		J2937™	OCT2021
SURFACE VEHICLE STANDARD		**Issued** 2016-04 **Reaffirmed** 2021-10	
		Superseding J2937 APR2016	
	Linear Impact Procedure for Occupant Ejection Protection		

RATIONALE

SAE J2937 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

The objective of this document is to enhance the test procedure that is used for ejection mitigation testing per the NHTSA guidelines as mentioned in the FMVSS226 Final Rule document (NHTSA Docket No. NHTSA-2011-0004).

The countermeasure for occupant ejection testing is to be tested with an 18kg mass on a guided linear impactor using the featureless headform specifically designed for ejection mitigation testing.

SAE does not endorse any particular countermeasure for ejection mitigation testing. However, the document reflects guidelines that should be followed to maintain consistency in the test results. Examples of currently used countermeasures include the Inflatable Curtain airbags and Laminated Glass.

The testing procedure is as follows:

1. Determine the daylight opening

2. Identify target locations per the FMVSS226 Final Rule §5.2

    a. Target locations for all windows and daylight openings

    b. Perform the target elimination process

    c. Reconstitute the targets

3. Determine the zero-plane

4. In case of advanced glazing, determine if the glazing has to be part of the test and pre-brake it at a 75mm offset

    a. If yes, than follow the procedure for pre-breaking the laminated glazing

5. Run the test

    a. At 5.6m/s with a 1.5s delay

    b. At 4.4m/s with a 6.0s delay

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, 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.

SAE J211/1 or ISO 6487	Instrumentation for Impact Test - Part 1 - Electronic Instrumentation
SAE J211/2	Instrumentation for Impact Test - Part 2 - Photographic Instrumentation
SAE J670	Vehicle Dynamics Terminology
SAE J1538	Glossary of Automotive Inflatable Restraint Systems
SAE J1733	Sign Convention for Vehicle Crash Testing

Mihora, D., Friedman, K., and Hutchinson, J., "Effect of Friction Between Head and Airbag Fabric on Ejection Mitigation Performance of Side Curtain Airbag Systems," SAE Technical Paper 2011-01-0004, 2011, doi:10.4271/2011-01-0004.

2.1.2 NHTSA Publications

Available from http://www.nhtsa.gov/Laws-Regs at http://www.nhtsa.gov

49 CFR Part 571 Federal Motor Vehicle Standards; ejection Mitigation; Final Rule, NHTSA Docket no. NHTSA-20130097, RIN 2127-AL40

Laboratory Test Procedure for FMVSS No.226 Ejection Mitigation, TP-226-00, March 01, 2011

2.1.3 Other Publications

Stein, Douglas J. 2009. "Linear Impactor Performance Characteristics for Ejection Mitigation Testing". Presented at Automotive Safety Council (ASC's, formerly known as AORC) quarterly meeting, Washington D.C., March 27, 2009

3. DEFINITIONS

3.1 DATA POLARITY AND SIGN CONVENTION

Data polarity and sign convention is consistent with SAE specification and is as follows:

The origin for the vehicle coordinate system is defined in the lateral (y-axis) direction as the longitudinal centreline for the vehicle.
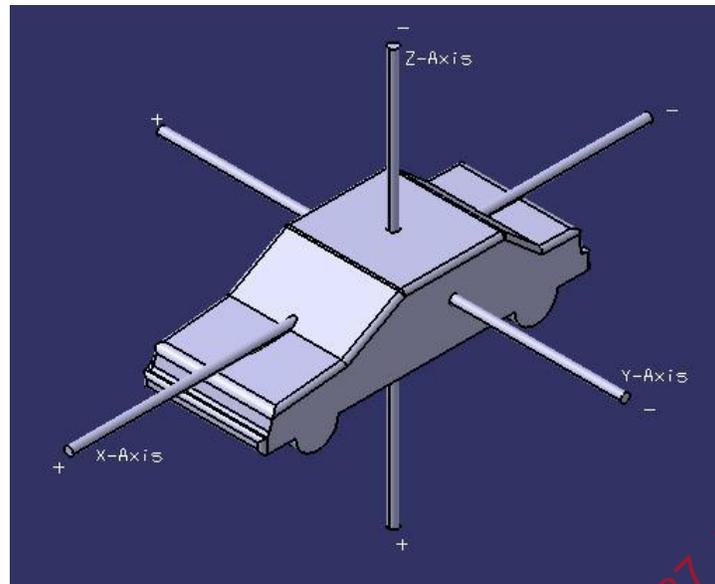
Figure 1

Polarities:

- The x-axis is positive in the forward longitudinal direction.

- The y-axis is positive in the right lateral direction.

- The z-axis is positive in the downward vertical direction.

- All ATD (Anthropomorphic Test Device) data is recorded with reference to the ATD in standing position or per ISO 4130.

3.2   PROCESSING UNITS

Table 1 - Unit table

QUANTITY	SI UNIT NAME	SI UNIT SYMBOL
*length	meter	m
mass	kilogram	kg
*time	second	s
current	ampere	A
*temperature	Kelvin	K
energy	joule	J
force/weight	Newton	N
frequency	hertz	Hz
power	watt	W
*pressure	Pascal	Pa
*velocity	meters/second	m/s
*acceleration	meters/second^2	m/s^2
moment/torque	Newton-meter	N·m

3.3   Terms

3.3.1   BODY-IN-WHITE (BIW)

An untrimmed sheet metal vehicle body from the assembly line - often painted white. It is used as the basis of a test buck. The sheet metal is then reinforced in critical areas to provide rigid mounting for those components that will be used each test to evaluate the restraint system's performance.

3.3.2   TEST BUCK

The test buck is defined as a fabricated, reusable structure typically made from a body-in-white, providing basic relevant vehicle geometry and rigid mounting for consumable test components. Structure must also include provisions for mounting all trim or interior components which may interact with and provide a reaction surface for the inflatable curtain. Test buck must also have provisions for mounting or retaining in a fixed position during testing.

3.3.3   QUARTER BUCK

The structure that is representative of the upper quarter of a test buck is referred to as a Quarter Buck. At a minimum the quarter buck will include the lower horizontal pinch flange used to determine the window opening. Quarter buck must also provide mounting locations for interior components which may affect or react with the curtain deployment. Reinforcements to the body structure are permissible to ensure the window plane remains in a fixed position. Frames or supports on the exterior of the vehicle must not interfere with headform or inflatable curtain during testing. In addition, the headliner must be affixed in a way that simulates vehicle installation.

3.3.4   VEHICLE

A fully assembled structure with all components and trims in place is referred to as a Vehicle. Vehicle should be supported by frame/sub frame (i.e., with jack stands) as to eliminate absorption of energy by vehicle suspension. Vehicle should also be retained to prevent lateral movement support equipment. Doors and/or glass may be removed from opposite side of vehicle to allow for access of impactor.

3.3.5   INFLATABLE CURTAIN (IC)

An Inflatable curtain (IC) is the restraint system which deploys along the side windows to protect occupants during certain crashes.

3.3.6   TRIM

A Trim is any interior component that provides a reaction surface with the cushion of the Inflatable Curtain and/or affects/interferes with the deployment of the Inflatable Curtain.

3.3.7   DAYLIGHT OPENING

A Daylight Opening is the inside perimeter of the window opening around the glass aperture, when observed in purely lateral direction, with a 25mm offset of the opening. This excludes any flexible gasket material or weather stripping. Any part of the vehicle, which is off the window plane by less than 100mm, would be considered as part of the window, and 25mm offset would be taken off this part. For example, instrument panel surface that is less than 100mm away from the daylight opening.

3.3.8   IMPACT LOCATION

An Impact Location is a point where the headform center, along the axis of motion, intersects the window opening.

3.3.9   WINDOW PLANE

The Window Plane is referred to a plane located at a point where the headform first touches a closed, unbroken window.

4.   TESTING DEVICE CHARACTERISTICS

4.1   Linear Impactor

This test requires a linear guided impactor that meets the following specifications:

- The impactor headform must comply with the FMVSS226 final rule.

- The total mass of the impactor should be 18kg.

- The impactor must be able to propel the featureless headform at the required velocity (5.6m/s or 4.4m/s), within +0.20 and -0.00 m/s.

- The impactor stroke should allow for the headform to travel minimum of 300mm beyond the window plane. (Ensure impactor design encompasses the small window openings and various vehicle widths)

- The impactor must contain some means for triggering the deployment of the impactor to achieve the desired impactor trigger time within +20ms, -0ms. Actual contact time will vary due to slight variations in bag geometry from the "design geometry", and due to the test-to-test variability.

- The impactor must be able to move longitudinally (x-dimension) with respect to the vehicle, and parallel with the vehicle's lateral centreline. The tolerance is one degree in any direction.

- The headform must be able to rotate up to 90° along it's y-axis at 5° increments per the FMVSS226 Final Rule.

The impactor must perform within specifications established by AORC (i.e., friction coefficient, deflection, etc.). See Appendix A for procedure and tables.

4.2   Instrumentation

The Tri-axis accelerometer is used to measure impactor acceleration.

The acceleration measurements are to be made in accordance with SAE J211/1 or ISO 6487. Accelerometers should be rated for 500 to 2000 g peak acceleration.

Velocity is calculated by differentiating displacement from the displacement sensor. A secondary method for calculating velocity is by integrating the acceleration.

Displacement measurement shall be recorded using a displacement sensor with an accuracy of at least ±1.0mm Examples include the use of LVDT, String Pot and non-contact IES Model 2098 (belt motion sensor)

4.3   Headform Assembly

Featureless headform (i.e., Humanetics part ATD-7304)

Total guided impactor mass: 18 kg ±0.1kg

Dimensions: aluminium headform base is 203.2 mm tall and 153.9 mm wide. It is covered with 11.4 mm thick head skin, which is made from the same material as a Hybrid III dummy head skin.

4.4   Anvil

The Anvil is capable of adjustment in the vertical, lateral, and/or longitudinal direction, as necessary, to achieve the necessary relationship between the impactor and the test fixture (i.e., quarter buck).

Rigidly constructed - shall have a minimum 500Hz first mode natural frequency to ensure that the vibration of the anvil does not affect the data up to 100Hz.

4.5   Test Fixture

A test fixture or buck must represent appropriate portion of vehicle and have the ability to attach any necessary trim parts that would provide a reaction surface.

SAE does not recommend any particular use of either the full buck, half buck or quarter buck for ejection mitigation testing.

However, it is suggested that if the testing is done with the full buck, a half buck or a quarter buck, then the buck be made rigid enough to measure the 'excursion along the same Z plane' of the impactor target location to be less than 5 mm.

5.   TEST PROCEDURE

5.1   Determine the Head Target Locations

5.1.1   Rearmost Offset Line

The rearmost offset line determines the rear edge of the daylight opening for the application of the ejection mitigation countermeasure.

In a vehicle with one or two rows of seating, the rearmost offset line is 1400mm rearwards of the SgRP (see Figure2). For the vehicles with 3 or more rows of seating, the rearmost offset line is 600mm rearwards of the SgRP (see Figure3).
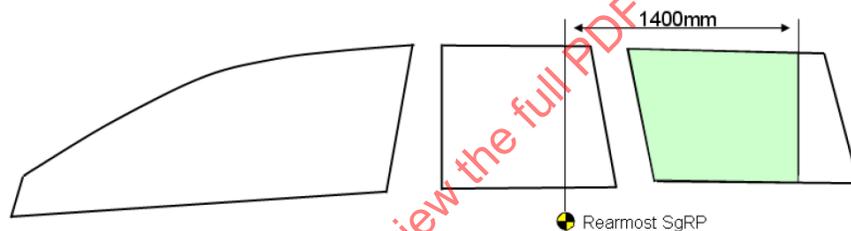
Figure 2 - Rearmost offset line rearwards of first and second rows
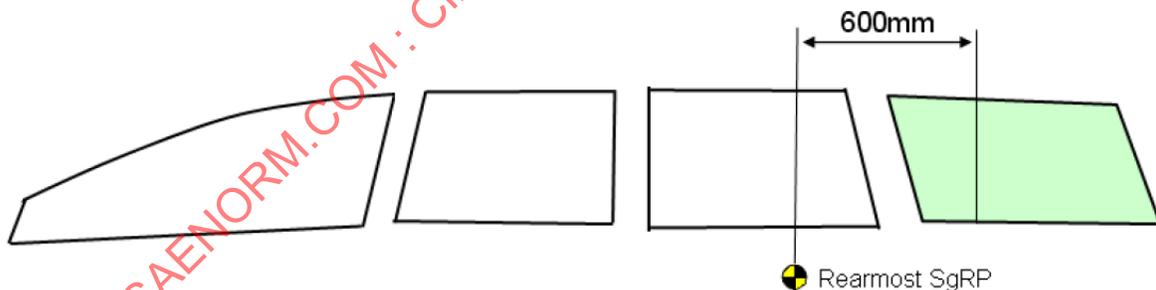
Figure 3 - Rearmost offset line rearwards of the third row

For the seats that are forward facing, but not fixed, find the rearmost point by adjust the seatback in the design location and any other orientation that positions the SgRP in the rearmost location. Follow the above mentioned guidelines to determine the rearmost offset line.

5.1.2   Front Window (see Figure 2)

Find all corners of the window opening. A corner is to be where two points of the headform are tangent to the 25mm clearance line.

Using the given geometric centre, divide the windows into quadrants.

Eliminate any target whose centre is not within the lower front or upper rear quadrants. If there is more than one target in each of the quadrants, eliminate the highest target in the lower quadrant and the lowest target in the upper quadrant. The targets left are the primary targets.

Find the distance, A, between the vertical centre lines (x-direction) of the two primary targets.

The first secondary target should be placed A/3 distance rearward of the front (lower) primary target and moved up to the 25mm clearance line.

The second secondary target should be placed A/3 distance forward of the rear (upper) primary target and moved down to the 25 mm clearance line.

5.1.3   Rear Window(s) (see Figure 4)

Find all corners of the window opening. A corner is to be where two points of the headform are tangent to the 25mm clearance line.

Using the geometric centre, divide the windows into quadrants.

Eliminate any target whose centre is not within the upper front or lower rear quadrants. If there is more than one target in each of the quadrants, eliminate the highest target in the lower quadrant and the lowest target in the upper quadrant. The targets left are the primary targets.

Find the distance, B, between the vertical centrelines (x-direction) of the two targets.

The first secondary target should be placed B/3 distance rearward of the front (upper) primary target and moved down to the 25 mm clearance line.

The second secondary target should be placed B/3 distance forward of the rear (lower) primary target and moved up to the 25 mm clearance line.

Table 1 - Naming convention for each of the daylight opening

Front:	Lower Primary	A1	Rear:	Upper Primary	B3
	Upper Secondary	A3		Lower Secondary	B1
	Lower Secondary	A2		Upper Secondary	B4
	Upper Primary	A4		Lower Primary	B2
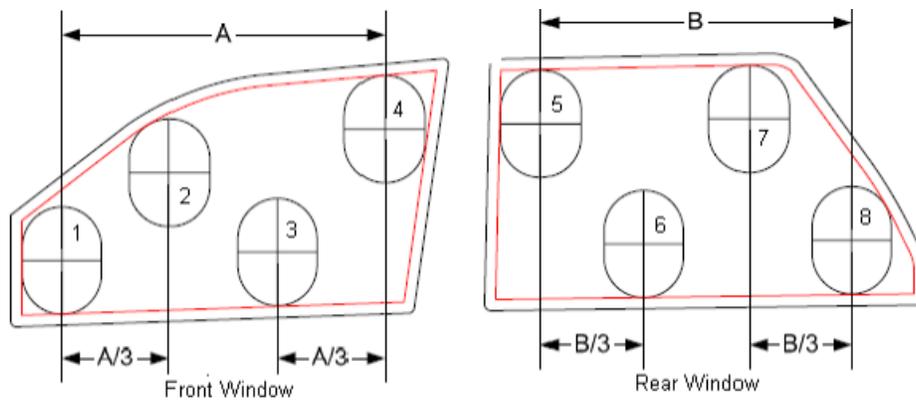
Figure 4 - Determining the primary and secondary head target locations

If the horizontal distance between the centres of two targets is less than 135mm and the vertical distance less than170mm, one of the targets can be eliminated (see figure3 and Table2). The table below instructs which target to eliminate. Insert info regarding the final impact location between target locations
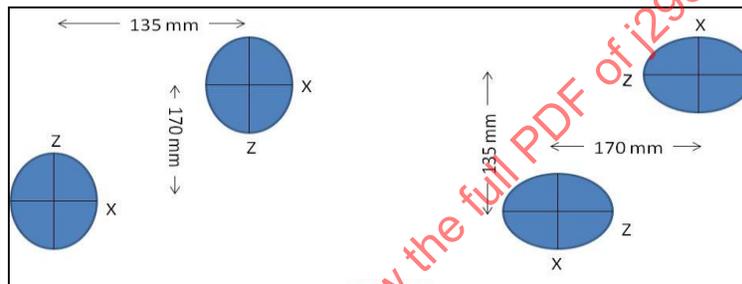
Figure 5 - Distances between the head target locations

Table 2

Step	Measure Distance from z Axis to z Axis and x Axis to x Axis for these Targets	Eliminate This Target If Distances Between z Axes of Targets and x Axes of Targets Are Less Than 135 mm and 170 mm, Respectively
1	Upper Secondary to Lower Secondary	Upper Secondary
2	Upper Primary to Upper or Remaining Secondary	Upper or Remaining Secondary
3	Lower Primary to Lower or Remaining Secondary	Lower or Remaining Secondary
4	Upper Primary to Lower Primary	Upper Primary

5.1.4   Target Reconstruction and Reorientation

If the horizontal distance between the centres of two targets is less than 135mm and the vertical distance less than170mm, one of the targets can be eliminated (see figure3 and Table2). The table below instructs which target to eliminate. Insert info regarding the final impact location between target locations.

If there are two or less target remaining, find the absolute distance between the target z-direction centrelines. If the distance is ≥360mm, then add a head target location in the centre of the original target locations.

If the targets in procedure 4.1.3 are less than 4 per the daylight opening, then rotate the headform 90° in the positive direction of the vehicle x-axis (counter clockwise if looking from outside of left side or clockwise if looking from outside of the right side). Go through the target elimination procedure in 4.1.3 for target reconstruction.

If 90° reorientated targets are more than the vertical targets, then these are the new head target locations. If 90° reoriented targets are less than or equal to the vertical targets, than revert back to the vertical head target locations.

5.1.5 No Coverage

If a target is considered to have no coverage of an ejection mitigation system, no test is needed to be run at that target location. A target is considered to have no coverage if the headform travels 200mm beyond the window plane with a force of 50N or less while extending the headform when the IC is inflated to 20kPa or until taut via shop air.

5.1.6 For 5.6m/s (20kmph) speed

Install accelerometers into the headform.

If test fixture is a quarter buck, rigidly secure to anvil. Ensure that minimum 250 mm distance between the anvil and the daylight opening plane of the quarter buck exists.

If test fixture is a buck or vehicle, secure it to prevent any movement. Jack stands may be used to support the vehicle by the frame/sub-frame to eliminate suspension jounce during testing. Straps may be used to prevent unwanted lateral movement on jack stands.

Install the set-up IC or foam on fixture.

Line up the centre of the headform to the centre of the determined Impact location.

If applicable, inflate IC using shop air at a regulated pressure of 20 to 30kPa so that full pressure is not exerted on the cushion.

Conduct calibration test and review data to confirm velocity of impactor and impactor trigger time, which is 6000 ms (+20 ms, -0 ms) from the time the IC current is initiated.

Install IC to be tested.

Connect pressure transducer(s) per ATS-203 (if applicable).

Adjust equipment so that zero displacement is read at the window plane. Negative displacement is inside window plane. Positive displacement is outside window plane.

Take pre-test photographs at each high-speed camera view.

Run test.

Take post-test photographs at each high-speed camera view and any anomalies.

Review video and data.

Time equals zero is the time the IC current is initiated.

5.1.7   For the 4.4m/s (16kmph) speed:

Install accelerometers into the headform.

If test fixture is a quarter buck, rigidly secure to anvil. Ensure that minimum 250 mm distance between the anvil and the daylight opening plane of the quarter buck exists.

If test fixture is a buck or vehicle, secure to prevent any movement. Jack stands may be used to support the vehicle by the frame/sub-frame to eliminate suspension jounce during testing. Straps may be used to prevent unwanted lateral movement on jack stands.

Install the set-up IC or foam on fixture.

Line up the centre of gravity of the headform to the centre of the determined Impact location.

If applicable, inflate IC using shop air at a regulated pressure of 20 to 30 kPa so that full pressure is not exerted on the cushion.

Conduct calibration test and review data to confirm velocity of impactor and impactor trigger time, which is 1500 ms (+20 ms, -0 ms) from the time the IC current is initiated.

Install IC to be tested.

Connect pressure transducer(s) per ATS-203 (if applicable).

Adjust equipment so that zero displacement is read at the window plane. Negative displacement is inside window plane. Positive displacement is outside window plane.

Take pre-test photographs at each high-speed camera view.

Run test.

Take post-test photographs at each high-speed camera view and any anomalies.

Review video and data.

5.2   Test Setup Conditions

5.3   Time equals zero is the time the IC current is initiated.

Camera Views:

- The videos are to be captured at a minimum of 1000 fps and with a resolution of 1024x768 pixels.

- Each view contains minimum of 30ms before and 125ms after bag contact (verified during calibration tests). One of the oblique views should capture the full duration, 0-1.5s or 0-6.0s, event. The frame rate, for the view that is capturing the full event, can be changed between the IC time to fire and the impact contact to the IC, to save viewing time and storage memory.

- Test number must be visible in all views.

Standard Views Collected:

- Front Oblique (View 1)

- Rear Oblique (View 2)

- Inboard Rear Profile (View 3) - to establish IC contact, OR

- Outboard Rear Profile (View 4) - to view excursion
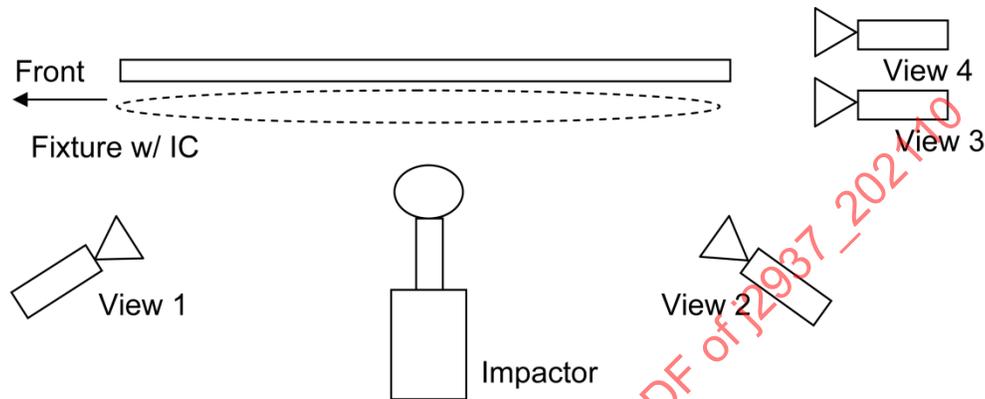
Figure 6 - Camera setup

5.4   Headform Friction

Headform friction is to be consistent from test series to test series and also during the test series.

Verify the headform friction characteristics prior to the test series using the SLIDO robotic testing system (SAE 2011-01-0004) or similar device. The device could obtain both the static and dynamic coefficients of friction. Headform versus airbag material could be used to verify the headform static and dynamic coefficients of friction prior to the test series. The total travel distance should be at least 100mm at 50mm/s.
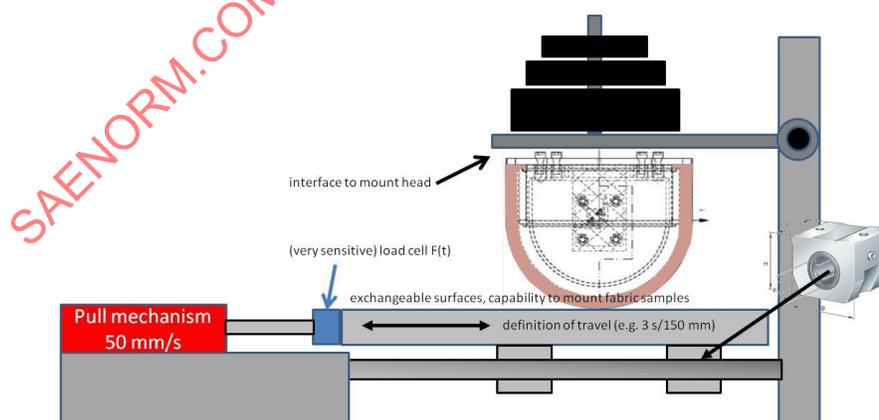
Figure 7 - Friction measuring device concept

Clean the headform skin with isopropyl alcohol prior to each test