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Emergency Egress From Mobile Homes: Anthropometric and Ergonomic Considerations

V. J. Pezoldt

Consumer Sciences Division
Center for Consumer Product Technology
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

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Final Report

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Abstract

This report summarizes a two task effort which is part of the National Bureau of Standards evaluation of the Federal Mobile Home Construction and Safety Standard. The first task consists of a review of relevant anthropometric data from which egress requirements might be drawn. The second task is an empirical study of egress designed to generate data which can assist HUD in evaluating the existing size requirements for egress devices. The degree to which the requirements in the current standard for location and operating characteristics of egress device latches and other operating mechanisms are acceptable varies for different segments of the population at risk. The limited applicable anthropometric data suggests that the requirements are sufficient, for the most part, for average, healthy, normally ambulatory adults. The minimum opening size requirements were also shown to be acceptable for average healthy adults under most conditions tested. However, devices which meet the maximum sill height allowed by the standard were shown to be extremely difficult to negotiate or unusable by a significant portion of the experimental test subjects. Implications of the present egress requirements for escape by handicapped or otherwise impaired individuals are discussed.

Emergency Egress from Mobile Homes: Anthropometric and Ergonomic Considerations

1. INTRODUCTION

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 (40FR58754) the final rules and regulations for the Federal Mobile Home Construction and Safety Standard. 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.

A previous study conducted by NBS (Adler, 1977) to identify the technical bases of the emergency egress provisions of the HUD standard and to assess the adequacy of these provisions concluded that, in general, there is neither readily available data that provides a technical basis for the egress provisions of the standard nor are these egress requirements adequate.

In light of the generally negative conclusions of the earlier work, HUD requested that NBS pursue further analytical and empirical efforts relative to emergency egress from mobile homes. This report summarizes the portion of that effort directed at further exploration of the anthropometric and ergonomic considerations of the egress problem, especially as they bear on recommendations for egress requirements.[1]

Two tasks are reported on here: (1) a review of existing anthropometric data from which egress requirements might be drawn and (2) an empirical study of egress designed to generate data which can assist HUD in evaluating and/or redefining the opening size requirements for egress devices.

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[1]Measurement data in this document are reported in both English and SI units where practicable. Because the HUD standard uses English units, they are given precedence. Where conversions from one system to the other are necessary, the following equivalences are used: 1 in = 2.54 cm, 1 lbf = 4.45 N, 1 in-lbf = .113 N-m.

2. ANTHROPOMETRIC CONSIDERATIONS FOR THE DESIGN OF EMERGENCY EGRESS DEVICES

2.1 Population at Risk

The design of emergency egress devices should take into account the characteristics of the population which may have the need to use such devices. Some evidence suggests that there are differences between the demographic characteristics of mobile home occupants in the U.S. and the population of the U.S. as a whole. The 1975 Annual Housing Survey (Bureau of the Census, 1975) indicates that the heads of households living in mobile homes and trailers are slightly younger than those in all occupied housing. Also, households in mobile homes are more likely to include one or more children under 6 years of age. Lacking more compelling data, these minor differences between mobile home occupants and the population at large do not warrant consideration of the population at risk in mobile homes as being significantly different from the general population in terms of those anthropometric considerations which may influence design options in the setting of standards for egress devices.

2.2 Review of Anthropometric Data

The application of anthropometric data to the specification of design and performance requirements for emergency egress devices must be undertaken very cautiously. Many theoretical and practical problems with existing data preclude the direct translation of such data into exact specifications. At best, the available data may be used to suggest guidelines or boundary conditions and, in a general sense, to evaluate the requirements of the existing standard in terms of the likelihood that they will provide adequate egress conditions for the population at risk.

Among the more obvious problems associated with the available data is that the vast majority of data is from military populations, primarily healthy young male adults, and is not generalizable to the whole U.S. population. As one proceeds from physical dimensions to static and dynamic forces, the already limited data become increasingly task specific and are based on even smaller samples. In addition, most anthropometric measurements are made under "best case" laboratory conditions and not in "worst case" real-life situations as may be encountered when an emergency egress device is used. Notwithstanding the limitations of applying the anthropometric data, the design requirements currently specified in the standard have been reviewed with respect to relevant anthropometric measurements.

2.2.1 Size of Egress Opening. For egress openings, the dimensions and height above the floor have been considered independently from other design features and are the subject of an empirical effort described in Section 3 of this report.

2.2.2 Location of Egress Device Control Mechanisms. The current standard requires that all latches, operating handles, tabs and any other device which needs to be operated to exit through the egress device be located a maximum of 60 inches (152 cm) above the floor. Table 1 and Figure 1 show the mean, 5th and 95th percentile[1] vertical grip reach of males and females as a function of age (Snyder et al, 1977). These data suggest that operating mechanisms which meet the maximum height requirements of the standard may be expected to be accessible to 95 percent of 10 year old children. Virtually all healthy, normally ambulatory people above the age of 11 years could reach control mechanisms located at the highest point currently allowed assuming that no obstacles prevent a direct vertical reach to the device. Only a very small percentage of 7 year old and younger children would be predicted to be capable of reaching a 60 inch (152 cm) high control without assistance.

2.2.3 Force Requirements for Operation of Control Mechanisms. The force required to operate control mechanisms may not exceed 20 pounds (89 N) for the primary window and 5 pounds (22 N) for appurtenances to comply with the standard. Although there is a considerable body of anthropometric data regarding applied forces, only a limited amount is applicable to the present situation. The forces which can be applied depend in large part on the type of device being operated and the spatial orientation of the device with respect to the operator.

Figure 2 shows the 5th percentile and mean maximum static forces exerted by adult males for three types of prehension (Taylor, 1954). For all three types; palmer, tip and lateral, the mean force exceeds 20 pounds (89 N). The 5th percentile maximum forces range from 12.6-15.3 pounds (56 - 68 N) depending on the type of prehension. A control mechanism which requires a pinching or squeezing operation with the fingers which does not require in excess of 12.6 pounds force (56 N) to operate should be suitable for about 95 percent of the adult male population. Although no

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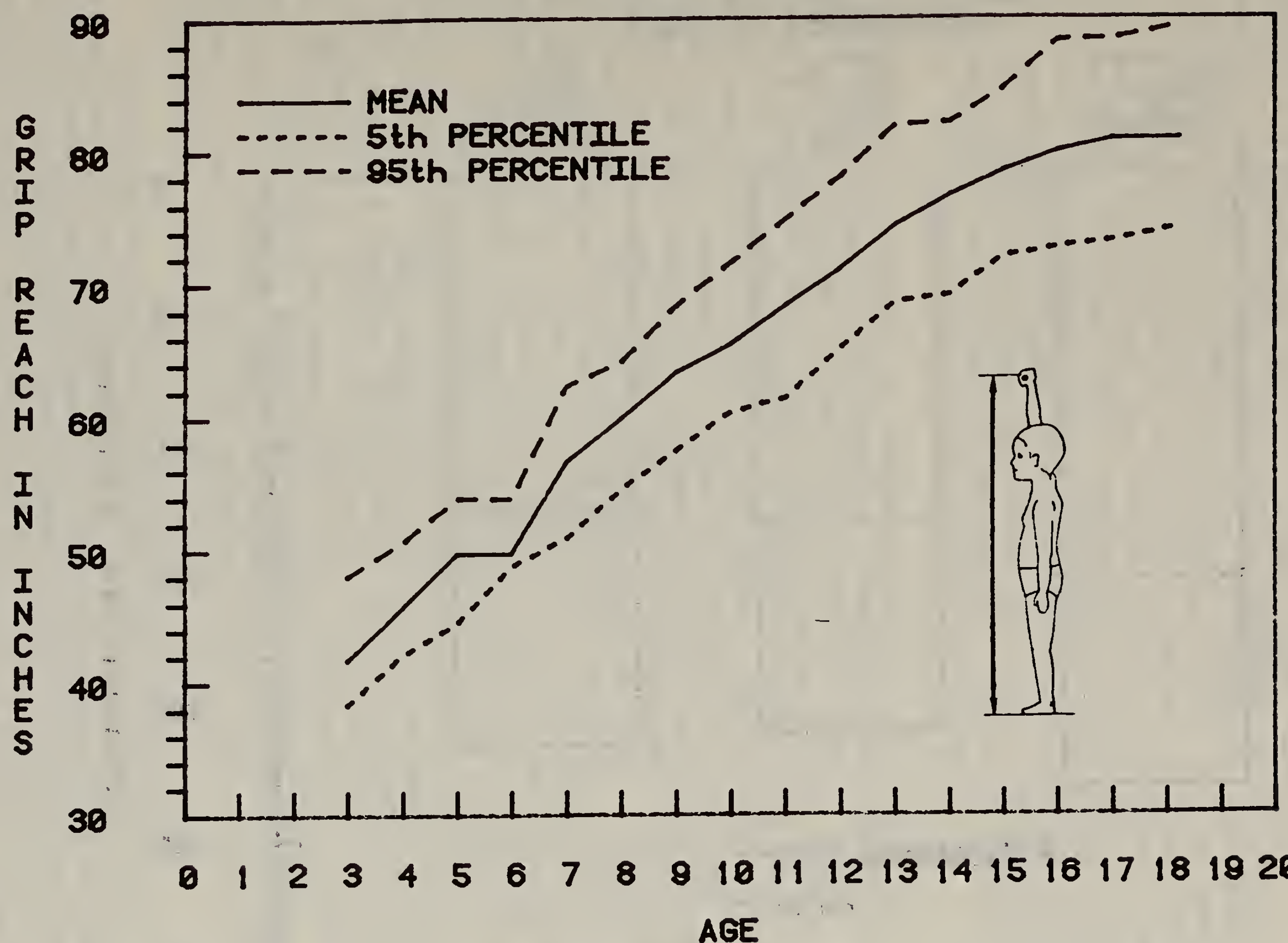
[1] A percentile point is defined as a specific point in a distribution which has a given percent of cases below it.

Table 1. Vertical Grip Reach As a Function of Age (Snyder et al, 1977)

Grip Reach

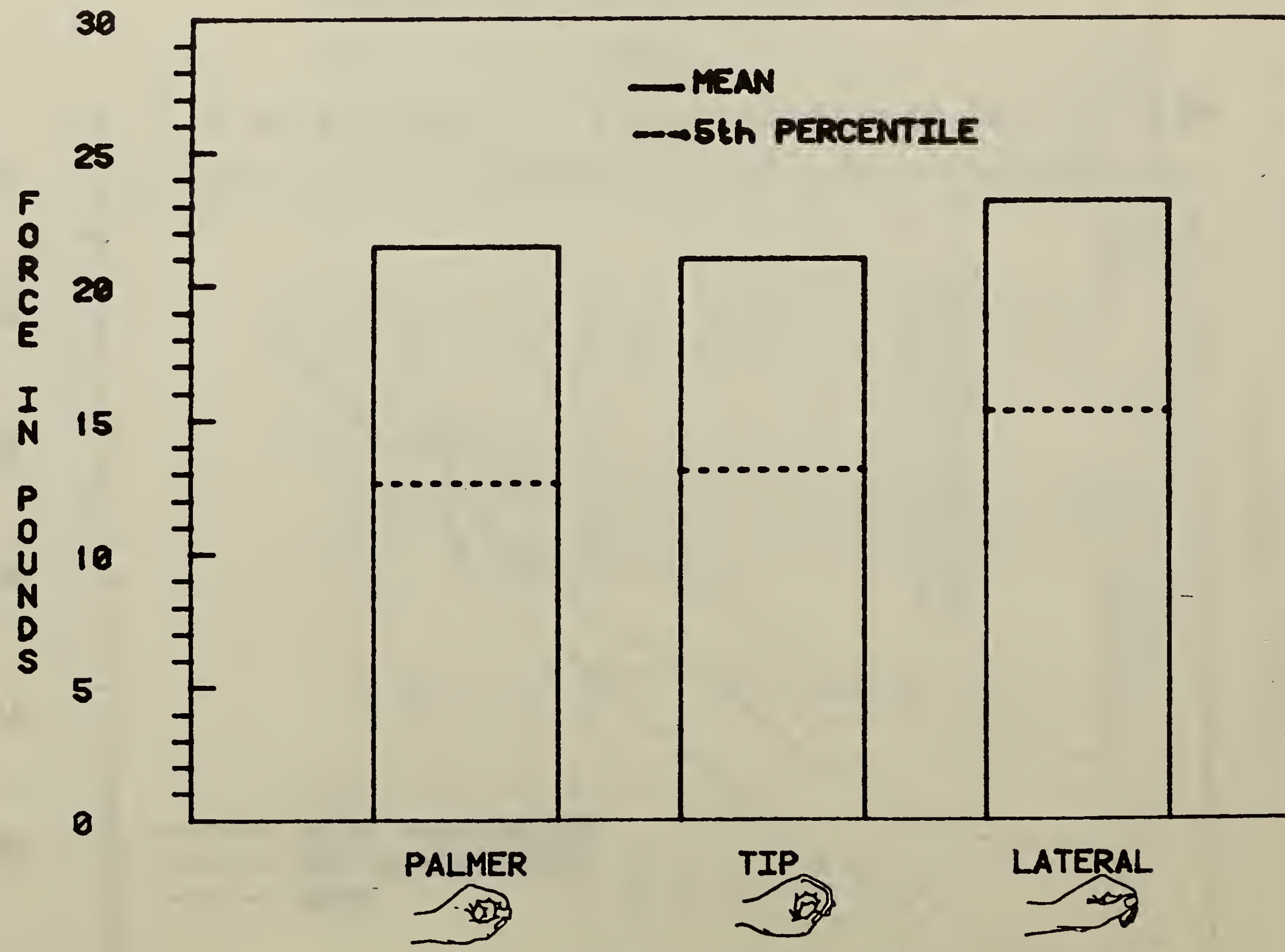
Age	Mean		5th Percentile		95th Percentile	
	cm	in	cm	in	cm	in
2.0- 3.5	107.3	42.2	97.5	38.4	121.8	48.0
3.5- 4.5	116.6	45.9	107.0	42.1	128.5	50.6
4.5- 5.5	126.1	49.6	113.1	44.5	136.9	53.9
5.5- 6.5	135.6	53.4	124.1	48.8	147.2	58.0
6.5- 7.5	144.6	56.9	129.5	51.0	158.5	62.4
7.5- 8.5	152.2	59.9	138.7	54.6	163.2	64.2
8.5- 9.5	160.8	63.3	146.1	57.5	173.8	68.4
9.5-10.5	167.1	65.8	153.5	60.4	182.0	71.6
10.5-11.5	174.7	68.8	156.0	61.4	190.3	74.9
11.5-12.5	181.6	71.5	165.4	65.1	198.5	78.1
12.5-13.5	190.5	75.0	174.3	68.6	208.4	82.0
13.5-14.5	195.3	76.9	175.8	69.2	211.3	83.2
14.5-15.5	199.8	78.7	183.2	72.1	215.4	84.8
15.5-16.5	205.0	80.7	185.0	72.8	224.4	88.3
16.5-17.5	205.6	80.9	186.3	73.3	224.5	88.4
17.5-19.0	206.9	81.4	188.9	74.4	227.0	89.4

FIGURE 1: VERTICAL GRIP REACH AS A FUNCTION OF AGE



(Adapted from Snyder et al, 1977)

FIGURE 2: MAXIMAL FORCE EXERTED BY MALE ADULTS



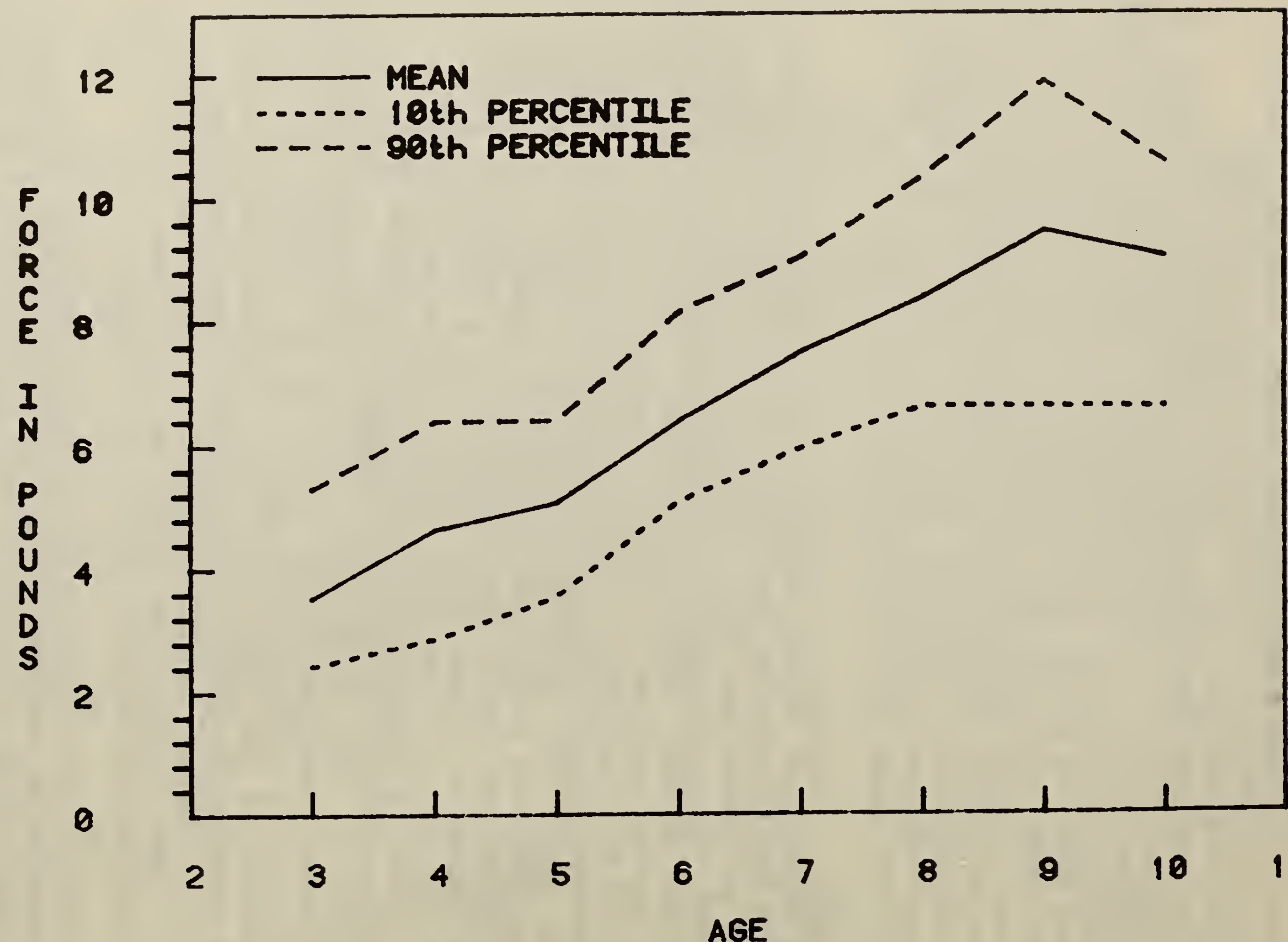
(Adapted from Taylor, 1954)

comparable data are available for women, Laubach (1976) suggests a procedure for estimating female strength capabilities from male data. In this case, the 5th percentile maximum force exerted by females is estimated at 67 percent of that for males shown in Figure 2, or about 8.4 pounds force (37 N). The pinch forces which can be exerted by 10 year old children do not differ markedly from those estimated for 5th percentile female adults. Figures 3 and 4 show the mean, 10th and 90th percentile forces applied by 3 to 10 year old children with a three-point pinch and lateral pinch respectively (Owings et al, 1975). The three-point pinch was performed using the thumb and first two fingers to pinch together two plates 20 mm apart. The lateral pinch employed the thumb and side of the first finger.

Figure 5 suggests the maximum forces which can be applied to devices which require a vertical movement and which can be gripped by the whole hand (Rohmert, 1966). Figure 5 provides data from standing male adults applying force with the right hand on a vertical hand-grip in three directions, to the right, up and down. The figure shows the maximal forces exerted in these directions at 100 and 50 percent of the subjects' maximum grip distance. Maximum grip distance occurs when the arm is fully extended away from the body. The data are presented at both 0 degrees, i.e. arm extended horizontally, and 30 degrees, i.e. arm raised 30 degrees above the horizontal. Estimates of the maximum forces of these types which could be exerted by females are about 58 percent of that of males (Laubach, 1976). Thus, a reasonable maximum force to allow for mechanisms requring a vertical downward pull is about 19 pounds (85 N). For mechanisms requiring movement upward or to the right a maximum force of 11 and 12 pounds (49 and 54 N) respectively should be allowed. These estimates are very conservative in the sense that they are based on a "worst case" situation in which the required forces would be applied in a manner least conducive to generating large forces. That is, they are based on data taken with the arm fully extended directly in front of the body.

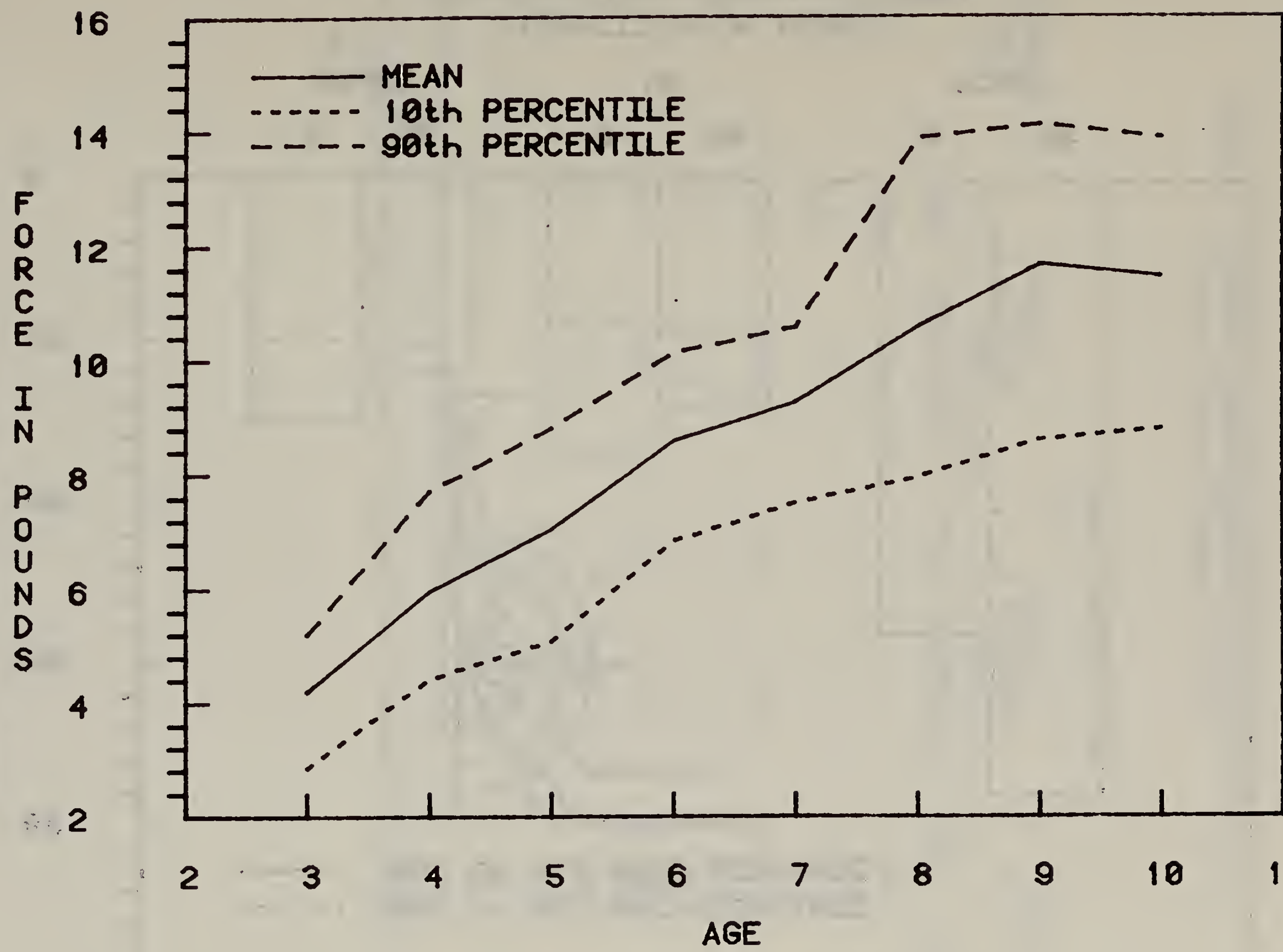
Although the current standard permits operating mechanisms which require rotary motion of up to 180 degrees, the maximum torque allowed for the operation of such devices is not specified. The magnitude of torque which can be applied to turn knobs varies greatly as a function of knob characteristics. In general, as shown in Table 2 (Roebuck, 1965), greater torque can be applied when knobs are knurled rather than smooth and, all else being equal, more torque

FIGURE 3: THREE-POINT PINCH FORCES AS A FUNCTION OF AGE



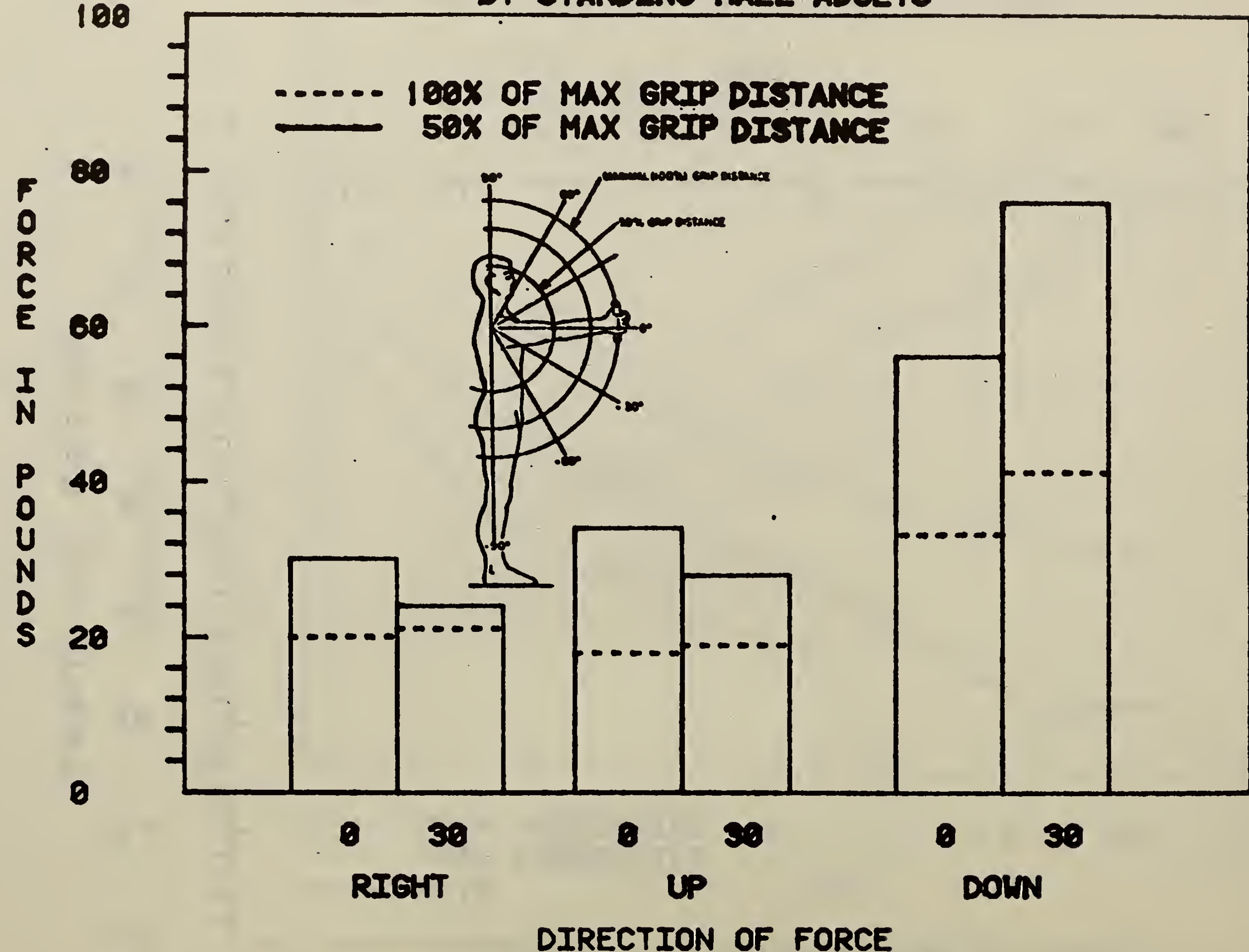
(Adapted from Owings et al, 1975)

FIGURE 4: LATERAL PINCH FORCES AS A FUNCTION OF AGE



(Adapted from Owings et al, 1975)

FIGURE 5
MAXIMAL FORCES EXERTED ON A VERTICAL HAND-GRIP
BY STANDING MALE ADULTS



(Adapted from Rohmert, 1966)

Table 2. Maximal Torque Applied to Cylindrical Knobs By Male Adults (Roebuck, 1965)

Knob Diameter (inches)	Knob Configuration: Smooth .5 in Thick — Mean[a]	Smooth .5 in Thick — 5th Percentile[b]	Knurled .5 in Thick — Mean	Knurled .5 in Thick — 5th Percentile	Knurled .65 in Thick — Mean	Knurled .65 in Thick — 5th Percentile
.125	.255	.145	--	--	.749	.580
.5	2.61	1.87	--	--	--	--
1.0	7.62	2.88	11.9	6.0	11.3	6.2
1.5	14.6	7.00	--	--	--	--
2.0	18.7	9.67	26.5	18.3	27.3	18.4
2.5	26.5	18.52	--	--	--	--

[a] All torque values are in inch-pounds.

[b] Fifth percentile values have been computed from standard deviations.

can be applied as knob diameter increases. For females, the magnitude of torque which can be applied is approximately 53 percent of the torque applied by males (Laubach, 1976). The computed estimates of mean and 5th percentile maximal torque applied by female adults are presented in Table 3.

2.3 Conclusions from the Anthropometric Literature

The degree to which the requirements in the current standard for location and operating characteristics of egress device latches or other control mechanisms are acceptable varies for different portions of the population at risk. Based on the limited applicable anthropometric data available the following conclusions can be drawn.

The maximum allowable height for operating devices, 60 inches, is acceptable for virtually all healthy adults and most children 10 years old and older. Most children less than 7 years old and adults who are unable to fully raise their arms likely will not be able to reach devices located at the maximum height without assistance.

The maximum operating forces which can be exerted on latches, knobs or other mechanisms is very task specific. For control tasks which require relatively gross whole arm forces, the current maximum allowable forces of 20 and 5 pounds for primary windows and appurtenances, respectively, is within the capability of most healthy adults. For devices which require greater dexterity and more precise application of force, the force which can be exerted drops significantly. Most adults will be able to operate mechanisms that are pinched or squeezed which do not require application of greater than eight pounds force. Depending on the specific type of pinching force required, most 10 year old children will also be able to operate such mechanisms.

The torque which can be applied to knobs requiring rotary motion, currently allowed only up to 180 degrees, varies significantly with knob size and surface characteristics. Knobs less than 1.5 inches in diameter should require a torque of less than 5 inch-pounds.

It must be remembered that the data upon which these conclusions are drawn were collected from healthy, normal adults under laboratory conditions. To the extent that egress devices are intended to be operable by the very young, old, or handicapped without assistance, the forces

Table 3. Estimated[a] Maximal Torque Applied to Cylindrical Knobs by Female Adults

Knob Diameter (inches)	Smooth .5 in Thick Mean[b]	Smooth .5 in Thick 5th Percentile	Knurled .5 in Thick Mean	Knurled .5 in Thick 5th Percentile	Knurled .65 in Thick Mean	Knurled .65 in Thick 5th Percentile
.125	.135	.077	—	—	.397	.31
.5	1.38	.99	—	—	--	--
1.0	4.04	1.53	6.31	3.2	6.0	3.3
1.5	7.74	3.71	—	—	--	--
2.0	9.91	5.13	14.04	9.7	14.5	9.8
2.5	14.04	9.82	—	—	--	--

[a]Estimates are .53 of torque applied by male subjects.

[b]All torque values are in inch-pounds.

which can be applied will be reduced, in some cases to essentially zero. On the other hand, maximum forces measured under laboratory conditions may be considerably less than those exerted in actual emergencies during which physiological changes associated with stress may serve to temporarily enhance physical capacity. Also, motivational levels attained in emergencies will likely be higher than in the experimental environment.

3. OPENING SIZE REQUIREMENTS FOR EMERGENCY EGRESS DEVICES

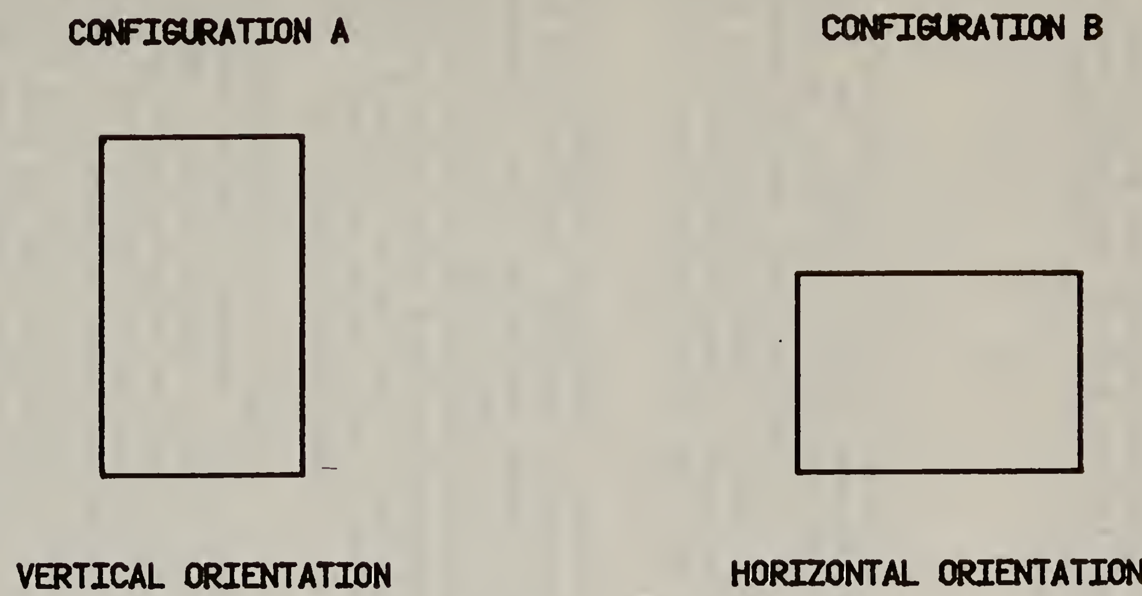
3.1 Background

The HUD standard requires all egress devices to provide a minimum opening of 720 in^2 (4645 cm^2) with a least dimension of 22 in (56 cm). The bottom of the opening may be a maximum of 36 in (91 cm) above the floor. Although these dimensions are compatible with the dimensions required by previous voluntary standards for mobile homes (MHMA, 1973 and NFPA, 1975) and with design recommendations for crawl-through openings (Woodson and Conover, 1964; Van Cott and Kinkade, 1974; and McCormick, 1976) in military and industrial settings, there is very little directly applicable anthropometric or other empirical data to support the current dimensional requirements.

A study by Robert Hunt Co. (1972) did directly address the issue of opening size for emergency egress. This study concluded that markedly smaller openings than those permitted by the current standard provide comparable or better egress efficiency. In the Hunt study, the mean time required to egress from the "standard" opening (32.75" w x 22" h) was compared with the mean egress times for five other opening configurations. Unfortunately several aspects of this study limit its usefulness in assessing the adequacy of the present standard.

The least dimension for each of the comparison openings employed in this study was the width (16 or 18 in), while the only "standard" opening used had the height as its least dimension. Thus, as shown in Figure 6, all comparison openings were tested in configuration A while the minimum size opening allowed by the standard was only tested in configuration B. Also, since the interior sill heights ranged from 42-48 in above the floor, an 18 in high step was used to assist subjects over the sill and a ladder was placed adjacent to the exterior of the opening to assist in

FIGURE 6. TWO EGRESS OPENING CONFIGURATIONS EMPLOYED BY HUNT CO.(1972) AND THE PRESENT STUDY



egress. These conditions cannot be assumed to exist at the time of actual use of emergency egress openings. Finally, although the ages of the 10 subjects (8 males, 2 females) in this study ranged from 20-60 years, all but four subjects were 31 years old or younger.

Given the inadequacy of existing data for determining the appropriate dimensions for emergency egress openings in mobile homes, an empirical study was performed. While this study could not ameliorate all of the deficiencies of past efforts, it does provide additional data under somewhat more realistic conditions.

3.2 Method

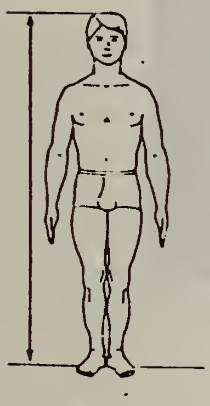
3.2.1 Subjects. A total of 25 paid volunteers, 16 females and 9 males, participated in the study. The only subject selection criteria were that all subjects be between 40 and 65 years of age, and in general good health with no history of chronic or acute heart, respiratory or back problems. The female subjects ranged from 40-63 years old (mean = 48.8, s.d. = 6.5) and the males ranged from 42-64 years old (mean = 57.4, s.d. = 6.8).

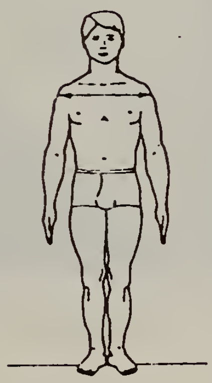
In addition to age, five other subject variables were measured and subsequently used in the analysis of the experimental data. These variables are: stature, weight, bideltoid breadth, hip breadth, and sitting acromial height. Also, a derived measure, the ratio of stature to weight, was computed. All measurements were made with subjects fully clothed with the exception of the height and weight measurements which were taken without shoes. Subject measurement data are summarized in Table 4.

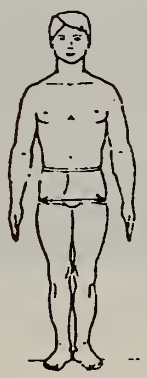
3.2.2 Apparatus. The primary test apparatus (see Figure 7) was a specially fabricated wooden fixture consisting of a wall with an egress opening simultaneously adjustable in both width and height, and an adjustable floor platform. The bottom of the egress opening was 122 cm (48 in) above the floor on the "exterior" side of the test wall. The "interior" floor was a platform which could be adjusted to provide interior sill heights of 15, 46 and 91 cm (6, 18 and 36 in). The width of the egress opening was continuously adjustable between 0 and 122 cm (0-48 in). The height of the opening could be adjusted in 2.54 cm increments from 41-122 cm (16-48 in).

Table 4. Anthropometric Measures of Experimental Subjects

Measure	Mean	S.D.	Mean	S.D.
Age	years			
Female	48.8	6.5		
Male	57.4	6.8		
Stature	cm		in	
Female	163.6	8.2	64.4	3.2
Male	172.0	5.7	67.7	2.3
Weight	kg		lb	
Female	68.4	15.7	150.7	34.6
Male	79.1	10.9	174.4	24.1
Bideltoid Breadth	cm		in	
Female	41.9	3.7	16.5	1.4
Male	44.4	2.7	17.5	1.1
Hip Breadth	cm		in	
Female	37.2	3.7	14.6	1.5
Male	36.4	2.3	14.4	1.9
Sitting Acromial Height	cm		in	
Female	58.5	3.7	23.0	1.4
Male	60.8	2.3	23.9	.9
Stature/Weight	cm/kg		in/lb	
Female	2.58	.63	.45	.11
Male	2.27	.36	.39	.05


Stature


Bideltoid Breadth


Hip Breadth

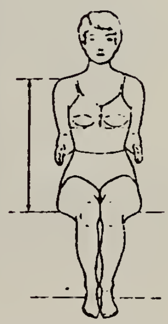
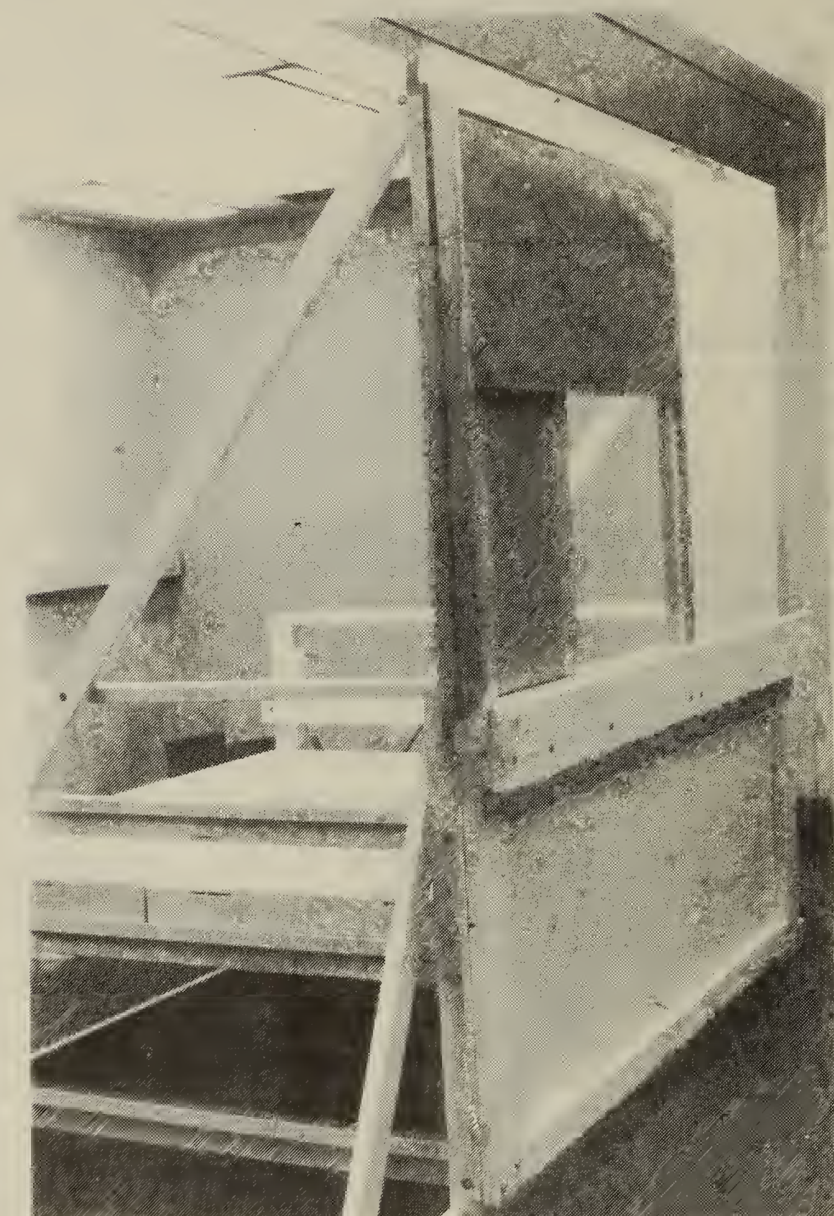

Sitting Acromial Height

Figure 7. Emergency Egress Test Device



The test apparatus differed from actual mobile home egress openings in several ways due to features of the apparatus designed to assure the safety of experimental subjects. The "exterior" landing area to which subjects egressed was covered with a 20 cm thick foam pad. All exposed surfaces of the egress opening were smooth sanded and the opening sill was covered with cloth tape to provide a smooth surface. Clearly, this provided a smoother surface for egress than that found in existing mobile home egress devices. Also, the exterior sill height was less than that likely to be encountered in mobile home installations.

3.2.3 Procedure. Subjects were informed that the purpose of the study was to provide data which would assist HUD in determining the appropriate size opening for escapes from mobile homes in the event of fire or other emergencies. Subjects were not told the current minimum dimensions until all testing was completed. They were instructed that they would make a series of simulated escapes though various size openings with three different interior sill heights (15, 46, and 91 cm) and that they would be free to egress in any manner they desired with the restriction that they must land on the exterior landing pad feet-first. No head-first dives or tumbles were permitted. Also, it was suggested that subjects imagine the exterior drop to be higher than it actually was to discourage egress techniques in which the sill was straddled and one foot placed on the landing mat while the other was still on the sill. Such egress strategies were only possible for the taller and more limber subjects tested.

The order of presentation of the sill heights was randomized across subjects. The first egress opening presented was, for all subjects and at each sill height, the minimum opening size currently permitted by the standard, i.e. 4645 cm^2 (720 in^2).

Before any egresses were attempted, subjects were instructed that they were to rate the ease/difficulty of each escape immediately upon completion of the trial. The rating was made on a 5 point scale where 1 = extremely easy and 5 = extremely difficult. A rating of "3" was to fall midway between the extremes of ease and difficulty. It is this moderately easy/moderately difficult rating of "3" which, for the purposes of this study, defines the "acceptable" size egress opening. After the first trial the height or the width of the opening was increased to 107 cm (42 in) by the experimenter and the remaining dimension was adjusted to that dimension which the subject predicted would be the smallest he or she would rate a "3." The subject then made an egress. If the rating was less than 3, the opening was decreased until the subject predicted a rating of "3" would be made. If the rating was greater than 3 the opening was increased along the pertinent dimension. This iterative process was then repeated for the second dimension. The process was continued until the smallest dimensions both in width and height for which the subject gave a rating of "3" was determined. The process was carried out in both configurations A and B (see Figure 6) for each subject at each of the three interior sill heights. Each series of trials always began with the "standard" size opening.

The iterative testing procedure described above resulted in approximately 5 test trials per sill height for each of the 2 opening configurations. Thus, each subject made a total of approximately 30 simulated emergency egresses. The dimensions of the egress opening and the associated rating were recorded for each trial.

Subjects were instructed to give their rating for each egress immediately upon completing a trial. They were further instructed not to make comparative ratings between the various trials, but rather, to the extent possible, to make independent ratings of each trial.

3.3 Results

The results of the present study are reported in several parts. Presented first are data relating to ratings of the minimum size opening currently permitted. These are followed by results concerning the area of subject generated egress openings and the least dimensions of these openings. The results of an attempt to generate a multiple regression model of the minimum acceptable area for egress openings are described in the Appendix.

3.3.1 Ratings of Current Minimum Opening. All subjects egressed through the minimum size opening now allowed by the standard, 4645 cm^2 (720 in^2), at each of the three sill heights. The mean difficulty ratings for these egresses are shown in Table 5. Sill height did not significantly influence the ratings of the men egressing through the standard opening ($F = 1.54$, $df = 2/24$, $p > .05$). The mean rating was "acceptable" i.e. 3 or less, for all sill heights. The mean ratings of the women was "acceptable" for

Table 5. Mean Difficulty Ratings for Minimum Size Egress Opening Allowed by HUD Standard--4645 cm^2 (720 in^2)

	Sill Height in cm (in)		
	15 (6)	46 (18)	91 (36)
Females	2.50	2.44	3.81
Males	2.00	2.89	2.00

the 15 and 46 cm sill heights, but significantly more difficult for the 91 cm sill, which received a mean rating of 3.81 ($F = 6.54$, $df = 2/45$, $p < .01$). Two of the women were incapable of egress at the highest sill height allowed by the standard.

3.3.2 Area of Subject Generated Openings. The raw data for each subject was reduced to yield the smallest area of egress opening which was rated "3" (i.e. defined as "acceptable") for both of the two initial configurations at each of the three sill heights. These data are shown in Tables 6 and 7 for females and males respectively. Note that no data are presented for female subjects 9 and 11 at the 91 cm sill height, since these subjects could not egress through any opening at this sill height because they could not negotiate this sill height unassisted. The missing data for female subject 6 at the 15 cm sill height is attributable to experimenter error while testing this subject. The empty cells produced by these missing data were accounted for by using unequal number of subjects analyses in all subsequent analyses.

These data were subjected to a two-way classification analysis of variance and the associated simple contrasts to identify any significant differences among the means as a function of sill height and opening configuration. Separate analyses were performed for males and females. The results of these analyses, presented in Tables 8 and 9, indicate that for females there was no statistically significant difference in the egress opening as a function of opening configuration. The opening size required for the 91 cm (36 in) sill was significantly greater than that required for either the 15 or 46 cm sill height but no difference between the size required for the 15 and 46 cm heights was observed. For males, no difference in size was detected as a function of sill height, however, opening configuration did produce a difference in the minimum size opening found acceptable. Configuration B (horizontal orientation) resulted in a significantly larger opening size than configuration A (vertical orientation). The interaction between sill height and opening configuration was not significant for either females or males.

When the mean acceptable opening size data under the various egress conditions of the present study are compared with the currently allowed minimum opening size (Table 10) the present areal dimension appears generous for all conditions except for females egressing over a 91 cm (36 in) sill and men egressing over a 46 cm (18 in) sill through a

Table 6. Smallest Acceptable Area of Egress Opening: Female Subjects

Subject	Sill Height Configuration	15 cm/6 in A*	15 cm/6 in B**	46 cm/18 in A	46 cm/18 in B	91 cm/36 in A	91 cm/36 in B
1	cm^2	4064	5419	4969	4268	3606	4355
	in^2	630	840	770	662	559	675
2	cm^2	3616	2400	2787	3523	3500	3484
	in^2	560	372	432	546	542	540
3	cm^2	5290	5400	6435	4723	6710	5403
	in^2	820	837	998	732	1040	838
4	cm^2	2710	3716	4771	5052	6000	4258
	in^2	420	576	740	783	930	660
5	cm^2	6774	5045	4361	4516	5110	5110
	in^2	1050	782	676	700	792	792
6	cm^2	4181	-	4529	5574	5161	5323
	in^2	648	-	702	864	800	825
7	cm^2	4297	4400	4023	4181	3774	3929
	in^2	666	682	624	648	585	609
8	cm^2	3832	5661	3613	4826	5284	4971
	in^2	594	878	560	748	819	770
9	cm^2	2768	2323	3658	2613	-	-
	in^2	429	360	567	405	-	-
10	cm^2	2806	3613	2800	4290	3193	4542
	in^2	435	560	434	665	495	704
11	cm^2	3071	3484	4658	3339	-	-
	in^2	476	540	722	518	-	-
12	cm^2	3103	3116	2768	3716	4258	4658
	in^2	481	484	429	576	660	722
13	cm^2	3071	3432	5200	4529	4935	4839
	in^2	476	532	806	702	765	750
14	cm^2	4045	4897	4452	3800	5987	5252
	in^2	627	759	690	589	928	814
15	cm^2	3716	4722	3729	4723	4403	4955
	in^2	576	732	578	732	682	768
16	cm^2	2890	4000	3071	4000	3290	4452
	in^2	448	620	476	620	510	690

* A = Vertical orientation
** B = Horizontal orientation

Table 7. Smallest Acceptable Area of Egress Opening: Male Subjects

Subject	Sill Height Configuration	15 cm/6 in A*	15 cm/6 in B**	46 cm/18 in A	46 cm/18 in B	91 cm/36 in A	91 cm/36 in B
1	cm^2	3181	4697	4045	3434	4852	3793
	in^2	493	728	627	540	752	588
2	cm^2	3432	5510	3613	6371	4606	5564
	in^2	532	854	560	988	714	862
3	cm^2	3819	2468	2981	4064	3071	4606
	in^2	592	383	462	630	476	714
4	cm^2	1548	1548	2323	2323	1355	1355
	in^2	240	240	360	360	210	210
5	cm^2	2200	2081	2600	3339	2864	3774
	in^2	341	322	403	518	444	585
6	cm^2	3613	5510	4877	5748	4542	5193
	in^2	560	854	756	891	704	805
7	cm^2	3619	5148	5148	5535	4645	5961
	in^2	561	798	798	858	720	924
8	cm^2	4413	4413	4181	5935	5332	5564
	in^2	684	684	648	920	826	862
9	cm^2	4064	4894	5555	5855	3274	4526
	in^2	630	758	861	908	508	702

* A = Vertical orientation
** B = Horizontal orientation

Table 8. Analysis of Variance:
Minimum Acceptable Egress Opening Area for Females

Source	SS	df	MS	F	P
Total	86052794	90			
Sill Height	8153156	2	4076578	4.51	.014
Configuration	587581	1	587581	<1	>.05
Sill Height & Configuration	27424	2	13712	<1	>.05
Error	76760121	85	903060		

Simple Contrasts for Sill Height

Contrast	SS	F	P
15 cm vs 46 cm	910197	1.01	>.05
15 cm vs 91 cm	8012779	8.87	.004
46 cm vs 91 cm	3697221	4.09	.046

SS = sum of squares
df = degrees of freedom
MS = mean square
F = F-ratio
p = probability of error

Table 9. Analysis of Variance:
Minimum Acceptable Egress Opening Area for Males

Source	SS	df	MS	F	p
Total	93342789	53			
Sill Height	4172587	2	2086294	1.22	> .05
Configuration	7046001	1	7046001	4.12	.048
Sill Height Configuration	66776	2	33388	< 1	> .05
Error	82057425	48	1709530		

SS = sum of squares
df = degrees of freedom
MS = mean square
F = F-ratio
p = probability of error

Table 10. Experimental Data Compared with Minimum Egress Opening Area Permitted by HUD Standard

Minimum Allowed by Standard	Configuration A 4645 cm^2 720 in^2				Configuration B 4645 cm^2 720 in^2			
Minimum "Acceptable" Experimental Data	Mean cm^2	Mean in^2	95th Percentile cm^2	95th Percentile in^2	Mean cm^2	Mean in^2	95th Percentile cm^2	95th Percentile in^2
15 cm, 6 in sill								
Female	3765	584	5587	866	4109	637	5480	849
Male	3321	515	4256	660	4030	625	5509	854
46 cm, 18 in sill								
Female	4114	638	5447	844	4230	656	5156	799
Male	3925	608	5372	833	4739	735	6175	957
91 cm, 36 in sill								
Female	4658	722	6213	963	4681	726	5347	829
Male	3838	595	5116	793	4482	695	5782	896

configuration B opening. In all other conditions, the mean size opening required was considerably less than the 4645 cm^2 (720 in^2) now required. In the conditions cited under which the mean opening size was greater than the current minimum, the largest difference between the mean observed size and the standard is only 94 cm^2 (15 in^2), or about 2%. Quite a different picture emerges, however, if we look at the 95th percentile data from the experimental subjects. These data indicate that under only one egress condition, (i.e. males, 15 cm sill height, configuration A), is the 95 percentile area smaller than the minimum size now permitted. For the other egress conditions, the 95th percentile area of opening required for acceptable egress ranged fom 11-34 percent larger than the minimum now allowed by the standard.

3.3.3 <u>Least Dimensions of Subject Generated Openings</u>. The mean and 95th percentile data for the least dimension of the smallest acceptable openings generated by the subjects are compared with the least dimension allowed by the standard in Table 11. As was the case with the areal dimension, the mean values for the least dimension of the openings determined empirically fare quite well with respect to the least dimension permitted by the standard. In only three of the experimental conditions does the mean least dimension exceed the 56 cm (22 in) minimum set by the standard. Under these conditions, the mean least dimension exceeds the standard by a maximum of 10 percent. When the 95th percentile data are examined, however, the least dimension observed was less than 56 cm under only two conditions for the men. For females, none of the 95th percentile least dimensions fall at or below the minimum allowed by the standard. Overall, under those conditions in which the least dimension was greater than allowed by the standard, the least dimension ranged from 9.5 to 66 percent larger than now permitted.

3.4 Conclusions

The results of the empirical study to determine an acceptable opening size for emergency egress devices are, unfortunately, equivocal. The major problem in interpreting the experimental results lies with the concept of "acceptable."

If the definition of acceptable adopted in this study, i.e. a rating of 3 on a five point scale of difficulty, is used, the results of this study indicate that the minimum opening size now allowed is generous for the average,

Table 11. Experimental Data Compared with Minimum Least Dimension of Egress Opening Permitted by HUD Standard

	Configuration A				Configuration B			
Minimum Allowed by Standard	56 cm, 22 in				56 cm, 22 in			
Minimum "Acceptable" Experimental Data	Mean		95th Percentile		Mean		95th Percentile	
	cm	in	cm	in	cm	in	cm	in
15 cm, 6 in sill								
Female	44.9	17.7	65.8	25.9	53.8	21.2	69.2	27.2
Male	39.5	15.6	46.5	18.3	61.8	24.3	92.8	36.5
46 cm, 18 in sill								
Female	49.3	19.4	66.2	26.1	54.3	21.4	68.4	26.9
Male	44.4	17.5	52.8	20.8	55.9	22.0	66.3	26.1
91 cm, 36 in sill								
Female	59.8	23.5	82.0	32.3	56.6	22.3	66.4	26.1
Male	46.7	18.4	66.7	26.2	51.9	20.4	61.2	24.1

healthy adult in the 40-65 year age group. The mean smallest acceptable area and least dimension generated by the subjects in this study fall below or very close to the minimums allowed by the standard under all of the experimental conditions. The 95th percentile subject generated openings, on the other hand, indicate that the current minimum opening size is too small. In only one of the experimental conditions was the 95th pecentile opening size smaller than the current minimum size in both area and least dimension. Further, an acceptable opening size could not be determined for two of the women egressing through an opening with a 91 cm (36 in) sill height since they were incapable of any egress over a sill of this height.

If the concept of "acceptability" as defined in this study is abandoned and replaced with the notion of "possibility," the experimental results become somewhat easier to interpret. With the exception of the two women noted, all subjects did successfully egress through the minimum size opening allowed by the standard at each of the three sill heights tested. Many subjects egressed through openings significantly smaller than the minimum currently allowed. Clearly, emergency egress through openings which meet the requirements of the current standard is possible for healthy adults in the age range tested, except at the greatest sill height permitted. The experimental data indicate that the maximum sill height should be less than the 91 cm (36 in) now allowed. Since no data were collected with sill heights between 46 and 91 cm (18 and 36 in), no recommendation for the maximum height can be justified by the data.

A final problem encountered in interpreting the present data involves the population sampled. For ethical and safety reasons, a condition of participation in the study was that all subjects be in general good health and, more specifically, have no history of heart, respiratory or back problems. Along with more incapacitating handicaps, these are the very conditions which would make egress the most difficult. While the experimental data provide some assurance that egress openings which meet the requirements of the current standard will provide a means of escape that is usable by healthy adults, no implications can be drawn from the present data concerning the accessibility of such devices to individuals who are in any way physically impaired. If emergency egress devices are to be usable, without assistance, by all mobile home occupants, the devices must be designed to offer no greater obstacle to use than the egress devices normally used by the occupants. In practice this would mean that the minimum acceptable emergency egress device would consist of an outside access door located in each occupied area of mobile homes.

Author's Note: After subject testing was completed, the HUD project officer requested information regarding the effect on the required egress opening which would be realized if a barrier, e.g. a table or chest, were situated in front of the egress device. It was suggested that if such a barrier were sufficiently wide and deep, it should have little effect on the opening area required for egress. For egress devices with high sill heights, a barrier could assist egress. Although no formal testing of this hypothesis was performed, one male and one female subject did egress through openings with a 36 in (91 cm) sill both with and without a 29 in (74 cm) high, 18 x 22 in (46 x 56 cm) table in front of the opening. The presence of the barrier did not result in a larger opening size required for egress for either subject. For the male, the barrier resulted in a significantly smaller size opening.

4. References

1. Adler, S.A., Evaluation of the egress provisions of the HUD mobile home construction and safety standard. NBSIR 77-1246, May 1977, National Bureau of Standards, Washington, D.C.

2. Annual housing survey, United States and regions. Current housing reports: series H-150-75A, April 1977, Bureau of the Census, Washington, D.C.

3. Anthropometric source book, Volume II: A handbook of anthropometric data. 1978, NASA Reference Publication 1024.

4. Federal mobile home construction and safety standards, Federal Register, 1975, 40, 58754.

5. Green, P.E. and Tull, D.S. Research for marketing decisions, 1970, Prentice-Hall: Englewood Cliffs, New Jersey.

6. Kerlinger, F.N. and Pedhazur, E.J. Multiple regression in behavioral research. 1973, Holt, Rinehart and Winston: New York.

7. Laubach, L.L. Muscular strength of women and men: A comparative study. AMRL-TR-75-32, 1976, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio.

8. McCormick, E.J. Human factors in engineering and design, 4th edition, 1976, McGraw-Hill: New York.

9. MHMA, Window specifications for utilization in mobile home and factory built housing, 1974, Mobile Home Manufacturing Association.

10. NFPA, Mobile Homes, 501B-1974, National Fire Protection Association (ANSI A119.1-1975).

11. Owings, C.L., Chaffin, D.B., Snyder, R.G. and Norcutt, R.H. Strength Characteristics of U.S. Children for Product Safety Design. October 1975, contract FDA-73-32, prepared for Consumer Product Safety Commission, Washington, D.C.

12. Robert W. Hunt Co. Results of a study to evaluate various size openings for use as emergency egress in residential housing. Report 6-179, August 1972, Robert W. Hunt Co., Chicago, Illinois.

13. Rohmert, W. Maximalkraft von maennern im hewegungsraum der arme und beine. 1966, Westdeulscher Verlaz: Koeln, Germany. cited in H.P. Van Cott and R.G. Kinkade (eds.), Human engineering guide to equipment design, 1972, Joint Army-Navy-Air Force Steering Committee.

14. Snyder, R.G., Schreider, L.W., Owings, C.L., Reynolds, H.M., Golomb, D.H., and Schork, M.A. Anthropometry of infants, children and youth to age 18 for product safety design. UM, HSRI-77-17, May 1977, Highway Safety Research Institute, University of Michigan: Ann Arbor, Michigan.

15. Taylor, C.L. The biomechanics of the normal and of the amputated upper extremity. In P.E. Klopsteg and P.D. Wilson (eds.) Human limbs and their substitutes, 1954, McGraw-Hill; New York.

16. Van Cott, H.P. and Kinkade, R.G. (eds.), Human engineering guide to equipment design. 1972, Joint Army-Navy-Air Force Steering Committee.

17. Woodson, W.E. and Conover, S.W. Human engineering guide for equipment designers. 1966, University of California Press: Berkeley, California.

APPENDIX

Regression Models for Predicting the Acceptable Area of Egress Openings

It was noted in the text that seven subject variables were computed for each experimental subject. These seven variables: age, stature, weight, bideltoid breadth, hip breadth, sitting acromial height and stature/weight ratio were selected as potentially useful in predicting the minimum acceptable opening size required for emergency egress. A series of linear multiple regression models were constructed using these variables as independent or predictor variables and the area of the egress opening as the dependent or criterion variable. A packaged computer program designed for use with a Tektronix 4051 terminal computer was employed in this analysis. This program permits the calculation of the least squares regression of Y on the set or any subset of the variables $x_1 \ldots x_k$, where, in the present case:

Y = acceptable egress opening area

x_1 = age

x_2 = stature

x_3 = weight

x_4 = bideltoid breadth

x_5 = hip breadth

x_6 = sitting acromial height

x_7 = stature/weight

The general model is the least squares approximation of opening size by a linear function of one or more of the independent variables. Thus, the general equation:

$$Y' = a + b_1x_1 + b_2x_2 + \ldots b_kx_k$$

where Y' = predicted value, a = intercept constant, b_1, b_2 ... b_k= regression coefficients associated with the independent variables $x_1 \ldots x_k$. No curvilinear regression analyses were carried out. That is, no statistical tests were performed to determine if any predictability in the present data is afforded by a nonlinear rule.

The present data were subjected to both forward and backward stepwise regression analyses (Kerlinger and Pedhazur, 1973). The data from one male and two female subjects were deleted from the analyses. Inclusion of their data resulted in very low correlations between the criteria and predictor variables. If these subjects represent a significant part of the total population, use of the regression models presented here becomes suspect on statistical bases. Despite the deficiencies of the present data, the models do shed additional light on the size of emergency egress openings which are required to rate "acceptable" as a function of anthropometric measures. Because of the limited number of subjects and the lack of any tests of model validity, the models presented cannot be considered definitive.

Table A1 presents the coefficients for the statistically significant regression equations resulting from the analysis for those models in which $\overset{*}{R}{}^2 > .50$ and the fewest number of variables are necessary. The square of the multiple correlation coefficient, R^2, expresses the proportion of variance of Y accounted for by the linear combination of $x_1 \ldots . x_k$. In the present case an adjusted value of R^2, $\overset{*}{R}{}^2$ has been used to decrease the likelihood of overestimating R^2 as occurs when a large number of independent variables are employed relative to the number of subjects (Green and Tull, 1970). $\overset{*}{R}{}^2$ is determined by the formula:

$$\overset{*}{R}{}^2 = 1 - (1-R^2)\frac{n-1}{n-q}$$

where n = number of subjects

q = number of variables in the regression equation.

Given the appropriate coefficient for each variable, we can predict the acceptable opening size for any individual for whom we know the pertinent anthropometric data. Anthropometric data on the variables of interest are compiled in Table A2.

As an example of the use of the regression coefficients, we can predict the minimum acceptable area for a configuration A opening with a 91 cm sill height by

Table A1. Selected Regression Coefficients for Predicting Area (cm^2) of Acceptable Egress Openings

Eq. No.	Sex	Sill Height (cm)	Config.	R^{*2}	Intercept	Coefficients for Variables 1	2	3	4	5	6	7
1	M	15	A	.97	-5461.1	44.4	194.69	---	-182.14	---	-301.98	-411.06
2	M	15	A	.80	-710.8	---	142.42	---	---	---	-341.00	---
3	M	15	B	.99	13990.9	82.8	207.72	136.67	-898.27	-274.79	-256.19	---
4	M	15	B	.67	-17470.0	---	245.89	---	-473.66	---	---	---
5	M	46	A	.95	15355.4	---	183.57	---	-398.15	---	-306.50	-3199.67
6	M	46	B	.80	-28853.6	---	241.39	---	-190.15	---	---	---
7	M	91	A	.74	-12172.6	---	187.31	---	-372.49	---	---	---
8	M	91	B	.98	-50549.7	---	---	489.13	-202.62	-395.59	---	17891.81
9	M	91	B	.93	-24010.9	---	301.49	---	-248.40	---	-208.94	---
10	M	91	B	.85	-2837.3	---	264.10	---	-290.42	---	---	---
11	F	46	A	.63	8762.9	70.6	---	124.94	-305.55	---	-100.84	892.16
12	F	46	A	.58	12748.4	69.5	---	88.46	-312.37	21.76	-96.09	---
13	F	91	A	.70	2765.0	---	---	44.65	-203.35	203.70	---	---
14	F	91	B	.66	8103.6	-23.9	-11.42	32.67	-54.78	---	---	---
15	F	91	B	.53	6037.0	---	---	---	---	---	---	-492.77

Table A2

Anthropometric Data for Males and Females Compiled from the Anthropometric Source Book,* 1978

	Percentile		
	5th	50th	95th
Stature (cm)			
Female	149.5	160.5	171.3
Male	161.8	173.6	184.4
Weight (kg)			
Female	46.2	61.1	89.9
Male	56.2	74.0	97.1
Bideltoid Breadth (cm)			
Female	38.2	41.8	45.9
Male	42.3	46.2	50.8
Hip Breadth (cm)			
Female	31.6	34.8	38.8
Male	30.9	33.9	37.9
Sitting Acromial Height (cm)			
Female	51.6	56.2	60.7
Male	56.5	61.0	65.9

*The original sources of the data in this table are a number of surveys which sampled different populations. These data represent, in the author's opinion, the best approximations of the relevant anthropometric measures for the U.S. population.

solving equations 7 and 13 in Table A1 for males and females, respectively. For a male with 50th percentile anthropometric measurements we have:

$$Y' = -12172.6 + (187.31 \times 173.6) + (-372.49 \times 46.2)$$

$$Y' = 3135 \text{ cm}^2 \ (486 \text{ in}^2)$$

The opening area for a female exhibiting 50th percentile body dimensions is predicted by the equation:

$$Y' = 2765+(44.65 \times 61.1)+(-203.35 \times 41.8)+(203.7 \times 34.8)$$

$$Y' = 4082 \text{ cm}^2 \ (633 \text{ in}^2)$$

In both of these cases, the predicted acceptable opening area is smaller than the minimum currently allowed by the HUD standard. Solving these equations using the same coefficients, but 95th percentile anthropometric data yields predicted acceptable opening areas of 3445 cm^2 (534 in^2) and 5349 cm^2 (829 in^2) for males and females, respectively. For females, the predicted minimum opening size is considerably larger than the 4645 cm^2 (720 in^2) minimum area permitted by the standard.

It is important to note that while the regression models generated from the present experimental data predict minimum opening sizes acceptable to healthy 40-65 years old individuals for whom the relevent anthropometric measurements are known, the use of population anthropometric data, as above, can lead to erroneous predictions. This is due to the fact that there is only a very low probability that any individuals exist whose anthropometric measures equal any given percentile on all of the body measurements required in the regression equations. Even if a given individual does exist who exhibits for example 5th percentile body dimensions on all relevant dimensions, it does not follow that this represents a 5th percentile person. The regression equations presented here, therefore, are best used only in cases where the dimensions are known for an actual individual.

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

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.)*

This report summarizes a two task effort which is part of the National Bureau of Standards evaluation of the Federal Mobile Home Construction and Safety Standard. The first task consists of a review of relevant anthropometric data from which egress requirements might be drawn. The second task is an empirical study of egress designed to generate data which can assist HUD in evaluating the existing size requirements for egress devices. The degree to which the requirements in the current standard for location and operating characteristics of egress device latches and other operating mechanisms are acceptable varies for different segments of the population at risk. The limited applicable anthropometric data suggests that the requirements are sufficient for the most part, for average, healthy, normally ambulatory adults. The minimum opening size requirements were also shown to be acceptable for average healthy adults under most conditions tested. However, devices which meet the maximum sill height allowed by the standard were shown to be extremely difficult to negotiate or unusable by a significant portion of the experimental test subjects. Implications of the present egress requirements for escape by handicapped or otherwise impaired individuals are discussed.

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)*

Anthropometry; emergency egress; escape behavior; HUD; mobile home; safety; standard; window

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