Designation: F320 – 10

Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures[1]

This standard is issued under the fixed designation F320; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This test method covers the determination of the impact resistance of an aerospace transparent enclosure, hereinafter called windshield, during hailstorm conditions using simulated hailstones consisting of ice balls molded under tightly controlled conditions.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements see Section 7.

2. Terminology

2.1 *Definitions:*

2.1.1 *damage*—any modification in visual properties or integrity of a windshield as a result of hail impact including scratches, crazing, delamination, cracks, or shattering.

2.1.2 *ice ball*—a frozen mass of water, with filler, that simulates a natural hailstone in weight, size, and toughness.

2.1.3 *impact angle*—the angle between the ice ball flight path and the target normal.

2.1.4 *sabot*—a plastic device for protecting the ice ball while in the launch tube. One type of sabot (see Fig. 1) consists of a split polycarbonate rod containing a central cavity for holding the ice ball. Each sabot half is designed to assure aerodynamic separation from the ice ball after ejection from the launch tube.

3. Summary of Test Method

3.1 The test method involves launching a series of ice balls of specified sizes at a sample windshield at a designated velocity and angle and in a specified pattern. Requirements are specified for the ice ball, test specimen, procedure, and data acquisition. The ice ball is photographed in flight to verify its integrity.

3.2 Requirements are specified for a particular apparatus and test procedure, but options are permitted for certain areas. However, it must be possible to demonstrate that the options used result in an ice ball impacting the test panel with the same size, consistency, and velocity as with the specified apparatus and procedure. Following are areas where options are allowed:

3.2.1 *Ice Ball Mold Material.*

3.2.2 *Launcher*—Any type of launcher is allowable as long as the iceball reaches the test specimen intact at the correct speed. The use of sabots and sabot material and geometry are optional.

3.2.3 *Method of Determining Ice Ball Integrity.*

3.2.4 *Ice Ball Speed Measurement,* Optional as long as accuracy standards are met.

3.2.5 *Test Specimen Sizes*—Those given are minimum.

3.2.6 *Safety*—Safety must satisfy the safety standards of the test facility being used.

4. Significance and Use

4.1 This test method may be used to determine the hail impact resistance of windshields for acceptance, design, service, or research purposes. By coupling this method with the installed angle and velocity of a specific aerospace vehicle, design allowables, criteria, and tolerances can be established for that vehicle's windshield.

5. Apparatus

5.1 The facilities and equipment required for the performance of this test procedure include a suitable firing range equipped with an ice ball mold, a launcher, blast deflector, sabot trap, velocity measuring system, test specimen holder, and a camera with strobe lights to verify ice ball integrity. Ancillary equipment required for this test include test

[1] This test method is under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.08 on Transparent Enclosures and Materials.

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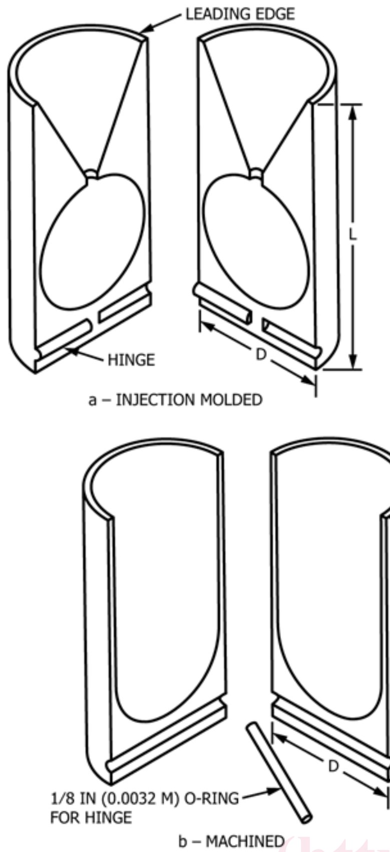


ICE BALL SIZE	D	L
B	B + 1/8" (B + .0032 M)	2D

FIG. 1 Sabot Configuration

specimen, ice balls, sabots, and firing cartridges. An example facility is described below.

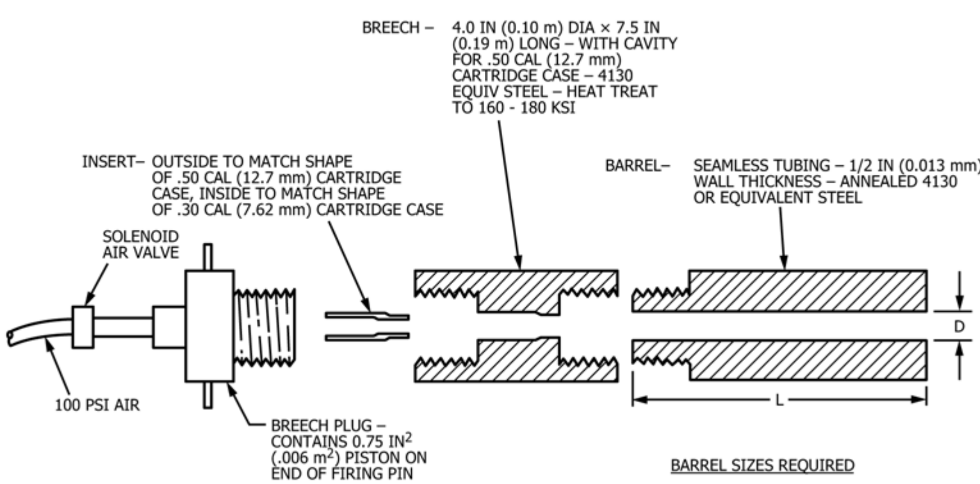
5.2 *Firing Range*—The firing range shall be a minimum of 9 by 18 ft (3 by 6 m) enclosed to contain flying debris and to exclude unauthorized personnel.

5.3 *Ice Ball Mold,* two aluminum blocks with hemispherical cavities and vent holes for filling with water and for water expansion during freezing.

5.4 *Launcher,* any launcher may be used as noted in 3.2.2. In addition to the powder gun described in this test method, laboratories have also successfully utilized compressed gas gun launchers. An example of a powder gun launcher is shown in Fig. 2, consisting of a barrel, breech, breech plug, and control. The barrel shall be made from high-quality AISI 4130 seamless steel tubing, or equivalent, in the annealed condition. The breech shall be made from AISI 4130 steel rod, or equivalent, heat treated to a 160- to 180-ksi (1104- to 1242-MPa) ultimate tensile strength condition. The size of cavity to be used in the breech depends on the desired test velocity (see Table 1). The breech plug, which locks the cartridge in place and contains the firing pin, shall be made of 4340 steel heat treated to a 160- to 180-ksi ultimate tensile strength condition. The firing pin is actuated by a kinetic impact air piston. Control is accomplished by an electrically actuated air valve. For a 100-psi (0.69-MPa) air source, a 0.75-in.^{2} (4.84-cm^2) piston traveling 0.5 in. (13 mm) is used.

5.5 *Blast Deflector*—Place a plate with a 4-in. (100-mm) diameter hole as shown in Fig. 3 between the sabot trap and the first velocity measuring station. Then place a corrugated cardboard plate over the hole. This deflector is not required for compressed gas gun systems.

5.6 *Sabot Trap* is made by placing two steel plates two to four ice ball diameters apart, centered on the flight path and located a minimum of 6 ft (1.82 m) from the launcher muzzle



BARREL SIZES REQUIRED

VELOCITY RANGE	L
200 - 1000 FPS (60 - 300 MPS)	10 IN (0.25 m)
600 - 3000 FPS (180 - 900 MPS)	60 IN (1.53 m)

HAIL SIZE	D
1/2 IN (0.013 m)	0.75 IN (0.019 m)
1.0 IN (0.025 m)	1.25 IN (0.032 m)
2.0 IN (0.051 m)	2.25 IN (0.058 m)

FIG. 2 Launcher Design

TABLE 1 Power Loads

Desired Velocity, ft/s (m/s)	Barrel Bore, in. (mm)	Barrel Length, in. (m)	Cartridge Size, caliber	Powder Type	Powder Weight, grains (g)
200 (60)	1.25 (32)	10 (0.25)	0.30	Bullseye[A]	6 (0.39)
	2.25 (57)	10 (0.25)	0.30	Bullseye	6 (0.39)
500 (150)	0.75 (19)	10 (0.25)	0.30	Bullseye	5 (0.32)
	1.25 (32)	60 (1.52)	0.50	4227[B]	40 (2.59)
	2.25 (57)	60 (1.52)	0.50	Bullseye	30 (1.94)
	2.25 (57)	10 (0.25)	0.30	Bullseye	12 (0.78)
1000 (300)	0.75 (19)	10 (0.25)	0.30	Bullseye	9 (0.58)
	1.25 (32)	60 (1.52)	0.50	Bullseye	60 (3.89)
	1.25 (32)	10 (0.25)	0.30	Bullseye	20 (1.30)
	2.25 (57)	60 (1.52)	0.50	Bullseye	70 (4.54)
2000 (600)	0.75 (19)	60 (1.52)	0.50	Bullseye	35 (2.27)
	1.25 (32)	60 (1.52)	0.50	Bullseye	70 (4.54)
	2.25 (57)	60 (1.52)	0.50	Bullseye	150 (9.72)

[A] The sole source of supply of the apparatus known to the committee at this time is Hercules, Inc., 1313 North Market Street Wilmington, DE 19894-0001. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [2], which you may attend.

[B] The sole source of supply of the apparatus known to the committee at this time is duPont, Chestnut Run Plaza 705/GS38 Wilmington, DE 19880-0705. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [2], which you may attend.

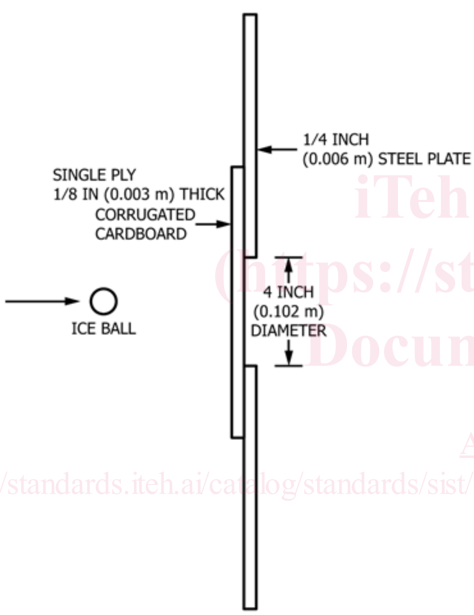


FIG. 3 Blast Deflector

as shown in Fig. 4. This trap is not required for systems that utilize aerodynamic separation of the sabot or other suitable mechanisms to ensure that the sabot does not impact the test article.

5.7 *Velocity Measurement System*—The break-screen velocity measurement consists of a set of screens, power supply, wiring, and counters. Three screens shall be made from a lightweight bond paper with an electrical circuit painted on the paper by the silk screen process. The paint for the circuit shall be electronic grade electrical conducting paint.[2] Do not thin the paint. The break-screen shall be made with lines ⅛ in. (3.2 mm) wide by 18 in. (460 mm) long as shown in Fig. 5 giving a resistance of no more than 300 Ω. Fig. 6 shows the arrangement of components and gives the electronic circuit to be used with the three screens. The system shall be accurate to ±1 % or better. Laser-based photo detector systems and high-speed-film-based systems may also provide the required accuracy of ±1 %.

5.8 *Test Specimen Holder*—Use one of two types of test specimen holders. The one in Fig. 7 is designed to hold an 18- by 18-in. (0.46- by 0.46-m) test specimen that can be impacted at angles ranging from 0 to 80° as detailed in Section 8. When testing a complete windshield, use edge restraints similar to the actual installation and place the windshield in the proper orientation (see 9.2).

[2] The sole source of supply of the apparatus known to the committee at this time is "Silver Preparation," duPont electronic grade No. 4817. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee [2], which you may attend.

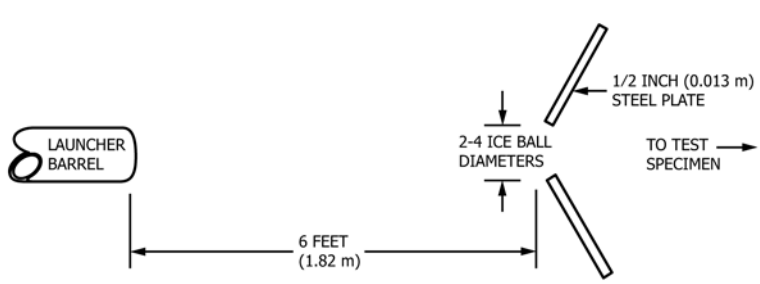


FIG. 4 Sabot Trap

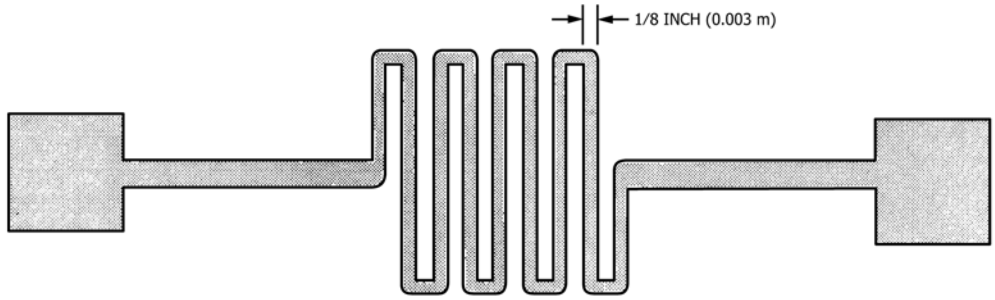


FIG. 5 Velocity Screen

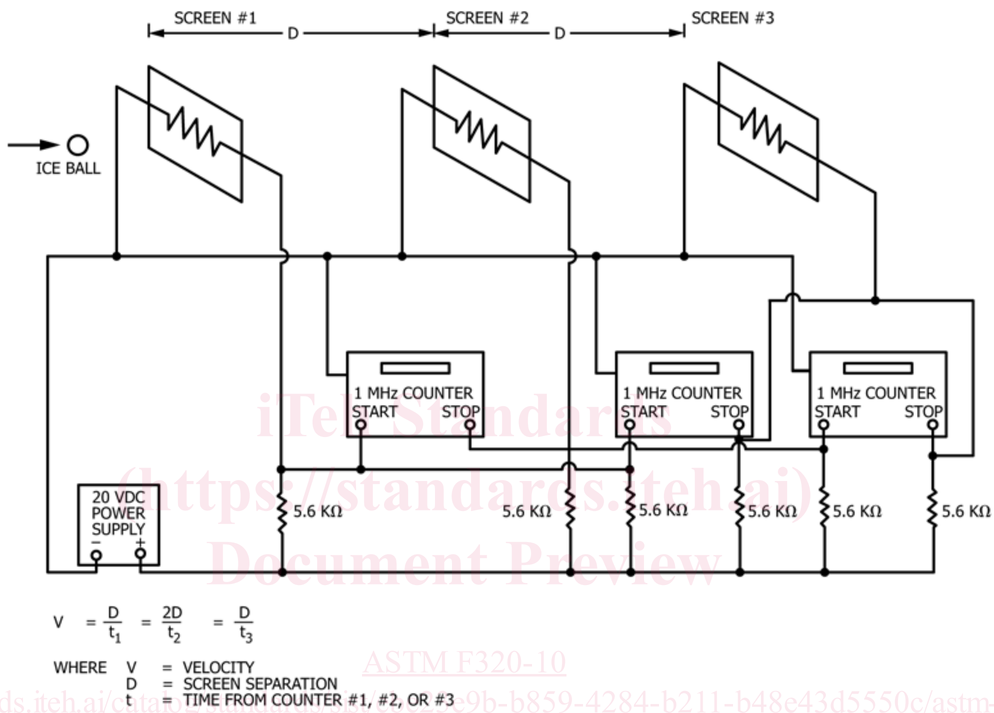


FIG. 6 Velocity Measuring System

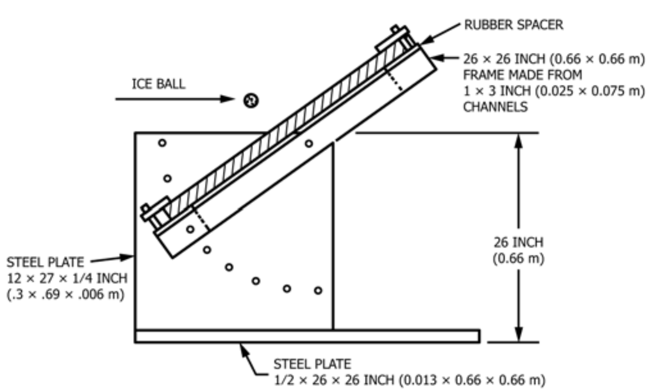


FIG. 7 Test Specimen Holder

5.9 *Ice Ball Integrity Camera*—Verify ice ball integrity before impact by obtaining a photograph of the ice ball in flight before impact. This may be accomplished by illuminating the ice ball with a strobe light while the ice ball is in the field of view of a camera lens. This synchronization can be obtained by using an open shutter with the strobe triggered at the second velocity screen. The signal is split with part going to the velocity counters and part to a variable time-delay generator. Using the estimated ice ball velocity, a time delay is selected so the ice ball will be in view of the camera lens when the strobe is triggered.

5.10 *Balance,* for powder and ice balls, capacity 0.2 lb (100 g), accuracy ±1 % (1.0 g).

5.11 *Clinometer or Protractor,* to measure impact angle, accuracy ±¼ °.

5.12 *Syringe,* 100-cm^3, for putting water into the ice ball mold.

6. Materials

6.1 *Sabot*—An effective injection molded sabot configuration is shown in Fig. 1*a*, while a machined configuration is shown in Fig. 1 *b*. In either design, polycarbonate material is used to form the two halves of the sabot at a minimum diameter equal to the ice ball diameter plus ⅛ in. (3.2 mm) with a length approximately twice this diameter to assure in-flight separation of the sabot halves. An acceptable tolerance of the sabot