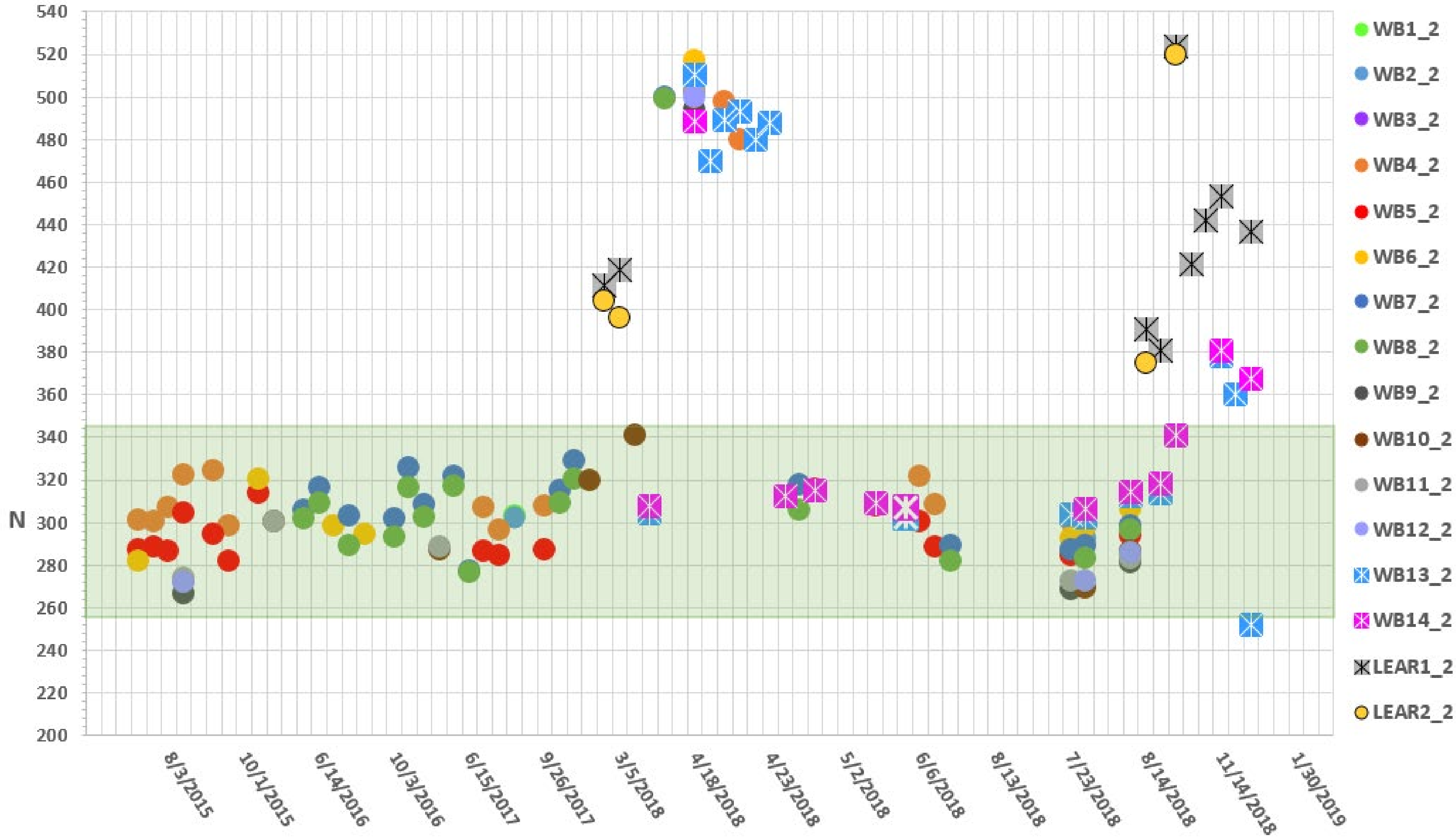


Figure D9: 50% Compression IFD Values for “Custom” Foams Seat Pan 51 millimeters (2 inches)

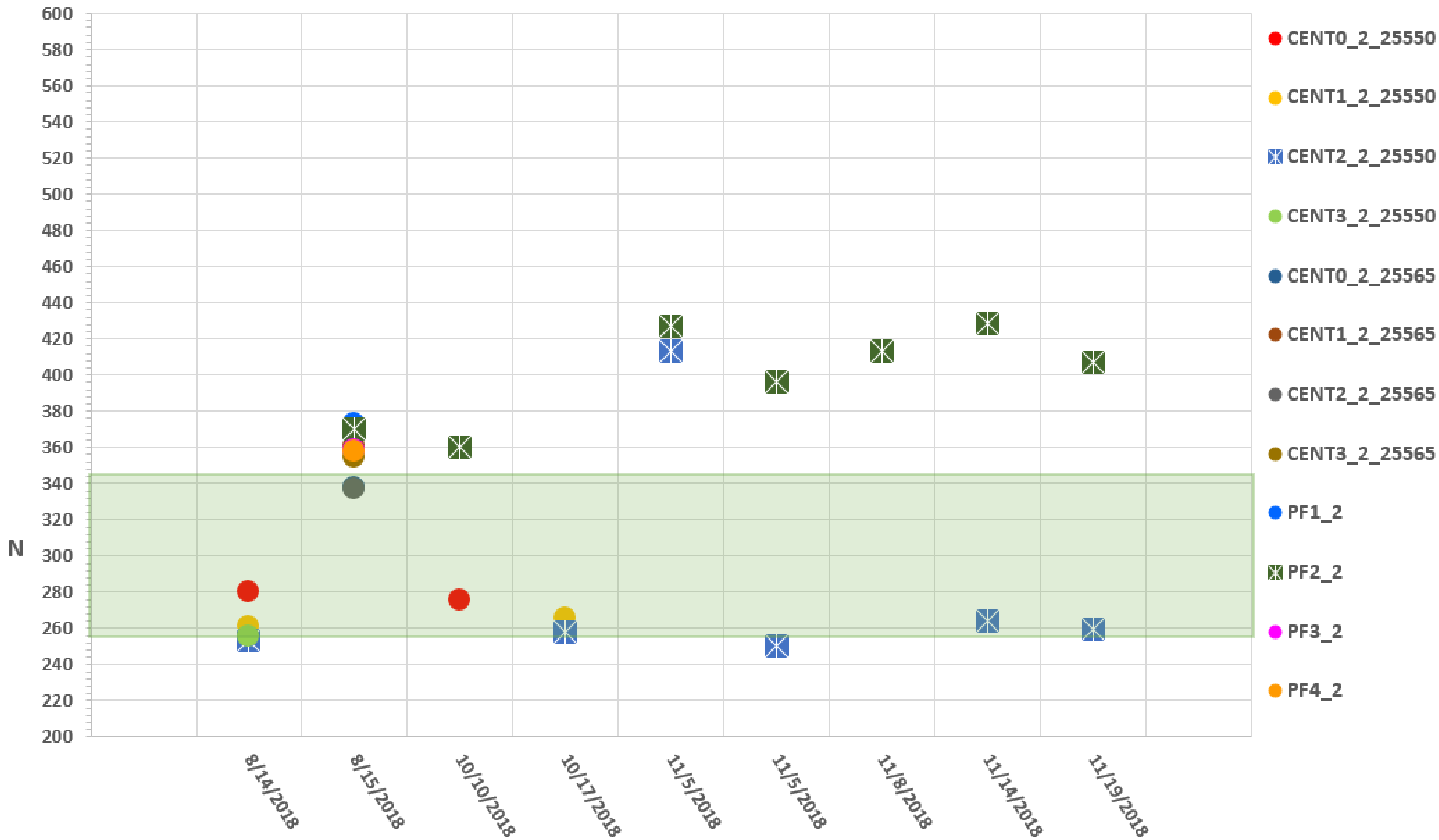


Figure D10: 50% Compression IFD Values for "Off the Shelf" Foams Seat Pan 51 millimeters (2 inches)

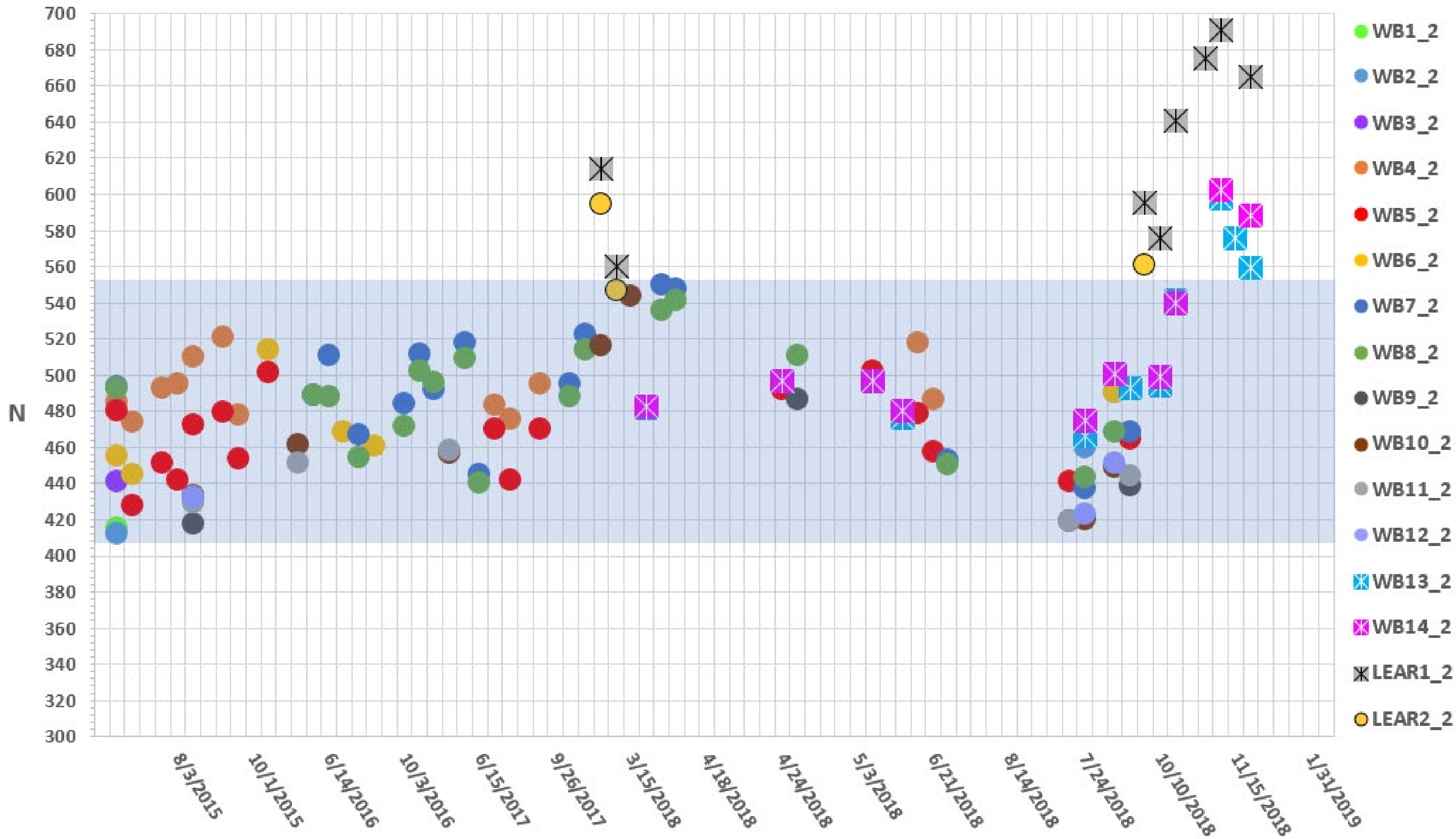


Figure D11: 65% Compression IFD Values for “Custom” Foams Seat Pan 51 millimeters (2 inches)

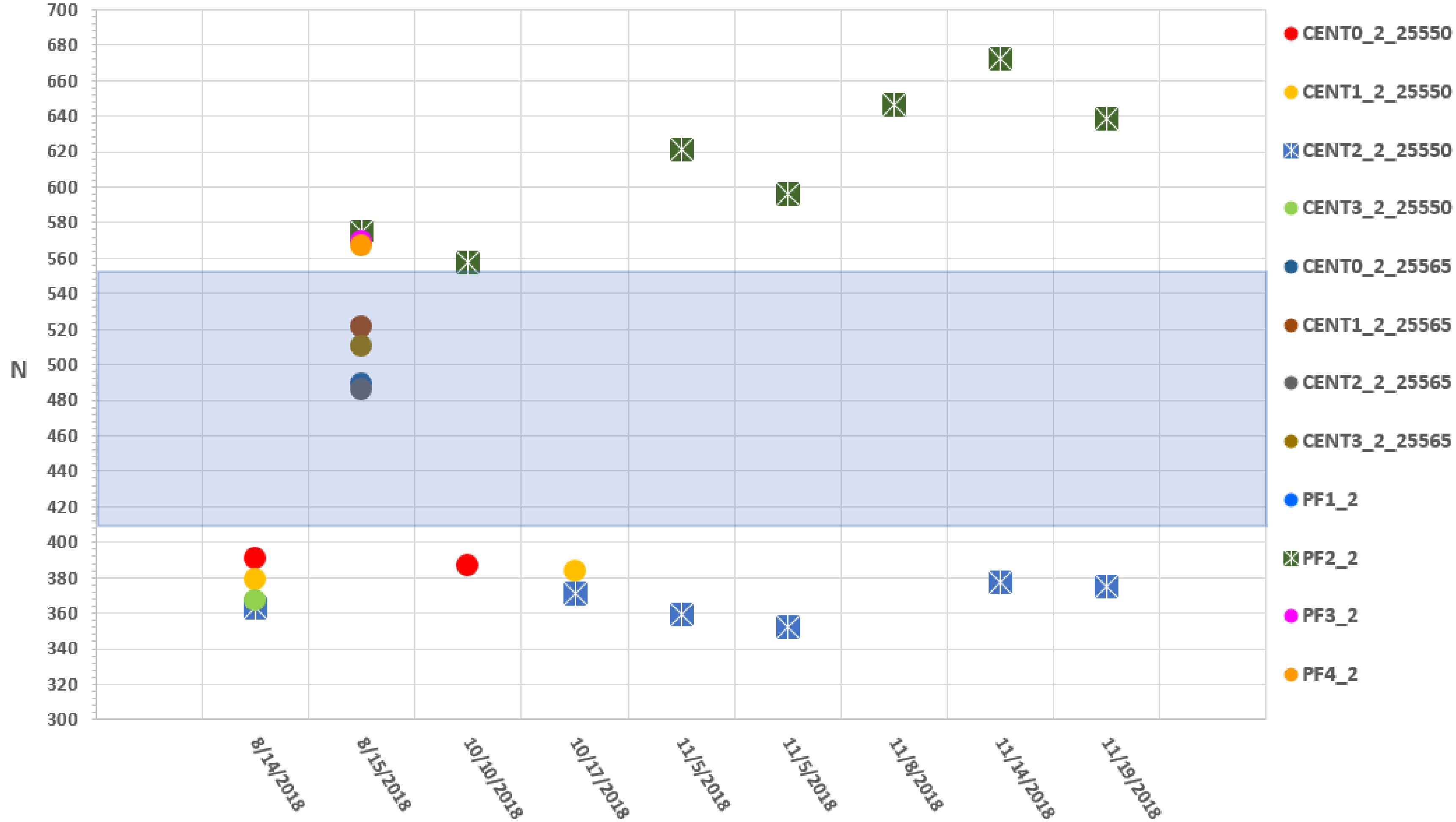


Figure D12: 65% Compression IFD Values for “Off the Shelf” Foams Seat Pan 51 millimeters (2 inches)

Appendix E: Calspan Data and IFD Results: Seat Pan 102-Millimeter (4-inch) Foams

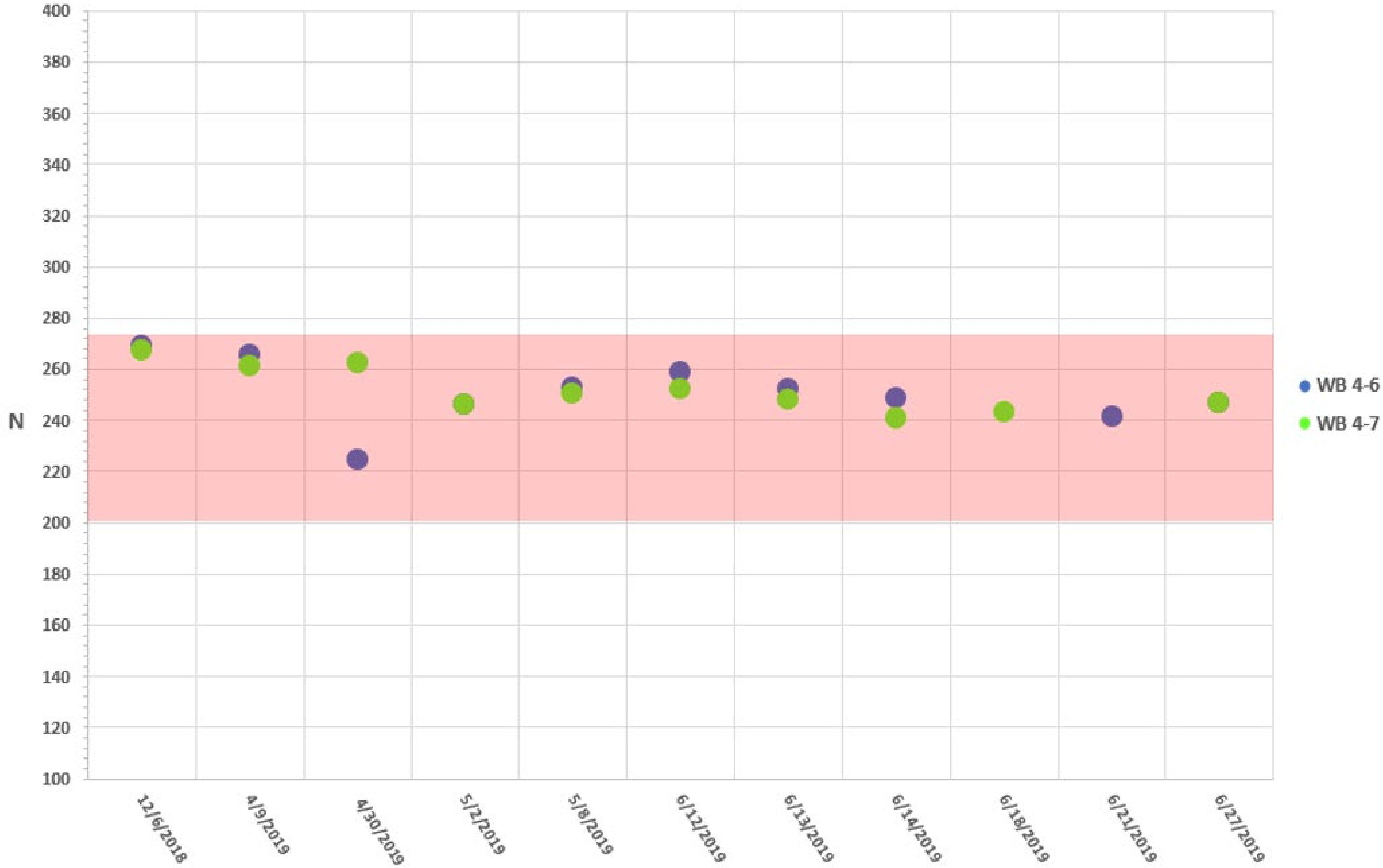


Figure E1: Calspan 25% Compression IFD Values for Seat Pan 102-millimeter (4-inch) Foams

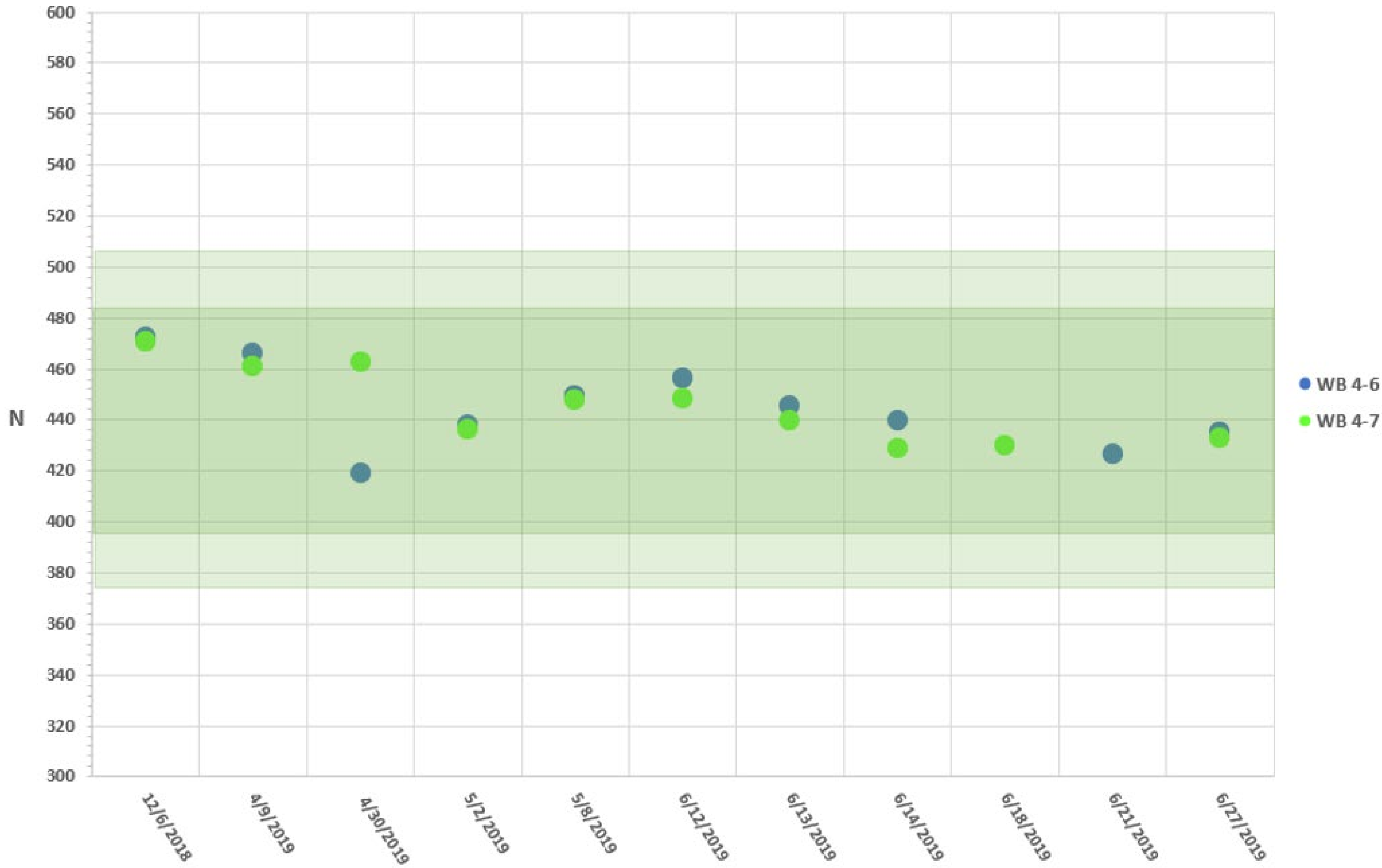


Figure E2: Calspan 50% Compression IFD Values for Seat Pan 102-millimeter (4-inch) Foams

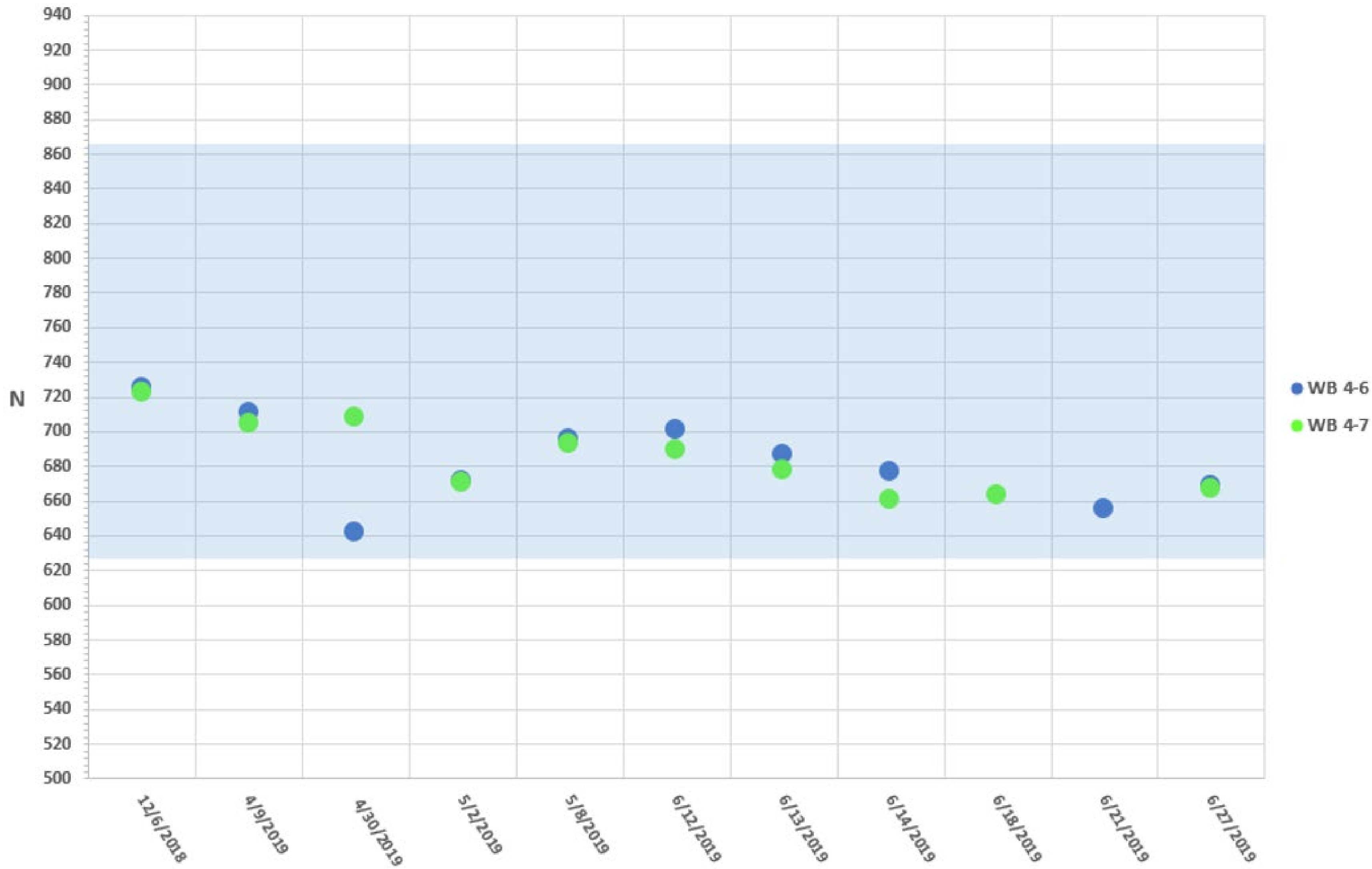


Figure E3: Calspan 65% Compression IFD Values for Seat Pan 102-millimeter (4-inch) Foams

Appendix F: Temperature and Humidity Data

To identify if there is correlation between the IFD responses and the temperature and humidity in the storage bay, the IFD values, humidity, and temperature were plotted using a subset of foams over the period of May 2018 to February 2019. The foams chosen were WB #14, one of the newer foams with fewer uses (Figure F1 & F2); Lear Corporation Foam Set #1 (Figures F3 & F4); Perfect Fit-McDonald Foam - 290 (Figures F5 & F6); and Century Foam-25550 (Figures F7 & F8).

Figures F1 through F8 illustrate the effect the variability of temperature and relative humidity have on the IFD compression responses recorded. The figures show a plot of each type of the foam set IFD compression response (25%/50%/65% IFD compression test method) on the left axis versus humidity or temperature on the right axis over time.

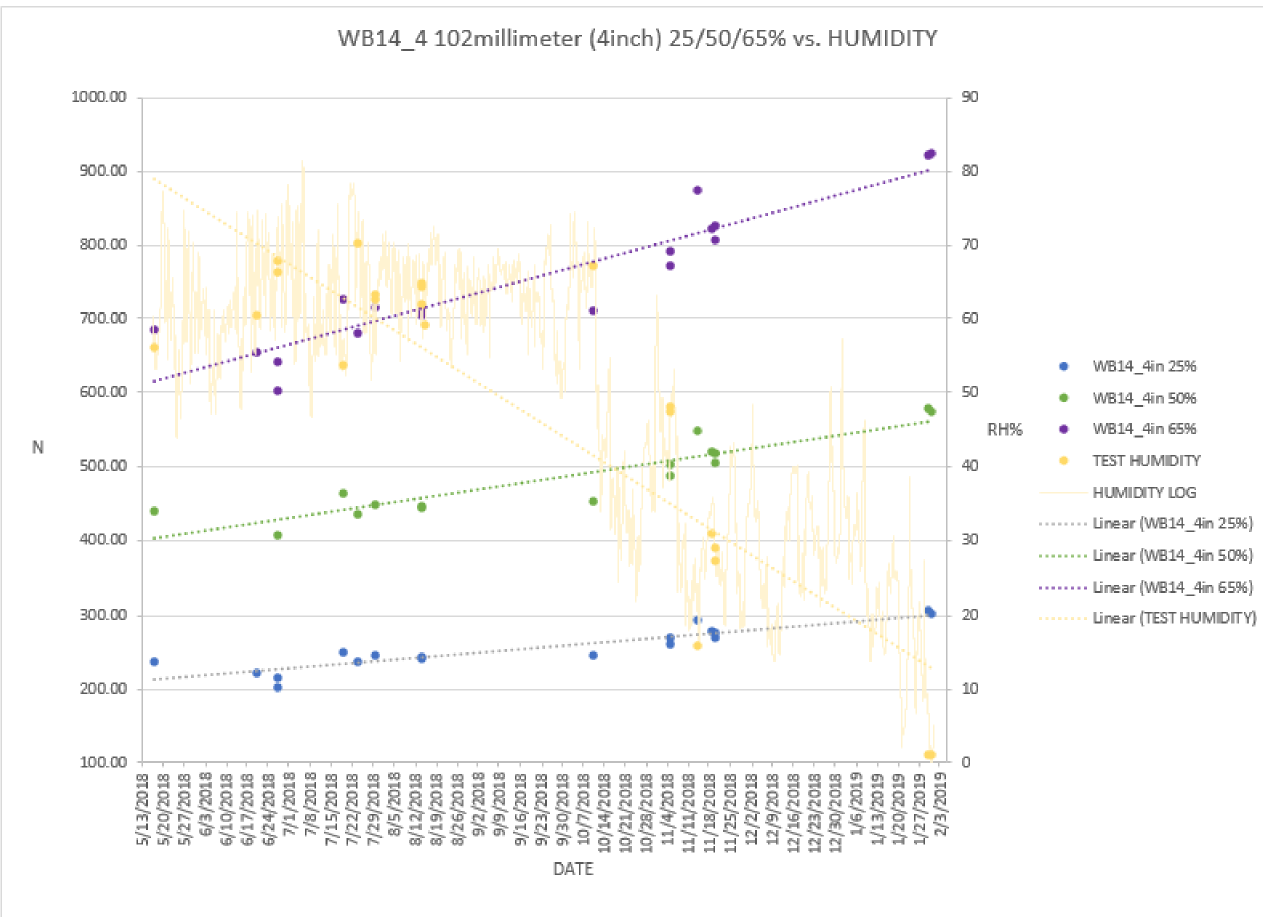


Figure F1: IFD Response vs. Humidity for WB #14

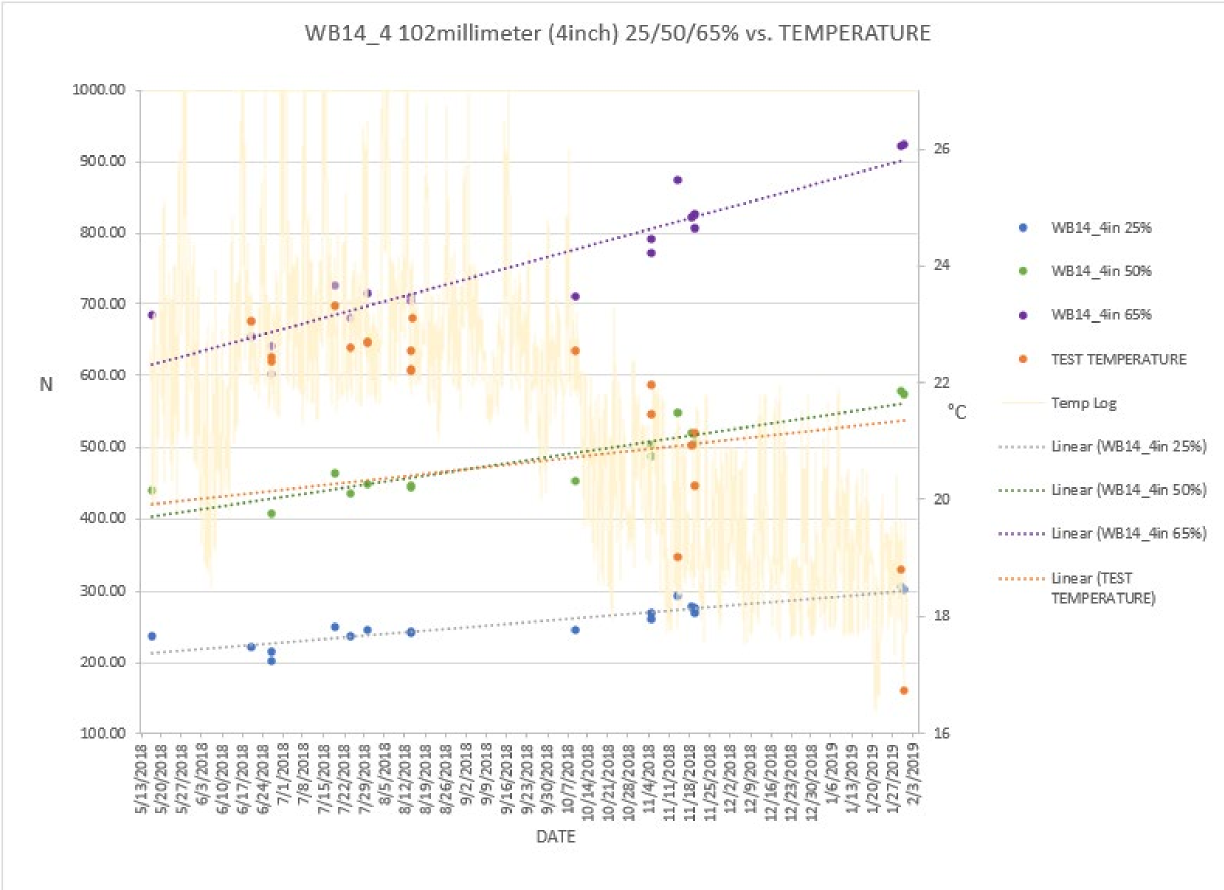


Figure F2: IFD Response vs. Temperature for WB #14

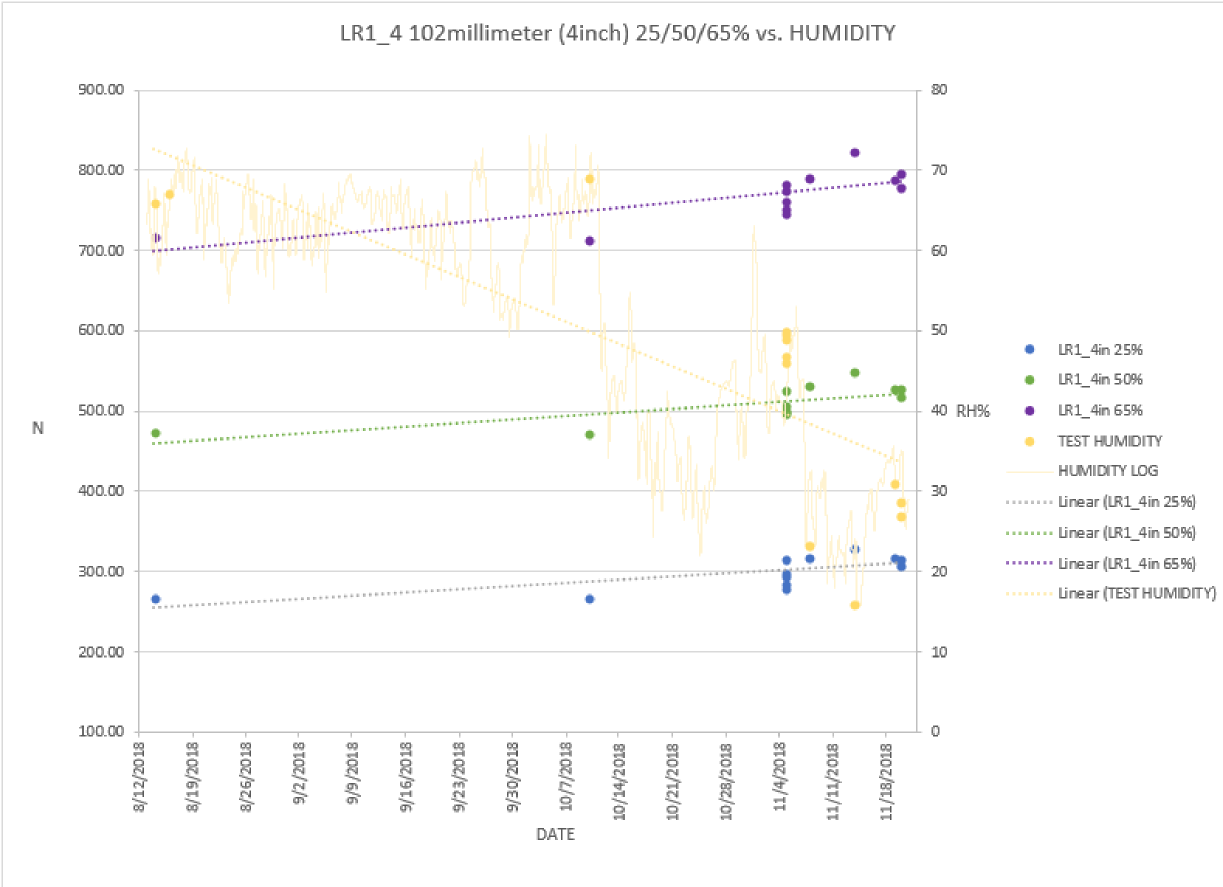


Figure F3: IFD Response vs. Humidity for LR1

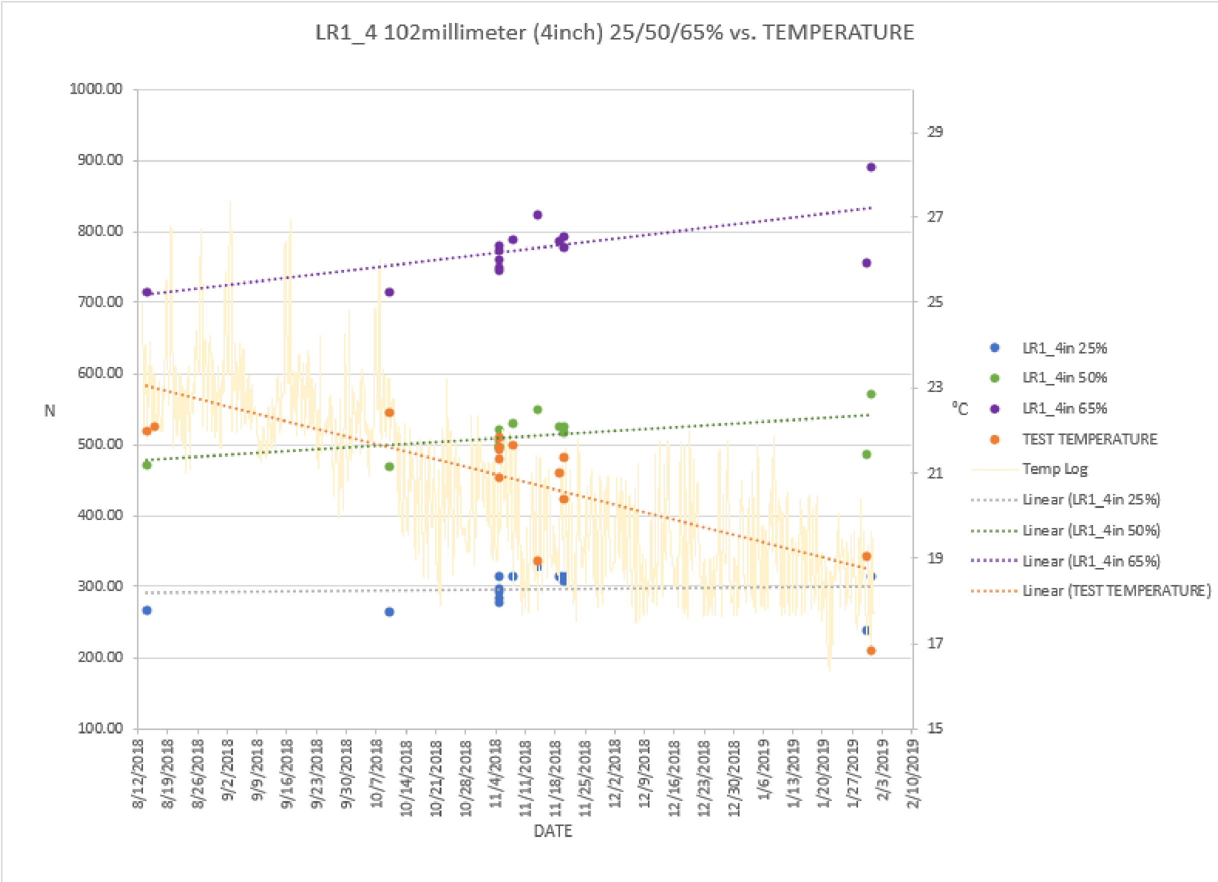


Figure F4: IFD Response vs. Temperature for LR1

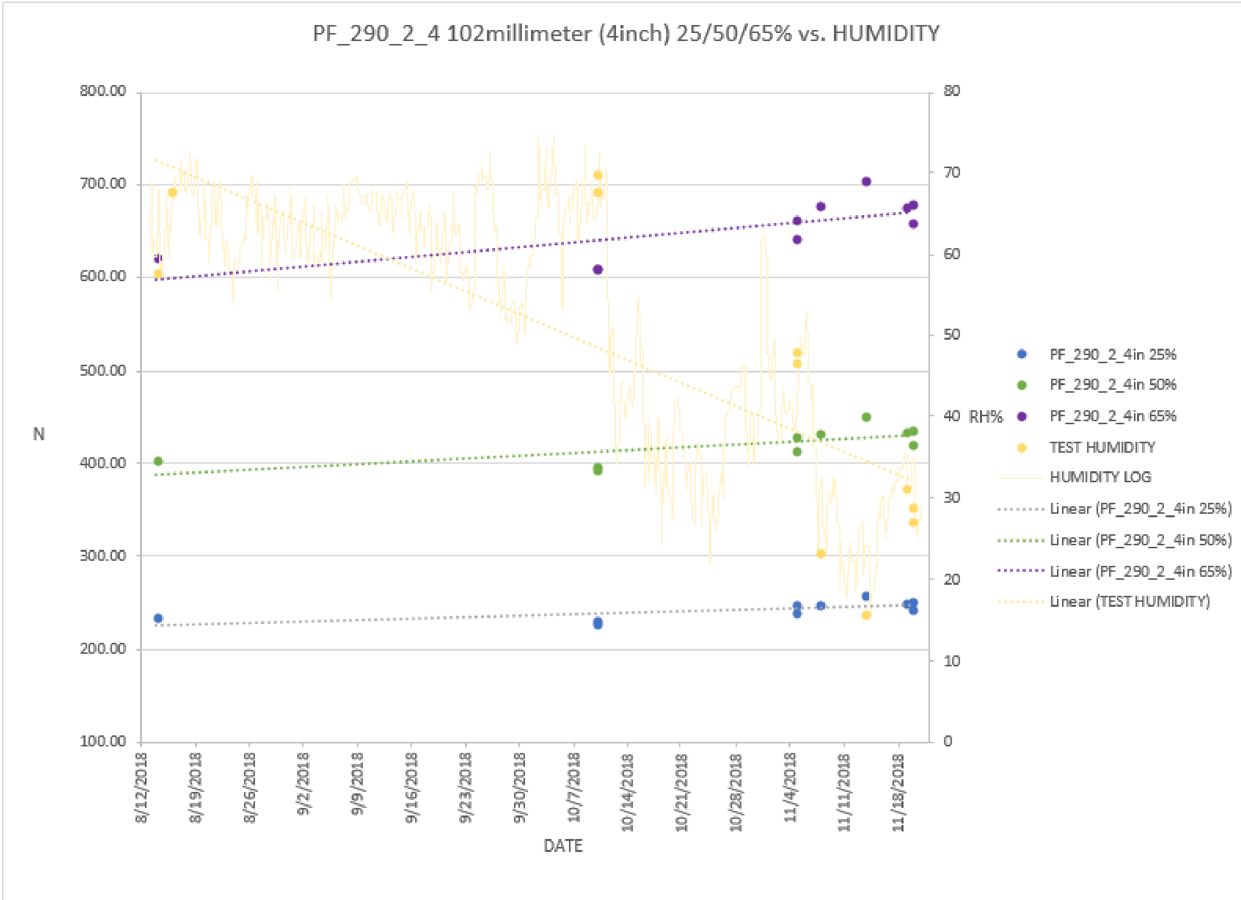


Figure F5: IFD Response vs. Humidity for Perfect-Fit McDonald 290

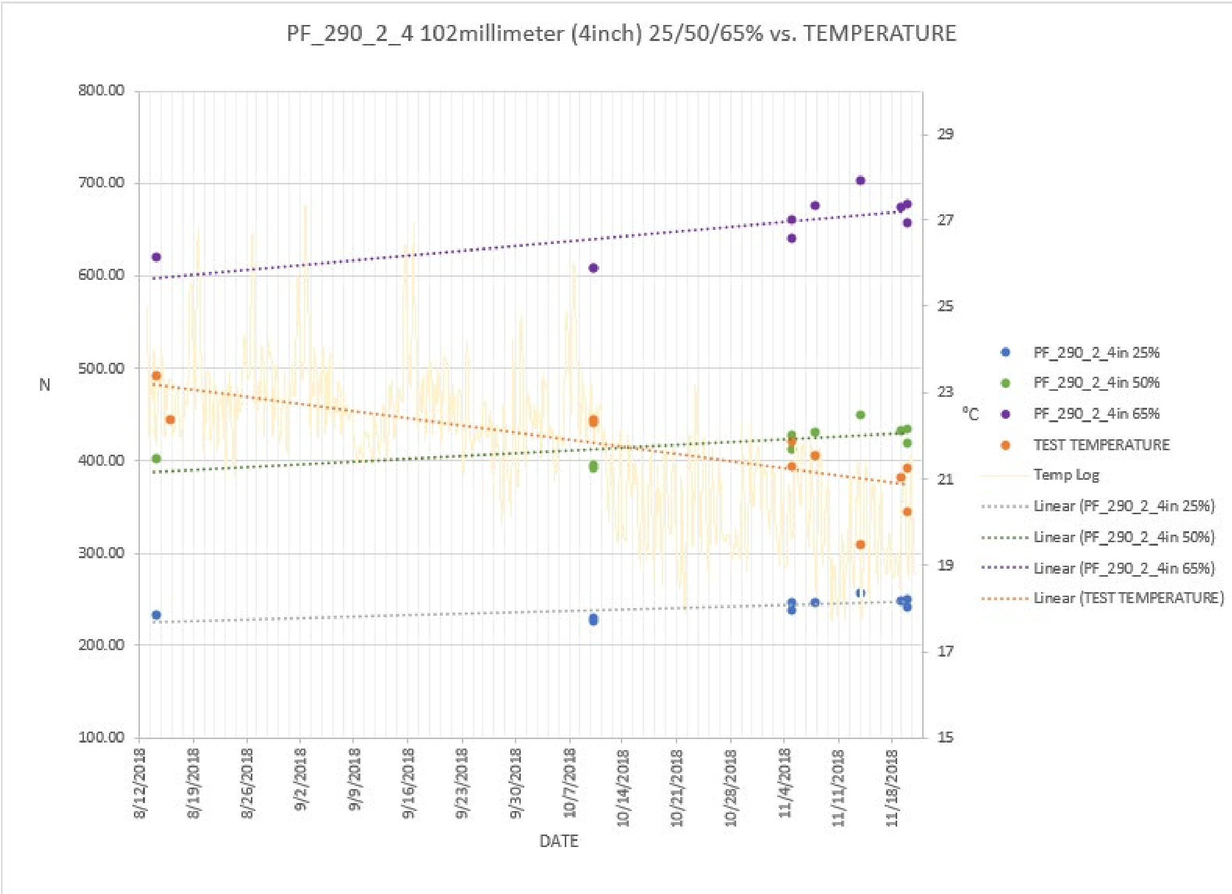


Figure F6: IFD Response vs. Temperature for Perfect-Fit McDonald 290

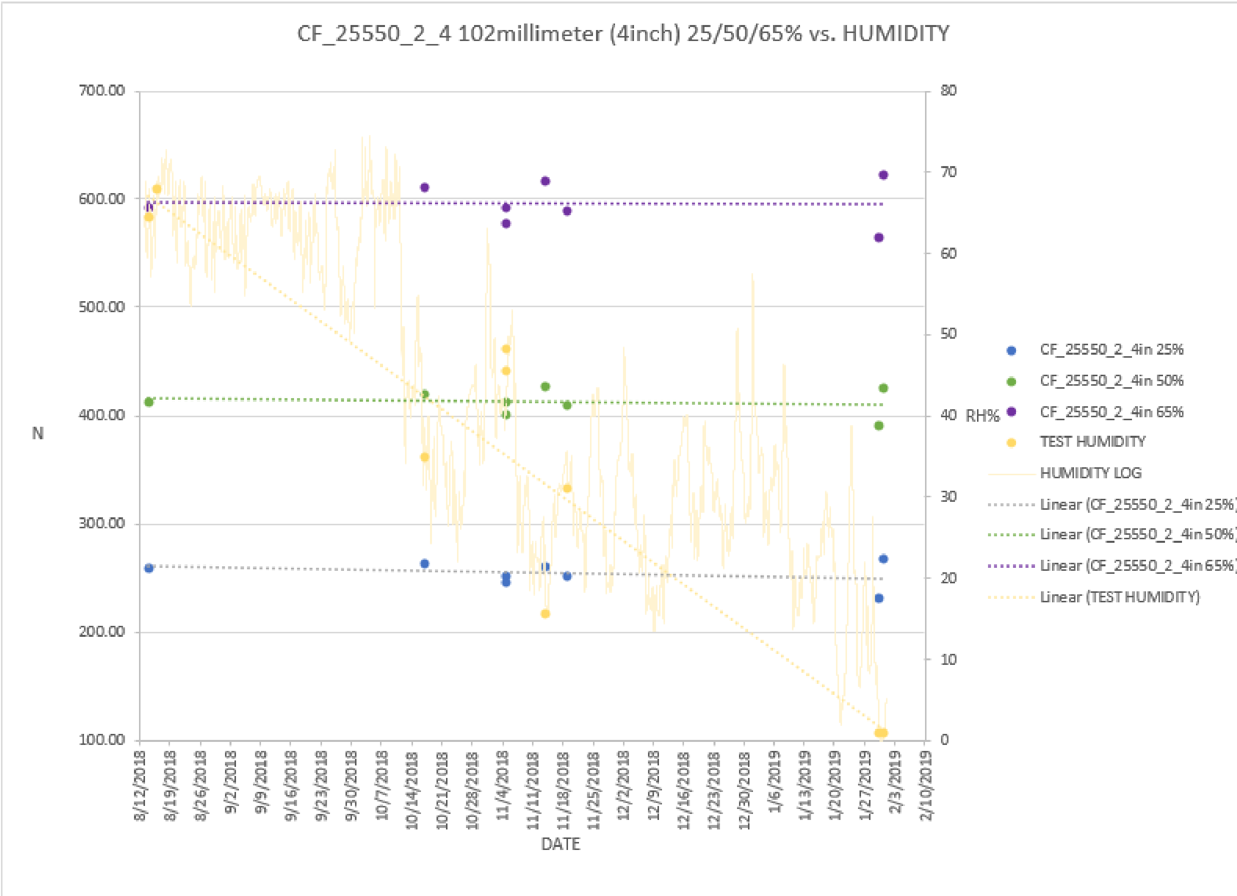


Figure F7: IFD Response vs. Humidity for Century Foam 25550

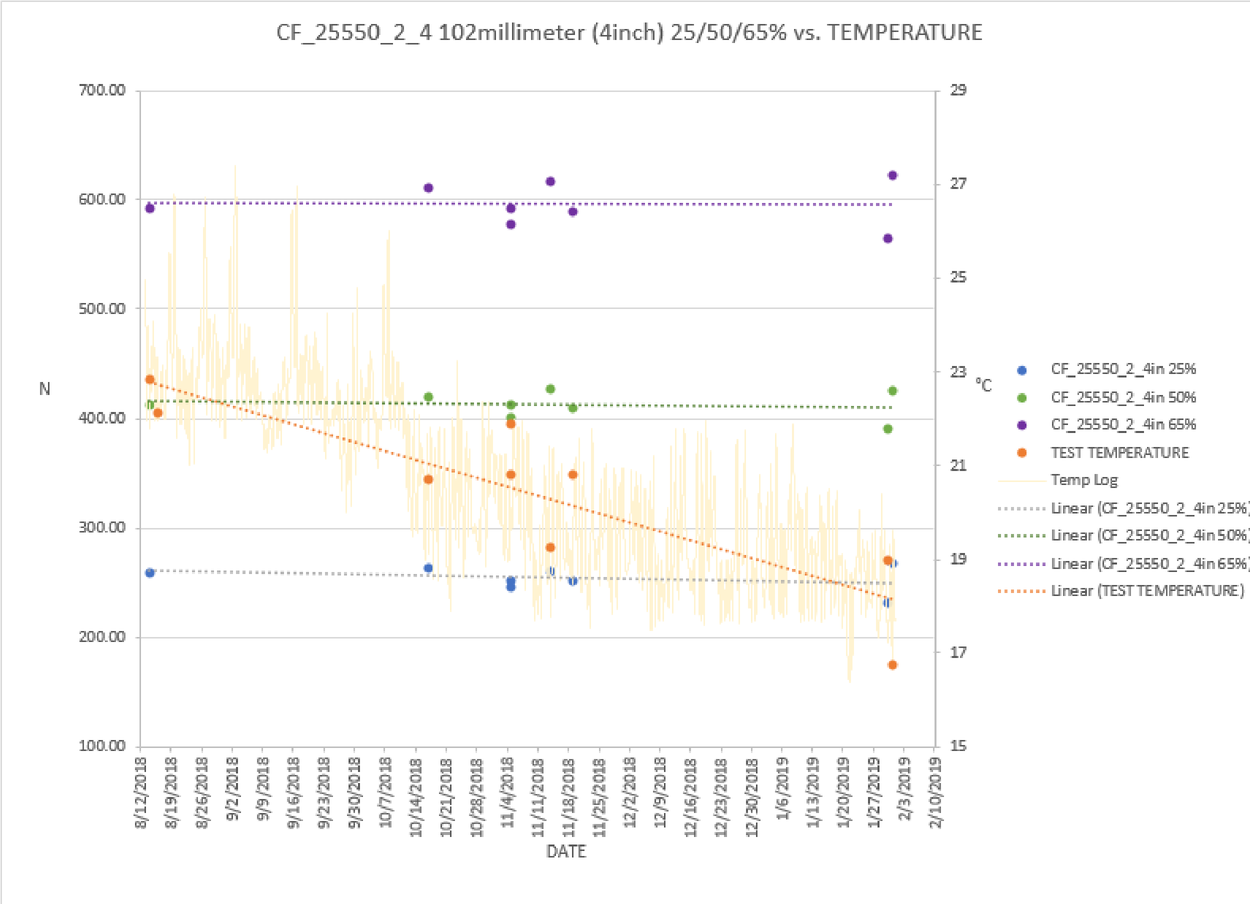


Figure F8: IFD Response vs. Temperature for Century Foam 25550

Comparing plots F1 through F8, an overall trend was observed for the two "custom" foams (Woodbridge and Lear). As the temperature or humidity decreased, the IFD response of the foam increased. The WB foam #14 foam produced the largest difference in IFD response when the temperature and humidity were low. The Lear 1 foam showed similar IFD response variability with the humidity and temperature as WB foam, however not as severe. For the "off the shelf" foams, the Perfect Fit-McDonald 290 foam showed just a slight sensitivity to humidity and temperature, while the Century Foam 25550 showed little to no sensitivity.

Appendix G: Foam Durability Sled Series

Foam Matrix and Testing Procedure

Table G1 lists the Foam and Durability sled test matrix, including the CRS, ATD, and anchorage configuration for each test. The foam sets used for this testing included the following: Century Foam 25550, Perfect Fit-McDonald 290, Lear Corporation, and the Woodbridge foam sets #13 and #14. Three repeatability tests were conducted on each non-Woodbridge foam set with each ATD. Five runs used a Woodbridge foam for comparison. Between each test, a minimum of an hour wait time was observed to allow the foam to relax and return to its original state. After each test, the foam set, and cover were inspected for any tears or cuts.

The sled test series evaluated the foams with a variety of CRSs and different sized ATDs. The non-Woodbridge foams were tested three times each for each type of CRS/ATD configuration to evaluate the repeatability and reproducibility of the foams. In addition, previous sled tests that utilized the Woodbridge foams were used for comparisons. The foams were also tested on the tensile test machine to analyze the foam stiffness differences during the dynamic tests.

Table G1: Foam and Durability Sled Test Matrix

Test Date	VRTC Number	Vehicle Database	CRS	Orientation	Installation Method	Dummy	Foam
S181030-1	FR_FM_07	10586	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Century Foam 25550-2
S181031-2	FR_FM_13	10592	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Century Foam 25550-2
S181023-1	FR_FM_01	10580	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Century Foam 25550-2
S181031-1	FR_FM_11	10590	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	LEAR-1
S181101-2	FR_FM_17	10596	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	LEAR-1
S181026-1	FR_FM_05	10584	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	LEAR-1
S181024-1	FR_FM_03	10582	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Perfect Fit 290 - 1
S181030-2	FR_FM_09	10588	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Perfect Fit 290 - 1
S181101-1	FR_FM_15	10594	Britax B-safe 35	Infant	Lower Anchors Only	12 MTH CRABI	Perfect Fit 290 - 1
S181105-1	FR_FM_24	10601	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Century Foam 25550-2
S181107-1	FR_FM_30	10607	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Century Foam 25550-2
S181108-1	FR_FM_36	10613	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Century Foam 25550-2
S181108-2	FR_FM_22	10599	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	LEAR-1
S181109-1	FR_FM_28	10605	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	LEAR-1
S181109-2	FR_FM_34	10611	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	LEAR-1
S181108-3	FR_FM_26	10603	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Perfect Fit 290 - 1
S181113-1	FR_FM_32	10609	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Perfect Fit 290 - 1
S181113-2	FR_FM_38	10615	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	Perfect Fit 290 - 1
S181107-2	FR_FM_40	10617	Safety 1st Air 65	FF Convertible	LA and Tether	Hybrid III 3YO	WB #14
S181114-1	FR_FM_42	10619	Cosco APT 40	RF Convertible	Lower Anchors Only	Hybrid III 3YO	Century Foam 25550-2
S181119-1	FR_FM_44	10621	Cosco APT 40	RF Convertible	Lower Anchors Only	Hybrid III 3YO	LEAR-1
S181116-2	FR_FM_46	10623	Cosco APT 40	RF Convertible	Lower Anchors Only	Hybrid III 3YO	Perfect Fit 290 - 1
S181116-1	FR_FM_48	10625	Cosco APT 40	RF Convertible	Lower Anchors Only	Hybrid III 3YO	WB #14
S181108-2	FR_FM_21	10598	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Century Foam 25550-2
S181109-1	FR_FM_27	10604	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Century Foam 25550-2
S181109-2	FR_FM_33	10610	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Century Foam 25550-2
S181108-3	FR_FM_25	10602	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	LEAR-1
S181113-1	FR_FM_31	10608	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	LEAR-1
S181113-2	FR_FM_37	10614	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	LEAR-1
S181105-1	FR_FM_23	10600	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Perfect Fit 290 - 1
S181107-1	FR_FM_29	10606	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Perfect Fit 290 - 1
S181108-1	FR_FM_35	10612	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Perfect Fit 290 - 1
S181119-1	FR_FM_43	10620	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	Perfect Fit 290 - 1
S181107-2	FR_FM_39	10616	Graco Nautilus 65 3-in-1	FF Combination	3-point Seat Belt	Hybrid III 6YO	WB #13
S181114-1	FR_FM_41	10618	Graco Turbo Booster	FF Booster	3-point Seat Belt	Hybrid III 6YO	WB #14
S181024-1	FR_FM_04	10583	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Century Foam 25550-2
S181030-2	FR_FM_10	10589	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Century Foam 25550-2
S181101-1	FR_FM_16	10595	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Century Foam 25550-2
S181023-1	FR_FM_02	10581	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	LEAR-1
S181030-1	FR_FM_08	10587	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	LEAR-1
S181031-2	FR_FM_14	10593	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	LEAR-1
S181026-1	FR_FM_06	10585	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Perfect Fit 290 - 1
S181031-1	FR_FM_12	10591	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Perfect Fit 290 - 1
S181116-1	FR_FM_47	10624	Evenflo Amp_no back	FF Booster	3-point Seat Belt	Hybrid III 10YO**	Perfect Fit 290 - 2
S181116-2	FR_FM_45	10622	Frontier Clicktight	FF with Harness	3 Point Seat Belt with Top Tether	Hybrid III 10YO**	WB #14

Since the Woodbridge foam was the baseline foam, only one foam set per CRS was tested during this series. The other foams were used three times to analyze the repeatability of the foams sets along with the durability. In addition, this series also tested some single CRS and other CRS configurations to address the durability of the foam.

Test Parameters

The sled test series was conducted with the proposed FMVSS No. 213 test bench[27] per the FMVSS No. 213 pulse specifications: acceleration within the corridor and velocity within the tolerance of 48, +0, -3.2 kilometers per hour (30, +0, -2 mph). All tests fell within the FMVSS No. 213 acceleration corridors (Figure G1).[28]

[27] NHTSA Docket # NHTSA-2013-0055-0015.

[28] FMVSS No. 213 test procedure. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/tp-213-10_tag.pdf.

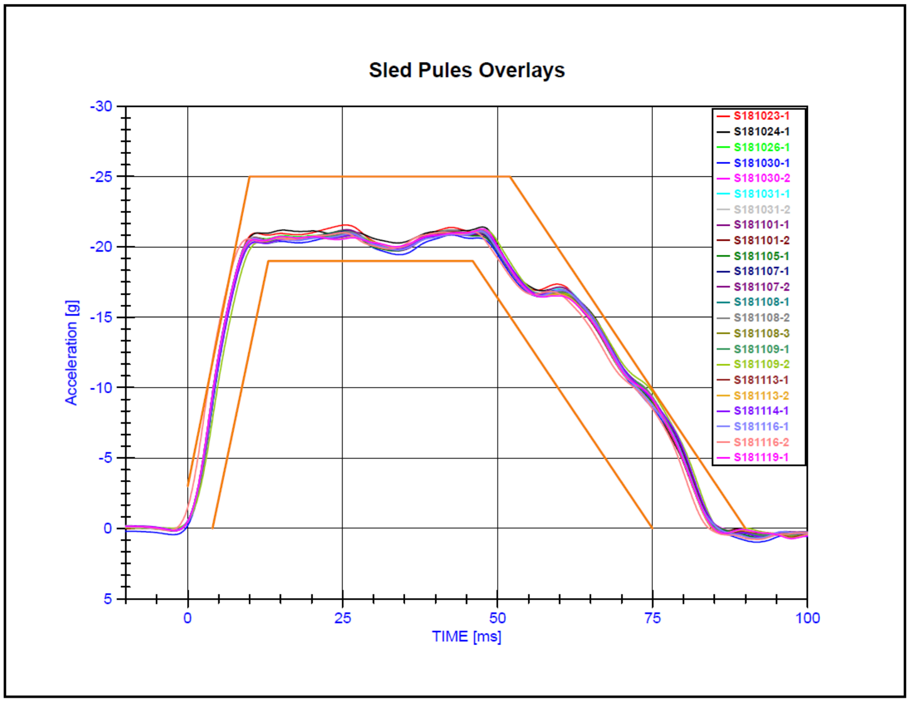


Figure G1: FMVSS No. 213 Acceleration Corridor and Sled Pulse Results

The proposed FMVSS No. 213 test bench used for this test series had two seat assemblies on the sled buck interface (Figure G2), which allowed two ATD and CRS configurations to be tested during the same sled run. This sled buck additionally allows two sets of foams to be tested per run.

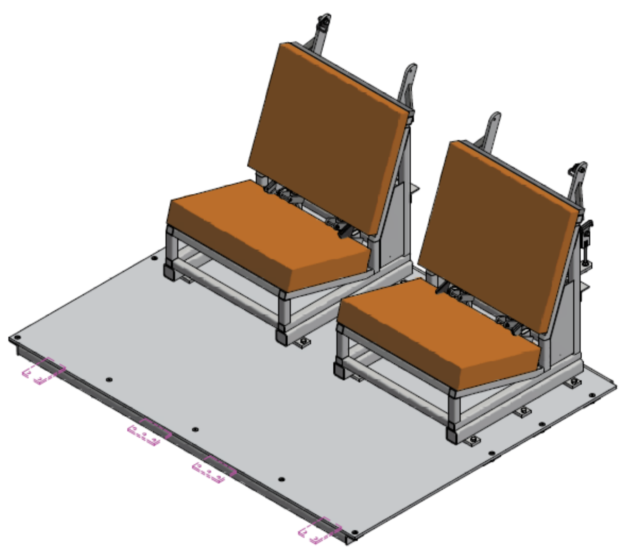


Figure G2: FMVSS No. 213 Seat Assemblies

Four child ATDs were used in the test series: CRABI 12 MO, HIII 3YO, HIII 6YO, and HIII 10YO. The CRABI 12 MO was utilized in the rear-facing (RF) configuration with infant and convertible CRSs. The HIII 3YO was tested in both rear-facing and forward-facing (FF) configurations with convertible and combination CRSs. The HIII 6YO was used in the FF configuration with convertible CRSs and belt positioning boosters (BPBs). The HIII 10YO was used in the FF configuration with convertible CRSs and BPBs. Table G2 lists the instrumentation used for each dummy.

Table G2: Summary of Instrumentation for ATDs

Location	Measurement	Instrument	Channels	ATDs			
				12MO	3YO	6YO	10YO
Head	Head C.G. Acceleration	Tri-Axial Accelerometer	3	✓	✓	✓	✓
Neck	Upper Neck Forces & Moments	6-Axis Load Cell	6	✓	✓	✓	✓
	Lower Neck Forces & Moments	6-Axis Load Cell	6	✓	✓	✓	✓
Thorax	Chest Acceleration	Tri-Axial Accelerometer	3	✓	✓	✓	✓
	Chest Displacement	Rotary Potentiometer	1		✓	✓	✓
Lumbar Spine	Forces & Moments	6-Axis Load Cell	6	✓	✓	✓	✓
	Velocity	Angular Rate Sensor	1			✓	
Pelvis	Pelvis Acceleration	Tri-Axial Accelerometer	3	✓	✓	✓	✓
Total Channels				27	28	29	28

Data from all the instruments used in each ATD were collected; however, analysis was only performed on those for which injury criteria are included in the FMVSS No. 213 procedure: head injury criteria (HIC36), 3ms chest acceleration, rear-facing angle, and occupant excursions. Although HIC36 is not specified as a criterion for the HIII 10YO in FMVSS No. 213, it was calculated for the HIII 10YO for consistency.

Test Set-Up:

The child restraints were placed on the bench and installed per the test matrix (Table G1) For the configurations tested, the webbing was tensioned to the values shown in Table G3, using a three-prong belt tensioning gauge (Borroughs BT3329S). The ATDs were seated based on the seating protocols in the FMVSS No. 213 test procedures. The CRSs and ATDs were measured with a coordinate measuring machine (Faro Arm). The measurements were used to seat the ATDs in the repeat testing.

Table G3: Belt Tension Specifications

	Lower Anchor Tethers	Top Tether	Internal Harness	3PT Seat Belt with CRS	3PT Belt with BPB
Tension	54-67 N (12-15 lbs)	45-54 N (10-12 lbs)	9-18 N (2-4 lbs)	54-67 N (12-15 lbs)	9-18 N (2-4 lbs)

Sled Results

Twenty-three sled runs (46 individual tests) were conducted for the foam durability sled series. All results are reported in Appendix H.

Repeatability and Reproducibility (R&R)

One objective of the test series analysis was to determine if the different manufactured foams produced repeatable and reproducible ATD responses in a FMVSS No. 213 type sled test. Each foam (Century Foam 25550-2, Lear-1, and Perfect Fit 290-1) was tested using four different ATDs. The same test (orientation, installation method, ATD, foam) was conducted three times for repeatability with each foam. In five of the runs, a Woodbridge foam set was used for comparison.

Repeatability was analyzed by using percent coefficient of variation (CV) on the ATD results for the different CRSs and the different foam sets. The target response for repeatability was a percent CV at or below 10 percent.

Table G4 reports the injury criteria and percent CV values for the CRABI 12 MO tests. The CRABI was tested in a Britax B-Safe infant seat. The repeatability with the CRABI 12 MO in an infant car seat was analyzed for HIC36, 3ms chest clip, maximum seat back angle, and head containment. Each foam had good repeatability, and when all the foams were combined, they had percent CV's of five, four, and three respectively.

Table G4: 12 MO Results and Foam Repeatability

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Max Seat Back Angle	Head CG Containment
V10580	F_FM_01	Britax B-Safe	Infant	Lower Anchors	Century	CRABI 12 MO	639	46	55	Yes
V10586	F_FM_07	Britax B-Safe	Infant	Lower Anchors	Century	CRABI 12 MO	671	44	53	Yes
V10592	F_FM_13	Britax B-Safe	Infant	Lower Anchors	Century	CRABI 12 MO	662	46	53	Yes
						Avg.	657	45	54	NA
						St. Dev.	17	1	1	NA
						%CV	3	3	2	NA

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Max Seat Back Angle	Head CG Containment
V10584	F_FM_05	Britax B-Safe	Infant	Lower Anchors	Lear	CRABI 12 MO	590	44	58	Yes
V10590	F_FM_11	Britax B-Safe	Infant	Lower Anchors	Lear	CRABI 12 MO	623	44	55	Yes
V10596	F_FM_17	Britax B-Safe	Infant	Lower Anchors	Lear	CRABI 12 MO	590	44	56	Yes
						Avg.	601	44	57	NA
						St. Dev.	19	0	5	NA
						%CV	3	0	3	NA

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Max Seat Back Angle	Head CG Containment
V10582	F_FM_03	Britax B-Safe	Infant	Lower Anchors	Perfect Fit	CRABI 12 MO	636	41	57	Yes
V10588	F_FM_09	Britax B-Safe	Infant	Lower Anchors	Perfect Fit	CRABI 12 MO	673	45	53	Yes
V10594	F_FM_15	Britax B-Safe	Infant	Lower Anchors	Perfect Fit	CRABI 12 MO	631	41	54	Yes
						Avg.	646	43	55	NA
						St. Dev.	23	2	2	NA
						%CV	4	5	3	NA

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Max Seat Back Angle	Head CG Containment
				All Foams Combined		Avg.	635	44	55	NA
						St. Dev.	31	2	2	NA
						%CV	5	4	3	NA

Repeatability with the HIII 3YO was analyzed using a forward-facing and a rear-facing convertible car seat. For the rear-facing test orientation, a more limited sample was used (one CRS per foam set). The Cosco APT 40 was selected due to the base's shape and size. In previous sled testing, it was determined that this CRS had penetrated the foam causing small tears in the foam. One test per foam, including Woodbridge, was tested using this test orientation. Table G5 shows the injury criteria results along with the percent CV values. HIC36, 3ms chest clip, maximum seat back angle, and head CG containment were analyzed for the rear facing HIII 3YO. These had percent CV's of nine, six, and three respectively. Additionally, there was no notable damage to any of the foam sets during this testing.

Table G5: RF HIII 3YO Repeatability with Various Foams

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Max Seat Back Angle	Head CG Containment
V10619	FR_FM_42	Cosco APT 40	RF Convertible	Lower Anchors Only	Century	Hybrid III 3YO	510	53	52	Yes
V10621	FR_FM_44	Cosco APT 40	RF Convertible	Lower Anchors Only	Lear	Hybrid III 3YO	516	51	54	Yes
V10623	FR_FM_46	Cosco APT 40	RF Convertible	Lower Anchors Only	Perfect Fit	Hybrid III 3YO	448	49	52	Yes
V10625	FR_FM_48	Cosco APT 40	RF Convertible	Lower Anchors Only	Wood-bridge	Hybrid III 3YO	431	46	50	Yes
						Avg.	476	50	52	NA
						St. Dev.	43	3	2	NA
						%CV	9	6	3	NA

Additionally, repeatability with the HIII 3YO was analyzed using a forward-facing convertible car seat. The Safety 1st Air 65 car seat was used for this test orientation. Table G6 shows the injury criteria results along with the percent CV values. HIC36, 3ms chest clip, and head and knee excursions were analyzed for the forward-facing HIII 3YO. Each foam had good repeatability, and when all the foams were combined with the one Woodbridge foam, they had percent CV's of seven, four, two, and one, respectively.

Table G6: FF HIII 3YO Results and Foam Repeatability

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
10601	FR_FM_24	Safety 1st Air 65	FF Convertible	LA and Tether	Century	Hybrid III 3YO	369	40	600	672
10607	FR_FM_30	Safety 1st Air 65	FF Convertible	LA and Tether	Century	Hybrid III 3YO	406	43	610	684
10613	FR_FM_36	Safety 1st Air 65	FF Convertible	LA and Tether	Century	Hybrid III 3YO	386	44	601	695
						Avg.	387	42	604	684
						St. Dev.	19	2	6	11
						%CV	5	5	1	2

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
10603	FR_FM_26	Safety 1st Air 65	FF Convertible	LA and Tether	Lear	Hybrid III 3YO	414	44	633	678
10609	FR_FM_32	Safety 1st Air 65	FF Convertible	LA and Tether	Lear	Hybrid III 3YO	443	46	638	696
10615	FR_FM_38	Safety 1st Air 65	FF Convertible	LA and Tether	Lear	Hybrid III 3YO	391	42	628	679
						Avg.	402	45	625	687
						St. Dev.	22	1	6	3
						%CV	5	2	1	0

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
10599	FR_FM_22	Safety 1st Air 65	FF Convertible	LA and Tether	Perfect Fit	Hybrid III 3YO	424	46	629	686
10605	FR_FM_28	Safety 1st Air 65	FF Convertible	LA and Tether	Perfect Fit	Hybrid III 3YO	401	44	618	685
10611	FR_FM_34	Safety 1st Air 65	FF Convertible	LA and Tether	Perfect Fit	Hybrid III 3YO	381	45	629	691
						Avg.	416	44	633	684
						St. Dev.	26	2	5	10
						%CV	6	5	1	1

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
10617	FR_FM_40	Safety 1st Air 65	FF Convertible	LA and Tether	Wood-bridge	Hybrid III 3YO	356	43	604	665
						Avg.	397	44	619	683
				All Foams Combined		St. Dev.	26	2	14	10
						%CV	7	4	2	1

The HIII 6YO was analyzed for repeatability using the Graco Nautilus 65 3-in-1. Table G7 shows the injury criteria results along with the percent CV values. HIC36, 3ms chest clip, and head and knee excursions were analyzed for the HIII 6YO. Each foam had good repeatability, and when all the foams were combined with the one Woodbridge foam, they had percent CV's of two, four, two, and one, respectively.

Table G7: FF HIII 6YO Repeatability

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10598	S181108-2	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Century	Hybrid III 6YO	529	46	697	769
V10604	S181109-1	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Century	Hybrid III 6YO	544	43	659	745
V10610	S181109-2	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Century	Hybrid III 6YO	522	43	671	747
						Avg.	532	44	676	754
						St. Dev.	11	2	19	13
						%CV	2	4	3	2

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10606	S181107-1	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Perfect Fit	Hybrid III 6YO	550	48	690	774
V10612	S181108-1	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Perfect Fit	Hybrid III 6YO	525	45	680	760
V10620	S181119-1	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Perfect Fit	Hybrid III 6YO	517	45	681	760
						Avg.	531	46	684	765
						St. Dev.	17	2	6	8
						%CV	3	4	1	1

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10602	S181108-3	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Lear	Hybrid III 6YO	539	44	679	751
V10608	S181113-1	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Lear	Hybrid III 6YO	539	48	684	769
V10614	S181113-2	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Lear	Hybrid III 6YO	547	45	682	759
						Avg.	542	46	682	757
						St. Dev.	5	2	3	9
						%CV	1	4	0	1

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10616	S181113-2	Graco Nautilus 65 3-in-1	FF Combination	3-Point Seat Belt	Wood-bridge	Hybrid III 6YO	476	45	682	759
						Avg.	529	45	680	759
				All Foams Combined		St. Dev.	12	2	11	10
						%CV	2	4	2	1

Repeatability with the HIII 10YO in an Evenflo Amp no back booster was analyzed for HIC36, 3ms chest clip, and head and knee excursions; results were repeatable as shown in Table G8. Each foam had good repeatability, and when all the foams were combined, they had percent CV's of ten, four, two and one, respectively. The HIC36 used for this analysis were truncated for two tests (V10581 and V10583) during rebound when the ATD's head struck the top of the seat.

Table G8: HIII 10YO Repeatability

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10583	FR_FM_04	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Century	Hybrid III 10YO	412	42	508	646
V10589	FR_FM_10	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Century	Hybrid III 10YO	492	42	487	666
V10595	FR_FM_16	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Century	Hybrid III 10YO	515	44	485	666
						Avg.	473	43	493	659
						St. Dev.	54	1	13	12
						%CV	11	2	3	2

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10585	FR_FM_06	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Perfect Fit	Hybrid III 10YO	551	43	497	660
V10591	FR_FM_12	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Perfect Fit	Hybrid III 10YO	438	40	496	656
V10624	FR_FM_02	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Perfect Fit	Hybrid III 10YO	517	42	474	674
						Avg.	502	42	489	663
						St. Dev.	58	1	13	10
						%CV	12	3	3	1

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10581	FR_FM_02	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Lear	Hybrid III 10YO	543	44	505	652
V10587	FR_FM_08	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Lear	Hybrid III 10YO	567	46	495	663
V10593	FR_FM_14	Evenflo Amp-No Back	FF Booster	3-Point Seat Belt	Lear	Hybrid III 10YO	525	44	504	666
						Avg.	545	45	501	661
						St. Dev.	21	1	6	7
						%CV	4	2	1	1

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
						Avg.	507	43	495	661
				All Foams Combined		St. Dev.	52	2	11	9
						%CV	10	4	2	1

Comparison of March 2015 Sled Testing Series

Tests from the March 2015 sled series were used to compare to the 2018 foam durability test series. Injury criteria were compared, and percent CV's were analyzed. Each previous test (Woodbridge) on the selective CRS was grouped with the corresponding test using the other manufacturers' foams for comparison. Tables G9 through G12 list the injury criteria averages and percent CVs for just the 2018 test series and for the 2015 and 2018 test series combined.

Table G9: 12MTH CRABI 2018 and 2015 Sled Test Comparison: Britax B-Safe 35 Infant Seat

		HIC36	Chest Clip 3ms	Max Seat Back Angle
NHTSA #9608 (FRUPG2_69)	Woodbridge #4	598	42	64
2018 Foam Series (non-Woodbridge Foam)	Average	635	44	55
	St. Dev.	31	2	22
	%CV	5	4	3
Combined All Foams (Years 2015 and 2018)	Average	631	44	56
	St. Dev.	31	2	3
	%CV	5	4	6

Table G10: HIII 3YO 2018 Sled Test Comparison: Safety 1st Air 65 FF Convertible

		HIC36	Chest Clip 3ms	Head Excursion	Knee Excursion
NHTSA #10617 (FR_FM_40)	Woodbridge #14	356	43	604	665
2018 Foam Series (non-Woodbridge Foam)	Average	402	44	621	685
	St. Dev.	23	2	14	8
	%CV	6	4	2	1
All Tests (2018 only)	Average	397	44	619	683

St. Dev.	26	2	14	10
%CV	7	4	2	1

Table G11: HIII 6YO 2018 and 2015 Sled Test Comparison: Graco Nautilus 65 FF Convertible

		HIC36	Chest Clip 3ms	Head Excursion	Knee Excursion
NHTSA#10616 (FR_FM_39)	Woodbridge#13	476	41	672	757
NHTSA#9611 (FR_UPG2_76)	Woodbridge #5	570	44	664	725
NHTSA#9612 (FR_UPG2_78)	Woodbridge #5	535	42	656	721
NHTSA#9613 (FR_UPG2_80)	Woodbridge #5	535	43	676	740
2018 Foam Series (non-Woodbridge Foam)	Average	535	45	680	759
	St. Dev	12	2	11	10
	%CV	2	4	2	1
All Tests (2015 and 2018)	Average	533	44	676	752
	St. Dev.	22	2	12	16
	%CV	4	5	2	2

Table G12: HIII 10YO 2018 and 2015 Sled Test Comparison: Evenflo Amp (NB) Booster

		HIC36	Chest Clip 3ms	Head Excursion	Knee Excursion
NHTSA#9619 (FR_UPG2_92)	Woodbridge #5	541	45	500	652
2018 Foam Series	Average	507	43	495	661
	St. Dev.	52	2	11	9
	%CV	10	4	2	1
All Tests (2015 and 2018)	Average	510	43	495	660
	St. Dev.	50	2	10	9
	%CV	10	4	2	1

Adding in the 2015 data set conducted with the Woodbridge foam sets did not significantly change the average or percent CV values of those reported for the various foams.

Two additional configurations were tested to compare an old WB foam set (WB#5) to a newer WB foam set (WB#14). The Hybrid III 6YO was tested in a Graco Turbo Booster (no back) in a belt position booster configuration. The Hybrid III 10YO was tested in the Britax Frontier Clicktight with the 5-point harness attached with a 3-point belt and top tether. The two additional tests conducted in 2018 used the WB#14 foam set. The results were similar between the two comparison tests. The HIC36, 3ms chest clip, and head and knee excursions for both the 2015 and 2018 tests are reported in Tables G13 and G14.

This limited test series further indicates that the different foam cushion sets did not affect the overall ATD responses when used on the proposed FMVSS No. 213 test bench.

Table G13: HIII 6YO 2018 and 2015 Sled Test Comparison for Graco Turbo Booster

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10618	S181114-1	Graco Turbo Booster	FF Booster	3-Point Seat Belt	WB#14	HIII 6YO	439	45	525	606
V9609	S150730-2	Graco Turbo Booster	FF Booster	3-Point Seat Belt	WB#5	HIII 6YO	485	46	568	620

Table G14: HIII 10YO 2018 and 2015 Sled Test Comparison for Frontier Clicktight

VDB Test No.	VRTC Number	Seat Name	Orientation	Installation Method	Foam	ATD	HIC36	Chest Clip (g)	Head Excursion	Knee Excursion
V10622	S181116-2	Britax Frontier Clicktight	FF with Harness	3PTSB and Top Tether	WB #14	HIII 10YO	336	37	730	826
V9601	S150721-1	Britax Frontier Clicktight	FF with Harness	3PTSB and Top Tether	WB #5	HIII 10YO	368	38	700	831

Appendix H: 2018 Dynamic Sled Test Results

					IARVs Used	1000	60	30 (12 MTH) 34 (3YO) 40 (6YO) 52 (10YO)	Head CG must be contained	70	720 (w/ tether) 813 (w/o tether)	915
Test Number	VRTC Number	Vehicle Database	CRS	ATD	Foam	HIC 36	Chest Clip 3ms (g)	Chest Deflection (mm)	RF Head Containment (Y or N)	Max Seat Back Angle (from vertical)	Head Excursion (mm)	Knee Excursion (mm)
S181023-1	FR_FM_01	10580	Britax B-safe 35	CRABI 12 MO	CENT_1	639	46	NA	Yes	55	NA	NA
S181023-1	FR_FM_07	10586	Britax B-safe 35	CRABI 12 MO	CENT_1	671	44	NA	Yes	53	NA	NA
S181024-1	FR_FM_13	10592	Britax B-safe 35	CRABI 12 MO	CENT_1	662	46	NA	Yes	53	NA	NA
S181024-1	FR_FM_05	10584	Britax B-safe 35	CRABI 12 MO	LEAR_1	590	44	NA	Yes	58	NA	NA
S181026-1	FR_FM_11	10590	Britax B-safe 35	CRABI 12 MO	LEAR_1	623	44	NA	Yes	55	NA	NA
S181026-1	FR_FM_17	10596	Britax B-safe 35	CRABI 12 MO	LEAR_1	590	44	NA	Yes	56	NA	NA
S181030-1	FR_FM_03	10582	Britax B-safe 35	CRABI 12 MO	PF_1	636	41	NA	Yes	57	NA	NA
S181030-1	FR_FM_09	10588	Britax B-safe 35	CRABI 12 MO	PF_1	673	45	NA	Yes	53	NA	NA
S181030-2	FR_FM_15	10594	Britax B-safe 35	CRABI 12 MO	PF_1	631	41	NA	Yes	54	NA	NA

S181114-1	FR_FM_42	10619	Cosco APT 40	Hybrid III 3YO	CENT_1	510	53	-13	Yes	52	NA	NA
S181114-1	FR_FM_44	10621	Cosco APT 40	Hybrid III 3YO	LEAR_1	448	49	-13	Yes	52	NA	NA
S181119-1	FR_FM_46	10623	Cosco APT 40	Hybrid III 3YO	PF_1	516	51	-14	Yes	54	NA	NA
S181119-1	FR_FM_48	10625	Cosco APT 40	Hybrid III 3YO	WB #14	431	46	-13	Yes	50	NA	NA
S181101-1	FR_FM_30	10607	Safety 1st Air 65	Hybrid III 3YO	CENT_1	406	43	-20	NA	NA	610	684
S181101-1	FR_FM_36	10613	Safety 1st Air 65	Hybrid III 3YO	CENT_1	386	44	-20	NA	NA	601	695
S181101-2	FR_FM_24	10601	Safety 1st Air 65	Hybrid III 3YO	CENT_1	369	40	-19	NA	NA	600	672
S181101-2	FR_FM_28	10605	Safety 1st Air 65	Hybrid III 3YO	LEAR_1	401	44	-20	NA	NA	618	685
S181108-2	FR_FM_34	10611	Safety 1st Air 65	Hybrid III 3YO	LEAR_1	381	45	-20	NA	NA	629	691
S181108-2	FR_FM_22	10599	Safety 1st Air 65	Hybrid III 3YO	LEAR_1	424	46	-21	NA	NA	629	686
S181105-1	FR_FM_26	10603	Safety 1st Air 65	Hybrid III 3YO	PF_1	414	44	-22	NA	NA	633	678
S181105-1	FR_FM_32	10609	Safety 1st Air 65	Hybrid III 3YO	PF_1	443	46	-21	NA	NA	638	696
S181108-3	FR_FM_38	10615	Safety 1st Air 65	Hybrid III 3YO	PF_1	391	42	-20	NA	NA	628	679
S181108-3	FR_FM_40	10617	Safety 1st Air 65	Hybrid III 3YO	WB#14	356	43	-19	NA	NA	604	665

S181107-1	FR_FM_21	10598	Graco Nautilus 65 3-in-1	Hybrid III 6YO	CENT_1	529	46	-19	NA	NA	697	769
S181113-1	FR_FM_27	10604	Graco Nautilus 65 3-in-1	Hybrid III 6YO	CENT_1	544	43	-16	NA	NA	659	745
S181113-1	FR_FM_33	10610	Graco Nautilus 65 3-in-1	Hybrid III 6YO	CENT_1	522	43	-16	NA	NA	671	747
S181109-2	FR_FM_25	10602	Graco Nautilus 65 3-in-1	Hybrid III 6YO	LEAR_1	539	44	-14	NA	NA	679	751
S181109-2	FR_FM_31	10608	Graco Nautilus 65 3-in-1	Hybrid III 6YO	LEAR_1	539	48	-17	NA	NA	684	769
S181108-1	FR_FM_37	10614	Graco Nautilus 65 3-in-1	Hybrid III 6YO	LEAR_1	547	45	-16	NA	NA	682	759
S181108-1	FR_FM_23	10600	Graco Nautilus 65 3-in-1	Hybrid III 6YO	PF_1	528	33	-14	NA	NA	674	753
S181113-2	FR_FM_29	10606	Graco Nautilus 65 3-in-1	Hybrid III 6YO	PF_1	550	48	-16	NA	NA	690	774
S181113-2	FR_FM_35	10612	Graco Nautilus 65 3-in-1	Hybrid III 6YO	PF_1	525	45	-16	NA	NA	680	760
S181107-2	FR_FM_43	10620	Graco Nautilus 65 3-in-1	Hybrid III 6YO	PF_1	517	45	-16	NA	NA	681	760
S181107-2	FR_FM_39	10616	Graco Nautilus 65 3-in-1	Hybrid III 6YO	WB #13	476	41	-17	NA	NA	672	757
S181031-2	FR_FM_41	10618	Graco Turbo Booster	Hybrid III 6YO	WB #14	439	45	-37	NA	NA	525	606
S181116-2	FR_FM_04	10583	Evenflo Amp no back	Hybrid III 10YO	CENT_1	412*	42	-43	NA	NA	508	646
S181116-2	FR_FM_10	10589	Evenflo Amp no back	Hybrid III 10YO	CENT_1	492	42	-38	NA	NA	487	666

S181116-1	FR_FM_16	10595	Evenflo Amp no back	Hybrid III 10YO	CENT_1	515	44	-37	NA	NA	485	666
S181116-1	FR_FM_02	10581	Evenflo Amp no back	Hybrid III 10YO	LEAR_1	543*	44	-39	NA	NA	505	652
S181030-2	FR_FM_08	10587	Evenflo Amp no back	Hybrid III 10YO	LEAR_1	567	46	-33	NA	NA	495	663
S181031-1	FR_FM_14	10593	Evenflo Amp no back	Hybrid III 10YO	LEAR_1	525	44	-37	NA	NA	504	666
S181031-1	FR_FM_06	10585	Evenflo Amp no back	Hybrid III 10YO	PF_1	551	43	-35	NA	NA	497	660
S181031-2	FR_FM_12	10591	Evenflo Amp no back	Hybrid III 10YO	PF_1	438	40	-38	NA	NA	496	656
S181109-1	FR_FM_47	10624	Evenflo Amp no back	Hybrid III 10YO	PF_1	517	42	-28	NA	NA	474	674
S181107-1	FR_FM_45	10622	Frontier Clicktight	Hybrid III 10YO	WB #14	336	37	-9	NA	NA	730	826

*Truncated HIC due to rebound strike on back of the seat assembly.