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ABSTRACT

Research was reviewed and conducted regarding the accessibility of buildings for physically disabled persons. Data was produced regarding anthropometrics (eye level and reach limits for ambulant, semiambulant, and wheelchair bound persons); wheelchair maneuvers: speed and distance (maximum travel distances for people with limitations of stamina): push-pull forces against windows and doors; ramps (maximum slopes): toilet stalls (dimensions, use of grab bars); bathtubs (location of grab bars, need for seat): showers (dimension of shower stalls, usability of wheelin showers and those with a curb); bathroom layouts: kitchen (dimensions, heights of shelves and work surfaces): doorways: elevators (size, location of control panels, timing of elevator doors); public telephones; and public mailboxes. A final section compares data with previous research. (CL)

Accessible Buildings for People with Walking and Reaching Limitations

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FOREWORD

Over the last decades, Americans have been learning to see what we have never seen before. I refer not to flying saucers but to people -- people who have been hidden from us by prejudice, by custom, and by ignorance. Ralph Ellison described the phenomenon for blacks in his powerful novel, The Invisible Man.

Today, finally, we see the black population; we are only beginning to see other groups -- women, the American Indian, the elderly, the handicapped -- see them both as national resources and as groups having claims on the national conscience.

This publication is one of a series of six, the titles of which are listed in the acknowledgements, that HUD's Office of Policy Development and Research has sponsored to accomplish the important task of making buildings accessible to and usable by the physically handicapped through improving the American National Standards Institute's A117 standard.

Prepared under the supervision of the Office of Policy Development and Research, these volumes have won a research award from Progressive Architecture. To quote from the jury comments: "In terms of the effect that the work will have on future architecture and planning, the new ANSI standard A117.1 has got to be the blockbuster of all.....It's a very solid piece of work."

It is indeed. I am proud to present it to you.

Donna E. Shalala

Donna E. Shalala
Assistant Secretary
for Policy Development
and Research

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We wish to thank the many people who contributed to the research and development of this report. In particular, Charles Gueli and Deborah Greenstein, Office of Policy Development and Research, HUD, who provided advice and assistance through their efforts as Government Technical Representatives for the contract. Without the cooperation and participation of the many people who served as subjects for the research and the Action Coalition of Citizens for Retirement with Dignity (ACCORD) of Syracuse, NY, who coordinated efforts to recruit them, the work described here could not have been completed. Finally, Jean Caraccilo, as the office secretary, provided immeasurable assistance through typing and day-to-day logistical support.

This report is one of a series of reports prepared under this contract. The full series includes:

1. Access to the Built Environment: A Review of Literature
2. Accessible Buildings for People with Walking and Reaching Limitations
3. Accessible Buildings for People with Severe Visual Impairments
4. The Estimated Cost of Accessible Buildings
5. A Cost-Benefit Analysis of Accessibility
6. Adaptable Dwellings

All of this research contributed to the development of the proposed revisions to ANSI A117.1, Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped.

Contents

Note: Research on lavatories is located under Kitchen Work Centers (and lavatories) in Section 9.

Introduction And Methods

1

Introduction and Objectives

The research reported here was initiated to fill some specific information needs. In the development of the proposed revisions to a voluntary building standard, ANSI A117.1, Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped, a major goal was the use of technical criteria generated from reliable, empirical research. A review of existing human factors research on accessibility of buildings for disabled people identified many serious deficiencies in existing information (see Steinfeld, 1978).

For accessibility concerns related to movement disabilities, limitations of stamina and difficulties maintaining balance, the major findings of the review were that there was:

1. Limited empirical data about the use of kitchens,
2. Limited empirical data about the use of doorways that can be applied to American construction practices,
3. No empirical data on strength and stamina limitations,
4. Conflicting data on use of ramps,
5. No empirical data about the use of bathrooms,
6. Limited empirical data about negotiating movements in small spaces such as elevators,
7. Limited information on reaching under actual conditions of use, i.e. other than anthropometric data.

In general, although a great many recommendations exist for accessibility design in all these areas, few are based on reliable empirical data. Most either have an anecdotal source, or rely on a limited or ambiguous data base.

It was determined that a series of empirical research studies would provide a more reliable and valid data base for the technical criteria of the standard. The objectives of the research were to:

1. Clear up confusion caused by differences in existing information,
2. Fill gaps where little or no research has been done,
3. Determine the differences in optimal conditions for people with different disabilities and degrees of disability.

The third objective is related to the process of developing standards. Since voluntary standards such as those of the ANSI (American National Standards Institute) must be accepted in a consensus process, the optimum in accessibility may not be acceptable due to political, economic or technological factors. We wanted to have data available so that as positions were taken on the technical criteria of the standard, it would be clear who was being included or excluded from access or use of buildings.

In addition to the work reported here, research was also initiated that focused on the mobility problems of blind and partially sighted individuals. That research is reported in a separate document (see Aiello and Steinfeld, 1978).

Laboratory Testing Methods

Testing Stations and General Procedures - Disabled and able-bodied people performed simulated tasks of daily living at mock-ups of actual public and residential environments. The research included studies of:

- Anthropometric measurements
- Speed/distance measurements
- Wheelchair maneuvering--"K" turn, "U" turns around walls, "L" turns from corridors into passageways
- Push and pull forces
- Kitchen work centers--oven, sink, range, mix center, kitchen layout (the bathroom lavatory was also included in this group due to its similarity with kitchen work centers)
- Ramp slope and length
- Doorways
- Elevator
- Toilet stall design
- Bathroom design, including bathtub, shower and bathroom layout
- Public telephone height
- Public mailbox use

Simulated tasks and environments were used for gathering data in order to study many different parts of buildings with a variety of different arrangements and configurations and to involve as large a sample of people as possible. The use of data gathered in the field would have been limited to the characteristics of existing settings and therefore would not provide a sufficient range of observations to identify optimal conditions and the full range of accessibility problems. In addition, the cost of building real environments for each of the testing stations and the time required to have each subject use them were prohibitive. The simulation method allowed the research to be as reality-based as possible within the constraints of information needs and budget.

The testing stations were located in an unused University building, which served as a laboratory for the project. The testing stations were selected and designed to generate the specific data necessary for meeting our information needs and objectives. The design and use of the stations are described in the reports for each station.

All testing procedures were standardized. Instructions were written for each testing station. All staff members were trained in the procedures and team leaders, who where professional staff, supervised all laboratory work. Subjects were encouraged to try alternative methods of using testing stations when it was apparent that they were using an ineffecient method to accomplish a task. All testing was completed in casual clothing and wheelchair users used their own wheelchairs.

Recording and Analyzing Data - All testing stations were designed, as far as possible, to allow automatic measurement. For example, measuring rules or grids were applied directly to equipment so that observers only had to record the result rather than measure every dimension. This reduced error in measurement as well as reducing the time required to take measurements.

In the analysis of data for individual testing stations, graphic representations were often used to identify patterns. Methods of analysis and presentation of results were based upon the data needs of developing standards. Thus, cut-off points for determining how many, or which, subjects could manage with a given design feature were selected by standard increments commonly used in design, e.g. six inch increments.

Recommendations - We have assumed, in making recommendations, that there will always be some people whose abilities will require specific and personal adaptation of the physical environment to allow them to use it independently. Thus, we have included a description of "marginal populations" for each set of recommendations. It is our judgment that recommended design criteria should not be based on the performance of these people because the nature of their disabilities is so idiosyncratic that they may or may not be able to successfully use buildings and facilities given any design criteria short of custom design. Our recommendations encompass the people with a range of abilities who clearly would be benefited by standardized design features. This means that such recommendations would be most convenient to the broadest range of individuals and not handicap other people in the convenient use of the environment.

Subject Selection Methods and Recruitment

These studies were concerned with the use of buildings by people with movement disabilities, limitations of stamina and balance. Ambulant, semi-ambulant and non-ambulant people participated. The major disabilities that subjects had were:

1. Incoordination and difficulty manipulating fingers and hook protheses users,
2. Difficulty lifting and reaching,
3. Inability to use lower extremities (wheelchair users),
4. Reliance on walking aids,
5. Difficulty bending and kneeling
6. Difficulty sitting down or getting up from a chair,
7. Difficulty using stairs or inclines or difficulty walking long distances,
8. Difficulty walking on rough surfaces,
9. Difficulty lifting and reaching combined with difficulty manipulating fingers or incoordination,
10. Difficulty lifting and reaching combined with inability to use lower extremities,
11. Reliance on walking aids combined with difficulty sitting down or getting up.

A group of able-bodied subjects also participated in the research.

Disability categories do not, in themselves, establish a description of an individual's functional ability for independent action. For example, one individual who cannot use their legs (category 3, above) may be young, trained in a rehabilitation clinic, have strong upper arms and good stamina. Another individual who cannot use their legs may be old, with little rehabilitation training, have general limitations in stamina and be obese. These differences in impairment and other characteristics result in different levels of functional ability for everyday activities, even though both may be wheelchair users.

To insure that the selection of subjects reflected differences in functional ability levels, each disability category was divided further into a range of functional levels. The range started with the most independent level of ability in a category and ended with the lowest level of ability that would allow independence in daily activities. A screening method, called the Diagnostic Interview, was developed which utilized a self-report interview about tasks of daily living in order to identify a person's disabilities and also their functional ability levels within each particular disability category. Since all the interviewing was to be done by telephone and by non-professionals, a clinical assessment or evaluation of function at the first contact with the subjects was impossible. This gave rise to the need for a pretest and also a validation procedure at the laboratory.

Three versions of the Diagnostic Interview were initially administered to a total of twenty people by telephone. Its accuracy was then checked by home visits to those individuals by a physical therapist. Most items proved to be valid indications of functional ability, but some corrections and improvements were made following the home visits. The Diagnostic Interview also contained several items of biographical data, including age and sex.

Our overall research goal was to establish requirements for accessibility and use of the environment by people who would be independent in daily activities. We were concerned that the sample of individuals would be representative of all those people, to the inclusion of marginally independent people. With such a sample, we could be assured that the results of our laboratory research would apply to the broadest possible population. Therefore, our objectives in obtaining subjects were:

1. Find people with all the disabilities on our list,
2. Find people within each category that reflected a range of functional abilities,
3. Minimize bias in sample selection caused by an individual's dependency on institutional services,
4. Obtain enough people in each ability level of each disability category to make generalizable conclusions from data,
5. Minimize bias in sample selection due to a high incidence of advanced rehabilitation training not available to the broad range of disabled people.

A review of demographic data on disability indicated that statistics are not available on functional ability of people within disability categories to the detail required for our research. Thus, there was no basis to utilize a proportionate sampling method. Furthermore, since the proportion of people in the general population with severe disabilities is well below twenty percent, any random sampling method used to identify subjects would have been exceedingly expensive and time consuming. The use of the Diagnostic Interview, combined with a validation procedure at the laboratory, provided a way to identify and verify disability and functional level, but we had to set an arbitrary target for the number of subjects in each group. Since we anticipated that wheelchair users would be critical in terms of performance, we over sampled for them. We utilized memberhip lists of elderly and disabled consumer organizations in the Syracuse Metropolitan area to generate an initial roster of potential subjects for telephone interviews. In addition, an intensive effort to recruit subjects was made through local radio, newspaper, newsletters and bulletin boards.

Subject recruitment was done by a local senior citizen's advocy organization, the Action Coalition to Create Opportunities for Retirement with Dignity, Inc. (ACCORD). Working on a sub-contractual agreement, they provided two telephone interviewers, whom we trained to use the Diagnostic Interview. Training included having the interviewers make telephone calls to our staff who simulated disabilities and difficult interviewing problems. When the interviewers were consistently accurate in administration of the interview, they were furnished with lists of prospective subjects. Quality control included reinterviewing a small, random sample of people interviewed by ACCORD workers and checking all interview forms for completion and logical consistency.

The ACCORD Office served as a receiving point for telephone calls in response to our adds and media announcements and the ACCORD workers scheduled subjects at our laboratory. Recruitment was not limited to older people--a concerted effort was made to recruit subjects from all age groups. Recruitment was limited to non-institutionalized people. A few exceptions to this rule were made, but such individuals were tested in a limited number of stations. The recruitment efforts took place over a six month period, running simultaneously with our testing procedures.

Free transportation to and from the laboratory testing site was provided and a wheelchair cab service was retained for people who needed or desired such a service. All subjects were paid between $12.50 and $20.00, based on the number of tasks each was requested to perform. The decision to perform more difficult tasks, such as toilet transfers, etc., was made by each individual. All staff members were trained in safety precautions. The testing period, for each individual, was broken into several morning or afternoon sessions if necessary, with coffee breaks and rest times as needed so that fatigue due to testing was not a factor in performance.

Subjects were tested only at testing stations where use was affected by their disability. For example, subjects who had difficulty handling and fingering were tested at stations whose use required finger dexterity. People who used walking aids or wheelchairs were tested at all testing stations. Table 1 shows the matching of subjects to testing stations. The total number of disabled subjects was 201.

The testing was done in two phases. The first phase objective was to establish basic ranges of performance for each testing station. This data was used to generate proposed standards. The second phase objectives were to validate some parts of the proposed standards, research some areas in more detail and to test some combinations of design elements, e.g. bathroom and kitchen layouts. The second phase subjects were selected from the larger subject pool as being representative of various ability levels. Thus, we could be sure that, even though small samples were used, the criteria derived from the second phase research activities would be satisfactory for the rest of the subjects in the sample, and to the disabled population in general, to the extent that our basic sample reflected the range of functional abilities in that population.

Upon arrival at the laboratory testing site, subjects' physical abilities were reassessed through actual performance of tasks that were self-reported on the Diagnostic Interview. This was necessary not only as a validation of the Diagnostic Interview, but also because the time lapse between the telephone interview and initial visit to the laboratory was often one month or longer. During this time, the physical status of many individuals could either improve or deteriorate.

After the validation, a change was made in the ability level if a discrepancy was noted. Approximately twenty-five percent of the subjects had a change in their functional ability level. Some of this was due to changes in physical status. The highest concentration of changes were in the categories of difficulty lifting and reaching and limitations of stamina. These two areas of the diagnostic interview appear to be the weakest in predictive value. Some subjects seemed to have difficulty judging how high they could reach or how far they could walk without fatigue. Also, some subjects perceived themselves as more disabled than they actually were.

We did not require wheelchair users to validate their self-reported performance in transferring since we felt it would be too fatiguing. A review of testing data showed that five wheelchair users who, on the Diagnostic Interview, reported that they could transfer, did not transfer at the time of testing. When investigating reasons for this, we found three of these people had reduced capacities since the Diagnostic Interview; one was able to transfer but had external collection devices and thus, did not need to use a toilet; and the other person was simply too fatigued. On the other hand, there were two wheelchair users, who, when interviewed, reported that they could not transfer, but did at the time of testing. One of these people had an improvement in her condition and the other one, who usually needs assistance to transfer, was able to transfer because he had grab bars on both sides at a preferred height and proximity to the toilet.

Initially, we had hoped to recruit not less than ten people in each functional ability level for each disability category in all but the category, "inability to use lower extremities." In that category, we made fine distinctions in ability levels and, thus, we sought only five people in each level but had a large number of levels. It was very difficult to find people at certain levels. This may reflect a very small incidence of such disabilities. In categories where we found only a few individuals at certain levels, we combined those levels for analysis purposes. Table 1 shows the breakdown for the total sample of subjects by disability category. Those people who, in the validation procedure, were found not to be disabled by our functional criteria were grouped in the able-bodied category.

Description of Subjects

A second interview was administered to all subjects during their first visit to the laboratory. This was called the Opinion/Adaptation Interview and was used to solicit background information about present living arrangements, use of technical aids and opinions regarding design features for increasing usability of dwelling units. The interview took approximately forty-five minutes to complete. Tables 3 through 5 describe the sample in terms of age, sex and living arrangements.

From the tables, it can be seen that the sample has over twice as many women than men, consists almost entirely of people who live in independent housing and is an adult group. Almost twenty percent of our sample comes from public housing. Compared to the adult population, this sample has a greater proportion of late, middle-aged and elderly people (over fifty-five years old) than found in the general population over eighteen years of age (US Census, 1970). The over-sampling of women is related to the "aged" nature of the sample in that women live longer than men and, therefore, form a larger proportion of the population in late adulthood. Moreover, they are much more likely to live in public housing than are men.

The characteristics of the sample mean that this group of people is likely to exhibit generally lower strength and stamina, reduced agility, smaller stature and a greater familiarity with kitchen work than a sample with a more equal distribution of men and women or a younger sample. Moreover, these people are far less likely, as a group, to have advanced rehabilitation training than, for example, a sample drawn solely from the lists of past patients at a spinal cord injury center or rehabilitation center. This is not necessarily a detriment to the generalizability of the research since the lower limits of performance are more likely to be over-represented among this group. If the lower limits can be satisfied by design recommendations based on this research, those people with better abilities will also be accommodated, unless there are conflicts between the needs of more able-bodied people and those with more severe disabilities.

The fact that middle-aged and elderly women are more familiar with kitchen work reduces bias. Unfamiliarity with kitchen tasks could result in poorer performance in the kitchen-related testing stations. It is our feeling, however, that the low level of skill required to complete any of the tasks should not make familiarity an issue except in the kitchen layout experiment where planning ahead would be important criteria for success.

Table 1: Subjects for First Phase Testing

Test Stations	Incoordination, Difficulty Manipulating Fingers	Difficulty Lifting & Reaching	Wheelchair Users	Reliance on Walking Aids	Difficulty Bending & Kneeling & Difficulty Sitting Down or Getting Up from a Chair	Difficulty Walking Long Distances	Difficulty Walking on Rough Surfaces	Hook Prosthesis Users	Reliance on Walking Aids & Difficulty Walking Long Distances	Walking Aid Users with Exceptionally Good Abilities	Wheelchair Users with Exceptionally Good Abilities	Total Disabled	Able-Bodied	Total
	Disability Categories													
Kitchen sink		14	57	11	19		23	4	4	6	4	142	11	153
Oven		13	54	11	20		22	4	4	5	4	137	11	149
Cooktop		14	54	11	19		21	4	4	6	4	137	11	148
Mix center		14	58	11	20		22	4	4	6	4	143	11	154
Turning radius			55								4	59		59
Doorways			54	9					4	5	4	78	10	89
Elevators			51	10			4		4	4	4	77	9	86
Bathtub/shower	14	15	53	9	20	29	23	4	4	6	4	181	11	192
Toilet	13	15	54	11	19	28	21	4	4	6	4	179	11	190
Anthropometrics	14	15	55	11	19	29	23	4	4	6	4	184	11	195
Push-pull forces	14	15	53	11		28	22	4	4	6	4	161	11	172
Ramp			53	11		27	19		4	6	4	124	9	133
Telephone												107	11	118
Mailbox	9	15	56	8				3	3	6	4	104	11	115
Bathroom lavatory		13	54	11	17		19	3	4	6	4	131	11	142

Table 2: Subjects for Second Phase Testing (Disabled Only)

	Disability Categories								
Test Stations	Difficulty Reaching	Wheelchair Users	Reliance on Walking Aids	Reliance on Walking Aids & Difficulty Walking Long Distances	Difficulty Walking Long Distances	Difficulty Walking on Rough Surfaces	Incoordination & Difficulty Manipulating Fingers	Wheelchair Users with Exceptionally Good Abilities	Total
Toilet stall		6				1	1	1	9
Ovens		4	1						5
Mix center		24						1	25
Lavatory	1	22	1			1	1	1	27
Conventional shower		5						1	6
Wheel-in shower		9						1	10
Speed/distance		24	1	1	2	2		2	32
3-Point turn		7						1	8
L-turn		9						1	10
Door closers		11							11
Ramp		17							17
Bathtub		4		1			1	1	7
U-turn with counter		11						1	12
U-turn around wall		7			1			1	9
Kitchen layout		7	1					1	9
Bathroom layout		6							6
Door thresholds		6							6
Telephone booth		8							8
Total									217

Table 3: Age Range of Subjects Compared to US Population (1970 Census)

Age	Distribution Range of Subjects	Age Distribution of Subjects by Percentage	Age Distribution of US Population by Percentage
Under 20	2	1.0	37.9
20-29	16	8.2	14.5
30-39	26	13.3	11.1
40-49	32	16.4	11.8
50-59	46	23.6	10.4
60-69	40	20.5	7.7
70-79	27	13.8	4.6
80 and Above	6	3.1	1.9
Total	195[a]	100.0	99.9

[a]There were six diagnostic interviews with incomplete data on age.

Table 4: Sex of Subjects

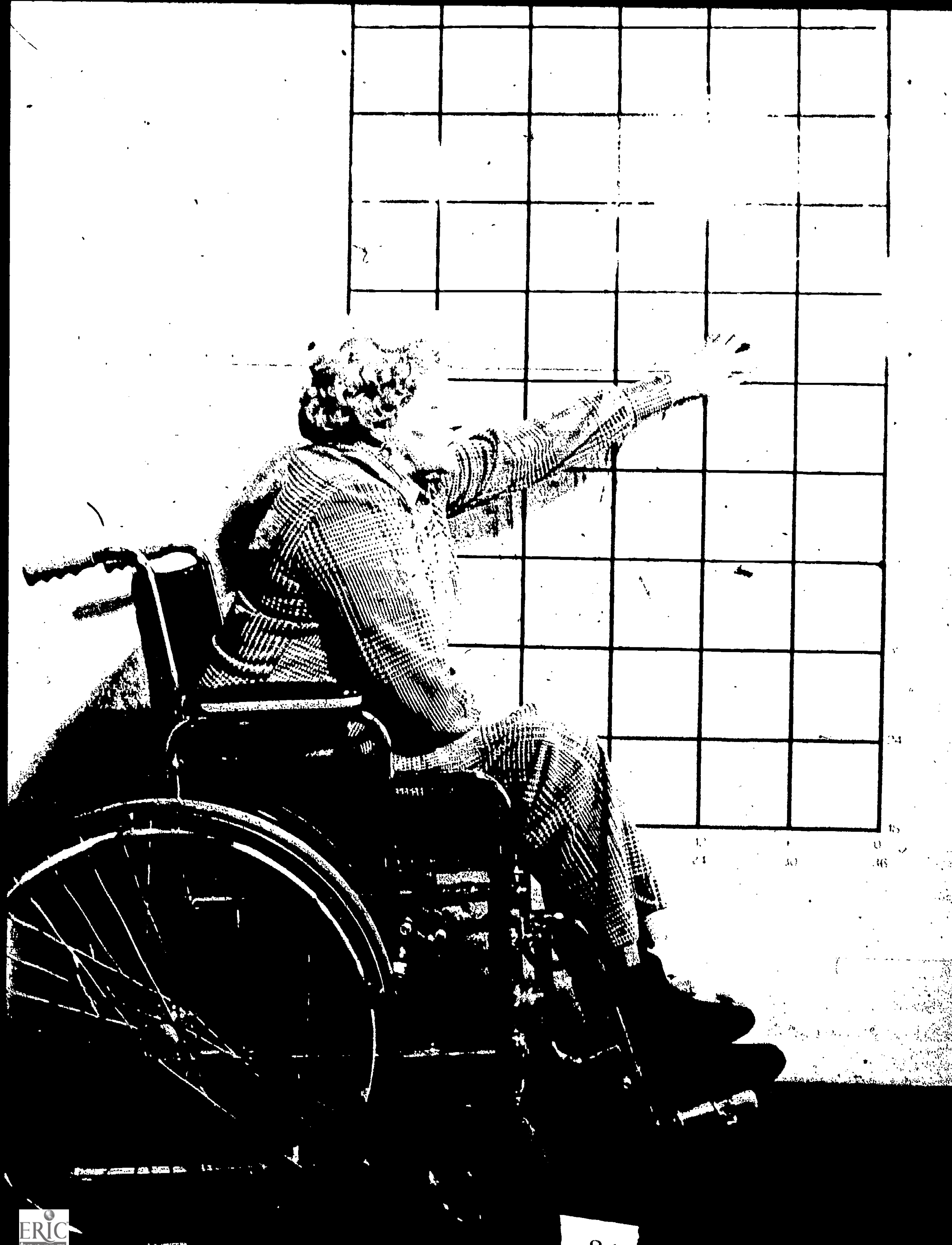
	Number	Percent
Male	61	30.3
Female	140	69.9
Total	201	99.9

Table 5: Residence of Subjects

Type	Number	Percent
Publicly subsidized housing[a]	37	18.3
Private	161	80.1
Home for the aged	1	0.5
Nursing home	1	0.5
Missing data	1	0.5
Total	201	99.9

[a]People in this category lived in housing that was either federally subsidized or public housing.

Anthropometrics 2



Anthropometrics

Objectives

- Obtain data about eye level and reach limits.
- Compare data for ambulant and semi-ambulant subjects with data for wheelchair users.
- Compare data from anthropometric measurements to abilities in actual use of the environment (other testing stations).

Apparatus

Eye level and reach measurements were recorded by measuring individuals against a 6 inch grid painted on a wall. Increments within the 6 inch lines were measured by ruler from the grid lines. A wooden rod was inserted into the wall and projected perpendicular to it at a height of 36 inches for seated subjects and wheelchair users. The rod was used as an alignment device for reach measurements. All measurements of seated subjects (except people using wheelchairs) were taken while subjects were seated in a chair with a seat height of 17 inches.

Procedures

For eye level dimensions, wheelchair users, ambulant and semi-ambulant subjects stood sideways next to the wall grid. Rulers were used to project eye level onto the grid. Subjects reached as high as they could against the wall grid, from which the measurement was taken. To measure forward reach, subjects first aligned their chest against the projecting rod. The rod was removed and subjects leaned as far forward as they could while stretching out their arm against the grid wall. The measurement was taken at maximum extension of the hand.

Subjects

The total number of subjects measured was 184. There were 59 wheelchair users, including four with exceptional abilities and 125 ambulant and semi-ambulant disabled people from all the other disability levels.

Findings

The data are presented in Tables 6A-6G and 7. Vertical reach for wheelchair users varied from less than 36 inches to almost 72 inches. Five wheelchair users could not reach vertically to 54 inches. Over 50 percent of the wheelchair users could reach to 60 inches or higher. For forward reach, the maximum for wheelchair users varied from 18 inches to over 42 inches, with over 50 percent reaching to 30 inches or greater and nine people reaching less than 24 inches. These data indicate the great variability in reaching abilities among this group. Data from other testing stations indicate that reaching abilities, when measured through actual task performance, can exceed those lower limits demonstrated here through conventional anthropometric measurement.

Comparing data for the ambulatory/semi-ambulatory group and the wheelchair users, shows that, as one would expect, the ambulatory and semi-ambulatory people in our sample have much higher reaching abilities while standing than wheelchair users. However, while sitting, their abilities are similar except at higher limits.

A comparison of eye level heights while seated shows that wheelchair users were, on the whole, similar in height to the ambulant and semi-ambulant subjects. The maximum forward reaching abilities of seated ambulant and semi-ambulant subjects was slightly greater than the wheelchair users. Comparing this group to statistics available for the general population (see Table 7), 39 percent of the sample had an eye level height below the 50 percentile eye level for the general ambulant female population. This sample is, therefore, not a short group.

Recommendations

The eye level of ambulant and semi-ambulant disabled people used in design should be based upon eye levels for the general population, taking into consideration a range of heights. The eye level for wheelchair users should be considered as a range from 35 to 52 inches. The maximum vertical reach for ambulant disabled people should be based upon the highest reach of the general population. The maximum vertical reach for people who use wheelchairs should be considered as a range from 42 to 72 inches. The maximum forward reach for ambulant disabled people should be considered as a range from 18 to 42 inches. The maximum forward reach for wheelchair users should be considered as a range from 18 to 39 inches. Forward reach should be measured from the position of the chest while in an upright position and without limitations on leaning forward.

These anthropometric dimensions should not be the basis for specific design dimensions. They describe a range of abilities without the imposition or challenge of any task or objective. Moreover, they do not reflect the needs of several user groups together. For example, if a telephone is to be used by all people, they must be convenient to tall ambulant people as well as wheelchair users. When such specific design features and goals are considered, meeting the very bottom of the range of abilities may not be feasible, although desirable.

The findings point out that anthropometric dimensions of the able-bodied population interpolated into a wheelchair will not give a true picture of the dimensions of reach for wheelchair users. Not only is there great variability among people who use wheelchairs, but reaching abilities vary as a function of task demands and challenges.

Tables 6A - 6G: Anthropometric Measurements (percentages in parentheses)

A. Wheelchair Users: Highest Reach

Equal to or Greater than	But less than		
-- in	36 in	1	(2)
36	42	0	(0)
42	48	1	(2)
48	54	4	(7)
54	60	19	(31)
60	66	30	(51)
66	72	3	(5)
72		0	(0)
Missing data		1	(2)
Total		59	(100)

B. Semi-Ambulant and Ambulant Seated: Highest Reach

Equal to or Greater than	But less than		
-- in	36 in	1	(1)
36	42	0	(0)
42	48	1	(1)
48	54	2	(2)
54	60	36	(29)
60	66	65	(52)
66	72	8	(6)
72		1	(1)
Missing data		11	(9)
Total		125	(100)

C. Standing: Highest Reach

Equal to or Greater than	But less than		
-- in	60 in	3	(2)
60	66	4	(3)
66	72	15	(12)
72	78	53	(43)
78	84	33	(27)
84	90	9	(7)
90		4	(3)
Missing data		4	(3)
Total		125	(100)

D. Wheelchair Users: Eye Level

Equal to or Greater than	But less than		
-- in	36 in	0	(0)
36	40	1	(2)
40	44	12	(20)
44	48	37	(62)
48	52	8	(14)
52		0	(0)
Missing data		1	(2)
Total		59	(100)

Semi-Ambulant and Ambulant Sitting: Eye Level

Equal to or Greater than	But less than		
-- in	36 in	0	(0)
36	40	2	(2)
40	44	19	(15)
44	48	79	(63)
48	52	19	(15)
52		0	(0)
Missing data		6	(5)
Total		125	(100)

F. Standing: Eye Level

Equal to or Greater than	But less than		
-- in	48 in	0	(0)
48	54	5	(4)
54	60	44	(35)
60	66	62	(50)
66	72	9	(7)
72		1	(1)
Missing data		4	(3)
Total		125	(100)

G. Seated: Maximum Forward Reach

Equal to or Greater than	But less than	Wheelchair		Ambulant	
18 in	21 in	6	(10)	3	(2)
21	24	3	(5)	11	(9)
24	27	6	(1)	13	(10)
27	30	11	(19)	18	(14)
30	33	11	(19)	23	(19)
33	36	11	(19)	22	(18)
36	39	9	(15)	26	(21)
39	42	0	(0)	4	(3)
42		1	(2)	1	(1)
Missing data		1	(2)	4	(3)
Total		59	(100)	125	(100)

Table 7: Eye Level of US Adults[a]

	Male	Female
97.5 percentile	69.3 in	64.6 in
50 percentile	64.6	60.0
2.5 percentile	60.0	55.0

[a]Source: Diffrient, et al., 1974

Wheelchair Maneuvers

3

Wheelchair Maneuvering

Objectives

- Determine minimum dimensions for making a U-turn within an enclosed space without any obstructions and with a counter on one wall.
- Determine minimum dimensions for completing a K-type turn within an enclosed space.
- Determine minimum dimensions for making a U-turn around a wall.
- Determine minimum dimensions for making an L-turn from a corridor.
- Determine if a relationship exists between corridor width and the minimal clear opening required for making an L-turn from a corridor.

Apparatus

Wooden walls were constructed that could be used to set up enclosed areas for the maneuvers described above. For the 180° and K-turns, two fixed partitions at right angles to each other were set up. A third wall could be moved back and forth to create a three-walled space with an adjustable width. A 1 1/2 inch thick counter was installed on the moving wall at a height of 36 inches to the top surface; the counter folded into the wall when not in use and was supported by a chain when in place. All walls were 6 feet high. For the U-turn around a wall, the end of a 4 1/2 inch thick wall, constructed for another experiment, was used to turn around--no enclosures were provided. For the L-turn, a movable wall, used in the door experiment, was set up in front of the door used in the elevator experiment, to provide an adjustable corridor width combined with an adjustable clear opening.

Procedure

U-turn: Wheelchair users completed a 180° U-turn in whatever way they found most efficient within the three-walled space. Several trials were completed while the adjustable wall was moved closer and their starting position was shortened, until the minimum space was found. The distance between walls and the distance from back wall measured to the foremost projection of the person's wheelchair, upon completion of the turn, were recorded. The same 180° maneuver was repeated with the 36 inch high counter in place on one side and the space was adjusted accordingly. The counter provided a completely clear space beneath. During a later phase of testing, wheelchair users returned to perform the 180° maneuver with a 31 1/2 inch high counter that provided 30 inches clearance from floor to underside of counter.

K-turn: Wheelchair users completed a three-point, 180° turn within a three-walled space (see U-turn). One wall was movable and was adjusted accordingly after several trials until the minimum space was found. The width of the space and the length, measured from the rear wall to the foremost projection of the person or wheelchair, were recorded.

U-turn Around a Wall: Wheelchair users were asked to do a 180° U-turn around the end of a wall. Subjects were aligned so that their toe or footrest was above the starting line and the wheel closest to the wall was 6 inches from the wall. Measurements were recorded for the greatest width on either side of the wall and the distance needed at the head of the wall. Several trials were made.

L-turn: Three clear opening widths--32 inches, 34 inches and 36 inches were tested separately with corridor widths ranging from 5 feet to 3 feet until the minimum conditions, for each subject, of the narrowest corridor width and narrowest clear opening was found. Each subject performed the more difficult turn, in terms of direction, hence a right-handed person turned right into the opening so that his left hand was operating the outboard wheel of the wheelchair.

Subjects

Fifty-four wheelchair users demonstrated the 180° turn without counters and with a 36 inch high counter. Three of these people used electric wheelchairs. Twelve wheelchair users, at all ability levels, demonstrated the 180° turn with a 31 1/2 inch high counter. A small group of nine subjects were selected from the total group of wheelchair users to complete the U-turn around a wall. A small group of eight subjects, selected from the total wheelchair group, completed the K-turn. One subject in each group had exceptional abilities. In the U-turn group, two individuals had completed the 180° turn in less than the average space, while the other seven had all required spaces larger than average. The K-turn group represented a wide range of abilities. In the L-turn, ten subjects representing a wide variation of abilities, were tested; six were either quadraplegics or had limitations of stamina.

Findings

180° turn: The testing indicated that more depth is needed than width, as shown in Fig. 2A. Also, the depth required was, for the most part, directly related to width required. A space 54 inches wide by 72 inches deep accommodated most subjects. The maximum space required was 68 inches wide by 84 inches deep. A space 60 inches wide by 78 inches deep accommodated all but five of the fifty-four subjects. The 36 inch high counter required no additional maneuvering space.

K-turn: Space required for the K-turn ranged from an area 42 inches by 48 inches, to an area 60 inches wide by 72 inches deep, as shown in Fig. 2C. The average size of the area necessary was 54 inches wide by 66 inches deep.

U-turn Around a Wall: The largest space required was 36 inches wide at the start side of the wall, 42 inches wide at the finish side of the wall and 48 inches at the head of the wall. People who could use their feet turned in spaces as small as 30 inches wide on each side and at the head of the wall.

L-turn: The data is presented in Table 8. Turning into a 32 inch clear opening, a 36 inch wide corridor accommodated seven of the ten subjects but a corridor width of 42 inches was needed to accommodate all subjects, including those in electric wheelchairs. The three people who could not turn into the narrowest clear door width (32 inches) from the narrowest corridor (36 inches) tried turning into wider doorways. All three were able to turn into a 34 inch wide doorway from the narrowest corridor (36 inches). It follows then that all ten users could turn into the 36 inch wide doorway from the 36 inch wide corridor.

Recommendations

U-turn: Rectangular or oval shaped spaces should be provided with a depth longer than the width. The minimum width should be 60 inches. The minimum depth should be 78 inches.

K-turn: K-turns can be accommodated in less space than U-turns. The space provided should be rectangular or oval, with a depth longer than the width. The minimum width should be 60 inches. The minimum depth should be 72 inches.

U-turn Around a Wall: A 42 inch clearance should be provided on each side of a wall while a 48 inch clearance should be provided at the head end.

L-turn: The minimum corridor width for an L-turn into a 32 inch clear opening or a 34 inch opening should be 42 inches; with a 36 inch clear opening, the corridor width can be reduced 6 inches to 36 inches.

Marginal Population

All wheelchair users who can maneuver independently should be able to maneuver within the recommended spaces except some hemiplegics with manual chairs. The five people who could not turn within a 60 inch by 78 inch space either had limited abilities in upper limbs or had limitations of stamina (level 6-11 or 6-14). They could all manage a K-turn within the recommended space for a U-turn.

Table 8: L-Turn Findings (percentages in parentheses)

	32 Inch Clear Door						34 Inch Clear Door					
	48 Inch Corridor		36 Inch Corridor		42 Inch Corridor		48 Inch Corridor		36 Inch Corridor		42 Inch Corridor	
Successful	10	(100)	7	(70)	3	(100)	3	(100)	3	(100)	3	(100)
Unsuccessful	0	(0)	3	(30)	0	(0)	0	(0)	0	(0)	0	(0)
Total = 10							Total = 3					

Note: Only subjects who could not complete the turn with a 32 inch clear opening and a 36 inch corridor were tested with the 34 inch clear opening.

Figure 1: Plan of L-Turn Apparatus

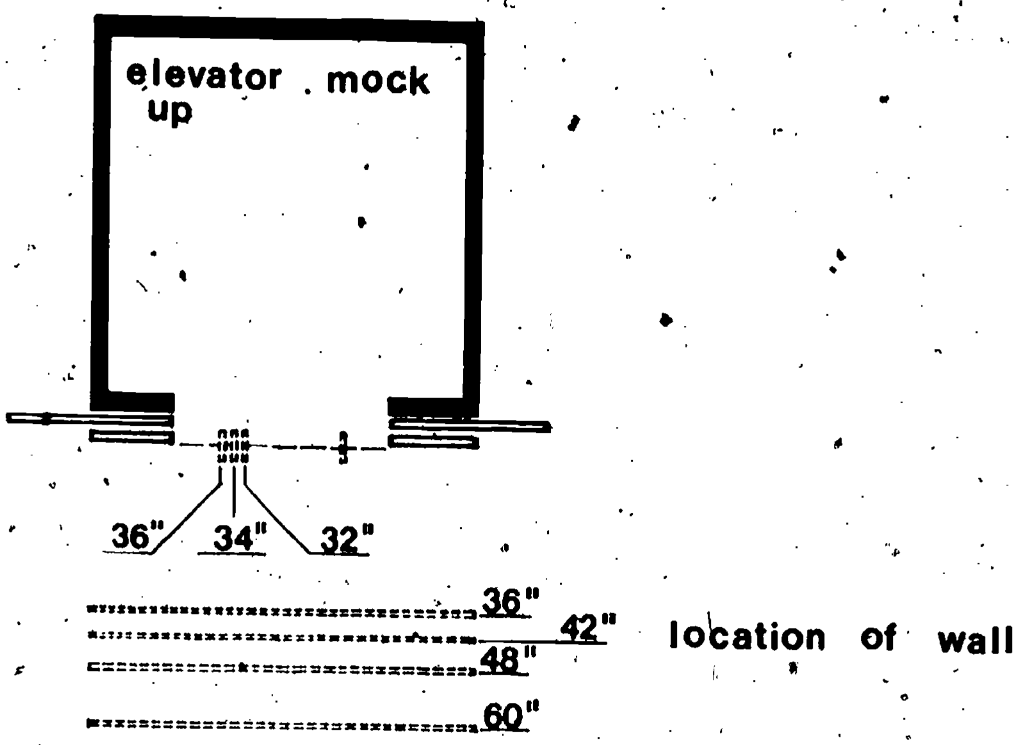


Figure 2: Results of Wheelchair Maneuvering Experiments

A. BASIC U-TURN

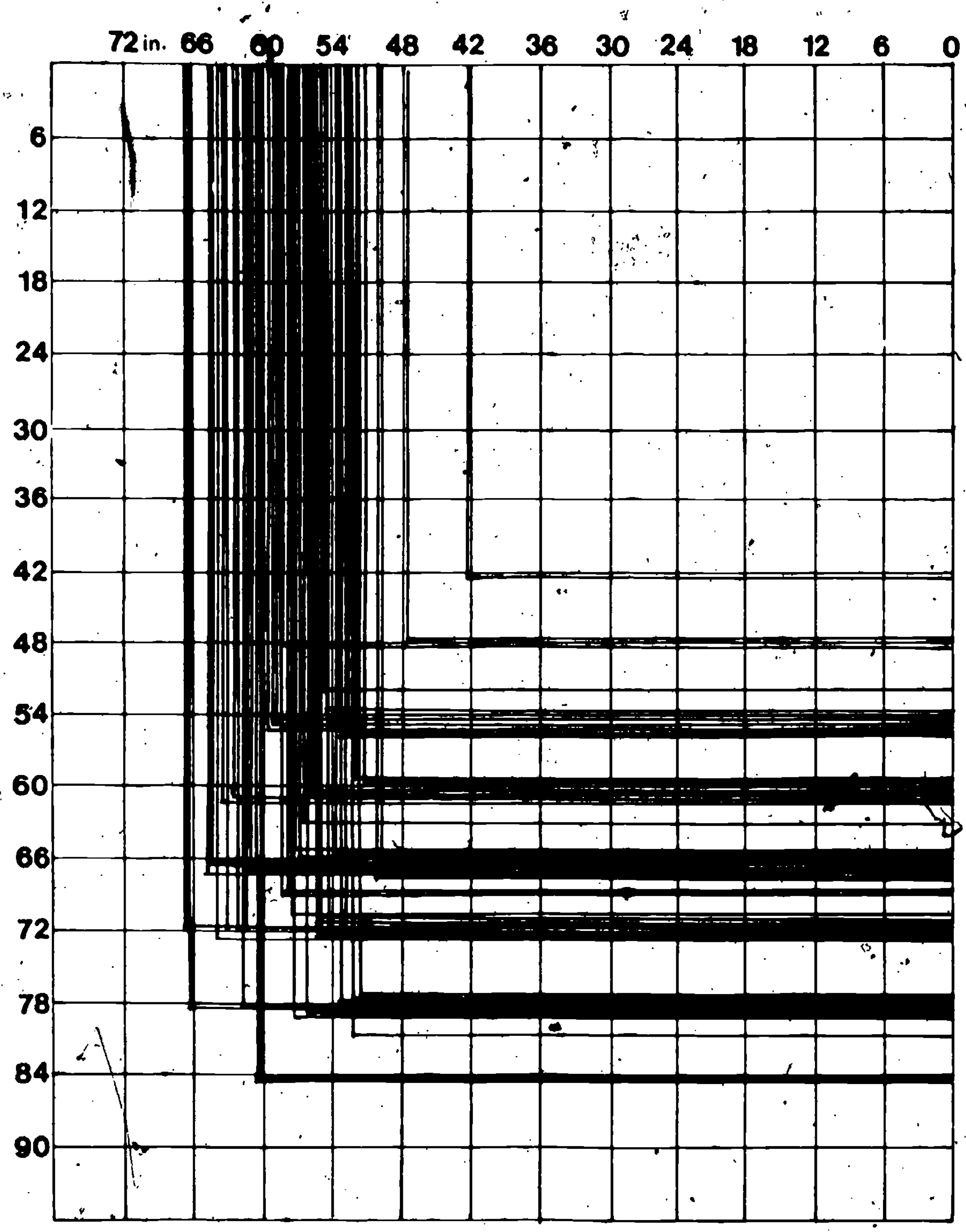


Figure 2 (continued)

B. U-TURN WITH COUNTER

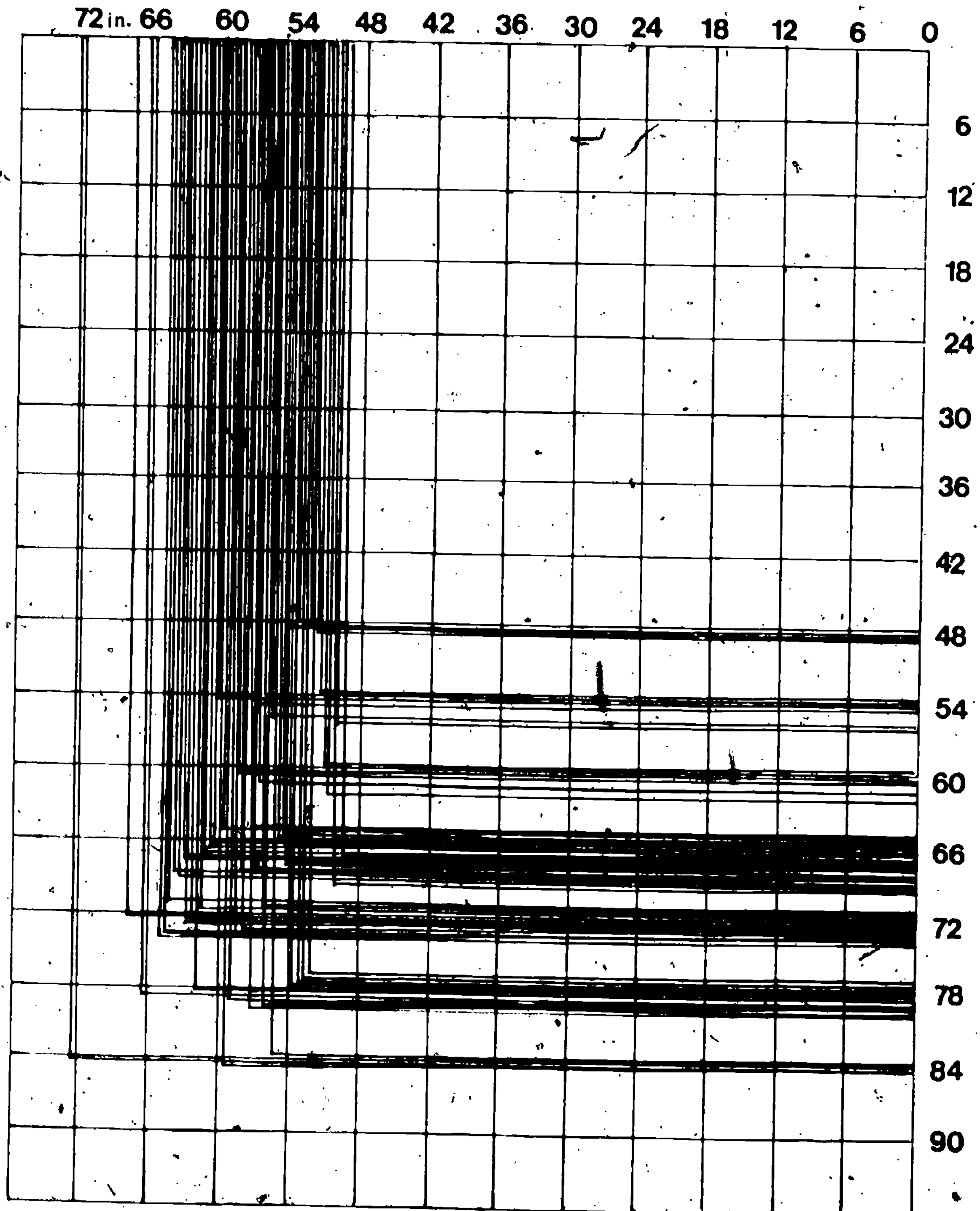


Figure 2: (continued)

C. K-TURN

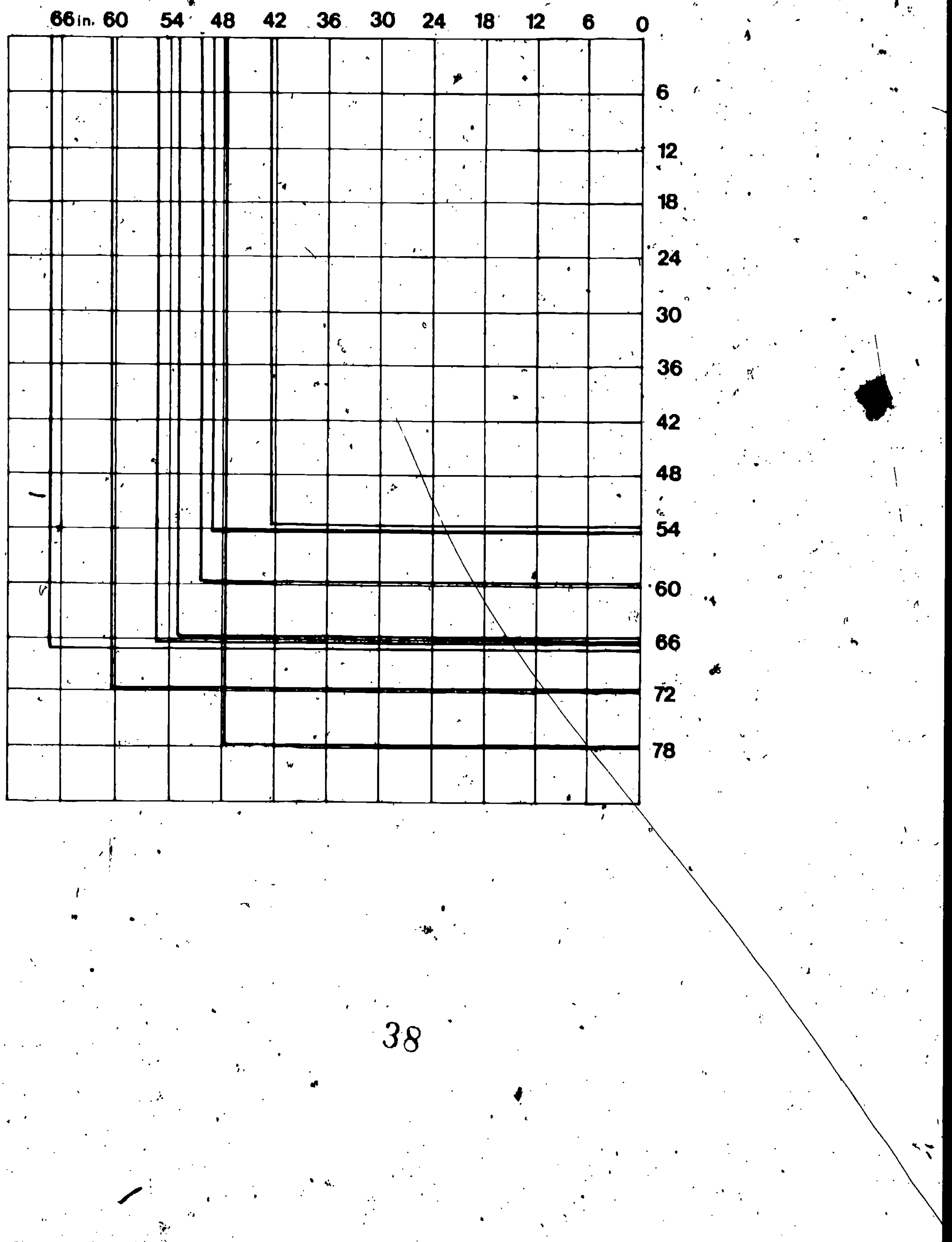


Figure 2: (continued)

D. U-TURN AROUND WALL

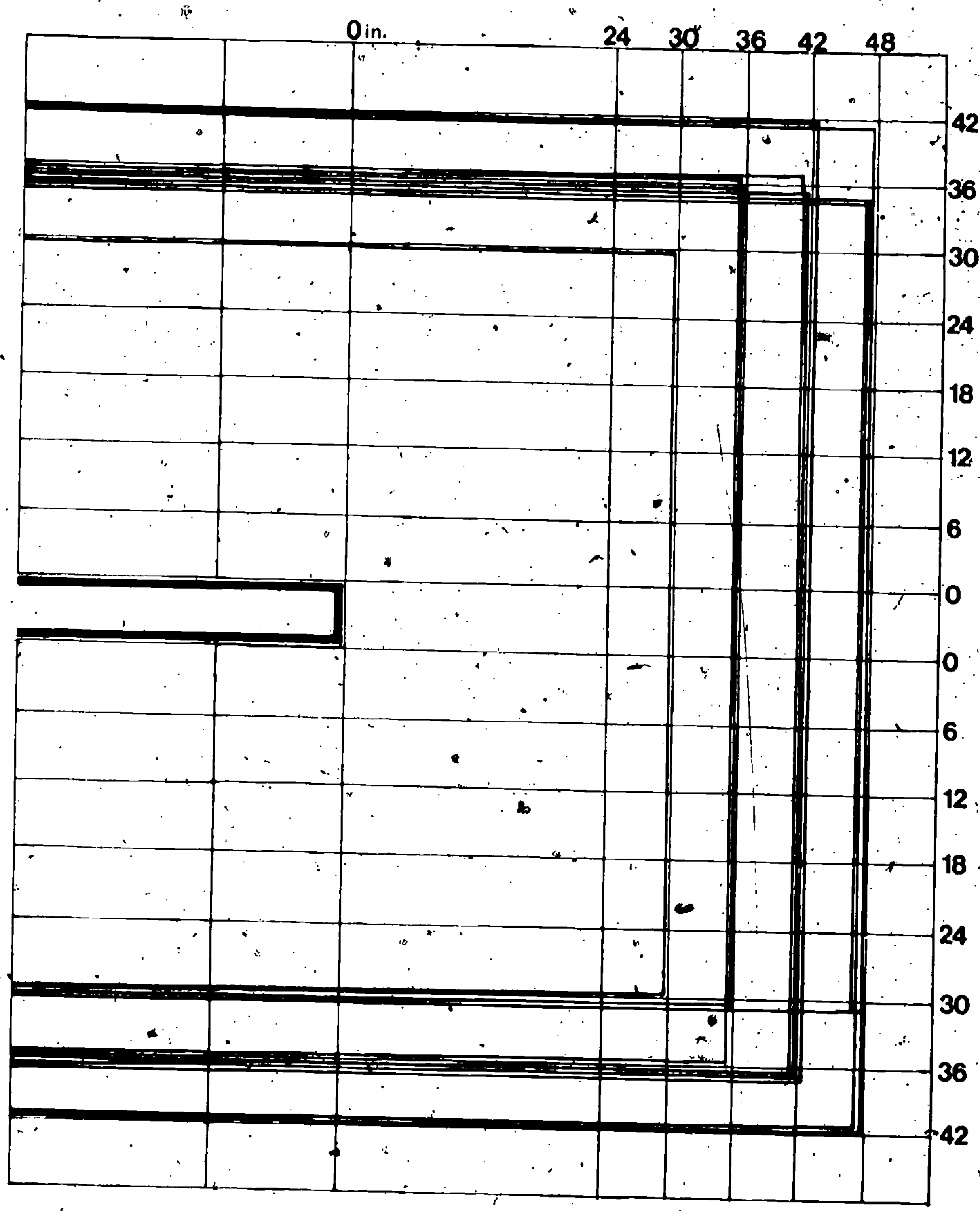
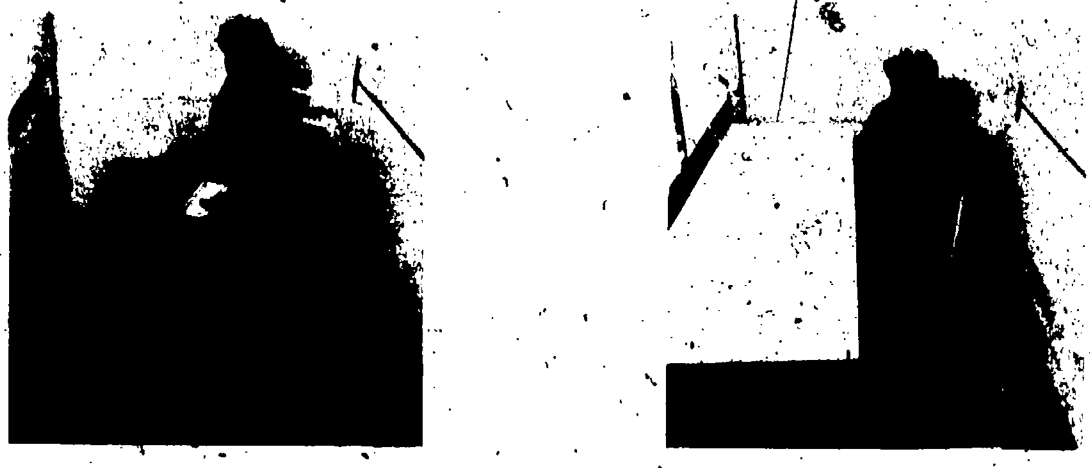


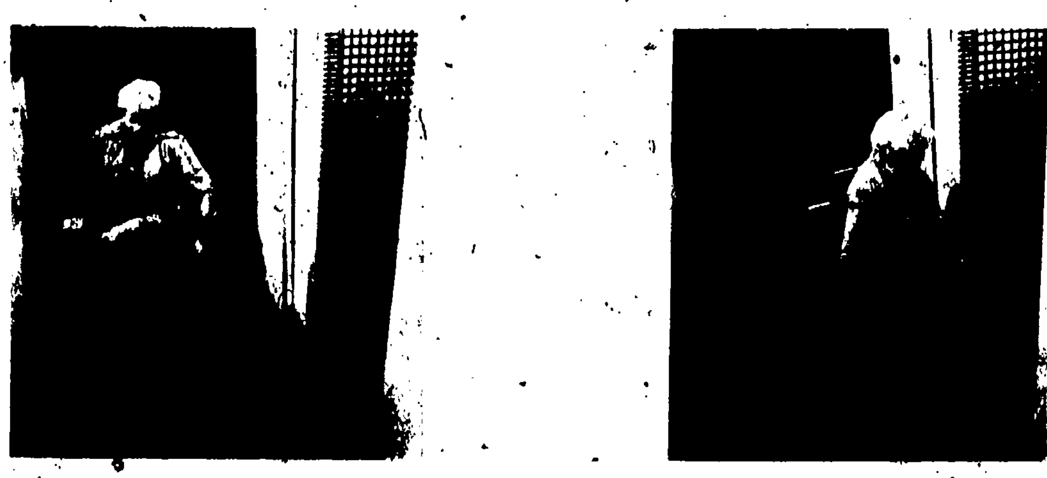
Figure 3 : Wheelchair Maneuvering Testing Procedures

U-Turn, K-Turn



U-Turn Around Wall

L-Turn Off Corridor



Speed And Distance 4

Push-Pull Forces 5

Speed and Distance

Objectives

- Determine maximum travel distances for people with limitations of stamina.
- Determine rate of travel for walking on level terrain.

Apparatus

A distance of 100 feet was plotted in a straight line on a level concrete floor. Using 5 foot high characters, the number 100 was painted on a wall located at the end of the course.

Procedure

From the starting line, subjects walked or wheeled to the end of the course. They were told to walk or wheel at a normal pace as far as they could but to try and reach the end of the course. Total elapsed time was measured with a stop watch. No stopping was allowed.

Subjects

Thirty-four people who had performed at a wide range of ability levels in the first phase were tested. Twenty-six wheelchair users from all wheelchair ability levels were tested. In addition, two walking aid users, two people with stamina problems, two people with balance problems and two able-bodied people were tested.

Findings

The average time necessary for wheelchair users to travel the 100 feet was approximately 65 seconds with a minimum time of 27 seconds (electric wheelchair) and a maximum time of 175 seconds. The average time for the ambulant people, those with walking aids and those with balance or stamina problems was 75 seconds, but several needed over 2 minutes. Two people in wheelchairs could not travel the full distance (their maximum distances were 42 feet and 50 feet) and stopped because of fatigue.

Recommendations

Increased travel times between two points are required for many disabled people. Times should be calculated using an average rate of travel of 1.5 ft/s, which would accommodate most, but not all people. Where many slow moving people are expected, such as in housing for the elderly, times should be calculated using a rate of 1 ft/s. Overall times should also include tolerances for resting. One hundred feet can be used as a maximum distance of travel between resting areas where such a measure is needed. For short distances, rates are not significantly different (see elevator results).

Travel times can be used to generate distance requirements where it is desirable to reduce exposure to bad weather to a minimum or where utilization of facilities is based on convenient distances, such as shopping malls. Disabled people should not be forced to travel for longer times than able-bodied people.

Marginal Population

A few people who use manual wheelchairs and also have low stamina or restricted use of their arms may have to rest along a 100 foot path of travel. Many semi-ambulant people, ambulant people and people who use wheelchairs who have low stamina will travel at a rate slower than 1.5 ft/s.

Table 9: Rate of Travel Findings

Time to Travel 100 Feet in Seconds	Rate of Travel	Wheelchair Users[a]	Other Disabled	Able-Bodied	Total
0-33	at least 3 ft/s	5	1	2	8
34-50	at least 2 ft/s	10	1	0	11
51-67	at least 1.5 ft/s	1	0	0	1
68-100	at least 1 ft/s	2	1	0	3
101-133	at least .75 ft/s	2	1	0	3
134-167	at least .6 ft/s	2	2	0	4
168-200	at least .5 ft/s	1	0	0	1
Null performance		2	0	0	2
Missing data		1	0	0	1
Total		26	6	2	34

[a] Includes two with exceptional abilities.

Push-Pull Forces

Objectives

- Determine maximum forces that people with limitations of strength can exert against doors and windows.

Apparatus

A device was constructed that could be mounted on a wall in a variety of positions. A wooden, push-pull bar was mounted on a wood plate that slid in channels, similar to the tracks of a window. The moving pieces were lubricated with wax. The push-pull bar activated a force gauge.

Procedure

Subjects demonstrated methods for operating sliding and double-hung windows, using right push, right pull, left push, left pull and vertical pull forces applied to the apparatus. The same motions, except for vertical pull are used to push and pull doors open. In lateral, push-pull operations, only one hand was used while both hands were used in the vertical pulling motion. Readings of maximum force exerted were read off the force gauge.

Subjects

People with reaching, handling, stamina and balance problems, as well as people who use walking aids and wheelchairs were tested. Able-bodied people were also tested.

Findings

Table 10 presents data collected for the five push-pull forces. There is great diversity in the abilities of people within both major groups of subjects for the five types of applied forces. Approximately 23 to 30 percent of the wheelchair users could exert forces greater than 15 pounds in all positions; whereas, 39 to 44 percent of all the other disabled subjects could exert forces greater than 15 pounds in all positions.

Recommendations

Operating forces for opening doors and windows should be as low as technology allows, preferably below 5 pound-forces. Door closers are designed for minimum closing force. They operate by storing mechanical energy in a spring or pneumatic chamber as a door is opened. Since they do not operate at perfect efficiency, more energy must be put into storage than can be taken out during the closing phase. Thus, it will always take more force to open doors with conventional closers than their minimum closing force. Closing forces for closers used on exterior doors, as recommended by product manufacturers, are often larger than 8 pounds.

Marginal Population

The disability groups which were unable to apply a force of 8 pounds were those in the categories who have difficulty lifting and reaching, the group with both difficulty lifting and reaching and difficulty manipulating fingers, wheelchair users who have poor stamina, those who have difficulty bending, kneeling and getting up and down from chairs and finally, a few ambulatory people with poor stamina.

Table 10: Maximum Push-Pull Forces in Pounds (percentages in parentheses)

Maximum Force (in lbf) Equal to or Greater than	But less than	Vertical Pull w/c[a]	Vertical Pull Other Disabled	Left Pull w/c	Left Pull Other Disabled	Left Push w/c	Left Push Other Disabled	Right Pull w/c	Right Pull Other Disabled	Right Push w/c	Right Push Other Disabled
/	5	7 (13)	10 (9)	6 (11)	13 (12)	3 (6)	5 (5)	7 (13)	14 (13)	3 (6)	3 (3)
5	10	19 (35)	28 (26)	19 (36)	31 (29)	15 (28)	34 (31)	20 (38)	19 (17)	16 (30)	31 (29)
10	15	13 (25)	28 (26)	8 (15)	23 (21)	15 (28)	34 (31)	14 (26)	32 (30)	18 (35)	31 (30)
15	20	7 (13)	18 (17)	5 (9)	14 (13)	10 (19)	14 (13)	6 (11)	14 (13)	7 (13)	21 (18)
20	25	3 (6)	9 (8)	10 (19)	15 (14)	4 (9)	14 (13)	3 (6)	14 (13)	5 (9)	12 (11)
25		4 (8)	15 (14)	5 (9)	12 (11)	6 (11)	8 (7)	3 (6)	15 (14)	4 (8)	10 (9)
Exert 8 lb maximum		23 (43)	32 (29)	23 (43)	38 (35)	16 (30)	31 (28)	24 (45)	30 (27)	16 (30)	25 (23)
Total		53 (100)	108 (100)	53 (100)	108 (100)	53 (100)	108 (100)	53 (100)	108 (100)	53 (100)	108 (100)

[a] Wheelchair users.

Figure 4 : Push-Pull Testing Procedures

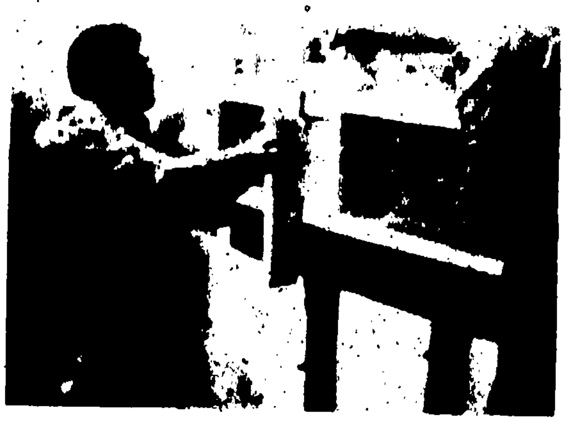
Vertical Pull

Push

Left

Right

Pull



Left

Right

6

Ramp

Ramp

Objectives

- Determine the maximum slopes that can be managed.
- Identify relationships between slope and length of ramp.

Apparatus

A 40 foot ramp could be adjusted to any slope. The ramp was marked in 1 foot intervals. It had handrails at both sides, mounted at 32 inches from the surface of the ramp. There were curbs on both sides of the ramp 3 1/3 inches high. The clear width between curbs was 48 inches. The ramp surface was untreated plywood.

Procedure

Although objectives of the research were to determine maximum slopes that could be managed, we also had a concern for the energy cost of using ramps. Extensive measurement of energy expenditure under controlled atmospheric conditions with standard clothing was not possible, but heart beat rates were measured to determine when subjects had over-extended themselves in using the ramp.

The ramp was initially set up at a 1:12 slope. All subjects who had unsuccessful trials with the ramp at 1:12 returned to test a ramp at 1:16. Those who were unsuccessful on that ramp returned to test a slope of 1:20.

Subjects

During the first phase, 124 disabled people were tested according to Table 11. Eighteen people returned to test the 1:16 ramp, whereas three wheelchair users came back once again to test the 1:20 ramp. Pulse was taken while the subject was at rest. Subjects negotiated the ramp; distance traveled, time of travel and problems they had were recorded. They then came down the ramp. Pulse was taken immediately after descension. After a two minute rest, the pulse was taken once more. The time necessary for the pulse to return to normal was recorded. If the user encountered excessive time delays during his negotiation of the ramp, or if after task completion the pulse rate had not returned to within ten beats of the resting pulse, the task performance was judged unsuccessful.

Findings

As seen in Table 11, almost half of the wheelchair users were unable to negotiate the full length of the steepest ramp (1:12). Approximately one third of the test sample could not complete a distance of even 5 feet. Sixty-seven percent of the users unable to manage the 1:12 ramp were able to travel at least 30 feet of the 1:16 slope ramp. Every member of the wheelchair user group, including quadriplegics was able to complete the full length of the ramp with a 1:20 slope. Many subjects required a very long time to negotiate the full length of the ramp at a slope of 1:12.

Railings were rarely used as direct mobility assists by wheelchair users. Only one or two hemiplegics in wheelchairs pulled themselves up the ramp using the railing at the side of their more useful arm. Railings were used by others, however, as course correcting guide rails both during ascent and descent of the ramp. Semi-ambulant and ambulant people almost always used one or both railings. Wheelchair users who have limited use of their feet may often use their feet to help propell themselves up a ramp. A successful method demonstrated by several people was a backward ascention, keeping their weight toward the head of the ramp as they propelled themselves with their feet.

Recommendations

Because of the wide variation in abilities of wheelchair users to negotiate ramps, alternatives to ramps should be encouraged. Where ramps are used, slope/length should be inversely related. Table 12 shows recommendations for maximum slopes and length of ramps. Railings should be provided at both sides. Means to insure that wheelchairs and walking aids will not slip off ramp edges should also be provided.

Marginal Population

While all subjects in the wheelchair user group were able to manage the shallowest ramp, it was clear that steeper slopes present problems to subgroups within the total wheelchair population. People with limitations of stamina, hemiplegics and quadriplegics all may have difficulty with ramps steeper than 1:20. Some ambulant users with stamina limitations and walking aid users may also have difficulty with steep ramps.

Figure 5: Ramp Slopes Tested

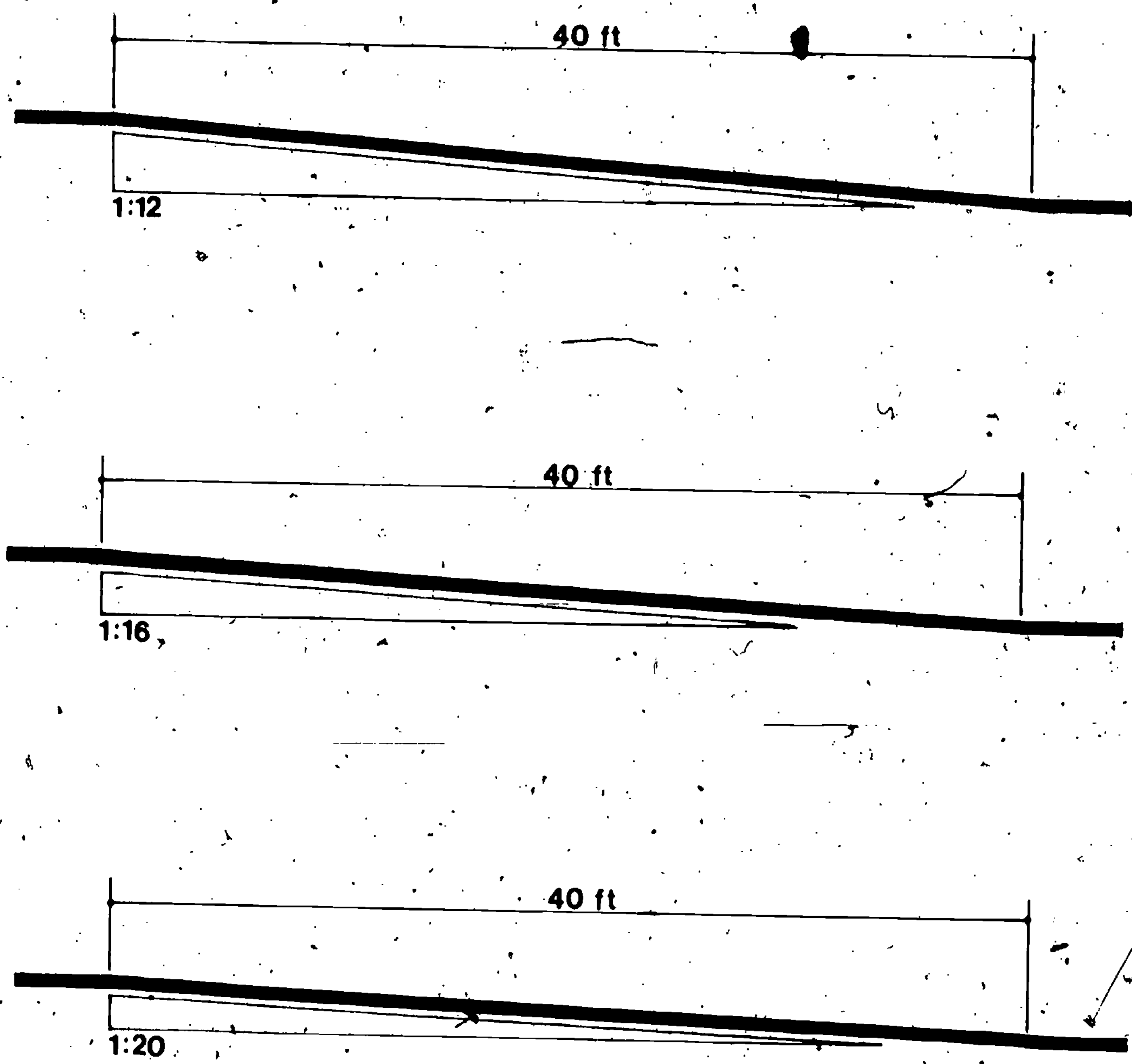


Table 11. Ramp Distances Traveled

A. Distance Traveled by Wheelchair Users (percentages in parentheses)

Distance Traveled (in ft) Equal to or Greater than	But less than	Slope: 1:12		1:16		1:20	
	5	17	(30)	2	(11)	0	
5	10	3	(5)	0		0	
11	20	2	(4)	3	(18)	0	
21	29	3	(5)	1	(6)	0	
30	40	32	(56)	11	(65)	3	(100)
Total		57[a]	(100)	17	(100)	3	(100)

[a] Includes wheelchair users with exceptional abilities.

B. Distance Traveled by All Others (percentages in parentheses)

Distance Traveled (in ft) Equal to or Greater than	But less than	Slope: 1:12		1:16		1:20	
	5	0		0		0	
5	10	0		0		0	
10	20	0		0		0	
21	29	1	(1)	0		0	
30	40	65	(98)	1	(100)	0	
Missing data		1	(1)	0		0	
Total		67	(100)	1	(100)	0	

Table 12: Ramp Slopes and Completion Time

A. Wheelchair Users Who Completed 40 Feet (percentages in parentheses)

Completion Time (in sec): Equal to or Greater than	But less than	Slope: 1:12		1:16		1:20	
	27	7	(23)	5	(50)	0	
28	40	6	(19)	2	(20)	1	(33)
41	60	5	(16)	2	(20)	0	
61	80	7	(23)	1	(10)	0	
81	120	5	(16)	0		0	
120		0		0		2	(67)
Missing data		1	(3)	0	—	0	—
Total		31[a]	(100)	10	(100)	3	(100)

[a] Includes wheelchair users with exceptional abilities.

B. All Others Who Completed 40 Feet (percentages in parentheses)

Completion Time (in sec): Equal to or Greater than	But less than	Slope: 1:12		1:16		1:20
	27	37	(57)	0		0
28	40	11	(17)	0		0
41	60	7	(11)	0		0
61	80	5	(8)	0		0
81	120	2	(3)	2	(100)	0
120		2	(3)	0		0
Missing data		1	(1)	0	—	0
Total		65	(100)	2	(100)	0

Table 13: Maximum Lengths and Slopes for Rampways

Allowable Horizontal Projection for Rampways[a] (in feet)	Maximum Horizontal Projection of Each Run (in feet)	Maximum Rise of a Single Run (in inches)	Allowable Slopes of Rampways[b]
2	2	3	If slope = 12.5% (1:8) or less steep[c]
8	8	9	If slope = 10.0% (1:10) or less steep[c]
60	30	30	If slope = 8.3% (1:12) or less steep
160	40	30	If slope = 6.25% (1:16) or less steep

[a]A rampway may have more than one ramp run; landings are not counted as part of total allowable horizontal projection.

[b]All slopes taken from a horizontal plane.

[c]Based on research of others (Templer, 1977 and Walters, 1971).

Toilet Stall

7

Toilet

Objectives

- Determine the minimum dimensions for toilet stalls that will accommodate all users.
- Determine comfortable heights for toilets satisfactory for both ambulant and non-ambulant users, if possible.
- Evaluate the need for grab bars at toilets and determine the best location for them.
- Determine the reach limits of people for establishing the location of toilet paper dispensers and flush controls.

Apparatus

A wall hung toilet was mounted on a device that allowed changing the height rapidly and easily. Toilet seat heights were adjustable from 15 1/2 inches to 22 1/2 inches, measured to the top of the seat. Four sets of horizontal grab bars were mounted on movable walls at either side of the toilet. These bars were 1 1/2 inches in diameter and could be pivoted out of the way so that only one bar at a time was available for use. The lowest grab bar was mounted at 27 inches on center and the three other bars were mounted at 3 inch intervals to 36 inches, measured from the floor to the center of the bar. A single horizontal bar was mounted 18 inches above the toilet rim on the rear wall. The walls were parallel with the toilet and could be moved from within 12 inches on center with the toilet bowl to 48 inches on center with the bowl. All bars and the walls were marked with a six inch grid. A grid was also painted on the floor.

Procedure

In the first phase of testing, subjects first demonstrated how they approached the toilet before sitting down or transferring. The stall width was then adjusted to the minimum size necessary to accommodate their particular technique. The stall width was not adjusted narrower than 36 inches. The toilet height was set at 14 1/2 inches at first. Subjects then selected bar heights with which they felt comfortable. Initial trials were made to evaluate the seat height and grab bar height selected. Adjustments were made until optimal, or most comfortable, conditions were found. On each trial, seat height, stall width and hand placement on bars were recorded. Maximum reach measurements were obtained for toilet paper dispensers along the closest side wall and for flush controls at the rear wall.

In the second phase of testing, wheelchair users who had used excessively wide stalls and walking aid users who had used narrow stalls in the first phase, returned to test 36 and 48 inch wide stalls with four different grab bar conditions. In each stall, the toilet was positioned so that its centerline was 18 inches from one side wall. The remaining wall was set at 18 inches and then 30 inches from the bowl centerline. The four grab bar conditions were: A) four bars affixed at each side as in previous testing, B) a mass-produced toilet seat with integral assists, C) a swing away bar on the wide side of the toilet, and D) a condition where grab bars were available on only one side. For all conditions, the toilet seat height was fixed at 17 1/2 inches to the top of the seat.

Subjects

In the first phase, people in all categories at all levels were tested, including eleven able-bodied subjects and fifty-eight wheelchair users, four of whom had exceptionally good abilities. During the second phase of testing, nine subjects who needed either excessively wide or narrow stalls returned to the laboratory for further testing. Two of these people had not been in the first phase sample.

Findings

Results for the first phase showed that 31 percent of the total wheelchair user group could not complete toilet transfers. Of the forty wheelchair users who could transfer, nine people needed stall widths larger than 48 inches. Figure 6 illustrates stall widths for all subjects using their optimal technique. A seat height of 17 to 19 inches was most often preferred.

Grab bars at heights of 33 and 36 inches on center were most preferred, as illustrated in Figs. 7A-D. Bars were used most often starting 18 inches from the rear wall to four feet from the wall, as illustrated in Figs. 7A-D. The grab bar at the rear wall was used by ambulant people and wheelchair users who could stand to transfer. Reach limits to the closest side wall extended from 36 to 42 inches from the rear wall at a height range of 30 to 36 inches from the floor. Reach limits to the back wall were within 12 inches of either side of the toilet centerline and above 6 inches from the top of the toilet seat.

In the second phase of testing, all subjects were able to complete a transfer to the toilet within a 48 inch wide stall, as seen from Table 14. Several people who normally preferred a side transfer technique could perform a diagonal front transfer but indicated that it was more difficult. The integral seat grab bar was the least preferred grab bar condition as the bars were too low for most users (9 inches above the seat or 26 1/2 inches above the floor). The bar supports became obstructions to people using diagonal front transfers. The swing away bar was useful to both semi-ambulant subjects and wheelchair users. The construction of the bar, however, caused a slight movement at the grasping end which made several people uneasy. When faced with the restriction of grab bars to only one side, subjects selected the side closest to the toilet (18 inches from bowl centerline). This situation was usable to most wheelchair users since their wheelchairs served as an additional assist on the other side. Ambulant people with balance problems, users of walking aids, and wheelchair users who stood to transfer expressed an uneasiness and preferred bars on both sides for security.

We were concerned not only with the width of stalls as they accommodated the various types of transfer techniques, but also as they are related to other aspects of use. Table 16 shows various stall sizes and how they accommodated the various transfer techniques, allow the user to easily close the stall door before transferring and allowed use of the stall without folding the wheelchair to move it out of the way. The depth dimensions were established by intensive testing with a large male (95th percentile) using a wheelchair. Since these size constraints are greatest, they will accommodate all smaller individuals.

In our sample, there were no quadriplegics with spinal cord injuries at the C-5 or C-6 levels who transferred onto the toilet. Many C-5 and C-6 quadriplegics can transfer. Bars on both sides of the toilet at 18 inches on center with the bowl can be helpful to these people since they can use both grab bars simultaneously to lift themselves forward onto the toilet, using their shoulder strength with forearms pressed along the bars. The close-in bars on both sides also help to maintain balance. However, most C-5 and C-6 quadriplegics are not taught this method and a wheelchair next to the toilet of the open side of a 48 or 60 inch wide stall can also serve to maintain balance. A pivoting bar can provide a close-in grab bar on the open side of a wide stall when needed. However, most bars of this sort have unacceptable "play" in their mechanism and the bar can be an obstacle to those people that don't have the strength to move it out of the way.

Recommendations

The width of a toilet stall should be at least 48 inches with 30 inches from the bowl-centerline to wall on one side. Grab bars should be located on both sides between 33 inches and 36 inches high on center. Although few subjects used grab bars between the back wall and 18 inches from the wall, an extra 6 inches would provide a measure of safety. Likewise, bars that extend 54 inches from the back wall also provide a measure of safety for a person who may be falling forward as they transfer off the toilet. Thus, side grab bars should start 1 foot from the rear wall and be 3 feet long. A bar should also be installed along the rear wall at the same height as other bars. The minimum depth of a 48 inch wide stall should be 66 inches. If a 60 inch wide stall is used, the back grab bar should extend further into the open space next to the toilet to give support to semi-ambulant people. In a 60 inch stall, the side furthest away from the toilet does not need a grab bar. The 60 inch stall can be a minimum of 56 inches deep. Toilet paper dispensers should be located on the close wall, no more than 36 inches from the back wall and between 30 inches and 36 inches high. Flush controls should be located on the wide side of the stall. These basic recommendations for toilet stalls can be used for toilet areas in residential bathrooms as well; however, the grab bars do not need to be installed unless they are needed by a dwelling occupant.

Marginal Population

The 48 inch wide toilet stall will accommodate all wheelchair users who normally transfer onto toilets. Because people who did not transfer came from virtually all disability levels, the issue of transfer seems related to previous training or personal preference and not strictly related to the level of disability. Thus, many paraplegics with strong upper extremities, capable of transferring, choose not to utilize public toilets, whereas some quadriplegics regularly transfer even though it is comparatively more difficult for them.

Figure 6: Minimum Widths for Toilet Stalls

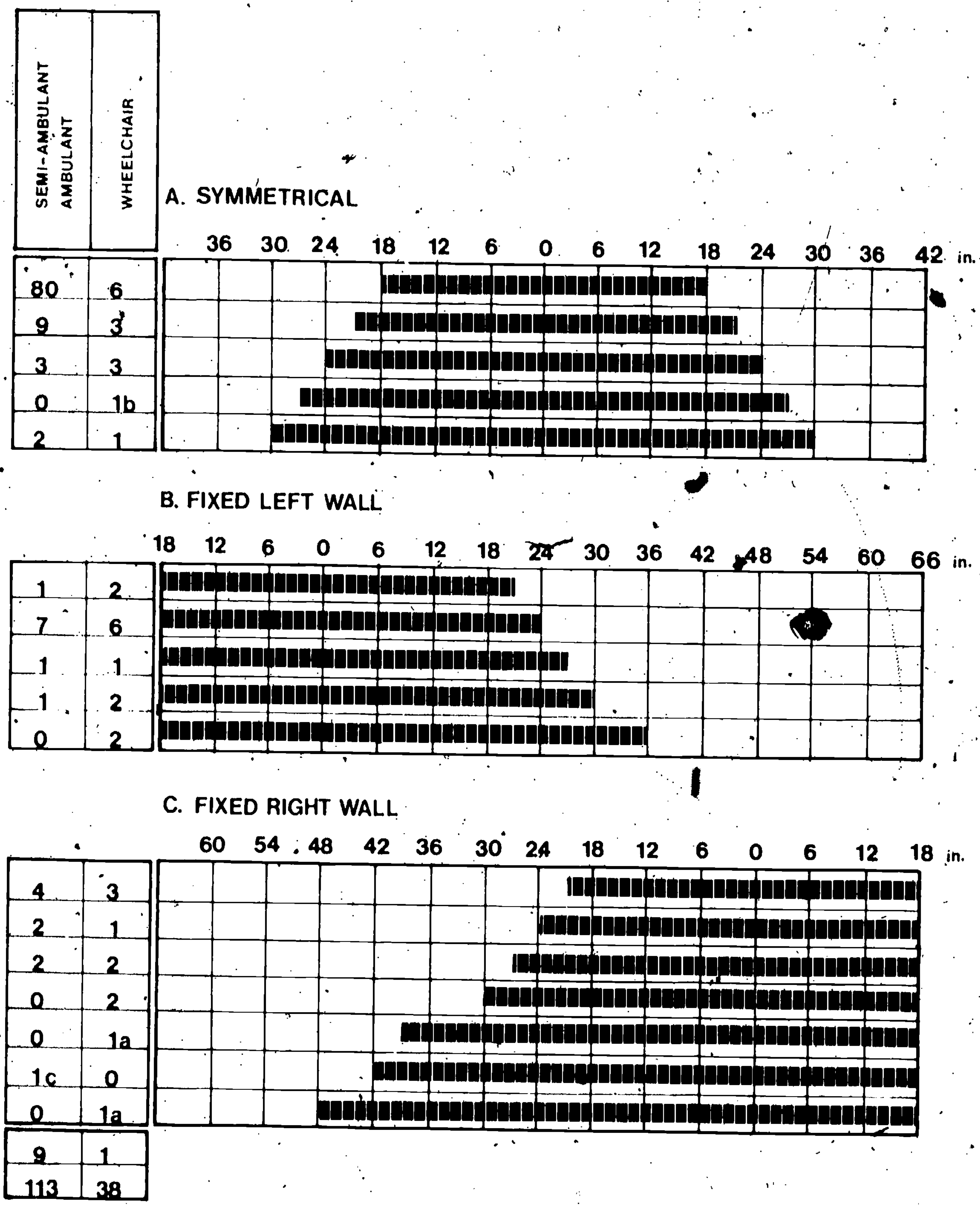


Figure 7A: Use of Grab Bars at the Toilet - Right Wall, Walking Aid Users

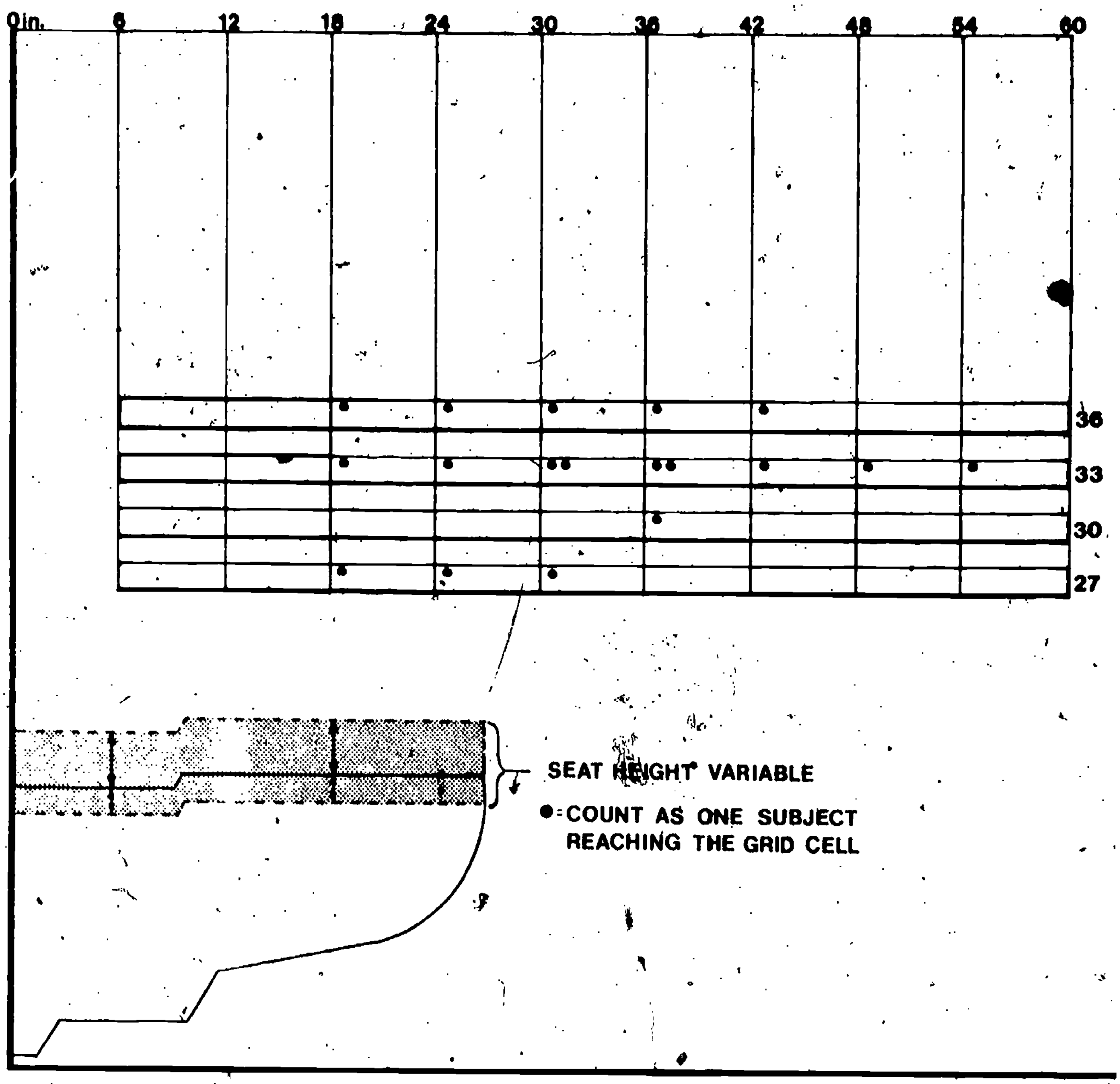


Figure 7B: Use of Grab Bars at the Toilet - Left Wall, Walking Aid Users

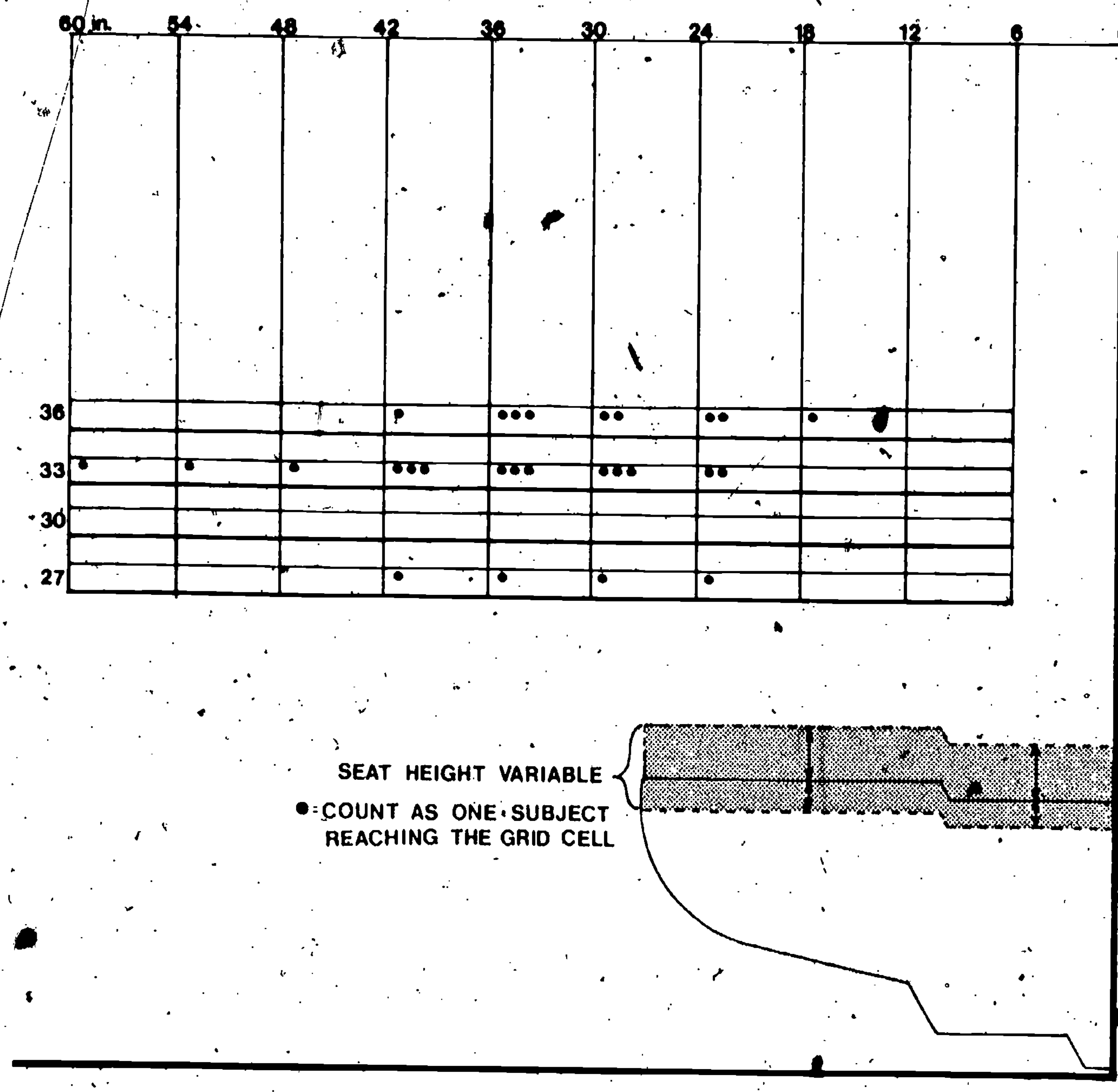


Figure 7C: Use of Grab Bars at the Toilet - Right Wall, Wheelchair Users

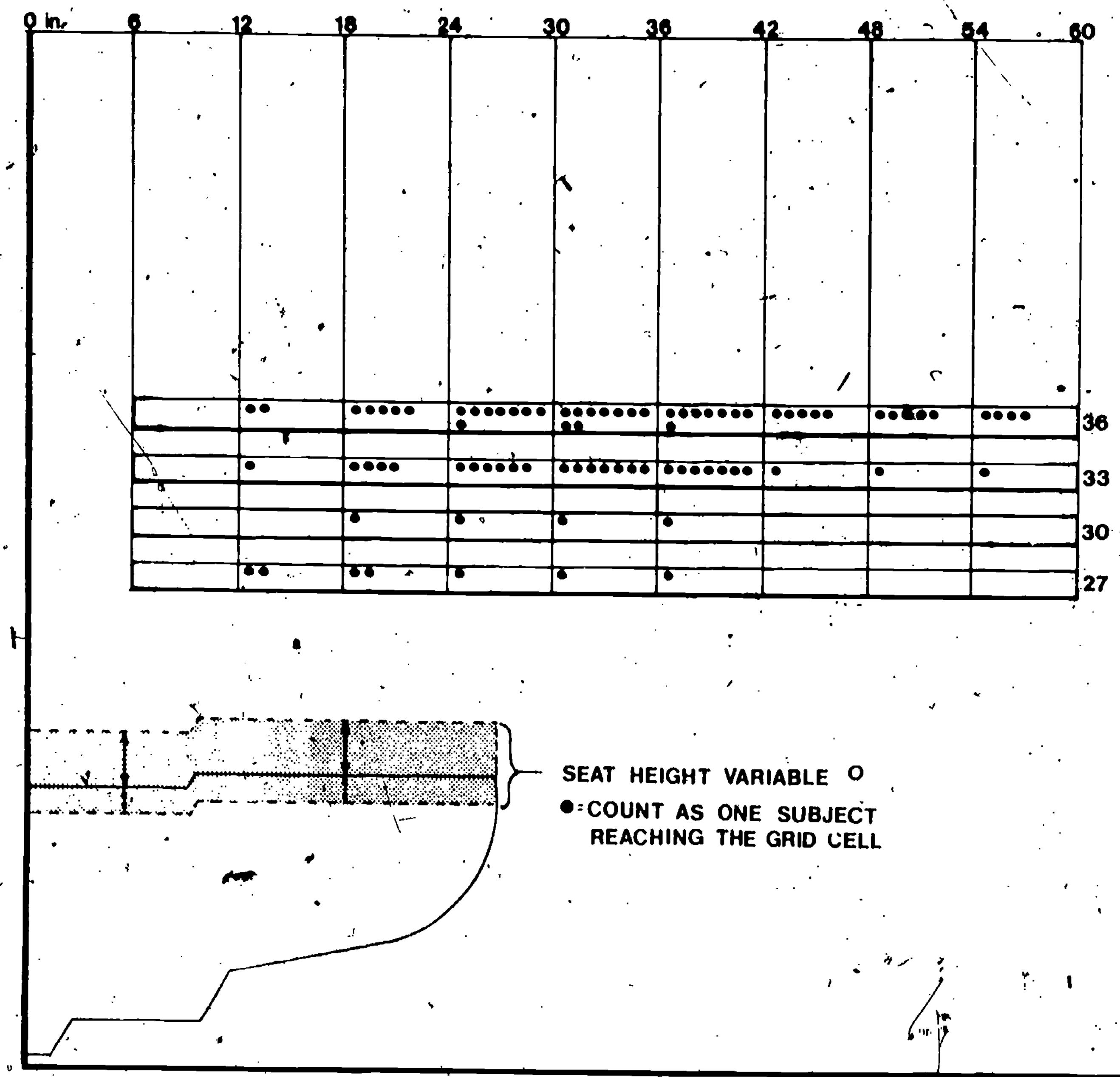


Figure 7D: Use of Grab Bars at the Toilet - Left Wall, Wheelchair Users

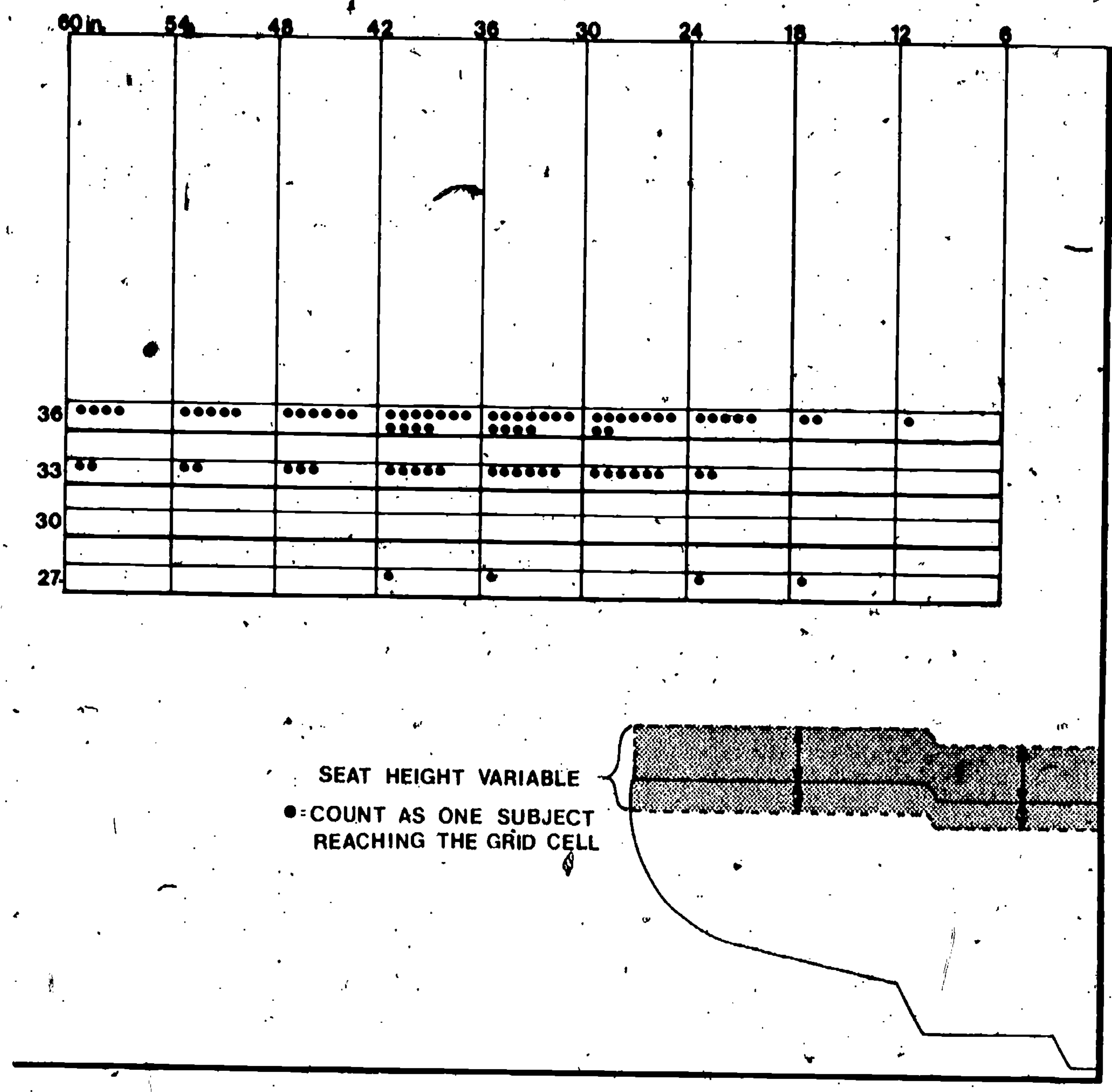


Table 14: Comparison of Four Stall Arrangements (Second Phase of Testing)

Data:			A					B					C					D		
Previous Stall Configuration (from Fig. 6)	Wheelchair	Ambulant or Semi-Ambulant	Left Wall Location	Right Wall Location	Uses Right Bar	Uses Left Bar	Transfer Type*	Left Wall Location	Right Wall Location	Uses Stall Bars	Uses Seat Bars	Transfer Type*	Left Wall Location	Right Wall Location	Uses Swing Bar	Uses Stall Bar	Transfer Type*	Remaining Wall	Wall Location	Uses Wall Bar
C.1	Y	N	18	18	Y	Y	3	18	20	Y	Y	3	18	20	Y	N	3	L	18	Y
C.2[a]	N	Y	18	18	N	Y	3	18	18	Y	N	3	18	18	Y	N	3	L	18	Y
A.1	Y	N	30	18	Y	Y	4	30	18	N	Y	4	30	18	Y	N	4	L	18	N
A.1[a]	N	Y	18	18	Y	Y	3	18	18	Y	N	3	18	18	Y	Y	3	R	18	Y
A.5	Y	N	18	30	Y	Y	5	18	30	Y	Y	5	18	30	Y	Y	5	L	18	Y
B.5	Y	N	18	18	N	N	3	18	18	N	N	3	18	18	N	N	3	R	18	N
B.5	Y	N	18	30	Y	Y	5	18	30	Y	N	5	18	30	Y	Y	5	L	18	Y
b	Y	N	30	18	Y	Y	1	18	18	Y	N	3	30	18	Y	Y	3	L	18	Y
b	Y	N	18	30	N	Y	2	18	30	N	Y	2	30	18	Y	Y	2	R	18	Y

*Key:
1 - diagonal front transfer
2 - 90° transfer
3 - front transfer
4 - side-by-side transfer
5 - other transfer method

Y - uses
N - does not use

[a]Used stalls narrower than 36 inches in first phase.

[b]Usually performed side transfers--not in original sample.

Table 15: Comfortable Seat Height[a] (percentages in parentheses)

Seat Height (in inches)	Wheelchair Users		Walking Aid Users	
15	2	(5)	0	
16	3	(8)	0	
17	14	(33)	4	(36)
18	12	(28)	2	(18)
19	5	(14)	2	(18)
20	1	(3)	2	(18)
21	2	(6)	1	(9)
22	1	(3)	0	
Total	40	(100)	11	(100)

[a]Measured to top of seat.

Table 16: Stall Width Comparison

Stall Depth (in inches)	Stall Width (in inches) 36	48	54	60
56	1	1	1,3	1,2,3,4
60	1	1,3	1,3	NA
66	1,3*	1,2,3	1,2,3	NA

Key: 1 - diagonal front transfer
2 - 90° transfer
3 - conveniently closes door before transferring
4 - side-by-side transfer
NA - not available
* - folds chair or removes footrest

Figure 8: Toilet Transfers

36 Inch Stall

48 Inch Stall

60 Inch Stall

Bathroom 8


F
H
J
K
L

Bathtub

Objectives

- Identify location of grab bars for convenient use by all users.
- Determine range of grab bar heights that accommodate all users.
- Establish reach limits from seated position for determining location of soap dish, controls, etc.
- Determine need for seat at end of tub.
- Determine space clearances required for transferring into tub.

Apparatus

Multiple sets of grab bars were installed around a standard 30 inch by 60 inch bathtub. Grab bar heights started at 30 inches above the floor and increased in three inch intervals to 36 inches. An additional horizontal grab bar was located nine inches above the rim of the tub, or 24 inches from the floor. All horizontal bars were continuous across the head, back and foot walls of the tub. Three vertical grab bars were installed: two 2 foot long bars on the side wall, each 18 inches from the end walls, and a floor-to-ceiling bar that could be located on a 2 inch interval anywhere against the front rim of the tub. Head, side and foot walls were marked in a 6 inch square grid pattern for the purpose of recording areas of reach (see Fig. 9A). The floor in front of the tub was also marked with a 6 inch grid to determine required space clearances for transferring from a wheelchair. In the second phase, a 4 inch high platform in front of the tub simulated a sunken tub with an 11 inch high rim measured from the floor.

Procedure

In the first phase, subjects transferred into the tub. Chairs were made available for placement in the tub and/or outside the tub. Also, a board was available to straddle both chairs if desired. Locations of chairs placed outside the tub and locations of wheelchairs were recorded. Hand placements on lateral and vertical grab bars were recorded as used. Measurements were recorded for highest left and right reaches on foot and back walls from a seated position.

In the second phase, ambulant users reached to foot and side walls while outside the tub and tested a sunken tub. Wheelchair users reached to the foot and side walls while outside the tub.

Subjects

People in all disability levels were tested in the first phase; the total number of disabled subjects was 187. In a second phase of testing, six ambulant people, four of whom had difficulty bending and kneeling returned to test a sunken bathtub. A four inch high platform reduced the height of the rim to approximately 11 inches. In addition, five wheelchair users who could use tubs returned to test areas of reach while outside the tub.

Findings

Thirty-three wheelchair users of the total 57 member wheelchair sub-sample did not test the bathtub because they did not use a bathtub (as bath or shower) in their home. These people included quadriplegics for the most part, but also included people who could transfer but did not take baths as a matter of personal preference. Ambulant users who elected not to test the bathtub were often either hemiplegics who could not negotiate the rim of the tub, or frail elderly persons with stamina or balance problems who feared accidents while using the bathtub.

While the lack of water and soap provided a more slip-resistant surface than in actual use, the benefits of water bouyancy were absent. With dry hands, however, users were much more able to maintain a better grasp on grab bars than they would with wet hands.

The horizontal grab bars which were used most often were those at 36 inches above the floor and 9 inches from the rim of the tub (see Fig. 9B). Bars on all three sides of the tub (head, side and foot walls) were used. Bars at the head and foot walls were most frequently used as stabilizing aids when negotiating the rim of the tub. Center portions of the bars on the side wall were used when standing and when raising or lowering into the bathtub. The 36 inch high bar was used as a stabilizing aid while standing in the tub by both ambulant people and wheelchair users who could stand. The 9 inch bar was used to lower into the tub or raise up from the tub. The lower bar was also used to pull close to the foot wall in order to adjust controls.

Hand placement along the vertical bar was usually 24 inches to 54 inches above the floor, with most wheelchair users utilizing the segment between 24 and 48 inches. Most areas of foot and side walls surrounding the tub were reached, from a seated position in the tub, to a height of 33 inches above the rim of the tub.

People transferred from wheelchairs in both parallel and frontal approaches. A 48 inch by 48 inch square in front of the tub will accommocate spatial needs of people who use both transfer techniques (see Fig. 12). People who could not stand to transfer, generally assumed a transfer approach parallel to the rim of the tub and transferred directly to the rim. A seat at the rear of the tub was beneficial to people who employ this transfer method.

Results of the second phase of testing showed that all six ambulant people could reach the side wall of the tub while outside the tub. They could reach a line 6 inches above the rim along the side wall. They could also reach the same height on the foot wall. Sunken tubs were not preferred by ambulant users maintaining balance. Four wheelchair users were tested in reaching from outside the tub. None could reach the side wall of the tub from outside the tub. They could, however, reach a line 6 inches above the rim at the foot end of the tub from the front edge to the center line of the tub.

Recommendations

Horizontal grab bars should be placed on the three walls of the tub. Two bars, each at least 2 feet in length, should be located on the side wall, starting 1 foot from the head wall. These bars should be located at 36 inches from the floor and 9 inches above the rim of the tub. Horizontal bars at the head and foot end of the tub should be 12 and 24 inches long, respectively, and should be placed at 36 inches from the floor and be aligned with the front rim of the tub. A horizontal bar would be more slip-resistent than a vertical bar for use when negotiating the tub rim, but the horizontal bar must be placed along the wall or it becomes an obstacle.

When access is parallel to the tub, an unobstructed floor space of 30 inches wide is needed, while perpendicular access requires a space 48 inches wide. Controls at the foot end of the tub, within reach of users outside of the tub are preferred, as such a location permits testing of water temperature and filling of the tub before getting in.

Marginal Population

In nearly all the disability levels of wheelchair users, there were some who could not transfer into the tub. However, the highest concentration of those who could not transfer was that group who have three or four limbs affected and those who have limitations of stamina. A smaller number of semi-ambulatory people could not transfer into the bathtub. These were people who use walking aids as well as a small scattering of people in other disability categories who, in most instances, were individuals with multiple disabilities.

Figure 9A: Bathtub Grab Bar Testing Apparatus - Plan

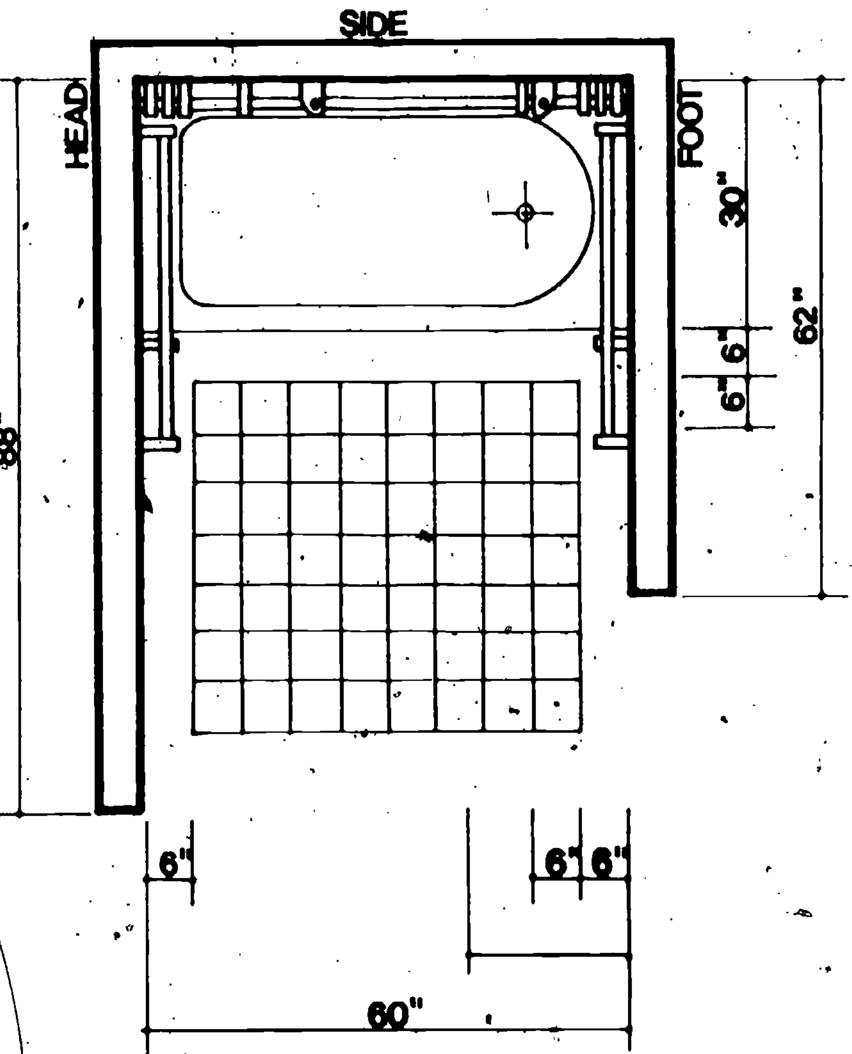


Figure 9B: Bathtub Grab Bar Testing Apparatus - Elevations

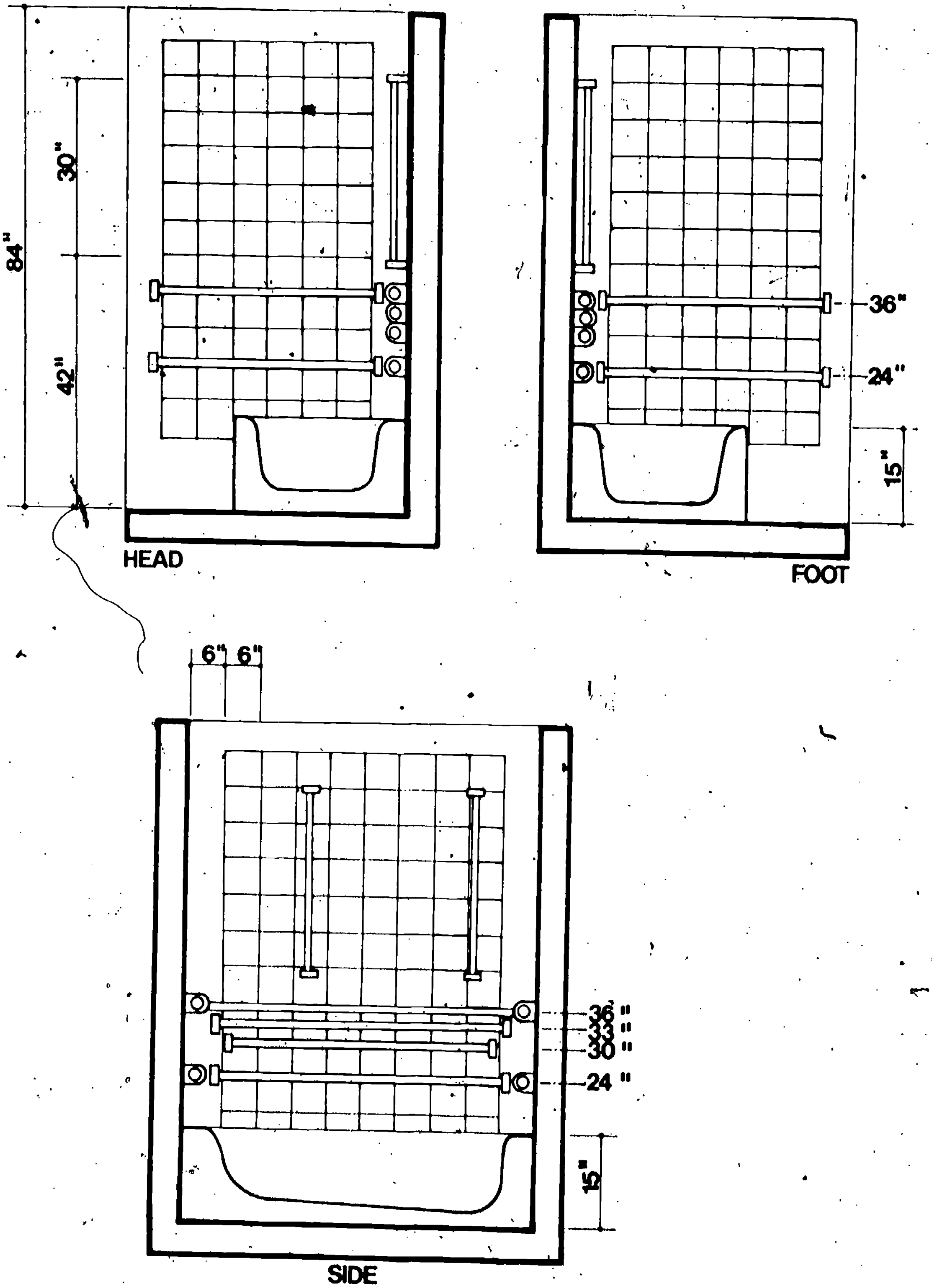


Figure 10A: Use of Grab Bars at Side Wall - Wheelchair Users Only

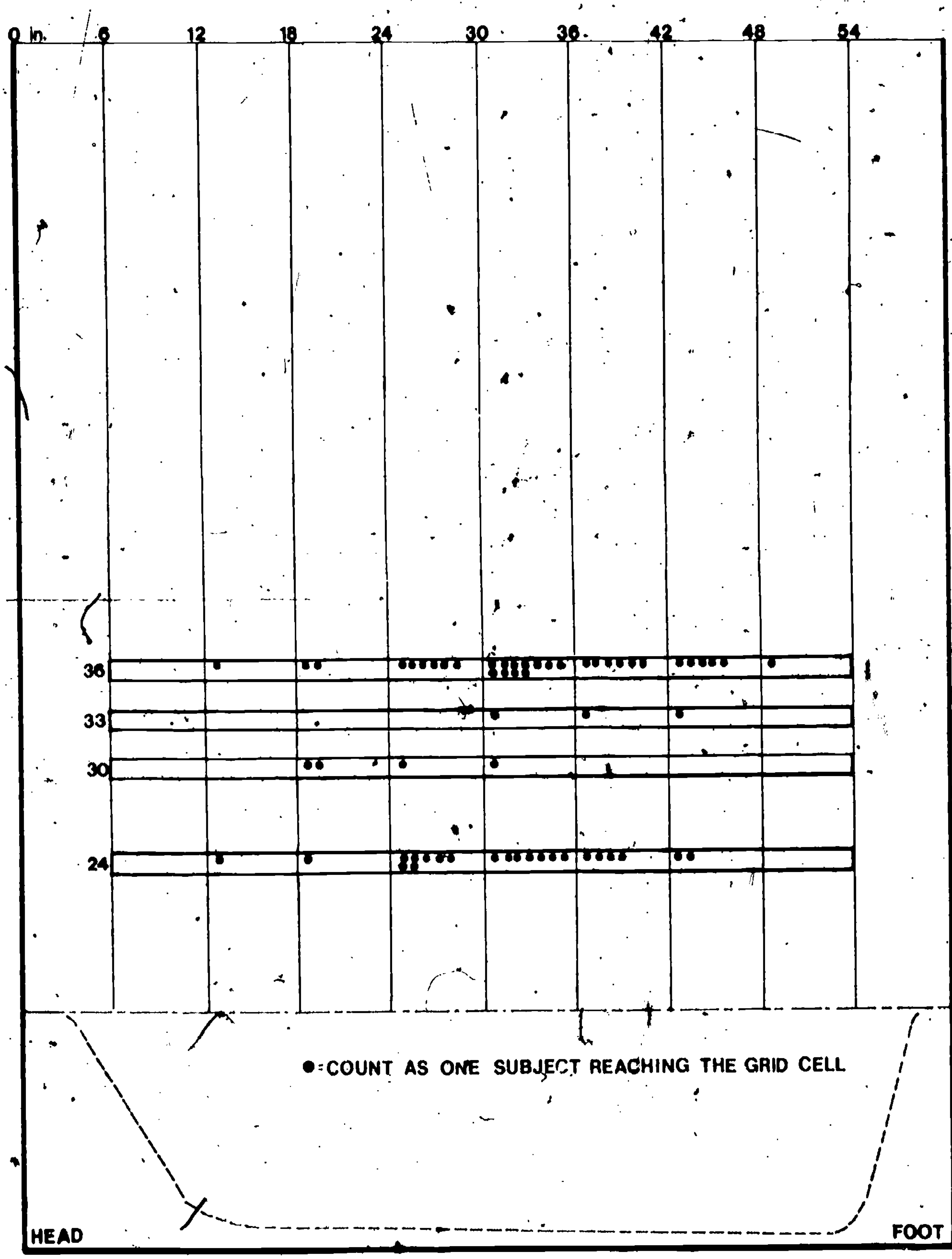


Figure 10B: Use of Grab Bars at Head Wall - Wheelchair Users

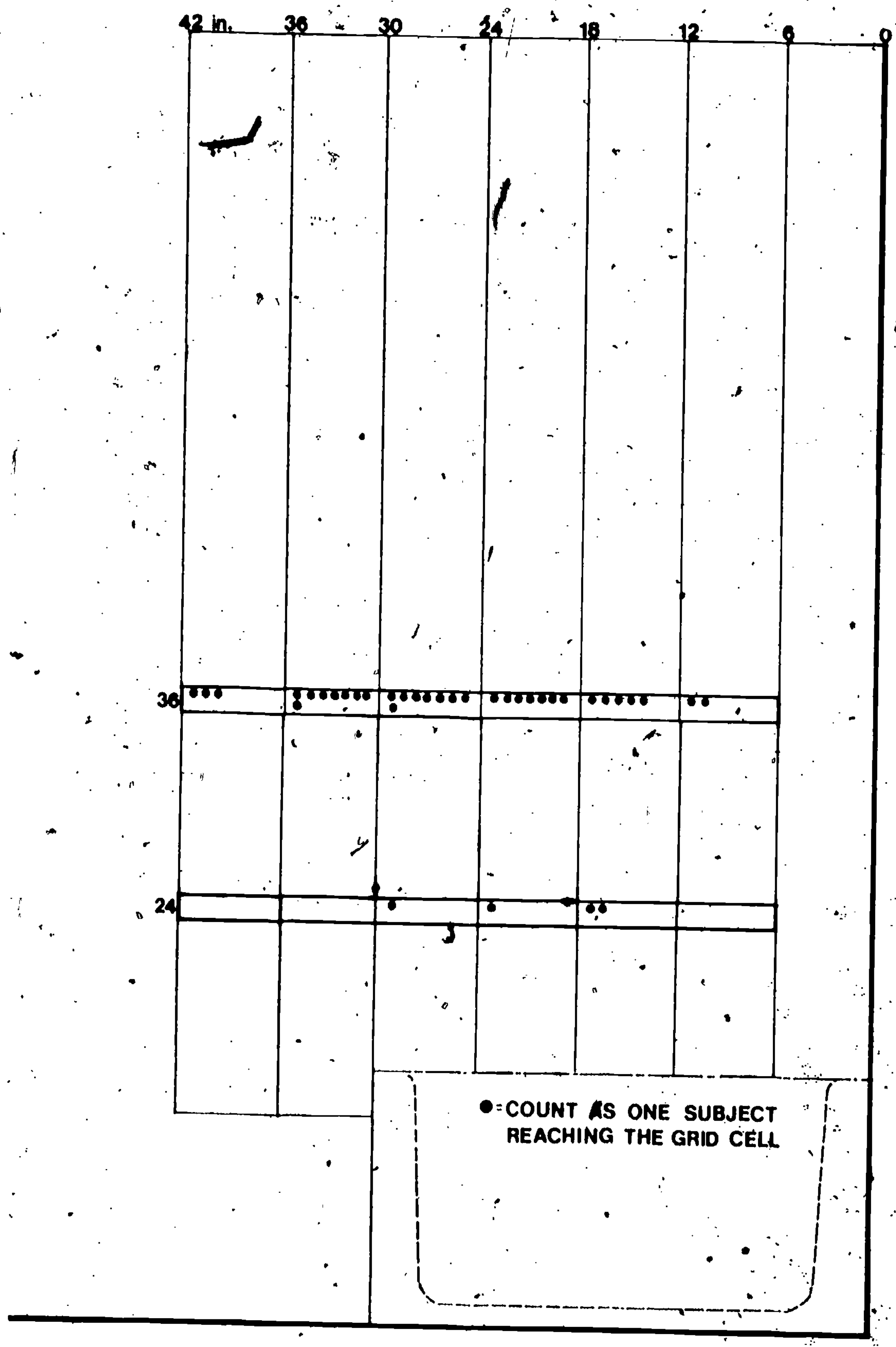


Figure 10C: Use of Grab Bars at Foot Wall - Wheelchair Users

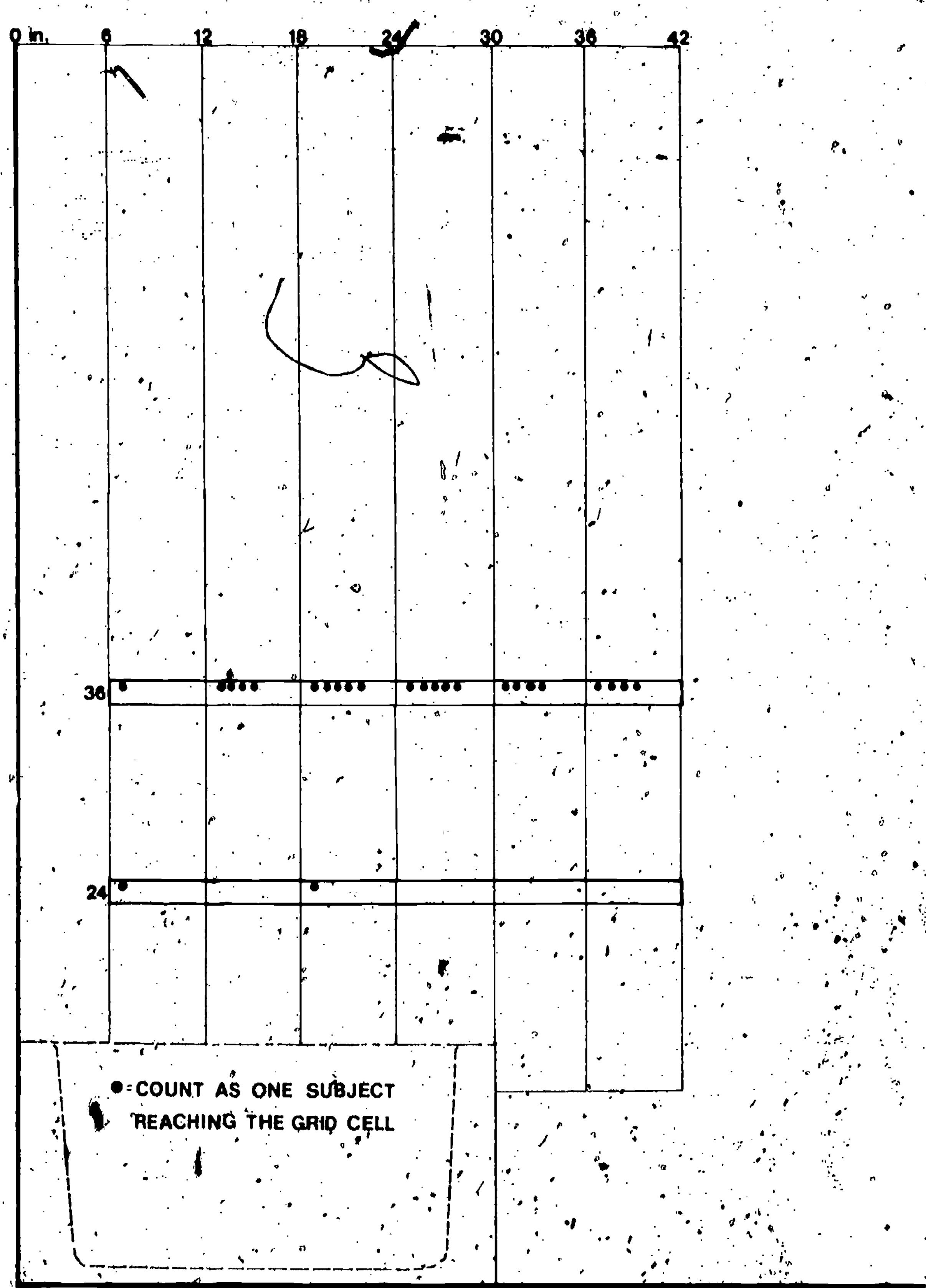


Figure 10D: Use of Grab Bars at Side Wall - Walking Aid Users

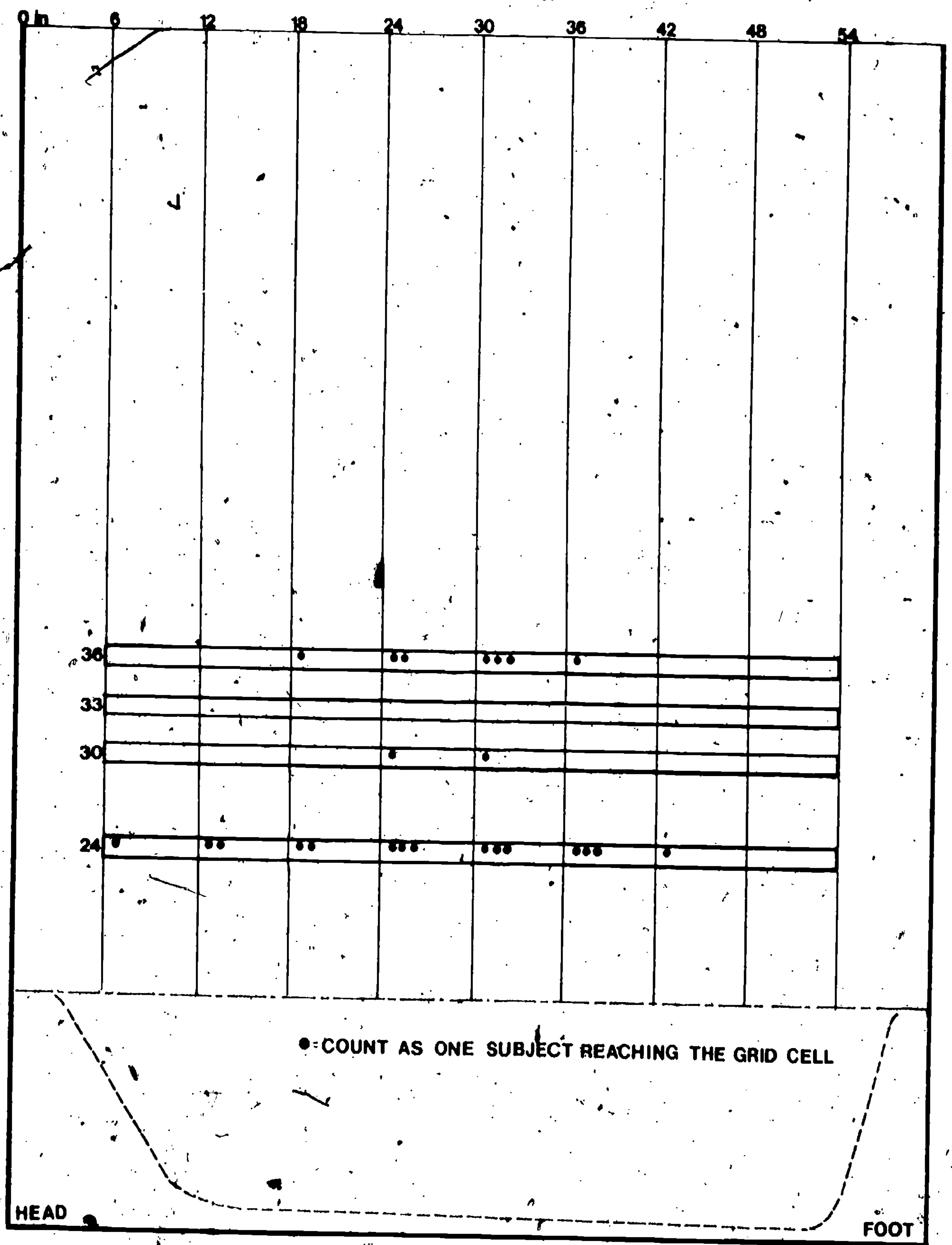


Figure 10E: Use of Grab Bars at Head Wall - Walking Aid Users

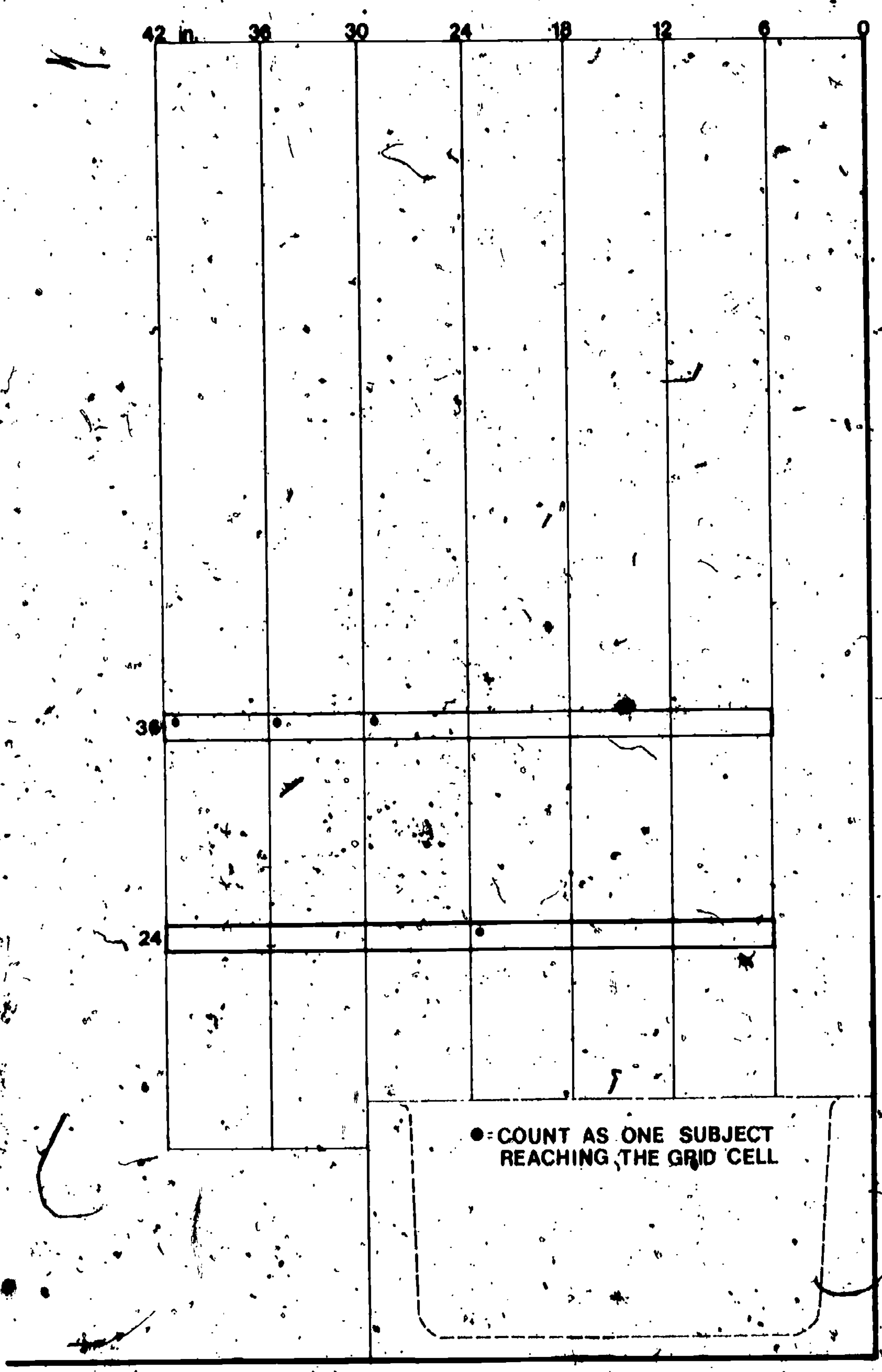


Figure 10F: Use of Grab Bars at Foot Wall - Walking Aid Users

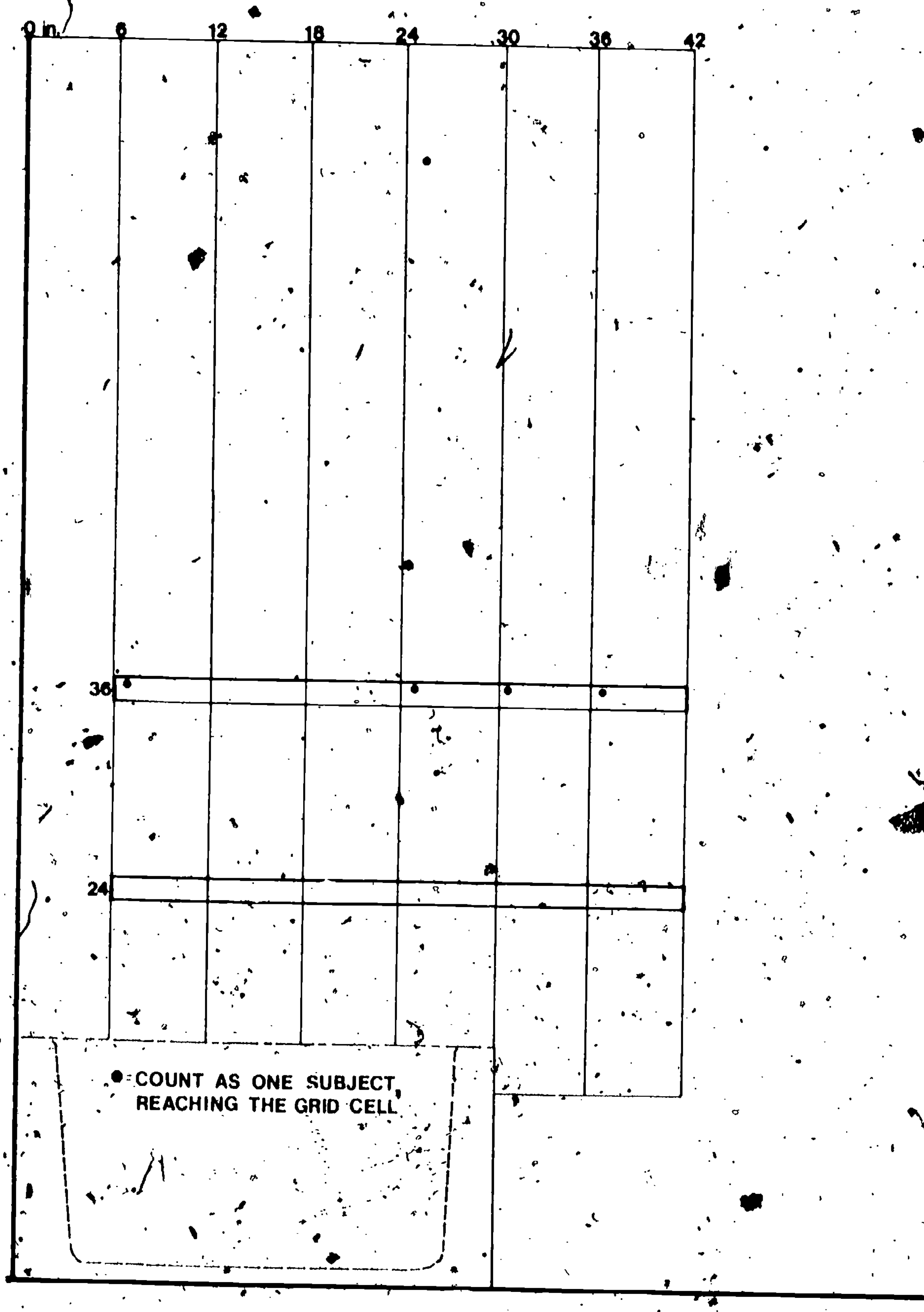


Figure 10G: Use of Vertical Grab Bar Placed at Outside of Edge of Bathtub - All Subjects

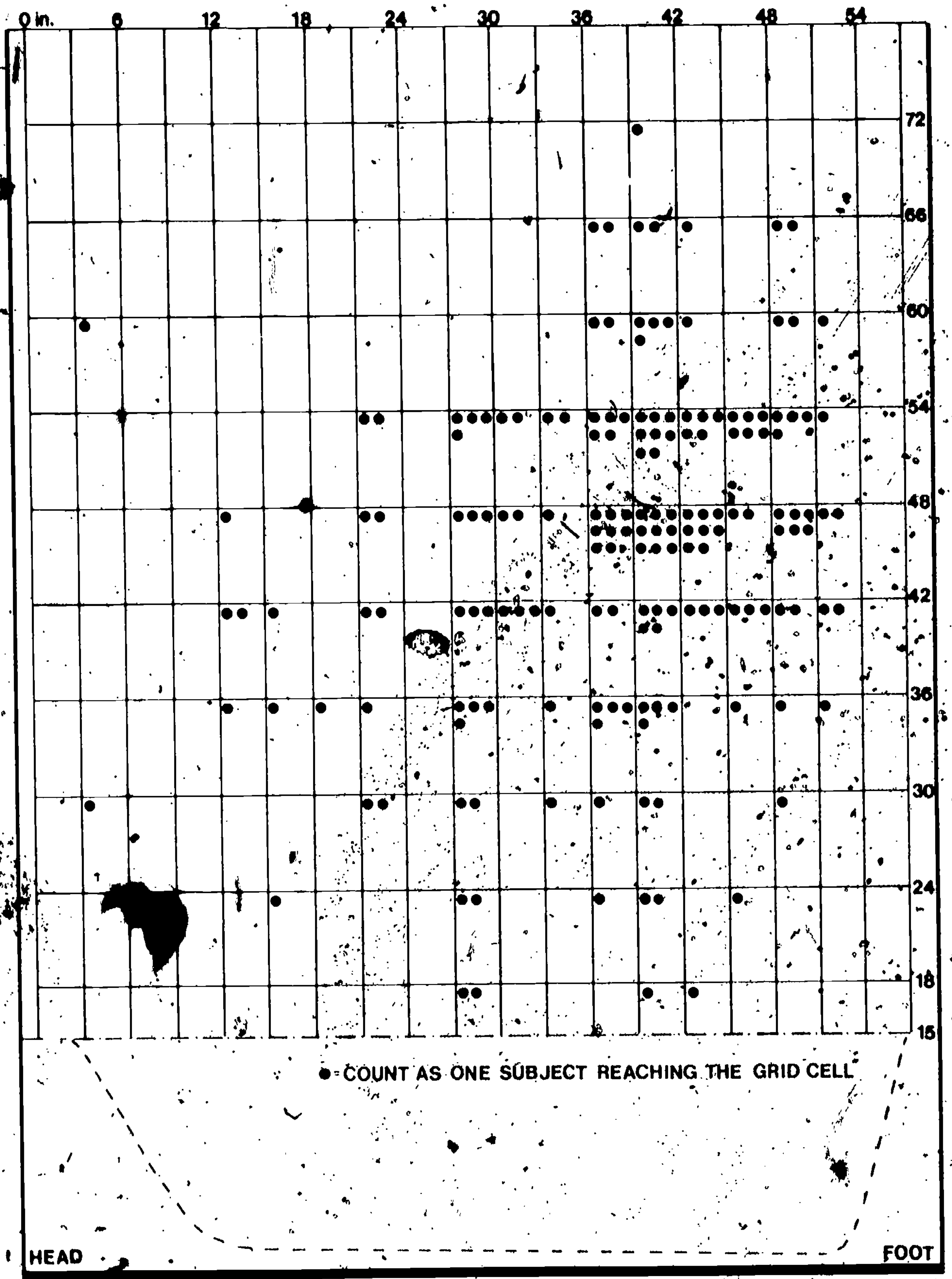


Figure 11A: Highest Reach While Seated in Tub to Extreme Left of Side Wall - All Subjects

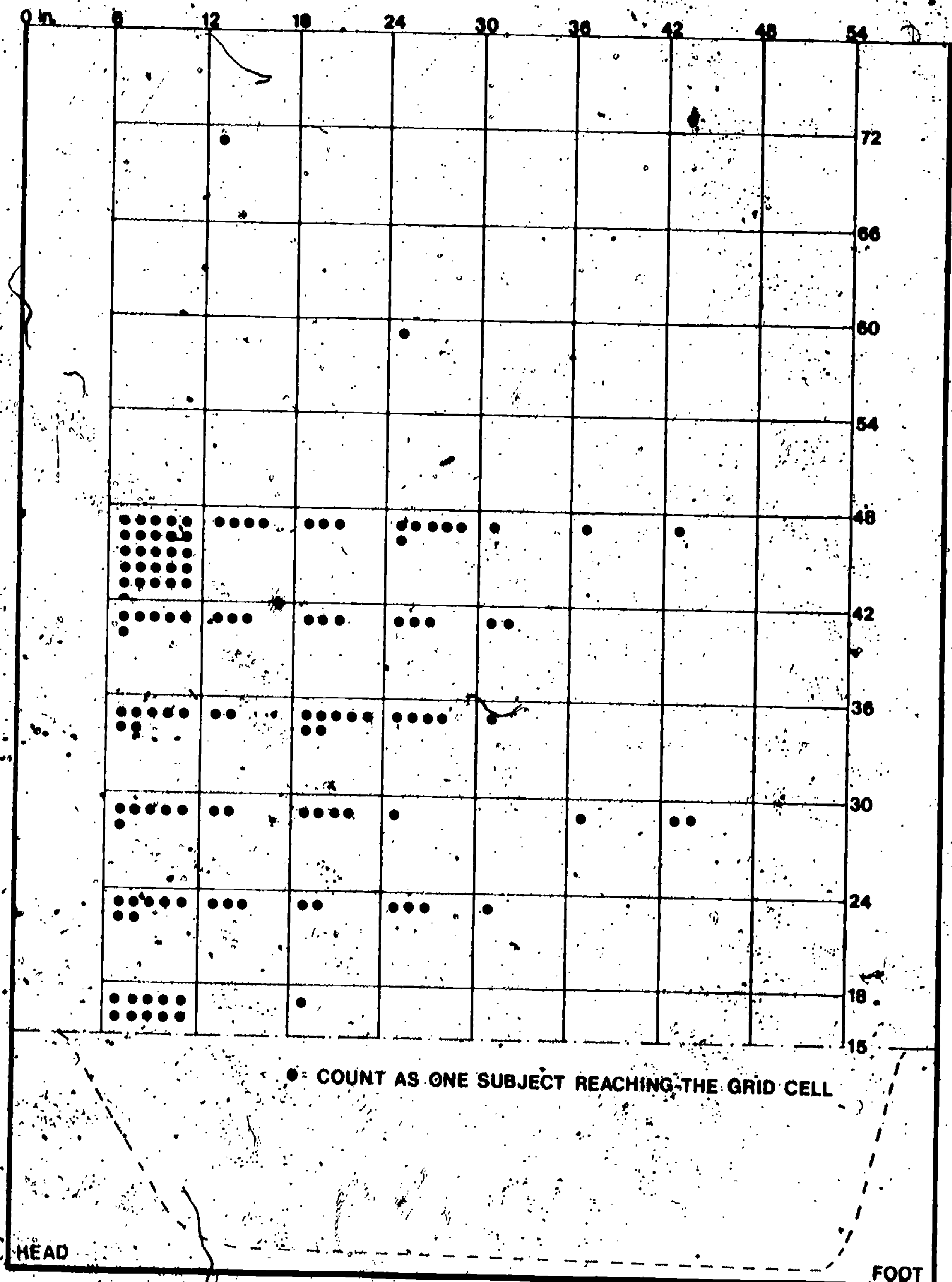


Figure 11B: Highest Reach While Seated in Tub to Extreme Right of Foot-wall - All Subjects

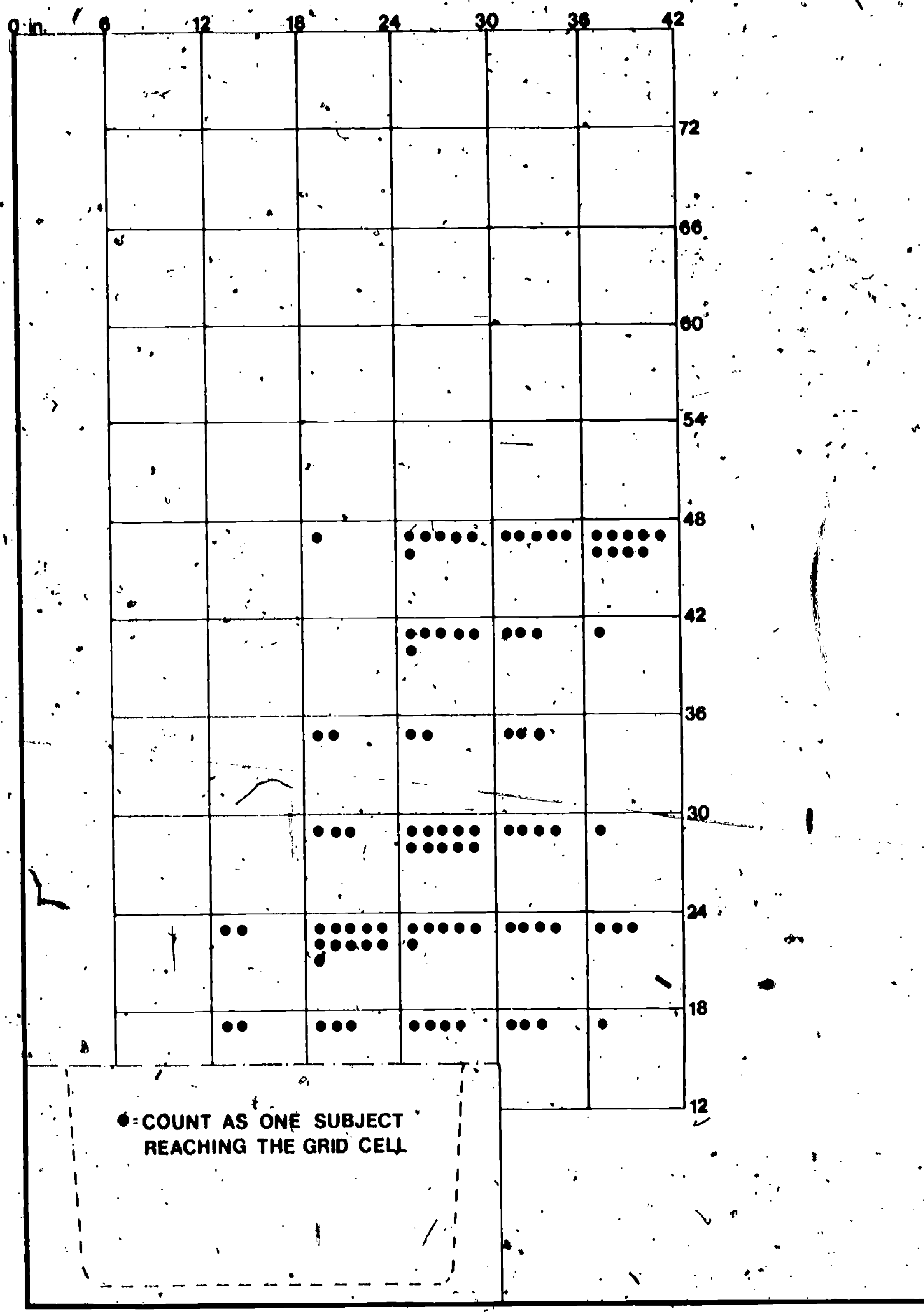


Figure 11C: Highest Reach While Seated in Tub to Extreme Left of Foot Wall - All Subjects

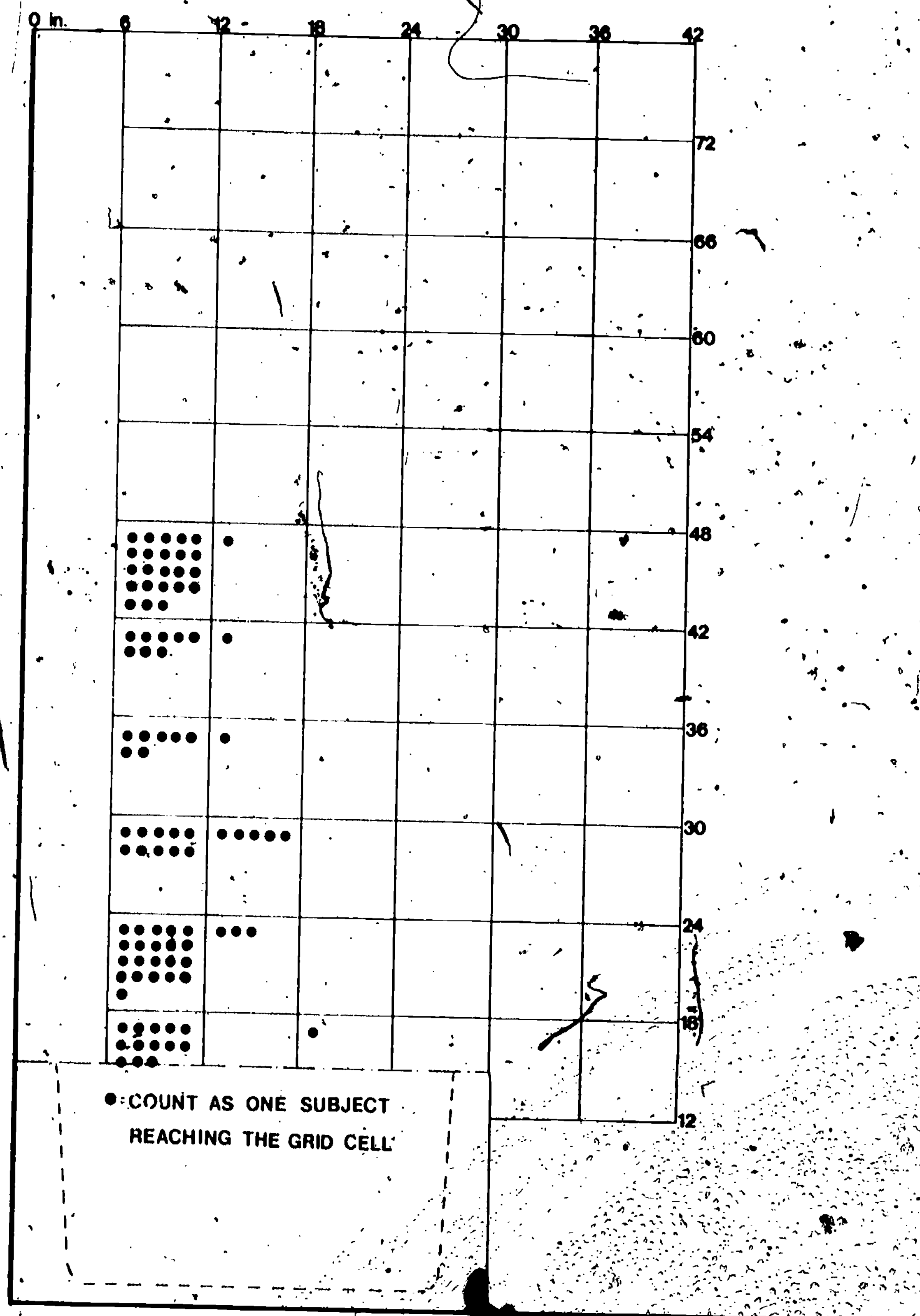


Figure 12: An Example Transfer

User assumes a parallel approach to the bathtub. If a seat is built at the head end of the tub, or if a seat across the tub is placed at the head end, additional space behind the tub is necessary to align the wheelchair for easy transfer.

The vertical grab bar in a position to aid semi-ambulant people would be an obstacle to this person.

The bathtub rim serves as a resting place during transfer.

The lower grab bar is used when lowering and raising oneself into and from the bathtub.

Showers

Objectives

- Compare the usability of a wheel-in shower with showers having a curb.
- Determine the minimum width required for shower stalls.

Apparatus

The bathtub testing station was modified into 60 inch wheel-in and 36 inch conventional shower stalls by removing the bathtub. In conjunction with the wheel-in stall, fiberboard mock-ups of a toilet and sink were built. The toilet was 17 inches high and the sink was 18 inches deep and mounted on the wall at a height of 32 inches to the rim. Either of these mock-ups could be positioned next to the shower space to simulate two different floor layout conditions in bathrooms: A) toilet next to a shower and B) sink next to shower. Both conditions assumed that the shower stall would be at one end of the bathroom and that the width of the bathroom would be five feet. The shower was five feet long and its width was variable. All layout conditions assumed that entry to the shower space would be through a 34 inch space--the difference between the minimum 60 inch bathroom width for typical full bathrooms and 26 inches, the depth of a typical residential toilet. This space was along the side of the bathroom opposite sink and toilet. Grab bars were identical to those used in the bathtub testing station, with the omission of the vertical bar.

In testing the 36 inch shower stall, a seat was provided in the shower as shown in Fig. 13A. The seat was 17 1/2 inches high and 18 inches deep. Due to the presence of grab bars above the seat, its effective depth was 15 inches. The seat was 30 inches long. A 4 inch curb could be installed along the shower space edge.

Procedure

Wheel-in shower: Subjects first were tested with a wheel-in shower (no curb and no seat). They approached the shower space through the 34 inch clear space, made an L-turn into the shower area and then came back out--in anyway they wished.

Two trials were made, one with the sink and a second with the toilet installed adjacent to the shower. The sink and toilet were installed initially at distances of 30 inches and 36 inches, respectively from the back wall of the shower. If the width of the shower space was not sufficient at these distances, the toilet or sink was moved out until a convenient width was established. Use of grab bars was recorded as in the bathtub and toilet stall experiments.

Conventional shower stall: Subjects approached the shower stall in the manner easiest to them. They were then asked to transfer onto the shower seat using any of the grab bars they wished. Each subject transferred twice, with the curb in place and with the curb removed. Wheelchair location, grab bar use and transfer performance were recorded.

Subjects

Ten wheelchair users were tested at the wheel-in shower. Nine of these subjects were hemiplegics or people with bending, turning and stamina limitation. Six of these people were tested in transferring into the 36 inch shower with and without the curb in place. Four were paraplegics and three were hemiplegics.

Findings

Wheel-in shower: The 34 inch wide entry space was sufficient for all users. With a toilet adjacent to the wheel-in-shower, a distance of 42 inches from the back wall to the edge of the bowl was necessary for every person to turn in and exit out of the shower space. A sink set at 36 inches from the back wall allowed every user to turn into and exit from the shower space. Most subjects could turn around in these spaces needed to enter the shower. The difference in required width of the stall area was due to the use of the clear space under the sink for maneuvering.

Conventional shower stall: The curb in the shower was a definite obstacle to all subjects. While they all managed to complete the transfer with the curb in place, all expressed a preference for showers with no or minimum-sized curbs. All subjects used the grab bars at either the 33 inch or 36 inch heights on either the seat wall or the back wall of the shower space.

When the curb was removed, four subjects approached the shower perpendicular to the front of the stall, penetrating part of the actual stall space with their wheelchairs. With the curb in place, all subjects approached the stall either parallel or diagonal to the front edge of the curb. The wall at the back of the seat prevented people using parallel approaches from aligning the front edge of their wheelchair seats with the front edge of the shower seat. Generally, a 48 by 30 inch space in front of the stall, parallel to the front edge was sufficient clearance in front of the stall.

Recommendations

If an L-turn is required to enter a wheel-in shower when no knee space is provided adjacent to the shower, e.g. when a toilet is so located, the clear space required is 60 inches wide by 42 inches deep. Where knee space is provided, such as under a lavatory, the clear space required, using a L-turn approach, is 60 inches wide by 36 inches deep. Shower seats should be of adequate depth (clear seat depth of at least fifteen inches) and should extend over shower threshold curbs if they are present. There is a great need for new designs for residential showers with areas of concern being mainly: 1) prevention of water spillage other than use of curbs, 2) design of seats and 3) design of transfer assists.

The seat design recommended by Timothy Nugent, of the University of Illinois, Rehabilitation-Education Center, provides a larger width seat at the back of the stall, enabling people with low strength in back muscles and difficulty maintaining balance to rest against both walls in the back corner (see Fig. 15). The seat folds up when the shower is used by ambulant people. Ambulant people should have grab bars encircling the shower and, as we found, a grab bar behind the seat can be useful for wheelchair users as well. However, for those wheelchair users who need the support of the back walls, bars located there can be dangerous and uncomfortable. Moreover, they prevent a seat from being folded up against the shower wall. To reconcile these varying needs, a structrual reinforcement area could be provided, allowing grab bars and seats to be installed as needed. This in an appropriate solution in residential bathrooms. In publicly used shower areas, a seat and grab bars should be provided initially. The design in Fig. 15 is recommended.

Marginal Population

Generally, people with three or four affected limbs would have a more difficult time making a 90° turn into a wheel-in shower stall. Thus, some hemiplegics and quadriplegics could enter a stall that favored their better arm but could not easily turn around or back out. Wheelchair users with limitations of stamina would also have a difficult time maneuvering wheelchairs in tighter spaces.

Figure 13A: Plan of Apparatus for Shower Stalls - 36 in Shower

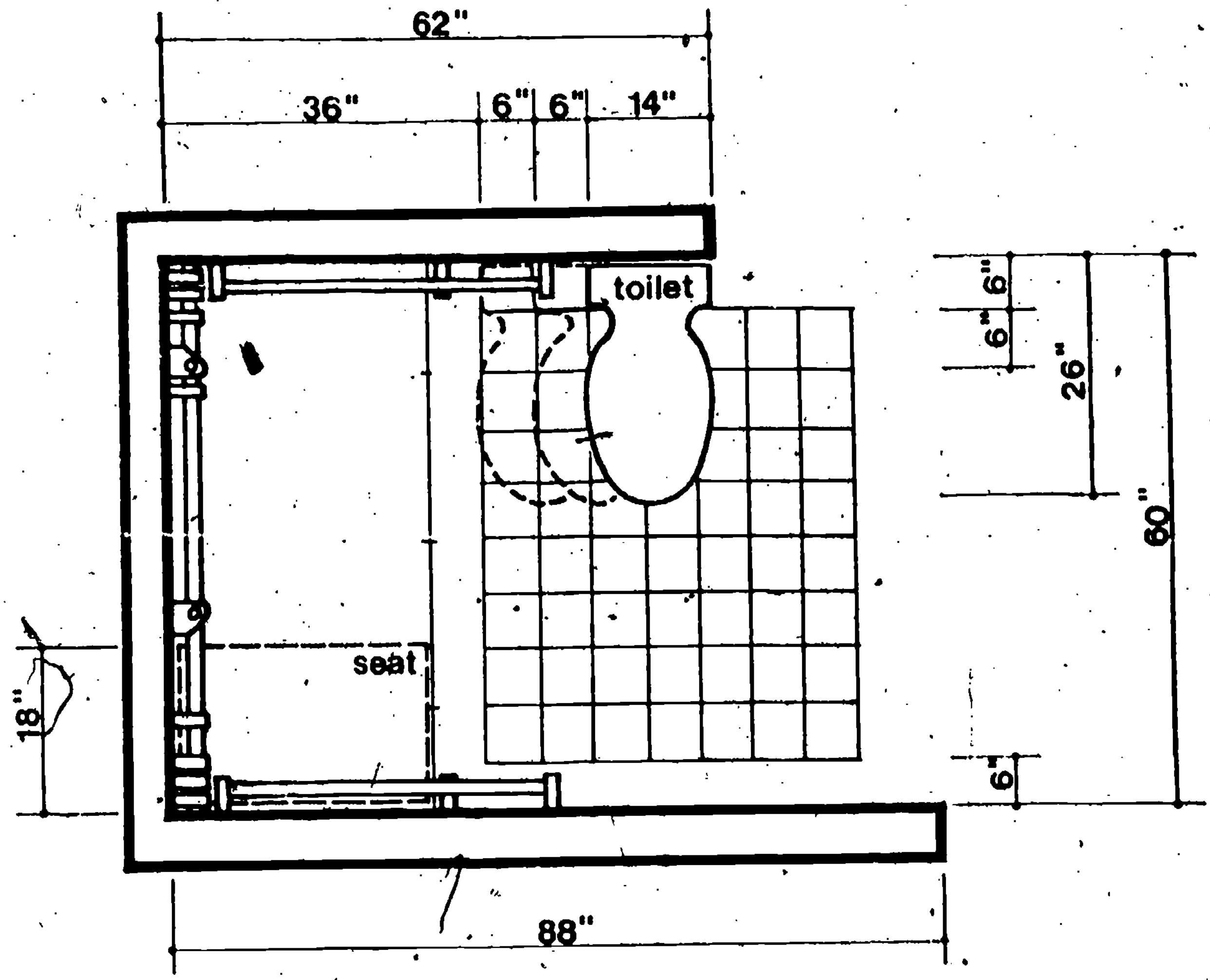


Figure 13B: Plan of Apparatus for Shower Stalls - 30 in Shower

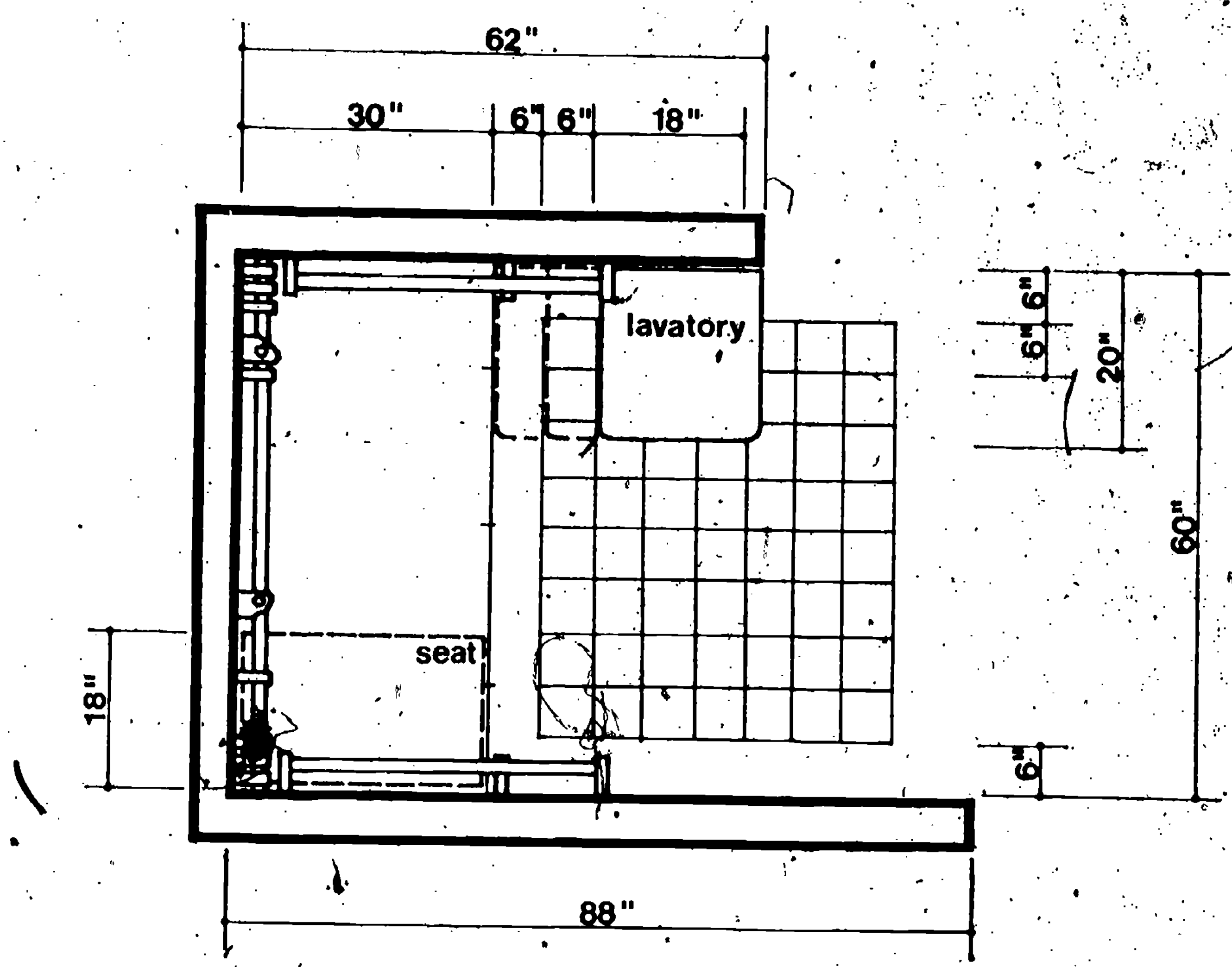
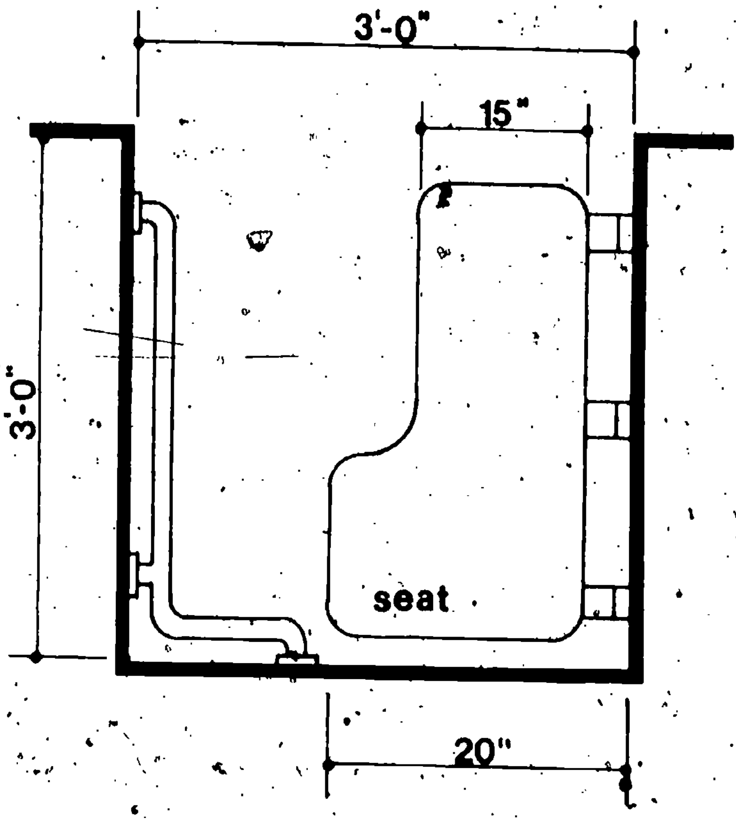


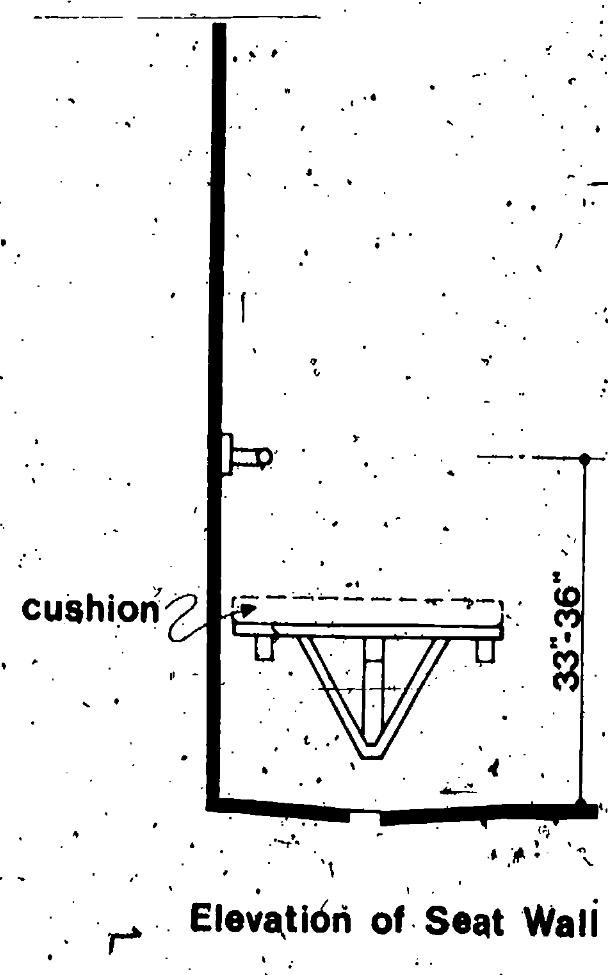
Table 17: Space Required for Smallest Shower/No Curb

Shower Adjacent to Toilet					Shower Adjacent to Sink			
Fixture Location	Enter Stall	Turn Around	Back Out		Enter Stall	Turn Around	Back Out	Fixture Location
34 in entry	7	6	6	Successful	7	7	7	
36 in toilet edge to	3	4	4	Unsuccessful	3	3	3	30 in from sink edge to
Back shower wall	10	10	10	Total	10	10	10	Back shower wall
34 in entry	4	3	4	Successful	3	3	3	
42 in toilet edge to	0	1	0	Unsuccessful	-	-	-	36 in from sink edge to
Back shower wall	4	4	4	Total	3	3	3	Back shower wall

Figure 14: Recommended Shower Seat

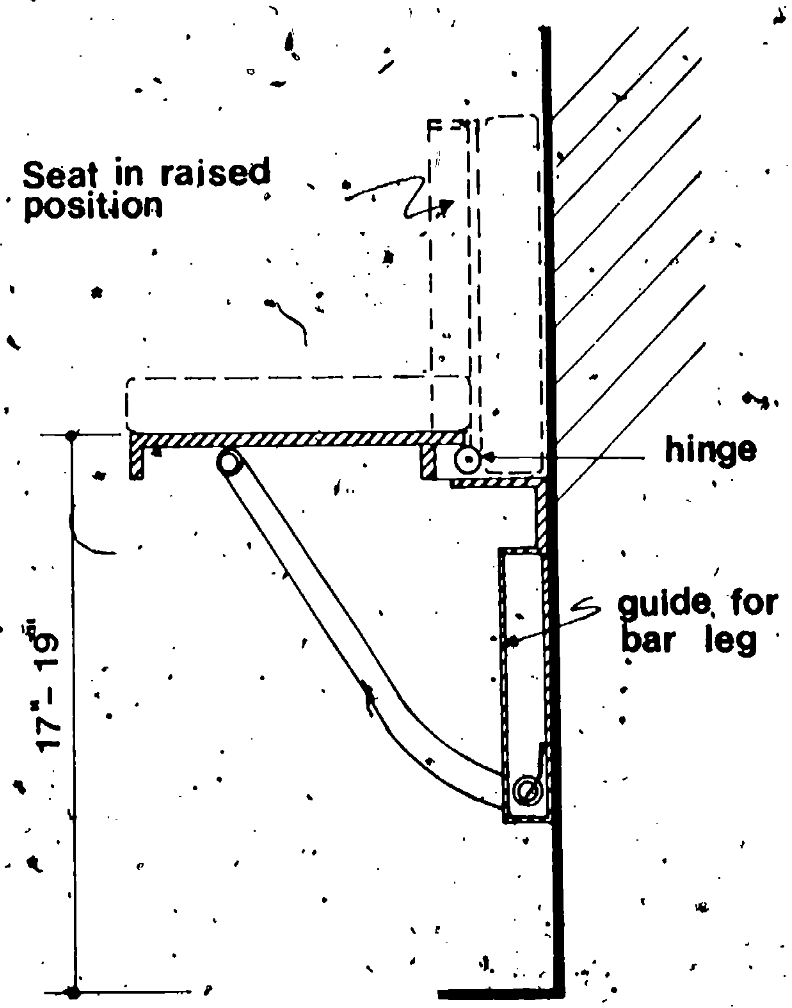


Plan



Elevation of Seat Wall

Figure 14: (continued)



Section

Bathroom Layouts

Objective

- Test the feasibility of using minimum size bathroom layouts for accessible bathrooms.

Apparatus

Using equipment constructed for the toilet stall and shower experiments, two minimum sized bathroom layouts were arranged. All walls were wooden partitions, either fixed in place or able to slide along the floor. One layout, the in-line, had the water closet, lavatory and a 2 1/2 foot by 5 foot wheel-in shower arranged so that all plumbing lines could be served by the same stacks, with the entry located opposite the water closet and lavatory. The second layout had the shower stall opposite the water closet and lavatory with the entry on a side wall. Entries in each layout had 32 inch clear widths. Both layouts were variations of typical 5 foot by 7 1/2 foot bathrooms. Grab bars were provided at the toilet along the full length of the adjacent wall.

Procedure

Subjects demonstrated the use of all fixtures in the bathrooms, including transferring onto the toilet seat and a seat in the shower. Each bathroom was tested with a wheel-in shower stall and a shower stall with a seat. Also, transfers were tested with and without a 4 inch high curb in place at the shower stall.

Subjects

Six subjects were tested. They were selected from the group of people who could transfer in phase one testing in the toilet stall, but who often had maneuvering problems. Bathrooms satisfactory for this group of people would also be satisfactory for all other subjects tested in phase one, including those who could not transfer.

Findings

Both bathrooms were fully usable when tested with wheel-in showers (no curb). There was sufficient maneuvering room at all fixtures. The layout with the shower opposite the toilet and lavatory was less convenient because there was not enough space to turn around--subjects had to back out. If curbs were installed at the shower, subjects needed a clearance space at the rear end of the shower to transfer onto the shower seat. They had to use a parallel transfer method because the curb precluded a 90° or diagonal approach. This means that in the layouts tested with curbs, subjects had to keep part of their wheelchair projecting through the doorway to transfer. In such a situation, the door could not be closed. Also, curbs in showers made it difficult to move wheelchairs out of the way after transferring to the toilet for certain transfer positions.

Recommendations

Minimum size bathroom layouts are accessible if they provide sufficient clearances for use of fixtures. In the standard 5 foot by 7 1/2 foot bathroom, the entry should be on the long wall as shown in Fig. 15A. If showers with curbs are used, then a space clearance of 12 inches beyond the wall of the shower at which the seat is located shall be provided.

Marginal Population

People who cannot transfer in a 90° approach or diagonal approach to a toilet cannot use typical minimal bathrooms unless 30 inch clearances are available at the side of toilets. But, we encountered no one in our sample who could not use one of these two transfer methods if they could transfer at all, although for some, the parallel transfer method is more convenient.

Figure 15A: Bathroom Layout: In-Line

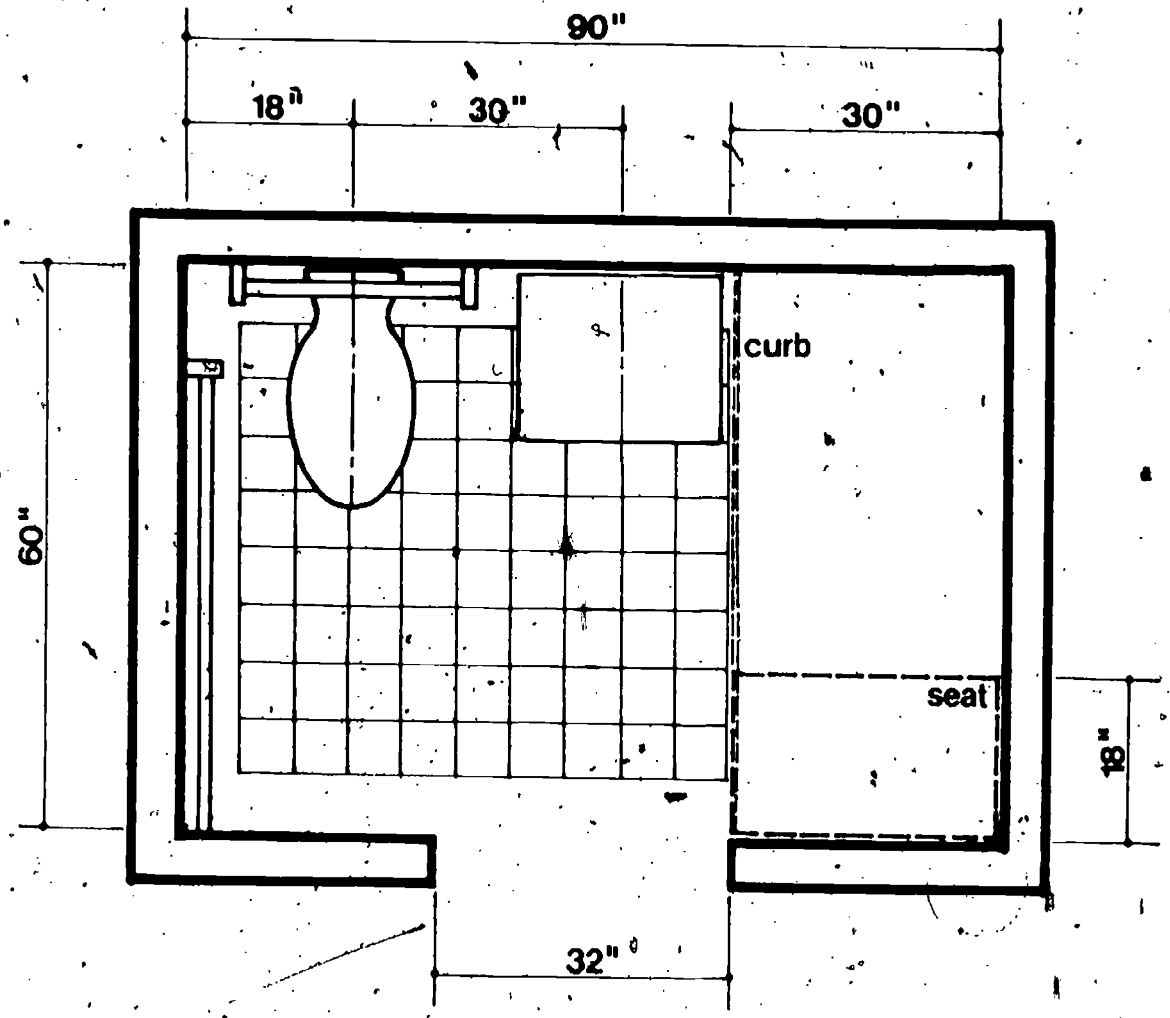


Figure 15B: Bathroom Layout: Opposing

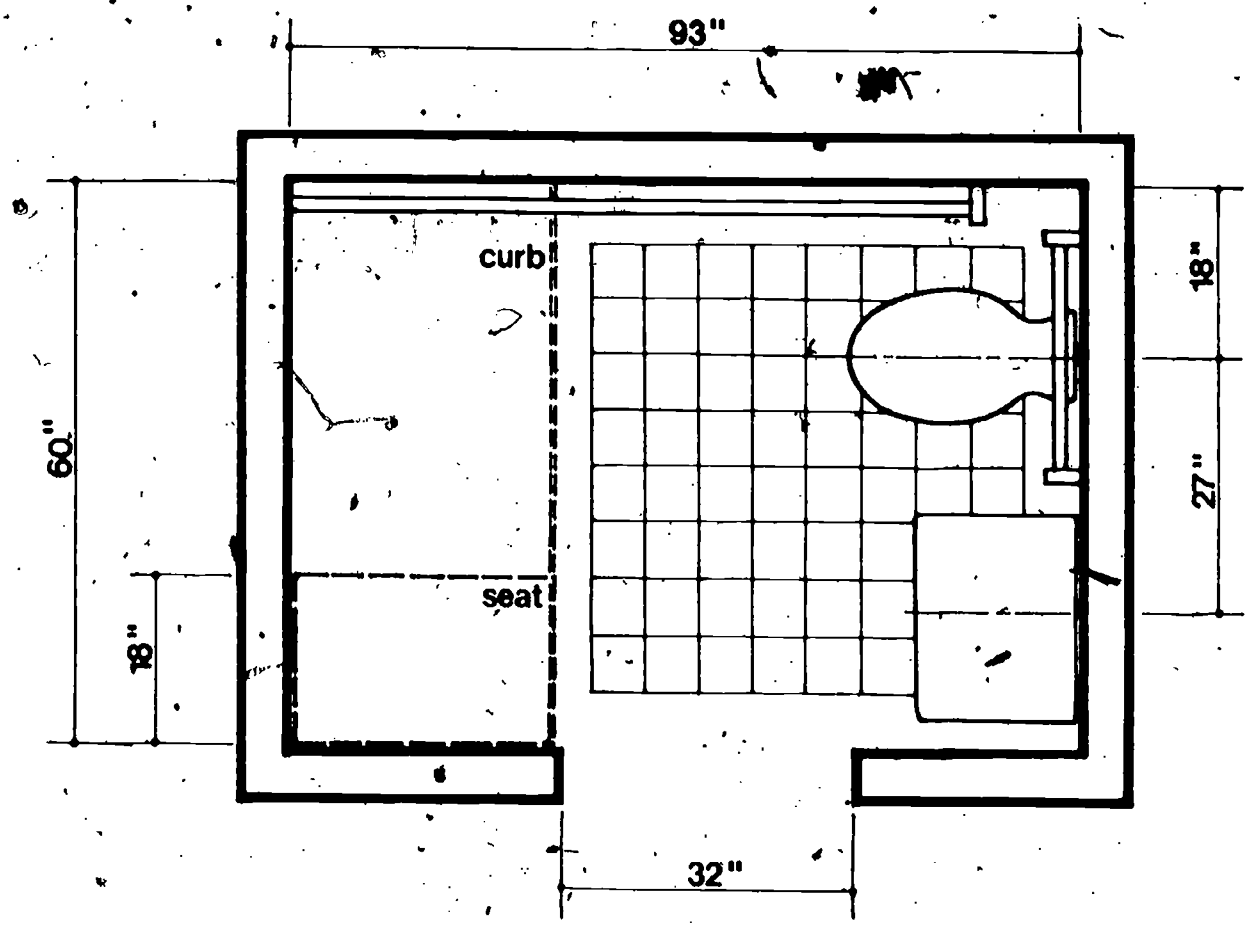


Figure 16A: Maneuvering in Bathrooms/1.

If a seat is used in the shower with a high curb, there has to be clearance behind the shower to allow the door to be closed.

If there is no curb, or a low curb, a wheelchair can be pulled into the shower space to transfer.

With no seat or curb and a 60 inch shower, wheelchairs can be turned around in the shower space, adding much convenience in use. With a folding seat, both the advantages of not having to use a wheelchair in the shower plus having the maneuvering space are obtained.

Figure 16B: Maneuvering in Bathrooms/2

With a high curb in the shower, after transferring onto the toilet, there is no place to move the wheelchair:

Curb

No Curb

Kitchen

9

Kitchen Work Centers (and Lavatory)

Objectives

- Determine comfortable heights of kitchen work surfaces and bathroom lavatories.
- Determine maximum and comfortable heights for shelves mounted above work counters.
- Determine minimum heights for base cabinets and electrical outlets.
- Evaluate the feasibility of faucet controls located in standard locations at the rear of sinks.

Apparatus

Similar testing stations were constructed for the kitchen sink, mix center, range and bathroom lavatory. All of these testing stations had adjustable counter and shelf heights and could be used with or without an opening under the counter. Sinks were set into counter tops. Counter heights were adjustable from 24 to 36 inches, measured from the floor to the top of the counter. An above counter shelf was adjustable from 40 to 70 inches. The upper shelf, where included, was constructed so that there would always be at least 15 inches clear distance between the counter top and underside of the shelf. The mix center had a feature that allowed us to test reach to the furthest corner inside a corner cupboard and the lowest reach below the counter (see Fig. 17). Counter tops were 1 1/2 inches thick and had supporting aprons 3 1/2 inches deep under the counter top surfaces.

Procedures

Testing procedures at each unit included two "fitting trials" for comfortable counter heights with an opening under the counter and reaching trials for maximum and comfortable heights of shelves above counters. Trials were conducted using simulated tasks common to each unit. At the mix center, subjects mixed ingredients in a bowl and simulated rolling dough with a rolling pin. At the sink, subjects reached to controls, scrubbed a pot with a brush and transferred the pot to the dishdrain. At the cooktop, subjects stirred contents in a pan on a front burner. At the lavatory, subjects reached to controls and simulated washing their faces.

In the first of each fitting trial, counter tops were set at the maximum height and lowered while subjects repeated the simulated tasks until the subject indicated a comfortable height had been reached. In the second trial, the counter was set at the minimum height and raised to a comfortable height.

At the mix center, users repeated the procedures with a closed counter front, reached to low shelves and reached laterally as well. Reaching trials to the shelves above counters utilized a 2 pound cylindrical cannister that could be grasped easily with one hand. When reaching above counters, shelf heights were first adjusted to the maximum height reached by an outstretched hand, measured to the thumb-forefinger joint. The shelf was then adjusted until the subject could reach and pick up the cannister when placed at the front edge. Finally, the shelf was adjusted to a comfortable height for removing the cannister from the rear of the shelf. Reaching trials to shelves below counters utilized a similar procedure.

In the second phase of testing, the mix center station was altered so that there was no front apron and the total depth of the counter assembly was only 1.5 inches. Twenty-five people in wheelchairs who had previously expressed comfortable counter top levels at heights as close as possible to the height of standard wheelchair arms, returned to repeat the procedure at the mix center. As in the first phase, comfortable working heights were found in two fitting trials. In addition, the counter top was set at 31 1/2 inches which provided 30 inches of knee clearance and enough clearance for standard wheelchair armrests. The counter top was adjusted further, if necessary, until a comfortable height was found. Once the user expressed preference for a particular height, the distance from the person's midriff to the counter edge was measured. Because standard wheelchair armrests may have restricted counter movement to lower, more comfortable heights, the counter was tested once more with wheelchair armrests removed. Only subjects with wheelchairs having removable armrests could be tested under this condition; thus, the sample size was reduced to seventeen.

Two lavatory heights were tested in the second phase (32 and 34 inch), measured from the floor to the rim. At each height, the distance was measured from counter edge to the nearest portion of the subject's body. After both heights were tested, subjects expressed their preference for one.

Subjects

Between 150 and 160 subjects tested each of the four adjustable counter work centers during the first phase of testing. The number of subjects at each work center varied somewhat because only cases without missing data were counted. Some subjects never completed testing during the first phase. There were 62 wheelchair users in the sample. Of these 62 subjects, twelve were paraplegics, eight were hemiplegics and thirteen had restrictions in use of three or four limbs. Sixteen had varying limitations of stamina. Nine had difficulty bending and turning and four had exceptional reaching and maneuvering abilities. The ambulant and semi-ambulant subjects included people with incoordination and manipulation difficulties, lifting and reaching difficulties, reliance on walking aids, difficulty bending and kneeling, difficulty sitting or getting up from a chair, difficulty using stairs, inclines or walking long distances and difficulty walking on rough surfaces. These 81 people plus eleven able-bodied people brought the total number of possible test subjects to 154.

During the second phase of testing, 25 wheelchair users returned to test the mix center. These people had expressed preferred counter top levels at or near wheelchair armrest heights. For the lavatory, 27 people returned who had larger than a 3 inch difference between comfortable open and comfortable closed front trials. This group included 23 wheelchair users.

Findings

As shown in Table 18, comfortable counter heights for all work centers for wheelchair users ranged from 26 to 36 inches. Subjects expressed preferences for open-front counters; the comfortable closed-front counters were usually less usable than the open-front counters. Because most people in wheelchairs assumed an approach parallel to the front of the counter in the closed-front position, their reach was limited in virtually all directions. Table 21 illustrates the dramatic increase in the number of users who could reach to the rear of upper shelves in the open-front mix center unit. With the 15 inch clearance between counter and over-counter shelf, few people (29 percent) could comfortably reach to the rear of the shelf. In other words, a low counter height of 25 inches to the work surface meant that the lowest limit of the upper shelf was 39 inches, which was still too high for most people to comfortably reach to the rear. Diagonal reach to the rear corner of shelves in a corner was virtually impossible for wheelchair users.

A comparison of data for comfortable counter top heights at the various work stations shows that a comfortable level is often a function of the task. At the kitchen sink station, a larger proportion of users preferred higher placement than in the mix center, because this brought the sink bottom, which is the actual work surface, to a comfortable level. Many users preferred the cooktop at lower heights, enabling them to see into a pan placed on the rear burner.

Comfortable counter heights for wheelchair users were often close to lap levels or below the height of wheelchair armrests. For those people who did not have desk arms or removable arms on their wheelchairs, this meant that their bodies were often positioned 8 or more inches away from the front edge of the counter. In the second phase of testing, the removal of the 3 1/2 inch supporting apron, did not alter this relationship; in fact, it allowed fifteen of the twenty-five wheelchair users to have the counter tops lowered even closer to their lap. In the first phase, many ambulatory and semi-ambulatory subjects also preferred counters lower than the standard 36 inch height.

There were wide differences between the two fitting trials for comfortable counter heights. However, these differences were consistently related to the starting position of the trial. The high starting position resulted in higher comfortable levels. This is most likely due to the short experience with each height provided by the testing situation. The two fitting trials must be viewed as bracketing the comfort range for an individual. Extensive work with each subject would probably narrow that range further for individuals. Considering the data in aggregate, a conservative approach to recommendations would utilize the raise-to-comfortable level trial to determine the lower range of comfort and the lower-to-comfortable trial to determine the upper range. It is also clear that some wheelchair users prefer the counter surface below armrest level and others above that level.

Many of the wheelchair users and a few of the ambulatory and semi-ambulatory subjects could not reach lower than 15 inches above the floor to pick up the cannister when located at the back of a shelf below a counter. All of the subjects could reach to at least 9 inches at the front of the low shelf. Over 80 percent of the subjects testing the two lavatory heights preferred the 32 inch height.

Recommendations

Residential kitchen counter tops should be adjustable to provide optimum working heights for different tasks and different users. A range of adjustability from 28 to 36 inches for a 1 1/2 inch thick work surface will provide comfortable height alternatives as well as leg clearance for most people. Another acceptable approach to adjustability could be to provide three alternative heights for: 1) standing work (36 inches), 2) sitting work with the work surface close to lap level (28 inches) and 3) sitting work with the work surface high enough for wheelchair arms to fit underneath (32 inches). Publicly-used facilities, such as lavatories, should be fixed at a compromise height of 32 inches, measured to the rim. Shelves above kitchen counters should be positioned so that at least one shelf of all cabinets above the counter is no more than 48 inches above the floor. Shelves below kitchen counters should have at least one shelf no lower than 15 inches above the floor.

Marginal Population

Wheelchair users who could not reach the front of the upper shelf set at 48 inches had poor stamina and difficulty bending and turning. A few wheelchair users with one or both legs affected were unable to reach the back part of the shelf. But most of those subjects who could not complete this task were in the groups having three or four limbs affected, those with limitations of stamina and those who have difficulty bending and turning.

Table 18: Comfortable Countertop Heights (with apron) for Wheelchair Users[a] (percentages in parentheses)

Counter Height: Equal to or Greater than	Counter Height: But less than	Cooktop: Open Front — Raise to Comfortable Level	Cooktop: Open Front — Lower to Comfortable Level	Kitchen Sink: Open Front — Raise to Comfortable Level	Kitchen Sink: Open Front — Lower to Comfortable Level	Bathroom Lavatory: Open Front — Raise to Comfortable Level	Bathroom Lavatory: Open Front — Lower to Comfortable Level	Mix Center: Open Front — Raise to Comfortable Level	Mix Center: Open Front — Lower to Comfortable Level
24 in	26 in	0	0	0	0	0	0	0	0
26	28	2 (3)	1 (2)	0	0	2 (4)	1 (2)	6 (10)	4 (7)
28	30	15 (28)	8 (14)	8 (14)	5 (8)	12 (22)	9 (17)	20 (34)	15 (26)
30	32	29 (54)	22 (41)	22 (39)	16 (28)	22 (41)	21 (39)	21 (36)	23 (40)
32	34	3 (6)	16 (30)	15 (26)	20 (35)	14 (26)	15 (28)	6 (10)	11 (18)
34	36	5 (9)	7 (13)	10 (17)	14 (25)	4 (7)	8 (15)	1 (2)	4 (7)
36		0	0	1 (2)	1 (2)	0	0	1 (2)	0
Missing data		0	0	0	1 (2)	0	0	3 (6)	1 (2)
No performance		0	0	1 (2)	0	0	0	0	0
Total		54 (100)	54 (100)	57 (100)	57 (100)	54 (100)	54 (100)	58 (100)	58 (100)

[a] Does not include those with exceptional abilities.

Table 19: Comfortable Countertop Heights (with apron) for Non-Wheelchair Users[a] (percentages in parentheses)

Counter Height: Equal to or Greater than	But less than	Cooktop: Closed Front — Raise to Comfortable Level		Cooktop: Closed Front — Lower to Comfortable Level		Kitchen Sink: Closed Front — Raise to Comfortable Level		Kitchen Sink: Closed Front — Lower to Comfortable Level		Bathroom Lavatory: Closed Front — Raise to Comfortable Level		Bathroom Lavatory: Closed Front — Lower to Comfortable Level		Mix Center: Closed Front — Raise to Comfortable Level		Mix Center: Closed Front — Lower to Comfortable Level	
24 in	26 in	0		0		0		0		0		0		1	(1)	1	(1)
26	28	0		1	(1)	0		0		2	(3)	0		2	(2)	1	(1)
28	30	3	(4)	0		3	(4)	2	(2)	0		0		7	(8)	1	(1)
30	32	9	(11)	6	(7)	6	(7)	3	(4)	7	(9)	0		20	(24)	9	(11)
32	34	23	(28)	10	(12)	15	(18)	4	(5)	18	(23)	15	(19)	23	(27)	20	(24)
34	36	35	(42)	35	(42)	28	(33)	24	(28)	30	(39)	27	(35)	20	(24)	23	(27)
36		13	(15)	30	(36)	31	(36)	50	(59)	19	(25)	32	(43)	11	(13)	29	(34)
Missing data		0	—	1	(1)	2	(2)	2	(2)	1	(1)	2	(3)	1	(1)	1	(1)
Total		83	(100)	83	(100)	85	(100)	85	(100)	77	(100)	77	(100)	85	(100)	85	(100)

[a]Does not include able-bodied subjects.

Table 20. Comfortable Countertop Heights for Able-Bodied Control Sample (percentages in parentheses)

Counter Height		Cooktop: Closed Front				Kitchen Sink: Closed Front				Bathroom Lavatory: Closed Front				Mix Center: Closed Front			
		Raise to Comfortable Level		Lower to Comfortable Level		Raise to Comfortable Level		Lower to Comfortable Level		Raise to Comfortable Level		Lower to Comfortable Level		Raise to Comfortable Level		Lower to Comfortable Level	
Equal to or Greater than	But less than																
24 in	26 in	0		0		0		0		0		0		0		0	
26	28	0		0		0		0		1	(7)	1	(7)	0		0	
28	30	1	(7)	1	(7)	0		0		0		0		1	(7)	0	
30	32	0		0		0		0		0		0		1	(7)	2	(14)
32	34	1	(7)	1	(7)	2	(14)	1	(7)	1	(7)	1	(7)	1	(7)	0	
34	36	3	(22)	1	(7)	0		1	(7)	3	(22)	3	(22)	3	(22)	4	(29)
36		9	(64)	11	(79)	12	(86)	12	(86)	9	(64)	9	(64)	8	(57)	8	(57)
Total		14	(100)	14	(100)	14	(100)	14	(100)	14	(100)	14	(100)	14	(100)	14	(100)

Table 21: Furthest Reach to Shelf Above Counter for Wheelchair Users (percentages in parentheses)

Shelf Height		Open Front: Front of Shelf	Closed Front: Front of Shelf	Open Front: Back of Shelf	Closed Front: Back of Shelf	Open Front: Comfortable Back of Shelf	Closed Front: Comfortable Back of Shelf
Equal to or Greater than	But less than						
40 in	44 in	0	0	0	0	0	0
44	48	6 (10)	16 (28)	21 (36)	23 (40)	17 (29)	9 (16)
48	52	12 (21)	19 (33)	18 (32)	11 (19)	11 (19)	6 (10)
52	56	21 (36)	14 (24)	6 (10)	1 (2)	2 (3)	0
56	60	13 (23)	5 (9)	2 (3)	1 (2)	0	0
60	64	2 (3)	0	0	0	0	0
64	68	3 (5)	1 (2)	1 (2)	0	1 (2)	0
68	72	0	0	0	0	0	0
72		0	0	0	0	0	0
No performance		1 (2)	3 (4)	10 (17)	23 (40)	27 (47)	48 (74)
Total		58 (100)	58 (100)	58 (100)	58 (100)	58 (100)	58 (100)

Table 22: Furthest Reach to Shelf Above Counter for Non-Wheelchair Users[a] (percentages in parentheses)

Shelf Height		Closed Front: Front of Top Shelf		Back of Top Shelf		Comfortable Back of Top Shelf	
Equal to or Greater than	But less than						
No performance		2	(2)	3	(4)	4	(5)
40 in	44 in	0		0		0	
44	48	1	(1)	0		4	(5)
48	52	2	(2)	5	(6)	4	(5)
52	56	2	(2)	3	(4)	15	(18)
56	60	4	(5)	11	(13)	20	(24)
60	64	12	(14)	20	(24)	21	(25)
64	68	19	(23)	21	(25)	14	(17)
68	72	38	(46)	17	(20)	0	
72		5	(6)	3	(4)	2	(2)
Total		83	(100)	83	(100)	83	(100)

[a] Does not include able-bodied subjects.

Table 23: Comparison of Comfortable Countertop Heights for Use With and Without Wheelchair Armrests in Place (percentages in parentheses)

Counter Height: Equal to or Greater than	But less than	Arm Rests: Trial 1: Raise to Comfortable		Arm Rests: Trial 2: Lower to Comfortable		Arm Rests: Trial 3: Adjust from 31 1/2 Inches		No Arm Rests: Trial 1: Raise to Comfortable		No Arm Rests: Trial 2: Lower to Comfortable		No Arm Rests: Trial 3: Adjust from 31 1/2 Inches	
26 in	27 in	5	(20)	2	(8)	0		7	(40)	0		0	
27	28	7	(28)	3	(12)	1	(1)	0		2	(12)	2	(12)
28	29	9	(36)	3	(12)	5	(20)	4	(24)	4	(24)	1	(6)
29	30	2	(8)	3	(12)	5	(16)	3	(18)	3	(18)	4	(24)
30	31	1	(4)	8	(32)	4	(16)	3	(18)	4	(24)	5	(28)
31	32	0		2	(8)	10	(40)	0		2	(12)	4	(24)
32	34	0		3	(12)	0		0		1	(6)	0	
34	36	1	(4)	1	(4)	0		0		1	(6)	0	
Missing data		0		0		1	(4)	0		0		1	(6)
Total		25	(100)	25	(100)	25	(100)	17	(100)	17	(100)	25	(100)

Table 24: Comparison of Distances to Body at Comfortable Countertop Heights for Use With and Without Wheelchair Arm Rests in Place (percentages in parentheses)

Counter Height		Arm Rests						No Arm Rests					
Equal to or Greater than	But less than	Trial 1: Distance to Body		Trial 2: Distance to Body		Trial 3: Distance to Body		Trial 1: Distance to Body		Trial 2: Distance to Body		Trial 3: Distance to Body	
-- in	2 in	2	(8)	3	(12)	2	(8)	7	(40)	6	(34)	7	(40)
2	4	4	(16)	5	(20)	6	(24)	4	(24)	4	(24)	2	(12)
4	6	6	(24)	5	(20)	6	(24)	3	(18)	4	(24)	5	(30)
6	8	6	(24)	5	(20)	4	(16)	2	(12)	2	(12)	2	(12)
8	10	4	(16)	2	(8)	3	(12)	0		0		0	
10		3	(12)	5	(20)	4	(16)	1	(6)	1	(6)	1	(6)
Total		25	(100)	25	(100)	25	(100)	17	(100)	17	(100)	17	(100)

Table 25: Reach Above Floor to the Rear of Low Shelves

Equal to or Greater than	But less than	Wheelchair Users		Non-Wheelchair Users	
-- in	6 in	15	30%	66	78%
6	9	9	15%	4	5%
9	12	7	11%	4	5%
12	15	1	8%	3	4%
15	18	7	11%	3	4%
18		9	15%	3	4%
Total		58	100%	83	100%

Table 26: Preferred Lavatory Heights

Distance to Body		32 Inch Height		34 Inch Height	
Equal to or Greater than	But less than				
-- in	2 in	7	26%	6	22%
2	4	3	12%	2	7%
4	6	6	22%	6	22%
6	8	6	22%	6	22%
8	10	2	7%	3	12%
10	12	1	4%	1	4%
12		2	7%	3	12%
Total		27	100%	27	100%
Preferred		22	81%	4	19%[a]

[a] Missing data: 1

Figure 17: Apparatus for Testing Kitchen Counter Work Centers and Lavatory

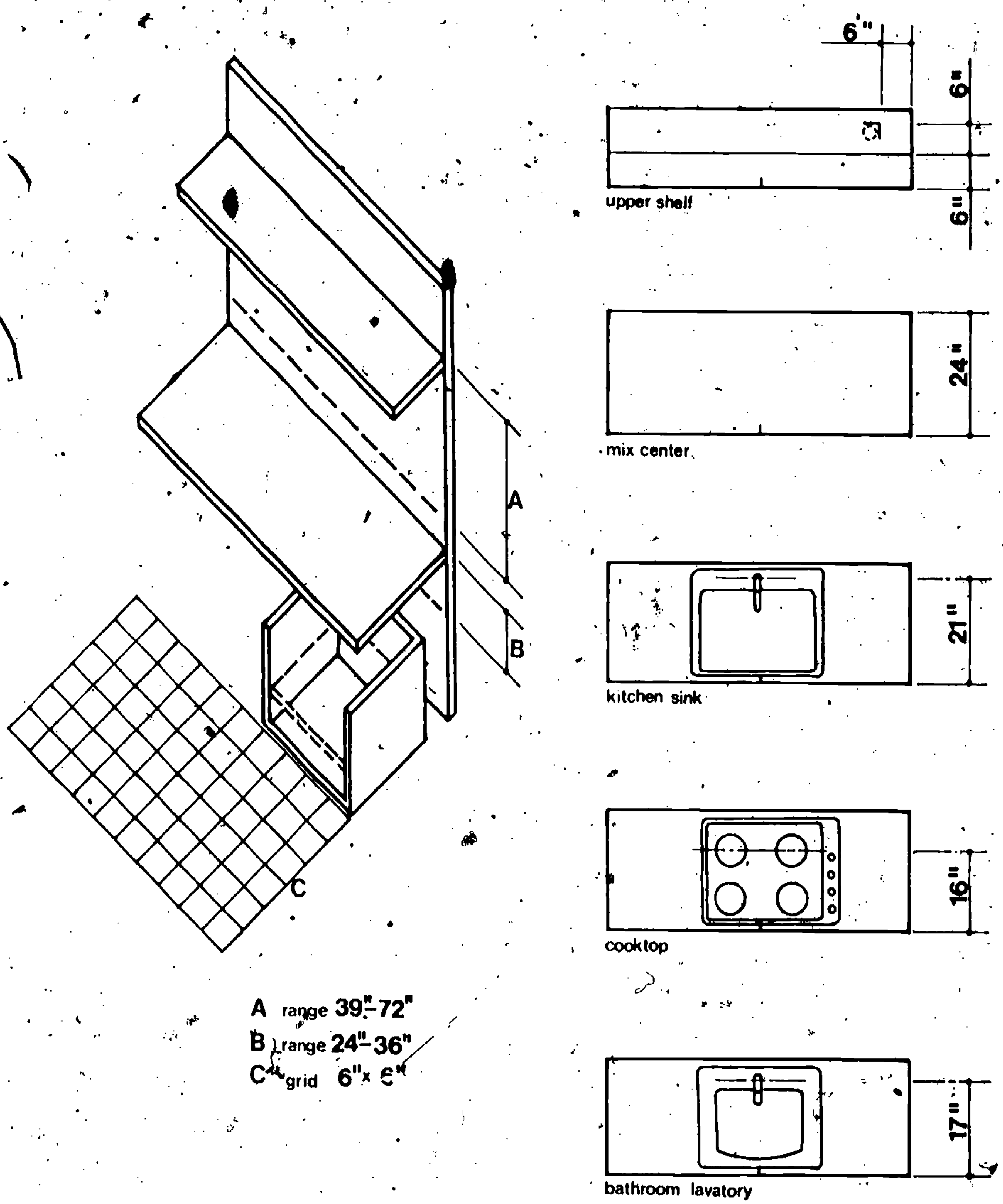


Figure 18: Mix Center Testing Procedures

Perpendicular Approach, Open Front

Closed Front, Parallel Approach

Maximum Reach Below Counter at Front of Shelf

Comfortable Reach Below Counter at Back of Shelf

Confortable Reach Above Counter at Front of Shelf

Maximum Reach Above Counter at Rear of Shelf

Maximum Reach in Simulated Corner Condition

Oven

Objectives

- Identify the optimal positions and door types for use of ovens by people with disabilities.
- Evaluate the usefulness of clear access space next to and in front of the oven for people who use wheelchairs.

Apparatus

A simulated oven could be set up in eight different configurations of height, door type and access space under a side counter, as shown in Fig. 19. A 6 inch grid was marked on the floor to determine space clearances necessary for seated users. Individuals simulated cooking in and cleaning ovens. In the first phase of testing, cooking in the oven was simulated by transferring a light cake pan from a counter top to an oven rack and reversing the procedure for removing the pan. A light pan was used in the first phase because we were interested in individuals' abilities to use various oven configurations, not their abilities to lift weights. Cleaning the oven was simulated by reaching behind a line located 6 inches from the back of the oven on the bottom surface of the compartment. Success in all these tasks with one oven configuration constituted a successful trial. A pull-out board was available for use in transferring the pan in and out of the ovens with side-hung doors. A chair was available for use if ambulant or semi-ambulant subjects preferred to sit down while using an oven.

Procedure

The oven configurations were assigned levels of difficulty. Subjects tested the most difficult first. The first oven tested was similar to most conventional floor model ranges--below counter level, drop-down door and no open access area at the side. The second oven tested was again below counter level with no access at the side, but the door could be side-hinged on either side. Successful performances in all tasks in either the first or second oven configurations precluded further testing of additional oven types.

If the subjects were unsuccessful in all tasks in both ovens, they were tested with a group of four ovens, and their preference was solicited among those at which all tasks were successfully performed. The four configurations in this group were: conventional below counter oven with drop-down door and access at one side, below counter oven with side-opening door and side access, an above counter oven with a drop-down door and no side access and an above counter oven with a side-opening door with no access at the side.

If, after testing with the first six ovens, the subject still was not able to successfully perform all tasks, he or she then was tested with the last two ovens. Preferences were solicited if they were successful with both. The last two oven configurations were both above counter models, one with a drop-down door and access at the side, the other with a side-opening door and access at the side.

After the subject had performed all tasks successfully at a particular oven or expressed their preference for one out of a group, that oven was retested. The position of a wheelchair, or if the subject was seated--the chair, was recorded. All ovens, either above or below counter, were attached to a counter that was adjusted to the individual's "comfortable" height for the cooktop work center.

During the second phase of testing, a group of five people, all of whom could at least cook with the conventional, below counter, drop-down door oven with no side access, returned to test three oven configurations with a weighted pan. Subjects used the heaviest weight they could manage ranging from 1 to 4 pounds. The three ovens--the conventional floor model with drop-down door and no side access, and two above counter models with side access--one with a drop-down door and one with a side-opening door, were heated with a hair dryer to simulate the inherent hazards of using an oven.

Subjects

During the first phase of testing, 137 subjects were tested from all disability categories except those people with incoordination and difficulties manipulating fingers and difficulty walking long distances. Eleven able-bodied people were also tested. During the second phase, the test group of five people consisted of four wheelchair users and one semi-ambulant person. All the people in the second phase group were active homemakers who regularly used their home ovens.

Findings

The data for the first round of testing are presented in Table 27. Almost all subjects were able to transfer pans to and from the conventional floor model oven. However, it was apparent that the above counter oven configurations were clearly easier to clean. The side opening door was easier for cleaning than the drop-down door. Open access next to the oven improved cleanability still further. For wheelchair users, the above counter, side-hinged door with open access at the side was most usable (cooking and cleaning). The drop-down door presented an obstacle to cleaning the rearmost parts of the oven for some wheelchair users, even if side access was provided. Although 67 percent of the wheelchair users could cook and clean without the open space (side-hinged door), 96 percent could cook and clean with it.

The drop-down door served as a convenient resting place for transferring pans into and from the oven. Therefore, a pullout board immediately below an above counter oven with a side-hinged door would be desirable. No one in the sample used the board provided, perhaps because of its unfamiliarity, but they agreed it would be helpful when the board was made known to them.

In the second phase of testing, the subjects tested the three oven configurations. While all people could use the conventional below counter oven with the drop-down door and no side access with the light weight pan, only two could use it with weighted pans. The crucial factors when using the weighted pans are the ability to get close to the oven and the ability to transfer the pan with a minimum of lifting and reaching (laterally extending the arms). Thus, the above counter ovens with side access remained the most usable ovens with virtually all people being able to use them with weighted pans.

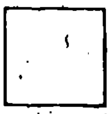
Recommendations

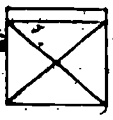
Counter top ovens with an accessible space below an adjacent counter should be required in housing for disabled people. Ovens not meeting these requirements would be minimally acceptable if they were self-cleaning. Such ovens could be used easily by most people to cook light weight dishes.

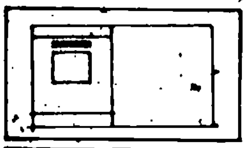
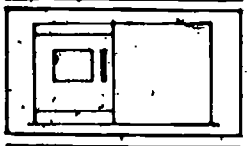
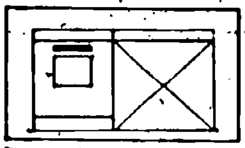
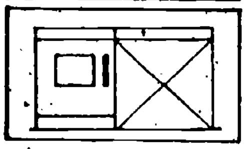
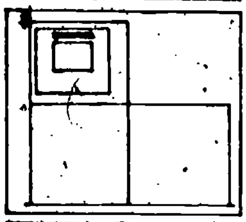
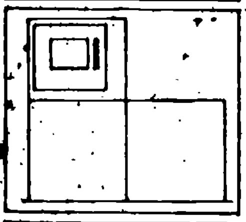
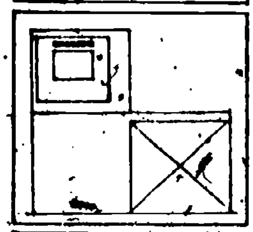
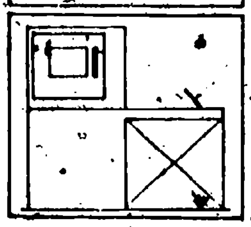
Marginal Population

Few people would have difficulty using a self-cleaning oven installed below a counter, as long as only light weight dishes were cooked. People with reaching or lifting problems, e.g. quadriplegics or hemiplegics, those with difficulty bending, would not be able to cook heavy dishes in such an oven. Ovens at counter height, with side access provided, would be usable by almost all people, even if they were not self-cleaning.

Table 27: Oven Use with Light Weight Pan

Closed 

Open 

	Oven	ambulant semi-ambulant: Total	Unsuccessful in all tasks	Cook, but could not clean	Successful in all tasks	Missing data	wheelchair users: Total	Unsuccessful in all tasks	Cook, but could not clean	Successful in all tasks	Missing data
1.		82 (100)	3 (4)	69 (84)	10 (12)	0 -	54 (100)	1 (2)	53 (98)	0 -	0 -
2.		72 (100)	2 (3)	66 (92)	4 (5)	0 -	54 (100)	3 (6)	49 (90)	2 (4)	0 -
3.		0 -	0 -	0 -	0 -	0[a] -	52 (100)	2 (4)	49 (9)	0 -	1 (2)
4.		0	0	0	0	0[a]	52 (100)	2 (4)	49 (94)	0 -	1 (2)
5.		71 (100)	3 (3)	15 (21)	52 (75)	1 (1)	52 (100)	6 (12)	34 (65)	11 (21)	1 (2)
6.		68 (100)	1 (2)	0 -	64 (94)	3 (4)	52 (100)	1 (2)	13 (25)	36 (69)	2 (4)
7.		0 -	0 -	0 -	0 -	0[a] -	16 (100)	2 (12)	11 (69)	3 (19)	0
8.		0 -	0 -	0 -	0 -	0[a] -	16 (100)	2 (12)	4 (24)	10 (64)	0

[a]Ovens 3 and 4 are essentially the same as 1 and 2, unless a person is seated or uses a wheelchair; only one person who was not a wheelchair user chose to sit, thus, these ovens were not tested for ambulant or semi-ambulant subjects.

Table 28: Oven Use with Weighted Pan

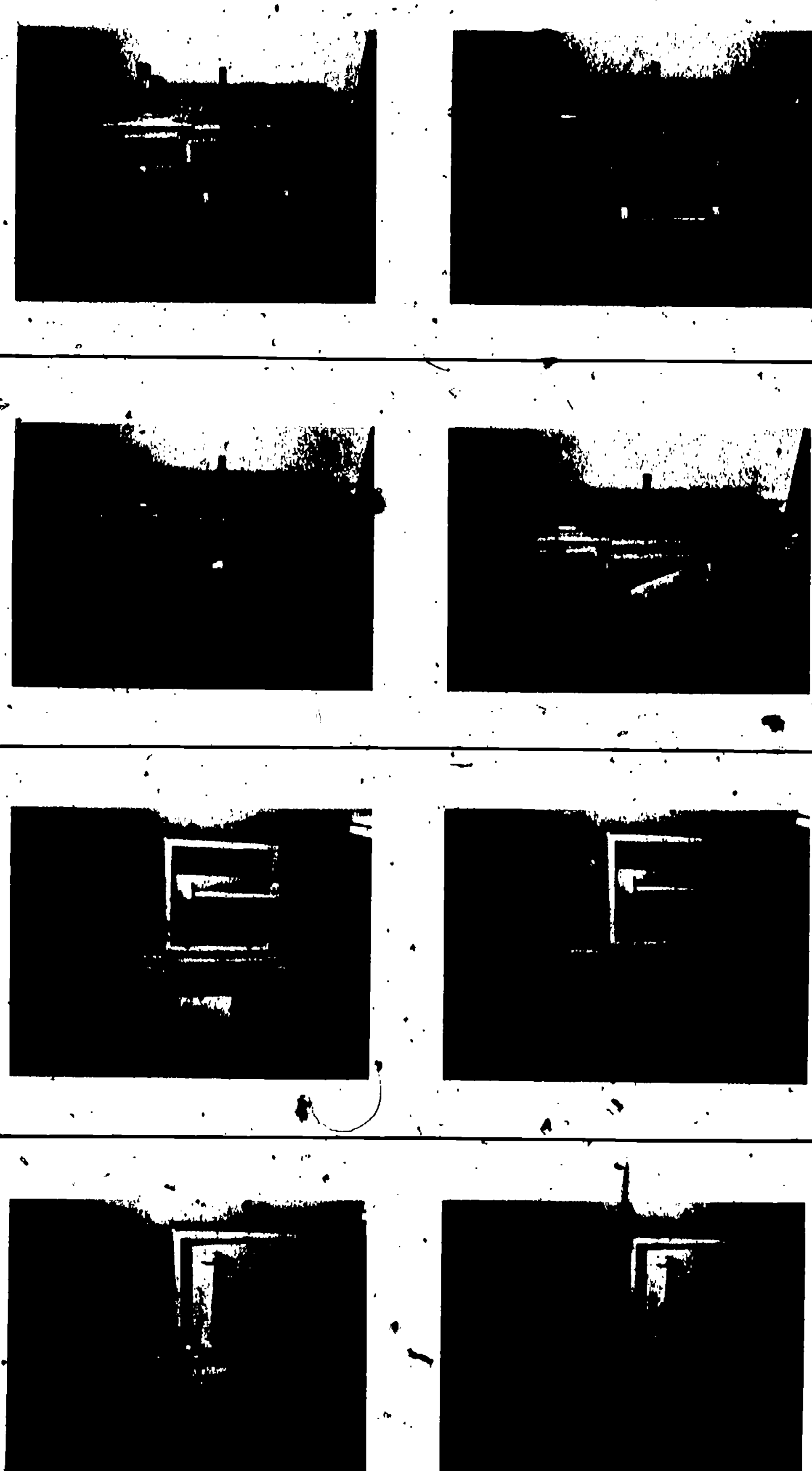
User Data		Phase 1	Phase 2		
			Oven Performance[b]		
Wheelchair	Ambulant or Semi-Ambulant	Oven Usability with Light Weight Pan[a]	Oven No. 1	Oven N[illegible]	[illegible]n No. 8
X		1	9	3	3
X		1	9	9	3
X		1	3	3	3
X		1	9	3	3
	X	1	3	3	3

[a] See Table 27

[b] 9 = Unable to cook
3 = Able to cook

Figure 19: Oven Applications

No Access | Side Access



Below Counter, Drop Door

Below Counter, Side-Hinged Door

Above Counter, Drop Door

Above Counter, Side-Hinged Door

Kitchen Layouts

Objectives

- Assess the feasibility of using minimum clearances from HUD's Minimum Property Standards in accessible kitchens.
- Determine the most suitable layouts for accessible kitchens.

Apparatus

Kitchen work centers were constructed with counter frontages as required by the US Department of Housing and Urban Development's Minimum Property Standards. Frontages based on a one bedroom apartment were used. Shelves were provided above the sink and the mix center work station. The work center units were designed as independent, movable units so that they could be combined in any desired order or layout. All counter and shelf heights were adjustable. The area under counters could be filled in with low partitions, left open or provided with a movable low shelf unit.

Procedure

Four kitchen layouts were tested: 1) U-shape, 2) L-shape, 3) in-line and 4) corridor. Sinks and mix centers were left open underneath; a low shelf unit was placed under one counter; all other under counter areas were closed. Layouts provided a space under or adjacent to every work center. Space clearances between counters were 40 inches for the in-line and corridor kitchen and 60 inches for the U-shape kitchen. Ovens were mounted below the counters with side access and a side opening door. Storage shelves were mounted at a height of 48 inches from the floor. All counters were set at 31 1/2 inches to the top surface and provided 30 inch clearance to the underside. A tray was provided for carrying materials.

Each subject completed a standardized sequence of tasks. The tasks simulated, in a compressed time frame, were all activities in preparing a meal and cleaning up. The set of tasks were designed to insure that subjects would utilize every part of the kitchen layout. Table 29 gives the tasks and their sequence. As subjects completed one task, they were then told the next task until the complete activity sequence was completed. Two observers counted the number of bumps made against counters and appliances and the number of accidents (e.g. spilling, dropping) at each layout. Total time required to complete the sequence at each layout was recorded. The order of testing the layouts was varied with each subject. After testing all four layouts, users were asked for their preferences regarding the layouts tested, counter heights and storage options.

Subjects

Ten female disabled subjects, including seven wheelchair users who had exhibited below-average abilities in maneuvering wheelchairs during the first phase of testing were tested. Kitchen clearances satisfactory for use by these subjects would also be satisfactory for use by all other subjects. All these subjects were active homemakers who used kitchens regularly and intensively. One female able-bodied subject was also tested.

Findings

When using the more open arrangements, U and L-shape, subjects generally had less bumps or accidents than in the other, more compact kitchens. The U and L-layouts were also the preferred types. Times varied considerably according to the individual's abilities to follow instructions and accommodate themselves to each layout. Efficiency in using the kitchen layouts would undoubtedly improve with practice.

Several problems and techniques in using kitchens were observed. One hemiplegic wheelchair user had difficulties maneuvering the chair while transporting materials. Similar problems were encountered by obese users who could not use their laps to support trays, etc. Several of these people used the front edge of the counter much like a railing, pulling themselves along.

Since we were interested in observing possible conflicts in movement between work stations, the instructions were designed to elicit the greatest number of trips between work stations. Subjects indicated that, had it been their own routine, they would have condensed and combined the tasks into fewer trips.

Subjects favored all counters at the same height rather than each work center set at a different height and found it easier to reach below counters to storage areas than above them. In the testing with separate kitchen work centers, it was found that comfortable counter heights were different for different stations. Thus, preference for counter heights at the same level conflicts with comfort criteria. This preference may be due to the convenience of sliding utensils along the counter or to an aesthetic concern.

Recommendations

HUD minimum clearances are usable but clearances in accessible kitchens should be increased for convenience and maintainability, particularly in in-line and corridor layouts. When making up the loss of storage cabinets due to required under-counter clearances, the use of full height storage units or under counter units (perhaps on wheels) is preferred. The U and L-shaped layouts are preferred for accessible housing.

Marginal Population

Those wheelchair users who have difficulties maneuvering will have slight problems using in-line and corridor arrangements. Those that are obese and have difficulty lifting would find L and U-shaped arrangements more convenient since objects can be slid along counters.

Table 29: Kitchen Layout Activities

Task No.	Task Description
1	Get celery from refrigerator, take to sink and wash celery.
2	Take celery to mix center.
3	Go to refrigerator, take meat and egg to mix center.
4	Get water from sink, bring back to mix center.
5	Reach above for bowl and other ingredients.
6	Reach below for the loaf pan, take to mix center.
7	Go to stove; get spices from back, bring to mix center.
8	Take prepared meatloaf and place in oven.
9	Get two dishes from above and silverware from drawer, take to kitchen table and set table.
10	Go to oven, take out meatloaf using potholder and bring to table.
11	Take two dishes and silverware to sink.
12	Take meatloaf to refrigerator.

Table 30: Use of Four Kitchen Layouts

User		Kitchen Shape: 1. U-Shape		2. L-Shape		3. Corridor		4. In-Line		Layout					
Wheelchair	Ambulant/Semi-Ambulant	Time	No. of Bumps	Time	No. of Bumps	Time	No. of Bumps	Time	No. of Bumps	Counters Same	Counters Different	Storage Above Counters Preferred	Storage Below Counters Preferred	Favorite Layout	Least Liked Layout
X		2:40	0	3:10	2	2:40	1	3:40	1	X			X	4	2
X		5:35	4	5:45	2	7:40	15	4:55	13	X			X	1	4
X		5:40	4	5:45	5	6:55	6	5:20	2		X		X	4	
X		3:50	3	5:46	0	4:20	2	4:10	4	X		X		1	3
X		5:15	4	8:17	3	8:25	2	7:00	2	X			X	1	3
X		5:25	2	4:42	2	6:30	5	7:30	11	X			X	1,2	3,4
X		[illegible]:05	1	3:03	0	3:00	0	3:05	2	X		NP*	NP*	2	4
X		2:40	0	2:10	0	4:02	1	3:27	11	X		X		2	3
	X	2:48	0	2:27	0	2:14	1	2:14	0		X	NP*	NP*	1	2
	X	8:35	0	4:30	0	3:45	0	10:45	0	X		X		4	1

*No preference.

Table 31: Layout Testing Sequence

U-Shape	1	2	3	4
L-Shape	2	3	4	1
Corridor	3	4	1	2
In-Line	4	1	2	3

Table 32: Kitchen Layout Subject Data

Disability Level	Height (in in.)	Weight (in lb.)	Age: Less than 20	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79	80 and Over	Cooking Frequency: At Least Once A Day	At Least Once A Week
Transfers, negotiates ramps & performs household tasks without help	60	110				X					X	
Maneuvers wheelchair well; needs help with transfers, ramps & some household tasks	65	250					X				X	
Maneuvers on level surfaces with shortness of breath	61	115				X					X	
Maneuvers on level surfaces without shortness of breath	64	155							X		X	
Maneuvers on level surfaces without shortness of breath	66	175					X				X	
Manages shallow inclines without shortness of breath	65	135					X				X	
Difficulty bending to reach lower than 1 ft from floor	63	175							X			X
Has exceptional maneuvering abilities	65	124					X				X	
Uses walking aid; unable to manage stairs & ramps without difficulty	64	120						X			X	
Able-bodied	65	165						X			X	

Figure 20: Kitchen Layouts Tested

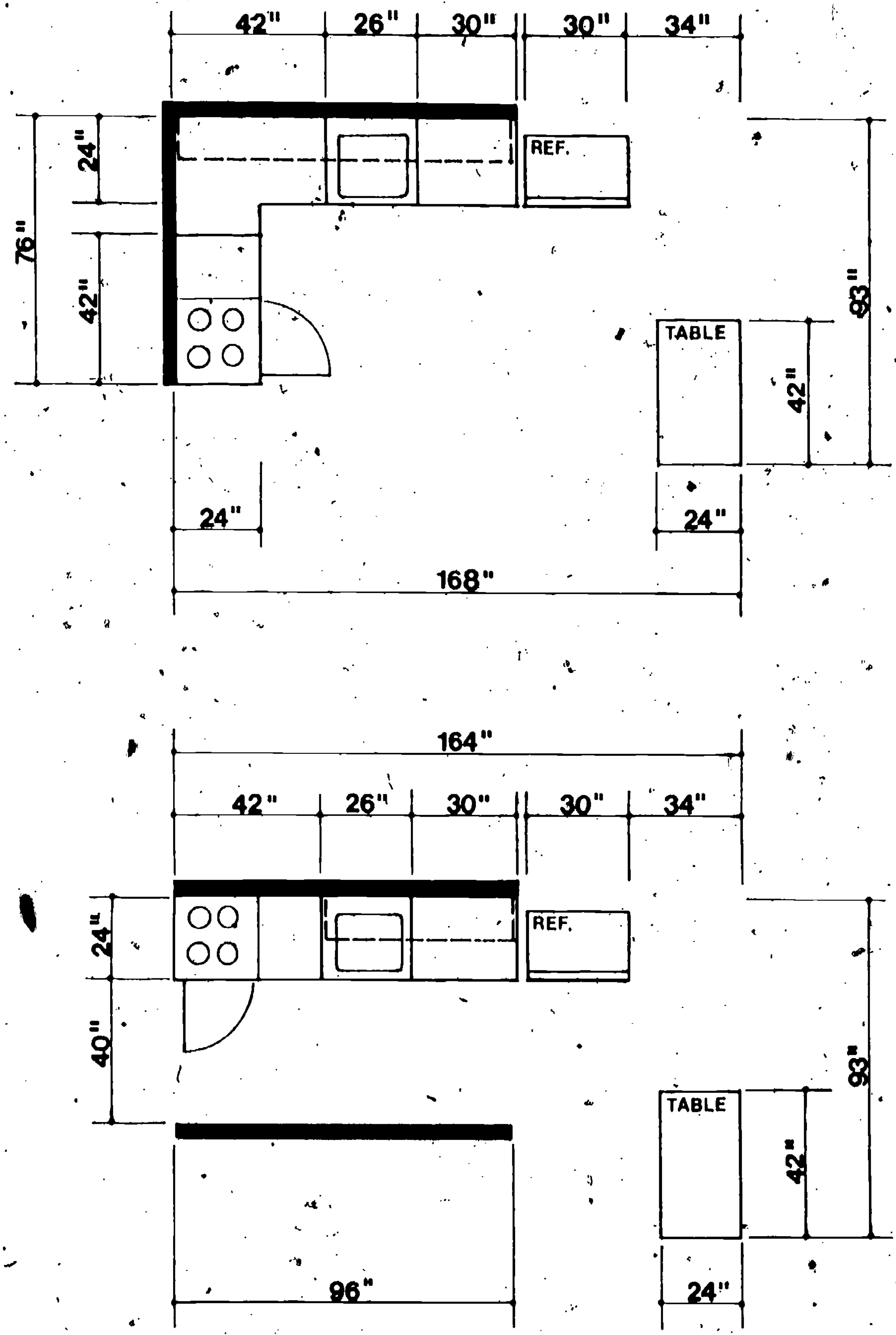


Figure 21: Kitchen Layouts Tested

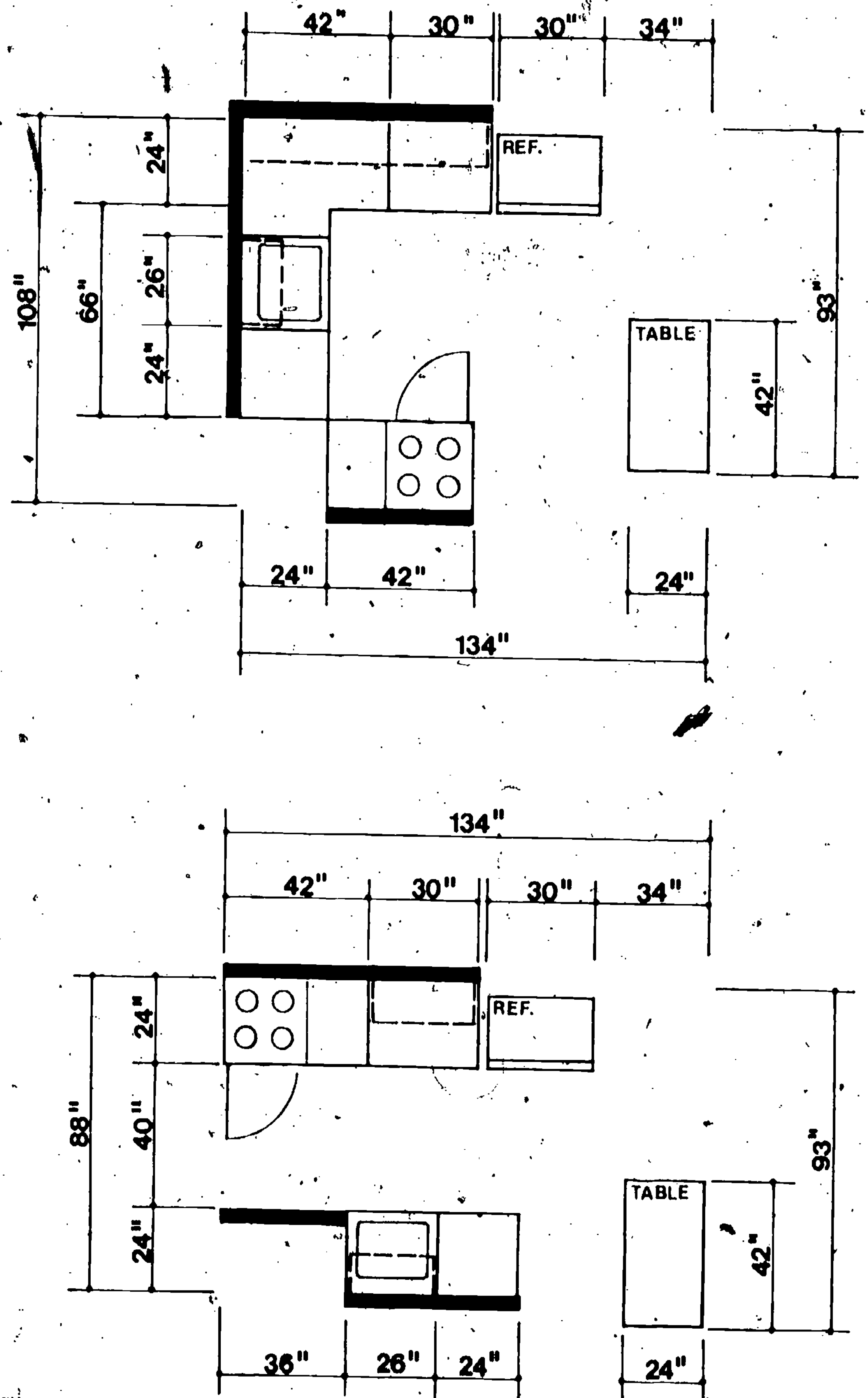
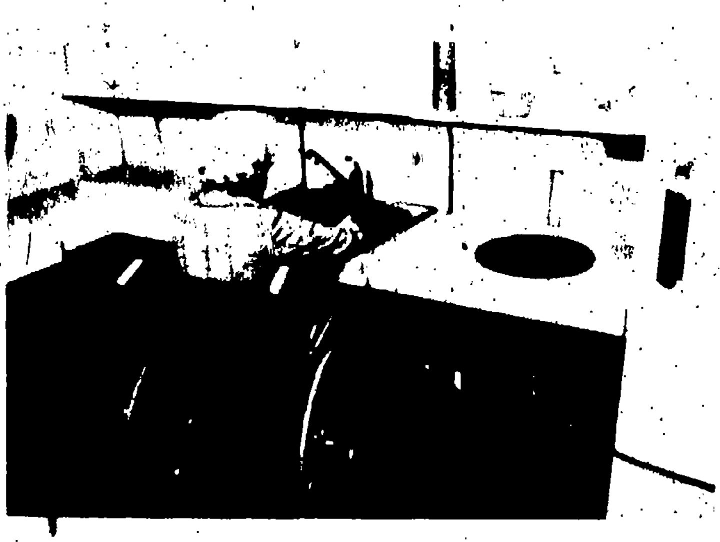


Figure 22: Kitchen Layout Testing Procedures

Reaching at Mix Center in L-Shape Layout

Placing Pan in Below-Counter Oven with Side-Hinged Door



Washing Pan at Sink

Transferring Pan from Mix Center to Refrigerator

Doorways 10

Doorways

Objectives

- Determine the minimum convenient clear width for hinged doors.
- Determine the minimum clearances required in front of doors for various types of approaches.
- Evaluate the impact of door closers and thresholds on the ability to manage hinged doors.

Apparatus

Two doorways with hinged, hollow-core interior doors were constructed--one with a 30 inch and the other with a 32 inch clear opening. Both had lever shaped door openers. Solid moving walls were constructed that could be positioned parallel to doors and fixed, by means of spring activated door stops, to provide any desired clearance in front of the doorways. A 6 inch grid was marked on the floor for measuring the clearance between wall and door frame and the space used by subjects beyond the latch side of a door. In a second phase of testing, three door closers were installed in the 32 inch clear door. The closers were adjusted to 5 lbf. for opening.

Procedure

A subject tested doors using his least favored hand in three opening approach patterns: 1) direct forward, 2) from the latch side and 3) from the hinge side. Thus, in the hinge side approach pattern, the right handed subjects tested a door hinged on the left side, approaching the door with their worse side (left) nearest the door. The subject had to reach across their body with their right hand in order to open the door or use their non-favored hand. All doors opened outward toward the subject and into the corridor.

Several trials of each approach pattern were run to determine minimal size door and corridor width possible for each person. In the approaches other than direct forward, the corridor width was initially set at 5 feet. The movable corridor wall was then adjusted within 6 inches of the space required. In the hinge side approach, two observers were used--one to check corridor width and one to check the space needed at the latch side.

Only wheelchair users participated in the trials using door closers. All closers were attached to the door with the 32 inch clear opening and subjects passed through using only the direct forward approach pattern.

In a final round of testing, wheelchair users tested the 32 inch clear opening door width when fitted with a 3/8 inch square edge threshold. All three approach patterns were tested.

Subjects

In phase one, wheelchair users, walking aid users, walking aid users with low stamina, and able-bodied people were tested. A total of 78 subjects with disabilities were tested, including 54 wheelchair users. Four wheelchair users with exceptional abilities were also tested but data is not reported here.

During the second phase of testing, eleven wheelchair users returned to test the door closers. Most of these people had either difficulty maneuvering and/or stamina problems. Six of these people returned to test the door outfitted with a threshold.

Findings

Only four of the 54 wheelchair users, in the first phase, could not manage the doorway with the 30 inch clear width, using a direct front approach. These four individuals were not able to use the 32 inch clear width door either. Three of these people were quadriplegics and one came to the testing site with a malfunctioning, one-arm drive wheelchair. In the two other approaches, latch side and hinge side, the same four individuals were the only subjects who could not use the 30 inch clear width.

Table 33 shows the clearances needed at the latch side of the door with the direct forward approach. Many of the subjects who needed over 24 inches at the latch side, had either difficulty maneuvering their wheelchairs or difficulty leaning forward and had to assume a position almost parallel to the door wall. Table 33 shows that a 12 inch clearance at the latch side was unsatisfactory to over half of the test sample, while a 24 inch clearance at the latch side was satisfactory to approximately 80 percent of the test sample.

The data for the latch side approach, shown in Table 34 shows that 63 percent of the test sample could negotiate the 30 inch doorway with a corridor width less than 42 inches. Increasing the corridor width to 48 inches would accommodate 87 percent of the sample. Generally, subjects who needed wider corridor widths also needed wider spaces at the latch side. Wheelchair users who were hemiplegics, quadraplegics or had limitations of stamina needed larger corridor widths and latch side clearances than others to manage the doorways.

Coming from the hinge side, approximately two-thirds of the subjects (65 percent) needed more than 24 inches clearance at the latch side. An additional 12 inches at the latch side, or 36 inches total clearance, accommodated 78 percent of the subjects. Virtually all subjects would be accommodated with a 48 inch clearance at the latch side. A 60 inch wide corridor would accommodate 92 percent of the subjects. A 6 inch reduction in width to 54 inches would reduce the number of subjects able to negotiate the maneuver to 66 percent of the total wheelchair sample. All walking aid users were able to complete the task with a corridor width of 48 inches or less and an 18 inch wide space at the latch side of the door.

In the second phase of testing, two-thirds of the subjects could negotiate the three second spring closer time as shown in Table 36. Those people who could not manage the door with the spring type closer all had severe disabilities restricting strength and arm movement. Increased times helped only one tester who satisfactorily completed the tasks with the closer set at 11 seconds. All users could use the manual devices and free-opening doors; a majority preferred the horizontal bar.

In the final phase of testing, the three approach patterns were tested with a threshold in place. All six subjects needed at least as much space as needed in their former trials without the threshold. In the direct forward approach, the latch side clearance in most cases was not increased. In the two other approaches, the clearances generally increased 6 inches at either the latch side and/or the corridor width. The principle problem here was that when subjects approached the threshold at an angle, their movement was impeded abruptly. The subjects had to realign themselves to pass through the door at a right angle to the threshold.

Recommendations

Clearances in front and at the latch sides of doors should be based on the approach pattern and direction of door swing. Where doors swing out into the direction of travel, toward the user, wider corridors and larger spaces at the latch side should be provided as follows: 1) direct forward approach--24 inches at the latch side, 60 inch clearance in front of the door; 2) latch side approach--48 inch corridor width (latch side clearance not applicable); and 3) hinge side approach--42 inches at the latch side, 60 inch corridor width.

Where doors swing away from the user, narrower corridors can be used. With this door condition, space requirements can be based on L-turns. Approaches from the hinge side and latch side each require a corridor width of 42 inches and no space at the latch side (for further information, see Wheelchair Maneuvering). With the direct forward approach, a 12 inch clearance at the latch side is preferred with a space 60 inches deep in front of the door.

Thresholds are not recommended at interior doorways. Even in exterior locations they should not exceed a 1/2 an inch in height and the edges should be beveled. Door closers are not recommended in interior locations but an assist such as the horizontal bar is desirable.

Marginal Population

The wheelchair users who required more than the recommended corridor widths or latch side clearances to pass through a 32 inch door opening were mainly those people with three or four limbs affected, one side of their body affected and those who have difficulty bending and turning.

Table 33: Clearance Required for Direct Forward Approach (percentages in parentheses)

Clearance at Latch Side: Equal to or Greater than	But less than	No. of Successful Subjects	
	6 in	16	(30)
7	12	7	(13)
13	18	9	(17)
19	24	6	(11)
25	30	6	(11)
31	36	4	(7)
37	42	1	(2)
43	48	0	
49		0	
No performance/ Missing data		5	(9)
Total		54	(100)

Table 34: Clearance Required for Latch Side Approach (percentages in parentheses)

Corridor Width: Equal to or Greater than	But less than	No. of Successful Subjects	
	36 in	12	(23)
36	42	21	(40)
42	48	13	(24)
48	54	4	(6)
54	60	3	(5)
60		0	
No performance/ Missing data		1	(2)
Total		54	(100)

Table 35: Clearances Required in Hinge Side Approach (percentages in parentheses)

Corridor Width: Equal to or Greater than	Corridor Width: But less than	No. of Successful Subjects	
	36	5	(11)
36	42	7	(12)
42	48	8	(15)
48	54	15	(28)
54	60	14	(26)
60		0	
No performance/ Missing data		5	(8)
Total		54	(100)

Clearance at Latch Side: Equal to or Greater than	Clearance at Latch Side: But less than	No. of Successful Subjects	
	6	9	(17)
7	12	2	(4)
13	18	3	(6)
19	24	4	(8)
25	30	5	(9)
31	36	18	(34)
37	42	5	(9)
43	48	2	(4)
48		1	(2)
No performance/ Missing data		5	(8)
Total		54	(100)

Table 36: Use of Three Door Closing Devices

	A. Spring Loaded Closer			B. Manual Closers	
	3 Sec.	5 Sec.	11 Sec.	Vertical Handle on Hinged Side	Horizontal Handle Across Door Width
Number of Subjects	11 (100%)	4 (100%)	4 (100%)	11 (100%)	11 (100%)
Successful	7 (64%)	0	1 (25%)	11 (100%)	11 (100%)
Unsuccessful	4 (36%)	4 (100%)	3 (75%)	0	0

Preferences: spring loaded closer - 8 subjects
manual closer - 3 subjects

Figure 23: Plan of Doorway Apparatus

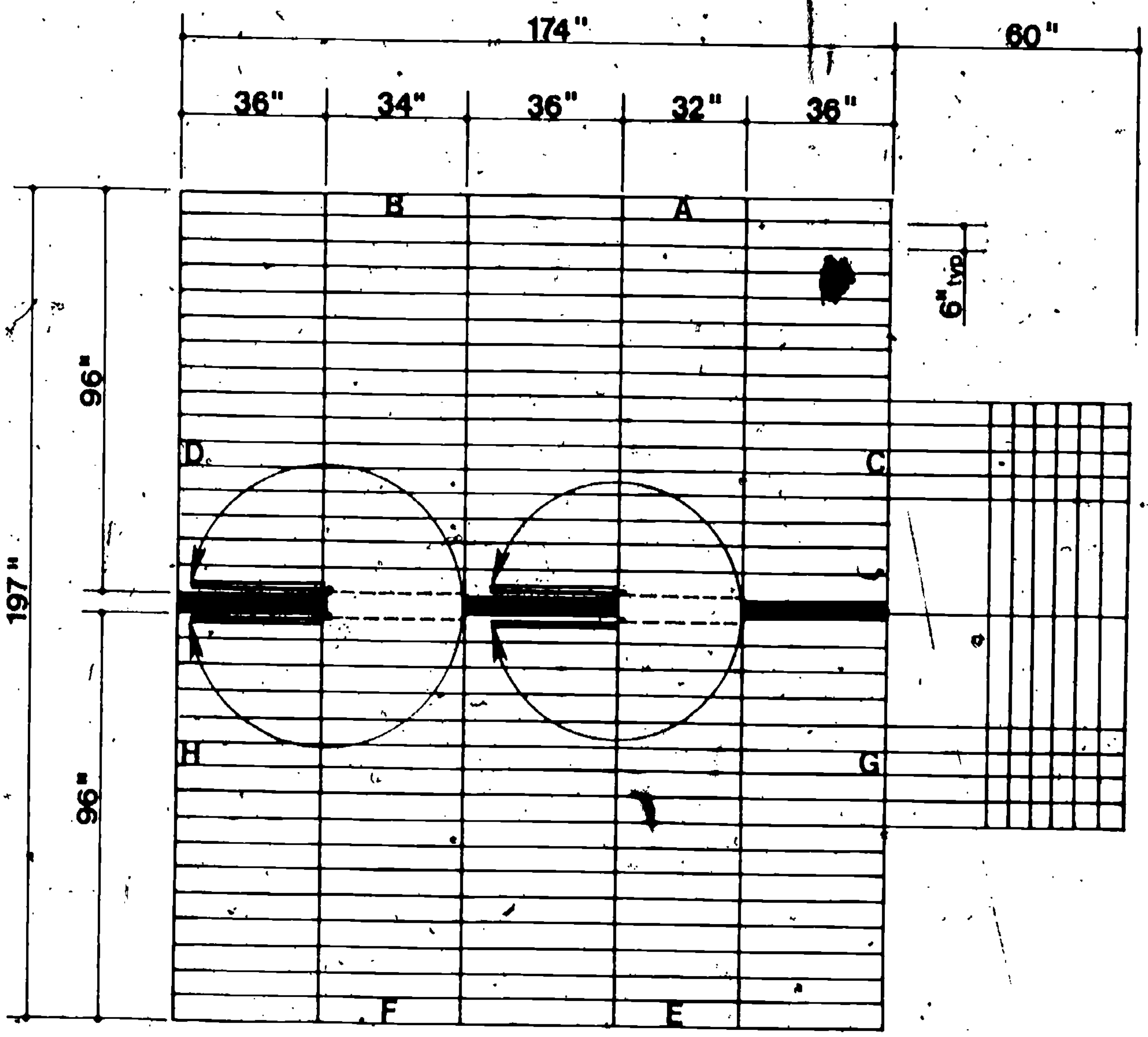


Figure 24: Doorway Testing Procedures

Forward Approach

Latch Side Approach

Hinge Side Approach

Elevator

11


14
13
12
11
10
9
8

Elevator

Objectives

- Determine the minimum size elevator required for wheelchair users.
- Determine the best location and height limits for control panels.
- Determine the timing of elevator doors and car arrival lights.

Apparatus

A simulated elevator car with center-opening doors was constructed with an adjustable depth and two alternative widths on one side. A 36 inch clear entry width was provided at the door. Grids with markings of 2 inch squares were applied on one front wall of the door and on one side wall of the car to simulate control panels. A line of the floor marked the minimum width of the car. A distance of 18 feet (maximum distance to a call button) was plotted in a straight line starting at the center-line of the entry and parallel to the front wall of the car. A light mounted above the entry was used to signal the arrival of the elevator. The movable walls and extra large width dimension allowed us to test two cab sizes: 4 feet, 3 inches by 5 feet, 8 inches and 4 feet, 9 inches by 6 feet, 8 inches.

Procedure

Subjects were positioned behind the line designating the call button. At the signal of the light, the subject traveled to the elevator and entered the car. Their elapsed time from the signal to the first penetration of the door plane was recorded (a door reopening device would hold the door open). With the movable walls adjusted to the smaller cab size, subjects entered the car and maneuvered to a position for reaching the control panels. The subjects were given two chances to maneuver without hitting the walls or crossing the narrow width line (5 feet, 8 inches). If the subject was unsuccessful, the rear wall was moved back to the larger car depth and the subject tried once more. This time the subject was allowed to cross the narrow width line. If the subject was still unsuccessful the wall was moved all the way back and the necessary car depth was recorded.

Once positioned in front of the control panels, the subjects reached to the highest squares to the left and right of each panel. If the subject had entered the cab frontwards, he or she repeated the entire procedure but this time entered the car backwards.

Subjects

Wheelchair users, people with walking aids, and people with balance problems, as well as able-bodied people tested the elevator. The 55 wheelchair users represented all disability levels, including four with exceptionally good abilities.

Findings

All the subjects were able to use a 4 foot, 3 inch by 5 foot, 8 inch car size (common smallest size for 2,000 pound capacity elevator). Table 37 shows the number of subjects who traveled at various speeds. Approximately 40 percent of both the wheelchair user group and the walking aid user group required more than 12 seconds to travel the distance of 18 feet (1.5 ft/s).

Table 38 shows the areas reached by all subjects on the front and side control panel locations. At the front panel, nine people could not reach to 54 inches on at least one side of the panel, six of these were wheelchair users. At the left side of the front panel, five (three wheelchair users) of these people reached to at least 48 in and four (three wheelchair users) reached below 48 inches. At the right side of the front panel, three of these people (two wheelchair users) reached to at least 48 inches, while six (4 wheelchair users) could not reach to 48 inches.

At the side panel, eleven people could not reach to 54 inches on at least one side. At the left side of this panel, three (two wheelchair users) reached to at least 48 inches, but eight (five wheelchair users) could not reach to 48 inches. At the right side of the panel, four subjects (three in wheelchairs) reached to at least 48 inches and seven (four wheelchair users) below 48 inches.

Recommendations

Elevator car sizes should be a minimum size of 4 feet, 3 inches by 5 feet, 8 inches to allow wheelchair users to maneuver and function when inside the car. Doors should have minimum clear openings of 32 inches. Automatic reopening devices should not require direct contact with the elevator user and should be located to be activated by wheelchair users' footrests. Control panels should have highest buttons 48 inches from from the floor (this may be impossible where such placement of long panels would put the lowest buttons below the comfortable reach of ambulant users). Control panels should be mounted on the front wall adjacent to the entry. Where the possibility of transporting stretcher-bound users exists, elevators and entry configurations should be larger.

Marginal Population

People with rates of travel less than 1.5 ft/s were primarily people with limitations of stamina and wheelchair users with three or four limbs affected. People who had difficulty reaching to 54 in were wheelchair users with three or four limbs affected or ambulant disabled people with chronic conditions producing limitations of reach. Many of these people however, could use aids such as pointers, extenders, etc. to activate call and floor buttons located beyond their ranges of motion.

Table 37: Time to Enter Elevator (percentages in parentheses)

Time to Enter Cab (in seconds)		Rate of Speed	No. of Wheelchair Users		No. of Walking Aid Users	
Equal to or Greater than	But less than					
	6	at least 3 ft/sec	2	(4)	0	
7	12	at least 1.5 ft/sec	32	(59)	10[a]	(72)
13	18	at least 1 ft/sec	11	(20)	1	(7)
19	24	at least .75 ft/sec	3	(5)	1	(7)
25	30	at least .6 ft/sec	3	(5)	2	(14)
31	36	at least .5 ft/sec	1	(2)	0	
37		less than .5 ft/sec	2	(4)	0	
Missing data			1	(2)	0	
Total			55	(100)	14	(100)

[a]Four of these people had exceptional abilities.

Table 38: Reaching to Elevator Control Panel (in inches)

Front Panel						Maximum Height Reached		Side Panel					
Left			Right			Equal to or Greater than	But less than	Left			Right		
Ambulant/Semi-Ambulant	Wheelchair Users	Total	Ambulant/Semi-Ambulant	Wheelchair Users	Total			Ambulant/Semi-Ambulant	Wheelchair Users	Total	Ambulant/Semi-Ambulant	Wheelchair Users	Total
19	49	68	19	49	68	54		18	48	66	18	48	66
2	3	5	1	2	3	48	54	1	2	3	1	3	4
1	3	4	2	4	6		48	3	5	8	3	4	7
22	55	77[a]	22	55	77[a]	Total		22	55	77[a]	22	55	77[a]

[a]Does not include able-bodied subject group.

Figure 25: Plan of Elevator Apparatus

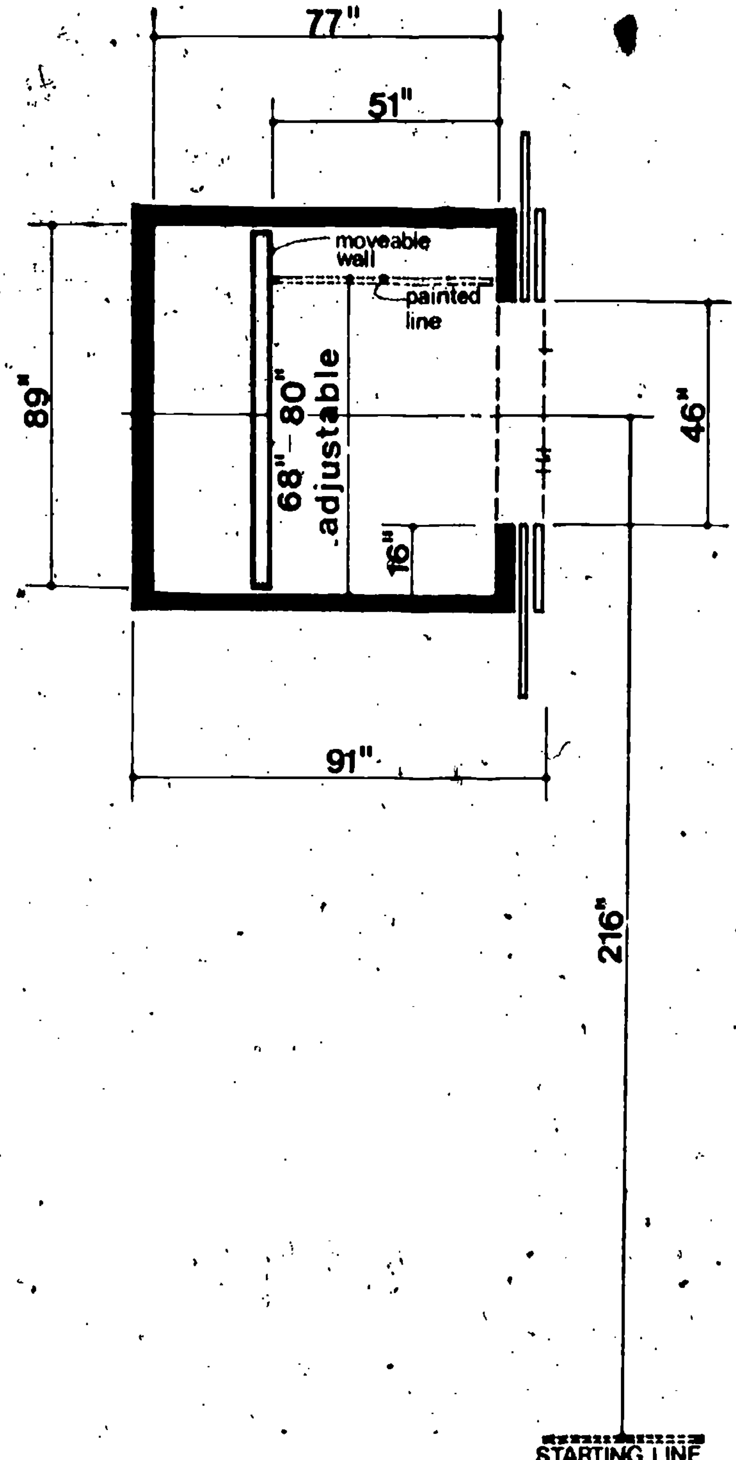
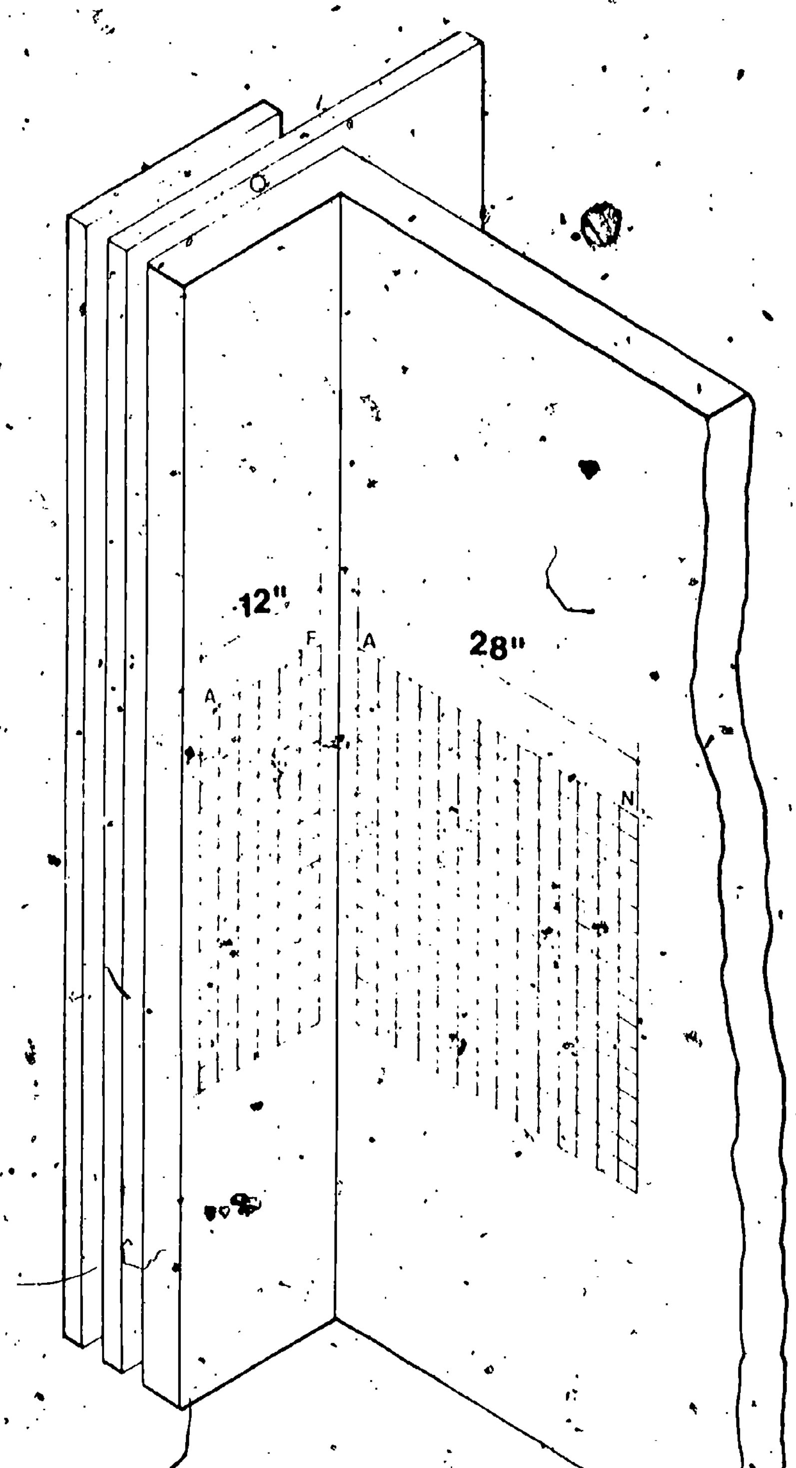


Figure 26: Control Panels



Public Telephone 12

Public Mailbox 13

Public Telephones

Objectives

- Validate a previous study that established a uniform height to telephone coin slots of 54 inches.
- Evaluate the feasibility of telephone booths for use by people who use wheelchairs.

Apparatus

In the first phase of research, a standard coin telephone was mounted on a wall in a way that allowed the telephone to be moved up and down smoothly. The space around the telephone was free of obstacles. In the second phase, a telephone booth manufactured by AT&T was tested. The booth had a clear opening of 30 inches, no doors and a coin telephone was mounted in the right rear corner, facing diagonally across the booth. The coin slot of the telephone was fixed at 54 inches. Lines were marked at a 48 inch height on the telephone and at 54 inches and 48 inches on the side walls of the booth.

Procedure

In the first phase the height of the coin slot was set at 54 inches from the floor. Subjects approached the telephone in anyway they desired. They reached for the coin slot and, if necessary, the telephone was lowered until they could reach the coin slot comfortably. In the second phase, subjects attempted to insert a dime into the coin slot and also reached to the markings on the telephone and booth sides.

Subjects

In the first phase, of the 118 subjects, 61 were wheelchair users, 18 were walking-aid users, 28 were people with handling, grasping and reaching difficulties, and 11 were able-bodied people. In the second phase, all subjects were wheelchair users who had difficulty reaching or bending or had low stamina (8 in all).

Findings

In the first testing phase, only five people could not reach the coin slot comfortably at 54 inches; those five people could not reach the coin slot comfortably at 48 inches either. Many wheelchair users utilized a side approach which would not be possible in the standard telephone enclosure. In the second phase, a standard telephone enclosure was obtained. All five people who had not reached the coin slot comfortably at 54 inches returned to test the telephone mounted in the enclosure. In addition, three other wheelchair users were tested. Two of the first five people could not insert the coin at the 54 inch height with either hand, using either the frontal approach or back-in approach. One of them could reach to the 54 inch height but was unable to insert the coin without a specially-made holding device which he had not brought to the laboratory. The other subject could not reach above 48 inches, except at the right side of the booth where she could reach to 54 inches. In order for her to be close enough to use the 54 inch slot, it was necessary for her to travel over a 1/4 inch high metal plate that served as a temporary structural support for the telephone enclosure. (The metal plate would not be present in a permanent installation.) This individual came to the laboratory in a rented chair that was difficult for her to operate. The five other wheelchair users could use the 54 inch slot with the telephone mounted diagonally in the corner.

Informal observations indicated that heavy outer clothing may significantly limit reaching abilities for people with limited movement of arms. Thus, the 54 inch height may be difficult to reach in winter where outdoor installations are found in cold weather climates.

Recommendations

The height of 54 inches to the coin slot was validated as an acceptable mounting height for public telephones. A mounting location and space clearances that allow a side approach are preferred. Telephone enclosures with diagonally-mounted telephones are acceptable if clearances allow entry of a wheelchair.

Marginal Population

Some wheelchair users with difficulty reaching will find telephones with coin slots located at 54 inches difficult but not usually impossible to use. A few people who also have difficulty maintaining balance while reaching forward may find the diagonally-mounted telephone in an enclosure with the coin slot at 54 inches impossible to use.

Table 39: Telephone Enclosure Findings by Subject

Description of Subject	Right Corner (in inches)			Right Side (in inches)			Left Side (in inches)			Left Corner (in inches)		
	Right Hand	Left Hand	Back-In Either Hand	Right Hand	Left Hand	Back-In Either Hand	Right Hand	Left Hand	Back-In Either Hand	Right Hand	Left Hand	Back-In Either Hand
Left Side Worse	54	48	54	54	54	54	54	54	54	54	54	54
Right Side Worse	NP	54	54	48	54	54	54	54	54	NP	54	54
Right Side Worse	NP	54	NP	NP	48	48	NP	54	48	NP	48	48
Both Sides Same	54	NP	NP	54	54	54	54	54	54	54	54	NP
Right Side Worse	NP	48	48	NP	48	54	NP	48	54	NP	48	54
Left Side Worse	54	48	NP	54	48	54	54	54	54	54	54	54
Left Side Worse	54	48	54	54	NP	54	54	54	54	54	54	54
Left Side Worse	54	54	54	54	54	54	54	54	54	54	54	NP

Table 40: Summary of Findings for Public Telephone Enclosures

	Phone Location and Slot Height (Maximum Operable Coin Height):											
	Right Corner			Right Side			Left Corner			Left Side		
Users Approach	48 in.	54 in.	NP	48 in.	54 in.	NP	48 in.	54 in.	NP	48 in.	54 in.	NP
Forward: at least one hand	1	6	1	2	6	0	2	6	0	1	7	0
Back: at least one hand	1	4	3	1	7	0	1	5	2	1	7	0
Total			8			8			8			8

Mailbox

Objective

- Evaluate the usability of standard US Postal Service mailboxes.

Apparatus

A standard US Postal Service mailbox was installed in our laboratory. An 11 inch letter and a package 9 inches by 12 inches and weighing 1 pound were prepared for use in the experiment.

Procedure

Users demonstrated mailing the letter and the package. Spatial requirements and problems were recorded noting the space required for use in front of or at the side of a standard, floor mounted postal service mailbox.

Subjects

People with handling, grasping and reaching difficulties as well as people using wheelchairs or walking aids and able-bodied people were included in the test sample. A total of 104 disabled subjects were tested.

Findings

Wheelchair users and people with handling and fingering difficulties had problems holding the door open while lifting the package with one hand (see Table 41).

Recommendations

Dispensers and receptacles should allow operation with only one hand.

Marginal Population

Severely disabled quadraplegics and people with severe difficulty in manipulation of fingers may have problems using receptacles and dispensers requiring one-hand operation. These people, plus hemiplegics and people with moderate manipulation difficulties may not be able to use dispensers or receptacles requiring two-hand operation.

Table 41: Mailbox Use

	Uses Space in Front of Box	Uses Space at Side of Box	Unable to Mail Letter	Unable to Mail Package	Total
Wheelchair Users[a]	53	3	4	4	56
Ambulant Users[b]	NA	NA	1	0	38

[a]Does not include wheelchair users with exceptionally good abilities.

[b]Does not include able-bodied ambulant and walking aid users with exceptionally good abilities.

Comparison with Previous Research

14

Comparison with Previous Research

The findings in this research study can be compared to the findings of several other human factors research studies focusing on accessibility and usability of the environment by people with disabilities.

1. Anthropometrics

Floyd, et al. studied anthropometrics of paraplegics; they found that comfortable vertical side reach in their sample ranged from 59 to 68 inches. Our findings were a range from less than 36 inches to almost 72 inches (only two people less than 48 inches) for a similar task. Floyd, et al. also found that forward vertical reach ranged from 42 to 66 inches. McCullough and Farnham studied reach of wheelchair users to the back of upper shelves in a task similar to the reaching task our subjects completed at the mix center testing station. Their findings, for shelves over an open counter, were a range of 43 to 56 inches. They did not report how heavy the weights used in their reaching task were. Our findings ranged from 44 to 68 inches (only one person above 60 inches with a 2 pound weight). Our findings and those of Floyd, et al. are different at both extremes. This is probably due to the differences in selection of samples and procedures. About 30 percent of Floyd, et al's. sample were athletes. All of their subjects were paraplegics who had spinal cord injuries and who had had or were undergoing rehabilitation training. Our sample included many wheelchair users with reaching limitations (i.e. with loss of arm function) and little or no rehabilitation training. However, it also included athletes who were very agile. The findings on vertical forward reach from all three studies were very close except for the upper range for the McCullough and Farnham results. Their sample was all female, which would explain that difference.

2. Wheelchair Maneuvering

Several researchers have studied turning a wheelchair within confined spaces. Recommendations from those studies and our own are shown in Table 42 and Table 43. The differences in findings for the 180 degree turn can be explained by the variety of methods used by the different researchers and how recommendations were abstracted from data. Brattgard had his subjects make two 90 degree turns in an open space. Backing and pivoting were allowed. Such a turn requires less space than a smooth U-turn. Moreover, lack of surrounding partitions reduces the need for tolerances and allowances for judgment. McCullough and Farnham utilized movable partitions; they did not report the type of turn used. Their findings in Table 42 are for the largest dimensions required by a member of their sample rather than minimum recommendations. The largest space required by a member of our sample was larger than the McCullough findings, but our recommendations were derived by eliminating several individuals who could do a K-type turn within the space that most other people could do the U-turn. The larger space requirements found by Walter, who used fixed partitions as we did can be attributed to: 1) the fact that his sample included electric and assistant-propelled chairs, which had much greater space requirements than those people in his sample using manual chairs independently (new electric chairs can make this maneuver in less space than people using manual chairs); and 2) the fact that he analyzed depth and width of turning area independently, which does not consider the relationship of length to depth of space. Nedrebo's methods are not reported.

The recommendations for L-turns are more consistent, with the main difference being our finding that both arms of the L can be the same, if the starting arm is sufficiently large. In our study, we never used a starting arm that was narrower than 36 inches (91 cm). It appears that Walter and Brattgard reduced the starting arm to a much smaller width. Nedrebo's methods are not reported. Thus, the various findings taken together, suggest that with a wider starting arm (36 inches is needed for passage in a straight corridor by crutch users) the end arm can be reduced in width.

3. Counter Heights

McCullough and Farnham tested preferred counter heights of wheelchair users. Although they only used one trial for comfortable height, they also found that wheelchair users often preferred counter heights as close to lap level as possible and often below arm rest height. They found, as we did, that preferred sink heights were higher than mix center heights. Their range of findings was similar to ours.

4. Doorway Maneuvering

Several researchers have studied maneuvering through doorways by wheelchair users. Their recommendations, together with our own, are presented in Table 44. Brattgard's research on door maneuvering utilized people with reduced arm function but the sample size was only six, and four out of the six used wheelchairs with the large propelling wheels in the front. Those two that had rear propelling wheels, as did all the subjects in our research, required consistently larger spaces. The fact that four out of the six subjects had the advantage of the front propelling wheels would account for Brattgard's smaller recommendations. Brattgard reports that Ownsworth's sample used only one person who propelled their chair manually with no assistance (Brattgard, 1974). The performance of electric wheelchair users and attendant-assisted pushers in Walter's study was better than that of people propelling themselves at doorways; unlike his findings for the 180 degree turn experiments, Walter's findings are quite different than ours for the direct frontal approach. Walter placed screens at both sides of the door perpendicular to the wall. He does not report how those screens were moved during the testing procedures. We did not use screens in this approach and thus, subjects were able to use more space close to the door at the latch side. Walter reports data for only 31 of the total sample of 40 independent wheelchair users; perhaps many subjects could not negotiate with the screens in place. Our findings show that over half of our sample of wheelchair users used more than the latch side space recommended by Walter. Our findings on this approach are close to those of Nedrebo, as reported by Brattgard.

For doorways opening out while approaching from the latch side, our recommendations are 4 cm smaller than Walter's. This difference can be attributed to the fact that Walter determined his recommendation through an arbitrary statistical procedure. Actually, only three of his subjects required more than 47 inches of corridor width in this maneuver. We had a number of people (11 percent of the wheelchair users) who required more space than 48 inches, however, we judged that 48 inches was a reasonable minimum. For turning into doorways that open out, away from the user, Walter gives recommendations for corridor width 10 cm more than ours. We did not test this maneuver but based it on our L-turn data. Walter aggregates data on one graph for four maneuvers-- from both the left and right, for both latch side and hinge side approach. For all of these approaches, only 8 out of 137 or 5 percent of the trials, required a greater space than our recommended minimums and, since the data are aggregated, there is no way to tell which of those 8 trials were for the individual maneuvers. It should be noted that the clear doorway width used in the various studies was different. The clear doorway width is inversely related to corridor clearance as shown by our research on L-turns.

5. Ramps

Walter's findings for ramps are similar to ours. Both studies found a 1:16 slope for 20 feet to be accessible to at least 95 percent of the wheelchair users. Elmer (1957) found that a 1:8 ramp slope was maximum for wheelchair users. However, his sample was taken from wheelchair users at a pioneering rehabilitation-education center and the findings probably reflect the high standard of excellence in rehabilitation training that the subjects received as part of their program. Both Walter's and our sample included large proportions of older people and many with reduced arm function and low stamina. The Elmer sample was much younger in age.

6. Public Telephones

The American Telephone and Telegraph Company, in a study on the height of coin telephones found that 54 inches to the coin slot was usable by all but a few wheelchair users. Our findings are consistent with those results.

Further Research Needs

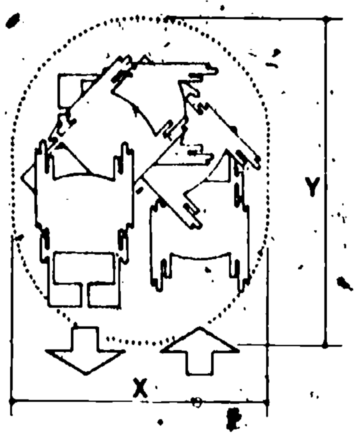
This research, as well as the other studies above, was limited to the study of behavior in simulated rather than actual buildings. The similarity of activities performed in the laboratory and the closeness to which laboratory conditions matched actual conditions allows a great degree of generalizability to actual buildings. However, there are conditions in the "real world" that cannot be adequately simulated in the laboratory. First, individual performance will vary considerably due to changes in health status and morale. In the laboratory, behavior cannot be studied over time, day in and day out -- when people feel good and when they feel bad. Moreover, the design features of buildings cannot be simulated in all their variety and complexity. Certainly, additional research with small samples in existing buildings is needed to bring our knowledge about accessibility to a finer level of detail than that provided by laboratory studies. The lack of information on many topics and the conflicts in existing data on others led us to an approach that demanded the largest sample possible and an extensive array of tasks to be studied. The use of simulations was the most appropriate method. Further research can now build upon the established data base to study individual topics in more detail.

It should also be noted that consumer preferences were not given major consideration in this work. It was limited, for the most part, to outwardly observable behavior. We followed this approach because the intended use of data was for application to minimum building standards. Considerable variation no doubt exists in the acceptance of different design conditions. Some people, for example, would rather not have to reach up for an object at all, regardless of whether it is within their reach or not. Attitudinal issues of this sort deserve a significant amount of research attention. In particular, such work should compare the attitudes of disabled and able-bodied people for similar tasks. Research of this kind would probably demonstrate that significant inconvenience in access and use of the environment is not restricted solely to disabled people.

The scope of this work did not allow us to give attention to environments for young children. There is no empirical data presently available on their needs. Further research should give attention to those specific parts of the environment where children's small stature, low strength and immature judgment require differences in design criteria.

Finally, the research reported here did not give in-depth attention to the design of products found in buildings. We used building products that, through professional judgment, were considered the optimal available (e.g. lever-handled door openers, single-lever faucets). Research is already underway by others that will provide empirically-based information about product design.

Table 42: Space Requirements for Making an 180° Turn in a Wheelchair (in centimeters)



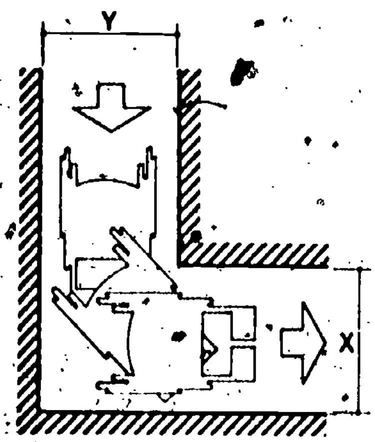
Researcher	X	Y
Walter	180	215
Brattgard[a]	150	150
Nedrebo[b]	150	150
McCullough[c]	162	193
Steinfeld	153	200

[a] Allowed two 90° turns.

[b] Source: Brattgard, 1974

[c] Not reported as a minimum.

Table 43: Space Requirements for Making a Right-Angle Turn (in centimeters)

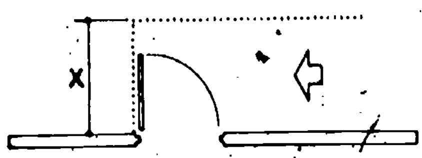


Researcher	X	Y
Walter	109	84
Brattgard	100	80
Nedrebo[a]	100	90
Steinfeld	91	91

[a] Reported by Brattgard, 1974

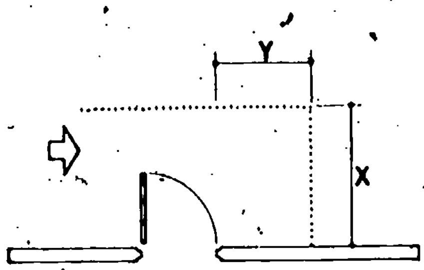
Table 44: Space Requirements for Maneuvering Wheelchairs in Front of Doorways (in centimeters)

A.



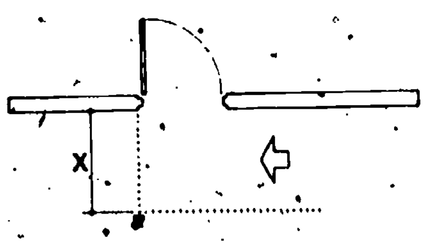
Researcher	X	Clear Opening
Walter	126	80
Brattgard	100	78
Ownsworth[a]	100	77.5
Nedrebo[a]	135[b]	76.1
Steinfeld	122	76

B.



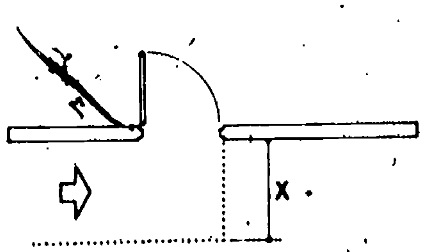
Researcher	X	Y	Clear Opening
Brattgard	120	110	78
Steinfeld	153	107	76

C.



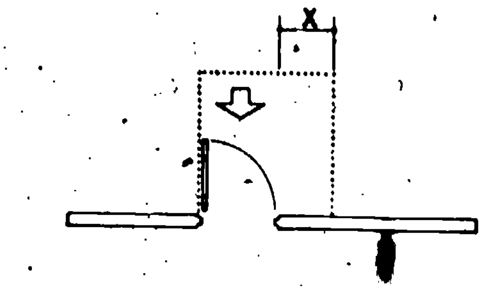
Researcher	X	Clear Opening
Walter	120	80
Brattgard	100	78
Ownsworth[a]	100	77.5
Nedrebo[a]	122[b]	76.1
Steinfeld	107	81

D.



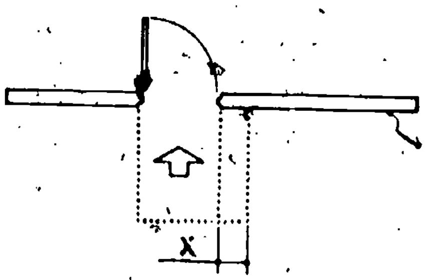
Researcher	X	Clear Opening
Walter	120	80
Brattgard	100	78
Ownsworth[a]	100	77.5
Nedrebo[a]	125[b]	76.1
Steinfeld	107	81

E.



Researcher	X	Clear Opening
Walter	33	80
Brattgard	30	78
Nedrebo[a]	60	76.1
Steinfeld	61	76

F.



Researcher	X	Clear Opening
Brattgard	20	78
Nedrebo[a]	30	76.1
Steinfeld	Not Tested	

[a]Source: Brattgard, 1974

[b]Not reported as a minimum.

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