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# Turf Playing Surface Testing with the Triax2015 E Missile

There is a need to provide a Test Method for testing Turf Playing Systems using the ASTM F355 E missile with the Triax2015 E. This test method is to be utilized on all synthetic turf and natural turf systems designed for American Football, Soccer, men's and women's Lacrosse and unlined fields used for recreational games such as the aforementioned. The Test Method will provide the description of the Triax2015 test device, manufactured they Alpha-Automation Inc.(Alpha), and the preparation required as per ASTM F355-16 as well as accessories, manufactured by Canadian Playground Advisory Inc. (CPA), that can be attached to the tripod system to ensure the appropriate drop pattern and drop height for the triangular drop configuration. Once the testing is performed the Triax2015 will provide g and HIC values along with velocity at the point of impact (drop height), angle, date and time of the test. There is also the requirement to test for the depth of the infill or entire system where there is an underlaying impact attenuating pad using the depth gauges manufactured by CPA.

The owner/operator or specifier (O/O) of the field will have certain responsibilities in the setting of parameters for the test and the use of the data collected. The O/O will set drop height for the testing, whether the drop pattern is triangular or three times from the same height to the same point (ASTM F3313-18, determine the test locations and the acceptable threshold for the g and HIC values. The discussion in the Annex provides the assessment process that an O/O might follow in the determination of some of these parameters.

The Test Methods for Impact Attenuation and Depth Measurement are summarized and presented in detail along with reporting requirements for the data collected. Fillable reporting forms and software are available from CPA.

# Test Method for Turf Fields with the Triax2015 E

## Introduction

This test method is for the impact testing of turf playing surfaces as found in the field in an as is condition using the Traix2015 E missile that conforms with all of the requirements of the most recent ASTM F355, procedure E.

Testing is to be performed in ambient conditions, but there shall be no rain during the performance of the testing and the testing is not to be performed in standing water, ice or snow. The Triax2015 is an electronic instrument and will not withstand exposure to moisture. Depth of infill with the analog depth gauges can be performed in most weather conditions.

## Information gathering prior to performing test

Prior to performance of the test it is recognized that the O/O or their designate and the organization or person performing the testing will set a scope of the testing to be performed and exchange certain information that is key to the successful performance of the test method allowing for delivery of the data in a useable fashion.

Information provided by the owner prior to commencement of the test;

- Name and contact information of the agency requesting the testing
- Name and location of field or other identifying information
- Manufacturer of the underlayment if there is one installed

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- Thickness of the underlayment in the installation contract
- Manufacturer/supplier of the Turf for either natural or synthetic
- Description of the natural turf system being installed, including soils and grass
- Description of the synthetic turf system at the time of installation
- Height of pile from backing to top of fiber at the time of installation
- Commercial product name for the turf system installed
- Infill type and depth to be installed at time of initial installation
- Drop pattern of the E missile, triangle pattern or 3 drops from a single height to a single point
- Drop height for the E missile for system at the time of installation
- Drop height for the E missile while field is in operation
- G not to exceed _______ at time of installation
- G not to exceed _______ during the life of field
- HIC not to exceed ________ at time of installation
- HIC not to exceed ________ during the life of the field
- ASTM F1936 requirement at time of installation Gmax < _____ ( if applicable)
- Dated of installation or ready for first use of the turf system
- List of locations to be tested on the field

## Preparation of the Triax2015 E Missile

ASTM F355 procedure E outlines in detail the testing device and Canadian Playground Advisory Inc. provides a detailed training package that includes preparation of the Triax2015 and the accessories, such as the depth gauge required in performing the test. A certificate of competency is provided at the completion of training and a reference to the training certificate shall be in the testing report and a copy of the certificate shall be made available to the agency requesting the testing upon request.

Test reporting software in the form of fillable forms as provided by CPA ensure comprehensive and consistent performance of the test and reporting. This is key in the comparison of field performance over the sport season and from year to year.

The testing agency shall ensure that their device is within the two year requirement for calibration of the accelerometer and the entire Triax2015. This calibration certificate shall be made available upon request to the agency requesting the testing.

The Triax2015, at the time of first purchase and each calibration, it provided with a reference pad, manufactured by EVERPLAY International Inc. This mat provides consistent impact values g from a drop height of 915mm (36") within the temperature range of 0°C (32°F) and 35°C (95°F). At the time calibration Alpha-Automation Inc. will provide a value for g and HIC for a set of three drops from 915mm to the surface and provide the average g value for the Triax2015 that is paired with the specific reference pad. The owner of the Triax2015 will establish a reference location on a smooth concrete floor with a minimum thickness of 100mm (4"). Within 24 hours prior to the performance of a test in the field the testing agency shall perform reference drops in a controlled setting. This shall consist of three drops on the reference pad from the 915mm drop height, from the same height to the same point at 1 minute intervals, and the average g value for the second and third drops shall be within 5% of the reference value established for the testing agency. The report shall confirm that the reference test prior to testing

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was performed and the result is within the 5% requirement. The impact test data, including the .trw file, shall be preserved by the testing agency and made available to the requesting agency upon request.


Triax2015 E missile and handheld and EVERPLAY reference mat

At the site to be tested the testing agency shall confirm the location of the field and describe and record a unique description of each end of the field and each side of the field. There shall be a record of the ambient conditions including weather conditions, ambient temperature (if during the test the intensity of the sun or cloud cover affect the ambient temperature this shall be noted), whether the field is wet or dry, frozen or not and any other descriptive comment that might influence the impact attenuation performance of the system.

The testing agency shall perform an inspection of the turf system and confirm that it is representative of the information collected from the owner. Should there be inconsistencies of infill depth, this will become obvious from depth measurements taken at each impact test location and any supplemental depth test locations.

The testing agency shall determine and record the locations to be tested for impact on the field and any additional locations for infill depth testing only.

When the triangular pattern is selected, the Triax2015 shall be assembled with the legs extended outwards to the maximum allowed by the machined leg fittings. The cable support fixtures, as manufactured by CPA, are attached to the tripod legs at the location and in the manner set out in the instructions from Canadian Playground Advisory Inc. Proper installation of the cable support fixtures ensures that the triangular drop pattern is consistent and the drop height for each of the three drops in the triangle are at the same drop height.


Cable support blocks

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The legs of the Triax2015 tripod have a rounded bottom and depending upon the configuration, infill materials and firmness of the turf system the rounded end might push into the turf system and affect the level of the triangular support block drop mechanism. If this is the case flat plates measuring at least 100mm x 100mm (4" x 4") are to be placed under the ends of the legs. Once the Tripod is stabilized a level shall be placed across the cable support fixtures on the tripod to ensure that all drops will from the same height above the turf being tested, with a 3% slope tolerance from block to block during testing. The velocity provided by the Triax2015 will confirm that the drop height from block to block does not exceed 2%.

Where the selection is to three drops from the same height to the same point, the settling of the legs is not as important as the cable is a pendulum ensuring the E missile drops in a consistent manner.

The Triax2015 is brought to each test location as determined by the O/O.

*Drop pattern option one (triangle)*

The tripod with test blocks is set up to perform the drops from the height stipulated by the O/O, by raising and lowering the suspending cable provided with the Triax2015 tripod system.

Make three consecutive drops of the missile, with no minimum time interval between drops, at each test location. The center of all three drops shall be within a 180mm (7") radius of the drop location and no closer than 160mm (6.3") to each other. Figure 8(a) shows a maximum allowable distance between drop points. Figure 8(b) shows a minimum allowable distance between drop points. Actual drop locations can fall within these two extremes.

When the series of three drops is completed and the g and HIC values are recorded the g and HIC value for that test location shall be the highest value for g or HIC. Where the variability between drops for g is greater than 5% or for HIC is greater than 10%, it shall be recorded and noted in the report.

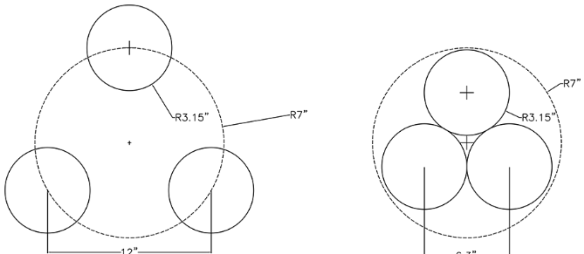

FIGURE 8(a) MAXIMUM

FIGURE 8(b) MINIMUM

*Drop pattern option 2 (three drops, same height to same point (similar to ASTM F3313))*

The Triax2015 with its supporting tripod is brought to the test location. The cable is raised and locked into position so that the distance from the bottom of the E missile to the turf is the drop height stipulated by the owner/operator prior to purchase. Three drops are performed from the same height to the same spot with a time interval of 1 minute ±30 seconds between drops. The height is not adjusted should the impact of the missile compress the turf or disperse the infill. The g and HIC values under this method shall be the average of the second and third drops for each value.

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Three drops from the same height to the same point with measuring rod

Canadian Playground Advisory Inc. provides licensed reports for the collection and reporting of data for the drop tests in either drop pattern and depth testing.

For each drop the Triax2015 will provide a display of the acceleration time curve. This curve shall be displayed and checked to verify the proper curve shapes as described in the equipment manufacturer's manual. If the displayed curve is verified, the drop testing is to continue. Where there are signal abnormalities, the results are to be discarded and if the abnormality continues the testing is to discontinue. Each graph shall be retained and made available on request.
If the testing at any location cannot be completed due to an anomaly, once the anomaly is corrected, the test shall resume at another location within the 910mm (36") tolerance and start over. Previous drops within the test location are to be ignored.

For each drop of the missile record the value for g, HIC, angle and velocity. The angle reported shall not exceed 20$^{o}$.
For each drop of the missile it is the option of the O/O to request that the critical time, used in the determination of HIC, is recorded.
The date and time of each drop is to be recorded.

Each system will have its depth of infill or infill with underlayment measured depending upon the system type. Where a system encompasses more than one type of system, an appropriate depth measurement for each system is taken. Depth testing is as follows;

- If testing an infill turf system, record infill depth data for each test location. (This data can be collected prior to or during impact testing. If collected during testing, it shall be recorded prior to the actual drop test.)
- Infill depth shall be measured using the CPA three prong infill depth gauge capable of measuring to the nearest 1mm ($^{1}/_{32}$"). Make three measurements at each test location, within a 610mm (24") diameter circle of the footprint of the impact test apparatus; calculate and report the average.
- If testing a field with an energy absorbing material under the backing of the turf system, the testing agency shall determine and record the depth of the underlying system to the extent it can be determined. (This data can be collected prior to or during testing and at the same time as the measuring of the infill depth.)

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# System and Infill Depth Testing of Synthetic Turf Systems

Synthetic Turf infill performs a number of functions that affect the performance of the turf as installed and the relationship or interface between the turf system and athlete. Infill has evolved from the initial sand and then tire rubber and then to sand/rubber to many other materials, both natural and synthetic. Some choices are made for concerns for the health of the field user and exposure to potential or perceived toxins or high field temperature.

Important aspects of infill are the contribution to impact attenuation and the control of rotational and lateral friction. Most infill materials move when in contact with the athlete or user and this ability to move and the depth of the infill are key elements to impact attenuation. As a result, injury prevention will be highly dependent on maintaining the infill depth at the height originally intended. Depth of infill also contributes to the delicate balance for the athlete changing direction of travel during play from slipping and sliding from an excess of infill and the “locking” of the shoe/surface interface from the higher friction due to lack of infill. Measuring the infill depth at the impact test locations allows the O/O to determine the relationship between infill depth and impact attenuation. This information can be used when additional locations of the field are tested for depth only and that data is compared to the depth measurements for impact testing. Where sand is a component of the infill, there is a tendency to separate, sink and compact and the person performing the test will have to make sure they are testing to the bottom of the infill and not just the top of the sand. The CPA depth gauges are designed to penetrate the sand layer.

There are increasingly more turf systems being installed with an impact attenuating material under the synthetic turf. These are made from a number of materials ranging from manufactured at side polyurethane bound rubber to systems to manufactured sheets that are installed on a prepared base and then the turf system, including infill is installed to a specified height. The underlayment, when a manufactured sheet is consistent in depth, but over years of use could compress, shrink or otherwise become displaced. Measuring the entire depth of the system including infill and underlayment is a requirement of ASTM F1936 and a good practice. To accomplish a test of the full depth, the depth gauge will have to be longer than 50mm (2”) and strong enough to penetrate any compressed sand, the backing of the turf, penetrate the underlayment and stop on the prepared base. Since the CPA large three prong analog and digital depth gauges are designed to penetrate running track and poured in place playground systems, they are ideally suited to this task.


The Canadian Playground Advisory Inc. Depth Testing Family

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Another factor that can affect the measurement of infill depth is the structure of the actual turf, through the density of fibers, inclusion of thatch and any other technique that is used to keep the turf vertical and rigid over time. The CPA depth gauges rely on the penetration of the 3 prongs into the turf and infill and through to the underlayment where applicable, while the plate or foot is in contact with the turf. The outer barrel is then raised with the 3 prongs remaining in place and the outer barrel is then brought down onto the turf exerting 13 kPa (2psi) onto the turf with the base plate. Depending upon the turf system the base plate should come to rest on the top of the infill, but should this not occur and the test be performed consistently, the readings should be repeatable and reproducible.

**Depth Test Procedure**

Prepare the depth gauge by placing on a smooth and rigid surface with the base plate in full contact with the surface and the three prongs also touching the surface. For the Analog Depth Gauges ensure that the scales on the side of the inner barrel read zero. For the Digital Depth Gauge press the zero button and ensure that the analog scales also read zero.

At each test location, three locations around the impact site for impact testing and one location for all other test locations, place the depth gauge onto the turf surface. The operator will hold the base plate in place, by hand with the small depth gauge or the operator's foot for the large gauges. It is important that the stabilizing does not disturb or compress the infill.

With the base plate fully in contact with the turf system, apply consistent pressure to the center rod only causing the 3 prongs to descent into the infill. If resistance is met that could be compacted sand the operator can apply additional pressure to the center rod and allow the gauge to remain against the turf backing or break through the sand to the turf backing. If compacted sand is suspected the operator can use a flat head screw driver to explore the extent of the compaction to the sand without damaging the depth gauge prongs.

Should the turf system have an energy absorbing underlayment, the operator shall apply pressure to the center rod to penetrate the turf backing and enter the underlayment, and penetrate to the granular or hard surfacing prepared base.

Once the 3 prongs of the depth gauge have come to the full depth of the system or infill, as appropriate, the operator shall read and record the depth as provided on the scale attached to the inner rod. For the digital depth gauge the reading is made from the digital readout.

Anaglog reading on short and tall depth gauges

Digital reading on Digital Gauge

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Once the reading is taken the operator once again places a hand or foot on to the base plate of the depth gauge and then retracts the 3 prongs by pulling on and raising the centre rod until the exposed rods are fully retracted.

The device is taken to the next location and procedure repeated.

# Annexes

# Owner/Operator considerations in the use of the Test Method and Determining a Performance Specification.

## Discussion

An athletic playing surface is to be invisible to the performance of the athlete and to the extent possible prevent injuries at an acceptable injury severity. Although injuries are inevitable, the frequency and severity of injuries is a matter of testing, risk assessment, athletic ability and surface performance. For an athlete to perform at their best, they must not fear or anticipate the occurrence of an injury or they will not perform at their best and will likely be replaced by another athlete. It is therefore the responsibility of the designer, manufacturer, builder and maintainer of the field to be part of the team working to provide injury prevention at a tolerable level. The predominant injuries related to player interaction with turf are concussion through upper body and head to turf impacts and lower extremity resulting from lack of firmness, stability and/or traction of the interface of the athlete's foot and the turf.

Impact attenuation, hardness, and traction have been a concern of athletes for decades. In the time before synthetic turf these properties where provided by the soil, root zone and blades of grass to extent they were present. Improvements in natural turf systems for elite athletics raised the athlete specific performance demanded; however the need to provide surfaces for indoor venues and more intense use gave rise to the synthetic turf systems. The broad variety of athletic turf systems has brought the need for testing in a repeatable, reproducible and accurate manner.

Impact attenuation for synthetic surfaces has been a concern from the beginning. It is for this reason the systems would have been tested for impact attenuation with the ASTM F355 A missile dropped from 610mm (2') height. This test became formalized in 1998 with ASTM F1936, *Standard Specification for Impact Attenuation of Turf Playing Systems as Measured in the Field*, with the failure being when the result was 200g or greater. This value was assumed to be equivalent to the 200 g that the US CPSC published as the threshold for life-threatening determined by the ANSI C missile and first published in the Consumer Product Safety Commission 1981 *Handbook for Public Playground Safety*. The 200g threshold was taken from the US automotive industry testing. A challenge to the 200g threshold for ASTM F1936 in 2010 initiated a questioning of what was being tested and how. The proposal was to lower the g value threshold as determined in ASTM F1936 to 160. The discussion of changing the impact value triggered a number of questions.

If the head injury was the concern; was the A missile the appropriate device?

> Research has shown that the E missile is more representative of the impact to the head as measured by the automotive Hybrid III headform. The E missile provides the same values as the Hybrid III up to 140g and for values between 140g and 200g, the E missile is slightly more conservative than the Hybrid III and is therefore an appropriate surrogate.
>
> Research has also shown that the A missile is not appropriate in representing an impact to the head nor a predictor of the head injury that would result.

If the current drop height for the A missile is 2', what should a new drop height be for the E missile?

> The drop height of the missile reflects the velocity of the impacting missile and when coupled with the mass of the missile reflects the energy of the impact. The A missile has a mass of 9.1kg (20lbs), while the E missile has a mass of 4.6kg (10.1lbs). The A missile dropped from 610mm (2') has a kinetic energy of 54.4 Joules. The E missile dropped from the same 610mm (2') would have a kinetic energy of 27.5 joules. To have the same kinetic energy with the E missile as with the 610mm (2') drop for the A missile, the drop height for the E missile would have to be at 1210mm (4').
>
> The drop height has in the case of playground testing been determined by considering the height from which a child falls from on a playground. For this reason ASTM F1487 (Playground Standard) has fall heights for different types of play structures. The ASTM F1292-17 and now ASTM F3313-18 Playground Surfacing test standard, in the field test allows the O/O to determine the drop height prior to purchase provided it is greater than the equipment fall height. A similar approached could be taken in the case of Turf testing with "the drop height being established by the O/O prior to purchase and that drop height cannot be less than that in ASTM F1936" (2').
>
> An O/O might consider that an athlete falls from a standing position or lower depending upon body orientation at the time of the fall. The athlete will rotate through to the impact with the ground. For an 1830mm (6') person falling over through an arc the equivalent free height of fall would be 1300mm (4.3'). This is one way of determining the drop height for the E missile. Where the field is being used primarily by children a similar calculation could be performed using the lower height.
>
> Other factors might have a roll in the selection of the drop height for the E missile. One of these might be that the sport being played on the turf playing system may require the wearing of a helmet. The helmet might be considered a mitigating factor in the prevention of head injury and the O/O might develop a factor to decrease the fall height when a helmet is worn.

The A missile has a flat surface and the E missile has a hemispherical surface and this can have an effect on the outcome of the test for various surface systems?

> The difference in shape between the A missile, flat with a 129mm diameter and the E missile, round with a 160mm diameter has been demonstrated as being aggressive toward synthetic systems with infill and natural turf systems. Obviously the flat missile does not penetrate the surface, spreading the load across the impact area, while the rounded shape of the E missile will have a tendency to penetrate or "dig" a hole in loose fill materials or compress natural turf, soil and root zones.

Since the role of a test method is accuracy, repeatability and reproducibility and the goal of this test method is to test all athletic turf playing surfaces, it is reasonable to test all systems in the same manner. For this reason the drop testing must be in a manner that is not biased against a particular system. It is also reasonable to assume that there will not be an impact to the exact same spot on the field and with the amount of foot traffic by players, this would change, redistribute, compress and have other effects on the system. Therefore a pattern of three drop tests from the same height that do not impact the same spot would be reasonable.

Currently ASTM F1936 performs 3 drops from the same height to the same point and the value for each test location is determined by averaging drops 2 and 3. How would the three drops be evaluated with the E missile if there is a triangular pattern?

The owner/operator must stipulate the pattern, triangle or three drops to the same location prior to purchase.

The argument has been made that three repeated impacts to the same spot does not represent the impacts by athletes to the playing surfaces, therefore a triangular pattern has been suggested. Impacting three times to the same location will be more aggressive for natural turf and infill only synthetic turf systems.

It has also been suggested that turf systems are uniform; however the consensus is that there is a need to perform 3 drops in close approximation to each other suggesting that there may well be variation within that space. One would hope that within the test space the impact and depth of infill, where there is infill, results would be consistent, but if they are not it is not reasonable to take either an average or the lowest value for g and HIC. The intent of any test, beyond accuracy, repeatability and reproducibility, is injury prevention and taking the highest value for g and the highest value for HIC from any of the three drops would be conservative and provide a greater degree of injury prevention. Measuring the depth of infill at the impact test locations will potentially explain some the variation in impact values as a result of variability in depths as well as allow for measurement of depths throughout the field and related the values to approximate impact values.

The ASTM F1292 suggests that the g and HIC values can be used to predict injury severity as it is related to values of g and HIC. How is this done?

Impact injuries have long been the concern of the automotive industry. The Abbreviated Injury Scale (AIS) was produced by the Association for Advancement of Automotive Medicine in 1971 to rank severity of injury and further define a specific injury to the human body. The AIS ranks injury severity in seven categories as indicated here.

| AIS | SEVERITY | TYPE OF INJURY |
|---|---|---|
| 0 | None | None |
| 1 | Minor | Superficial Injury |
| 2 | Moderate | Recoverable |
| 3 | Serious | Possibly recoverable |
| 4 | Severe | Not fully recoverable without care |
| 5 | Critical | Not fully recoverable with care |
| 6 | Fatal | Unsurvivable |

TABLE I
DEFINITION OF THE ABBREVIATED INJURY SCALE.

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An AIS score of 4 or Severe has also been described as Life-Threatening with Survival Probable

The AIS scale has been used to map injury severity based on values for g and HIC. These mappings can be used to determine the tolerable threshold for g and HIC an O/O is prepared accept for their athletes.

Currently ASTM F1936 determines and reports a value for g, whereas the E missile in playgrounds determines and reports both g and HIC values; which value should be used in the case of testing the turf with an E missile?

The A missile by virtue of not being shaped like a head and not being intended to simulate a head is not an appropriate device for the reporting of an HIC value that is useable in the context of head injury. It must be remembered that HIC is a calculation based on the impact pulse including g and duration of the impact. Therefore HIC can be calculated for any impact, but it is only to be used where appropriate. HIC is appropriate for the E missile and therefore is used in the evaluation of turf systems when tested with the Triax2015 E missile.

The Triax2015 E missile has long been used in the testing of playground surfaces, wall padding, pole vault mats, rugby fields and other playing surface with the inclusion of HIC. The new ASTM F3146, *Standard Test Method for Impact Attenuation of Turf Playing Systems Designated for Rugby*, utilizes only the HIC value from the ASTM F355 E missile. HIC is one of three predictors of Head Injury and risk curves known a Prasad/Mertz AIS curves have been used for many years to consider the injury risk at various values for HIC. The second and most traditional predictor of head injury is linear acceleration expressed in values of g or gravity, with the third predictor being rotational acceleration. Rotational acceleration is difficult to measure with current instrumentation, but the linear acceleration is a good predictor of rotational acceleration. As linear acceleration increases so does rotational acceleration, leaving the HIC and g values as valid.

As mentioned above the AIS has been used to map severity of injury in relation to g and HIC values as they are related to Head Injury. You will notice these are curves and there is an overlap of curves and a single value for g or HIC will intersect with more than one curve. This reflects that not all impacts result in the same severity of injury. There are many factors such as body structure, level of fitness, orientation of the body during the injury, personal protective equipment, etc. that will affect the final injury outcome. The first chart is the AIS plotted against values of g.

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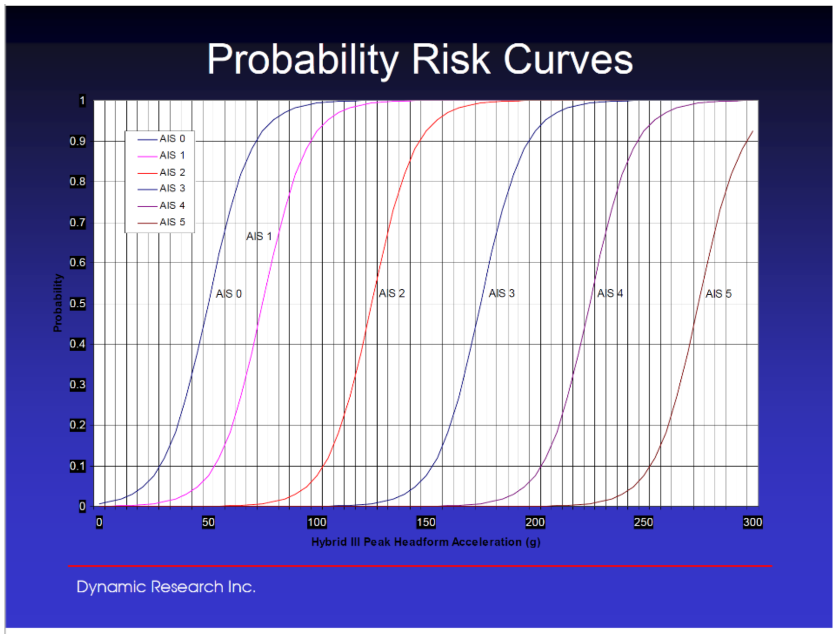
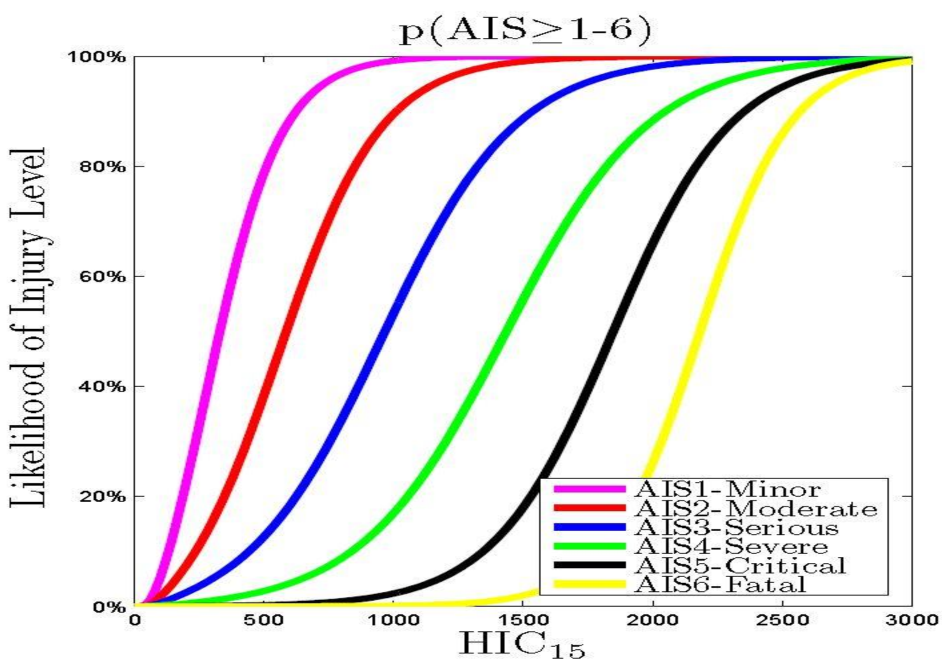



The second chart is the AIS plotted against value of HIC




Each graph shows, on the vertical axis, the risk of an injury and the horizontal axis shows the magnitude of g or HIC value. The way these curves can be used in establishing the g or HIC values or the risk of injury that are acceptable for a field by an O/O is to find the g or HIC value across the bottom of the graph and drawing a vertical line. Where the vertical line crosses and AIS curve that is the selected injury threshold,

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a horizontal line can be drawn to the left to determine the % risk of occurrence of that severity of head injury.

As a guide the current threshold for g in ASTM F1292 for playgrounds is 200g and the threshold for HIC in playgrounds is 1000. The European Playground Surfacing Standard has summarized the AIS for 1000 HIC for head injury as 5% risk of AIS >5, 18% risk of AIS>4, 55% risk of AIS>3, 89% risk of AIS>2 and 99.5% risk of AIS>1.

Alternatively the US National Highway Transportation Safety Administration (NHTSA) has adopted the following HIC values for head impacts in automobiles;

| Dummy type | Large Male | Mid-sized male | Small sized female | 6 year old child | 3 year old child | 1 year old infant |
|---|---|---|---|---|---|---|
| HIC Limit | 700 | 700 | 700 | 700 | 570 | 390 |

World Rugby in Regulation 22 requires that the surface not have an HIC exceeding 1000 at a drop height of 1300mm ((4.3').

Using the AIS in evaluating a selection for a g value is not as well defined as the automotive data is for HIC. The curves should provide guidance; however, the study of NFL concussions in published in 2003 indicated that 80g is a 50% risk of a concussion and concussions were occurring at 98g ±28g. Another study in 2011 by Rowson and Duma using the HITS football helmet data indicates that concussions were occurring at 105g ±27g.

It must be remembered that not all impacts result in a head injury and not every player is exposed to the same threat of an impact with the surface. Each O/O will have to assess their tolerance to injury and establish the threshold value for g and HIC for a given drop height.

ASTM F1936 currently provides for test locations; should these be used with the test method?

ASTM F1936 was originally established to evaluate fields exclusively as they were intended to be used during the playing of a specific sport. As a result 6 test locations were established for each sport configuration that should indicate high traffic during a game and therefore reflect locations that should reflect poor or less than optimal performance. Later two locations, one just inside and one at the back of the endzones was added along with a random location within the field of play and a random location outside the field of play, but anticipated to have player activity when a play goes out of bounds. Other than the two random locations, these are prescribed and the testing must take place within a 910mm (36") radius of the predetermined point. This does not reflect how fields actually are used.

Using the locations expressed in ASTM F1636 would be a starting point for any O/O. Another consideration would be to supplement these locations based on the actual use of the field. During practice certain areas will be subject to greater use than others and these should be added to the locations being tested.

ASTM F1936 requires the determination of the depth of infill of a turf system with infill; is this also a requirement of this test method?

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Impact attenuation is determined by a number of factors, with depth of infill being one. Infill is also subject to disruption during play and environmental factors. A change in the depth of the infill will likely result in a change in the value for g and HIC. It also might change the values for firmness, stability and traction as measure with other devices that would indicate other risk of injury to lower extremities. As a result it is a requirement of this test method that the depth of the infill at three location around the test location be taken with a three-prong depth gauges, as manufactured by CPA.

Since depth of infill has a significant influence on the performance of the field, it is recommended that infill depth is measured at least once a month and more frequently, depending upon intensity of use. The O/O will have the depth of infill tested with a three prong depth gauge at the locations where the impact testing with the Triax2015 has been performed and compared for consistency. Other areas of the field could also have their depth of infill measured to ensure they are within an acceptable depth range related to the impact testing.

**Report** A licensed report format is offered by Canadian Playground Advisory Inc. capturing the data that is required in the above procedures.