A Summary Report on

DEBRIS IMPACT RESISTANCE OF BUILDING ASSEMBLIES

Submitted to

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Windstorm Mitigation Initiative

A Compilation of Testing Performed by

The Wind Science and Engineering Research Center
Texas Tech University

&

Florida A & M University, Florida State University &
University of Florida

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The following report is a compilation of test reports written by the Wind Science and Engineering Research Center at Texas Tech University and by the Departments of Civil, Environmental and Coastal Engineering at Florida A&M, Florida State University and the University of Florida. The complete Florida report can be viewed on the internet at the following address:
http://floridadisaster.org/bpr/Response/engineers/library.htm.

Other debris impact data can be found in the *Enhanced Protection from Severe Wind Storms Report* produced by Clemson University (2000). This data is not included in the report due to differences Pass/Fail Criteria.

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ABSTRACT

Since the early 1970's, Texas Tech University has been deeply involved in wind engineering research conducted through the Institute for Disaster Research and the Wind Science and Engineering Research Center. Research has shown that in violent wind storms, hurricanes and tornadoes, windborne debris causes considerable damage to buildings and poses a threat to life, even to building occupants. Based upon field research, guidelines and standards have been developed for the protection of building envelopes and building occupants from windborne debris. Those guidelines and standards are included, in part, in FEMA Publications, the Florida Building Code, the Standard Building Code and the International Building Code. The following report is a compilation of studies conducted by Texas Tech University, Florida A&M University, Florida State University and the University of Florida.

The purpose of these studies was to investigate the performance of wall and roof assemblies when subjected to the impact of windborne debris. Due to the differences in speed between the types and classes of wind events, specific criteria were developed to simulate the results of such an impact event. Missile type, weights and speeds were developed that were unique to the storm type and classification. Wall and roof assemblies were constructed and tested for their performance when subjected the impacts. The results of both studies was the development of building assemblies, utilizing commonly available materials, that could resist the windborne debris propelled by a storm of specific type and speed.

INTRODUCTION

General

Tornadoes, tropical storms and hurricanes are natural disaster-causing phenomenon. There is a high probability of severe windstorms and tornadoes occurring any where in the United States east of the Rocky Mountains and tropical storms and hurricanes occurring along the Gulf and Atlantic Coast. Such severe storm events threaten approximately ¾ of the nation's building stock and population.

Experience with tornadoes and hurricanes in the U.S. and around the world have established the importance of windborne debris to the performance of buildings in windstorms. Compromising of the building envelope by windborne debris during a hurricane leads to major economic loss through damage to building content, possible failure of structural systems, and present a hazard to building occupants. Hence, it is important that the building design process address these important hurricane effects, which affect building performance

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The ferocity and devastation of killer tornadoes was illustrated in the Lubbock tornado of 1970 when 26 lives were lost; in the 1974 Super Outbreak in the upper Midwest when 300 people perished; and in the storm that struck Oklahoma and Kansas in 1999 in which 44 deaths were recorded. Extensive research work has been performed at the Texas Tech University (TTU) Wind Science and Engineering Research Center (WISE) and other places on the effect of windborne debris impact on the building envelope and it's components (McDonald 1985, 1988, 1990, 1999, Cook *et al* 1998, 1999, 2000). Based on this research, several national and regional building codes have adopted the TTU missile impact testing procedure (with modifications as deemed necessary) for establishing minimum debris resistance acceptance criteria of the external envelope for buildings (ASCE-7 2002, SBC 2000, FBC 2001). In 1998 FEMA published FEMA 320, *"Taking Shelter from the Storm,"* a prescriptive document that provided information for homeowners to assess their risk utilizing a severe wind map developed at Texas Tech and provided builder's plans for the construction of various types of shelters. The research and guidelines was further developed for larger shelters, and FEMA 361, *"Design and Construction Guidance for Community Shelters"* was released in 2000.

The TTU missile impact test procedure is designed to represent tornado wind speeds up to 250 mph. The TTU large missile test involves shooting 2 by 4 in. lumber weighing 15 lb at 100 mph horizontally. In concurrence with FEMA 361 and the included wind map impact protocols were further developed for the 200 mph, 160 mph and the 130 mph wind zones.

The importance of windborne debris protection to building performance in hurricanes became quite evident to experts involved in the building industry following the devastating effects of Hurricane Andrew in 1992. This hurricane created an enormous amount of windborne debris, which caused substantial damage to building envelopes. The

impact of Hurricane Andrew, the costliest hurricane in the U.S. (prior to Katrina 2005) prompted engineers and building officials to address issues concerning building design to account for enhanced turbulent wind pressures and debris carried by these winds. New requirements for design have been developed to ensure the integrity of the building envelope during a hurricane. One such requirement is the missile impact test, where the impact of windborne debris in a hurricane is simulated by launching a wooden 2x4 at glazed openings, exterior walls and the roof of a building. To comply with the test, the building's exterior must withstand the perpendicular impact of a wooden 2x4 striking at a designated velocity.

The recently adopted Florida Building Code (FBC) specifies that all parts of systems of a building envelope must meet the impact test criteria or be protected with a device satisfying the test criteria. According to the FBC and the International Building Code (IBC 2003), the Large Missile Impact Test is valid for assemblies and materials used up to 30 ft. in height. ASCE 7-02 specifies a maximum applicable height of 60 ft. for this test. In this test, entire assembled units are subjected to a 2 by 4 in. lumber weighing 9 lb impacting at a speed of 34 mph (equivalent to 50 ft/sec), representing hurricane conditions in Florida. The Division of Emergency Management (DEM) at the Florida Department of Community Affairs (DCA) is in the process of developing a comprehensive standard (NHC 2002) for NHC Category 5 hurricane resistant Emergency Operations Centers (EOC). Among various features, the survivable EOCs must be "*…Designed and built to survive the range of anticipated hazards and to function effectively…*" In the absence of such a standard, the Enhanced Hurricane Protection Areas (EHPA) guidelines from the FBC are being used for EOCs. The EOC buildings also must satisfy wind load provisions from the ASCE 7-98 specifications, and most importantly, windborne debris impact criteria from the Standard Building Code (SBC 2000), ASTM standard E-1996 (2004), ASTM standard E-1886 (2004), or TAS 201 (2001). The expected DCA EOC standard will be very useful in providing a comprehensive single source guideline. The EHPA guidelines state that wind and debris exposure can be supplied through the FBC criteria provided an enhanced wind speed of 40 mph above the code specified basic design wind speed is used. A draft EOC Survivability Performance Category table from DCA lists Performance Category 3 (from 0 – 4 scale) as "Hurricane Enhanced Protection", with missile impact resistance of a 2 by 4 in. 15 lb stud traveling at 50 mph.

Some other building standards for hazard design have incorporated more stringent missile impact criteria. For example, the U.S. Department of Energy (DOE) standard 1020 *Natural Phenomena Hazards Design and Evaluation Criteria for DOE Facilities* lists Performance Categories 1 – 4 (DOE 2002). For Categories 3 - 4 for essential facilities in this standard provides missile impact criteria as a 2 by 4 in. 15 lb plank traveling at 50 mph. The International Code Council (ICC 2006) Storm Shelter Standard Committee has proposed a draft (ICC/NSSA Standard for the Design & Construction of Storm Shelters) for large windborne debris impact criteria for hurricanes with design wind speeds between 160 and 220 mph (3-sec gust) that is based on an extreme wind map with a 10,000 year return period. The hurricane shelter projectile is a 2 by 4 in. 9 lb plank traveling at 0.40 times the design wind speed.

The University of Florida (UF) performed a number of large missile impact tests on various wall and roof assemblies (Braden 2004, Cook *et al* 1998, 1999, 2000, Ellifritt and Johnson 1998, Staley 1999, Anderson 1995), based on the FBC large missile impact standards. Since 1970, TTU has performed numerous missile impact tests on wall and roof assemblies that was primarily focused on tornadic missile criteria. Some testing using the enhanced missile impact criteria was conducted by TTU and UF. Additional testing was conducted to cover all the wind zones for tornadoes and hurricanes by TTU and is included in this compiled report.

Objectives

1. To prepare a comprehensive list of wall and roof assemblies that has been tested with the large missile.

2. To report additional testing conducted on assemblies constructed for wind zones not previously tested.

TEST PROGRAM

Performance Classifications and Expectations

Failure of a test assembly is defined in this section based on previous research and test standards, as previously described. Failure of a barrier or target may be defined in various ways, depending upon the intended application or use of the target. According to FBC (2001), penetration of the missile is the failure criteria. A wall or roof assembly passes the test, if it rejects the missile without penetration. Anderson (1995) performed large missile impact tests on metal-clad structures. It was observed that even if the missile did not penetrate or perforate the test panels, large openings in the seam between panels were developed in a few tests. These openings were of sufficient size to allow the wind to pass through. According to the FBC (2001), these test assemblies passed the large missile impact test although there was a possibility of wind passing through the assemblies. This does not meet the intent of the code, which is to prevent damaging wind from entering the building during a hurricane. FBC (2001) further states that any specimen that passes the large missile impact test needs to be tested for small missile impact test if the specimen has an opening that a 3/16 in. sphere can pass through. SSTD 12 (1999) and ASTM C-1996 (2004) provide an acceptance criterion, which may be used to overcome this deficiency in FBC (2001) standard. SSTD 12 (1999) and ASTM C-1996 (2004) state that porous test specimens must resist the large missile impact without penetration to pass the test. For non-porous specimens, these standards allow an opening with diameter less than 3 in.

The Florida study primarily followed the FBC (2001) large missile impact test acceptance criteria, which states that a specimen passes the test if it rejects the missile without any penetration. As this criterion is not clear, a few more conditions were added. The objective of the study was to provide a safe place for the occupants during a hurricane. Based on this objective, test acceptance criteria for the basic, enhanced-A and enhanced-B large missile impact tests were the same. The test criteria are provided in Table 1. The FEMA recommended 3 in. or more permanent deformation of the metal assembly was not utilized in Florida research, mainly due to two reasons. Firstly, FEMA recommendations were applicable to areas, which are susceptible to tornadoes, whereas, this research was applicable to hurricane-prone regions in Florida. Secondly, any deformation in the wall or roof assembly does not lead to the total failure of the structure, as it may happen in case of an opening in the assembly.

FEMA-361 (2002) developed a large missile impact test standard for tornado shelters or components based on the research performed at TTU (2002). In this standard, failure is defined as the behavior that might cause injury to occupants of a building. Perforation by the missile, scabbing of target material that would create debris, or large deformations of the target would constitute failure. But the definition of failure of a test assembly is not clear in the above statement. It does not mention the amount of scabbing material or deformation that may be considered as failure of the specimen. According to FEMA-361 (2002), permanent deformation of 3 in. or more after impact is deemed unacceptable.

Research related to the design of nuclear power facilities produced relatively large body of information and design guides for predicting the response of reinforced concrete walls and roofs to the impact of windborne debris. The failure modes were identified as penetration, threshold spalling, spalling, barrier perforation, and complete missile perforation (Twisdale and Dunn 1981). From a sheltering standpoint, penetration of the missile into, but not through, the wall surface is of no consequence unless it creates spalling, where concrete is ejected from the inside surface of the wall or roof. As the size of the spalling increases, so does the velocity with which it is ejected from the wall or roof surface. When spalling occurs, physical injury and death to people directly behind the impact point are possible. In barrier penetration, a hole occurs in the wall, but the missile still bounces off the wall or becomes stuck in the hole. A plug of concrete about the size of the missile is knocked into the room and may injure or kill occupants. Complete missile perforation may cause injury or death to people hit by the primary missile or wall fragments. So, failure criteria for reinforced concrete barriers should be the spalling of concrete.

Testing Method

Significance of the Test: The basic large hurricane missile impact test may not be sufficient for EOCs, schools and light commercial buildings. To provide "Hurricane Enhanced Protection" to the EOCs or according to DCA, schools and other commercial buildings, enhanced large missile impact test needs to be performed. The enhanced impact is termed as enhanced-A in this study. In the present study, both the basic and enhanced-A tests were performed. The basic test was performed according to the TAS 201-94, Impact Test Procedures, described in FBC (2001). The missile test criteria for the basic and enhanced-A tests were FBC specified 2x4 in. 9 lb missile at 34 mph and DOE specified 2x4 in. 15 lb missile at 50 mph, respectively. For the enhanced-B test, a 2x4 in. 15 lb missile was impacted at a speed of 60 mph. The missile test criteria for basic, enhanced-A and enhanced-B tests are given in Table 1. The missile impact test procedure provides a means of determining whether a particular wall, roof, exterior window, exterior door and any other similar device used as external protection to maintain the envelope of the building, provides sufficient resistance to windborne debris. The tornado and hurricane shelter impact standards were developed for life safety. The missile test criteria for these standards are shown in Table 1.

Table 1: Large Missile Impact Test Criteria

Tests	Missile	Missile Size (lb)	Missile Speed (mph)
Basic Hurricane	2x4 in. wood stud	9	34
Hurricane Enhanced-A	2x4 in. wood stud	15	50
Hurricane Enhanced-B	2x4 in. wood stud	15	60
Tornado	2x4 in. wood stud	15	100
Hurricane Shelter	2x4 in. wood stud	9	0.40 x wind zone speed

Large Missile Cannon: The large missile cannon at both TTU and UF used compressed air to propel a large missile at the test specimen at standard testing speeds in accordance with FBC (2001) TAS 201-94 Impact Test Procedures and DOE Standard 1020 (1994) and the FEMA 320/361 guidelines. The major components of the missile cannon include the following:

1. Compressed air supply
2. Pressure release mechanism
3. Pressure gage
4. Barrel and frame
5. Timing system
6. Data Acquisition System

Missile: Each missile was constructed using surface dry Southern Pine 2x4 in. boards. The missiles were sized such that the weight was between 9 and 9 1/2 lb with a length between 7 and 9 ft. or with a weight between 15 and 15 1/2 lb. and a length between 11 and 13 ft. in accordance with FEMA-361 (2002). Missiles were chosen such that no knots appeared within 12 in. of the leading edge. The trailing edge of each missile was affixed with a plastic sabot to facilitate launching. This connection was accomplished by using a 3 in. long, 5/8 in. diameter screw. The sabot's weight did not exceed 1/2 lb.

Test Specimens: Specimen sizes ranged from 4 ft. x 4 ft. panels to 9 ft. x 10 ft. panels. The size differences was a function of standard material dimensions, stud spacing and reinforcing spacing that was being studied. All specimens were mounted and clamped to a rigid load frame capable of resisting the impacts without rebound.

APPENDIX A

PREVIOUS LARGE MISSILE IMPACT TESTS PERFORMED ON WALL AND ROOF ASSEMBLIES

Tests Performed on Wall/Roof Assemblies

Large missile impact tests performed at TTU (1973-2006), UF (Cook *et al* 1998, 1999, 2000, Ellifritt and Johnson 1998, Staley 1999, Anderson 1995), Miami-Dade Building Code Compliance Office (2003) and Florida Department of Education (2003) are listed in this appendix. They are summarized as follows:

• *Basic large missile impact test on wall/roof assemblies*
(a) Wall/roof assemblies passing previous basic large missile impact tests (Table A.1)
(b) Wall/roof assemblies failing previous basic large missile impact tests (Table A.2)

• *Enhanced large missile impact test on wall/roof assemblies*
(c) Wall/roof assemblies passing previous enhanced large missile impact tests (Table A.3)
(d) Wall/roof assemblies failing previous enhanced large missile impact tests (Table A.4)

• *Non-standard large missile impact test on wall/roof assemblies*
(e) Wall/roof assemblies passing previous large missile impact tests for various missile sizes and speeds (Table A.5)
(f) Wall/roof assemblies failing previous large missile impact tests for various missile sizes and speeds (Table A.6). The following information is provided for each wall and roof section: type of wall/roof systems, source of the test, and description of the wall/roof construction, test missile size and speed, and description of damage.

• L*arge missile impact test on wall/roof assemblies for hurricane shelters.*
(a) Wall/roof assemblies passing previous basic large missile impact tests (Table A.7)

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph)

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
1	CMU (Wall)	UF	6 in. ASTM C-90 single-wythe CMU wall, Width: 6 ft. Reinforcement: #5 bar @ 5 ft. 4 in. o.c., 2x4 in. joists @ 24 in. o.c.	> 34	Impact point at the center of the wall. No penetration or perforation. Punch-out of the front face. Slight horizontal cracking on the back face. Mortar joint cracking along the bottom and side of the block.
				> 34	Impact point near the right support. Punch-out of the front face and vertical cracking between the point of impact and the edge of the support. back face was unable to withstand the impact.
				> 34	Impact point near the left support (mortar joint). No penetration or perforation. Punch-out of the front face with the removed portion remaining intact. Back face experienced vertical cracking along the web and along the joints on both sides of the block.
2	CMU (Wall)	UF	8 in. ASTM C-90 single-wythe CMU wall, Width: 6 ft. 8 in. Reinforcement: #5 bar @ 6 ft. o.c., 2x4 joists @ 24 in. o.c.	> 34	Impact point at the center of the wall. No penetration or perforation. Complete punch-out of the front face. Slight joint cracking on the back face.
				> 34	Impact point near the right support. No penetration or perforation. Punch-out of the front face with the removed portion remaining intact. The back face experienced vertical cracking along the web and horizontal cracking along the joints above and below the block.

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
2 (contd.)	CMU (Wall)	UF	8 in. ASTM C-90 single-wythe CMU wall, Width: 6 ft. 8 in. Reinforcement: #5 bar @ 6 ft.o.c., 2x4 in. joists @ 24 in. o.c.	> 34	Impact point near the left support (mortar joint). No penetration or perforation. Punch-out of the front face with the removed portion remaining intact. Back face experienced extensive vertical cracking along the web and horizontal cracking along the joints above and below the block.
3	Metal (Roof)	UF	Galvanized 24 ga. roof panel clip allows for roof expansion and contraction. The panel seams are locked into place with a snap-on batten strip with a factory applied sealant. Panel size: 3 panels, 24 in. x 20 ft. Girts: Z 8.25, 0.071 in. thick	35.4	Impact point at the center. No penetration or perforation. Seam opening: none
				34.5	Impact point near the seam. No penetration or perforation. Seam opening: right (1/4 in. max x 5 in.)
				34.3	Impact point near the seam. No penetration or perforation. Seam opening: left (1/8 in. max x 1/8 in.)
4	Metal (Roof)	UF	22 ga. painted metal panel with standing seam, mechanical seam, Panel size: 4 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick, @ 3 ft. o.c. (vertically spaced)	35.1	Impact point at the center. No penetration or perforation. Seam opening: none
				35.1	Impact point near the seam. No penetration or perforation. Seam opening: none
				34.3	Impact point near the seam. No penetration or perforation. Seam opening: none

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
5	Metal (Roof)	UF	22 ga. standard 1.5 in. wide-rib steel (galvanized, 33 ksi) deck, Ribs spaced at 6 in. o.c., Girts: Z 8.25 @ 5 ft.	35.4	Impact point at the center of the panel. No penetration or perforation.
				35.1	Impact point at 6 in. from the support. No penetration or perforation.
				36.2	Impact point at the center of the panel. No penetration or perforation.
				36.2	Impact point at 6 in. from the support. No penetration or perforation.
6	Hollow Core Slab (Roof)	UF	Company A: 6 in. hollow core grouted slab	34.6	Impact point at the center of the slab. No damage.
				33.3	Impact point at the bottom of the support. Cracked corner off.
				33.6	Impact point at the mid-height of the support. Crack entire length front/back.
				33.1	Impact point at the top of the support. Crack from impact to edge.
				34.7	Impact point at the top-center of the slab. Knocked chunk off slab.
				33.4	Impact point at the bottom-center of the slab. No damage.
				42	Impact point at the grouted edge of the support. No damage.
				34.1	Impact point at the grouted edge of the support. No damage.

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
7	Hollow Core Slab (Roof)	UF	Company A: 8 in. hollow core grouted slab	34.5	Impact at the center of slab. No damage.
				33.5	Impact point at the bottom of the support. No damage.
				31.9	Impact point at the bottom-center of the slab. No damage.
				33.3	Impact point near the support. Cracked 1/4 of span through core.
8	Hollow Core Slab (Roof)	UF	Company A: 10 in. hollow core grouted slab	34.5	Impact point at the center of the slab. No damage.
				34.8	Impact point at the bottom of the support. Slight crack visible near edge.
				34.7	Impact point at the bottom-center of the slab. No damage.
				34.6	Impact point near the support. Cracked 1/4 of span out edge.
9	Hollow Core Slab (Roof)	UF	Company B: 6 in. hollow core slab	34.5	Impact point at the center of the slab. No damage.
				34.1	Impact point at the bottom of the support. No damage.
				33.6	Impact point at the bottom-center of the slab. No damage.
10	Hollow Core Slab (Roof)	UF	Company B: 8 in. hollow core slab	34.5	Impact point at the center of the slab. No damage.
				34.6	Impact point at the top of the support. No damage.
11	Hollow Core Slab (Roof)	UF	Company B: 10 in. hollow core slab	36.4	Impact point at the center of the slab. No damage.
				35.4	Impact point at the top of the support. No damage.

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
12	Hollow Core Slab (Roof)	UF	Company C: 6 in. hollow core slab	34.6	Impact at the center of slab. No damage.
				34.5	Impact point at the top of the support. No damage.
13	Hollow Core Slab (Roof)	UF	Company C: 8 in. hollow core slab	33.6	Impact point at the center of the slab. No damage.
				34.1	Impact point at the top of the support. No damage.
14	Hollow Core Slab (Roof)	UF	Company C: 10 in. hollow core slab	34.5	Impact point at the top of the support. No damage.
				34.5	Impact point at the center of the slab. No damage.
15	Hollow Core Slab (Roof)	UF	Company C: 12 in. hollow core slab	35.4	Impact point at the center of the slab. No damage.
				36.4	Impact point at the top of the support. No damage.
16	Metal (Wall/Roof)	UF	Galvanized 24 ga. rolled-form panel with structural ribs on 12 in. in. apart were used on the overlap seams. Panel size: 3 panels, 36 in. x 20 ft. Girts: Z 8.25, 0.071 in. thick centers. Sidelap screws spaced 12 in. on center.	34	Impact point at the center. No penetration or perforation. Seam opening: none
				34.8	Impact point on the seam. No penetration or perforation. Seam opening: none
				34.1	Impact point near the seam. No penetration or perforation. Seam opening: none
				35.1	Impact point near the seam. No penetration or perforation. Seam opening: 1/4 in. max x 2-1/2 in. max

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
17	Metal (Wall/Roof)	UF	24 ga. sheet metal (50 ksi) Girts: Z 8.25, 5 ft. spacing	37	No penetration or perforation. 1 in. tear.
				35	No penetration or perforation. 1.5 in. tear.
				34.8	No penetration or perforation. 9.5 in. tear.
				34.2	No penetration or perforation.
				35	No penetration or perforation.
				34	No penetration or perforation. 7.5 in. tear.
				36	No penetration or perforation.
				35.4	No penetration or perforation.
18	Metal (Wall/Roof)	UF	26 ga. sheet metal (50 ksi) Girts: Z 8.25, 5 ft. spacing	34.8	No penetration or perforation.
				Not available	No penetration or perforation.
				33.8	No penetration or perforation.
				33.6	No penetration or perforation.
				34.5	No penetration or perforation.
				33.6	No penetration or perforation.
				Not available	No penetration or perforation.
				35	No penetration or perforation. 8 in. tear.
19	Metal (Wall/Roof)	UF	26 ga. sheet metal (80 ksi) Girts: Z 8.25, 5 ft. spacing	35.4	No penetration or perforation.
				35.1	No penetration or perforation.
				34.3	No penetration or perforation > 30 in. tear
				Not available	No penetration or perforation.
				32.5	No penetration or perforation.
				33.5	No penetration or perforation.
				33	No penetration or perforation.
				Not available	No penetration or perforation.
				34.0	No penetration or perforation. 21 in. tear.

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
20	Metal (Wall/Roof)	UF	24 ga. standing seam panel (0.0228 in. thick, 55 ksi) Girts: Z 8.25, 6 ft. spacing	35.9	Impact point at 12 in. above the girt. No penetration or perforation.
				N/A	Impact point at 10 in. above the girt. No penetration or perforation.
				35.9	Impact point at the center of the panel. No penetration or perforation.
21	Metal (Wall/Roof)	UF	26 ga. standard panel (0.018 in. thick, 55 ksi) Girts: Z 8.25, 6 ft. spacing	35.1	Impact point at 4 in. above the girt. No penetration or perforation.
				34.5	Impact point at the center of the panel. No penetration or perforation.
22	Metal (Wall/Roof)	UF	1.5 in. deep, 2.5 in. wide ribs spaced @ 6 in. o.c., 22 ga. steel roof deck, 10-ft span of deck sidelaped with #10 TEK screws spaced at 12 in. o.c. along the length of the span, K24 bar joists spaced at 5 ft. o.c.	> 34	Impact point at the center of the panel. No penetration or perforation.
				> 34	Impact point at 6 in. from the support. No penetration or perforation.
23	Metal (Wall/Roof)	UF	1.5 in. deep, 2.5 in. wide ribs spaced @ 6 in. o.c., 18 ga. steel roof deck, 10-ft span of deck sidelaped with #10 TEK screws spaced at 12 in. o.c. along the length of the span, K24 bar joists spaced at 5 ft. o.c.	> 34	Impact point at the center of the panel. No penetration or perforation.
				> 34	Impact point at 6 in. from the support. No penetration or perforation.
				> 34	Impact point at the supported edge of the panel. No penetration or perforation.
24	Stud walls with plywood (Wall)	TTU	2 layers of 3/4 in. CD grade plywood mounted with 3 in. #8 wood deck screws at 6 in. on center to the double stud 4x4 ft frame.	< 41	The missiles repercussed.
				41-44	Threshold was observed
				> 44	The missile perforated the barrier (failure).

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
25	Wood/Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Hardipanel siding Interior: 5/8 in. plywood sheathing Vertical support: 2x4 in. wood studs or 3-5/8x1-3/8 in. steel studs @ 16 in. (max.) o.c.	Not available	Not available
26	Wood/Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Various layers of Dryvit products, Interior: 1/2 in. gypsum sheathing and 1/2 in. dens-glass gold, Vertical support: 3-5/8 in.x1-3/8 in.x18 ga. steel studs @ 16″ o.c.	Not available	Not available
27	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 24 ga. 0.0225 in. (min.) structural galvanized steel (11/2x36 in.) with horizontal girts	Not available	Not available
28	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Grade 50, G90 galvanized steel with 0.031 in. min. thickness, Interior: Grade 50, G90 galvanized steel with 0.030 in. min. thickness, Core material: urathane foam	Not available	Not available
29	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 3/16 in. natural stone veneer epoxy, vertical support: 16 ga. steel studs @ 24 in. o.c. (max.), channel @ 22-1/2 in. o.c.	Not available	Not available
30	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 0.04 thick aluminum panel Interior: 0.035 thick aluminum panel G90 steel, Vertical support: 2x2 in. steel wall studs @ 22 in. o.c., 2 in. thick polystyrene insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
31	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 0.024 in. thick steel panel (50 Grade), support: Min. 16 ga. (0.056″) Z girt @ 5 ft. o.c. (max.)	Not available	Not available
32	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Vee Rib structural metal siding (24 ga., Grade 50, min. thickness 0.025 in.) support: Z girt @ 2 ft. up to 4 ft.	Not available	Not available
33	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Style rib 20 ga. Metal panel support: JW studs: 8 in.x12 ga. (0.1004 in. thick)	Not available	Not available
34	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 0.026 in. (min.) thick Rib-12 structural panel (Grade 80), support: Z girt @ 4 ft. 10 in. o.c.	Not available	Not available
35	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 24 ga. (min. thickness 0.024 in., Grade 50) Florida Rib Panel, support: Stringers (min. 16 ga., Grade 50)	Not available	Not available
36	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 0.024 in. thick steel panel support: Z girt @ 4 ft. o.c.	Not available	Not available
37	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 0.026 in. (min.) thick galvalume steel wall panel with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
38	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 24 ga. Structural Galvalume Steel (1-1/4 x 36 in. Kirby Rib) Wall Panel, Vertical support: 8″ Z 12 ga. @ 4 ft. 10 in., Horizontal support: 9x5 in. C 12 ga. @ 8 ft.	Not available	Not available
39	Metal/Wood (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: Pro-panel II profile, 26 ga. (min.) Grade 50 steel, Interior: 5/8 in. thick CDX grade plywood, support: Girts: 2 x wood member, #2 SP, Studs: 2 x wood member, #2 SP	Not available	Not available
40	Metal (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 26 ga. (thickness 0.018 in.) steel panel, Interior: 26 ga. (thickness 0.018 in.) steel panel, support: Girts: min 14 ga. @ 4 ft. o.c., Urethane core (3 in.).	Not available	Not available
41	Concrete (Wall)	Information obtained from Miami Dade Building Code Compliance Office	3-D welded wire space frame integrated with a polystyrene insulation core. Wythes of concrete or mortar are applied to both sides.	Not available	Not available
42	Glass Fiber Reinforced Concrete (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: 3/4 in. (min. thickness) GFRC panel, support: Min. 4x0.056 in. thick (Grade 50) studs @ 18 in. (max.) and steel bridging at max. 48 in. o.c. (min. 0.056 in. thick)	Not available	Not available
43	Fiber Reinforced Concrete (Wall)	Information obtained from Miami Dade Building Code Compliance Office	Exterior: DuroCrete veneer, support: steel studs	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
44	Wood (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 19/32 in. or greater plywood or wood plank	Not available	Not available
45	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: "Superlock 16" 22 ga. Standing Seam Metal Roof Panel, support: purlin	Not available	Not available
46	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: "Superlok 16" 0.024 in. Structural Galvalume Coated Steel Standing Seam Roof Panel, support: purlin	Not available	Not available
47	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.026 in. (min.) Structural Galvalume Steel "Rib-12" Roof Panel, support: purlin	Not available	Not available
48	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: "Rib Roof" Structural Standing Seam Roof Panel	Not available	Not available
49	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.030 in. (min) Structural Loc-Seam 360 Galvalume Steel Roof Panel, support: purlin	Not available	Not available
50	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.0248 in. (min) SS-360 Structural Metal Roof Panel, support: purlin	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
51	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.03 in. (min) Structural Standing Seam 360 Steel Roof Panel (22 ga.), support: purlin	Not available	Not available
52	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 24 ga. Kirby Rib II Roof Panel, support: purlin	Not available	Not available
53	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.042 in. Structural Galvanized Steel Roof Panels, support: purlin	Not available	Not available
54	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.024 in. (min) Galvanized Steel "Dyna-Rib" Roof Panel, support: purlin	Not available	Not available
55	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.0325 in. (min) Structural Galvalume Coated Standing Seam Steel Roof panel, support: purlin	Not available	Not available
56	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.026 in. Galvalume Steel Roof Panel System, support: purlin	Not available	Not available
57	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 24 ga. (min. thickness 0.024 in.) Structural Steel Roof Panel, support: purlin	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
58	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: 0.026 in. (min) UC-5 Structural Standing Seam Roof Panel	Not available	Not available
59	Steel (Roof)	Information obtained from Miami Dade Building Code Compliance Office	Deck: Super Span 24 ga. (0.024 in. min. thickness) Steel Roof Panel	Not available	Not available
60	Concrete	FBC (2001)	Min. 4 in. thick precast concrete deck	Not available	Not available
61	Prestressed Concrete	FBC (2001)	Min. 4 in. thick precast prestressed concrete deck	Not available	Not available
62	Metal (Roof)	Florida Department of Education, Testing by: Architectural Testing Inc., York, PA	Deck: Min. 24 ga steel or concrete Membrane: Min. 45 mil Carlisle non-reinforced, reinforced, or fleeceback EPDM, Insulation: Polyisocyanurate (16 psi), min. total thickness 1 in.	Not available	Not available
63	Metal (Roof)	Florida Department of Education, Testing by: Architectural Testing Inc., York, PA	Deck: Min. 24 ga steel or concrete Membrane: Min. 45 mil Carlisle reinforced or fleeseback TPO, Insulation: Polyisocyanurate (16 psi), min. total thickness 1 in.	Not available	Not available
64	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., type B, Grade 33 galv. Steel deck, over supports @ 5 ft. o.c., Membrane: Fiber Tite, Insulation: Two layers, min. 1.5 in. thick ASTM C-1289 Type 2 polyisocyanurate	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
65	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., type B, Grade 33 galv. Steel deck, over supports @ 5 ft. o.c., Membrane: Fiber Tite, XT, Insulation: Two layers, min. 1.5 in. thick ASTM C-1289 Type 2 polyisocyanurate	Not available	Not available
66	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., type B, Grade 33 galv. Steel deck, over supports @ 5 ft. o.c., Membrane: Fiber Tite, Xtreme, Insulation: Two layers, min. 1.5 in. thick ASTM C-1289 Type 2 polyisocyanurate	Not available	Not available
67	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., type B, Grade 33 galv. Steel deck, over supports @ 5 ft. o.c., Membrane: Fiber Tite, Xtreme, Coverboard: 1/4 in. thick Dens-Deck, Insulation: Two layers, min. 1.5 in. thick ASTM C-1289 Type 2 polyisocyanurate	Not available	Not available
68	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 1-1/2 in. deep, 22 ga Type B metal deck, galvanized, Membrane: Fiber Tite FB 45 mil , Insulation: 2 in. Elastizell lightweight insulating concrete (200 psi min.), over 3-1/2 in. Apache Holey Board	Not available	Not available
69	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B, Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Surnfil 10-S327, 80 mil thick (5/8 in. thick Dens-Deck) Insulation: One layer, 1.5 in. thick polyisocyanurate, AC Foam 2	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
70	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B, Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Surnfil 10-S327, 80 mil thick (1/2 in. thick High-Density Wood Fiberboard), Insulation: One layer, 1.5 in. thick polyisocyanurate, AC Foam 2	Not available	Not available
71	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B, Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Surnfil 6-S327, 60 mil thick (5/8 in. thick Dens-Deck), Insulation: One layer, 1.5 in. thick polyisocyanurate, AC Foam 2	Not available	Not available
72	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B, Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Surnfil 6-S327, 60 mil thick (1/2 in. thick High-Density Wood Fiberboard), Insulation: One layer, 1.5 in. thick polyisocyanurate, AC Foam 2	Not available	Not available
73	Metal/Concrete (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: Galvanized 22 ga. Type B steel or concrete, Membrane: Stevens EP minimum 45 mil, Insulation: Two layers of 1.5 in. ASTM C-1289 type 2 polyisocyanurate	Not available	Not available
74	Metal/Concrete (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: Galvanized 22 ga. Type B steel or concrete, Membrane: Stevens EV minimum 45 mil, Insulation: Two layers of 1.5 in. ASTM C-1289 type 2 polyisocyanurate	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
75	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga. Type B, profiled steel over supports @ 5 ft. o.c., Membrane: Tripolymer FB, Insulation: One layer, 1.5 in. thick polyisocyanurate, ASTM C-1289, Type II	Not available	Not available
76	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga. Type B, profiled steel over supports @ 5 ft. o.c., Membrane: Tripolymer FB, Insulation: 200 psi cellular lightweight concrete cast with ¼ in. slurry coat over steel deck followed by (optional) 1 in. Apache Holey Board and a 2 in. min. top coat	Not available	Not available
77	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 1-1/2 in. deep, 22 ga. corrugated metal deck, galvanized, Membrane: Layer #75 nailed base sheet, layer of polyster reinforced SBS modified bitumen (min. 0.16 in. thick) set in hot asphalt, Insulation: 2 in. Celcore cellular concrete over min. 1 in. thick celcore EPS Holey Board	Not available	Not available
78	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 1-1/2 in. deep, 22 ga., Type B metal deck, Membrane: GAF membrane, Insulation: 2 in. Elastizell lightweight insulating concrete (200 psi min.)	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
79	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 1-1/2 in. deep, 22 ga., Type B metal deck, Membrane: layers of Manville Dyna base sheet, Insulation: 2 in. Elastizell lightweight insulating concrete (200 psi min.)	Not available	Not available
80	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Johns Manville Dynalastic 180 set, 180 FR, or 250 FR set in hot asphalt, Insulation: 3/4 in. Fesco Board or Dura Board adhered in hot asphalt	Not available	Not available
81	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: Johns Manville DynaGrip cap FR, over Johns Manville DynaGrip base, Insulation: Min 1.5 in. Nailboard	Not available	Not available
82	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 22 ga., Type B Grade 33 profiled steel over supports @ 5 ft. o.c., Membrane: layers of Johns Manville Dynalastic mat., Insulation: Min 1.5 in. Nailboard	Not available	Not available
83	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 1-1/2 in. deep, 22 ga. corrugated metal deck, galvanized, Membrane: Siplast: Parabase, P30HT FR Granulated Cap sheet, Insulation: 2 in. ZIC concrete over 3-1/2 in. Insultperm board	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
84	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 15/16 in. deep, 24 ga. corrugated metal deck, galvanized Membrane: 2 layers of 250 gram polyster reinforced modified bitumen, Board: 3 layers of 1/2 in. Loadmaster Duraflex mineral board	Not available	Not available
85	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 15/16 in. deep, 24 ga. corrugated metal deck, galvanized Membrane: 2 layers of 250 gram polyster reinforced modified bitumen, Board: 3 layers of 1/2 in. Loadmaster Duraflex mineral board, with insulation	Not available	Not available
86	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	Deck: 15/16 in. deep, 24 ga. corrugated metal deck, galvanized Membrane: 1 layer 250 gram, 1 layer 180 gram polyster reinforced modified bitumen, Board: 3 layers of ½ in. Loadmaster Duraflex mineral board, with insulation	Not available	Not available
87	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade C profiled steel deck, over supports @ 5 ft. o.c., Base sheet: Soprafix (X), Top sheet: Sopralene Flam, Insulation: Min. 1.5 in. thick polyisocyanurate	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
88	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: ASTM D4601, type 2, Ply sheet: Sopreme cap membrane Top sheet: same as Ply sheet, with Insulation	Not available	Not available
89	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: ASTM D4601, type 2, Ply sheet: Two or more plies of ASTM D2178, Type 4 or Type 6 ply sheet applied in hot asphalt Top sheet: Sopreme cap membrane, with insulation	Not available	Not available
90	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S, F, H or X), Top sheet: Sopreme cap membrane, with insulation	Not available	Not available
91	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S, F, H or X), Top sheet: Sopralene Flam 350 GR or FR GR, with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
92	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S, F or X), Top sheet: Sopralene Flam 250 or 350 GR or FR GR, with insulation	Not available	Not available
93	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S, F or X), with either 190 or 180 g/m $_2$ mat, Top sheet: Sopralene Flam 250 or 350 GR or FR GR, with insulation	Not available	Not available
94	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S, F or X), with either 190 or 180 g/m $_2$ mat, Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available
95	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (X), Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
96	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S or F), with either 190 or 180 g/m ^{2} mat, Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available
97	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet optional, Ply sheet: Elastophene 180 sanded; Sopralene 180, 250 or 350, Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available
98	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet optional, Ply sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available
99	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Soprafix (S or F), Ply sheet: Sopralene Flam 180, 250 or 350, Top sheet: Sopralene Flam 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
100	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet optional, Ply sheet: Sopralene 250 or 350, Top sheet: Sopralene Flam 250 or 350 GR or FR GR, with insulation	Not available	Not available
101	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Sopralene 180, 250 or 350, Ply sheet: Elastophene 180 sanded; Sopralene 180, 250 or 350, Top sheet: Sopralene 180, 250 or 350 GR or FR GR, with insulation	Not available	Not available
102	Metal (Roof)	Florida Department of Education, Testing by: Exterior Research and Design, Seattle, WA	Deck: 1-1/2 in. deep, 22 ga., Type B, Grade 33 profiled steel deck, over supports @ 4 ft. o.c., Base sheet: Sopralene Flam 180, 250 or 350, Ply sheet: Sopralene Flam 180, 250 or 350, Top sheet: Sopralene Flam 180, 250 or 350, with insulation	Not available	Not available
103	Metal (Roof)	Florida Department of Education, Testing by: Architectural Testing Inc., York, PA	15/16 in. x 25 ga. Corrugated metal Metal paneling: 0.032 in. x 16 in. (24 ga.) Zip-rib panel by Merchant and Evans, Underlayment: 40 mil Duraclad, Board: 1 layer of ½ in. Loadmaster Duraflex mineral board, with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
104	Metal (Roof)	Florida Department of Education, Testing by: Hurricane Test Laboratory, Riviera Beach, FL	LOC-seam 360 panels, 24 ga. steel (0.241) with 2 in. high seams at 16 in. o.c., Metal paneling: SS-360 panels, 24 ga steel with 3/32 in. high ribs at 5/16 in. o.c., Supports: 0.06 in. Z-shape, 8 in. deep, 2.5 in. flanges at 60 in. o.c.	Not available	Not available
105	Metal (Roof)	Florida Department of Education, Testing by: Architectural Testing Inc., York, PA	1-15/32 in. deep, 0.030 in. thick, Type BR-28 corrugated metal deck, Membrane: Morin steel roof paneling 2-1/2 in. deep, 0.026 in. to 0.027 in. thick, with insulation	Not available	Not available
106	Metal (Roof)	Florida Department of Education, Testing by: Farabaugh Engineering and Testing, Inc., Turtle Creek, PA	MBCI Superlock, 24 ga. steel (0.023 in.) with 2 in. high seam at 16 in. o.c., Support: 16 ga structural member @ 5 ft. o.c.	Not available	Not available
107	Metal (Roof)	Florida Department of Education, Testing by: Farabaugh Engineering and Testing, Inc., Turtle Creek, PA	MBCI Superlock, 24 ga. steel (0.023 in.) with 2 in. high seam at 16 in. o.c., Support: 16 ga structural member @ 5 ft. o.c., with insulation	Not available	Not available
108	Metal (Roof)	Florida Department of Education, Testing by: Farabaugh Engineering and Testing, Inc., Turtle Creek, PA	MBCI R-Panel Standing Seam Roof Panel 36 in. wide, 24 ga. (0.023) with Superlock, 24 ga steel (0.023 in.) with 2 in. high seam at 16 in. o.c., Support: 16 ga structural member @ 5 ft. o.c., with insulation	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
109	Metal (Roof)	Florida Department of Education, Testing by: Farabaugh Engineering and Testing, Inc., Turtle Creek, PA	1-1/2 in. x 22 ga. B-Deck Metal paneling: MBCI Superlock, 24 ga. steel (0.023 in.) at 16 in. o.c., with insulation	Not available	Not available
110	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	BEMO, USA 400 16 in. x 0.032 aluminum roofing panel system Support: 22 ga. x 50 ksi in. B in. profile steel deck, with insulation	Not available	Not available
111	Metal (Roof)	Florida Department of Education, Testing by: Certified Testing Laboratories, Orlando, FL	BEMO, USA 400 16 in. x 0.024 aluminum roofing panel system, Support: 14 ga. Z purlins @ 4 ft. oc over steel joist	Not available	Not available
112	Metal (Roof)	Florida Department of Education, Testing by: Hurricane Test Laboratory, Riviera Beach, FL	Berridge "S" metal deck, 7/8 in. deep x 24 ga., Metal paneling: Berridge Double-Locked Z-Lock, 24 ga. Purlins: 8 in. x 2-1/2 in., 16 ga. channel @ 4 ft. oc, with insulation	Not available	Not available
113	Metal (Roof)	Obtained from Florida Department of Education	Exterior: SUMTECH International, 22 ga., G-90 galvanized steel Interior: 26 ga., G-90 galvanized steel, with insulation	Not available	Not available
114	Metal (Roof)	Florida Department of Education, Testing by: Force Engineering & Testing, Inc., Humble, TX	UNACLAD/Copper Sales, Inc. 22 ga. steel UC5 Batten Seam, Support: 16 ga. steel purlins	Not available	Not available

Table A.1: Wall/Roof Assemblies Passing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
115	Metal (Roof)	Florida Department of Education, Testing by: Force Engineering & Testing, Inc., Humble, TX	UNACLAD/Copper Sales, Inc. 22 ga. steel UC6 Batten Seam, Support: 16 ga. steel purlins	Not available	Not available
116	Metal (Roof)	Florida Department of Education, Testing by: Farabaugh Engineering and Testing, Inc., Turtle Creek, PA	Whirlwind Weather Lok-16, 24 ga. steel (0.023) with 2 in. high seam @ 16 in. o.c., Support: 16 ga. Structural members @ 5 ft.-2 in. o.c.	Not available	Not available

Table A.2: Wall/Roof Assemblies Failing Previous Basic Large Missile Impact Tests (2x4 in. 9 lb missile @ 34 mph)

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
1	Metal (Wall/Roof)	UF	24 ga. sheet metal (80 ksi)	34.5	No penetration or perforation.
				35.7	No penetration or perforation.
				35	No penetration or perforation.
				36.8	No penetration or perforation.
				36	No penetration or perforation.
				33.5	No penetration or perforation.
				34.3	No penetration or perforation.
				Not available	No penetration or perforation.
				36.7	The missile penetrated the barrier.

Table A.3: Wall/Roof Assemblies Passing Previous Enhanced Large Missile Impact Tests (2x4 in. 15 lb missile @ 50 mph)

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
1	Metal	UF	20 ga. galvanized metal panel with standing seam, manual seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.085 in. thick, @ 3 ft. o.c. (vertically placed)	> 50	Impact point at the center of the middle panel. No penetration or perforation. Seam opening: right (1/4 in. max x 2 in.)
2	Metal	UF	20 ga. galvanized metal panel with standing seam, manual seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick, @ 3 ft. o.c. (vertically placed)	57	Impact point on the seam. No penetration or perforation. Seam opening: none
3	Metal	UF	20 ga. galvanized metal panel with standing seam, manual seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.058 in. thick, @ 3 ft. o.c. (vertically placed)	51.3	Impact point near the seam. No penetration or perforation. Seam opening: none
4	Metal	UF	20 ga. galvanized metal panel with standing seam, mechanical seam, Panel size: 4 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick, @ 3 ft. o.c. (vertically placed)	56.4	Impact point at the center (middle right). No penetration or perforation. Seam opening: none
				55.5	Impact point near the seam. No penetration or perforation. Seam opening: right (1/4 in. max x 2 in.)
5	Metal	UF	22 ga. painted metal panel with standing seam, manual seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.058 in. thick, @ 3 ft. o.c. (vertically placed)	48.7	Impact point at the center. No penetration or perforation. Seam opening: left (1 1/2 in. max x 1 1/2 in.)
				51.7	Impact point at the center. No penetration or perforation. Seam opening: right (1/2 in. max x 6 in.) and left (1 in. max x 8 in.)
6	Metal	UF	A composite section using a rubber energy absorbing material (EAM) sandwich between gal. 20 ga. and gal. 26 ga. floating panels, Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.058 in. thick, @ 3 ft. o.c. (vertically placed)	52.1	Impact point at the center. No penetration or perforation. Seam opening: none

Table A.3: Wall/Roof Assemblies Passing Previous Enhanced Large Missile Impact Tests (2x4 in. 15 lb missile @ 50 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
7	Metal	UF	A composite section using a rubber energy absorbing material (EAM) sandwich between painted 22 ga. and gal. 26 ga. floating panels. Panel size: 3 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.058 in. thick, @ 3 ft. o.c. (vertically placed)	52.9	Impact point at the center. No penetration or perforation. Seam opening: none
				54.9	Impact point on the seam. No penetration or perforation. Seam opening: none
				52.9	Impact point on the seam. No penetration or perforation. Seam opening: none
				52.4	Impact point near the seam. No penetration or perforation. Seam opening: none
8	Metal (Wall)	UF	Steel panel (24 ga., 50 ksi) Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	53.6	Impact point at the center panel near female side of the rib. No penetration or perforation. Panel tearing: none. Sidelap opening: none.
				55.8	Impact point near girt. No penetration or perforation. Panel tearing: 3 in. tear. Sidelap opening: none
				55.7	Impact point at the center panel near female side of the rib. No penetration or perforation. Panel tearing: none. Sidelap opening: none
9	Metal (Wall)	UF	Steel panel (24 ga., 80 ksi arch II/ 1 in. Thermax/ 26 ga., 50 ksi back panel). Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	53.1	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: split outer panel 10 in. in length. Sidelap opening: none.
				52.7	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: tore the arch II panel. Sidelap opening: none
				52.8	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: none Sidelap opening: none

Table A.3: Wall/Roof Assemblies Passing Previous Enhanced Large Missile Impact Tests (2x4 in. 15 lb missile @ 50 mph) – contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
10	Metal (Wall/Roof)	UF	Steel panel (24 ga., 80 ksi), sidelap fasteners at 9 in. o.c. Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	57.8	Impact point near the sidelap. No penetration or perforation. Panel tearing: none Sidelap opening: 2 in. max x 5 ft.
11	Metal	UF	Steel panel (24 ga., 80 ksi), sidelap fasteners at 6 in. o.c. Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	55.5	Impact point near the sidelap. No penetration or perforation. Panel tearing: none Sidelap opening: minimal
12	Metal	UF	22 ga. painted metal panel with standing seam, mechanical seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft. Girts: Z 8.25, 0.058 in. thick	73.9	Most of the right seam separated from the batten strip. Opening size was 1 ft. max x 3 ft. long. No penetration or perforation.
13	Metal	UF	A composite section using a rubber energy absorbing material (EAM) sandwich between painted 22 ga. and gal. 26 ga. floating panels Panel size: 3 panels, 1 ft. 6 in. x 9 ft. Girts: Z 8.25, 0.058 in. thick	74.9	Left seam opening: 3 in. max x 1 ft. 6 in. Right seam opening: 5 in. max x 1 ft. 6 in.
14	Stud walls with plywood	TTU	3 layer of 3/4 in. CD grade plywood mounted with 3 in. #8 wood deck screws spaced 6 in. on center to the double stud 4x4 ft frame.	< 59	The missiles repercussed.
				59-61	Threshold was observed
				> 61	The missile perforated the barrier (failure).
15	Stud walls with plywood	TTU	4 layer of 3/4 in. CD grade plywood mounted with 3 in. #8 wood deck screws spaced 6 in. on center to the double stud 4x4 ft frame.	< 71	The missiles repercussed.

Table A.4: Wall/Roof Assemblies Failing Previous Enhanced Large Missile Impact Tests (2x4 in. 15 lb missile @ 50 mph)

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
1	Stud walls with combination of infill and siding materials	TTU	Masonite siding wall; 7/16 in. masonite siding on the front face and 1/2 in. gypsum wallboard on the back face	54.0	The missile perforated the target.
2	Stud walls with combination of infill and siding materials	TTU	Insulation board /masonite siding wall; 1/2 in. insulating board and 7/16 in. masonite siding on the front face and 1/2 in. gypsum wallboard on the back face	54.0	The missile perforated the target.
3	Stud walls with combination of infill and siding materials	TTU	Plywood masonite siding wall; 1/2 in. plywood sheathing and 7/16 in. masonite siding on the front face and 1/2 in. gypsum wallboard on the back face	52	The missile perforated the target.
4	Stud walls with combination of infill and siding materials	TTU	Plywood wall; 1/2 in. plywood sheeting in the front face and 1/2 in. gypsum wallboard on the back face	52	The missile perforated the target.
5	Stud walls with combination of infill and siding materials	TTU	Plywood wall; 3/4 in. plywood sheeting in the front face and 1/2 in. gypsum wallboard on the back face	53	The missile perforated the target.
6	Stud walls with combination of infill and siding materials	TTU	Stucco wall; 1/2 in. plywood sheeting topped by 3 course stucco exterior on the front face and 1/2 in. gypsum wallboard on the back face	53	The missile perforated the target.
7	Stud walls with combination of infill and siding materials	TTU	Lapboard siding wall; 3/4 in. plain lapboard siding on the front face and ½ in. gypsum wallboard on the back face	53	The missile perforated the target.
				67	The missile perforated the target.
8	Stud walls with combination of infill and siding materials	TTU	Insulation board / lapboard siding wall; 1/2 in. insulating board and 3/4 in. plain lapboard siding on the front face and 1/2 in. gypsum wallboard on the back face	52	The missile perforated the target.

Table A.4: Wall/Roof Assemblies Failing Previous Enhanced Large Missile Impact Tests (2x4 in. 15 lb missile @ 50 mph)– contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Speed (mph)	Damage Description
9	Brick veneer walls	TTU	Interior finish consists of 5/8 in. gypsum board attached directly to the wood studs. 3-1/2 in. fiberglass batt insulation was placed between studs. Exterior finish consists of 3/4 in. plywood sheeting attached to the studs with a 3 in. brick veneer	69.4	The missile perforated completely through the brick veneer, exterior and interior sheeting. The brick veneer was cracked horizontally and vertically from the point of impact.
10	Metal (Wall/Roof)	UF	Steel panel (24 ga., 80 ksi) Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	54.7	Impact point near the girt. No perforation. The missile penetrated and produced a large tear in the panel. Panel tearing: 18 in. horz. x 18 in. vert. (in the shape of inverted-L) Sidelap opening: none
11	Wood	UF	Two 3/4 in. sheets of plywood Panel size: 26 in. x 65 in. Girts: Z 8.25, 0.058 in. thick	53.2	Missile perforated both sheets of plywood
12	Metal (Wall)	UF	Steel panel (24 ga., 80 ksi) Panel size: 3 panels, 16 in. x 10 ft. Girts: Z 8.0, 16 ga.	52.5	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: none. Sidelap opening: none
				52.7	Impact point at the center panel on girt. No penetration or perforation. Panel tearing: none. Sidelap opening: none
				52.5	Impact point at the left panel near girt. No perforation. The missile penetrated. Panel tearing: in the shape of inverted-U. Sidelap opening: none.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
1	Reinforced Masonry Unit (CMU) (Wall)	TTU	8 in. CMU reinforced with concrete and #4 rebar in every cell; truss type horizontal reinforcement was placed every 16 in.	2x4 in. 15 lb	100.0+	The target was impacted over 30 times with the design missile.
				2x4 in. 15 lb	116.0	Wall remained intact; no stress cracks in block nor joints could be found. Missile splintered on impact
				2x4 in. 15 lb	121.0	Minor surface indention (1/8 in.)
2	Reinforced Masonry Unit (CMU) (Wall)	TTU	8 in. CMU reinforced with grout filled in every cell	2x4 in. 12.5 lb	98	No damage was observed. The impact point was at the joint between cells.
3	Reinforced Masonry Unit (CMU) (Wall)	TTU	6 in. CMU reinforced with concrete and #4 rebar in every cell	2x4 in. 15 lb	< 130	The missile repercussed.
				2x4 in. 15 lb	130 – 137	Threshold was observed.
				2x4 in. 15 lb	> 137	The missile perforated the barrier.
4	Reinforced brick cavity walls with concrete infill (Wall)	TTU	Brick cavity wall reinforced with #4 rebar every 12 in. and concrete infill	2x4 in. 15 lb	> 100	The target proved successful.
5	Stud walls with concrete infill (Wall)	TTU	Stud wall with CD grade plywood, 14 ga. 1/2 in. expanded metal, and concrete infill.	2x4 in. 15 lb	106.1 101.0	Impacted 1-1/2 in. to the left of a stud. No damage was visible on the back of the target.
				2x4 in. 15 lb	105.4 100.4	Impacted 1 in. to the right of a stud. No damage was visible on the back of the target.
				2x4 in. 15 lb	105.0 100.0	Impacted 4 in. to the left of a stud. No damage was visible on the back of the target.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
6	Stud walls with concrete infill (Wall)	TTU	Stud wall filled with concrete with no plywood and 14 ga. 1/2 in. expanded metal on the non impact face	2x4 in. 15 lb	107.7 102.6	The missile made partial contact with the stud. The concrete was cracked around the impact area.
				2x4 in. 15 lb	107.2 102.1	The missile made partial contact with the stud. The concrete was severely damaged and a 4 in. deflection on the back of the target was observed.
				2x4 in. 15 lb	107.1 102.0	The missile impacted the concrete. No visible damage was observed.
				2x4 in. 15 lb	104.5 99.5	The missile hit the stud fully. There was 3 in. of deflection to the back of the target but no perforation.
7	Stud walls with concrete block infill (Wall)	TTU	4 in. concrete block in a 2x4 in. stud wall with two layers of ¾ in. CD grade plywood on the non-impact side, one layer of plywood on the impact side, and 14 ga. 1/2 in. expanded metal	2x4 in. 15 lb	106.7 101.6	3/4 in. of penetration. No evident damage to the non-impact side
				2x4 in. 15 lb	106.1 101.0	The missile impacted the stud and sheared it in two. The non-impact side showed no damage
8	Stud walls with concrete block infill (Wall)	TTU	4x4 in. stud wall with1x4 ft.s on the studs, containing 4 in. concrete block, gypsum board infill, and one layer of 3/8 in. CD grade plywood on the impact face and two layers on non-impact face	2x4 in. 15 lb	106.5 101.4	Missile penetrated the target, but did not perforate when impacted at the interface between the block and the 4x4 in. stud
				2x4 in. 15 lb	111.2 105.9	The missile impacted the stud and 1/2 in. of deflection occurred on the non-impact face
9	Stud walls with plywood and steel plate (Wall)	TTU	Double 2x4 in. stud wall with one layer of 12 ga. Steel on the impact side and one layer of 3/4 in. CD grade plywood on the non-impact side	Not mentioned	Not mentioned	The missile impacted near the stud and was deflected.
				Not mentioned	Not mentioned	The missile impacted near the stud and was deflected, there was some damage to the non-impact face.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
9 (contd)	Stud walls with plywood and steel plate (Wall)	TTU	Double 2x4 in. stud wall with one layer of 12 ga. Steel on the impact side and one layer of 3/4 in. CD grade plywood on the non-impact side	2x4 in. 15 lb	105.2	The missile impacted next to the stud and was destroyed.
				2x4 in. 15 lb	103.6	The missile impacted next to the stud and was destroyed.
10	Stud walls with plywood and steel plate (Wall)	TTU	2x8 in. stud wall with two layers of 3/4 in. plywood and one layer of 14 ga. steel	2x4 in. 15 lb	100.9	The missile impacted the stud and broke it, but did not perforate the target.
11	Stud walls with plywood and steel plate (Wall)	TTU	Double stud wall with 4 layers of 3/4 in. CD grade plywood and 14 ga. Steel on the back face of the target	2x4 in. 15 lb	104-107 99-102	1 in. of deformation on the back face of the steel but no perforation.
				2x4 in. 15 lb	106.6 101.5	The target was impacted next to a stud. Several heads of screws were popped off the back of the target. The steel had 1 in. of deformation. No perforation.
				2x4 in. 15 lb	104.9 99.9	The target was impacted on the stud line. The stud was cut in two. No deformation was observed on the back side. No perforation.
12	Stud walls with plywood and steel plate (Wall)	TTU	Stud wall with 2 layers of 3/4 in. CD grade plywood with 16 ga. Metal on non-impact side	2x4 in. 15 lb	105.7 100.7	1 in. deformation of 16 ga. Metal on non-impact side of target. No perforation.
				2x4 in. 15 lb	104.7 99.7	Wood screws pulled out of studs and 16 ga. Metal had 3-1/2 in. of deformation. No perforation.
				2x4 in. 15 lb	105.1 100.1	Wood screws pulled through metal and 1 in. of deformation of 16 ga. Metal. No perforation.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
13	Stud walls with plywood and steel plate (Wall)	TTU	Stud wall with 3 layers of 3/4 in. CD grade plywood inserts with 14 ga. Metal on non-impact side.	2x4 in. 15 lb	105.7 100.7	The first insert of plywood failed in shear while the interior two failed in bending. The studs started to be torn in half and there was 3 in. deformation in the steel.
14	Stud walls with plywood and steel plate (Wall)	TTU	2 layers of 3/4 in. CD grade plywood with 14 ga. Steel on the non-impact side, and gypsum board on both the impact and non-impact faces.	2x4 in. 15 lb	97.2 92.6	4 in. of deformation on the non-impact side. The wood screws were pulled from the studs and the studs were torn in half. The inserts were sheared through with no bending action.
				2x4 in. 15 lb	104.6 99.6	4 in. of deformation on the non-impact side. The wood screws were pulled from the studs and the studs were torn in half. The inserts were sheared through with no bending action.
				2x4 in. 15 lb	108.4 103.2	The metal screws were pulled from the studs 6 in.
15	Stud walls with plywood and steel plate (Wall)	TTU	1 layer of 12 ga. Steel that was hot rolled A569 Grade 33 on top of the double stud frame followed by a layer of 3/4 in. plywood	2x4 in. 15 lb	< 145	The missiles repercussed.
				2x4 in. 15 lb	145-148	Threshold was observed
				2x4 in. 15 lb	> 148	The missile perforated the barrier.
16	Stud walls with plywood and steel plate (Wall)	TTU	2 layers of 3/4 in. plywood, one layer of 14 ga. steel	2x4 in. 15 lb	< 130	The missiles repercussed.
				2x4 in. 15 lb	130-133	Threshold was observed
				2x4 in. 15 lb	> 133	The missile perforated the barrier.
17	Stud walls with inserts between studs (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with 14 ga. Steel insert with spacers between all inserts.	2x4 in. 15 lb	104.6 99.6	All plywood inserts failed in bending. The top third of the inserts were shot out the non-impact side of the target.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
18	Reinforced Masonry Units (CMU) (Wall)	TTU	8 in. CMU reinforced with #4 rebar @ 24 in. o.c. cells with rebar filled with grout	2x4 in. 13.75 lb	92	45 degree impact angle, no damage was observed. The impact point was at the joint between cells.
				2x4 in. 11.5 lb	116	45 degree impact angle, no damage observed. The impact point at the joint between cells.
19	Metal (Roof)	UF	20 ga. galvanized metal panel with standing seam, manual seam, Panel size: 4 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick	2x4 in. 15 lb	> 34	Impact point at the center. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	> 34	Impact point at the center. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	36.9	Impact point at the center. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	35.8	Impact point on the seam. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	35.8	Impact point near the seam. No penetration or perforation. Seam opening: right (2 in. max x 3 ft. 2 in.)
				2x4 in. 15 lb	35.7	Impact point near the seam. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	36.1	Impact point near the seam. No penetration or perforation. Seam opening: right (1/4 in. max x 1 ft. 3 in.)
				2x4 in. 15 lb	36.4	Impact point near the seam. No penetration or perforation. Seam opening: right (1/4 in. max x 1 ft. 4 in.), right (1/4 in. max x 1 ft. 5 in.)

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
20	Metal (Roof)	UF	22 ga. painted metal panel with standing seam, manual seam, Panel size: 4 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick	2x4 in. 15 lb	36.3	Impact point at the center. No penetration or perforation. Seam opening: left (1/4 in. max x 1 ft. 5 in.)
				2x4 in. 15 lb	37.3	Impact point near the seam. No penetration or perforation. Seam opening: left (3/8 in. max x 7 in.)
				2x4 in. 15 lb	36	Impact point on the seam. No penetration or perforation. Seam opening: left (1/8 in. max x 3 in.)
				2x4 in. 15 lb	35.8	Impact point near the seam. No penetration or perforation. Seam opening: left (1/4 in. max x 1/4 in.)
21	Metal (Roof)	UF	22 ga. painted metal panel with standing seam, mechanical seam, Panel size: 4 panels, 1 ft. 6 in. x 9 ft., Girts: Z 8.25, 0.071 in. thick	2x4 in. 15 lb	33.9	Impact point at the center. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	34.1	Impact point at the center. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	33.3	Impact point near the seam. No penetration or perforation. Seam opening: none
				2x4 in. 15 lb	34	Impact point near the seam. No penetration or perforation. Seam opening: right (1/2 in. max x 5 in.)
22	Metal (Roof)	UF	Steel panel with standing seam (24 ga., 50 ksi), Panel size: 3 panels, 36 in. x 10 ft. Girts: Z 8.0, 16 ga.	2x4 in. 15 lb	35.9	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: none, Sidelap opening: none
				2x4 in. 15 lb	35	Impact point at the center panel. No penetration or perforation. Panel tearing: none, Sidelap opening: minimal

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
23	Hollow Core Slab (Roof)	UF	Company C: 6 in. hollow core slab	2x4 in. 9 lb	50.2	Impact point at the top of the support. Penetrated top core for ¼ span.
				2x4 in. 9 lb	50.8	Impact point at the center of the slab. No damage.
24	Hollow Core Slab (Roof)	UF	Company C: 8 in. hollow core slab	2x4 in. 9 lb	50.2	Impact point at the top of the support. No damage.
				2x4 in. 9 lb	51.3	Impact point at the center of the slab. No damage.
25	Hollow Core Slab (Roof)	UF	Company C: 10 in. hollow core slab	2x4 in. 9 lb	50.0	Impact point at the center of the slab. No damage.
				2x4 in. 9 lb	50.2	Impact point at the top of the support. No damage.
26	Hollow Core Slab (Roof)	UF	Company C: 12 in. hollow core slab	2x4 in. 9 lb	50.0	Impact point at the center of the slab. No damage.
				2x4 in. 9 lb	50.2	Impact point at the top of the support. No damage.
27	Metal (Roof)	UF	A composite section using a rubber energy absorbing material (EAM) sandwich between gal. 20 gage and gal. 26 ga. floating panels, 3.5 in. R11 fiberglass insulation was used for the EAM**.** Panel size: 3 panels, 1 ft. 6 in. x 9 ft. Girts: Z 8.25, 0.058 in. thick	2x4 in. 15 lb	39.6	Both seams separated from batten strips. No penetration or perforation.
28	Metal (Roof)	UF	22 ga. painted metal panel with standing seam, mechanical seam, Panel size: 3 panels, 1 ft. 6 in. x 9 ft. Girts: Z 8.25, 0.058 in. thick	2x4 in. 15 lb	73.9	Most of the right seam separated from the batten strip. Opening size was 1 ft. max x 3 ft. long. No penetration or perforation.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
29	Metal (Roof)	UF	A composite section using a rubber energy absorbing material (EAM) sandwich between painted 22 ga. and gal. 26 ga. floating panels. Panel size: 3 panels, 1 ft. 6 in. x 9 ft. Girts: Z 8.25, 0.058 in. thick	2x4 in. 15 lb	74.9	Left seam opening: 3 in. max x 1 ft. 6 in. Right seam opening: 5 in. max x 1 ft. 6 in.
30	Reinforced concrete walls constructed using Concrete Forms (ICF) (Wall) Insulating	TTU	6 in. thick GREENBLOCK ICF (Exterior finish consists of vinyl siding attached to ICF fastening strips)	2x4 in. 15 lb	103.8	No cracking, front face spalling, or back face scabbing of the concrete core was observed. The missile penetrated the vinyl siding and the Greenblock form
				2x4 in. 15 lb	119.9	No cracking, front face spalling, or back face scabbing of the concrete core was observed. The missile penetrated the vinyl siding and the Greenblock form
31	Reinforced concrete walls constructed using Insulating Concrete Forms (ICF) (Wall)	TTU	6 in. thick BLUE MAXX ICF (Interior finish consists of 5/8 in. gypsum board attached directly to ICF fastening strips. Exterior finish consists of 3 in. brick attached to ICF strips with brick ties)	2x4 in. 15 lb	99.0	No cracking, front face scabbing, or back face spalling of the concrete core was observed. The missile penetrated the brick veneer, cracking it from the point of impact to the top of the sample. The Blue Maxx ICF was indented but the missile never made direct contact with the concrete core.
32	Reinforced concrete walls constructed using Insulating Concrete Forms (ICF) (Wall)	TTU	4 in. thick LITE FORM ICF (Interior finish consists of 5/8 in. gypsum board attached directly to ICF fastening strips. Exterior finish consists of vinyl siding attached to ICF fastening strips)	2x4 in. 15 lb	96.7	No cracking, front face scabbing, or back face spalling of the concrete core was observed. The missile penetrated the vinyl siding and the Lite Form ICF form. The missile made contact with the concrete core.

Table A.5: Wall/Roof Assemblies Passing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
33	Reinforced concrete walls constructed using Concrete Forms (ICF) (Wall) Insulating	TTU	6 in. thick POLYSTEEL (WAFFLE) ICF (Exterior finish consists of 1/4 in. thick Exterior Insulation Finish System (EIFS) applied directly to ICF)	2x4 in. 15 lb	103.8	No cracking, front face scabbing, or back face spalling of the concrete core was observed. The missile penetrated the EIFS siding and the Polysteel ICF. The missile made contact with the concrete core. The missile hit the target at the side of the thicker column.
				2x4 in. 15 lb	100.2	No cracking, front face scabbing, or back face spalling of the concrete core was observed. The missile penetrated the EIFS siding and the Polysteel ICF. The missile made contact with the concrete core. The missile hit the target exactly at the most vulnerable area.
34	Brick veneer walls (Wall)	TTU	Brick veneer wall with 1/2 in. insulation board and 1/2 in. gypsum board	2x4 in. 15 lb	120	The missile penetrated the target and the brick veneer crushed into small pieces. The backside wallboard remained intact.
35	Reinforced concrete slabs (Roof)	TTU	6 in. thick pea-gravel concrete, #4 rebar reinforcement 12 in. o.c. each way	2x4 in. 15 lb	102.4	No cracking, front face spalling, or back face scabbing was observed.
36	Metal (Roof)	UF	Standing Seam panel (22 ga., 50 ksi), Panel size: 3 panels, 24 in. x 10 ft. Girts: Z 8.0, 16 ga.	2x4 in. 15 lb	> 34	Impact point at the center panel near girt. No perforation. The missile penetrated. No panel tearing or sidelap opening
				2x4 in. 15 lb	> 34	Impact point at the left panel near girt. No penetration or perforation. No panel tearing or sidelap opening
				2x4 in. 15 lb	> 50	Impact point at the right panel near girt. No perforation. The missile penetrated. Panel tearing: none, Sidelap opening: none

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
1	TTU	Reinforced Masonry Unit (CMU) (Wall)	6 in. CMU reinforced with concrete and #4 rebar in every cell; truss type horizontal reinforcement was placed every 16 in.	2x4 in. 15 lb	106.7 101.6	No visible damage was observed. 1/8 in. to 3/8 in. indention on impact side.
				2x4 in. 15 lb	103.4 98.5	The missile impacted the target at a mortar joint. The target was cracked from the point of impact to the top of the target, both in the front and in the back. The mortar spilled out of the joint on the back of the target.
				2x4 in. 15 lb	97.0 92.4	The missile impacted the target at a mortar joint. The cracking of the wall was extended into the base. A new crack appeared in the next joint 8 in. away and extended to the top of the target. The missile perforated the target and spilled the concrete fill out of the back of the target.
				Not mentioned	Not measured	No penetration of the target occurred. The target was cracked from the point of impact to the top of the target.
				2x4 in. 15 lb	111.3 106.1	The target was impacted at a vertical mortar joint. There was a 1/16 in. indentation on the impact face but no visible damage to either side of the target.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
1 (contd.)	Reinforced Masonry Unit (CMU) (Wall)	TTU	6 in. CMU reinforced with concrete and #4 rebar in every cell; truss type horizontal reinforcement was placed every 16 in.	2x4 in. 15 lb	106.9 101.8	The target was impacted at a vertical mortar joint. There was a 1/16 in. indentation on the impact face. The joint spalled slightly on the non-impact side of the target. A small crack was detected at the impact point terminating at the top of the target.
2	Reinforced Masonry Unit (CMU) (Wall)	TTU	8 in. CMU with no reinforcement	2x4 in. 15 lb	> 100	The missile perforated the barrier.
3	Stud walls with concrete block infill (Wall)	TTU	4x4 in. stud wall, containing 4 in. concrete block, and one layer of 3/8 in. CD grade plywood on the impact and two layers of 3/4 in. CD grade plywood on non-impact faces	2x4 in. 15 lb	115.7 110.1	No missile penetration
				2x4 in. 15 lb	109.0 103.8	The missile impacted the interface between the block and the 4x4 in. stud perforating the target 3 ft.
4	Stud walls with concrete block infill (Wall)	TTU	4 in. concrete block in a 2x4 in. stud wall with two layers of 3/4 in. CD grade plywood	2x4 in. 15 lb	109.1 103.9	The missile impacted the stud and perforated the target 18 in.
5	Stud walls with concrete block infill (Wall)	TTU	Double studded 2x4 in. wall with furring. Two layers of ¾ in. CD grade plywood on the non-impact side, one layer on the impact face, and a layer of 3/8 in. gypsum board. The wall is filled with 4 in. concrete block.	2x4 in. 15 lb	103.0	The missile 1/2 in. on the stud and 1/2 in. on the concrete block infill. There was 1/2 in. of deformation on the non-impact side.
				2x4 in. 15 lb	100.7	The missile impacted next to the stud. There was 1/2 in. of deformation and cracking on the non-impact side

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
6	Stud walls with concrete block infill (Wall)	TTU	Double studded 2x4 in. wall with furring. Two layers of 3/4 in. CD grade plywood on the non-impact side, one layer on the impact face, and a layer of 3/8 in. gypsum board. The wall is filled with 4 in. concrete block place vertically in the cell	2x4 in. 15 lb	101.9	The missile perforated the target 3 in.
7	Stud walls with concrete block infill (Wall)	TTU	4 in. concrete block in a 2x6 in. wall with 1-1/2 in. of polystyrene between block on the non-impact side and one layer of 3/4 in. CD grade plywood. There are also two layers of plywood on the non-impact side.	2x4 in. 15 lb	85.1 81.0	The missile penetrated the target. The non-impact plywood was punched out in the area of impact.
				2x4 in. 15 lb	111.3 106.0	The missile penetrated the target. There was no damage to the back side of the target.
8	Stud walls with concrete block infill (Wall)	TTU	4 in. concrete block in a 2x6 in. wall with 1-1/2 in. of polystyrene between block and the impact face of 3/4 in. CD grade plywood. There are also two layers of plywood on the non-impact side.	2x4 in. 15 lb	100.7 105.4	The missile penetrated the target but did not perforate it. The back face plywood pulled from the studs and the studs were torn in half. There was catastrophic damage to the structure.
9	Stud walls with concrete block infill (Wall)	TTU	4 in. concrete block in a 2x6 in. wall with 1-1/2 in. of polystyrene on each side of the block, one layer of 3/4 in. CD grade plywood on the impact side, and two layerson the non-impact side.	2x4 in. 15 lb	104.0 99.0	The missile penetrated the target but did not perforate it. The back face plywood pulled from the studs and the studs were torn in half. There was catastrophic damage to the structure.
10	Stud walls with plywood and steel plate (Wall)	TTU	2 layers of 3/4 in. plywood, one layer of 14 ga. Steel and the 4x4 ft double stud frame	2x4 in. 15 lb	112.8-117.8	The target was perforated.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
11	Stud walls with plywood and expanded metal (Wall)	TTU	3 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the impact side.	2x4 in. 15 lb	109.0 103.8	The missile perforated the target 12 ft.
12	Stud walls with plywood and expanded metal (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the non-impact side.	2x4 in. 15 lb	104.2 99.2	The missile perforated the target 7 ft.
				2x4 in. 15 lb	107.8 102.7	The missile perforated the target 3 ft.
13	Stud walls with plywood and expanded metal (Wall)	TTU	3 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the non-impact side.	2x4 in. 15 lb	105.9 100.9	The full length of the missile perforated the target
14	Stud walls with plywood and expanded metal (Wall)	TTU	5 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the impact side.	Not mentioned	Not measured	The missile perforated the target 3 ft.
15	Stud walls with plywood and expanded metal (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the impact side.	2x4 in. 15 lb	103.6 98.7	The missile perforated the target 10 ft.
16	Stud walls with inserts between studs (Wall)	TTU	4 layers of 3/4 in. plywood with 14 ga. Steel insert with spacers between inserts and the back face of the target.	2x4 in. 15 lb	109.4 104.2	The missile penetrated the target 1-1/2 to 2 in.. A crack in the plywood on the back face caused bending, but total separation did not occur.
17	Stud walls with inserts between studs (Wall)	TTU	14 ga. steel insert with spacers between all the inserts and the back face has two layers of 3/4 in. CD grade plywood	2x4 in. 15 lb	108-110 103-106	The missile penetrated the target 1-1/2 to 2 in.. A crack in the plywood on the back face caused bending, but total separation did not occur.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
18	Stud walls with plywood (Wall)	TTU	2x8 in. stud wall with 3/4 in. CD grade plywood inserts	2x4 in. 15 lb	106.4 101.3	The full length of the missile perforated the target
19	Stud walls with plywood (Wall)	TTU	4 layers of 3/4 in. CD grade plywood on the impact side	2x4 in. 15 lb	100.8 96.0	The missile perforated the target 4 ft.
				2x4 in. 15 lb	97.7 93.0	The missile perforated the target 2 ft.
				2x4 in. 15 lb	89.7 85.4	The missile perforated the target 2 ft.
				2x4 in. 15 lb	91.0 86.7	The missile perforated the target 1 ft.
20	Stud walls with plywood (Wall)	TTU	4 layers of 3/4 in. CD grade plywood glued together and attached to the frame with screws on the impact side	2x4 in. 15 lb	86.1 82.0	The missile perforated the target 3 ft.
21	Stud walls with plywood (Wall)	TTU	4 layers of 3/4 in. BC grade plywood glued together and attached to the frame with screws on the non-impact side	2x4 in. 15 lb	103.1 98.2	The missile perforated the target 7 ft.
				2x4 in. 15 lb	90.6 86.3	The missile perforated the target 3 ft.
				2x4 in. 15 lb	82.8 78.9	The missile perforated the target 1 ft.
22	Stud walls with plywood (Wall)	TTU	1 layer of 3/4 in. CD grade plywood mounted with 3 in. #8 wood deck screws spaced 6 in. on center to the double stud 4x4 ft frame.	2x4 in. 15 lb	< 29	The missiles repercussed.
				2x4 in. 15 lb	29-31	Threshold was observed
				2x4 in. 15 lb	31	The missile perforated the barrier.
23	Stud walls with polystyrene infill (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with two layers of energy absorbing polystyrene inserts	2x4 in. 15 lb	105.4 100.4	The missile penetrated the target but did not perforate it. The back of the target had 6 in. of deformation and the back layer of plywood was pulled from the frame.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
23 (contd.)	Stud walls with polystyrene infill (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with two layers of energy absorbing polystyrene inserts	2x4 in. 15 lb	109.3 104.1	The missile perforated the target 4 ft.
				2x4 in. 15 lb	> 100	The full length of the missile perforated the target.
24	Stud walls with corrugated infill materials (Wall)	TTU	3 layers of corrugated tin with four layers of 3/4 in. CD grade plywood	2x4 in. 15 lb	109.3 104.1	The missile perforated the target 8 ft.
				2x4 in. 15 lb	105.9 100.9	The missile perforated the target 7 ft.
25	Stud walls with combination of infill and siding materials (Wall)	TTU	3 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the non-impact side and bead-board infill	2x4 in. 15 lb	95.3 90.8	The full length of the missile perforated the target.
26	Stud walls with combination of infill and siding materials (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with two layers of energy absorbing bead board as inserts	2x4 in. 15 lb	107.3 102.2	The missile perforated the target 7 ft.
27	Stud walls with combination of infill and siding materials (Wall)	TTU	3 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the impact side and bead-board infill	2x4 in. 15 lb	110.0 104.8	The full length of the missile perforated the target.
28	Stud walls with combination of infill and siding materials (Wall)	TTU	4 layers of 3/4 in. CD grade plywood with 14 ga. 1/2 in. expanded metal on the impact side and bead-board infill	2x4 in. 15 lb	108.5 103.3	The missile perforated the target 3 ft.
29	Reinforced Masonry Units (CMU) (Wall)	TTU	8 in. CMU with no reinforcement	2x4 in. 11.5 lb	131	The missile perforated the barrier. The impact point was at the joint between cells.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
30	Reinforced Masonry Units (CMU) (Wall)	TTU	8 in. CMU reinforced with #4 rebar @ 16 in. o.c. cells with rebar filled with grout	2x4 in. 11 lb	135	No penetration of the target occurred. One big crack was observed. The impact point was at the center of the cell.
				2x4 in. 11.25 lb	104	The missile perforated the barrier. The impact point was at the joint between cells.
				2x4 in. 11 lb	49	No damage was observed. The impact point was at the center of the cell where the rebar and the grout are located.
				2x4 in. 12 lb	120	No damage was observed. The impact point was at the center of the cell where the rebar and the grout are located.
31	Reinforced Masonry Units (CMU) (Wall)	TTU	8 in. CMU with no reinforcement	2x4 in. 13.75 lb	71	The missile perforated the barrier. The impact point was at the joint between cells. The missile had pointed ends.
				2x4 in. 13.75 lb	100	The missile perforated the barrier. The impact point was at the joint between cells. The missile had pointed ends.
32	Reinforced Masonry Units (CMU) (Wall)	TTU	12 in. CMU with no reinforcement	2x4 in. 11.75 lb	75	The missile perforated the barrier. The impact point was at the center of the cell.
				2x4 in. 12 lb	85	The missile perforated the barrier. Impact point: at the joint between CMU ft.s.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
33	Reinforced Masonry Units (CMU) (Wall)	TTU	12 in. CMU with steel trusses in horizontal joints	2x4 in. 11.75 lb	125	No penetration of the target occurred. Small cracks were observed. The impact point was at the joint between cells.
				2x4 in. 11.75 lb	124	The missile perforated the barrier. The impact point was at the center of the cell.
				2x4 in. 12.75 lb	86	The missile perforated the barrier. The impact point was at the center of the cell.
				2x4 in. 12 lb	76	The missile penetrated the barrier 2.5 in. The impact point was at he center of the cell, the missile had pointed end.
				2x4 in. 12.75 lb	72	The missile perforated the barrier. The impact point was at he center of the cell, the missile had pointed end.
				2x4 in. 13 lb	85	The missile perforated the barrier. The impact point was at the center of the cell.
34	Reinforced Masonry Units (CMU) (Wall)	TTU	8 in. CMU with steel trusses in horizontal joints	2x4 in. 12.5 lb	104	The missile perforated the barrier. The impact point was at the joint between cells.
				2x4 in. 12.5 lb	89	The missile perforated the barrier. The impact point was at the center of the cell.
35	Reinforced concrete slabs (Roof)	TTU	2 in. thick pea-gravel concrete with #4 rebar reinforcement 12 in. o.c. each way	2x4 in. 15 lb	< 26	The missile repercussed.
				2x4 in. 15 lb	26-30	Threshold was observed.
				2x4 in. 15 lb	> 30	The missile perforated the barrier.

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
36	Reinforced concrete slabs (Roof)	TTU	3 in. thick pea-gravel concrete, #4 rebar reinforcement 12 in. o.c. each way	2x4 in. 15 lb	< 102	The missile repercussed.
				2x4 in. 15 lb	102-106	Threshold was observed.
				2x4 in. 15 lb	> 106	The missile perforated the barrier.
37	Reinforced concrete slabs (Roof)	TTU	4 in. thick pea-gravel concrete, #4 rebar reinforcement 12 in. o.c. each way	2x4 in. 15 lb	< 162	The missile repercussed.
				2x4 in. 15 lb	Assumed	Threshold was observed.
				2x4 in. 15 lb	> 162	The missile perforated the barrier.
38	Metal (Roof)	UF	Standing Seam panel (24 ga., 50 ksi), Panel size: 3 panels, 24 in. x 10 ft., Girts: Z 8.0, 16 ga.	2x4 in. 15 lb	36.3	Impact point at the center panel near sidelap. No penetration or perforation. Panel tearing: none, Sidelap opening: none
				2x4 in. 15 lb	35.1	Impact point at the left panel on girt. No penetration or perforation. Panel tearing: none, Sidelap opening: none
				2x4 in. 15 lb	34.2	Impact point at the right panel on girt. No penetration or perforation. Panel tearing: none Sidelap opening: none
				2x4 in. 15 lb	34	Impact point at the center panel near girt. No penetration or perforation. Panel tearing: 6 in. long Sidelap opening: none
				2x4 in. 15 lb	35	Impact point at the right panel near girt. No penetration or perforation. Panel tearing: none Sidelap opening: none
				2x4 in. 15 lb	35.3	Impact point at the center panel near girt. No penetration or perforation. Panel tearing: none Sidelap opening: none

Table A.6: Wall/Roof Assemblies Failing Previous Large Missile Impact Tests for Various Missiles Sizes and Speeds (contd.)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
38 (contd.)	Metal (Roof)	UF	Standing Seam panel (24 ga., 50 ksi), Panel size: 3 panels, 24 in. x 10 ft., Girts: Z 8.0, 16 ga.	2x4 in. 15 lb	36.6	Impact point at the left panel near girt. No penetration or perforation. Panel tearing: none Sidelap opening: minimal
				2x4 in. 15 lb	34.3	Impact point at the center panel near girt. No perforation. The missile penetrated. Panel tearing: none, Sidelap opening: none
				2x4 in. 15 lb	34.5	Impact point at the left panel near girt. No penetration or perforation. Panel tearing: none, Sidelap opening: none
				2x4 in. 15 lb	34.1	Impact point at the left panel near girt. No perforation. The missile penetrated. Panel tearing: none, Sidelap opening: none

Table A.7: New Large Missile Impact Tests for Wall/Roof Assemblies Hurricane Shelters (9 lb 2x4 @ speeds based on 0.40 x extreme wind speed, 150 – 220 mph)

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
1	Wood Stud Wall	TTU	4 ft. x 4 ft. single stud frame sheathed with 3 layers of ¾ in. CD plywood (impact side) with first two layers loosely attached and the final layer attached with 12d nails at 3 in. around perimeter and 6 in. on interior studs.	2 x 4 in. 9 lb	60 – 88	Panel failed to resist all missile speeds. Impact adjacent to a stud fractured the stud, sending 2 x 4 shards into the protective compartment.
2	Wood Stud Wall	TTU	4 ft. x 4 ft. double stud frame sheathed with 3 layers of ¾ in. CD plywood (impact side) with first two layers loosely attached and the final layer attached with 12d nails at 3 in. on alternating studs around perimeter and 6 in. on alternating interior studs	2 x 4 in. 9 lb	60 – 88	Panel held at all missile speeds. Panel experienced a maximum of 1 ½-in. of missile embedment through the range of impacts. Interior delamination of the plywood and slight fracturing of the studs was observed, but is containable with interior sheathing.
3	Wood Stud Wall	TTU	4 ft. x 4 ft. double stud frame sheathed with 2 layers of ¾ in. CD plywood (impact side) with first layer loosely attached and the final layer attached with 12d nails at 3 in. on alternating studs around perimeter and 6 in. on interior studs on alternating interior studs	2 x 4 in. 9 lb	60 – 68	Sample held missile speeds up to 68 mph with delamination on the interior plywood surface local to the impacts that are containable with inter sheathing. Impacts at higher speeds produced perforation greater than 3 in. into the protective compartment.
4	Wood Frame Roof Assembly	TTU	4 ft. x 4 ft. single 2 x 4 frame sheathed with 1 layer of ¾ in. CD plywood (impact side) with 12d nails at 3 in. around perimeter and 6 in. on interior frame members	2 x 4 in. 9 lb	15 – 22*	No remarkable damage observed.

** Missile speed = 0.10 x extreme wind speed per the proposed ICC/NSSA Shelter Standard*

Table A.7: New Large Missile Impact Tests for Wall/Roof Assemblies Hurricane Shelters (9 lb 2x4 @ speeds based on 0.40 x extreme wind speed, 150 – 220 mph) - contd.

Test No.	Wall/Roof System	Source	Sample Description	Missile Size	Missile Speed (mph)	Damage Description
5	Wood Stud Wall	TTU	4 ft. x 4 ft. double stud frame sheathed with 2 layers of ¾ in. CD plywood (interior wall side) with first layer loosely attached and the final layer attached with 12d nails at 3 in. on alternating studs around perimeter and 3 in. on alternating interior studs. Panel top and bottom edges clamped to load frame.	2 x 4 in. 9 lb	60	Panel held 60 mph impact but disassociated from studs at higher speeds.
6	Wood Stud Wall	TTU	4 ft. x 4 ft. double stud frame sheathed with 2 layers of ¾ in. CD plywood (interior wall side) with first layer loosely attached and the final layer attached with 12d nails at 3 in. on alternating studs around perimeter and 6 in. on alternating interior studs. Panel top and bottom corners were legged against load frame to allow full edge impact response.	2 x 4 in. 9 lb	60	Panel held 60 mph impact but disassociated from studs at higher speeds.
7	Wood Stud Wall	TTU	4 ft. x 4 ft. double stud frame sheathed with 3 layers of ¾ in. CD plywood (interior wall side) with first two layers loosely attached and the final layer attached with 12d nails at 3 in. on alternating studs around perimeter and 6 in. on alternating interior studs. Panel top and bottom corners were legged against load frame to allow full edge impact response.	2 x 4 in. 9 lb	60	Panel failed to hold 60 mph impact and was disassociated from the studs.