

Appendix F

Doors and Hardware That Passed Previous Missile Impact Tests

The tables on the following pages document the performance of some available doors and door hardware that passed wind pressure and impact requirements contained in previous editions of FEMA 320, *Taking Shelter From the Storm*. The inclusion of door systems in this appendix does not signify that the systems will necessarily pass the current missile impact and pressure criteria. The doors and door hardware included herein provide only a starting point to see what type of doors could withstand the old standards. However, the testing program focused on a variety of doors and hardware systems rather than multiple tests of a single type of door system. The data presented are single-test results, which are intended to be used as indicators of expected performance and not a certification that the door will pass the requirements in this publication and the ICC-500, which are, in some areas, more stringent.

A residential shelter in FEMA 320 is considered a partially enclosed structure (“enclosed” and “partially enclosed” buildings are defined by ASCE 7-05) that uses an internal pressure coefficient of $GCP_i = \pm 0.55$ for components and cladding (C&C) design. The previous edition of FEMA 320 (the standard to which these door systems were tested) used an enclosed structure in the design of the safe rooms that used $GCP_i = \pm 0.18$. This reduced value for the internal pressure coefficient resulted in lower loads, to which these door systems were tested. It is important that any door and door hardware to be used in a safe room application be tested to the current requirements.

The change in pressure coefficients has increased the design wind pressures for doors and windows in community safe rooms. Most of the door systems discussed in this publication and presented in this appendix have been successfully tested to wind pressure values associated with a 200-mph wind speed (Figure 2-2). However, many safe rooms will be located in areas with 250-mph speeds. The maximum wind pressures on a safe room occur at building corners.

This appendix attempts to provide information on door/door hardware systems that are readily available from manufacturers. All doors in this appendix have passed the 15-lb 2x4 at 100 mph missile impact criteria. Chapter 7 discussed wide single-door systems (greater than 36 inches wide, specifically 44-inch widths) and double-door systems.

It is important to note that the size of the door that is being tested will affect the design wind pressure to which a door should be designed. Specifically, the external pressure coefficient (GC_p) will vary with location along the wall (proximity to the building corner) and with the area of the door when calculating C&C loads using ASCE 7-05.

The testing of standard doors and door hardware will continue after the publication of this manual. The goal of this testing is to determine whether available doors and door hardware will be capable of resisting the highest of wind pressures associated with 250-mph wind speeds. Updates on tested door systems will be posted on the Texas Tech University (TTU) web page at <http://www.wind.ttu.edu>.

The information presented in this appendix includes the internal pressure coefficient used, dimensions, lock details and other factors of door construction, and whether it passed the missile impact and pressure tests from the previous editions of FEMA 361 and 320. Due to proprietary concerns and federal policy, door, window, and lock manufacturers are not listed by name in the table. The designer should note that these test results were derived from door systems that used door hardware systems that may not be acceptable for egress under some occupancy classifications.

Results of Wind Pressure Tests on Doors with Individually Activated Latching Mechanisms

Date	Test Type	Door Description	Lock Description	Failure Pressure	Pressurization Results
3/31/98	Pressure	14-gauge steel door with 20-gauge metal ribs. The door was installed and tested as a swing-out door.	Sargent mortise lock with deadbolt function.	0.97 psi	Lock held to 0.97psi. The lock failed internally when the bar connecting the deadbolt bent, allowing the door to swing open.
3/6/98	Pressure	14-gauge steel door with polystyrene infill. The door was installed and tested as a swing-out door.		1.37 psi	The door failed at a pressure of 1.37 psi. The door failure was due to the failure of the lock set; also, the door did open due to the pressure.
3/26/98	Pressure	14-gauge door with a polystyrene infill. The door was mounted and tested as a swing-in door.	Yale mortise lock set with deadbolt function.	1.2 psi	The door failed at a pressure of 1.2 psi. The door failure was due to the failure of the lock set; also, the door did open due to the pressure.
3/31/98	Pressure	20-gauge door, a honeycomb infill, with a 14-gauge steel plate mounted on the non-impact side. The door was mounted and tested as a swing-in door.	Standard heavy-duty lock with three 1.2-inch slide bolts mounted opposite the hinges.	1.36 psi	The modified door held a pressure of 1.36 psi for 5 seconds.
4/1/98	Pressure	20-gauge door, a honeycomb infill, with a 14-gauge steel plate mounted on the non-impact side. The door was mounted and tested as a swing-in door.	Standard heavy-duty lock with three 1.2-inch slide bolts mounted opposite the hinges.	1.46 psi	The modified door held a pressure of 1.46 psi for 5 seconds.
5/98	Pressure	Six-panel metal-covered wood-frame door with a sheet of 14-gauge steel attached.	Standard off-the-shelf doorknob with three deadbolt locks placed opposite the hinges.	1.21 psi	The modified door failed at the location of the deadbolts at 1.21 psi. The hardware appeared to cause the door to fail.
5/98	Pressure	Solid-core wood door with a sheet of 14-gauge steel attached.	Standard off-the-shelf doorknob with three deadbolt locks placed opposite the hinges.	1.13 psi	The modified door failed at the location of the deadbolts at 1.13 psi. The hardware appeared to cause the door to fail.
5/98	Pressure	Six-panel solid-wood door with a sheet of 14-gauge steel attached.	Standard off-the-shelf doorknob with three deadbolt locks placed opposite the hinges.	1.12 psi	The modified door failed at the location of the deadbolts at 1.12 psi. The hardware appeared to cause the door to fail.

Results of Missile Impact Tests on Doors with Individually Activated Latching Mechanisms

Date	Test Type	Door Description	Lock Description	Missile Threshold (mph)	Impact Results	Impact Speed (mph)
	Missile	14-gauge steel door with 20-gauge metal ribs. The door was installed and tested as a swing-out door.	Sargent mortise lock with deadbolt function.	> 100	The door withstood several impacts at the midpoint of the door next to the hardware and at the upper and lower corners next to the hinges and on the lock side, respectively.	82.35 81.99 104.83 106.57
3/26/98	Missile	14-gauge door with a polystyrene infill. The door was mounted and tested as a swing-in door.	Yale mortise lock with deadbolt function.	81	Door failed the impact test due to hardware failure. When modified with three slide bolt locks mounted opposite the hinges, the door was successful.	81.3
3/31/98	Missile	20-gauge door, a honeycomb infill, with a 14-gauge steel plate mounted on the non-impact side. The door was mounted and tested as a swing-in door.	Standard heavy duty lock with three 1/2-inch slide bolts mounted opposite the hinges.	104	There was a local failure of the hardware, but the redundancies in the hardware held the door in place. The missile penetrated the impact skin, but did not perforate the non-impact side or the 14-gauge steel plate. There was permanent deformation.	103.88
4/1/98	Missile	20-gauge door, a honeycomb infill, with a 14-gauge steel plate mounted on the non-impact side. The door was mounted and tested as a swing-in door.		104	The missile did not penetrate the door, but it caused permanent deformation in the internal door frame. (The door buckled around the standard lock set.)	104.09

Results of Wind Pressure and Missile Impact Tests on Double-Door Set with Panic Bar Hardware and Single-Action Lever Hardware

Date	Test Type	Door Description	Hardware Description	Test Results
5/00	Pressure and Missile	3-foot x 7-foot steel 14-gauge door with 14-gauge steel channels as hinge and lock rails and 16-gauge channels at top and bottom. Polystyrene infill or honeycomb core. 14-gauge steel frame with 14-gauge center steel mullion.	Externally mounted three-point latching mechanism with panic bar release, 5/8-inch headbolt and footbolt with 1-inch throw, and mortised center deadbolt.	Pressure reached 1.37 psi without failure. Missile impact at 100 mph did not perforate.
5/00	Pressure and Missile	3-foot x 7-foot steel 14-gauge door with 14-gauge steel channels as hinge and lock rails and 16-gauge channels at top and bottom. Polystyrene infill or honeycomb core. 14-gauge steel frame with 14-gauge center steel mullion.	Externally mounted three-point latching mechanism with single-action lever release, 1-inch solid mortised center deadbolt with 1-inch throw, and two 1-inch x 3/8-inch solid hookbolts, one below and one above the deadbolt.	Pressure reached 1.37 psi without failure of door, although top hookbolt failed. Missile impact at 100 mph pushed door through frame, causing center mullion to rotate. Testing inconclusive; further testing required.

Door/Widow- Manufacturer (D/W Mfr)	Internal Pressure Coefficient	Pressure Test?	Impact Test?	Size w x h	Center Mullion	Lock Manufacturer (L Mfr)	Locking Mechanism	Push Bar?	Latch (3/4")	Deadbolts (1")	Hinges	Door Swing	Remarks
D Mfr 1	enclosed	yes	yes	3' x 7'	no	L Mfr 1	3-point	no	yes	yes	1 1/2 pair	Out	
D Mfr 2	enclosed	yes	yes	3' x 7'	no	L Mfr 2	3-point	no	yes	yes	1 1/2 pair	In	
D Mfr 3	enclosed	yes	yes	3' x 7'	no	L Mfr 1	3-point	no	yes	yes	1 1/2 pair	In	
D Mfr 3	enclosed	yes	yes	3' x 7'	no	L Mfr 2	3-point	no	yes	yes	1 1/2 pair	In	
D Mfr 4	enclosed	yes	yes	3' x 7'	no	L Mfr 3	M.P. ¹	no	yes	no	1 1/2 pair	In	14 Lock Points, M. Security Frame
D Mfr 5	enclosed	yes	yes	3' x 7'	no	L Mfr 4	3-point	no	yes	yes	1 1/2 pair	In	
D Mfr 6	enclosed	yes	yes	32" x 83"	no	L Mfr 5	M.P. ¹	no	yes	no	1 pair	In	10 Lock Points
D Mfr 6	enclosed	yes	yes	32" x 81"	no	L Mfr 5	M.P. ¹	no	yes	no	1 1/2 pair	In	6 Lock Points
D Mfr 6	enclosed	yes	yes	36" x 80"	no	L Mfr 5	M.P. ¹	no	yes	no	1 1/2 pair	In	6 Lock Points
D Mfr 7	enclosed	yes	yes	3' x 7'	no	L Mfr 6	3-point	no	yes	no	1 1/2 pair	In	
D Mfr 8	enclosed	yes	yes	3' x 7'	no	L Mfr 6	3-point	no	yes	no	1 1/2 pair	In	
D Mfr 9	partially enclosed	yes	yes	3' x 7' pair	Removable	L Mfr 6	3-point	yes	no	no	1 1/2 pair	Out	
D Mfr 9	partially enclosed	yes	yes	4' x 8' pair	Removable	L Mfr 6	3-point	yes	no	no	2 pair	Out	
D Mfr 2	partially enclosed	yes	yes	3' x 7'	no	L Mfr 6	3-point	yes	no	no	1 1/2 pair	Out	
D Mfr 2	partially enclosed	yes	yes	3' x 7' pair	Removable	L Mfr 7 ²	3-point	yes	no	no	1 1/2 pair	Out	16-gauge hollow metal frame
D Mfr 10	partially enclosed	yes	no	10' x 10'	no	L Mfr 8		no	no	no		N/A	Colling Overhead Door
D Mfr 3	partially enclosed	yes	yes	3' x 7'	no	L Mfr 9	3-point	yes	no	no	1 1/2 pair	Out	2.55 psi max. pressure
D Mfr 3	partially enclosed	yes	yes	3' x 7'	no	L Mfr 9	3-point	yes	no	no	1 1/2 pair	Out	5.00 psi max. pressure
D Mfr 4	partially enclosed	yes	yes	3' x 7'	no	L Mfr 3	M.P. ¹	yes	no	no	1 pair	Out	14 Lock Points, M. Security Frame
D Mfr 5	partially enclosed	yes	yes	3' x 7'	no	L Mfr 6	3-point	yes	no	no	1 1/2 pair	Out	
D Mfr 7	partially enclosed	yes	yes	3' x 7'	no	L Mfr 6	3-point	yes	no	no	1 1/2 pair	Out	
D Mfr 7	partially enclosed	yes	yes	3' x 7' pair	no	L Mfr 6	2-point	yes	no	no	1 1/2 pair	Out	
D Mfr 7	partially enclosed	yes	yes	3' x 7' pair	no	L Mfr 10	2-point	yes	no	no	1 1/2 pair	Out	Exit Only Hardware
D Mfr 7	partially enclosed	yes	yes	3' x 7' pair	Removable	L Mfr 6	3-point	yes	no	no	1 1/2 pair	Out	
W Mfr 3	partially enclosed	yes	no	40" x 60"		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Window - 5.00 psi pressure
W Mfr 3	partially enclosed	yes	no	36" x 36"		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Window - 5.00 psi pressure
W Mfr 3	partially enclosed	yes	no	40" x 60"		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Window - 9.50 psi pressure
W Mfr 3	partially enclosed	yes	no	36" x 36"		N/A	N/A	N/A	N/A	N/A	N/A	N/A	Window - 8.98 psi pressure
W Mfr 11	partially enclosed	yes	yes	100" x 88"	yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2-50"x44" openings, special glass and frame

Testing Details refer to: <http://www.wind.ttu.edu/Research/DebrisImpact/TestingLab.php>
 Except where noted, all door frames are 14-gauge hollow metal.

¹ Multi-point Locking Device

² Rim Type Exit Device