Handbook of test methods for wearable EPTS devices

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Contents

Test protocol for wearable EPTS devices

The following test methods were developed by CSER (Centre for Sports Engineering Research, Sheffield Hallam University) in relation to wearable EPTS (Electronic Position Tracking Systems) devices, on behalf of FIFA.

About the IMS standard for wearable tracking devices

The FIFA Technology Innovation Department is working on the standardisation of electronic performance and tracking systems and thereby looking to provide guidance to football's stakeholders in regards to the use of EPTS in competitive matches.

The Laws of the Game 17/18 were updated to account for the use of EPTS (Law 4) and introduced the minimum standard that should be met by any wearable tracking system that is to be used in match. Any such device must meet the IMS standard as set out in the newly-launched FIFA Quality Programme for EPTS.

Electronic communication

Players (including substitutes/substituted and sent off players) are not permitted to wear or use any form of electronic or communication equipment (except where EPTS is allowed). The use of any form of electronic communication by team officials is not permitted except where it directly relates to player welfare or safety.

Electronic performance and tracking systems (EPTS)

Where wearable technology (WT) as part of electronic performance and tracking systems (EPTS) is used in matches played in an official competition organised under the auspices of FIFA, confederations or national football associations, the technology attached to the player's equipment must bear the following mark:

IMS INTERNATIONAL MATCH STANDARD™

This mark indicates that it has been officially tested and meets the minimum safety requirements of the International Match Standard developed by FIFA and approved by The IFAB. The institutes conducting the tests are subject to the approval of FIFA. The transition period runs until 31 May 2018.

Where electronic performance and tracking systems (EPTS) are used (subject to the agreement of the national football association/competition organiser):

- they must not be dangerous
- information and data transmitted from the devices/systems is not permitted to be received or used in the technical area during the match

In order to obtain the IMS mark and be listed as approved wearable technology, each system must be tested by an accredited independent test institute. The testing is only open to wearable EPTS systems and approval of the hardware does not constitute any assessment of the quality of information generated by the devices. Any device must be tested before 1 June 2018 in order to be eligible for use in official competitions.

Further testing will then also be introduced around the performance of EPTS which will include wearables as well as non-invasive performance tracking systems (e.g. optical). This standard will be a performance standard and not constitute a formal requirement by the IFAB.

1. Introduction

Electronic position and tracking systems (EPTS), particularly wearable GPS and LPS based devices, are becoming ubiquitous in performance sport. A specific feature of these systems is the requirement of the user to wear a device, normally mounted on a player's upper back. There is a potential risk that during a backward fall (identified as a likely injury scenario), the EPTS device may inflict injury to the player. An injury might be contusion, although laceration or even fracture might be possible. As a result, a test protocol has been developed to assess the impact of an EPTS device when mounted on the upper back.

2. Test Protocol

2.1. EPTS Device samples

Identical models of the EPTS sample to be tested shall be sent to the test institute. A total of five samples are required for testing. A sample constitutes:

1. EPTS Device
2. Manufacturers vest/pocket for mounting device

Devices and vest/pockets submitted for testing must be fully representative of the final product, including but not limited to; manufacturing and assembly processes, materials and components, and graphic designs. Upon receipt of the samples the test institute will allocate a unique identification code to each sample.

Manufacturers must also provide a product declaration specifying the device name, dimensions, mass, performance characteristics, and intended mounting position.

2.2. Types of test

A sample batch as supplied by a manufacturer will undergo a geometric assessment and an impact test. Both assessment and test are conducted within a laboratory setting. These must be conducted by an independent FIFA-accredited test institute.

2.2.1. EPTS geometric assessment

A geometric assessment of the EPTS devices as supplied by the manufacturer. The devices are visually inspected, dimensions measured using precision calipers, and mass taken. Maximum sectional area is determined and documented.

2.2.2. EPTS Impact Test

The EPTS device, placed upon a skin surrogate, is impacted with a flat faced drop hammer at a set velocity and mass. Devices are tested within a baseline pocket as specified by this standard and manufacturers vest pocket. Mean pressure values are obtained through the use of pressure sensitive film. Visual and photographic inspection are used to determine physical damage to skin surrogate. Visual inspection to determine any external damage to EPTS device.

2.2.3. Testing order

Sample	Test order
1,2,3,4,5	EPTS Geometric Assessment
1	EPTS Impact Test Baseline Pocket
2,3,4,5	EPTS Impact Test Manufacturers Pocket

2.3. Sample preparation

EPTS device samples must be in a new, un-used and un-tested condition. The EPTS devices shall be prepared by being conditioned for 12 hours at 23±2 °C and at an ambient humidity.

The ambient conditions during testing shall be a room temperature of 20°C~26°C. Test conditions must be monitored and recorded during all tests.

2.3.1. Skin surrogate preparation

Principle
A skin surrogate of multilayer construction, silicone and ballistic gel. This section describes the preparation and storage of the skin surrogate to be used in FQP EPTS Impact Test. The skin surrogate is single use only, no constitutive part may be used for multiple impacts.

Apparatus

Description
Apparatus shall comprise:

- Digital Measurement Scales
- Vacuum Chamber
- Mixing Equipment
- Environmental Chamber
- Surrogate Moulds
- Water Bath

Digital measurement scales
Digital measurement scales capable of ± 0.01 g accuracy for measurement of silicone curing agent.

Vacuum Chamber
A vacuum chamber suitable for degassing of silicone, as per manufacturer instructions.

Mixing Equipment
General mixing and handling equipment for preparation of silicone and ballistic gel.

Environmental Chamber
Environmental chamber for storage and curing of silicone samples. Capable of 10 ~ 25 ± 1°C

Surrogate Moulds
Moulds suitable for casting skin surrogate. It is recommended to line the base of the mould with closed cell polyurethane to provide a mat finish to silicone.

Water Bath
A water bath for use in preparation of ballistic gel, temperature of bath should not exceed 75°C.

Technical Data
The multilayer skin surrogate utilises Silastic 3484 and ballistic gel formulated to NATO specification. Epidermis and dermis layers should be cast in Silastic 3484, with underlying subcutaneous adipose cast in ballistic gel. The layers should be of thickness:

Layer	Material	Thickness
Epidermis/Dermis	Silastic Silicone	2 ± 0.25 mm
Adipose	Ballistic Gel	2 ± 0.25 mm

Surrogate materials

Surrogate base materials required:

- Silastic 3483 silicone
- Silastic 81F curing agent
- Gelatin granules
- Cinnamon Oil

Refer to manufacturers guidelines on handling of materials.

Procedure

1. Measure 100 parts Silastic 3483 base silicone to 5 parts Silastic 81F in quantities to give required thickness of epidermis/dermis layer. Mix thoroughly and vacuum degas.
2. Pour silicone evenly into a mould and allow to cure for 24 hours at 22°C.
3. Following 24 hours of Silastic layer curing, measure 80 parts cold water to 20 parts gelatin in quantities to give required thickness of adipose layer dependent on mould size. Mix in suitable container and leave to stand until all water is absorbed. Add a minimum of two drops of cinnamon oil. Place container in a hot water bath, stir mixture gently until fully dissolved.
4. Pour gelatin onto previously prepared Silastic layer. Wrap mould in PVC or LDPE wrap. Place within environmental conditioning chamber at 10°C for minimum 12 hours prior to use. Note. If chamber contains a conditioning fan, this should be set to minimum power to limit any dehydration of ballistic gel. Skin surrogate should be used within 48 hrs of gelatin preparation.
5. Prior to impact testing, cut out required skin surrogate samples from mould using a sharp knife, to avoid delamination of Silastic and gelatin layers.

3. Test Methods

3.1. EPTS geometric assessment

Principle

A geometric examination and assessment of the EPTS devices as supplied by the manufacturer.

The EPTS devices are visually inspected, dimensions measured using precision calipers, and mass taken. Maximum sectional area is determined and documented. Devices must be assessed for external integrity before impact test can be conducted. EPTS vest as supplied is examined, material thickness and any method of padding documented.

Apparatus

Test apparatus shall comprise:

- Precision Calipers
- Digital Measurement Scales

Precision Calipers
Digital calipers capable of +/- 0.01 mm

Digital Measurement Scales
Digital scales capable of +/- 0.01 g

Procedure

Each EPTS sample device as supplied is visually inspected and then dimensions are measured with the precision calipers. Mass is then taken and recorded with the digital measurement scale.

Devices must be assessed for external integrity before impact test can be conducted. The EPTS vest or pocket as supplied by the manufacturer is examined and material thickness and any method of padding documented

Calculation and Expression of Results

Visual Inspection of EPTS Structural Integrity
Supplied sample are visually examined for any pre-existing structural issues.

Visual Inspection of EPTS Features

Supplied sample are examined for any potentially injurious features. i.e. sharp edges, and protrusions. Any such features to be documented.

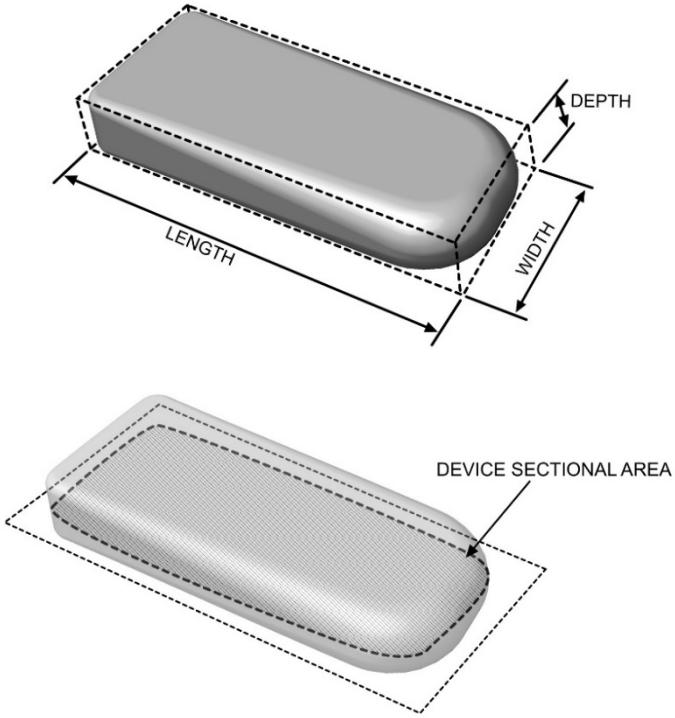
Device sectional area

The maximum planar sectional area of the sample is to be determined and reported.

Mass
Mass of the EPTS sample is measured and documented to +/- 0.01 g accuracy.

Inspection of Vest

Measurement and documentation of thickness of material and any padding within the vest/pocket as supplied.



3.2. EPTS Impact test

Principle

The EPTS device, placed upon a skin surrogate, is impacted with a flat faced drop hammer at set velocity and mass. Mean pressure values are obtained through the use of pressure sensitive film assessed using film analysis software. Visual and photographic inspection are used to determine physical damage to skin surrogate. Visual inspection to determine any external damage to EPTS device.

Apparatus
Description
Test apparatus shall comprise:

- Drop Hammer
- Skin Surrogate
- Surrogate and Device Location Rig.
- Attenuation Rubber Base
- EPTS Calibration Block
- EPTS Baseline Foam
- EPTS Baseline Pocket
- Pressure Sensitive Film
- Thermo Hygrometer
- Digital Camera

- Colour Flatbed Scanner
- Pressure Analysis Software

Drop Hammer
The drop hammer comprises a drop weight held in a guided rail system (total mass 2.25 +/- 0.1 kg) allowing the drop weight to fall in a guided linear free fall. The drop weight shall be cylindrical and flat faced, with diameter not less than 100 +/- 5 mm. The face of the drop hammer should be covered with a 14 +/- 0.25 mm thick attenuation layer of Silastic 3483 silicone. This should be regularly inspected for damage and replaced as needed. The drop hammer should have a drop velocity of at least 5.8 +/- 0.4 m/s. The drop hammer shall be positioned above a base that is either monolithic or monolithic table but shall have mass of at least 400 kg.

Skin Surrogate
A multilayer skin surrogate with separate material layers for epidermis/dermis and adipose. This is to be manufactured as outlined in section 2.3.2.

Surrogate and Device Location Rig
A location rig for retaining the surrogate and EPTS device in plane perpendicular to the impact direction. This must be able to locate and retain the surrogate and EPTS device without causing interference to the impact drop. The skin surrogate is clamped at the perimeter edge. The EPTS device is restrained in a fabric pouch clamped in rig. The rig is to be mounted upon an attenuation rubber base material to reduce hammer vibration at impact. Details are provided in APPENDIX A.

Attenuation Rubber Base
An attenuation rubber base is positioned between the surrogate rig and base. This is used to reduce hammer vibration at impact. The rubber base should have a shock absorption of 26.4% and vertical deformation of 2.5mm as testing with an Advanced Artificial Athlete that conforms to FprCEN/TS 16717 and a thickness of 17mm.

EPTS Calibration Block
A calibration block with overall dimensions of 63.00 +/-0.05 mm x 31.50 +/-0.05 mm x 16.00 +/-0.05 mm, and constant edge radii 2 mm. Block design is found in APPENDIX B. This is to be used in all device testing for verification of skin surrogate.

EPTS Baseline Foam
A baseline open cell polyurethane foam block of 12 mm thickness.

EPTS Baseline Pocket
A baseline polyester fabric pocket used to restrain the EPTS calibration block, and to be used in baseline test of EPTS device.

Pressure Sensitive Film
Pressure sensitive film is used to assess the pressure applied to the skin surrogate on impact. The film should have a sensitivity capable of measuring the maximum mean pressure thresholds as specified in this standard.

Thermo Hygrometer
A thermo hygrometer for measuring temperature and humidity of test environment.

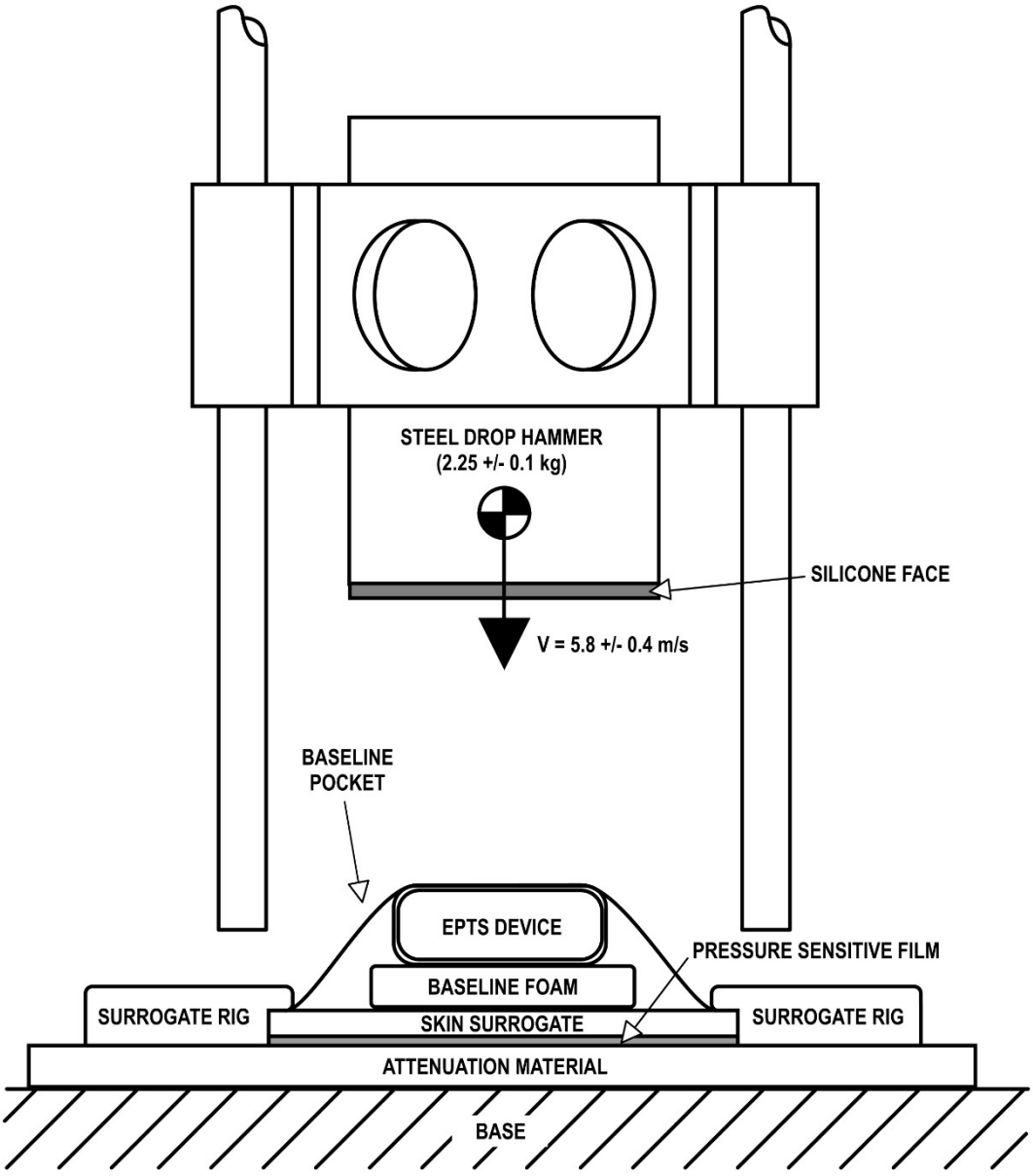
Digital Camera
A digital camera and tripod for systematic documentation of damage to skin surrogate and device.

Colour Flatbed Scanner

A colour flatbed scanner capable of six colour scanning and minimum 300 dpi resolution for scanning impacted pressure sensitive film samples.

Pressure Analysis Software
Pressure analysis software for determination of pressure values attained during impact.

Apparatus Arrangement



Technical Data
Test to be conducted at recommended temperature of 20°C~26°C. Test conditions must be monitored and recorded during all tests.

Procedure
The following procedure should be followed when conducting impact testing on EPTS devices. Calibration of skin surrogate, and experimental arrangement should be conducted prior to testing of EPTS sample batch. EPTS devices are tested with a baseline foam padding and pocket, and with the manufacturers vest as supplied.

1. **Calibration Test**. Assemble pressure sensitive film, ensuring the matte sides of the donor and receiver sheets are in contact. Position the pressure sensitive film, with the receiver sheet on the bottom, and skin surrogate sample within surrogate location rig, and clamp. Locate baseline foam sample on skin surrogate. Locate the EPTS calibration block within device location rig, measuring to ensure there is an equal distance between the block and all sides of the location rig. Secure using the baseline pocket. Impact calibration block with drop hammer at 5.8 +/- 0.4 m/s. Rebound impact is permitted but should be minimized if possible. Remove EPTS device and visually inspect the surface profile of post-impact surrogate surface. Photograph and document any damage found. Remove pressure sensitive film and place within a light resistant envelope. Repeat impact test twice more. After 30 mins, within 90 mins, use flatbed scanner to record impacted pressure sensitive film samples. Using pressure analysis software determine mean pressure of calibration block. If within specified range proceed to EPTS device test.

2. **EPTS Baseline Test** (Test Sample 1). Assemble pressure sensitive film, ensuring the matte sides of the donor and receiver sheets are in contact. Position the pressure sensitive film, with the receiver sheet on the bottom, and skin surrogate sample with surrogate location rig. Locate baseline foam sample on skin surrogate. Locate the EPTS device within device location rig, measuring to ensure there is an equal distance between the block and all sides of the location rig. Secure using the baseline pocket. Impact EPTS device with drop hammer at 5.8 +/- 0.4 m/s. Rebound impact is permitted but should be minimized if possible. Remove EPTS device and visually inspect the surface profile of post-impact surrogate surface. Remove pressure sensitive film and place within a light resistant envelope. Repeat impact twice more. After 30 mins, within 90 mins, use flatbed scanner to record impacted pressure sensitive film samples. Using pressure analysis software determine mean pressure values. Inspect and photographically record adipose layer of skin surrogate. Visually inspect and record any damage to EPTS device.

3. **EPTS Manufacturers Vest Test** (Test Samples 2,3,4,5). Assemble pressure sensitive film, ensuring the matte sides of the donor and receiver sheets are in contact. Position the pressure sensitive film, with the receiver sheet on the bottom, and skin surrogate sample with surrogate location rig. Locate the EPTS device within device location rig, measuring to ensure there is an equal distance between the block and all sides of the location rig. Secure using the manufacturers vest pocket. Impact EPTS device with drop hammer at 5.8 +/- 0.4 m/s. Rebound impact is permitted but should be minimized if possible. Remove EPTS device and visually inspect the surface profile of post-impact surrogate surface. Remove pressure sensitive film and place within a light resistant envelope. Repeat impact twice more for each individual EPTS device. After 30 mins, within 90 mins, use flatbed scanner to record impacted pressure sensitive film samples. Using pressure analysis software determine mean pressure values. Inspect and photographically record adipose layer of skin surrogate. Visually inspect and record any damage to EPTS device. Repeat test for each EPTS device in batch sample.

Calculation and Expression of Results

Mean Pressure

1. The receiver sheet of the pressure sensitive film samples are to be scanned at a minimum of 300 dpi using six colour scanning. The calibration colour scale as supplied with pressure sensitive film, should be scanned accordingly.
2. Pressure analysis software is calibrated using scanned calibration colour scale, temperature and humidity values as recorded during impact test. Individual mean pressure values for each sample are calculated in the software.
3. Report individual device and average total sample mean pressure values in MPa.

Inspection of Epidermis/Dermis Layer

1. The epidermis/dermis layer should be visually inspected post impact for any failure, i.e laceration or rupture. If this is present, photograph and document damage of impact surrogate Epidermis/Dermis layer surface.

Inspection of Adipose Layer

1. Inspect and photographically record adipose layer of skin surrogate. Document any signs of crush, cavitation onset, or full cavitation damage to layer.

Visual Inspection of EPTS Device

1. Visually inspect the EPTS device for structural compromise i.e. full thickness cracking of device shell, breakage, and other associated damage. Any failure should be photographed, documented and presented in the report.

4. Test Requirements

The following tables specify the requirements that must be met by EPTS devices.

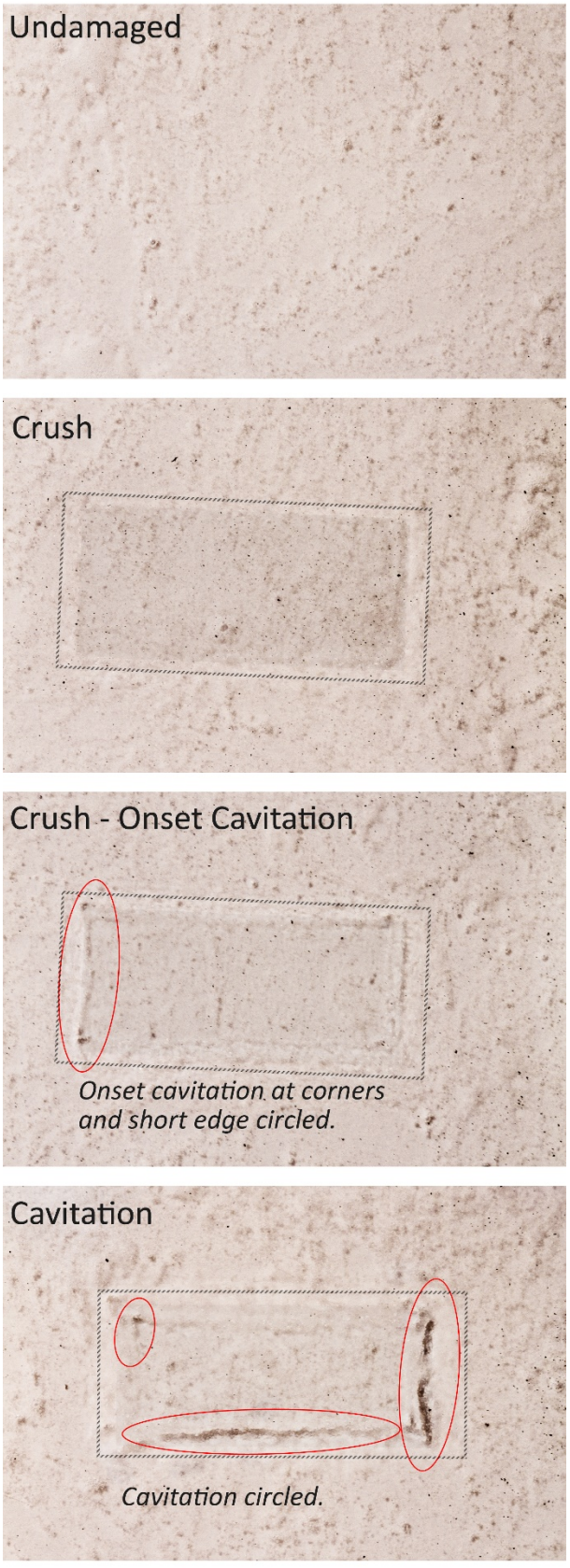
4.1. EPTS geometric assessment

	Test	Test sample	Specification	Test condition	Requirements
1	Visual Inspection of integrity suitable for test	1,2,3,4,5	Geometric	Laboratory	No signs of device structural compromise
2	Visual Inspection of structural features				-
3	Dimensions				-
4	Cross-sectional Area				-
5	Mass				-

4.2. EPTS Impact test

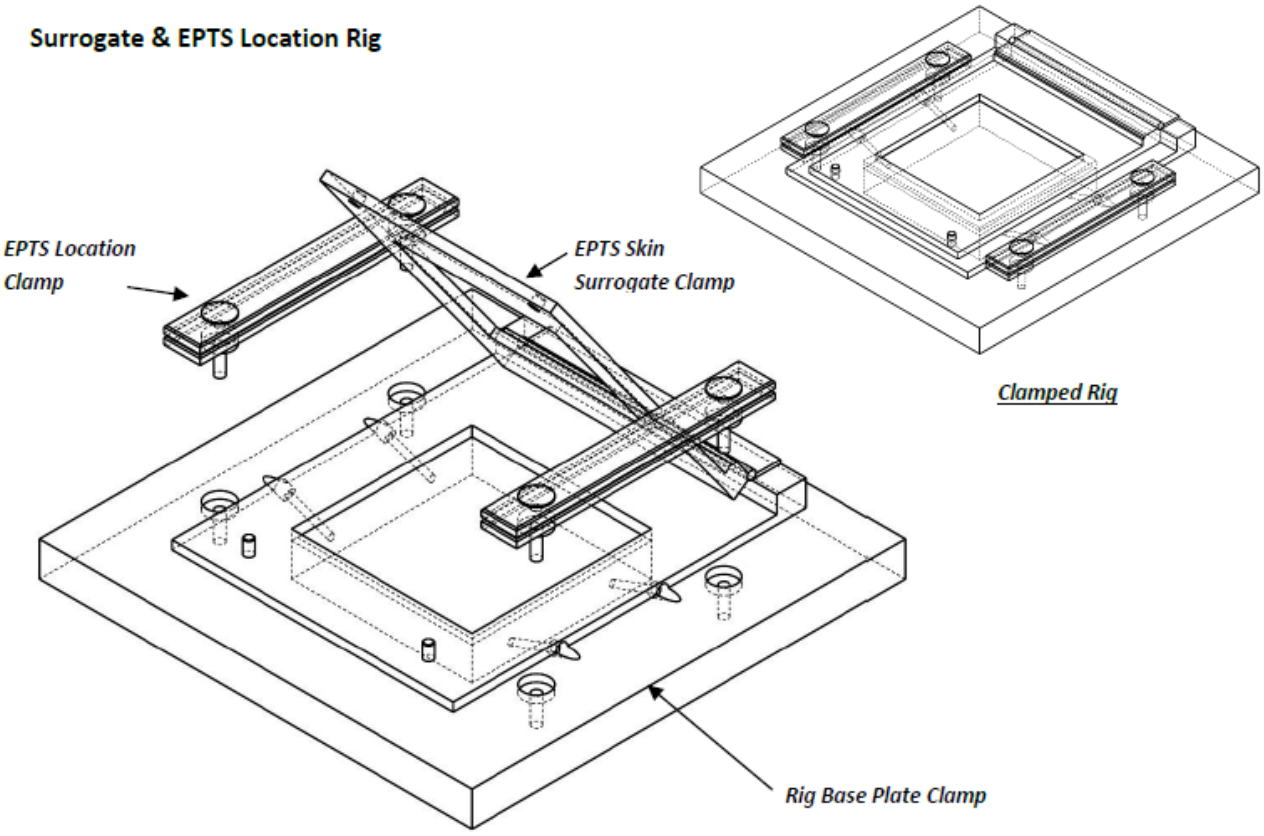
	Test Designation	Test	Test sample	Specification	Test condition	Impacts	Requirements
1	Calibration	Mean & Peak Pressure	Calibration Block	Impact	Laboratory	3	For calibration sample: Mean pressure = 1.25 +/- 0.1 MPa
2	EPTS Baseline	Mean & Peak Pressure	1	Impact	Laboratory	3	Results should be documented and presented in report, however these will not constitute a pass/fail.
3		Inspection of Epidermis /Dermis					
4		Inspection of Adipose					
5		Visual Inspection of EPTS Device					
6	EPTS Manufacturer Equipment as Supplied i.e. vest and padding	Mean Pressure	2,3,4,5	Impact	Laboratory	12	For total sample: Mean pressure < 3 MPa
7		Inspection of Epidermis/ Dermis					No external rupture or laceration
8		Inspection of Adipose					No signs of internal cavitation or cavitation onset
9		Visual Inspection of EPTS Device					No signs of device structural compromise

Note. Example of possible adipose layer damage. Region of impact indicated by dotted line.


Undamaged
Crush
Crush - Onset Cavitation
Onset cavitation at corners and short edge circled.
Cavitation
Cavitation circled.

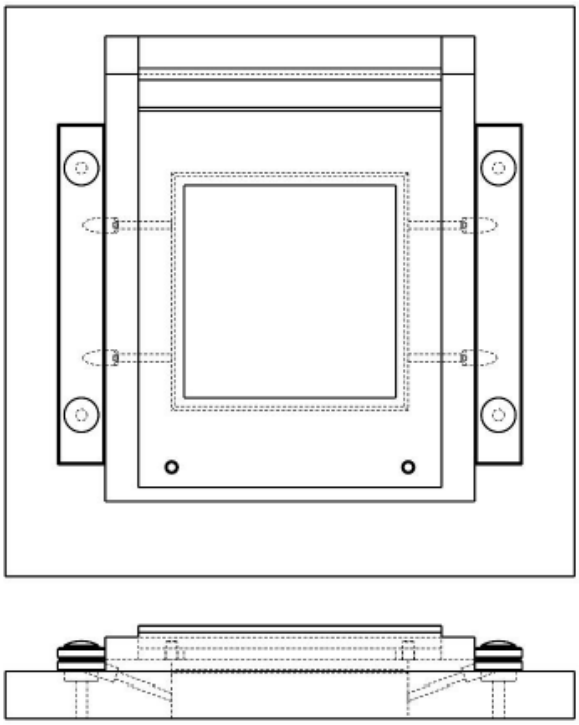
Appendix A

Surrogate & EPTS Location Rig

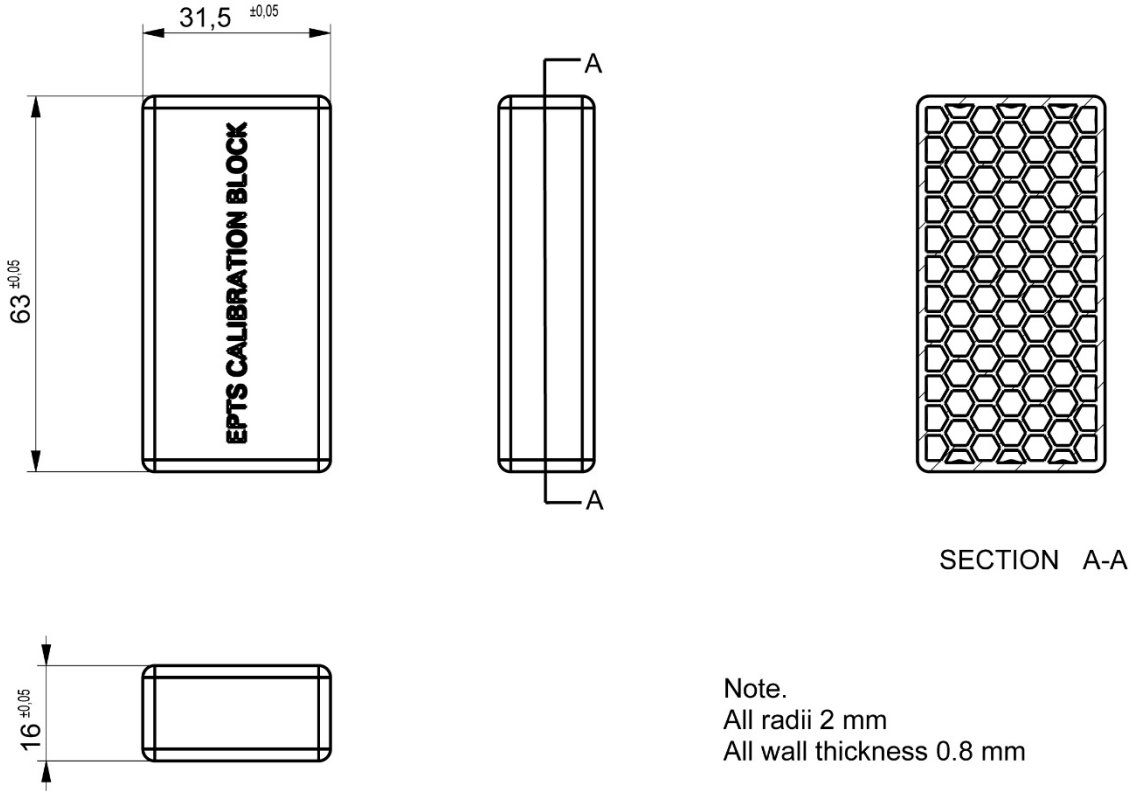


Clamped Rig

Open Rig



Appendix B



SECTION A-A

Note.
All radii 2 mm
All wall thickness 0.8 mm