Test Report

INVESTIGATION OF THE PRESSURE & PROJECTILE RESISTANCE OF FEMA 361/ICC-500 SHELTER DOORS FOR COMMUNITY SHELTERS PRODUCED BY STEEL STORM SHELTERS, LLC

Submitted to

Mr. David Hughes
Steel Storm Shelters, LLC
1345 S. Highland Ave.
Jackson, TN 38301

Investigators

Ernst W. Kiesling, Ph.D., P.E.
Larry J. Tanner, P.E.

Date Submitted

October 2, 2009

WIND SCIENCE AND ENGINEERING
TEXAS TECH UNIVERSITY
LUBBOCK, TEXAS 79409

Wind Science & Engineering Research Center
Debris Impact Test Facility
P.O. Box 41023
Lubbock, Texas 79409-1023

Report No. _2009-2409A
Specimen No. ____1_& 2___
Test Date: Sept. 24, 2009

1.0 MANUFACTURER'S IDENTIFICATION

1.1 NAME OF APPLICANT: **Steel Storm Shelters, LLC**
1345 S. Highland Ave.
Jackson, Tennessee 38301

1.2 CONTACT PERSON: **Mr. David Hughes**

1.3 TEST LAB CERTIFICATION: Federal Emergency Management Agency (FEMA) and National Storm Shelter Association (NSSA) approved; ISO 17025 certified tests available.

2.0 TEST UNIT IDENTIFICATION

2.0 PRODUCT TYPE: Above Ground FEMA 361/ICC-500 Community Shelter Steel Doors
2.1 MODEL NUMBER: **Series 1** – 36-in. x 80-in. pair; **Series 2** – 48-in. x 80-in. single
2.2 CONFIGURATION: Pre-hung out-swinging door assemblies
2.3 SAMPLE SIZE: **Series 1** – 36-in. x 80-in. pair; **Series 2** – 48-in. x 80-in. single
2.4 DOOR ASSEMBLY: Custom fabricated steel door and frames
2.5 DRAWINGS: **Series 1** – Unavailable; **Series 2** – see Appendix A

3.0 TEST UNIT DESCRIPTION

3.0 TEST FRAME UNIT CONSTRUCTION: N/A

3.1 ASSEMBLY CONSTRUCTION: **Series 1 & 2 -** Custom door assemblies with exterior door pan constructed of 1/4" steel; and the door is strengthened by a TS 1 ½-in. x 1 ½-in. x 1/8-in. tube frame along the door edges, and two additional TS 1 ½-in x 1 ½-in. x 3/8-in. located horizontally at third points of the door height. A 14 gage steel pan was tack welded to the backside of the door. The frame on which the door is swung is a 2-in. x 4-in. x 1/4-in. TS.

3.1.1 2-Point locking system manufactured by Positive Lock with an interior paddle that simultaneously throws a ¾-in. bolt in the door head and sill.
3.1.2 Door leafs were hinged with 4 - 3-in. x 2 knuckle bullet type hinges welded to the door pan lip and door frame.
3.1.3 Series 2 door pair were backed at the center with a 4-in. x 4-in. x ¼-in. mullion.

4.0 TEST RESULTS

4.1 SCOPE: Conduct Pressure and Missile Impact Test on Door Assemblies.

4.2 SUMMARY OF RESULTS:

Test Method	Test Conditions	Test Conclusion
Missile Impact Test FEMA 361 / ICC-500 Tornado Protocol 4, See Appendix B	15-lb. 2 x 4 & 2.12 psi Static Pressure	Door Assemblies passed Pressure & Missile Impact Tests

4.3 OUTDOOR WEATHER CONDITIONS:

Temperature	63 degrees
Wind	6 mph
Relative Humidity	49 %

4.4 PRESSURE AND MISSILE IMPACT TEST RESULTS:
Static Pressure (ICC-500/FEMA 361): 1.12 psi
Missile Type: 2 x 4
Missile Weight: 15 lb.
Missile Impact Speed: 100 mph

Series Tests

Series/Test No.	Test Condition	Location	Results
Series 1 Pressure	1.12 psi	Across face of door	Single door unit of pair tested and held static pressure for 10 seconds. No permanent deformation recorded; see photos, pages 5 & 6.
Impact 1	103	Lower left corner adjacent a hinge	1/4-in. indentation at point of impact; no remarkable interior damage; see Impact 1 photos, pages 7 & 8.
Impact 2	103	Impact near center locking handle	13/16-in. indentation at point of impact; 9-in. x 12-in. affected area; door lip near impact was bent ¼-in.; see Impact 2 photos, pages 9-11.

Impact 3	104	Top right corner	7/16-in. indentation at point of impact; 6-in. x 9-in. affected area; 12 tack welds on the backside door pan were broken, but the pan remained attached; the door remained locked throughout all tests; see Impact 3 photos, pages 12 & 13.
Series 2 Pressure	1.12 psi	Across face of door	Single door unit tested and held static pressure for 10 seconds. The door dynamically deflected under pressure 13/16-in. on the strike side, but no permanent deformation recorded; see photos, pages 14 & 15
Impact 1	104	Lower right corner adjacent a hinge	1/4-in. indentation at point of impact; 8-in. x 10-in. affected area; no remarkable interior damage; see Impact 1 photos, pages 16 & 17.
Impact 2	102	Impact near center locking handle	7/8-in. indentation at point of impact; 12-in. x 12-in. affected area; two screws on the interior pull handle were loosened, but remained attached; see Impact 2 photos, pages 18 & 19
Impact 3	102	Top left corner	1/4-in. indentation at point of impact;10-in. x 10-in. affected area; 13 tack welds on the backside door pan were broken, but the pan remained attached; the door remained locked throughout all tests; see Impact 3 photos, pages 20 & 21.

5.0 CONCLUSIONS

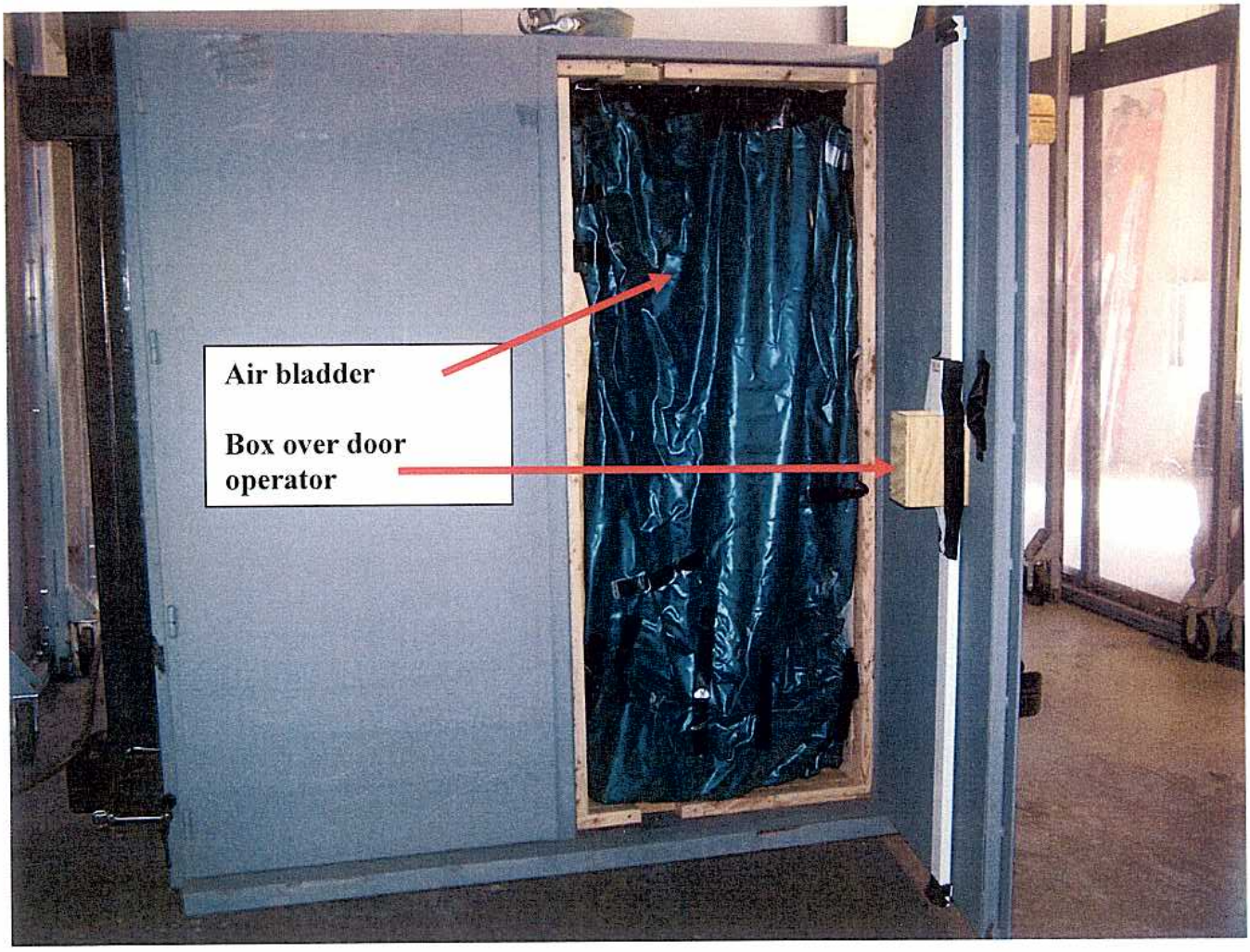
Within the bounds of reasonable engineering and technical certainty, and subject to change if additional information becomes available, the following is my professional opinion:

Pressure and impact tests were conducted on September 24 & 25, 2009 on the FEMA 361/ICC-500 **Series 1** – 36-in. x 80-in. door pair and **Series 2** – 48-in. x 80-in. single door for Steel Storm Shelters of Tennessee for ground community shelters. The pressure and the missile impacts were successful and thereby meet FEMA 361 and ICC-500 guidelines for doors intended to be installed in community shelters.

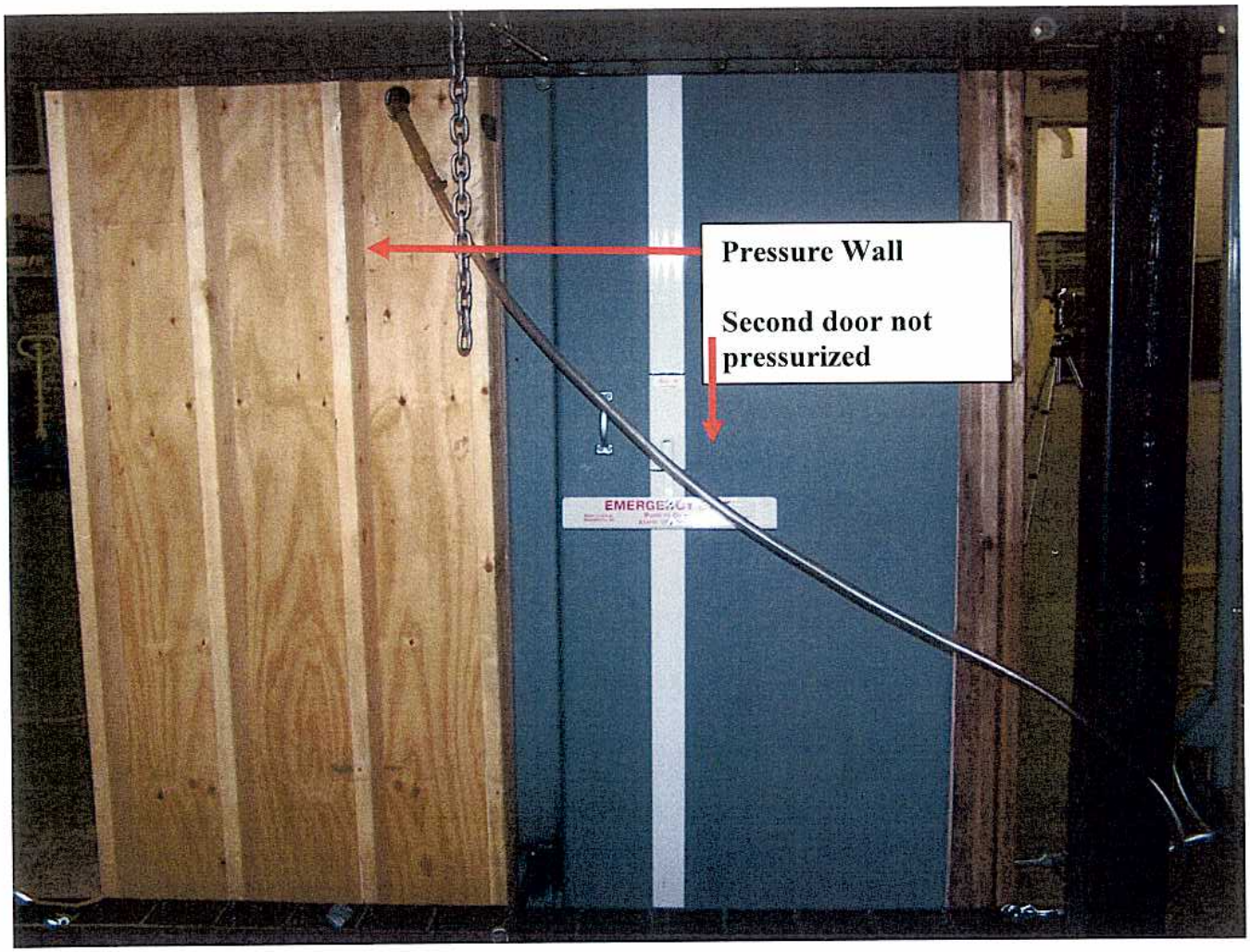
Any alterations made to the door assemblies must be approved or retested by WISE at Texas Tech University.

Engineer of Record
Larry J. Tanner, P.E.

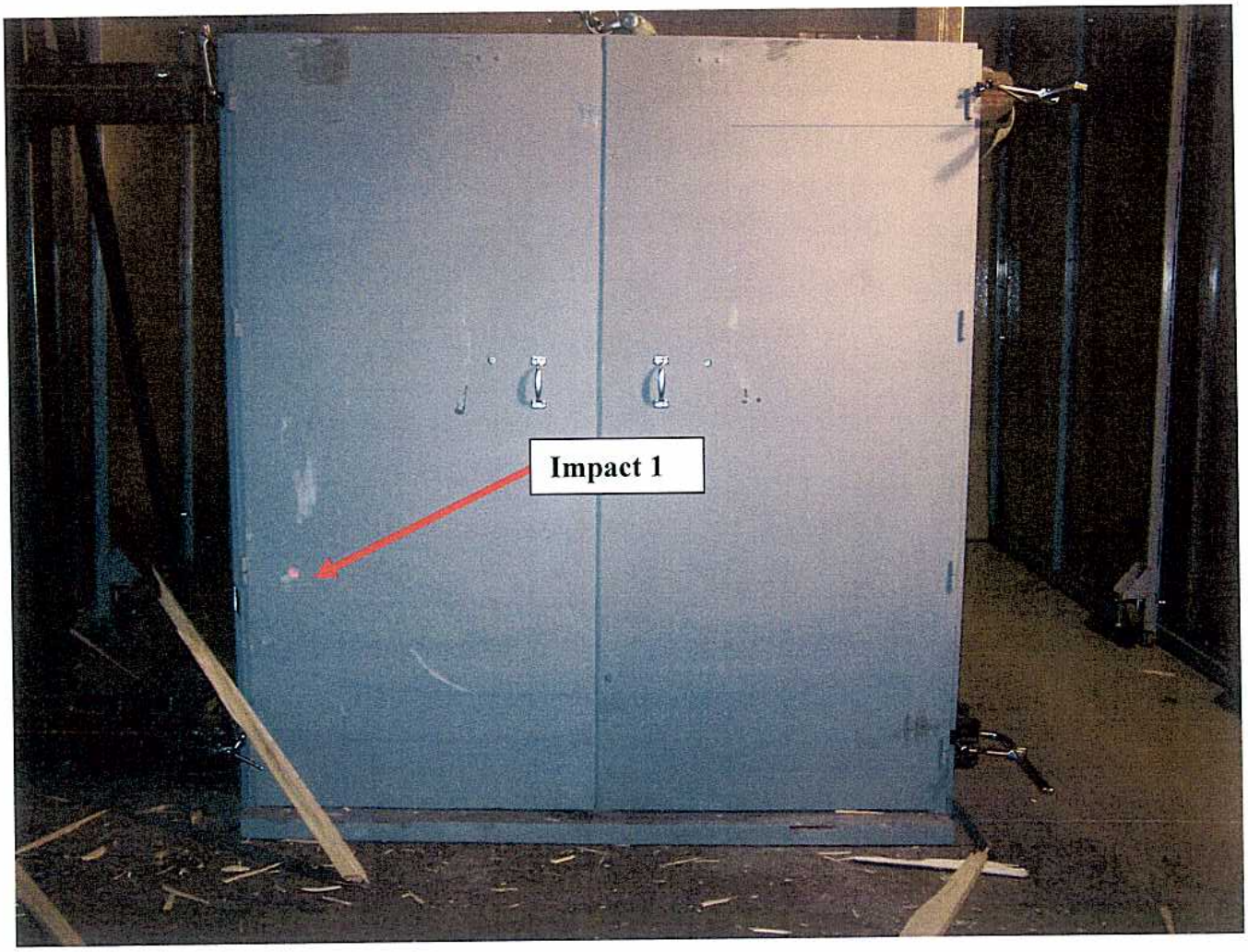
Series 1 – Pressure Test



Series 1 Pressure Wall



Series 1 - Impact 1



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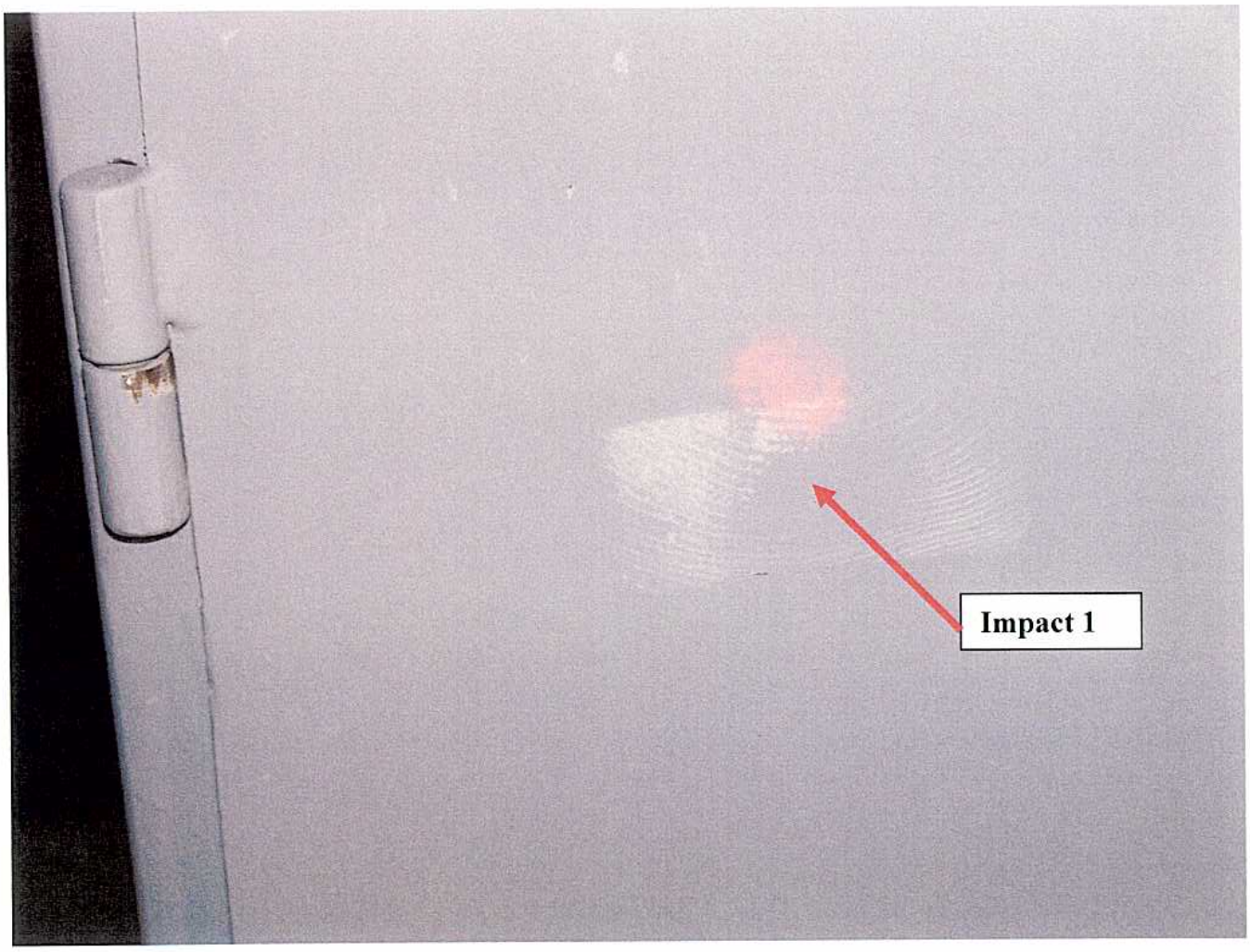
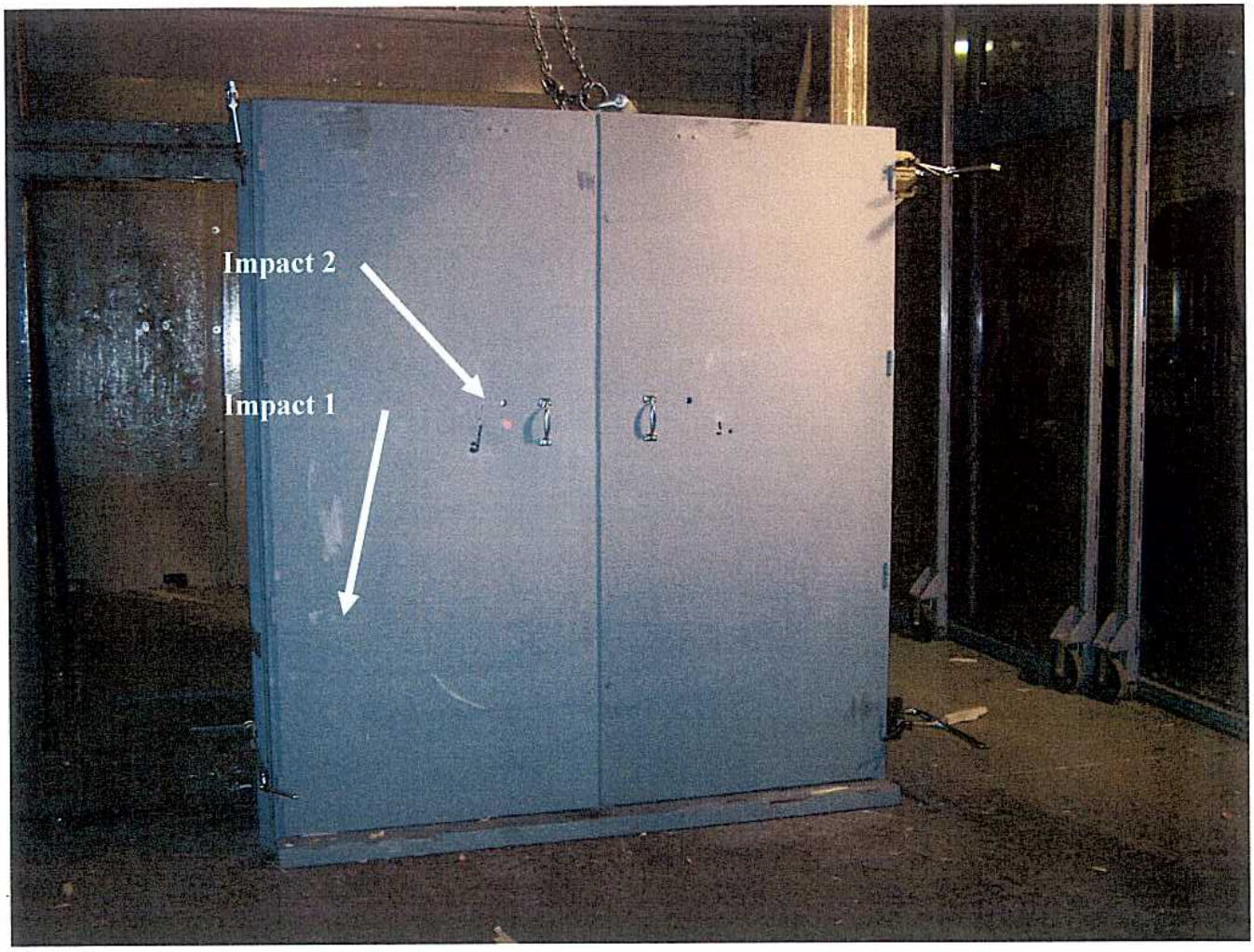
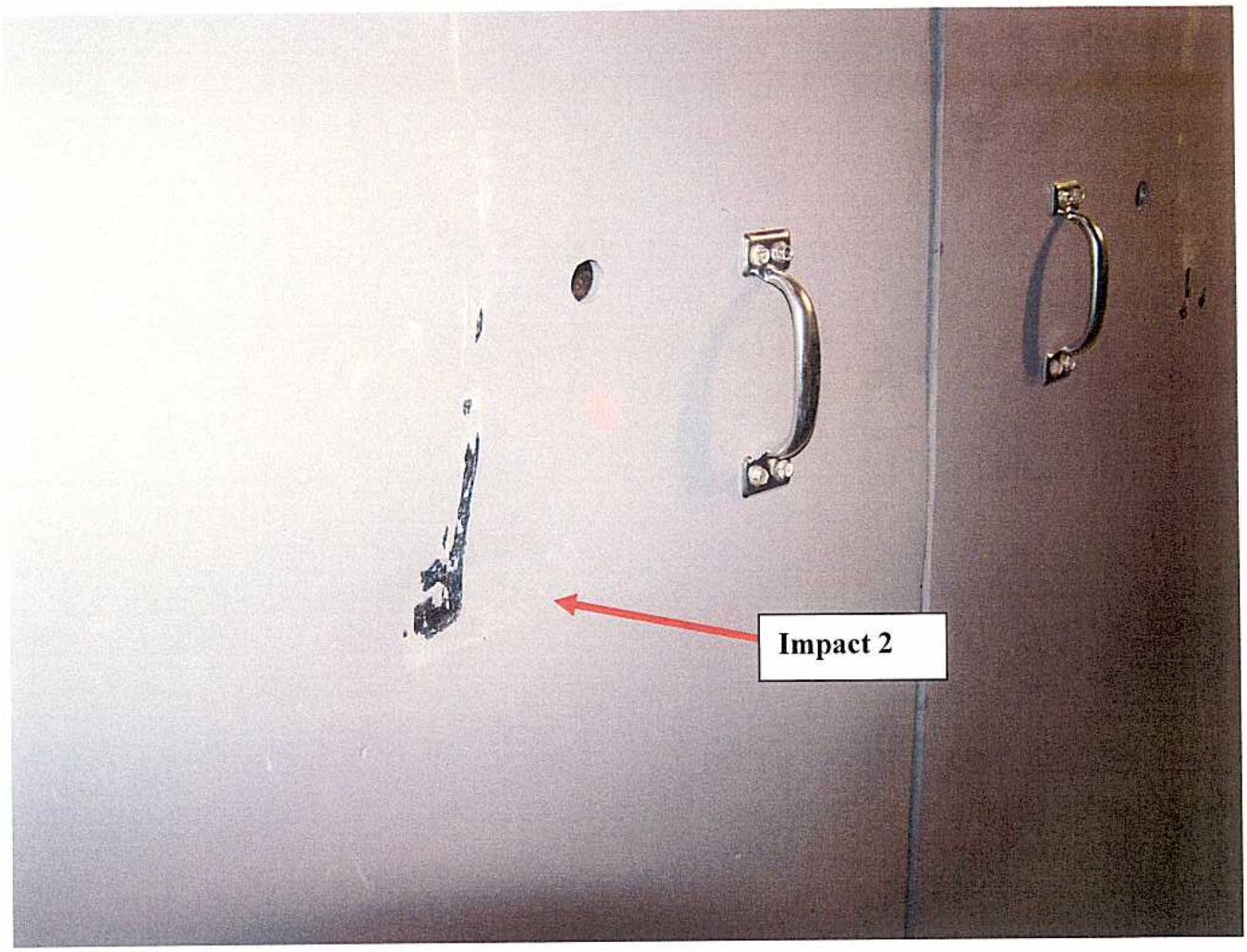
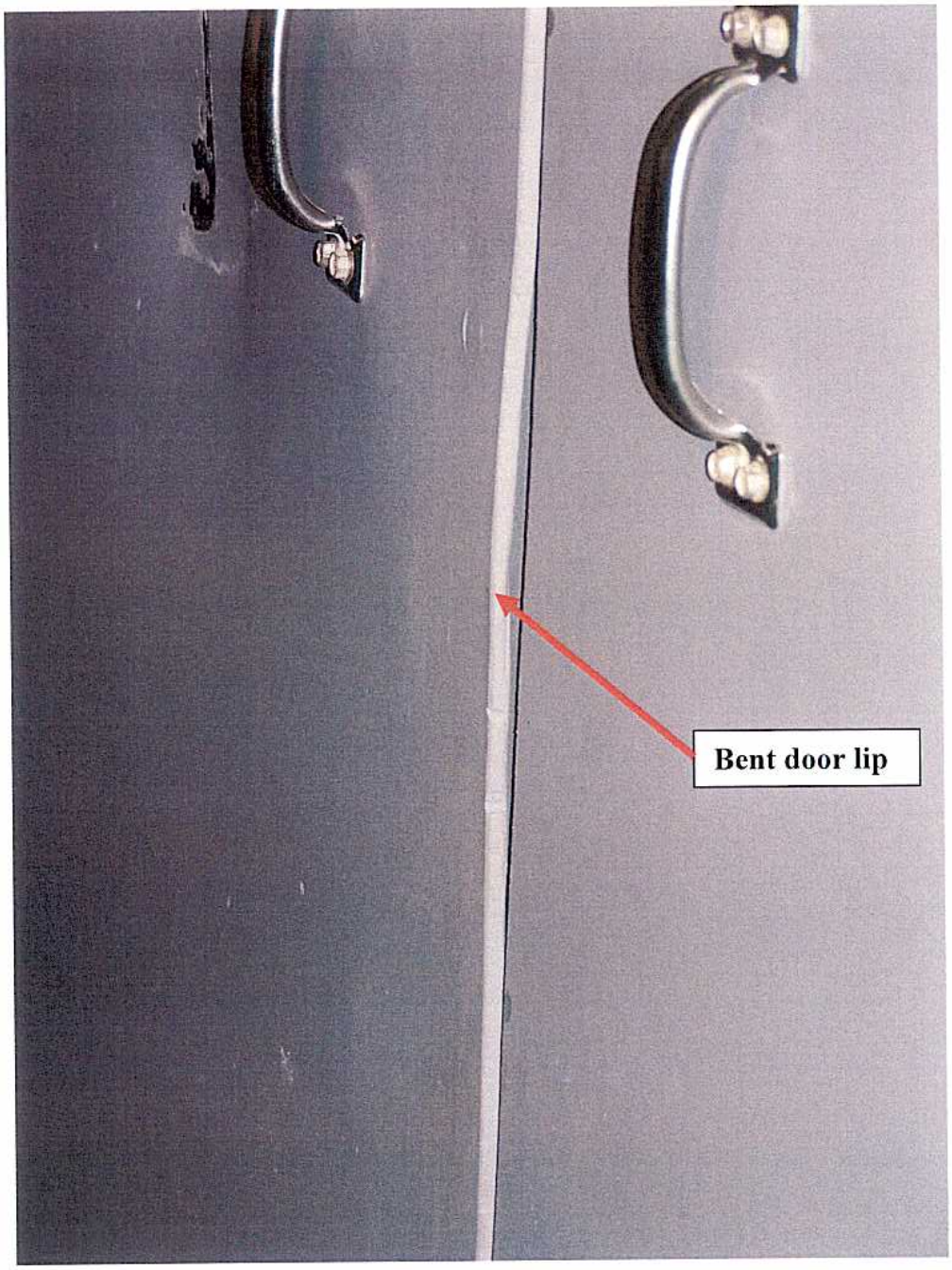
Series 1 – Impact 1



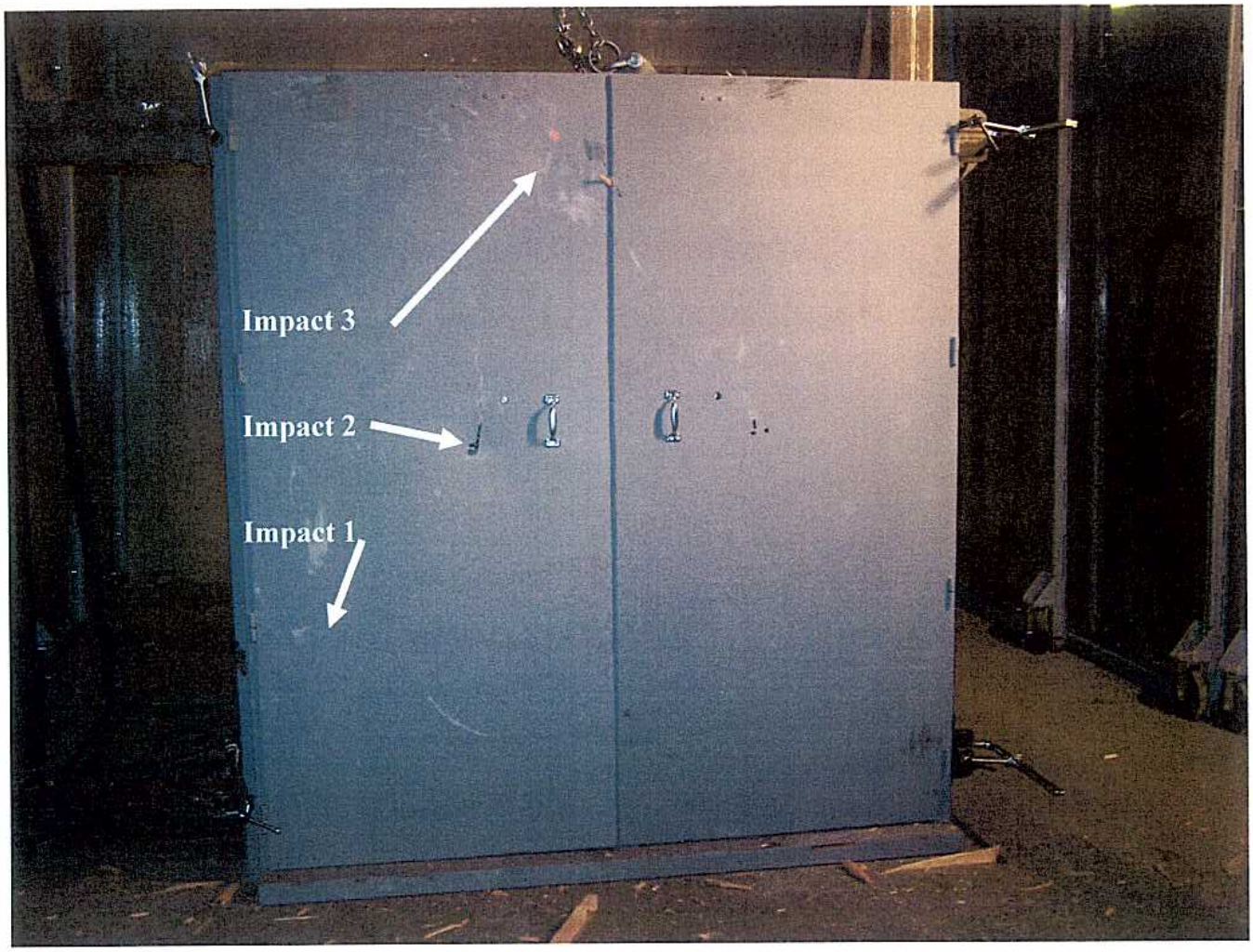
Series 1 - Impact 2

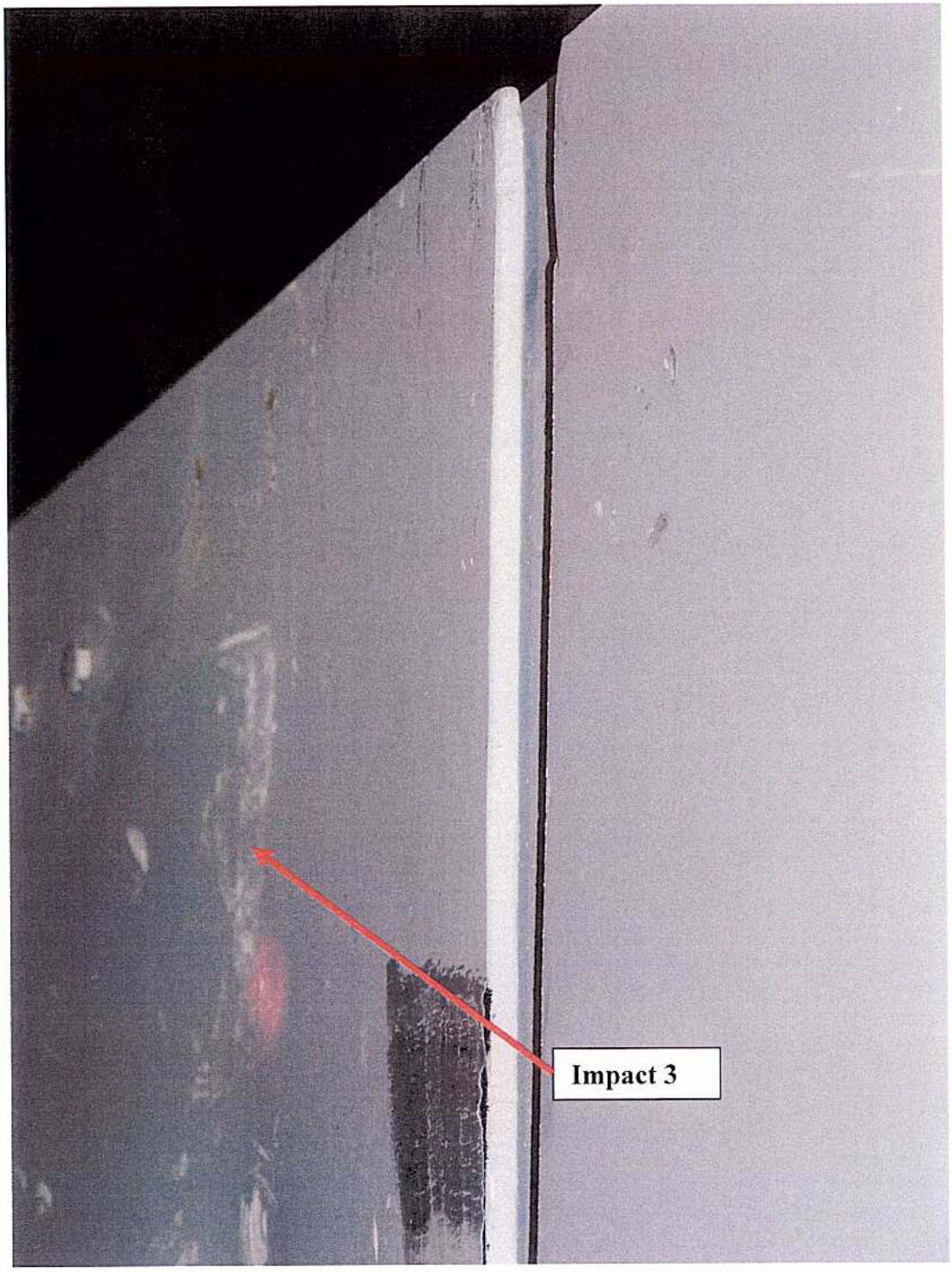



Impact 2


Bent door lip

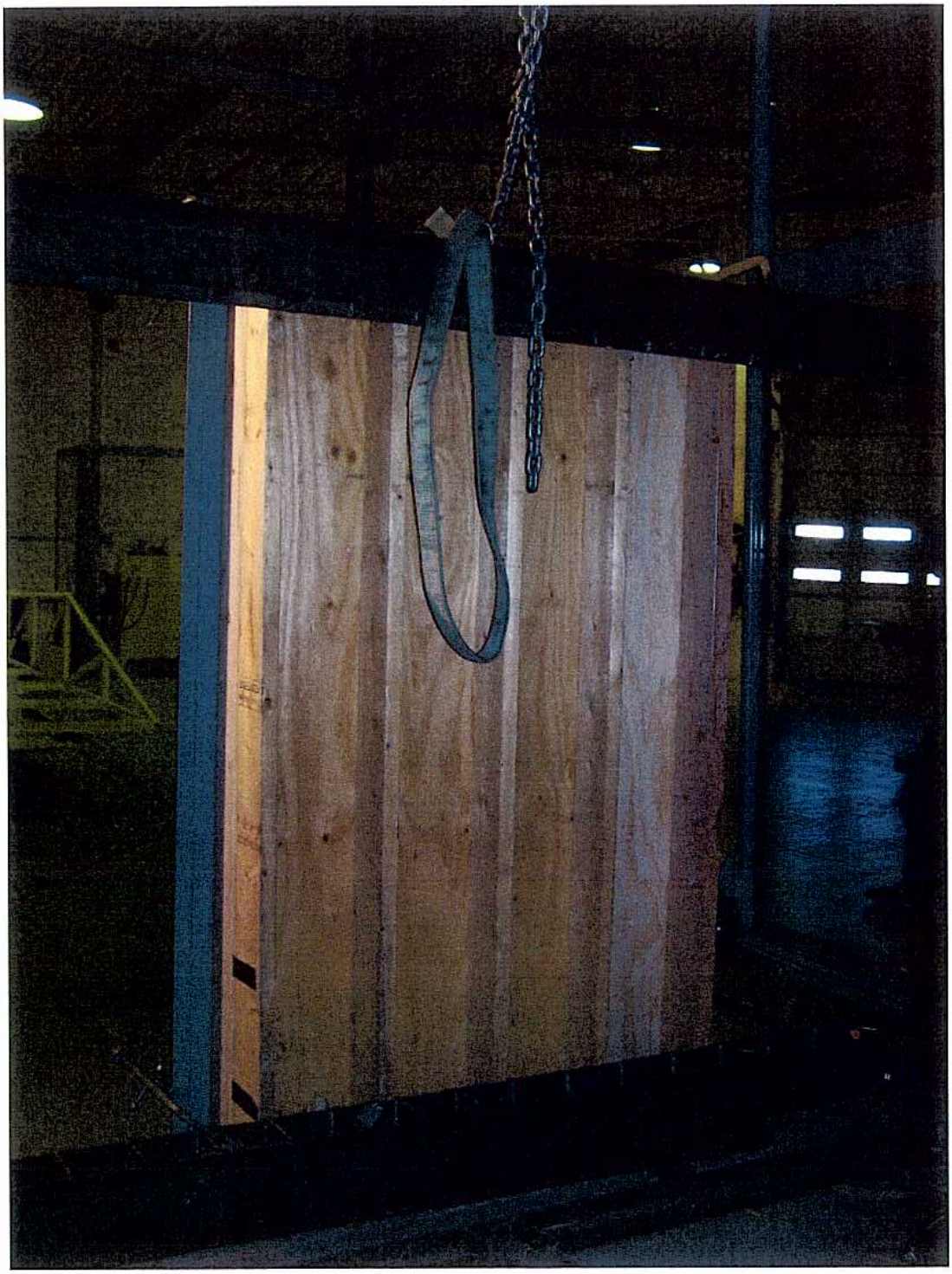
Series 1 - Impact 3



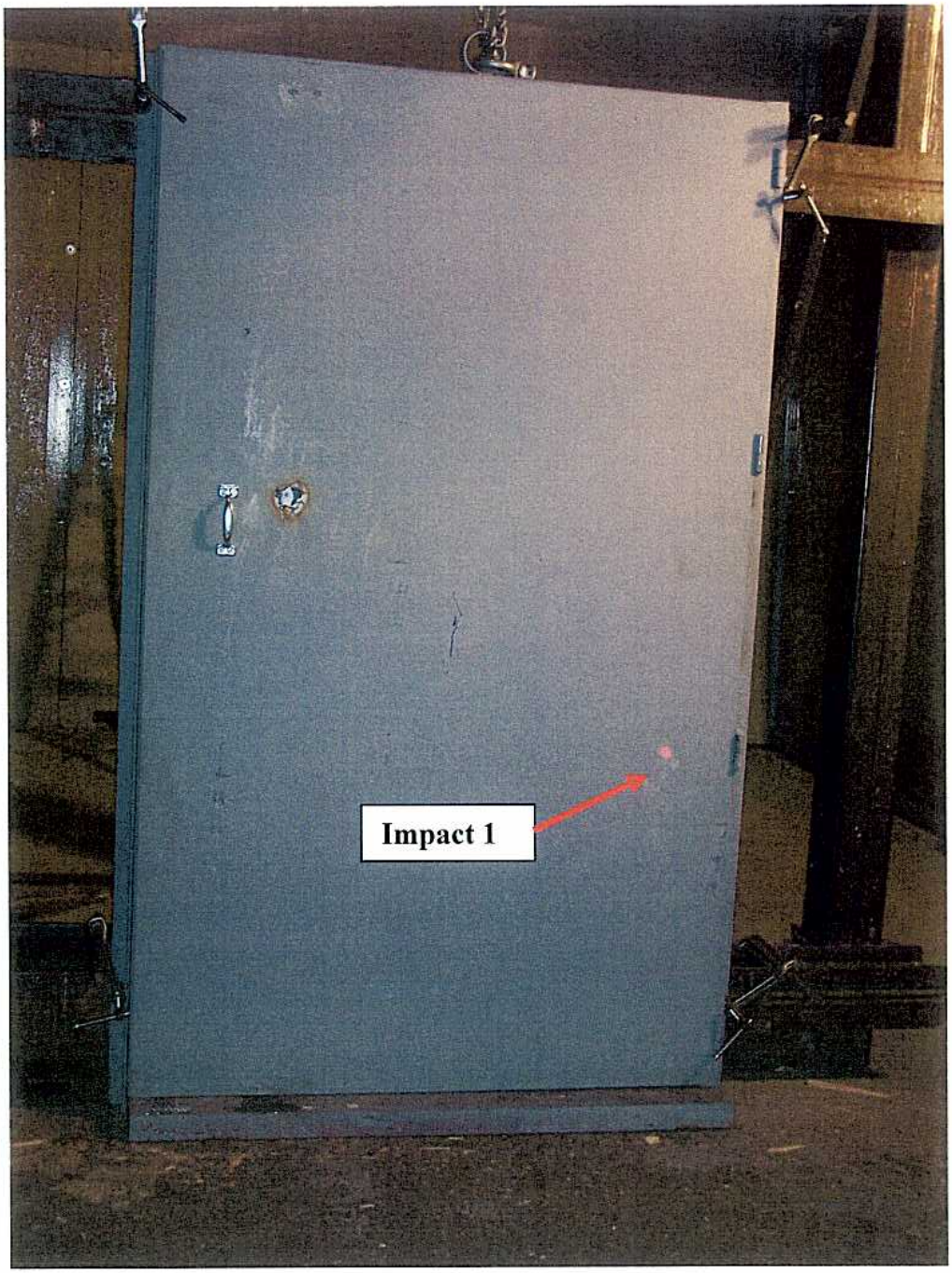

Impact 3

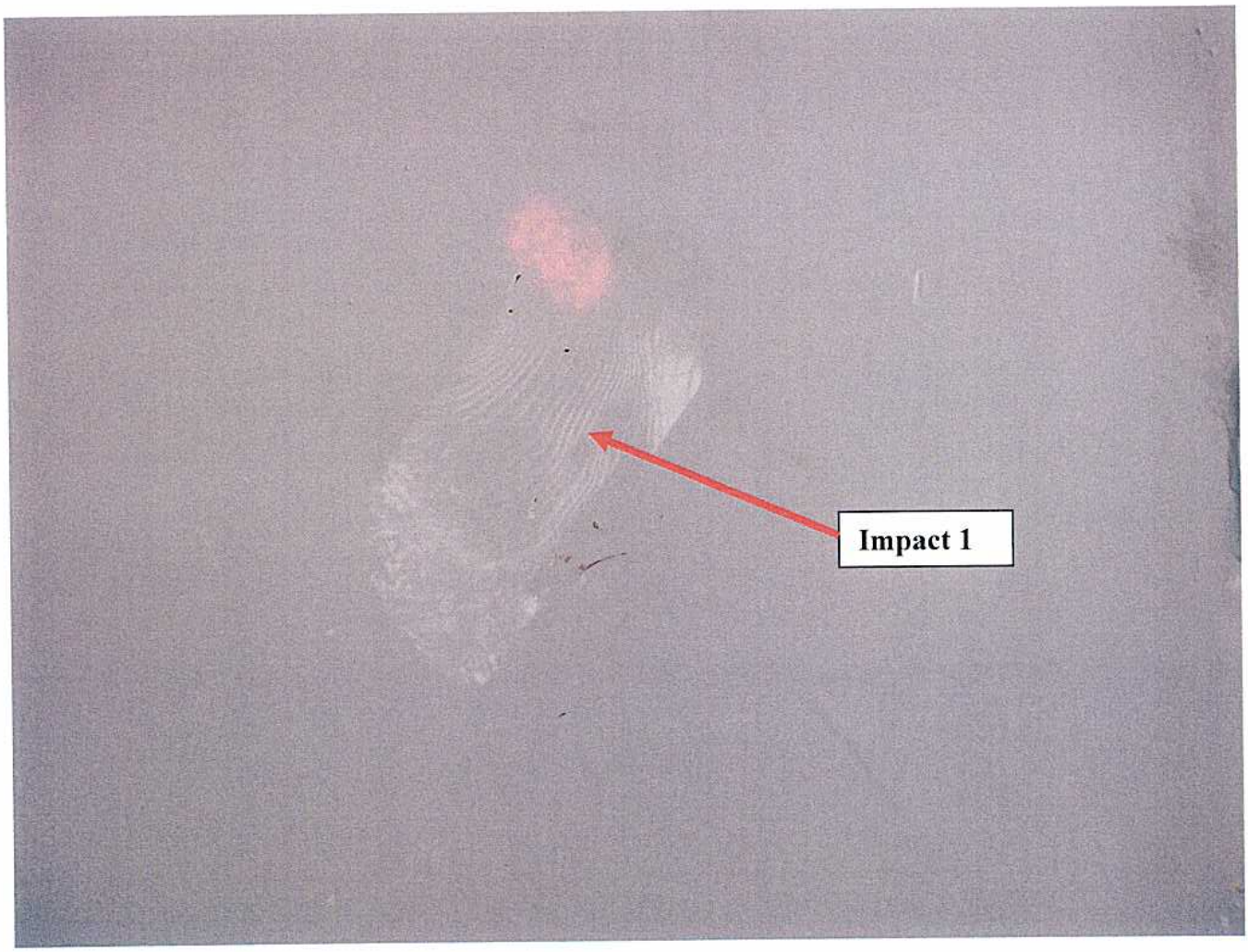
Series 2 – Pressure

Series 2 – Pressure Wall

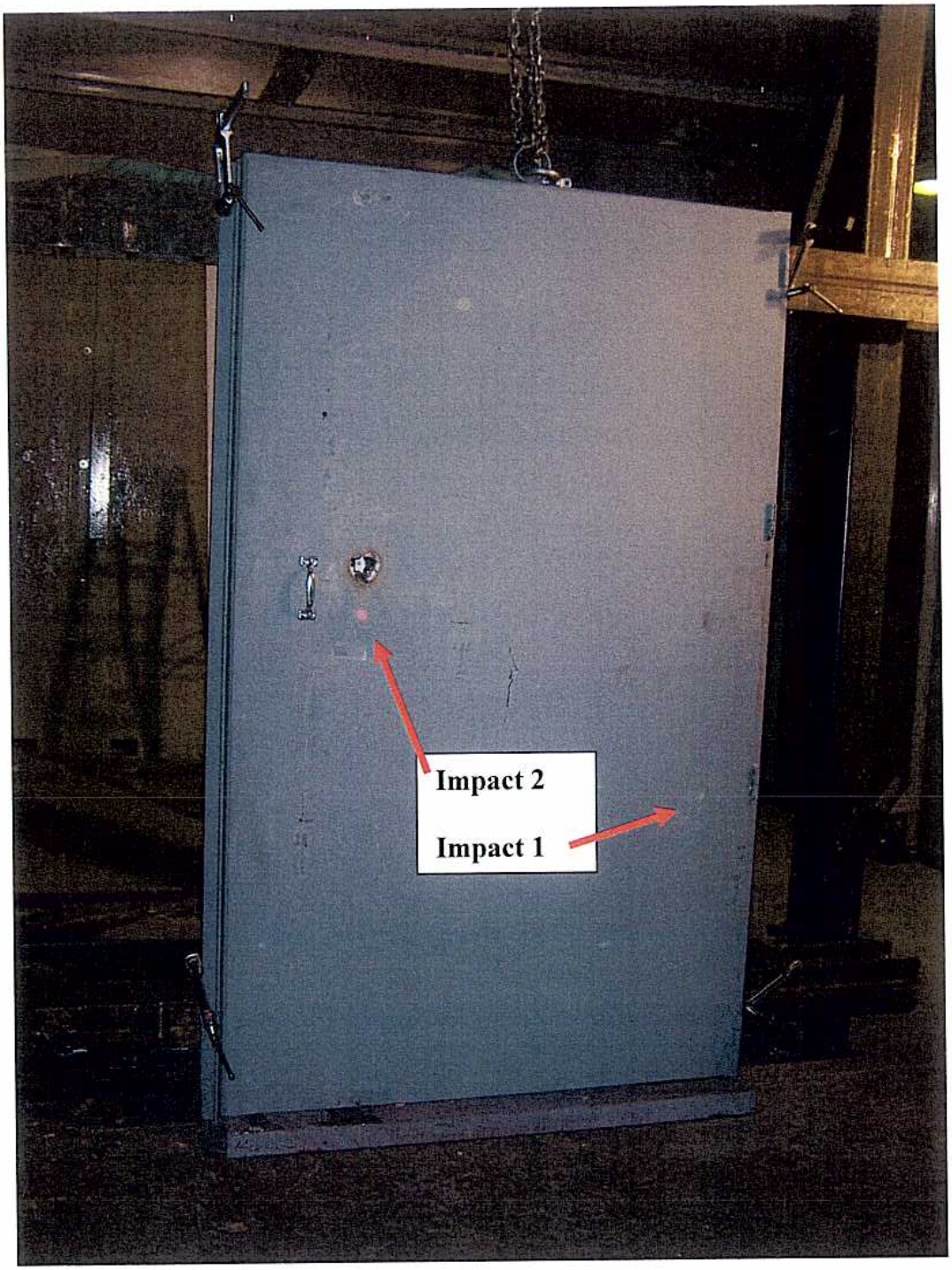


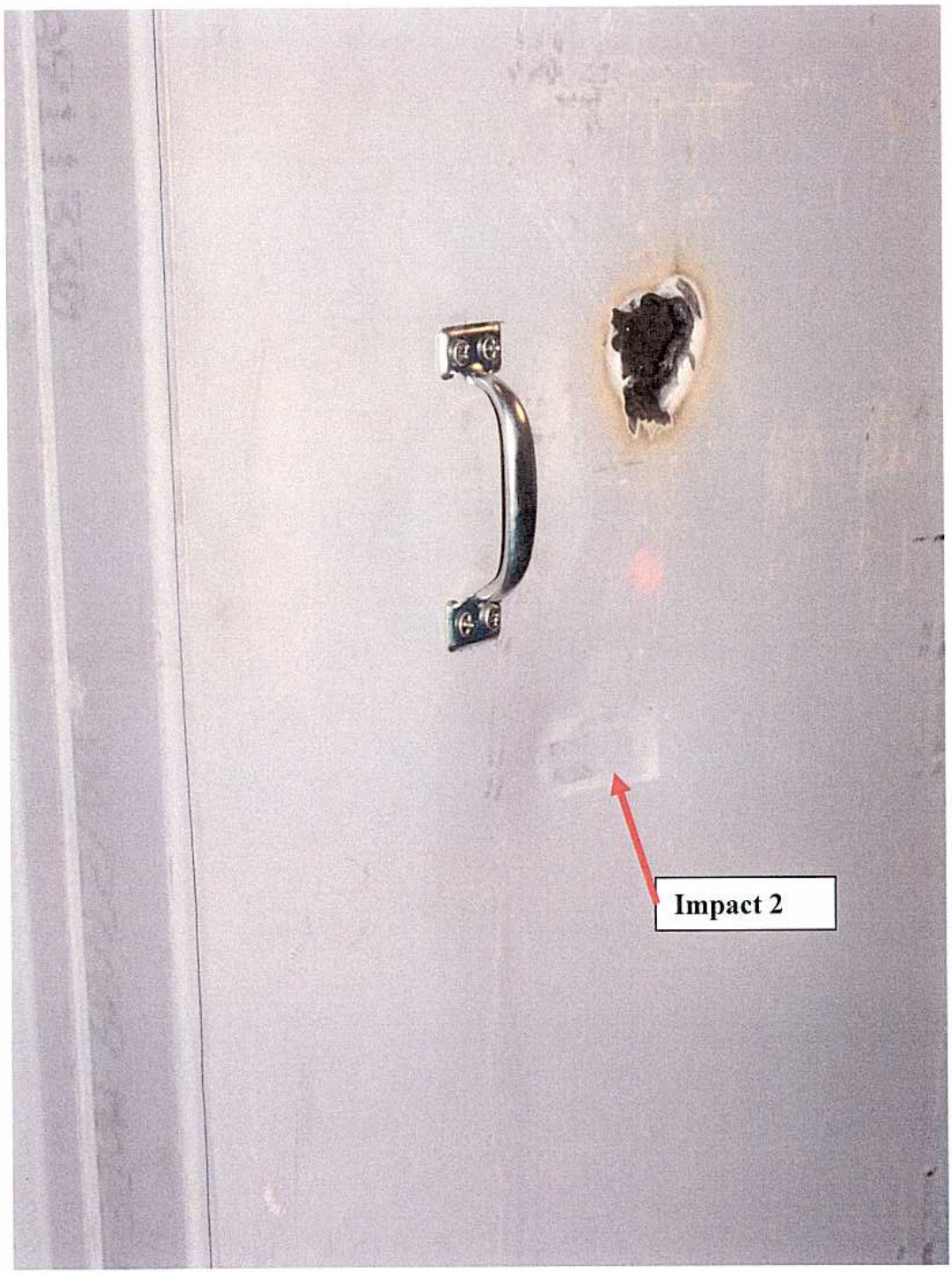
Series 2 - Impact 1



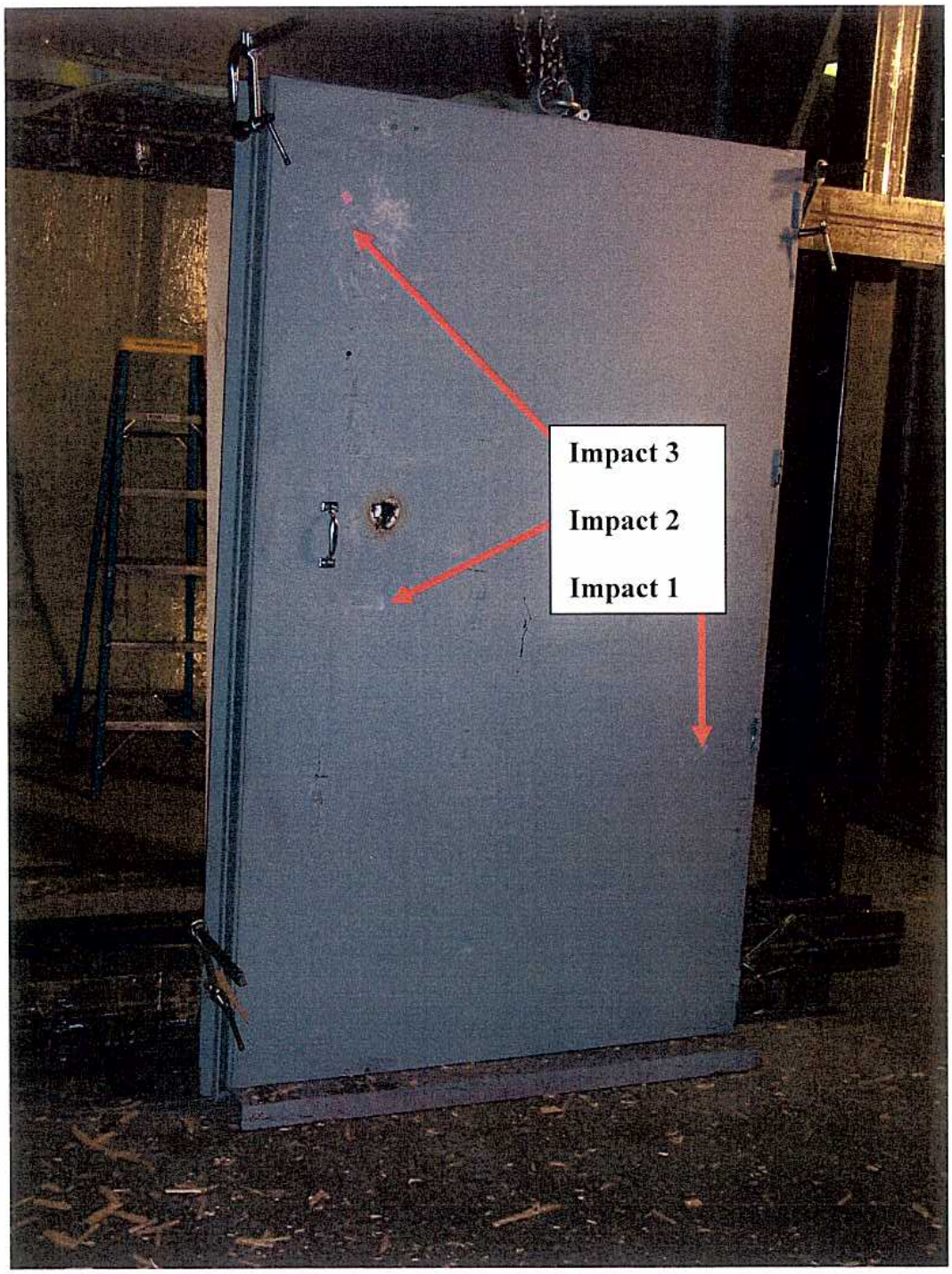

Impact 1

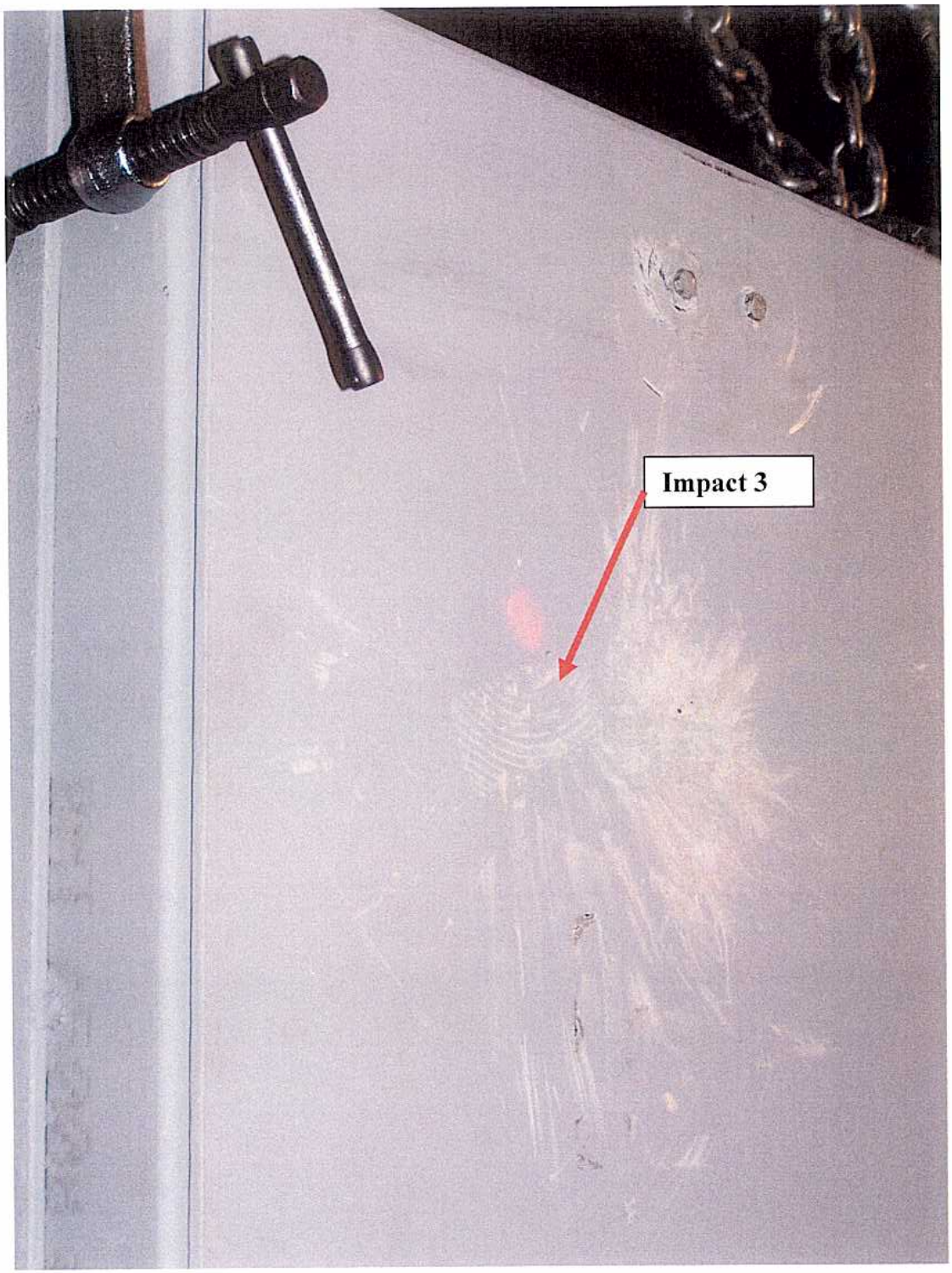
Series 2 - Impact 2




Impact 2

Impact 3




Impact 3

APPENDIX B – TEST PROTOCOLS

The Wind Science and Engineering research Center performs debris impact tests on storms shelters, shelter components, and building materials to evaluate their ability to resist various types of projectiles propelled at different speeds in accordance to accepted and proposed test protocols as follows:

Protocols for Debris Impact Testing

Protocol 1	Hurricane envelope impact by a 9 lb. wood 2"x4" propelled at 34 mph, in accordance with the Florida building Code, the International Code Council and the Texas Dept. of Insurance windstorm Resistant Construction Guide.
Protocol 2	Hurricane shelter speed impact by a 9 lb. wood 2"x4" propelled at 0.40 x the design wind speed (mph) for horizontal impacts and 0.10 x the design wind speed (mph) for vertical impacts, in accordance to the proposed ICC 500[1] – ICC/NSSA Standard for the Design and Construction of Storm Shelters.
Protocol 3	Hurricane shelter speed impact by a 9 lb. wood 2"x4" propelled at 0.50 x the design wind speed (mph) for horizontal impacts and 0.33 x the design wind speed (mph) for vertical impacts, in accordance with FEMA 320, "Taking Shelter from the Storm," 2008 Edition and FEMA 361, "Design and Construction Guidance for Community Saferooms," 2008 Edition.
Protocol 4	Tornado shelter speed impact by a 15 lb. wood 2"x4" propelled at 100 mph for horizontal impacts and 67 mph for vertical impacts, in accordance with FEMA 320, "Taking Shelter from the Storm," 2008 Edition and FEMA 361, "Design and Construction Guidance for Community Saferooms," 2008 Edition; and the ICC-500 "Standard for the Design of Storm Shelters," 2008 Edition.[1]
Protocol 5	Department of Energy (DOE) Impact Standards

[1]The ICC 500 – ICC/NSSA Standard for the Design and Construction of Storm Shelters is a referenced standard in the 2009 editions of the International Residential Code and the International Business Code. This is a Life Safety Standard for protection from tornadoes and hurricanes. For hurricanes the Standard uses an Extreme Wind Map with wind speeds starting at 225 mph and with contours along the Atlantic and Gulf Coast stepping inland in 10 mph increments to 160 mph.

Introduction

The primary objective in debris impact testing of storm shelters and shelter components is to assure compliance with a high standard of performance in protecting shelter occupants from wind-borne debris. Performance criteria include preventing perforation of the shelter or component by the design missile and preventing deformations which could cause injuries to the occupants.

Test Criteria

The testing described is for simulated windborne debris. The primary simulations are impacts of a 2x4-in. wood board traveling along the board's longitudinal axis, striking the test subject perpendicular to the test subject face. Standards that use this type of simulated debris include ASTM E 1886-04 "Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protection Systems Impacted by Missiles and Exposed to Cyclic Pressure Differentials," SSTD 12-99 "SBCII Test Standard for Determining Impact Resistance From Windborne Debris," ANSI A250.13-2003, "Testing and Rating of Severe Windstorm Resistant Components for Swing Door Assemblies," the National Storm Shelter Association (NSSA), "Standard for the Design, Construction, and Performance of Storm Shelters," and Texas Tech University, Wind Science and Engineering's Tornado Test Criterion adopted by the Federal Emergency Management Agency in publication FEMA 320, "Taking Shelter from the Storm," and FEMA 361, " Design and Construction Guidance for Community Shelters." The hurricane test criterion uses a 9-lb. 2x4-in. wood board called a missile, traveling horizontally at 34-mph (50 feet/second), which corresponds to a 110-150-mph wind, and is the criterion used for property protection. The tornado test criterion uses a 15-lb. 2x4-in. wood board traveling horizontally at 100-mph, which corresponds to a 250-mph wind, and is the criterion used in designing vertical surfaces for occupant protection. The criterion for falling debris from a tornado is a 15-lb. 2x4-in. board traveling at 67-mph striking perpendicular to the surface. The 67-mph criterion is used for surfaces horizontal to the ground and inclined less than 30-degrees. Additional factors of safety are inherent in the criterion since there is a very small probability that a missile will be traveling along its axis and will strike perpendicular to the surface.

Test Procedure

The first test on a system is to determine if the basic concept or structural element is capable of resisting the impact. This done by impacting the target in a general field or the area deemed most vulnerable. If the system resists the impact then the testing is concentrated on connections and material support conditions. Shelter walls or test panels are impacted with three test missiles in different and vulnerable locations. Shelter roofs/ceilings constructed differently from the walls are impacted with three test missiles in different and vulnerable locations. Shelter appurtenances, vents, louvers, windows, electrical boxes, shelves, seats, etc., are impacted by a single missile.

Laboratory pressure tests are not conducted on shelters and shelter panels. Numerical analysis of wind pressures is outlined in the above listed standards in the **Test Criteria**. Pressure tests are required for swinging door assemblies. In accordance to FEMA 320, the residential shelter guideline, swinging door assemblies should resist a static pressure of 1.37-psi for a 5-second period. In accordance to FEMA 361, the community shelter guideline, swinging door assemblies should resist a static pressure of 1.75-psi for a 5-second period.

Pass/Fail Criteria

The criterion for the shelter/shell/panel test pass/fail is as follows:

1) The test subject must be impacted by a minimum three missiles in areas of perceived vulnerability;
2) The missile may penetrate that test subject, but may not perforate the safe side (back face) of the subject;
3) The test subject permanent deflection after impact must be less than 3-in.;
4) Segments, spallings or otherwise de-laminated portions of the test subject, though still attached to the subject, may not extend into the safe compartment 3-in. or more; and
5) Segments of the test subject or appurtenances attached to the test subject must not be ejected or otherwise released into the safe compartment by the impact force.

Passage of the shelter door tests requires:

1) The door assembly must hold the required test pressures,
2) Resist perforation by the missiles,
3) Exhibit permanent deflection less than 3-inches,
4) Prevent disassociation of door components or shelter wall materials into the safe compartment,
5) Maintain two door locking points engaged and locked. FEMA 320/361 recognizes that one test missile can destroy or otherwise disengage one locking point. The guideline therefore requires that at least two locking points remained engaged and doors with only two points of locking must have both locks remain engaged and locked at the conclusion of the impact tests.
6) Pass/fail rating of the door relates to the full door assembly, including door, locking hardware, hinge, hinge screws and door frame.

Test Equipment

Debris Impact Air Cannon:

1) Air Tank – 30 gallon, Manchester Model Number 301853.
2) Electric Over Air Valve – Matryx Model Number MX200 – 600501.
3) 4-in. aluminum quick coupler to connect barrel to valve.
4) 4-in. x 20-ft. long schedule 40 PVC barrel.
5) Pair Optical Timing Sensors – Keyence Model Number PZ251R and PZ125T 12/24-volt.
6) Signal Conditioner.
7) Pair Precision Timers – BK Precision Timer Model Number 1823 Universal Counter.
8) Control panel with pressure controls, laser sighting and a three stage firing system to eliminate unintentional missile shots.
9) Horizontal articulating cannon carriage with DC motor drive and variable speed controller.
10) Cannon carriage mounted to a hydraulic scissor lift on wheels - Autoquip Model Number 84B16F20.
11) Steel reaction frame made of vertical and horizontal steel beams anchored to the floor to provide simple support at the top and bottom of the test specimen.

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II. Whenever the logo is used one of the two alternative statements below is to be employed in the text:

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Alternate 2 - shelter component
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