VKF AEAI

Vereinigung Kantonaler Feuerversicherungen
Association des établissements cantonaux d’assurance incendie

SWISS HAIL IMPACT PROTECTION REGISTER (HSR)

CFIA Test Specification No. 00a
General Part A

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Version 1.03

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0 General part A

0.1 General

The hail impact resistance test specifications form the basis for uniform, product-neutral testing and classification of building components vis-a-vis their hail impact resistance. These specifications include the generally valid guidelines for the execution of a hail impact resistance test (Part A), and mandatory instructions for documenting the test set-up and the results achieved (Part B), as well as supplementary specifications relevant to specific building components.
The standard SIA 261/1 (2003), Art. 6.2.4 refers to the Swiss Hail Register of the CFIA. The Swiss Hail Register publishes all measured hail impact resistance classes, as achieved by hail impact resistance tests for functions required in the component-specific test specifications. The Swiss Hail Register of the CFIA should make it easier for users to select a product that has been tested and classified.

Managed by the Cantonal Fire Insurance Association CFIA, the Austrian Center for Natural Hazard Prevention and the German Insurance Association GDV have collaborated in establishing the test protocols of the hail register. Test results are assessed and evaluated by a three country joint working group.

This version 1.03 replaces the version 1.02 from February 1, 2014.

0.2 Hail impact resistance (HR)

0.2.1 General

Natural hailstones take on many different shapes. For assessing the effects of natural hail on a building component, a spherical hailstone is assumed.

For the determination of the physical properties in nature and in the laboratory, the following correlations are used.

Calculation of kinetic energy (without wind influence):

$$E_H = \frac{m_H \cdot v_A^2}{2} \qquad [1]$$

E_H: Energy of hailstone [J]
m_H: Mass of hailstone [kg]
v_A: Speed on impact [m/s]

Calculation of the mass of the hailstone:

$$m_H = V_H \cdot \rho_{Eis} = \frac{4 \cdot \pi \cdot \left(\frac{d_H}{2}\right)^3}{3} \cdot \rho_{Eis} \qquad [2]$$

m_H: Mass of hailstone [kg]
V_H: Volume of hailstone [m^3]
ρ_{ice}: Ice density, 870 [kg/m^3]
d_H: Diameter of hailstone [m]

The speed on impact according to SIA 261/1 (referred to as "velocity of free fall" in SIA 261/1) is calculated from the diameter of the hailstone, density of the ice and density of the air, gravitational acceleration, and the air drag coefficient:

Calculation of the speed on impact:

$$v_{max} = \sqrt{\frac{4 \cdot \rho_{Eis} \cdot d_H \cdot g}{3 \cdot \rho_{Luft} \cdot c_w}} \qquad [3]$$

v_A: Speed on impact [m/s]
ρ_{ice}: Ice density [kg/m^3]
ρ_{air}: Air density [kg/m^3]
d_H: Diameter of hailstone [m]
g: Gravitational acceleration, 9.81 [m/s^2]
c_w: Air drag coefficient [unit less]

0.2.2 Hail impact resistance class (HR)

- The definition of a hail impact resistance class is based on the diameter of a hailstone:
- Hail impact resistance class 1 (HR 1) is defined by the kinetic energy on the impact of a hailstone with a 10 mm diameter
- Hail impact resistance class 2 (HR 2) is defined by the kinetic energy on the impact of a hailstone with a 20 mm diameter
- Hail impact resistance class 3 (HR 3) is defined by the kinetic energy on the impact of a hailstone with a 30 mm diameter
- Hail impact resistance class 4 (HR 4) is defined by the kinetic energy on the impact of a hailstone with a 40 mm diameter
- Hail impact resistance class 5 (HR 5) is defined by the kinetic energy on the impact of a hailstone with a 50 mm diameter

A tested product is assigned to the hail resistance class in which it was evaluated as undamaged. Example: A product with a hail impact resistance class HR 3 remained undamaged by the impact of a 30 mm ice ball.

For the above-described hailstone diameters of 10 to 50 mm, the class levels (kinetic energy) as well as the hailstone masses and velocities are derived according to Equations [1], [2], and [3] (given above). The following values are assumed for each hailstone diameter:

ρ_{Ice} = *870 [kg/m^3]*
ρ_{Air} = *1.2 [kg/m^3]*
c_w = *0.50 [unit less], slightly rough sphere*

0.2.3 Laboratory values

For hail resistance tests, projectiles (spheres and special projectiles) made of optically clear ice are used. They are produced by various procedures. The quality of the ice must be periodically certified by round robin tests conducted by the test institutes.

The specified values for laboratory tests for mass and kinetic energy are listed in the following table.

Class	Nominal Diameter	G_{min} Minimum Mass	G_{max} Maximale Mass	v_R Reference Speed	Min. Energy Class Level E_{min}	Max. Energy Class Lvel E_{max}
	[mm]	[g]	[g]	[m/s]	[J]	[J]
HW 1	10	0.43	0.51	13.77	**≥ 0.04**	**≤ 0.09**
HW 2	20	3.46	4.04	19.48	**≥ 0.69**	**≤ 1.0**
HW 3	30	11.68	13.65	23.85	**≥ 3.5**	**≤ 4.4**
HW 4	40	27.70	32.35	27.54	**≥ 11.1**	**≤ 13.2**
HW 5	50	54.09	63.18	30.79	**≥ 27.0**	**≤ 31.5**

Tabelle 1 Specified values for laboratory tests

For hail resistance tests, the following main conditions must be maintained based on the values given in Table 1:

- For a valid shot, the projectile mass must be between Gmin and Gmax according to Table 1.
- The speed of the projectile is not restricted. The value for projectile speed in Table 1 is a guideline. The speed shall be selected by the test institute - relative to the measured mass - so that the kinetic energy lies above the minimum class level, Emin, and below the maximum class level, Emax.
- For a valid shot, the measured kinetic energy at impact must meet the minimum class level, Emin.
- Up to the maximum class level Emax, any shot taken is valid, regardless of whether or not the specimen is damaged. If the Emax level is exceeded and the test specimen remains undamaged, the shot is taken as valid. If the Emax level is exceeded and the test specimen is damaged, the shot is taken as invalid and the result will not be valued as damaged.

Tests with Teton projectiles must conform to the values given in Table 2 (Appendix B).

Projectiles with diameters greater than 50 mm must conform to the values given in Table 1 mentioned above. The values for 60, 70, and 80 mm are given in Appendix B (Table 3).

Impact energies according to European standards must also conform to the values given in Table 1. Intermediate values for projectile sizes 25 mm, 35 mm, 45 mm, 55 mm, 65 mm, and 75 mm are listed in Appendix B (Table 4).

0.2.4 Classification

The results are recorded in the test report and forwarded to the CFIA by the manufacturer. The building component functions and damage criteria for the individual components are defined in the component-specific test specifications. Classification varies according to the building component function and to the appearance of the component.

The final classification of the hail impact resistance, certified in the CFIA document, is made by the expert body of the CFIA commission for registration in the natural hazards register (FER).

0.3 Definition of damage

0.3.1 General

Building components often have to fulfil several functions (e.g. watertightness, appearance, mechanical performance). The definition of the occurrence of damage can also be just as varied. The individual functions of building components can be affected by quite different mechanical effects. When a building component is regarded as damaged has to be specified for each individual component function. This threshold is specified with the damage criterion.

0.3.2 Building component function

The building component fulfils one or more functions. The energy of the hail resistance class must be determined for each function whenever the test specimen is regarded as damaged. The following building component functions are addressed in the test specifications:

Watertightness:	The watertightness of a building component is addressed at two levels. The building component protects fully or partly the subjacent construction against water penetration. Or, the watertightness is limited to the building component and the subjacent construction is not protected. Furthermore cracks that do not penetrate through the component can lead to intermediate-term damage. Examples: The plaster on an external insulation EIFS protects fully the subjacent thermal insulation against water penetration/leaks. A roofing tile itself has to be watertight (impermeable); however, the subjacent roof construction is not fully protected from water penetration. Elongation over the limits of a polymeric component is also associated with the watertightness function (weakening of the material and consequently future leaking).
Light transmission:	The light transmission of a building component is associated with the physical transparency (transmission) of light and describes the capacity of how well an object behind the component is visible. Example: Window glass has a high light transparency and an object behind it is highly visible.
Light screening:	The light screening of a building component is associated with the protection against light radiation and represents the inverse of light transparency. Example: Closed roller blinds have a high light screening capability. These building components are used for light screening.
Mechanical performance:	The mechanical performance of a building component may be different depending of its intended use. This building component function applies to all building components having a physical-mechanical function. Example: Pool covers must be able to be rolled up and unrolled. Also

	the attachments of façade glass shall have no cracks of delaminations. For a photovoltaic module, the building component function associated with mechanical performance is considered failed if the cover plate is damaged, i.e., the glass is fractured.
Appearance:	The appearance of a building component describes the aesthetics. It has no relevant effects on the functionality of the building component in the case of damage. Example: Sheet metal components on a façade or roof may have indents, but are still watertight.

To keep testing costs to a minimum, the test specifications are limited to these five most important building component functions. Other functions, such as self-cleaning and light reflection, for example, are deliberately not addressed in these test specifications. The hail impact resistance test must include all the component functions listed in the component-specific test specifications.

In a CFIA certificate, only the building component function “appearance” and the term “functionality” are listed. Thus, the term functionality encompasses the building component functions “watertightness,” “light transparency,” “light screening,” and “mechanical performance.”

0.3.3 Damage criterion

The boundary between an undamaged and damaged building component is defined using the damage criterion. The damage criterion defines the threshold at which, if it is reached or exceeded, the building component function can no longer be fulfilled, and the component is considered damaged in relation to this function. For each component function defined in the component-specific test specifications, the test report must document whether the component is considered undamaged or damaged in regard to the damage criterion.

0.3.4 Measurement method

The measurement method describes how the building component function is to be tested. If the building component fulfils a number of functions, then a correspondingly higher number of measurement methods are to be applied.

0.4 General test specifications

0.4.1 Ageing

The test specifications are applicable both to the testing of new products and to the testing of older materials that have already been incorporated into a building. Generally, in the hail register only results of tests on new products are listed. In the case of products that are subjected to accelerated ageing (in particular plastics and components which include plastic), there is a note in the certificate of the Swiss Hail Impact Protection Register (HR).

0.4.2 Test principle

The test simulates the effects of natural hail impact on building components by firing at them prepared ice projectiles under laboratory conditions.

0.4.3 Test apparatus

The test takes place in the laboratory. The test apparatus accelerates the projectile to the required speed and measures it. The projectile trajectory can be selected as desired (horizontal, vertical, or inclined); however, the angle of impact defined in the component-specific test specifications must be complied with. The target area is aimed at and the results of the impact are inspected. The test specimen is fixed on the support frame according to the component-specific test specifications (Figures 1 & 2).

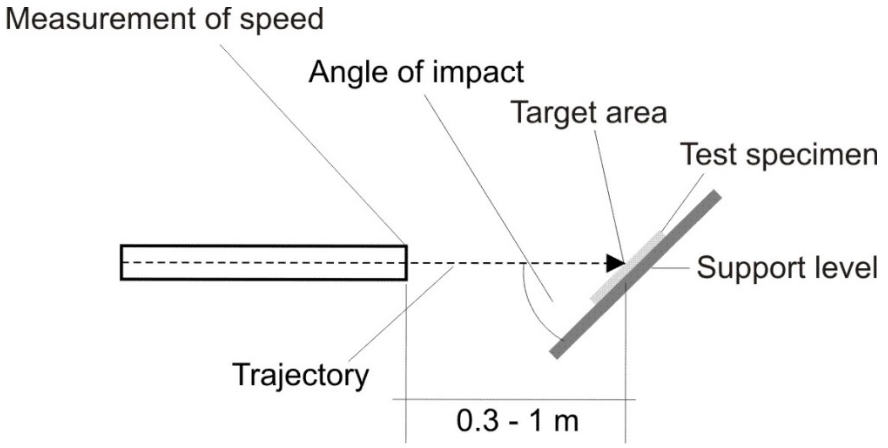


Figure 1 Test apparatus for the simulation of hail impact with horizontal trajectory and angle of im-pact of 45° ± 2° (dimensions in metres)

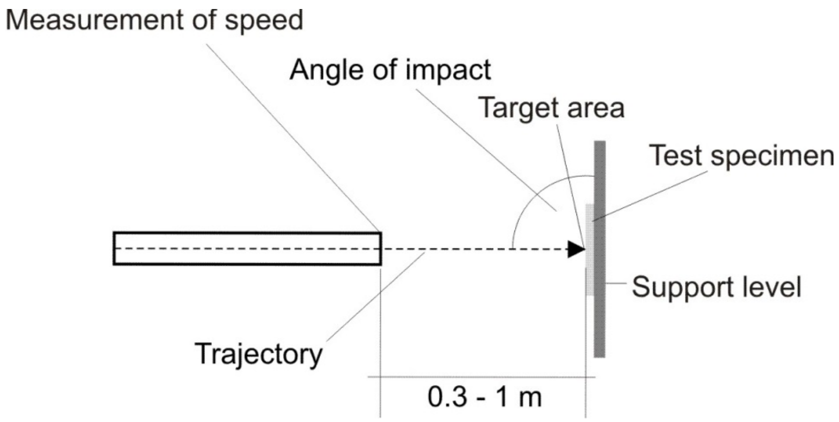


Figure 1 Test apparatus for the simulation of hail impact with horizontal trajectory and angle of impact of 90° ± 2° (dimensions in metres)

0.4.4 Test specimen support frame

The test specimen support frame is used for securing test specimens in the line of fire and is matched to the test apparatus (vertical or horizontal trajectory). To comply with the prespecified an-gle of impact, the test specimen support frame must be adjustable and it must be possible to meas-ure the angle. The test specimen support frame must not shift or be deformed due to the impact of the shot.

In the case of a vertical trajectory set-up, the test specimen can also be supported directly on a la-boratory bench or floor (roof application). In this case, the load transfer mechanisms of test speci-men must match the conditions in practice. Vibration transmission between the bench or floor and the specimen support frame must be prevented using suitable means.

As a rule, the test specimens are fastened rigidly and without cushioning to the support frame by means of clamps and other equipment so they cannot move.

0.4.5 Angle of impact

The angle of impact is defined as the angle between the trajectory and support plane of the test specimen (Figures 1 & 2). The angle of impact for components that are to be used as part of roofs is 90° ± 2°; whereas for components on a facade the angle of impact is 45°± 2°.

0.4.6 Target area

The target areas are defined in the component-specific test specifications and represent the suspected weak points of the building component. They are known as "critical target areas." Additional weak points are listed in a separate CFIA document called the ”Collection of Decisions”. If further component weak points, which are not described in the above-mentioned documents, are suspected, they must also be targeted. The results must be recorded both in words and pictures in the test report. It is the responsibility of the individual performing the test to find and to test the weakest points of the specimen.
After identifying the weakest points, testing is carried out according to chapter 04.12.

0.4.7 Projectile

Spheres and special shapes made of laboratory ice are used as projectiles. They are stored at -20°C.

For valid testing, the following conditions must be fulfilled:

- Projectiles: Made of optically clear ice
- Storage temperature: Freezer at -20°C ± 3°C
- Storage period: Period from manufacture to impact testing, at least 48 hours; maximum storage period in a freezer, 4 weeks if loose-packed and 4 months if vacuum sealed
- Shape: Sphere (standard) or special shapes
- Diameter: 10 to 50 mm, according to Table 2
- Mass: according to Tables 2, 3, and 4
- Appearance: On visual inspection, devoid of any cracks and with few pores; mould seam scraped off
- Handling: With insulated gloves only

*In principle, projectiles are to be used at an ice temperature of -20°C ± 3°C. Exceptions are de*scribed in the component-specific test specifications.

If impacts with a non-spherical projectile are required in accordance with the component-specific test specification, the Teton (i.e., nipple-shaped) projectile shown in the detailed drawings in Appen-dix A can be used. The mass of the appropriate Teton projectile corresponds to that of a spherical projectile with the same diameter. The Teton projectiles are fired "nose-first" (hemispherical protuberance) at the test specimen.

In addition to using the same diameter, the component is also be targeted with the next-smallest Teton projectile.

Testing with non-spherical projectiles is treated in the following component-specific test specifications:

- No. 22 Air inflated cushion structure

- No. 23 Draped curtains
- No. 27 Tent like structures
- No. 28 Membrane covered framework structures
- No. 33 Textiles for building envelopes

In addition, the building component has to be tested also with the next smaller projectile size than the critical projectile size.
If the test is not performed with the Teton projectile, the test institute must justify that the chosen projectile causes the same damage pattern.

0.4.8 Test conditions

The test is conducted at an ambient temperature of 20°C ± 2°C and relative air humidity of 50% ± 20%.

0.4.9 Dimensions of test specimen

The test specimen must incorporate the details encountered in the practical installation of the building component (e.g., corner details), even if these are not mentioned in the relevant component-specific test specifications. The testing program has to be agreed upon by the product supplier and the test institute. When setting up the specimens for testing, the information provided by the product supplier must be taken into account (e.g., installation guidelines, material thickness). These must be verified and included in the test report by the test institute.

The dimensions of the test specimens are given in the component-specific test specifications. It is possible to deviate from these dimensions, provided there is justification.

Parts that wear (e.g., cover caps) and small pieces of the building components are part of the test specimen, if they can't be replaced without installer support. Such items have to be listed in the test report.

0.4.10 Specimen storage and specimen treatment prior to testing

Specimen storage prior to testing and specimen treatment prior to testing are defined in the component-specific test specifications. The specimen storage prior to testing describes the long-term storage of the test specimen before the test. The specimen treatment prior to testing describes the handling of the specimen before impact.

0.4.11 Speed of projectile

The speed of the projectile is measured with the aid of an electronic measuring device having an accuracy of ± 1% at a distance of 0.3 – 1 m from the surface of the test object (object – middle of speed measuring section). The speed must be measured electronically to at least 2 decimal places.

0.4.12 Execution of test

To test the specimen for a specific hail impact resistance, the specimen is targeted with the kinet-ic energy of the appropriate hail impact resistance class (Figure 3).

The appropriate projectile diameter must be used for each hail impact resistance measurement: the test for a hail impact resistance class of 2 (HR 2) necessitates a diameter of at least

20 mm, for HR 3 a diameter of 30 mm, etc.

At first, exploratory shots are performed (Figure 3, step1). The exploratory shots serve to find the weakest points on the test specimen. The target areas mentioned in the component-specific test specifications and CFIA Collection of Decisions serve as input for the exploratory shots. The individual performing the test must search for and test additional weak points using professional engineering judgment.

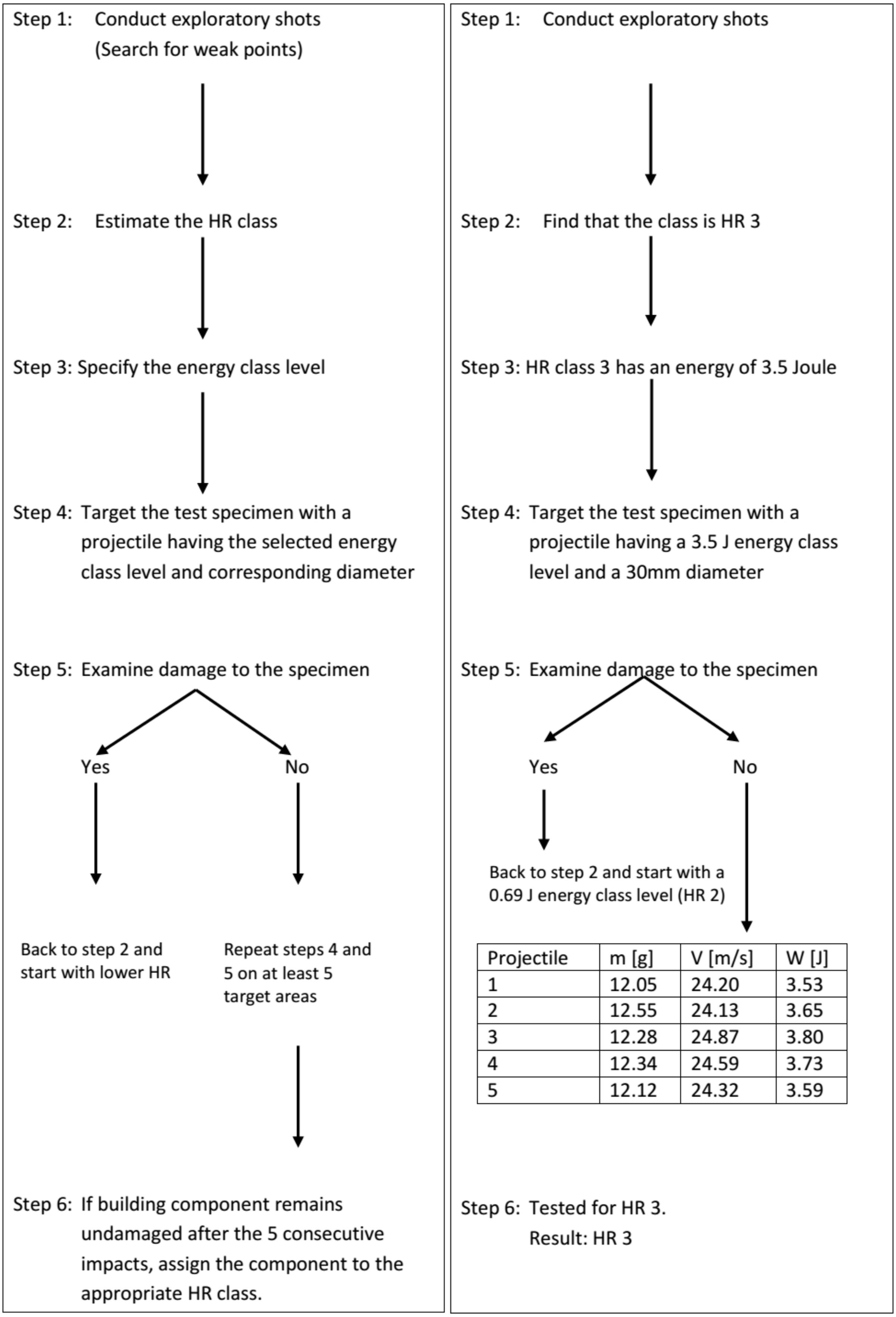
As a general rule, the detected weak points have to be tested according to steps 2 through 6 in Figure 3. The results must be documented in the test report.

If the test specimen is damaged with a specific projectile size and corresponding speed, a new test specimen or an undamaged area of the test specimen is targeted with the projectile size and speed of the next lower hail impact resistance (HR) class. If the test specimen remains undamaged, the test is repeated on four other weak points of the specimen or using four new specimens (total of at least 5 tests). If the test specimens remain undamaged after impact, the building component can be assigned to the appropriate hail impact resistance class. The weak points associated with the different building functions may be at different locations. Therefore, multiple weak points may exist on one test specimen.

It is noted that:

- The projectile must be fired within 60 seconds after its removal from the storage freezer.
- Multiple targeting of the same test specimen is possible, if there is no damage to the specified target area for that particular building component.

If a building component is damaged when hit with a 20 mm projectile, it is possible, at the discretion of the test institute, to forego a further test with a projectile having a 10 mm diameter, and assign the building component to a hail impact resistance class 1 (HR 1). The prerequisite is that the building component can clearly be expected to be in sound condition because of the strikingly low kinetic energy (class level). Foregoing the test with a projectile having a 10 mm diameter is to be explicitly recorded and explained in the test report .
In the case of building materials that are not homogeneous in their structure, targeting with a projectile that has a smaller diameter (usually 20 or 30 mm) may cause damage; whereas a projectile with a larger diameter would not cause damage. Also, firing at the same target zone with several projectiles may sometimes lead to damage more rapidly in the case of inhomogeneous materials (e.g., plaster). The test institute decides on the execution of additional tests at critical points. The weakest point must be tested by firing at it five times. The results must be recorded in the test report.



Projectile	m [g]	V [m/s]	W [J]
1	12.05	24.20	3.53
2	12.55	24.13	3.65
3	12.28	24.87	3.80
4	12.34	24.59	3.73
5	12.12	24.32	3.59

Figure 2 Schematic sequences (left) and example (right) for carrying out the hail impact testing

0.5 Extension of a CFIA certificate without further impact testing

If it can be demonstrated that no changes have been made in a component's material composition, design, and intended purpose, testing re-examining the component's hail impact resistance when its certificate is up for renewal can be dispensed with. The test institute has to confirm this and to justify it in an expert opinion document. After examination of the submitted documentation, the CFIA will decide on the option of foregoing further testing. Such expert opinion documents are only accepted from CFIA accredited test institutes. When considering waiving further testing, it is mandatory to respect the latest CFIA hail resistance test protocols . This process is used primarily for an extension of an existing CFIA certificate.

0.6 Test in the absence of a test a test specification

Generally, the hail resistance tests are to be performed in accordance with existing CFIA test specifications. If a building component cannot be clearly allocated to a specific test specification, the testing shall be performed on the basis of additional suitable test specifications. If no suitable test specification is available, a proposal can be submitted to the board of the CFIA Commission for Natural Hazards. The CFIA decides on the proposal.

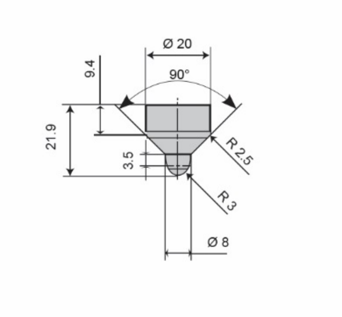
0.7 Building components with certificates according to EN standards

If building components or component categories have already been tested for hail impact re-sistance in accordance with EN standards, further testing is waived. If tests with projectiles made of other materials or of different shapes are conducted, assignment to hail impact resistance classes HR 1 to HR 5 is undertaken using the conversion table given in the test specifications.

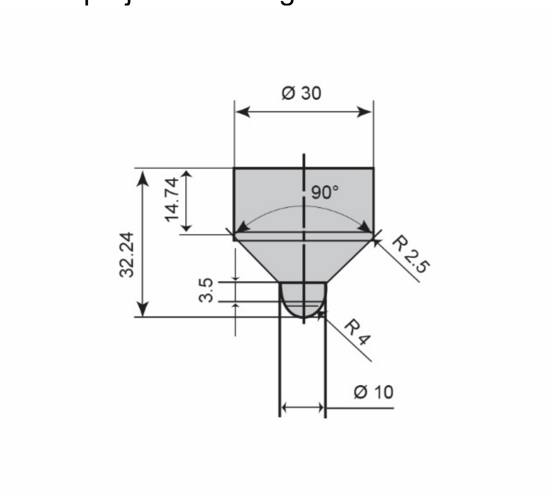
Appendix A

Drawings showing the dimensions of non-spherical projectiles (Teton projectiles)

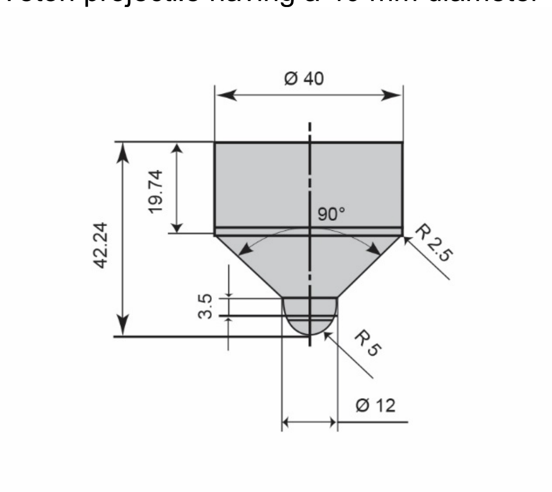
Teton projectile having a 20 mm diameter



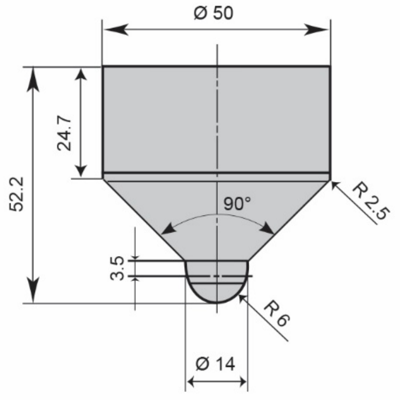
Teton projectile having a 30 mm diameter



Teton projectile having a 40 mm diameter



Teton projectile having a 50 mm diameter



Appendix B

Table 2: Laboratory values for Teton projectiles in accordance with appendix A (20, 30, 40 and 50 mm)

Class	Nominal Diameter	G_{min} Minimum Mass	G_{max} Maximum Mass	v_R Reference Speed	Energy Class Level min. E_{min}	Energy Class Level max. E_{max}
	[mm]	[g]	[g]	[m/s]	[J]	[J]
HR 2	20	3.41	3.98	19.64	**≥ 0.69**	**≤ 1.0**
HR 3	30	11.71	13.68	23.82	**≥ 3.5**	**≤ 4.4**
HR 4	40	27.72	32.38	27.53	**≥ 11.1**	**≤ 13.2**
HR 5	50	54.06	63.14	30.81	**≥ 27.0**	**≤ 31.5**

Table 3: Laboratory values for projectiles having diameters of 60 mm and greater (60, 70 and 80 mm)

Class	Nominal Diameter	G_{min} Minimum Mass	G_{max} Maximum Mass	v_R Reference Speed	Energy Class Level-min. E_{min}	Energy Class Levelmax. E_{max}
	[mm]	[g]	[g]	[m/s]	[J]	[J]
HR 5	60	93.47	109.18	33.73	**≥ 56.0**	**≤ 64.7**
HR 5	70	148.43	173.38	36.44	**≥ 104**	**≤ 120**
HR 5	80	221.57	258.80	38.95	**≥ 177**	**≤ 204**

Table 4: Laboratory values for projectiles having atypical projectile diameters

Class	**Nominal Diameter**	**G_{min} Minimum Mass**	**G_{max} Maximum Mass**	**v_R Reference Speed**	**Energy Class Level-min. E_{min}**	**Energy Class Levelmax. E_{max}**
	[mm]	[g]	[g]	[m/s]	[J]	[J]
HR 1	15	1.46	1.71	16.87	**≥ 0.22**	**≤ 0.37**
HR 2	25	6.76	7.90	21.77	**≥ 1.7**	**≤ 2.3**
HR 3	35	18.55	21.67	25.76	**≥ 6.5**	**≤ 7.9**
HR 4	45	39.43	46.06	29.21	**≥ 17.7**	**≤ 20.9**
HR 5	55	72.00	84.10	32.30	**≥ 39.5**	**≤ 45.9**
HR 5	65	118.85	138.81	35.11	**≥ 77.1**	**≤ 89.0**
HR 5	75	182.57	213.24	37.72	**≥ 137**	**≤ 157**

* Remarks: According to the actual test protocol, only classes HR 1 to HR 5 exist. If a building component has been tested successfully with larger projectile diameters, the Hail Resistance Certificate may state it as well.