SAE INTERNATIONAL

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Linear Impactor Calibration Procedure

RATIONALE

Linear impactor tests have been used for decades to create dynamic performance data of occupant protection materials and safety systems. This data is generally used for comparative purposes, to compute energy management capability, and as input to mathematical models and computer simulations. There are also examples of linear impact tests used for vehicle component certification such as the FMVSS 226 Ejection Mitigation test used by NHTSA.

Linear impactor test result variability is a problem that can be traced to many sources. One source of variability in the FMVSS 226 linear impactor test is associated with the characteristics of the impactor itself. A calibration procedure for the linear impactor is needed to reduce the variability associated with it.

This document establishes a standard for linear impactor performance that will ensure a level of test accuracy, repeatability, and reproducibility. No such standard exists today, resulting in a complete lack of these elements among the various laboratories and institutions that regularly utilize linear impact test methods.

In this version, SAE J3095 is being revised to adjust captions that were cropped in Figure 1 and to add onto Section 6.

1. SCOPE

This SAE Recommended Practice provides a procedure for measuring quantitatively the physical characteristics of linear impactors that are believed to effect impact test accuracy, repeatability, and reproducibility. Suggested values and tolerance are also provided for specific applications of linear impactor testing (i.e., ejection mitigation tests, head form impact tests, body block tests). Two functional groups of linear impactors are considered: those whose function is related primarily to displacement, and those related to measuring acceleration or force.

1.1 Purpose

The purpose of this SAE Recommended Practice is to establish sufficient calibration of the linear impactor test device so that results of similar tests conducted at different facilities can be compared. The linear impactor test device can be one of several types, such as those used for FMVSS 226 and Euro NCAP upper leg impactor.

1.2 Objective

The primary objective of this linear calibration test procedure is to reduce variability associated with the linear impactor test device between test facilities.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

Evans, N.C. and Leigh, M.J., "FMVSS 226 Ejection Mitigation: A Review," SAE Technical Paper 2013-01-0469, 2013, doi: 10.4271/2013-01-0469

Heading, M., Stein, D., and Dix, J., "Effects of Headroom Friction to Ejection Mitigation Testing," SAE Technical Paper 2014-01-0533, 2014, doi:10.4271/2014-01-0533.

Sharma, M. et al., "Instrument Panel Head Form Impact Test: Effects of Different Impactors & Test Methodologies

Kang, S.H., Barnes, E., and Feustel, J., "Driver Airbag Linear Impactor Dynamic Testing Method and Data Analysis", SAE Technical paper, 2006-01-1436. 2006, doi: 10.4271/2006-01-1436

Mihora, D., Friedman, K., and Hutchinson, J. "Effect of friction between head and airbag fabric on ejection mitigation performance of side curtain airbag systems," 2011 SAE World Congress, April 11-13, 2011, Detroit, Michigan, Paper 2011-01-0004

SAE J211-1 Instrumentation for Impact Test - Part 1 - Electronic Instrumentation

SAE J211-2 Instrumentation for Impact Test - Part 2 - Photographic Instrumentation

SAE J944 Steering Control System - Passenger Car - Laboratory Test Procedure

SAE J921 Motor Vehicle Instrument Panel Laboratory Impact Test Procedure - Head Area - SAE J921b

SAE J1733 Sign Convention for Vehicle Crash Testing

SAE J2937 Linear Impact Procedure for Occupant Ejection Protection

SAE J2961 Linear Impact Test for Passenger Airbag Modules Component Evaluation

2.1.2 Code of Federal Regulations (CFR) Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

49 CFR Part 571, Federal Motor Vehicle Safety Standard (FMVSS)

49 CFR Parts 571 and 585, Docket No. NHTSA-2011-0004, RIN 2127-AK23, Federal Motor Vehicle Safety Standards, Ejection Mitigation; Phase-In Reporting Requirements; Incorporation by Reference

Federal Register, Vol. 78, No. 174, Part II, 49 CFR Part 571, Federal Motor Vehicle Safety Standards; Ejection Mitigation, Final Rule, September 9, 2013

FMVSS 226, Ejection Mitigation

FMVSS 203, Laboratory Test Procedure

FMVSS 201, Laboratory Test Procedure

2.1.3 Other Publications

Bhattaharjee, S., Chaka, M., Elkins, W., Foster, M., Panoff, S., and Stiyer, M., “Linear Inverse and Pendulum Calibration Evaluation,” presented at Pedestrian Protection Flex-Pli, 5th TR-RUCC, July 30, 2012.

ECE Global Registry, Article 6 of the Agreement Concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Be Used on Wheeled Vehicle, Addendum, Global technical regulation No.1 “Door Locks and Door Retention Components (ECE/TRANS/132 and Corr.1),” Geneva, June 25, 1998.

ECE Global Registry, Article 6 of the Agreement Concerning the Establishing of Global Technical Regulations for Wheeled Vehicles, Equipment and Parts Which Can Be Fitted and/or Be Used on Wheeled Vehicle, Addendum, Global technical regulation No.1 “Door Locks and Door Retention Components (ECE/TRANS/132 and Corr.1),” ECE/Trans/180/add.1, April 1, 2005.

Ferguson, S., “FMVSS No. 226 - Ejection Mitigation, Final Rule,” Presentation at the 2nd Meeting of the Pole Side Impact GTR, Brussels, Belgium, March 3-4, 2011.

GTR No. 9.

Heidon Shinto Scientific Co., Ltd, Tribogear General Catalogue, 2015. http://www.heidon.co.jp/.

Kett Online Store: Products, Handheld Friction Analyzers - Tribometers, May 15, 2015.

Laboratory Safety Training Manual,
http://www.mae.virginia.edu/NewMAE/wp-content/uploads/2010/12/Safety_Training_Manual.pdf.

Qi, L., Yong, X., and Qing, Z., “Friction Effects in Pedestrian Headform Impacts with Engine Hoods,” Tsinghua Science and Technology, ISSN 1007-0214, 13/18 pp631-638, Vol 14, Number 5, October 2009.

Microsys Brochure, “Ejection Mitigation (FMVSS 226) & Pedestrian Protection Head.” April 2013, www.micro-sys.com.

National Operating Committee on Standards for Athletic Equipment, “Equipment Calibration Procedures, NOCSAE DOC (ND) 101-00m14a,” modified November 2014.

National Operating Committee on Standards for Athletic Equipment, “Football Helmet Standards Overview,” updated June 2014.

Regulation (EC) No 78/2009.

NHTSA, “ Laboratory Test Procedure for FMVSS 203, Impact Protection for the Driver from the Steering Control System,” Laboratory Test Procedure TP-203-02, May 4, 1990.

NHTSA, “Laboratory Test Procedure for FMVSS 201 Rigid Pole Side Impact Test,” Laboratory Test Procedure No. TP-201P, August 19, 1999.

NHTSA, “Laboratory Test Procedure for FMVSS No,. 226 Ejection Mitigation,” OVSC Laboratory Test Procedure No. TP-226-00, March 1, 2011.

NHTSA, “Laboratory Test Procedure for New Car Assessment Program Frontal Impact Testing,” September 2012.

SFI Foundation, Inc., Quality Assurance Specifications, “SFI Specification 45.1,” Effective August 11, 2005.

ECE 631 Pedestrian Upper Leg Hood Impactor.

3. DEFINITIONS

3.1 IMPACTOR APPLIANCE

Portion of the linear impactor that makes direct contact with the article being tested. This could include representations of a head form, a chest, an upper leg, or other items.

3.2 RADIAL DEFLECTION

Maximum radial deflection of the impactor appliance.

3.3 FRICTION

Resistance to linear motion due to friction and/or binding

3.4 IMPACT VELOCITY

Velocity at the time of contact with the test specimen.

3.5 IMPACT TIMING

Time to achieve impact velocity, after impactor “fire” signal is generated.

3.6 EXCURSION

Measurement of impactor appliance linear displacement beyond a defined reference surface.

3.7 IMPACTOR POSITIONING ACCURACY

Ability to position the impactor accurately; an increment of adjustment.

3.8 IMPACTOR MASS

Moving mass of impactor device (mass to be decelerated by the article being tested).

3.9 REFERENCE TESTING PROCEDURE

The test procedure being carried out using the linear impactor.

3.10 SETUP POSITION

Configuration of the impactor (including impactor appliance) just prior to initiating a test for a given reference test procedure. The impactor device is secured to its base; the impactor appliance is in the orientation defined by the reference testing procedure relative to the article being tested. (See example in Figure 1.)

3.11 REFERENCE VELOCITY

Impact velocity specified in the reference testing procedure.

3.12 REFERENCE MASS

Mass of impactor appliance previously specified by the reference testing procedure.

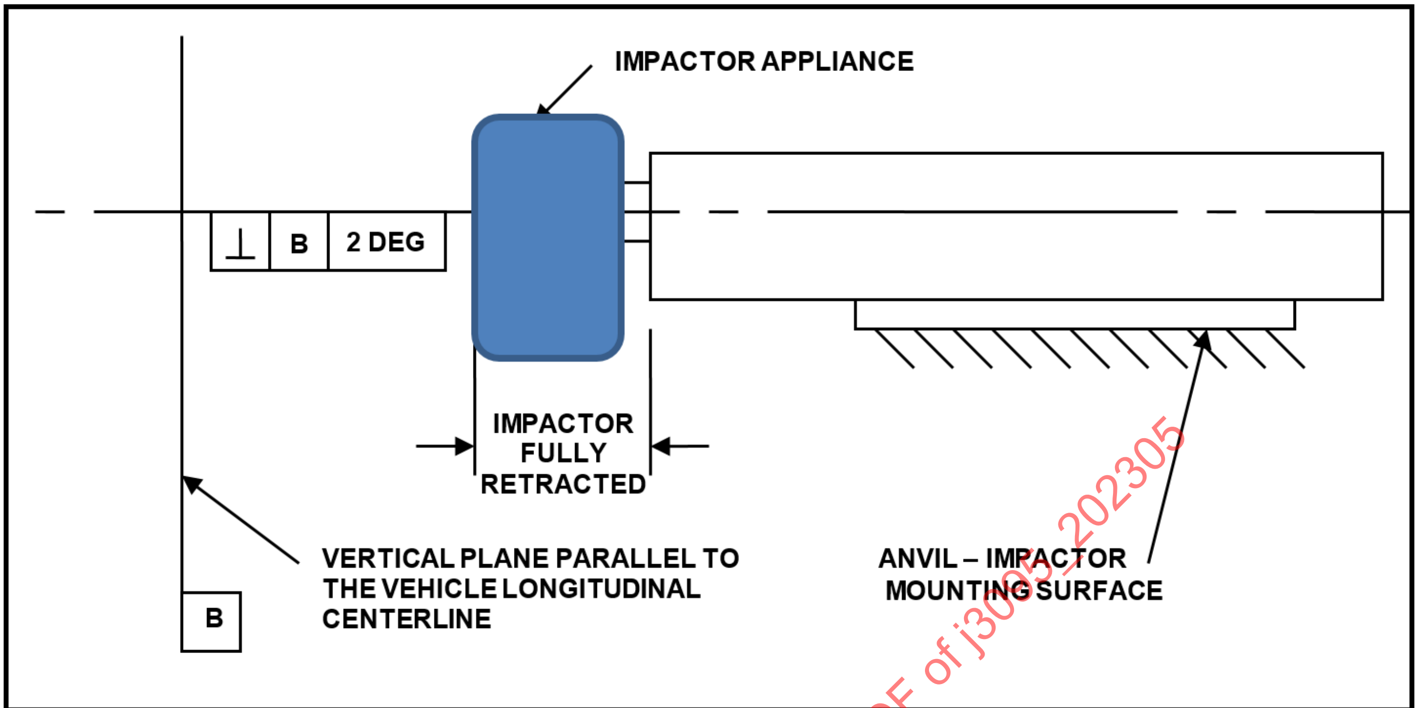

Figure 1 - Example linear impactor setup

4. LINEAR IMPACTOR FACILITY

4.1 Linear Impactor Site, General

The linear impactor test site should encompass sufficient area to provide accommodations for the linear impactor fixture, various photographic/video equipment, and a protected observation area.

4.1.1 Allowances for precise positioning of photographic/video equipment should be made, both on-board and off-board.

4.2 Linear Impactor

A linear impactor facility suitable for testing of passenger cars, light trucks, and vans should have the characteristics listed as follows:

Stabilized humidity of 40% ± 30%

Stabilized temperature of 20 °C ± 4 °C

4.3 Protective Measures

Protective measures consistent with the example laboratory safety training manual in the reference section should be taken to ensure the safety of test personnel and observers.

5. CALIBRATION PROCEDURES

The procedure described below is a generalized procedure that can be applied to the range of linear impactor applications currently in use. The specific parameters associated with each application have been defined in Section 6.

5.1 Measurement of Radial Deflection and Friction Characteristics

The static force used in the following tests to measure radial deflection and friction force was determined through computer modeling to be a typical radial force on an impactor appliance during actual testing. The results of this testing can be used to approximate the energy absorbed by friction as a percentage of the total kinetic energy intended for the test.

5.1.1 With the impactor in “setup” position, extend the impactor to distance “C” (minimum available stroke) as described in Figure 3.

5.1.2 Push on center of the impactor appliance in a direction parallel to the axis of motion, using a constant rate of 50.8 mm/s ± 10 mm/s (2.0 in/s ± 0.5 in/s), while using a suitable load cell to record the forces (N) needed start, and to maintain that motion over a stroke of at least 200 mm ± 2 mm. Using a suitable data recording system (with 100 Hz minimum sampling rate), record the maximum force needed to start motion in Table 1 as “F1(s)” in column (+Z), and record the nominal (average) force needed to maintain motion in Table 1 as “F1(d)” in column (+Z), and the standard deviation “F1(dev)” in column (+Z). Run a total of five tests (four repeat tests) and record the data in Table 1.

5.1.3 Return the impactor to the extended position as in 5.1.1.

5.1.4 Measure the vertical distance between the bottom surface of the impactor appliance quasi and a fixed horizontal plane.

5.1.5 Hang a mass or 100 kg ± 1 kg from the back face of the impactor appliance as shown in Figure 2.

5.1.6 Measure the vertical distance between the bottom surface of the impactor appliance quasi and a fixed horizontal plane.

5.1.7 Record the difference between 5.1.4 and 5.1.6 as “radial deflection” (D) in the (+Z) column of Table 1.

5.1.8 Push on center of the impactor appliance in a direction parallel to the axis of motion, using a constant rate of 50 mm/s ± 10 mm/s (2.0 in/s ± 0.5 in/s), while using a suitable load cell to record the forces (N) needed start, and to maintain that motion over a stroke of at least 200 mm ± 2 mm. Using a suitable data recording system (with 100 Hz minimum sampling rate), record the maximum force needed to start motion in Table 1 as F1(s) in column (+Z), and record the nominal force needed to maintain motion in Table 1 as “F2(d)” in column (+Z), and the standard deviation F2(dev) in column (+Z). Run a total of five tests (four repeat tests) and record the data in Table 1.

5.1.9 Remove the impactor from its base, rotate the entire device clockwise 90 degrees (looking at the back of the head-form), and re-secure it to the base (may need additional fixture).

5.1.10 Repeat steps 5.1.1 through 5.1.8 to obtain the +X direction radial deflection and friction data.

5.1.11 Remove the impactor from its base, rotate the entire device clockwise another 90 degrees (now 180 degrees from “setup”), and re-secure it to the base (may need additional fixture).

5.1.12 Repeat steps 5.1.1 through 5.1.8 to obtain the -Z direction radial deflection and friction data.

5.1.13 Remove the impactor from its base, rotate the entire device clockwise another 90 degrees (now 270 degrees from setup position), and re-secure it to the base (may need additional fixture).

5.1.14 Repeat steps 5.1.1 through 5.1.8 to obtain the -X direction radial deflection and friction data.

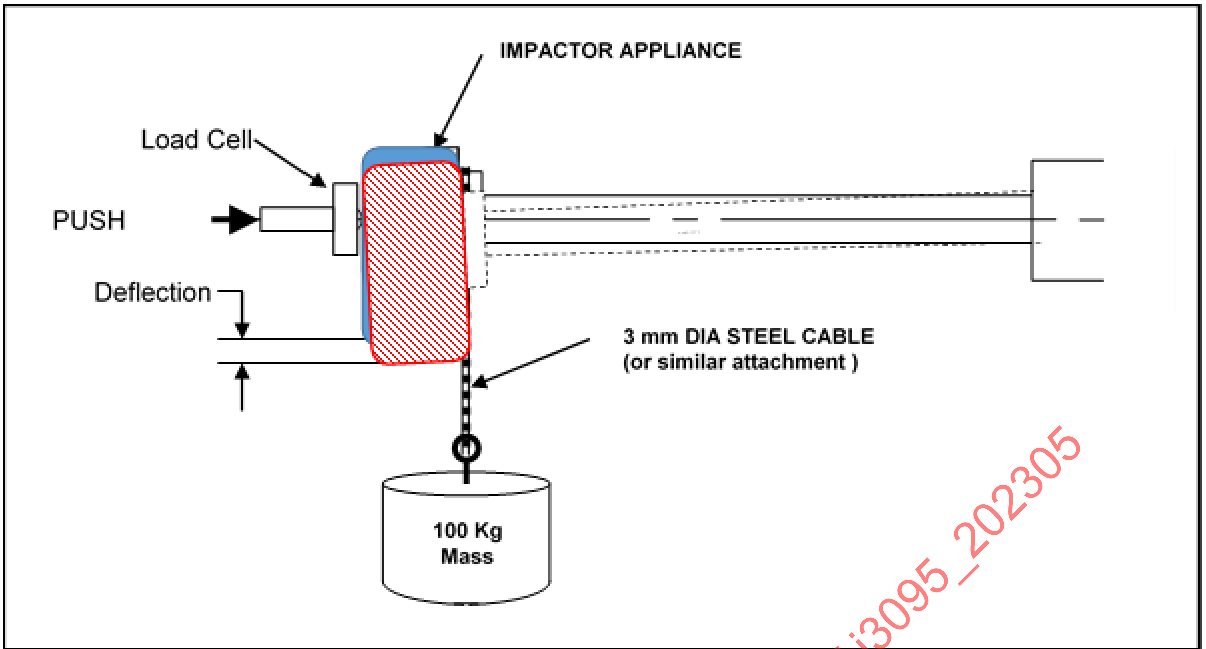

Figure 2 - Mass application to linear impactor

5.2 Impact Velocity, Timing, and Excursion Measurement

5.2.1 Perform calibration tests as needed to determine the setup parameters needed to achieve impact speeds of 16 km/h, 20 km/h, and 24 km/h (or speeds consistent with reference test procedure plus 25% for due diligence). Record impactor displacement data during these tests for determining stroke requirements (see below).

5.2.2 Determine the impactor stroke needed to obtain the impact speed of 16 km/h from the speed calibrations performed in 5.2.1. This distance will be referred to as distance “A.”

5.2.3 With the impactor in the setup position and a suitable anvil provided, prepare a calibration pad as follows (see Figure 3):

5.2.3.1 Mount a suitable energy absorbing material (able to absorb full KE of the impactor) to the anvil such that it will be contacted by the impactor appliance at a stroke distance 400 mm past distance “A” (per 5.2.2). The material should be of sufficient initial stiffness such that initial contact by the impactor can be determined by examining the impactor accelerometer data. If no such material is available, mount a contact switch that will accurately indicate the time at which the impactor appliance reaches that position.

5.2.3.2 Mount a wood splint (of sufficient strength and stiffness to create a discernable change in the impactor appliance acceleration data) to the anvil so it is supported only at its ends, and so that it will be contacted by the impactor appliance at a stroke distance 200 mm before impactor appliance contact with the energy absorber mounted per 5.2.3.1. As an alternative to the wood splint, a contact switch could be used to indicate when the impactor appliance reaches that position. This information is needed to determine the time interval between T=0 (signal to fire the impactor) and theoretical contact with the test article. This data also provides an independent means to verify the accuracy of the displacement measurement—particularly with impactor systems that rely on double integration of the acceleration to obtain displacement data (if the difference in computed displacement between time of contact with plane “B” and time of contact with plane “C” is 200 mm, the system is accurate).

5.2.4 Conduct five tests using this setup at this speed. Compute the appropriate responses and document the results in Table 2.

5.2.5 Repeat 5.2.3 through 5.2.4 for the 20 km/h impact speed (may need to adjust distance "A" for this velocity).

5.2.6 Repeat 5.2.3 through 5.2.4 for the 24 km/h impact speed (may need to adjust distance "A" for this velocity).

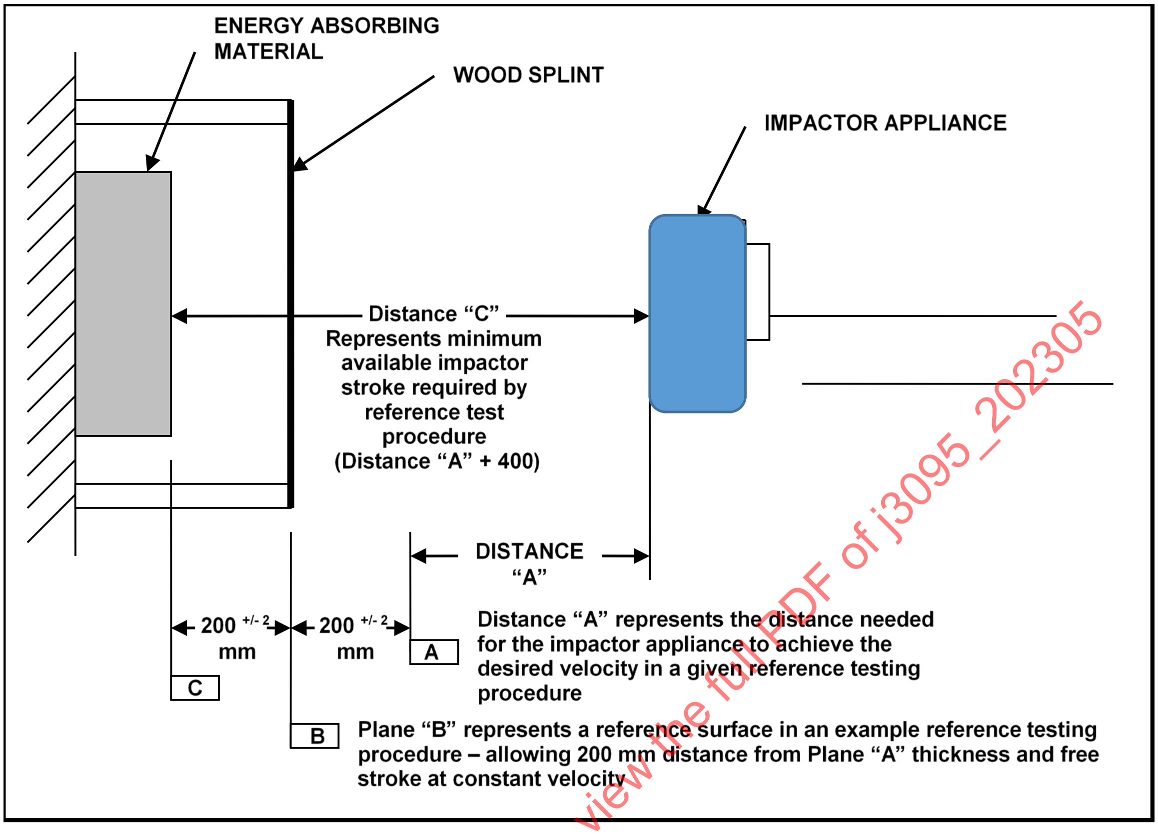

Figure 3 - Impact velocity, timing, and excursion measurement setup

5.3 Impactor Positioning Accuracy

If the positioning of the impactor is not infinitely adjustable within its vertical and lateral adjustment range, indicate the increment of adjustment in Table 2.

5.4 Impactor Mass

Indicate the actual total moving mass of the linear impact and impactor appliance to the nearest 0.01 kg in Table 2.

Table 1 - Impactor friction data

		Run	+X	-X	+Z	-Z	Max
Radial Deflection	D	1					0
Unloaded Static Friction Force (peak force needed to get the impactor moving)	F1(s)	1					0
		2					0
		3					0
		4					0
		5					0
Unloaded Dynamic Friction Force (average force needed to maintain motion - excluding data pertaining to the static friction)	F1(d)	1					0
		2					0
		3					0
		4					0
		5					0
Standard Deviation of F1 data	F1(dev)	1					0
		2					0
		3					0
		4					0
		5					0
Unloaded Static Friction Force (peak force needed to get the impactor moving)	F2(s)	1					0
		2					0
		3					0
		4					0
		5					0
Unloaded Dynamic Friction Force (average force needed to maintain motion - excluding data pertaining to the static friction)	F2(d)	1					0
		2					0
		3					0
		4					0
		5					0
Standard Deviation of F2 data	F2(dev)	1					0
		2					0
		3					0
		4					0
		5					0