Designation: F 320 – 94 (Reapproved 1999)

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

This standard is issued under the fixed designation F 320; 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 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 *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.

1.3 The values in inch-pound units are the preferred units. The values in parentheses are for information only.

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.

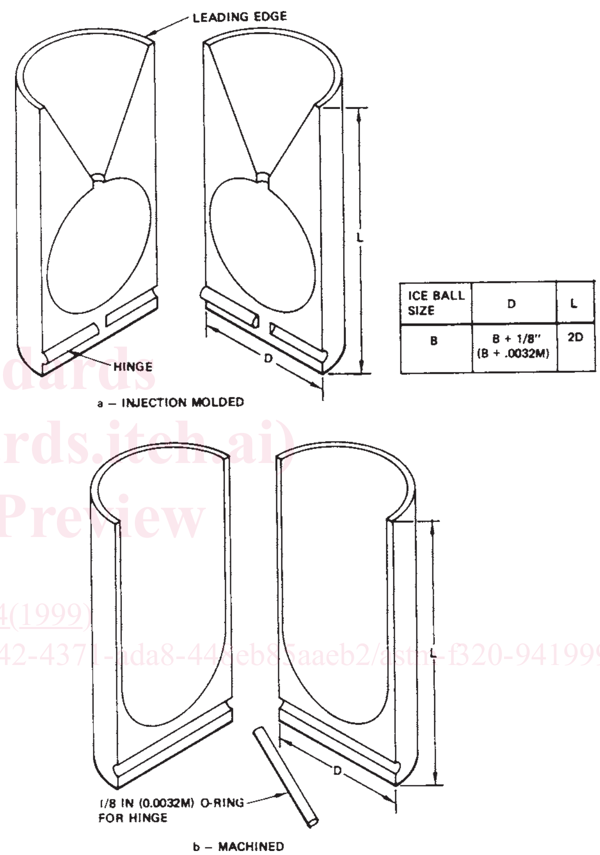
2.1.2 *ice ball*—a frozen mass of water, with filler, that simulates a natural hailstone in weight, size, and toughness.

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. The 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 particular 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.



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

FIG. 1 Sabot Configuration

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 at 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 at the correct speed. The use of sabots and sabot material and geometry are optional.

3.2.3 *Method of Determining Ice Ball Integrity.*

[1] This test method is under the jurisdiction of ASTM Committee F-7 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.08 on Transparent Enclosures and Materials.

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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 specimen, ice balls, sabots, and firing cartridges.

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*, shown in Fig. 2, consists 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.

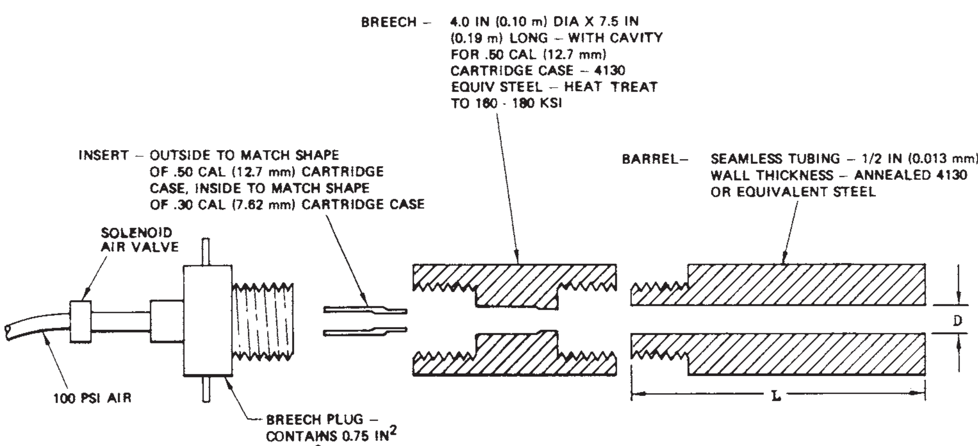
5.5 *Blast Deflector*—Place a plate with a 4-in. (100-mm) diameter hole as shown in Fig. 3 between the sabot trap and the first velocity measuring station. Then place a corrugated cardboard plate over the hole.

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 as shown in Fig. 4.

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.

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

[2] "Silver Preparation," duPont electronic grade No. 4817, has been found to be satisfactory.



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 (0.019m)
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]Made by Hercules.
[B]Made by duPont.

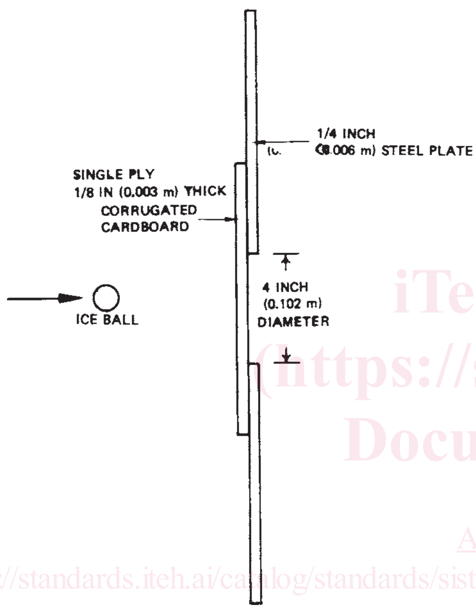


FIG. 3 Blast Deflector

testing a complete windshield, use edge restraints similar to the actual installation and place the windshield in the proper orientation (see 9.2).

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. Tolerance of the sabot diameter shall be within 0.005 in. (0.127 mm) of the minimum barrel diameter.

6.2 *Gunpowder*—The brands listed in Table 1 have been found to be satisfactory.

6.3 *Cartridge Cases*, with primers, 0.30 and 0.50 caliber.

6.4 *Cotton Fiber*—Standard pharmaceutical cotton balls.

6.5 *Bags, Polyethylene*, commercial grade.

6.6 *Plastic Wrapping*—Poly(vinylidene chloride).

7. Hazards

7.1 *Powder Storage and Handling*—Powder handling and storage shall conform to all Federal and local regulations. The handling facility in which the powder charges are weighed and loaded must be reserved for this purpose alone. Procure primers already mounted in the cartridge cases or special facilities provided for this dangerous operation.

7.2 *Firing Area*—Exclude all personnel from the firing area except the operator.

7.3 *Locked Switch*—There shall be a locked switch on the firing circuit which can be closed only by a key kept in the operator's possession during the entire calibration and test procedure.

8. Test Specimen

8.1 The test specimen shall be a duplicate of the windshield being simulated or a section thereof. If a section is used, it shall measure 18 by 18 in. (0.46 by 0.46 m). Surface condition shall be dry. Temperature shall be ambient unless special temperatures are associated with the particular installation being simulated. In the case of special temperatures, the temperature to use and the method of attainment are to be established by mutual agreement between the user and the testing agency. Use a strong backlight to aid visual inspection of the windshield both before and after the test.