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Evaluation of the Egress Provisions of the HUD Mobile Home Construction and Safety Standard

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A STUDY OF THE EGRESS PROVISIONS OF THE HUD MOBILE HOME CONSTRUCTION AND SAFETY STANDARD

by

Sanford C. Adler

ABSTRACT

Evaluative tests were carried out to assess the adequacy and sufficiency of the HUD Mobile Home Construction and Safety Standards. Project activities included library research, laboratory testing and construction of a Mobile Home Emergency Egress Demonstration Unit. The study recommended: (1) establishment of performance goals to relate the desired objective (safe egress) to the specific requirements of the standard; (2) expansion of the scope of the requirements to assure that egress devices do not adversely affect the safety or security of the mobile home under normal living conditions; and (3) support of applied research to interrelate egress requirements, device characteristics, and human capabilities.

KEY WORDS: Emergency egress; HUD; mobile home; racking; research; safety; standard; window

EXECUTIVE SUMMARY

This study was carried out to identify the technical basis of the emergency egress provisions of the HUD Mobile Home Construction and Safety Standard, and to conduct evaluative tests to assess the adequacy and sufficiency of the egress provisions. There are two basic questions addressed by this study:

1. Is there readily available technical data that can be pointed out as the technical basis for the current emergency egress provisions of the standard?

2. Are the emergency egress requirements of the standard adequate?

In general, the answer to both of these questions is "no."

The standard appears to adequately address the deficiencies which existed in mobile home egress windows and appurtenances (screens and/or storm windows) in use at the time the standard was written. However, it does not appear to adequately address the potential deficiencies which are inherent in some of the newly-designed egress devices.

Library research was carried out to identify the technical basis of the egress requirements of the standard. With the exception of limited studies concerned with the minimum dimensions of an egress device, very little relevant data was found which addressed the physical and sensory limitations of mobile home occupants or the behavior of adults and children under emergency conditions. State-of-the-art research on tenability criteria and maximum time for egress in a mobile home fire is currently under way at the National Bureau of Standards.

Laboratory research to assess the current requirements and test procedures identified several areas where the current requirements appear to be inadequate and conflicting. These problems are discussed in detail in the body of the report.

A demonstration unit was constructed by installing new prototype egress windows in a 1972 mobile home obtained from the Disaster Housing Management Office, HUD. The unit contains nine different devices which can be compared as alternative methods of egress.

The following recommendations provide a rational framework for future improvement of the egress provisions of the Federal Mobile Home Construction and Safety Standards.

1. Establish Performance Goals

The standard should establish performance goals which explicitly define the potential hazards which justify the need for emergency egress (such as fire); the population of mobile home occupants expected to be able to exit unassisted; and the tenability criteria and appropriate safety factors which determine the maximum allowable time for egress.

2. Expand the Scope of the Standard

The scope of the standard should be expanded to assure that the introduction of an egress device does not reduce the livability of the mobile home by adversely affecting safety or security under normal living conditions.

3. Support Applied Research

Applied research should be supported which explicitly relates the emergency egress requirements of mobile homes to the physical, sensory, and behavioral attributes of representative mobile home occupants.

EVALUATION OF THE EGRESS PROVISIONS OF THE HUD MOBILE HOME CONSTRUCTION AND SAFETY STANDARD

Sanford C. Adler

I. INTRODUCTION

A. Background

In accordance with congressional legislation which mandated the development of a national mobile home standard, the Department of Housing and Urban Development (HUD) published in the Federal Register (40 FR 58754) the final rules and regulations for the Federal Mobile Home Construction and Safety Standards. The standard, dated December 18, 1975, became effective June 15, 1976, and is in substantial measure based on previously existing National Fire Protection Association and American National Standards Institute standards (NFPA-501B-1974, ANSI, A119.1-1975). In addition, parts of the HUD standard are derived from state standards, enforcing agency standards, and the results of mobile home research conducted at the National Bureau of Standards (NBS) and elsewhere.

An important segment of this standard is that part which contains the emergency egress provisions. There has been concern among officials of HUD and building officials in general that there is no published or readily available technical data that can be pointed to as the technical basis for the current provisions. As a result, the Division of Energy, Building Technology, and Standards of the Office of Research and Demonstration, HUD, asked NBS to conduct evaluative tests to assess the adequacy and sufficiency of the egress provisions of these standards.

B. Objective

The objective of this study is to provide a technical basis for judging the adequacy and sufficiency of the emergency egress provisions (other than doors) of the HUD Mobile Home Construction and Safety Standards.

There are two basic assumptions (leading to four possible outcomes) underlying the use of standardized test procedures or requirements.

1. Assumptions

(a) There are "good" devices and "bad" devices. (In simplest terms, a "good" device would permit rapid, safe egress in an emergency, while a "bad" device might not.)

(b) The test procedures or requirements of the standard can distinguish between "good" and "bad" devices.

2. Possible Outcomes

(a) A device is "bad," and it fails the requirements of the standard. This is a desirable outcome.

(b) A device is "bad," but it does not fail the requirements of the standard. This is a serious error which permits a high risk of injury or loss of life in an emergency. (Type I error)

(c) A device is "good," and it passes the requirements of the standard. This is a desirable outcome.

(d) A device is "good," but does not meet the requirements of the standard. This kind of error leads to increased cost without benefit. (Type II error)

In general, test procedures or requirements which tend to decrease the Type I error tend to increase the Type II error. Hence, every standard should strike a balance between benefit (increased public safety) and cost. A cost-benefit analysis was beyond the scope of this study.

C. Work Statement

The work was carried out as three distinct but interrelated tasks.

1. Literature Search

A literature review was conducted to determine whether existing data relating to physical and sensory limitations of mobile home occupants, behavior of children and adults under emergency conditions, characteristics of egress devices, and our knowledge of life-threatening elements of a hazardous situation were or could be related to the specific egress requirements of the standard.

2. Demonstration Unit

A demonstration unit was constructed to test and demonstrate the functional characteristics of typical emergency egress devices as they are installed in a mobile home.

3. Laboratory and Field Research

Laboratory studies were conducted to examine the general functional characteristics of existing emergency egress devices and to determine the feasibility and applicability of the physical test requirements of the standard. Planned field studies to determine the effect of installation, transportation and use on the functional characteristics of egress windows could not be conducted at the time of the study, since mobile homes containing new egress devices were not available.

D. Egress Requirements of the Standard

The emergency egress requirements (other than doors) are contained in sections 280.106 and 280.404 of the HUD standard and are summarized in Table 1. The requirements cover construction, operation, and installation of windows, window appurtenances, and egress devices. Construction and operation requirements include:

1. Windows

(a) Size. Windows must have a clear opening of at least 5 ft^2 (.46 m^2), and minimum horizontal and vertical dimensions of 22 in (56 cm).

(b) Latches - No more than two latches, permanently attached or requiring special tools to remove, located no more than 60 in (152 cm) above the floor of the mobile home. Rotary operation in excess of 180° not allowed.

(c) Operating forces. Operating forces on latches or for lifting or sliding cannot exceed 20 lbs (89 N).

(d) Instruction. Instructions for operating windows and appurtenances must be permanently attached to the window and contain the legend "do not remove."

2. Appurtenances (Screens and/or Storm Windows)

(a) Size. Same minimum dimensions and area as windows.

(b) Latches. No more than four latches, which cannot be misapplied with normal household tools, located no more than 60 in (152 cm) above the floor of the mobile home. Contact area of operating latch must be equal to or greater than .25 in^2 (1.61 cm^2).

(c) Operating Forces. Operating forces on latches or for lifting or sliding cannot exceed 5 lbs (22 N).

3. Egress Devices

(a) Latches. Latches cannot be more than 60 in (152 cm) above the floor.

TABLE 1

EGRESS PROVISIONS OF HUD MOBILE HOME STANDARD

Requirement	Egress Device	Window	Appurtenance
Dimensions			
Minimum Height		280.404(b)(3)(i) 22" minimum	280.404(c)(1) Shall not encroach upon requirement of section (b)(3)
Minimum Width		280.404(b)(3)(i) 22" minimum	280.404(c)(1)
Minimum Area		280.404(b)(3)(ii) 5 square feet	280.404(c)(1)
Location			
Rooms in Mobile Home	280.106(a) Every room designed for sleeping and not having an exit door, shall have a window or device which meets 280.404	280.106(a) Every room designed for sleeping and not having an exit door, shall have a window or device which meets 280.404	Not Required
Place in Room	None (280.106(b) Specifies windows)	280.106(b) Bottom of opening maximum 36" above the floor	
Operation			
Number of Latches		280.404(b)(4)(ii) Maximum 2	280.404(c)(2)(i) Maximum 4
Location of latches, operating handles, tabs and any other window, screen or storm window device which needs to be operated to exit	280.106(c) Maximum 60" above floor	280.106(c) Maximum 60" above floor	280.106(c) 60" above floor
Surface to which operating force is applied		None	280.404(c)(2)(iv) minimum .25 square inch area
Rotary operation (More than 180°)		280.404(b)(4)(v) Not allowed	
Forces - operating forces on locks, latches, lifting and sliding		280.404(b)(4)(iii) 20 pounds	280.404(c)(2)(ii) 5 pounds
Operating Instructions			
When required		280.404(b)(1) Window manufacturers supply written instruction to home manufacturers	
Content		280.404(b)(4)(i) on window with legend "Do Not Remove" and reminder to remove all shipping clips	280.404(c)(4)(i) Instructions on removal included on window label specified in 280.404 (b)(4)(i)
Construction			
Method of attachment of handles, latches		280.404(b)(4)(iv) Permanent or requiring special tools to remove	280.404(c)(2)(iii) Cannot be misapplied with normal household tools
Performance		280.404(b)(2) Meet requirements of 280.403	

II. DEMONSTRATION UNIT

A demonstration unit was constructed by installing prototype egress windows and devices in a 1972 model mobile home obtained from the Disaster Housing Management Office of the Department of Housing and Urban Development. The mobile home is a two-bedroom, 60 ft x 12 ft unit manufactured by Elcona Homes Corporation of Elkhart, Indiana. (See Fig. 1.)

A list of egress window manufacturers was obtained with the assistance of Associated Certification, Inc. (Dallas Labs.). Using this listing, manufacturers were contacted directly to obtain samples of egress windows. It is important to note that the windows installed in the demonstration unit are representative of the types of windows being manufactured, but are not necessarily identical in construction. The devices installed in the demonstration unit are described below and summarized in table 2.

A. Newly-Manufactured Windows and Egress Devices

1. Casement Window

Figure 2 illustrates a 24 in (61 cm) wide by 33 in (84 cm) high double-glazed casement window with a clip-on inside screen. The window can be mounted with the vertical hinge on either the left or right side. The latch mechanism located on the right side of the window is used for normal operation or for egress when the screen is first removed.

A similar, but larger casement window, 30 in (76 cm) wide by 39 in (99 cm) high is also installed in the demonstration unit.

2. Awning Window - Egress Frame

Figure 3 illustrates a 30 in (76 cm) wide by 39 in (99 cm) high awning window mounted in an egress frame. The window was supplied with a separate interior frame for mounting either a storm window or screen. A rotary crank near the lower right side of the frame is used for normal operation of the window. The egress latch is a vertical bar on the left side of the window frame which can be reached after the storm window or screen is removed. When the egress latch-bar is displaced vertically a few inches, it releases the frame and the entire window assembly can be pushed open like a casement window.

3. Vertical Sliding Window - Egress Frame

Figure 4 illustrates a 30 in (76 cm) wide by 39 in (99 cm) high vertical sliding window mounted in an egress frame. The window has an outside screen and was supplied with a separate interior frame for mounting a storm window. For normal operation, the bottom half of the window slides up and down. The egress frame and mechanism operates the same as the awning window described in 2. above.

4. Horizontal Sliding Window

Figure 5 illustrates a 46 in (117 cm) wide by 39 in (99 cm) high horizontal sliding window with an inside double track storm window and an outside screen. During normal operation or egress, the right-most window and storm window are pushed to the left. To egress, the screen must also be removed.

5. Awning Window, Pop-out Panes

Figure 6 illustrates a 30 in (76 cm) wide by 53 in (135 cm) high awning window with pop-out panes. No appurtenances were supplied with the window. During normal use, a rotary crank located mid-way along the right side of the window opens and closes the top two lights. To egress, a latch located on each side of the window (near the top of the bottom pane) is lifted, permitting the bottom two panes to fold out and down.

6. Vertical Sliding Window

Figure 7 illustrates a 30 in (76 cm) wide by 59 in (150 cm) high vertical sliding window with an inside double track storm window and an outside screen. Normal and egress operation of the window are identical except for the additional step of removing the screen for egress. To operate either the prime window or the storm window, you must simultaneously disengage latches at both sides of the bottom of the frame and lift the window.

7. Knock-Out Panel

Figure 8 illustrates a 22 in (56 cm) by 22 in (56 cm) wall panel mounted a few inches above the floor. The panel is used only for emergency egress which is accomplished by opening the two latches (in either order) and pushing the panel out.

B. Original Equipment

1. Awning Window, Piggyback Egress Frame

Figure 9 illustrates a 30 in (76 cm) by 40 in (102 cm) high awning window mounted in an egress frame with a piggyback design.[1] A rotary crank at the lower right side of the frame is used for normal operation of the window. To egress, two latches located along the left side of the frame are released and the window is pushed open. The entire window assembly, including the attached storm window or screen, opens like a casement window. The mobile home had one of these windows installed in each of the two bedrooms.

2. Non-Egress Awning Window

Figure 10 illustrates a 30 in (76 cm) wide by 40 in (102 cm) high awning window of conventional (non-egress) design. The window was installed with an interior frame for securing an inside clip-on screen or storm window. A rotary crank near the lower right side of the frame (missing in Fig. 10) is used for normal operation of the window. There are two of these windows remaining in the demonstration unit.

[1]Piggyback design - A window design which includes a frame within a frame. The inner frame contains all of the functional components for normal window operation, including storm windows or screens. If the outer frame is released for egress, the entire window assembly moves as a unit.

TABLE 2

WINDOWS AND EGRESS DEVICES INSTALLED IN DEMONSTRATION UNIT

New Windows and Egress Devices

1.	Casement window, double glazed, inside screen (two specimens)	30 in (76 cm) wide x 39 in (99 cm) high and 24 in (61 cm) wide x 33 in (84 cm) high
2.	Awning window, egress frame, inside clip-on screen/storm window	30 in (76 cm) wide x 39 in (99 cm) high
3.	Vertical sliding window, egress frame, inside clip-on storm window, outside screen	30 in (76 cm) wide x 39 in (99 cm) high
4.	Horizontal sliding window, inside double track storm window, outside screen	46 in (117 cm) wide x 39 in (99 cm) high
5.	Awning window, pop-out panes, no appurtenances	30 in (76 cm) wide x 53 in (135 cm) high
6.	Vertical sliding window, inside double track storm window, outside screen	30 in (76 cm) wide x 59 in (150 cm) high
7.	Knock-out wall panel (two specimens)	22 in (56 cm) wide x 22 in (56 cm) high

Original Equipment (1972 Mobile Home)

1.	Awning window, conventional design, clip-on inside screen/storm window	30 in (76 cm) wide x 40 in (102 cm) high
2.	Awning window, egress frame, piggyback inside screen/storm window	30 in (76 cm) wide x 40 in (102 cm) high

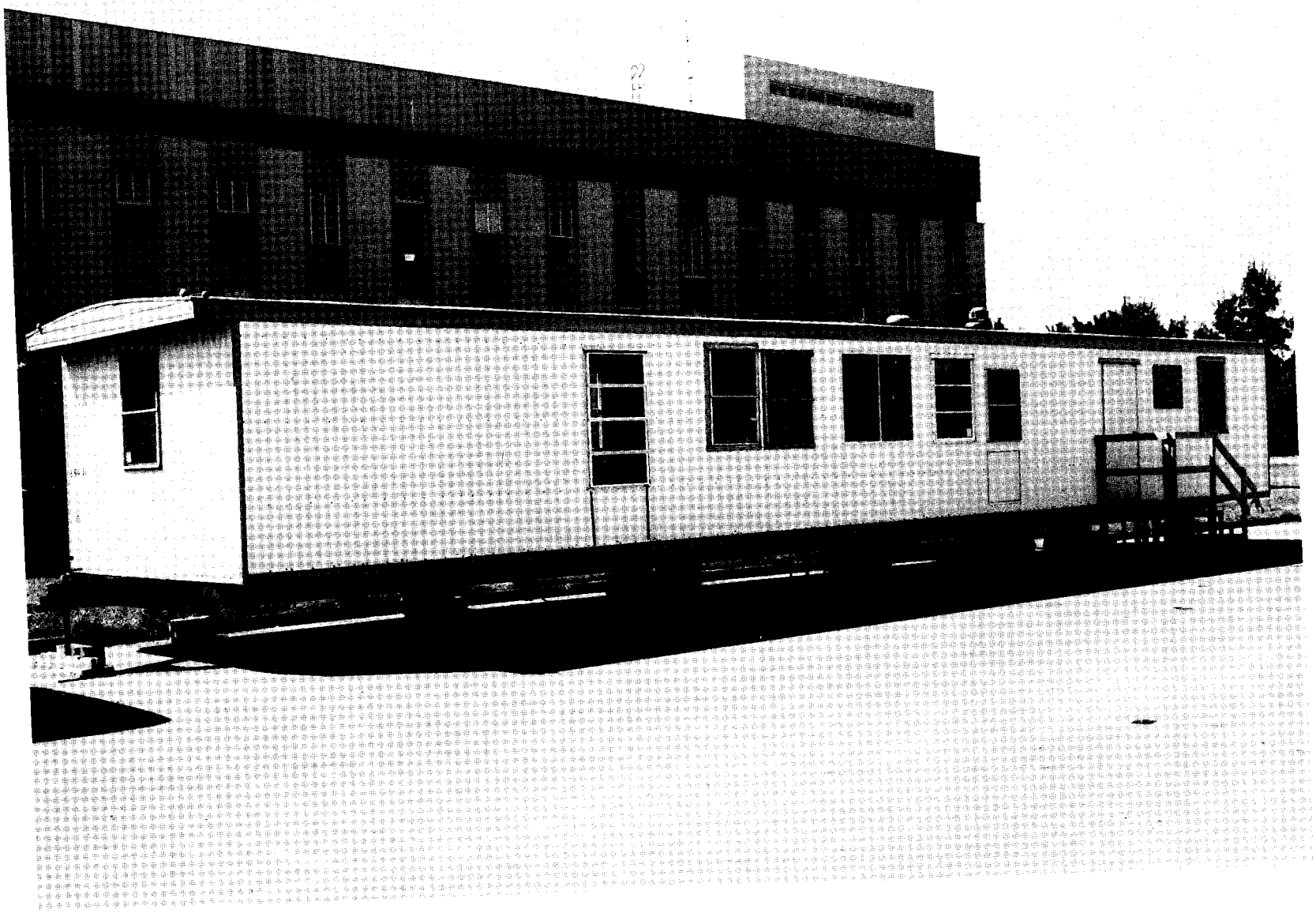

Figure 1. Emergency Egress Demonstration Unit
Side view of the Mobile Home Emergency Egress Demonstration Unit, showing several of the egress devices installed in the unit.

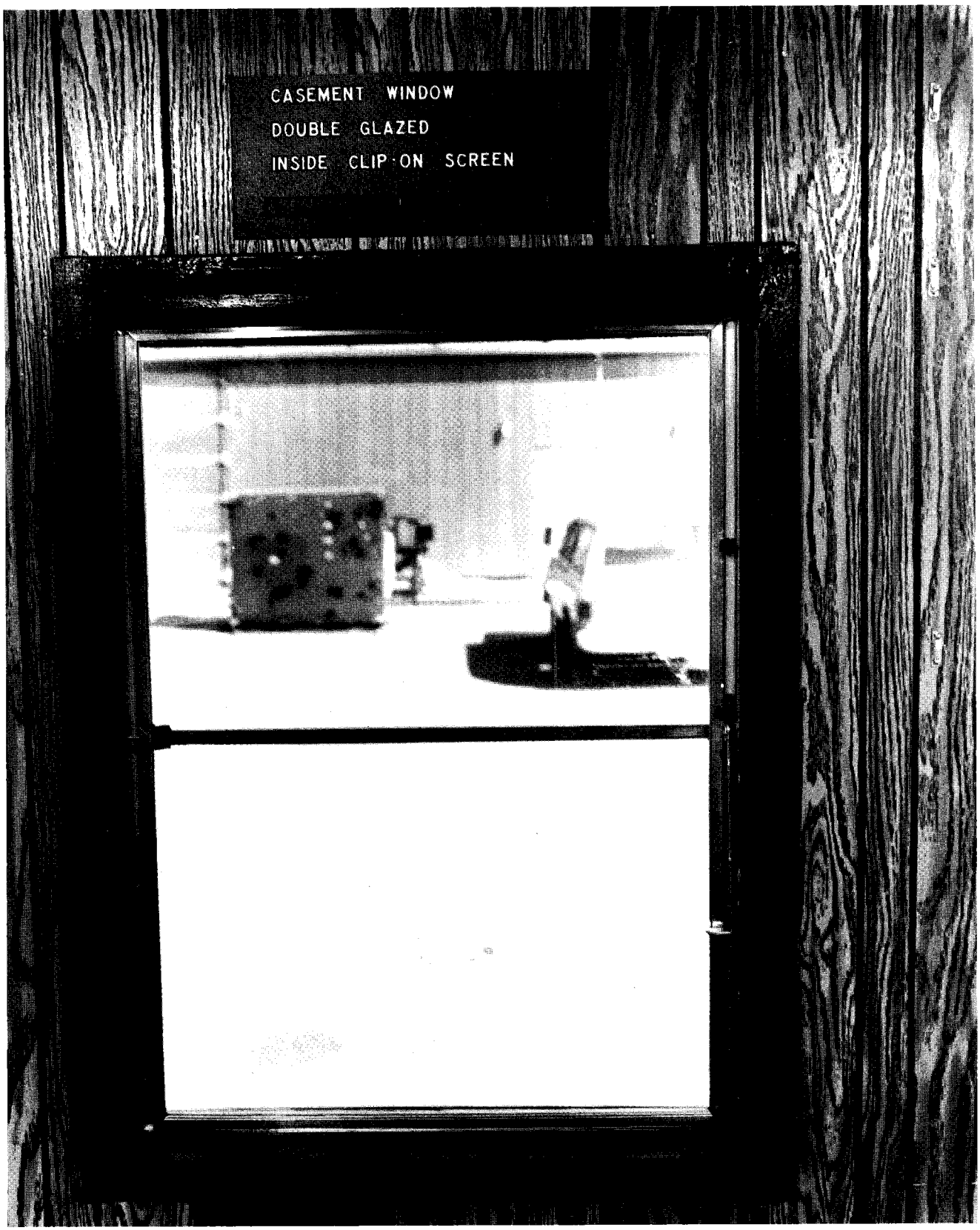

Figure 2. Demonstration Unit.
Casement window

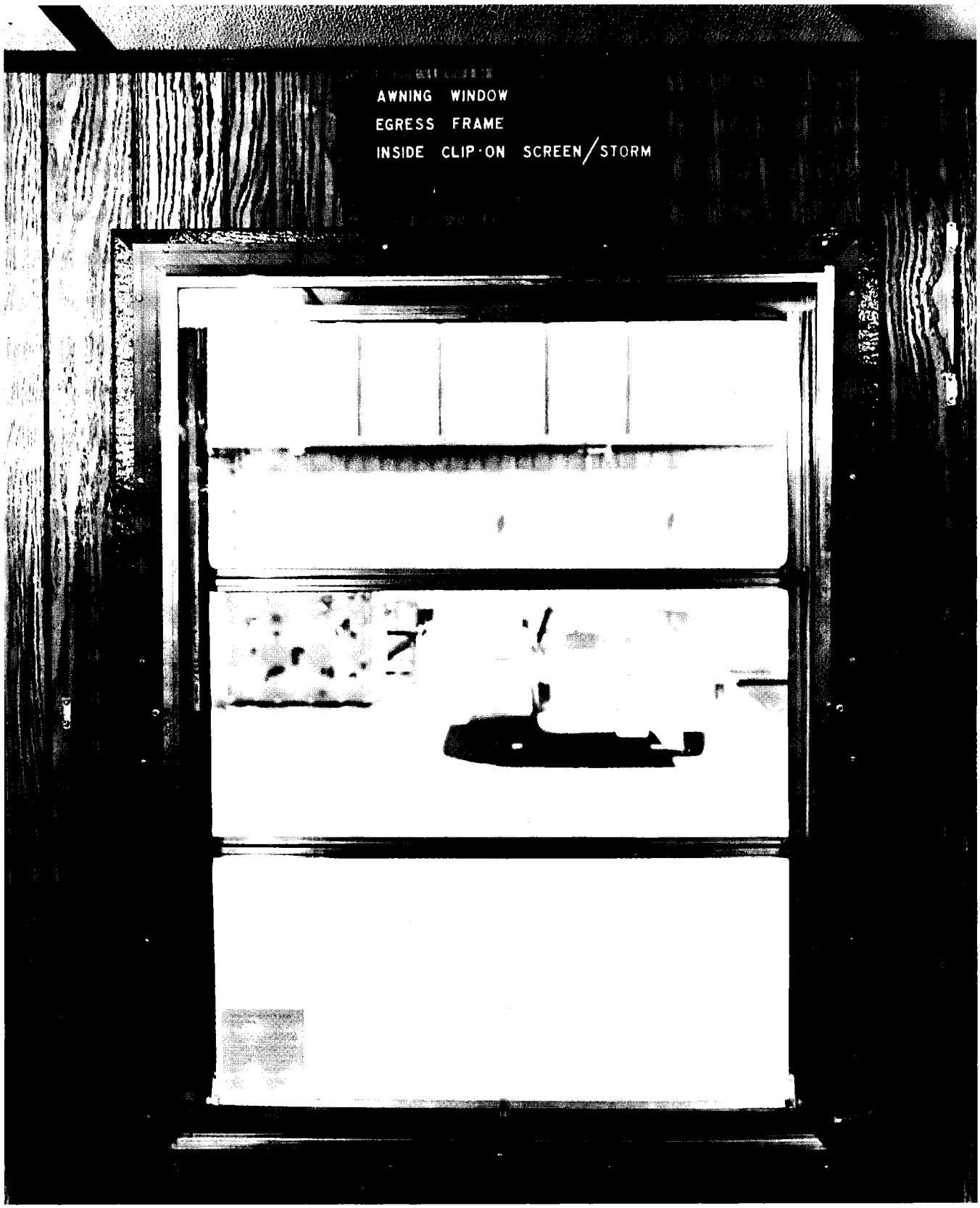

Figure 3. Demonstration Unit.
Awning window in egress frame

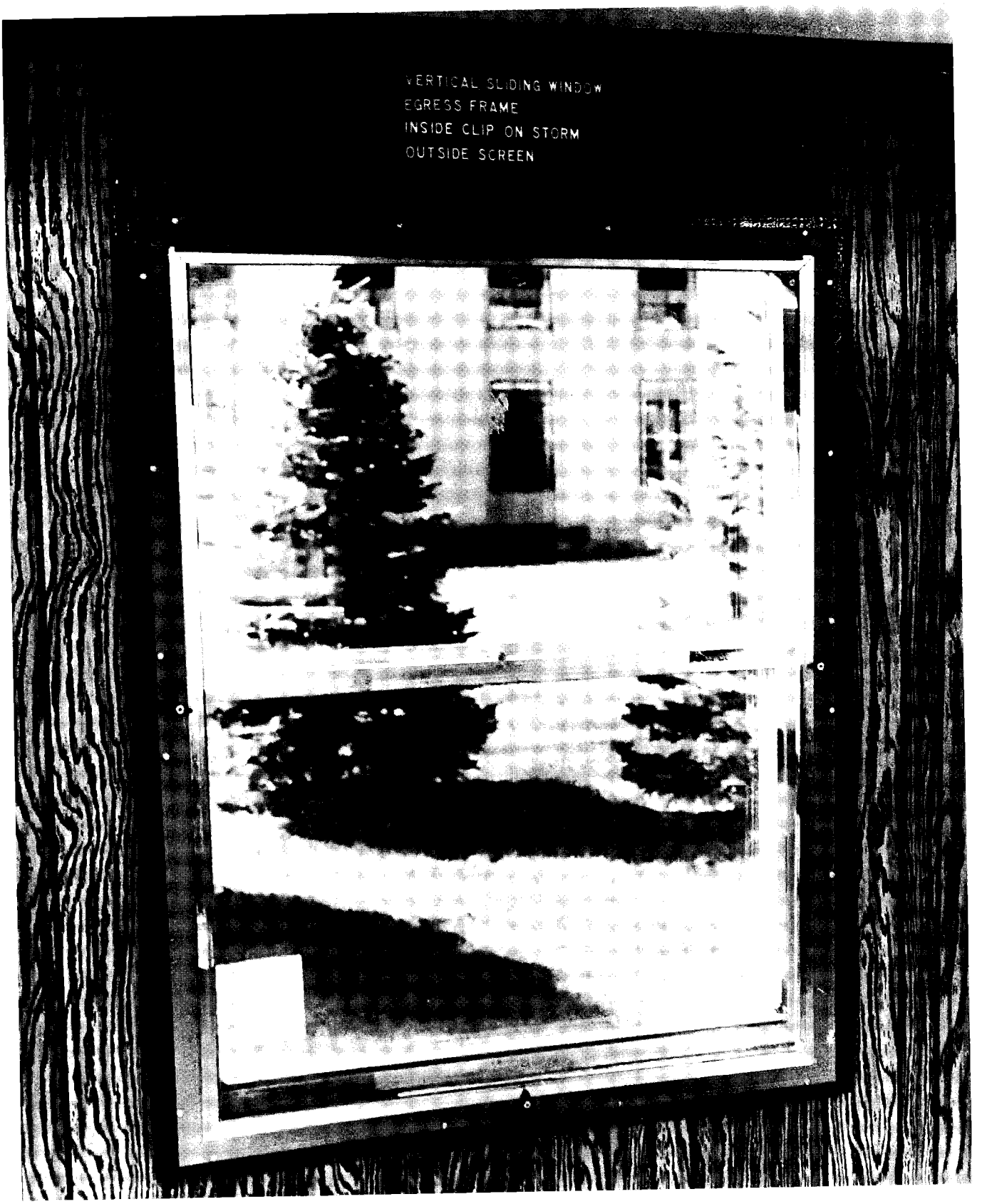

Figure 4. Demonstration Unit.
Vertical sliding window in egress frame

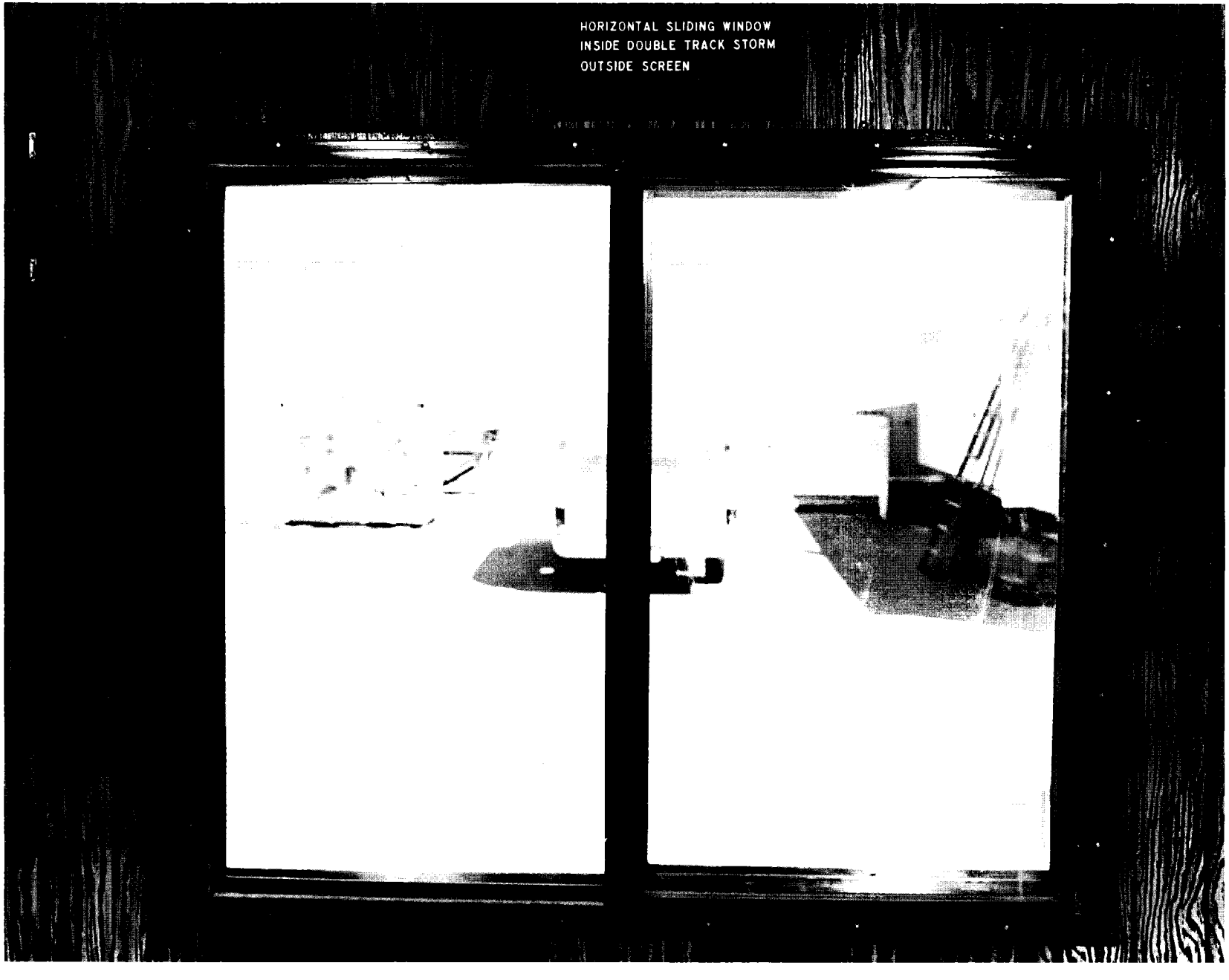

Figure 5. Demonstration Unit.
Horizontal sliding window

Figure 6. Demonstration Unit.
Pop-out awning window

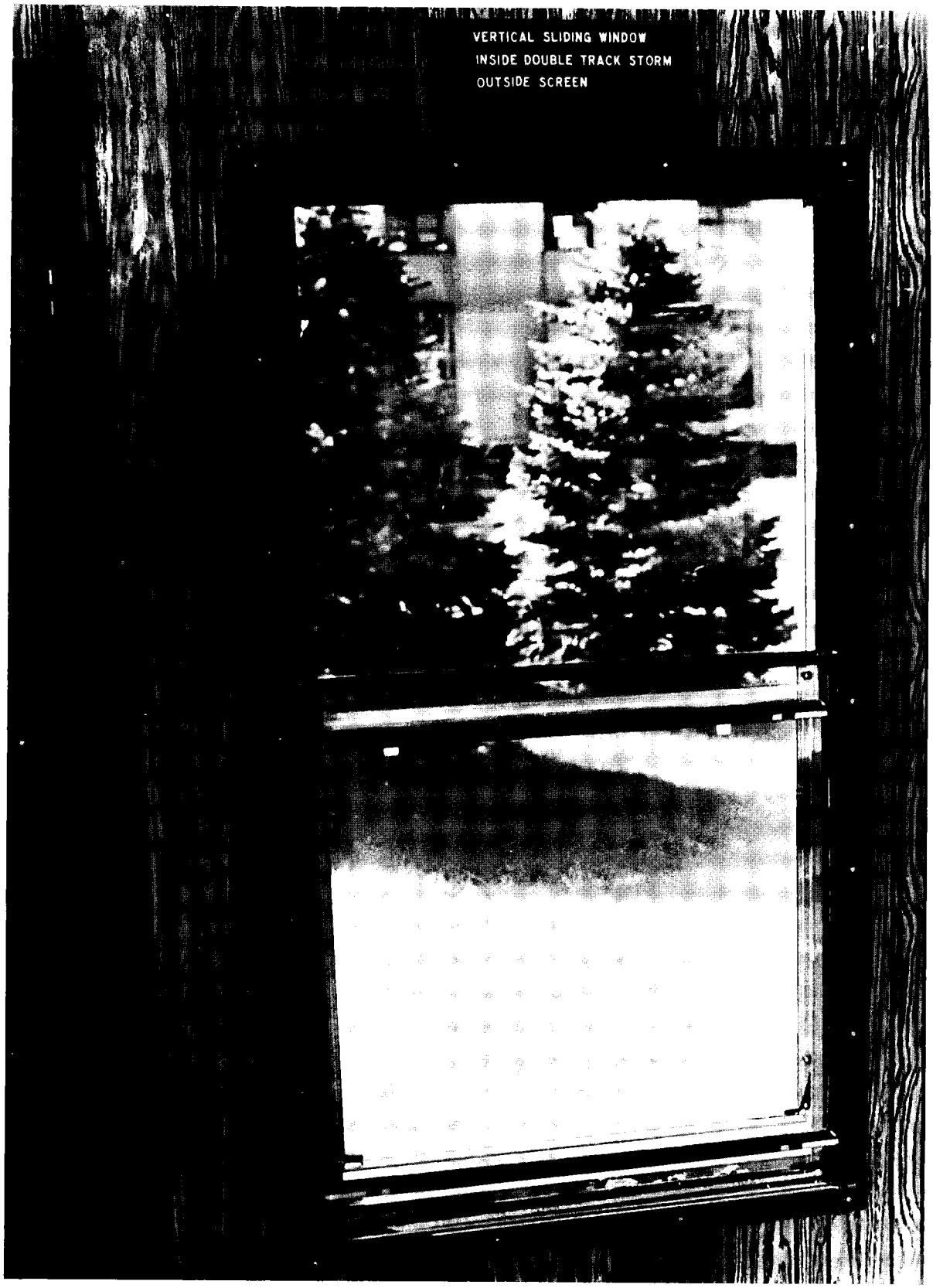

Figure 7. Demonstration Unit.
Vertical sliding window

Figure 8. Demonstration Unit.
Knock-out panel

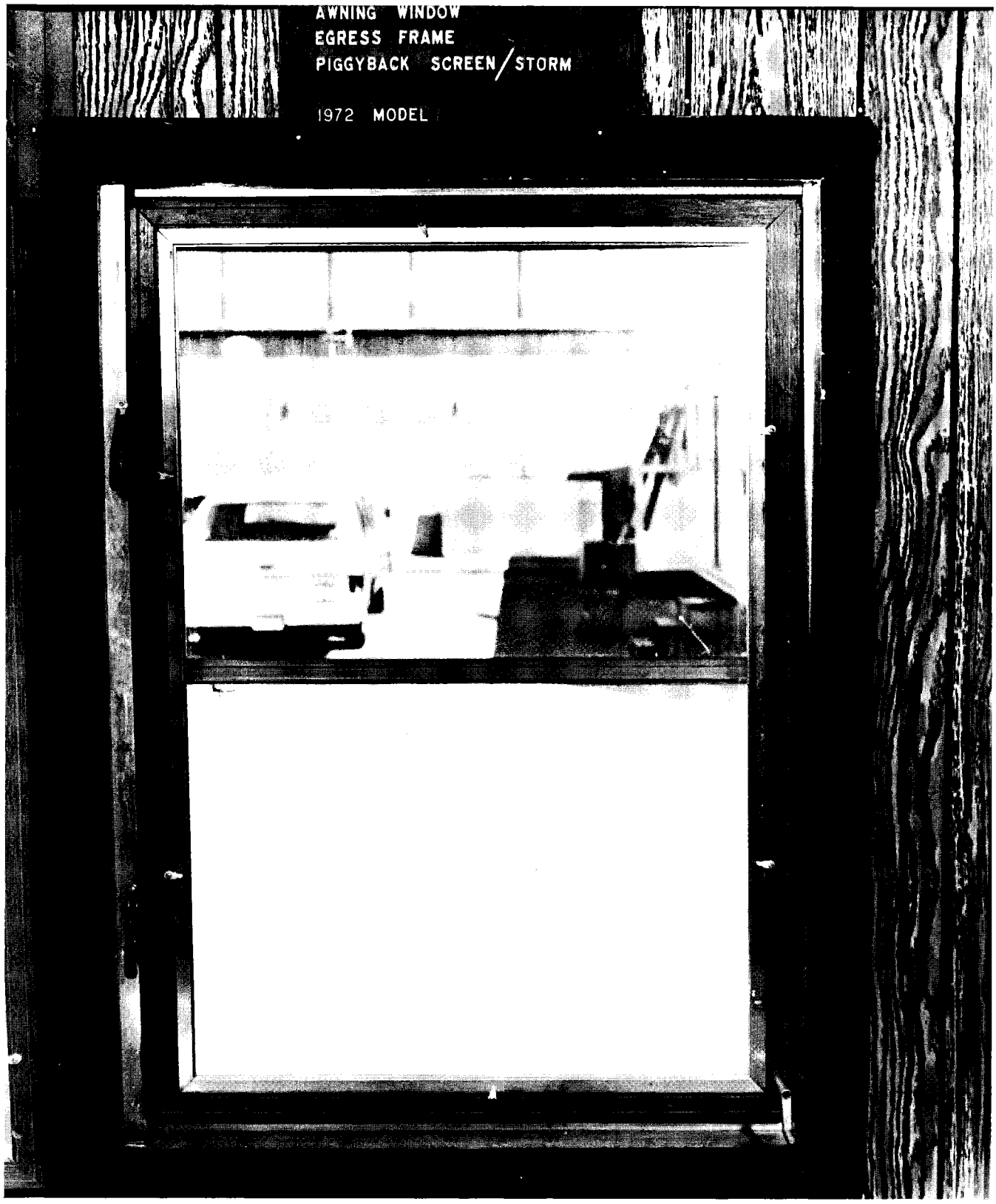

Figure 9. Demonstration Unit.
Awning window in piggyback egress frame

Figure 10. Demonstration Unit.
Non-egress awning window

III. LABORATORY TESTS

Laboratory tests were conducted on eight egress devices in accordance with the test procedure described in section 280.404(d) of the HUD standard. Two windows and an egress panel were tested in the mobile home demonstration unit and five windows were tested in the Building Safety Laboratory. After completing the basic tests required by the standard, the five windows tested in the laboratory were subjected to mild and severe racking,[1] such as might occur due to the foundation settlement or physical displacement of a mobile home. Data was collected on forces required to operate the racked windows.

A. Procedure (general)

A large steel test frame was constructed in the Building Safety Laboratory to conduct tests as specified in the standard and also permit controlled racking of window specimens as large as 75 in (190 cm) wide and 66 in (168 cm) high. (See Figs. 11 and 12.)

Windows were prepared in the following manner:

1. For tests in the Safety Laboratory, the steel test frame was leveled and locked in position.

2. A wooden frame was constructed of standard 2 x 4 lumber, and secured inside the steel test frame or built into the wall of the mobile home. The dimensions of the window frame opening were determined from the manufacturer's installation instructions or by adding 1/4 in (64 mm) to the measured dimensions of the window.

3. After carefully leveling and squaring the wooden frame, the window unit was installed and attached using the manufacturer's pre-drilled screw holes.

4. All shipping clips were removed and the window was checked for proper normal and egress operations.

5. Appurtenances which required separate mounting frames were tested in the mobile home demonstration unit. (Mounting them in the laboratory test frame would have interfered with the racking tests on the prime windows.)

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[1] Racking - a vertical force was applied to the framed window to cause the window and frame to be displaced relative to their original position.

6. Operating forces were measured by pushing or pulling the window mechanisms with a Chatillion DPP-50 Force Gauge. Prior to testing, the accuracy of the gauge was verified using dead weight loads up to 25 lbs (11.3 kg). When the window configuration permitted, a crank was used to pull the gauge at a uniform rate of approximately 15 in/min (38 cm/min). Otherwise, the laboratory technician applied the gauge manually at a uniform but somewhat faster load rate. (See Fig. 13.)

B. Tests Required by Standard

The general procedure for testing each device is described above. It is important to remember that these tests were carried out to evaluate the test procedure rather than the test specimens. Since the specimens were not randomly selected, but were specially prepared for shipment to the National Bureau of Standards, the test results have no statistical significance.

Eight egress devices were subjected to physical testing. The devices are identified and the results described by the following format:

Description - identification of the device tested.

Egress Procedure. Test data are reported for each step of the procedure required to utilize the device for egress. Force values reported are the highest and lowest value of three or more consecutive readings.[1]

Comments. Discussion of the device and/or specific omissions or requirements of the standard.

The test results are summarized in table 3.

1. Specimen 1. (See Figs. 2, 14, 15, and 16.)

Description

Double-glazed casement window with inside clip-on screen. Nominal dimensions 24 in (61 cm) wide by 33 in (84 cm) high.

[1]Technical footnote: References to the 'weight' of the window or appurtenance in "lbs" are properly to be interpreted as the mass in pounds (lbm) avoirdupois, converting to kilograms. References to forces in "lbs" are properly to be interpreted as pounds force (lbf) avoirdupois, converting to newtons. Where convenient, the weight can be interpreted as gravitational force in lbf, but the kilogram equivalent then must be interpreted as given in kilograms force (kgf), a non-SI unit.

Egress Procedure

(a) Unlock screen by turning latch (located on left side 16.5 in (42 cm) above bottom of window) 90° up or down. Contact areas of latch equalled .25 in^2 (1.61 cm^2). Operating force, 3.5-4.5 lbs (15.6-20.0 N).

(b) Remove screen by pulling on .62 in^2 (4.0 cm^2) tab (located on left side 16.5 in (42 cm) above bottom of window) and lifting screen out. Force required to release .6 lb (.27 kg) screen ranged from 2.8-3.0 lbs (12.5-13.3 N).

(c) Bend clip to release egress handle located on right side 9 in (23 cm) above bottom of window. Force required to disengage egress handle ranged from 2.8-3.0 lbs (12.5-13.3 N).

(d) Lift egress handle to horizontal position (17 in (43 cm) above bottom of window) and push window open. Force required to push open window ranged from 0.4-4.1 lbs (1.8-18.2 N).

(e) Exit through clear opening 23 in (58 cm) wide by 32 in (81 cm) high (area = 5.1 ft^2 (.47 m^2)).[1]

Comments

This specimen was tested in the mobile home demonstration unit using a hand-held Chatillion DPP-50 Force Gauge.

The appurtenance does not appear to meet the egress requirements of the mobile home standard. A Phillips head screw is used to retain the latch which secures the screen. This screw may be misapplied (made too tight) with normal household tools (section 280.404(c)(2)(iii)).

The operating instructions which are on the window cannot be read because the screen is mounted inside the window and obscures the label. This is not a violation of the standard. In all other respects, this is an acceptable egress device. It required five distinct sequential operations to egress through this window.

[1]Actual egress was not attempted during this study.

2. Specimen 2. (larger, but otherwise identical to specimen 1)

Description

Double-glazed casement window with inside clip-on screen. Nominal dimensions 30 in (76 cm) wide by 39 in (99 cm) high.

Egress Procedure

(a) Unlock screen by turning latch (located on left side 19 in (48 cm) above bottom of window) 90° up or down. Contact area of latch equalled .25 in^2 (1.61 cm^2). Operating force, 7.0-10.4 lbs (31.1-46.3 N).

(b) Remove screen by pulling on .62 in^2 (4.0 cm^2) tab (located on left side 19 in (48 cm) above bottom of window) and lifting screen out. Force required to release 1.1 lb (.5 kg) screen was less than 0.1 lb (.4 N).

(c) Bend clip to release egress handle located on right side 12 in (30 cm) above bottom of window. Force required to disengage egress handle ranged from 0.3-4.1 lbs (1.3-18.2 N).

(d) Lift egress handle to horizontal position 1.9 in (4.8 cm) above bottom of window) and push window open. Force required to push open window ranged from 1.4-4.9 lbs (6.2-21.8 N).

(e) Exit through clear opening 29 in (74 cm) wide by 38 in (97 cm) high, (area = 7.6 ft^2 (.71 m^2)).

Comments

This specimen was tested in the Building Safety Laboratory using a hand-held Chatillion DPP-50 Force Gauge.

See specimen 1 for additional comments.

3. Specimen 3. (See Figs. 4, 17, 18, 19, and 20.)

Description

Vertical sliding window in egress frame with inside clip-on storm window and outside screen. Nominal dimensions 30 in (76 cm) wide by 39 in (99 cm) high.

Egress Procedure

(a) Rotate three clips (located 20 in (51 cm) above bottom of window on left and right sides of frame, and in center of bottom of frame) 90° to release storm window. Contact area of each latch equalled .28 in^2 (1.8 cm^2). Forces required to open clips ranged from 0.6-7.3 lbs (2.7-32.5 N).

(b) Lift out storm window and set aside. Weight of window equalled 8.4 lbs (3.8 kg).

(c) Pull down on vertical bar located on left side of window to release egress mechanism. The 34.5 in (88 cm) bar mounted 2.5 in (6 cm) above bottom of window required forces ranging from 11.4-13.6 lbs (50.7-60.5 N) to operate.

(d) Push hinged window out (force range 5.0-6.0 lbs (22.2-26.7 N)).

(e) Exit through 29.5 in (75 cm) wide by 40 in (102 cm) high opening (8.2 ft^2 (0.76 m^2)).

Comments

The egress frame and egress mechanisms are identical on specimens 3 and 4.

This specimen was tested in the Building Safety Laboratory using a crank-driven Chatillion DPP-50 Force Gauge.

The force required to remove and lift the storm window exceeds 5 lbs (22.2 N) which appears to be a violation of section 280.404(c)(ii) of the standard.

The large storm window (8.4 lbs (3.8 kg), 30 in (76 cm) x 40 in (102 cm)) is difficult to handle. It requires seven distinct sequential operations to egress through this window.

4. Specimen 4. (See Figs. 3, 17, 18, 19 and 20)

Description

Awning window in egress frame with inside clip-on screen (or storm window). Nominal dimensions 30 in (76 cm) wide by 39 in (99 cm) high.

Egress Procedure

(a) Rotate three clips (located 20 in (51 cm) above bottom of window on left and right sides of frame and in center of bottom of window frame) 90° to release screen or storm window. Contact area of each latch equalled .28 in^2 (1.8 cm^2). Forces required to open clips ranged from 0.6-7.2 lbs (2.7-32.0 N).

(b) Lift out storm window and set aside. Weight of window equalled 9.6 lbs (4.4 kg).

(c) Pull down on vertical bar located on left side of window to release egress mechanism. The 34.5 in (88 cm) long bar mounted 2.5 in (6 cm) above bottom of window required forces ranging from 14.8-17.4 lbs (65.8-77.4 N) to operate.

(d) Push hinged window out (force range 12.4-15.9 lbs (55.2-70.7 N)).

(e) Exit through 29.5 in (75 cm) wide by 40 in (102 cm) high opening (8.2 ft^2 (.76 m^2)).

Comments - See comments under specimen 3.

5. Specimen 5. (See Figs. 5, 21, 22, 23, and 24)

Description

Horizontal sliding window with inside double track storm window and outside screen. Nominal dimensions 46 in (117 cm) wide by 39 in (99 cm) high.

Egress Procedure

(a) Simultaneously disengage two latches (located on left and right sides of window, 3.25 in (8.26 cm) above bottom of frame) to release storm window. Contact area of each latch equalled .47 in^2 (3.03 cm^2). Forces required to operate latches ranged from 3.6-6.7 lbs (16.0-29.8 N).

(b) Lift out storm window and set aside. Weight of window equalled 8.6 lbs (3.9 kg).

(c) Unlock window by lifting latch handle (in center of left side of window 18.5 in (47 cm) above bottom of window) upward approximately 90°. Operating force ranged from 5.4-8.4 lbs (24.0-37.4 N).

(d) Slide window to left as far as it will go. Operating force ranged from 5.8-9.6 lbs (25.8-42.7 N).

(e) Simultaneously pull tabs (located 5.5 in (14 cm) and 33.5 in (85 cm) above bottom of window) on screen to the left and push screen out. Tab contact area equalled 1 in^2 (6.45 cm^2). Force required to release tabs ranged from 0.1-5.1 lbs (.4-22.7 N).

(f) Exit through 22 in (56 cm) wide by 37 in (94 cm) high opening (5.7 ft^2 (.53 m^2)).

Comments

The window and appurtenances did not appear to meet the egress requirements of the mobile home standard. The force required to remove the storm window exceeds 5 lbs (22.2 N) (section 280.404(c)(ii)). The top tab on the screen is located 69 in (175.3 cm) above the floor when the window is mounted with the bottom 36 in (91 cm) above the floor (section 280.106(c)). The operating instructions placed on the window describe a clip-on storm window which is different from the double track storm window supplied (section 280.404(c)(4)(i)).

The window also has two design deficiencies. Installation of the double track storm window obscures from view the locking latch on the prime window, and makes it physically difficult to reach and operate. The large storm window cannot be easily held by the two latches on the bottom of the window (recommended egress procedure). During initial evaluation of this window, a laboratory staff member lost control of the storm window, resulting in broken glass and a minor cut.

This window requires two distinct simultaneous operations and five additional distinct sequential operations to egress.

6. Specimen 6. (See Figs. 6, 25, and 26)

Description

Awning window with pop-out panes. Nominal dimensions 30 in (76 cm) wide by 53 in (135 cm) high. No appurtenances were available at time of test.

Egress Procedure

(a) Lift latches (mounted 13 in (33 cm) above bottom) on both sides of window. Force required to lift latches ranged from 0.9-3.6 lbs (4.0-16.0 N).

(b) Push hinged window (lower two lights) out. Force required ranged from 0.4-0.8 lbs (1.8-3.6 N).

(c) Exit from 29 in (74 cm) wide by 25 in (64 cm) high opening (5 ft^2 (.46 m^2)).

Comments

This window meets the requirements of the mobile home standard. It requires four distinct operations to egress from this window. This device permits very fast egress, but it is likely that it would be damaged during use, since the hinged window falls against the side of the mobile home.

7. Specimen 7. (See Figs. 7, 27, and 28)

Description

Large vertical sliding window with inside double track storm window and outside screen. Nominal dimension 30 in (76 cm) wide by 59 in (150 cm) high.

Egress Procedure

(a) Simultaneously pull in two latches located on sides of storm window near bottom. Contact area of each latch equalled .12 in^2 (.77 cm^2). Force required to operate latches ranged from 1.0-1.5 lbs (4.4-6.7 N).

(b) Slide window up until latched in fully open position. Force ranged from 12.6-12.8 lbs (56.0-56.9 N).

(c) Simultaneously squeeze latches located at bottom left and right of prime window. Forces required to operate ranged from 5.0-6.3 lbs (22.2-28.0 N).

(d) Slide window up until latched in fully open position. Force range 16.0-17.4 lbs (71.2-77.4 N).

(e) Pull down on two tabs located on top of screen (27 in (69 cm) above bottom of window) and push screen out. Force required ranged from 8.5-12.1 lbs (37.8-53.8 N).

(f) Exit from 28 in (71 cm) wide by 28 in (71 cm) high opening (5.5 ft^2 (.51 m^2)).

Comments

The appurtenances do not appear to meet the egress requirements of the mobile home standard. Both the force required to lift the storm window and that required to release the tabs of the screen exceeded 5 lbs (22.2 N) (section 280.404(c)(2)(ii)). The surface area to which an operating force is applied on the storm windows is less than the required 0.25 in^2 (1.61 cm^2) (section 280.404(c)(2)(iv)).

This window requires three distinct simultaneous operations and three additional distinct sequential operations to egress.

8. Specimen 8. (See Figs. 8, 29, and 30)

Description

Egress panel mounted in wall 5 in (13 cm) above floor. Nominal dimensions 22 in (56 cm) wide by 22 in (56 cm) high.

Egress Procedure

(a) Release two latches mounted on left and right sides 11 in (28 cm) above bottom of panel. Forces required to operate latches ranged from 2.3-4.5 lbs (10.2-20.0 N).

(b) Push out panel. Force range 9.6-10.1 lbs (42.7-44.9 N).

(c) Exit through 22 in (56 cm) wide by 22 in (56 cm) high opening (3.36 ft^2 (.31 m^2)).

Comments

This egress device appears to meet the requirements of the mobile home standard. However, if it was the intent of the standard to require egress devices to meet the minimum area requirements for windows (5 ft^2 (.46 m^2),

section 280.404(b)(3)(ii)), this device would fail the standard. It requires four distinct sequential operations to egress through this device.

Due to its location (5 in (13 cm) above floor) and ease of operation, this device permits very fast egress. However, this could present a potential hazard to a very small child capable of operating the latch mechanism.

C. Racking Tests

Measurements were made of forces required to unlock and open egress windows after simulated racking loads (frame distortions) were applied. Such loads might occur due to foundation settling or physical displacement of a mobile home following an accident or natural disaster.

1. Racking Test Procedure

Using a hydraulic ram attached to the test frame, angular distortions of the following magnitude were applied to test specimens 2, 3, 4, 5, and 6:

Angle between base of frame and horizontal reference point	Equivalent vertical displacement of the floor at one end of a 60 ft (18.29 m) mobile home
.2°	2.5 in (6.4 cm)
.4°	5.0 in (12.7 cm)
.8°	10.1 in (25.7 cm)
1.5°	18.8 in (47.8 cm)
3.0°	37.7 in (95.8 cm)

2. Racking Test Results

The lightweight construction of the windows permitted them to function even after being severly racked. Operating forces generally increased with increased racking and some specimens could not be closed after being opened in the racked position. The numerical results of the racking tests are summarized in Table 4.

TABLE 3

LABORATORY TEST RESULTS

Device Tested	Test Results: Window	Test Results: Appurtenance
1. Casement window (small)	Pass	Fail - Section 280.404(c)(2)(iii) Phillips head screw
2. *Casement window (large)	Pass	Fail - Section 280.404(c)(2)(iii) Phillips head screw
3. *Vertical sliding window, egress frame	Pass	Fail - Section 280.404(c)(2)(ii) Storm window weight greater than 5 lbs (2.27 kg).
4. *Awning window, egress frame	Pass	Fail - Section 280.404(c)(2)(ii) Storm window weight greater than 5 lbs (2.27 kg).
5. *Horizontal sliding window	Fail	Fail - Section 280.404(c)(2)(ii) Storm window weight greater than 5 lbs (2.27 kg). Section 280.106(c) Screen tab over 60 in (152 cm) from floor. Section 280.404(c)(4)(i) Incorrect instructions on window.
6. *Awning window, pop-out panes	Pass	Appurtenances not available at time of test.
7. Vertical sliding window	Pass	Fail - Section 280.404(c)(2)(ii) Storm window weight greater than 5 lbs (2.27 kg).
8. Knock-out wall panel	Pass	N/A

*Subjected to racking tests in addition to and following tests required by standard

TABLE 4

Racking Test Results[a]

Force in lbs (newtons)

No.	Specimen[b] Description/Mechanism	Amount of Racking: None 0 in/60 ft 0 cm/18.29 m	.2° 2.5 in/60 ft 6.4 cm/18.29 m	.4° 5.0 in/60 ft 12.7 cm/18.29 m	.8° 10.1 in/60 ft 25.7 cm/18.29 m	1.5° 18.8 in/60 ft 47.8 cm/18.29 m	3.0° 37.7 in/60 ft 95.8 cm/18.29 m
2	Casement window (large)						
	Remove screen	0.1 (.4)	0.3 (1.3)	0.2 (.9)	0.1 (.4)	0.1 (.4)	[d] [d]
	Push window	4.9 (21.8)	4.6 (20.5)	5.3 (23.6)	16.2 (72.1)	25.0 (111.2)[c]	[d] [d]
3	Vertical slider, egress frame						
	Latch	13.6 (60.5)	14.1 (62.7)	12.7 (56.5)	12.6 (56.0)	14.9 (66.3)	14.2 (63.2)
	Push window	6.0 (26.7)	[e] [e]	2.8 (12.5)	6.5 (28.9)	13.6 (60.5)	28.4 (126.3)
4	Awning window, egress frame						
	Latch	17.4 (77.4)	18.6 (82.7)	19.9 (88.5)	19.4 (86.3)	24.6 (109.4)	24.5 (109.0)
	Push window	15.9 (70.7)	[e] [e]	21.0 (93.4)	23.8 (105.9)	28.0 (124.6)	13.6 (60.5)
5	Horizontal slider						
	Latch	8.4 (37.4)	4.5 (20.0)	8.4 (37.4)	5.8 (25.8)	26.6 (118.3)	[d] [d]
	Push window	9.6 (42.7)	4.4 (19.6)	5.3 (23.6)	19.5 (86.7)	9.4 (41.8)	25.3 (112.5)
6	Awning window, pop-out						
	Left latch	3.6 (16.0)	4.2 (18.7)	4.2 (18.7)	4.2 (18.7)	3.1 (13.8)	6.5 (28.9)
	Right latch	1.2 (5.3)	1.2 (5.3)	1.4 (6.2)	3.0 (13.3)	4.2 (18.7)	3.5 (15.6)
	Push window	0.8 (3.6)	1.4 (6.2)	3.6 (16.0)	4.5 (20.0)	10.0 (44.5)	16.2 (72.1)

[a] Table values are maximum forces required in lbs (newtons) to operate the windows after racking forces were applied.

[b] All windows tested could be operated even after severe racking.

[c] Estimated value. Gauge did not hold maximum reading.

[d] Latch and/or window popped open due to racking--no force was required to operate device.

[e] Values were not recorded.

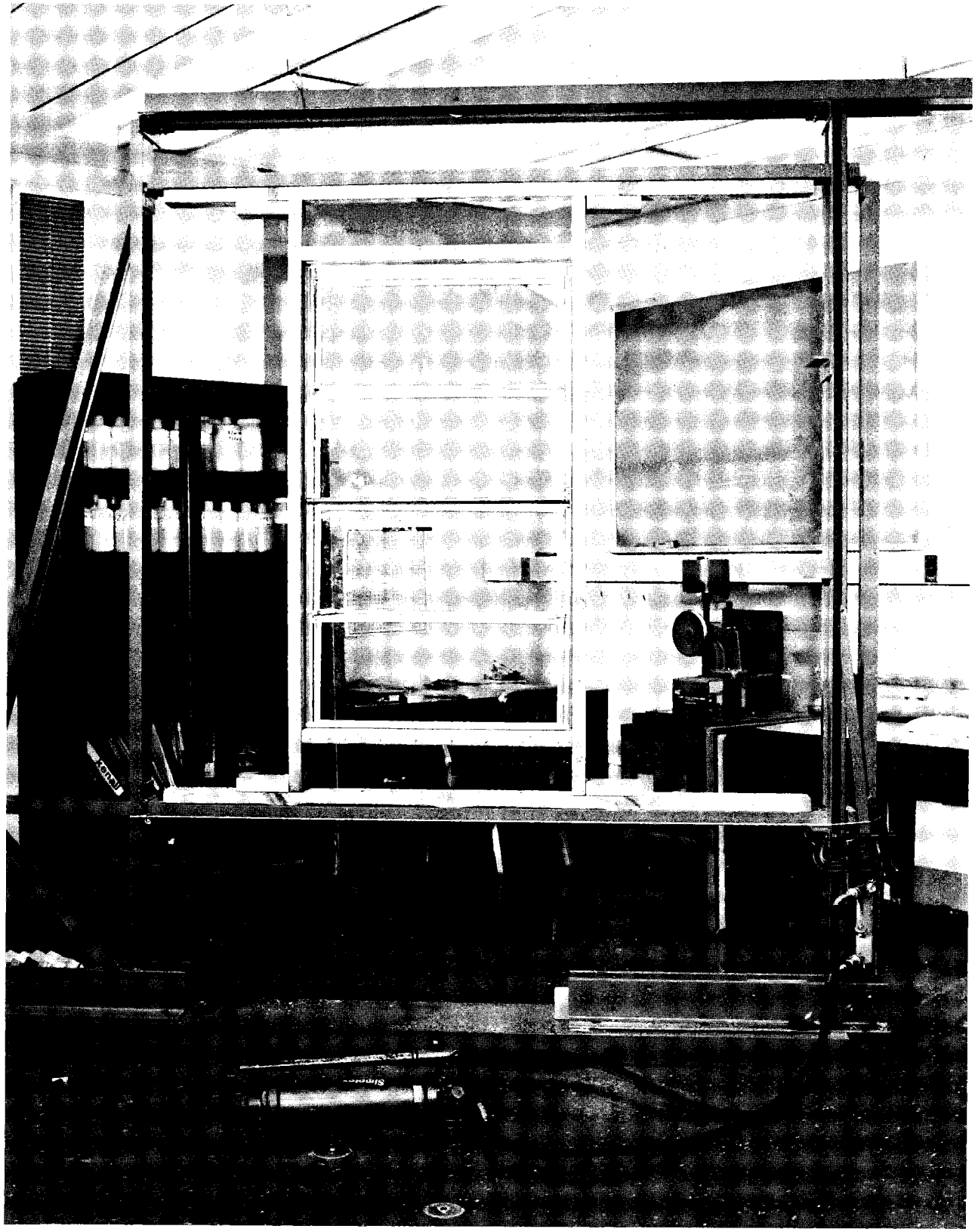

Figure 11. Racking Test. Normal (level) position.

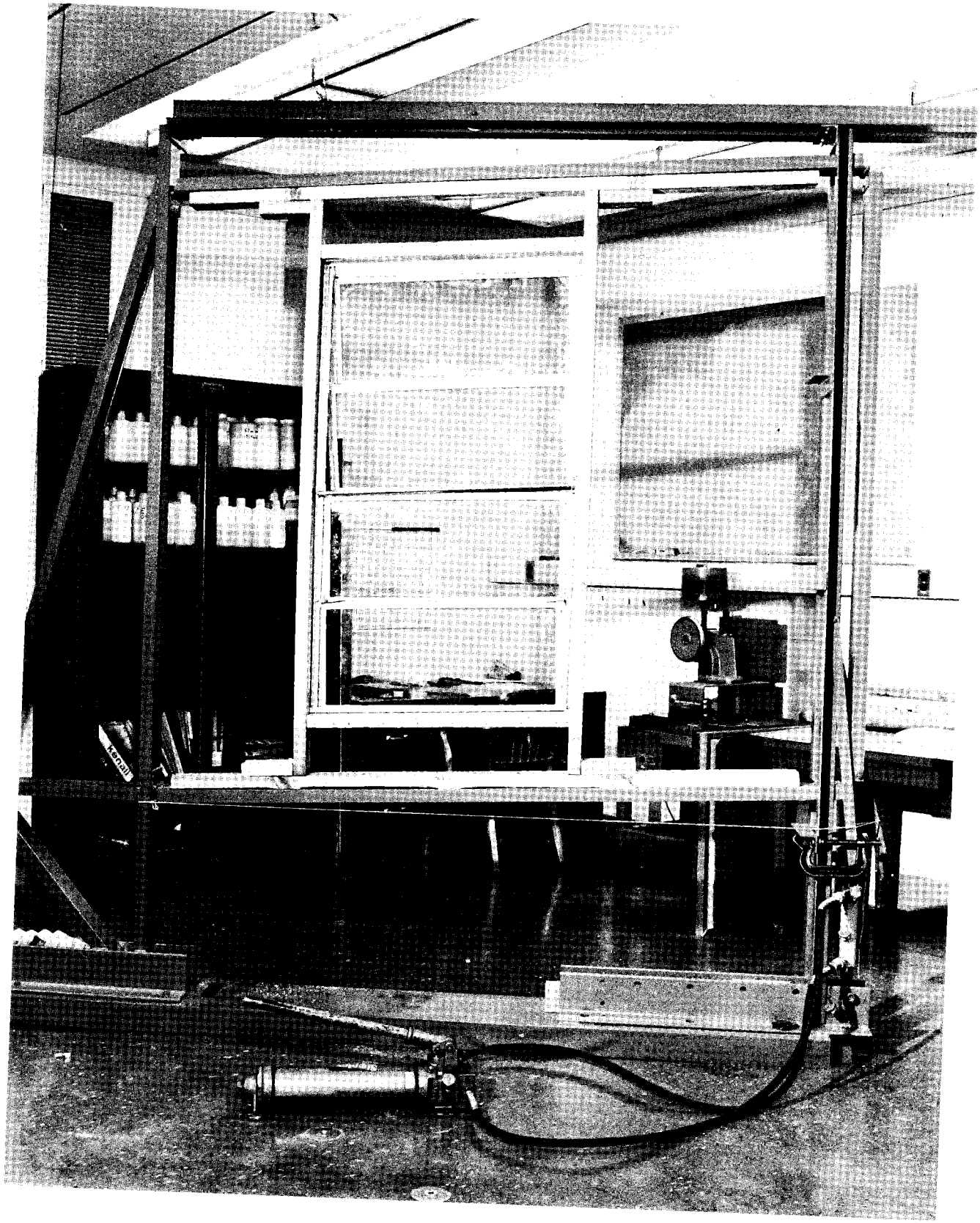

Figure 12. Racking Test. Racked position.

Figure 13. Use of Force Gage.
Procedure used to measure force required to open window latch.

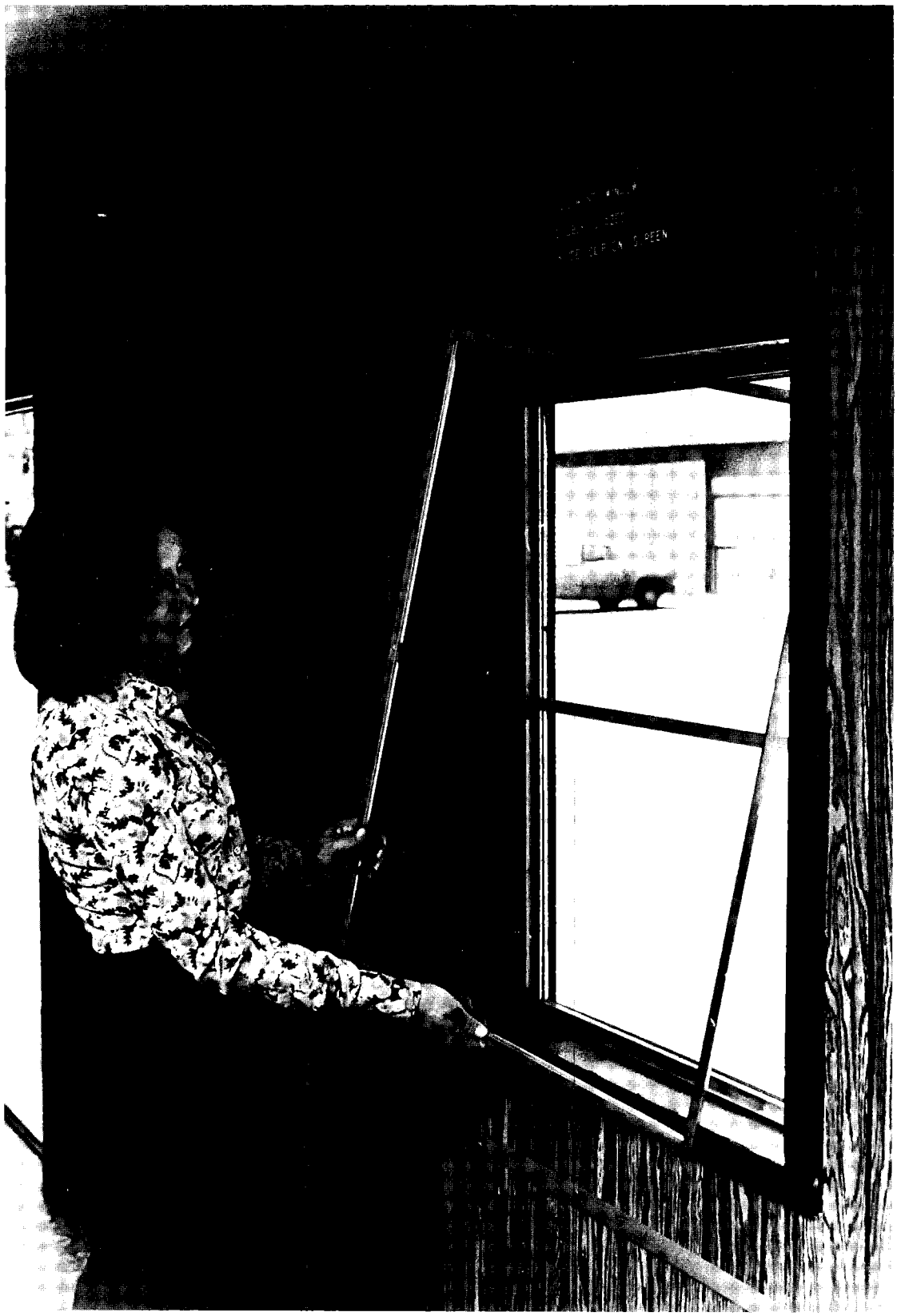

Figure 14. Egress Test. Specimen 1.
Removing screen

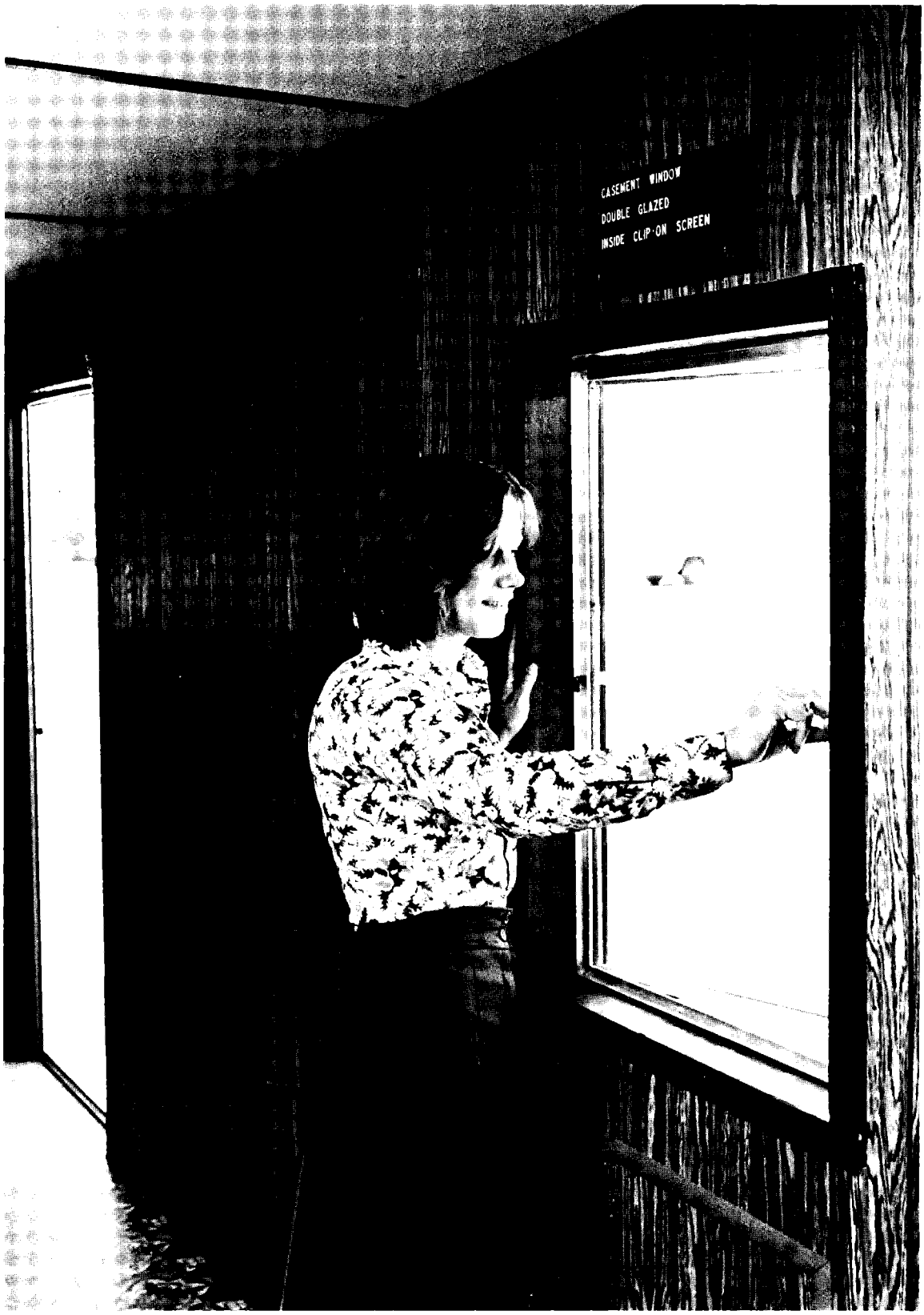

Figure 15. Egress Test. Specimen 1.
Pushing window open

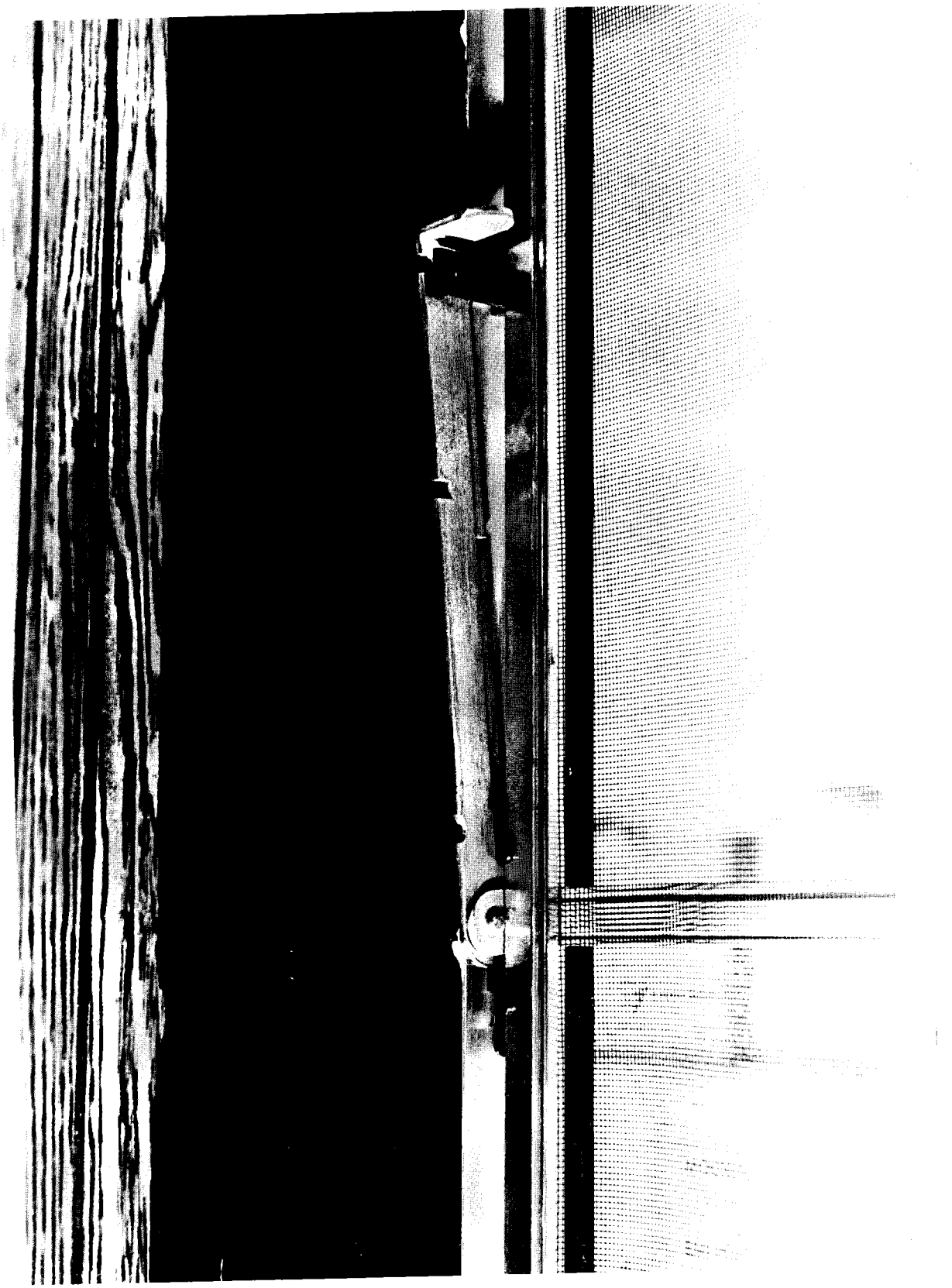

Figure 16. Egress Test. Specimen 1.
Detail of egress handle and retaining clip

Figure 17. Egress Test. Specimen 3.
Releasing storm window retaining clip
Releasing one of three clips which retain inside clip-on storm window.
The same storm window frame is used on specimen 4.

Figure 18. Egress Test. Specimen 3.
Removing screen
The same procedure is used on specimen 4.

Figure 19. Egress Frame. Specimen 3.
Operating egress mechanism
Pulling down on vertical bar to release egress mechanism.
The same procedure is used on specimen 4.

Figure 20. Egress Test. Specimen 4.
Pushing window open
The same egress frame is used on specimen 3.

Figure 21. Egress Test. Specimen 5.
Removing storm window

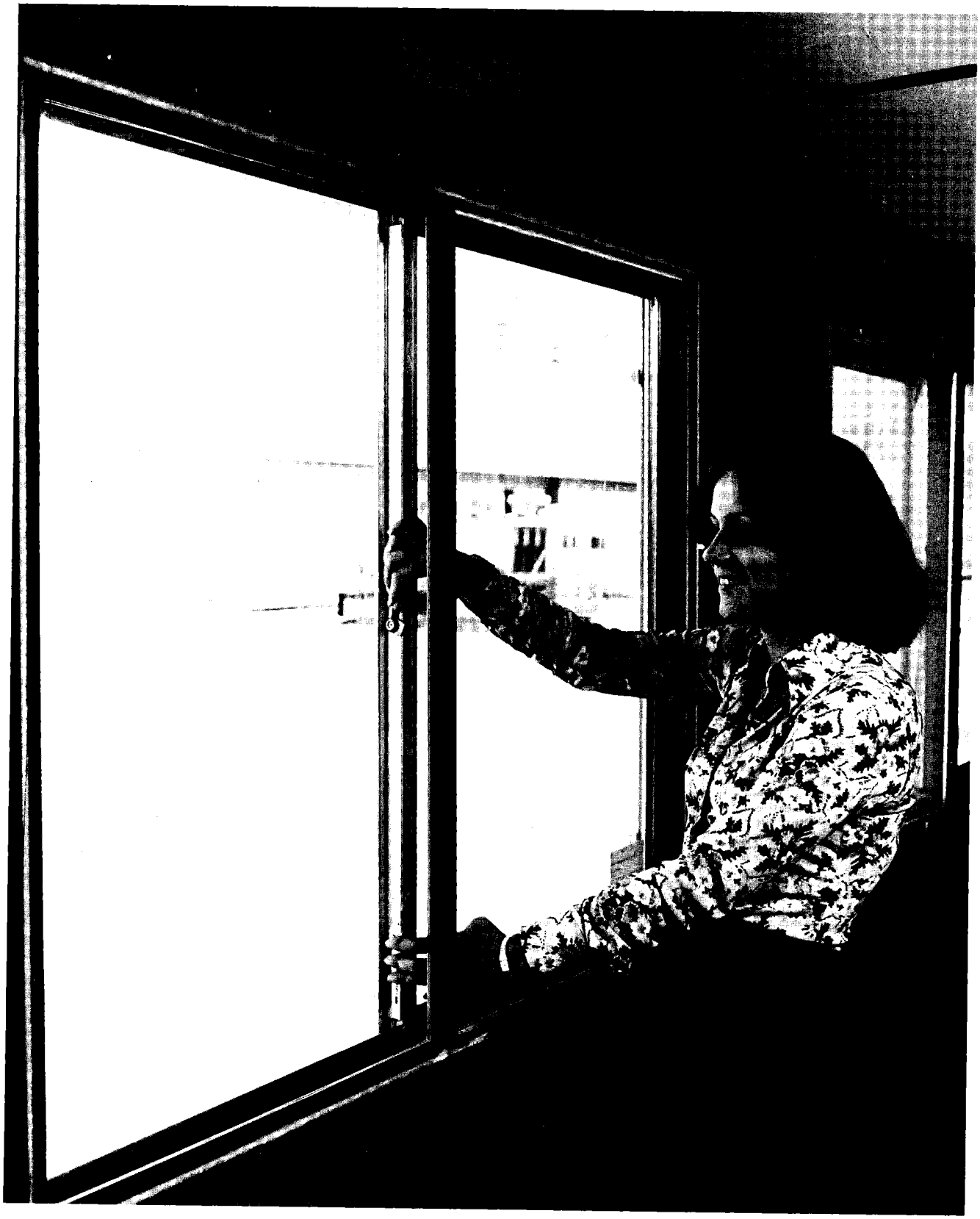

Figure 22. Egress Test. Specimen 5.
Unlatching prime window
Note that latch mechanism is blocked by remaining storm window.

Figure 23. Egress Test. Specimen 5.
Opening prime window

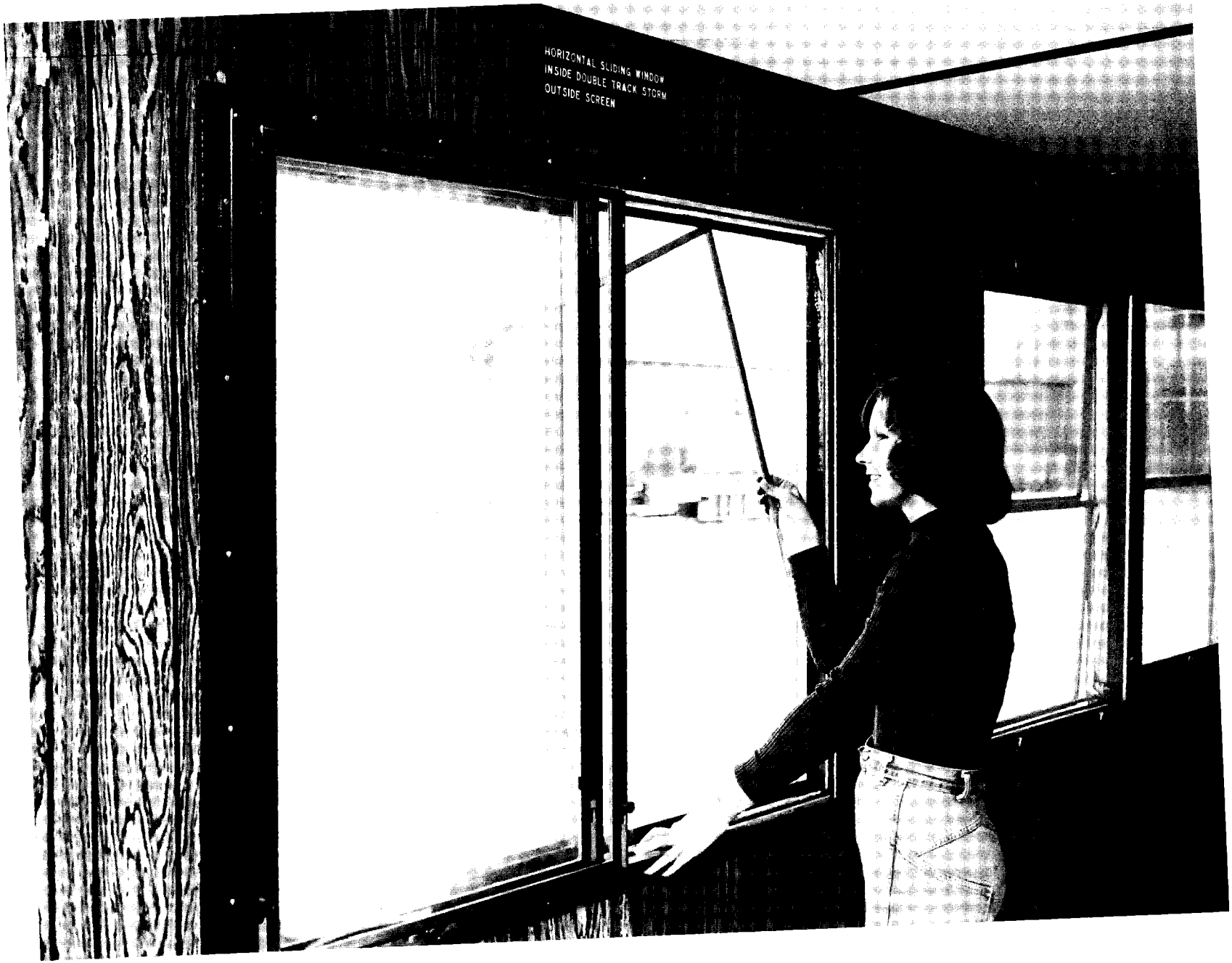

Figure 24. Egress Test. Specimen 5.
Removing screen

Figure 25. Egress Test. Specimen 6.
Releasing egress latches

Figure 26. Egress Test. Specimen 6.
Opening window
When dropped, hinged window falls flat against side of mobile home.

Figure 27. Egress Test. Specimen 7.
Opening prime window

Figure 28. Egress Test. Specimen 7.
Releasing screen

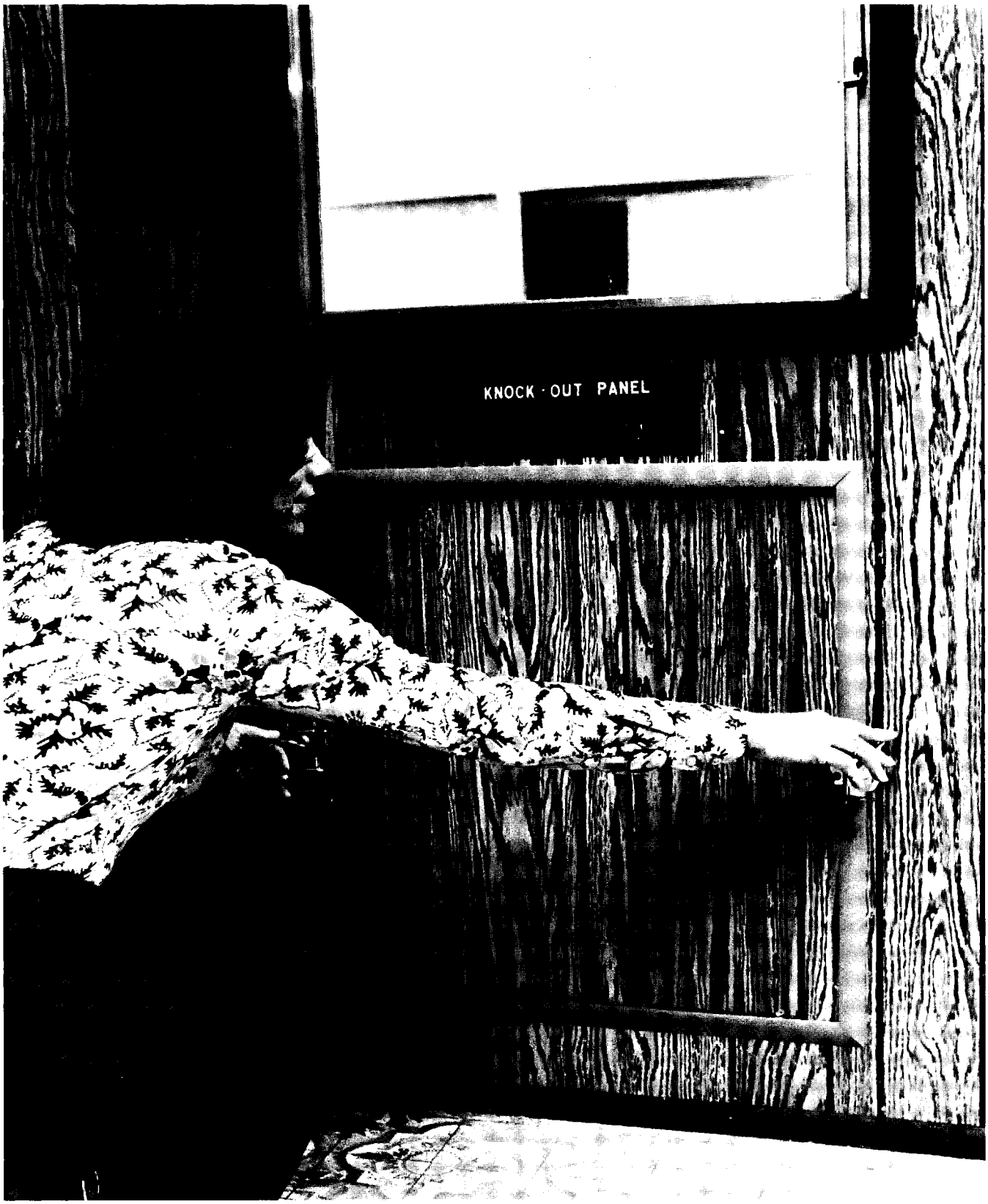

Figure 29. Egress Test. Specimen 8.
Unlatching panel

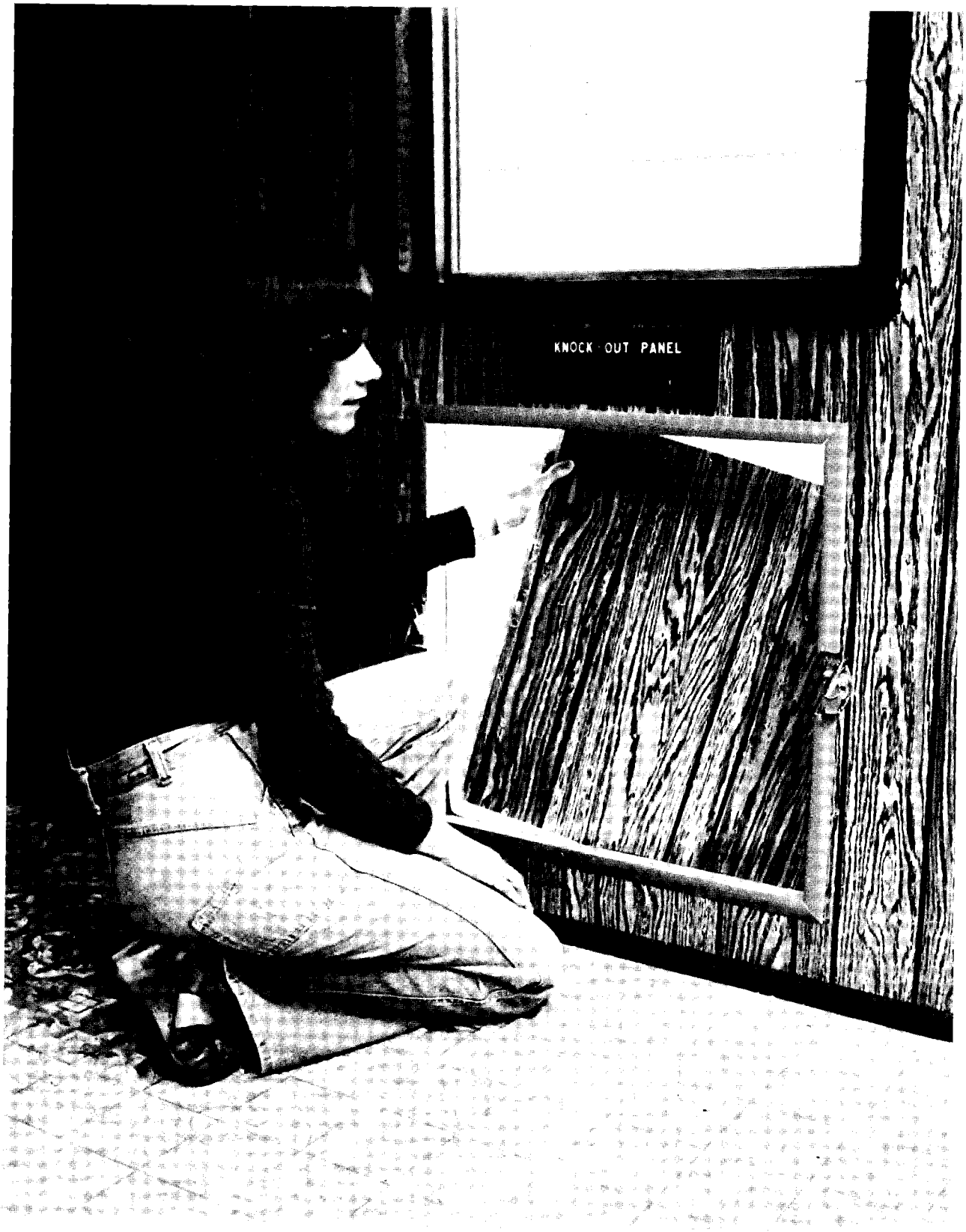

Figure 30. Egress Test. Specimen 8.
Dropping panel

IV. DISCUSSION OF RESULTS

A. Technical Basis of the Egress Provisions of the Mobile Home Standard

The egress requirements of the Mobile Home Standard are based in substantial measure on earlier voluntary standards, in particular NFPA 501B-1974 (Ref. 7) and MHMA Specification 2-73 (Ref. 4).

Library research was carried out to identify, through existing standards and other documents, the technical basis of the egress requirements of the standard. With the exception of limited studies concerned with the minimum dimensions of an egress device, very little relevant data was found. Where research data was found, it did not appear to support the specifications contained in the standard. These findings are discussed below.

1. Dimensions and Location

Table 5 summarizes the information found relating to the dimensions and location of egress devices. A review of the available data suggests the following:

(a) Dimensions should be related to the anticipated method of egress. Openings close to the floor, which permit egress by crawling, will require different dimensions than openings mounted at higher levels, requiring the occupant to climb out for egress.

(b) For mobile home occupants of average size, the following dimensions appear to be adequate for emergency egress. If the mobile home occupant is expected to crawl through the egress device, minimum dimensions should be approximately 22 in (56 cm) wide by 22 in (56 cm) high. If the mobile home occupant is expected to climb through the egress opening, minimum dimensions should be 18 in (46 cm) wide and 32 in (81 cm) high.

(c) No data was found which established the height above the floor at which occupants generally would shift from a crawling to a climbing method of egress. The method of egress may also be affected by the height of the egress device above ground level. (Note Fig. 31.)

2. Operating Forces and Location of Operating Mechanisms

Tables 6 and 7 summarize the information found relating to operating forces and the location of latches. These two factors are interrelated and should be studied together. A review of the available data suggests:

(a) Maximum allowable forces should be determined on the basis of anticipated occupant strength and stature, height at which the device is mounted, and method of operation (push, pull, squeeze, twist).

(b) Young children can generally exert forces in excess of 10 lbs (44.5 N) on operating devices which are mounted at or below their shoulder height. However, almost all children under 9 years of age cannot reach or operate devices 60 in (152 cm) above the floor.

(c) No data was found which established the relationship between forces which could be applied as a function of the individual's basic strength and the difference between the individual's height and the height of the operating device.

3. Tenability Criteria

Tenability criteria relate to specific elements of a hazardous environment which are capable of incapacitating an individual attempting escape or rescue. Examples include critical factors such as oxygen, carbon dioxide and carbon monoxide levels, temperature, and smoke density. Determination of tenability criteria and maximum allowable time for egress is a state-of-the-art research activity currently under way at the Center for Fire Research at the National Bureau of Standards.

B. Adequacy of the Egress Provisions of the Mobile Home Standard

In addition to the specific shortcomings discussed below, the egress requirements of the standard appear to be too narrow in scope. (See recommendations) Laboratory research to assess the current requirements and test procedures identified areas where the current standard appears to be inadequate, inconsistent, and conflicting. With respect to the comments which follow, it is assumed that the reader is familiar with Table 1 of this report and sections 280.106 and 280.404 of the Mobile Home Standard.

1. Inconsistency

(a) Dimensions (280.404(b) and (c))

Windows and appurtenances must provide a 5 ft^2 (.46 m^2) opening with a minimum dimension of 22 in (56 cm).

Egress devices are not mentioned.

(b) Location (280.106(a))

Bottom of window opening must be within 36 in (91 cm) of floor.

Egress devices are not mentioned.

(c) Number of Latches (280.404(b) and (c))

Windows may have two latches.

Appurtenances may have four latches.

Egress devices are not mentioned.

(d) Surface Area Where Force is Applied (280.404(c))

Latches on appurtenances must have a contact area of at least .25 in^2 (1.61 cm^2).

Windows and egress devices are not mentioned.

(e) Rotary Operation of Latches (280.404(b))

Not permitted on windows.

Appurtenances and egress devices are not mentioned.

(f) Maximum Operating Forces (280.404(b) and (c))

Twenty lbs (89.0 N) for windows.

Five lbs (22.2 N) for appurtenances.

Egress devices are not mentioned.

2. Conflict

There is a direct conflict between section 280.404(b)(3)(ii) (minimum area of 5 ft^2 (.46 m^2) and section 280.404(c)(ii) (maximum lifting force of 5 lbs (22.2 N) for appurtenances). A storm window which is 5 ft^2 (.46 m^2) in area weighs more than 5 lbs (2.27 kg). It is impossible to simultaneously meet both requirements.

3. Incomplete Specification of Test Methods

(a) Test Methods A and B - Dimensions (280.404(d)(1) & (2))

It is not clear how to calculate dimensions when latches or operating handles protrude into the egress area.

(b) Test Methods C and D - Operating Forces (280.404(d)(3) & (4))

The rate at which the force is applied is not specified and only a single reading of the gauge is required. This is likely to generate a situation in which different techniques will yield significantly different force readings on the same device or mechanism.

In test method C, the requirement that the window be subjected to five opening and closing cycles before testing should be deleted, since it creates a test condition which is unrealistic with respect to actual use of an egress device.

TABLE 5

BACKGROUND INFORMATION

DIMENSIONS AND LOCATION OF EGRESS DEVICES

Information Source	Recommendation or Requirement
Fed. Standard 217 - Bus windows (Ref. 2)	Nominally 20 in (51 cm) wide x 13 in (33 cm) high for each egress window.
MHMA Spec. 2-73 (Ref. 4)	Minimum dimension 22 in (56 cm). Minimum area 5 ft^2 (.46 m^2). Maximum height from floor to bottom of opening is 36 in (91 cm).
NFPA 101 - Life Safety Code (Ref. 5)	1973 Edition - 22 in (56 cm) minimum dimension, 5 ft^2 (.46 m^2) minimum area, maximum height from floor to bottom of opening is 32 in (81 cm). 1976 Draft - Minimum 20 in (51 cm) wide, 24 in (61 cm) high, minimum area 5.7 ft^2 (.53 m^2), maximum height from floor to bottom of opening is 44 in (112 cm).
NFPA 501B-1974 ANSI A119.1-1975 (Ref. 7)	Minimum dimensions 22 in (56 cm). Minimum area 5 ft^2 (.46 m^2). Maximum height from floor to bottom of opening is 48 in (122 cm).
NFPA 501C-1974 (Ref. 8)	Nominally 20 in (51 cm) wide x 13 in (33 cm) high for each egress window.
McCormic (Ref. 22)	Minimum dimension for a crawl through opening with normal clothing is 22 in (56 cm).
Van Cott (Ref. 33)	Minimum dimension for crawling or sliding through is 20-22 in (51-56 cm).
Woodson & Conover (Ref. 35)	Minimum dimension for crawl through opening is 22 in (56 cm), step or climb through opening is 20 in (51 cm) wide x 32 in (81 cm) high.
Safiredoor Corp. (Ref. 38)	Opening 22.5 in (57 cm) square near floor permits ingress by fire fighter with breathing apparatus.
Hunt Co. (Ref. 42)	Height more important than width for climb through egress. Opening 16 in (41 cm) wide x 28 in (71 cm) high is acceptable for climb through egress. Openings 16 in (41 cm) wide x 42 in (107 cm) high or 18 in (46 cm) wide x 32 in (81 cm) high, acceptable for egress and ingress by fire fighter with backpack.

TABLE 6

BACKGROUND INFORMATION

EGRESS DEVICE OPERATING FORCES

Information Source	Recommendation, Requirement or Comment
Fed. Standard 217 - Bus window (Ref. 2)	Low force, less than 20 lbs (89 N), within 71 in (180 cm) of floor, rotary or straight force application. High force, less than 60 lbs (267 N), within 52 in (132 cm) of floor, straight force application perpendicular to exit.
MHMA Spec. 2-73 (Ref. 4)	Locks, latches, lifting and sliding operational forces shall not exceed 20 lbs (89 N), window appurtenance operating forces shall not exceed 5 lbs (22 N).
NFPA 101 - Life Safety Code (Ref. 5)	Windows for rescue must be readily openable from inside without use of tools. Panic hardware shall cause door latch to release when a force not to exceed 15 lbs (67 N) is applied.
NFPA 501B-1974 NASI A119.1-1975 (Ref. 7)	Window which can be opened from the inside without the use of tools.
Brown, Buchanan, and Mandel (Ref. 11)	Figure 4 shows that essentialy all of the 5-year-olds tested could squeeze, push, pull, or twist with forces in excess of 10 lbs (44 N) on devices mounted at or below their shoulder length.

TABLE 7

BACKGROUND INFORMATION

LOCATION OF EGRESS DEVICE OPERATING MECHANISMS

Information Source	Recommendation, Requirement or Comment
Fed. Standard 217 - Bus windows (Ref. 2)	Low force window release within 71 in (180 cm) of floor. High force window release within 52 in (132 cm) of floor.
MHMA Spec. 2-73 (Ref. 4)	No latch, lock or operating handle be located in excess of 72 in (183 cm) from the finished floor.
NFPA 101 - Life Safety Code (Ref. 5)	Releasing bar on door shall be not less than 30 in (76 cm) nor more than 44 in (112 cm) above the floor.
Diffrient, et al (Ref. 16)	97% of all 8-year-old children cannot reach a device located 60 in (152 cm) above the floor (estimate based on human scale 1a).

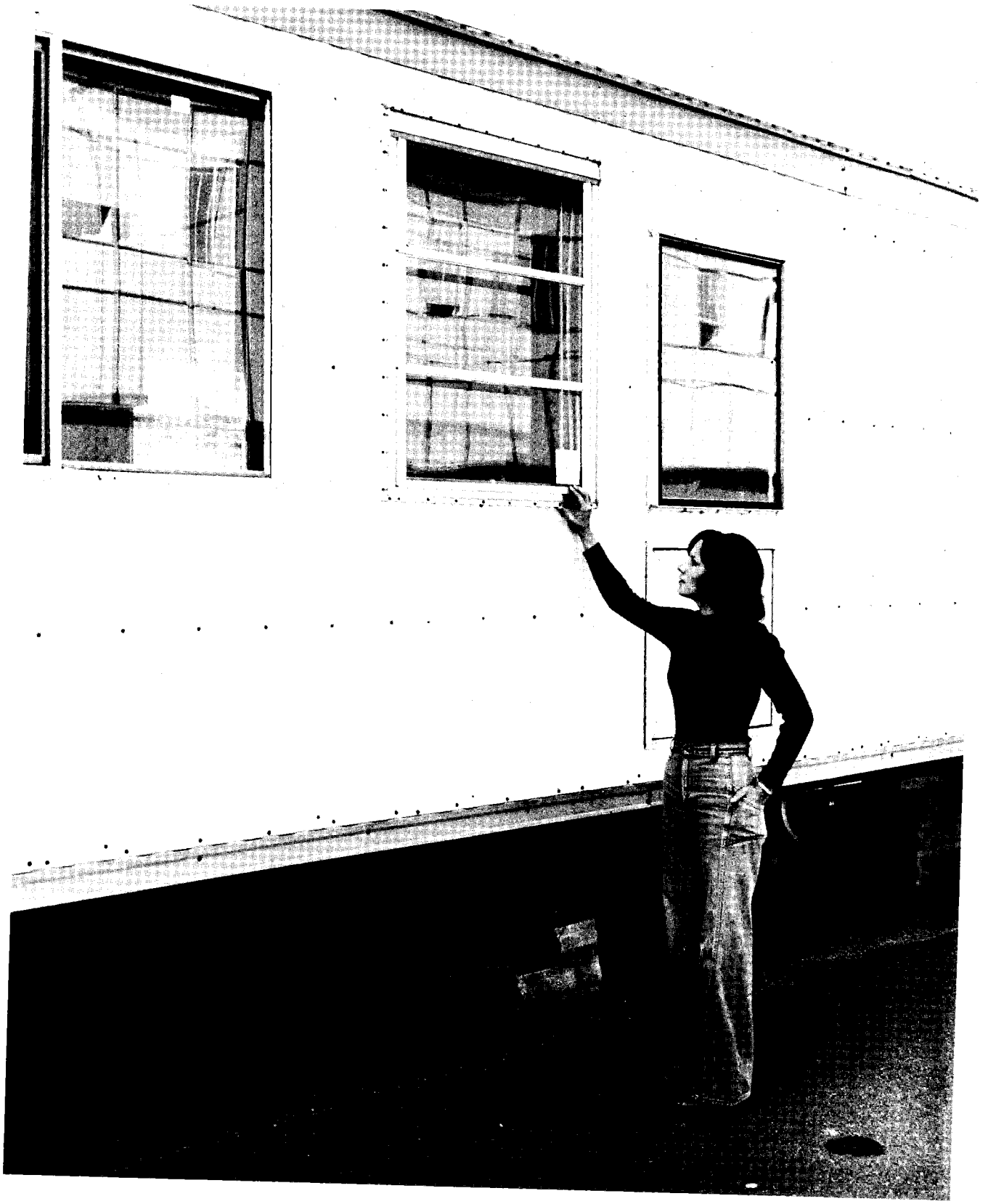

Figure 31. Height of Egress Windows above Ground
Egress windows installed in the demonstration unit with the bottom of the window opening 36 in (91 cm) above the floor place the bottom of the window approximately 70 in (178 cm) above the ground. Note that the bottom of the egress panel (behind the model) is only 39 in (99 cm) above the ground.

V. RECOMMENDATIONS

A. Establish Performance Goals

In the absence of available data to the contrary, it is assumed that the most critical need for emergency egress occurs during a nighttime fire when sleeping occupants of a mobile home are jarred awake by an alarm or by sensing the smoke, flame, or noise of a fire.

Emergency egress devices should be located and operable in such a manner that essentially all occupants capable of independent movement can safely evacuate unassisted.

With these two assumptions in mind, the following goals are recommended:

1. Primary Goal

Provide a device with an opening large enough and so placed and operated as to permit 95 percent of all mobile home occupants wearing normal clothing to exit from a darkened room unassisted within 30 seconds without significant risk of serious injury.

Comments

A design goal of 95 percent is suggested by Henry Dreyfuss Associates (see reference 16) as desirable for civilian environments. It is however, a subjective number which is based on what society is willing to accept as a reasonable level of risk. Whatever level is selected, to design for it requires a detailed knowledge of the age distribution of mobile home occupants. It is anticipated that this data will be available from the Bureau of the Census in early 1977.

The design goal of 30 seconds to egress is also subjective. It represents the average time it took the author's 9-year-old daughter to exit from a locked bedroom window in a conventional single family home and includes unlocking the prime window, raising the prime window, unlocking the storm window, and raising the storm window. Egress time must be kept to a minimum, since preliminary fire studies indicate that untenable conditions can be reached in a mobile home in less than four minutes (see reference 13).

2. Secondary Goal

The egress device should not reduce the safety or security of the mobile home under normal living conditions.

3. Complementary Goals

(a) Without compromising the primary goal of egress, the dimensions of the egress device should consider standard mobile home construction practices.

(b) Without unduly increasing the cost of construction, the dimensions of the egress device should consider ingress by fully equipped rescue personnel.

Acceptance of these goals necessarily requires expanding the scope of the egress requirements of the Mobile Home Standard.

B. Expand Scope of the Standard

1. Size and Location of Egress Opening

(a) Placement

Every room designed for sleeping should have an egress device or door.

(b) Relationship Between Height Above Floor and Minimum Dimensions

The review of the published data on minimum dimensions for egress suggests that there should be different acceptable dimensions for egress devices installed near the floor of a mobile home and egress windows installed at higher levels (see references 2, 4, 5, 7, 22, 33, 35, 38, & 42). Table 5 summarizes published requirements/recommendations for egress dimensions and heights above the floor.

The dimensions should be based on the anticipated method of egress; i.e. climb vs. crawl. In general, openings placed so that the occupant must climb through them require a greater vertical dimension than openings which permit the occupant to exit by crawling through them.

2. Operation of Egress Devices

(a) Number of Operations Required

There are two questions which should be addressed in the standard.

(i) The maximum total number of operations which are permitted, including unlocking, lifting, pushing, etc. (the present standard allows 13).

(ii) The maximum number of simultaneous operations (if any) which are permitted. If simultaneous operations are permitted, separate specifications may be needed relating to their operating forces, method of operation, and distance from each other.

(b) Allowable Maximum Operating Forces and Location of Operating Devices

The allowable maximum operating force of a latch or other mechanism must be related to the operation involved (push, pull, squeeze, twist) and the height of the mechanism above the floor.

3. Security

The egress window or device should offer the same resistance to forced entry as any window, door or other opening into the mobile home.

4. Practice

The egress window or device should be designed to permit occupants to practice all of the steps necessary for egress. This implies that there should be minimal risk of personal injury or damage to the device during operation.

5. Safety

The egress window or device should not reduce the safety of the mobile home during normal conditions. Design features such as the following might be considered.

(a) Operating forces large enough so that latches are not inadvertently operated by very young children, pets, or normal household activities, such as cleaning.

(b) Shields which prevent small fingers from reaching operating mechanisms.

(c) Operating devices placed outside the reach of crawling infants.

(d) Latches which combine two distinct movements to operate, i.e. a latch with a button that must be depressed before the latch will turn.

6. Operating Instructions

The operating instructions should be visible, easy to read, and easy to understand. Proposed operating instruction labels should be pretested by children. The use of nonverbal, pictorial instructions should be encouraged.

7. Time to Egress

This is the basic test of an egress device and in a sense, it incorporates all of the other criteria. A statistically valid procedure should be developed for applying this criteria as a performance test.

C. Support Applied Research

Tables 8 and 9 summarize and compare the existing standard and the recommended requirements for emergency egress devices for mobile homes. The actual levels for these criteria can best be established by supporting additional research in the following areas:

1. Occupant Analysis - Physical

The objective of this research is to identify the physical and sensory limitations of mobile home occupants which are relevant to the use of emergency egress devices. This program should include the following activities, which were beyond the scope of the present study.

(a) Request a special tabulation based on the 1970 Census of Population to determine the frequency adjusted age and sex distribution of mobile home occupants.

(b) Utilize existing anthropometric information sources or, if necessary, conduct additional research to determine typical body dimensions, strength (push, pull, twist, squeeze) and reach capabilities of mobile home occupants.

2. Occupant Analysis - Behavioral

Research models should be developed and tested to gain an insight into predictable behavior modes of adults and children under emergency conditions. In particular, studies should be carried out to determine whether behavior under emergency conditions can be modified through experience (such as fire drills) and education.

3. Device Characteristics

The objective of this effort is to utilize human engineering principles to assure that the location and physical characteristics of egress devices are consistent with the physical capabilities and behavior of mobile home occupants. Research should be carried out to determine:

(a) The minimum dimensions necessary to permit average (50 percentile) and large (95 percentile) occupants to egress by crawling through an opening.

(b) The minimum dimensions necessary to permit average and large occupants to egress by climbing through an opening.

(c) The maximum height above the floor that small (5 percentile) and average size occupants can egress by crawling through an opening.

(d) The maximum height above the floor that small and average size occupants can egress by climbing through an opening.

(e) With respect to operating mechanisms, the maximum height-force that can be applied for each type of operation (push, pull, twist, squeeze) for small and average size mobile home occupants.

4. Egress Tests

A statistically valid procedure should be developed for estimating the time to egress utilizing an egress device. There are two basic approaches:

(a) Develop a single test which would be uniformly applied to every type of egress device manufactured. This approach is direct, but might be difficult to implement if there are a large number of different egress devices manufactured.

(b) Explore the feasibility of developing a computer model to predict the average egress time of an egress device based on factors such as size, location, number of operations, and forces required to utilize the device, as well as physical characteristics of mobile home occupants. The model parameters would necessarily be based on a series of egress tests conducted with representative mobile home occupants and devices. This approach is initially more difficult, but may be easier to implement.

5. Hazard Analysis

Research (such as the activities currently being carried out in the Center for Fire Research at NBS) to categorize the specific elements of a hazardous situation which are life-threatening would be continued in order to develop estimates for maximum acceptable egress time.

Section 280.1(b) of the Federal Mobile Home Construction and Safety Standard summarizes the overall intent of these recommendations and is quoted herewith without further comment.

> "These Federal Mobile Home Construction and Safety Standards seek, to the maximum extent possible, to establish performance requirements. In certain instances, however, the use of specific requirements in the Standard is necessary because, at this time, that is the best available means of identifying the desired performance. The use of specific requirements is not intended to prohibit the utilization of any material, piece of equipment, or system which cannot meet the precise specifications, but which upon evaluation provides equivalent or superior performance."

TABLE 8

SCOPE OF EGRESS REQUIREMENTS OF CURRENT

HUD MOBILE HOME STANDARD

Requirement	Criteria
1. Location	1.1 Every sleeping room
	1.2 Bottom within 36 in (91 cm) of floor
2. Size of opening	2.1 Minimum dimensions of 22 in (56 cm)
	2.2 Minimum area of 5 ft^2 (.46 m^2)*
3. Operation	3.1 Up to 13 operations allowed for egress (3 for prime window, 5 for each appurtenance)
	3.2 No restrictions on simultaneous operation
	3.3 Maximum operating forces must be less than 20 lbs (89 N) for windows, 5 lbs (22 N) for appurtenances*
	3.4 Rotary operations not permitted on windows
	3.5 Latches no more than 60 in (152 cm) above floor
4. Security	4.1 No requirement
5. Practice	5.1 No requirement
6. Safety during non-emergency	6.1 No requirement
7. Operating instructions	7.1 Instructions on window for operation of window and appurtenance
8. Time to egress	8.1 No requirement

*Conflict - 5 ft^2 (.46 m^2) of window glass weighs more than 5 lbs (2.27 kg). Hence, the weight of the window and frame exceeds the maximum force allowed to lift the window out.

TABLE 9

RECOMMENDED SCOPE OF EGRESS REQUIREMENTS FOR MOBILE HOME STANDARD

Requirement	Criteria
1. Location	1.1 Every sleeping room
	1.2 Bottom within ** of floor
2. Size of opening	2.1 If bottom of opening is within ** of floor, minimum of 22 in (56 cm) wide x 22 in (56 cm) high (crawl)*
	2.2 If bottom of opening is more than ** above floor, minimum of 18 in (46 cm) wide x 32 in (81 cm) high (climb)*
3. Operation	3.1 No more than ** operations required for egress
	3.2 Simultaneous operations permitted if distance between operating devices is less than ** inches and the operating forces are less than ** or simultaneous operations not permitted.
	3.3 Operating forces less than ** pounds
	3.4 No rotary operations required for egress
	3.5 Latches no more than ** above floor
4. Security	4.1 Same resistance to forced entry as other openings in mobile homes
5. Practice	5.1 To encourage practice, design should minimize risk of injury or damage to device during operation
6. Safety during non-emergency	6.1 Infant-proof design
	6.2 Minimum force requirement to prevent accidental operation
7. Operating instructions	7.1 Should be simple and easy to understand by children and adults, placed in easy to see/read location
8. Time to egress	8.1 Most occupants, including children and elderly, should be able to egress within 30 seconds

*Additional research required to establish "best" values.

**Specific recommendation cannot be made without additional research.

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Evaluative tests were carried out to assess the adequacy and sufficiency of the HUD Mobile Home Construction and Safety Standards. Project activities included library research, laboratory testing and construction of a Mobile Home Emergency Egress Demonstration Unit. The study recommended: (1) establishment of performance goals to relate the desired objective (safe egress) to the specific requirements of the standard; (2) expansion of the scope of the requirements to assure that egress devices do not adversely affect the safety or security of the mobile home under normal living conditions; and (3) support of applied research to interrelate egress requirements, device characteristics, and human capabilities.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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