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Effect of Pelvic Loading during Anthropomorphic Test Device Storage

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16. Abstract As part of a larger project aimed at gaining a better understanding of factors that affect the quality of test results using Anthropomorphic Test Devices (ATDs), the FAA tested the effects of long-term static ATD pelvis loading during storage. Testing simulated two types of ATD pelvis storage methods of the 50th percentile Hybrid III ATD for one year. The objective was to measure any changes to the rubber and foam that cover the metallic pelvis of the ATD. In one storage method, the ATD pelvis had no contact between the foam and rubber shell and an external surface. The second storage method had the pelvis loaded with 125 lbs on the bottom side of the pelvis. This is a similar weight to what an FAA Hybrid III ATD loads the bottom of the pelvis when seated in the upright position. Pelvises were removed from storage every three months to measure the effects of their respective storage methods. The data collected suggest that the way an ATD pelvis is stored significantly changes the height of the foam and rubber; this change occurs quickly (within three months) and is likely permanent. The observed change suggests that a conformed pelvis will likely become nonconformed if stored so that the foam and rubber on the pelvis are loaded.					
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Effect of Pelvic Loading during Anthropomorphic Test Device Storage

Background

The Federal Aviation Administration (FAA) has regulations that require aircraft seating systems to protect occupants in the event of a crash. These regulations require dynamic testing to substantiate the safety of seating systems. Dynamic testing uses anthropomorphic test devices (ATD) and sensor sets to collect data in simulated aircraft impacts and crashes that relate the engineering data to the risk of occupant injury. Due to the severe environment of dynamic testing, reusable parts on the ATD break down or wear out, and often, this damage cannot be determined by visual inspection. ATD parts, such as the head and neck, have evaluation methods outlined in 49 CFR 572 to test specific components to ensure they are acceptable (U.S. Code of Federal Regulations, n.d.). These calibration tests are designed to be conducted before a test series is started and are used to determine when the component is no longer operating within the designed criteria. The criteria allow test engineers and technicians to measure the response of a component and determine the need for component replacement.

One of the two dynamic tests required by 14 CFR 2X.562 is a primarily vertical impact with an impact angle of 30° off vertical (U.S. Code of Federal Regulations, n.d.). In this test, the principal measurement is the compressive load in the lumbar spinal column, which has a regulatory limit of 1500 lb. The measured load is a function of the seat compliance (which can reduce the lumbar load), the seat bottom cushion (which amplifies the load), and the compliance of the rubber and foam of the ATD pelvis (which could increase or decrease the load from a nominal value; see *Figure 1* for the foam and rubber cross section). Previous testing has shown significant variability in measured lumbar loads that are, in part, attributed to variability in ATD pelvises (DeWeese et al., 2021; Taylor et al., 2017; DeWeese, 2006). The ATDs required in the aviation regulations were initially developed for the automotive crash environment, which does not include a vertical component. As a result, 49 CFR 572 does not define a calibration test to determine if the pelvis is acceptable for initial use and to monitor testing degradation to determine the need to remove components from service.



Figure 1: Pelvis Foam and Rubber Shell Cross Section

While a vertical calibration test to determine the suitability of the pelvis does not exist, a manufacturing tolerance is defined. This evaluation is conducted by mounting the pelvis upside down on a 5.362-in tall pedestal and setting a static load of 75 lbs onto the pelvis (see Figure 2). Following a five-minute wait, the distance from the pelvis's top surface to the pedestal's bottom surface (referred to as an inspection surface) is recorded. For the Hybrid II pelvis, this measurement should be between 10.802 in and 10.402 in, resulting in a tolerance of ± 0.2 in about the nominal height. For the Hybrid III pelvis, this height range is 10.242 in and 10.362 in. This number is based on GM drawing 78051-58, which specifies the distance from the H-point to the inspection surface must be 3.620 ± 0.060 in (Figure 3).

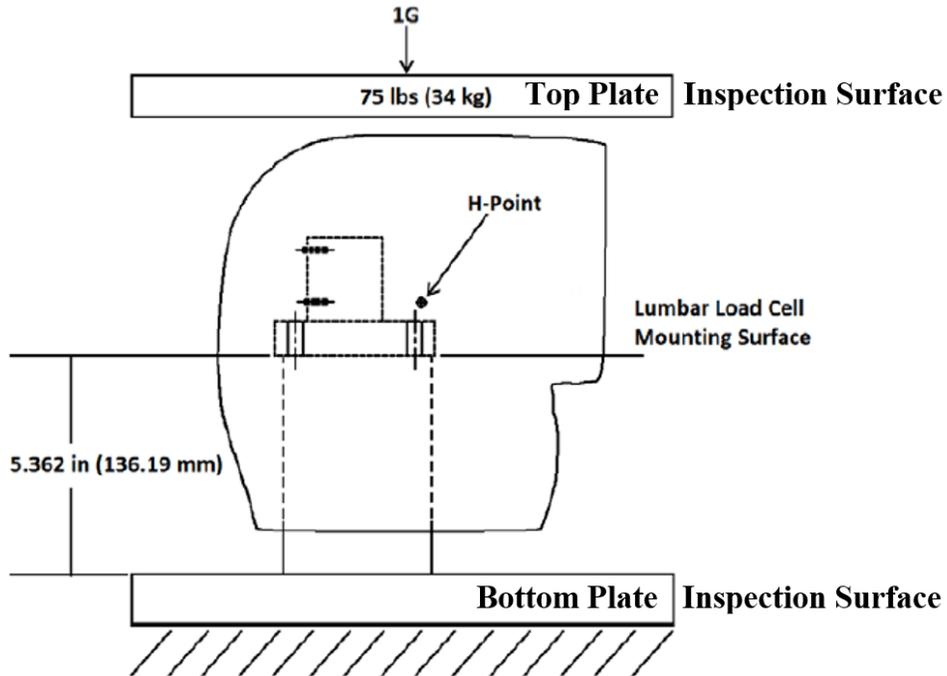


Figure 2: SAE ARP 5765B – Pelvis Compression Illustration

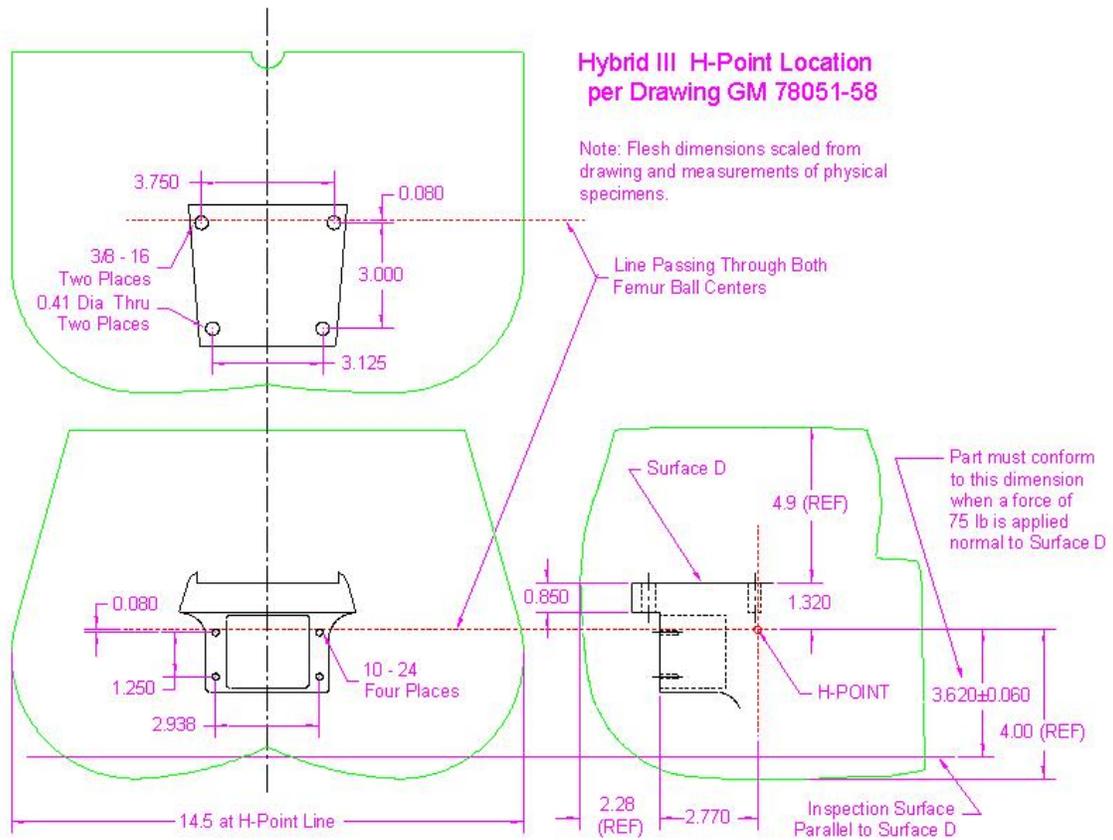


Figure 3: Hybrid III H-Point Location Drawing based on GM drawing 78051-58

A common method of storing ATDs is to place them in a chair, as shown in *Figure 4-A*. The feet may or may not be in contact with a support surface. When the ATD is seated on a flat surface with its feet firmly supported, approximately 125 lbs of force loads the bottom of the pelvis. Because of this constant loading, there is concern that the pelvic foam and rubber shell could degrade. An alternate seating method is supporting the ATD by its armpits (*Figure 4-B*). This method is not recommended for the Hybrid II because a pair of pots in the chest extend when the ATD is hung by the armpits, which causes the pots to degrade. Given these concerns, a chair was designed to use the holes in the pelvis cover and bone casting to support the ATD without loading the pelvis or the shoulder pots (*Figure 4-C and Figure 4-D*). Drawings of the chair are included in the appendix. Care must be taken utilizing the pin-through-pelvis method when using this seating method. If a pin is installed too far into the pelvis, damage can occur to the lumbar load cell and wiring routed near the load cell. Storing the ATD by the sides of the pelvis—where the metallic bone supports the ATD weight—would be preferred if loading the bottom of the pelvis during storage causes significant degradation of the rubber and/or foam. Therefore, as a first step of evaluating pelvis degradation and developing a vertical calibration test, phase one of this project is a yearlong study of the effects of loading the ATD pelvis during storage.

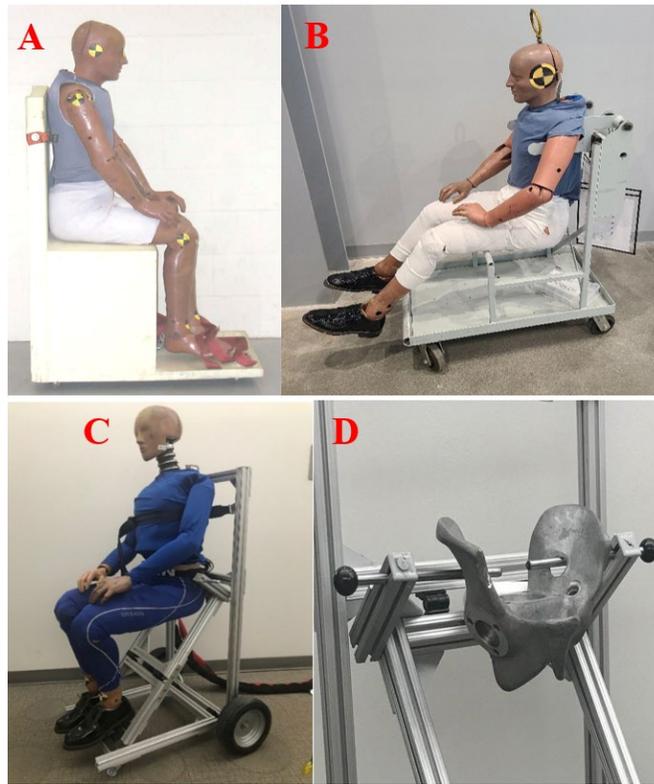


Figure 4: ATD Storage Examples: (A) ATD Seated on Chair, (B) ATD Supported Under Arms (Photo Courtesy of National Institute for Aviation Research), (C) Seated ATD with Pins Through Pelvis, and (D) Bare Pelvis Casting with Pins to Identify Points of Loading

Methods

Static Load Test Stand

To evaluate the effects of loading the ATD pelvis during storage, two identical test stands were developed based on the pedestal used for checking the manufacturing tolerance. The stands allowed a static load to be applied to an ATD pelvis for long-term storage and allowed length measurements to be collected. Each test stand consists of three main components: base plate with pedestal, support arm, and top plate with weight mount (see *Figure 5*). The base plate served three purposes: ATD pelvis mounting fixture, measurement reference points, and support arm guide. The pelvises were attached to the pedestal using the bolt pattern that connects the lumbar load cell mounting surface to the pelvis. The height of the two pedestals used for this project were 4.863 inches for the pedestal used with pelvis serial number DY9938 and 4.858 inches for the pedestal used with pelvis serial number DZ0225. The pedestals are shorter than specified in *Figure 2* (5.362 in) to mount the pelvis as close to the surface as was practical while preventing contact between the rubber cover and the bottom surface. As such, the criteria (10.242 in and 10.362 in) were adjusted for the difference in the pedestal heights: for the DY9938 fixture, 9.743 to 9.863 in, and for the DZ0225 fixture, 9.738 to 9.858 in. The support arm aligned the guide rods for both the base plate and the top plate to hold the two surface planes of the plates parallel. The support arm also prevented the rotation of the top plate around the X-axis and Y-axis about the ATD pelvis (see *Figure 6* for the ATD coordinate system). The top plate served as the weight mount and measurement reference point and distributed the weight evenly over the bottom of the pelvis. The top plate, weighing 25 lbs, was designed to hold a maximum of four 25-lb Olympic-style plate weights. The test stand could apply a load to the pelvis at the nominal weight of an ATD sitting on a flat surface (125 lbs) and the weight used for the manufacturing evaluation (75 lbs).



Figure 5: Test Stand Components: (A) Base Plate with Pedestal, (B) Support Arm, (C) Top Plate with Weight Mount, and (D) Complete Assembly with 75 lbs of Load

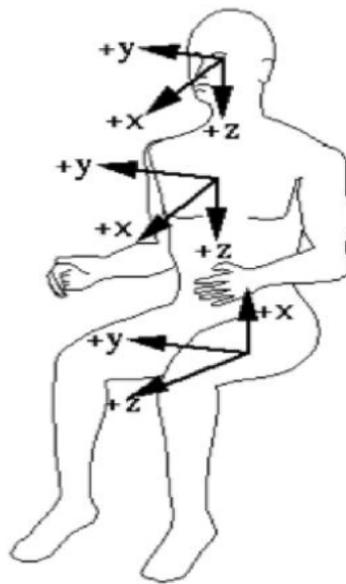


Figure 6: ATD Coordinate System SAE International

Due to a communication error, the test stand was manufactured narrower in length and width than the pelvises. The pelvises overhung the front and side edges. A 90-degree bracket was used to align the back edges of the top, and bottom plates of the test stand to assist in the repeatability of test fixture setup and alignment. Once assembled, both the left and right edges were checked to verify that the back edges of the top plate and bottom plate were on the same plane, as shown in *Figure 7*. A precaution to minimize binding in the support arm was taken. A thin film of grease was used inside the support arm tubes to mitigate the binding of sliding parts on the top and bottom plate guide rods. The support arms were checked for binding routinely throughout the 12 months of testing. No issue of binding was noted throughout the test series.



Figure 7: Test Stand Back Edge Alignment

Procedure

The test duration was 12 months to monitor the effects of a pelvis loaded during storage versus a pelvis unloaded during storage. Measurements were collected on day one and then at three, six, nine, and 12 months for five dates. The pelvis loaded during storage had additional measurements taken at the 18-month mark. Per 49 CFR 572, performance tests are to be conducted at any temperature from 66 °F to 78 °F and at any relative humidity from 10% to 70% after exposure of the dummy to these conditions for not less than four hours (U.S. Code of Federal Regulations, n.d.). The temperature requirement was met for this test series. The humidity requirement was likely met, although the sensor used to check temperature and humidity failed calibration for linearity of the humidity component (see limitations).

The test series used two brand-new Hybrid III pelvises from the same manufacturer (Humanetics Group, Farmington Hills, MI). The manufacturer tested both pelvises for their range of motion in July 2016, and the Biodynamics team received both in July 2017. The pelvises were stored in the shipping box until this test series. Before testing, the H-point was projected and marked on each side of the pelvis with a scribe line and a photometric quad target. The quad target allowed measurement to the H-point on the rubber surface. Pelvis DY9938 had no load during the storage periods. Pelvis DZ0225 was loaded with 125 lbs mounted in the test stand during the storage

periods. The following procedure was used on the measurement dates: first, the 125-lb weight was removed from pelvis DZ0225 20 minutes before starting the measurement procedure. Next, a 75-lb load was applied to the bottom of each pelvis for 5 minutes. At the end of the 5-min period, three measurements were taken on each side of the pelvis. This cycle was repeated two times (i.e., weight removed for 20 minutes, weight applied for 5 min, and measurements collected) for three cycles for each pelvis. For six months after the end of the 1-year static testing (i.e., 18 months from the start of the evaluation), pelvis DZ0225 was stored and unloaded. After six months, the pelvis was measured to determine if the 1-year loaded storage produced permanent effects.

Three distance measurements were collected on each side of the pelvis for each loading cycle (*Figure 8*, *Figure 9*). Those measurements consisted of the bottom plate to the top plate (A), the bottom plate to H-point (B), and H-point to the top plate (C). The A measurement is the distance specified in the manufacturing tolerance. Measurement B is the distance from the base plate to the H-point on the pelvis used to measure rubber cover migration on the sides of the pelvis concerning the loading of the bottom of the pelvis. Measurement C is the distance between the H-point and the top plate to determine the change in pelvis compression. Due to the pelvis overhang on the edges of the test stand, the distance measured is not solely in the vertical direction for both measurements B and C; thus, B plus C is not equal to A. Measurements were taken with 12-in dial calipers (Mitutoyo, Aurora, IL; S/N: 14501520, with a readout to 0.001 in). The same calipers were used for all the measurements taken in this report. *Figure 8* and *Figure 9* show the location of the A, B, and C dimensions; *Figure 10* shows the measurement method with the calipers.

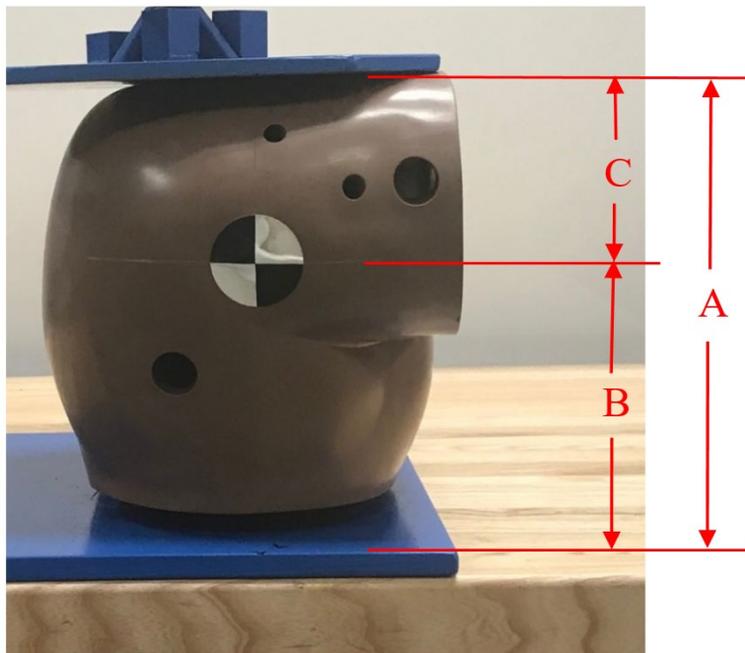


Figure 8: Measurement Locations, Side View, Left to Right: A, B, and C

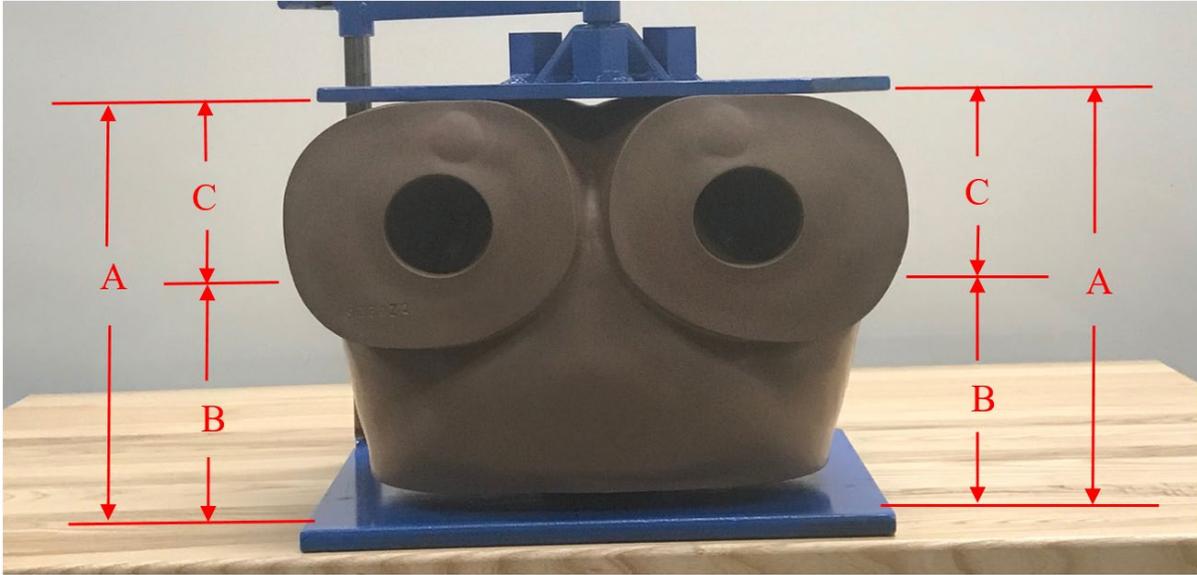


Figure 9: Measurement Locations, Front View

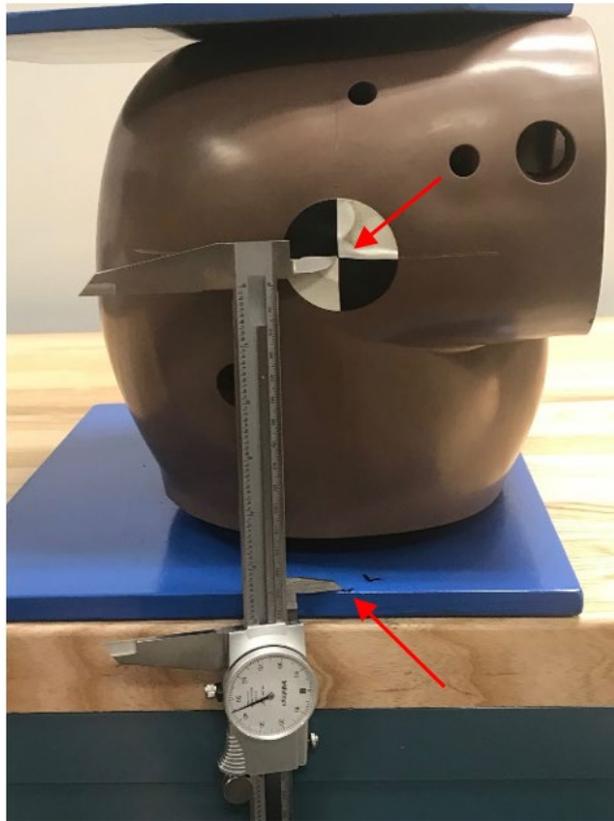


Figure 10: Caliper Measurement Methods

Results

Raw data

The procedure defined above was followed for three loadings to obtain measurements A, B, and C on each pelvis side on each measurement day. The specific dates of the measurements, along with the temperature and humidity condition of the storage room, are in *Table 1*, *Table 2*, *Table 3*, *Table 4*, and *Table 5* are measurements taken during the test series with the average values, range, and difference in loadings.

Month	Date (MM/DD/YYYY)	Temperature (°F)	Relative Humidity (%)
0	05/19/2020	70.4	52.9
3	09/04/2020	71.2	50.7
6	11/20/2020	71.5	46.9
9	02/24/2021	70.5	23.5
12	05/19/2021	73.1	48.4
18	10/25/2021	72.7	46.5

Table 1: Temperature and Relative Humidity for Test Dates

Measurement	Month	1st Loading, L1 (in)	2nd Loading, L2 (in)	3rd Loading, L3 (in)	Loading Average (in)	Loading Range (in)	L1-L2 (in)	L2-L3 (in)
A	0	10.018	10.050	10.022	10.030	0.032	-0.032	0.028
B	0	6.080	6.097	6.089	6.089	0.017	-0.017	0.008
C	0	3.933	3.970	3.935	3.946	0.037	-0.037	0.035
A	3	9.984	9.991	9.986	9.987	0.007	-0.007	0.005
B	3	6.074	6.052	6.075	6.067	0.023	0.022	-0.023
C	3	3.906	3.929	3.914	3.916	0.023	-0.023	0.015
A	6	10.014	10.002	10.012	10.009	0.012	0.012	-0.010
B	6	6.063	6.059	6.067	6.063	0.008	0.004	-0.008
C	6	3.910	3.883	3.919	3.904	0.036	0.027	-0.036
A	9	10.030	10.030	10.025	10.028	0.005	0.000	0.005
B	9	6.081	6.076	6.079	6.079	0.005	0.005	-0.003
C	9	3.949	3.950	3.951	3.950	0.002	-0.001	-0.001
A	12	10.054	10.011	10.026	10.030	0.043	0.043	-0.015
B	12	6.075	6.074	6.072	6.074	0.003	0.001	0.002
C	12	3.968	3.943	3.953	3.955	0.025	0.025	-0.010

Table 2: Pelvis DY9938 Left Measurements

Measurement	Month	1st Loading, L1 (in)	2nd Loading, L2 (in)	3rd Loading, L3 (in)	Loading Average (in)	Loading Range (in)	L1-L2 (in)	L2-L3 (in)
A	0	9.927	9.966	9.922	9.938	0.044	-0.039	0.044
B	0	6.070	6.072	6.076	6.073	0.006	-0.002	-0.004
C	0	3.882	3.894	3.862	3.879	0.032	-0.012	0.032
A	3	9.904	9.915	9.899	9.906	0.016	-0.011	0.016
B	3	6.052	6.042	6.036	6.043	0.016	0.010	0.006
C	3	3.866	3.866	3.875	3.869	0.009	0.000	-0.009
A	6	9.935	9.885	9.925	9.915	0.050	0.050	-0.040
B	6	6.044	6.039	6.044	6.042	0.005	0.005	-0.005
C	6	3.877	3.885	3.88	3.881	0.008	-0.008	0.005
A	9	9.929	9.934	9.925	9.929	0.009	-0.005	0.009
B	9	6.038	6.032	6.039	6.036	0.007	0.006	-0.007
C	9	3.886	3.885	3.863	3.878	0.023	0.001	0.022
A	12	9.927	9.925	9.915	9.922	0.012	0.002	0.010
B	12	6.037	6.039	6.028	6.035	0.011	-0.002	0.011
C	12	3.886	3.887	3.885	3.886	0.002	-0.001	0.002

Table 3: Pelvis DY9938 Right Measurements

Measurement	Month	1st Loading, L1 (in)	2nd Loading, L2 (in)	3rd Loading, L3 (in)	Loading Average (in)	Loading Range (in)	L1-L2 (in)	L2-L3 (in)
A	0	10.075	10.070	10.075	10.073	0.005	0.005	-0.005
B	0	6.057	6.058	6.053	6.056	0.005	-0.001	0.005
C	0	3.930	3.935	3.920	3.928	0.015	-0.005	0.015
A	3	9.772	9.788	9.784	9.781	0.016	-0.016	0.004
B	3	5.994	5.994	5.984	5.991	0.010	0.000	0.010
C	3	3.791	3.815	3.796	3.801	0.024	-0.024	0.019
A	6	9.752	9.803	9.780	9.778	0.051	-0.051	0.023
B	6	5.973	5.985	5.987	5.982	0.014	-0.012	-0.002
C	6	3.805	3.829	3.827	3.820	0.024	-0.024	0.002
A	9	9.748	9.746	9.772	9.755	0.026	0.002	-0.026
B	9	5.976	5.992	5.985	5.984	0.016	-0.016	0.007
C	9	3.780	3.775	3.796	3.784	0.021	0.005	-0.021
A	12	9.738	9.755	9.755	9.749	0.017	-0.017	0.000
B	12	5.978	5.985	5.990	5.984	0.012	-0.007	-0.005
C	12	3.746	3.767	3.775	3.763	0.029	-0.021	-0.008
A	18	9.879	9.891	9.864	9.785	0.027	-0.012	0.027
B	18	6.043	6.038	6.044	6.004	0.006	0.005	-0.006
C	18	3.832	3.861	3.834	3.775	0.029	-0.029	0.027

Table 4: Pelvis DZ0225 Left Measurements

Measurement	Month	1st Loading, L1 (in)	2nd Loading, L2 (in)	3rd Loading, L3 (in)	Loading Average (in)	Loading Range (in)	L1-L2 (in)	L2-L3 (in)
A	0	9.855	9.845	9.857	9.852	0.012	0.010	-0.012
B	0	6.045	6.045	6.045	6.045	0.000	0.000	0.000
C	0	3.811	3.814	3.815	3.813	0.004	-0.003	-0.001
A	3	9.681	9.705	9.674	9.687	0.031	-0.024	0.031
B	3	5.984	5.992	5.986	5.987	0.008	-0.008	0.006
C	3	3.708	3.719	3.675	3.701	0.044	-0.011	0.044
A	6	9.647	9.667	9.665	9.660	0.020	-0.020	0.002
B	6	5.959	5.972	5.974	5.968	0.015	-0.013	-0.002
C	6	3.690	3.701	3.680	3.690	0.021	-0.011	0.021
A	9	9.646	9.673	9.655	9.658	0.027	-0.027	0.018
B	9	5.965	5.974	5.970	5.970	0.009	-0.009	0.004
C	9	3.687	3.707	3.692	3.695	0.020	-0.020	0.015
A	12	9.639	9.671	9.690	9.667	0.051	-0.032	-0.019
B	12	5.962	5.975	5.976	5.971	0.014	-0.013	-0.001
C	12	3.675	3.710	3.730	3.705	0.055	-0.035	-0.020
A	18	9.797	9.789	9.785	9.785	0.012	0.008	0.004
B	18	6.02	6.016	6.004	6.004	0.016	0.004	0.012
C	18	3.788	3.791	3.775	3.775	0.016	-0.003	0.016

Table 5: Pelvis DZ0225 Right Measurements

Measurement Repeatability

The data were reviewed to evaluate any trends of pelvis compression or rebound between loading cycles. The primary assumption in this analysis was that the pelvic compression would increase as the loadings increased on a given day. Columns L1-L2 and L2-L3 in *Table 2*, *Table 3*, *Table 4*, and *Table 5* were used to identify trends throughout the 12 months. Columns L1-L2 took the first loading value and subtracted the second loading value. Columns L2-L3 took the second loading value and subtracted the third loading value. Positive values indicate the foam and rubber compressed between loadings. If the value was negative, the foam and rubber rebounded between loadings. All the measurements were taken with a 12-in caliper with an error of ± 0.001 . The A measurements for Pelvis DZ0225 showed the foam and rubber from loading 1 to loading 2 rebounded for seven tests and compressed for three tests. Loading 2 to loading 3 showed five instances of compression, four instances of rebound, and one where the values were the same. For pelvis DY9938, the difference in measurement A from loading 1 to 2 had five instances of rebound, four instances of compression, and one instance of the values being equal. Loading 2 to 3 had three rebound instances and seven compression instances. There was no predictable effect of how the pelvis would respond to the next loading cycle. Thus, the average values for each test date were used to assess the overall effect on the pelvis for the test series.

Foam and Rubber Compression over Time

The average value of measurement A was used to determine the amount of compression over the 12 months. *Figure 11* and *Figure 12* show the average values of measurement A with range bars versus time and trend line. For the unloaded pelvis (DY9938), the difference in the average A measurement from month 0 to month 3 was 0.043 in for the left side (*Figure 11*). However, the difference from month 0 to month 12 was 0.000 in. The average values at six months and nine months fell between the three-month and 12-month average. For the right side, the difference in the average A measurement was 0.016 in from 0 to 12 months, with a max of 0.032 in for 0 to 3 months. Therefore, it appears that the pelvis did not appreciably change during the year of storage (i.e., the linear trend lines are flat). The maximum difference of 0.043 in suggests some variation in either the pelvis performance in this test or the measurements themselves.

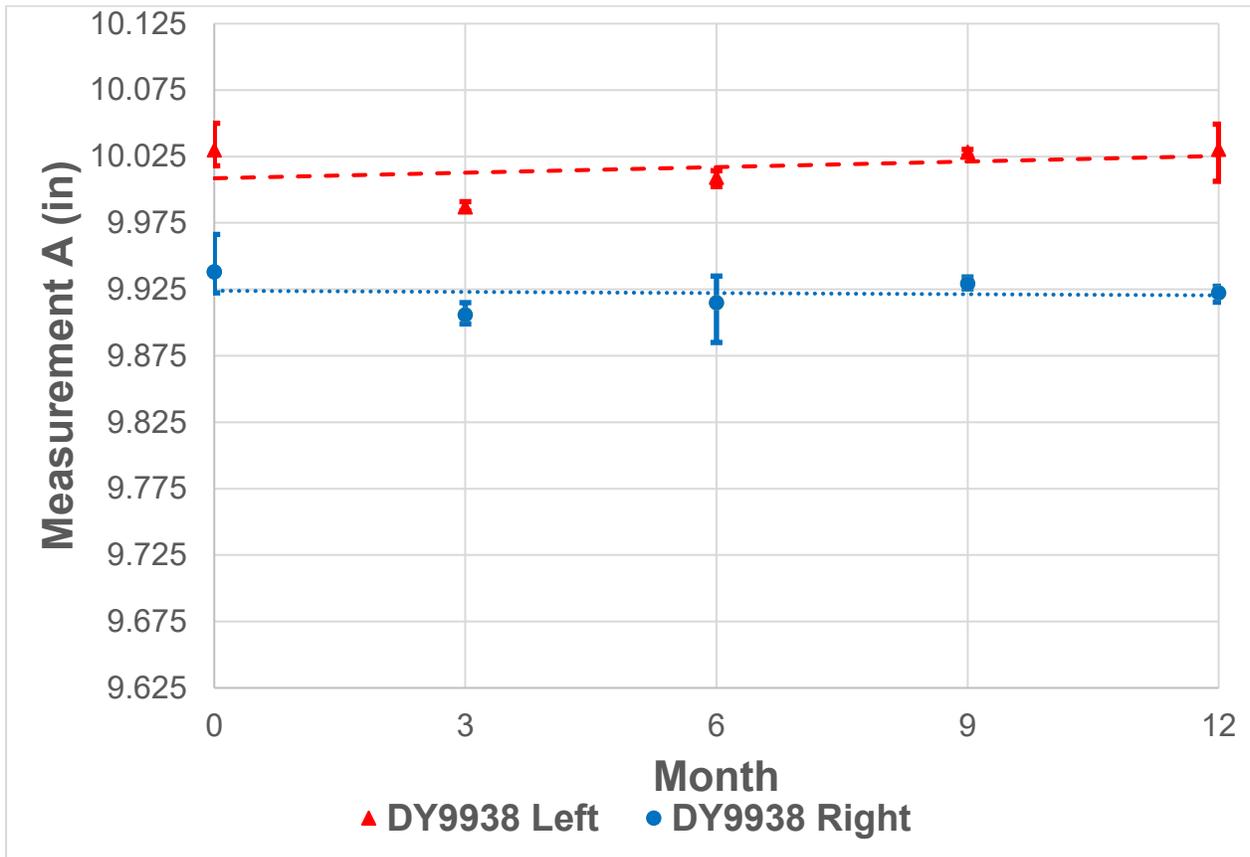


Figure 11: Unloaded Pelvis (DY9938) Measurement A versus Time

For the loaded pelvis (DZ0225), the difference in the average A measurement from month 0 to month 3 was 0.292 in for the left side (*Figure 12*). The difference from month 0 to month 12 was 0.324 in. The average values at six months and nine months were less than the 12-month average. For the right side, the difference in the average A measurement was 0.185 in from 0 to 12 months, with a maximum of 0.192 in for 0 to 6 months. The difference over the first three months was 0.165 in. Therefore, it appears that the pelvis did appreciably change during the year of storage, with the majority of this change occurring in the first three months (approximately 90%), as shown

with the power trend line.

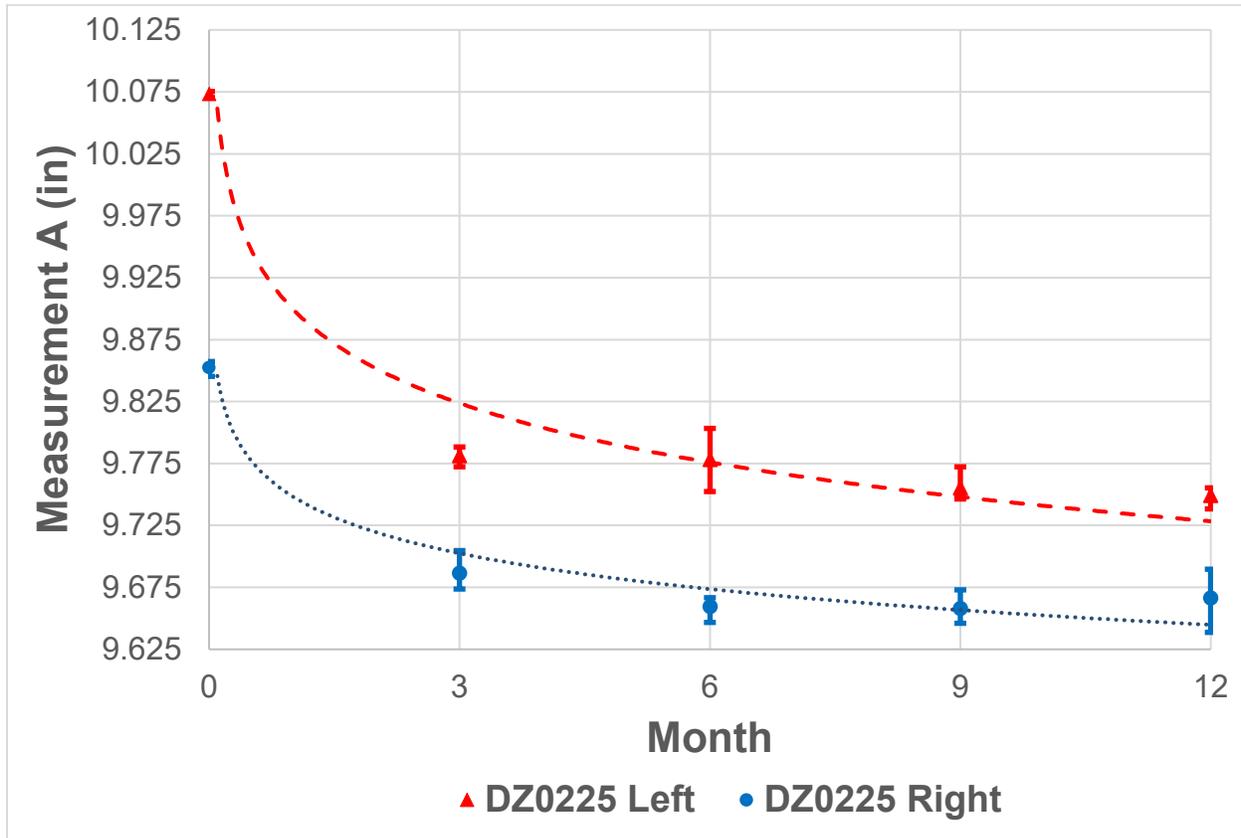


Figure 12: Loaded Pelvis (DZ0225) Measurement A versus Time

For the Hybrid III pelvis, the distance from the H-point to the inspection surface must be 3.620 ± 0.060 in to be conformed for use. Measurement A, as detailed in *Figure 3*, *Figure 8*, and *Figure 9*, can be directly correlated to the conformed distance once the following distances are subtracted from the A measurements: the pedestal height (varies from left to right) and height from the top of the pedestal to the H-point (1.320 in). In this series of measurements, the loaded pelvis, DZ0225, compressed enough (0.292 in on the left and 0.165 in on the right) to fall outside of that tolerance in the first three months. This suggests that a conformed pelvis will likely become nonconformed if stored so that the pelvis is loaded. For the unloaded pelvis (DY9938), the difference in the A measurement over the one year was essentially zero; however, some measurements showed differences (i.e., 0.043 in on the left and 0.032 in on the right at three months). This suggests that individual measurements could produce measurements outside the conformed corridor, although the risk is lower than with the stored loaded pelvis.

It is unclear how much pelvic height affects the measured lumbar load in a dynamic impact sled test. The literature has conflicting results on whether lumbar load varies with seat bottom cushion thickness, with a National Institute for Aviation Research report showing the load increase with cushion thickness and a Civil Aerospace Medical Institute (CAMI) report showing no variation

with cushion thickness for monolithic cushions (Lankarani & Beheshti, 2004; DeWeese, 2006). These tests looked at cushions ranging from approximately 2 in to 4.5 in thick; the foam within the ATD pelvis is on the order of 0.5 in.

Loaded Storage Long-Term Results

After the 12-month testing, the load on Pelvis DZ0225 was removed. The pelvis was stored unloaded to allow the foam and rubber on the bottom of the pelvis to rebound. After six months of unloaded storage, Pelvis DZ0225 was measured as outlined in the procedure section. This check was to determine if the compression of the rubber and foam was permanent. Data for the series are found in *Table 4* and *Table 5*. Over the six months, the left side rebounded 0.038 in, approximately 10% of total compression. The right side rebounded 0.127 in, approximately 65% of the total compression. The effects of long-term loaded storage of the ATD pelvis seem permanent or extremely slow to recover.

Discussion and Limitations

Asymmetrical Results

The test stand was designed to apply the weight directly over the center of the lumbar mounting point on the pelvis. Due to the overhang of the pelvis on the front and sides, aligning the top and bottom plate's backside allowed for consistent setup and repeatability. All the A-length measurements during the test series showed a notable side-to-side lean. The lean was consistent for both pelvises, and both tests stands, with the pelvis left side higher than the right side for all the data collected. *Figure 12* and *Figure 13* are plots of the A measurements to illustrate the lean. The vertical distance in *Figure 12* and *Figure 13* is exaggerated due to the zooming in of the vertical axis. Both plots have the same Y-axis range for comparison. The height difference was calculated for each loading and measuring cycle, subtracting the right A measurement from the left A measurement. The average of those differences was 0.109 in.

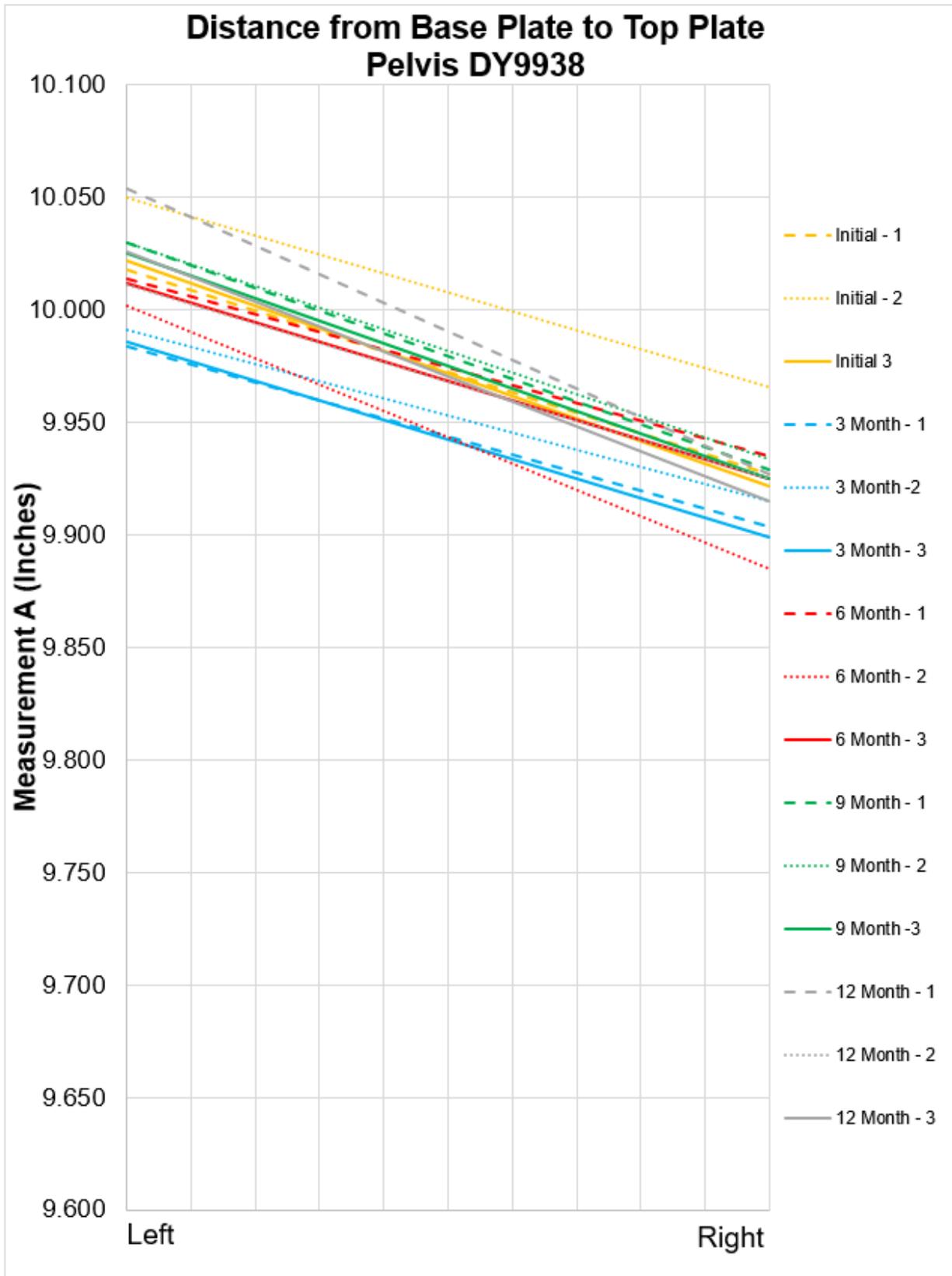


Figure 13: Pelvis DY9938 Measurement A Data Points for Months 0-12

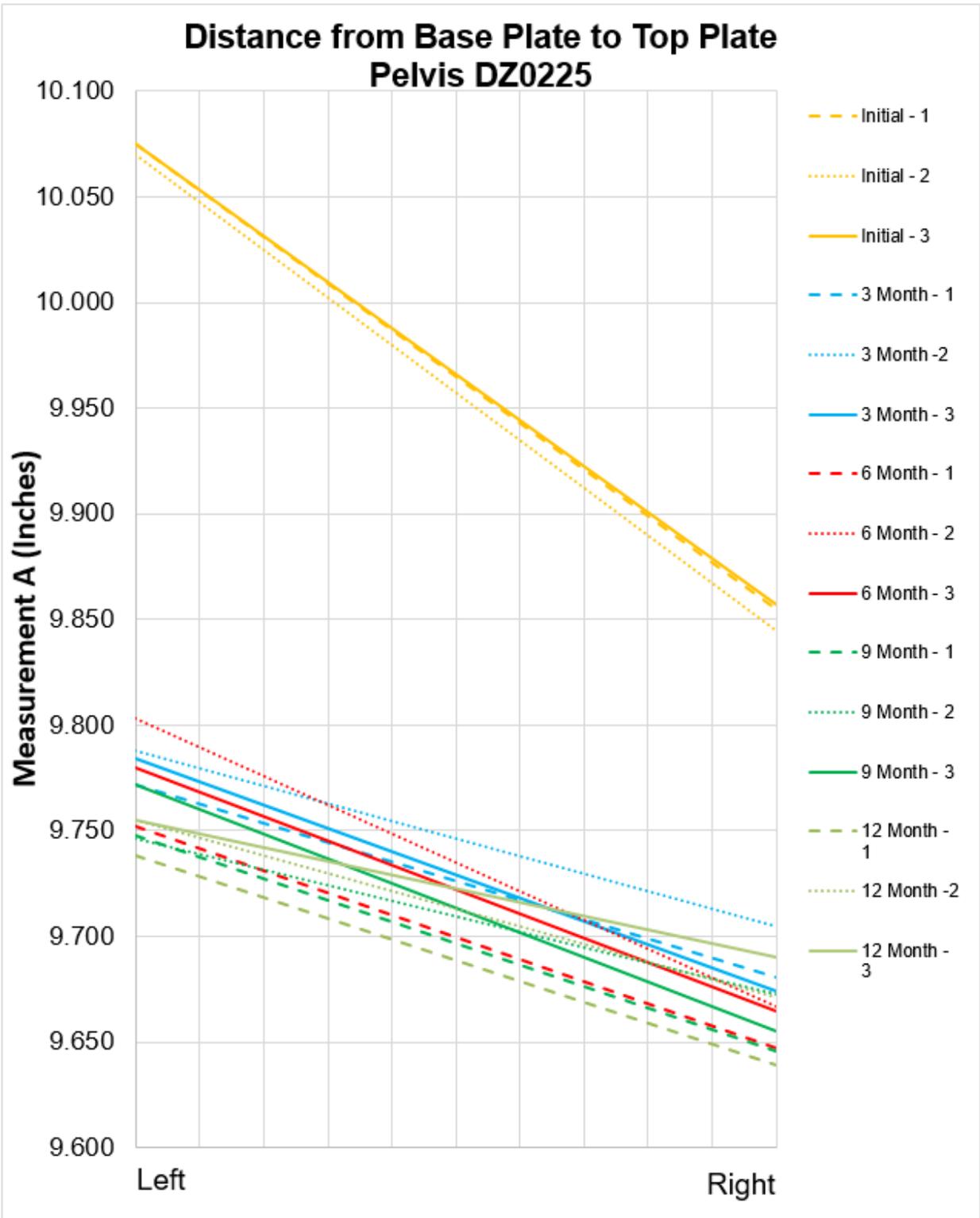


Figure 14: Pelvis DZ0225 Measurement A Data Points for Months 0-12

The following checks were conducted on the test stand to investigate the lean between the right and the left. For the first check, the test stand was aligned on the side with a 90° bracket between the lumbar mount and the top plate weight holder aligned to the same cylindrical centerline axis. The test stand was measured with no weight, no pelvis, and the top plate resting on the lumbar mounting point (*Figure 15*). The length of the test stand is 14 in. The distance between the top and bottom plate was 4.914 in on the left and 4.876 in on the right side. The second check used the same setup but the back edges of the top and bottom plates were aligned (*Figure 16*). Aligning the test stand on the back edge shifted the position of the top plate 0.63 in to the right and 0.25 in to the rear of the lumbar mount cylindrical centerline. The distance between the top plate and bottom plate on the left side was 4.869 in, and the right was 4.935 in. Side alignment produced a difference of 0.038 in with the left side higher. Back alignment produced a difference of 0.066 in, with the right side higher. The support arm rod was checked for deflection while the test stand was completely assembled with 50 lbs of weight, in the same manner as shown in *Figure 7*. The support arm rod deflected 0.012 in toward the pelvis's right side. The deflection was measured at 11.60 in from the base plate, creating an angle of deflection of approximately 0.06°. Finally, the test stand's bottom plate and pedestal mount were checked for parallel along the Y-axis of the ATD coordinate system. There was a 0.2° difference between the bottom plate and the pedestal mount, allowing the right side of the pelvis to contact the top plate before contacting the left side of the pelvis. A 0.2° lean over the 14-in plate length is 0.048 of an inch, almost half of the average difference (0.109 in). The 0.109-in asymmetric lean of the pelvis measurements contributed to three identified factors: the pelvis mount and base plate out of parallel, the deflection of the support arm rod when loaded, and the weight center of gravity is offset to the right of the pelvis by 0.63 in.

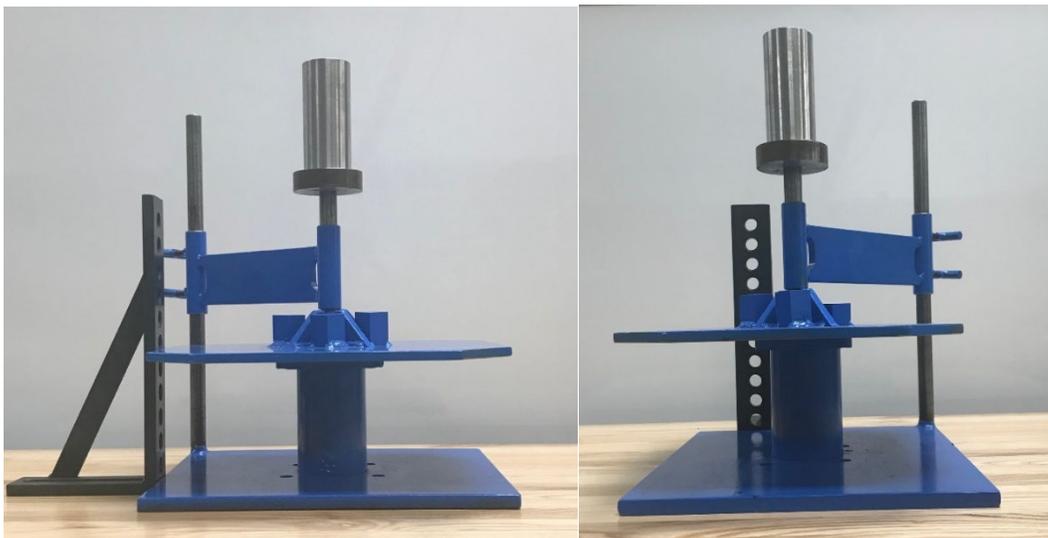


Figure 15: Side Alignment of Empty Test Stand. Front View (Left), Side View (Right)

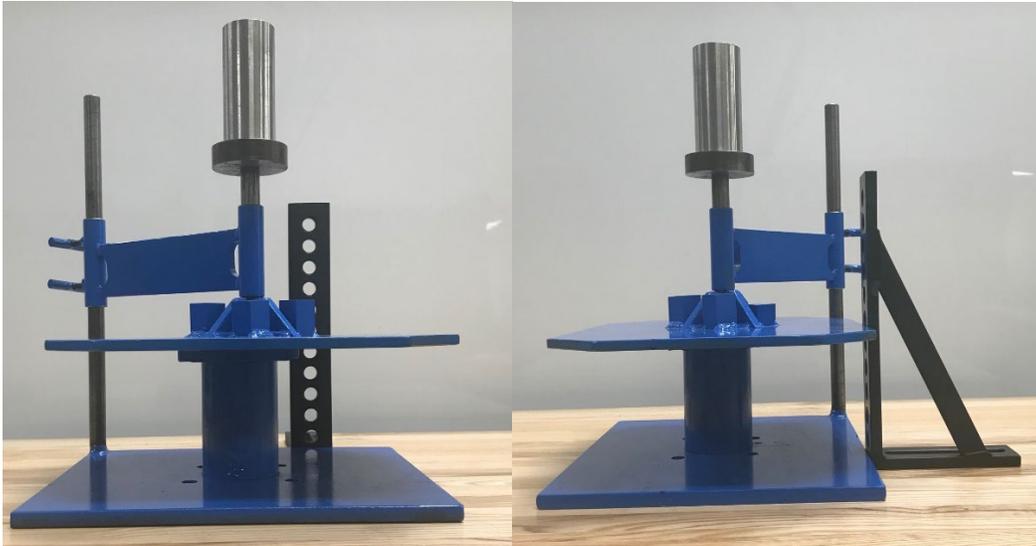


Figure 16: Back Alignment of Empty Test Stand. Front View (Left), Side View (Right)

ATD Rubber and Foam Movement on Sides of Pelvis

The distance from the base plate to the H-point on the metal skeleton of the pelvis is constant throughout the test series. However, the H-point was projected to the outer surface of the pelvis rubber cover on the left and right sides. To evaluate whether the rubber and foam on the sides of the pelvis position moved during the test series, the maximum change was calculated by subtracting the minimum B value from the maximum B value for each side (see [Table 6](#) and [Table 7](#)). This assumes that the compression of the foam and rubber on the bottom of the pelvis only affects the A and C measurements and not the B measurement. Therefore, any differences in the B measurement over time indicate that the compression of the pelvis affects the H-point projection. For pelvis DZ0225, the maximum change in projected H-Point height was 0.080 in on the left and 0.086 in on the right. For pelvis DY9938, the maximum migration calculated for the left and right side were 0.045 in and 0.048 in, respectively.

	Left (in)	Right (in)
Maximum B Value	6.097	6.076
Minimum B Value	6.052	6.028
Difference	0.045	0.048

Table 6: Pelvis DY9938

	Left (in)	Right (in)
Maximum B Value	6.058	6.045
Minimum B Value	5.978	5.959
Difference	0.080	0.086

Table 7: Pelvis DZ0225

Pedestal Height

The pedestals used for this project are shorter than the height defined in SAE ARP 5765B to minimize the system's overall height. SAE ARP 5765B (see [Figure 2](#)) specified a height of 5.362 in, while the pedestals used for this test series were 4.858 and 4.863 in. Direct comparisons should not be made between these test series measurements and those using the pedestal height outlined in [Figure 2](#).

Test Stand Dimensions

Due to a communication error, the base plate and top plate of the test stand were manufactured narrower in length and width than the pelvises. This allowed the pelvises to overhang the front and side edges of the top plate. Because of this, aligning the stand was more difficult (as discussed in the asymmetrical results subsection), and the B and C measurements include a small out-of-plane component.

Failed Equipment Calibration

The temperature and humidity gauge was calibrated before this test series and then sent for verification calibration after the 12 months. The gauge failed this second calibration (dated 5/21/2021) because the humidity measurement was out of tolerance. During the testing of the pelvis compression, the equipment and pelvises were stored in a classroom within CAMI. The classroom is temperature-controlled year-round. The facility managers informed us that the temperature set points were 70 °F to 78°F in the summer months and 68°F to 72 °F in the winter months. The facility managers do not monitor or control the relative humidity. Per 49 CFR 572.11(h), performance tests are conducted at any temperature from 66 °F to 78 °F and at any relative humidity from 10% to 70% after exposure of the dummy to these conditions for not less than four hours (U.S. Code of Federal Regulations, n.d.). Historical humidity data are unavailable for the classroom; however, an adjacent laboratory has been monitored for decades. The laboratory area meets the humidity requirement in the CFR during test days, although it did exceed the upper range on a small number of non-test days in recent years. These instances of high humidity did not occur during this test series. The laboratory is a much larger area, with higher ceilings and external walls and doors (including a large roll-up door), while the classroom has no external walls. Based on this, it is reasonable to assume that the humidity in the classroom met the requirements of the CFR for the majority, if not all, of the time the pelvises were measured (including a 4-hour presoak before the measurements were taken).

Conclusion

ATDs are used to predict occupant injury in dynamic tests required by FAA regulations to substantiate the safety of seating systems. The ATD pelvis does not have a set of calibration tests defined in 49 CFR 572 to determine if the component is acceptable for initial use or to monitor degradation to determine the need to remove components from service (U.S. Code of Federal Regulations, n.d.). The drawings for the Hybrid III ATD require the H-point to be a certain height when loaded by a 75-lb plate with a tolerance of ± 0.060 in. This report details an 18-month project evaluating what happens to H-point height when a pelvis is stored under a constant static load (e.g., the ATD sitting in a chair). We collected measurements every three months for one year, comparing two pelvises: one loaded and one unloaded during storage. Our results indicate that the loaded pelvis had a six-fold change in pelvic height compared to the change in pelvic height of a pelvis stored unloaded. The maximum compression distance of 0.324 in suggests that a conformed pelvis will likely become nonconformed if stored so that the foam and rubber on the pelvis are loaded. Most of this compression (85% to 90%) occurred within the first three months of storage. The data collected suggest that how an ATD pelvis is stored significantly changes the dimensions of the foam and rubber, and this change occurs quickly.

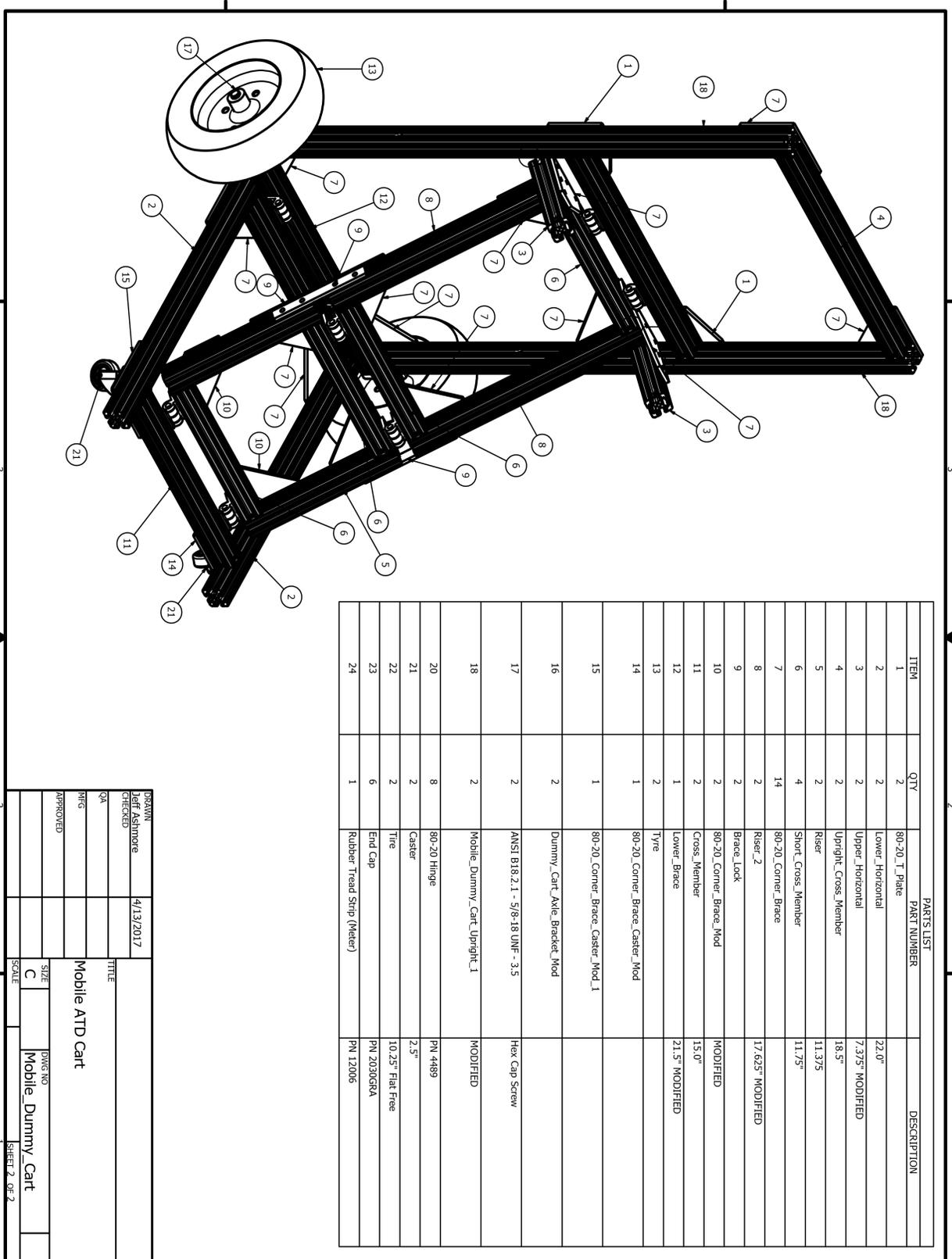
Six months after the loaded storage was complete, the pelvis was reevaluated for the long-term effects of loaded storage. Results showed that the left side rebounded approximately 10%, and the right side rebounded 65% of the maximum compression measured during testing. Thus, the change

in pelvic height due to loaded storage seems permanent. Therefore, it is recommended that an ATD pelvis is stored unloaded. Additionally, regular testing will likely degrade the pelvis. Thus it is recommended that the pelvis be regularly checked to determine if it is within tolerance, regardless of storage method.

References

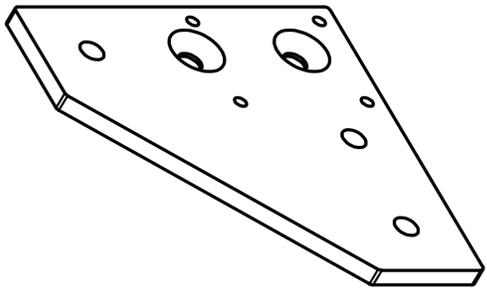
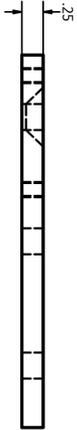
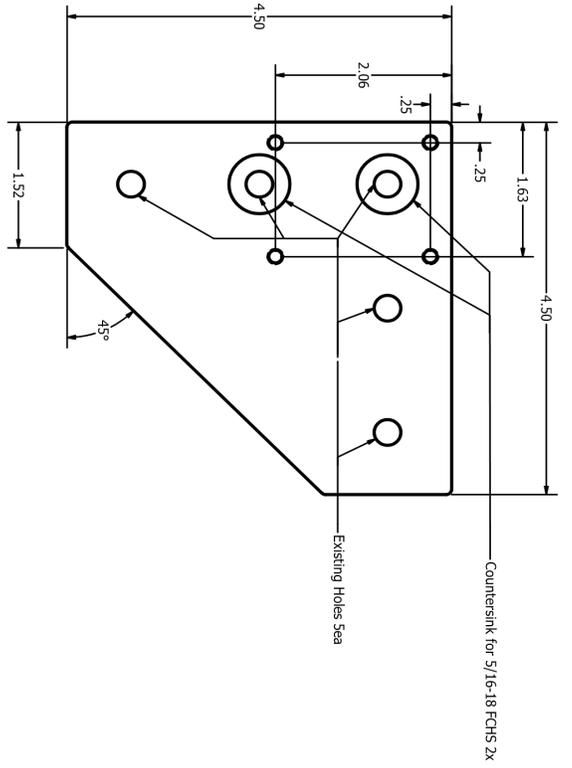
- DeWeese, R. (2006). Measurement of Aircraft Seat Cushion Dynamic Properties and Associated Occupant Lumbar Spine Loads Using Full-scale Sled Tests. SAE General Aviation Technology Conference; Wichita, KS, Aug 30, 2006.
- DeWeese, R., Moorcroft, D., & Taylor, A. (2021). Lumbar Load Variability in Dynamic Testing of Transport Category Aircraft Seat Cushions. US Government Printing Office, Office of Aerospace Medicine Report (AM21-09).
- Lankarani, H. M., & Beheshti, H. K. (2004). Aircraft Seat Cushion Replacement Program, FAA Airworthiness, Assurance Center of Excellence (AACC), Final Report DOT/FAA/AR-00-45, Wichita State University, KS, USA.
- Taylor, A., DeWeese, R., & Moorcroft, D. (2017). Comparison of AC and Original Formulation Confor Foam Performance in Civil Aircraft Vertical Impact Tests. Office of Aviation Medicine Report. DOT/FAA/AM-17/1.
- U.S. Code of Federal Regulations. (n.d.). Title 14 Parts, 23.562, 25.562, 27.562, 29.562. Washington, DC: US Government Printing Office.
- U.S. Code of Federal Regulations. (n.d.). Title 49, Subpart L, 572.1-4, 572.9, 572.32-34, 572.100-103. Washington, DC: US Government Printing Office.

Appendix – ATD Chair Drawings



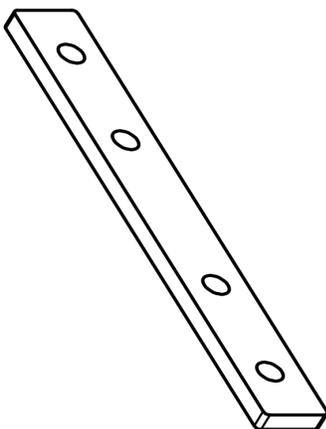
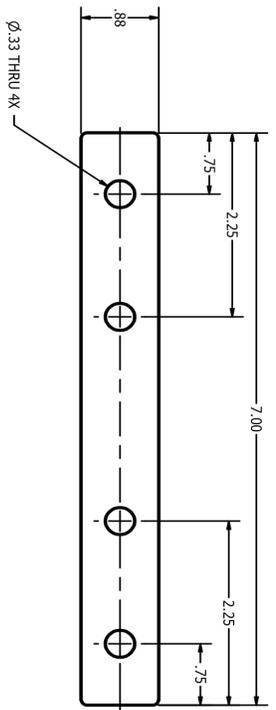
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3	2	Upper Horizontal	18.5"
4	2	Upright_Cross_Member	11.375"
5	2	Riser	11.75"
6	4	Short_Cross_Member	17.625" MODIFIED
7	14	80-20_Corner_Brace	
8	2	Riser_2	
9	2	Brace_Lock	
10	2	80-20_Corner_Brace_Mod	MODIFIED
11	2	Cross_Member	15.0"
12	1	Lower_Brace	21.5" MODIFIED
13	2	Type	
14	1	80-20_Corner_Brace_Caster_Mod	
15	1	80-20_Corner_Brace_Caster_Mod_1	
16	2	Dummy_Cart_Axle_Bracket_Mod	
17	2	ANSI B18.2.1 - 5/8-18 UNF - 3.5	Hex Cap Screw
18	2	Mobile_Dummy_Cart_Upright_1	MODIFIED
20	8	80-20 Hinge	PN 4489
21	2	Caster	2.5"
22	2	Tile	10.25" Flat Free
23	6	End Cap	PN 2030GRA
24	1	Rubber_Tread Strip (Meter)	PN 12006

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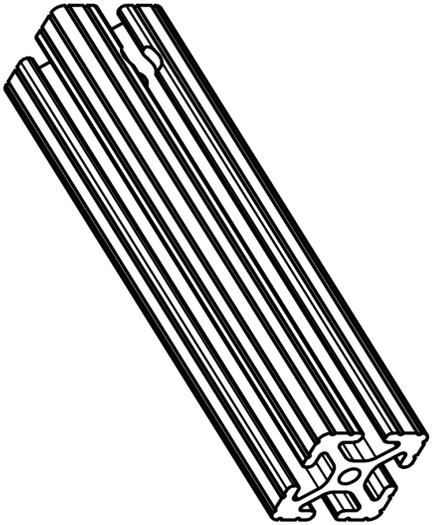
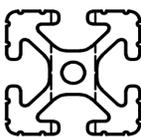
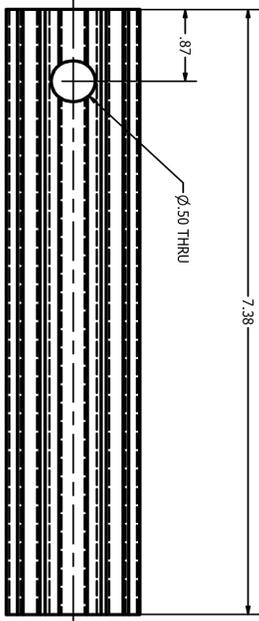


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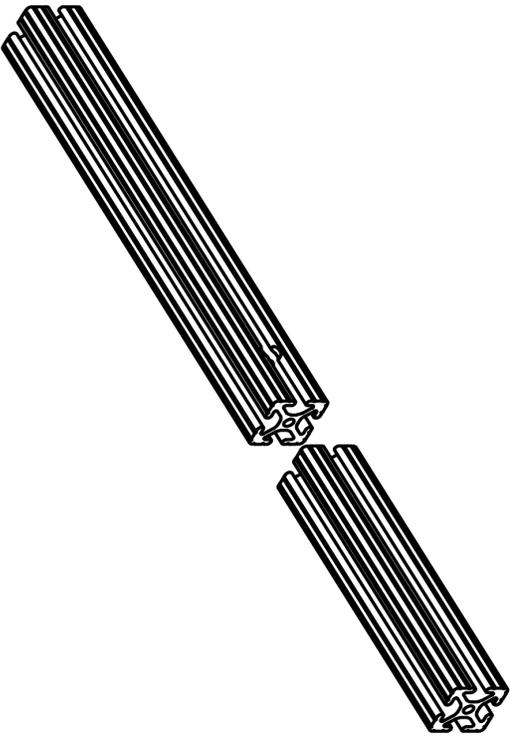
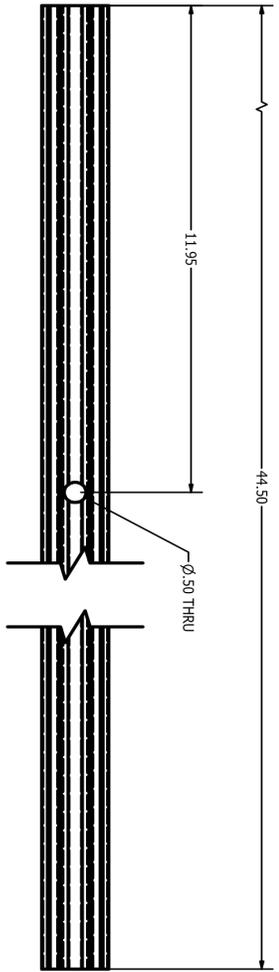


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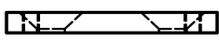
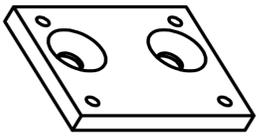
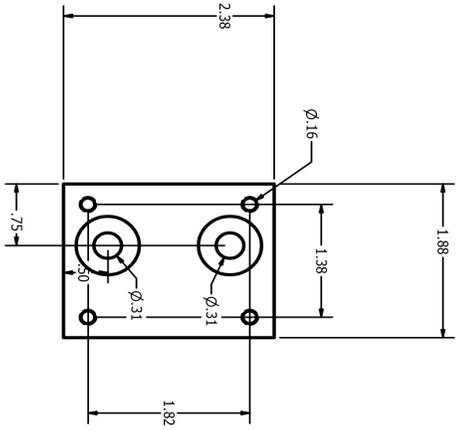
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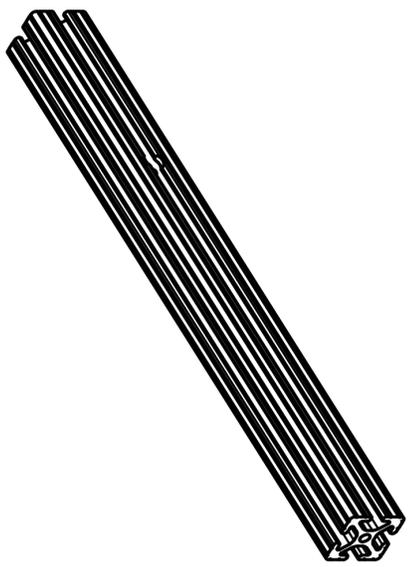
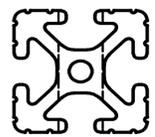
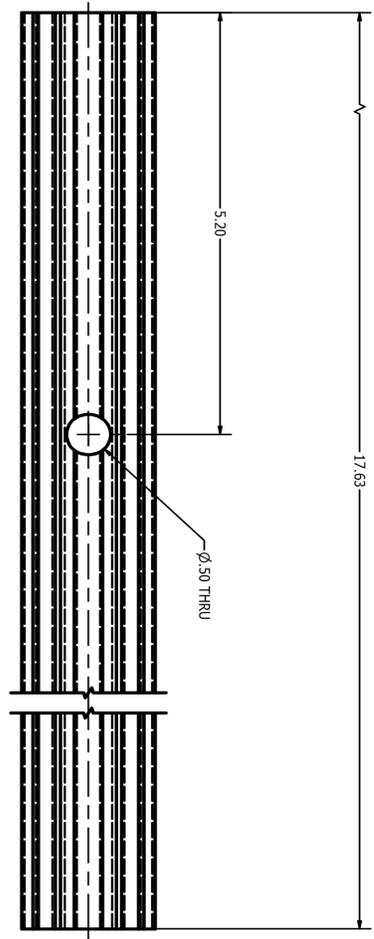


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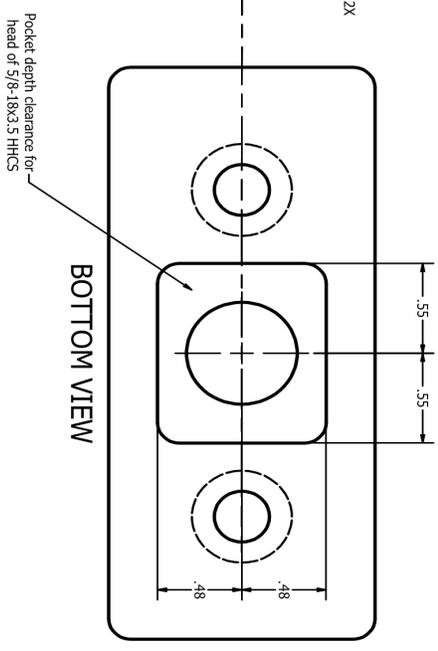
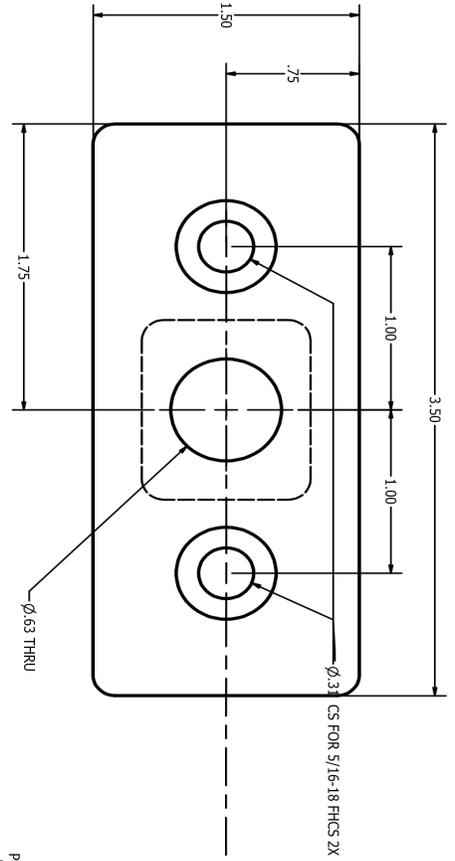


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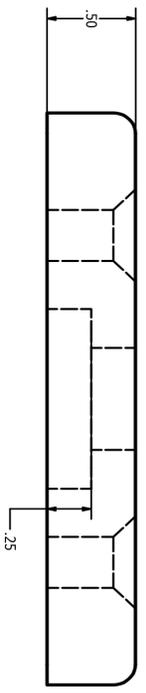


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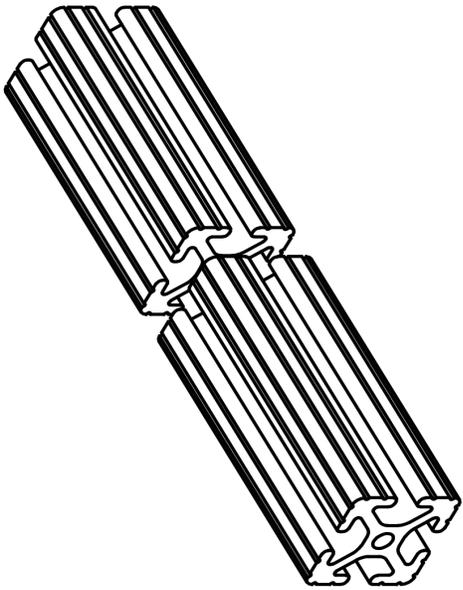
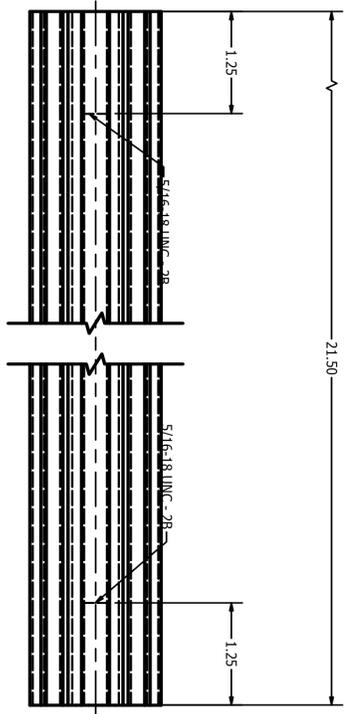


BOTTOM VIEW



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