



QUASI-STATIC AND DYNAMIC RESEARCH TESTING OF CRASHWORTHY TABLES

SUMMARY

Researchers crash-tested donated, fixed workstation tables according to the procedures in the February 17, 2021, draft of the “Fixed Workstation Tables in Passenger Railcars” safety standard [1] from the American Public Transportation Association (APTA), APTA-PR-CS-S-018-13, Rev. 2 (S-018). Researchers dynamically sled-tested the tables with anthropomorphic test devices (ATDs) using the two different options provided by the table standard:

- **Option A** used a Test device for Human Occupant Restraint 50th Percentile Male (THOR-50M) ATD in the wall seat and a Hybrid-III 50th percentile male (H3-50M) ATD in the aisle seat
- **Option B** used H3-50M ATDs in the wall and aisle seats and a destructive quasi-static test

Figure 1 shows the pre-test setup of an S-018 sled test. The sled test evaluates the structural integrity of passenger railcar interior equipment, compartmentalization of occupant ATDs, the energy absorption capabilities of crashworthy workstation tables, and the injury criteria resulting from simulated collision conditions.



Figure 1. Pre-test Photo of a Workstation Table

One objective of this test series was to compare the safety equivalence of Options A and B in the revised standard. After analyzing the test data, researchers concluded the changes in Revision 2 of the table standard have improved the safety equivalence of Options A and B compared to Rev. 1.

Researchers presented the results and lessons learned from the tests to the APTA Construction and Structural (C&S) Working Group which informed discussions in finalizing the draft procedures and requirements in Rev. 2 of S-018 before putting the standard to ballot.

BACKGROUND

Passenger rail accident investigations motivated FRA research on occupant protection strategies for passengers seated at workstation tables. FRA sponsored occupant protection research at the Volpe National Transportation Systems Center (Volpe Center) which resulted in recommendations for human injury performance requirements. The researchers presented recommendations on injury threshold criteria to the APTA Passenger Rail Construction and Structural Working Group which were adopted into the original table standard in 2013.

The original version of APTA S-018 required dynamic testing of fixed workstation tables in passenger railcars with advanced frontal crash ATDs — either a THOR-NT or a modified H3-50M, named Hybrid-III Rail Safety (H3-RS). The THOR-NT was an older version of the modern THOR-50M.

When APTA published the original version of S-018, there was limited availability of THOR-NT and H3-RS ATDs for dynamic sled testing of



crashworthy tables; however, H3-50M ATDs were readily available for testing. The standard required either a THOR-NT or H3-RS to be seated in the wall-side seat because it generally presents the most severe test condition, and the advanced ATDs are better-equipped to evaluate chest and abdomen injury. However, table manufacturers could not dynamically test their tables if they were unable to find a willing testing lab due to ATD availability or the potential for ATD damage. The Volpe Center conducted occupant protection research [2] to address this limitation, leading to the development of an option (Option B) to test with an H3-50M in both seat positions. The new option required a companion destructive quasi-static test to evaluate the energy-absorption capacity of the table, since the H3-50M was limited in its ability to measure chest and abdomen displacements, which can be correlated with injury. Researchers intended Option B to be equivalent in safety to Option A by ensuring the table would have enough energy-absorption capacity at low force levels to arrest the motion of an occupant without inducing severe injury. The APTA working group added Option B in Rev. 1 of the table standard in 2015.

After Revision 1 of the table standard, the design of the THOR-50M was finalized. Since the type, location, and number of displacement transducers in the abdomen were changed, Calspan Corp. performed research for FRA to evaluate the biofidelity of the THOR-50M [3]. The results of the pendulum impact testing indicated the human injury performance requirements for the THOR-50M should be updated in Rev. 2 of APTA S-018 to maintain safety equivalence with the H3-RS ATD. Volpe Center researchers proposed a new abdomen compression limit for the THOR-50M for APTA S-018 based on the results of the pendulum impact testing. Additionally, they found the safety equivalency of Option A and B needed to be improved, as tables which met the energy-absorption requirements in the Option B quasi-static test could fail the human injury performance criteria in a dynamic sled test [4].

OBJECTIVES

1. Perform six sled tests per Option A, three sled tests per Option B, and three quasi-static tests per Option B on anonymously donated, fixed workstation tables following the procedures in the February 2021 draft of S-018, Rev. 2.
2. Evaluate table performance regarding human injury, compartmentalization, structural integrity, survival space, and energy-absorption, as specified in the most recent May 2022 balloted draft of S-018, Rev. 2.

METHODS

Researchers conducted the dynamic and quasi-static workstation table tests in accordance with the procedures in Section 5 of the APTA table standard dated February 17, 2021, draft Rev. 2, (current at the time of testing). The test results were interpreted in accordance with the May 2022 balloted draft, Rev. 2.

Each sled test consisted of a pair of commuter seats fastened to a simulated carbody structure, rigidly secured to the test sled. Two 50th percentile male ATDs were positioned in the forward-facing row of seats (see test setup above in [Figure 1](#)). Researchers instrumented each ATD to measure tri-axial head and chest acceleration, axial neck load, extension/flexion neck bending moment, and axial femur load. The THOR-50M ATD can measure bilateral upper chest, lower chest, and abdomen deflection. The H3-50M ATD can only measure sternum compression. The test lab subjected the sled to a prescribed, idealized 8g crash pulse, depicted in [Figure 2](#). The tests were documented using three high-speed video cameras as well as pre- and post-test photographs and geometry measurements.

Researchers performed the quasi-static table tests by simultaneously loading the table with rigid body blocks actuated by hydraulic cylinders, depicted in [Figure 3](#). The quasi-static test requires that the table absorb a certain



amount of energy at each seat position before reaching a threshold force.

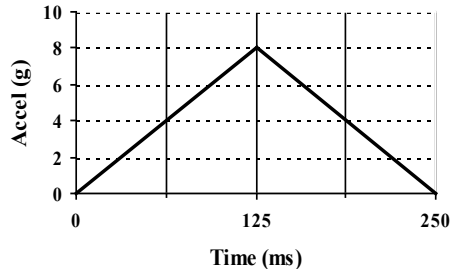


Figure 2. Target Crash Pulse

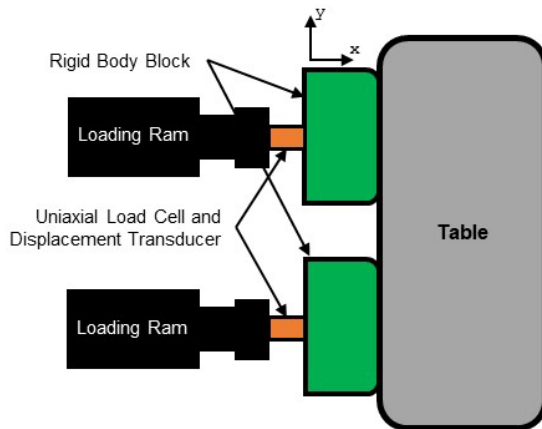


Figure 3. Top View of Quasi-static Test Setup [1]

RESULTS

The H3-50M seated in the aisle seat did not exceed any injury criteria in the Option A tests. This is likely a result of the occupant in the aisle seat experiencing lower contact forces from the table, since tables are typically stiffer at the wall seat position which is closer to the wall bracket. Also, the H3-50M only has a single deflection sensor in the chest (located at the sternum), and no sensors in the abdomen, whereas the THOR-50M has four deflection sensors in the chest and two deflection sensors in the abdomen.

Table 1 summarizes the compliance of each table design for Options A and B of the May 2022 balloted draft of S-018, Rev. 2. The Table 1 Option A test was conducted twice. Table 1 met the requirements in Option A in the second test, but not in the first test. Table 1 did not meet the requirements in either Option B test. It is possible that Table 1 could meet the

requirements for the Option B tests, but the energy-absorption system did not consistently perform as intended. Tables 2 and 3 did not fully meet the requirements of Options A or B. Table 4 was the only table design that was tested per Options A and B that met all requirements; however, the Table 4 Option B tests presented below in Table 1 were performed separate from this test series and were shared by the manufacturer. Table 5 met the requirements of Option A, but the design does not lend itself to a quasi-static test.

Table 1. Compliance Matrix for Table Designs

Table Design	Options A & B	Option A Dynamic	Option B Dynamic	Option B Quasi-static
Table 1	No	Yes/No	No	No
Table 2	No	No	No	No
Table 3	No	No	No	No
Table 4	Yes	Yes	Yes	Yes
Table 5	N/A	Yes	N/A	N/A

Tables which impact the ATDs far below the sternum (i.e., low tables) typically result in low peak sternum compression. An example of this situation was observed in Table 3, where the peak sternum compression of the H3-50M was only 18 mm, but the peak abdomen compression for the THOR-50M was 97 mm. This discrepancy in measured injury from the two ATDs demonstrates the need for a quasi-static energy-absorption evaluation when only testing with H3-50M ATDs. Table 3 did not meet the quasi-static energy absorption requirements, indicating this table provides equivalent safety when evaluated according to Options A and B.

CONCLUSIONS

This test series evaluated the structural integrity of passenger railcar workstation tables, compartmentalization of occupant ATDs, the energy absorption capabilities of crashworthy



tables, and the injury criteria resulting from dynamic impacts.

The results of the test series indicate an improvement in the safety equivalence in Options A and B in Revision 2 of the table standard over Revision 1. By increasing the energy-absorption requirements in Revision 2 of the standard, tables are less likely to pass Option B and fail Option A. This was desirable for the APTA C&S Working Group because Option A directly evaluates chest and abdomen injury criteria at more anatomic locations with advanced frontal crash ATDs (i.e., H3-RS or THOR-50M) while Option B is limited to sternal compression (H3-50M).

FUTURE ACTION

More manufacturers are testing workstation tables with Option A now that advanced ATDs are becoming more available. Subject to the acceptance of the APTA C&S Working Group, the researchers recommend removing Option B for workstation table testing at that time so that (1) the safety equivalence of the options is no longer of concern, and (2) abdomen injury criteria can be directly evaluated.

REFERENCES

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